Chapter 8
Oil Burner Test for Cargo Liners

8.1 Scope

8.1.1 This test method evaluates the flame penetration resistance capabilities of aircraft cargo compartment lining materials utilizing a high-intensity open flame to show compliance to the requirements of FAR 25.855.

8.2 Definitions

8.2.1 Burnthrough

Burnthrough is defined as flame penetration of the test specimen or the development of a visible breach, opening, gap, fissure, or any void through which a flame penetrates during the test. The development of any such void that allows flame passage during the test period shall be cause for failure.

8.2.2 Specimen Set

A specimen set consists of three or more replicates of a ceiling and sidewall cargo liner panel installation.

8.3 Apparatus

8.3.1 Test Specimen Frame

The test specimen frame is shown in figures 8-1 and 8-2.

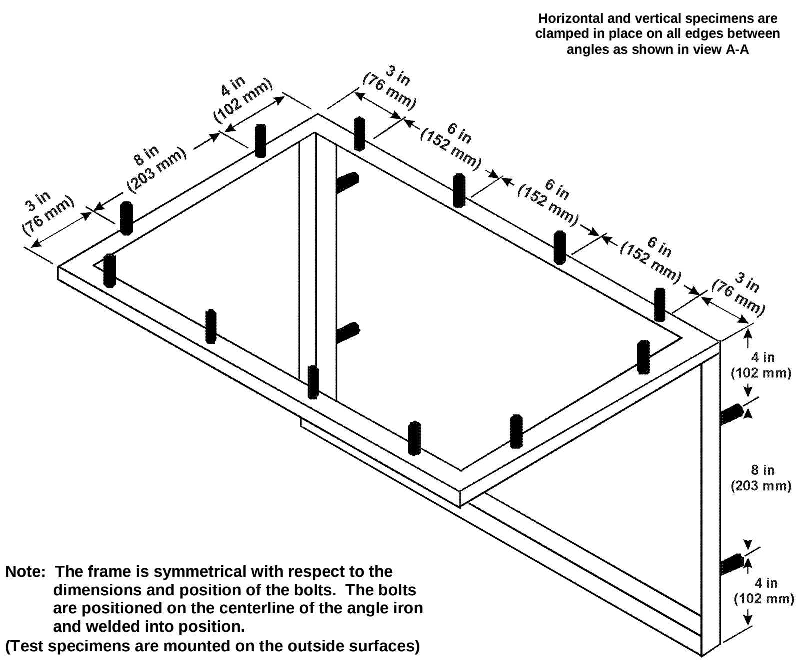


Figure 8-1. Cargo Liner Test Specimen Frame

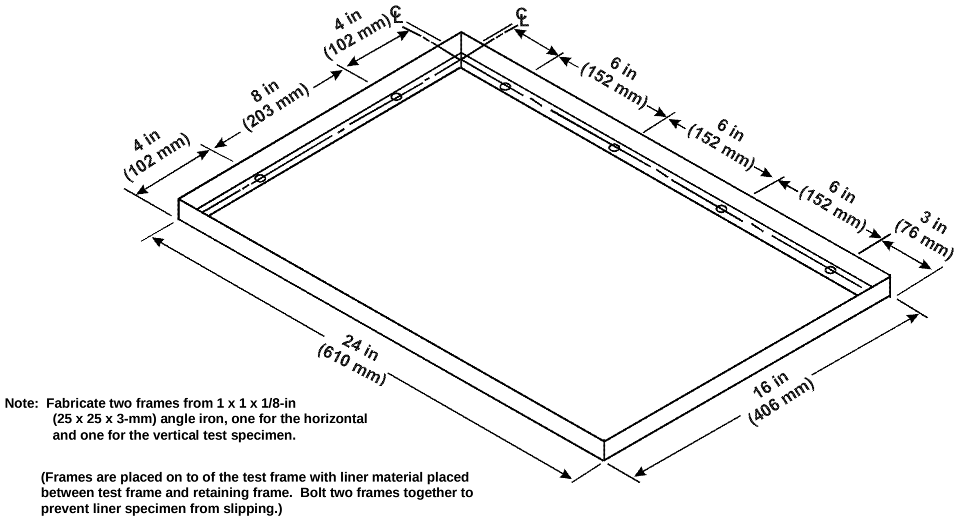


Figure 8-2. Cargo Liner Test Specimen Retaining Frame

8.3.2 Test Burner

If a NexGen Sonic type burner is to be used, see section 8.3 in the Chapter 8 Supplement for all test burner information. Otherwise, the burner will be mounted on a swiveling device capable of allowing it to be directed away from the test specimen during warmup as shown in figure 8.3. The burner will be a modified gun type, such as Park Model DPL 3400, Lennox Model OB-32, or Carlin Model 200 CRD. Flame characteristics can be enhanced by the optional use of a static disk or tabs. Major deviations, such as a different burner type, should have thorough comparison testing. Temperature and heat flux measurements, as well as test results, must correspond to those produced by an FAA approved burner.

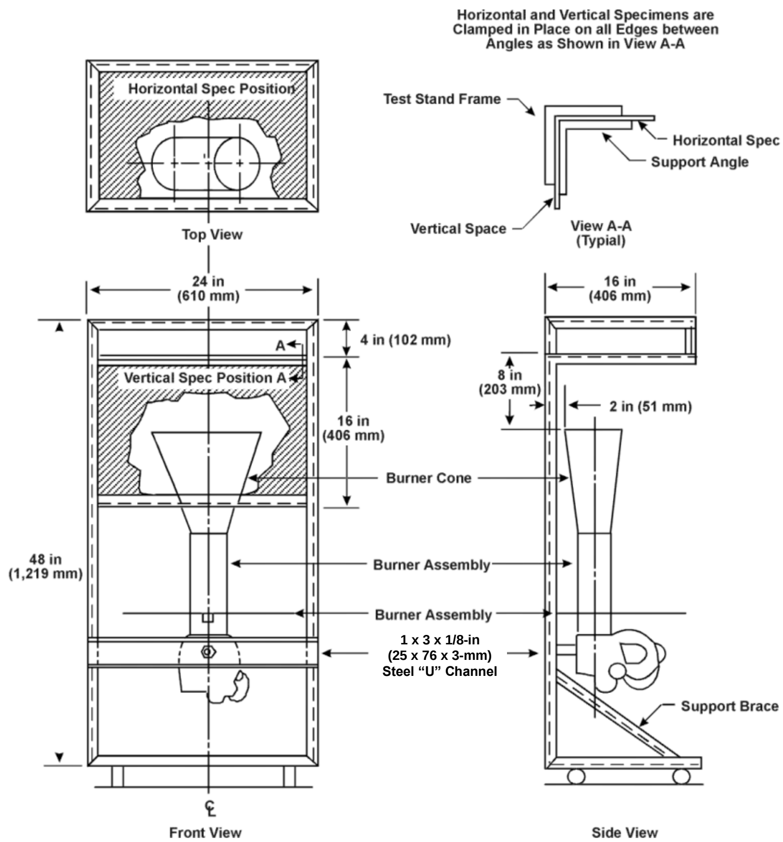


Figure 8-3. Test Apparatus for Horizontal and Vertical Mounting for Cargo Liner Oil Burner Testing

8.3.2.1 Nozzle

A nozzle will be provided to maintain the fuel pressure to yield a nominal 2 ± 0.1 gal/hr (0.126 ± 0.0063 liter/min) fuel flow (see Chapter 8 Supplement).

8.3.2.2 Burner Cone

A 12 ± 1/8-inch (305 ± 3-mm) burner cone will be installed at the end of the draft tube. The cone will be made of stainless steel or a similar type of noncorrosive high-temperature metal and will have a thickness of 0.065 ± 0.015 inch (1.65 ± 0.381 mm). The opening of the cone will be 6 ± 1/4 inches (152 ± 6 mm) high and 11 ± 1/4 inches (280 ± 6 mm) wide
(see figures 8-4a and 8-4b).

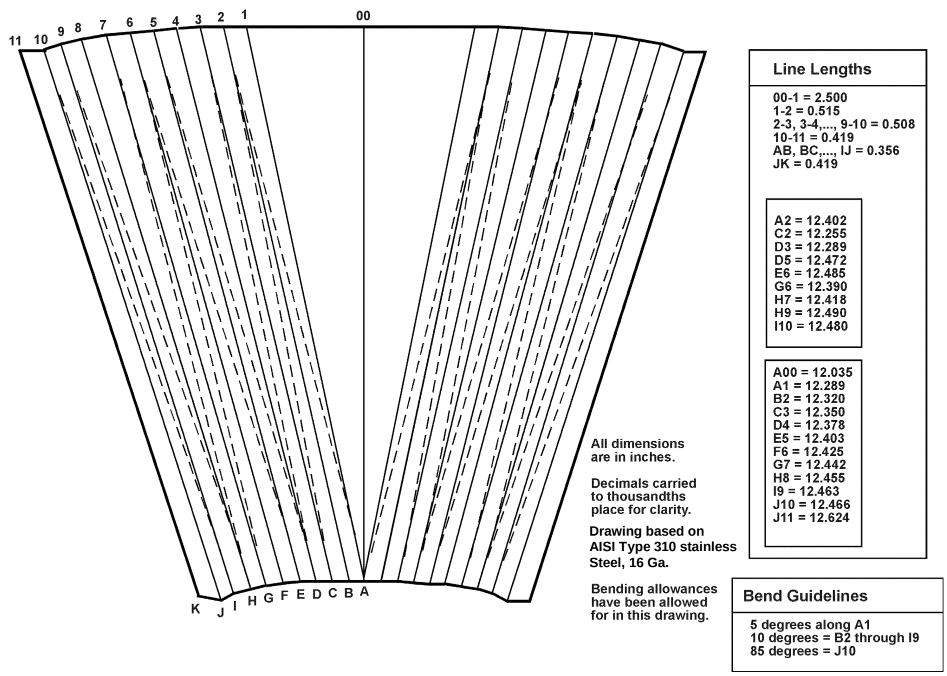


Figure 8-4a. Burner Cone Layout and Bending Pattern

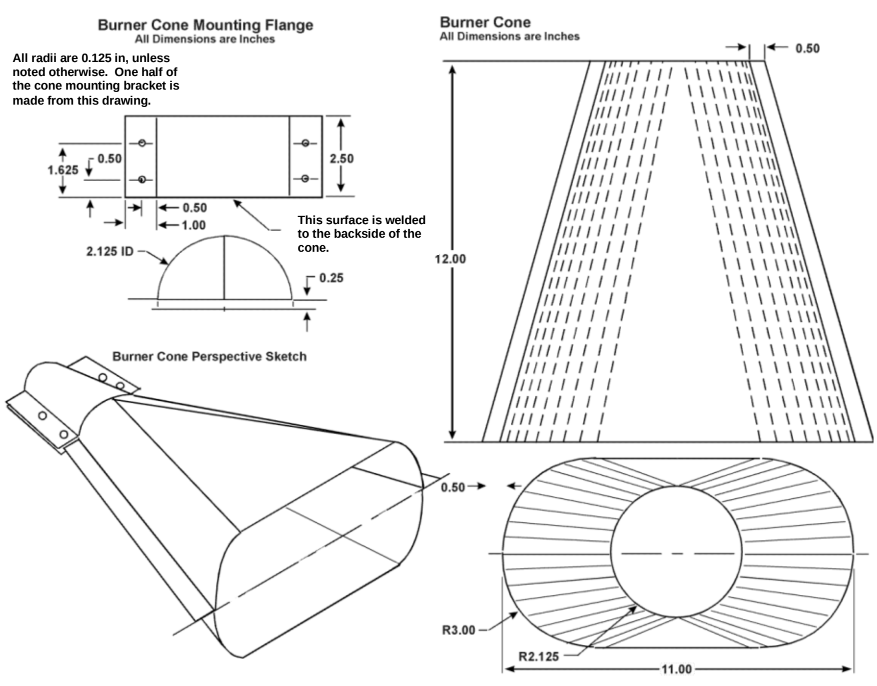


Figure 8-4b. Burner Cone Details

8.3.2.3 Fuel Pressure Regulator

A fuel pressure regulator, adjusted to deliver 2 gal/hr ± 0.1 gal/hr (0.126 ± 0.0063 liter/min), will be provided (see Chapter 8 Supplement).

