SAE Aerospace
An SAE International Group

AEROSPACE STANDARD

SAE AS8040 | REV. B

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Superseding AS8040A

(R) Heater, Aircraft
Internal Combustion Heat Exchanger Type

RATIONALE

This document is being revised to incorporate pertinent information from predecessor documents AS143B and AS143C.

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1. SCOPE

This SAE Aerospace Standard (AS) covers combustion heaters used in the following applications:

a. Cabin heating (all occupied regions and windshield heating)

b. Wing and empennage anti-icing

c. Engine and accessory heating (when heater is installed as part of the aircraft)

d. Aircraft de-icing

1.1 Purpose

This document details the minimum safety, performance, design, and testing requirements for combustion heaters and certain auxiliary devices that are considered necessary for the utilization of heaters in fixed and rotary wing aircraft. This standard is to be considered currently applicable and necessarily subject to revision from time to time due to advances in the aircraft industry. This standard is based on practical engineering requirements for aircraft heaters currently in use and is applicable to aircraft heaters that shall be developed to meet future requirements.

The requirements of this standard are primarily intended to be applicable to civil aircraft whose primary function is transporting passengers or cargo.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this document to the extent specified herein. The applicable issue shall be the issue in effect on the date of the purchase order or as noted below. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1.1 EASA Publications

Available from European Aviation Safety Agency, Postfach 10 12 53, D-50452, Koeln, Germany, Tel: +49-221-8999-000, www.easa.eu.int.

CS-23 Certification Specifications for Normal, Utility, Aerobatic and Commuter Category Aeroplanes

CS-25 Certification Specifications for Large Aeroplanes

CS-27 Certification Specifications for Small Rotorcraft

CS-29 Certification Specifications for Large Rotorcraft

2.1.2 FAA Publications

Available from Federal Aviation Administration, 800 Independence Ave., SW, Washington, DC 20591, Tel: 866-835- 5322, www.faa.gov.

14 CFR Part 23 Airworthiness Standards: Normal, Utility, Acrobatic, and Commuter Category Airplanes

14 CFR Part 25 Airworthiness Standards: Transport Category Airplanes

14 CFR Part 27 Airworthiness Standards: Normal Category Rotorcraft

14 CFR Part 29 Airworthiness Standards: Transport Category Rotorcraft

2.1.3 U.S. Government Publications

Available from U.S. Government Printing Office, Washington, D.C. and from the NASA Technical Reports Server at http://ntrs.nasa.gov/

U.S. Standard Atmosphere, 1976, U.S. Government Printing Office, Washington, D.C.

2.2 DEFINITION

A combustion heater is one that utilizes the heat produced by combustion of a fuel within the heater for the purpose of heating air being supplied to various aircraft systems.

3. GENERAL REQUIREMENTS

3.1 Heater Components

A combustion heater shall include:

a. Combustion chamber and heat exchanger assembly

b. Casing or shroud for combustion chamber and heat exchanger assembly

c. Igniter

d. Burner

e. Ventilating air inlet

f. Ventilating air outlet

g. Combustion air inlet

h. Exhaust outlet

i. Fuel inlet

j. Fuel drain(s)

A typical installation of an aircraft combustion heater is shown in Figure 1. Heater components and accessories are identified in the figure.

