

Chapter 5

Heat Release Rate Test for Cabin Materials

5.1 Scope

- 5.1.1 This test is intended for use in determining heat release rates to show compliance with the requirements of FAR 25.853.
- 5.1.2 Heat release rate is measured for the duration of the test from the moment the specimen is injected into the controlled exposure chamber and encompasses the period of ignition and progressive flame involvement of the surface.

5.2 Definitions

5.2.1 Heat Release

Heat release is a measure of the amount of heat energy evolved by a material when burned. It is expressed in terms of energy per unit area (kilowatt minutes per square meter— $\text{kW} \cdot \text{min}/\text{m}^2$).

5.2.2 Heat Release Rate

Heat release rate is 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/m^2). The maximum heat release rate occurs when the material is burning most intensely.

5.2.3 Heat Flux

Heat flux density is the intensity of the thermal environment to which a sample is exposed when burned. In this test, the heat flux density used is $3.5 \text{ W}/\text{cm}^2$.

5.3 Test Apparatus

5.3.1 Release Rate Apparatus

The apparatus shown in Figures 5-1a and 5-1b will be used to determine heat release rates. All exterior surfaces of the apparatus, except the holding chamber, will be insulated with 1-inch (25 mm) thick, low-density, high-temperature, fiberglass board insulation. A gasketed door through which the sample injection rod slides will be provided to form an airtight closure on the specimen holding chamber.

5.3.2 Thermopile

The temperature difference between the air entering and leaving the environmental chamber will be monitored by a thermopile having five hot and five cold 24-gauge chromel-alumel junctions (see Figure 5-2). The bead to be formed by the thermocouple junction will be 0.050 ± 0.010 inch (1.3 ± 0.3 mm) in diameter. Each junction will be free of insulation for a minimum of 0.75 inch (19 mm). The cold junctions will be located in the pan below the air distribution plate (see section 5.3.4). The hot junctions will be located 0.38 inch (10 mm) below the top of the chimney. One of the hot junctions will be placed at the center of the chimney's cross-section, and the other four will be placed on the chimney diagonals, 1.18 inches (30 mm) from the center thermocouple.

5.3.3 Radiant Heat Source

A radiant heat source for generating a flux up to $10 \text{ W}/\text{cm}^2$, using four silicon carbide elements Type LL, 20 inches (508 mm) by 0.63 inch (16 mm), nominal resistance 1.4 ohms, as shown in Figures 5-1a, 5-1b, and 5-3, will be used. The silicon carbide elements will be mounted in the stainless steel panel box by inserting them through 0.63 inch (16 mm) holes in ceramic insulating devices or calcium silicate millboard. Locations of the holes in the pan and stainless steel cover plates are shown in Figure 5-3. A truncated, diamond-shaped mask, constructed of 0.042 ± 0.002 inch (1.07 ± 0.05 mm) stainless steel, will be added to provide uniform heat flux density over the area occupied by the 5.94 by

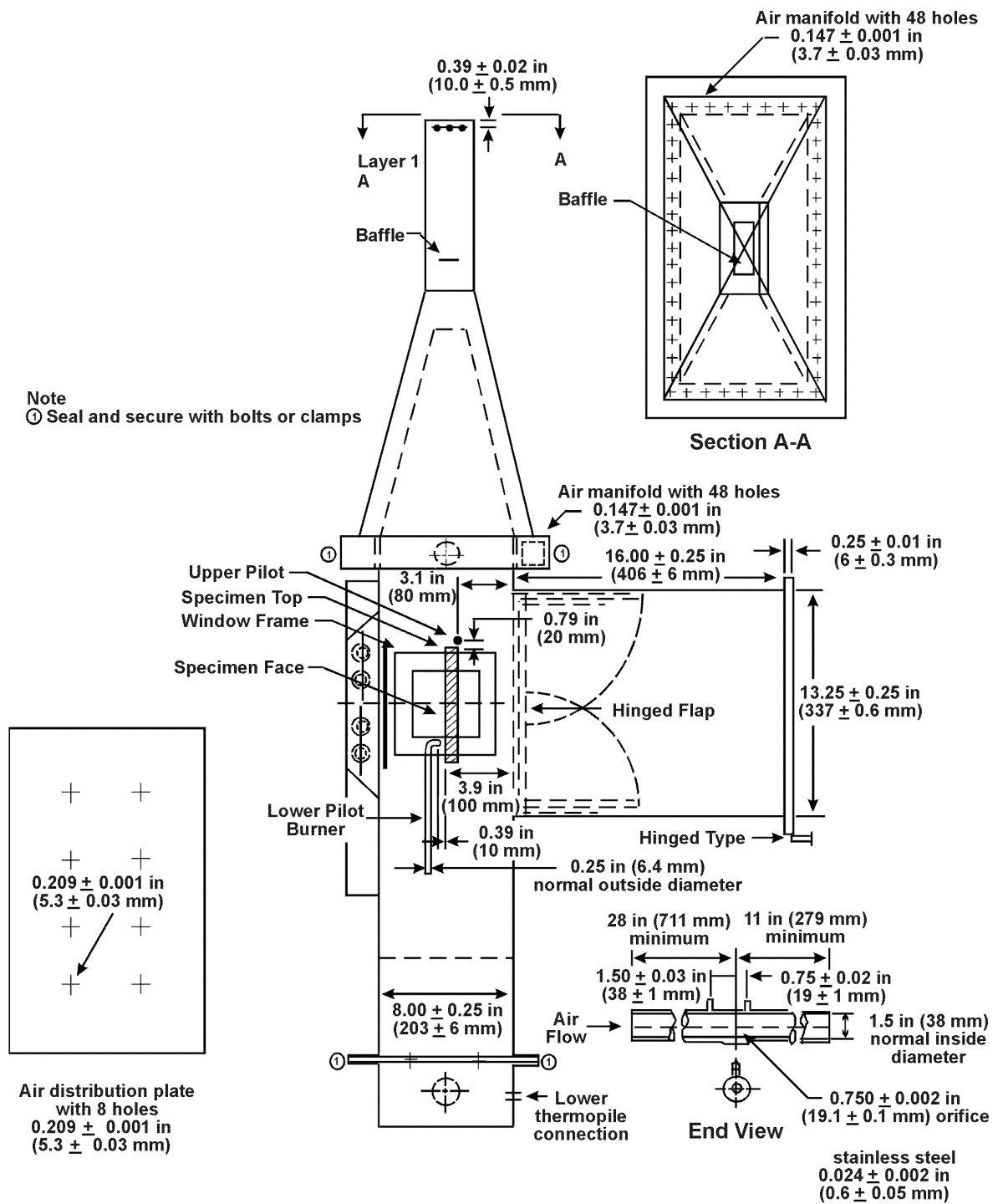


Figure 5-1a. Rate of Heat Release Apparatus (Side View)

