SUBPART F - EQUIPMENT
(Propulsion Considerations)

Section 1. General

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Section 25.1301 Function and installation.

a. **Rule Text.**

Each item of installed equipment must-

(a) Be of a kind and design appropriate to its intended function;

(b) Be labeled as to its identification, function, or operating limitations, or any applicable combination of these factors;

(c) Be installed according to limitations specified for that equipment; and

(d) Function properly when installed.

b. **Intent of Rule.** The intent of this rule is self-evident.

c. **Background.** The regulatory history shows that this requirement originated from section 4b.601 of Civil Air Regulations (CAR) 4b, December 31, 1953. Amendment 25-AD was published in the Federal Register on December 24, 1964 (29 FR 18289), which added Part 25 [New] to the Federal Aviation Regulations and replaced Part 4b of the CAR. It was part of the Agency recodification program announced in Draft Release 61-25, published in the Federal Register on November 15, 1961 (26 FR 10698). It was recodified from CAR 4b.601 without any substantive changes.

d. **Policy/Compliance Methods.**

(1) The following excerpt is from Advisory Circular AC 29-2B, "Certification of Transport Category Rotorcraft," and provides guidance for the application of this section to transport rotorcraft airplane propulsion systems, including engine accessories, airplane and engine fuel systems and APU's. (Although the AC concerns transport category rotorcraft, it may also provide additional insight into compliance methods useful for other aircraft.)

> Information regarding installation limitations and proper functioning is normally available from the equipment manufacturers in their installation and operations manuals. In addition, some other paragraphs in this AC include criteria for evaluating proper functioning of particular systems.

(2) This general rule is quite specific in that it applies to each item of installed equipment. It should be emphasized, however, that even though a general rule

is relevant, a rule that gives specific functional requirements for a particular system would prevail over a general rule. Therefore, if a rule exists that defines specific system functioning requirements, its provisions should be used to evaluate the acceptability of the installed system and not the provisions of this general rule. It should also be understood that an interpretation of a general rule should not be used to lessen or increase the requirements of a specific rule. Section 25.1309 is another example of a general rule, and this discussion is appropriate when applying its provisions.

e. **References.**

(1) Civil Aeronautics Manual 4b (CAR 4b.451), December 31, 1953.

(2) Amendment 25-AD (29 FR 18289, December 24, 1964).

(3) Advisory Circular 29-2B, "Certification of Transport Category Rotorcraft," July 30, 1997.

Section 25.1305 Powerplant instruments.

a. **Rule Text.**

The following are required powerplant instruments:

(a) For all airplanes:

(1) A 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) A fuel quantity indicator for each fuel tank.

(3) An oil quantity indicator for each oil tank.

(4) An oil pressure indicator for each independent pressure oil system of each engine.

(5) An oil pressure warning means for each engine, or a master warning means for all engines with provision for isolating the individual warning means from the master warning means.

(6) An oil temperature indicator for each engine.

(7) Fire-warning indicators.

(8) An augmentation liquid quantity indicator (appropriate for the manner in which the liquid is to be used in operation) for each tank.

(b) For reciprocating engine-powered airplanes. In addition to the powerplant instruments required by paragraph (a) of this section, the following powerplant instruments are required:

(1) A carburetor air temperature indicator for each engine.

(2) A cylinder head temperature indicator for each air-cooled engine.

(3) A manifold pressure indicator for each engine.

(4) A fuel pressure indicator (to indicate the pressure at which the fuel is supplied) for each engine.

(5) A fuel flowmeter, or fuel mixture indicator, for each engine without an automatic altitude mixture control.

(6) A tachometer for each engine.

(7) A device that indicates, to the flight crew (during flight), any change in the power output, for each engine with --

(i) An automatic propeller feathering system, whose operation is initiated by a power output measuring system; or

(ii) A total engine piston displacement of 2,000 cubic inches or more.

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

(c) For turbine engine-powered airplanes. In addition to the powerplant instruments required by paragraph (a) of this section, the following powerplant instruments are required:

(1) A gas temperature indicator for each engine.

(2) A fuel flowmeter indicator for each engine.

(3) A tachometer (to indicate the speed of the rotors with established limiting speeds) for each engine.

(4) A means to indicate, to the flight crew, the operation of each engine starter that can be operated continuously but that is neither designed for continuous operation nor designed to prevent hazard if it failed.

(5) An indicator to indicate the functioning of the powerplant ice protection system for each engine.

(6) An indicator for the fuel strainer or filter required by § 25.997 to indicate the occurrence of contamination of the strainer or filter before it reaches the capacity established in accordance with § 25.997(d).

(7) A warning means for the oil strainer or filter required by § 25.1019, if it has no bypass, to warn the pilot of the occurrence of contamination of the strainer or filter screen before it reaches the capacity established in accordance with § 25.1019(a)(2).

(8) An indicator to indicate the proper functioning of any heater used to prevent ice clogging of fuel system components.

(d) For turbojet engine powered airplanes. In addition to the powerplant instruments required by paragraphs (a) and (c) of this section, the following powerplant instruments are required:

(1) An indicator to indicate thrust, or a parameter that is directly related to thrust, to the pilot. The indication must be based on the direct measurement of thrust or of parameters that are directly related to thrust. The indicator must indicate a change in thrust resulting from any engine malfunction, damage, or deterioration.

(2) A position indicating means to indicate to the flight crew when the thrust reversing device is in the reverse thrust position, for each engine using a thrust reversing device.

(3) An indicator to indicate rotor system unbalance.

(e) For turbopropeller-powered airplanes. In addition to the powerplant instruments required by paragraphs (a) and (c) of this section, the following powerplant instruments are required:

(1) A torque indicator for each engine.

(2) Position indicating means to indicate to the flight crew when the propeller blade angle is below the flight low pitch position, for each propeller.

(f) For airplanes equipped with fluid systems (other than fuel) for thrust or power augmentation, an approved means must be provided to indicate the proper functioning of that system to the flight crew.

(Amdt. 25-23, 35 FR 5678, Apr. 8, 1970, as amended by Amdt. 25-35, 39 FR 1831, Jan. 15, 1974; Amdt. 25-36, 39 FR 35461, Oct. 1, 1974; Amdt. 25-38, 41 FR 55467, Dec. 20, 1976; Amdt. 25-54, 45 FR 60173, Sept. 11, 1980; Amdt. 25-72, 55 FR 29785, July 20, 1990)

b. **Intent of Rule.** The intent of this rule is to provide guidance and define minimum instrumentation requirements for transport category airplanes.

c. **Background.**

(1) The regulatory history shows that this requirement originated from the Civil Air Regulations (CAR) 4b, December 31, 1953. Amendment 25-AD was published in the Federal Register on December 24, 1964 (29 FR 18289), which added Part 25 [New] to the Federal Aviation Regulations and replaced Part 4b of the CAR. It was part of the Agency recodification program announced in Draft Release 61-25, published in the Federal Register on November 15, 1961 (26 FR 10698). It was recodified from the CAR without any substantive changes.

(2) Notice of Proposed Rulemaking 65-43 (31 FR 93, January 5,1966), proposed the addition of indicating requirements for engine starters. This proposal was prompted by uncontained engine starter failures on certain airplanes that resulted in fire warnings. The following excerpt is from the preamble to Notice 65-43:

> Section 25.1305 would be amended to require for each air turbine engine starter not designed for continuous use, a means to indicate to the flight crew when that starter is energized. For these starters, overspeed conditions can result from continued energization after engine starting is accomplished. Overspeeding may cause overheating and hazardous disintegration of high-energy rotating parts. These hazards are not present in the case of starters designed to remain continuously engaged with the engine.

Amendment 25-11 (32 FR 6906, May 5, 1967) followed Notice 65-43. The preamble to that amendment provides additional information on the intent of the regulation:

> The notice proposed to add a new § 25.1305(x) to require "a means, for each air turbine engine starter not designed for continuous use, to indicate to the flight crew when that starter is energized."
>
> One commenter states that, for starters designed to contain failures of high energy rotating parts, no indicator should be required because no hazard would result even if the starter is not designed for continuous operation. Another commenter states that numerous possible factors, such as use of starters that cannot be used continuously, protection by starter location, and containment of failed components should obviate the need for an indicating means regardless of whether the starter is designed for continued operation. The Administrator agrees with these comments. This amendment, therefore, covers only starters that can be used continuously, but that are neither designed for continuous operation nor designed to prevent hazard if they fail.

