

Chapter A4

Test Method to Determine Heat Release Rate and Total Heat Release of Aircraft Cabin Materials

A4.1 Scope

This test method describes the determination of the heat release rates of materials and products when exposed to one level of radiant heat using the test apparatus, specimen configurations, and procedures described in this test method. Information can be found in associated Appendix L (section L4.) relative to monitoring smoke emissions during testing.

This test method is intended to measure and describe the properties of materials, products, or assemblies in response to heat and flame under controlled laboratory conditions and is not used to describe or appraise the fire hazard under actual fire conditions. However, the results of this test may be used as elements of a fire risk assessment, which takes into account all of the factors relevant for an assessment of the fire hazard of a particular end use.

The heat release rate is measured for the duration of the test from the moment the specimen is injected into the controlled environmental chamber and encompasses the period of ignition and progressive flame involvement of the material.

The results of this test describe the behavior of material and product specimens due to specified fire exposure in terms of heat release rates.

A4.2 Definitions

A4.2.1 Calibration Factor (K_h)

A proportionality constant is determined by performing the calibration procedure described in this document. It is expressed in terms of power per degree Celsius (Watts per degree Celsius—W/°C). The calibration factor is developed by burning known flow rates of methane in the apparatus while recording the resultant thermopile temperature rise (ΔT). This process correlates the heat released by a specimen when burned to the known heat content of methane.

A4.2.2 Applied Calibration Factor (K_H)

A 5-point simple moving average shall be used to compute the applied calibration factor (K_H). The calibration factor is derived from point-in-time measurements and is sensitive to inherent random variation within the apparatus. A simple moving average mitigates this variation by filtering the variable ‘noise’ and improving the probability that the applied calibration factor will represent the actual calibration value at any given time.

A4.2.3 Heat Release Rate

A measure of the rate at which heat energy is evolved by a material when burned. It is expressed in terms of power per unit area (kilowatts per square meter, kW/m²). The maximum heat release

rate occurs when the material is burning most intensely. The peak heat release rate that occurs during the 5-minute test is reported.

A4.2.4 Total Heat Release

A measure of the amount of total heat energy evolved by a material when burned. It is expressed as energy per unit area (kilowatt minutes per square meter, $\text{kW} \cdot \text{min}/\text{m}^2$). The total amount of heat energy released during the first 2 minutes of testing is reported.

A4.2.5 Heat Flux Density

The intensity of the thermal environment to which the specimen is exposed when burned. In this test method, the total heat flux density is $3.65 \text{ W}/\text{cm}^2$ ($3.21 \text{ BTU}/\text{ft}^2 \cdot \text{sec}$).

NOTE: Traditionally (and as specified in part IV of Appendix F, 14 CFR 25), the heat flux requirement was $3.5 \text{ W}/\text{cm}^2$ ($3.08 \text{ BTU}/\text{ft}^2 \cdot \text{sec}$). The increase in measured irradiance is a consequence of a change in the method used to determine the heat flux level. Previously the determination was made by inserting the calibration assembly into the heated section of the apparatus for a short period. The current method requires the assembly to remain in the same position until conditions become stable. This change creates some additional heating of the calibration assembly, which slightly increases the sensor's output. The parameters have been adjusted to account for this shift in output to maintain previous heat flux levels and help improve reproducibility. The test itself is no more severe.

A4.2.6 Thermopile

The temperature of the air entering and exiting the chamber is continuously monitored. Once baseline temperature is determined, an increase in exit gas temperature is known to be directly proportional to the heat released by a burning material. Integrating such data over a given time yields the total amount of heat released during that period.

A4.2.7 Mass Flow Controllers

Accurate, reliable gas flow delivery and control are crucial to this test method. Mass flow controllers (MFCs) provide precision measurement and control of airflow through the apparatus and gas flow for calibration (methane) and pilot burner operation (methane and air).

Warning! *Condensing liquids in the main chamber air and upper/lower pilot burner mixing air supply could severely damage mass flow control equipment. Air filters, dryers, chillers, and condensate traps should be installed as needed.*

A4.2.8 Methane Gas (CH_4)

Methane gas (dry) is used as a fuel for an upper and lower pilot burner, and as a calibration gas. For this test method, the methane gas must have a minimum purity of 99% and be regulated to a supply pressure of $25 \pm 5 \text{ psig}$ ($274 \pm 34 \text{ kPa}$) from the supply cylinder.

The main air supply and air used to mix with methane gas for the upper and lower pilot flames must also be regulated to the controllers/flow meters at 25 ± 5 psig (274 ± 34 kPa).

A4.2.9 National Institute of Standards and Technology

The National Institute of Standards and Technology (NIST; USA).

A4.2.10 NIST Traceability

A calibration entity using NIST traceable calibration instrumentation.

A4.2.11 Stability

The term ‘stable’, as it relates to heat flux density and chamber equilibrium, is calculated using a moving average and expressed in terms of percent standard deviation over a defined period. Typically, stable conditions can be achieved between 60 and 90 minutes after heating has begun.

Heat flux (60-second moving average)

Heat flux gauge (HFG) millivolt signal that varies less than 1.0% standard deviation during the last 60 seconds and has a calculated heat flux density that is within range (see section A4.6).

Chamber equilibrium (15-minute moving average)

Thermopile temperature signal that varies less than 1.0% standard deviation during the last 15 minutes commencing no sooner than 30 minutes after turning the heating elements on.

A4.2.12 Standard Temperature and Pressure (STP)

For this test method, STP is 0°C (273.15 K) at 760 mmHg (101.325 kPa) unless otherwise stated. Flow units are expressed as SLPM or NLPM and m^3/s .

A4.3 Principle of the Method

A4.3.1 General

The test method is used for the determination of the heat release of parts or subassemblies of the aircraft interior.

A4.3.2 Details of the Method

The specimen to be tested is injected into an environmental chamber through which a constant flow of air passes. A radiant heat source evolves the desired total heat flux to which the specimen is exposed. The specimen is tested with the exposed surface in the vertical direction. Combustion may be initiated by point ignition on the surface or piloted ignition of evolved gases. The calculation of the heat release rate is based on the changes in temperature of the gas entering and leaving the apparatus.

A4.4 Apparatus

A4.4.1 Heat Release Rate Apparatus

This test method uses the Ohio State University heat release rate apparatus to determine heat release rates. This is a modified version of the heat release rate apparatus standardized by the ASTM (ASTM E906) (see figure A4-1).

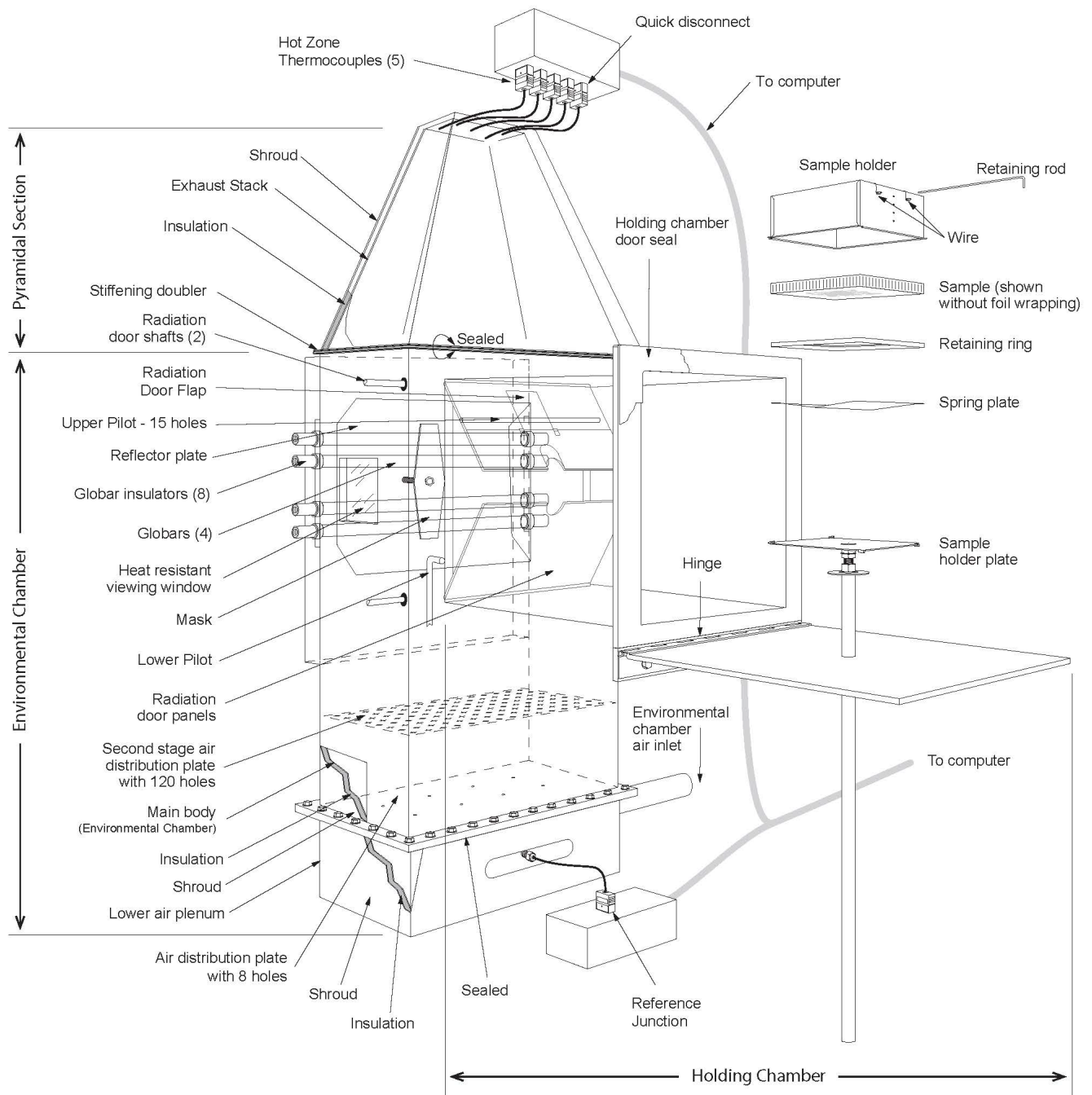


Figure A4-1. Heat release rate apparatus

The apparatus has three main sections:

