Chapter 24 Test Method to Determine the Burnthrough Resistance of Thermal/Acoustic Insulation Materials

24.1 Scope

24.1 Applicability

Use the following test method to evaluate the burnthrough resistance characteristics of aircraft thermal/acoustic insulation materials when exposed to a high intensity open flame.

24.2 Definitions

24.2.1 Burnthrough Time

Burnthrough time means the time, in seconds, for the burner flame to penetrate the test sample, and/or the time required for the heat flux to reach 2.0 Btu/ft^{2}sec (2.27 W/cm^2) on the inboard side, at a distance of 12 inches (30.5 cm) from the front surface of the insulation blanket test frame, whichever is sooner. The burnthrough time is measured at the inboard side of each of the insulation blankets.

24.2.2 Insulation Blanket Sample

Insulation blanket sample means one of two blankets positioned in either side of the test rig, at an angle of 30^o with respect to vertical.

24.2.3 Sample Set

Sample set means two insulation blanket samples. Both samples must represent the same production insulation blanket construction and materials, proportioned to correspond to the sample size.

24.3 Apparatus

24.3.1 Test Apparatus

The arrangement of the test apparatus is shown in figures 24-1 and 24-2 and must include the capability of swinging the burner away from the test sample during warm-up.

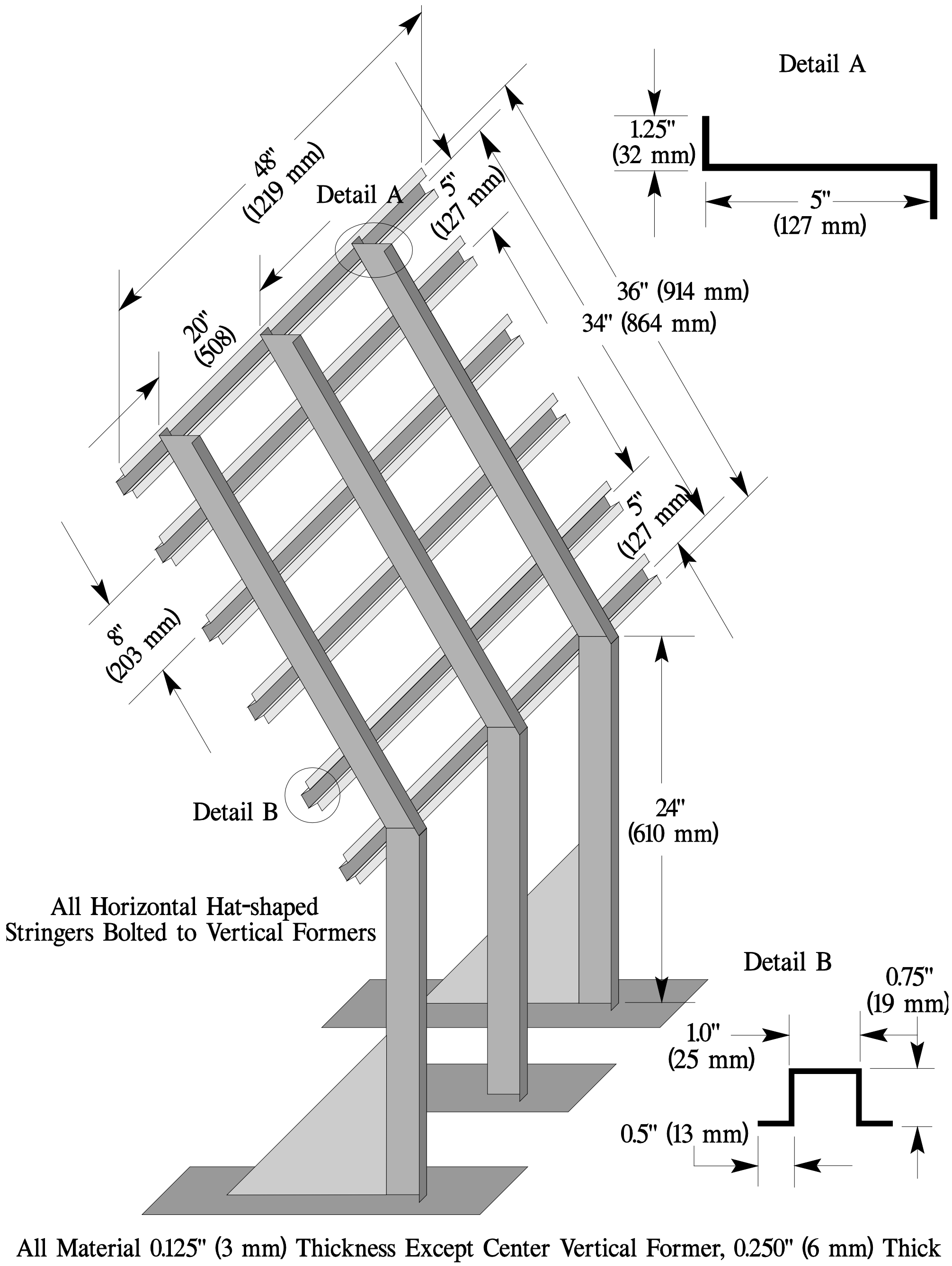


Figure 24-1. Burnthrough Test Apparatus Sample Holder

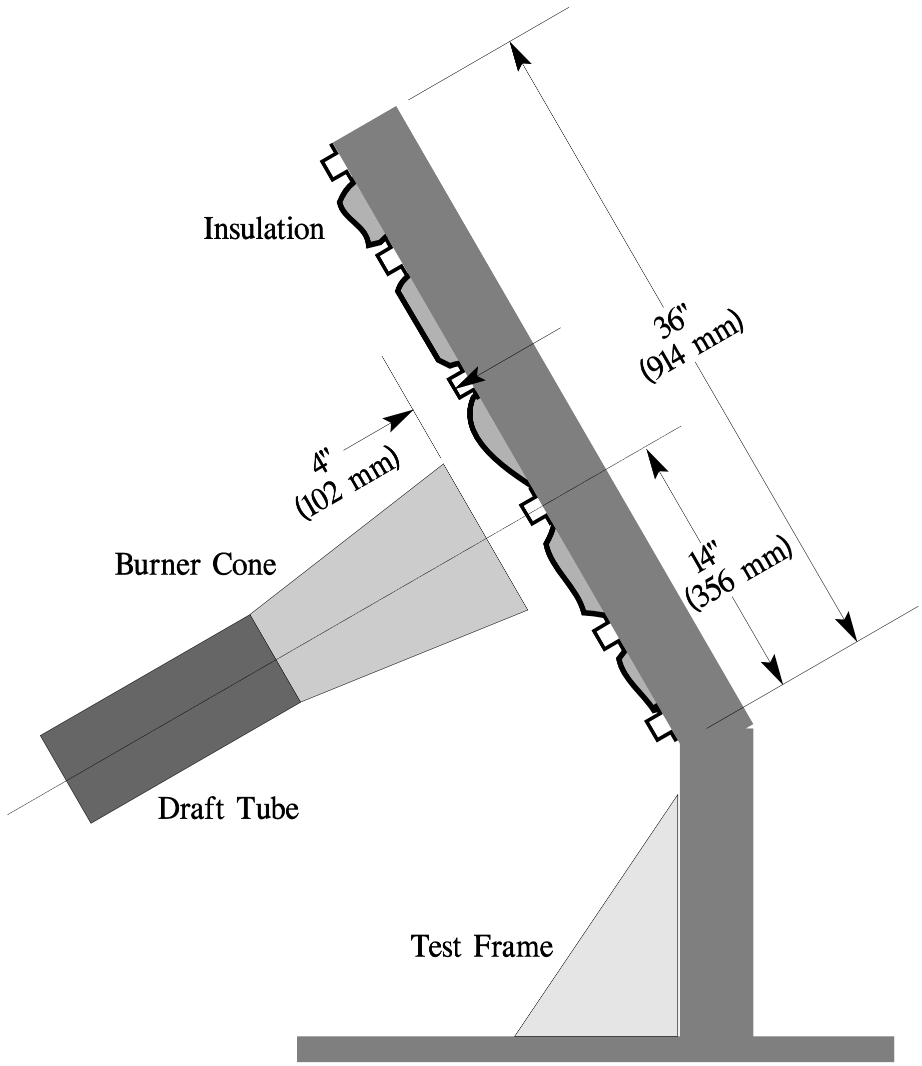


Figure 24-2. Burnthrough Test Apparatus Sample Holder

24.3.2 Test Burner

The test burner must be a modified gun-type such as the Park Model DPL 3400. Flame characteristics are highly dependent on actual burner set-up. Parameters such as fuel pressure, nozzle depth, stator position, and intake airflow must be properly adjusted to achieve the correct flame output.

NOTE: If a sonic type burner is to be used, see Chapter 24 Supplement for all test burner information.

24.3.2.1 Fuel Nozzle

A nozzle must maintain the fuel pressure to yield a nominal 6.0 gal/hr (0.378 L/min) fuel flow. A Monarch-manufactured 80º PL (hollow cone) nozzle nominally rated at 6.0 gal/hr at 100 lb/in^2 (0.71 MPa) delivers a proper spray pattern.

24.3.2.2 Fuel Rail

The fuel rail must be adjusted to position the fuel nozzle at a depth of 0.3125 inches (8 mm) from the end plane of the exit stator, which must be mounted in the end of the draft tube.

24.3.2.3 Internal Stator

The internal stator, located in the middle of the draft tube, must be positioned at a depth of 3.75 inches (95 mm) from the tip of the fuel nozzle. The stator must also be positioned such that the integral igniters are located at an angle midway between the 10 and 11 o'clock position, when viewed looking into the draft tube. Minor deviations to the igniter angle are acceptable if the temperature and heat flux requirements conform to the requirements of paragraphs 24.6.4 and 24.6.5 of this chapter.

24.3.2.4 Blower Fan

The cylindrical blower fan used to pump air through the burner must measure 5.25 inches (133 mm) in diameter by 3.5 inches (89 mm) in width.

24.3.2.5 Burner Cone

Install a 12 ±0.125-inch (305 ±3 mm) burner extension cone at the end of the draft tube. The cone must have an opening 6 ± 0.125-inch (152 ± 3 mm) high and 11 ± 0.125-inch (280 ± 3 mm) wide (see figure 24-3). A reinforcement frame may be added to the cone to reduce the potential of cone warpage. Refer to figure 24-4 for detailed drawings.

NOTE 1: It is critical to periodically check the cone exit plane dimensions to ensure they remain within specified tolerances. It is recommend this be performed at the beginning and end of each day the burner is operated.

NOTE 2: Park type burner cones are 18 gauge 310 stainless steel or similar alloy while sonic type burners are 16 gauge 310 stainless steel.

24.3.2.6 Fuel

Use JP-8, Jet A, or their international equivalent, at a flow rate of 6.0 ± 0.2 gal/hr (0.378 ± 0.0126 L/min). If this fuel is unavailable, ASTM K2 fuel (Number 2 grade kerosene) or ASTM D2 fuel (Number 2 grade fuel oil or Number 2 diesel fuel) are acceptable if the nominal fuel flow rate, temperature, and heat flux measurements conform to the requirements of paragraphs 24.6.4 and 24.6.5 of this appendix.