(3) Notice of Proposed Rulemaking 68-18 (33 FR 11913, August 22, 1968) proposed to reorganize this section. The following excerpt from the preamble to the Notice provides explanation for the change

> The arrangement of § 25.1305 is difficult to follow, as there is an intermix of reciprocating, turbo-propeller, and turbojet requirements. The proposal would rearrange and classify the requirements to provide clarity without changing the substance of the rule.

Amendment 25-23 (33 FR 5665, April 8, 1970) followed Notice 68-18 and adopted the proposed reorganization.

(4) Notice of Proposed Rulemaking 71-12 (36 FR 8383, May 5,1971) proposed that the requirements of § 25.1305 be revised to add:

- an indicator to show the status of the ice protection system for each engine (per § 25.1093),
- new indicators to determine the status of a fuel strainer or filter (per § 25.997), and
- an oil strainer or filter (per § 25.1019).

New engine imbalance indicators also were proposed. The following excerpt from the preamble to the Notice provides an explanation for these proposals:

> Proposed new subparagraph (c)(5) is merely a transfer from the current requirement of § 25.1093(b).
>
> The indicator and warning means proposed in new subparagraphs (c)(6) and (7) are necessary to implement the requirements of proposed § 25.997 and § 25.1019, respectively.

> The indicator proposed in new subparagraph (c)(8) is necessary in the event that a mechanical means, such as a fuel heater, is used in the airplane to heat the fuel as it passes through a filter or screen in the fuel system. Such an indicator could be used in meeting the requirements of proposed § 25.951.
>
> The rotor system unbalance indicator proposed in new subparagraph (d)(3) is necessary since the effect of a rotor system failure can be catastrophic because of the resulting engine unbalance if the flight crew is not provided with an appropriate vibration warning. While present requirements concerning failure of turbine engine installations do not cover the flight crew warning necessary for safety, vibration monitoring systems have been voluntarily installed in most turbine powered transport airplanes currently in operation and special conditions have been issued requiring the indicator on transport category airplanes using turbojet engines. The FAA is aware that, to the extent that currently available vibration detectors are not as reliable as engines, this proposal may impose economic penalty. Nevertheless, the FAA believes that for airplanes using turbojet engines, a vibration indicator is necessary in the interest of safety.

Amendment 25-35 (39 FR 1831, January 15, 1974) followed Notice 71-12. The following excerpts from the preamble to that amendment contain the disposition of comments received to the Notice, and provide further guidance on the intent of this rule.

> Several commenters express doubt as to the reliability of presently available engine vibration indicating systems, and suggest that proposed § 25.1305(d)(3) not be adopted. They further point out that the present equipment is expensive and difficult to maintain. As stated in the Notice, the FAA is aware that the currently available vibration detectors are not as reliable as the engines they monitor and to that extent, they may impose an economic penalty; however, a rotor system failure can be catastrophic and the contributions to flight safety gained from a vibration monitoring system that provides the flight crew with an appropriate vibration warning far outweigh, any difficulties that may be experienced. The value of the system has been recognized by the aviation industry in that vibration monitoring systems have been voluntarily installed in most turbine powered transport category airplanes currently in production.
>
> Several commenters express concern that inadvertent engine shutdowns might possibly result from the failure of the flight crew to differentiate between normal and abnormal engine vibration readings. They point out that variations in vibration levels exist between different engines of the same type as well as on the same engine at different flight and power conditions. The rule, however, does not require that a level of acceptable vibration be specified. It merely requires an indication of “rotor system imbalance” in the engine as installed in the aircraft. The indicator may be employed to sense a trend of vibrations over a period of time, rather than a specific level at a particular instant. The FAA considers the addition of a vibration indicator to be necessary in the interest of safety and that flight crews will be able to properly interpret the indicator readings.
>
> One commenter expresses concern that the proposed vibration indicating system could not be used effectively as the principle means of detecting engine failure. The intent of the amendment does not, however, make the vibration indicator the sole or exclusive monitoring indicator. Rather, it is an addition to the present engine instrumentation and provides additional information on engine conditions.

(5) Notice of Proposed Rulemaking 75-10 (40 FR 10802, March 7, 1975) proposed the addition of an indicator to monitor any [non-combustible] fluid used in thrust or power augmentation systems. The following excerpt from the preamble to the Notice provides an explanation for this proposal:

> Engine manufacturers quantify fluid flow rates needed to obtain takeoff power. The proposal would require that a means be provided to indicate to the flight crew the proper functioning of the fluid augmentation system.

Amendment 25-38 (41 FR 55454, December 20, 1976) followed Notice 75-10. The following excerpt from the preamble to the Amendment discussed the proposal and provides additional insight into the intent of this rule:

> Several commenters suggest that the proposed change to § 25.1305 be revised to except anti-detonant injection (ADI) systems from the powerplant instrument proposal for fluid augmentation systems. The commenters express the opinion that the proposal for § 25.1143(d) concerning automatic controls for fluid injection systems (other than fuel) eliminated the need for a powerplant instrument for the ADI system. The FAA believes that the flight crew should be able to monitor the proper functioning of any fluid system that is used for thrust or power augmentation and the section as adopted is applicable to ADI systems. However, the section has been clarified to ensure application only to fluids systems that are used for thrust or power augmentation.

(6) Notice of Proposed Rulemaking 75-31 (40 FR 29410, July 11, 1975) proposed the addition of indicators to:

- warn of engine failure [§ 25.1305(c)(9)(i)],
- show status of the automatic takeoff power / thrust system [§ 25.1305(c)(9)(ii)], and
- indicate thrust [§ 25.1305(d)(1)].

Parts 25.1305(c)(9)(i) and (c)(9)(ii) were subsequently withdrawn from consideration. The following excerpt from the preamble to the Notice provides further explanation for § 25.1305(d)(1) as follows.

> The proposed § 25.1305(d)(1) would revise the current requirement to more clearly indicate the kinds of engine deficiencies to be considered, and would require a direct measurement either of thrust or of a parameter that is related to thrust. The use of gas stream pressure as a parameter would no longer be permitted for all engines since for some engines it does not provide an adequate indication of a change in thrust caused by all engine malfunctions, damage, or deterioration.

Amendment 25-54 (45 FR 60154, September 11, 1980) followed Notice 75-31. The following excerpts from the preamble to the Amendment discuss the proposal and provide additional insight into the intent of the regulation:

> One commenter objects to revising § 25.1305(d)(1), stating that significant aerodynamic forces acting on the powerplant nacelle make the direct measurement of thrust impractical. The FAA agrees that such forces may be significant.
>
> This commenter further objects to the revision, stating that it is beyond the state of the art to prohibit a parameter from being used if the accuracy of the indication will be adversely affected by any engine malfunction or damage. The FAA agrees that precise values of thrust provided by a malfunctioning, damaged, or deteriorated engine are unnecessary, provided that any changes in thrust due to engine malfunction, damage, or deterioration are indicated to the pilot. The paragraph is revised to require that the indication must be based on the direct measurement of thrust or of parameters that are directly related to thrust.
>
> Although concurring with § 25.1305(d)(1), one commenter states that he would prefer to retain the existing requirements and delete the words *", or to indicate a gas stream pressure that can be related to thrust . . ."* The FAA does not agree. The change suggested by this commenter would eliminate the requirement for thrust information and would retain the requirement for change-of-thrust information only. It also would provide a lower level of safety than the adopted paragraph.
>
> This commenter also states that § 25.1305(d)(1) should be complementary to a similar requirement in Part 33 of this chapter. The FAA does not agree. In current practice, the airframe manufacturer determines how performance should be met. The choice of a means to indicate thrust is negotiated between the airplane manufacturer and the engine manufacturer. The factors that influence the final choice are substantial and may vary among airplane designs. These factors may not be known to the engine manufacturer at the time of engine type certification.
>
> Another commenter states that the need for an actual value of thrust is not obvious, whereas indication of a loss of thrust would satisfy the original proposal. The FAA agrees that the actual value of thrust is of little value to the pilot. § 25.1305(d)(1) is revised to specify that the indicator must indicate thrust, or a parameter related to thrust, to the pilot.

(7) Notice of Proposed Rulemaking 84-21 (49 FR 47358, December 3, 1984) proposed the removal of § 25.1305(e)(3). The following excerpt from the preamble to the Notice provides additional explanation for this proposal:

> Prior to Amendment 25-23, a means to indicate reverse pitch was required for reciprocating powered airplane, and a means to indicate blade angle below the flight low pitch position (Beta) was required for turbopropeller airplanes. Due to an apparent editorial error, this section was revised to require both indicating means for turbopropeller aircraft. As the additional reverse indication serves no useful purpose for turbopropeller airplanes, § 25.1305 would be amended to specify that only Beta indication is required for turbopropeller airplanes.