1. Holding chamber
2. Environmental chamber
3. Pyramidal section

All exterior surfaces of the apparatus, except the holding chamber, must be insulated with 1-inch-thick, low-density (8 pcf), high-temperature, Rockwool (mineral wool or stone wool) insulation having a thermal conductivity (K-value) of $0.23 \text{ BTU} \cdot \text{in}/(\text{hr} \cdot \text{ft}^2 \cdot ^\circ\text{F}) \pm 10\%$ and all seams taped. A thin aesthetic sheathing material or shroud used to conceal the insulation is permissible.

Note: K-value = 1/R-value

Formed seams, butt joints, and corner joints are recommended in the construction of the apparatus, including specimen holders. Except for the exhaust stack, lap joints in construction are permitted but not to exceed 0.375 inches (9.5 mm) and kept to a minimum.

A4.4.1.1 Holding Chamber

The holding chamber of the apparatus acts as an antechamber, in which the specimen is held (in the specimen holder) before being injected into the environmental chamber. The specimen injection rod slides through the outer door of the holding chamber having a snug fit to avoid air leakage. The door is sealed to form an airtight closure and is hinged to make a rapid injection easier and, therefore, prevent excessive heat loss.

A4.4.1.2 Environmental Chamber

The environmental chamber contains radiant heating elements known as globars, a reflector plate, and a diamond-shaped mask to aid in heat flux uniformity, an upper pilot burner to ignite any surplus combustible residues released during the test, a lower pilot burner to initiate combustion of the specimen, air distributor plates that provide a constant laminar flow of air through the apparatus, and a lower plenum that contains the air inlet port and the cold junction of the thermopile. The area between the air distributor plates is commonly referred to as the interspace area.

The environmental chamber also contains a two-part, hinged/insulated radiation door assembly that separates the holding chamber from the environmental chamber. The doors are constructed of two sheets of 0.030 ± 0.003 inch (0.76 ± 0.08 mm) stainless steel with a layer of the 0.25 inch (6.4 mm) rigid refractory board in between. The doors have an overall thickness of approximately 0.31 inches (7.9 mm) with a horizontal overlap where they meet in the center and a door flap to cover the injection rod-hole opening.

To provide a view for observation, there is a 4 ± 0.5 inch (102 ± 12.7 mm) by 4 ± 0.5 inch (102 ± 12.7 mm) heat-resistant window located on one side of the chamber. A sealed hinged-type access is permissible and will help to improve accessibility for maintenance work and cleaning.

A4.4.1.3 Pyramidal Section

The pyramidal section acts as a chimney or exhaust stack to the environmental chamber. Sensors measure the average exhaust gas temperature as it exits the system. This section is fastened to the environmental chamber using 28 to 32 #10-32 by 0.75 inch (19 mm) bolts, washers, and nuts distributed around the perimeter flange. A 0.048 ± 0.004 inch (1.2 ± 0.1 mm) steel stiffening doubler and gasket are required to form an airtight seal.

The exhaust stack must be constructed using formed seams, butt joints, or corner joints. No lap joints are permitted. A covering or shroud made of 0.036 ± 0.003 inch (0.9 ± 0.08 mm) aluminum must be used to conceal and protect the exhaust stack insulation (see Appendix L, figures 5-8). Aside from insulation, nothing can be attached to or in contact with the pyramid-shaped exhaust that could impact heat release data or impede the gas flow from exiting the system, including thermopile support bracketry.

A4.4.2 Apparatus Components

A4.4.2.1 Radiation Source

A power supply capable of producing 12 kVA is satisfactory but not required. The radiation source must be adequately protected from variations in the power supply. A device for monitoring the voltage and current through each globar during testing must be provided. Line voltage fluctuations to the globars shall not exceed $\pm 1.0\%$.

The radiant heat source consists of four silicon carbide elements, 20 inches (508 mm) in length (L), 0.63 inch (16 mm) diameter (D), 12 inch (305 mm) central hot zone (CHZ) with two low resistivity cold ends and a total nominal resistance at 1000°C (1273 K) of $1.4 \text{ ohms} \pm 15\%$. The use of globar sets of similar amperage ratings is recommended to aid in even heat distribution across the test specimen.

The silicon carbide heating elements are mounted in a 2-inch (50.8 mm) deep stainless-steel pan by inserting them through 0.63-inch (16 mm) holes in ceramic insulating devices or calcium-silicate millboard.

A stainless-steel, truncated, diamond-shaped mask 0.042 ± 0.004 inches (1.1 ± 0.1 mm) thick and a stainless-steel reflector plate 0.036 ± 0.003 (0.91 ± 0.08 mm) inches thick are added to provide uniform heat flux over the area occupied by the vertical sample. The vertical mask position and the sloped areas of the plate, top, and bottom, which are 3.15 inches (80 mm) in length, can be adjusted for this purpose. A 0.5-inch (12.7 mm) diameter machine screw or equivalent, approximately 4 inches (102 mm) in length, is used to mount the mask into position. Typically, the mask position is located approximately 3 inches (76 mm) from the reflector plate. Locate the shaft head or nut on the side of the mask facing the specimen (no threads extending toward the specimen).

Variable control of power to the upper and lower global pairs or each individually allows for refined heat flux uniformity adjustments. Extreme care must be taken not to alter the uniformity while making minor daily heat flux adjustments (see sections A4.6.1 and A4.6.2).

A4.4.2.2 Thermopile

The temperature difference between the air entering and leaving the apparatus is continuously monitored by a thermopile constructed of Type K - chromel (nickel-chromium alloy)/alumel (nickel-aluminum alloy) material. The chromel wire is generally yellow in the USA and green in Europe; the alumel wire is red in the USA and white in Europe. Check the color coding of the thermocouple wire used to ensure correct usage.

The components of the thermopile consist of five hot zone thermocouples, one reference thermocouple (cold junction), and an extension harness leading to a data-acquisition system.

The six thermocouples are 0.0625 ± 0.007 inches (1.59 ± 0.18 mm) in diameter, not exceeding 12 inches (305 mm) in length with stainless-steel sheathing. They have an exposed bead junction (ungrounded) 0.030 ± 0.006 inches (0.76 ± 0.15 mm) in diameter and a quick disconnect connection. The distance from the end of the temperature-sensing tip to the sheathing shall not exceed 0.125 inches (3.2 mm).

The hot zone thermocouples are located 0.394 inches (10 mm) below the top of the exhaust stack (see figure A4-2). One of the thermocouples is placed at the center of the exhaust stack cross-section, and the other four are placed on the exhaust diagonals 1.18 inches (30 mm) from the center thermocouple. To protect the connectors from excessive heat rising from the globars, the thermocouples should be positioned above the holding chamber side of the exhaust stack. The hot zone thermocouples are frequently cleaned using a spray of distilled water.

The Type K extension harness will connect the five hot zone thermocouples and the reference thermocouple to the data-acquisition system. The wiring is a 24-gauge solid conductor thermocouple-grade wire with quick disconnect connections on each end to accommodate the thermocouples.

A leak-tight connection is required for the reference junction thermocouple where it enters the lower plenum. The thermocouple sensing tip is geometrically centered in the plenum below the distribution plate. Sealed access ports should be provided to facilitate periodic inspection, cleaning, maintenance, and pressure measurements.