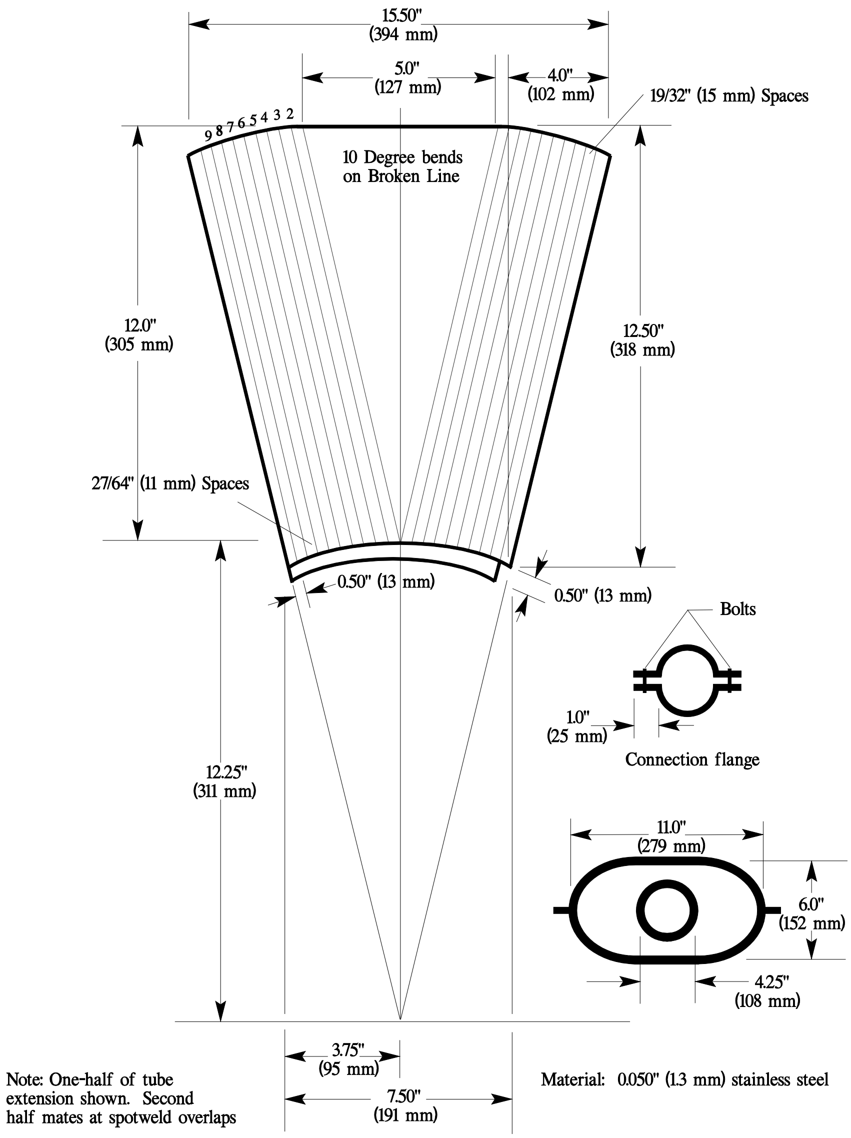


Figure 24-3. Burner Draft Tube Extension Cone Diagram

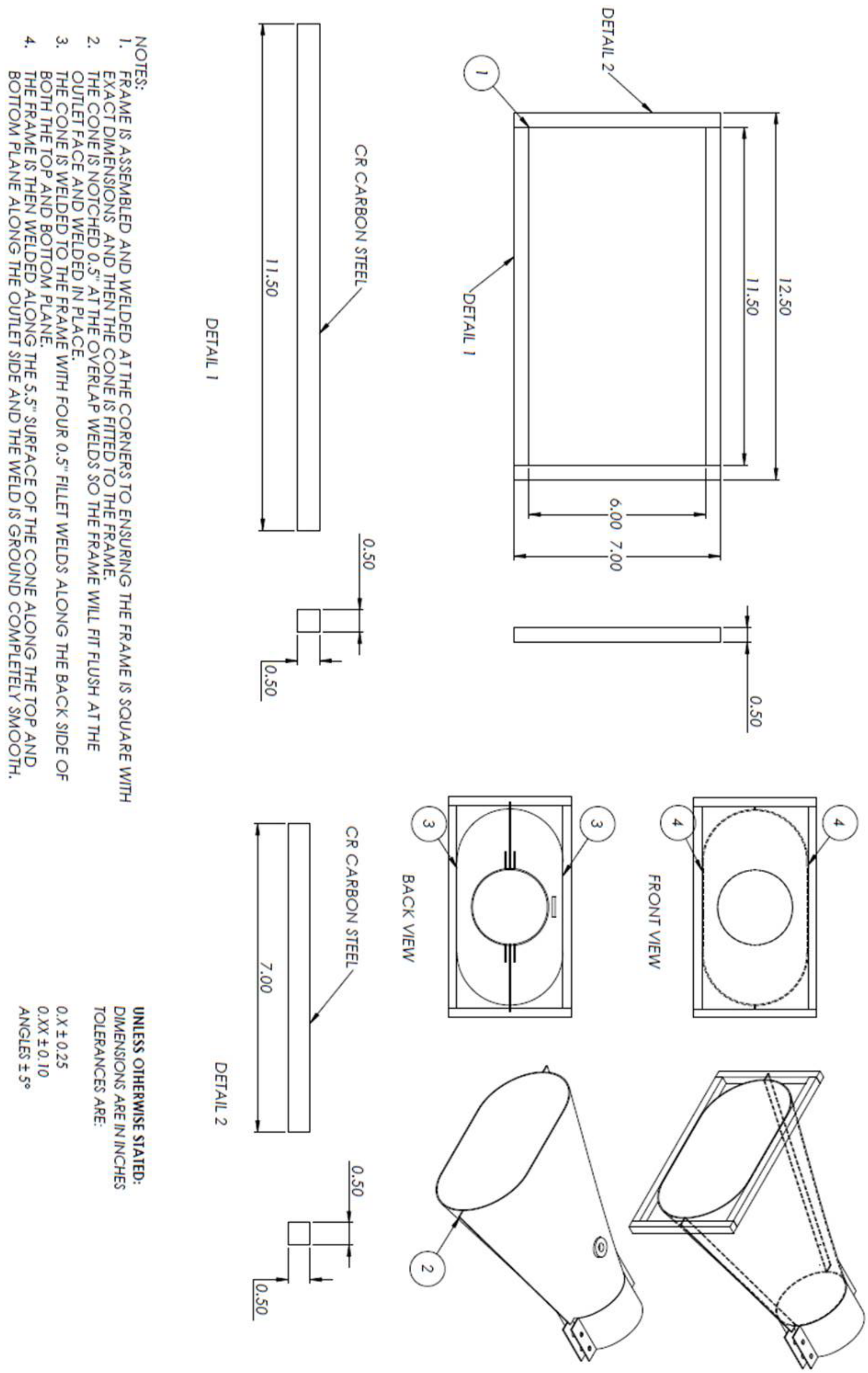


Figure 24-4. Burner Cone Reinforcement Frame

24.3.2.7 Fuel pressure regulator

Provide a fuel pressure regulator, adjusted to deliver a nominal 6.0 gal/hr (0.378 L/min) flow rate. An operating fuel pressure of 100 lb/in^2 (0.71 MPa) for a nominally rated 6.0 gal/hr 80^o spray angle nozzle (such as a PL type) delivers 6.0 $\pm$ 0.2 gal/hr (0.378 $\pm$ 0.0126 L/min).

24.3.3 Calibration Rig and Equipment

24.3.3.1 Heat Flux and Temperature Measuring Rigs

Construct individual calibration rigs to incorporate a heat flux gauge and thermocouple rake for the measurement of heat flux and temperature. Position the calibration rigs to allow movement of the burner from the test rig position to either the heat flux or temperature position with minimal difficulty.

24.3.3.2 Heat Flux Gauge

The heat flux gauge must be a total heat flux, foil type Gardon Gage of an appropriate range such as 0-20 Btu/ft^2-sec (0-22.7 W/cm^2), accurate to $\pm$3% of the indicated reading.

24.3.3.2.1 Heat Flux Gauge Mounting

Mount the heat flux gauge in a 6- by 12- $\pm$ 0.125 inch (152- by 305- $\pm$ 3 mm) by 0.75 $\pm$ 0.125 inch (19 mm $\pm$ 3 mm) thick insulating block which is attached to the heat flux calibration rig during calibration (figure 24-5). Monitor the insulating block for deterioration and replace it when necessary. Adjust the mounting as necessary to ensure that the heat flux gauge face is parallel to the exit plane of the test burner cone.

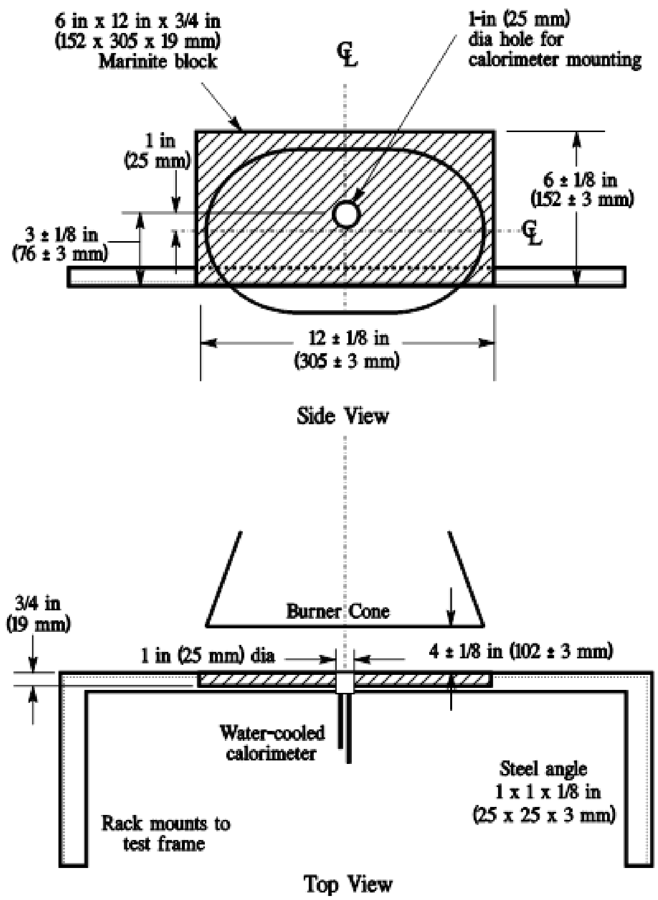


Figure 24-5. Heat flux gauge Position Respective of Burner Cone

24.3.3.3 Thermocouples

Provide seven 0.125-inch (3.2 mm) insulation packed, metal sheathed, type K (Chromel-Alumel), grounded junction thermocouples with a nominal 24 American Wire Gauge (AWG) size conductor for calibration. Thermocouples purchased with a certificate of calibration may provide more accurate readings but are not required. Attach the thermocouples to a steel angle bracket to form a thermocouple rake for placement in the calibration rig during burner calibration (figure 24-6).

NOTE: The thermocouples are subjected to high temperature durations during calibration. Because of this type of cycling, the thermocouples may degrade with time. Small but continuing decreases or extreme variations in temperature or "no" temperature reading at all are signs that the thermocouple or thermocouples are degrading or open circuits have occurred. In this case, the thermocouple or thermocouples should be replaced in order to maintain accuracy in calibrating the burner. Although not required, it is recommended that a record be kept for the amount of time the thermocouples are exposed to the oil burner's flame.

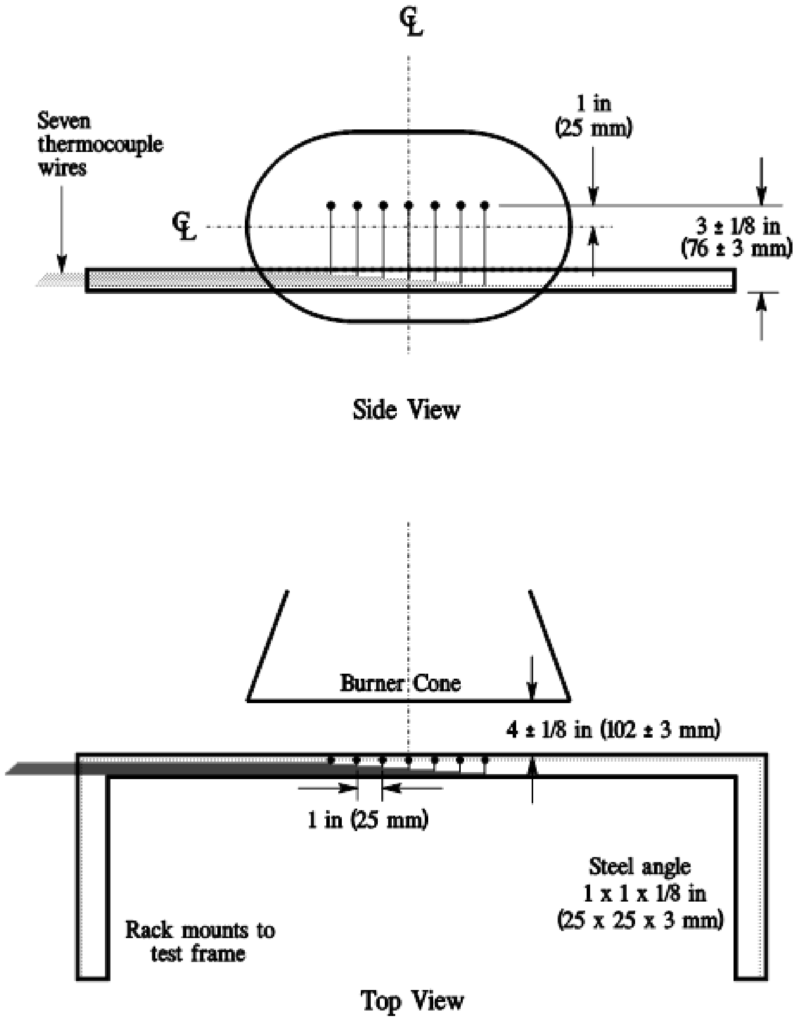


Figure 24-6. Thermocouple Rake Position Respective of Burner Cone

24.3.3.4 Air Velocity Meter

Use a vane-type air velocity meter to calibrate the velocity of air entering the burner. An Omega Engineering Model HH30A is satisfactory. Use a suitable adapter to attach the measuring device to the inlet side of the burner to prevent air from entering the burner other than through the measuring device, which would produce erroneously low readings. Use a flexible duct, measuring 4 inches wide (102 mm) by 20 feet (6.1 meters) long, to supply fresh air to the burner intake, to prevent damage to the air velocity meter from ingested soot. An optional airbox permanently mounted to the burner intake area can effectively house the air velocity meter and provide a mounting port for the flexible intake duct.

24.3.4 Test Sample Mounting Frame

Make the mounting frame for the test samples of 0.125-inch (3.2 mm) thick steel as shown in figure 24-1, except for the center vertical former, which should be 0.25-inch (6.4 mm) thick to minimize warpage. The sample mounting frame stringers (horizontal) should be bolted to the test frame formers (vertical) such that the expansion of the stringers will not cause the entire structure to warp. Use the mounting frame for mounting the two insulation blanket test samples as shown in figure 24-2.

24.3.5 Backface Heat Flux Gauges

Mount two total heat flux Gardon type heat flux gauges behind the insulation test samples on the back side (cold) area of the test sample mounting frame as shown in figure 24-7. Position the heat flux gauges along the same plane as the burner cone centerline, at a distance of 4 inches (102 mm) from the vertical centerline of the test frame.

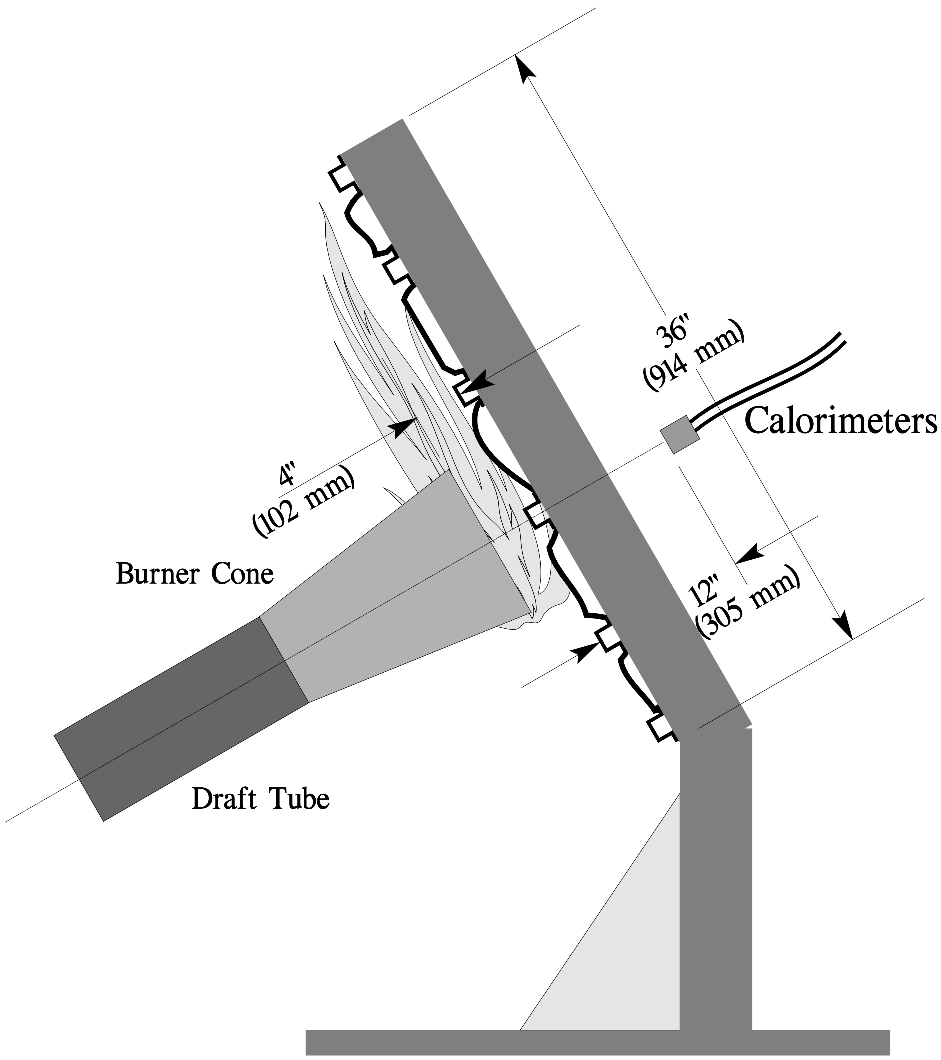


Figure 24-7. Position of Backface Heat flux gauges Relative to Test Sample Frame

24.3.5.1 Backface Heat Flux Gauge Requirements

The heat flux gauges must be a total heat flux, foil type Gardon Gage of an appropriate range such as 0-5 Btu/ft^2-sec (0-5.7 W/cm^2), accurate to $\pm$3% of the indicated reading.

24.3.6 Instrumentation

Provide a recording potentiometer or other suitable calibrated instrument with an appropriate range to measure and record the outputs of the heat flux gauge and the thermocouples.

24.3.7 Timing Device

Provide a stopwatch or other device, accurate to ±1%, to measure the time of application of the burner flame and burnthrough time.

24.3.8 Test Chamber

Perform tests in a suitable chamber to reduce or eliminate the possibility of test fluctuation due to air movement. Although not required, the recommended minimum of the test chamber floor area is 15 feet by 15 feet (4.57 m by 4.57 m) or larger.