8.3.2.4 Fuel

Either number 2 Grade kerosene or American Society for Testing and Materials (ASTM) D2 fuel (number 2 Grade fuel oil) will be used.

8.3.2.5 Burner Airflow

Adjust the shutter to attain an airflow of 67 ± 4 ft^3/min (1.89 ± 0.11 m^3/min). See paragraph 8.3.5.2 of Chapter 8 Supplement.

8.3.3 Calorimeter

The calorimeter will be a total heat flux density, foil type Gardon Gauge of an appropriate range, such as 0-15 BTU/(ft^2 second) (0-17 W/cm^2), accurate to ± 3 percent of the indicated reading.

8.3.3.1 Calorimeter Mounting

The calorimeter will be mounted in a 6 by 12 ± 1/8-inch (152 by 305 ± 3-mm) by 3/4-inch (19-mm) -thick insulating block that is attached to a steel angle bracket for placement in the test stand during burner calibration (see figure 8-5). The insulating block will be monitored for deterioration and the mounting shimmed as necessary to ensure that the calorimeter face is parallel to the exit plane of the test burner cone.

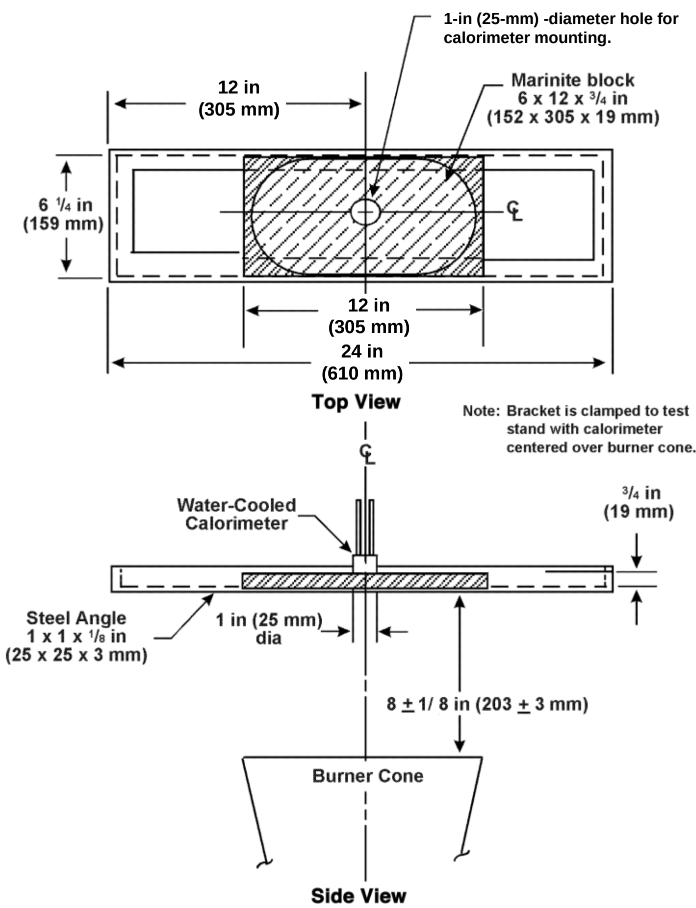


Figure 8-5. Top and Side Views of Calorimeter Bracket

8.3.4 Thermocouples

The seven thermocouples to be used for calibration will be 1/16-inch (1.6-mm) ceramic packed, metal sheathed, type K (Chromel-Alumel), grounded junction thermocouples with a nominal 30 AWG size conductor. The seven thermocouples will be attached to a steel angle bracket to form a thermocouple rake for placement in the test stand during burner calibration, as shown in figure 8-6.

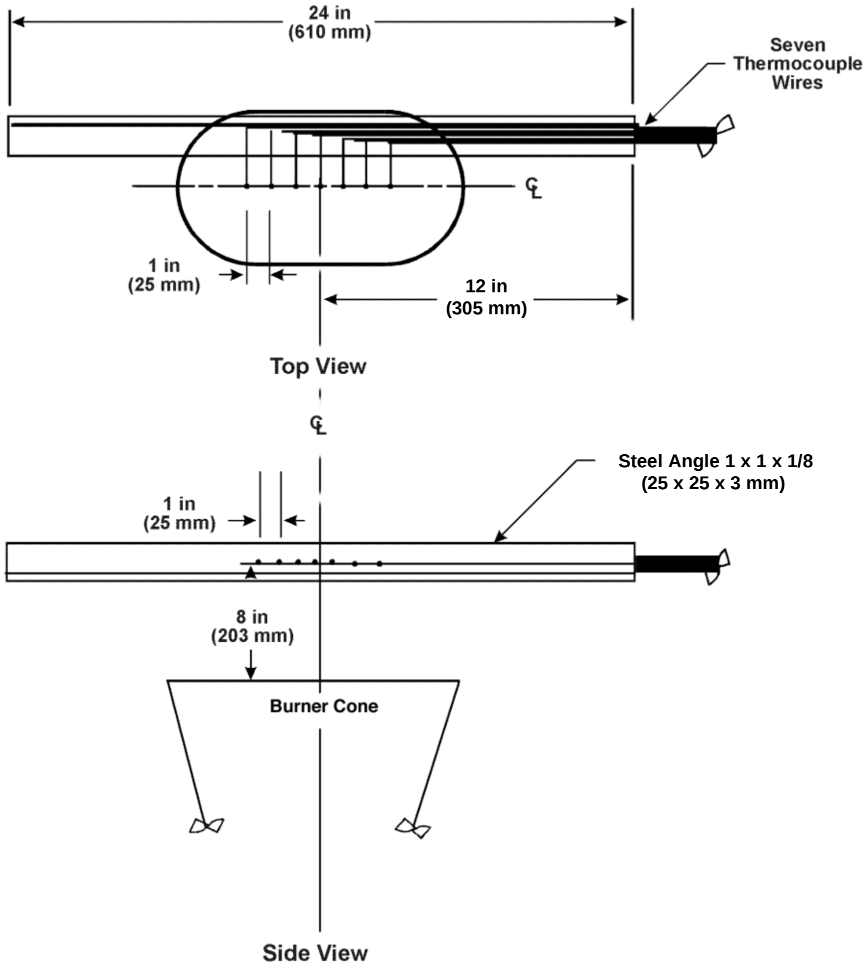


Figure 8-6. Top and Side View of Thermocouple Rake Bracket

8.3.5 Instrumentation

A calibrated recording device or a computerized data acquisition system with an appropriate range will be provided to measure and record the outputs of the calorimeter and the thermocouples.

8.3.5.1 Timing Device

A stopwatch or other device, accurate to within 1 second/hour, will be provided to measure the time of application of the burner flame, the material flaming time, and the burnthrough time.

8.3.5.2 Anemometer

A vane-type air velocity sensing unit will be used to monitor the flow of air at the inlet of the oil burner. The inlet will be completely sealed except for an opening for the air velocity sensor where the inlet will be centered and mounted. See the anemometer setup in figure 8-7.

8.4 Test Specimen(s)

8.4.1 Specimen Configuration

Each cargo liner panel type and design configuration will be tested. Design configuration includes cargo compartment design features such as corners, joints, seams, lamp assemblies, pressure relief valves, temperature sensors, etc., that may affect the capability of a cargo compartment to safely contain a fire (see section 8.8.9).

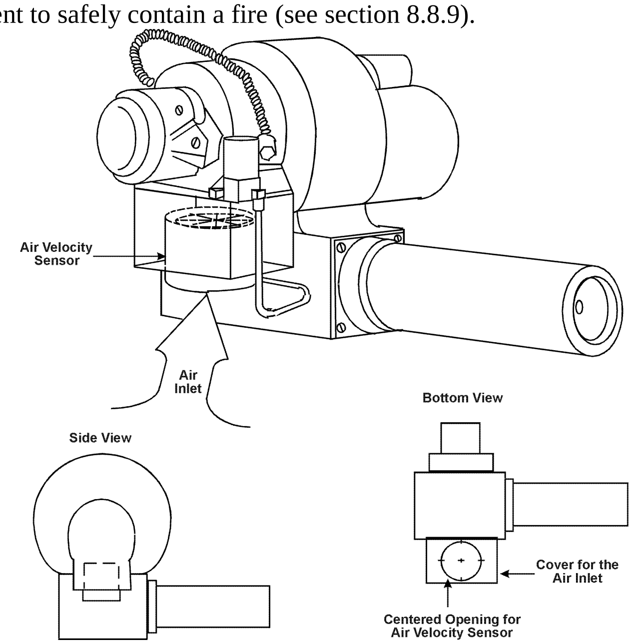


Figure 8-7. Illustration for the Location of the Air Velocity Sensor

8.4.1.1 Ceiling and sidewall liner panels may be tested individually provided a baffle of fire-resistant material, such as Superwool® or Marinite, is used to simulate the missing panel.

8.4.2 Specimen Number

A minimum of three specimens or specimen sets for each panel type or design configuration will be prepared for testing.

8.4.3 Specimen Size

The specimens to be tested will measure 16 ± 1/8 inches (406 ± 3 mm) by 24 ± 1/8 inches (610 ± 3 mm).

8.5 Specimen Conditioning

8.5.1 The specimens will be conditioned at 70° ± 5°F (21° ± 2°C) and 55% ± 10 % relative humidity for a minimum of 24 hours prior to testing.

8.6 Preparation of Apparatus

8.6.1 If a NexGen Sonic type burner is to be used, see section 8.6 in the Chapter 8 Supplement for all test burner information. Otherwise, the air inlet of the oil burner must be completely sealed except for an opening where the air monitoring device will be placed. With the anemometer setup for measuring, turn the motor on and run it for at least 30 seconds to allow the blower to reach its operating speed (it is not necessary for the ignitor and fuel flow to be turned on). Set the airflow to 67 ± 4 ft^3/min (1.89 ± 0.11 m^3/min) by adjusting the air shutter (see paragraph 8.3.5.2 of Chapter 8 Supplement for airflow conversion). Once this airflow value is attained, keep the air shutter in position by tightening the lock screw. This will be the initial airflow setting. Later adjustments may be necessary to reach calibration temperatures and heat flux within the specified airflow range.

8.6.2 If a calibrated flow meter is not available, measure the fuel flow using a graduated cylinder of appropriate size. Turn on the fuel pump and the burner motor, making sure the igniter system is off. Collect the fuel by placing one end of a plastic or rubber tube over the fuel nozzle and the other end into the graduated cylinder for a 2-minute period. Ensure that the flow rate is 2 ± 0.1 gal/hr (0.126 ± 0.0063 L/min).

8.7 Calibration

8.7.1 Secure the calorimeter in its bracket and place it on the specimen mounting test frame, making sure it is centered over the burner cone at a distance of 8 ± 1/8 inches (203 ± 3 mm) from the exit of the burner cone, as shown in figure 8-5. Ensure that the burner is in the proper position relative to the specimen mounting frame, 2 ± 1/8 inches (51 ± 3 mm) from the sidewall panel frame. Position the center of the calorimeter over the center of the burner cone.

8.7.2 Prior to starting the burner, ensure that the calorimeter face is free of soot deposits and that there is water running through the calorimeter.

CAUTION! Exposing the calorimeter to the burner flame without water running through it will destroy the calorimeter.

8.7.3 Rotate the burner from the test position to the warmup position. Examine and clean the burner cone of any evidence of buildup of productions of combustion, soot, etc.

8.7.4 While the burner is in warmup position, turn on the fuel flow and light the burner. Allow it to warmup
for at least 2 minutes. Move the burner into test position and adjust the air intake to produce a heat flux of 7.5 BTU/(ft^2 second) (8.6 W/cm^2) or greater. Record the heat flux measurements at least once per second averaged over a 30-second time period to ensure that steady-state conditions have been achieved. After steady-state conditions have been achieved, turn the burner off.

8.7.5 Replace the calorimeter bracket with the thermocouple rake. Check the distance of each of the seven thermocouples to ensure that they are located 8 ± 1/8 inches (203 ± 3 mm) from the horizontal plane of the burner exit. Place the center thermocouple (thermocouple number 4) over the center of the burner cone exit (see figure 8-6).