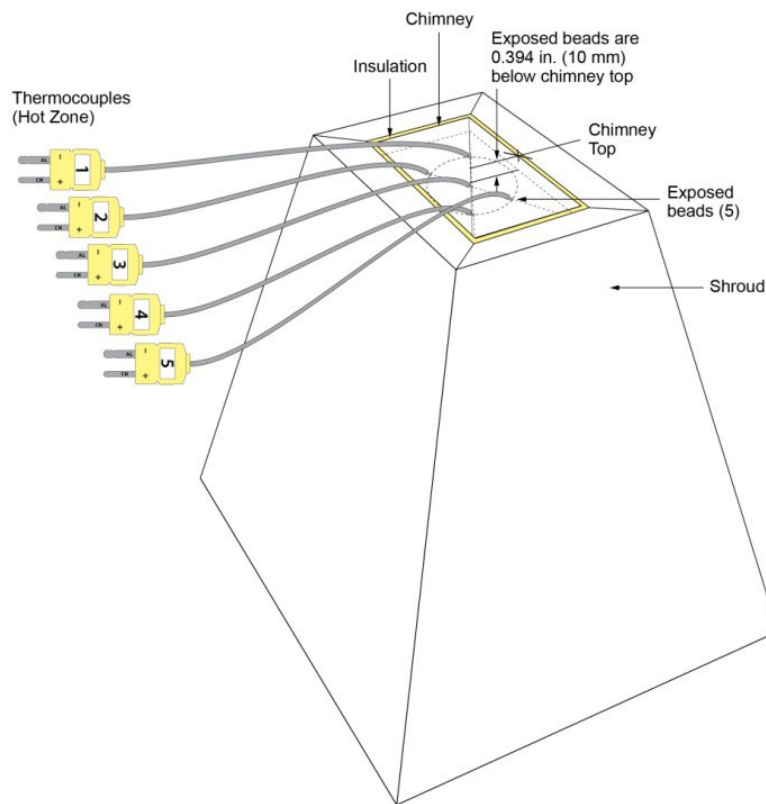


Figure A4-2. Hot zone thermocouples

A4.4.2.2.1 Calculation of Thermopile Temperature Output

The thermopile temperature is calculated as the temperature differential (ΔT) between the air entering and leaving the chamber. Each of the five hot zone thermocouple inputs is recorded and the average value is determined. The reference junction temperature is then subtracted from the average hot zone temperature to calculate the temperature rise of the thermopile signal. Annual calibration of each thermocouple and temperature input (DAQ) is required.

A4.4.2.3 Lower Pilot Burner

The lower pilot burner location serves a dual purpose: a lower pilot burner to begin the ignition process of materials during testing and a calibration burner for the calibration process (see sections A4.4.2.8.2 and A4.6.3).

The lower pilot burner is constructed from stainless steel tubing with a nominal OD of 0.25 inches (6.4 mm) and a wall thickness of 0.03 inches (0.76 mm) (see figure A4-3). The normal position of the end of the pilot burner tubing is 0.394 inches (10 mm) from and perpendicular to the exposed vertical surface of the specimen. The centerline at the outlet of the burner tubing must

intersect the vertical centerline of the sample at a point 0.197 inches (5 mm) above the lower exposed edge of the specimen (see Appendix L, figure 20).

A mixture of 120 ± 15 milliliter/minute (mL/min) of methane and 700 ± 50 mL/min of air (STP of $21^\circ\text{C}/1$ atm.) must be fed to the lower pilot burner. The test is invalid if there is any period longer than 3 seconds when the flame is not burning.

NOTE: Pilot-burner flow settings are referenced to sea-level conditions. Facilities located at higher elevations shall adjust flow accordingly. When adjusted properly, these flow settings produce a pointed, luminous inner-cone flame approximately the same length as the OD of the burner tube (0.25 inches) and a dim outer cone approximately 0.5 inches in length.



Figure A4-3. Lower pilot-flame profile (shown with electronic igniter)

A4.4.2.4 Upper Pilot

The upper burner purpose is to ignite off-gassing products during testing. The burner is constructed from a 15-inch (381 mm) length of stainless-steel tubing with an OD of 0.25 inches (6.4 mm) and a wall thickness of 0.03 inches (0.76 mm) (see figure A4-4). There are 15 holes 0.041 ± 0.0005 inches (1.0 ± 0.01 mm) in diameter, each radiating in the same direction, drilled into the tubing. A #59 drill bit provides the proper hole diameter. The holes are spaced 0.5 inches (12.7 mm) apart with the first hole located 0.5 inches (12.7 mm) from the closed end (see Appendix L, figure 21). Each hole must be completely burr-free inside and outside, but not chamfered.

The burner is inserted into the environmental chamber through a 0.25-inch (6.4 mm) hole drilled to locate the centerline of the tubing 0.875 inches (22.2 mm) above and 0.875 inches (22.2 mm) behind the upper front edge of the specimen holder. The tubing is oriented such that the holes are directed horizontally toward the radiant heat source. One end of the tubing is closed with a silver solder plug or equivalent.

It is critical that the upper pilot burner tube is not moved out of position once set correctly. If the tube is inadvertently moved forward (toward the globars), there is a chance that a large portion of the upper pilot flames will extinguish completely in the presence of fire retardants, whereas when in the correct position, only the flame tips are impacted while the material is burning off. The difference between the two conditions could have a dramatic effect on the data.

When used as an upper pilot burner for testing, methane gas is set to 1.5 ± 0.03 SLPM ($2.5 \pm 0.05 \times 10^{-5} \text{ m}^3/\text{s}$) then mixed with air set to 1.0 ± 0.02 SLPM ($1.66 \pm 0.033 \times 10^{-5} \text{ m}^3/\text{s}$) via the MFCs. During the test, if there is any period longer than 3 seconds when any three or more of the flames on the upper pilot burner are not burning, the test is invalid.

NOTE: When adjusted properly, these flow settings produce upward-bending blue flames, having a yellow tip (0.25 inches). The overall flame length is approximately 1 inch.

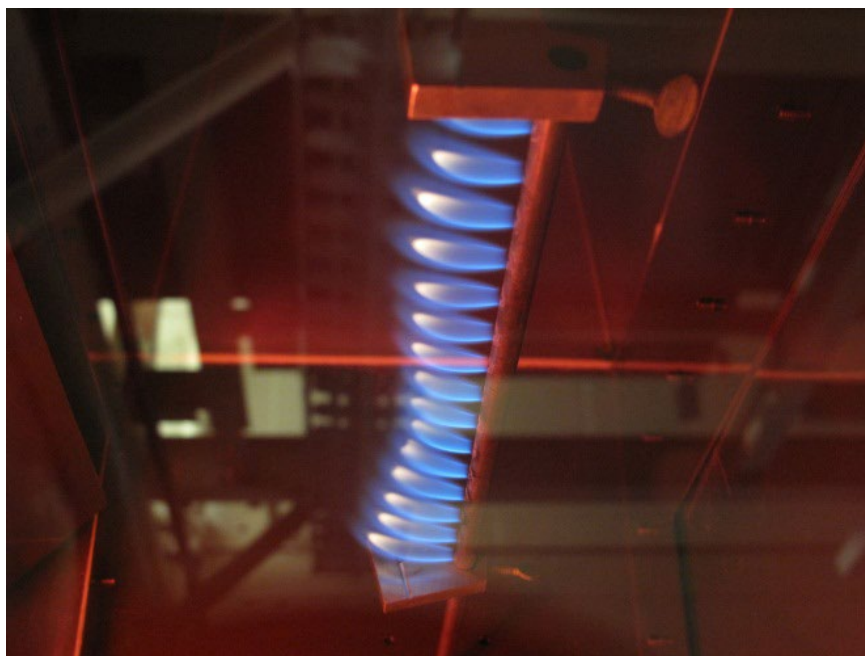


Figure A4-4. Upper pilot flame profile

A4.4.2.4.1 Upper Pilot Burner Hot Surface Igniter (HSI)

A 0.125 ± 0.005 inch (3.2 ± 0.1 mm) diameter ceramic rod 8.0 ± 0.5 inches (203 ± 12.7 mm) in length is positioned directly in the flames of the upper pilot burner (see figure A4-5). The rod is continuously heated by the flames, acting as a hot-surface igniter to auto-ignite any upper pilot flames should they go out. The distance from the centerline of the burner tube to the centerline of the HSI rod is 0.75 ± 0.125 inches (19 ± 3.2 mm).

Two stainless-steel support brackets are mounted on the upper pilot burner tube. The brackets are separated 8.0 ± 0.06 inches (203 ± 1.6 mm) from each other (outer dimension) with one bracket aligned flush with the closed end of the burner tube. The upper pilot flames tend to curve upward because of forced airflow through the chamber and convection. To locate the HSI rod in the hottest portion of the burner flames, the brackets are rotated upward $15 \pm 5^\circ$ on each end. Setting the bottom

of the bracket level will achieve the correct angle. Each bracket doesn't need to be at the same angle, provided the rod is in the direct flame path across its entire length (see figure A4-6). Set screws are used to secure the brackets in position.

The HSI rod must be cleaned or replaced when showing signs of soot buildup or wear.