Amendment 25-72 (55 FR 29756, July 20, 1990) followed Notice 84-21. It adopted the proposed removal of the requirement of indication of reverse pitch in § 25.1305. No adverse comments were received in response to the Notice.

d. **Policy/Compliance Methods**.

(1) When Amendment 25-36 (39 FR 35461, October. 1, 1974) was promulgated, it was understood that full-time display of the parameters required by § 25.1305 would be provided to the flight deck, which included the flight engineer. The flight engineer's main responsibility was to monitor and manage the fuel system. Review of the text of § 25.1305 shows that, within this and later amendments, there was a differentiation made between parameters based on which member of the flight crew needed to know the information. For example, for oil filter bypass indication (for engines without a bypass where sudden engine failure was likely), the rule states "indicator to warn the pilot." For other parameters such as fuel heat, fuel filter bypass, rotor system imbalance, etc., the rule states that an indicator is required, but leaves it up to the designer to define which flight crew member needs to know the information so that appropriate action could be taken.

With the advent of new technology flight deck display systems, and the application of two crew flight deck designs, all actions must now be performed by the two crew members; therefore, display of the parameters defined in § 25.1305 must be provided to the flight crew. This new technology allowed time sharing of displays such that continuous monitoring of displays by the flight engineer was not required. The FAA adapted its accepted compliance methods to this new technology. The fundamental policy was that all required instruments must be displayed when crew awareness or action was required. This display philosophy is provided in Advisory Circular (AC) 25-11, Transport Category Airplane Electronic Display Systems." The following excerpt comes from AC 25-11 and provides insight into FAA guidance

> **Full Time vs. Part Time Displays.** Some airplane parameters or status indicators are required by the Federal Aviation Regulations to be displayed, yet they may only be necessary or required in certain phases of flight. If it is desired to inhibit some parameters from full-time display, an equivalent level of safety to full-time display must be demonstrated. Criteria to be considered include the following:
>
> (1) Continuous display of the parameter is not required for safety of flight in all normal flight phases.
>
> (2) The parameter is automatically displayed in flight phases where it is required.
>
> (3) The inhibited parameter is automatically displayed when its value indicates an abnormal condition, or when the parameter reaches an abnormal value.
>
> (4) Display of the inhibited parameter can be manually selected by the crew without interfering with the display of other required information
>
> (5) If the presence of the new parameter is not sufficiently self-evident, suitable altering must accompany the automatic presentation.

(2) The following guidance supplements previous guidance regarding powerplant instruments published in AC 25-11, "Transport Category Airplane Electronic Display Systems," Section 4(a)(3)(ix), Propulsion System Parameter Displays:

A. Propulsion system parameter displays must be arranged and isolated from each other so that any failure or malfunction that affects the display or accuracy of any propulsion system parameter for one engine will not cause the loss of display for any remaining engine or adversely affect the accuracy of any parameter for any remaining engine.

B. For any propulsion parameter display system, no single failure, or malfunction, or probable combination of failures, shall result in the loss of display, or in the misleading display, of any propulsion parameter(s) that would jeopardize the continued safe operation of the airplane.

C.1. Propulsion system parameters that are not displayed continuously must be displayed automatically when any operating limit is reached or exceeded. If the propulsion parameter does not have an operating limit associated with it, then the parameter must either be displayed automatically when a predetermined level requiring crew awareness is reached, or an indication must be provided to alert the crew to manually select the parameter display page when the level is reached. If the crew indicator option is selected, the indication must be compatible with the design philosophy employed for the airplane's flight deck message system. Independent of whether the parameter has an operating limit or not, the required displays and alerts for each phase of flight and airplane configuration must be provided in a timely manner and in a form that enables the crew to identify and carry out necessary actions.

C.2. If a monitoring indicator is operational during only specific portions of the flight envelope, then an additional means must be provided to alert the crew of a failure, if failure of the monitored system would constitute a threat to the continued safety of the aircraft.

D. Because of the concern for pilot distraction during the critical takeoff flight phase, crew alerts and automatic or pop-up type instrument displays should be inhibited from the takeoff powersetting speed to a minimum of 400 ft AGL, unless immediate crew action is required to preclude an unsafe condition.

E. Propulsion system parameters necessary for safe operation, including engine restart, must be displayed automatically after the loss of normal electrical power.

(3) In addition, the FAA has established guidelines for specific systems and through these reflect established design philosophy:

A. The presence of self monitoring systems may mitigate the need for certain of the § 25 required flight deck instruments. For example, regarding APU systems. Certain APU parameters are, by design, monitored by the APU electronic control unit, and in the event a monitored parameter reaches its operating limit, or a fault develops, an automatic APU shutdown is initiated. Depending on the integrated design in the airplane and the automatic protective features of the airplane electrical system, together with the protective features built into the APU control unit, an automatic fault shutdown can have a resulting action essentially the same as the flightcrew would take under the same fault or condition event. This kind of installation may delete the need for certain of the Federal Aviation Regulation (FAR) 25 required APU flight deck instruments. In general, however, some kind of APU status (off or operating), along with fire protection status has been found to be required.

B. Compliance with the literal interpretation of a regulation may not be sufficient. For example, while § 25.1305(c)(5) literally requires only an indication of the functioning powerplant ice protection system; the FAA position has been that there are additional safety considerations that should be addressed (i.e., requiring status of critical systems).

C. Crew awareness must be of prominent importance. It must be remembered that status level messages do not provide immediate crew awareness and, therefore, do not qualify as “indicators” as required by § 25.1305(c)(6). The only sign given to the crew regarding status level information is a general message on the EICAS screen. The crew would have to take action in order to find out the nature of this status level information and this is not generally done in flight. Advisory messages, on the other hand, are brought to the crew’s attention by means of a light or sound. No crew action must be taken in order to find out the nature of advisory alerts and they do qualify as “indicator(s)”. In addition, the FAA is concerned that this message level may result in a crew being unaware of an increasing potential for engine loss and, thereby, continuing a flight they would otherwise divert.

D. The presence of self collation systems may mitigate the need for certain of the FAR 25-required flight deck instruments. For example, to detect changes in engine thrust resulting from any engine malfunction, damage or deterioration requires the flight crew to observe more than one engine parameter. Systems that provide concise, collated information upon malfunction would enhance flight safety.

E. Design of a system should reflect component and total system inaccuracies that should be accounted for by compensating margins in the aircraft flight manual. For example, the design of a thrust indicating system should be such that it will indicate thrust to the pilot. The parameter selected must be directly related to thrust, except that a parameter may not be used if the accuracy of the indication based on that parameter will be adversely affected by any engine malfunctions, damage, or deterioration. The instrument must also assure that the engine is producing the desired thrust to provide the airplane performance shown in the flight manual. The purpose is to provide airplane takeoff and flight path performance at the weight, altitude, and temperature encountered for that particular operation.

F. Criticality of the system display should be evaluated in accordance with the requirements in §§ 25.1309 and 25.1333. Advisory Circular 25.1309-1 clarifies the meaning of these requirements and the types of analyses that are appropriate to show that systems meet them. Advisory Circular 25.1309-1 also provides criteria to correlate the depth of analysis required with the type of function the system performs (nonessential, essential, or critical); however, a system may normally be performing nonessential or essential functions from the standpoint of required availability and have potential failure modes that could be more critical. In this case, a higher level of criticality applies.

G. The readability and repeatability of any “smart system” (self testing, diagnosis and collation) should be such that :

1. the pilots ability to read the instrument will not increase any inaccuracies of the overall system or result in errors in thrust settings, and,

2. failures will be so infrequent that the crew can use it with confidence, and rarely need to rely on back-up instruments. critical.

H. Software based systems should have the computer software verified and validated in an acceptable manner. One acceptable means of compliance for the verification and validation of computer software is outlined in RTCA Document DO-178A. Software documentation appropriate to the level to which the verification and validation of the computer software has been accomplished should be provided as noted in DO-178A.

e. **References.**

(1) Civil Air Regulations 4b, dated December 31, 1953, per Amdt. 4b-1 through 4b-12, and the editorial changes required by special Regulation SR-430, effective December 31, 1958.

(2) Amendment 25-AD (29 FR 18289, December 24, 1964).

(3) Notice of Proposed Rulemaking 65-43 (31 FR January 5,1966).

(4) Amendment 25-11 (32 FR 6906, May 3, 1967).

(5) Notice of Proposed Rulemaking 68-18 (33 FR 11913, August 22, 1968).