8.7.6 Turn on the burner and allow it to warm up for at least 2 minutes. After warmup, record the temperature of the thermocouples at least once per second averaged over a 30-second time period. The temperature of each thermocouple will be 1600°F (871°C) or greater.

8.7.7 If the temperature of each thermocouple is not within the specified range, repeat sections 8.7.1 through 8.7.3 until all parameters are within the calibration range. When required thermocouple temperatures have been achieved, check that the airflow is within the required range. Once the parameters are within the specified range, secure the air shutter by tightening the lock screw.

8.7.8 Calibrate prior to each test until consistency (heat flux and temperature remaining within calibration tolerance) has been demonstrated. After consistency has been confirmed, several tests can be performed with calibration conducted before and after the tests. See the Chapter 8 Supplement for recommendations on achieving calibration.

8.8 Procedure

8.8.1 Examine and clean the cone of soot deposits and debris.

8.8.2 Mount the sidewall and/or ceiling cargo liner specimen(s) on the respective frame(s) and secure to the test frame(s) using the retaining frame(s). Bolt the retaining frame(s) and the test frame(s) together. Verify that the horizontal test frame is level.

8.8.3 Mount the thermocouple or thermocouple rake 4 ± 1/8 inches (102 ± 3 mm) above the top side of the horizontal ceiling panel test specimen. If the thermocouple rake is being used, position the center thermocouple (thermocouple number 4) over the center of the burner cone exit.

8.8.4 Move the burner or sample test rig into the warmup position so that the flame does not impinge on the test specimen during the warmup period. Turn on the burner and allow it to stabilize for at least 2 minutes.

8.8.5 Move the burner or sample test rig into the test position, and simultaneously start the timing device when the burner or sample test rig is fully in the test position.

8.8.6 Record the temperature of the thermocouple (thermocouple number 4, if using the thermocouple rake also used for calibration) at least once a second for the duration of the test.

8.8.7 Expose the specimen to the flame for 5 minutes or until flame penetration occurs.

8.8.8 Turn off the burner to terminate the test.

8.8.9 The following sections present testing procedures for patch repairs, seams, joints, fastening systems, lighting fixtures, and corners.

8.8.9.1 Patch Repairs

See Chapter 15 for instructions.

8.8.9.2 Seams, Joints, Fastening Systems, Lighting Fixtures, and Corners

The barrier material used for design features such as recessed lighting fixtures and pressure relief valves will be tested in the same manner as a cargo liner specimen. Seams, joints, and fasteners in the ceiling position will be tested longitudinally extending the length of the liner and centered over the burner cone. Seams or joints used on the sidewall will be positioned longitudinally, 2 inches from the top of the vertical test specimen as representative of the aircraft application. Apply the test procedures in sections 8.8.1 through 8.8.8 to test these design features.

8.9 Report

8.9.1 Report a complete description of the material(s) being tested, including manufacturer, thickness, etc.

8.9.2 Report the orientation of the panels tested (i.e., ceiling and/or sidewall).

8.9.3 Record any observations regarding the behavior of the test specimen during flame exposure, such as delamination, resin ignition, smoke, etc., and the time each event occurred.

8.9.4 Report the time of occurrence of flame penetration, if applicable, for each of the three specimens tested.

8.9.5 If flame penetration does not occur, report the maximum backside temperature and time of occurrence.

8.9.6 Provide a record of calibration.

8.10 Requirements

8.10.1 None of the three specimens tested will burn through within the 5-minute flame exposure.

8.10.2 Each of the three specimens tested will not exceed 400°F (204°C) at the backside temperature monitored during flame exposure.

8.10.3 Specimens that pass in the ceiling orientation may be used as a sidewall panel without further test.

8.10.4 For the patch adhesion test, the patch must be intact after the 5-minute flame exposure.

Chapter 8 Supplement

This supplement contains advisory material pertinent to referenced paragraphs.

8.3 Apparatus

8.3.2 Test Burner

The test specimen frame has the capability of moving away from the stationary burner during warmup (figure 8-S-3).

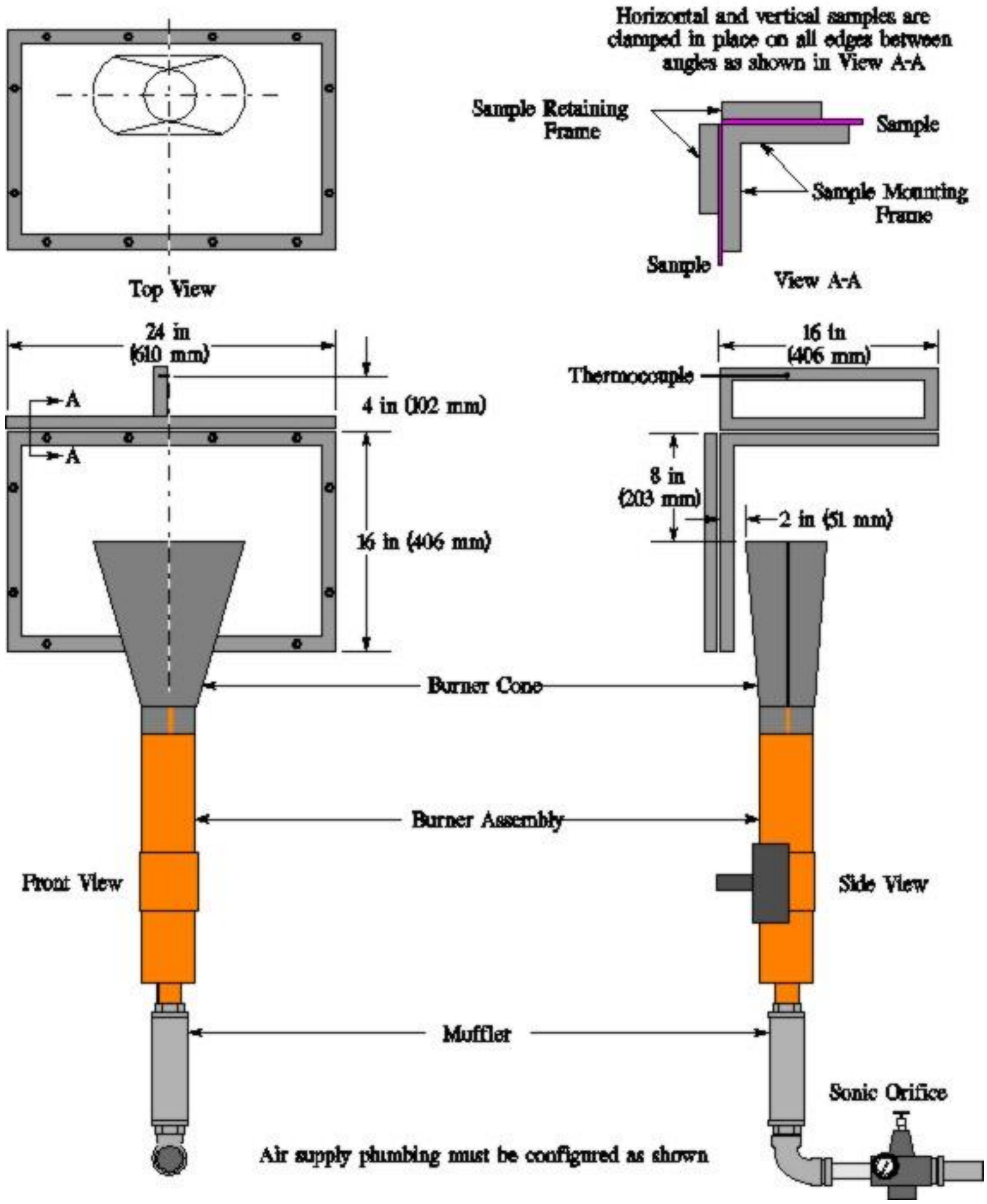


Figure 8-S-3. Test Apparatus for Horizontal and Vertical Mounting for Cargo Liner Oil Burner Testing

8.3.2 Test Burner

This section describes in detail the Federal Aviation Administration Next Generation Fire Test Burner, also known as the Sonic burner or the NexGen burner. The NexGen 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 orifice 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 orifice. A schematic of the next generation fire test burner is displayed in figure 8-S-4.

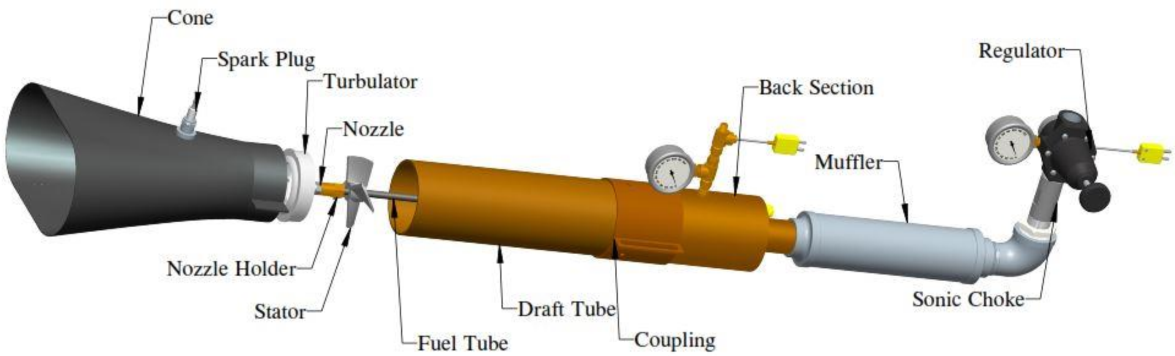


Figure 8-S-4. Schematic of the NexGen Burner - Exploded View

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 mild-seam steel tubing with a wall thickness of 0.125-inch. The length of the draft tube is 15 inches, with 3 inches of the tube inserted into the coupling, resulting in a coupling-to-tip distance of 12 inches (figure 8-S-5). The coupling is constructed of 4.25-inch inner diameter mild-seam steel tubing that is 4 inches long with an outer diameter of 4.5 inches. Three set-screw holes are 120 degrees apart and are drilled 1 inch 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 8-S-6). The back section is made of the same 4-inch tubing as the draft tube, but is 6 inches long, with 1 inch inserted into the coupling and welded in place (figure 8-S-7). A back plate is constructed of a 0.125-inch steel plate cut into a 4.25-inch diameter circle to cap the back section, with holes for the air inlet and fuel inlet (figure 8-S-8). A 1.5-inch National Pipe Thread (NPT) pipe nipple is cut to a length of 2.90 inches and welded into the recessed cut on the center of the back plate (figure 8-S-9).