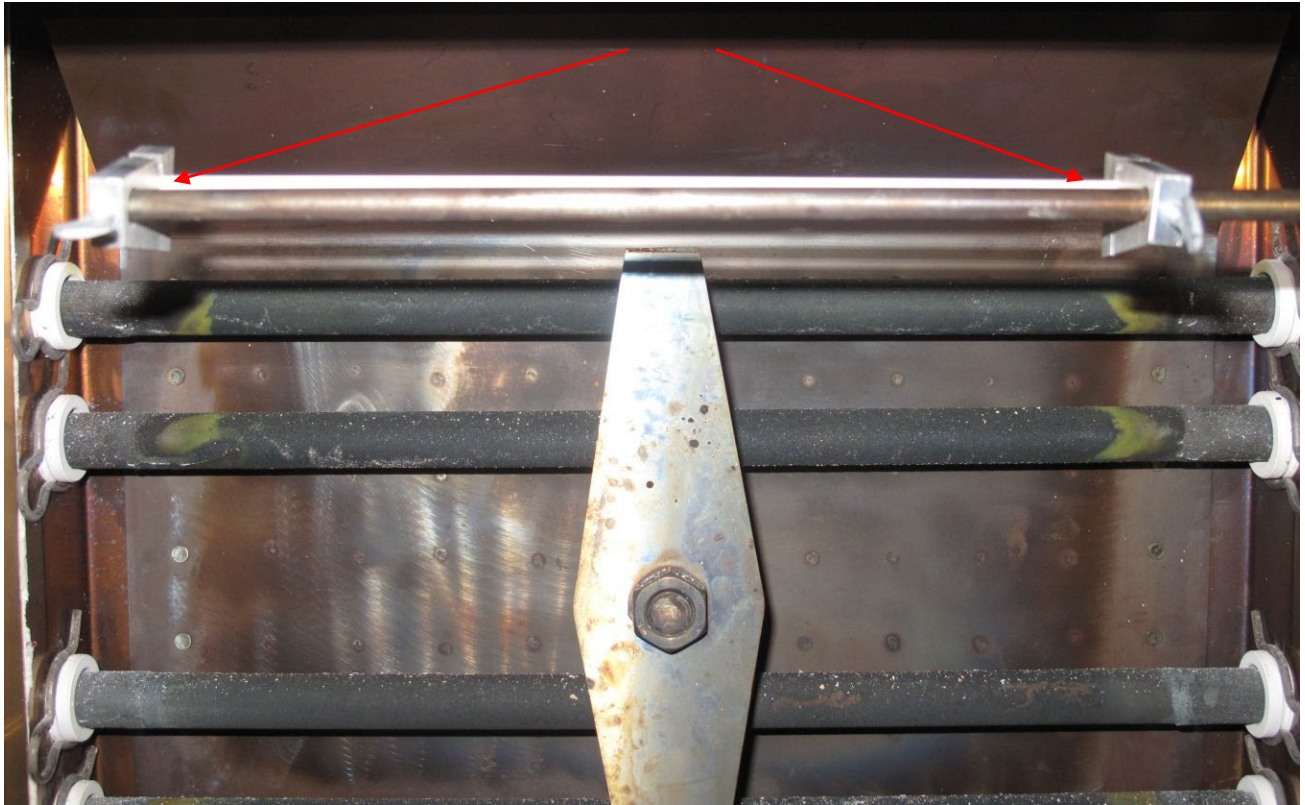


Figure A4-5. Upper pilot burner HSI rod and bracket installation

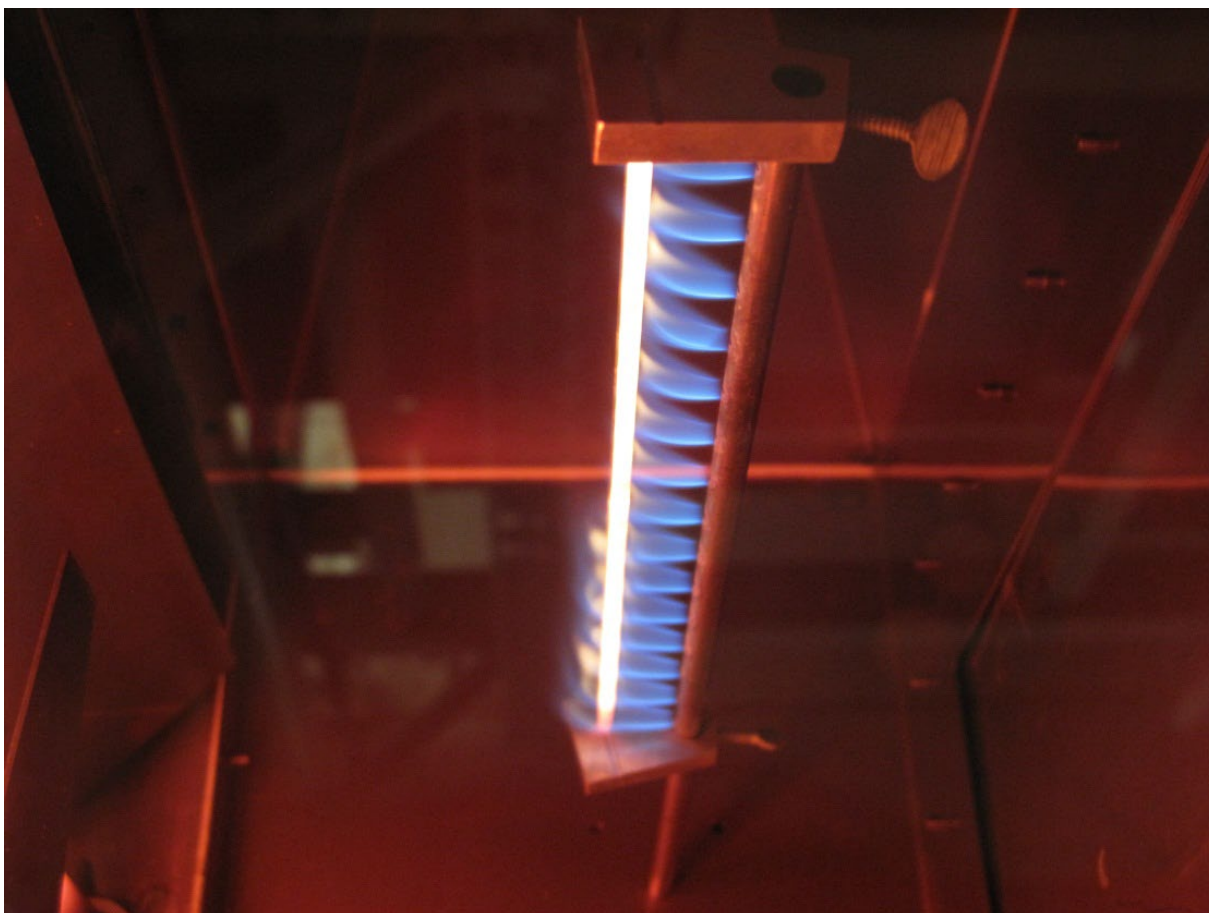


Figure A4-6. Upper pilot burner/HSI operation

A4.4.2.5 Electronic Igniter System

An igniter system for the upper and lower pilot burner is permitted to relight the flames to ensure they do not extinguish for more than 3 seconds during the test.

If an electric sparking device is used, an appropriate method of suppression and equipment shielding must be applied to have no interference with the ability of the data-acquisition equipment to accurately record data.

Extreme care must be taken to ensure the igniter(s) do not interfere with or shade the HFG center or corner reading while determining heat flux levels. Also, it must not come in contact with the sample holder drip pan during testing.

A4.4.2.6 Air Distribution System(s)

A dried and well-regulated supply is required for main chamber airflow as well as pre-mixed gas (methane and air) for upper and lower pilot burner operation. The supplied air shall be clean and free of non-condensing water vapor ($\leq 65\%$ RH), oil mist, and foreign particles.

A4.4.2.6.1 Airflow Mass Flow Controller

Airflow through the apparatus must be precisely measured and controlled using an MFC having a pressure-regulated input of 25 ± 5 psig (274 ± 34 kPa). Airflow is measured in standard cubic feet per minute (SCFM) referenced to STP 0°C (273.15 K) at 760 mm Hg (101.325 kPa). The flow rate through the environmental chamber is set to 20.0 ± 0.4 SCFM ($9.44 \pm 0.18 \times 10^{-3}$ m³/s) at $22.5 \pm 1.4^\circ\text{C}$ (296 ± 1.4 K). The MFC is calibrated for air annually with NIST traceability. The meter shall have a minimum accuracy of $\pm 2\%$ of full scale. The MFC shall have a signal output to a data-acquisition system used for monitoring airflow.

The main airflow mass flow controller (MFC) connection shall be located 24 inches or less from the lower plenum port (see A4.4.2.6.2). The connection must use only straight pipe or fittings (no angles or bends are permitted). If the inner diameter of the main airflow MFC outflow connector is not 1.5 inches, this run shall include a transition to the 1.5-inch inner diameter of the lower plenum port. Static pressure and airflow temperature shall be centrally measured inside the lower plenum and recorded at a frequency of once per minute, at a minimum.

A4.4.2.6.2 Air Distribution Plate

The environmental chamber airflow enters through a nominal 1.5-inch (38 mm) port in the lower plenum and is distributed by a 0.25-inch (6.4 mm) thick aluminum plate having eight 0.209 ± 0.001 inch (5.3 ± 0.03 mm) diameter holes located 2 inches (50.8 mm) from the side walls of the environmental chamber on 4 inch (101.6 mm) centers (see Appendix L, figure 24). A #4 drill provides the proper hole diameter. The plate is mounted between the lower plenum and the base of the environmental chamber main body with a leak-tight connection. Each hole must be completely burr-free on each side but not chamfered.

NOTE: The hole diameter mentioned in this plate (8) is extremely critical. Incorrect sizing may cause high or low back pressure in the main air supply (lower plenum pressure) resulting in increased or decreased air velocities through each orifice. This may impact peak heat release rate (PHRR), time to PHRR, and Total HR of materials during testing.

