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Section 7. Exhaust System

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Section 25.1121 General.

a. Rule Text.

For powerplant and auxiliary power unit installations the following apply:

a. Each exhaust system must ensure safe disposal of exhaust gases without fire hazard or carbon monoxide contamination in any personnel compartment. For test purposes, any acceptable carbon monoxide detection method may be used to show the absence of carbon monoxide.

b. Each exhaust system part with a surface hot enough to ignite flammable fluids or vapors must be located or shielded so that leakage from any system carrying flammable fluids or vapors will not result in a fire caused by impingement of the fluids or vapors on any part of the exhaust system including shields for the exhaust system.

c. Each component that hot exhaust gases could strike, or that could be subjected to high temperatures from exhaust system parts, must be fireproof. All exhaust system components must be separated by fireproof shields from adjacent parts of the airplane that are outside the engine and auxiliary power unit compartments.

d. No exhaust gases may discharge so as to cause a fire hazard with respect to any flammable fluid vent or drain.

e. No exhaust gases may discharge where they will cause a glare seriously affecting pilot vision at night.

f. Each exhaust system component must be ventilated to prevent points of excessively high temperature.

g. Each exhaust shroud must be ventilated or insulated to avoid, during normal operation, a temperature high enough to ignite any flammable fluids or vapors external to the shroud.

(Doc. No. 5066, 29 FR 18291, Dec. 24, 1964, as amended by Amdt. 25-40, 42 FR 15043, March 17, 1977)

b. **Intent of Rule.** The intent of this rule is to ensure adequate fire protection of the exhaust system as well as the adjacent areas of the airplane.

c. **Background.**

(1) The regulatory history shows that the requirement originated from Section 467(a) of the Civil Air Regulations (CAR) 4b, December 31, 1953. Amendment 25-AD (29 FR 18289, December 24, 1964) added Part 25 [New] to the Federal Aviation Regulations and replaced Part 4b of the Civil Air Regulations. 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). Part 25 [New] was published as a notice of proposed rule making in the Federal Register on June 2, 1964 (29 FR 7169), and given further distribution as Notice No. 64-28. It was recodified from CAR 4b without any substantive changes.

(2) Amendment 25-40 (42 FR 15034, March 17, 1977) was based on two Notices of Proposed Rulemaking:

- Notice 75-10 (40 FR 10802, March 7, 1975) and
- Notice 75-19 (40 FR 21866, May 19, 1975).

Notice 75-19 proposed to revise both § 25.1121 and § 23.1121. The lead-in text to the provisions of § 25.1121 and § 25.1121(c) were revised to include reference to the Auxiliary Power Unit (APU), to make it clear that the subject requirements apply to APU exhaust systems as well as to engine exhaust systems. Likewise, § 25.1121(b) was revised to clarify that the shields used for shielding exhaust system parts are, indeed, considered part of the exhaust system.

d. **Policy/Compliance Methods.**

(1) The following excerpt from CAR 4b.467-1 provides guidance.

> The carbon monoxide detection policies, which have been applied to § 25.1121(a) and § 25.1125(b), are as follows:
>
> (a) **Conditions for tests**. Any acceptable carbon monoxide detection method may be used in demonstrating compliance with the above sections. The tests should be conducted with the airplane's heater system in operation if there is any possibility of a system containing carbon monoxide. In aircraft employing thermal deicing, tests should be conducted with the system operating at full capacity.
>
> (b) **Configuration**. Carbon monoxide tests should be conducted in the configurations that follow:
>
> (1) Power-on level flight.
> - Weight--optional
> - C.G. position--optional
> - Wing flaps--retracted
> - Landing gear--retracted
> - Engines--maximum continuous power

- Cowl flaps--appropriate for flight condition

(2) Power-off glide.
- Wing flaps--retracted
- Landing gear--retracted
- Engines--idling
- Cowl flaps--appropriate for flight condition

(3) Power approach:
- Wing flaps--approach position
- Landing gear--extended
- Engines--power for level flight
- Cowl flaps--appropriate for flight condition
- Airspeed--any speed from 1.4 to 1.6 V_{s1}

(c) **Test procedure and required data.** The air should be sampled with a carbon monoxide indicator in front of cabin heater opening(s) with heat on and at representative passenger and crew locations. If the airplane does not have pressurization equipment installed, the air should be sampled at the above locations with the windows closed and also partially opened. If the airplane is equipped for pressurization, carbon monoxide indications should be taken when the cabin is pressurized and also unpressurized.