(April 2023)

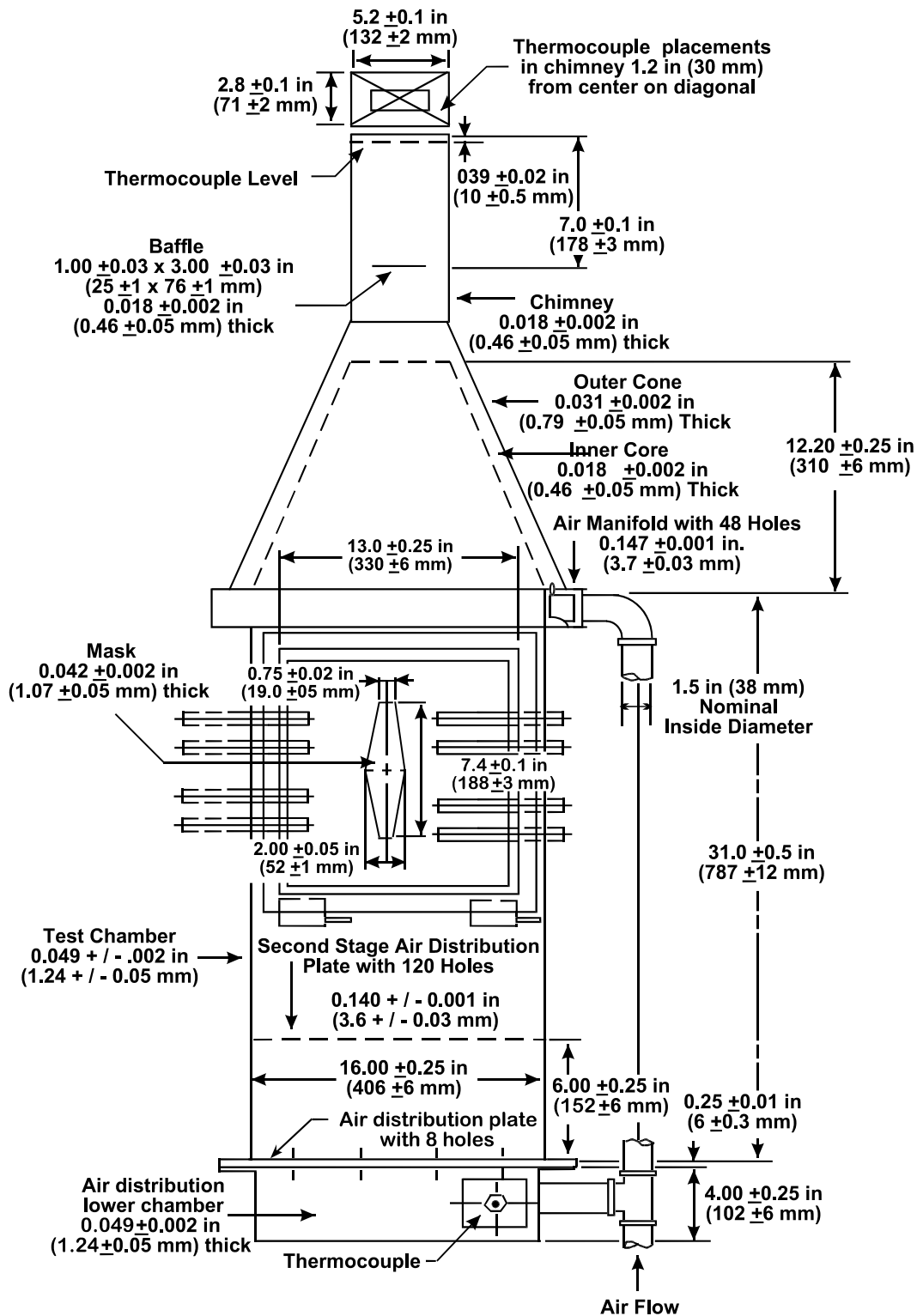


Figure 5-1b. Rate of Heat Release Apparatus (Front View)

(April 2023)