A4.4.2.6.3 Second Stage Plate

A removable second-stage plate is constructed of stainless steel 0.048 ± 0.004 inches (1.2 ± 0.1 mm) thick and mounted 6 ± 0.25 inches (152 ± 12.7 mm) above the air distribution plate.

There are 120 holes, 0.140 ± 0.001 inches (3.6 ± 0.03 mm) in diameter. A #28 drill provides the proper hole diameter. The hole pattern is centered on the plate within the environmental chamber and spaced in rows of 15 along the long dimension at 1 inch (25.4 mm) spacing and rows of 8 along the narrow dimension at 0.875 inch (22.2 mm) spacing (see Appendix L, figure 25). Each hole must be completely burr-free on each side but not chamfered.

The plate is mounted such that the perimeter is sealed airtight to force all airflow through the 120 holes.

A4.4.2.7 Specimen Holder

Specimen holders are fabricated from a stainless-steel sheet 0.018 ± 0.002 inches (0.46 ± 0.05 mm) thick. Each holder is provided with a specimen holder frame touching the specimen only along the

perimeter, a V-shaped spring plate, and a retaining rod that holds the assembly together. The position of the spring pressure plate can be changed to accommodate different specimen thicknesses by inserting the retaining rod in different holes of the specimen holder. Applying equal spring plate pressure to specimens of equal thickness by inserting the specimen retaining rod in the same holes for each specimen tested is recommended.

Each holder also has 0.020 inch (0.51 mm) stainless-steel wires (2) attached vertically to the front of the holder to secure the face of the specimen in the holder. These wires are required to be tight and may need to be replaced frequently. When testing, these wires are in place for all specimens (see Appendix L, figure 26).

A4.4.2.7.1 Drip Pan

Drip pans are for optional use to prevent melting specimens from dripping into the lower test section of the environmental chamber. A drip pan is fabricated from a stainless-steel sheet 0.018 ± 0.002 inches (0.46 ± 0.05 mm) thick and clipped to the specimen holder using attachment flanges (see Appendix L, figures 30–31). Foil may be used to line the drip pan to facilitate cleaning after use.

A4.4.2.7.2 Holding Chamber/Injection Mechanism

The specimen holder is attached to an injection mechanism mounting plate. The plate is made of 0.036 ± 0.003 inch (0.91 ± 0.08 mm) stainless steel, which incorporates metal locking tabs that secure the specimen holder in place. A large area washer forms a tight seal with the inner radiation doors when closed (see Appendix L, figures 32–33). The sample face, when inserted into the holding chamber before testing, is located 9 ± 0.5 inches (229 ± 12.7 mm) from the inner radiation doors.

When the sample is inserted into the environmental chamber, the front surface of the vertical specimen is parallel to the radiant heat elements and located 3.94 inches (100 mm) from the inner wall of the environmental chamber where the radiation doors close.

A4.4.2.8 Calibration Equipment

A4.4.2.8.1 HFG

Two water-cooled HFGs, as specified in Appendix H, are used to determine the total heat flux density. One gauge is used to measure heat flux at a point where the center of the sample surface is located at the start of the test. A corner HFG is used to determine heat flux uniformity and its centerline is located diagonally 2.75 ± 0.25 inches (70 ± 12.7 mm) from the center.

The HFG cooling water temperature, pressure, and flow are maintained within the manufacturer's recommendations. Ensure no condensation occurs on the gauge surface at any time (often caused by cooling water being too cold). Do not connect cooling water circuits in series. It is recommended to use rigid tubing cooling water lines because of the high temperatures within the environmental chamber.

Each HFG has a thin, full-faced, opaque coating of high-temperature, high-emissivity, ultra-flat black paint. The sensitivity of the gauge is a function of the surface condition. Changes in the coating may cause drift in the overall performance of the gauge. Regularly inspect the measuring surface for physical damage or dust particles that may have accumulated. Cleaning can be accomplished by gently wiping a soft, water-dampened sponge across the sensor face. Damage to the coating during the cleaning process will affect the measurement accuracy of the sensor. To maintain accuracy, the measuring surface must be recoated at regular intervals, followed by recalibration (see Appendix H).

The HFGs are mounted in a supporting device in a sample holder assembly or equivalent, protruding through a 0.5-inch (12.7 mm) thick rigid refractory board having a density of 50 ± 10 lb./ft³ (800 ± 160 kg/m³). Each gauge has a 180° field of view; therefore, the surface must be mounted flush with the insulation board and not recessed.

The gauges must be parallel to the radiant heat elements when positioned in the environmental chamber to measure heat flux. The complete assembly shall be lightweight to minimize warmup time while in use. The HFGs are calibrated annually per Appendix H.

A4.4.2.8.2 Methane/Mixing Air MFCs

Thermal-based MFCs having nominal 0.25 inch (6.4 mm) inlet/outlet fittings are used to provide precision measurement and control of gas flow for the calibration process and the upper pilot burner flame during testing. The methane MFC is calibrated annually with NIST traceability for methane gas and is capable of controlling flow rates up to 4 SLPM (6.66×10^{-5} m³/s). The meter shall have a minimum accuracy of $\pm 1\%$ of full scale and is referenced to STP 0°C (273.15 K) at 760 mm Hg (101.325 kPa). The controller must have a response time of 2 seconds or less to get within $\pm 2\%$ of the final value. The upper pilot burner mixing air MFC has the same requirements; however, it must be calibrated for air.

The MFCs shall have a signal output to a data-acquisition system used for monitoring gas flow. The tubing from the MFCs to the upper pilot/calibration burner must be as short as possible and direct in routing with all joints leak-tight.

A4.4.3 Data-Acquisition System/Display Devices

The data-acquisition system and indicating devices (millivolt, flow, temperature, etc.) must be calibrated annually to NIST traceability with a measurement uncertainty of less than 1.0% reading.

A4.4.3.1 Digital Data Collection

The data collection system used must have facilities for the recording of the output from the mass flow controllers, heat flux gauges and thermocouples. The data collection system shall have an accuracy corresponding to at least 0.5°C for the temperature measuring channels, and 0.01 % of full-scale instrument output for all other instrument channels. The system shall be capable of recording data at intervals of once per second (1 hertz).

A4.5 Test Specimens

A4.5.1 Specimen Number

A minimum of three specimens is prepared and tested for each material/part.

A4.5.2 Specimen Size

The standard size for specimens is $5.94 + 0, - 0.06$ (151 +0, - 1.5 mm) by $5.94 + 0, - 0.06$ inches (151 +0, - 1.5 mm) in lateral dimensions. For calculation purposes, the area of the specimen is 36 in² (0.02323 m²). Specimen thickness is used in the relevant application up to 1.75 inches (44.5 mm); applications requiring thicknesses greater than 1.75 inches (44.5 mm) will have specimens constructed and tested in 1.75 inch (44.5 mm) thicknesses.

A4.5.3 Specimen Preparation

Only one surface of a specimen is exposed during a test. A single layer of 0.0012 ± 0.0005 (0.03 $\pm$ 0.01 mm) inch-thick aluminum foil is wrapped tightly on all unexposed sides (see figure A4-7). The foil must be continuous and not torn. The retaining frame is placed behind the specimen between the back of the specimen and the pressure plate. After the specimen is placed tightly into the specimen holder, all aluminum foil on the exposed side is removed to avoid covering any of the exposed specimen areas or obstructing airflow across the material surface. When trimming excess foil from the test specimen, care must be taken not to score or make an incision into the perimeter surface of the material.

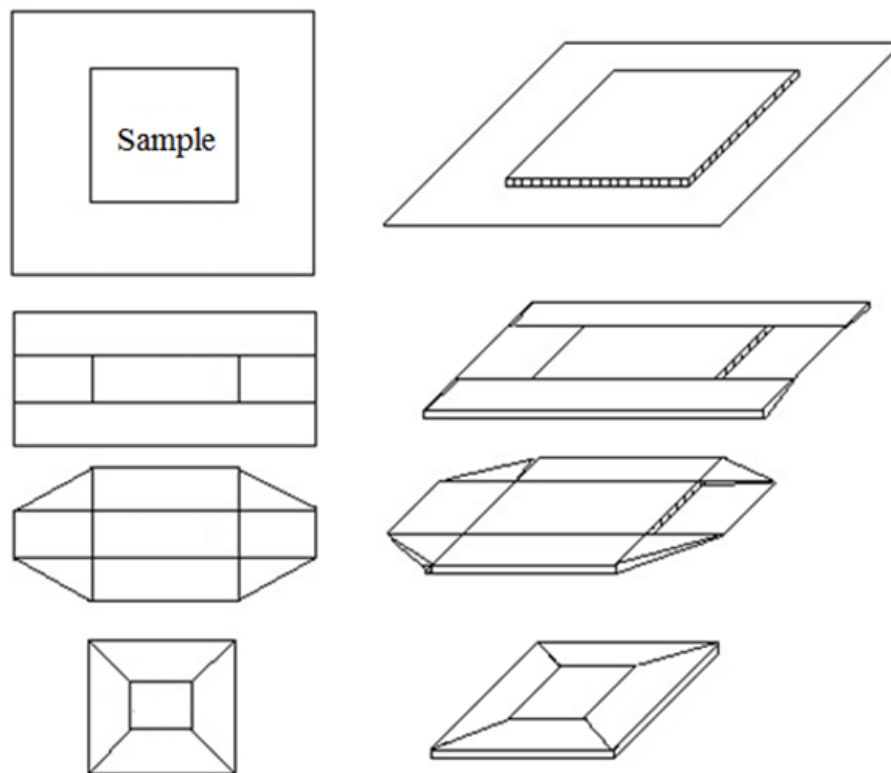


Figure A4-7. Recommended specimen foil wrapping

A4.5.4 Specimen Orientation

For materials that may have anisotropic properties (i.e., different properties in different directions, such as machine and cross-machine directions for extrusions, warp, and fill directions of woven fabrics), the specimens shall be tested in both orientations and both must pass the requirements specified under section A4.10.