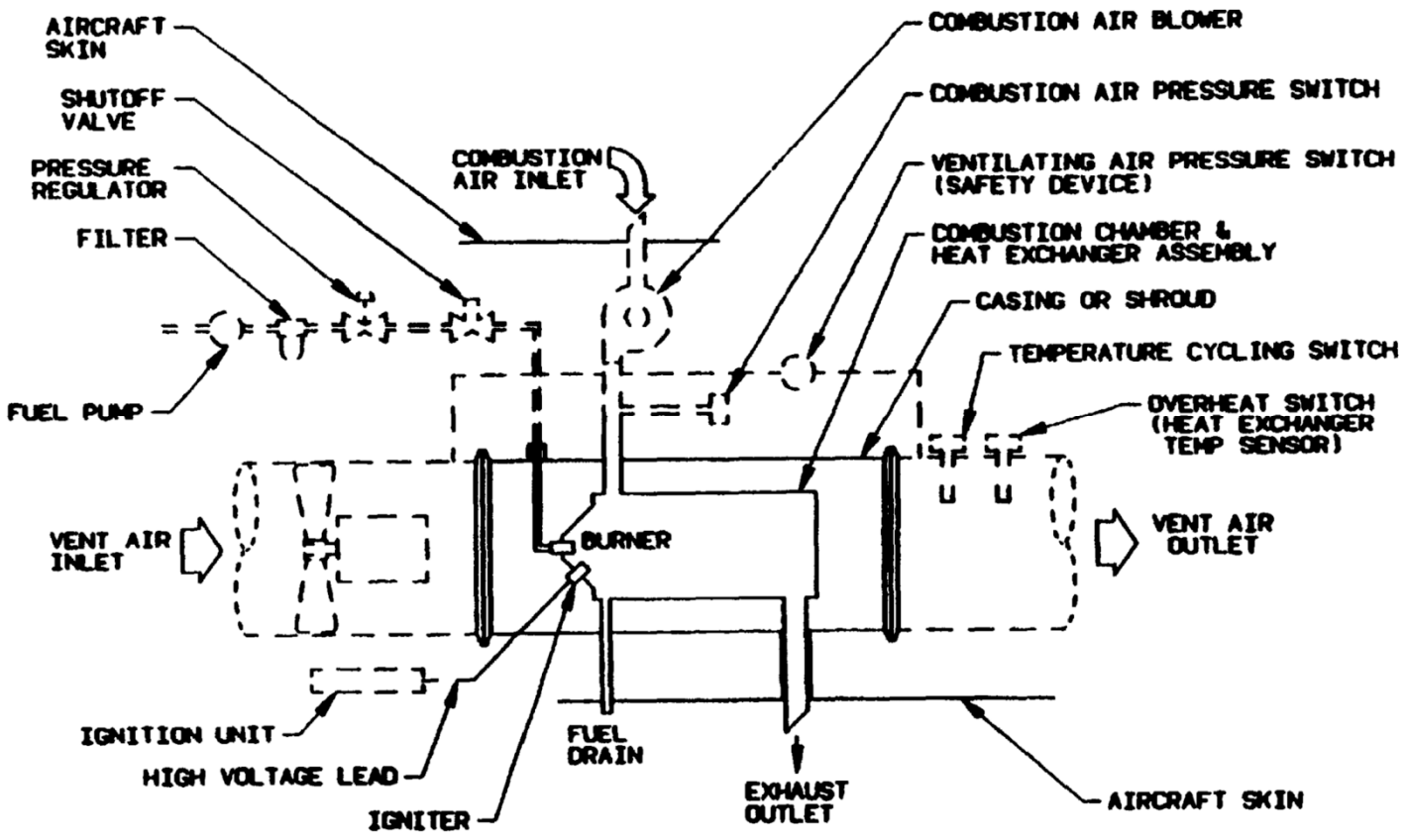

FIGURE 1 - TYPICAL AIRCRAFT INSTALLATION, COMBUSTION HEATER

3.2 Accessories

There are several accessory devices considered necessary to the safety and performance of the heater and shall be covered in that respect by this standard. These devices may be furnished separately or as part of the heater. This standard does not cover all tests necessary on these devices, but only those relevant to the heater.

The following accessories are discussed to the extent that they are relevant to heater design and operation:

a. Fuel System: The fuel system supplies fuel to the heater at the correct pressure, temperature, and flow rate. Components included in the heater fuel system are as follows:

   1. Fuel nozzle, restrictor, orifice, or equivalent

   2. Fuel shutoff valve

   3. Fuel filter

   4. Fuel pressure regulator

   5. Fuel pump

b. Spark Ignition System: The spark ignition system uses aircraft electrical power to generate a high temperature electric discharge across an air gap within the combustion chamber of the heater. Components of the spark ignition system include:

   1. Device to provide high voltage power

   2. High-voltage ignition lead assembly or equivalent electrical linkage between high voltage device and spark plug.

   3. Radio interference shielding. Radio interference suppression and test method shall be specified by the procuring and/or regulatory agency.

      Heaters with output ratings of 11 700 W (40 000 Btu/h) or less may use an electrically heated resistance wire as an ignition source.

c. Air Supply System: The air supply system provides both air for the combustion process and air (usually referred to as ventilation air) to be heated and distributed for various aircraft uses. Major devices of the air supply system include:

   1. Combustion air blower

   2. Combustion air inlet scoop

   3. Ventilation blower

   4. Safety device(s) to hold off fuel to the heater in the event of insufficient combustion airflow or excessive ventilation air discharge temperature.

d. Temperature Control System: The heater shall be supplied with a temperature control system to maintain the desired heater downstream temperature. In a typical installation, three thermostats are used to control heater operation.

   1. A cabin or compartment thermostat that is usually adjustable

   2. A cycling switch located on or just downstream of the heater that limits heater air discharge temperature

   3. An overheat switch, located on the heater, that prevents overheating

e. Safety Controls: Heater controls must be provided to prevent hazardous or unsafe operation of the heater. Unsafe conditions include excessive heat exchanger temperature, insufficient combustion air to support complete combustion of the fuel, and insufficient ventilating airflow. Heater accessories that may be installed to prevent unsafe operating conditions include:

   1. A thermostat to sense heat exchanger temperature

   2. A device to sense combustion airflow or inlet pressure

   3. A thermostat to sense excessive downstream air temperature

   4. A device that senses heater ventilating air pressure differential

3.3 Materials and Workmanship

3.3.1 The heater and auxiliary equipment shall be constructed throughout of materials that are considered acceptable for the particular use intended and shall be made and furnished with a degree, uniformity and grade of workmanship generally accepted in the aircraft industry.

3.3.2 The heater casing or shroud shall be constructed of fireproof material.

3.4 Design Features

3.4.1 The design shall be such as to preclude the possibility of discharging harmful concentrations of carbon monoxide or other combustion products into the ventilating air stream. See 5.2.2.2.

3.4.2 Where specified, the design shall be such as to preclude the excessive loss of pressurized fuselage air. See 5.2.7 and 5.2.8.

3.4.3 The design shall include protection against excessive radio interference as specified by the procuring agency.

3.4.4 The design shall include protection against overheating that may arise from lack of sufficient ventilating airflow through the heater. See 5.2.10.6.

3.4.5 The design shall be such as to preclude harmful effects on construction or performance due to aircraft induced vibration. See 5.2.9.

3.4.6 The design shall be such that the life of the heater and accompanying devices shall be comparable to other similar airframe components and accessories. See 5.2.10.