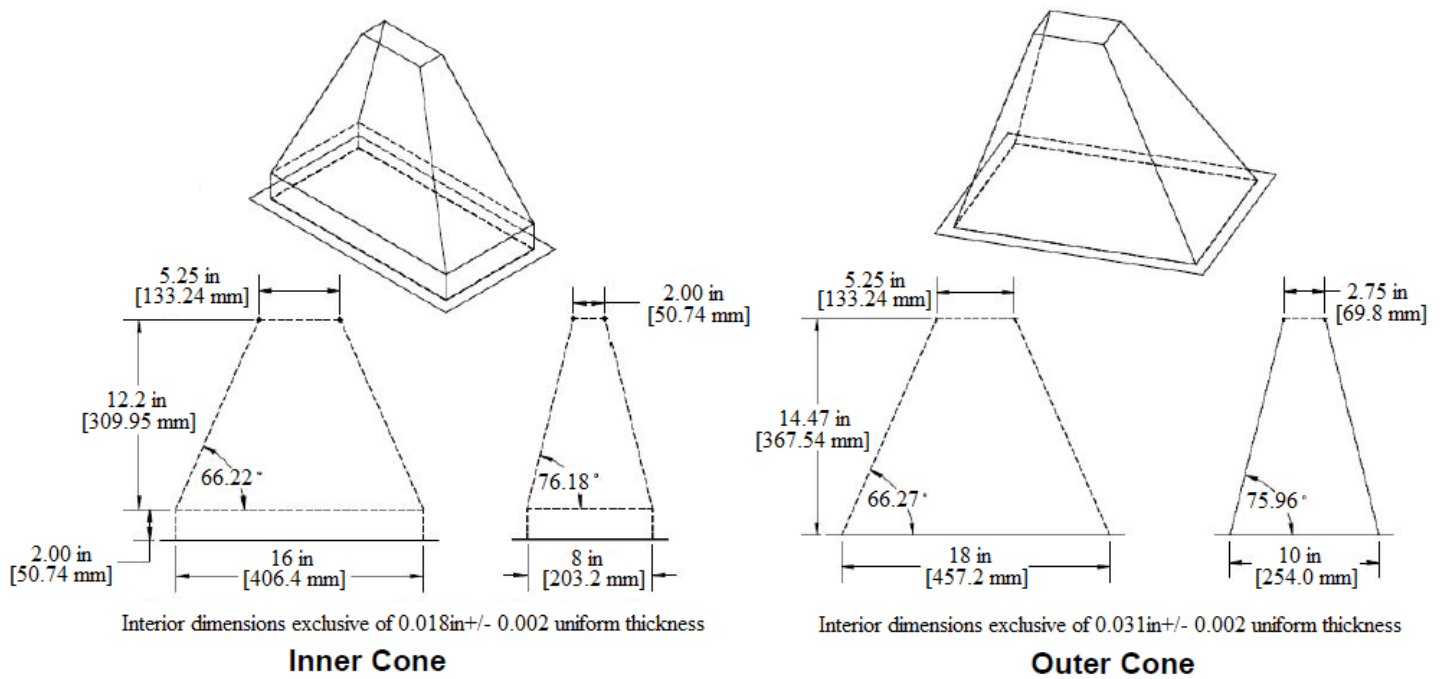


Figure 5-1c. Rate of Heat Release Apparatus (Inner and Outer Cone Detail)

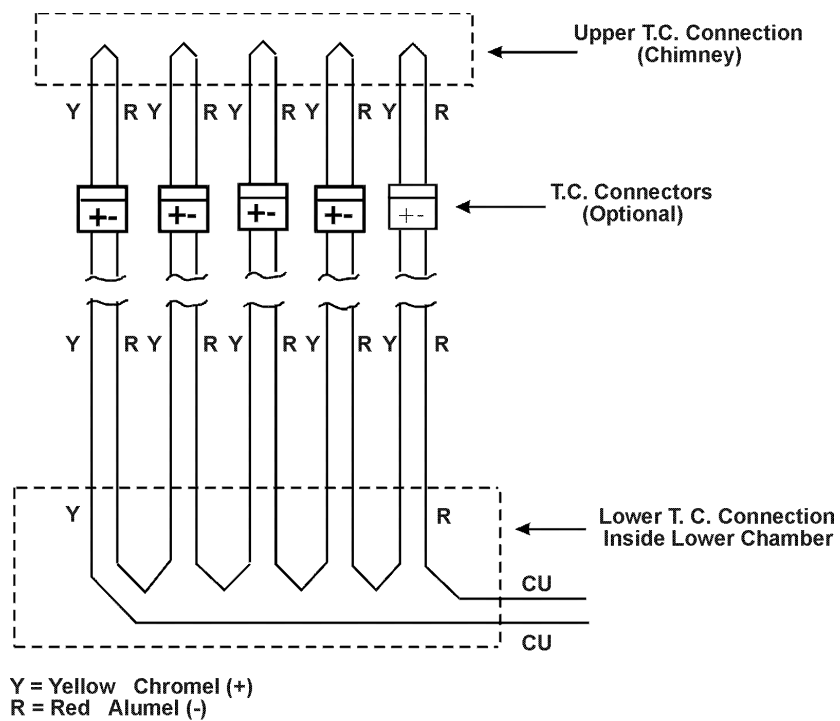


Figure 5-2. Thermopile

(April 2023)

5.94 inch (151 by 151 mm) vertical sample. An adjustable power supply capable of producing 12.5 kVA will be provided. The heat flux over the specimen surface when set at 3.5 W/cm^2 will be uniform within 5 percent and will be checked periodically and after each heating element change. The uniformity of heat flux density will be determined by heat flux gauge measurements at the center and the four corners of the specimen surface.

5.3.4 Air Distribution System

The air entering the apparatus will be 70 to 75°F (21 to 24°C) and set at approximately 85 ft³/min (0.04 m³/s) using an orifice meter. The orifice meter will be comprised of a squared-edged, circular plate orifice, 0.024 inch (0.5 mm) thick, located in a circular pipe with a nominal diameter of 1.5 inches (38 mm), with two pressure measuring points located 1.5 inches (38 mm) upstream (above) and 0.75 inch (19 mm) downstream (below) the orifice and connected to a mercury manometer. The inlet pipe will remain a nominal diameter of 1.5 inches (38 mm) (see Figure 5-1a).

5.3.4.1 The air entering the environmental chamber will be distributed by a 0.25 inch (6.3 mm) thick aluminum plate having eight 0.209 ± 0.001 inch (5.3 ± 0.03 mm) diameter holes, 2 inches (51 mm) from the sides on 4 inch (102 mm) centers, mounted at the base of the environmental chamber. A second plate having 120 evenly spaced, 0.140 ± 0.001 inch (3.6 ± 0.03 mm) diameter holes, will be mounted 6 inches (152 mm) above the aluminum plate (see Figure 5-1b).

5.3.4.2 The air supply manifold at the base of the pyramidal section will have 48 evenly spaced, 0.147 ± 0.001 inch (3.7 ± 0.03 mm) diameter holes 0.38 inch (10 mm) from the inner edge of the manifold, resulting in an airflow split of approximately three to one within the apparatus (see Figure 5-1a).

5.3.5 Exhaust Stack

An exhaust stack, 5.25 by 2.75 inches (133 by 70 mm) in cross section and 10 inches (254 mm) long, fabricated from stainless steel, 0.018 ± 0.002 inch (0.46 ± 0.05 mm), will be mounted on the outlet of the pyramidal section (see Figures 5-1a and 5-1b). A 1-inch by 3-inch (25 by 76 mm) plate of 0.018 ± 0.002 inch (0.46 ± 0.05 mm) thick stainless steel will be centered inside the stack, perpendicular to the airflow, 3 inches (76 mm) above the base of the stack.

