tion 4b.182 (a) is demonstrated with less clearance.

(c) ***Structure.***

(1) One inch radial clearance shall be provided between the blade tips and the airplane structure, or whatever additional radial clearance is necessary to preclude harmful vibration of the propeller or airplane.

(2) One-half inch longitudinal clearance shall be provided between the propeller blades or cuffs and all stationary portions of the airplane.

(3) Positive clearance shall be provided between other rotating portions of the propeller or spinner and all stationary portions of the airplane.

[CAR, 15 F. R. 3543, June 8, 1950, as amended by Amdt. 4 b-7, 17 F. R. 11631, Dec. 20, 1952.]

4b.406 ***Propeller de-icing provisions.***

(a) Airplanes intended for operation under atmospheric conditions conducive to the formation of ice on propellers or on accessories where ice accumulation would jeopardize engine performance shall be provided with means for the prevention or removal of hazardous ice accumulations.

(b) If combustible fluid is used for propeller de-icing, the provisions of sections 4b.480 through 4b.483, inclusive, shall be complied with.

4b.406–1 *Fluid type propeller de-icing test (CAA policies which apply to sec. 4b.406).* If the propellers are equipped with fluid type de-icers, the flow test should be conducted starting with a full tank of fluid and operated at maximum flow for a 15-minute timed period. The operation should be checked at all engine speeds and powers. The tank should be refilled to determine the amount of fluid used after the airplane is landed.

(19 F. R. 4463, July 20, 1954, effective Sept. 1, 1954.)

4b.407 ***Propeller reversing system.*** **The propeller reversing system, if installed, shall be such that no single failure or malfunctioning of the system during normal or emergency operation will result in unwanted travel of the propeller blades to a position substantially below the normal flight low-pitch stop. Failure of structural elements need not be considered if occurrence of such failure is expected to be extremely remote.**

4b.407–1 *Investigation of propeller systems which produce negative thrust (CAA policies which apply to sec. 4b.407).*

(a) Compliance with section 4b.407 may be demonstrated by failure analysis, testing, or a combination of both for propeller systems that allow propeller blades to move from the flight low-pitch position to a position [27] that is substantially less than that at the normal flight low-pitch stop position.

(b) The analysis should disclose, for all components involved in the reversing system, the types of failure or malfunction likely to occur, how such failures or malfunctions affect propeller pitch, and the design feature that prevents unwanted travel of the propeller blades to a position substantially below the normal flight low-pitch stop. The analysis may include, or be supported by, the analysis made to demonstrate compliance with the requirements of section 14.103 of this subchapter for the propeller and associated installation components supplied with it.

(c) When necessary, testing should be conducted to verify assumptions made in the analysis of how the propeller will function with a failed system component and that the design feature provided does in fact prevent unwanted travel of the propeller blades.

(22 F. R. 6885, Aug. 27, 1957, effective Sept. 15, 1957).

4b.408 ***Turbo-propeller-drag limiting systems.*** **For turbo-propeller-powered airplanes, propeller-drag limiting systems shall be such that no single failure or malfunction of any of the systems during normal or emergency operation will result in propeller drag in excess of that for which the airplane was designed in compliance with section 4b.216 (d). Failure of structural elements of the drag limiting systems need not be considered if occurrence of such failure is expected to be extremely remote. (See also sec. 4b.310.)**

[4b.409 ***Turbine powerplant operating characteristics.*** **Turbine powerplant operating characteristics shall be investigated in flight to determine that no adverse characteristics, such as stall, surge, or flameout, are present to a hazardous degree during normal**

[27] Where the blade position is intended to provide increased drag during the landing run (ground fine pitch) or a reversed propeller blade position.

and emergency operation of the airplane within the range of operating limitations of the airplane and of the engine.]

Fuel System Operation and Arrangement

4b.410 *General.*

(a) The fuel system shall be constructed and arranged in such a manner as to assure a flow of fuel to each engine at a rate and pressure which have been established for proper engine functioning under all normal conditions, including all maneuvers for which the airplane is intended. (For fuel system instruments see sec. 4b.604.)

(b) The fuel system shall be so arranged that no one fuel pump can draw fuel from more than one tank at a time unless means are provided to prevent introducing air into the system.

4b.411 *Fuel system independence.* The design of the fuel system shall comply with the requirements of section 4b.401 (b). Unless other provisions are made in compliance with this requirement, the fuel system shall be arranged to permit the supply of fuel to each engine through a system independent of any portion of a system supplying fuel to any other engine.

4b.412 *Pressure cross-feed arrangements.*

(a) Pressure cross-feed lines shall not pass through portions of the airplane intended to carry personnel or cargo, unless means are provided to permit the flight personnel to shut off the supply of fuel to these lines, or unless the lines are enclosed in a fuelproof and fumeproof shroud which is ventilated and drained to the exterior of the airplane.

(b) The shrouds specified in paragraph (a) of this section need not be used if the lines are routed or protected to safeguard against accidental damage and if they do not incorporate any fittings within the personnel or cargo areas.

(c) Lines which can be isolated from the remainder of the fuel system by means of valves at each end shall incorporate provisions for the relief of excessive pressures which might result from exposure of the isolated line to high ambient temperatures.

4b.413 *Fuel flow rate.*

(a) The ability of the fuel system to provide the required fuel flow rate shall be demonstrated when the airplane is in the attitude which represents the most adverse condition from the standpoint of fuel feed which the airplane is designed to attain. The following shall be considered in this respect:

(1) Normal ground attitude,

(2) Climb with take-off flaps, landing gear up, using take-off power, at speed V_2 as determined in section 4b.114 (b), at landing weight,

(3) Level flight at maximum continuous power or at the power required for level flight at V_C, whichever is the lesser,

(4) Glide at a speed of 1.3 V_{s_0}, at landing weight.

(b) During the demonstration prescribed in paragraph (a) of this section, fuel shall be delivered to the engine at a pressure not less than the minimum pressure established for proper engine operation. In addition the following shall be met.

(1) The quantity of fuel in the tank being considered shall not exceed the amount established as the unusable fuel supply for that tank, as determined by demonstrating compliance with the provisions of section 4b.416 (see also secs. 4b.420 and 4b.613 (b)), together with whatever minimum quantity of fuel it may be necessary to add for the purpose of conducting the flow test.

(2) If a fuel flowmeter is provided, the meter shall be blocked during the flow test and the fuel shall flow through the meter by-pass.

(3) It shall be acceptable to conduct the demonstration prescribed in paragraph (a) of this section by a ground test on the airplane or on a representative mock-up of the fuel system.

(4) In systems where sec. 4b.435 (d) requires a fuel filter by-pass arrangement, the fuel flow rate corresponding with 100 percent of the engines' maximum fuel demand at standard atmospheric conditions shall be demonstrated with the fuel filter blocked.

4b.414 *Pump systems.*

(a) For reciprocating engines, the fuel flow rate for pump systems (main and reserve supply) shall be 0.9 pounds per hour for each take-off horsepower or 125 percent of the actual take-off fuel consumption of the engine, whichever is the greater.

(b) For turbine engines, the fuel flow rate for

pump systems shall be 125 percent of the fuel flow required to develop the standard sea level atmospheric condition take-off power selected by the applicant and included as an operating limitation in the Airplane Flight Manual.

(c) The fuel flow rate specified in this section shall be applicable to both the primary engine-driven pump and to emergency pumps. The fuel flow rate shall be available when the pump is running at the speed at which it would nor-

valve while the cover plate is removed. In addition to the normal means provided in the airplane for limiting the tank content, a means shall be installed to prevent damage to the tank in case of failure of the normal means.

Fuel System Components

4b.430 *Fuel pumps.*

(a) *Main pumps.*

(1) If the engine fuel supply is maintained by means of pumps, one fuel pump for each engine shall be engine-driven.

(2) Fuel pumps shall meet the pertinent flow requirements of section 4b.413.

(3) All positive displacement fuel pumps shall incorporate an integral bypass, unless provision is made for a continuous supply of fuel to all engines in case of failure of any one pump. Reciprocating engine fuel injection pumps which are approved as an integral part of the engine need not incorporate a by-pass.

(4) If the emergency fuel pumps are all dependent upon the same source of motive power, the main fuel pumps shall be capable of providing sufficient fuel flow and pressure to maintain level flight at maximum weight and normal cruising power at an altitude of 6,000 feet with 110° F. fuel without the aid of any emergency fuel pump.

(b) *Emergency pumps.*

(1) Emergency fuel pumps shall be provided to permit supplying all engines with fuel in case of failure of any one main fuel pump, except in the case of reciprocating engine installations in which the only fuel pump used in the system is an engine fuel injection pump which is approved as an integral part of the engine.

(2) Emergency fuel pumps shall be available for immediate use in case of failure of any other fuel pump. No manipulation of fuel valves shall be necessary on the part of the crew to make an emergency fuel pump available to the engine which it is normally intended to serve when the fuel system is being operated in the configuration complying with the provisions of section 4b.411.

4b.431 *Fuel pump installation.*

(a) Provision shall be made to maintain the fuel pressure at the inlet to the carburetor within the range of limits established for proper engine operation. In turbine engine fuel systems, provisions shall be made to maintain the fuel pressure at the inlet to the engine fuel system within the limits established for engine operation.

(b) When necessary for the maintenance of the proper fuel delivery pressure, a connection shall be provided to transmit the carburetor air intake static pressure to the proper fuel pump relief valve connection. In such cases, to avoid erroneous fuel pressure reading, the gauge balance lines shall be independently connected to the carburetor inlet pressure.

4b.432 *Fuel system lines and fittings.*

(a) Fuel lines shall be installed and supported to prevent excessive vibration and to withstand loads due to fuel pressure and due to accelerated flight conditions.

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

(c) Flexible connections in fuel lines which may be under pressure and subjected to axial loading shall employ flexible hose assemblies rather than hose clamp connections.

(d) Flexible hose shall be of an approved type or shall be shown to be suitable for the particular application.

(e) Flexible hoses which might be adversely affected by exposure to high temperatures shall not be employed in locations where excessive temperatures will exist during operation or after engine shut-down.

4b.433 *Fuel lines and fittings in designated fire zones.* Fuel lines and fittings in all designated fire zones (see sec. 4b.480) shall comply with the provisions of section 4b.483.

4b.434 *Fuel valves.* In addition to the requirements of section 4b.482 for shutoff means, all fuel valves shall be provided with positive stops or suitable index provisions in the "on" and "off" positions and shall be supported so that loads resulting from their operation or from accelerated flight conditions are not transmitted to the lines attached to the valve.

4b.435 *Fuel strainer* **[***or filter***]**. A fuel strainer **[**or filter**]** shall be provided between the fuel tank outlet and the fuel metering device of the engine. The following provisions of this section shall be complied with:

(a) If an engine-driven fuel pump is provided, the strainer [or filter] shall be located between the tank outlet and the engine-driven pump inlet.

(b) The fuel strainer [or filter] shall be accessible for drainage and cleaning, and the strainer screen shall be easily removable.

(c) The strainer [or filter] shall be mounted in a manner not to cause its weight to be supported by the connecting lines or by the inlet or outlet connections of the strainer [or filter] itself.

(d) When [strainers or filters] susceptible to icing are incorporated in the fuel system, a means shall be provided to maintain automatically the fuel flow in the event ice particles accumulate and restrict flow by clogging the filter or screen.

[(e) The fuel strainer or filter shall be of adequate capacity, commensurate with operating limitations established to insure proper service and of appropriate mesh to insure proper engine operation with the fuel contaminated to a degree, with respect to particle size and density, which can be reasonably expected to occur in service. The degree of fuel filtering shall be not less than that established for the engine in accordance with Part 13 of this subchapter.]

4b.436 *Fuel system drains.* Drainage of the system shall be accomplished by fuel strainer drains and other drains as provided in section 4b.424. The following shall apply:

(a) Drains shall discharge clear of all portions of the airplane and shall incorporate means for positive locking of the drain in the closed position, either manually or automatically.

(b) All fuel system drains shall be accessible.

(c) If drainage of the fuel strainer permits compliance with paragraphs (a) and (b) of this section, no additional drains need be provided unless it is possible for a hazardous quantity of water or sediment to be trapped therein. (See also sec. 4b.483 (c).)

4b.437 *Fuel jettisoning system.* If the maximum take-off weight for which the airplane is certificated exceeds 105 percent of the certificated maximum landing weight, provision shall be made for the jettisoning of fuel from the maximum take-off to the maximum landing weight.

(a) The average rate of fuel jettisoning shall be 1 percent of the maximum take-off weight per minute, except that the time required to jettison the fuel need not be less than 10 minutes. Compliance with these provisions shall be shown at maximum take-off weight, with flaps and landing gear up, and in the following flight conditions:

(1) Power-off glide at a speed of 1.4 V_{S_1}.

(2) Climb at the one-engine-inoperative best rate-of-climb speed with the critical engine inoperative, the remaining engine(s) at maximum continuous power.

(3) Level flight at a speed of 1.4 V_{S_1}, if the results of tests in conditions specified in subparagraphs (1) and (2) of this paragraph indicate that this condition could be critical.

(b) During the flight tests prescribed in paragraph (a) of this section it shall be demonstrated that the fuel jettisoning system complies with the following provisions:

(1) The fuel jettisoning system and its operation shall be free of fire hazard.

(2) The fuel shall discharge clear of all portions of the airplane.

(3) Fuel or fumes shall not enter any portion of the airplane.

(4) The jettisoning operation shall not affect adversely the controllability of the airplane.

(c) The design of the jettisoning system shall be such that it would not be possible to jettison fuel in the tanks used for take-off and landing below the level providing 45 minutes flight at 75 percent maximum continuous power, except that it shall be permissible to jettison all fuel where an auxiliary control is provided independent of the main jettisoning control. For turbine-powered airplanes, the design of the jettisoning system shall be such that it would not be possible to jettison fuel in the tanks used for take-off and landing below the level providing climb from sea level to 10,000 feet and thereafter providing 45 minutes cruise at a speed for maximum range.

(d) The fuel jettisoning valve shall permit the flight personnel to close the valve during any portion of the jettisoning operation. (See sec. 4b.475 for fuel jettisoning system controls.)

(e) Unless it is demonstrated that lowering of the flaps does not adversely affect fuel jettisoning, a placard shall be provided adjacent to the jettisoning control to warn flight personnel against jettisoning fuel while the flaps are lowered. A notation to this effect shall also be included in the Airplane Flight Manual. (See sec. 4b.740.)

(f) The design of the fuel jettisoning system shall be such that any reasonably probable single malfunction in the system will not result in a hazardous condition due to unsymmetrical jettisoning or inability to jettison fuel.

electric circuit associated with the fire-detection system.

(d) Wiring and other components of detector systems which are located in fire zones shall be of fire-resistant construction.

(e) Detector system components for any fire zone shall not pass through other fire zones, unless they are protected against the possibility of false warnings resulting from fires in zones through which they pass. This requirement shall not be applicable with respect to zones which are simultaneously protected by the same detector and extinguisher systems.

4b.485–1 *Fire detector test circuit (CAA policies which apply to sec. 4b.485 (c)).*

(a) The checking means should serve to assure the crew that a fire within the zone of coverage will produce a fire warning if all fire-responsive (detector) elements are operative. The means need not be designed to disclose whether fire detector sensor elements themselves would respond properly to a fire.[31]

(b) The check should reveal any probable malfunction or failure in the fire-detection system, external to the detector elements, which could interfere with, or prevent, fire warning. Open and short circuits in wiring, and inoperative lights, bells, switches, or relays are examples of malfunctions which should be revealed by such a check.

(22 F. R. 6885, Aug. 27, 1957, effective Sept. 15, 1957.)

4b.486 *Fire walls.* All engines, auxiliary power units, fuel-burning heaters, and other combustion equipment which are intended for operation in flight as well as the combustion, turbine, and tail pipe sections of turbine engines shall be isolated from the remainder of the airplane by means of fire walls, shrouds, or other equivalent means. The following shall apply:

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

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

[31] This is normally a separate ground maintenance operation.

(c) Firewalls and shrouds shall be constructed of fireproof material and shall be protected against corrosion.

4b.487 *Cowling and nacelle skin.*

(a) Cowling shall be constructed and supported so as to make it capable of resisting all vibration, inertia, and air loads to which it would be subjected in operation.

(b) Cowling shall have drainage and ventilation provisions as prescribed in section 4b.489.