A4.5.5 Conditioning

Specimens are conditioned at $21 \pm 2^\circ\text{C}$ ($294 \pm 2\text{ K}$) and $55 \pm 10\%$ RH for a minimum of 24 hours before testing. The conditioning equipment shall be calibrated annually and the parameters checked daily for proper operation.

If possible, remove only one specimen at a time from the conditioning environment immediately before being tested. If this is not possible, it is acceptable to remove more than one specimen at a time if each specimen is placed in a closed container to protect it from contamination until it is subjected to the flame.

A4.6 Calibration Procedure of Equipment

A4.6.1 Heat Flux Calibration (Center position)

For the determination of total heat flux density, a sensor is positioned at a point where the center of the specimen is located when the test is started. The center heat flux must be $3.65 \pm 0.05\text{ W/cm}^2$ ($3.21 \pm 0.04\text{ BTU/ft}^2\cdot\text{sec}$) and verified daily before testing. The HFG remains exposed to the radiant heat source inside the environmental chamber, with radiation doors closed, until a stable reading is achieved (see section A4.2.10).

An adjustable stop in the insertion mechanism, together with a positioning template, should be used to ensure the HFG adopts the correct position when inserted into the chamber. This will improve the repeatability of the heat flux measurement.

A4.6.1.1 Procedure

A4.6.1.1.1

Verify air and methane gas are off at the upper and lower pilots.

A4.6.1.1.2

Ensure the lower and upper pilot burners are positioned correctly.

A4.6.1.1.3

Turn on the airflow through the environmental chamber (see section A4.4.2.6).

A4.6.1.1.4

Verify cooling water is flowing to the HFGs and output wiring is connected to the data-acquisition system (see section A4.4.2.8.1).

A4.6.1.1.5

Position and secure the HFG calibration assembly into the holding chamber, ensuring an airtight seal. Insert the HFGs into the environmental chamber hot zone, close the inner radiation doors, and begin recording the transducer millivolt outputs.

A4.6.1.1.6

Turn on the power to globars and begin heating the apparatus.

A4.6.1.1.7

The HFGs remain exposed to the radiation heat source inside the environmental chamber until a stable reading of $3.65 \pm 0.05 \text{ W/cm}^2$ ($3.21 \pm 0.04 \text{ BTU/ft}^2\cdot\text{sec}$) is achieved (see section A4.2.10 Stability).

A4.6.1.1.8

If the heat flux is unacceptable, adjust the power and wait for the heat flux to re-stabilize (see section A4.4.2.1). Repeat this procedure until an acceptable heat flux level is obtained.

A4.6.2 Heat Flux Uniformity Calibration (Corner Positions)

The uniformity of heat flux is determined by heat flux sensor measurements at each of the four corners of the specimen surface. The heat flux at each corner must be $3.65 \pm 0.1 \text{ W/cm}^2$ ($3.21 \pm 0.09 \text{ BTU/ft}^2\cdot\text{sec}$). The heat flux uniformity checks shall be carried out daily when testing and after each repair or maintenance of radiant heat source components. Some examples include (but are not limited to): the replacement of globars, wiring terminal connections, insulator devices, reflector plate, or diamond-shaped mask including mounting hardware. Additional examples include the repair or replacement of the global power supply or its components, and recalibration of HFGs, data-acquisition system, and display devices.

A4.6.2.1 Procedure

A4.6.2.1.1

Conduct the heat flux calibration procedure (see section A4.6.1).

A4.6.2.1.2

Once complete, start with any one of the four corner measurements and determine the heat flux level.

A4.6.2.1.3

Open the inner radiation doors, return the HFG assembly to the holding chamber, and rotate 90°.

NOTE: Extreme care must be taken during this step not to make contact with the upper pilot tube. Do not rotate the calibration assembly until it is fully withdrawn into the holding chamber. Ensure it has been rotated a full 90 degrees before reinserting it into the environmental chamber.

A4.6.2.1.4

Reinsert the assembly back into the chamber and close the doors. Allow time to re-stabilize and record heat flux levels. Repeat this process for the remaining corners.

A4.6.2.1.5

The heat flux at each corner must be $3.65 \pm 0.1 \text{ W/cm}^2$ ($3.21 \pm 0.09 \text{ BTU/ft}^2\cdot\text{sec}$).

NOTE: Adjustments can be made to improve the heat flux uniformity by varying the power settings accordingly, repositioning the globars (in appearance) from hottest to coolest starting from the bottom position, moving the diamond-shaped mask closer to or farther from the center HFG (in and out), sliding the globars left or right, or by adjusting the reflector plate slope top and bottom as needed.

A4.6.2.1.6

If adjustments were necessary during this procedure, the center heat flux shall be rechecked before continuing.

A4.6.3 Determination of the Calibration Factor (K_h)

The calibration factor shall be determined weekly when testing and additionally after each repair or maintenance of the apparatus that may influence heat-release results. Some examples include (but are not limited to): the replacement of apparatus insulation or sheathing; recalibration of MFCs, HFGs, data-acquisition systems, or display devices; and the replacement of thermopile or radiant heat components.

Before calibration, clean the upper thermocouples using a spray of distilled water. Ensure airflow through the unit is verified to be correct and maintained within the specified temperature range. Calibration can begin once the heat flux is determined to be within range, the HFG calibration assembly has been removed and the system has achieved the stability criteria (see section A4.2.10). Methane gas is directed to the lower pilot calibration burner for calibration of the thermopile. The methane gas is pure and not diluted with air. Calibration is conducted with the HSI installed, the sample injection mechanism withdrawn into the holding chamber, and all doors closed.

During calibration a T-shaped burner will be provided that fits in place of the lower pilot with a gas-tight connection. The centerline of the burner tube must be located at the same height and position as the centerline of the lower pilot burner outlet ± 0.125 inch.

The calibration burner will be constructed from a 6 ± 0.5 inch length of stainless steel tubing with an outside diameter of 0.375 inch and a wall thickness of 0.06 inches. There are six holes 0.116 ± 0.001 inch in diameter drilled into the top of the tubing spaced 1 inch apart. Both ends of the tubing will be closed with a silver solder plug or equivalent.

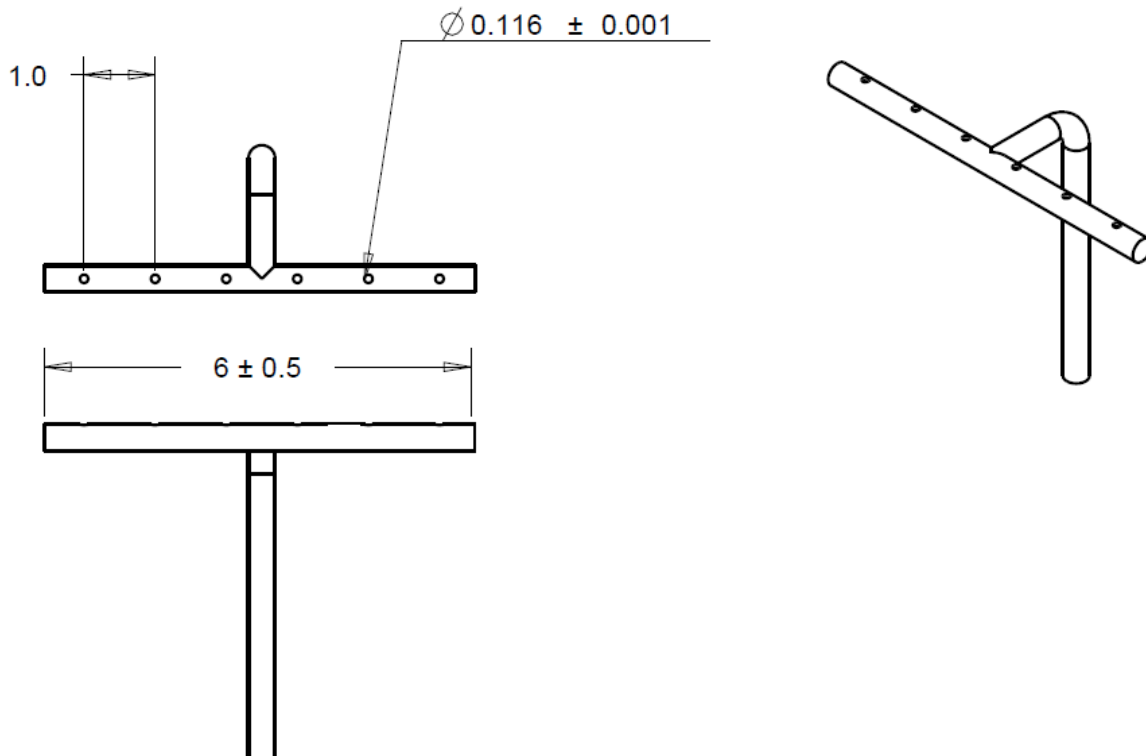


Figure A4-8. Calibration Burner

Begin calibration once the system has stabilized from the removal of the HFG calibration assembly (approximately 10 – 15 minutes). The zero gas flow data point is recorded by allowing the system to stabilize for 4 minutes averaging the final 20-second values of the thermopile. Gas flow is considered to be 0 SLPM.