3.5 Heater Identification

The following minimum information shall be legibly and permanently marked on the heater or on a nameplate attached thereto:

a. Manufacturer’s Name or Trademark or both

b. Manufacturer’s Part Number

c. Manufacturer’s Serial Number

d. Rated Output (Btu/h or W)

e. Type of Fuel

f. Rated Fuel Pressure (lbf/in^2 gage or kPa gage)

g. Electrical Characteristics

h. Specification Number

i. Approvals: unpressurized cabin, pressurized cabin, wing or others (may be abbreviated, for example, Unpr. Cabin, Press. Cabin)

j. Minimum Fuel Temperature

3.6 Preventive Maintenance

The heater manufacturer shall specify the preventive maintenance requirements necessary to ensure the continued airworthiness of the heater throughout the useful life of the heater. A heater maintenance manual shall be provided by the manufacturer and shall contain a separate section titled "Airworthiness Limitations". This section shall contain inspection times, inspection intervals, and related procedures necessary for continued airworthiness. The heater components and related accessories addressed in the "Airworthiness Limitations" section shall consist of, as a minimum, the following:

a. Combustion Chamber/Heat Exchanger Integrity

b. Fuel Pressure Regulator

c. Fuel Nozzle

d. Fuel Pump

e. Safety Controls

f. Ignition System

3.7 Aircraft Installation

This document is primarily intended to specify heater design requirements irrespective of the particular aircraft installation. However, it should be emphasized that the heater installation within the aircraft should comply with applicable FAA, JAA, and EASA regulations including:

a. 14 CFR/CS 23.859 Combustion Heater Fire Protection

b. 14 CFR/CS 23.863 Flammable Fluid Fire Protection

c. 14 CFR/CS 25.859 Combustion Heater Fire Protection

d. 14 CFR/CS 25.863 Flammable Fluid Fire Protection

e. 14 CFR/CS 25.869 Fire Protection: Systems

f. 14 CFR/CS 27.859 Combustion Heater Fire Protection

g. 14 CFR/CS 27.863 Flammable Fluid Fire Protection

h. 14 CFR/CS 29.859 Combustion Heater Fire Protection

i. 14 CFR/CS 29.863 Flammable Fluid Fire Protection

The heater installation should also comply with the fire safety criteria specified by the airplane manufacturer.

4. DETAIL REQUIREMENTS

4.1 Rating Conditions

Heater shall deliver rated output as specified by manufacturer at the following conditions:

a. Sea level ambient pressure

b. Specified type of fuel

c. Rated fuel flow, pressure, and temperature

d. Rated sea level combustion air flow rate and temperature

e. Ventilating air temperature rise of 139 °C (250 °F)

f. Ventilating air inlet at ambient pressure and temperature

4.2 Air Supply

4.2.1 The heater ventilating and combustion air inlet and outlet ports shall be sized to provide the minimum possible pressure loss consistent with the aircraft system and installation requirements.

4.2.2 When sufficient combustion or ventilating air for safe operation is not available, the heater shall be made automatically inoperative. See 5.2.10.6.

4.2.3 The combustion air and ventilating air inlets on the heater shall be separated from each other.

4.3 Fuel Supply

4.3.1 The fuel supplied shall be aviation-grade gasoline or aviation-grade kerosene, or both, as specified by 4.1.

4.3.2 The fuel lines and fittings under pressure in the heater shall be enclosed in such a manner as to prevent any fuel leakage from entering the ventilating air stream, and the enclosure shall have adequate provision for draining the combustion chamber to a fuel drain fitting.

4.3.3 A fuel drain outlet shall be provided to prevent accumulation of liquid fuel in the combustion chamber and heat exchanger assembly in the event that fuel flows into the combustion chamber without igniting.

4.3.4 All fuel lines in the heater shall be constructed of steel or other fire-resistant material. Where flexibility is required in these lines, flexible fire-resistant coupled hose assemblies shall be used to eliminate the possibility of using hose clamp connections. Connections in metal fuel lines shall not employ solder or other relatively low-melting-point materials which cannot withstand a 1093 °C (2000 °F) flame for 5 min.

4.3.5 All gaskets, synthetic rubber seals, etc., shall be suitable for use with no lead or low lead type gasoline and kerosene fuels and shall be satisfactory for use at the temperatures encountered from initial low starting temperature limit of -54 °C (-65 °F) for gasoline or -29 °C (-20 °F) for kerosene to the overheating limits of the heater.

4.3.6 The fuel system lines, fittings, and controls shall be sufficiently isolated from the combustion side of the heater to prevent their being damaged by flame, radiant heat, or backfire.

4.4 Combustion Chamber and Heat Exchanger Assembly

4.4.1 The combustion chamber and heat exchanger assembly shall be constructed from a corrosion and heat resistant material suitable for the intended use and in accordance with SAE Aerospace Material Specifications, or equivalent. Heater materials should be selected to withstand the deteriorating effects of high humidity, condensation, fungus and abrasive particles in the air.

4.4.2 Means shall be provided to minimize malfunctioning due to lead or carbon deposits and to permit disassembly and cleaning of all parts affected by products of combustion.

4.4.3 The accumulation of lead scale or products of combustion deposits shall not cause functional failure before 500 h of normal heater operation.

4.4.4 The heater combustion chamber and heat exchanger assembly shall be so designed that it shall not rupture under the most severe explosion conditions that can occur with any possible fuel air mixture as demonstrated by the test outlined in 5.2.8.