(c) On airplanes equipped with a diaphragm complying with section 4b.488, the parts of the accessory section cowling which might be subjected to flame in the event of a fire in the engine power section of the nacelle shall be constructed of fireproof material and shall comply with the provisions of section 4b.486.

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

(e) The airplane shall be so designed and constructed that, in the event of fire originating in the engine power or accessory sections, the probability is extremely remote for fire to enter either through openings or by burning through external skin into any other zone of the nacelle where such fire could create additional hazards. If the airplane is provided with a retractable landing gear, this provision shall apply with the landing gear retracted. Fireproof materials shall be used for all nacelle skin areas which might be subjected to flame in the event of a fire originating in the engine power or accessory sections.

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

4b.489 *Drainage and ventilation of fire zones.*

(a) Complete drainage of all portions of designated fire zones shall be provided to minimize

the hazards resulting from failure or malfunctioning of components containing flammable fluids. The drainage provisions shall be effective under conditions expected to prevail when drainage is needed and shall be so arranged that the discharged fluid will not cause an additional fire hazard.

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

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

4b.490 *Protection of other airplane components against fire.*

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

(b) Consideration shall be given to the effect on adjacent parts of the airplane of heat within designated fire zones and within the combustion, turbine, and tail pipe sections of turbine engines.

Equipment

General

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

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

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

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

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

(d) Demonstrated to function properly in the airplane.

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

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

[(a) *Air-speed indicating system.* If the air-speed limitations vary with altitude, the air-speed indicator shall incorporate a maximum allowable air-speed indication showing the variation of V_{NE} with altitude including compressibility limitations. (See sec. 4b.732.)]

(b) Altimeter (sensitive),

(c) Clock (sweep-second),

(d) Free air temperature indicator,

(e) Gyroscopic bank and pitch indicator,

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

(g) Gyroscopic direction indicator,

(h) Magnetic direction indicator,

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

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

(a) Carburetor air temperature indicator for each reciprocating engine.

(b) Cylinder head temperature indicator for each air-cooled reciprocating engine.

(c) Gas temperature indicator for each turbine engine.

(d) Manifold pressure indicator for each reciprocating engine.

(e) Fuel pressure indicator for each reciprocating engine to indicate the pressure under which the fuel is being supplied.

(f) Fuel pressure warning means for each engine or a master warning means for all engines with provision for isolating the individual warning means from the master warning means.

(2) The vertical acceleration sensor, or the unit of the instrument in which it is contained, should be attached to a rigid structural member of the airplane so that vertical acceleration forces present in that area can be sensed with a minimum of error.

(3) Sensing of only the in-flight vertical acceleration forces is necessary; impact forces need not be sensed.

(c) *Connection to sources of data.* The airspeed, altitude, and heading data should be obtained from either [34a] the existing duplicate instrument system (copilot system), or from a source independent of required flight and navigation instrument systems, or a combination thereof. No connection should be made within the case itself of the copilot's airspeed and altimeter indicators. If data are obtained from an independent source, such source should provide data which has an accuracy equivalent to corresponding data furnished by required flight and navigation instrument systems. Provisions need not be made to disconnect or isolate the recorder in flight from sources or data which are independent of required flight and navigation instruments.

(d) *Connection to electrical power.* The flight recorder instrument should be connected to a bus of maximum reliability when such connection does not jeopardize service to essential or emergency loads. If service to such loads is affected, the instrument should be connected to a bus of the next lower reliability.

(23 F. R. 2728, Apr. 24, 1958, effective May 5, 1958.)

Instruments; Installation

4b.610 *General.* The provisions of sections 4b.611 through 4b.613 shall apply to the installation of instruments.

NOTE: It may be necessary to duplicate certain instruments at two or more crew stations to meet the instrument visibility requirements prescribed in section 4b.611, or when required by the operating rules of the Civil Air Regulations for reliability or cross-check purposes in particular types of operations. In the latter case, independent operating systems would be required in accordance with the provisions of section 4b.612 (f).

[34a] See section 4b.612 (f) for requirements concerning the connection of additional instruments to required duplicate and duplicated instrument systems.

4b.611 *Arrangement and visibility of instrument installations.*

(a) Flight, navigation, and powerplant instruments for use by each pilot shall be plainly visible to him from his station with the minimum practicable deviation from his normal position and line of vision when he is looking out and forward along the flight path.

(b) Flight instruments required by section 4b.603 shall be grouped on the instrument panel and centered as early as practicable about the vertical plane of the pilot's forward vision. The four basic instruments specified in subparagraphs (1) through (4) of this paragraph shall be located on the flight instrument panel as follows:

(1) The top center position on the panel shall contain that instrument which, of all instruments on the panel, most effectively indicates attitude.

(2) The position adjacent to and directly to the left of the top center position shall contain that instrument, which, of all instruments on the panel, most effectively indicates air speed.

(3) The position adjacent to and directly to the right of the top center position shall contain that instrument which, of all instruments on the panel, most effectively indicates altitude.

(4) The position adjacent to and directly below the top center position shall contain that instrument which, of all instruments on the panel, most effectively indicates direction of flight.

(c) All the required powerplant instruments shall be closely grouped on the instrument panel.

(d) Identical powerplant instruments for the several engines shall be located to prevent any misleading impression as to the engines to which they relate.

(e) Powerplant instruments vital to the safe operation of the airplane shall be plainly visible to the appropriate crew members.

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

4b.611–1 *Procedure for checking arrangement and visibility of instrument installations (CAA policies which apply to sec. 4b.611).* The arrangement and visibility of the instruments should be checked throughout the type tests in order to supply the information which is necessary to complete the pertinent portions of Form ACA 283–4b, Type Inspection Report.

(19 F. R. 4466, July 20, 1954, effective Sept. 1, 1954.)

4b.612 ***Flight and navigational instruments.***

(a) *Air-speed indicating systems.*

(1) Air-speed indicating instruments shall be of an approved type and shall be calibrated to indicate true airspeed at sea level in the standard atmosphere with a minimum practicable instrument calibration error when the corresponding pitot and static pressures are applied to the instrument.

(2) The air-speed indicating system shall be calibrated to determine the system error, i. e., the relation between IAS and CAS, in flight and during the accelerated take-off ground run. The ground run calibration shall be obtained from 0.8 of the minimum value of V_1 to the maximum value of V_2, taking into account the approved altitude and weight range for the airplane. In the ground run calibration, the flap and power settings shall correspond with the values determined in the establishment of the take-off path under the provisions of section 4b.116, assuming the critical engine to fail at the minimum approved value of V_1.

(3) The air-speed error of the installation, excluding the air-speed indicator instrument calibration error, shall not exceed 3 percent or 5 mph, whichever is the greater, throughout the speed range from V_{NO} to 1.3 V_{S_1} with flaps retracted, and from 1.3 V_{S_0} to V_{FE} with flaps in the landing position.

(4) The air-speed indicating system shall be arranged in so far as practicable to preclude malfunctioning or serious error due to the entry of moisture, dirt, or other substances.

(5) The air-speed indicating system shall be provided with a heated pitot tube or equivalent means of preventing malfunctioning due to icing.

(6) Where duplicate air-speed indicators are required, their respective pitot tubes shall be spaced apart to avoid damage to both tubes in the event of a collision with a bird.

(b) *Static air vent and pressure altimeter systems.*

(1) All instruments provided with static air case connections shall be vented to the outside atmosphere through an appropriate piping system.

(2) The vent(s) shall be so located on the airplane that its orifices will be least affected by air flow variation, moisture, or other foreign matter.

(3) The installation shall be such that the system will be air-tight, except for the vent into the atmosphere.

(4) Pressure altimeters shall be of an approved type and shall be calibrated to indicate pressure altitude in standard atmosphere with a minimum practicable instrument calibration error when the corresponding static pressures are applied to the instrument.

[(5) The design and installation of the altimeter system shall be such that the error in indicated pressure altitude at sea level in standard atmosphere, excluding instrument calibration error, does not result in a value more than the ± 30 feet per 100 knots in speed for the appropriate configuration in the speed range between 1.3 V_{S_0} (flaps extended) and 1.8 V_{S_1} (flaps retracted), except that the error need not be less than ± 30 feet.]

(c) *Magnetic direction indicator.*

(1) The magnetic direction indicator shall be installed so that its accuracy will not be excessively affected by the airplane's vibration or magnetic fields of a permanent or transient nature.

(2) After the magnetic direction indicator has been compensated, the calibration shall be such that the deviation in level flight does not exceed $\pm 10°$ on any heading.

(3) A calibration placard shall be provided as specified in section 4b.733.

(d) *Automatic pilot system.* If an automatic pilot system is installed, it shall be of an approved type, and the following shall be applicable:

(1) The system shall be so designed that the automatic pilot can be quickly and positively disengaged by the human pilots to prevent it from interfering with their control of the airplane.

(2) A means shall be provided to indicate readily to the pilot the alignment of the actuat-

dispensing equipment for each occupant, arranged so that the mask and oxygen are immediately available in the event of uncontrolled cabin pressure loss, unless it is demonstrated that the rate of cabin pressure reduction following any probable failure and the emergency descent rate of the airplane are such that this type of equipment will not be necessary for protection of the occupants.

(b) *Required minimum mass flow of supplemental oxygen.* The minimum mass flow of supplemental oxygen required per person at various cabin pressure altitudes shall be at least that indicated on figure 4b–21.

(c) *Equipment standards for distribution system.* Where oxygen is to be supplied to both crew and passengers, the distribution system shall be designed to provide either:

(1) A source of supply for the flight crew on duty and a separate source for the passengers and other crew members, or

(2) A common source of supply with means provided so that the minimum supply required by the flight crew on duty can be separately reserved.

(d) *Equipment standards for dispensing units.* An individual dispensing unit shall be provided for each crew member and passenger for whom supplemental oxygen is required to be furnished. Dispensing units required for aircraft certificated for operation at altitudes above 25,000 feet shall cover the nose and mouth. Crew members on flight deck duty in airplanes certificated to operate above 25,000 feet shall be provided with demand equipment. All dispensing units for airplanes certificated to operate at altitudes of not more than 25,000 feet shall be designed to cover the nose, and at least 25 percent of the units required to be furnished shall, in addition, cover the mouth. Crew masks shall permit utilization of necessary communication equipment. (For crew masks to be used for protective breathing purposes see paragraph (h) of this section.)

(e) *Means for determining use of oxygen.* Means shall be provided to enable the crew to determine whether oxygen is being delivered to each user.

(f) *Fire protection.*

(1) Oxygen equipment and lines shall not be located in any designated fire zone.

(2) Oxygen equipment and lines shall be protected from heat which may be generated in or escape from any designated fire zone.

(3) Oxygen equipment and lines shall be so installed that escaping oxygen cannot cause ignition of accumulations of grease, fluids, or vapors which are likely to be present in normal operation or as a result of failure or malfunctioning of any system.

(g) *Protection from rupture.* Oxygen pressure tanks and lines between tanks and the shutoff means shall be protected from the effects of unsafe temperatures, and shall be so located in the airplane as to minimize the possibility and the hazards of rupture in a crash landing.

(h) *Protective breathing system.* When protective breathing equipment is required by the Civil Air Regulations, it shall be designed to protect the flight crew from the effects of smoke, carbon dioxide, and other harmful gases while on flight deck duty and while combating fires in cargo compartments (see sec. 4b.380 (c)). The protective breathing equipment and the necessary supply of oxygen shall be in accordance with the following provisions:

[(1) The protective breathing equipment shall include masks covering the eyes, nose, and mouth, or only the nose and mouth when accessory equipment is provided to protect the eyes. Such equipment while in use shall not prevent the flight crew from using the radio equipment of the airplane or from communicating with each other while at their assigned duty stations. That part of the equipment provided to protect the eyes shall be of a type and construction which will not cause any appreciable adverse effect on vision and shall permit wearing corrective glasses by individual members of the flight crew.]

(2) A supply of protective oxygen per crew member shall be of 15-minute duration at a pressure altitude of 8,000 feet and a respiratory minute volume of 30 liters per minute BTPD.

NOTE: When a demand type oxygen system is employed, a supply of 300 liters of free oxygen at 70° F. and 760 mm Hg. pressure is considered to be of 15-minute duration at the prescribed altitude and minute volume. When a continuous flow protective breathing system is used, including a mask with a standard rebreather bag, a flow rate of 60 liters per minute at 8,000 feet (45 liters per minute at sea level) and a supply

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of 600 liters of free oxygen at 70° F. and 760 mm Hg. pressure is considered to be of 15-minute duration at prescribed altitude and minute volume. (BTPD refers to body temperature conditions, i. e., 37° C., at ambient pressure, dry.)

(19 F. R. 4466, July 20, 1954, effective Sept. 1, 1954.)

4b.651–1 *Safety precautions (CAA policies which apply to sec. 4b.651 (a))*. The oxygen system should be so located that leakage or failure in other systems carrying inflammable liquids or gases will not cause the inflammable liquid or gas to come in contact with oxygen lines or equipment. A relief valve or some other means is desirable in low pressure (400 p. s. i.) oxygen systems to safely relieve excessive pressures such as might be caused by overcharging. (See also sec. 4b.481 concerning location of tanks containing inflammable fluids.)

(15 F. R. 8904, Dec. 15, 1950, effective Jan. 1, 1951.)

4b.651–2 *Protective breathing equipment (CAA policies which apply to sec. 4b.651 (h))*.

(a) *Conditions under which protective breathing equipment may be necessary*. These conditions are those outlined in sections 4b.484–1, 40.205–2, 41.24c–2, and 42.29–2.

(b) *Oxygen systems for flight deck duty*. The demand type oxygen system, or the diluter-demand type system with the lever of the diluter-demand regulator set at "100% OXYGEN" (Automix "OFF") are recommended for use as protective breathing equipment. However, a continuous flow protective breathing system may also be used. In any case the equipment should meet the requirements of section 4b.651 (h).

(c) *Portable equipment for flight deck duty*. Portable protective breathing units of the demand type may be used to meet the requirement of section 4b.651 in lieu of installing a fixed protective breathing system. Portable continuous flow protective breathing units may also be used, but should not be used during fire fighting in Class A or B cargo compartments since any unused oxygen escaping from around the face mask might aggravate the existing fire.

(d) *Masks and goggles*.

(1) Protective breathing masks should fit snugly to prevent the entry of noxious gases. Continuous flow protective breathing masks should have no apertures through which outside air could be drawn into the system and should have a rebreathing bag of at least ⅔ liter capacity. The masks should be installed so as to be readily available to the appropriate crew members. It should be possible for at least the pilot or copilot to maintain ground to air radio voice communications when utilizing the protective breathing masks.

(2) Eye protecting goggles may be a part of or separate from the breathing mask. The goggles should provide an adequate field of vision and a means should be provided to overcome any unsatisfactory fogging tendency of the goggles. Periodic application of an effective antifogging agent on the lens is a satisfactory means of overcoming fogging.

(e) *Operating Instructions*. Operating instructions appropriate to the type of system and masks installed should be provided for the flight crew on placards and/or in the Airplane Flight Manual.

(15 F. R. 8904, Dec. 15, 1950, effective Jan. 1, 1951, revised 19 F. R. 4446, July 20, 1954, effective Sept. 1, 1954.)

4b.651–3 *Supplemental breathing equipment (CAA policies which apply to sec. 4b.651)*.

(a) *Oxygen systems*.

(1) Either a continuous flow type system which uses a rebreather type mask or a diluter-demand type system with the lever of the diluter-demand regulator set in the "NORMAL" (Automix "ON") position will satisfactorily provide the supplemental oxygen required for protection against anoxia. The continuous flow system may be of the type which controls the oxygen flow by means of a hand adjustment type regulator, or an automatic type regulator.

(2) A diluter-demand type system with the lever of the diluter-demand regulator set in the "100% OXYGEN" (Automix "OFF") position or a straight demand type system which uses a nondiluter-demand regulator may be used for supplementary breathing purposes as protection against anoxia. However, such use is not recommended due to the lack of oxygen economy of these systems when used to supply supplementary oxygen. As mentioned in sec-

tion 4b.651–2, either of these closed demand systems is satisfactory for protection against toxic gases.

(b) *Operating instructions.* Operating instructions appropriate to the type of system and masks installed should be provided for the flight crew and other crew members concerned.

These instructions should include a graph or a table which will show the duration of the

(c) *Burst pressure strength.* Individual hydraulic system elements shall be designed to withstand pressures which are sufficiently increased over the pressures prescribed in paragraph (b) of this section to safeguard against rupture under service conditions.