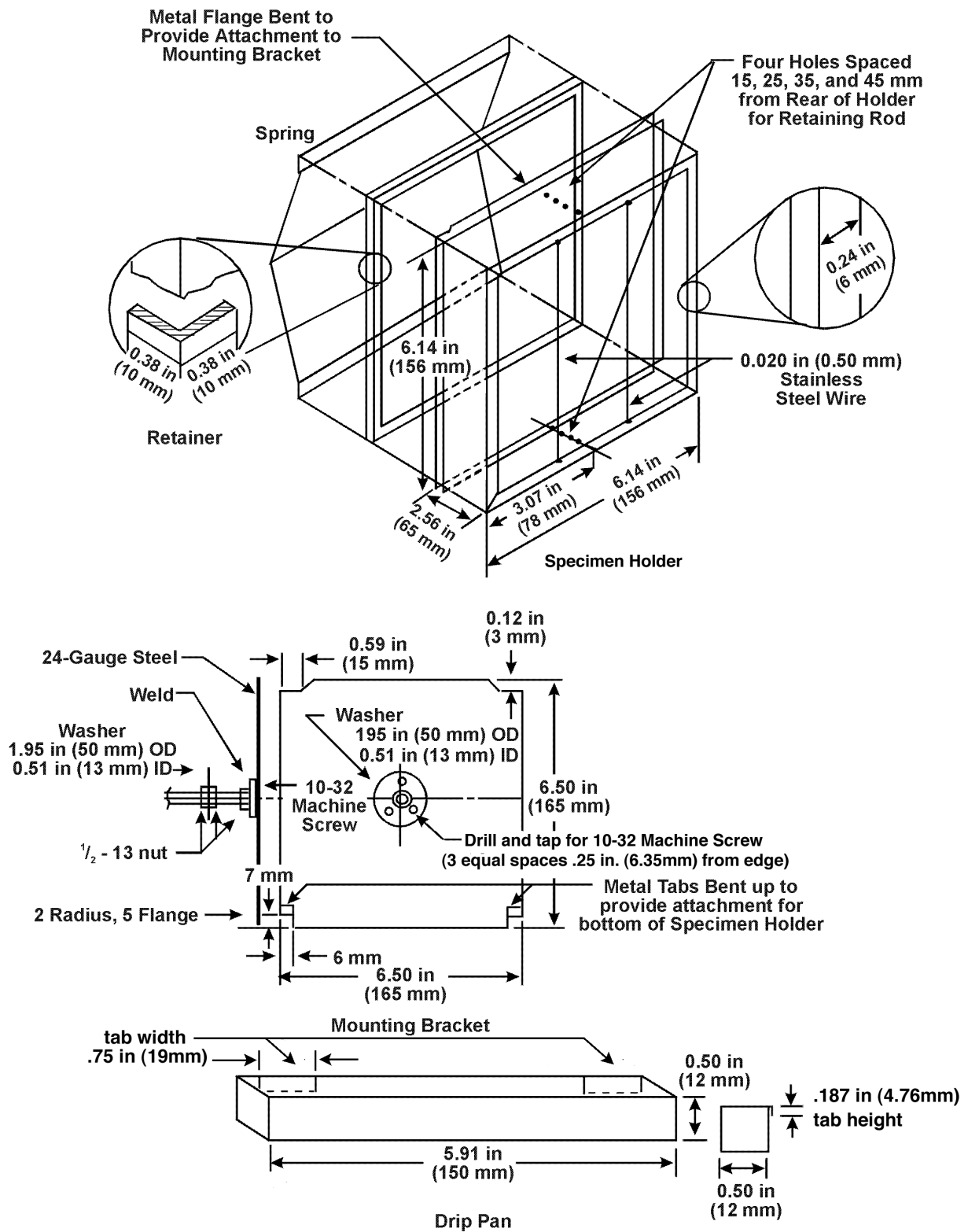


Figure 5-4. Heat Release Specimen Holder, Mounting Bracket, and Drip Pan

5.3.8 Pilot Burners

Pilot burners will be placed at locations near the bottom and top of the specimens (see Figure 5-1a). The burners will be constructed of stainless steel tubing with a 0.25-inch (6.4 mm) outside diameter and 0.03-inch (0.8 mm) wall thickness.

5.3.8.1 Lower Pilot Burner

The lower pilot burner will be located as shown in Figure 5-1a. The lower pilot burner will have its centerline perpendicular to the surface of the specimen and 0.19 inch (5 mm) above the specimen's lower exposed edge and will have its end 0.38 inch (10 mm) from the specimen surface. A methane/air mixture will be used, consisting of 0.004 ft³/min (120 cm³/min) (at standard temperature and pressure) methane (99 percent minimum purity) and an air supply adjusted to produce a flame such that the inner cone is approximately the same length as the diameter of the burner tube. (See Figure 5.5.)

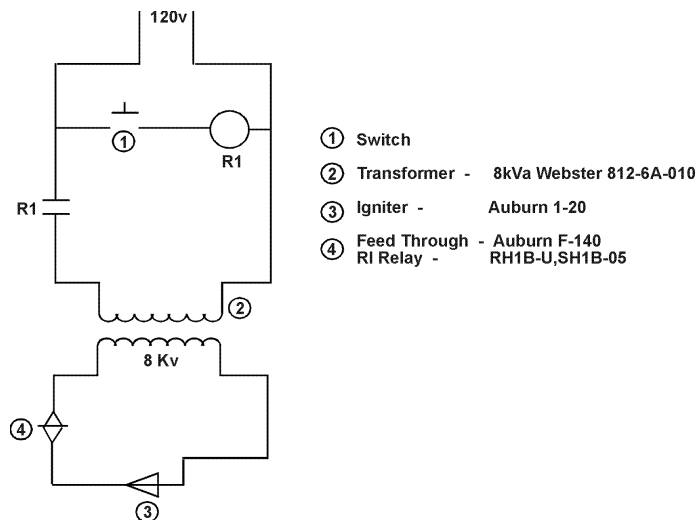


Figure 5-5. Lower Pilot Burner Igniter Schematic

5.3.8.2 Upper Pilot Burner

An upper pilot burner will be provided to produce 15 flamelets above the test specimen to ignite flammable gases (see Figure 5-6). During the test, if there is any period of time longer than 3 seconds when any three or more of the flamelets on the upper pilot burner are not burning, the test is invalidated.