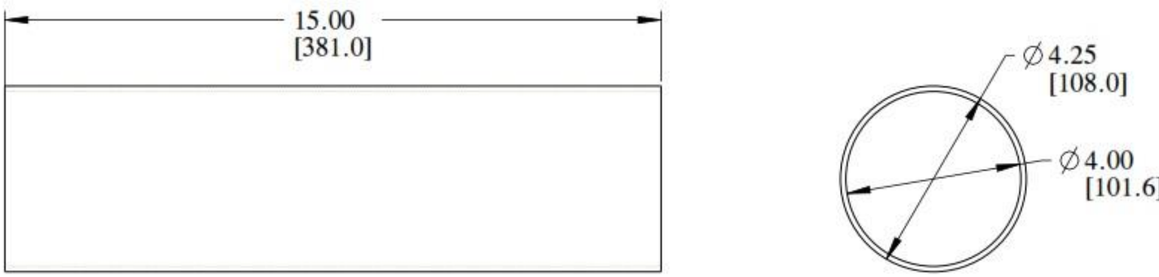


Figure 8-S-5. Dimensioned Drawing of the Draft Tube

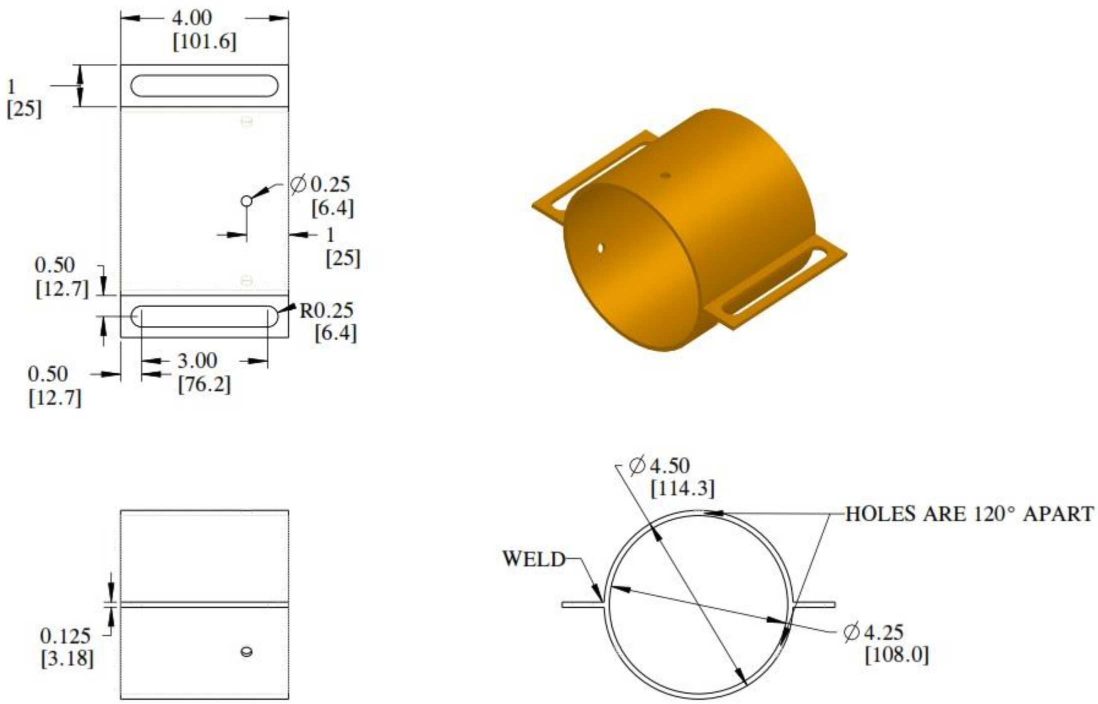


Figure 8-S-6. Dimensioned Drawing of the Coupling

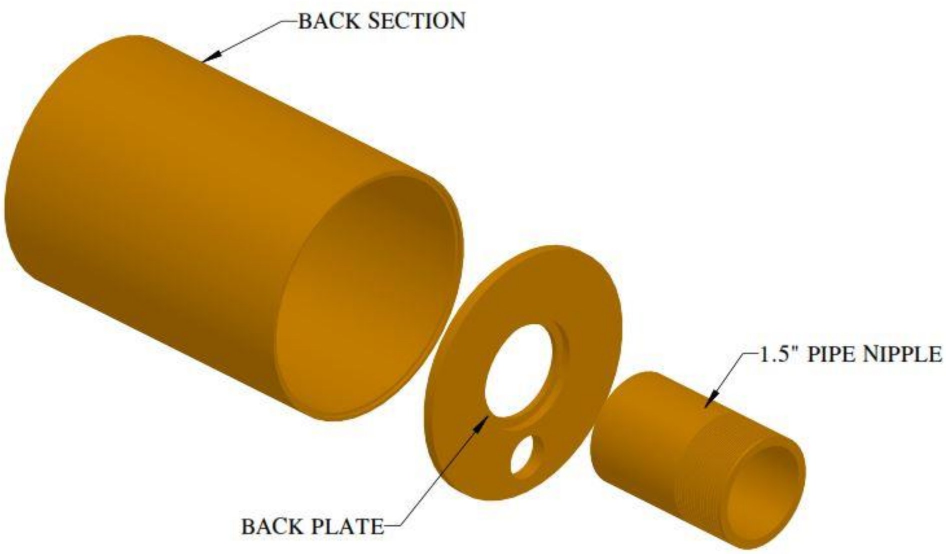


Figure 8-S-7. Back Section Components - Exploded View

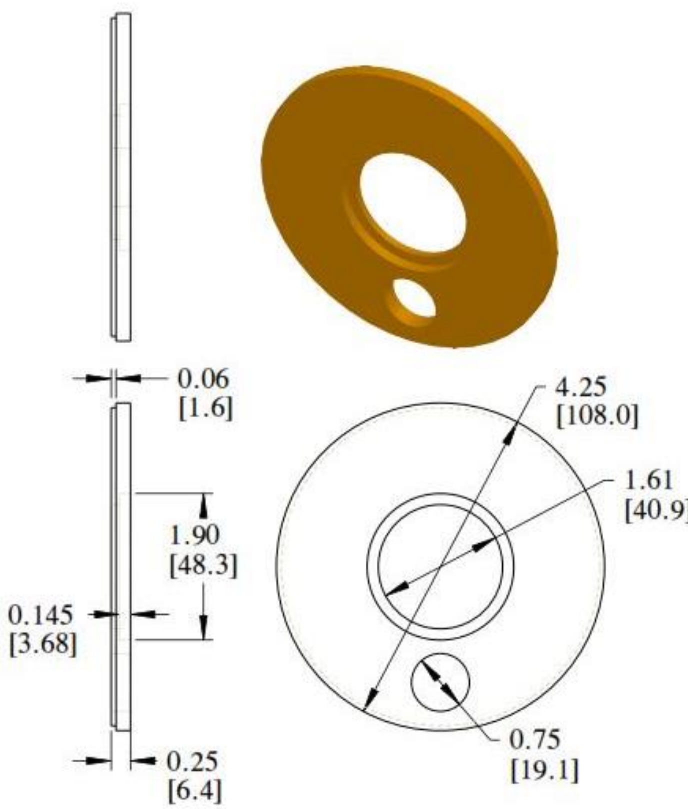


Figure 8-S-8. Dimensioned Drawing of the Back Plate

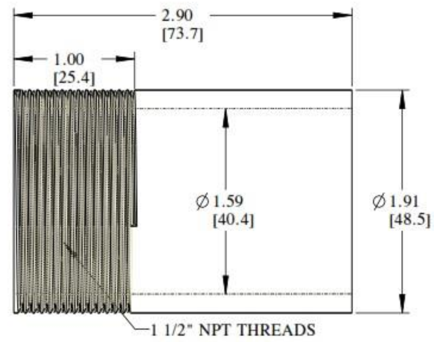


Figure 8-S-9. Dimensioned Drawing of the Pipe Nipple

Sonic Nozzle

The NexGen burner airflow is regulated with a sonic nozzle, which will deliver a constant mass flow rate depending on the supplied inlet air pressure (figure 8-S-10). The nozzle is constructed from stainless steel with 1-inch NPT male thread ends. The throat diameter must be 0.25 inches, 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 NexGen burner is manufactured by Fox Venturi Products of Dover, New Jersey, and is identified by part number 612021-8.

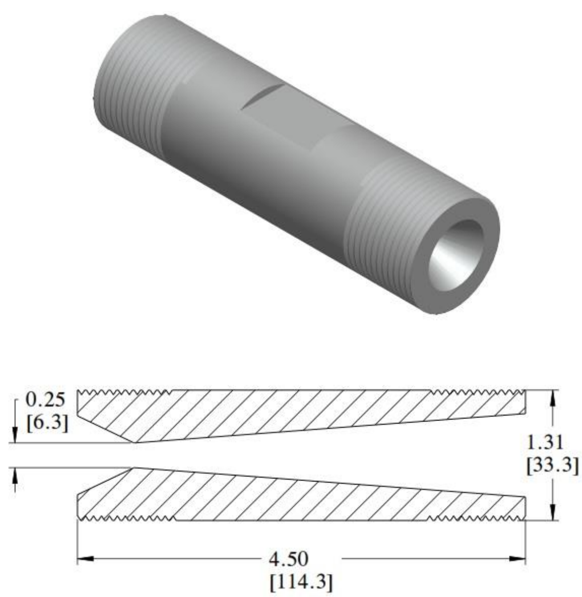


Figure 8-S-10. Schematic of the Sonic Nozzle with Cutaway View Showing Converging and Diverging Interior Sections

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. The regulator must also maintain the desired pressure for the length of a test (figure 8-S-11). A suitable regulator is available from McMaster-Carr, part number 49305K23 with an operating range of 0-55 lbs/in^2.

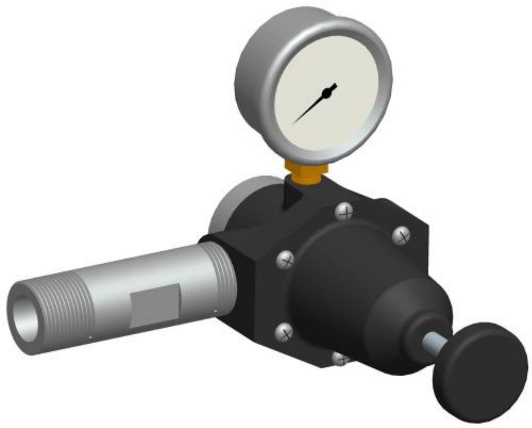


Figure 8-S-11. Schematic of Air Pressure Regulator with Sonic Nozzle Attached

Air Pressure Gauge

The outlet pressure of the regulator is critical for establishing the proper flow of air into the sonic nozzle. The pressure gauge must have NIST traceable certification with a ± 2% accuracy or less. Digital gauges capable of reading in increments of 1 lbs/in^2 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 air pressures typically used during tests. 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 pressure range (figure 8-S-12).

Figure 8-S-12. 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 3-inch outside diameter muffler has 1.5-inch NPT female thread connections, an overall length of 12 inches, and has no internal baffles or tubes. A suitable muffler is supplied by McMaster-Carr, part number 5889K73 (figure 8-S-13). 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 in diameter by 12 inches long and should have a density of approximately 1.20-1.50 lbs/ft^3 with a porosity of approximately 20 pores/inch. 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 into the burner housing. The two wires should be arranged perpendicular to each other in a cross pattern. The male outlet of the sonic nozzle connects to a 1-inch NPT female to 1.5-inch male hex bushing. The hex bushing male outlet connects to the intake side of the muffler via a 1.5-inch NPT female to 1.5-inch NPT male 90-degree street elbow.

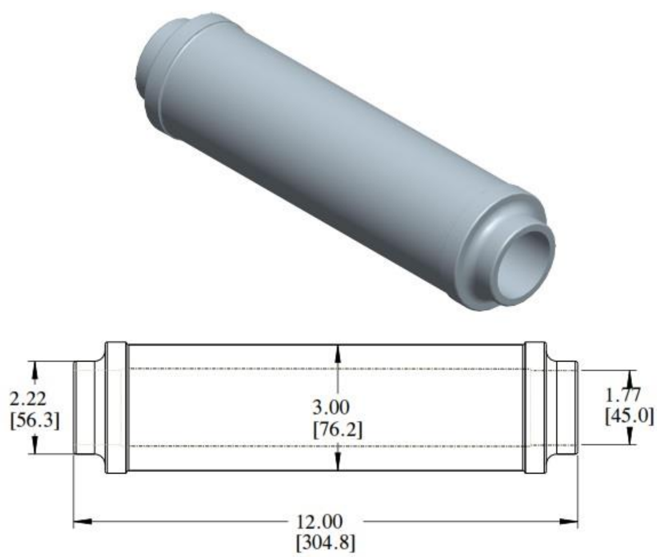


Figure 8-S-13. Schematic of the Muffler

Air Temperature

The air temperature must be maintained at 50 ±10°F (10°C± 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

Various components can be used to deflect and diffuse the airflow within the NexGen burner. The most common are the stator and turbulator. 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 flow aligning the fuel tube with the center axis of the draft tube. The stator is 4 inches in diameter and should have a snug fit when placed inside the draft tube (figure 8-S-14). A suitable stator is supplied by Marlin Engineering, part number ME1513-3.

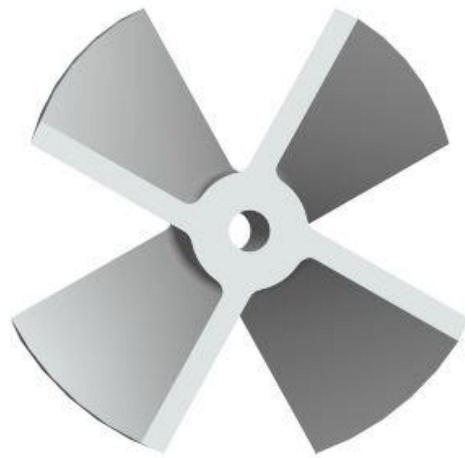


Figure 8-S-14. Stator

Turbulator

The turbulator is a 4-inch diameter component, for air swirling, placed in the end of the draft tube. The center hole is 2.75 inches in diameter (figure 8-S-15). A suitable turbulator is supplied by Marlin Engineering, part number ME1512-1.