NOTE: The following pressures, in terms of percentage of maximum operating pressure for the particular element, in most instances are sufficient to insure against rupture in service: 250 percent in units under oil pressure, 400 percent in units containing air and oil under pressure and in lines, hoses, and fittings, 300 percent in units of system subjected to back pressure.

4b.654 *Hydraulic systems; design.*

(a) *Pressure indication.* A means shall be provided to indicate the pressure in each main hydraulic power system.

(b) *Pressure limiting provisions.* Provision shall be made to assure that pressures in any part of the system will not exceed a safe limit above the maximum operating pressure of the system and to insure against excessive pressures resulting from fluid volumetric changes in all lines which are likely to remain closed long enough for such changes to take place. In addition, consideration shall be given to the possible occurrence of detrimental transient (surge) pressures during operation.

(c) *Installation.* Hydraulic lines, fittings, and components shall be installed and supported to prevent excessive vibration and to withstand inertia loads. All elements of the installation shall be protected from abrasion, corrosion, and mechanical damage.

(d) *Connections.* Flexible hose, or other means of providing flexibility, shall be used to connect points in a hydraulic fluid line between which there is relative motion or differential vibration.

4b.655 *Hydraulic system fire protection.* When flammable type hydraulic fluid is used, the hydraulic system shall comply with the provisions of sections 4b.385, 4b.481, 4b.482, and 4b.483.

4b.658 *Vacuum systems.*

(a) Means, in addition to the normal pressure relief, shall be provided to relieve automatically the pressure in the discharge lines from the vacuum pump, if the delivery temperature of the air reaches an unsafe value.

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(b) Vacuum system lines and fittings on the discharge side of the pump which might contain flammable vapors or fluids shall comply with section 4b.483 if they are located in a designated fire zone. Other vacuum system components located in designated fire zones shall be fire-resistant.

[4b.659 *Equipment incorporating high energy rotors.* Equipment incorporating high energy rotors shall be demonstrated as capable of containing a failed rotor or shall be so located that failure will not affect the ability of the airplane to continue safe flight.]

Operating Limitations and Information

General

4b.700 *Scope.*

(a) The operating limitations listed in sections 4b.710 through 4b.723 shall be established as prescribed in this part.

(b) The operating limitations, together with any other information concerning the airplane found necessary for safety during operation, shall be included in the Airplane Flight Manual (sec. 4b.740), shall be expressed as markings and placards (sec. 4b.730), and shall be made available by such other means as will convey the information to the crew members.

4b.700–1 *Automatic propeller feathering operating limitations and information (CAA policies which apply to sec. 4b.700).*

(a) All limitations on the use of automatic feathering system, including flight conditions when the system must be operative or inoperative, should be determined and noted when appropriate.

(b) Any placards found necessary should be provided in the airplane.

(c) A complete statement of operating limitations and instructions for the use of the system should be included in the Airplane Flight Manual.

(d) If certification is desired both with and without the feathering system operative, two corresponding sets of performance data properly identified should be included in the Airplane Flight Manual. (See also sec. 4b.10–2.)

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

Operating Limitations

4b.710 *Air-speed limitations; general.* When air-speed limitations are a function of weight, weight distribution, altitude, or Mach number, the values corresponding with all critical combinations of these values shall be established.

4b.711 *Never-exceed speed* V_{NE}.

(a) To allow for possible variations in the airplane characteristics and to minimize the possibility of inadvertently exceeding safe speeds, the never-exceed speed V_{NE} shall be a speed established sufficiently below the lesser of:

(1) The design dive speed V_D chosen in accordance with section 4b.210 (b) (5), or

(2) The maximum speed demonstrated in flight in accordance with section 4b.190.

(b) In the absence of a rational investigation, the value of V_{NE} shall not exceed 0.9 times the lesser of the two speeds referred to in paragraph (a) of this section.

NOTE: Where speeds are limited by compressibility effects, this section is intended to provide an adequate margin between M_{NE} and the lowest of the following Mach values: M_D, M_{DF}, or the Mach number where adverse flight characteristics, such as the following, occur: Undue reduction in ability to recover; rapid or large changes in stability during level flight or recovery which would cause the airplane to exceed structural limits; buffeting so severe as to endanger the structural integrity of the airplane. The speed margin required usually depends upon the effectiveness of the warning provided to the pilots whenever M_{NE} is reached or exceeded, and upon the recovery or speed control characteristics of the airplane. In any case the margin should be sufficient: To enable recovery from mild upsets due to gusts or inadvertent control movements or trim changes; to allow for inadvertent increases in Mach number due to horizontal gusts or temperature inversions; and, for instrument inaccuracies or airplane production differences. The probability of the simultaneous occurrence of the aforementioned speed margin conditions are usually considered, but the effects of all such conditions are not necessarily additive.

4b.712 *Normal operating limit speed* V_{NO}.

(a) The normal operating limit speed V_{NO} shall be established not to exceed the design cruising speed V_C chosen in accordance with section 4b.210 (b) (4) and sufficiently below the never-exceed speed V_{NE} to make it unlikely that V_{NE} would be exceeded in a moderate upset occurring at V_{NO}.

(b) In the absence of a rational investigation, the value of V_{NO} shall not exceed 0.9 times V_{NE}.

(c) At altitudes where V_{NE} is limited by compressibility, a spread between V_{NO} and V_{NE} shall not be required; i. e., M_{NO} equal to the lesser of M_{NE} or M_C shall be acceptable.

4b.713 *Maneuvering speed.* The maneuvering speed shall not exceed the design maneuvering speed V_A determined in accordance with section 4b.210 (b) (2).

4b.714 *Flap extended speed* V_{FE}.

(a) The flap extended speed V_{FE} shall be established not to exceed the lesser of:

(1) The design flap speed V_F chosen in accordance with section 4b.210 (b) (1), or

(2) The design speed for slipstream effects with flaps in the landing position, chosen in accordance with section 4b.221.

(b) The value of V_{FE} established in accordance with paragraph (a) of this section shall not be less than a value which provides a safe speed margin above the stall during approach and landing.

(c) It shall be acceptable to establish supplementary values of V_{FE} for other combinations of flap setting, air speed, and engine power, if the structure and the flight characteristics of the airplane have been shown to be satisfactory for such combinations.

4b.715 *Landing gear operating speed* V_{LO}. The landing gear operating speed V_{LO} shall be established not to exceed a speed at which it is safe to extend or retract the landing gear as limited by design in accordance with section 4b.334 or by flight characteristics.

4b.716 *Landing gear extended speed* V_{LE}. The landing gear extended speed V_{LE} shall be established not to exceed a speed at which it has been shown that the airplane can be safely flown with the landing gear secured in the fully extended position, and for which the structure has been proven in accordance with section 4b.334.

4b.717 *Minimum control speed* V_{MC}. (See sec. 4b.133.)

[4b.718 *Powerplant limitations.* The following powerplant limitations shall be established for the airplane as applicable for the

type(s) of engine(s) installed. They shall not exceed the corresponding limits established as part of the type certification of the engine and propeller installed in the airplane.

[(a) *Take-off operation.*

[(1) Maximum rotational speed (r. p. m.);

[(2) Maximum permissible manifold pressure;

[(3) Maximum permissible gas temperature for turbine engines;

[(4) The time limit for use of the power which corresponds with the values established in subparagraphs (1) through (3) of this paragraph;

[(5) When the time limit established in subparagraph (4) of this paragraph exceeds 2 minutes, the maximum allowable cylinder head and oil temperatures; and

[(6) Maximum cylinder head and oil temperatures if these differ from the maximum limits for continuous operation.

[(b) *Maximum continuous operation.*

[(1) Maximum rotational speed (r. p. m.);

[(2) Maximum permissible manifold pressure; and

[(3) Maximum permissible cylinder head, oil, and gas temperatures.

[(c) *Fuel grade or specification designation.*

[(1) The minimum grade of fuel required for satisfactory operation at the limits specified in paragraphs (a) and (b) of this section for reciprocating engines, and

[(2) The designation of the fuel required for satisfactory operation at the limits specified in paragraphs (a) and (b) of this section for turbine engines.]

4b.718–1 *Powerplant limitations governing minimum quantity of anti-detonant fluid required for takeoff (CAA policies which apply to sec. 4b.718).* The Airplane Flight Manual should include a limitation indicating that the minimum quantity of anti-detonant fluid required is that determined from section 4b.420–1 (a) and (b). If the performance characteristics of the airplane are such that wet power is required for takeoff but may or may not be required for landing, depending upon airport location or characteristics, the Airplane Flight Manual may include information covering minimum allowable quantities under both conditions.

(20 F. R. 2281, Apr. 8, 1955, effective Apr. 30, 1955.)

4b.719 *Airplane weight, center of gravity, and weight distribution limitations.* The airplane weight, center of gravity, and weight distribution limitations shall be those prescribed in sections 4b.101, 4b.102 and 4b.103. Where the airplane is certificated for more than one center of gravity range, the appropriate limitations with regard to weight and loading procedures shall be set forth in the Airplane Flight Manual for each separate center of gravity range.

4b.720 *Minimum flight crew.* The minimum flight crew shall be established by the Administrator as that number of persons which he finds necessary for safety in the operations authorized under section 4b.721. This finding shall be based upon the work load imposed upon individual crew members with due consideration given to the accessibility and the ease of operation of all necessary controls by the appropriate crew members.

4b.721 *Types of operation.* The types of operation to which the airplane is limited shall be established by the category in which it has been found eligible for certification and by the equipment installed. (See the operating rules in this subchapter.)

4b.722 *Maximum operating altitude.* A maximum altitude shall be established up to which operation is permitted, as limited by flight, structural, powerplant, functional, or equipment characteristics.

4b.723 *Maneuvering flight load factors.* Load factor limitations shall be established not to exceed the positive limit load factors determined from the maneuvering diagram, figure 4b–2. (See sec. 4b.211 (a).)

Markings and Placards

4b.730 *General.*

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

(b) Additional information, placards, and instrument markings having a direct and im-

portant bearing on safe operation of the airplane shall be required when unusual design, operating, or handling characteristics so warrant.

4b.730–1 *Reverse thrust placards (CAA policies which apply to sec. 4b.730).* The policies outlined in section 4b.402–1 (b) will apply.

(20 F. R. 2281, Apr. 8, 1955, effective Apr. 30, 1955.)

4b.731 ***Instrument markings; general.***

(a) When markings are placed on the cover glass of the instrument, provision shall be made to maintain the correct alignment of the glass cover with the face of the dial.

(b) All arcs and lines shall be of sufficient width and so located that they are clearly visible to the pilot.

[4b.732 ***Air-speed limitation information.*** **The air-speed limitations (see sec. 4b.741 (a)) shall be presented in such a manner that they can be easily read and interpreted by the flight crew.]**

4b.733 ***Magnetic direction indicator.*** **A placard shall be installed on or in close proximity to the magnetic direction indicator which shall comply with the following:**

(a) The placard shall contain the calibration of the instrument in a level flight attitude with engine(s) operating.

(b) The placard shall state whether the calibration was made with radio receiver(s) on or off.

(c) The calibration readings shall be in terms of magnetic headings in not greater than 45° increments.

4b.734 ***Powerplant instruments; general.*** **All required powerplant instruments shall be marked as follows:**

(a) The maximum and the minimum (if applicable) safe operational limits shall be marked with red radial lines.

(b) The normal operating ranges shall be marked with a green arc not extending beyond the maximum and minimum safe operational limits.

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

(d) Engine or propeller speed ranges which are restricted because of excessive vibration stresses shall be marked with red arcs.

4b.735 ***Oil quantity indicators.*** **Oil quantity indicators shall be marked in sufficient increments to indicate readily and accurately the quantity of oil.**

4b.736 ***Fuel quantity indicator.*** **When the unusable fuel supply for any tank exceeds 1 gallon or 5 percent of the tank capacity, whichever is the greater, a red arc shall be marked on the indicator extending from the calibrated zero reading to the lowest reading obtainable in the level flight attitude. A notation in the Airplane Flight Manual shall be made to indicate that the fuel remaining in the tank when the quantity indicator reaches zero in not usable in flight. (See sec. 4b.613 (b).)**

4b.737 ***Control markings; general.*** **All cockpit controls, with the exception of the primary flight controls and other controls the function of which is obvious, shall be plainly marked and/or identified as to their function and method of operation. The markings shall include the following:**

(a) ***Aerodynamic controls.*** **The secondary aerodynamic controls shall be marked to comply with sections 4b.322 and 4b.323.**

(b) ***Powerplant fuel controls.***

(1) Controls for fuel tank selector valves shall be marked to indicate the position corresponding with each tank and with all possible cross-feed positions.

(2) When more than one fuel tank is provided, and if safe operation depends upon the use of tanks in a specific sequence, the fuel tank selector controls shall be marked adjacent to or on the control itself to indicate the order in which the tanks should be used.

(3) Controls for engine selector valves shall be marked to indicate the position corresponding with each engine.

(c) ***Accessory and auxiliary controls.***

(1) When a retractable landing gear is used, the visual indicator required in section 4b.334 (e) shall be marked so that the pilot can ascertain at all times when the wheels are locked in either extreme position.

(2) Emergency controls, including fuel jettisoning and fluid shutoff controls, shall be

(i) The two engines shall be assumed to fail at the most critical point along the route.

(ii) If fuel jettisoning is provided, the airplane's weight at the point where the two engines are assumed to fail shall be considered to be not less than that which would include sufficient fuel to proceed to the airport and to arrive there at an altitude of at least 1,000 feet directly over the landing area.

(iii) The consumption of fuel and oil after the engines become inoperative shall be that which is accounted for in the net flight path data shown in the Airplane Flight Manual.

40T.84 *Landing limitations.*

(a) *Airport of destination.* No airplane shall be taken off at a weight in excess of that which, in accordance with the landing distances shown in the Airplane Flight Manual for the elevation of the airport of intended destination and for the wind conditions anticipated there at the time of landing, would permit the airplane to be brought to rest at the airport of intended destination within 60 percent of the effective length of the runway from a point 50 feet directly above the intersection of the obstruction clearance plane and the runway. The weight of the airplane shall be assumed to be reduced by the weight of the fuel and oil expected to be consumed in flight to the airport of intended destination. Compliance shall be shown with the conditions of subparagraphs (1) and (2) of this paragraph. (See secs. 4T.123 (b) and 4T.743 (b).)

(1) It shall be assumed that the airplane is landed on the most favorable runway and direction in still air.

(2) It shall be assumed that the airplane is landed on the most suitable runway considering probable wind velocity and direction and taking due account of the ground handling characteristics of the airplane and of other conditions (i. e., landing aids, terrain, etc.). If full compliance with the provisions of this subparagraph is not shown, the airplane may be taken off if an alternate airport is designated which permits compliance with paragraph (b) of this section.

(b) *Alternate airport.* No airport shall be designated as an alternate airport is a dispatch release unless the airplane at the weight anticipated at the time of arrival at such airport can comply with the provisions of paragraph (a) of this section, provided that the airplane can be brought to rest within 70 percent of the effective length of the runway.

SPECIAL CIVIL AIR REGULATION NO. SR-422A

Effective: July 2, 1958
Adopted: July 2, 1958

Turbine-Powered Transport Category Airplanes of Current Design

On July 23, 1957, the Board adopted Special Civil Air Regulation No. SR-422 which sets forth airworthiness requirements applicable to the type certification and operation of turbine-powered transport category airplanes for which a type certificate is issued after August 27, 1957. Included in that regulation was a new set of performance requirements, with respect to which the Board indicated that consideration would be given to any changes found necessary as a result of further study and experience. The preamble to SR–422 contains the relevant considerations leading to its promulgation and is considered to provide the basic background for this regulation.

Since the adoption of SR–422, considerable study has been devoted to the new performance requirements by all interested parties. As a result of these studies and of further experience gained in the design, certification, and operation of turbine-powered airplanes, certain issues with respect to SR–422 require re-evaluation. This regulation reflects the resolution of most of the outstanding issues in the light of the best information presently available to the Board.