(6) Amendment 25-23 (33 FR 5665, April 8, 1970).

(7) Notice of Proposed Rulemaking 71-12 (36 FR 8383, May 5, 1971).

(8) Amendment 25-35 (39 FR 1831, January 15, 1974).

(9) Notice of Proposed Rulemaking 75-10 (40 FR 10802, March 7, 1975).

(10) Amendment 25-38 (41 FR 55454, December 20, 1976).

(11) Notice of Proposed Rulemaking 75-31 (40 FR 29410, July 11, 1975).

(12) Amendment 25-54 (45 FR 60154, September 11, 1980).

(13) Notice of Proposed Rulemaking 84-21 (49 FR 47358, December 3, 1984).

(14) Amendment 25-72 (55 FR 29756, July 20, 1990(

(15) Advisory Circular 20-88A, “Guidelines on the Marking of Aircraft Powerplant Instruments (Displays),” September 30, 1985.

(16) Advisory Circular 25-11, “Transport Category Airplane Electronic Display Systems,” July 16, 1987.

(17) Advisory Circular 25.1309-1A, “System Design Analysis,” June 21, 1988.

(18) Advisory Circular 25.1329-lA, “Automatic Pilot Systems Approval,” July 8, 1968.

(19) Advisory Circular 90-45A, “Approval of Area Navigation Systems for Use in the U.S. National Airspace System.” February 21, 1975.

(20) Advisory Circular 120-28C, “Criteria for Approval of Category III Landing Weather Minima.,” March 9, 1985.

(21) Advisory Circular 120-29, “Criteria for Approving Category I and Category II Landing Minima for FAR 121 Operators,” September 25, 1970.

(22) The following documents can be obtained from the Radio Technical Commission for Aeronautics (RTCA), One McPherson Square, Suite 500, 1425 K Street NW, Washington, D.C. 20005;

(a) RTCA DO-160B, “Environmental Conditions and Test Procedures for Airborne Equipment.”

(b) RTCA DO-178A, “Software Considerations in Airborne Systems and Equipment Certification.”

(c) RTCA DO-187, “Minimum Operational Performance Standards for Airborne Area Navigation Equipment Using Multi-Sensor Inputs.”

(23) The following documents can be obtained from the Society of Automotive Engineers, Inc. (SAE), 400 Commonwealth Drive, Warrendale, PA l5096:

(a) ARP 268F, “Location and Actuation of Flight Deck Controls for Transport Aircraft.”

(b) AS 425B, "Nomenclature and Abbreviations, Flight Deck Area."

(c) ARP 450D, "Flight Deck Visual, Audible and Tactile Signals."

(d) ARP 926A, "Fault/Failure Analysis Procedure."

(e) ARP 1068B, "Flight Deck Instrumentation, Display Criteria and Associated Controls for Transport Aircraft."

(f) AIR 1093, "Numeral, Letter, and Symbol Dimensions for Aircraft Instrument Displays."

(g) ARP 1161, "Crew Station Lighting - Commercial Aircraft."

(h) ARP 1834, "Fault/Failure Analysis for Digital Systems and Equipment."

(i) ARP 1874, "Design Objectives for CRT Displays for Part 25 (Transport) Aircraft."

(j) AS 8034, "Minimum Performance Standards for Airborne Multipurpose Electronic Displays."

(k) ARP 1782, "Photometric and Colormetric Measurement Procedures for Direct View CRT Display Systems."

(l) ARP 4032, "Human Integration Color Criteria and Standards."

(24) The following documents can be obtained from the National Technical Information Service, Springfield, Virginia 22161:

(a) DOT/FAA/RD-81/38 II, "Aircraft Alerting Systems Standardization Study, Volume II, Aircraft Alerting Systems Design Guidelines."

(b) DOT/FAA/PM-85-19, "The Development and Evaluation of Color Systems for Airborne Applications."

Section 25.1307 Miscellaneous equipment.

a. **Rule Text.**

The following is required miscellaneous equipment:

(a) [Reserved]

(b) Two or more independent sources of electrical energy.

(c) Electrical protective devices, as prescribed in this part.

(d) Two systems for two-way radio communications, with controls for each accessible from each pilot station, designed and installed so that failure of one system will not preclude operation of the other system. The use of a common antenna system is acceptable if adequate reliability is shown.

(e) Two systems for radio navigation, with controls for each accessible from each pilot station, designed and installed so that failure of one system will not preclude operation of the other system. The use of a common antenna system is acceptable if adequate reliability is shown.

(Amdt. 25-23, 35 FR 5678, April 8, 1970, as amended by Amdt. 25-46, 43 FR 50598, Oct. 30, 1978; Amdt. 25-54, 45 FR 60173, Sept. 11, 1980; Amdt. 25-72, 55 FR 29785, July 20, 1990)

b. **Intent of Rule.** This regulation provides a listing of several items of required miscellaneous equipment and the intent is self-evident.

c. **Background.**

(1) The regulatory history shows that this requirement originated from Section 605 of the Civil Air Regulations (CAR) 4b, December 31, 1953. Amendment 25-AD was published in the Federal Register on December 24, 1964 (29 FR 18289), which added Part 25 [New] to the Federal Aviation Regulations and replaced Part 4b of the CAR. It was part of the Agency recodification program announced in Draft Release 61-25, published in the Federal Register on November 15, 1961 (26 FR 10698). It was recodified from CAR 4b.605 without any substantive changes.

(2) The rule was first modified by Amendment 25-23 (35 FR 5678, April 8, 1970), which followed Notice of Proposed Rulemaking 68-18 (33 FR 11913, August 22, 1968). The following excerpt from the preamble to Amendment 25-23 provides additional insight into the change and intent of the rule:

> With respect to the proposed amendment to § 25.1307, it was recommended that certain items listed in the proposal should be deleted on the basis that they are covered in other sections of Part 25. The FAA does not agree with this comment. While equipment listed in § 25.1307 may be referred to in other sections of Part 25, the listing of such equipment in § 25.1307 is necessary since it is only there

> that the equipment is required. The other sections generally treat the equipment from the standpoint of performance, reliability, and installation.
>
> It was contended by one commenter that the duplication of communication and navigation radio equipment required by § 25.1307 imposes type certification rules more stringent than § 91.33 or § 121.345. While the FAA agrees that under Parts 91 and 121 there are situations in which an airplane can be operated without two communication and navigation systems, there are always operations in which a transport category airplane would be involved which do require dual systems. Therefore, the FAA considers it necessary to make this a design requirement for all future transport category airplanes.
>
> In response to another comment, § 25.1307 has been amended to make it clear that some interconnection or component sharing is permissible if system reliability is not impaired. In this connection, the word "independent" has been removed and the regulation now requires that there be two systems for two-way radio communication designed and installed so that failure of one system will not preclude operation of the other system. In addition, the use of a common antenna is acceptable, if adequate reliability is shown.

(3) This rule was further modified by Amendment 25-46 (43 FR 50578, October 30, 1978) and Amendment 25-54 (45 FR 60154, September 11, 1980). Those amendments followed five separate Notices of Proposed Rulemaking:

- Notice 75-10 (40 FR 10802, March 7, 1975);
- Notice 75-19 (40 FR 21866, May 19, 1975);
- Notice 75-23 (40 FR 23048, May 27, 1975);
- Notice 75-26 (40 FR 24802, June 10, 1975); and
- Notice 75-31 (40 FR 29410, July 11, 1975).

Few substantive changes were made to the rule, however.

(4) The rule was further modified by Amendment 25-72 (55 FR 29756, July 20, 1990), which followed Notice of Proposed Rulemaking 84-21 (49 FR 47358, December 3, 1984). The following excerpt is from the preamble to Amendment 25-72:

> [The Notice proposed to amend] § 25.1307 . . . by transferring the contents of paragraph (a) to § 25.785, and removing paragraphs (f), (g), and (h). No comment concerning this proposal was received; therefore, § 25.1307 is amended as proposed.

d. **Policy/Compliance Methods.**

(1) FAA policy and guidance for this regulation appear in several advisory circulars and internal FAA memos. Compliance has been demonstrated though proper design with adherence to FAA guidelines. In general, these guidelines are reflected in the following excerpt from Advisory Circular 25-23, paragraph 752 :

752. **AMENDMENT 25-23, Effective May 8, 1970**.

a. Change to Regulation. The following is required miscellaneous equipment:

(1) A seat and safety belt, for each occupant.

(2) Two or more independent sources of electrical energy.

(3) Electrical protective devices, as prescribed in this Part.