4.5 Exhaust

The temperature of the exhaust gases at the point of discharge from the heater shall not exceed 649 °C (1200 °F) at the specified rating condition of 4.1. The point of discharge is defined as a point in the exhaust tube 0.30 m (12 in) from the heater casing. See 5.2.2.

4.6 Ignition

4.6.1 Ignition shall be defined as having occurred when the exhaust temperature of the heater rises 83 °C (150 °F).

4.6.2 Ignition time shall be defined as the time from the instant the heat switch is actuated until ignition occurs.

4.6.3 Heaters of 11 700 W (40 000 Btu/h) capacity or less may be ignited by means of an electrically heated resistance wire.

4.6.4 Heaters of any capacity may be ignited by means of an electric high voltage spark plug.

4.6.5 Ignition power may be sustained during heater operation or discontinued if satisfactory combustion is assured.

4.6.6 The ignition system shall be capable of functioning over a period of 200 heater operating hours without service. See the test specified in 5.2.10.

4.6.7 In the event of ignition delay for an indefinite period, either with or without fuel supply, no hazardous condition shall result. The heater should be designed to preclude violent explosions on being started.

4.6.8 Glow plug ignited heaters shall ignite within 200 s. Spark ignited heaters shall ignite within 15 s when burning gasoline type fuels, and within 60 s when burning kerosene type fuels. See 5.2.3.

4.6.9 Heaters that are intended for wing-empennage heating shall ignite within 15 s when using gasoline, and 60 s when using kerosene type fuels, under conditions of 5.2.5.

4.7 Safety Controls

Heater safety controls are covered in FAA Regulations. Controls must be provided to automatically shut off the ignition and fuel supply to the heater in the event any of the following occurs:

a. Heat Exchanger temperature exceeds safe limits

b. Ventilating air temperature exceeds safe limits

c. Insufficient combustion airflow

d. Insufficient ventilating airflow

These safety controls must be independent of the controls normally used to control heater operation. The shut off of ignition and fuel must occur at a point remote from the heater itself. The requirement to shut off fuel at a point remote from the heater requires an additional fuel shut off be supplied in addition to the valve usually supplied with the heater as an accessory. This valve is usually the responsibility of the using agency. See 5.2.10.6 for tests conducted on safety controls.

4.8 Lines and Fittings

All lines and fittings shall comply with applicable aircraft standards.

4.9 Electrical Equipment

All electrical equipment shall conform to applicable aircraft standards. Heater electrical wiring must be suitable for the intended application. Wiring must be selected so that the maximum conductor temperature cannot be exceeded for any combination of electrical loading, ambient temperature, and heating effects of bundles, conduit, and other enclosures. Factors to consider in wire selection are voltage, current, ambient temperature, mechanical strength, abrasion, flexure, and pressure altitude requirements.

Electrical connection to aircraft heaters must be made using either approved terminal strips or MS type connectors or receptacles or both.

4.10 Vibration

The heater and auxiliary equipment shall be capable of withstanding and satisfactorily operating when subjected to a steady vibration over a range of frequencies from 10 to 45 Hz with a total excursion of 1.59 mm (0.062 in), and from 45 to 53 Hz with an acceleration of 6 g. Unless otherwise specified in detail specifications, the equipment shall be mounted on the vibrating surface of the apparatus and normal to the direction of vibration.

4.11 High Temperature

The heater and its accompanying devices should not be adversely affected if subjected to ambient temperatures of 71 °C (160 °F) for indefinite periods.

5. REQUIRED TESTING

All required testing shall be conducted on a test unit that is typical of production hardware. Test units shall be inspected to applicable engineering drawings. Drawings shall be available for review. Unless otherwise specified, all tests shall be conducted at ambient pressure and temperature. All test measurement equipment shall be calibrated prior to testing. The manufacturer shall furnish reports, on request, describing test procedures and results. Reports shall include an introduction, a description of the test apparatus, instrumentation and tests, the results, a discussion, and conclusions.

5.1 Test Sequence

Two test units shall be subjected to the tests described herein. The sequence of testing shall be as shown in Table 1 as follows:

TABLE 1 - HEATER TESTING SEQUENCE

Test	Procedure Paragraph	Unit No. 1	Unit No. 2
Inspection	5.2.1	X	X
Rated Sea Level Performance	5.2.2	X	X
Ignition Envelope	5.2.3	X	
Low Temperature Performance	5.2.4	X	
Altitude Performance	5.2.5	X	
Electrical Characteristics	5.2.6	X	
Collapsing Pressure	5.2.7	X	
Burst Pressure	5.2.8	X	
Vibration	5.2.9		X
Rated Sea Level Performance	5.2.2		X
Endurance	5.2.10		X
Rated Sea Level Performance	5.2.2		X
Inspection Teardown	5.2.1	X	X

5.2 Test Procedure

The following procedures describe the general test conditions, test inputs, and success criteria for various heater tests. Alterations to the procedures may be necessary depending on the particular heater undergoing test evaluation. When success criteria are not specified, they shall be mutually agreed upon by the manufacturer and purchaser.

5.2.1 Inspection

The heater shall be inspected for conformance to applicable engineering drawings. Critical dimensions shall be measured and recorded. The heater and accessories shall be weighed to determine conformance to weight requirements.