24.3.9 Ventilation Hood

Provide the test chamber with an exhaust system capable of removing the products of combustion expelled during tests.

24.4 Test Samples

24.4.1 Sample Preparation

Prepare a minimum of three sample sets of the same construction and configuration for testing.

24.4.2 Insulation Blanket Test Sample

24.4.2.1 For batt-type materials such as fiberglass, the constructed, finished blanket sample assemblies must be 32 inches wide by 36 inches long (81.3 by 91.4 cm), exclusive of heat sealed film edges.

24.4.2.2 For rigid and other non-conforming types of insulation materials, the finished test samples must fit into the test rig in such a manner as to replicate the actual in-service installation.

24.4.3 Construction

Make each of the samples tested using the principal components (i.e., insulation, fire barrier material if used, and moisture barrier film) and assembly processes (representative seams and closures).

24.4.3.1 Fire Barrier Material

If the insulation blanket is constructed with a fire barrier material, place the fire barrier material in a manner reflective of the installed arrangement. For example, if the material will be placed on the outboard side of the insulation material, inside the moisture film, place it the same way in the test sample.

24.4.3.2 Insulation Material

Blankets that utilize more than one variety of insulation (composition, density, etc.) must have sample sets constructed that reflect the insulation combination used. If, however, several blanket types use similar insulation combinations, it is not necessary to test each combination if it is possible to bracket the various combinations.

24.4.3.3 Moisture Barrier Film

If a production blanket construction utilizes more than one type of moisture barrier film, perform separate tests on each combination. For example, if a polyimide film is used in conjunction with insulation in order to enhance the burnthrough capabilities, also test the same insulation when used with a polyvinyl fluoride film.

24.4.4 Installation on Test Frame

Attach the blanket test samples to the test frame using 12 steel spring-type clamps as shown in figure 24-8. Use the clamps to hold the blankets in place in both of the outer vertical formers, as well as the center vertical former (4 clamps per former). The clamp surfaces should measure 1 inch by 2 inches (25 by 51 mm). Place the top and bottom clamps 6 inches (15.2 cm) from the top and bottom of the test frame, respectively. Place the middle clamps 8 inches (20.3 cm) from the top and bottom clamps.

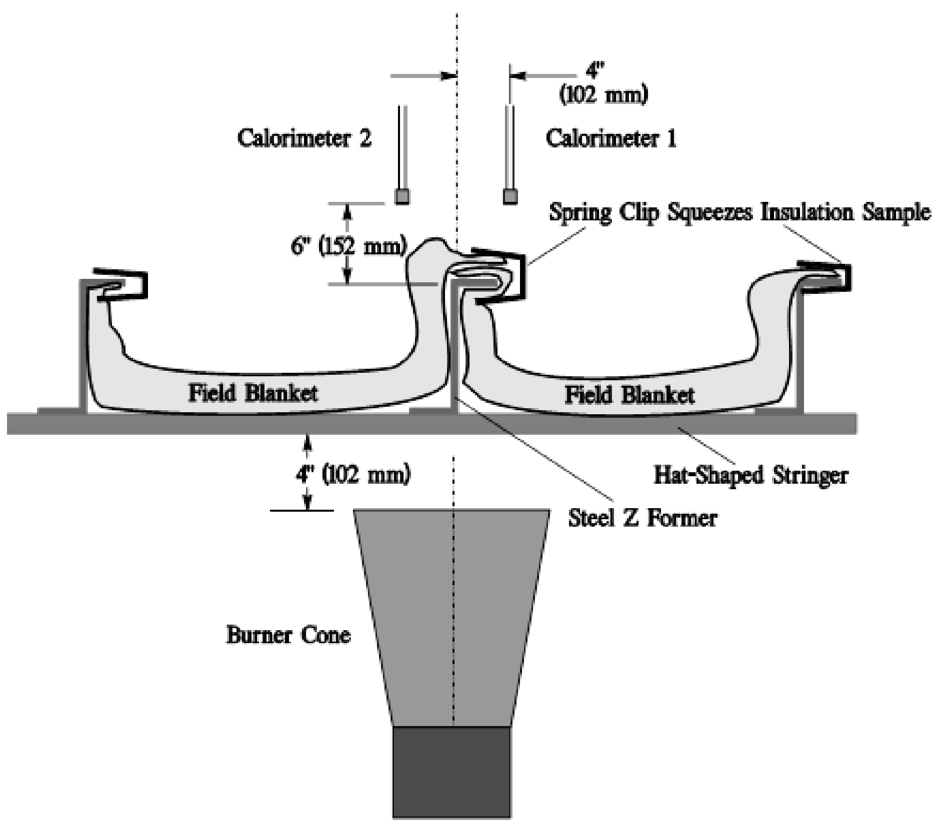


Figure 24-8. Test Sample Installation on Test Frame

NOTE: For blanket materials that cannot be installed in accordance with figure 24-8 above, the blankets must be installed in a manner approved by the FAA.

24.4.5 Conditioning

Condition the samples at 70º ± 5ºF (21º ± 2ºC) and 55% ± 10% relative humidity for a minimum of 24 hours prior to testing.

24.5 Preparation of Apparatus

24.5.1 Apparatus Leveling

Level and center the frame assembly to ensure alignment of the heat flux gauge and/or thermocouple rake with the burner cone.

24.5.2 Air Velocity Measurement

Turn on the ventilation hood for the test chamber. Do not turn on the burner blower. Measure the airflow of the test chamber using a vane anemometer or equivalent measuring device. The vertical air velocity just behind the top of the upper insulation blanket test sample must be 100 ± 50 ft/min (0.51 ± 0.25 m/s). The horizontal air velocity at this point must be less than 50 ft/min (0.25 m/s).

NOTE: A suitable hotwire anemometer, which may be mounted to the sample test frame, is manufactured by Dwyer Instruments, model number 641-6-LED. A suitable handheld hotwire anemometer is manufactured by TSI, model number 9515.

24.5.3 Fuel Flow Calibration

If a calibrated flow meter is not available, measure the fuel flow rate using a graduated cylinder of appropriate size. Turn on the burner motor/fuel pump, after insuring that the igniter system is turned off. Collect the fuel via a plastic or rubber tube into the graduated cylinder for a 2-minute period. Determine the flow rate in gallons per hour. The fuel flow rate must be 6.0 ± 0.2 gallons per hour (0.378 ± 0.0126 L/min).

24.6 Calibration

24.6.1 Alignment of Instrumentation

Position the burner in front of the heat flux gauge so that it is centered and the vertical plane of the burner cone exit is 4 ± 0.125 inches (102 ± 3 mm) from the heat flux gauge face. Ensure that the horizontal centerline of the burner cone is offset 1 inch below the horizontal centerline of the heat flux gauge (figure 24-9). Without disturbing the heat flux gauge position, rotate the burner in front of the thermocouple rake, such that the middle thermocouple (number 4 of 7) is centered on the burner cone.

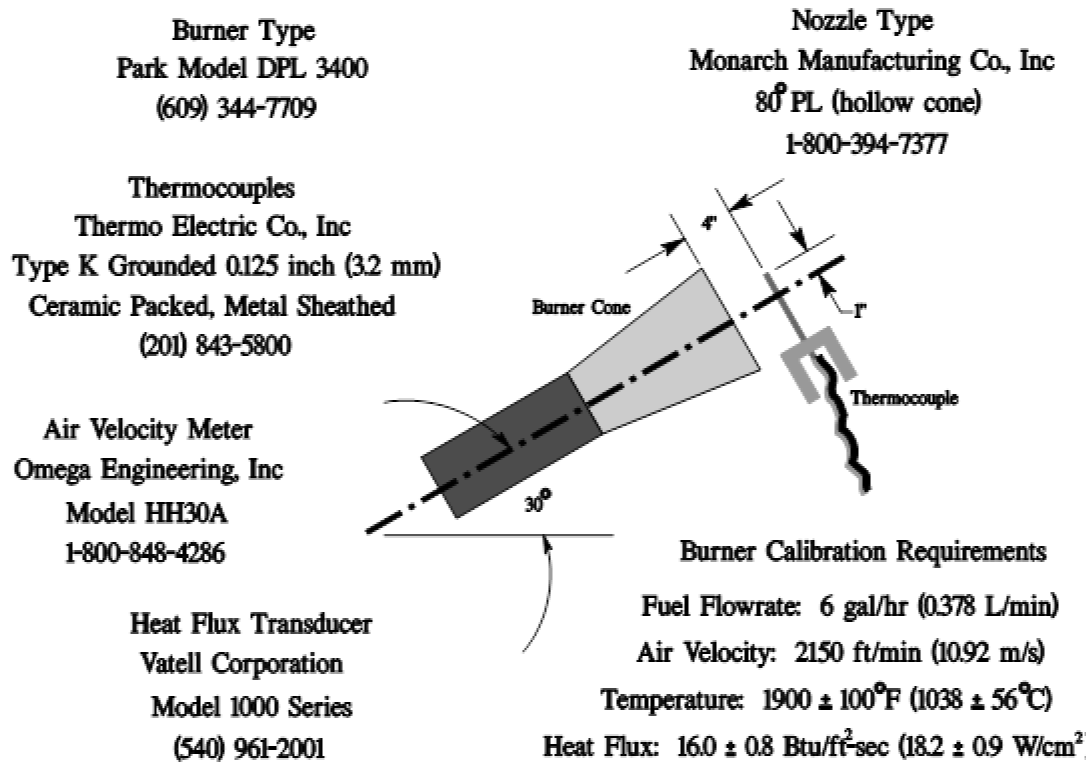


Figure 24-9. Burner Information and Calibration Settings

Ensure that the horizontal centerline of the burner cone is also offset 1 inch below the horizontal centerline of the thermocouple tips. Re-check measurements by rotating the burner to each position to ensure proper alignment between the cone and the heat flux gauge and thermocouple rake. (Note: The test burner mounting system must incorporate "detents" that ensure proper centering of the burner cone with respect to both the heat flux gauge and the thermocouple rakes, so that rapid positioning of the burner can be achieved during the calibration procedure.)

24.6.2 Intake Air Adjustment

Position the air velocity meter in the adapter or airbox, making certain that no gaps exist where air could leak around the air velocity measuring device. Turn on the blower/motor while ensuring that the fuel solenoid and igniters are off. Adjust the air intake velocity to a level of 2150 ft/min, (10.92 m/s) then turn off the blower/motor.

NOTE: The Omega HH30 air velocity meter measures 2.625 inches in diameter. To calculate the intake airflow, multiply the cross-sectional area (0.03758 ft^2) by the air velocity (2150 ft/min) to obtain 80.80 ft^3/min. An air velocity meter other than the HH30 unit can be used, provided the calculated airflow of 80.80 ft^3/min (2.29 m^3/min) is equivalent.

24.6.3 Instrumentation Cleaning and Final Check

Rotate the burner from the test position to the warm-up position. Prior to lighting the burner, ensure that the heat flux gauge face is clean of soot deposits, and there is water running through the heat flux gauge. Examine and clean the burner cone of any evidence of buildup of products of combustion, soot, etc. Soot buildup inside the burner cone may affect the flame characteristics and cause calibration difficulties. Since the burner cone may distort with time, dimensions should be checked periodically.

24.6.4 Heat Flux Calibration

While the burner is still rotated to the warm-up position, turn on the blower/motor, igniters and fuel flow, and light the burner. Allow it to warm up for a period of 2 minutes. Move the burner into the calibration position and allow 1 minute for heat flux gauge stabilization, then record the heat flux once every second for a period of 30 seconds. Turn off burner, rotate out of position, and allow to cool. Calculate the average heat flux over this 30-second duration. The average heat flux should be 16.0 $\pm$0.8 Btu/ft^2 sec (18.2 $\pm$0.9 W/cm^2).

24.6.5 Temperature Calibration

Position the burner in front of the thermocouple rake. After checking for proper alignment, rotate the burner to the warm-up position, turn on the blower/motor, igniters and fuel flow, and light the burner. Allow it to warm up for a period of 2 minutes. Move the burner into the calibration position and allow 1 minute for thermocouple stabilization, then record the temperature of each of the 7 thermocouples once every second for a period of 30 seconds. Turn off burner, rotate out of position, and allow to cool. Calculate the average temperature of each thermocouple over this 30- second period and record. The average temperature of each of the 7 thermocouples should be 1900°F $\pm$ 100°F (1038 $\pm$ 56°C).

24.6.6 Burner Readjustment

If either the heat flux or the temperatures are not within the specified range, adjust the burner intake air velocity and repeat the procedures of paragraphs (4) and (5) above to obtain the proper values. Ensure that the inlet air velocity is within the range of 2150 ft/min $\pm$50 ft/min (10.92 $\pm$0.25 m/s).

24.6.7 Calibration Frequency

Calibrate prior to each test until consistency has been demonstrated. After consistency has been confirmed, several tests may be conducted with calibration conducted before and after a series of tests.

24.7 Test Procedure

24.7.1 Secure the two insulation blanket test samples to the test frame. The insulation blankets should be attached to the test rig center vertical former using four spring clamps positioned as shown in figure 24-8 (according to the criteria of paragraph 24.4.4 of this Chapter.

24.7.2 Ensure that the vertical plane of the burner cone is at a distance of 4 $\pm$ 0.125 inch (102 $\pm$3 mm) from the outer surface of the horizontal stringers of the test sample frame, and that the burner and test frame are both situated at a 30° angle with respect to vertical.

24.7.3 When ready to begin the test, direct the burner away from the test position to the warm-up position so that the flame will not impinge on the samples prematurely. Turn on and light the burner and allow it to stabilize for 2 minutes.

24.7.4 To begin the test, rotate the burner into the test position and simultaneously start the timing device.

24.7.5 Expose the test samples to the burner flame for 4 minutes and then turn off the burner. Immediately rotate the burner out of the test position.

24.7.6 Determine (where applicable) the burnthrough time, or the point at which the heat flux exceeds 2.0 Btu/ft^2-sec (2.27 W/cm^2).

24.8 Report

24.8.1 Identify and describe the sample being tested.

24.8.2 Report the number of insulation blanket samples tested.

24.8.3 Report the burnthrough time (if any), and the maximum heat flux on the back face of the insulation blanket test sample, and the time at which the maximum occurred.

24.9 Requirements

24.9.1 Each of the two insulation blanket test samples must not allow fire or flame penetration in less than 4 minutes.

24.9.2 Each of the two insulation blanket test samples must not allow more than 2.0 Btu/ft^2-sec (2.27 W/cm^2) on the cold side of the insulation samples at a point 12 inches (30.5 cm) from the face of the test rig.

Chapter 24 Supplement
Sonic Burner

Apparatus

The test sample frame must be capable of moving away from the stationary burner during warmup (figure 24-S-1). The recommmened distance between the sample frame and burner cone during burner warmup is 36 inches (914.4 mm).

NOTE: The sample frame may be positioned closer to the burner cone during warmup but may create a more severe test condition.