(2) Use of Shields. Concerns with § 25.1121(b) have been raised concerning the location and shielding of exhaust system parts because of the lack of specifics on how to determine whether the location of a system carrying flammable fluid is acceptable. The rule specifically allows the use of exhaust system shielding as a method of avoiding impingement of flammable fluids on a hot surface. It is not intended to state how an acceptable location would be determined since a number of acceptable methods might exist depending on the installation. Flammable fluid leak sources to be considered are those around fittings as well as those caused by rupture of a fluid carrying line, i.e., any leakage from a flammable fluid system including lines, fittings, and joints.

(3) Windshield Glare. The following guidance is from CAR 4b.467-2:

Determination of exhaust gas interference with visibility.

The effects of exhaust gas interference with visibility should be observed during tests to demonstrate other night flying requirements.

e. **References:**

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

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

(3) Amendment 25-40 (42 FR 15034, March 17, 1977).

Section 25.1123 Exhaust piping.

a. **Rule Text:**

For powerplant and auxiliary power unit installations, the following apply:

a. Exhaust piping must be heat and corrosion resistant, and must have provisions to prevent failure due to expansion by operating temperatures.

b. Piping must be supported to withstand any vibration and inertia loads to which it would be subjected in operation; and

c. Piping connected to components between which relative motion could exist must have means for flexibility.

(Doc. No. 5066, 29 FR 18291, Dec. 24, 1964, as amended by Amdt. 25-40, 42 FR 15044, March 17, 1977)

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

c. **Background.**

(1) The regulatory history shows that this requirement originated from section 4b.467(b) 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 Civil Air Regulations. 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). Part 25 [New] was published as a notice of proposed rule making in the Federal Register on June 2, 1964 (29 FR 7169), and given further distribution as Notice No. 64-28. It was recodified from CAR 4b.467(b) without any substantive changes.

(2) In Amendment 25-40 (42 FR 15034, March 17, 1977), the lead-in to § 25.1123 was revised to include reference to the Auxiliary Power Unit (APU) to make it clear that the requirements apply to APU exhaust piping installations as well as engine exhaust installations.

d. **Policy/Compliance Methods.**

(1) This section contains the requirements that must be met for proper certification of exhaust piping on engines, auxiliary power units (APU) and other similar devices. These requirements are summarized in Amendment 25-40 (42 FR 15034, March 17, 1977), as follows:

- § 25.1123(a) requires that the piping be heat- and corrosion-resistant so that it performs its intended function during its operational life (either the life of the aircraft or a specified limited life) without significant metal corrosion, metal erosion, or creation of hazardous hot spots. The piping system should be designed, have an installation design, or a combination that allows performance of its function without thermal expansion (thermal strain) induced structural failures, such as ruptures caused by operating temperature excursions and by overpressurization during its operational life.

- § 25.1123(b) requires that the piping must be supported to withstand the vibration and loading environment (including inertia loads) to which it will be subjected in service.

- § 25.1123(c) requires that the piping that connects to components between which relative motion exists in service must have the necessary flexibility and structural integrity to withstand the relative motion without exceeding limit load (at the maximum operating temperature) of the piping, or creating unintended loads (or load paths) on the components to which the piping connects.

(2) Exhaust Piping. The following guidance for transport category airplanes is based on material published in Advisory Circular (AC) 29-2B, "Certification of Transport Category Rotorcraft." (Although that AC provides guidance for transport rotorcraft, may also provide insight into acceptable compliance methodology useful for other category aircraft.)