The following provisions of this regulation differ from, or are additional to, the provisions of SR–422: Introductory paragraph; item 1; sections 4T.111 (c); 4T.112; 4T.114 (b), (b) (1), (b) (4), and (c); introductory paragraph of 4T.116; 4T.116 (b), (c), (e), and (g); 4T.117; 4T.117a; 4T.119; 4T.120 (a), (a) (1), (b), (b) (1), (c), (c) (2), (c) (3), (d), and (d) (3); 4T.121 (a) and (b); introductory paragraph of 4T.122; 4T.122 (b), (f), and (g); 4T.123 (a) (1), (a) (2), (a) (3), and (b); 4T.743 (c); 40T.81 (b) and (c); 40T.82; 40T.83 (a) (2) (iii), (b) (2), and (b) (2) (ii); item 4; and item 5. Of these provisions, the following differ from those proposed in Civil Air Regulations Draft Release No. 58–6: sections 4T.111 (c); 4T.112 (a) (4); 4T.114 (b) (4), (c), (c) (2), (c) (3), and (c) (4); 4T.116 (c) and (e); 4T.117 (b) (1) and (b) (2); 4T.119 (a); 4T.120 (a); 40T.81 (c) and 43T.11 (c).

With respect to the applicability of this regulation, experience with certification under SR–422 indicates that a lead time of about two months between the date of adoption of the regulation and the date of issuance of the type certificate should provide a reasonable period of time within which to show compliance with this regulation. In view of this, and in the interest of having uniform regulations applicable to most of the turbine-powered airplanes, it is considered advisable to have this regulation apply to all such airplanes for which a type certificate is issued after September 30, 1958. Turbine-powered transport category airplanes for which a type certificate is issued on or prior to September 30, 1958, may comply with the provisions of this regulation in lieu of SR–422. If this option is exercised, it is intended that compliance be shown with all the provisions of this regulation and it is not intended to permit a showing of compliance with portions of this regulation and portions of SR–422.

The provisions of this regulation involved the following technical issues:

A substantive change is made by introducing an all-engine-operating take-off in establishing the take-off distance. Presently, the take-off distance is based only on a one-engine-out take-off. To insure that an adequate margin of safety will exist for day-in and day-out operations, the minimum take-off distance is being related to both the one-engine-inoperative distance now prescribed and to the distance with all engines operating, with a factor of 1.15 being applied to the latter.

There are also included important changes with respect to the speeds applicable to the take-off path. The provisions of SR–422 prescribe that the airplane shall be accelerated on or near the ground to the speed V_2. This provision has been subject to varying interpretations having a marked difference in effect on the resultant level of performance. The issue in this matter is whether or not the airplane should be permitted to lift off the runway at some speed below V_2. Because of the increased acceleration of turbine-powered airplanes, the tendency to overshoot the lift-off speed will be greater than on piston-engine airplanes and this tendency increases with the reduction in weight of the airplane. To restrict lift-off to the minimum take-off safety speed V_2 would unduly extend the take-off distance in cases where such overshooting of speed occurs. Such a restriction would be unnecessarily conservative and would not reflect realistic take-off procedures. For these reasons this regulation permits the airplane to lift off the ground at a speed lower than the V_2 speed, but prescribes certain limiting conditions. The lift-off speed is related to a rotational speed V_R which must not be less than 95 percent of the minimum V_2 speed and must be 10 percent greater than a speed at which no hazardous characteristics are displayed by the airplane, such as a relatively high drag condition or a ground stall. The V_2 speed has been re-defined to take into account the increment in speed arising from overshoot tendencies. Under the new definition, the minimum V_2 speed corresponds with the minimum take-off safety speed as now defined in SR–422. With respect to the take-off path, the V_2 speed is required to be attained prior to reaching a height of 35 feet above the take-off surface and thus is related to the selection of the rotational speed. Further, there is a revision which requires V_2 to be maintained as close as practicable at a constant value from the 35-foot point to a height of 400 feet above the take-off surface. This speed is the speed at which the prescribed minimum take-off gradients must be met.

There is introduced in this regulation the concept of unbalanced take-off field lengths. SR–422 does not preclude unbalancing of field lengths, provided that the unbalancing is within the length of the runway. Other countries have employed unbalancing with respect to so-called "stopways" and "clearways." It appears that United States operators ultimately will find it advantageous to resort to the use of unbalancing, but probably not to the same extent as practiced in other countries. On the premise that only clearways will be utilized, the amendments have been formulated accordingly. Clearways, as defined herein, are areas not suitable for stopping the airplane in the event of an aborted take-off, but adequate to provide additional take-off distance for climb-out. To safeguard operations utilizing clearways, there is introduced the concept of a take-off run which operationally relates to the determination of the minimum runway length required. The take-off run is defined as the greater of the horizontal distances along the take-off path to a given point with one engine inoperative or with all engines operating, with a margin of 15 percent being added to the latter. The take-off run is measured from the beginning of take-off to a point equidistant between the point where the airplane lifts off and the point where a height of 35 feet is reached. The required runway length must not be less than the take-off run nor less than the accelerate stop distance.

According to the definition given, a clearway is subjected to the control of the airport authorities. It is not intended, however, that there be ownership by the airport authorities of the area in which the clearway lies. The objective for requiring control by the airport authorities is to insure that no flight will be initiated using a clearway unless it is determined with certainty that no movable obstacle will exist within the clearway when the airplane flies over.

It is anticipated that the introduction of clearways will offer further possibilities of increasing the utility of existing airport facilities in this country. When such areas can be integrated into existing facilities, economical benefits will accrue to the community and the operators. In addition, since clearways are presently available at some of the airports in other countries, United States operators will have the opportunity of taking advantage of such facilities.

There are included changes with respect to the prescribed minimum altitude of 1,000 feet relative to the take-off path and to the one-engine-inoperative and two-engine-inoperative requirements applicable to the vicinity of the airport. Heretofore, the Civil Air Regulations have incorporated the reference altitude of 1,000 feet in respect of performance criteria over the airport. Obscure as is the significance of this altitude operationally, the altitude of 1,500 feet has worldwide precedent of being used as the altitude above the airport at which, generally, IFR approaches are initiated and go-around procedures executed. For this reason, the changes made extend the take-off path to a minimum altitude of 1,500 feet and make this altitude applicable to the prescribed performance criteria above the airport for the one- and two-engine-inoperative en route requirements. It is not anticipated that these changes will create any problem with respect to the en route stages of flight; however, it is realized that a further extension of the take-off path might add to the problem of obtaining accurate data on obstacles relatively distant from the airport. The Board finds that the extension of the flight path to 1,500 feet is warranted in light of the operational significance of this altitude and because the extended flight paths will provide more fully for adequate terrain clearance at the end of the take-off path.

There is included a change with respect to the take-off path whereby the take-off flight path is established as starting from a 35-foot height at the end of the take-off distance and a net take-off flight path is prescribed for operational use. This latter change is for consistency with the specification of net flight paths for the en route stages of flight and to simplify determination of obstacle clearances operationally. The net flight path is specified to be the actual flight path diminished by a gradient of 1.0 percent. It is intended that the net flight path be obtained from the gross flight path by simple geometric means.

The change in the altitude from 1,000 to 1,500 feet previously mentioned, as well as a re-evaluation in other respects of some of the climb gradients in SR-422, justify certain changes. The gradients of 1.4 and 1.8 applicable to the take-off path and the final take-off climb are being reduced to 1.2 and 1.7 for two-engine and four-engine airplanes, respectively. In addition, the gradients of 1.4 and 1.8 in the one-engine-inoperative en route case are being reduced to 1.1 and 1.6, respectively.

Changes are made with respect to the one-engine-inoperative take-off climb by interrelating more realistically the prescribed airplane configuration, weight, and power. These changes, in effect, permit meeting the prescribed gradients of climb at slightly higher airplane weights than would be possible under the presently effective provisions.

There is included a change to the provisions applicable to the one-engine-inoperative take-off climb with landing gear extended which increases the prescribed minimum gradient from substantially zero to 0.5 percent for four-engine airplanes. This change is made to attain consistency in the difference between gradients applicable to twins and fours.

Changes are incorporated in connection with the two-engine-inoperative en route requirement. Representations have been made that the gradient of 0.6 percent now prescribed is unduly conservative. On the other hand, it has been pointed out that the fuel requirements for this case are not realistically covered. Both of these contentions warrant consideration and changes are included which reduce the margin gradient from 0.6 to 0.5 percent, reduce the prescribed altitude from 5,000 to 2,000 feet, and require scheduling the flight so that there is sufficient fuel on board to reach the airport and subsequently to fly for 15 minutes at cruise power or thrust.

Changes are also made relative to the approach and landing stages of flight. There is a new provision which requires the establishment of procedures for the execution of missed approaches and balked landings. A question has been raised as to whether the speed limitation of 1.5 V_S applicable to the approach condition is realistically related to the normal day-in and day-out landing procedures. To insure that it will be so related, it is required that the speed used for demonstrating the approach climb be established consistent with the landing procedures, but that it not exceed 1.5 V_S. In addition, the approach gradient of 2.8 percent prescribed for four-engine airplanes is being reduced to 2.7 percent to obtain consistency in the differences between gradients applicable to twins and fours.

A change is made to the "all-engines-operating landing climb" provisions which now require a 4.0 percent gradient of climb in the landing configuration. On the premise that requiring the landing configuration during the climb after a balk is unduly conservative, consideration was given to a proposal to permit showing of compliance with the 4.0 percent gradient of climb in the configuration which would exist 5 seconds after the initiation of the climb. Further study of this proposal indicated that such a rule would tend to introduce complications in design and lead to less favorable operating procedures which ultimately would not contribute to safety. One of the most important factors in connection with this configuration is the response of the engines to throttle movement. Therefore, there is a provision which requires that the power used in showing compliance with the climb gradient be that power or thrust attained 8 seconds after initiation of movement of the power controls to the take-off position from the minimum flight idle position. In addition, for consistency with the procedures used for determining the landing distance, the speed limitation of 1.4 V_S is reduced to 1.3 V_S. Concern has been indicated to the effect that any reduction in the prescribed gradient of 4.0 percent might not insure in all cases the ability of the airplane to continue a safe climb after a balk. To provide a further safeguard, the take-off weight-altitude-temperature limitations (WAT limitations stemming from the application of the one-engine-inoperative take-off climb requirements) are being made applicable to the maximum landing weight at the airport of landing. In the past, the landing weight limitations were applicable to the airport of destination but not to the weather alternates. This regulation makes both the take-off weight and landing weight limitations equally applicable to the airport of destination and the weather alternates. In view of the aforementioned changes, a reduction of the required climb gradient from 4.0 to 3.2 percent is justified and included in this regulation.

In addition to the substantive changes which have been discussed, there are three significant changes of a clarifying nature. The first deals with the determination of the landing distance as effected by devices or means other than wheel brakes. There is included a provision similar to the one applicable to the accelerate-stop distance for application to the landing distance. This provision permits the use of means other than wheel brakes in the determination of the landing distance. Additionally, there is a change to the provision which requires in some cases the determination of the landing distance with one engine inoperative. It is believed that the new requirement expresses the intent more clearly. One of the more obvious applications of this provision is in respect of turbo-propeller airplanes. Such airplanes usually are landed with the propellers in a relatively high drag position. If one of the engines becomes inoperative, its propeller would be expected to be in a relatively low drag position with the consequence of a longer landing distance than with all engines operating. In such a case it is required that the landing distance be determined with one engine inoperative unless use could be made by the crew of other means (e. g., reverse thrust not otherwise considered in determining the landing distance) which would reduce the landing distance at least to that determined for all-engine operation.

The second clarification being included deals with the provision setting forth the procedures which must be included in the Airplane Flight Manual. This provision in SR–422 does not make clear what procedures are involved and whether the procedures are considered to be limitations on the operation of the airplane. The clarification in language specifies that the procedures which are included with the performance limitations shall be considered only as guidance material.

The third clarification concerns the applicability of the performance limitations prescribed in SR–422. These consist of the "certificate limitations" and the "operating limitations." The former relate to maximum take-off and landing weights, minimum take-off distances, accelerate-stop distances, and the operational limits imposed upon the airplane. These limitations, being part of the conditions of the type and airworthiness certificates, must be complied with at all times irrespective of the type of operation being conducted (e. g., air carrier, private, cargo). The "operating limitations," distinct from the "certificate limitations," are only applicable when required by the operating parts of the regulations (Parts 40, 41, and 42 require compliance for passenger operations). Although it appeared that previous Board pronouncements regarding this general principle as well as the explanation contained in the preamble to SR–422 would make the issue quite clear, it has come to the Board's attention that there is still some misunderstanding of this matter. Apparently this misunderstanding stems from the fact that SR–422 prescribes operating rules for air carrier operations which contain both the "certificate limitations" and the "operating limitations" while no prescription is given to non-air-carrier operations; thus giving an impression that not even the "certificate limitations" are applicable to non-air-carriers. The inclusion of "certificate limitations" for air carrier operation with the "operating limitations" was meant only to provide the operators with the convenience of having together the complete prescription of the applicable performance limitations, notwithstanding that such an inclusion, in fact, duplicates the general requirement of compliance with the "certificate limitations" contained in the Airplane Flight Manual. In view of the possible misunderstanding which might exist from the aforementioned inclusion, there are included in this regulation the same "certificate limitations" for application to all operations under the provisions of Part 43 of the Civil Air Regulations.

In addition, other changes of a minor nature are included herein, the most significant of which is the generalization of the stall speed V_S, eliminating reference to V_{S_0} and V_{S_1}.

Of the changes to SR–422 made in this regulation, there are a number which might require further consideration as studies continue and as additional experience is gained with the application of these new rules. Several of these involve new concepts with which U. S. operators have had little or no experience. These entail the requirements relative to unbalanced field lengths with respect to clearways, to the rotational speed, and to the all-engine take-off distance. Strong representation has been made to the Board to the effect that the numerical factors applicable to the aforementioned rules are too high and should be reduced pending further experience. The Board considers that it would not be in the public interest to reduce any of these factors until such time as further experience indicates that they are in fact overly conservative. Realizing, however, that these issues are of considerable importance in prescribing a practicable level of performance, the Board stands ready to reconsider the relevant provisions of this regulation at such time as substantiating information is received.

There are areas other than those previously mentioned where additional refinement of details may be advisable. This is so particularly in the case of the requirements pertaining to the landing stage of flight, to the take-off lateral clearances, and to the two-engine-inoperative en route gradient margin. It is anticipated that, after further study of the regulation and especially after its application in the design, certification, and operation of forthcoming turbine-powered airplanes, the desirability of changes may become more apparent. It is the intent of the Board to consider without delay such changes as might be found necessary. Only after the provisions of this Special Civil Air Regulation are reasonably verified by practical application will the Board consider incorporating them on a more permanent basis into Parts 4b, 40, 41, 42, and 43 of the Civil Air Regulations.

This Special Civil Air Regulation is not intended to compromise the authority of the Administrator under section 4b.10 to impose such special conditions as he finds necessary in any particular case to avoid unsafe design features and otherwise to insure equivalent safety.

Interested persons have been afforded an opportunity to participate in the making of this regulation (23 F. R. 2139), and due consideration has been given to all relevant matter presented.

In consideration of the foregoing, the Civil Aeronautics Board hereby makes and promulgates the following Special Civil Air Regulation, effective July 2, 1958:

Contrary provisions of the Civil Air Regulations notwithstanding, all turbine-powered transport category airplanes for which a type certificate is issued after August 27, 1957, shall comply with Special Civil Air Regulation No. SR–422 or, alternatively, with the following provisions, except that those airplanes for which a type certificate is issued after September 30, 1958, shall comply with the following provisions:

1. The provisions of Part 4b of the Civil Air Regulations, effective on the date of application for type certificate; and such of the provisions of all subsequent amendments to Part 4b, in effect prior to August 27, 1957, as the Administrator finds necessary to insure that the level of safety of turbine-powered airplanes is equivalent to that generally intended by Part 4b.

2. In lieu of sections 4b.110 through 4b.125, and 4b.743 of Part 4b of the Civil Air Regulations, the following shall be applicable:

PERFORMANCE

4T.110 *General.*

(a) The performance of the airplane shall be determined and scheduled in accordance with, and shall meet the minima prescribed by, the provisions of sections 4T.110 through 4T.123. The performance limitations, information, and other data shall be given in accordance with section 4T.743.

(b) Unless otherwise specifically prescribed, the performance shall correspond with ambient atmospheric conditions and still air. Humidity shall be accounted for as specified in paragraph (c) of this section.

(c) The performance as affected by engine power and/or thrust shall be based on a relative humidity of 80 percent at and below standard temperatures and on 34 percent at and above standard temperatures plus 50° F. Between these two temperatures the relative humidity shall vary linearly.

(d) The performance shall correspond with the propulsive thrust available under the particular ambient atmospheric conditions, the particular flight condition, and the relative humidity specified in paragraph (c) of this section. The available propulsive thrust shall correspond with engine power and/or thrust not exceeding the approved power and/or thrust less the installational losses and less the power and/or equivalent thrust absorbed by the accessories and services appropriate to the particular ambient atmospheric conditions and the particular flight condition.