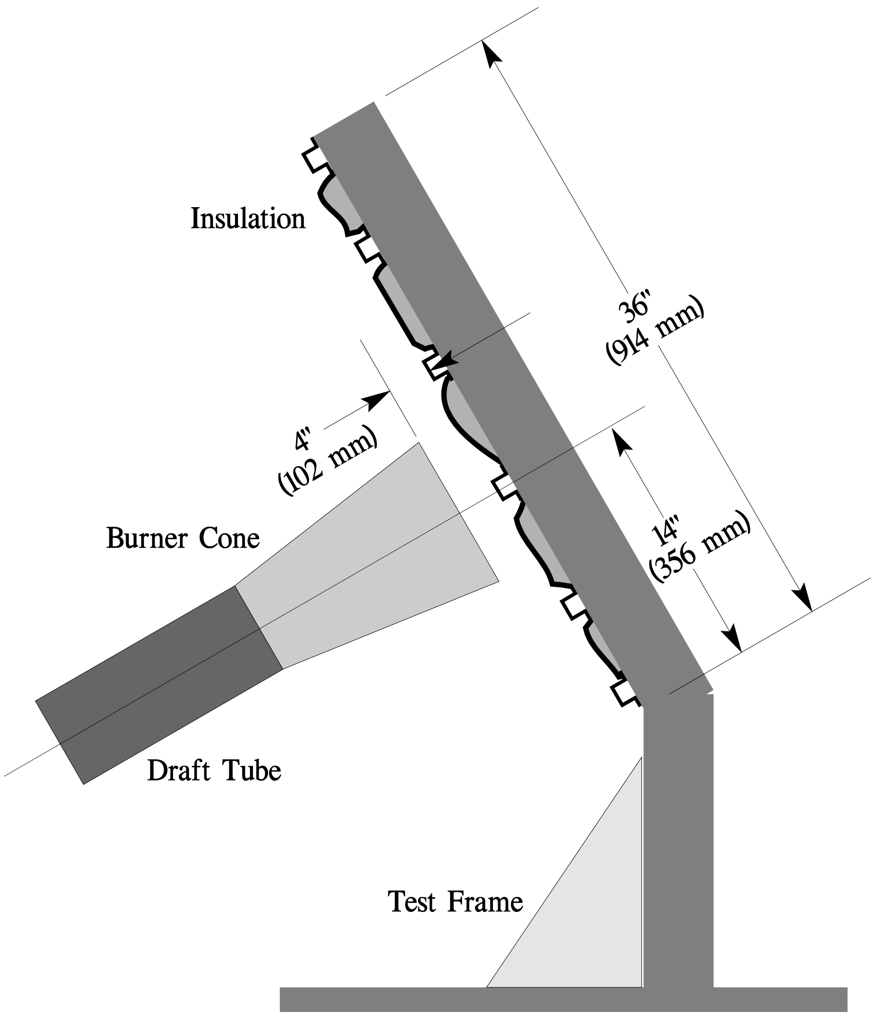


Figure 24-S-1. Test Apparatus for Seat Cushion Oil Burner Testing

Test Burner

This section describes in detail the Federal Aviation Administration Sonic Fire Test Burner, also known as the Next Generation or the NexGen burner. The Sonic burner is specified in multiple FAA fire test methods, although certain burner adjustments differ according to each specific test method.

The burner is a gun-type, using a pressurized, sprayed fuel charge in conjunction with a ducted air source to produce the burner flames. An interchangeable, screw-in fuel nozzle will be used to produce the conically-shaped fuel charge from a pressurized fuel source. A pressurized air source controlled via a regulated sonic nozzle will supply the combustion air. The combustion air will be ducted through a cylindrical draft tube containing a series of diffusing vanes. There are several types of internal vanes used to diffuse the combustion air. The diffused combustion air will mix with the sprayed fuel charge in a bell-shaped combustion cone. The fuel/air charge will be ignited by a high-voltage spark plug positioned in the burner cone. Flame characteristics can be adjusted by varying the pressure of the regulated air into the sonic nozzle, and proper positioning of the fuel spray nozzle. A schematic of the Sonic fire test burner is displayed in figure 24-S-2.

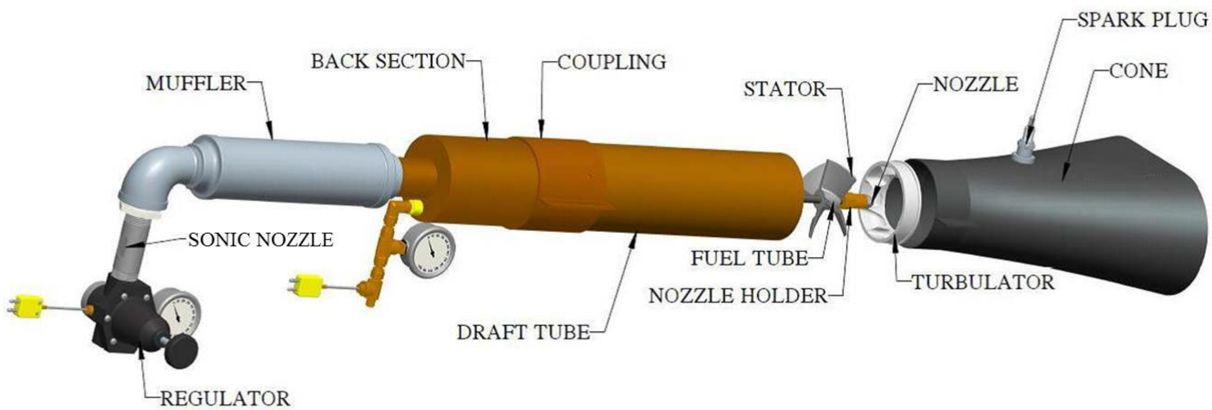


Figure 24-S-2. Schematic of the Sonic Burner - Exploded View

Burner Housing

The burner housing is comprised of three main sections, the draft tube, the coupling, and the back section. The draft tube is constructed of 4-inch inner diameter steel tubing with a wall thickness of 0.125-inch (3.2-mm). The length of the draft tube is 15 inches (381 mm), with 3 inches (76.2 mm) of the tube inserted into the coupling, resulting in a coupling-to-tip distance of 12 (304.8 mm) inches (figure 24-S-3). The coupling is constructed of 4.25-inch (108-mm) inner diameter steel tubing that is 4 inches (102 mm) long with an outer diameter of 4.75 inches (120.7 mm). Three set-screw holes are 120 degrees apart and are drilled 1 inch (25.4 mm) in from the edge to hold the draft tube in place. The coupling has two mounting brackets welded to the sides for easy mounting and adjustment (figure 24-S-4). The back section is made of the same 4-inch (101.6-mm) tubing as the draft tube, but is 6 inches (152.4

mm) long, with 1 inch (25.4 mm) inserted into the coupling and welded in place (figure 24-S-5). A back plate is constructed of a 0.25-inch (6.4-mm) steel plate cut into a 4.25-inch (108-mm) diameter circle to cap the back section, with holes for the air inlet and fuel inlet (figure 24-S-6). A 1.5-inch National Pipe Thread (NPT) pipe nipple is cut to a length of 2.90 inches (73.7 mm) and welded into the 1.90-inch (48.3-mm) diameter recess cut to a depth of 0.145 inches (3.68 mm) on the center of the back plate (figure 24-S-7).

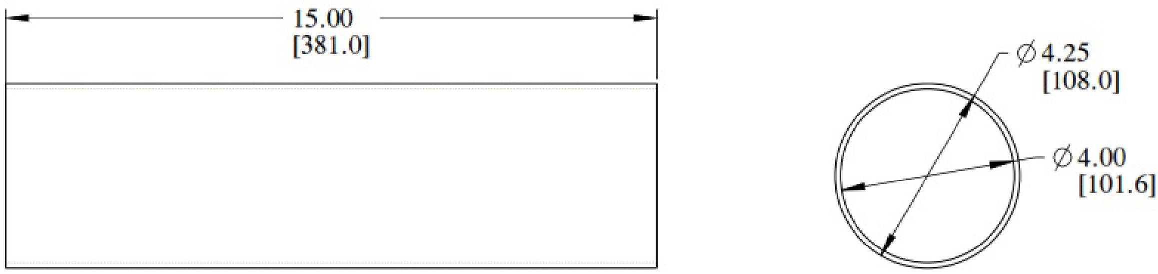


Figure 24-S-3. Dimensioned Drawing of the Draft Tube

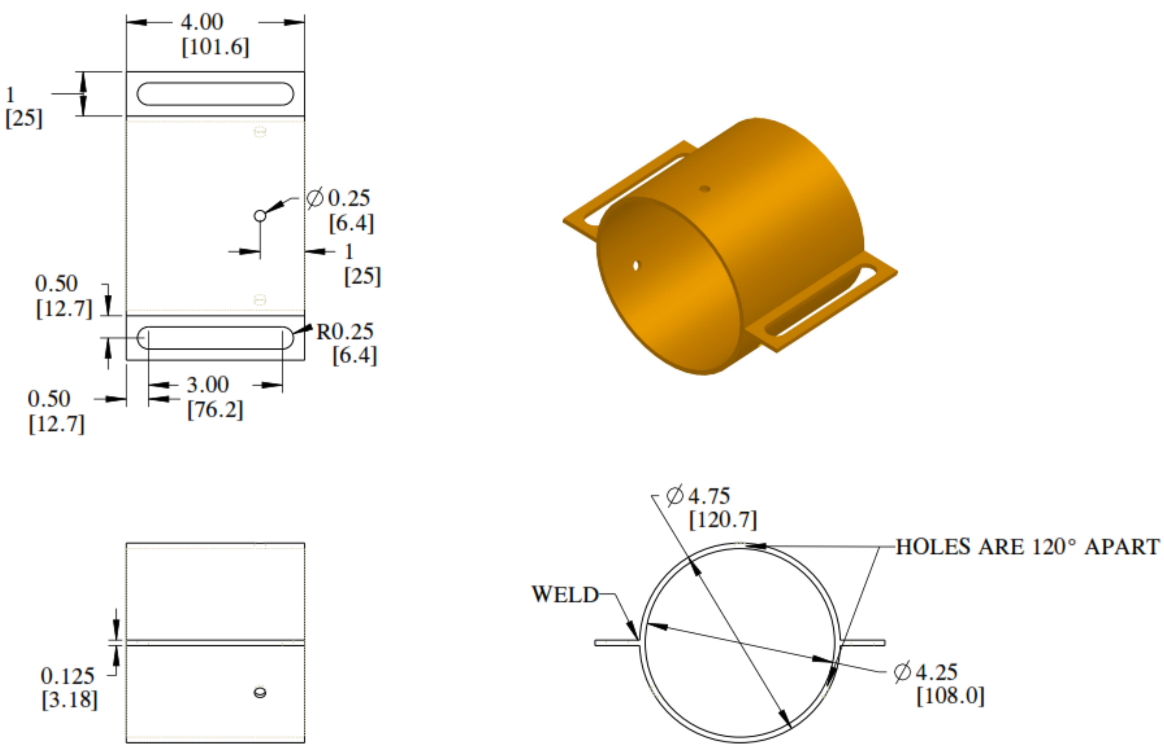


Figure 24-S-4. Dimensioned Drawing of the Coupling

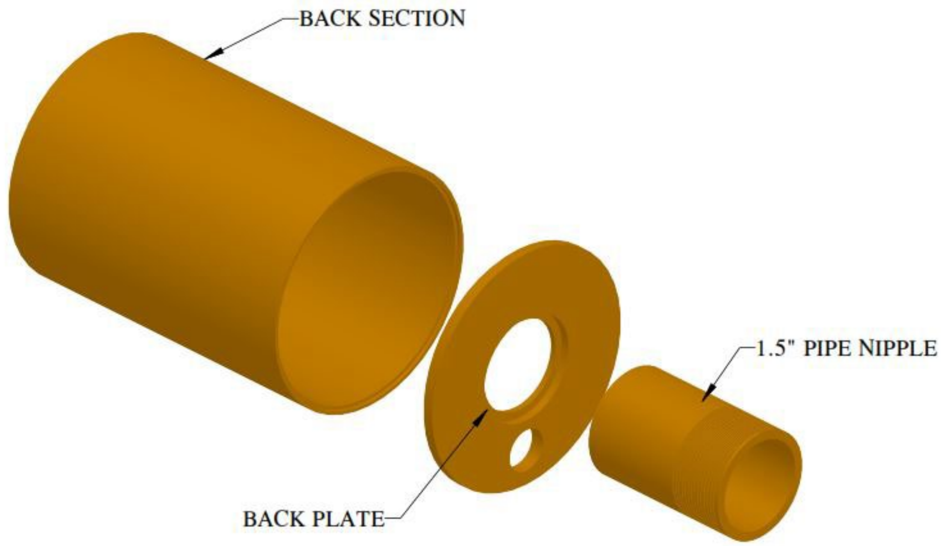


Figure 24-S-5. Back Section Components - Exploded View

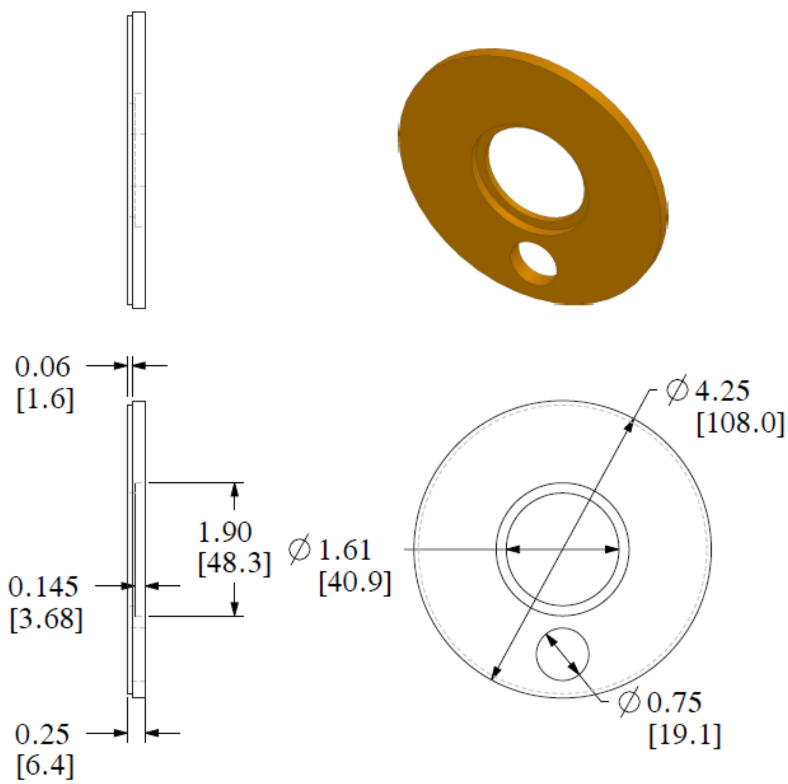


Figure 24-S-6. Dimensioned Drawing of the Back Plate

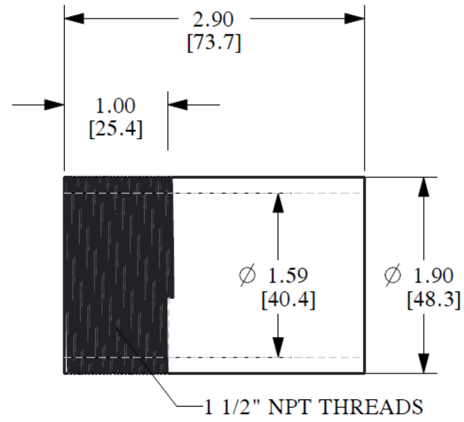


Figure 24-S-7. Dimensioned Drawing of the Pipe Nipple

Sonic Nozzle

The Sonic burner airflow is regulated with a sonic nozzle, which will deliver a constant mass flow rate depending on the supplied inlet air pressure (figure 24-S-8). The nozzle is constructed from stainless steel with 1-inch NPT male thread ends. The throat diameter must be 0.25 inches (6.3 mm), which will deliver a mass flow rate, in standard cubic feet per minute, as a function of inlet pressure, in pounds per square inch gauge, at a rate of

$$\dot{m} = 0.89 * P_i + 12.43$$

The exact inlet air pressure, and hence mass flow rate, will be test-method specific and is described in the respective chapter. The nozzle that the FAA has used to develop the Sonic burner is manufactured by Fox Venturi Products of Dover, New Jersey, and is identified by part number 612021-8.