5.2.2 Rated Sea Level Performance

5.2.2.1 Rated Heater Output

The test unit shall be installed in a test set up capable of supplying the inputs specified in 4.1. The specified type of fuel at the rated pressure and temperature shall be supplied to the heater fuel system. Combustion air at the rated sea level mass flow rate and temperature shall be supplied to the heater. Ventilation air shall be provided at the rated mass flows and temperature specified. The following test parameters shall be measured and recorded:

a. Barometric pressure

b. Fuel flow rate

c. Fuel inlet temperature

d. Fuel inlet pressure

e. Combustion airflow rate

f. Combustion air inlet pressure

g. Exhaust gas temperature

h. Combustion air pressure drop

i. Ventilating airflow rate

j. Ventilating air inlet pressure

k. Ventilating air inlet temperature

l. Ventilating air outlet temperature

m. Ventilating air pressure drop

Rated output shall be defined at a ventilating air temperature rise of 139°C (250 °F). Output is defined as follows in Equation 1:

$$Q = W_v \times C_p \times (T_{vo} - T_{vi}) \text{ , kW} \quad \text{(Eq. 1)}$$

where:

Q = Rated Output, kW

W_v = Ventilating airflow rate, kg/s

C_P = Specific heat of air , kJ/kg - K

T_{vo} = Ventilating air outlet temperature - °C

T_{vi} = Ventilating air inlet temperature - °C

T_{vo}-T_{vi} = 139°C (250 °F)

5.2.2.2 Carbon Monoxide (CO) Contamination

At rating conditions specified in 5.2.2.1 and with the burner operating, the heater downstream ventilating airstream shall be checked for the presence of CO. The test shall be run with the heater exhaust discharging to atmosphere. The ventilating air samples shall be taken from an unrestricted duct fastened to the heater ventilating air outlet. The duct shall be the same diameter as the heater casing and at least five diameters in length. A suitable instrument, calibrated against a known standard, will be used to determine CO concentration. The CO concentration shall not exceed 50 ppm.

5.2.2.3 Combustion Chamber Leakage

The test unit shall be removed from the performance test set up. Cap the fuel circuit, fuel drain lines, and the combustion air inlet tube. Apply air pressure at 55.1 kPa gage (8 lbf/in^2 gage) to the heater exhaust connection thereby applying internal pressure to the heater combustion chamber. Measure the airflow required to maintain the internal pressure. The air leakage shall not exceed 4.1 kg/h (9 lb/h) at sea level and 15 °C (59 °F). In addition, a test will be conducted to show that there will be no leakage of fuel into the ventilating air circuit in the event that the heater fails to ignite. For this additional test, the heater is to be mounted as normally installed with all fuel drains open.

5.2.2.4 Pressurized Heater Leakage

Heaters intended for use in pressurized aircraft shall be checked for ventilation air circuit leakage. The heater ventilation air inlet and outlet shall be capped. Air pressure at 110 kPa gage (16 lbf/in^2 gage) shall be applied to the capped ventilation air circuit. Measure the air flow required to maintain the internal pressure. The air leakage shall not exceed 4.5 kg/h (10 lb/h) at sea level and 15 °C (59 °F).

5.2.2.5 Post-Endurance Test Output: Wing-Empennage Anti-Icing

When heater is to be used for wing-empennage anti-icing, the output shall be no less than 90% of the original rating after the endurance test.

5.2.3 Ignition Envelope

Install the test unit into a test set up that simulates the aircraft installation as closely as possible. The test unit and mating duct work shall be installed in an altitude chamber (or equivalent) capable of simulating altitudes from sea level to the altitude specified or 6100 m (20 000 ft). The test set up shall be capable of monitoring the operating parameters specified in 5.2.2.1. The ability of the heater to ignite repetitively within the time specified in 4.6.8 and burn continuously shall be determined for various combustion air differential pressures at various altitudes. The results are plotted as altitude versus combustion air differential pressure. Figure 2 shows a typical ignition envelope curve.

Ignition shall be defined as having occurred when the exhaust temperature rise reaches 83 °C (150 °F). The area under the curve shown in Figure 2 shall represent the envelope of operation where the heater can be repetitively restarted. The service ceiling (altitude) of the heater and its accompanying ignition devices shall be defined as the peak of the ignition characteristics curve. The service ceiling determined by this test shall meet the requirement specified by the purchaser.

5.2.4 Low Temperature Performance

Install the test unit in to the test set up used in 5.2.2.1. Supply combustion air and ventilating air to the heater at sea level pressure and -54 °C (-65 °F) temperature. The fuel temperature supplied to the heater shall be -54 °C (-65 °F) for gasoline type heaters and -29 °C (-20 °F) for kerosene type heaters. Combustion and ventilating air pressure levels and mass flow rates shall be the same as 5.2.2.1. Measure and record the parameters specified in 5.2.2.1.