Exhaust piping is typically certified by analysis and installation tests conducted during the basic certification process, including flight tests, as follows:

(a) For compliance with § 25.1123(a), because of its durability in the hot exhaust environment, exhaust piping is typically made from stainless steel or alloy steel of the appropriate structurally and thermally derived wall thickness. Hot aircraft exhaust gases are very corrosive; thus, proper material selection and corrosion protective design should be performed and validated during certification. Advisory Circular (AC) 43-4, "Corrosion Control For Aircraft," contains a detailed discussion of exhaust gas corrosion problems. Analysis and/or verification tests of the exhaust system should be conducted. This work is necessary to ensure thermal and structural integrity; to ensure that thermal expansion does not cause a structural overload or failure; and, to ensure that exhaust piping does not contact (or come close to) ambient temperature materials (such as structure or system components). Hot exhaust piping in contact with (or close to) ambient temperature materials can either create a fire hazard or cause an unintended strength reduction. To ensure that thermal expansion analyses and tests are properly conducted, the maximum in-service temperature excursion should be properly defined.

The maximum temperature excursion should be based on the maximum temperature of the piping and exhaust gases, as affected by the insulatory characteristics of the piping's enclosure, and as affected by a worst-case hot day. Worst-case temperature environment used for analysis can be verified by a temperature survey. If run on cooler days, the survey can be adjusted for the worst-case hot day environment using methods identical to those used for engine cooling tests (reference § 25.1043). The piping should be designed to expand freely so that thermal expansion (thermal strain) induced loads on the piping and its restraint system are minimized. If thermal expansion induced loads [in conjunction with deflection induced loads and exhaust flow loads, discussed in paragraph(4)] are significant relative to limit load of any item in the load path, then a fatigue check on the critical design point(s) should be performed. The fatigue check should establish a safe life or an approved limited life for the critical component(s) in the system. An accurate analytical fatigue check on exhaust piping may be difficult to perform because of erosion, corrosion, etc., in service; therefore, phased inspections should be considered to ensure the exhaust piping's continued airworthiness.

(b) For compliance with § 25.1123(b), exhaust piping should be properly supported so that the maximum loads anticipated in service are properly distributed and reacted, and, as previously discussed, so that thermal expansion induced loading is minimized. Typically the worst-case static design load conditions are either the inertia loads from an emergency impact (reference § 25.561) or the combined loading from thermal expansion, in-flight deflections and internal exhaust gas flow [see paragraph (4)]. It should be noted that several combinations of these loads should be examined to determine the critical combination. The piping should be supported and restrained such that critical frequencies are avoided and the induced vibration environment's effect is minimized. Flight test vibration surveys may be necessary, in some cases, to properly define or validate the critical modes and environment and their effect on the exhaust piping design. Operating modes such as ground idle, flight idle, 40 percent and 80 percent of maximum continuous power, maximum continuous power, takeoff power settings, and other power settings should be investigated to determine their vibratory effect on the exhaust gas piping system. The strength reduction of the piping materials at operating temperature (and at worst-case temperature) should be properly considered in the design and structural substantiation. MIL-HDBK-5D contains material allowables versus temperature data for a wide variety of metallic engineering materials.

(c) For compliance with § 25.1123(c), the piping and its restraint system should be designed to minimize loading induced on the piping by the relative motion (in-service deflections) of the components to which the system attaches. Isolation of significant deflection induced loading (if required based on analysis and strain surveys) by use of flexible joints or other equivalent devices or designs should be considered. Any such in-line device used to reduce deflection loading should be fireproof and leak free when performing its intended function.

(d) For critical load case determination, the expansion- induced thermal loading should be added in with mechanical relative-motion-induced loads and internal exhaust gas flow loads to provide total critical loads for both a proper static and a proper fatigue structural substantiation. The critical combined static load should be compared with the emergency impact loads of § 25.561 to determine the critical design load case for static strength substantiation.

e. **References:**

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

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

(3) Amendment 25-40 (42 FR 15034, March 17, 1977).

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

(5) Advisory Circular 43-4A, “Corrosion Control for Aircraft,” July 25, 1991.