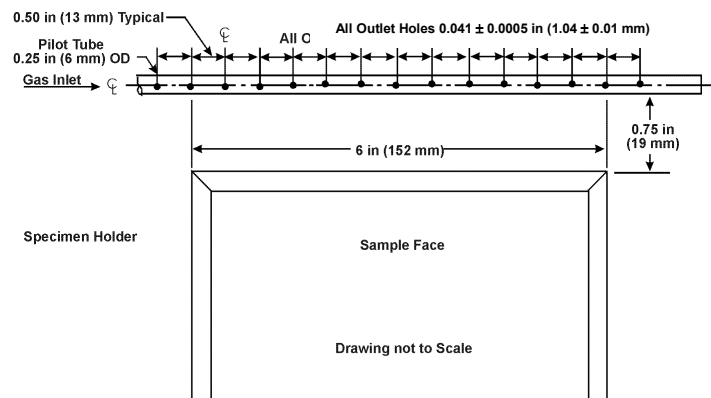


Figure 5-6. Upper Pilot Burner - 15 Hole Burner

(April 2023)

- 5.3.8.2.1 The upper pilot burner will be constructed from a piece of stainless steel tubing with an outside diameter (OD) of 0.25 inch (6.3 mm) and a wall thickness of 0.03 inch (0.8 mm). Fifteen 0.041 ± 0.0005 inch (1.04 ± 0.01 mm) diameter holes, each radiating in the same direction, will be drilled into a 15-inch (381 mm) length of tubing. The holes will be spaced 0.5 inch (13 mm) apart with the first hole located 0.5 inch (13 mm) from the closed end, as shown in Figure 5-6. The tubing will be inserted into the environmental chamber through a 0.25 inch (6.3 mm) hole drilled to locate the tubing 0.79 inch (20 mm) above and 0.79 inch (20 mm) behind the upper front edge of the specimen holder and installed so that the holes are directed horizontally toward the radiant heat source. One end of the tubing will be closed with a silver solder plug or equivalent.
- 5.3.8.2.2 The burner will be positioned above the specimen holder so that the holes are placed above the specimen holder facing the heat source, as shown in Figure 5-1a.
- 5.3.8.2.3 The fuel fed to this burner will be methane of 99 percent minimum purity mixed with air in a ratio of approximately 50/50 by volume. The total fuel flow will be adjusted to provide flamelets approximately 1 inch (25 mm) long. When the gas/air ratio and its fuel flow rate are properly adjusted, approximately 0.25 inch (6 mm) of the flame length tip appears yellow.

5.4 Test Specimens

5.4.1 Specimen Size

The standard size for specimens is $5.94 + 0, -0.06$ by $5.94 + 0, -0.06$ inches ($150 + 0, -2$ by $150 + 0, -2$ mm) in lateral dimensions. Specimen thickness is as used in the relevant application up to 1.75 inches (45 mm); applications requiring thicknesses greater than 1.75 inches (45 mm) will be tested in 1.75 inch (45 mm) thicknesses.

5.4.2 Specimen Number

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

5.4.3 Specimen Mounting

Only one surface of a specimen will be exposed during a test. A single layer of 0.0012 ± 0.0005 inch (0.03 ± 0.01 mm) thick aluminum foil will be wrapped tightly on all unexposed sides with the dull side of the foil facing the specimen surface. The foil must be continuous and not torn. The retaining frame will be placed behind the specimen between the back of the specimen and the pressure plate.

5.4.4 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, etc.), the specimens will be tested in the orientation thought to give the highest results. If the average maximum heat release rate exceeds 58 kW/m^2 or the average total heat released during the first 2 minutes exceeds $58 \text{ kW} \cdot \text{min/m}^2$, a second set of specimens will be prepared and tested in the orientation that is perpendicular to the orientation used for the first set of specimens. The higher value for the average maximum heat release rate and the higher value for the average total heat released during the first 2 minutes will be reported.

5.5 Conditioning

- 5.5.1 Specimens will be conditioned at $70 \pm 5^\circ\text{F}$ ($21 \pm 3^\circ\text{C}$) and $50\% \pm 5\%$ relative humidity for a minimum of 24 hours prior to the test.

5.6 Calibration

5.6.1 Calibration Burner

A calibration burner, as shown in Figure 5-7, will be provided that fits over the end of the pilot flame tubing with a gas-tight connection. T-bar outlets will be approximately the same height as the lower pilot outlet.

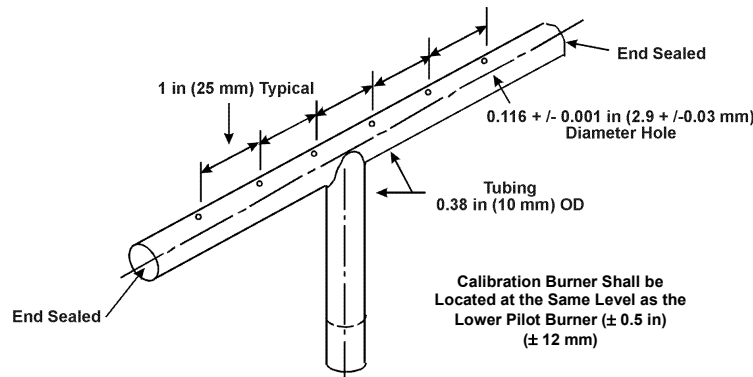


Figure 5-7. Typical Calibration Burner

5.6.2 Calibration Gas

Methane of at least 99 percent purity will be used for calibration purposes.

5.6.3 Wet Test Meter

A wet test meter accurate to $0.007 \text{ ft}^3/\text{min}$ ($0.2 \text{ L}/\text{min}$) will be provided to measure the gas flow rate to the calibration burner. Before usage, the wet test meter will be leveled and filled with distilled water to the tip of the internal pointer, according to manufacturer instructions.

5.6.4 Calibration Gas Manifold

5.6.4.1 A means will be provided upstream of the wet test meter to control calibration gas flow. The means will have flow orifices preset to provide calibration gas at approximate (uncorrected for the presence of water vapor) flow rates of 0.035 , 0.14 , 0.21 , and $0.28 \text{ ft}^3/\text{min}$ (1 , 4 , 6 , and $8 \text{ L}/\text{min}$), as indicated by revolution rate (measured by a stopwatch accurate to 1 second) of the wet test meter. Output from each of the flow orifices will be controlled by an on/off means and be plumbed into a single-flow line so that the calibration gas flow rate to the calibration burner can be set at 0.035 , 0.14 , 0.21 , or $0.28 \text{ ft}^3/\text{min}$ (1 , 4 , 6 , and $8 \text{ L}/\text{min}$).

5.6.4.2 The actual, corrected value, F , of each of the flow rates will be determined to an accuracy of $0.007 \text{ ft}^3/\text{min}$ ($0.2 \text{ L}/\text{min}$), and these corrected values are used for calibration calculations in section 5.6.6.

5.6.5 Calibration Procedure

- 5.6.5.1 Replace the lower pilot burner with the calibration burner shown in Figure 5-7.
- 5.6.5.2 Install the wet test meter. Ensure that it is leveled and filled with distilled water. Ambient temperature and water pressure are based on the internal wet test meter temperature.
- 5.6.5.3 Turn on the air distribution system.