(4) Two systems for two-way radio communications, with controls for each accessible from each pilot station, designed and installed so that failure of one system will not preclude operation of the other system. The use of a common antenna system is acceptable if adequate reliability is shown.

(5) Two systems for radio navigation, with controls for each accessible from each pilot station, designed and installed so that failure of one system will not preclude operation of the other system. The use of a common antenna system is acceptable if adequate reliability is shown.

(6) A windshield wiper, or equivalent, for each pilot station.

(7) An ignition switch for each engine.

(8) Portable fire extinguishers as prescribed in § 25.853(e) and (f).

b. Guidance.

(1) While equipment listed in § 25.1307 may be referred to in other sections of Part 25, the listing of such equipment in § 25.1307 is necessary since it is only there that the equipment is required. The other sections generally treat the equipment from the standpoint of performance, reliability and installation.

(2) Regarding duplication of communication and navigation radio equipment, although under Parts 91 and 121, there are situations in which an airplane can be operated without two communication and navigation systems, there are always operations in which a transport category airplane would be involved which do require dual systems. Therefore, it is considered necessary to make this a design requirement for all future transport category airplanes.

(3) In order to make it clear that some interconnection or component sharing is permissible if system reliability is not impaired, the regulation now requires that there be two systems for two way radio communication designed and installed so that failure of one system will not preclude operation of the other system.

(2) In addition, these guidelines are reflected in the following excerpt from Advisory Circular 23-8A C1, “Flight Test Guide for Certification of Part 23 Airplanes,” paragraph 291, Section 23.1307:

291. **SECTION 23.1307 (as amended by amendment 23-23), MISCELLANEOUS EQUIPMENT.**

. . .

b. Procedures. Verify the proper functioning of each required equipment item. Confirm that when approved production seats are in place, the seats can be easily adjusted and will remain in a locked position. Confirm that the master switch arrangement is prominently located and marked. Where applicable, proper function of these items may be verified by ground tests.

(3) Guidelines also are reflected in the following excerpt from Advisory Circular 29-2B, "Certification of Transport Category Rotorcraft," paragraph 620:

620. **§ 29.1307 (through Amendment 25-24) MISCELLANEOUS EQUIPMENT.**

. . .

b. Procedure. When reviewing possible solutions to the master switch arrangement requirement, the following considerations should be included.

(1) *System separation*. Since wiring from each electrical system will be brought in close proximity to each other, extra care should be taken to maintain some separation. As examples, common connectors, common grounds, and common wire routing should be avoided.

(2) *Installation of switches*. The single switch should be avoided since it introduces the possibility of a single failure turning off the entire electrical system. One solution that is commonly used provides a close grouping of the switches such that the pilot can easily reach all switches and turn them all off with one action. This solution requires a cockpit evaluation to ensure the installation will be suitable for different hand sizes. Another solution involves a gang bar that can be moved with a single motion to turn off all sources. This solution has been found to be acceptable in several instances. Other solutions should be evaluated on their own merits, and the primary emphasis should be on maintaining some minimum system separation and conducting a cockpit evaluation by flight test personnel.

e. **References.**

(1) Civil Air Regulations 4b (CAR 4b.451), December 31, 1953.

(2) Amendment 25-AD (29 FR 18289, December 24, 1964).

(3) Amendment 25-23 (35 FR 5678, April 8, 1970).

(4) Amendment 25-46 (43 FR 50598, October 30, 1978).

(5) Amendment 25-54 (45 FR 60173, Sept. 11, 1980).

(6) Amendment 25-72 (55 FR 29785, Jul 20, 1990)

(7) Advisory Circular 23-8A C1, "Flight Test Guide for Certification of Part 23 Airplanes," August 30, 1993.

(8) Advisory Circular 25-23, May 8, 1970.

(9) Advisory Circular 29-2B, “Certification of Transport Category Rotorcraft,” July 30, 1997.

Section 25.1309 Equipment, systems, and installations.

a. **Rule Text.**

(a) The equipment, systems, and installations whose functioning is required by this subchapter, must be designed to ensure that they perform their intended functions under any foreseeable operating condition.

(b) The airplane systems and associated components, considered separately and in relation to other systems, must be designed so that --

(1) The occurrence of any failure condition which would prevent the continued safe flight and landing of the airplane is extremely improbable, and

(2) The occurrence of any other failure conditions which would reduce the capability of the airplane or the ability of the crew to cope with adverse operating conditions is improbable.

(c) Warning information must be provided to alert the crew to unsafe system operating conditions, and to enable them to take appropriate corrective action. Systems, controls, and associated monitoring and warning means must be designed to minimize crew errors which could create additional hazards.

(d) Compliance with the requirements of paragraph (b) of this section must be shown by analysis, and where necessary, by appropriate ground, flight, or simulator tests. The analysis must consider --

(1) Possible modes of failure, including malfunctions and damage from external sources.

(2) The probability of multiple failures and undetected failures.

(3) The resulting effects on the airplane and occupants, considering the stage of flight and operating conditions, and

(4) The crew warning cues, corrective action required, and the capability of detecting faults.

(e) Each installation whose functioning is required by this subchapter, and that requires a power supply, is an ''essential load'' on the power supply. The power sources and the system must be able to supply the following power loads in probable operating combinations and for probable durations:

(1) Loads connected to the system with the system functioning normally.

(2) Essential loads, after failure of any one prime mover, power converter, or energy storage device.

(3) Essential loads after failure of --

(i) Any one engine on two-engine airplanes; and

(ii) Any two engines on three-or-more-engine airplanes.

(4) Essential loads for which an alternate source of power is required by this chapter, after any failure or malfunction in any one power supply system, distribution system, or other utilization system.

(f) In determining compliance with paragraphs (e)(2) and (e)(3) of this section, the power loads may be assumed to be reduced under a monitoring procedure consistent with safety in the kinds of operation authorized. Loads not required in controlled flight need not be considered for the two-engine-inoperative condition on airplanes with three or more engines.

(g) In showing compliance with paragraphs (a) and (b) of this section with regard to the electrical system and equipment design and installation, critical environmental conditions must be considered. For electrical generation, distribution, and utilization equipment required by or used in complying with this chapter, except equipment covered by Technical Standard Orders containing environmental test procedures, the ability to provide continuous, safe service under foreseeable environmental conditions may be shown by environmental tests, design analysis, or references to previous comparable service experience on other aircraft.

(Amdt. 25-23, 35 FR 5679, April 8, 1970, as amended by Amdt. 25-38, 41 FR 55467, Dec. 20, 1976; Amdt. 25-41, 42 FR 36970, July 18, 1977)

b. **Intent of Rule.** This regulation covers, but is not limited to, electrical, pneumatic, and hydraulic power sources, associated distribution, and corresponding utilization systems. The intent of each section of this rule is self-evident.

c. **Background.**

(1) The regulatory history shows that this requirement originated from Section 606 of the Civil Air Regulations (CAR) 4b, December 31, 1953. Amendment 25-AD was published in the Federal Register on December 24, 1964 (29 FR 18289), which added Part 25 [New] to the Federal Aviation Regulations and replaced Part 4b of the CAR. It was part of the Agency recodification program announced in Draft Release 61-25, published in the Federal Register on November 15, 1961 (26 FR 10698). It was recodified from CAR 4b.606 without any substantive changes.

(2) This regulation was modified by Amendment 25-23 (35 FR 5665, April 8, 1970), which followed Notice of Proposed Rulemaking 68-18 (33 FR 11913,

August 22, 1968). The following excerpt is from the preamble to the Amendment and provides additional insight into the intent of the rule:

> The Notice also proposed to amend the equipment systems and installation requirements of § 25.1309.
>
> In response to a comment, the words “and installed” have been deleted from paragraph (a) of § 25.1309 to make it consistent with the remaining provisions of that section.
>
> Numerous and detailed changes have been made to paragraph (b) of § 25.1309 in response to various comments received. Several comments concerned the flush paragraph following proposed subparagraph (b)(2) which states that failure condition means a single failure or malfunction or damage from external sources, and any combination of failures, malfunctions, and damage from external sources. The commenters contend that this provision would require protection against any number of improbable conditions involving any combination of system failure and damage from external sources. This was not the intent, since other provisions of the proposal would limit the failure combinations to those that would preclude safe flight and are not extremely improbable. The proposal has been clarified in this respect by deleting the paragraph in question, and adding another requirement which states that the failure analysis must include consideration of the probability of multiple failures and undetected failures.
>
> However, the FAA does not agree that the proposal should be changed to require that multiple failures of airplane systems and associated components be considered only when the first malfunction would not be detected during normal operation of the system or when the first failure would inevitably lead to other failures. Existing transports exceed such a requirement in critical systems, and service experience has shown that these additional back-up provisions are necessary for safety.
>
> With further references to paragraph (b), the FAA has determined that the phrase “without exceptional skill or strength on the part of the crew” is redundant and that the word “minimized” should be replaced by the word “improbable.” Moreover, while the term “marginal physiological condition” would generally include oxygen depletion, depressurization, and other similar conditions, it was the intent of the proposal to cover only these occurrences that could cause injury to an occupant. For this reason, the final rule has been changed to require that airplane systems and components be designed so that the occurrence of a failure condition that would result in injury to the occupants is improbable.
>
> Finally, the FAA does not agree that the requirements of proposed § 25.1309 (c) and (d) are repetitious or too detailed. The provisions of paragraphs (c) and (d) were proposed to introduce monitoring and failure warning requirements and failure analysis criteria which do not exist in the current regulations.
>
> In response to a comment received, proposed § 25.1309(e)(4) has been clarified by replacing the words “two sources of power” with the words an “alternate source of power.” This is necessary to remove the implication that the “two sources of power” refers to systems that require two different forms of power, such as AC. and DC at different voltages.