Section 25.1125 Exhaust heat exchangers.

a. **Rule Text:**

For reciprocating engine-powered airplanes, the following apply:

a. Each exhaust heat exchanger must be constructed and installed to withstand each vibration, inertia, and other load to which it would be subjected in operation. In addition --

(1) Each exchanger must be suitable for continued operation at high temperatures and resistant to corrosion from exhaust gases;

(2 There must be means for the inspection of the critical parts of each exchanger;

(3) Each exchanger must have cooling provisions wherever it is subject to contact with exhaust gases; and

(4) No exhaust heat exchanger or muff may have any stagnant areas or liquid traps that would increase the probability of ignition of flammable fluids or vapors that might be present in case of the failure or malfunction of components carrying flammable fluids.

b. If an exhaust heat exchanger is used for heating ventilating air --

(1) There must be a secondary heat exchanger between the primary exhaust gas heat exchanger and the ventilating air system; or

(2) Other means must be used to preclude the harmful contamination of the ventilating air.

(Doc. No. 5066, 29 FR 18291, Dec. 24, 1964, as amended by Amdt. 25-38, 41 FR 55467, Dec. 20, 1976)

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

c. **Background.**

(1) The regulatory history shows that this requirement originated from section 4b.467(c) 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 Civil Air Regulations. 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). Part 25 [New] was published as a notice of proposed rule making in the Federal Register on June 2, 1964 (29 FR 7169), and given further distribution as Notice No. 64-28. It was recodified from CAR 4b.467(c) without any substantive changes.

(2) Amendment 25-38 (41 FR 55454, December 20, 1976) revised the lead-in text to make it clear that this section applies only to reciprocating engine powered airplanes. While some early turbine-powered airplanes have had an ejector installation in the exhaust system to pull cooling air through the nacelle, this type of installation is not considered to be an exhaust heat exchanger and, therefore, turbine engine installations would not require compliance with this section based on the intent of the rule.

d. **Policy/Compliance Methods.** The following is an excerpt from the guidance material contained in Advisory Circular (AC) 29-2B, "Certification of Transport Category Rotorcraft." (Although that AC provides guidance for transport rotorcraft, it may also provide insight into acceptable compliance methodology useful for other category aircraft.)

Exhaust Heat Exchangers:

Exhaust Heat Exchangers (EHE) and their installations are typically certified by analysis and installation tests conducted during the basic certification process, including flight tests or simulated flight tests, as follows:

(a) Because of their durability in the hot exhaust environment, EHE's are usually constructed from stainless steel or alloy steel of the appropriate structurally and thermally derived wall thickness. The EHE and its system should be designed to expand freely to minimize thermal expansion (thermal strain) induced loads on the EHE and its restraint system. If thermal expansion-induced loads (in conjunction with deflection-induced loads and exhaust flow loads) are significant relative to the limit load of the EHE or its attachments, a fatigue check on critical design point(s) should be performed. The fatigue check should establish a safe life or an approved limited life for the critical component(s) in the EHE system.

(b) EHE's should be properly supported so that the maximum loads anticipated in service are properly distributed and reacted and so that thermal-expansion-induced loading is minimized. Typically, the worst-case static design load conditions are either the emergency impact loads acting alone (reference § 29.561), or the critical combination of loads from thermal expansion, in-flight deflections and internal exhaust gas flow. Several combinations of these loads should be examined to determine the critical combination. The EHE should be supported and restrained so that critical frequencies are avoided and the induced vibration environment is minimized. Flight tests or bench tests, such as vibration surveys conducted during rotor system endurance testing, may be necessary in some cases, to properly define or validate the vibration environment and EHE's critical modes and their effect on EHE design. Operating modes such as ground idle, flight idle, 40 percent and 80 percent of maximum continuous power, maximum continuous power, OEI power settings, and other critical power settings should be investigated to determine their vibratory effect on the EHE system. The strength reduction of EHE materials at operating temperature and at critical temperatures should be properly considered in EHE design and structural substantiation (MIL-HDBK-5D contains material allowables versus temperature data for a wide variety of metallic engineering materials). The EHE and its restraint system should be designed to minimize loads induced by the relative motion (in-service deflections) of the components to which the EHE attaches. Isolation of significant deflection-induced loading (as required, based on analysis and strain surveys) by use of flexible joints, other equivalent flexible devices, or designs should be considered. Any such in-line device used to reduce deflection loading should meet applicable certification requirements and be leak-free.