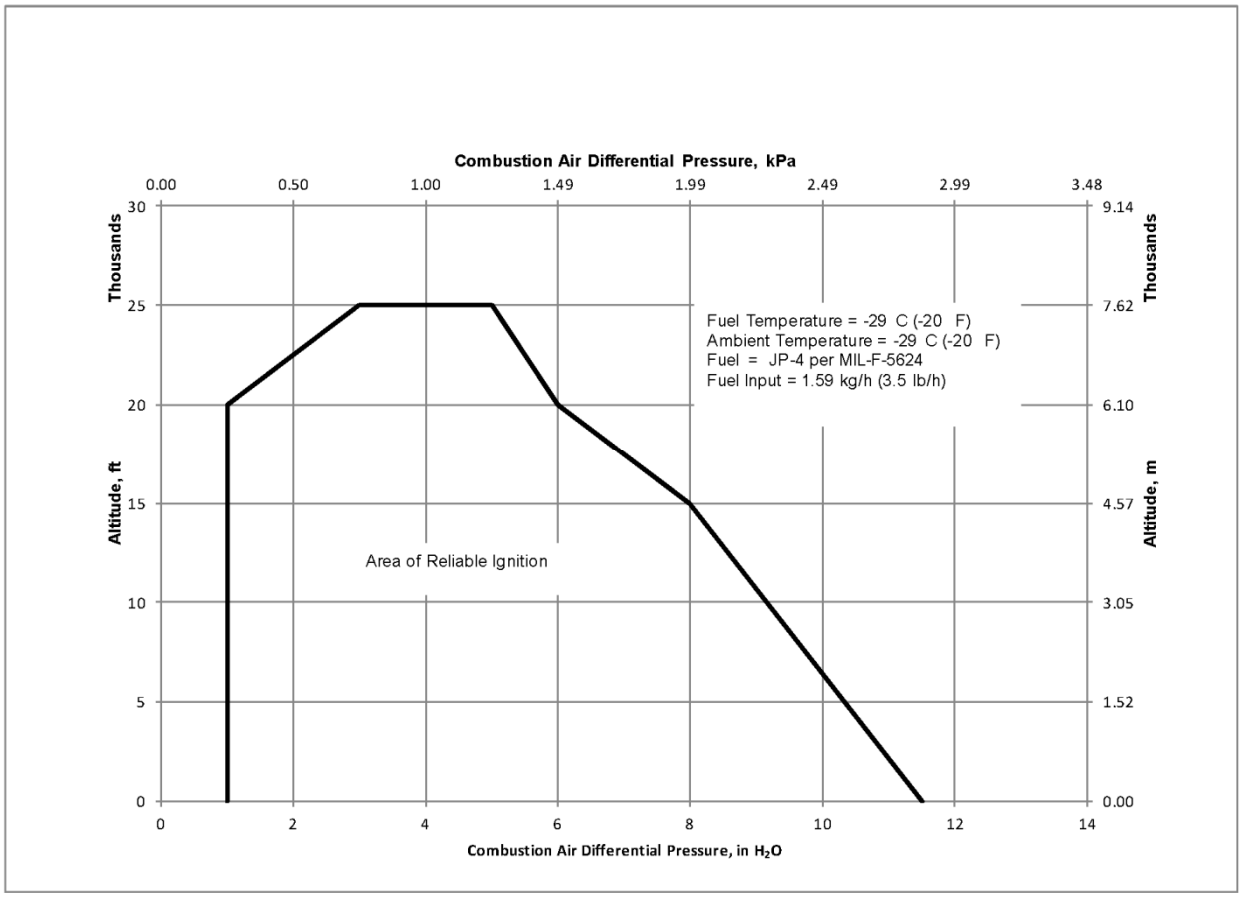

FIGURE 2 - TYPICAL IGNITION CHARACTERISTIC CURVE

5.2.5 Altitude Performance

Install the heater into an altitude chamber capable of simulating the design altitude of the heater. Supply ventilating air to the heater at -54 °C (-65 °F) and at the flow rate determined in 5.2.2.1. Supply combustion air to the heater at -54 °C (-65 °F). Fuel at the rated flow and pressure and the temperature specified in 5.2.4 shall be supplied to the heater. The combustion air differential pressure shall be adjusted to be midway between the ignition limits determined in 5.2.3 at 6100 m (20 000 ft) altitude or the specified altitude. Combustion air shall be supplied from an air source maintained at a pressure corresponding to the test altitude. See the U.S. Standard Atmosphere for the ambient pressure corresponding to the test altitude. At the specified altitude, the heater shall be capable of heating the ventilating air to a minimum of 82 °C (180 °F). In addition, the heater shall be capable of delivering a minimum of 50% of the rated heat specified in 4.1.

5.2.6 Electrical Characteristics

The heater while installed in the test set up described in 5.2.2.1 shall be tested for maximum starting and maximum running amperes when supplied with rated voltage at sea level conditions. The voltage shall be varied to determine the range that the heater will start and operate satisfactorily.

5.2.7 Collapsing Pressure Resistance

The heater shall be set up with an adjustable restriction on the combustion air inlet and a source of vacuum connected to the exhaust outlet. The ventilating air shall discharge freely to atmosphere (sea level). A static pressure tap shall be provided in the exhaust pipe within 0.30 m (12 in) of the connection to the heater.

Collapsing pressure test of the combustion chamber and heat exchanger assembly shall be as follows:

5.2.7.1 For a nonpressurized cabin heater or a wing-empennage heater, the heater shall be operated at sea level rating, except that the exhaust outlet pressure is to be maintained at a value which is at least 28 kPa gage (4 lbf/in^2 gage) below the ventilating air outlet pressure. After operating the heater for at least 1 h at these conditions, there must be no permanent distortion of any part of the heater, unless it can be demonstrated that such distortion does not affect the performance or life of the heater.