(3) This rule was further modified by Amendment 25-38 (41 FR 55454, December 20, 1976), which followed Notice of Proposed Rulemaking 75-10 (40 FR 10802, March 7, 1975). The following excerpt is from the preamble to the Amendment and provides additional insight into the intent of the rule:

> The proposed changes to §§ 25.1309(a) and (e) with respect to inserting the word “chapter” in place of “subchapter” were also proposed for § 27.1309(a) and §§ 29.1309(a) and (d) (Proposals 5-40 and 5-55, respectively).
>
> Several commenters object to the proposed change from the term “subchapter” to “chapter” because it would broaden the scope of the requirement to include equipment, systems, and installations required by the subchapters dealing with various operating rules. One commenter contends that the proposal would require that equipment prescribed in an operating subchapter be designed and installed in each aircraft in order to obtain a type certificate. In light of these comments, and after further review, the FAA believes that the proposed change of the word “subchapter” to “chapter” in §§ 25.1309(a) and (e), 27.1309(a) and 29.1309(a) and (d) would impose an unreasonable burden on the aircraft manufacturer. Accordingly, this proposed change has not been made.
>
> Two commenters object to proposed § 25.1309(b)(1) on the grounds that the added provision dealing with the loss of all propulsive power is already adequately covered in current § 25.671(d), and that the occurrence of any failure condition which would preclude controlled flight to an emergency landing after loss of all propulsive power would have to be “extremely improbable,” and this cannot be achieved. The FAA agrees, and proposed § 25.1309(b)(1) is withdrawn.

(4) This rule was again modified by Amendment 25-41 (42 FR 36960, July 18, 1977), which followed Notice of Proposed Rulemaking 75-10 (40 FR 10802, March 7, 1975) and Notice 75-23 (40 FR 23048, May 27, 1975). The following excerpt is from the preamble to the Amendment and provides additional insight into the intent of the rule:

> One commenter objects to proposed § 25.1300(b)(2) on the grounds that “operational or performance capability,” without qualification, is not a matter for safety regulation. In light of this comment, and after further consideration, the FAA believes that the phrase “operational or performance capability of the airplane” could be misinterpreted and could cause difficulties in administering the requirement. Therefore, the FAA believes that the language in the current rule should not be changed in this regard.
>
> In addition, other commenters note that the phrase “or the ability of the crew to cope with adverse operating conditions” in current § 25.1309(b)(2) had been omitted from proposed § 25.1309(b)(2) without explanation, and recommend that it be restored as necessary for safety. The FAA agrees. The phrase was inadvertently omitted from the proposal. Accordingly § 25.1309(b)(2) as adopted retains the language in current § 25.1309(b)(2), except that the phrase “result in injury to the occupants, or. . .” is deleted.
>
> One commenter objects to proposed § 25.1309(d) contending that the method of compliance set forth in paragraph (d), which is applicable to paragraph (b), mandates unreasonably burdensome procedures. The requirements objected to

by the commenter are contained in current § 25.1309. The FAA does not believe that requiring compliance with those provisions is unreasonably burdensome. Analyses along the lines prescribed in proposed § 25.1309(d) are being conducted by some manufacturers on a voluntary basis.

One commenter recommends that the term “flight simulator” in proposed § 25.1309(d) be changed to “simulator” to allow the use of simulators other than flight simulators. The FAA agrees, and proposed § 25.1309(d) is revised accordingly.

One commenter objects to proposed §§ 25.1309 (d) and (e) because they are less stringent than the current requirements, which call for an analysis, and tests where necessary, showing that systems, controls, and associated monitoring and warning means are designed “so that crew errors that would create additional hazards are improbable.” As pointed out in the explanation of [the proposal], the FAA has concluded that requiring a showing of compliance with current § 25.1309(d) is unreasonably burdensome. In particular, the FAA believes that it is not practicable to quantify the probability of crew errors. The FAA believes that the requirement, “. . . to minimize crew errors which would create additional hazards,” in proposed § 25.1309(c) would provide an adequate level of safety. Accordingly, proposed § 25.1309(c) is adopted without substantive change and the lead-in text of § 25.1309(d) is amended to delete the references to paragraph (c).

The proposed changes to §§ 25.1309 (e) and (f), with respect to the two-engine-inoperative condition on aircraft with three engines, are substantively identical to the proposed changes to §§ 29.1309 (d) and (e). One commenter objects to proposed §§ 25.1309 (e)(3) and (f), and proposed §§ 29.1309 (d)(3) and (e), on the grounds that they do not provide adequate guidance as to which loads are required during the proposed two-engine-inoperative condition on aircraft with three engines. This commenter recommends that the term “flight safety loads” be used instead of “essential loads” for that condition. The FAA does not agree. The FAA believes that proposed §§ 25.1309(f) and 29.1309(e) are clear in that the monitoring of power loads is allowed in those circumstances and loads not required in controlled flight need not be considered for the two-engine-inoperative condition on airplanes with three or more engines.

One commenter objects to the proposed two-engine-inoperative condition on aircraft with three engines, on the grounds that it would impose a requirement for an unreasonable amount of power, in that both units of dual systems would be required to operate during that condition. The FAA disagrees. The procedure set forth in proposed §§ 25.1309(f) and 29.1309(e), which would apply to the two-engine-inoperative condition on three-engine aircraft, would allow the monitoring of one unit of a dual system in those circumstances.

Another commenter objects to proposed § 29.1309(d)(3)(ii), contending that the requirement was unreasonable for rotorcraft since they cannot maintain flight with only one-third of installed power. The FAA does not agree that the requirement is unreasonable for rotorcraft. The proposal would ensure that at least those power loads necessary for controlled descent to a safe landing are supplied for the two-engine-inoperative condition on a three-engine rotorcraft. Accordingly, proposed §§ 25.1309 (e)(3) and (f), §29.1309(d)(3) and the proposed change to § 29.1309(e) are adopted without substantive change.

d. **<u>Policy/Compliance Methods.</u>**

(1) The following material comes from an internal FAA memorandum entitled, “Application of FAR 25.1309, Amendment 25-23, to [*certain model*] Airplanes; Memorandum of 12-23-80,” dated July 20, 1983:

> We have reviewed your proposal for a flight manual limitation for [*certain model airplanes*], which would require that these airplanes always be operated within 30 minutes of an alternate airport in order to comply with § 25.1309. We believe that this limitation is more restrictive than necessary. We believe that, in order to comply with the requirements of § 25.1309(b)(1) for “continued safe flight and landing” after the occurrence of failures not shown to be extremely improbable, the following criteria should be used for evaluating these airplanes.
>
> 1. The improbable failure condition should be assumed to occur in IFR conditions.
>
> 2. The airplane should be demonstrated to be capable of continued operation in IFR conditions until VFR conditions can be reached. Based on the apparent success of the 30-minute operating requirement for the third attitude indicator since 1970, we believe that a reasonable assumption can be made that large turbojet transport airplanes are capable of achieving VFR conditions within 30 minutes of experiencing the failure.
>
> 3. After 30 minutes of operation in IFR conditions, the airplane should be demonstrated to be capable of continued safe flight in VFR conditions indefinitely, followed by a safe landing in VFR conditions.
>
> For the specific failure conditions that require operation of the emergency standby power system of the [*certain model airplanes*], we believe that it is also necessary to demonstrate that an IFR approach with a manual landing can be satisfactorily accomplished by-the captain within the 30 minutes during which operation of the standby instruments is assured. This is necessary because the standby instruments provide radio navigation information (both VOR and ILS) to the captain and when such equipment is installed; [the system’s] ability to properly perform its intended function must be demonstrated in accordance with § 25.1301.
>
> Operations using the emergency standby power system should be addressed with an emergency procedure in the Airplane Flight Manual that clearly indicates the limited time available for IFR operations.