(c) Expansion analysis and verification tests of the EHE should be conducted to ensure its thermal (and structural) integrity and to ensure that thermal expansion does not cause the EHE to contact (or come close to) ambient temperature aircraft materials, structure, or system components, and either create a fire hazard or an unintended reduction in strength. To ensure that expansion analyses and tests are properly conducted, the maximum in-service temperature excursion should be properly defined. The maximum temperature excursion should be based on the maximum temperatures of the EHE and exhaust gases, as affected by the insulatory characteristics of the EHE's enclosure, and as affected by a worst-case hot day. The worst-case temperature environment used for analysis can be verified by a temperature survey which, when run on cooler days, can be adjusted to the worst-case hot day environment using methods identical to those used for engine cooling tests (reference § 25.1043).

(d) Hot aircraft exhaust gases are very corrosive; thus, proper material selection and corrosion protection design should be performed and validated during certification. Advisory Circular (AC) 43-4, "Corrosion Control For Aircraft" contains a detailed discussion of exhaust gas corrosion problems. The in-service corrosive environment should be identified and characterized as thoroughly as possible by chemical analysis, tests and service experience. Once defined, appropriate design techniques and materials should be selected. Certification tests may be required to ensure proper substantiation. Phased inspections and inspectability should be considered.

(e) The EHE's design should be reviewed for inspectability to ensure that structural and thermal integrity is maintained over the intended life of the EHE. Also, if the design review is not conclusive relative to inspectability, a tear down inspection should be conducted.

(f) Each EHE design should be reviewed, analyzed, and tested to ensure that cooling provisions are adequate where EHE surfaces are subjected to hot exhaust gases. This is necessary to prevent hazardous hot spots or a burn through which may cause a fire and contaminate the occupied environment.

(g) Each EHE design should be reviewed, analyzed, and tested to ensure that stagnation areas and liquid traps do not exist. This can be a done using bench flow test. These stagnant areas and traps could become ignition sources if wetted with a leaking flammable fluid. A review of potential leaking flammable fluid hazards should be conducted and appropriate preventative measures such as drains and drip fences installed to ensure they are routed away from EHE's.

(h) Each EHE design which will be used to heat ventilating air for occupants should be reviewed to ensure that the EHE is a double walled system, (i.e., it would require failure of two EHE surfaces to allow toxic exhaust gases to intermix with cabin ventilating air). Each EHE wall should be designed with equal thermal and structural resistance since a single undetected inner wall failure would subject the outer wall to the primary heat load. Also, inspectability provisions should be provided or means identified to ensure that inner wall failures can be detected in service. Any equivalent means, which is applied for, must clearly provide an equivalent level of safety to a double walled EHE.

e. **References:**

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

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

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

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

Section 25.1127 Exhaust driven turbo-superchargers.

a. **Rule Text.**

a. Each exhaust driven turbo-supercharger must be approved or shown to be suitable for the particular application. It must be installed and supported to ensure safe operation between normal inspections and overhauls. In addition, there must be provisions for expansion and flexibility between exhaust conduits and the turbine.

b. There must be provisions for lubricating the turbine and for cooling turbine parts where temperatures are critical.

c. If the normal turbo-supercharger control system malfunctions, the turbine speed may not exceed its maximum allowable value. Except for the waste gate operating components, the components provided for meeting this requirement must be independent of the normal turbo-supercharger controls.

b. **Intent of Rule.** The intent of this section is to provide a basis for regulation of a propulsion system with a turbocharger. The addition of a turbocharger to an engine may be expected to have varied effects on the reliability and power output of the engine and on the overall safety of the propulsion installation.

c. **Background.**

(1) The regulatory history shows that this requirement originated from section 4b.467(e) 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 Civil Air Regulations. 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). Part 25 [New] was published as a notice of proposed rule making in the Federal Register on June 2, 1964 (29 FR 7169), and given further distribution as Notice No. 64-28. It was recodified from CAR 4b.467(e) without any substantive changes.

d. **Policy/Compliance Methods.** No policy is currently available.

e. **References.**

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

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

(3) Advisory Circular 23.909-1, “Installation of Turbochargers in Small Airplanes with Reciprocating Engines,” February 3, 1986.