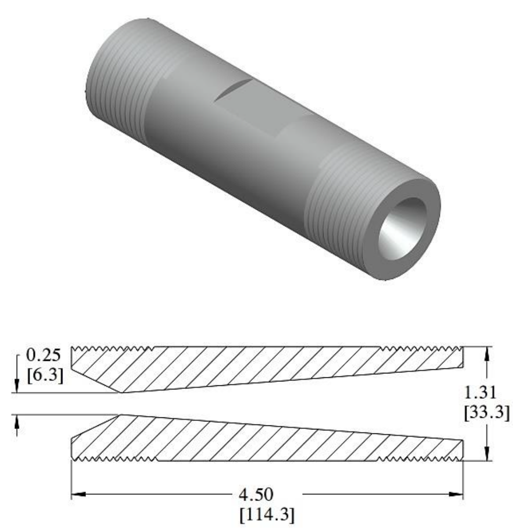


Figure 24-S-8. Schematic of the Sonic Nozzle with Cutaway View Showing Converging and Diverging Interior Sections

Air Pressure Regulator

The air pressure regulator is critical to maintaining the stability of the airflow supplied to the burner. The regulator should have 1-inch NPT female connections, at least one pressure tap for measurement of outlet pressure, and should regulate over the range at which the burner is normally operated (figure 24-S-9). The regulator must also maintain the desired pressure for the duration of a test. A suitable regulator is available from Grainger, item number 4ZM10 (manufactured by Speedaire) with an adjustment range of 5-125 lbs/in^2 (0.034-0.862 MPa). Another suitable regulator is available from MSC Industrial, part number 73535627, manufactured by Parker (model R119-08CG/M2) with an adjustment range of 2-125 lbs/in^2 (0.014-0.862 MPa).

NOTE: A 1-inch NPT "tee-fitting" or similar 1-inch NPT fitting may be added between the regulator and sonic nozzle for a more accurate or additional air pressure measurement location.

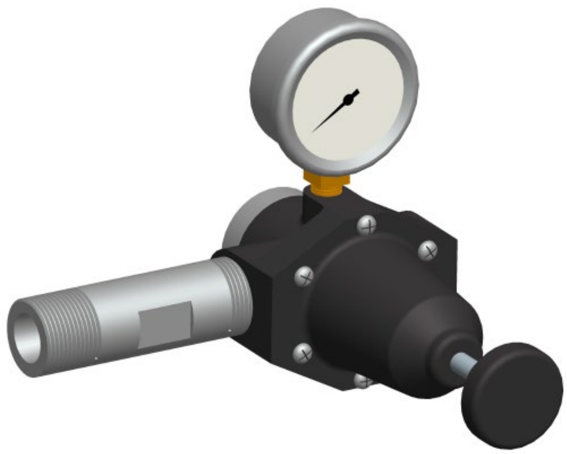


Figure 24-S-9. Schematic of Air Pressure Regulator with Sonic Nozzle Attached

Air Pressure Measurement Device

The air pressure measured just prior to the sonic nozzle is critical to the proper mass flow rate of air through the sonic nozzle. The pressure gauge or transducer must have NIST (or equivalent) traceable certification with a $\pm$ 2% accuracy or less. Digital gauges capable of reading in increments of 1 lbs/in^2 (0.007 MPa) or less are recommended if a pressure transducer is not used. Should an analog gauge be used (figure 24-S-10), it should be glycerin-filled to reduce needle flutter, and have a dial that is easily read. The gauge or transducer must also have a working range appropriately suited for the range of air pressures typically used during tests. A suitable pressure transducer is supplied by Omega Engineering, part number PX329-100G5V. A suitable digital gauge is supplied by Omega Engineering, part number DPG1001B-100G; a suitable analog gauge is supplied by McMaster-Carr, part number 4053K23with a 0-60 psi (0-0.414 MPa) pressure range.

Figure 24-S-10. Analog Pressure Gauge

Muffler

An air flow muffler is used to reduce the high frequency noise created by the air expanding from the sonic nozzle throat. The 2.625-inch (66.7-mm) outside diameter muffler has 1.5-inch NPT female thread connections, an overall length of 12 inches (305 mm), and has no internal baffles or tubes. A suitable muffler is supplied by McMaster-Carr, part number 5889K73 (figure 24-S-11). Low pressure-drop polyurethane foam must be used to further reduce the noise issuing from the burner. The foam can be cut into a cylinder 3 inches (76.2 mm) in diameter by 12 inches (305 mm) long and should have a density of approximately 1.20-1.50 lbs/ft^3 (19.2-24.0 kg/m^3) with a porosity of approximately 20 ± 2 pores/inch (787 ± 79 pores/m). It is necessary to affix two pieces of safety wire to the muffler's internal steel mesh at the outlet end to prevent the foam cylinder from moving out of position and into the burner housing. The two wires should be arranged perpendicular to each other in a cross pattern and have a wire diameter of 0.032 inches (0.8 mm) or less (figure 24-S-12). The male outlet of the sonic nozzle connects to a 1-inch NPT female to 1.5-inch male hex reducing bushing. The hex bushing male outlet connects to the intake side of the muffler.

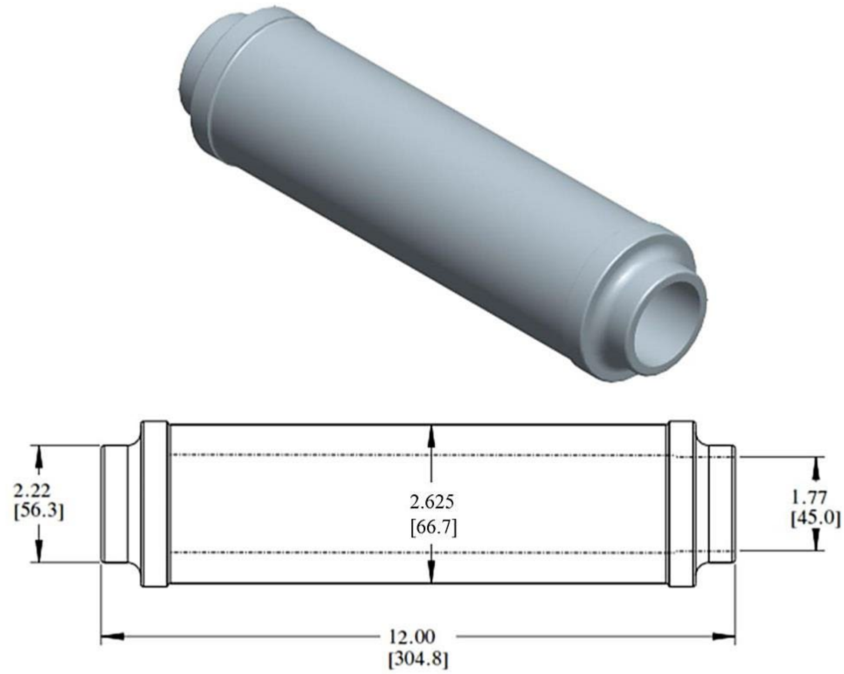


Figure 24-S-11. Schematic of the Muffler

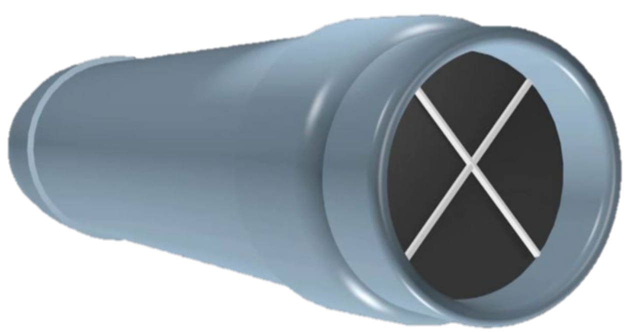


Figure 24-S-12. Safety Wire Affixed to inside of the Muffler for Restraining Foam Insert

Air Temperature

The temperature of the inlet air measured at the sonic nozzle must be maintained at 50 ± 10°F (10 ± 6°C) for the duration of a test. This can be achieved by constructing a heat exchange system as described later in this section.

Air Diffusion Using Stator and Turbulator

The stator and turbulator are used to deflect and diffuse the airflow within the Sonic burner. Three-dimensional drawing files can be used to fabricate the components on a Computer Numerical Control (CNC) milling machine. These files can be downloaded from the Fire Safety Website:

http://www.fire.tc.faa.gov/materials/burnthru/nexgen.stm

Stator

The stator is a four-vane internal component that creates a swirling of internal airflow, and aligns the fuel tube with the center axis of the draft tube (figure 24-S-13). The stator is 4 inches (102 mm) in diameter and should have a snug fit when placed inside the draft tube. A suitable stator is supplied by Marlin Engineering, part number ME1513-3.

Figure 24-S-13. Stator

Turbulator

The turbulator is a 4-inch (102-mm) diameter component, for air swirling, placed in the end of the draft tube. The center hole is 2.75 inches (69.9 mm) in diameter (figure 24-S-14). A suitable turbulator is supplied by Marlin Engineering, part number ME1512-1.

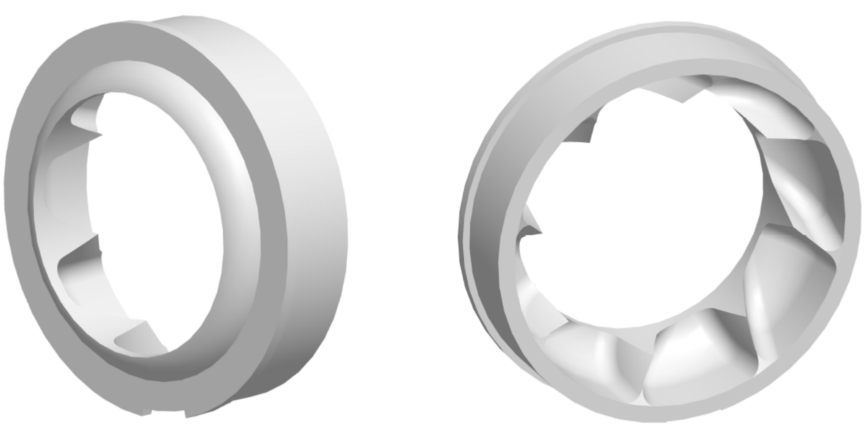


Figure 24-S-14. Turbulator, Front View and Back View

Stator and Turbulator Configuration

The stator slides onto the fuel tube, is oriented in the proper direction, and is locked into place with a set screw located at the twelve o'clock position (figure 24-S-15). The turbulator is placed on the end of the draft tube with the tab located at the six o'clock position (figure 24-S-16). The typical configuration positions the face of the stator approximately 2.6875 inches (68.263 mm) from the exit plane of the turbulator (figure 24-S-17). Refer to the Preparation of Apparatus section of this supplement for the exact positioning of the stator and turbulator.

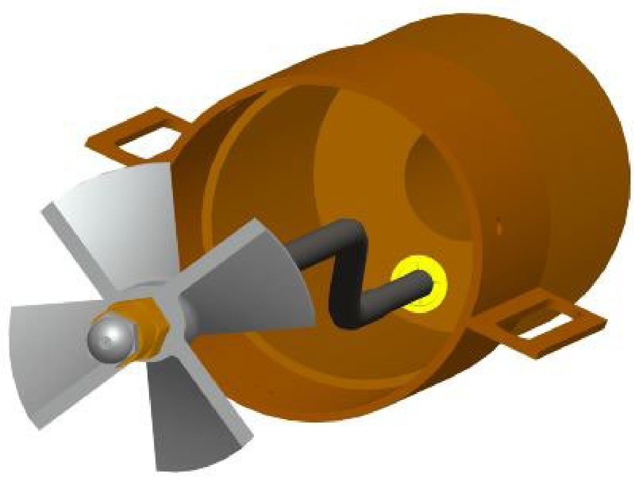


Figure 24-S-15. Location of the Stator on the Fuel Tube

Figure 24-S-16. Position of Turbulator at the end of the Draft Tube

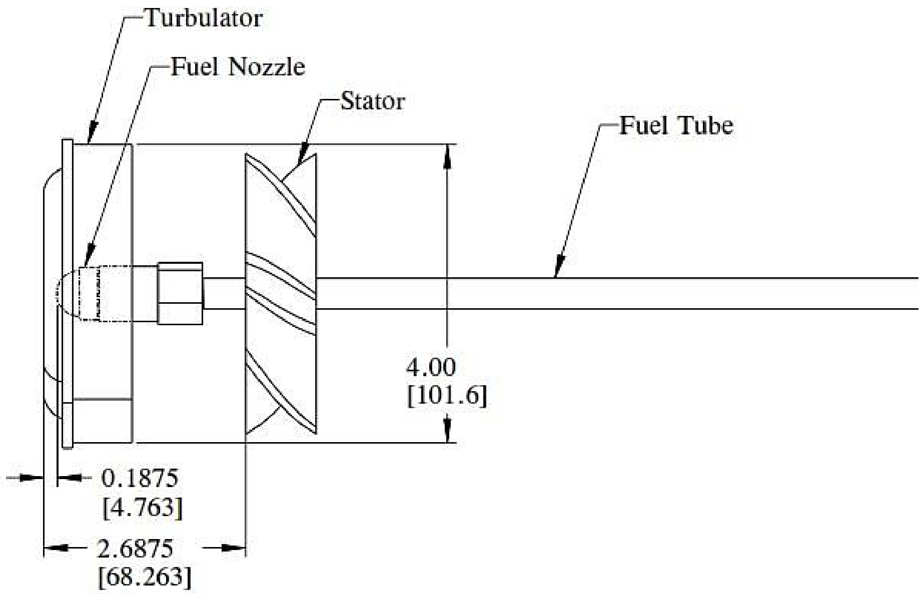


Figure 24-S-17. Typical Configuration of the Stator and Turbulator

Fuel System

A method of fuel pressurization is required to deliver the proper amount of fuel to the spray nozzle for consistent atomization. The delivered fuel pressure is typically in the range of 100 – 120 lbs/in^2 (0.689 – 0.827 MPa), and must maintain the desired pressure for the duration of a test. A suitable method of fuel pressurization is a pressurized fuel tank (figure 24-S-18). Alternatively, a fuel pump may be used provided it can maintain the required pressure for the duration of a test with minimal fluctuation so as to maintain 6 gal/hr ± 0.2 gal/hr (22.68 L/hr ± 0.756 L/hr).

A fuel pressure vessel, or tank, such as McMaster-Carr part number 1584K7 with a 15-gallon (56.8-liter) capacity, measuring 12 inches (305 mm) in diameter and 33 inches (838 mm) tall, or 35 inches (889 mm) tall including mounting base, can be used to contain the fuel. The tank has various fittings on the top, bottom, and sides to allow for connection of pipe fittings for filling, discharging, fuel quantity level, pressure measurement, pressurization, and venting. Nitrogen is used to pressurize the headspace of the fuel tank. Solenoid or manual valves can be used to start and stop the flow of fuel, nitrogen, and vent gas. The headspace gas pressure is controlled by a precision regulator, and monitored using a fuel pressure gauge. A high pressure translucent tube can be used for indicating the fuel level in the tank.