4T.111 *Airplane configuration, speed, power, and/or thrust; general.*

(a) The airplane configuration (setting of wing and cowl flaps, air brakes, landing gear, propeller, etc.), denoted respectively as the take-off, en route, approach, and landing configurations, shall be selected by the applicant except as otherwise prescribed.

(b) It shall be acceptable to make the airplane configurations variable with weight, altitude, and temperature, to an extent found by the Administrator to be compatible with operating procedures required in accordance with paragraph (c) of this section.

(c) In determining the accelerate-stop distances, take-off flight paths, take-off distances, and landing distances, changes in the airplane's configuration and speed, and in the power and/or thrust shall be in accordance with procedures established by the applicant for the operation of the airplane in service, except as otherwise prescribed. In addition, procedures shall be established for the execution of balked landings and missed approaches associated with the conditions prescribed in sections 4T.119 and 4T.120 (d), respectively. All procedures shall comply with the provisions of subparagraphs (1) through (3) of this paragraph.

(1) The Administrator shall find that the procedures can be consistently executed in service by crews of average skill.

(2) The procedures shall not involve methods or the use of devices which have not been proven to be safe and reliable.

(3) Allowance shall be made for such time delays in the execution of the procedures as may be reasonably expected to occur during service.

4T.112 *Stalling speeds.*

(a) The speed V_S shall denote the calibrated stalling speed, or the minimum steady flight speed at which the airplane is controllable, in knots, with:

(1) Zero thrust at the stalling speed, or engines idling and throttles closed if it is shown that the resultant thrust has no appreciable effect on the stalling speed;

(2) If applicable, propeller pitch controls in the position necessary for compliance with subparagraph (1) of this paragraph; the airplane in all other respects (flaps, landing gear, etc.) in the particular configuration corresponding with that in connection with which V_S is being used;

(3) The weight of the airplane equal to the weight in connection with which V_S is being used to determine compliance with a particular requirement;

(4) The center of gravity in the most unfavorable position within the allowable range.

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

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

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

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

(a) The take-off data in sections 4T.114 through 4T.117 shall be determined under the conditions of subparagraphs (1) and (2) of this paragraph.

(1) At all weights, altitudes, and ambient temperatures within the operational limits established by the applicant for the airplane.

(2) In the configuration for take-off (see sec. 4T.111).

(b) Take-off data shall be based on a smooth, dry, hard-surfaced runway and shall be determined in such a manner that reproduction of the performance does not require exceptional skill or alertness on the part of the pilot. In the case of seaplanes or float planes, the take-off surface shall be smooth water, while for skiplane it shall be smooth dry snow. In addition, the take-off data shall be corrected in accordance with subparagraphs (1) and (2) of this paragraph for wind and for runway gradients within the operational limits established by the applicant for the airplane.

(1) Not more than 50 percent of nominal wind components along the take-off path opposite to the direction of take-off, and not less than 150 percent of nominal wind components along the take-off path in the direction of take-off.

(2) Effective runway gradients.

4T.114 *Take-off speeds.*

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

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

(1) 1.2 V_S for two-engine propeller-driven airplanes and for airplanes without propellers which have no provisions for obtaining a significant reduction in the one-engine-inoperative power-on stalling speed;

(2) 1.15 V_S for propeller-driven airplanes having more than two engines and for airplanes without propellers which have provisions for obtaining a significant reduction in the one-engine-inoperative power-on stalling speed;

(3) 1.10 times the minimum control speed V_{MC}, established in accordance with section 4b.133 of Part 4b of the Civil Air Regulations;

(4) The rotation speed V_R plus the increment in speed attained in compliance with section 4T.116 (e).

(c) The minimum rotation speed V_R, in terms of calibrated air speed, shall be selected by the applicant, except that it shall not be less than:

(1) The speed V_1;

(2) A speed equal to 95 percent of the highest speed obtained in compliance with subparagraph (1) or (2), whichever is applicable, and with subparagraph (3) of paragraph (b) of this section;

(3) A speed which permits the attainment of the speed V_2 prior to reaching a height of 35 feet above the take-off surface as determined in accordance with section 4T.116 (e);

(4) A speed equal to 110 percent of the minimum speed above which the airplane, with all engines operating, can be made to lift off the ground and to continue the take-off without displaying any hazardous characteristics.

4T.115 *Accelerate-stop distance.*

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

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

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

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

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

4T.116 *Take-off path.* The take-off path shall be considered to extend from the standing start to a point in the take-off where a height of 1,500 feet above the take-off surface is reached or to a point in the take-off where the transition from the take-off to the en route configuration is completed and a speed is reached at which compliance with section 4T.120 (c) is shown, whichever point is at a higher altitude. The conditions of paragraphs (a) through (i) of this section shall apply in determining the take-off path.

(a) The take-off path shall be based upon procedures prescribed in accordance with section 4T.111 (c).

(b) The airplane shall be accelerated on the ground to the speed V_1 at which point the critical engine shall be made inoperative and shall remain inoperative during the remainder of the take-off. Subsequent to attaining speed V_1, the airplane shall be accelerated to speed V_2 during which time it shall be permissible to initiate raising the nose gear off the ground at a speed not less than the rotation speed V_R.

(c) Landing gear retraction shall not be initiated until the airplane becomes airborne.

(d) The slope of the airborne portion of the take-off path shall be positive at all points.

(e) The airplane shall attain the speed V_2 prior to reaching a height of 35 feet above the take-off surface and shall continue at a speed as close as practical to, but not less than, V_2 until a height of 400 feet above the take-off surface is reached.

(f) Except for gear retraction and propeller feathering, the airplane configuration shall not be changed before reaching a height of 400 feet above the take-off surface.

(g) At all points along the take-off path starting at the point where the airplane first reaches a height of 400 feet above the take-off surface, the available gradient of climb shall not be less than 1.2 percent for two-engine airplanes and 1.7 percent for four-engine airplanes.

(h) The take-off path shall be determined either by a continuous demonstrated take-off, or alternatively, by synthesizing from segments the complete take-off path.

(i) If the take-off path is determined by the segmental method, the provisions of subparagraphs (1) through (4) of this paragraph shall be specifically applicable.

(1) The segments of a segmental take-off path shall be clearly defined and shall be related to the distinct changes in the configuration of the airplane, in power and/or thrust, and in speed.

(2) The weight of the airplane, the configuration, and the power and/or thrust shall be constant throughout each segment and shall correspond with the most critical condition prevailing in the particular segment.

(3) The segmental flight path shall be based on the airplane's performance without ground effect.

(4) Segmental take-off path data shall be checked by continuous demonstrated take-offs to insure that the segmental path is conservative relative to the continuous path.

4T.117 *Take-off distance and take-off run.*

(a) *Take-off distance.* The take-off distance shall be the greater of the distances established in accordance with subparagraphs (1) and (2) of this paragraph.

(1) The horizontal distance along the take-off path from the start of the take-off to the point where the airplane attains a height of 35 feet above the take-off surface, as determined in accordance with section 4T.116.

(2) A distance equal to 115 percent of the horizontal distance along the take-off path, with all engines operating, from the start of the take-off to the point where the airplane attains a height of 35 feet above the take-off surface, as determined by a procedure consistent with that established in accordance with section 4T.116.

(b) *Take-off run.* If the take-off distance is intended to include a clearway (see item 5 of this regulation), the take-off run shall be determined and shall be the greater of the distances established in accordance with subparagraphs (1) and (2) of this paragraph.

(1) The horizontal distance along the take-off path from the start of the take-off to a point equidistant between the point where the airplane first becomes airborne and the point where it attains a height of 35 feet above the take-off surface, as determined in accordance with section 4T.116.

(2) A distance equal to 115 percent of the horizontal distance along the take-off path, with all engines operating, from the start of the take-off to a point equidistant between the point where the airplane first becomes airborne and the point where it attains a height of 35 feet above the take-off surface, as determined by a procedure consistent with that established in accordance with section 4T.116.

4T.117a *Take-off flight path.*

(a) The take-off flight path shall be considered to begin at a height of 35 feet above the take-off surface at the end of the take-off distance as determined in accordance with section 4T.117 (a).

(b) The net take-off flight path data shall be determined in such a manner that they represent the airplane's actual take-off flight paths, determined in accordance with paragraph (a) of this section, diminished by a gradient of climb equal to 1.0 percent.

4T.118 *Climb; general.* Compliance shall be shown with the climb requirements of sections 4T.119 and 4T.120 at all weights, altitudes, and ambient temperatures, within the operational limits established by the applicant for the airplane. The airplane's center of gravity shall be in the most unfavorable position corresponding with the applicable configuration.

4T.119 *All-engine-operating landing climb.* In the landing configuration the steady gradient of climb shall not be less than 3.2 percent, with:

(a) All engines operating at the power and/or thrust which is available 8 seconds after initiation of movement of the power and/or thrust controls from the minimum flight idle to the take-off position;

(b) A climb speed not in excess of 1.3 V_S.

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

(a) *Take-off; landing gear extended.* In the take-off configuration existing at the point of the flight path where the airplane first becomes airborne, in accordance with section 4T.116 but without ground effect, the steady gradient of climb shall be positive for two-engine airplanes and shall not be less than 0.5 percent for four-engine airplanes, with:

(1) The critical engine inoperative, the remaining engine(s) operating at the available take-off power and/or thrust existing in accordance with section 4T.116 at the time retraction of the airplane's landing gear is initiated, unless subsequently a more critical power operating condition exists along the flight path prior to the point where the landing gear is fully retracted;

(2) The weight equal to the airplane's weight existing in accordance with section 4T.116 at the time retraction of the airplane's landing gear is initiated;

(3) The speed equal to the speed V_2.

(b) *Take-off; landing gear retracted.* In the take-off configuration existing at the point of the flight path where the airplane's landing gear is fully retracted, in accordance with section 4T.116 but without ground effect, the steady gradient of climb shall not be less than 2.5 percent for two-engine airplanes and not less than 3.0 percent for four-engine airplanes, with:

(1) The critical engine inoperative, the remaining engine(s) operating at the available take-off power and/or thrust existing in accordance

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with section 4T.116 at the time the landing gear is fully retracted, unless subsequently a more critical power operating condition exists along the flight path prior to the point where a height of 400 feet above the take-off surface is reached;

(2) The weight equal to the airplane's weight existing in accordance with section 4T.116 at the time the airplane's landing gear is fully retracted;

(3) The speed equal to the speed V_2.

(c) *Final take-off.* In the en route configuration, the steady gradient of climb shall not be less than 1.2 percent for two-engine airplanes and not less than 1.7 percent for four-engine airplanes, at the end of the take-off path as determined by section 4T.116, with:

(1) The critical engine inoperative, the reamining engine(s) operating at the available maximum continuous power and/or thrust;

(2) The weight equal to the airplane's weight existing in accordance with section 4T.116 at the end of the take-off path;

(3) The speed equal to not less than 1.25 V_S.

(d) *Approach.* In the approach configuration such that the corresponding V_S for this configuration does not exceed 110 percent of the V_S corresponding with the related landing configuration, the steady gradient of climb shall not be less than 2.2 percent for two-engine airplanes and not less than 2.7 percent for four-engine airplanes with:

(1) The critical engine inoperative, the remaining engine(s) operating at the available take-off power and/or thrust;

(2) The weight equal to the maximum landing weight;

(3) A climb speed established by the applicant in connection with normal landing procedures, except that it shall not exceed 1.5 V_S (see sec. 4T.111 (c)).

4T.121 *En route flight paths.* With the airplane in the en route configuration, the flight paths prescribed in paragraphs (a) and (b) of this section shall be determined at all weights, altitudes, and ambient temperatures within the limits established by the applicant for the airplane.

(a) *One engine inoperative.* The one-engine-inoperative net flight path data shall be determined in such a manner that they represent the airplane's actual climb performance diminished by a gradient of climb equal to 1.1 percent for two-engine airplanes and 1.6 percent for four-engine airplanes. It shall be acceptable to include in these data the variation of the airplane's weight along the flight path to take into account the progressive consumption of fuel and oil by the operating engine(s).

(b) *Two engines inoperative.* For airplanes with four engines, the two-engine-inoperative net flight path data shall be determined in such a manner that they represent the airplane's actual climb performance diminished by a gradient of climb equal to 0.5 percent. It shall be acceptable to include in these data the variation of the airplane's weight along the flight path to take into account the progressive consumption of fuel and oil by the operating engines.

(c) *Conditions.* In determining the flight paths prescribed in paragraphs (a) and (b) of this section, the conditions of subparagraphs (1) through (4) of this paragraph shall apply.

(1) The airplane's center of gravity shall be in the most unfavorable position.

(2) The critical engine(s) shall be inoperative, the remaining engine(s) operating at the available maximum continuous power and/or thrust.

(3) Means for controlling the engine cooling air supply shall be in the position which provides adequate cooling in the hot-day condition.

(4) The speed shall be selected by the applicant.

4T.122 *Landing distance.* The landing distance shall be the horizontal distance required to land and to come to a complete stop (to a speed of approximately 3 knots in the case of seaplanes or float planes) from a point at a height of 50 feet above the landing surface. Landing distances shall be determined for standard temperatures at all weights, altitudes, and winds within the operational limits established by the applicant for the airplane. The conditions of paragraphs (a) through (g) of this section shall apply.

(a) The airplane shall be in the landing configuration. During the landing, changes in the airplane's configuration, in power and/or thrust, and in speed shall be in accordance with procedures established by the applicant for the operation of the airplane in service. The procedures shall comply with the provisions of section 4T.111 (c).

(b) The landing shall be preceded by a steady gliding approach down to the 50-foot height with a calibrated air speed of not less than 1.3 V_S.

(c) The landing distance shall be based on a smooth, dry, hard-surfaced runway, and shall be determined in such a manner that reproduction does not require exceptional skill or alertness on the part of the pilot. In the case of seaplanes or float planes, the landing surface shall be smooth water, while for skiplanes it shall be smooth dry snow. During landing, the airplane shall not exhibit excessive vertical acceleration, a tendency to bounce, nose over, ground loop, porpoise, or water loop.

(d) The landing distance shall be corrected for not more than 50 percent of nominal wind components along the landing path opposite to the direction of landing and not less than 150 percent of nominal wind components along the landing path in the direction of landing.

(e) During landing, the operating pressures on the wheel braking system shall not be in excess of those approved by the manufacturer of the brakes, and the wheel brakes shall not be used in such a manner as to produce excessive wear of brakes and tires.

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

(g) If the characteristics of a device (e. g., the propellers) dependent upon the operation of any of the engines noticeably increase the landing distance when the landing is made with the engine inoperative, the landing distance shall be determined with the critical engine inoperative unless the Administrator finds that the use of compensating means will result in a landing distance not greater than that attained with all engines operating.

4T.123 *Limitations and information.*

(a) *Limitations.* The performance limitations on the operation of the airplane shall be established in accordance with subparagraphs (1) through (4) of this paragraph. (See also sec. 4T.743.)

(1) *Take-off weights.* The maximum take-off weights shall be established at which compliance is shown with the generally applicable provisions of this regulation and with the take-off climb provisions prescribed in section 4T.120 (a), (b), and (c) for altitudes and ambient temperatures within the operational limits of the airplane (see subparagraph (4) of this paragraph).

(2) *Landing weights.* The maximum landing weights shall be established at which compliance is shown with the generally applicable provisions of this regulation and with the landing and take-off climb provisions prescribed in sections 4T.119 and 4T.120 for altitudes and ambient temperatures within the operational limits of the airplane (see subparagraph (4) of this paragraph).

(3) *Accelerate-stop distance, take-off distance, and take-off run.* The minimum distances required for take-off shall be established at which compliance is shown with the generally applicable provisions of this regulation and with sections 4T.115 and 4T.117 (a), and with 4T.117 (b) if the take-off distance is intended to include a clearway, for weights, altitudes, temperatures, wind components, and runway gradients, within the operational limits of the airplane (see subparagraph (4) of this paragraph).

(4) *Operational limits.* The operational limits of the airplane shall be established by the applicant for all variable factors required in showing compliance with this regulation (weight, altitude, temperature, etc.). (See secs. 4T.113 (a) (1) and (b), 4T.118, 4T.121, and 4T.122.)