Next, 3.0 ± 0.15 SLPM ($5.01 \pm 0.25 \times 10^{-5} \text{ m}^3/\text{s}$) of methane gas is permitted to flow to the calibration burner, the doors are opened, and the burner is lit. Alternatively, an igniter may be used for remotely lighting the burner without opening the doors. Within 10 seconds of ignition, all doors are closed and a 4-minute stabilization of the chamber begins. As an overall systems check, the final 20-second average thermopile temperature is calculated as the thermal stability temperature (TST) and must be $370 \pm 10^\circ\text{C}$ ($643 \pm 10\text{K}$). Difficulties achieving the TST criteria may be indicative of system air leakage, thermopile malfunction or misalignment, HFG malfunction, misalignment or improper calibration, or MFC malfunction or improper calibration (main airflow or methane gas control).

The 20-second average thermopile temperature and corresponding average MFC gas flow rate are recorded, and the calibration factor is determined (see section A4.6.3.2). Immediately after the conditioning period has lapsed, the gas flow to the burner is shut off.

If the burner flames were lit but a calibration restart is necessary, there must be a 10 - 15 minute waiting period for the system to reset before a new calibration can be attempted (no flames lit; doors closed).

A4.6.3.1 Calibration Procedure

A4.6.3.1.1

With the unit at operational temperature, clean the upper thermocouples (hot junctions of the thermopile) using a spray of distilled water, and check their position using a handheld template (For a more thorough cleaning, ethyl alcohol may be used with the soft brush while the unit is cold).

A4.6.3.1.2

With a soft brush, remove soot buildup from the exhaust stack's inner walls.

A4.6.3.1.3

Vacuum the environmental chamber and second-stage plate.

A4.6.3.1.4

Turn on the exhaust-hood ventilation system.

A4.6.3.1.5

Isolate the upper and lower pilot air and methane gas supplies (methane gas to the upper pilot/calibration burner is turned on in A4.6.3.1.10).

A4.6.3.1.6

Verify proper airflow/temperature. Conduct the heat flux calibration procedure as necessary (see sections A4.6.1 and A4.6.2).

A4.6.3.1.7

Remove the HFG calibration assembly. Close all doors, ensuring the sample injection mechanism remains withdrawn into the holding chamber. Satisfy stability criteria.

A4.6.3.1.8

Replace the lower pilot burner with the calibration T-burner.

A4.6.3.1.9

Allow proper warmup time for MFC as recommended by the manufacturer.

A4.6.3.1.10

Turn on methane gas and ensure correct supply pressure to the MFC (see section A4.2.8)

A4.6.3.1.11

With no gas flowing, start the calibration program. Allow the system to stabilize for 4 minutes and determine the final 20-second average thermopile temperature.

A4.6.3.1.12

With methane gas flowing, open the doors, light the burner, then close the doors.

A4.6.3.1.13

Ensure gas flow is set to 3 SLPM ($5.01 \times 10^{-5} \text{ m}^3/\text{s}$). Begin a 4-minute countdown.

A4.6.3.1.14

Calculate the final 20-second average TST ($375 \pm 10^\circ\text{C}$) and gas flow.

A4.6.3.1.15

Immediately shut off the gas.

A4.6.3.1.16

Determine the calibration factor.

A4.6.3.2 Calculation of Calibration Factor K_h

The gross heat of combustion of methane or higher heating value (HHV) is briefly defined as the amount of heat released when a unit amount of gas is completely combusted. For this test method, the heating value of methane used is the net heat of combustion (LHV). The LHV assumes that any water in the combustion products is not condensed and remains a vapor (Hv). The relation between the HHV and the LHV is expressed as:

$$\text{LHV} = \text{HHV} - H_v \quad (1)$$

$$K_h = \text{Combustion Heat Transfer Coefficient, } h = \frac{(H_c \dot{m})_{\text{CH}_4}}{T_{\text{out}} - T_{\text{in}}} = \frac{(H_c \rho F)_{\text{CH}_4}}{T_{\text{out}} - T_{\text{in}}} \quad (2)$$

Where:

H_c = Net heat of complete combustion of methane = 50.03 MJ/kg

$\dot{m}$ = Mass flow rate of methane calibration burner = $\rho F = 3.58 \times 10^{-5} \text{ kg/s}$

ρ = Methane density at STP = 0.714 kg/m³

F = Volumetric methane calibration flow rate = 3 SLPM ($5.01 \times 10^{-5} \text{ m}^3/\text{s}$)

Insert values into equation #3:

$$K_h = \frac{(50.03 \text{ MJ/kg})(0.714 \text{ kg/m}^3)(5.01 \times 10^{-5} \text{ m}^3/\text{s})}{T_{out}-T_{in}} \quad (3)$$

$$K_h = \frac{1790 \text{ W}}{T_{out}-T_{in}} \quad (4)$$

Calculate the actual power (W) recorded during calibration as:

$$K_h = \frac{(50.03 \text{ MJ/kg})(0.714 \text{ kg/m}^3)(Flow \text{ m}^3/\text{s})}{T_{out}-T_{in}} \text{ W/}^\circ\text{C} \quad (5)$$

Where:

Flow = 20s average volumetric methane flow rate, in m³/s

T_{out} = 20s average thermopile temperature at the upper flow rate, in °C

T_{in} = 20s average thermopile temperature at baseline (zero flow), in °C

The calibration factor *K_h* must be 20.0 ± 2.0 W/°C.

If the TST or the calibration factor is out of range, ensure that the stability requirements have been met (see section A4.2.10), there are no air leaks, and all equipment and components of the apparatus are functioning/calibrated properly. Once confirmed, repeat the complete calibration procedure.

A4.6.3.3 Applied Calibration Factor (*K_H*) Rationale and Formula

Continuous measurements indicate that the calibration factor varies slightly due to inherent apparatus variation. These random and systemic variations cannot be reduced by design or the operator. Slight differences in calibration factor, even if within the acceptable calibration factor range, directly influence calculated peak and total heat release values. A simple moving average offers a straightforward method to reduce this variation by providing an applied calibration factor value that is more representative of the mean apparatus performance.

The calibration factors (*K_h*) used to compute the applied calibration factor must fall within the acceptable calibration factor range. Only the last five calibration factor values shall be used for the computation. A new set of five calibration factors shall be generated after any repair or maintenance that may influence heat release values.

Given a set of measured calibration factors (*K_{h1}, K_{h2}, ..., K_{hn}*)

Compute the applied calibration factor (*K_H*) as follows:

$$K_H = \frac{K_{h_n} + K_{h_{n-1}} + K_{h_{n-2}} + K_{h_{n-3}} + K_{h_{n-4}}}{5} \quad (6)$$

A4.7 Preparation/Test Procedure

A4.7.1 Preparation

A4.7.1.1

Clean the upper thermocouples (hot junctions of the thermopile) if necessary and check their position using a handheld template.

A4.7.1.2

Remove any debris that may have settled on the second-stage air distribution plate.

A4.7.1.3

Check the position of the injected sample holder with the pilot burners by using a positioning tool and an adjustable stop on the insertion mechanism.

A4.7.1.4

Turn on the exhaust hood system.

A4.7.1.5

Ensure correct airflow through the apparatus (see section A4.4.2.6).

A4.7.1.6

Set the power supply to the globars to produce a total heat flux density of $3.65 \pm 0.05 \text{ W/cm}^2$ ($3.21 \pm 0.04 \text{ BTU/ft}^2 \cdot \text{sec}$).

NOTE: The thermopile baseline temperature must be carefully observed during daily testing. Changes in the baseline temperature can be an indicator of developing problems, such as variations in heat flux (HFG malfunction), defects in the thermopile, or air leakage in the environmental chamber/lower plenum, exhaust stack, or holding chamber door seal. Additionally, there is the possibility of the inlet airflow MFC not functioning properly. It is good practice to also monitor daily globar power control settings.

A4.7.1.7

Turn on methane gas and mixing air to ensure correct supply pressure (see section A4.2.8).

A4.7.1.8

Light the upper and lower pilot flames and check the gas flow and respective flame profile (see A4.4.2.3 and A4.4.2.4).

A4.7.1.9

Close all doors.

A4.7.1.10

Allow the system time to re-stabilize with burners lit for 10 – 15 minutes before testing.

A4.7.1.11

Activate the spark igniter(s) if used.

A4.7.1.12

Ensure the HSI is positioned correctly (see section A4.4.2.4.1).

A4.7.1.13

Prepare the specimen for testing (see section A4.5.3).

A4.7.1.14

If needed, attach the drip pan to the specimen holder (see section A4.4.2.7.1).