5.2.7.2 For pressurized cabin heaters, the test shall be the same as 5.2.7.1, except that the exhaust outlet pressure shall be maintained at a value that is at least 69 kPa (10 lbf/in^2) below the ventilating air outlet pressure.

5.2.8 Combustion Chamber Burst Pressure

Combustion chamber burst pressure test shall demonstrate compliance with 4.4.4 as follows:

5.2.8.1 With the combustion chamber and heat exchanger assembly at room temperature, introduce a gasoline fuel air mixture in a ratio of 0.085 to 0.095. Purge the combustion chamber and heat exchanger assembly with this mixture to the extent of at least 10 times the volume of the combustion chamber and heat exchanger assembly. Ignite the mixture with a spark plug. Repeat the procedure to complete 50 explosions. The heater shall then meet the leakage requirements of 5.2.2.3.

5.2.9 Vibration Test

The heater and auxiliary equipment shall be capable of withstanding and satisfactorily operating when subjected to a steady vibration over a range of frequencies from 10 to 45 Hz with an acceleration of 6 g. Unless otherwise specified in the detail specification, the heater shall be vibrated in each of three mutually perpendicular axes. The requirements specified in 5.2.9.1 through 5.2.9.5 shall be repeated for each vibration axis. The heater shall be operated at rated sea level performance per 5.2.2 during the vibration test.

5.2.9.1 The heater shall be vibrated over a range of 10 to 45 Hz with a double amplitude of 1.59 mm (0.062 in). Frequencies at which resonance occurs, if any, shall be observed and noted.

5.2.9.2 The heater shall then be vibrated over a range of 45 to 53 Hz with an acceleration of not less than 5 g and not more than 6 g. The frequencies at which resonance occurs, if any, shall be observed and noted.

5.2.9.3 If resonance is observed under the tests of 5.2.9.1 or 5.2.9.2, a vibration test shall be conducted for 15 h at the frequency showing the maximum resonance and at the appropriate vibration input specified in 5.2.9.1 or 5.2.9.2.

5.2.9.4 If no resonance is observed under the tests of 5.2.9.1 or 5.2.9.2, a vibration test shall be conducted for 15 h at 45 Hz with a double amplitude of 1.59 mm (0.062 in).

5.2.9.5 At the conclusion of the vibration test, there shall be no evidence of structural failure and the heater and auxiliary equipment shall operate satisfactorily.

5.2.10 Endurance Tests

Endurance tests shall be conducted in such a manner as to qualify the heater and auxiliary equipment for cabin heating, wing-empennage anti-icing, or both. For cabin heating only, the duration of the test shall be at least 850 h on time. For wing-empennage anti-icing only, the duration of the test shall be at least 500 h on time. For qualification of the heater and accompanying devices under both cabin heating and wing-empennage classifications, the duration shall be 850 h on time with 500 h on time performed at the wing-empennage conditions.

5.2.10.1 General Conditions

The general conditions applying to both cabin and wing-empennage heater endurance tests shall be as follows:

Tests shall be performed at sea level rated fuel pressure and sea level rated combustion airflow rate.

Inlet air temperature shall be between -54 °C (-65 °F) and 52 °C (125 °F).

Approximately 50% of the endurance test shall be with continuous operation, and the remainder of the test with cycling operation.

During continuous operation, the ventilating airflow shall be adjusted as required to give the specified temperature rise under steady conditions. At least once, and not more than twice, during each 2 h of operating time, the fuel and ignition system shall be shut off and the heater permitted to cool for at least 10 min with continuous ventilating air and combustion airflow. In calculating total on time for the heater, the 10 min cooling periods shall not be included.

During cycling operation, a thermostatic switch in the ventilating air outlet stream shall cycle the fuel on and off or high to low input to maintain a specified outlet air temperature. The ventilating air rate shall be adjusted so that the average heater output (assuming that the setting of the cycling switch represents the average outlet temperature) is between 60 and 75% of the rated output. At least once, and not more than twice during each 2 h of operating time, the fuel and ignition system shall be shut off and the heater permitted to cool for at least 10 min with continuous ventilating air and combustion airflow. The cycling rate shall fall within the range of 1 to 4 min per cycle.

For cycling, operation on time is defined as the total elapsed time during which the cycling switch controls the heater operation. It does not include the 10 min cooling periods.

5.2.10.2 Cabin Heater Endurance Tests

The cabin heater endurance tests shall be divided into four periods, as follows:

a. First period: 250 h continuous operation, with the ventilating air rate adjusted to maintain a temperature rise of at least 93 °C (200 °F) and an outlet temperature of at least 121 °C (250 °F).

b. Second period: 250 h cycling operation, with the cycling switch set to control at 121 °C ± 6 °C (250 °F ± 10 °F) outlet air temperature.

c. Third period: 175 h same conditions as (a).

d. Fourth period: 175 h same conditions as (b).

5.2.10.3 Wing-Empennage Anti-Icing Endurance Tests

Wing-empennage anti-icing heater endurance tests shall be divided into two periods, as follows:

a. First period: 250 h continuous operation with the ventilating air rate adjusted to maintain a temperature rise of at least 149 °C (300 °F) and an outlet air temperature of at least 177 °C (350 °F).

b. Second period: 250 h cycling operations with the cycling switch set to control at 177 °C ± 6 °C (350 °F ± 10 °F) outlet air temperature.