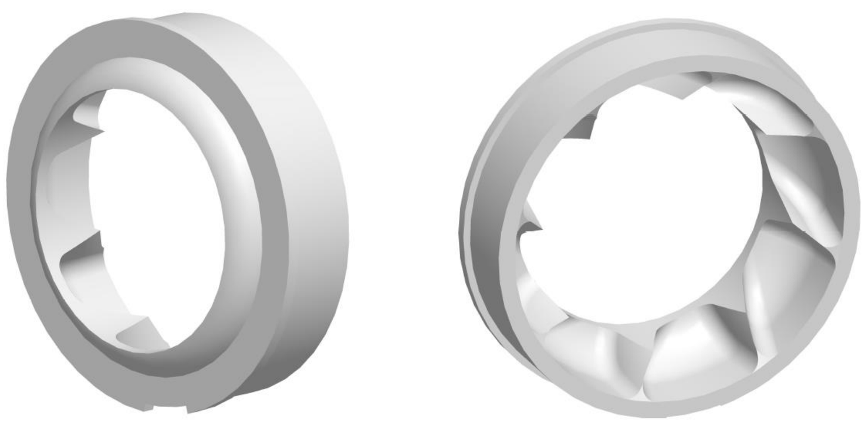


Figure 8-S-15. Turbulator, Front and Back

Stator and Turbulator Configuration

The stator slides onto the fuel rail, is oriented in the proper direction, and is locked into place with a set screw located at the twelve o'clock position (figure 8-S-16). The turbulator is placed on the end of the draft tube with the tab located at the six o'clock position (figure 8-S-17). The typical configuration positions the face of the stator approximately 2.6875 inches from the exit plane of the turbulator (figure 8-S-18). Refer to the Preparation of Apparatus section (Supplement section 8.6) for the exact positioning of the stator and turbulator.

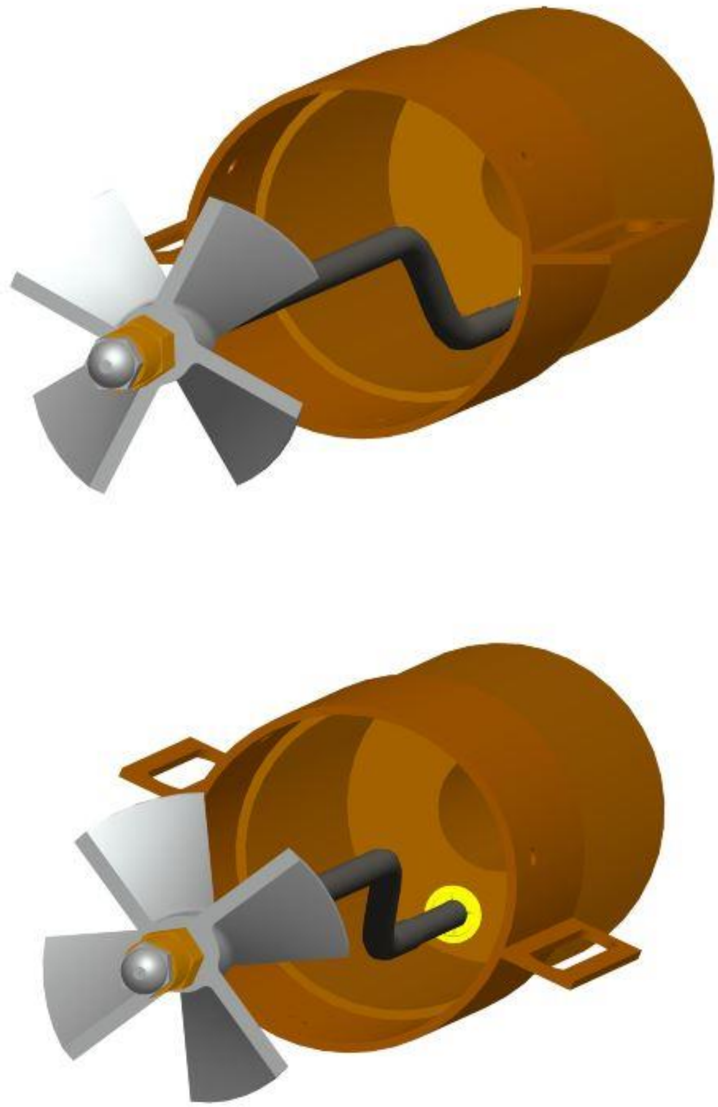


Figure 8-S-16. Location of the Stator on the Fuel Tube

Figure 8-S-17. Position of Turbulator at the end of the Draft Tube

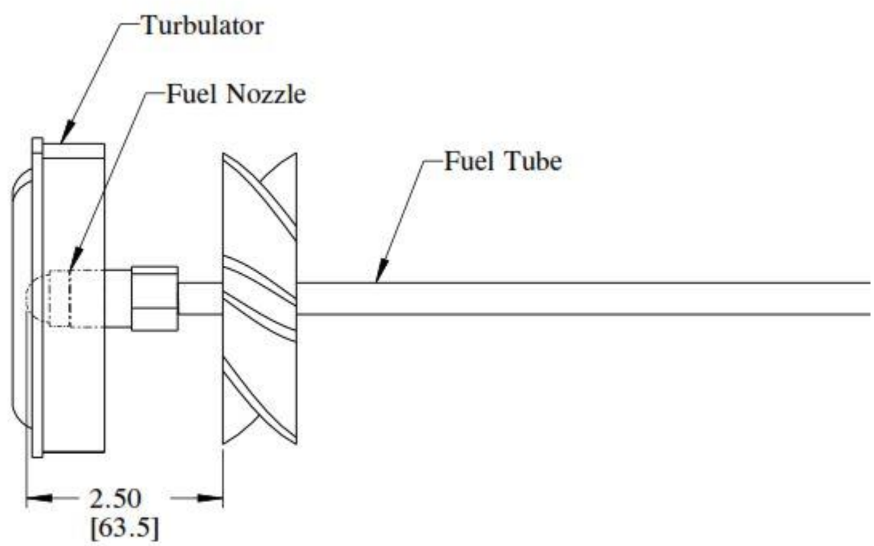


Figure 8-S-18. Typical Configuration of the Stator and Turbulator

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 (6.9 – 8.3 bar), and must maintain the desired pressure for the duration of a test. A suitable method of fuel pressurization is a pressurized fuel tank (figure 8-S-19). 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 2 gal/hr ± 0.1 gal/hr (0.126 ± 0.0063 liter/min).

A pressure vessel, such as McMaster-Carr part number 1584K7 with a 15-gallon capacity, measuring 12 inches in diameter and 33 inches tall 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.

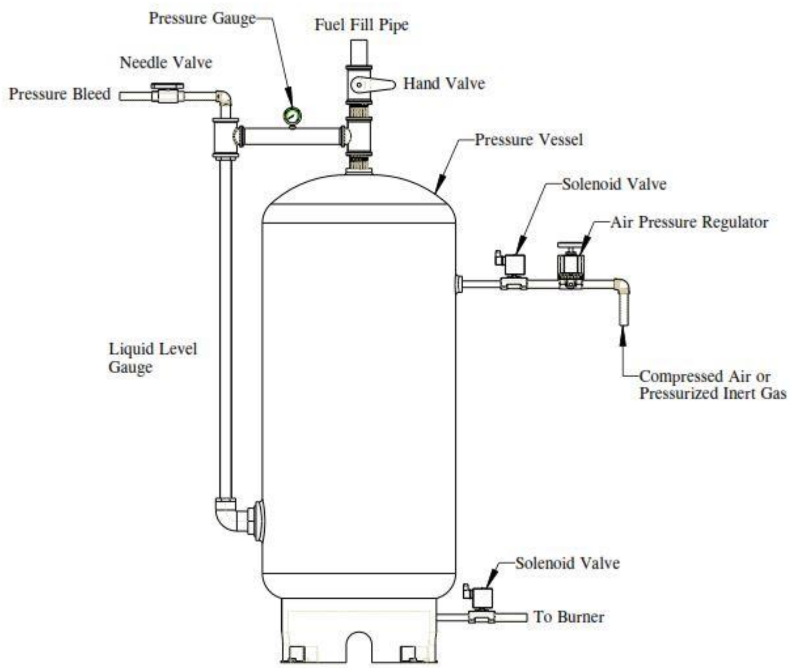


Figure 8-S-19. Schematic of Pressurized Fuel Tank System

Fuel Pressure Gauge

A suitable pressure gauge 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 must have NIST traceable certification with a ± 2% accuracy or less. Digital gauges capable of reading in increments of 1 lbs/in^2 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 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 pressure range (figure 8-S-20).

Figure 8-S-20. Analog Pressure Gauge

Fuel Temperature

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

Fuel Tube

The fuel tube in the NexGen 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 8-S-21). The tube is constructed from schedule-80, thick wall,0.125-inch steel pipe with an outside diameter of 0.405-inch, an inside diameter of 0.215-inch, and a wall thickness of 0.095-inch. The pipe is cut to a length of approximately 21.5 inches; a section of the outer wall is removed on a lathe to fit the pipe through the keyless bushing that holds the tube in place. The outer diameter of the fuel tube is reduced to approximately 0.3750 inch for a length of 4 inches 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 1/8-inch NPT pipe threads. Heavy duty 0.004-inch-thick thread seal tape is wrapped on the pipe threads to prevent fuel leakage. A 1.375-inch-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.

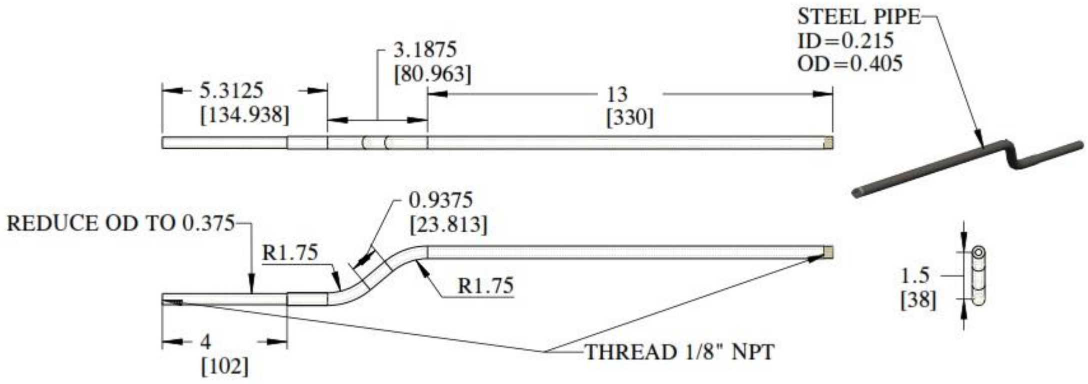


Figure 8-S-21. Schematic of the Fuel Tube

Fuel Nozzle

The fuel nozzle for the NexGen 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 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. For example, if a 5.5-gallon/hr-rated nozzle is operated at 120 lb/in^2, a flow rate of 6.0 gallon/hr will be achieved. A Delavan 80-degree 2.0 gallons/hour (B-type) spray nozzle has been found suitable for this application.

Nozzle Adapter

The fuel nozzle adapter is a brass fitting 1.375 inches in length with a 1/8-inch NPT thread on the inlet side and 0.5625-inch 24 Unified Fine Thread (UNF) thread where the nozzle attaches (figure 8-S-22).

Figure 8-S-22. 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 8-S-23). 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.