(2) In addition, guidelines are reflected in the following excerpt from Advisory Circular (AC) 29-2B, “Certification of Transport Category Rotorcraft,” paragraph 621, Section 23.1309. (Although that AC provides guidance for transport rotorcraft, it may also provide insight into acceptable compliance methodology useful for other category aircraft.)

621. **§ 29.1309 (through Amendment 29-19) EQUIPMENT, SYSTEMS, AND INSTALLATIONS.**

. . .

b. Environmental Qualification.

(1) *Laboratory Tests*.

(i) ENVIRONMENTAL STANDARDS. In order to assure that the components/systems under consideration will function properly when exposed to adverse environments, they should be tested in the laboratory under a simulated adverse environment. If a TSO exists and it is appropriate in environmental range and performance for an equipment installation it is preferable the equipment be TSO approved. If there is no applicable TSO or an existing TSO does not provide for a sufficiently adverse environment, Radio Technical Commission for Aeronautics (RTCA) document DO-160A is an acceptable environmental standard for laboratory qualification of aircraft equipment.

(ii) ADVERSE ENVIRONMENTAL VARIABLES for all types of required and critical equipment include, but are not necessarily limited to temperature, humidity, vibration, shock, altitude, overpressure, and power source transients.

(iii) FOR ELECTRICAL/ELECTRONIC EQUIPMENT, adverse environmental variables include all of (b) above overvoltage and undervoltage. Electronic equipment should also be tested for electromagnetic interference (EMI). These tests should include both emission and susceptibility evaluations of both conducted and radiated EMI.

(iv) EXPLOSION TESTS. Those items of electrical/electronic equipment that are to be located in areas subject to flammable fluids and vapors, as a result of any single probable malfunction or failure, including failure of couplings or lines should be tested as an ignition source. These tests consist of normal operation of the equipment in a physically contained explosive atmosphere. The explosion test procedure in DO-160A will satisfy this requirement. Paragraph 362 of this advisory circular provides further guidance on safety from explosion. If another standard is used that is at least as good as DO-160A, it may also be accepted to satisfy this requirement.

(2) *Installed Environmental Tests*. After the environmental ratings of the components/systems have been established, it should be assured that, as installed, these ratings will not be exceeded. Normally, installed equipment need not be instrumented and tested in flight, nor is it necessary to instrument the compartment or rack where the equipment is installed. Satisfactory environment and equipment compatibility are assured by selection of the proper environmental category of laboratory tests. The category is determined by the type of aircraft (reciprocating or turbine) and flight envelope (altitude and temperature). Exceptions to normal installations are: (a) alternator / generator cooling, where radiated and conducted heat is almost always uncertain, also cooling air temperatures and flow rates are uncertain; (b) where flight tests reveal excessive instrument panel vibration (in this case, the panel should be instrumented, tested, and, if necessary, design improvements made); and (c) any other cases where good engineering judgment and application of sound engineering principles indicate a high likelihood that the installed environment is more severe than the equipment is capable of handling.

(i) TEMPERATURE TESTS.

(A) Temperature tests may be accomplished by instrumenting the installed equipment environment with a recorder that provides a permanent record of time, altitude, and temperature. The pertinent temperature should be recorded as the rotorcraft is operated throughout its altitude range, including ground operation. The maximum and minimum temperatures recorded should be corrected degree for degree to assure the equipment under test remains within its temperature rating while the rotorcraft operates throughout its approved ambient temperature envelope. (For generator/ alternator cooling test procedures, refer to paragraph 778 of this advisory circular). Section 29.1043, paragraph (b) requires the maximum approved operating OAT to be at least 100°F for powerplant mounted accessories such as starter generators, vacuum pumps, etc. Due to the impracticality of the 100°F hot day temperature limit, helicopter systems mounted on the powerplant are normally evaluated for at least 115°F hot day sea level conditions with corresponding 3.6°F/1,000 feet correction. The maximum hot day OAT at sea level must be specified in the rotorcraft flight manual. § 29.1043, paragraph (b) is the regulatory basis for the lapse rate of 3.6°F/1,000 feet. This lapse rate should be applied regardless of the hot day sea level temperature the applicant chooses to certify for operation.

(B) The § 29.1043, paragraph (b) maximum ambient temperature definition should not be confused with operating temperatures in closed areas. Closed equipment rack areas can easily reach temperatures of 140°F when sitting on the ramp in the southern United States in midsummer. Normally, proper selection of the altitude temperature category in DO-160A will assure compliance.

(C) In some cases, the equipment manufacturer furnishes temperature limits for internal critical parts. For example, brushes, bearings, or field windings on DC generators. In these cases it is better to record the critical component temperature rather than equipment or equipment environment temperature.

(D) In most cases, the equipment is laboratory tested to minimum temperatures as severe as that of the rotorcraft's maximum certified altitude on a minimum temperature day. Therefore, unless equipment minimum temperature is affected by refrigeration or other temperature reducing environments, actual installed instrumented minimum temperature tests are unnecessary. If low temperature evaluation is necessary for the installed equipment the following is an acceptable method [refer to AC 29-9A C2]:

(ii) VIBRATION TESTS. Normally, installed vibration tests are not necessary for equipment qualified in accordance with RTCA document DO-160A. This paper categorizes vibration tests according to installed rotorcraft equipment location such as fuselage, engine compartment, instrument panel, equipment rack, etc. However, installed equipment vibration tests may be necessary when it appears the equipment location environment may exceed the laboratory tested equipment vibration limits.

(iii) ALTITUDE TESTS. If the equipment has been laboratory tested to the maximum certified altitude of the helicopter, installed altitude tests are unnecessary. The installed equipment must be either laboratory tested or tested in the rotorcraft to the maximum certified altitude of the helicopter.

(3) *Lightning Strike Protection of Full Authority Digital Engine Controls*.

(i) EXPLANATION.

(A) The following discussion is written specifically for full authority digital engine controls (FADEC) with an alternate technology backup fuel control installed on rotorcraft with Category A engine isolation. The requirement for increased consideration of lightning strike encounter effects on avionics equipment and systems has been brought about by the increased use of avionics to perform functions, the failure or malfunction of which could result in a hazard to the helicopter. The susceptibility of current high technology avionics systems is increased by the use of large scale integration (LSI), very large scale integration (VLSI), and complementary metallic oxide silicon (CMOS) technologies which exhibit a greatly reduced tolerance to large amplitude, low energy electrical transients as compared to conventional bipolar technology, and the reduced physical protection and electromagnetic shielding afforded aircraft avionics systems by the advanced technology composite airframe materials. Additionally, processor-based systems have the failure phenomenon of digital upset. A digital upset occurs when a system, perturbed by an electrical transient, ceases proper operation in accordance with its embedded software while suffering no apparent component or device damage.

(B) Since elements of electrical/electronic engine subsystems are typically spread throughout much of the helicopter, transients caused by lightning are coupled into the subsystem interface cables and may damage the system or cause upset. Effective lightning protection must be designed and incorporated into these systems. Reliance upon redundancy as a means of protection against lightning effects is generally not adequate because lightning electromagnetic fields and structural IR voltages usually interact (to some extent) with all electrical wiring aboard a helicopter.

(C) The testing and analysis outlined in this discussion are methods by which the FAA may be assured that when the helicopter experiences “the foreseeable operating condition” of a worst-case lightning strike encounter that the electronically controlled engines will continue to “perform their intended function” and therefore be in compliance with § 29.1309(a) as installed.

(D) The definition of what constitutes a full authority engine control is not at this time clearly defined. However, it has been accepted in past certification that any control which depends upon the electronics for the function on which Civil Certification or Military Qualification is based (e.g. rotor speed governing) is a full authority control, regardless of the backup control mode provided. If engine certification or qualification can be achieved without the electronic control that is subsequently added to achieve improved operational efficiency in the aircraft, the control is "supervisory." However, if the controls are used in a multiengine helicopter, a common failure caused by a lightning strike could result in simultaneous failures, which would cause a reduction in power greater than the loss of one engine. This would also be considered "full authority."