5.2.10.4 Igniter

Whenever it becomes necessary due to ignition failure during the endurance test, the igniter may be cleaned, adjusted, or replaced. However, the igniter shall not require servicing or replacement more than twice during the endurance test of a wing-empennage heater or more than four times during the endurance test of a cabin heater.

5.2.10.5 Fuel System

5.2.10.5.1 Whenever necessary due to stoppage or failure, the fuel orifice or nozzle may be cleaned or replaced. Such servicing shall not be required more than once during a wing-empennage heater endurance test or twice during a cabin heater endurance test.

5.2.10.5.2 The fuel shutoff valve may be cleaned once during a wing-empennage heater endurance test and twice during a cabin heater endurance test. It shall not be cleaned, serviced, or replaced due to failure to close during the endurance test. The valve leakage in the closed position with rated fuel pressure shall not exceed 0.068 fluid oz (2 ml) of fuel in 10 min when new, at the end of the endurance test, or when removed during the endurance test program.

5.2.10.5.3 The fuel filter may be cleaned or the filter element replaced but the filter body shall not be replaced during the endurance test. At the end of the test, there shall be no leakage through the case or body.

5.2.10.6 Safety Control

5.2.10.6.1 The device used to prevent the heater from becoming overheated shall not be serviced or replaced during the endurance test due to failure to shut off the heater. At the beginning of the endurance test and at the end of each test period (5.2.10.2 or 5.2.10.3), any cycling or intermediate controls shall be bypassed and the ventilating air rate gradually reduced over a period of 15 min to permit operation of this device. Operation shall be within 14 °C (25 °F) of the value obtained at the beginning of the endurance test.

5.2.10.6.2 The device to prevent fuel flow when combustion air is insufficient for safe operation shall be sensitive to heater combustion air pressure differential or combustion air pressure. The device may be an air-actuated electrical switch designed for use with an electrical fuel shutoff valve, or an air-actuated mechanical valve designed to control the flow of fuel.

5.2.10.6.2.1 If an air-actuated electrical switch is used, it shall be checked as follows at the end of each test period (5.2.10.2 or 5.2.10.3) with the heater in operation.

Reduce the combustion air differential pressure or combustion air pressure gradually (approximately 30 s) from normal rating to a point where the switch closes the electrical fuel shutoff valve. The combustion air differential pressure or combustion air pressure at which the fuel shutoff valve closes shall not be less than the minimum value required for safe heater operation. At the end of 15 min, fuel off time, the combustion air differential pressure or combustion air pressure, as applicable, shall be gradually increased at the same rate and the switch shall open the electrical fuel shutoff valve at or above the minimum safe combustion air pressure differential.

5.2.10.6.2.2 If an air actuated mechanical fuel valve is used, it shall be checked as follows at the end of each test period (5.2.10.2 or 5.2.10.3).

With the heater operating and the fuel shutoff valve open, the combustion air differential pressure shall be reduced gradually (approximately 30 s) from normal rating to the value required for safe heater operation. Leakage through the air-actuated mechanical fuel valve shall then be measured and shall not exceed 2 cm^3 in 10 min. At the end of 15 min fuel off time, the combustion air differential pressure shall be gradually increased at the same rate and the valve shall permit rated fuel flow when the rated combustion air pressure differential is reached.

5.2.10.7 Ignition System: If necessary, the high voltage device or the high voltage ignition lead or both (or equivalent) may be serviced or parts replaced once during the endurance test.

5.2.10.8 Unless otherwise specified, items covered in 5.2.10.6 and 5.2.10.7, if furnished separately, need not be tested more than once, provided no changes are made in their design, construction, or adjustment.

5.2.10.9 In case of endurance test failure of one or more of the devices in items covered in 5.2.10.6 and 5.2.10.7, the test may be continued to qualify the heater or devices that have not failed. A separate endurance test shall apply only to the failed device if necessary to establish reliability.

6. DESIRABLE FEATURES

6.1 Operation

6.1.1 The operation of the heater and accompanying devices should require a minimum of moving parts.

6.1.2 The heater should start operation within 5 s at -54 °C (-65 °F) with gasoline or within 60 s at -29 °C (-20 °F) using kerosene type fuels at sea level and at its service ceiling and should reach its maximum output within 3 min after being started.

6.1.3 The heater ventilating air circuit pressure drop shall be consistent with aircraft heating system requirements.

6.1.4 Where necessary, additional devices such as the following, may be provided to improve heater operation:

a. Air Pressure Regulator

b. Fuel Pressure Regulator

c. Combustion Air Blower

d. Ventilating Air Blower

e. Fuel Ratio Control

f. Thermal Cycling Switch

g. Cabin Heat Controls

h. Combustion Detector Assembly (No heat shut off)

6.2 Igniter

The igniter should be accessible for quick replacement or servicing. The heater should be designed so that fuel does not drip on the spark plug or igniter.

6.3 Fuel Nozzle

The fuel nozzle should be easily accessible for replacement or servicing.

7. NOTES

7.1 A change bar (l) located in the left margin is for the convenience of the user in locating areas where technical revisions, not editorial changes, have been made to the previous issue of this document. An (R) symbol to the left of the document title indicates a complete revision of the document, including technical revisions. Change bars and (R) are not used in original publications, nor in documents that contain editorial changes only.

7.2 Dimensions and properties in SI units and the Celsius temperatures are primary; dimensions and properties in inch/pound units and the Fahrenheit temperatures are shown as the approximate equivalents of the primary units and are presented only for information.

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