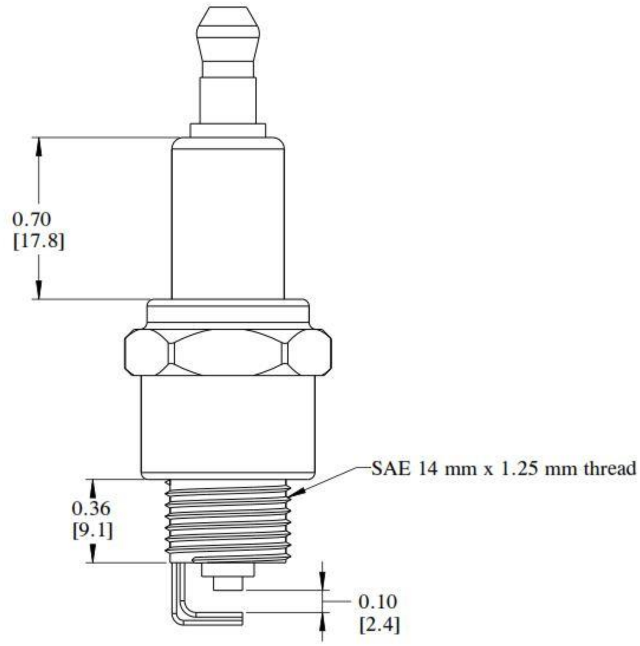


Figure 8-S-23. Dimensioned Drawing of a Spark Plug

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 8-S-24. 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.

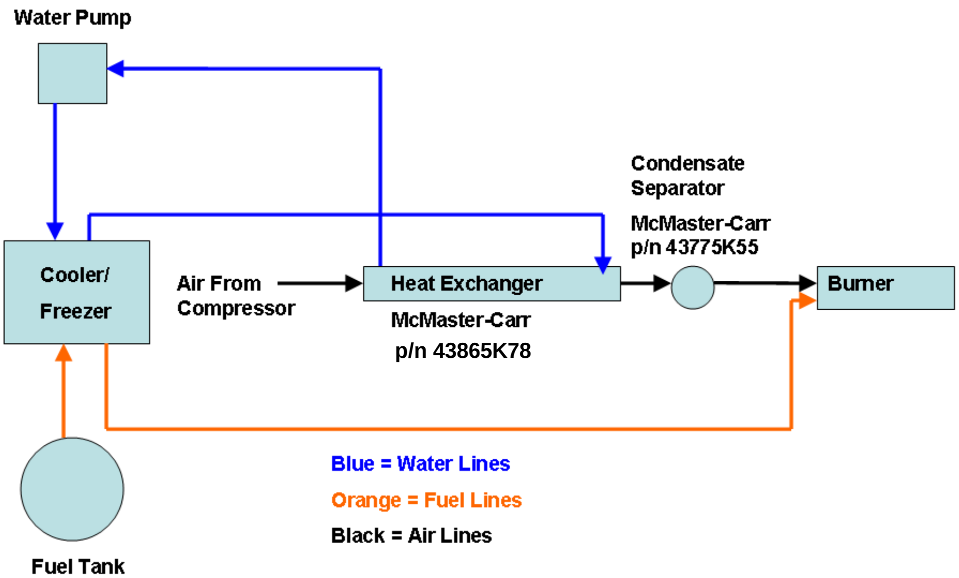


Figure 8-S-24. Schematic of Air/Fuel Heat Exchange System

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 0.065 ±0.015 inch (1.65 ± 0.375 mm). See figures 8-S-25 and figure 8-S-26 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 check the exit plane dimensions to ensure they remain within the specified tolerances.

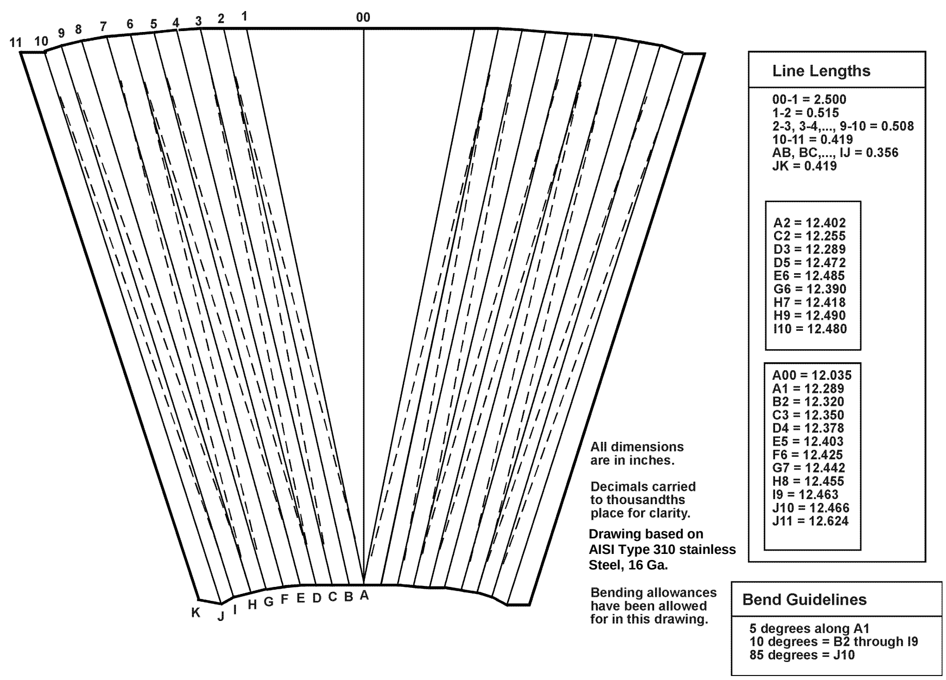


Figure 8-S-25. Burner Cone Layout and Bending Pattern

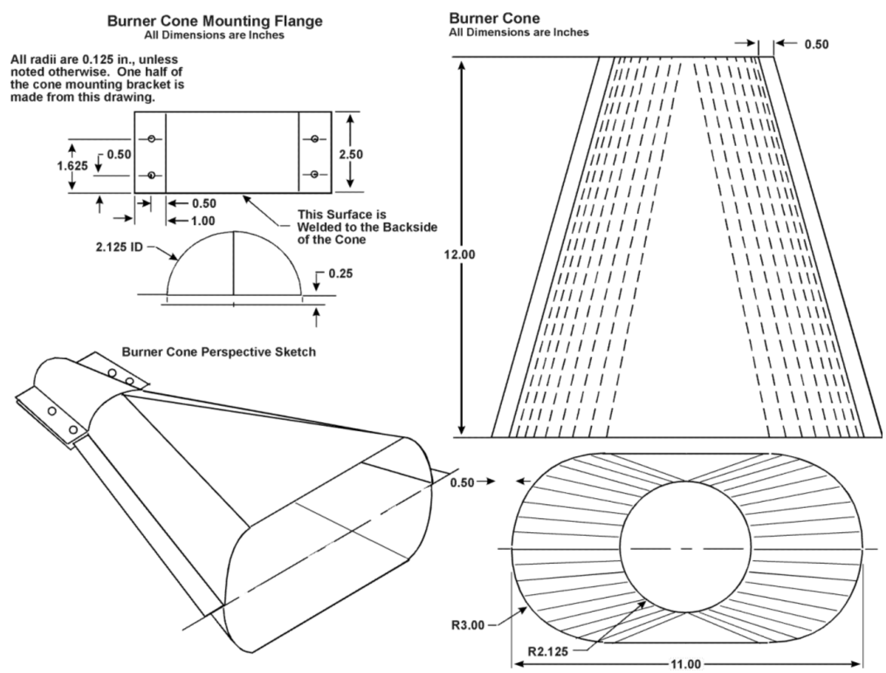


Figure 8-S-26. Burner Cone Details

Threaded Boss for Spark Plug

A threaded boss must be welded to 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 8-27).

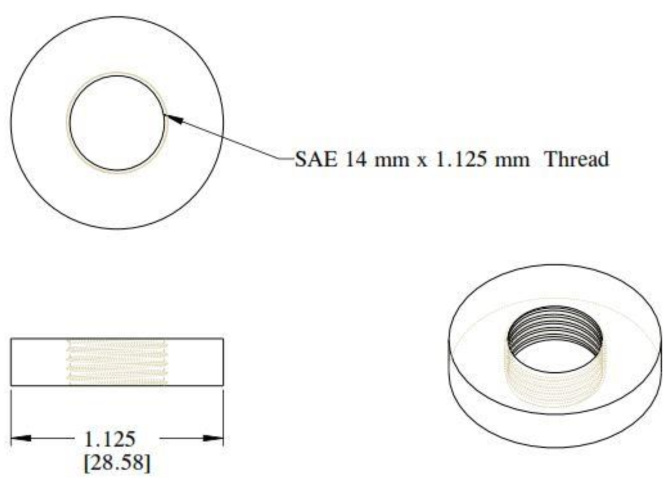


Figure 8-S-27. Threaded Boss

Burner Measurement Locations

Accurate measurements of the burner inlet parameters are critical to proper operation. The measurement locations of the burner air and fuel supply are indicated in figure 8-S-28.

Air Pressure

The sonic choke inlet pressure is measured with a suitable pressure gauge mounted just upstream of the sonic choke, preferably at the outlet pressure tap on the pressure regulator. The gauge should measure accurately in the range of 0-60 lb/in^2 (0-4.14 bar), 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 Gauge above).

Air Temperature

The burner air temperature is measured with a 0.125-inch (3.2 mm) diameter, ceramic 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. 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 Gauge 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, ceramic 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.

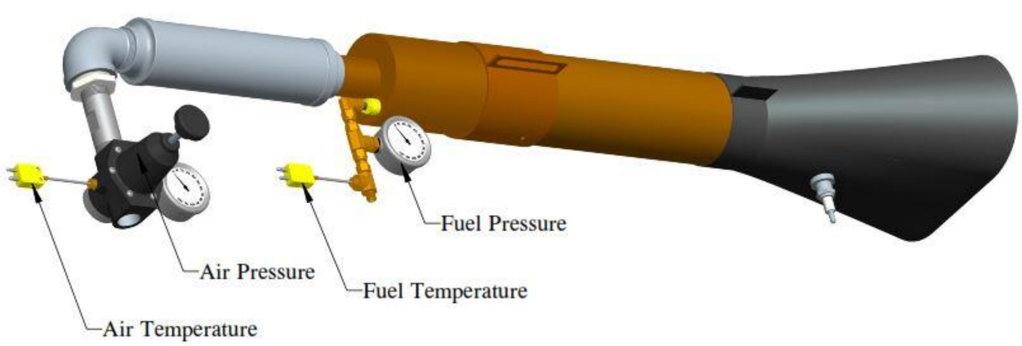


Figure 8-S-28. Burner Schematic Showing Inlet Measurement Locations

This concludes the apparatus information for the NexGen burner. Return to chapter section 8.4 for further test method instructions.

8.3.2 The basic burner and the use of tabs are described in FAA Powerplant Engineering Report No. 3A, “Standard Fire Test Apparatus and Procedure for Flexible Hose Assemblies,” dated March 1978, and Report No. DOT/FAA/RD/76/213, “Re-evaluation of Burner Characteristics for Fire Resistant Tests,” dated January 1977. The test settings specified in this specification, however, differ from those specified in the above reports.

8.3.2.1 A Monarch 80-degree AR or 80°R nozzle, nominally rated at 2.25 gal/hr (0.142 L/min) at 100 lb/in^2 (0.69 MPa) and operated at 85 lb/in^2 (0.59 MPa) gauge, has been found satisfactory to maintain a fuel flow of 2 gal/hr (0.126 L/min) and produce a proper spray pattern. A Monarch 80-degree CC nozzle, nominally rated at 2 gal/hr at 100 lb/in^2 and operated between 95 and 105 lb/in^2 gauge, is also acceptable. Minor deviations to the fuel nozzle spray angle, fuel pressure, or other parameters of the nozzle are acceptable if the fuel flow rate, flame temperature, and burner heat flux density conform to the requirements of section 8.6 of the handbook.

8.3.2.3 A fuel pressure regulator that is adjusted to deliver 2 ± 0.1 gal/hr (0.126 ± 0.0063 L/min) flow through the nozzle should be provided. An operating fuel pressure of 85 ± 4 psig (0.59 ± 0.02 MPa) for a 2.25 gal/hr (0.142 L/min) 80-degree spray angle nozzle has been found satisfactory.