- 5.6.5.4 Turn on the radiant heat source and ensure that the heat flux is $3.5 \pm 0.05 \text{ W/cm}^2$.
- 5.6.5.5 Using the calibration gas manifold, set the baseline flow rate of 1 L/min of methane to the calibration burner and light the burner. Measure the thermopile baseline voltage.
- 5.6.5.6 Immediately before recording the thermopile outputs, as discussed in section 5.6.5.7, precondition the chamber at a methane flow rate of 8 L/min for 2 minutes. Do not record the thermopile output for this step as part of the calibration.
- 5.6.5.7 The gas flow to the burner is increased to a higher flow rate and then decreased to the baseline flow rate. After 2 minutes of burning at each rate, monitor the thermopile output (millivolts) for 10 seconds, record the average reading, and decrease the flow rate to the baseline flow of 1 L/min. This sequence of increasing and decreasing the methane flow rate is as follows: 0.035 - 0.14 - 0.035 - 0.21 - 0.035 - 0.28 - 0.035 - 0.21 - 0.035 - 0.14 ft³/min (1 - 4 - 1 - 6 - 1 - 8 - 1 - 6 - 1 - 4 L/min).
- 5.6.6 Compute the calibration factor for each upward rate step (i.e., 1 - 4, 1 - 6, 1 - 8, 1 - 6, 1 - 4 L/min) according to the following formula:

$$k_h = 25.31 \times \frac{273}{T_a} \times \frac{(P_a - P_v)}{760} \times \frac{(F_1 - F_0)}{(V_1 - V_0)} \text{ kW} / \text{m}^2 - \text{mv}$$

where:

- F_1 = Actual upper flow rate of calibration gas, in L/min (either 4, 6, or 8)
- F_0 = Actual baseline flow rate of methane, in L/min (approximately 1 L/min)
- P_a = Ambient atmospheric pressure, in mm Hg
- P_v = Water vapor pressure of wet test meter water temperature, in mm Hg
- T_a = Ambient temperature, in °K
- V_1 = Thermopile voltage at the upper flow rate, in mv
- V_0 = Thermopile voltage at the baseline flow rate, in mv

- 5.6.7 Average the five results and compute the percent relative standard deviation. If the percent relative standard deviation is greater than 5 percent, repeat the determination. If it is less than 5 percent, use the average as the calibration factor.

5.7 Test Procedure

- 5.7.1 Set the airflow to the equipment by adjusting the pressure differential across the orifice plate to 7.87 inches (200 mm) of mercury.
- 5.7.2 Set the power supply to the Globars to produce a radiant flux density of $3.5 \pm 0.05 \text{ W/cm}^2$ at the point that the center of the front surface of the specimen will occupy when positioned for the test.
- 5.7.3 Light the pilot flames and check that their positions are as described in sections 5.3.8.1 and 5.3.8.2. Activate the spark igniter if a spark igniter is used.
- 5.7.4 If the test specimen consists of material that sags and/or drips to the extent that part of it may fall out of the holder during the test, attach the drip pan to the specimen holder, as described in section 5.3.6.1.
- 5.7.5 Place the specimen in the holding chamber with the radiation shield doors closed. Secure the airtight outer door and start the recording devices. Hold the specimen in the holding chamber for 60 ± 10 seconds.

- 5.7.6 Record, at least once a second, the thermopile millivolt output during the final 20 seconds of the hold time before the specimen is injected, and report the average as the baseline thermopile reading (millivolts).
- 5.7.7 After recording the baseline reading and within a timeframe not exceeding 3 seconds, open the radiation doors, inject the specimen into the burn chamber, and close the radiation doors. Record thermopile millivolt outputs at least once a second for the duration of the test.
- 5.7.8 After the test has run for 5 minutes, terminate the test and remove the sample.
- 5.7.9 Observe and note any extinguishment of pilot flames then discard data from any test during which the lower pilot burner was extinguished for any period of time exceeding 3 seconds or during which at least three of the upper pilot flamelets were extinguished simultaneously for any period of time exceeding 3 seconds.
- 5.7.10 Calculate the heat release rate for any point of time from the reading of the thermopile output voltage, V at that time as heat release rate $= k_h \times (V_1 - V_0)$, where k_h and V_0 are the calibration factor and thermopile millivolt reading at the baseline, respectively.
- 5.7.11 Determine and record the maximum heat release rate during the 5-minute test.
- 5.7.12 Compute and record the total heat released during the first 2 minutes of testing by integrating the heat release rate versus time curve during the first 2 minutes.
- 5.7.13 Clean the thermopile hot junctions to remove soot after testing each set of specimens.

5.8 Report

- 5.8.1 Fully identify the material tested, including thickness.
- 5.8.2 Determine and record the average maximum heat release rate during the 5-minute test, and the average total heat released during the first 2 minutes for all specimens tested (in worst-case direction).
- 5.8.3 Report the radiant heat flux to the specimen in W/cm^2 and data giving release rates of heat (in kW/m^2) as a function of time, either graphically or tabulated at intervals no greater than 10 seconds, and the calibration factor k_h .
- 5.8.4 Report any melting, sagging, delamination, or other behavior that affected the exposed surface area or mode of burning that occurred and the time(s) at which such behavior occurred.

5.9 Requirements

- 5.9.1 The average maximum heat release rate during the 5-minute tests will not exceed $65 \text{ kW}/\text{m}^2$.
- 5.9.2 The average total heat released during the first 2 minutes will not exceed $65 \text{ kW} \cdot \text{min}/\text{m}^2$.

NOTE: The 65/65 acceptance criteria above are the definitive requirements in FAR 25, Amendment 25-61 (FAR 25.853[a-1]), covering affected new design airplanes whose Type Certificate is applied for after August 20, 1986. These definitive requirements are referenced in FAR 121, Amendment 121-189, and are required for all affected airplanes manufactured after August 20, 1990. All affected airplanes manufactured after August 20, 1988, but before August 20, 1990, must meet interim requirements of $100 \text{ kW}/\text{m}^2$ for the average heat release rate and $100 \text{ kW} \cdot \text{min}/\text{m}^2$ for the average total heat released during the first 2 minutes.

Chapter 5 Supplement

This supplement contains advisory material pertinent to referenced paragraphs.

5.3.2 The upper thermocouples in the thermopile must remain in the same position as when the last calibration was completed. A template may be necessary to maintain this position. Caution must be taken while cleaning the thermocouple junctions not to move them.

5.3.3 A device should be provided to monitor the current of the heating elements (globars) during testing; additionally, this may be used to adjust the globar current during initial warm up, before final adjustment.