A4.7.2 Test Procedure

A4.7.2.1

Ensure the radiation doors are closed.

A4.7.2.2

Within approximately 10 seconds, open the holding chamber door, place the specimen holder on the mounting plate, close the door, and start the recording device.

A4.7.2.3

Keep the specimen in the holding chamber for 60 seconds. Record, at least once a second, the thermopile temperature output during the final 20 seconds of the hold time before the specimen is injected, and report the average as the baseline thermopile reading (Baseline_{°C}).

NOTE: Extreme caution must be used to ensure that the baseline reading is completed before opening the inner doors for sample injection.

A4.7.2.4

After recording the baseline reading and within a timeframe not exceeding 5 seconds, open the radiation doors, inject the specimen into the environmental chamber, and close the doors. The 5-minute test starts when the sample stops its transition into the environmental chamber (inner radiation doors close immediately after). Record the thermopile temperature output (Thermopile_{°C}) at least once a second for the duration of the test.

A4.7.2.5

Watch the burning process and record any observation of melting, sagging, dripping, delaminating, or other behavior that affected the exposed surface area or mode of burning and the time (in seconds) at which such behavior occurred.

A4.7.2.6

Watch the pilot flames during the test. If the lower pilot burner was extinguished for a period longer than 3 seconds or at least 3 of the upper pilot flames were extinguished simultaneously for any period exceeding 3 seconds, mark this test run as invalid.

NOTE: The use of an externally positioned mirror or camera may assist in viewing upper pilot flames during testing.

A4.7.2.7

After the test has been running for 5 minutes, open the radiation doors, return the specimen to the holding chamber, and close the radiation doors.

A4.7.2.8

When ready to remove the sample, open the holding chamber door, remove the specimen holder from the mounting plate, and close the door.

Caution: Hot and toxic gases could be present!

A4.7.2.9

Spray clean the hot zone thermocouples with distilled water.

A4.7.3 Preparation of Further Test Runs

Wait until the baseline temperature has re-stabilized before beginning another test. Depending on the construction of the material or its burning intensity, wait times may vary. For dripping materials or products that fall to the lower plate during testing, debris must be removed from the chamber before the next test.

Clean the upper thermocouples of soot after each test using a spray of distilled water. Ensure that the thermocouples are in their proper position before proceeding with the next specimen; a handheld template may be used to facilitate this step.

A4.8 Presentation of Results

For all specimens tested, determine and record the maximum heat release rate during the 5-minute test. Also, compute and record the total heat released during the first 2 minutes of testing by integrating the heat release rate over time. When calculating the total heat release, only positive heat release rate values are included in the summation.

A4.8.1 Heat Release Rate

At a data-collection frequency of 1 Hz or 1 scan per second, calculate the heat release rate for any point in time during a test from the reading of the thermopile temperature output at that time using the:

$$\text{Heat Release Rate} = (\text{Thermopile}_{\circ\text{C}} - \text{Baseline}_{\circ\text{C}}) \times \left(\frac{K_H \div 1000}{0.02323 \text{ m}^2} \right) \text{ kW/m}^2 \quad (7)$$

Where K_H and $\text{Baseline}_{\circ\text{C}}$ are the applied calibration factor and average thermopile temperature at the baseline, respectively.

A4.8.2 Total Heat Release

Using this formula, the total heat release ($\text{kW} \cdot \text{min/m}^2$) as a function of time (in minutes) based on the integral of the heat release rate can be determined:

$$\text{Total Heat Release} = \int_0^2 (\text{Thermopile}_{\circ\text{C}} - \text{Baseline}_{\circ\text{C}}) \times \left(\frac{K_H \div 1000}{0.02323 \text{ m}^2} \right) (t) dt \text{ kW} \cdot \text{min/m}^2 \quad (8)$$

Simplifying this gives:

$$\text{Total Heat Release} = \frac{\sum_{t=0}^{n-1} (\text{Thermopile}_{\circ\text{C}} - \text{Baseline}_{\circ\text{C}}) \times \left(\frac{K_H \div 1000}{0.02323 \text{ m}^2} \right)}{x} \text{ kW} \cdot \text{min/m}^2 \quad (9)$$

Where:

n = Total number of data collection points in 2 minutes.

x = Total number of data collection points in 1 minute.

$\text{Baseline}_{\circ\text{C}}$ = Average thermopile temperature reading at baseline ($^{\circ}\text{C}$).

$\text{Thermopile}_{\circ\text{C}}$ = Thermopile temperature reading at any point during the test ($^{\circ}\text{C}$).

K_H = Applied calibration factor ($\text{W}/^{\circ}\text{C}$)

Sample area = Total calculated area of test specimen (m^2)

NOTE: This formula uses the Riemann Left-Hand Sum method of integration ($t=0$).

A4.9 Accuracy, Units, and Rounding

For this test method, all values are rounded up (see Table A4-1). If the next place beyond where a digit is terminated is greater than or equal to 5, the terminating digit is increased by a value of 1, and the digits to the right are dropped off (e.g., 25.476 accurate to the hundredths place is rounded up to 25.48).

Unless otherwise stated, the following shall apply:

Table A4-1. Accuracy, Units, and Rounding

Accuracy	Description	Units
Tenths place (e.g., x.x)	Peak heat release rate	kW/m^2
	Time to peak	Sec
	2-minute total heat release	$\text{kW}\cdot\text{min/m}^2$
	Heat release rate	kW/m^2
	Temperature	$^{\circ}\text{F}/^{\circ}\text{C}$
	Relative humidity	% RH
Hundredths place (e.g., x.xx)	Heat flux	W/cm^2
	Airflow	SCFM
	Calibration factor	$\text{W}/^{\circ}\text{C}$
	Methane gas flow	SLPM
	% Standard deviation	%
Hundred-thousandths place (e.g., x.xxxxx)	Sample area	m^2

A4.10 Requirements

A4.10.1 Quantity of Samples

A minimum of three samples must be tested, and 80% or greater must pass both criteria specified in A4.10.1.1 and A4.10.1.2.

A4.10.1.1 Peak Heat Release Rate (kW/m^2)

The maximum heat release rate during the 5-minute test will not exceed 65 kW/m^2 .

A4.10.1.2 Initial 2-Minute Total Heat Release ($\text{kW}\cdot\text{min/m}^2$)

The total heat released during the first 2 minutes will not exceed $65 \text{ kW}\cdot\text{min/m}^2$.

A4.11 Test Report

A4.11.1

Report the laboratory conducting the tests.

A4.11.2

Fully identify the material tested.

A4.11.3

Graphically report the heat release rate (kW/m^2) at 1 hertz (Hz) as a function of time (in seconds) for each test.

A4.11.4

Report the maximum heat release rate and time (in seconds) it occurs during each test.

A4.11.5

Report the total heat released during the first 2 minutes of each test.

A4.11.6

Report the radiant heat flux to the specimen.

A4.11.7

Report the applied calibration factor K_H ($W/^\circ C$).

A4.11.8

Report the average baseline temperature for each specimen tested.

A4.11.9

Report any melting, sagging, dripping, delaminating, or other behavior that affected the exposed surface area or mode of burning that occurred and the time (in seconds) at which such behavior occurred.

A4.11.10

Report the total number of materials tested and the total number of materials that passed.

Table A4-2. Nominal Operating Parameters/Ranges

PARAMETER	DESCRIPTION	MIN.	NOMINAL	MAX.
Inlet Airflow Rate	SCFM	19.6	20.0	20.4
Inlet Air Temperature	°C	21.1	22.5	23.9
Inlet Air Relative Humidity	% RH (<i>see NOTE¹</i>)	-	-	≤ 65
Heat Flux (W/cm ²)	Center	3.60	3.65	3.70
	Each Corner (4)	3.55	3.65	3.75
Average Baseline Thermopile Temperature	No Flame (°C)	275	285	295
	With pilot flames (°C)	330	340	350
Calibration Factor Ranges	SLPM	2.85	3.00	3.15
	W/°C	18.0	20.0	22.0
	3 SLPM ΔT (°C)	80	90	100
Interspace Pressure	inH ₂ O	0.50	0.55	0.60
Lower Plenum Pressure	inH ₂ O	12.0	12.5	13.0
Methane Gas Supply Pressure	PSIG	20	25	30
Main Air Supply Pressure	PSIG	20	25	30
Mixing Air Supply Pressure	PSIG	20	25	30
Thermal Stability Thermopile Temperature (TST)	20-sec average (°C)	365	375	385
Specimen Conditioning	Temperature (°C)	18	21	24
	Relative Humidity (%)	45	55	65
Upper Pilot Gas Flow	Air (SLPM)	0.98	1.00	1.02
	Methane (SLPM)	1.47	1.50	1.53
Lower Pilot Gas Flow	Air (mL/min)	650	700	750
	Methane (mL/min)	105	120	135

NOTE¹: The % RH value is derived from sample conditioning criteria; however, severe damage could result if condensed liquid penetrates internal components of a mass flow controller. It is recommended to maintain an extremely low moisture level in the air supply system (including pilot burner MFC's).

NOTE²: When not a requirement, the values in this table may be used as a guide for overall system performance. Not all parameters listed are absolute or required but may help identify underlying problems that may be present.