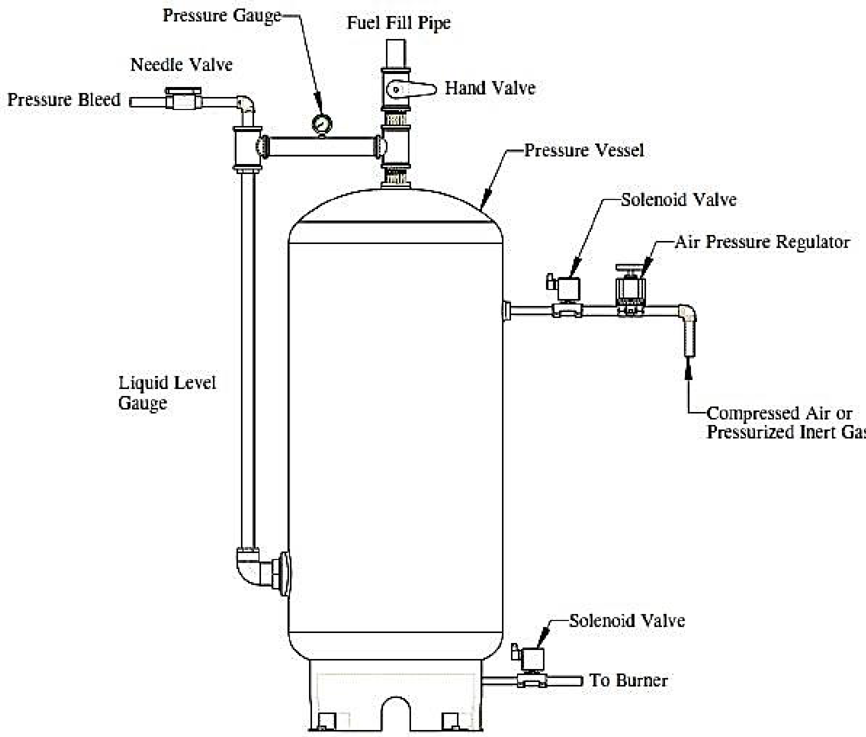


Figure 24-S-18. Schematic of Pressurized Fuel Tank System

Fuel Pressure Measurement Device

A suitable pressure gauge or transducer must be used to monitor the pressure inside the fuel tank, which is critical for establishing the proper flow of fuel into the fuel nozzle. The pressure gauge or transducer must have NIST (or equivalent) traceable certification with a $\pm$ 2% accuracy or less. If a pressure transducer is not used, digital gauges capable of reading in increments of 1 lbs/in^2 (0.007 MPa) or less are recommended. If an analog gauge is used, it should be glycerin-filled to reduce needle flutter, and have an easily readable dial. The gauge must also have a working range appropriately suited for the range of fuel pressures typically used during tests. A suitable pressure transducer is supplied by Omega Engineering, part number PX329-150G5V. A suitable digital gauge is supplied by Omega Engineering, part number DPG1001B-500G; a suitable analog gauge is supplied by McMaster-Carr, part number 4053K23 with a 0-160 psi (0-1.1 MPa) pressure range (figure 24-S-19).

Figure 24-S-19. Analog Fuel Pressure Gauge

Fuel Temperature

The fuel entering the burner fuel tube must be maintained at a temperature range of 42 ± 10°F (5.5 ± 5.5°C) for the duration of a test. This can be achieved by constructing a heat exchange system as described later in this supplement.

Fuel Tube

The fuel tube in the Sonic burner is designed to allow both the fuel nozzle and the airflow to be aligned with the axis of the draft tube. This is accomplished by creating two bends in the section of the fuel tube that enters the back of the burner (figure 24-S-20). The tube is constructed from schedule-80, thick wall, 0.125-inch (3.175-mm) steel pipe with an outside diameter of 0.405-inch (10.287-mm), an inside diameter of 0.215-inch (5.461-mm), and a wall thickness of 0.095-inch (2.413-mm). The tube is cut to a length of approximately 21.5 inches (546.1 mm); a section of the outer wall is removed on a lathe to fit the fuel tube through the keyless bushing that holds the tube in place. The outer diameter of the fuel tube is reduced to approximately 0.3750 inch (9.525 mm) for a length of 4 inches (101.6 mm) at one end. The tube is then shaped with a pipe bender according to the dimensions in the drawing. A die is used to thread both ends of the tube with 0.125-inch NPT pipe threads. Heavy duty 0.004-inch-thick (0.102-mm-thick) thread seal tape is wrapped on the pipe threads to prevent fuel leakage. A 1.375-inch-long (34.925-mm-long) brass fuel nozzle adapter is threaded onto the front end of the fuel tube where the fuel nozzle will be attached. A keyless bushing (Fenner Drives p/n 6202109) is used to hold the back end of the fuel tube in place. A pipe fitting is attached to the back end of the fuel tube to connect the pressurized fuel system to the fuel tube.

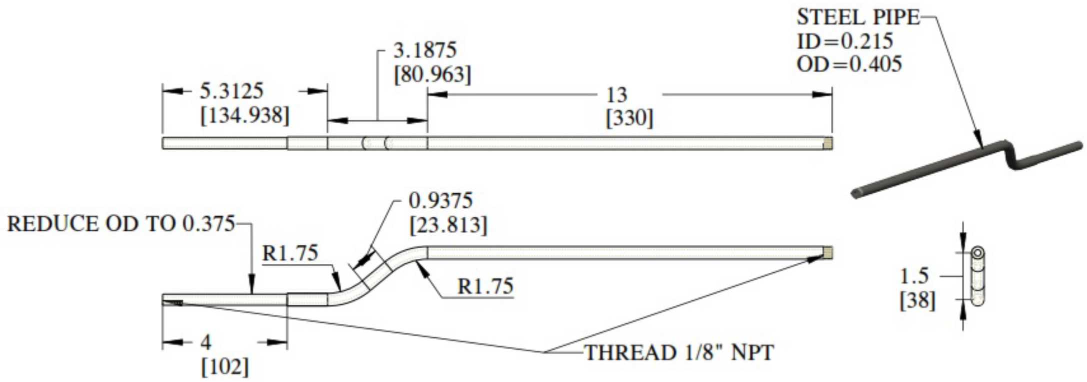


Figure 24-S-20. Schematic of the Fuel Tube

Fuel Nozzle

The fuel nozzle for the Sonic burner should be an 80-degree solid conical spray pattern oil burner nozzle. The nozzle flowrate will depend on the test method. The rated flow rate provided by the manufacturer is achieved when applying a 100 lb/in^2 (0.71 MPa) pressure to the nozzle. If a different flow rate is desired, the pressure can be adjusted accordingly to achieve a wide range of flow rates. In general, the flow rate is related to the pressure by:

$$F_d = F_r \sqrt{P_d / P_r}$$

In which F_d is the desired flow rate, F_r is the rated flow rate, P_d is the desired pressure, and P_r is the rated pressure, typically 100 psig (0.71 MPa). For example, if a 5.5-gal/hr (20.8 L/hr)-rated nozzle is operated at 120 lb/in^2 (0.83 MPa), a flow rate of 6.0 gal/hr (22.7 L/hr) will be achieved. A Delavan, 80-degree, 6.0 gal/hr (22.68 L/hr), all purpose W-type spray nozzle has been found suitable for this application.

Nozzle Adapter

The fuel nozzle adapter is a brass fitting 1.375 inches (34.9 mm) in length with a 0.125-inch NPT thread on the inlet side and 0.5625-inch 24 Unified Fine Thread (UNF) thread where the nozzle attaches (figure 24-S-21).

Figure 24-S-21. Fuel Nozzle and Brass Adapter

Fuel

Use jet fuel (JP-8, Jet A, or their international equivalent), or ASTM K2 fuel (Number 2 grade kerosene) to yield the desired fuel flow rate within the specified pressure range for the test method being performed. Diesel fuel may also be used, however the test condition may be more severe.

Ignition

A high voltage oil burner ignition transformer with an output of 10 kilovolts is used to create an arc across an automotive type spark plug mounted in the burner extension cone. The spark plug uses a standard 14 mm diameter thread size with a thread pitch of 1.25 mm. The threaded segment of the spark plug is 0.36 inches (9.1 mm) in length. The exposed portion of the central insulator measures 0.70 inches (17.8 mm) in length. The spark plug gap must be opened to 0.100 inches (2.5 mm) in order to consistently ignite the fuel/air charge in the burner cone (figure 24-S-22). A suitable spark plug is manufactured by Champion Products, manufacturer part number RJ19LM, and can be purchased through Grainger (www.Grainger.com), part number 12U891.

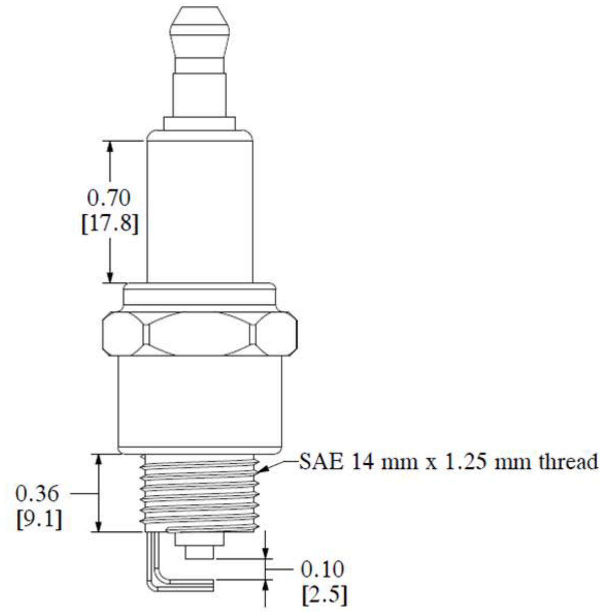


Figure 24-S-22. Dimensioned Drawing of a Spark Plug

Heat Exchange System

A heat exchange system is used to regulate the temperature of the burner inlet air and fuel as the flow rate of each is dependent upon the density of the air and fuel. A schematic of a suitable heat exchange system is displayed in figure 24-S-23. The ice bath can be constructed from an insulated cooler or a chest freezer with temperature control capability. The fuel travels through coiled copper tubing in the ice bath and out to the burner. The air is cooled in a heat exchanger, such as McMaster-Carr part number 43865K78, which has ice water traveling through the outer shell, removing heat from the air. The ice water is circulated in a closed-loop from the cooler to the heat exchanger by means of a submersible pump. The exact dimensions of the copper coils and the flowrate of the water pump will be dependent upon the particular conditions in the laboratory. Alternate methods such as active heating and cooling systems can be used, allowing greater precision, but may be more costly.

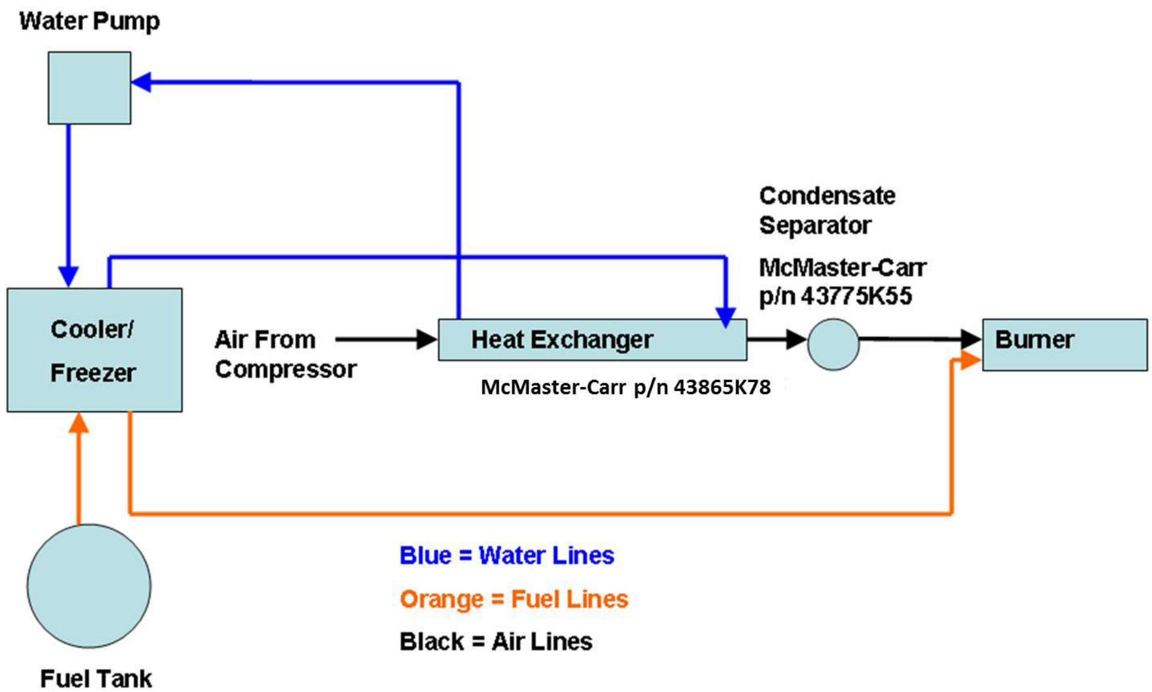


Figure 24-S-23. Schematic of Air/Fuel Heat Exchange System

Burner Cone

A 12 ± 0.125-inch (305 ± 3-mm) burner extension cone is fitted to the end of the draft tube. The cone is constructed from 16 gauge American Iron and Steel Institute (AISI) type 310 stainless steel. The cone exit plane must be 6 ± 0.250 inches (152 ± 6 mm) high and 11 ± 0.250 inches (280 ± 6 mm) wide, with a thickness of 0.0625 ± 0.015 inch (1.59 ± 0.381 mm). Refer to figures 24-S-24 and figure 24-S-25 for detailed drawings. The hot and cold cycling that occurs during typical testing can cause the cone exit plane dimensions to shift due to warpage. It is critical to periodically check the cone exit plane dimensions to ensure they remain within the specified tolerances. It is recommended this check be performed at the beginning and end of each day the burner is operated. A cone found to be out of tolerance should be repaired or replaced before continuing operation of the burner. A reinforcement frame may be added to the cone to reduce the potential of cone warpage. Refer to figure 24-S-26 for detailed drawings.

NOTE 1: Park type burner cones are 18 gauge 310 stainless steel or similar alloy while Sonic type burners are 16 gauge 310 stainless steel.

NOTE 2: The welded seam connecting the burner cone mounting flange and burner cone extension should align with the end of the burner draft tube.