5.3.4 The air distribution system circular plate orifice should be no thicker than 0.125 inch. The inner edges of the holes must be sharp. The holes in the lower plate are #4 drill size. The holes in the upper manifold are #26 drill size. The holes in the intermediate plate used for air flow disbursement are #28 drill size.

5.3.5 The exhaust stack and area above the upper manifold should be cleaned periodically of soot deposits.

5.3.7 A second calorimeter should be used periodically to check the active calorimeter and its calibration should be first generation from the National Institute of Standards and Technology (NIST) or the calorimeter manufacturer.

5.3.8 Upper Pilot Burner Hot Surface Igniter

5.3.8 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 (towards the globars) there is a chance that a large portion of the upper pilot flames will go out entirely in the presence of fire retardants whereas when in the correct position only the flame tiplets will be impacted while the material is burning off. The difference between the two conditions could have a dramatic effect on the data.

In the event a material continues to impact the upper pilot flames even with the burner tube in the correct position, an optional Hot Surface Igniter (HSI) may be installed. Alternatively, the HSI may be installed and used for all materials tested. If the option of using the HSI is installed, the center heat flux and 5% uniformity requirement (See section 5.6) must be verified before conducting a Methane gas calibration.

A 0.125 ± 0.005 inch (3 ± 0.1 mm) diameter ceramic rod 8.0 ± 0.0625 inches (203 ± 1.6 mm) in length is positioned directly in the flames of the upper pilot burner. The rod is continuously heated by the flamelets 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 inch (19 ± 3 mm).

Note: Non-Porous High-Alumina Ceramic Rod (McMaster-Carr P/N 87065K42) has been found acceptable.

Two stainless steel support brackets are mounted on the upper pilot burner tube. The brackets are separated 8.0 ± 0.0625 inches (203 ± 1.6 mm) from each other (outer dimension) with one bracket aligned flush with the closed end of the burner tube. Due to forced airflow through the chamber and convection, the upper pilot flames tend to curve upward. 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 brackets 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 (Figure 4). Set screws secure the brackets in position.

Note: Marlin Engineering, Inc. Bracket P/N ME1240-45 has been found acceptable.

The HSI rod must be cleaned or replaced when showing signs of soot buildup or wear. Unless otherwise specified, dimensions are nominal values in inches.