(ii) PROCEDURE. Although not a regulatory requirement, it is recommended that a formal written certification plan be used to assure regulatory compliance. The use of this plan is beneficial to both the applicant and the FAA because it identifies and defines an acceptable resolution to the critical issues early in the certification process. These are the usual steps to be followed when utilizing a certification plan:

(A) Prepare a certification plan that describes the analytical procedures and/or the qualification tests to be utilized to demonstrate protection effectiveness. Test plans should describe the helicopter and FADEC system to be utilized, test drawing(s) as required, the method of installation that simulates the production installation, the lightning zone(s) applicable, the lightning simulation method(s), test voltage or current waveforms to be used, diagnostic methods, and the appropriate schedules and location(s) of proposed test(s).

(B) Obtain FAA concurrence that the certification plan is adequate.

(C) Obtain FAA detail part conformity of the test articles and installation conformity of applicable portions of the test setup.

(D) Schedule FAA witnessing of the test.

(E) Submit a final test report describing all results and obtain FAA approval of the report.

(iii) DEFINITION OF ENVIRONMENT. The SAE AE4L Committee report dated June 20, 1978, is an acceptable criteria to define the worst-case lightning strike which may be encountered by the helicopter in service. An additional explanation of the lightning environment may be found in FAA Report DOT/FAA/CT-83/3, "User's Manual for AC 20-53A, Protection of Airplane Fuel Systems Against Fuel Vapor Ignition Due to Lightning," paragraph 5.2, "Establishment of the Lightning Environment." This definition of the environment is considered the minimum acceptable standard for a FADEC with an alternate technology backup. For a full fly-by-wire system, with no mechanical backup or other future technology designs, this criteria may not be sufficient to describe a worst-case lightning encounter. On 3/5/90, the FAA Advisory Circular AC 20-136, "Protection of Aircraft Electrical/Electronic Systems Against the Indirect Effects of Lightning" was issued. Appendix 3 of that document contains an updated quantification of the severe natural lightning environment. It is recommended that for new designs and applications after 3/5/90, this revised definition of the lightning be used.

(iv) CERTIFICATION PLAN. The following subjects are not intended to provide a complete list of the items that should be included in the certification plan, but rather highlight some of the areas that should receive consideration. The certification plan should address the total protection that is required to allow the FADEC to continue to operate properly when the helicopter experiences a worst-case lightning strike encounter.

(A) Determination of Lightning Strike Attachments. Determine the locations on the helicopter where lightning strike attachment is likely to occur and the portions of the airframe through which currents may flow between attachments. The main and tail rotors are recognized as likely attachment points; however, consideration should be given to all possible attachment points. The swept stroke phenomenon may not exist for all lightning strike encounters due to the fact that the helicopter may be airborne with little or no airspeed.

(B) Establish the Lightning Environment. Establish the components of the total lightning event to be considered. These are the currents and voltages that are described in the definition of the environment.

(C) Full-Level, Complete Vehicle Testing. In accordance with traditional FAA policy, the demonstration that the FADEC installed in a complete type design helicopter will continue to operate properly when exposed to a worst-case lightning strike is sufficient to compliance with § 29.1309(a). Because of the difficulties involved in utilizing this type of an approach, it is generally not used.

(D) Analytical Processes. A description should be given in the certification plan of the analytical process and/or certification tests to be utilized to demonstrate protection effectiveness. Typically, the certification plan will include a combination of analysis and tests. (Analytical techniques are most often utilized to predict the levels of lightning-induced transients in interconnecting wiring.) In most cases, successful analyses are based upon well-defined geometrical or electrical parameters such as structural dimensions and materials resistivities. When electrical characteristics of structural materials are not well established, development tests are often utilized to obtain this data which is subsequently utilized in an analysis. In more complex structures and/or electrical/electronic system installations, it is sometimes difficult or impossible to define the problem in terms that can be analyzed. In these cases, development or verification testing is often relied upon. The purpose of the certification plan is to show how developmental tests, analyses, and verification tests are combined to demonstrate protection design adequacy. In certain cases, previously verified designs can be incorporated and their adequacy confirmed by references to previous verifications. Such references should also be incorporated in the certification plan.

<u>1</u> The verification testing should be conducted on a system which simulates as closely as possible the installed configuration. As few items as possible of actual hardware should be simulated.

2 The use of various analytical processes usually requires that the system component tolerance is established. The SAE AE4L Committee Report No. AE4L-81-2 is the recommended References to be used for testing accomplished to determine these tolerances. The testing which is performed to determine the tolerance level of the control computer should include a consideration the occurrence of a nonrecoverable upset. One method to provide consideration is to have the unit powered the processor operating normally software control (usually this should be the exact software for which approval is sought) when the test is performed. If strike testing is used, then several shots should be made to develop enough data to provide a reasonable confidence level. It is an acceptable procedure for the engine manufacturer, while he is obtaining his type certificate, to accomplish this bench testing to determine the level of tolerance of the FADEC system components to lightning encounter indirect effects. This approach has the advantages that the bench tests are not necessarily required to be repeated when the engine is installed in a different airframe. This recommendation is not meant to add a requirement to the engine manufacturer but to propose a more efficient method of certification. If this tolerance was not determined by the engine manufacturer, the applicant installing the FADEC in a helicopter would be expected to furnish this data.

3 For complete airframe verification testing, a minimum level of at least 4KA peak and a current rise time of 2KA/microsecond are recommended. It is often difficult to obtain valid results at lower levels due to poor signal-to-noise ratios. When complete vehicle testing is accomplished at some lower level, or through some alternate test technique such as low level swept CW testing, consideration should be given to nonlinear airframe response, diffusion effects, and alterations in current paths caused by arcing and flashover.

4 As with any analytical method, it is prudent to include a margin of safety to account for the uncertainties involved in the analytical and testing processes. A level of 6 dB is recommended for those analyses that are confirmed by the use of reduced level, full-scale vehicle testing. This safety margin is the difference between the airframe installed system responses and the system component tolerance, not an adjustment to the quantification of the atmospheric environment. (The airframe system response to the worst case lightning event should be at least 6 dB less than the FADEC system computer and components tolerance level. Number of dB is defined as 20 LOG10 (V1/V2) and 20 LOG10 (I1/I2), where V1 and I1 are the determined tolerance levels of the system components and V2 and I2 are the extrapolated airframe response.)

5 When an analysis has no associated full-scale vehicle testing to confirm the analysis, the analysis should be very rigorous. Additionally, it should be expected in this situation that this analysis indicates a very large margin of protection. Many

factors must be considered in determining what constitutes an acceptably large margin. The specific additional margin required should be based on an assessment of the inherent uncertainty of a given analysis. Approximately an additional 25 dB of protection has been deemed acceptable for a reasonably rigorous analysis performed on an airframe for which the response characteristics are known.

(E) Pass/Fail Criteria. The certification plan should address a pass/fail criteria for the testing and analysis to be performed. The following items should be satisfied to assure acceptable system performance:

1 No immediate crew action must be required.

2 Automatic control of the engine cannot be lost for any appreciable period of time. The engine must not be allowed to be out of control for a period of time that will result in a hazard in a worst-case flight condition. Obviously, any rapid, uncontrolled divergence is not acceptable.

3 No crew action should be required to reset the system. This is not to imply that the system cannot be designed with a manual reset, but the manual reset cannot be used to show compliance to recover from a digital upset.

4 The resumption of engine control after an upset must be reasonably within the range which existed before the upset.

5 No critical data can be lost.

6 After the system recovers, if the system has been degraded in a noncritical manner that would reduce the capability of the helicopter or the ability of the pilot to cope with adverse operating conditions, then the crew must be alerted to this system degradation.

(v) SYSTEM INSTALLATION CONSIDERATIONS. In most cases, the installation of the system components is a constituent part of the lightning protection. This is particularly true in the use of shielding techniques. If these installation features are required for adequate lightning protection, consideration should be given to ensure that their effectiveness is not derogated in service. Information should be made available to the parties who service and operate the helicopter to allow them to take actions necessary to ensure the continued effectiveness of the system lightning protection.

e. **References.**

(1) Civil Air Regulations 4b (CAR 4b.606), December 31, 1953.

(2) Amendment 25-AD (29 FR 18289, December 24, 1964).

(3) Amendment 25-23 (35 FR 5665, April 8, 1970).

(4) Amendment 25-38 (41 FR 55454, December 20, 1976).

(5) Amendment 25-41 (42 FR 36960, July 18, 1977).

(6) Advisory Circular 29-2B, “Certification of Transport Category Rotorcraft,” July 30, 1997.

(7) Advisory Circular 25.1309-1A, “System Design Analysis,: June 21, 1988.