(b) *Information.* The performance information on the operation of the airplane shall be scheduled in compliance with the generally applicable provisions of this regulation and with sections 4T.117a (b), 4T.121, and 4T.122 for weights, altitudes, temperatures, wind components, and runway gradients, as these may be applicable, within the operational limits of the airplane (see subparagraph (a) (4) of this section). In addition, the performance information specified in subparagraphs (1) through (3) of this paragraph shall be determined by extrapolation and scheduled for the ranges of weights between the maximum landing and maixmum take-off weights established in accordance with subparagraphs (a) (1) and (a) (2) of this section. (See also sec. 4T.743.)

(1) Climb in the landing configuration (see sec. 4T.119);

(2) Climb in the approach configuration (see sec. 4T.120 (d));

(3) Landing distance (see sec. 4T.122).

AIRPLANE FLIGHT MANUAL

4T.743 *Performance limitations, information, and other data.*

(a) *Limitations.* The airplane's performance limitations shall be given in accordance with section 4T.123 (a).

(b) *Information.* The performance information prescribed in section 4T.123 (b) for the application of the operating rules of this regulation shall be given together with descriptions of the conditions, air speeds, etc., under which the data were determined.

(c) *Procedures.* Procedures established in accordance with section 4T.111 (c) shall be given to the extent such procedures are related to the limitations and information set forth in accordance with paragraphs (a) and (b) of this section. Such procedures, in the form of guidance material, shall be included with the relevant limitations or information, as applicable.

(d) *Miscellaneous.* An explanation shall be given of significant or unusual flight or ground handling characteristics of the airplane.

3. In lieu of sections 40.70 through 40.78, 41.27 through 41.36 (d), and 42.70 through 42.83, of Parts 40, 41, and 42 of the Civil Air Regulations, respectively, the following shall be applicable:

OPERATING RULES

40T.80 *Transport category airplane operating limitations.*

(a) In operating any passenger-carrying transport category airplane certificated in accordance with the performance requirements of this regulation, the provisions of sections 40T.80 through 40T.84 shall be complied with, unless deviations therefrom are specifically authorized by the Administrator on the ground that the special circumstances of a particular case make a literal observance of the requirements unneccessary for safety.

(b) The performance data in the Airplane Flight Manual shall be applied in determining compliance with the provisions of sections 40T.81 through 40T.84. Where conditions differ from those for which specific tests were made, compliance shall be determined by approved interpolation or computation of the effects of changes in the specific variables if such interpolations or computations give results substantially equalling in accuracy the results of a direct test.

40T.81 *Airplane's certificate limitations.*

(a) No airplane shall be taken off at a weight which exceeds the take-off weight specified in the Airplane Flight Manual for the elevation of the airport and for the ambient temperature existing at the time of the take-off. (See secs. 4T.123 (a) (1) and 4T.743 (a).)

(b) No airplane shall be taken off at a weight such that, allowing for normal consumption of fuel and oil in flight to the airport of destination and to the alternate airports, the weight on arrival will exceed the landing weight specified in the Airplane Flight Manual for the elevation of each of the airports involved and for the ambient temperatures anticipated at the time of landing. (See secs. 4T.123 (a) (2) and 4T.743 (a).)

(c) No airplane shall be taken off at a weight which exceeds the weight shown in the Airplane Flight Manual to correspond with the minimum distances required for take-off. These distances shall correspond with the elevation of the airport, the runway to be used, the effective runway gradient, and the ambient temperature and wind component existing at the time of take-off. (See secs. 4T.123 (a) (3) and 4T.743 (a).) If the take-off distance includes a clearway as defined in Item 5 of this regulation, the take-off distance shall not include a clearway distance greater than one-half of the take-off run.

(d) No airplane shall be operated outside the operational limits specified in the Airplane Flight Manual. (See secs. 4T.123 (a) (4) and 4T.743 (a).)

40T.82 *Take-off obstacle clearance limitations.* No airplane shall be taken off at a weight in excess of that shown in the Airplane Flight Manual to correspond with a net take-off flight path which clears all obstacles either by at least a height of 35 feet vertically or by at least 200 feet horizontally within the airport boundaries and by at least 300 feet horizontally after passing beyond the boundaries. In determining the allowable deviation of the flight path in order to avoid obstacles by at least the distances prescribed, it shall be assumed that the airplane is not banked before reaching a height of 50 feet as shown by the take-off path data in the Airplane Flight Manual, and that a maximum bank thereafter does not exceed 15 degrees. The take-off path considered shall be for the elevation of the airport, the effective runway gradient, and for the ambient temperature and wind component existing at the time of take-off. (See secs. 4T.123 (b) and 4T.743 (b).)

40T.83 *En route limitations.*

(a) *One engine inoperative.* No airplane shall be taken off at a weight in excess of that which, according to the one-engine-inoperative en route net flight path data shown in the Airplane Flight Manual, will permit compliance with either subparagraph (1) or subparagraph (2) of this paragraph at all points along the route. The net flight path used shall be for the ambient temperatures anticipated along the route. (See secs. 4T.123 (b) and 4T.743 (b).)

(1) The slope of the net flight path shall be positive at an altitude of at least 1,000 feet above all terrain and obstructions along the route within 5 miles on either side of the intended track.

(2) The net flight path shall be such as to permit the airplane to continue flight from the cruising altitude to an alternate airport where a landing can be made in accordance with the provisions of section 40T.84 (b), the net flight path clearing vertically by at least 2,000 feet all terrain and obstructions along the route within 5 miles on either side of the intended track. The provisions of subdivisions (i) through (vii) of this subparagraph shall apply.

(i) The engine shall be assumed to fail at the most critical point along the route.

(ii) The airplane shall be assumed to pass over the critical obstruction following engine failure at a point no closer to the critical obstruction than the nearest approved radio navigational fix, except that the Administrator may authorize a procedure established on a different basis where adequate operational safeguards are found to exist.

(iii) The net flight path shall have a positive slope at 1,500 above the airport used as the alternate.

(iv) An approved method shall be used to account for winds which would otherwise adversely affect the flight path.

(v) Fuel jettisoning shall be permitted if the Administrator finds that the operator has an adequate training program, proper instructions are given to the flight crew, and all other precautions are taken to insure a safe procedure.

(vi) The alternate airport shall be specified in the dispatch release and shall meet the prescribed weather minima.

(vii) The consumption of fuel and oil after the engine becomes inoperative shall be that which is accounted for in the net flight path data shown in the Airplane Flight Manual.

(b) *Two engines inoperative.* No airplane shall be flown along an intended route except in compliance with either subparagraph (1) or subparagraph (2) of this paragraph.

(1) No place along the intended track shall be more than 90 minutes away from an airport at which a landing can be made in accordance with the provisions of section 40T.84 (b), assuming all engines to be operating at cruising power.

(2) No airplane shall be taken off at a weight in excess of that which, according to the two-engine-inoperative en route net flight path data shown in the Airplane Flight Manual, will permit the airplane to continue flight from the point where two engines are assumed to fail simulateneously to an airport where a landing can be made in accordance with the provisions of section 40T.84 (b), the net flight path having a positive slope at an altitude of at least 1,000 feet above all terrain and obstructions along the route within 5 miles on either side of the intended track or at an altitude of 2,000 feet, whichever is higher. The net flight path considered shall be for the ambient temperatures anticipated along the route. The provisions of subdivisions (i) through (iii) of this subparagraph shall apply. (See secs. 4T.123 (b) and 4T.743 (b).)

(i) The two engines shall be assumed to fail at the most critical point along the route.

(ii) The airplane's weight at the point where the two engines are assumed to fail shall be considered to be not less than that which would include sufficient fuel to proceed to the airport and to arrive there at an altitude of at least 1,500 feet directly over the landing area and thereafter to fly for 15 minutes at cruise power and/or thrust.

(iii) The consumption of fuel and oil after the engines become inoperative shall be that which is accounted for in the net flight path data shown in the Airplane Flight Manual.

40T.84 *Landing limitations.*

(a) *Airport of destination.* No airplane shall be taken off at a weight in excess of that which, in accordance with the landing distances shown in the Airplane Flight Manual for the elevation of the airport of intended destination and for the wind conditions anticipated there at the time of landing, would permit the airplane to be brought to rest at the airport of intended destination within 60 percent of the effective length of the runway from a point 50 feet directly above the intersection of the obstruction clearance plane and the runway. The weight of the airplane shall be assumed to be reduced by the weight of the fuel and oil expected to be consumed in flight to the airport of intended destination. Compliance shall be shown with the conditions of subparagraphs (1) and (2) of this paragraph. (See secs. 4T.123 (b) and 4T.743 (b).)

(1) It shall be assumed that the airplane is landed on the most favorable runway and direction in still air.

(2) It shall be assumed that the airplane is landed on the most suitable runway considering the probable wind velocity and direction and taking due account of the ground handling characteristics of the airplane and of other conditions (i. e., landing aids, terrain, etc.). If full compliance with the provisions of this subparagraph is not shown, the airplane may be taken off if an alternate airport is designated which permits compliance with paragraph (b) of this section.

(b) *Alternate airport.* No airport shall be designated as an alternate airport in a dispatch release unless the airplane at the weight anticipated at the time of arrival at such airport can comply with the provisions of paragraph (a) of this section, provided that the airplane can be brought to rest within 70 percent of the effective length of the runway.

4. In lieu of section 43.11 of Part 43 of the Civil Air Regulations, the following shall be applicable:

43T.11 *Transport category airplane weight limitations.* The performance data in the Airplane Flight Manual shall be applied in determining compliance with the following provisions:

(a) No airplane shall be taken off at a weight which exceeds the take-off weight specified in the Airplane Flight Manual for the elevation of the airport and for the ambient temperature existing at the time of the take-off. (See secs. 4T.123 (a) (1) and 4T.743 (a).)

(b) No airplane shall be taken off at a weight such that, allowing for normal consumption of fuel and oil in flight to the airport of destination and to the alternate airports, the weight on arrival will exceed the landing weight specified in the Airplane Flight Manual for the elevation of each of the airports involved and for the ambient temperatures anticipated at the time of landing. (See secs. 4T.123 (a) (2) and 4T.743 (a).)

(c) No airplane shall be taken off at a weight which exceeds the weight shown in the Airplane Flight Manual to correspond with the minimum distances required for take-off. These distances shall correspond with the elevation of the airport, the runway to be used, the effective runway gradient, and the ambient temperature and wind component existing at the time of take-off. (See secs. 4T.123 (a) (3) and 4T.743 (a).) If the take-off distance includes a clearway as defined in Item 5 of this regulation, the take-off distance shall not include a clearway distance greater than one-half of the take-off run.

(d) No airplane shall be operated outside the operational limits specified in the Airplane Flight Manual. (See secs. 4T.123 (a) (4) and 4T.743 (a).)

5. The following definitions shall apply:

DEFINITIONS

Clearway. A clearway is an area beyond the airport runway not less than 300 feet on either side of the extended center line of the runway, at an elevation no higher than the elevation at the end of the runway, clear of all fixed obstacles, and under the control of the airport authorities.

SPECIAL CIVIL AIR REGULATION NO. SR-423

Effective: December 20, 1957
Adopted: November 15, 1957

Type Certification of Transport Category Airplanes With Turbo-Prop Replacements

The airworthiness requirements with which a particular airplane is required to comply are established by the date of application for the type certificate. After the type certificate is issued, the holder of the type certificate or an applicant for a supplemental type certificate, at his option, can obtain approval of changes in the design in accordance with requirements in effect at the time of the original application for type certificate or in accordance with later requirements in effect at the time of the change.

Prior to May 18, 1954, the regulations placed no specific limit on the extent of changes to the airplane which could be approved in this manner nor did they define a new type design for which a new application for type certification would be required. Amendment 4b-1 effective on that date, among other changes in Part 4b, lists certain changes in design which if made to an airplane would require it to be considered as a new type. In such a case, a new application for type certification would be required and the regulations, together with all amendments thereto effective on the date of the new application, would have to be complied with (sec. 4b.11 (a)). One such change which would require a new type certificate is a change to engines employing different principles of operation or propulsion (sec. 4b.11 (e) (2)).

Interest has been shown recently within the aviation industry in the installation of turbo-propeller engines on airplanes presently equipped with reciprocating engines. In accordance with sec. 4b.11 (e) (2) such a change would require a showing of compliance with the latest airworthiness requirements of Part 4b. The Board is of the opinion that showing of compliance with all of the latest requirements might be burdensome, impractical, and not essential to safety.

This Special Civil Air Regulation will permit the certification of a turbo-propeller-powered airplane, which previously was type certificated with the same number of reciprocating engines, if compliance is shown with the airworthiness provisions applicable to the airplane as type certificated with reciprocating engines, together with certain later provisions of the Civil Air Regulations in effect on the date of application for a supplemental or new type certificate which are applicable or related to the powerplant of the turbo-propeller-powered version.

In order to insure that the level of safety of the turbine-powered airplane is equivalent to that intended by Part 4b, the Board considers that compliance must be shown with the later provisions of Part 4b which apply to the powerplant installation, airplane performance, and cockpit standardization, and such other requirements as the Administrator finds are otherwise related to the changes made in the engines.

Special Civil Air Regulation No. SR–422 establishes certain certification and operational requirements for all turbine-powered airplanes for which a type certificate is issued after the effective date of that regulation. Except as otherwise provided, all of the provisions of SR–422 remain applicable to airplanes certificated in accordance with the regulation prescribed herein. Therefore, to be certificated in accordance with the regulation prescribed herein compliance must be shown with the certification performance requirements prescribed in paragraph 2 of SR–422.

It must be emphasized that the certification performance limitations established by the performance requirements; i. e., the take-off weights, landing weights, take-off and accelerate-stop distances, and the operational limits, become part of the airworthiness certificate and must be complied with at all times, regardless of the type of operations conducted with the airplane. (See sec. 43.10, as amended, of Part 43 of the Civil Air Regulations.)

In addition to certification performance limitations, SR–422 prescribes performance operating limitations which are applicable to turbine-powered transport category airplanes when used in air carrier passenger operations. Since turbo-propeller-powered airplanes certificated in accordance with the regulation prescribed herein are required to comply with the certification performance requirements of SR–422, they are also subject to the performance operating limitations prescribed in paragraph 3 of SR–422 when used in air carrier passenger operations.

Since a change in engines will require a rather extensive change in the cockpit to accommodate the new instruments and controls for turbine engines, the Board considers that compliance with the latest cockpit standardization requirements can be accomplished without any undue burden and such compliance would speed up the cockpit standardization of other airplanes in an airline's fleet in accordance with the Board's objectives. Therefore, this regulation makes the latest cockpit standardization requirements applicable, with the exception of such detailed requirements as the Administrator finds are impracticable, and do not contribute materially to standardization. It should be noted that in referring to this exception in the preamble to Draft Release No. 56–29, the use of the conjunction "or" after the word "impracticable" was inadvertent. As the language of the proposed regulation clearly indicated, "and" was the proper conjunction following the word "impracticable."

The Board also considers it appropriate to call attention to the fact that if other changes to the airplane are made simultaneously with, or subsequent to, such an engine change, then compliance will also have to be shown with all requirements related to the additional changes in effect on the date of the new application for a supplemental or new type certificate. In this regard, if an airplane converted to turbo-propeller power is to be certificated for operation at altitudes, speeds, or weights higher than those which are applicable to the reciprocating-engine-powered airplane, compliance will be required with all the latest provisions of the regulations which are related to such changes.

In order to assure that all airplanes converted to turbo-propeller power meet the minimum requirements considered essential to safety, this regulation is made retroactive and requires compliance with the provisions of the Civil Air Regulations as set forth herein for all of such airplanes for which application for a supplemental or new type certificate was made prior to the effective date of this regulation.

This Special Civil Air Regulation shall continue in effect for 5 years, at the end of which time the effectiveness of the regulation will be evaluated for the purpose of considering the incorporation of the substance of these rules in the permanent body of the Civil Air Regulations.

Interested persons have been afforded an opportunity to participage in the making of this Special Civil Air Regulation (21 F. R. 9436), and due consideration has been given to all relevant matter presented.

In consideration of the foregoing, the Civil Aeronautics Board hereby makes and promulgates the following Special Civil Air Regulation effective December 20, 1957.