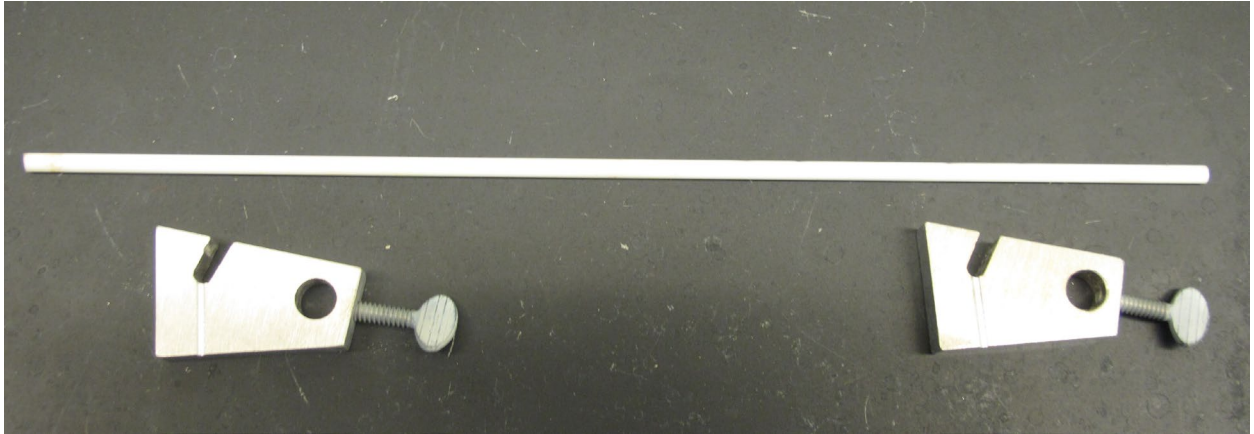


Figure 1. HSI Rod and Bracket

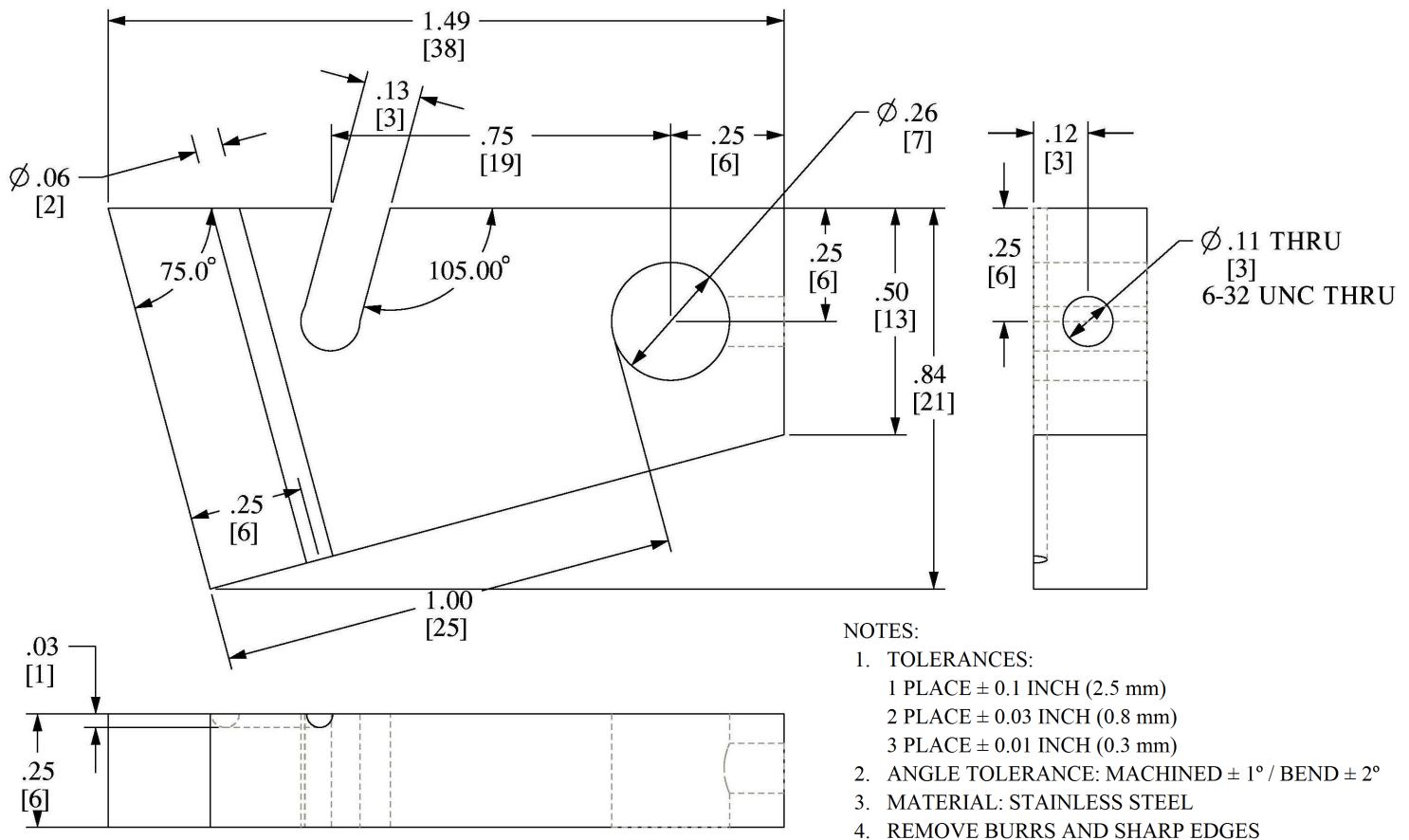


Figure 2. Upper Pilot Burner HSI Bracket

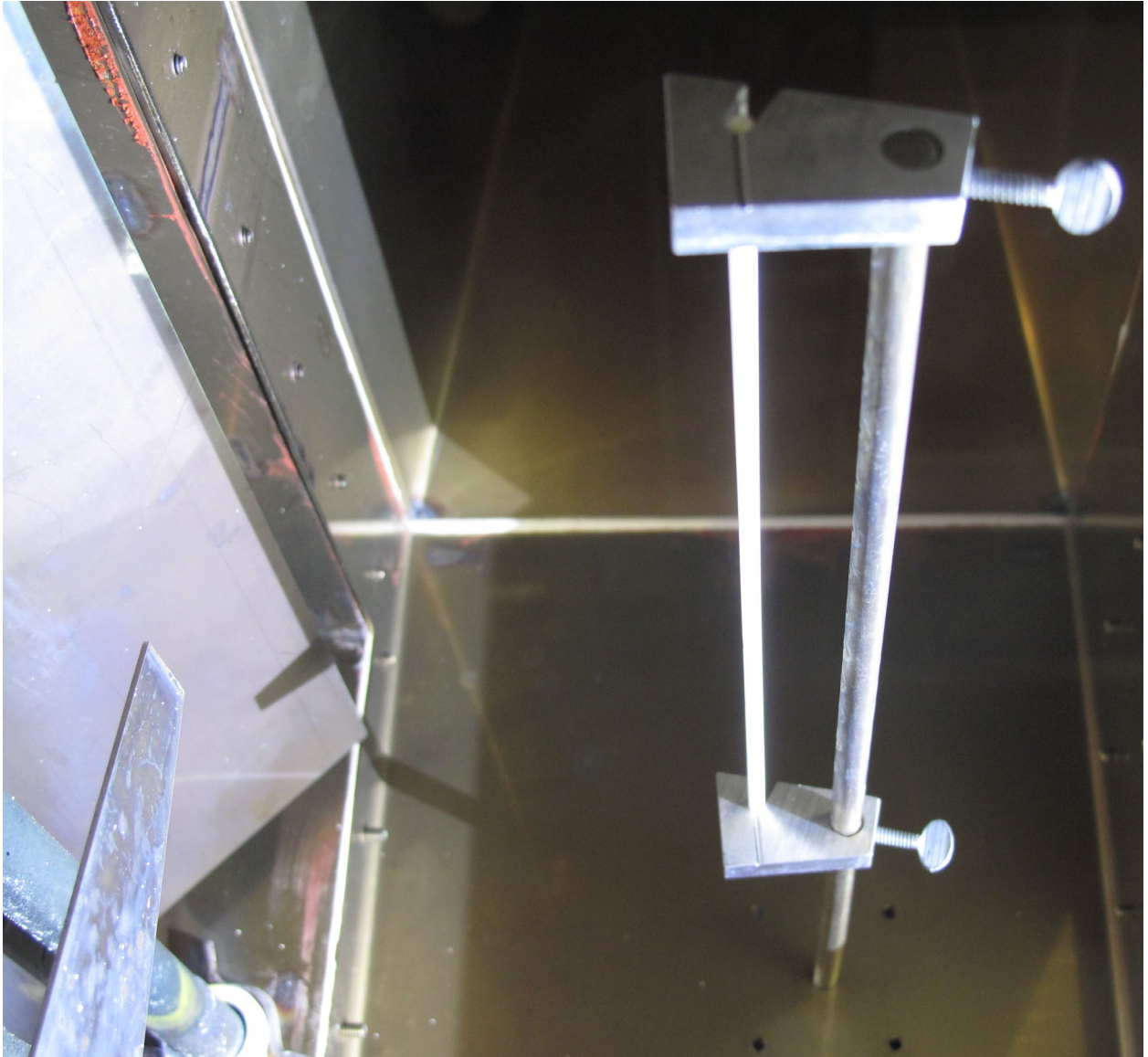


Figure 3. HSI / Upper Pilot Burner Installation

(April 2023)



Figure 4. HSI / Upper Pilot Burner Operation

(April 2023)

5.3.8.2 The upper pilot holes are #59 drill size.

5.4.2 For test purposes, specimens should be marked with an arrow by manufacturers or operators for a consistent direction.

5.4.4 If there is evidence that a material does not demonstrate isotropic flammability characteristics and its heat release numbers in any one direction average greater than 58, either the 2-minute total or peak, the material must be tested in both directions. Examples of those types of materials that may not exhibit isotropic flammability characteristics are rugs and textiles.

5.6.1 The calibration T-bar burner holes are #32 drill size.

5.6.3 The tubing from the wet test meter to the calibration T-bar must be as short as possible and direct in routing. Also, the wet test meter must be last in line with the calibration T-bar.

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

5.7.9 The use of an externally positioned mirror may assist in viewing upper pilot flames during testing.

5.7.13 A small, soft-bristled brush has been found satisfactory. Do not disturb the position of the thermocouples. Ensure that the thermocouples are in their proper position before proceeding with the next specimen; a template may be used to facilitate this step.