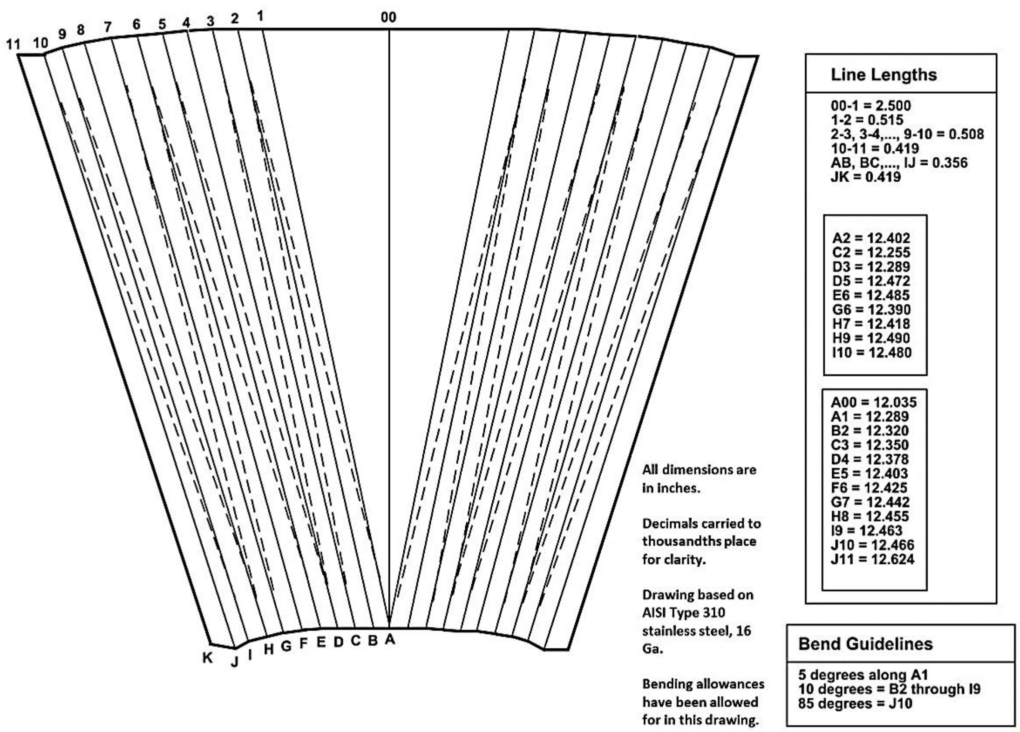


Figure 24-S-24. Burner Cone Layout and Bending Pattern

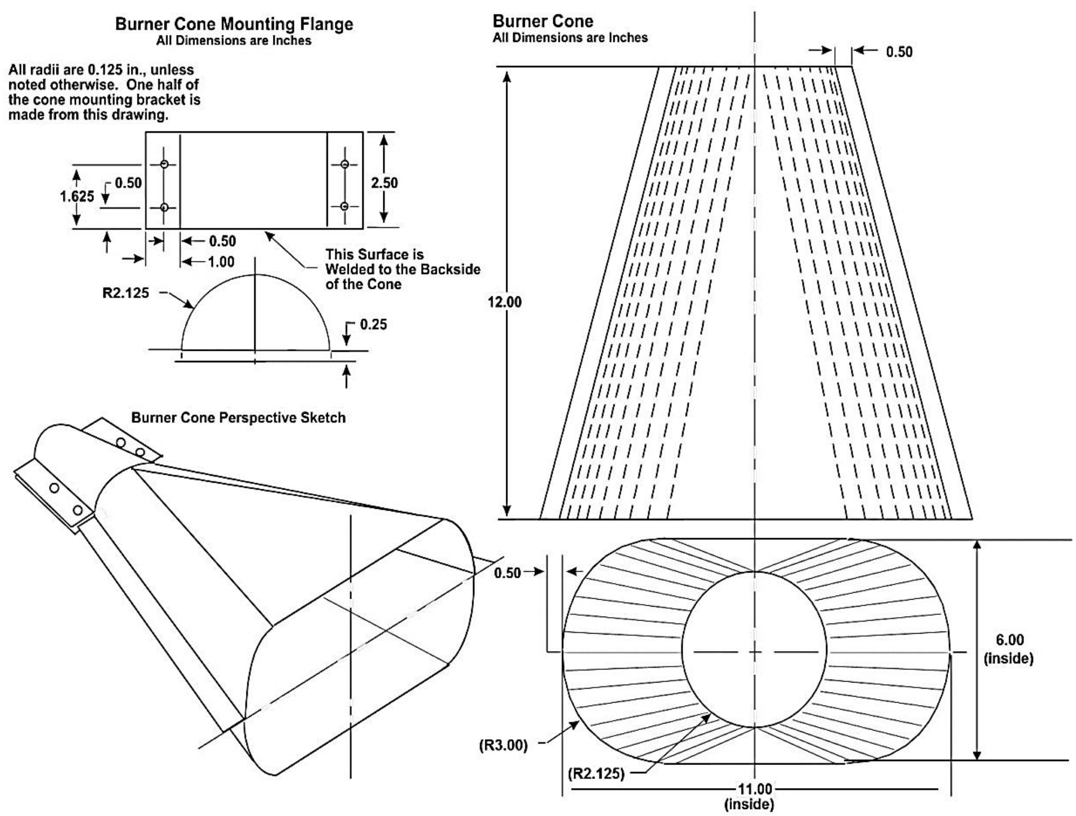


Figure 24-S-25. Burner Cone Details

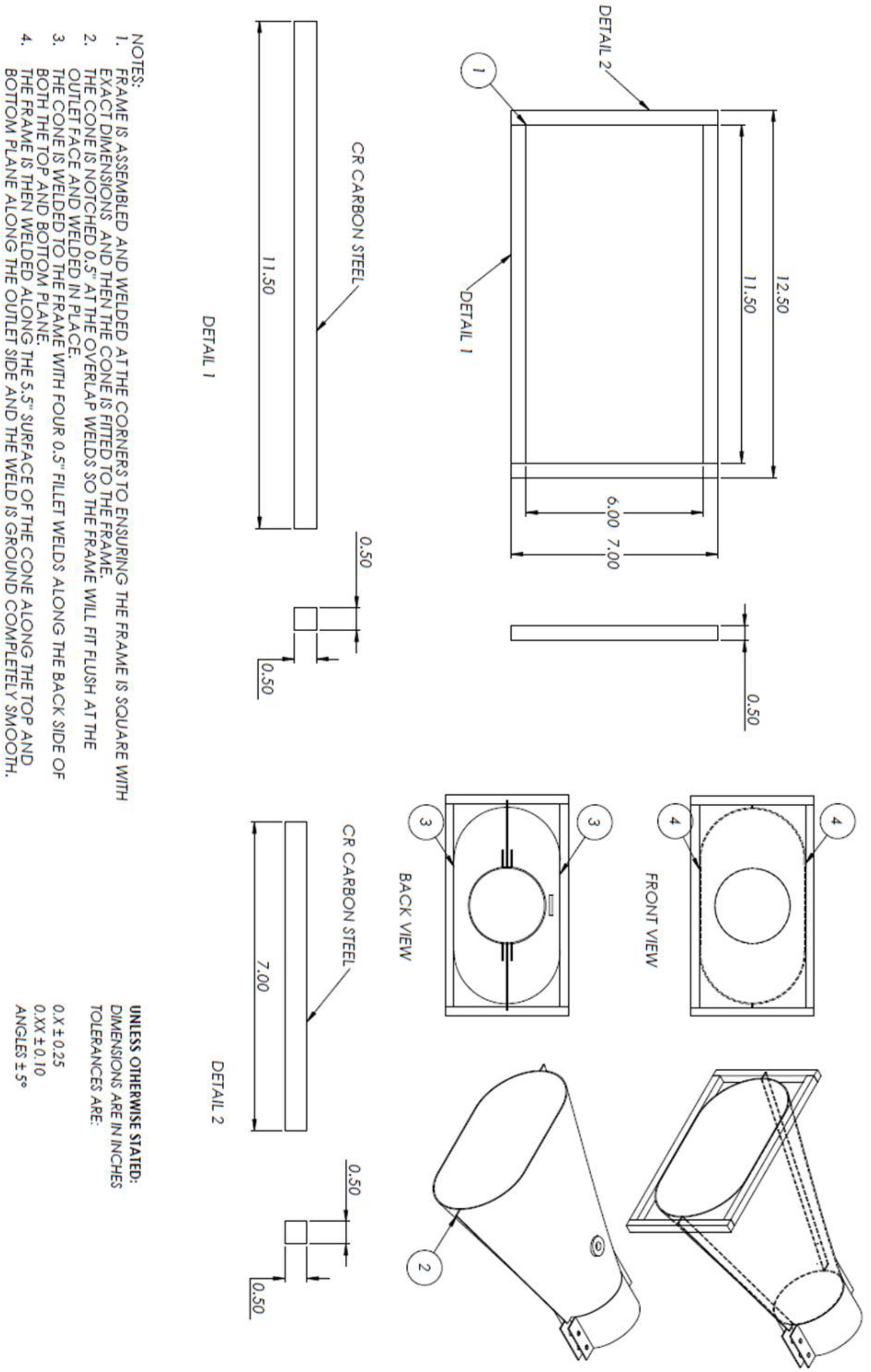


Figure 24-S-26. Burner Cone Reinforcement Frame

Threaded Boss for Spark Plug

A threaded boss must be welded to the side of the burner extension cone for acceptance of the spark plug used to ignite the fuel charge. The threaded boss must be fabricated from American Iron and Steel Institute (AISI) type 310 stainless steel. The cylindrical boss must measure 1.125 inches (28.58 mm) in diameter, with a thickness of 0.250 inches (6.4 mm). The boss must be threaded using an SAE standard 14 mm x 1.25 mm spark plug tap (figure 24-S-27).

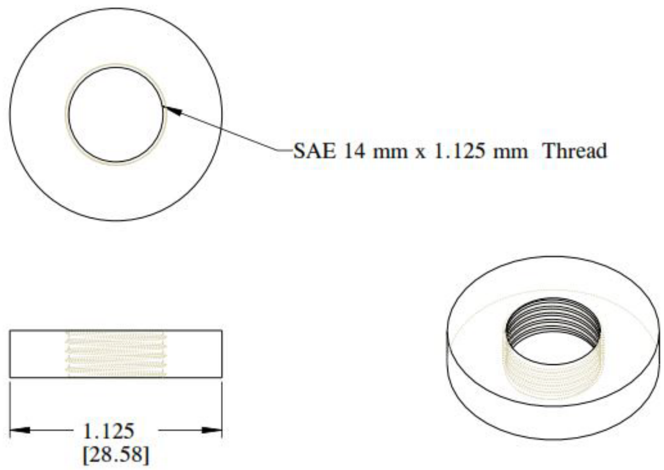


Figure 24-S-27. Threaded Boss

Burner Measurement Locations

Accurate measurements of the Sonic burner inlet parameters are critical to proper operation. The measurement locations of the burner air and fuel supply are typically located just prior to entering the burner housing, or as near the burner housing as possible. An example of acceptable measurement locations of the burner air and fuel supply are indicated in figure 24-S-28.

Air Pressure

The sonic nozzle inlet pressure is measured with a suitable pressure gauge or transducer mounted just upstream from the sonic nozzle. The gauge or transducer should measure accurately in the range of 0-60 lbs/in^2 (0-0.41 MPa), with an accuracy of $\pm$ 2% maximum. Bourdon type gauges and pressure transducers have proven to be suitable for this measurement (see details in Air Pressure Measurement Device above).

Air Temperature

The burner air temperature is measured with a 0.125-inch (3.2 mm) diameter, insultation packed, 310 stainless steel sheathed, type K (Chromel-Alumel) grounded junction thermocouple with a nominal 24 AWG conductor. The thermocouple should be inserted into the air stream just upstream of the sonic nozzle with the tip located near the center of the air supply stream. In some testing situations, flame radiation may be incident upon the inlet air lines, causing heating of the air and possible bursting of flexible hoses. It is important to shield all air lines with thermal wrapping to prevent an unsafe condition and maintain steady air temperature.

Fuel Pressure

The burner fuel pressure is measured with a suitable pressure gauge (see Fuel Pressure Measurement Device above) mounted in a T-connection in the fuel inlet line near the back of the burner. It is important that the measurement location be as close to the back of the burner as possible to accurately measure the fuel pressure at the point it enters the burner.

Fuel Temperature

The burner fuel temperature is measured with a 0.125-inch (3.2 mm) diameter, insulation packed, 310 stainless steel sheathed, type K (Chromel-Alumel) grounded junction thermocouple with a nominal 24 AWG conductor. The thermocouple should be mounted in a T-fitting such that the probe tip is located near the center of the fuel tube. In some testing situations, flame radiation may be incident upon the inlet fuel lines, causing heating of the fuel and possible bursting of flexible hoses. It is important to shield all fuel lines with thermal wrapping to prevent an unsafe condition and maintain steady air temperature.

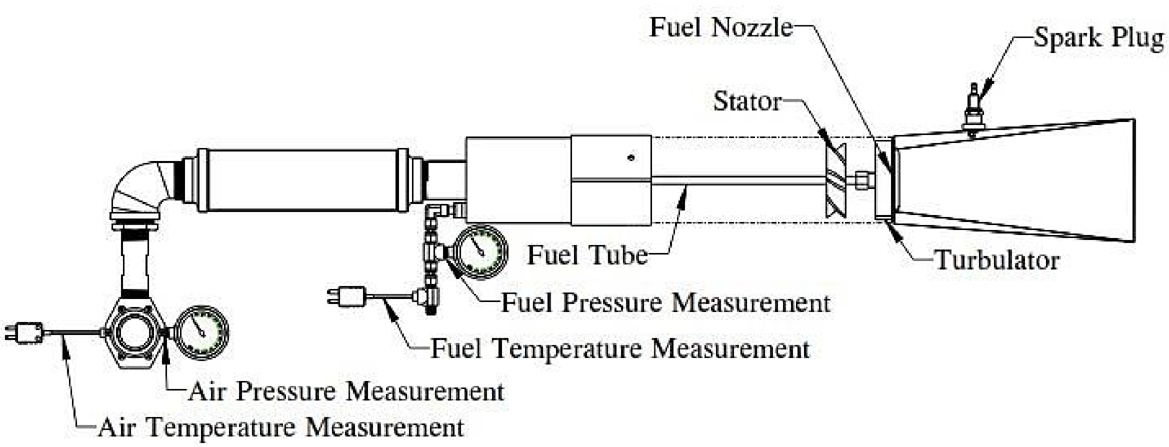


Figure 24-S-28. Burner Schematic Showing Inlet Measurement Locations

Sonic Burner Configuration

Fuel Nozzle Location

The tip of the fuel nozzle, or fuel exit plane, must be located 0.1875 ± 0.020 inch (4.763 ± 0.5 mm) from the exit plane of the turbulator (figure 24-S-29).

Stator Adjustment

The stator is positioned by adjusting its translational position as well as its axial position on the fuel tube.

Stator Translational Position

The front face of the stator must be located 2.6875 ± 0.020 inches (68.263 ± 0.5 mm) from the exit plane of the turbulator (figure 24-S-29). This stator translational position is also 2.5 inches (63.5 mm) from the tip of the fuel nozzle.

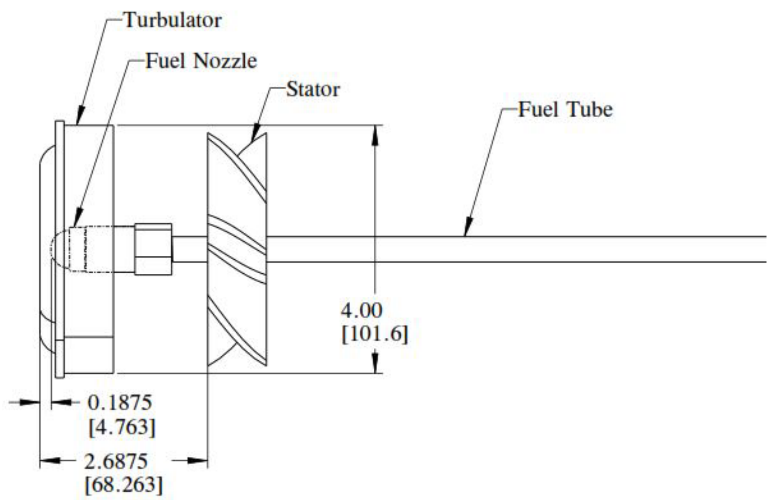


Figure 24-S-29 Fuel Nozzle and Stator Locations

Stator Axial Position

The line running through the set screw and geometric center of stator will be used as a reference for properly orienting the rotational position of the stator. The stator must be positioned so the reference line angle is 0 degrees (12 o'clock) from the zero position when looking into the burner draft tube. (figure 24-S-30).