Contrary provisions of section 4b.11 (a) as it applies to section 4b.11 (e) (2) of Part 4b of the Civil Air Regulations and paragraph (1) of Special Civil Air Regulation No. SR–422 notwithstanding, the following provisions shall be applicable to the certification of a turbo-propeller-powered airplane which was previously type certificated with the same number of reciprocating engines:

(1) The airworthiness regulations applicable to the airplane as type certificated with reciprocating engines and, in addition thereto or in lieu thereof as appropriate, the following provisions of the Civil Air Regulations effective on the date of application for a supplemental or new type certificate (see paragraph (3)):

(a) The certification performance requirements prescribed in Special Civil Air Regulation No. SR–422;

(b) The powerplant installation requirements of Part 4b applicable to the turbo-propeller-powered airplane;

(c) The requirements of Part 4b for the standardization of cockpit controls and instruments, except where the Administrator finds that showing of compliance with a particular detailed requirement would be impracticable and would not contribute materially to standardization; and

(d) Such other requirements of Part 4b applicable to the turbo-propeller-powered airplane as the Administrator finds are related to the changes in engines and are necessary to insure a level of safety of the turbo-propeller-powered airplane equivalent to that generally intended by Part 4b.

(2) If new limitations are established with respect to weight, speed, or altitude of operation and the Administrator finds that such limitations are significantly altered from those approved for the airplane with reciprocating engines, compliance shall be shown with all of the requirements, applicable to the specific limitations being changed, which are in effect on the date of application for the new or supplemental type certificate.

(3) Airplanes converted to turbo-propeller power, for which application for a supplemental or a new type certificate was made prior to the effective date of this Special Civil Air Regulation, shall comply with all of the provisions of the Civil Air Regulations specified in paragraphs (1) and (2) effective on the date of this special regulation, rather than those provisions effective on the date application was made for the supplemental or the new type certificate.

This Special Civil Air Regulation shall terminate December 20, 1962 unless sooner superseded or rescinded by the Board.

SPECIAL CIVIL AIR REGULATION NO. SR-425

Effective: June 20, 1958
Adopted: June 20, 1958

Provisional Certification and Operation of Multiengine Turbine-Powered Transport Airplanes for Which Type Certificates Have Not Been Issued

The aviation industry of the United States has been engaged for several years in a concentrated program of design, development, and construction of turbine-powered transports. Several hundred of these transports have been ordered by United States' air carriers at a cost of nearly two billion dollars. One airplane of this type has already been flown by the manufacturer for several hundred hours in an extremely varied and rigorous flight test program. Other types are in various stages of design, construction, and flight testing by their manufacturers.

Air carriers have expressed the desire to operate these airplanes prior to final completion of the type certification programs. The air carriers have indicated in particular that they desire to conduct crew training and obtain as much experience as possible in ground handling, maintenance, and flight of these new airplanes prior to their introduction into commercial service.

Although certain limited operations of this nature have been permitted by the Administrator in the past, he has advised the Board that he considers his authority under Part 1 of the Civil Air Regulations inadequate for him to authorize the operations presently contemplated by the air carriers. The Board is of the opinion, however, that such operations by air carriers intending ultimately to use the airplanes in air carrier service will be in the public interest and should be permitted and encouraged prior to completion of type certification procedures, provided that such operations can be conducted safely. This will afford technical personnel of the air carriers, the Civil Aeronautics Administration, the Civil Aeronautics Board, and others an excellent opportunity to become familiar with the new equipment before it is used in air transportation.

The airplanes under consideration are being built to comply with the requirements of the Civil Air Regulations applicable to transport category airplanes. However, manufacturers of several of these types of airplanes have not yet demonstrated full compliance with the standards established in these regulations for the issuance of type certificates.

Normally, during the development of a new type airplane, the manufacturer applies to the Administrator for an experimental certificate. The Administrator thereafter issues such a certificate in accordance with Part 1 of the Civil Air Regulations if he finds that the airplane may be safely test flown by the manufacturer to show compliance with the Civil Air Regulations for the issuance of a type certificate. The Administrator prescribes appropriate operating restrictions, including the prohibition of carrying persons or property for compensation or hire. It is the policy of the CAA during this certification process to do everything possible to encourage legitimate experimentation leading to improvement in airplanes whenever this may be done without endangering persons and property not involved in the experimentation. In the present situation, turbine-powered transports have been issued experimental certificates in order that flight test programs may be completed. Historically, however, and in keeping with the intent of Section 603 (a) (1) and (c) of the Civil Aeronautics Act of 1938, as amended, operations conducted in airplanes so certificated have been limited for the most part to flight test work and related purposes.

It is the practice of manufacturers to initiate production of airplanes of a new type while they are accomplishing the type certification program. Thus, many airplanes may be completed prior to the issuance of the type certificate; the number produced by various manufacturers will, of course, vary with orders on hand and anticipated demand for the airplanes.

In this period, however, the manufacturer is actively pursuing type certification of his airplane. Among other things he submits such descriptive data, test reports, and computations as are necessary to demonstrate that the airplane complies with the requirements of Part 4b. In addition, it is the CAA policy that the manufacturers' test pilots certify that the airplanes have been flown at least in all maneuvers necessary for proof of compliance with the flight requirements of Part 4b and Special Civil Air Regulation No. SR-422.

The Board considered that air carriers should be able to utilize those airplanes which are pending type and airworthiness certification under provisional certification to permit essential crew training and service tests, and to gain other useful information concerning, for example, fuel management, dispatching, and traffic control procedures, prior to operation in air transportation, subject, of course, to appropriate limitations.

Accordingly, the Bureau of Safety, on April 22, 1958, circulated to interested persons Civil Air Regulations Draft Release No. 58-9, "Special Regulations to Provide for Provisional Certification and Operation of Multiengine Turbine-Powered Transport Airplanes for Which Type Certificates Have Not Been Issued." In this proposal the Bureau of Safety described in some detail the problems associated with such operations and some of the objectives which could be achieved. It was pointed out that much useful technical information could be obtained and in addition the introduction of jets into service in the U. S. could be expedited on a sound and efficient basis. This proposal set forth various procedures and limitations covering three aspects of the problem: Provisional type certification, provisional airworthiness certification, and operational rules. A detailed explanation of each of these provisions is contained in Draft Release 58–9.

The response to this draft release from all persons who would be affected by its provisions was uniformly favorable. There were recommendations, however, for amendment to specific provisions, the most significant of which are discussed below:

Representatives of operators of executive transports recommended that the provisions of the proposed regulation should be made applicable not only to air carriers but to operators of executive transports, advising that there was equal need for provisional certification of these aircraft and that any other action would be arbitrary and discriminatory. The Board's proposal applying to certificated air carriers only was prompted by the need for full assurance that new design aircraft in air transportation have as much service experience as possible before entering such service consistent with statutory requirements to insure the highest degree of safety in air transportation. It was considered that this approach to type and airworthiness certification should be pioneered by the air carriers in which the public interest was greatest; however, the Board considers these recommendations to be well taken and will consider appropriate extensions of this special regulation.

The Administrator of Civil Aeronautics stated that the provisions of Section I (b) (2), which would require the Administrator to predict that a type certificate for a particular airplane would be issued not later than 6 months from the date application was made for a provisional type certificate, presented administrative difficulties without a commensurate contribution to the safety of operations. The Board concurs in this opinion, and is not including this provision in this regulation. The CAA, as well as the manufacturers and air carriers, also indicated that the provisions of Section I (d) concerning duration were not wholly clear and should be amended. The Board intends that the privileges of this regulation shall be of limited duration only in order to achieve the objectives stated in this rule, namely, to permit air carriers to use new turbine transports in training and other operations only if it has been shown that the normal certification requirements are close to being met. The 6 months' duration period was selected, therefore, to insure that only airplanes which were in the latter stages of type certification would be eligible for provisional certification and operation. Since this will not be an issue for some time, the Board will consider this problem on its merits should experience under this regulation indicate that revision of the duration requirements with respect to reissuance or renewal is in the public interest. The proposed 30 day grace period for the duration of a provisional type certificate after the issuance of a transport category type certificate is being extended to 60 days to provide the air carriers with sufficient time to return the provisionally certificated airplanes to the manufacturers for modifications should such be necessary as the result of type certification tests. In order to clarify this requirement further, a proviso has been added to insure that should a transport category type certificate be issued, for example, 5 months after the issuance of a provisional type certificate, the applicant will still have 60 days to return airplanes to the factory as necessary. Similar revisions have been made to the duration of the provisional airworthiness certificates in order to insure consistency.

The Aircraft Industries Association, in commenting on Draft Release 58–9, indicated that it considered an amendment to Part 1 of the Civil Air Regulations would be a more appropriate method for authorizing the proposed operations. The Board is aware of other problems connected with the operation of airplanes holding experimental certificates and will give attention to them in separate rule making. AIA, however, also commented on certain of the specific provisions of the proposed regulation, particularly as those provisions affected the manufacturers of jet transports. Concern was expressed that the requirement of Section I (b) might require the submission of the kind of report not currently required by the Civil Air Regulations. The Board, intends, however that the manufacturer will be required to report only to the extent that he is currently required under the provisions of section 4b.16 of Part 4b of the Civil Air Regulations and that this will not be an additional requirement.

The Board has given careful consideration to the air carriers' recommendations pursuant to Draft Release 58–9 that the operation rules in Section III be modified to permit the carriage of cargo and mail in the provisionally certificated jet transports. The Board wishes to reiterate the statement of the Bureau of Safety in Draft Release 58–9 that it does not consider that at this time these transports should be operated in air transportation; i. e., carrying persons, cargo, or mail for compensation or hire. After the Board has had opportunity to evaluate experience gained under this regulation, further consideration will be given to the limited carriage of cargo and mail if such is determined to be in the public interest. The Board anticipates that interested carriers, after they have established and operated their crew training and familiarization programs, may petition the Board for special authority to conduct cargo and mail operations. The Board would expect that carriers make a clear showing that such operations would advance the safety objectives of this regulation and would not be based solely on economic considerations.

In Draft Release 58–9 the Bureau of Safety solicited specific comment on a recommendation that provisionally certificated airplanes be equipped with flight recorders. Comment received indicated that a requirement for a flight recorder of a type designed to meet the requirements of presently effective operating rules would be extremely burdensome. At least one major potential operator of the provisionally certificated airplanes has informed the Board that installation provisions for a NACA VGH recorder and a recorder designed to meet the requirements of the operating rules will be accomplished on the first airplane to be delivered. At this time, however, such operator is not certain whether either type of recorder will be delivered in time for installation on the airplane at the initiation of operations under this special regulation. Every effort is promised, however, to have them installed as soon as possible; other carriers also are in the same position. In view of this situation and the fact that extensive plans have been made for the installation in these transports of NACA recorders in a cooperative effort among aircraft manufacturers, air carriers, and the NACA, the Board will not require by regulation the installation of flight recorders in provisionally certificated airplanes. The Board urges both the manufacturers and air carriers, however, to make every effort to install flight recorders at the earliest opportunity in order that valuable technical data can be obtained with respect to the operation of these airplanes and that operating experience of the flight recorders themselves may be obtained also.

The Air Line Pilots Association recommended that the minimum flight time required for issuance of both the provisional type certificate and related airworthiness certificate should be increased. While the Board recognizes the validity of the general proposition that more flight time might be desirable, it considers that the minimums contained in the proposed regulation are adequate to insure a satisfactory level of safety for the type of operation authorized.

The Flight Engineers' International Association recommended that special certification standards be established for flight engineers who will be affected by this regulation. Specifically, FEIA requested that the regulation require that flight engineers demonstrate to the Administrator a complete and absolute knowledge of the aircraft, its accessories and systems, and that this information be added to the flight engineer certificate. The air carrier is charged by this regulation with the responsibility for conducting appropriate training and maintaining adequate records. The Board is of the opinion, therefore, that the provisions of Section III (e) adequately provide for the training of the crew members who will engage in operations under this regulation.

Interested persons have been afforded an opportunity to participate in the making of this regulation (23 F. R. 2843), 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 June 20, 1958.

Contrary provisions of the Civil Air Regulations notwithstanding, a turbine-powered transport airplane for which the issuance of a transport category type certificate is pending shall be eligible for provisional certification and operation in accordance with the provisions of this special regulation.

Section I—Provisional type certificate.

(a) *Applicant.*

(1) Any U. S. manufacturer of a turbine-powered airplane may apply for the issuance of a provisional type certificate provided that he has applied to the Administrator for the issuance of a transport category type certificate for such airplane. The application for a provisional type certificate shall be made in a manner prescribed by the Administrator.

(2) The applicant shall be a manufacturer who has previously received a type certificate for at least one airplane in the transport category and has a currently effective production certificate for that type.

(b) *Requirements for issuance.* The Administrator shall issue a provisional type certificate for an airplane for which application is made in accordance with paragraph (a) of this section when the conditions of subparagraphs (1) through (8) of this paragraph are met.

(1) The applicant shall submit the report of flight tests required by section 4b.16 of Part 4b of the Civil Air Regulations and the Civil Aeronautics Administration's official flight test program with respect to the issuance of the type certificate shall be in progress.

(2) The applicant shall certify that, to the best of his knowledge, the airplane for which provisional type certification is sought has been designed

and constructed in accordance with those aiı worthiness requirements applicable to the issuance of the type certificate for that airplane.

(3) An airplane conforming with the type for which a type certificate has been applied shall have been flown at least 100 hours by the applicant under the provisions of an experimental certificate issued in accordance with the provisions of Part 1 of the Civil Air Regulations.

(4) The applicant shall have flown the airplane in all maneuvers necessary to show compliance with those flight requirements applicable to the issuance of the type certificate.

(5) The applicant shall have prepared a provisional airplane flight manual containing all the limitations, information, and procedures as are required for the issuance of the type certificate for that airplane: *Provided*, That where all limitations, information, and procedures have not been established, the applicant shall establish appropriate restrictions on the operation of the airplane.

(6) The applicant shall state that the airplane is considered safe for operation for the purposes set forth herein when conducted in accordance with the provisional airplane flight manual prescribed in subparagraph (5) of this paragraph.

(7) The applicant shall establish special inspections and maintenance instructions which are considered necessary to insure continued airworthiness of the airplane.

(8) The Administrator shall find, on the basis of the provisions contained in this special regulation, that the airplane has no feature, characteristic, or condition which renders it unsafe when operated in accordance with the provisional airplane flight manual prescribed in subparagraph (5) of this paragraph and maintained in accordance with the inspections and maintenance instructions prescribed in subparagraph (7) of this paragraph.

(c) *Transferability.* A provisional type certificate issued under this special regulation shall not be transferable.

(d) *Duration.* A provisional type certificate shall remain in effect for 6 months or until the airplane is issued a transport category type certificate, whichever occurs first, unless sooner superseded, revoked, or otherwise terminated by the Administrator or the Board: *Provided*, That a provisional type certificate which would terminate prior to 6 months after issuance due to the issuance of a transport category type certificate may remain in effect for an additional 60 days.

Section II—Provisional airworthiness certificate.

(a) *Applicant.* The holder of a provisional type certificate or a certificated U. S. air carrier authorized to conduct operations by Section III of this regulation may apply for the issuance of a provisional airworthiness certificate for an airplane for which a provisional type certificate has been issued in accordance with the provisions of Section I of this special regulation. The application for a provisional airworthiness certificate shall be made in a manner prescribed by the Administrator.

(b) *Requirements for issuance.*

(1) An applicant for a provisional airworthiness certificate for an airplane for which a provisional type certificate has been issued shall be issued such provisional airworthiness certificate upon presentation of a statement of conformity by the manufacturer that such airplane conforms to the provisional type certificate.

(2) The airplane shall have been manufactured under a quality control system established in anticipation of, and intended to be used as a basis for, the production certificate to be issued to cover that airplane.

(3) The airplane shall have been flown at least 5 hours by the manufacturer and found by him to be in safe operating condition.

(4) The airplane shall be furnished with a provisional airplane flight manual as required by subparagraph (b) (5) of Section I of this special regulation.

(5) The Administrator shall find, on the basis of the provisions contained in this special regulation, that the airplane has no feature, characteristic, or condition which renders it unsafe when operated in accordance with the provisional airplane flight manual prescribed in subparagraph (b) (5) of Section I of this special regulation and maintained in accordance with the inspections and maintenance instruction prescribed in subparagraph (b) (7) of Section I of this special regulation.

(6) The words "provisional airworthiness" shall be displayed on the exterior of the airplane near each entrance to the cabin or cockpit of the airplane with letters not less than 2 inches in height.

(c) *Transferability.* A provisional airworthiness certificate issued under this special regulation shall be transferable only to an air carrier authorized to conduct operations by Section III of this regulation.