8.3.2.4 Number 2 Grade diesel fuel, Jet A, or the international equivalent is the recommended fuel because it has been found to produce satisfactory results if the flow rate and inlet airflow conform to the requirements of sections 8.6 and 8.7 of the handbook.

8.3.4 The thermocouples are subjected to high temperatures 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.

8.3.5.2 The Omega microprocessor-based portable air velocity kit, model HH-30, is a recommended unit. The kit includes a vane-type air velocity sensor, hand-held digital readout displaying air velocity, extension rods, and a 9-volt lithium battery. Since the unit monitors air velocity in FPM or MPS ± 1 percent reading accuracy, necessary conversions must be made to attain airflow values. To do this, the area of the opening of the air sensor must be measured. Once the area is found, install the air velocity sensor at the oil burner inlet (see figure 8-7 for location). Following the procedures prescribed in section 8.6.1, this value should be multiplied by the air velocity reading. (The area of the air velocity sensor for the Omega model HH-30 is 0.037 ft^2 [0.0034 m^2]. As an example, by maintaining an air velocity reading of 1800 ft/min using the Omega air sensor described above, an air flow of 67 ft^3/min should be achieved.) If an air velocity sensor other than the Omega model HH-30 is being used, the same conversions apply.

$$\text{Airflow} = \text{Air Velocity} \times \text{Area of Opening (Air Velocity Sensor)}$$

8.6 Preparation of Apparatus

8.6.1 Alignment

Level the sample holder frame assembly to ensure proper alignment with the burner cone. Move the test sample mounting frame into position above the burner, and check for proper alignment (i.e., distance from exit of burner cone to face of test sample, proper sample position with respect to cone centerline, etc.). The movable assembly should incorporate mechanical stops or detents to ensure that the samples can be moved into position quickly without measurement during testing.

8.6.2 Chamber Ventilation

Turn on the ventilation hood for the test chamber. Do not turn on the pressurized burner air. Measure the airflow in the test chamber using a handheld vane-type anemometer or equivalent measuring device. The vertical air velocity within a 12-inch (30.5 cm) radius from any point on the horizontally-positioned sample must be less than 100 ft/min (50.8 cm/second). The horizontal air velocity within a 12-inch (30.5 cm) radius from any point on the sample must be less than 50 ft/min (25.4 cm/second).

8.6.3 Test Chamber Air Temperature

The temperature of the test chamber should be between 50^{o}F and 100^{o}F (10^{o}C and 38^{o}C) before the start of each test. The chamber air temperature should be measured at the same height as the center of the test sample, within 12 inches (30.5 cm) laterally.

8.6.4 Sonic Burner Configuration

8.6.4.1 Fuel Nozzle Location
The tip of the fuel nozzle, or fuel exit plane, must be located 0.1875 ± 0.020 inch (4.8 ± 0.5 mm) from the exit plane of the turbulator (figure 8-S-29).

8.6.4.2 Stator Adjustment
The stator is positioned by adjusting its translational position as well as its axial position on the fuel rod.

8.6.4.2.1 Stator Translational Position
The front face of the stator must be located 2.6875 ± 0.020 inches (68.3 ± 0.5 mm) from the exit plane of the turbulator (figure 8-S-29). This stator translational position is also 2.5 inches (63.5 mm) from the tip of the fuel nozzle.

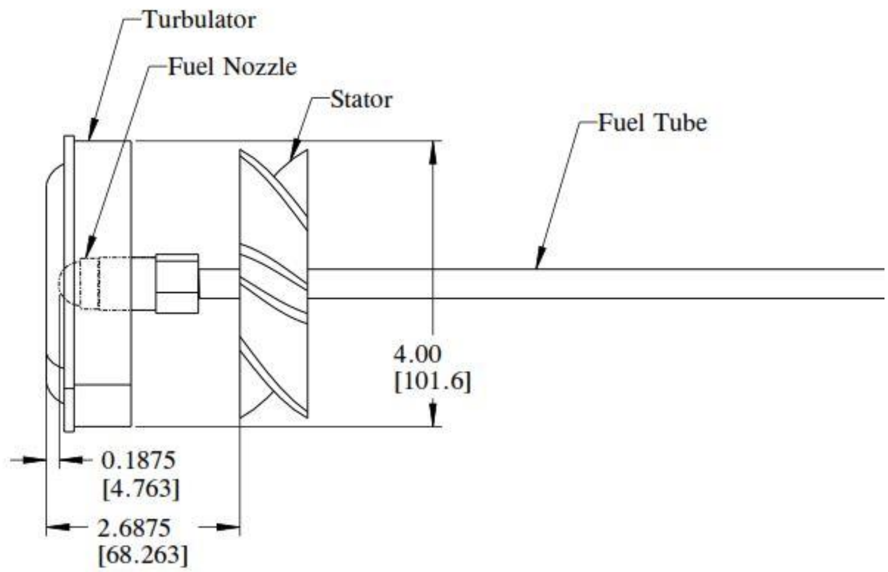


Figure 8-S-29 Fuel Nozzle and Stator Locations

8.6.4.2.2 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 8-S-30).

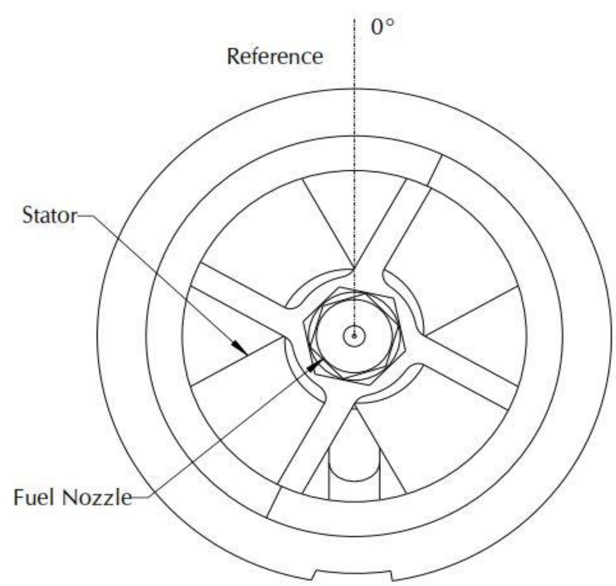


Figure 8-S-30 Stator Axial Position (looking into draft tube)

8.6.4.3 Spark Plug

8.6.4.3.1 Spark Plug Location

The spark plug should be mounted in a threaded boss, on the surface of the burner cone facing away from the vertical sample frame. The spark plug is located at a distance 6 ± 0.125 inches (152 ± 3 mm) from the end (intake plane of burner cone) (figure 8-S-31).

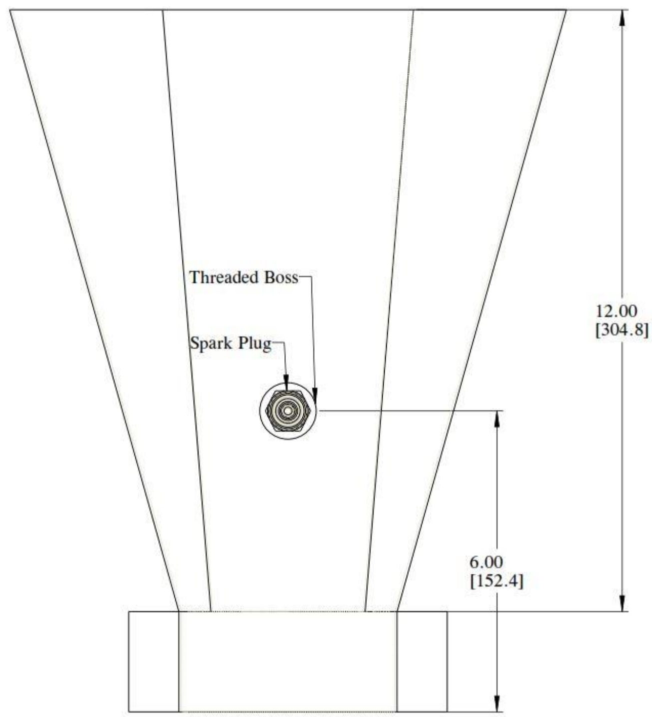


Figure 8-S-31. Spark Plug Location in Burner Cone

8.6.4.3.2 Spark Plug Gap

The spark plug gap (distance) between the two electrodes must be 0.100 inches (2.5 mm) as shown in figure 8-S-32

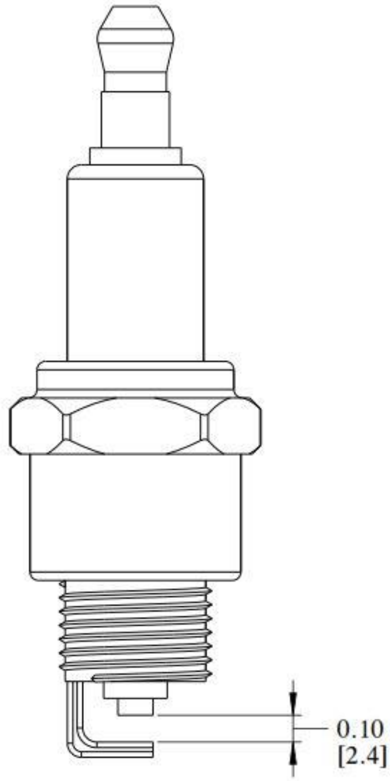
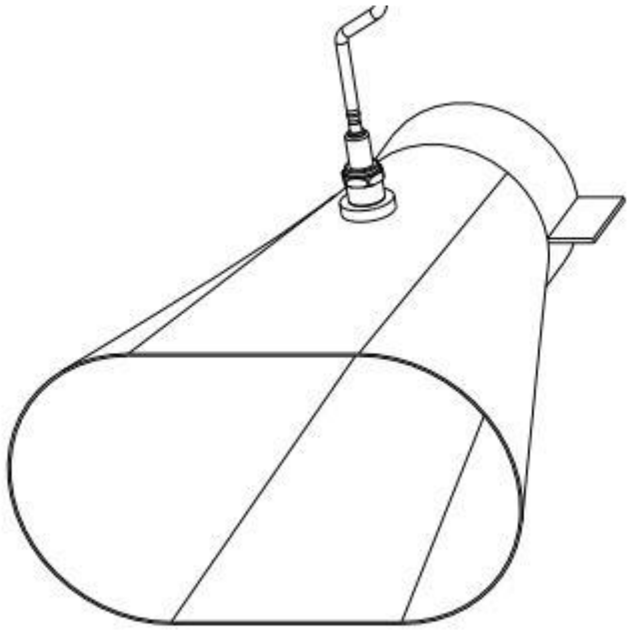


Figure 8-S-32. Spark Plug Gap Measurement

8.6.4.4 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 8-S-33, in which the wire does not contact any components in the vicinity of the burner cone.



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

8.6.4.5 Volumetric Air Flow Control

The volumetric airflow is controlled via a regulated sonic orifice. Adjust the upstream supply air pressure to 45 lbs/in^2 $\pm$ 1 lbs/in^2 (310 $\pm$ 6.9 kPa). The intake air temperature must be maintained within the range of 40^{o}F to 60^{o}F (4^{o}C to 16^{o}C). For additional details, refer to Chapter 8 Supplement, section 8.3.2, Sonic Nozzle and Air Pressure Regulator.

8.6.4.6 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[1], 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 2 ± 0.1 gal/hr (0.126 ± 0.0063 L/min). If the flow rate is not within the tolerance, adjust the fuel pressure accordingly. The temperature of the fuel must be maintained within the range of 32^{o}F to 52^{o}F (0^{o}C to 11^{o}C).

8.6.5 Burner Flame 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, ceramic packed, 310 stainless steel sheathed, type K (Chromel-Alumel), grounded-junction with a nominal 24 American Wire Gauge (AWG) size conductor. 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 8-S-34). The

[1] When collecting fuel, it is important to establish a steady stream of fuel before starting the measurement process. A 10-second period is recommended.

thermocouple mounting plate should be a minimum of 8 inches (203 mm) away from the tips of the thermocouples.