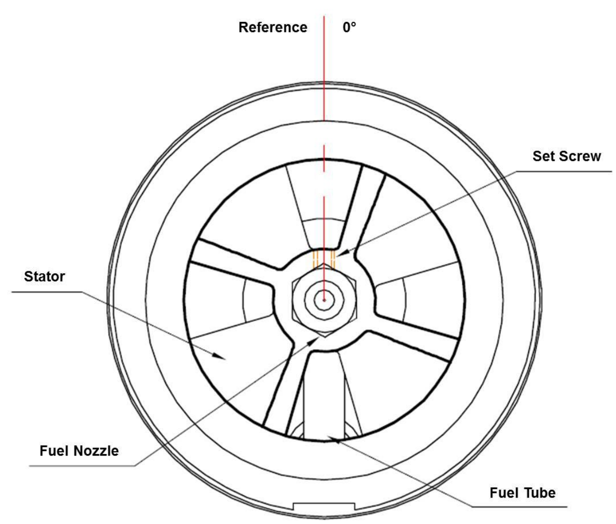


Figure 24-S-30 Stator Axial Position (looking into draft tube)

Spark Plug Location

The spark plug should be mounted in a threaded boss, on the surface of the burner cone. The spark plug is located at a distance 6 ± 0.125 inches (152 ± 3 mm) from the end (intake plane of burner cone) (figure 24-S-31).

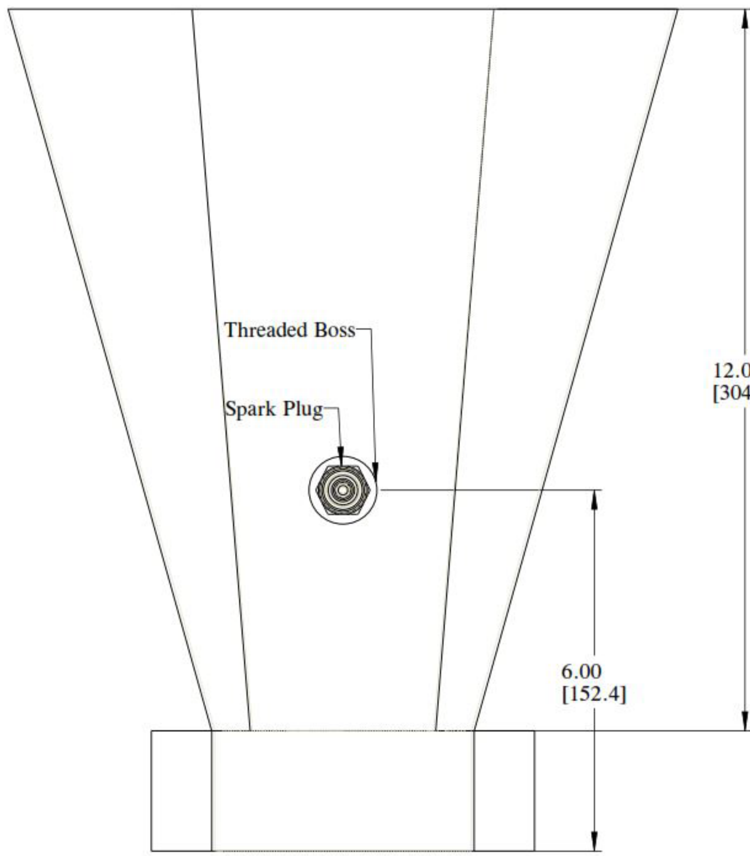


Figure 24-S-31. Spark Plug Location in Burner Cone

Spark Plug Gap

The spark plug gap (distance) between the two electrodes must be 0.100 inches (2.5 mm) as shown in figure 24-S-32.

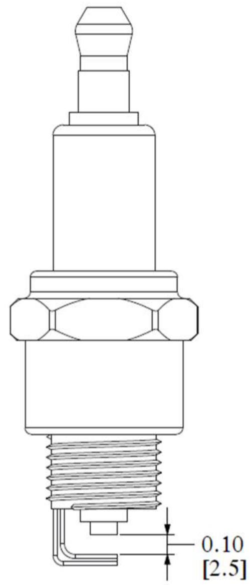
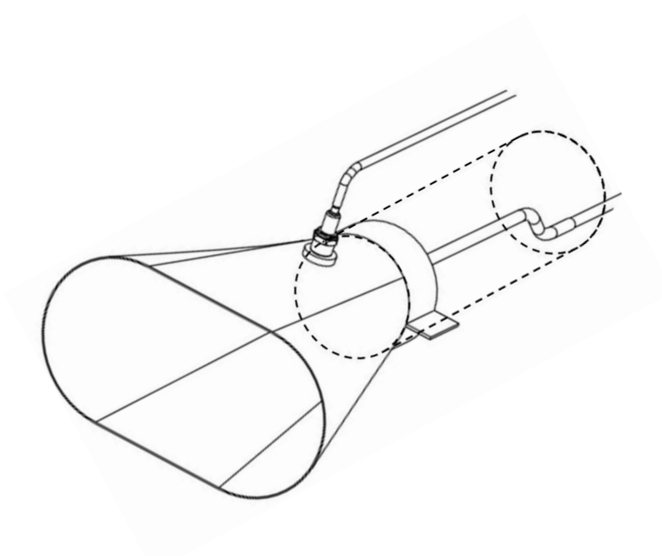


Figure 24-S-32. Spark Plug Gap Measurement

Spark Plug Wire Routing

The length and arrangement of the spark plug wires must be monitored to prevent heat damage during flame consistency validation and testing. Once the air/fuel mixture is ignited, the outside surface temperature of the burner cone will increase rapidly, becoming capable of damaging the wire if it comes in contact with the cone. The spark plug wire should be carefully routed to prevent contact with the cone or other hot surfaces, and should also be shielded in a heat-resistant covering to further protect it from convective heat damage from the burner flames. The wire can be routed as shown in figure 24-S-33, in which the wire does not contact any components in the vicinity of the burner cone.



24-S-33. Proper Routing of the Spark Plug Wires

Volumetric Air Flow Control

The volumetric airflow is controlled via a regulated sonic nozzle. Adjust the upstream supply air pressure to 60 ± 2 lbs/in^2 (0.41 ± 0.014 MPa). The intake air temperature must be maintained within the range of 40ºF to 60ºF (4ºC to 16ºC). For additional details, refer to sections "Sonic Nozzle" and "Air Pressure Regulator" in this supplement.

Fuel Flow Calibration

If a calibrated flow meter is not available, measure the fuel flow directly using a length of Tygon® tubing and appropriately sized graduated cylinder. Slip the Tygon® tubing over the end of the fuel nozzle, making certain to establish a good seal. Direct the exit of the Tygon® tubing into a small bucket or other collection basin. Turn on the fuel solenoid, making sure the ignition system is off. After establishing a steady stream of fuel flow, simultaneously direct the tubing exit into the graduated cylinder while beginning the stopwatch or timing device. Collect the fuel for a 2-minute period, making certain to immediately direct the tubing exit away from the graduated cylinder at precisely 2 minutes. Calculate the flow rate and ensure that it is 6 ± 0.2 gal/hr (22.68 L/hr ± 0.756 L/hr). If the flow rate is not within the tolerance, adjust the fuel pressure accordingly. Record the fuel pressure necessary to achieve the required fuel flow. The recorded fuel pressure must be monitored and maintained during burner operation, and fluctuate no more than ± 2 lbs/in^2 (± 13.8 kPa) during flame consistency validation and sample testing. A flame temperature validation or sample test will be void should the fuel pressure fluctuate outside of this range during either procedure. The temperature of the fuel must be maintained within the range of 32ºF to 52ºF (0ºC to 11ºC).

NOTE: It is important to establish a steady stream of fuel before starting the fuel flow measurement process. It is recommended the fuel flow steadily from the hose for a minimum 10-second period before collecting fuel in the graduated cylinder.

Instrumentation and Supporting Equipment

Burner Flame Temperature Consistency Validation Thermocouples

Seven thermocouples must be used to check the flame temperature of the burner. The thermocouples must be 0.125-inch (3.2-mm) diameter, insulation packed, 310 stainless steel sheathed, type K (Chromel-Alumel), grounded-junction with a nominal 24 American Wire Gauge (AWG) size conductor. Thermocouples purchased with a certificate of calibration may provide more accurate readings but are not required. The seven thermocouples must be attached to a steel mounting plate to form a thermocouple rake for placement in the test stand during the burner flame consistency validation (figure 24-S-34). It is recommended the thermocouple mounting plate be a minimum of 4 inches (102 mm) away from the tips of the thermocouples.

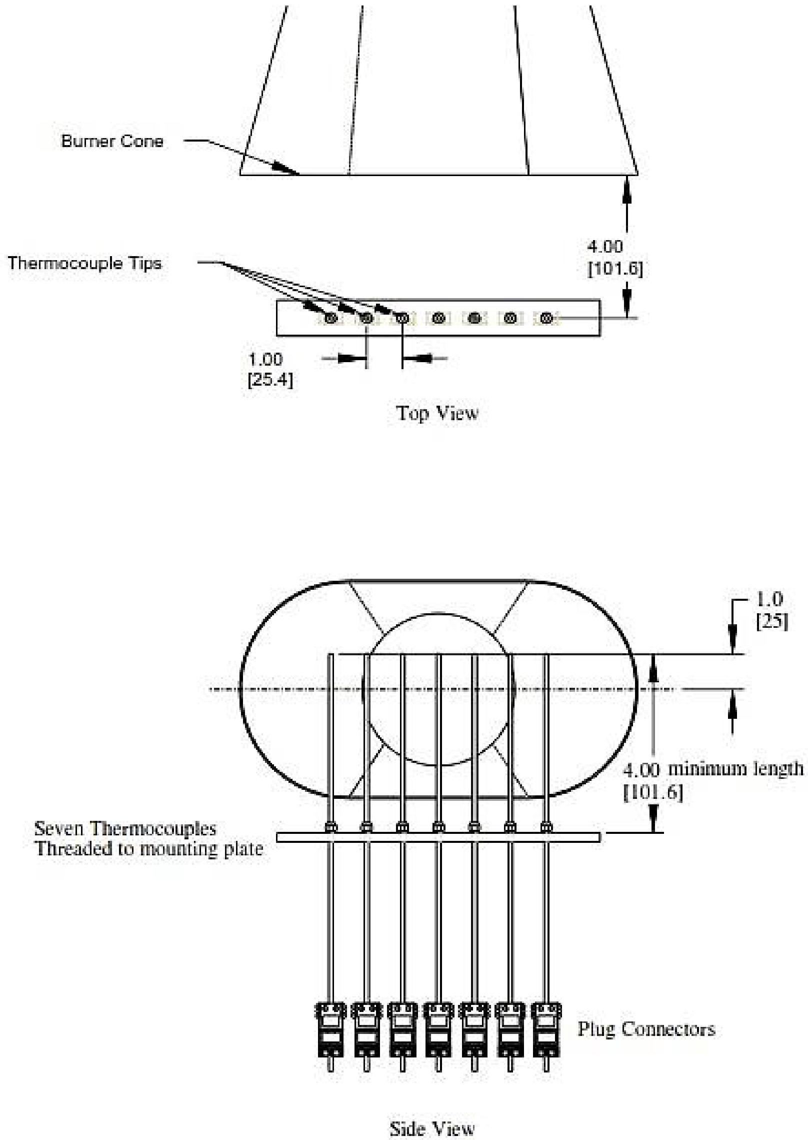


Figure 24-S-34. Top and Side View of Thermocouple Rake Bracket

Burner Flame Temperature Consistency Validation

Examine and clean the burner cone of any evidence of buildup of combustion products, soot, etc. Soot build-up inside the cone may affect the flame characteristics and cause difficulties during flame consistency validation. Check the burner cone dimensions are within specified tolerances before flame validation.

Mount the thermocouple rake on a movable stand that is capable of being quickly translated into position in front of the burner. Move the rake into flame validation test position and check the distance of each of the seven thermocouples to ensure that they are located 4 ± 0.125 inches (102 ± 3 mm) from the vertical plane of the burner cone exit. Ensure that the horizontal centerline of the thermocouples are offset 1 ± 0.0625 inch (25.4 ± 1.6 mm) above the horizontal centerline of the burner cone (see figure 24-S-34). Place the center thermocouple (thermocouple number 4) in front of the vertical centerline of the burner cone exit. Note that the thermocouple rake movable stand must incorporate detents that ensure proper centering of the thermocouple rake with respect to the burner cone, so that rapid positioning of the rake can be achieved during the validation procedure. Once the proper position is established, move the thermocouple rake away, and move back into the validation position to re-check distances. When all distances and positions are confirmed, move the thermocouple rake away from burner.

While the thermocouple rake is away from the burner, turn on the spark plug, pressurized air and fuel flow, and light the burner. Allow the burner to warm up for a period of 2 minutes. After warm-up, move the thermocouple rake into position and allow 1 minute for thermocouple stabilization, then record the temperature of each of the seven thermocouples once every second for a period of 30 seconds. Remove the thermocouple rake from flame temperature validation position and turn off burner. Calculate the average temperature of each thermocouple over this period and record. Although not a requirement for testing, the recommended average temperature of each of the seven thermocouples should be 1900°F ± 100°F (1038°C ± 55°C). The burner should be rechecked to ensure it is configured properly if temperatures are measured outside of this recommended range. A flame that appears biased to one side, or produces significantly higher temperatures on one end of the flame validation thermocouple rake, may indicate an adjustment of the fuel nozzle and/or internal stator orientation and/or distance from the end of the draft tube may be necessary, provided the adjustments are within allowable tolerances. If no problems are found with the burner, any thermocouple reading outside of this range may require replacement. It is recommended that the burner flame temperature be validated at the beginning and end of each day testing is performed.

NOTE 1: The thermocouples are subjected to high temperature durations during calibration. Because of this type of cycling, the thermocouples may degrade with time. Small but continuing decreases or extreme variations in temperature or "no" temperature reading at all are signs that the thermocouple or thermocouples are degrading or open circuits have occurred. In this case, the thermocouple or thermocouples should be replaced in order to maintain accuracy in calibrating the burner. It is recommended that a record be kept for the amount of time the thermocouples are exposed to the oil burner's flame.

NOTE 2: The Sonic burner is sensitive to proper alignment of the fuel nozzle. It is crucial that the fuel nozzle be aligned to the geometric center of the turbulator. A slight adjustment of the fuel tube between the stator and fuel nozzle may be required to obtain an even temperature profile across the thermocouple rake. The center point of the nozzle where the fuel exits should not deviate more than 0.0625 inches from the geometric center of the turbulator exit plane when looking into the burner draft tube. This should be performed only after checking the burner for proper configuration.