(d) *Duration.* A provisional airworthiness certificate shall remain in effect for 6 months, or until the airplane is issued a transport category type certificate, whichever occurs first, unless sooner superseded, revoked, or otherwise terminated by the Administrator or the Board: *Provided,* That provisional airworthiness certificates which would terminate prior to 6 months after issuance due to the issuance of a transport category type certificate may remain in effect for an additional 60 days.

Section III—Operation rules. An air carrier holding an air carrier operating certificate issued by the Administrator in accordance with Part 40, 41, or 42 of the Civil Air Regulations may operate turbine-powered transport category airplanes certificated in accordance with Sections I and II of this special regulation in accordance with the following operating rules:

(a) An air carrier may conduct flights for the purpose of crew training, service testing, and simulated air carrier operations not in air transportation, or as otherwise specifically authorized by the Board.

(b) Operations which are conducted for the purposes delineated in the definition of "flight test" in section 60.60 of Part 60 of the Civil Air Regulations shall be conducted in accordance with section 60.24.

(c) The airplane shall be operated in accordance with the limitations, information, and procedures prescribed in the provisional airplane flight manual prepared in accordance with subparagraph (b) (5) of Section I of this special regulation.

(d) An air carrier shall establish procedures for the use and guidance of flight and ground operations personnel in the conduct of its operations. Specific procedures shall be established for operations from airports where the runways may require a take-off or approach over populated areas. These procedures shall be approved by the Administrator.

(e) In addition to crew members, only those persons listed in section 40.356 (c) of Part 40 shall be carried in operations conducted under this special regulation.

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(f) Each air carrier shall insure that each flight crew member possesses adequate knowledge of, and familiarity with, the airplane and the procedures to be used by him.

(g) Each air carrier shall maintain current records for each flight crew member. These records shall contain such information as is necessary to show that the crew member is properly trained and qualified to perform his assigned duties.

(h) The appropriate instructor, supervisor, or check airman shall certify as to the proficiency of each flight crew member and such certification shall become a part of the flight crew member's record.

(i) Airplanes operated under this special regulation shall be maintained in accordance with applicable Civil Air Regulations, including any special inspections and maintenance instructions prescribed by the manufacturer or the Administrator.

(j) A log of flights conducted under this special regulation, and accurate and complete records of the inspections made, shall be kept by each air carrier and made available to the manufacturer and the Administrator.

(k) No airplane issued a provisional airworthiness certificate under this special regulation shall be operated if the manufacturer or the Administrator determines that a change in design, construction, or operation is necessary to insure safe operation until such change is made. (See also section 1.24 of Part 1 of the Civil Air Regulations.)

(l) The provisional airworthiness certificate shall be prominently displayed in the airplane at all times.

(m) Operations under this special regulation shall be restricted to the United States, its territories, and possessions, unless otherwise authorized by the Board.

This Special Civil Air Regulation shall terminate in 3 years unless sooner superseded or rescinded by the Board.

Appendix H

FATIGUE EVALUATION OF FLIGHT STRUCTURE

The procedures outlined in this appendix are acceptable to the CAA for showing compliance with the fatigue evaluation requirements of Civil Air Regulation 4b.270. However, the information contained in this appendix is presented merely for guidance purposes and is not mandatory nor regulatory in nature.

Although a uniform approach to fatigue evaluation is desirable, it is recognized that in such a complex and highly controversial field, new design features and methods of fabrication, new approaches to fatigue evaluation, and new configurations may require variations and deviations from the procedures described in this appendix. Therefore, engineering judgment should be exercised for each particular application.

Experience with the application of methods of fatigue evaluation indicates that fatigue tests are essential to achieve the design objective. Even under the fail-safe method discussed in section II of this appendix, it is the general practice within industry to conduct fatigue tests for design information and guidance purposes. Fatigue tests are also useful in establishing a recommended inspection program; in assessing in the early design stages the fatigue characteristics of certain structural elements, such as major fittings, joints, typical skin units, and splices; in insuring that the anticipated service life assumed at the inception of the design can reasonably be attained; and in determining the crack propagation qualities of materials selected in specific design applications.

Section I.—FATIGUE STRENGTH EVALUATION

A. *General.* The evaluation of the flight structure under the fatigue strength evaluation method is intended to insure that a serious fatigue failure will not occur as a result of the repeated loads of variable magnitude expected in service. The evaluation usually includes the following procedures:

1. Estimating or measuring the expected loading spectrum for the structure.
2. Conducting a structural analysis including consideration of the stress concentration effects.
3. Fatigue testing the structure to cover the typical loading spectrum expected in service.
4. Determining reliable service periods by interpreting the results of the loading history, the variable load stress analyses, the fatigue tests, the service experience, and the fatigue analyses.
5. Providing inspection and maintenance instructions and guidance information to the operators to minimize the possibility of a serious fatigue failure in service.

In some instances, it may be desirable to verify the loadings used in the analyses by flight load and strain surveys.

B. *Typical loading spectrum expected in service.* The loading spectrum should be based on measured statistical data of the type derived from government and industry load history studies, and where insufficient data are available, a conservative estimate of the anticipated use of the aircraft. The principal loads to be considered in establishing a loading spectrum for the flight structure are:

1. Flight loads—gust and maneuver.
2. Ground loads—taxiing, landing impact, turning, engine runup, braking.
3. Pressurization loads.
4. Other loads—ground-air-ground cycle, vibratory.

The development of the loading spectrum requires the definition of the expected flight plan which involves climb, cruise, descent, flight times, operational speeds and altitudes, the approximate percentage of time to be spent in each of the operating regimes, and any other pertinent effects, such as dynamic overstress and the stress decay characteristics of a flexible structure excited by turbulence.

For pressure cabins, the typical loading spectrum should include the repeated application of the normal operating pressure, and the superimposed effects of flight loads and external aerodynamic pressures. A recommended source of information in the development of a loading spectrum is the *Aircraft Fatigue Handbook, Volume I—Environmental Conditions*, published by the Aircraft Industries Association.

C. *Fatigue analysis*. Some better-known methods for structural fatigue evaluation are briefly outlined in the *Aircraft Fatigue Handbook, Volume II—Design and Analysis*, published by the Aircraft Industries Association. Experience with these methods indicates that no one method is wholly satisfactory in yielding accurate or consistently reliable results, but that in many cases they may be used as approximations in design. Any method used in the fatigue analysis should be supported by test or service experience.

D. *Components to be analyzed and tested*. In assessing the possibility of serious fatigue failure, the design should be carefully examined to determine possible points of failure in service. In this examination, consideration should be given to the results of stress analyses, static tests, strain gage surveys, tests of similar structural configurations, and service experience. Service experience has shown that special attention should be focused on the design details of important discontinuities, main attach fittings, tension joints and splices, and cutouts such as windows, doors, and other openings.

Unless it is determined from the foregoing examination that the normal operating stresses at critical regions in the structure are of such a low order that the possibility of serious fatigue damage is extremely remote, repeated load tests should be conducted on complete full-scale components such as the wing, control surfaces, and pressure cabin. In any event, it is advisable that repeated load tests be conducted on representative portions of the complete flight structure.

Test specimens for the wing and empennage should include attachment fittings, major joints, changes in section, tensile area cutouts, and discontinuities. Test specimens for a pressure fuselage should include the cockpit area; typical joints; a sufficient part of the cabin area to include typical windows, doors, and other cutouts; and the pressure bulkheads and attachments.

E. *Life determination-scatter*. The main purpose of the fatigue tests is to establish for the first and subsequent failures, the component involved and its corresponding fatigue life. If possible, the structure should be repaired after each failure until a stage is reached where further repair is impossible or further testing is considered unnecessary.

In the interpretation of fatigue test data, the effect of variability should be accounted for by an appropriate factor. Relating of such factors to the recommended service life is extremely difficult as there are a number of considerations peculiar to each design that require evaluation by the applicant. The factor will depend on the number of representative test specimens, the material, the type of specimen employed, the type of repeated load test, the load levels, and environmental conditions.

F. Replacement times. Parts should be replaced or retired at the established reliable service period unless additional data indicate that an extension of the service period is possible. Important factors in the consideration of such extensions would be:

1. *Satisfactory service experience*. Satisfactory service experience includes establishing from the history of operation of the aircraft that no significant or premature fatigue failure has occurred.
2. *Recorded load data*. Recorded load data entails instrumenting aircraft in service to obtain a representative sampling of actual loads experienced. The data measured should include airspeed, altitude, and load factor versus time; or the airspeed, altitude, and strain ranges versus time, or similar data. The data obtained by instrumenting aircraft in service should provide a basis

for correlating the estimated loading spectrum with the actual service experience.

3. *Additional analyses and tests.* If test data and analyses based on repeated load tests of additional specimens are obtained, a reevaluation of the initial scatter factor may be made.
4. *Tests of parts removed from service.* Repeated load tests of replaced parts may be utilized to reevaluate the initial scatter factor selected. The tests should closely simulate service loading conditions. Repeated load testing of parts removed from service is especially useful where recorded load data obtained in service are available, since the actual loading experienced by the part prior to replacement is known.
5. *Repair or rework of the structure.* In some cases, repair or rework of the structure may gain further service life.

G. *Type design developments and changes.* For design developments or changes involving structural configurations similar to those of a design already shown to comply with the provisions of CAR 4b.270 (a), it may be possible to evaluate the variations in critical portions of the structure on a comparative basis. Typical examples would be redesign of the wing structure for increased loads, and the introduction of different locations and/or shapes of cutouts in pressure cabins. This evaluation involves analysis of the estimated stresses of the redesigned primary structure and correlation of the analysis with the analytical and test results obtained in showing compliance of the original design with CAR 4b.270 (a).

Section II.—FAIL-SAFE STRENGTH EVALUATION

A. *General.* The fail-safe strength evaluation of the flight structure is intended to insure that should a serious fatigue failure occur, the remaining structure can withstand reasonable flight loads without excessive structural deformation. The fail-safe evaluation generally encompasses establishing the components which are to be made fail-safe, defining the loading conditions and extent of damage for which the structure is to be designed, conducting structural tests and analyses to substantiate that the design objective has been achieved, and establishing inspection programs aimed at detection of fatigue damage. Design features which may be used in attaining a fail-safe structure are:

1. Use of multipath construction and the provision of crack stoppers to limit the growth of cracks.
2. Use of composite duplicate structures so that a fatigue failure occurring in one-half of the composite member will be confined to the failed half and the remaining structure will still possess appreciable load-carrying ability.
3. Use of backup structure wherein one member carries all the load, with a second member available and capable of assuming the extra load if the primary member fails.
4. Selection of materials and stress levels that provide a controlled slow rate of crack propagation combined with high residual strength after initiation of cracks.
5. Arrangement of design details to permit easy detection of failures in all critical structural elements before the failures can become dangerous or result in appreciable strength loss, and to permit replacement or repair.

B. *Identification of principal structural elements.* Principal structural elements are those which contribute significantly to carrying flight and pressurization loads and whose failure could result in catastrophic failure of the aircraft. Typical examples of such elements are:

1. *Wing and empennage—*
   a. Control surface attachment hinges and fittings.
   b. Integrally stiffened plates.
   c. Primary fittings.
   d. Principal splices.
   e. Skin or reinforcement around cutouts or discontinuities.
   f. Skin-stringer combinations.
   g. Spar cap.
   h. Spar web.
2. *Fuselage.—*
   a. Circumferential frame and adjacent skin.
   b. Door frames.

c. Pilot window post.
d. Pressure bulkheads.
e. Skin and any single frame or stiffener element around a cutout.
f. Skin and/or skin splices under circumferential loads.
g. Skin and/or skin splices under fore-and-aft loads.
h. Skin around a cutout.
i. Skin and stiffener combination under fore-and-aft loads.
j. Window frames.

C. *Extent of fail-safe damage.* Each particular design should be carefully assessed to establish appropriate damage criteria. In any fatigue damage determination, when it is not possible to establish the extent of damage in terms of an "obvious partial failure," the damage should be considered in terms of the complete failure of the single element involved. Thus, an obvious partial failure can be considered to be the extent of the fail-safe damage, provided a positive determination is made that the fatigue cracks will propagate in the open; for example, cracks that occur in exterior skins and which can be detected by a visual inspection at an early stage of the crack development. In a pressurized fuselage, an obvious partial failure can be verified through the inability of the cabin to maintain operating pressure or controlled decompression after occurrence of the damage.

Typical examples of the fatigue damage which should be considered are outlined below:

1. Skin cracks emanating from the edge of structural openings or cutouts which can be readily detected by visual inspection of the area.
2. A circumferential or longitudinal skin crack in the basic fuselage structure of such a length that it can be readily detected by visual inspection of the surface area.
3. Complete severence of interior frame elements or stiffeners in addition to a visually detectable crack in the adjacent skin.
4. Failure of one element where dual construction is utilized in components such as spar caps, window posts, window or door frames, and skin structure.
5. The presence of a fatigue failure in at least the tension portion of the spar web or similar elements.
6. Failure of primary attachments, including control surface hinges and fittings.

D. *Inaccessible areas.* In cases where inaccessible or blind areas are unavoidable, emphasis should be placed on determining crack propagation and residual strength of the particular fatigue-damaged structure in order to assure continued airworthiness of the structure with reasonable inspection methods and controls by the operator. Alternative procedures would be to provide additional fatigue strength to preclude fatigue cracking in the blind element or to conduct fatigue tests of the blind areas to establish that a high service life is provided.

E. *Testing of principal structural elements.* The nature and extent of tests on complete structures and/or portions of the primary structure will depend upon previous experience with similar types of structures regarding tests of this nature and the crack propagation characteristics of the structure. Single elements or members such as stringers, spar caps, and frames should be completely severed and 1.15 times the critical fail-safe load applied after severing. In cases where definite evidence is furnished that the dynamic failure effects are not present, the 1.15 factor may be eliminated or reduced in accordance with the effects noted. Alternatively, the fail-safe loads may be applied to the structure before severing and the 1.15 factor omitted.

In the case of distributed members such as a sheet-stringer combination or an integrally stiffened tension skin, a cut may be made to represent an initial crack in the element under test. If there is no failure, the length of the cut may be increased and the fail-safe load applied until either:

1. The fail-safe damage has been simulated, or
2. The crack propagation rate decreases due to redistribution of load paths, or
3. The crack propagation stops due to a crack stopper.

The simulated cracks should be as representative as possible of actual fatigue damage. In cases where it is not practical to produce actual fatigue cracks, damage may be simulated by cuts made with a fine saw, sharp blades, or a guillotine. In those cases where it is necessary to simulate damage at joints or fittings, bolts may be removed to simulate the failure if this condition would be representative of an actual failure.

F. *Analysis of principal structural elements.* In some instances, the fail-safe characteristics may be shown analytically. The analytical approach may be used when the structural configuration involved is essentially similar to one already verified by fail-safe tests, whether conducted on a previously approved type design, or whether conducted on other similar areas of the design currently being evaluated.

The analytical approach may also be used when conservative failures are assumed such that the failure would be detected considerably before the critical crack length is approached, and margins of safety resulting from the analysis are well in excess of the fail-safe residual static strength level. In any such analysis, the 1.15 factor should be included unless it can be shown, as indicated in section II H, that this factor is not required.

G. *Selection of a critical area.* Single principal structural elements and detail design points requiring investigation are identified under section II B. The process of actually locating where fail-safe damage should be simulated in an element, such as a wing spar chord or fuselage frame, requires use of sound engineering judgment that takes into account a variety of factors, such as:

1. Conducting an analysis to locate areas of maximum stress and low margin of safety.
2. Conducting strain gage surveys on undamaged structure to establish points of high stress concentration as well as the magnitude of such concentration.
3. Examining static test results to determine locations where execssive deformations occurred.
4. Determining from repeated load tests where failure may have initiated or where the crack propagation rate is a maximum.
5. Selecting locations in an element (such as a spar cap) where the stresses in adjacent elements (such as the spar web or wing skin) would be the maximum with the spar failed.
6. Selecting points in an element (such as a spar web or frame) wherein high stress concentrations are present in the residual structure with the web failed.
7. Assessing detail design areas which service experience records of similarly designed components indicate are prone to fatigue damage.

H. *Dynamic effects.* The dynamic magnification factor of 1.15 should be applied to all loads, including pressure cabin loads, unless fail-safe tests are preformed under load, or the dynamic effects are shown to be negligible by dynamic test data from a similar structure.

I. *Inspection.* Detection of fatigue cracks before they become dangerous is the ultimate control in insuring the fail-safe characteristics of the flight structure. Therefore, the aircraft manufacturer should provide sufficient guidance information to assist operators in establishing the frequency and extent of the repeated inspections of the critical structure.