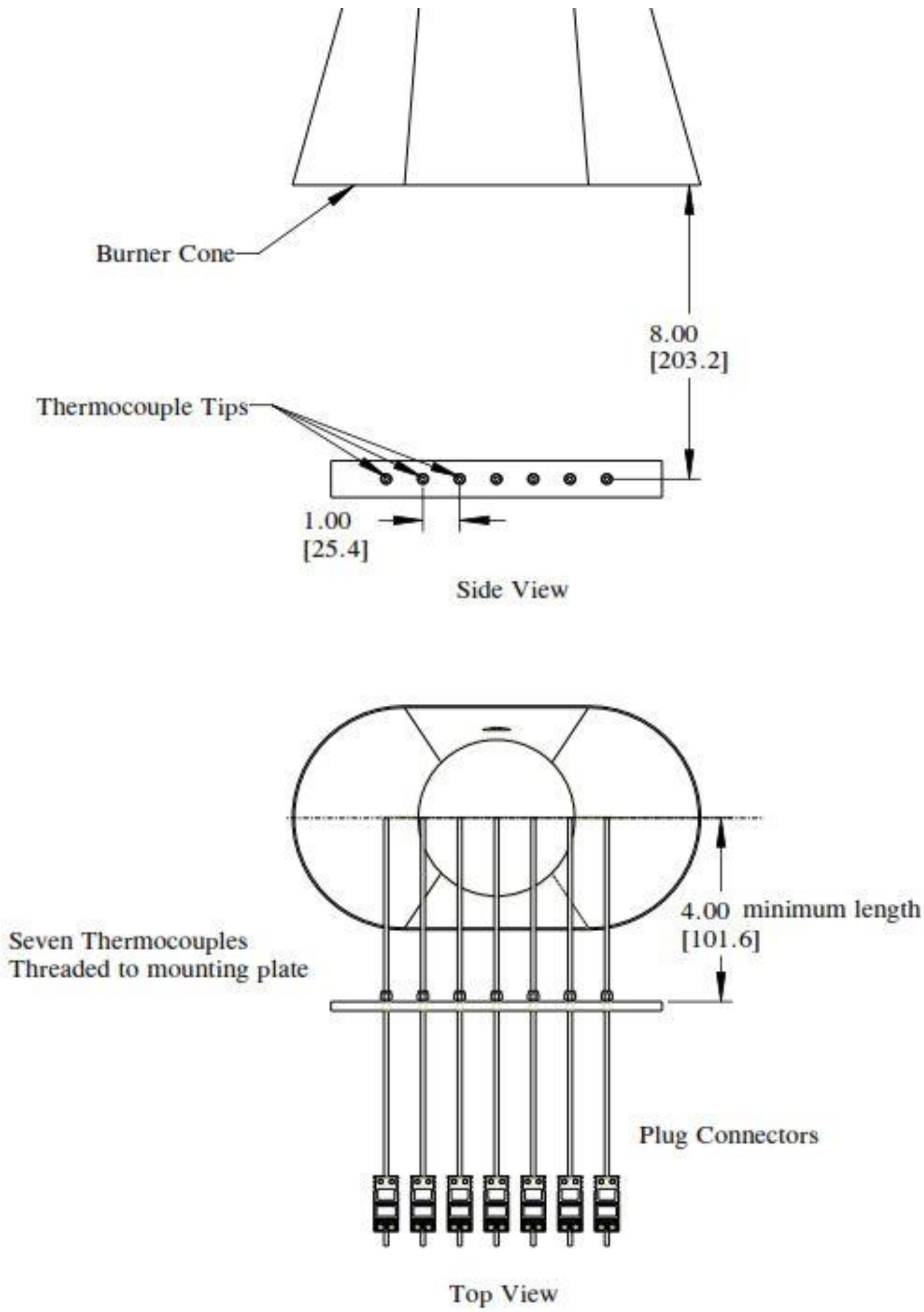


Figure 8-S-34. Top and Side View of Thermocouple Rake Bracket

8.6.6 Instrumentation and Supporting Equipment

8.6.6.1 Data Acquisition

A calibrated recording device or a computerized data acquisition system with an appropriate range must be used to measure and record the outputs of the thermocouples.

8.6.6.2 Timing Device
A stopwatch or other device, accurate to within ± 1 second per 8 hours (± 3 seconds/day), must be used to measure the time of application of the burner flame, and the test sample ignition and extinguishment times.

8.6.6.3 Anemometer
A handheld vane-type or hot-wire type air velocity sensing unit must be used to monitor the flow of air inside the test chamber when the ventilation hood is operating.

8.6.6.4 Test Chamber
A suitable test chamber must be used to reduce or eliminate the possibility of test fluctuation due to air movement. The test chamber must have a minimum floor area of 10 feet by 10 feet (305 by 305 cm).

8.6.6.5 Ventilation Hood
The test chamber must have an exhaust system capable of removing the products of combustion expelled during the tests.

8.7 Burner Flame Consistency Validation

8.7.1 Sonic Burner

The sonic burner used in the test must be checked to ensure the proper flame temperature is being produced for consistent and accurate test results.

8.7.1.1 Move the sample test frame from the test position to the warm-up position. 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. Since the burner cone may distort with time, dimensions should be checked periodically.

8.7.1.2 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 calibration position and check the distance of each of the seven thermocouples to ensure that they are located 8 ± 0.125 inch (203 ± 3 mm) from the horizontal plane of the burner cone exit. Ensure that the horizontal centerline of the thermocouples is directly above the horizontal centerline of the burner cone (see figure 8-S-34). Place the center thermocouple (thermocouple number 4) in front of the center 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 calibration position to re-check distances. When all distances and positions are confirmed, move the thermocouple rake away from burner.

8.7.1.3 While the thermocouple rake is away from the burner, turn on the spark plug, pressurized air and fuel flow, and light the burner. Allow 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 thermocouple rake from calibration 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 1700°F ± 100°F (927°C ± 55°C). The burner should be rechecked to ensure it is configured properly if temperatures are measured outside of this recommended range. A fine adjustment of the internal stator orientation and/or distance from the end of the draft tube may be necessary to achieve the required temperatures, 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 burner flame temperature be validated prior to running a series of tests to ensure test result consistency.

This concludes the preparation of apparatus section for the NexGen burner. Return to chapter section 8.8 for further test procedure instructions.

8.6.1 An alternate method of airflow measurement involves removing the burner extension from the end of the draft tube. Turn on the blower portion of the burner without turning on the fuel or igniters. Measure the air velocity using a hot-wire anemometer. Adjust the airflow using the damper so that the airflow is in the range of 1550 to 1800 ft/min (787 to 914 cm/second). (If tabs are being used, the tabs should be removed prior to measuring the airflow. After the measurement is complete, reinstall the tabs and the cone extension.)

8.7 Static Disks

Static disks were developed to stabilize the air before entering the combustion area, and are an optional feature. Disks 1 and 2 (see figure 8-S-35) are made for easy assembly, only requiring the removal of the draft tube and installation of the disk. Both are made of steel. Disk 3 is made of a Nomex honeycomb material. Disks 1 and 2 were designed by Park Oil Burner Manufacturing Company of Atlantic City, New Jersey. Disk 3 was developed by CEAT, the French Ministry of Defense.
These disks and are used in whatever combination of one or more that will produce a more full and even flame pattern. For example, CEAT uses two honeycomb disks positioned behind the stabilizer. However, given that there are various makes and models of burners used throughout the industry, there is no exact prescription for achieving calibration using a disk(s).

8.7.3 A stainless steel wire brush is one possible cleaning tool. Soot buildup inside the burner cone can affect the flame characteristics and cause calibration difficulties. Since the burner cone may distort with time, dimensions will need to be checked periodically.

8.7.4 The airflow should be adjusted to produce the proper flame as well as the proper temperature and heat flux density. Two different flame profiles may yield the same temperature and heat flux density. The correct flame is generally 8 to 10 inches in length and orange-yellow in color.

8.7.8 Following are recommendations for achieving calibration temperatures and heat flux:

1. Set the stabilizer 3.25 ± 0.25 inches from the end of the draft tube.
2. Rotate the igniter to the 6 o'clock and 9 o'clock position (viewpoint: looking toward the stabilizer from the end of the draft tube).
3. Seal all possible air leaks around the burner cone and draft tube area.
4. Use static disk to improve flame characteristics.
5. Replace thermocouples after 50 hours of use.

8.8.8.2 Test procedures for cargo liner design features are described in FAA Technical Note DOT/FAA/CT-TN88/33, dated September 1988.

8.10.1 Flames that may appear on the side of the specimen away from the burner or as a result of the ignition of flammable smoke and/or gases produced from the specimen by the heat from the burner do not constitute burnthrough. Burnthrough occurs only if the flame from the burner passes through the specimen.

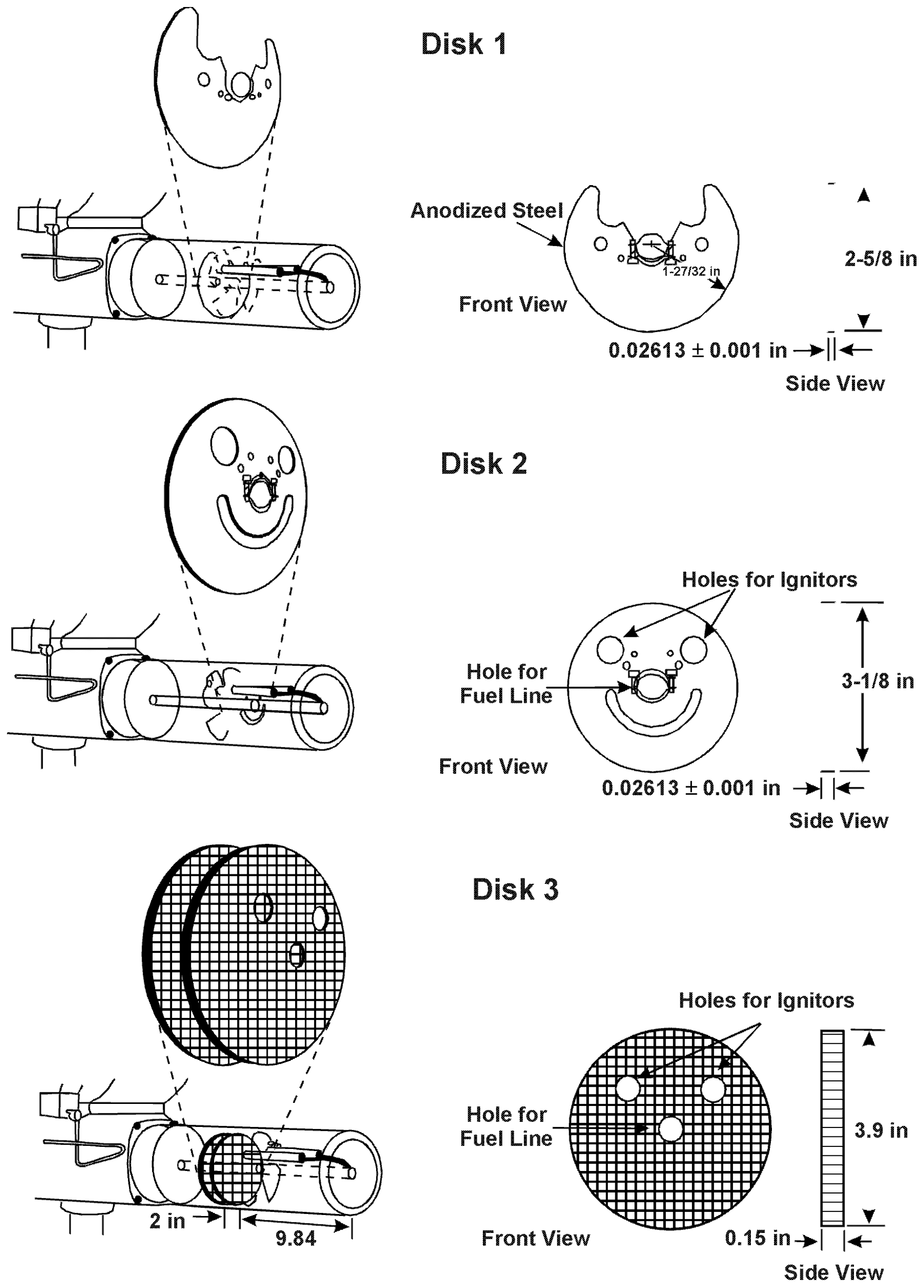


Figure 8-S-35. Static Disk Illustration