Next Generation (NexGen) Fire Test Burner Apparatus

1 Scope

1.1 Applicability

This chapter describes in detail the Federal Aviation Administration Next Generation Fire Test Burner, also known as the “Sonic” or the “NexGen” burner.

2 Description

2.1 Next Generation or Sonic 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 top of the combustion cone in the vicinity of the fuel spray nozzle. 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 1. Note that the configuration of the burner components will be test method specific and described in the respective chapter.

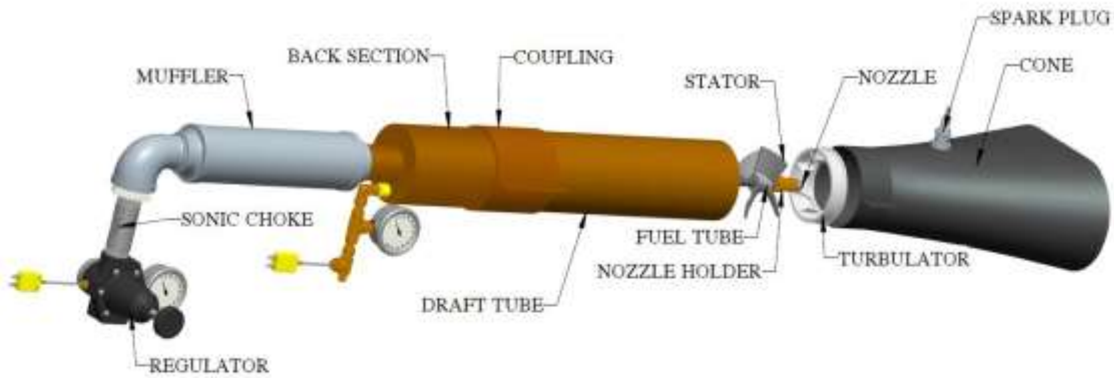

Figure 1. Schematic of the NexGen Burner - Exploded View

3 Test Apparatus Components

3.1 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 an outer diameter of 4.25 inches, and a length of 15 inches (figure 2). One end of the draft tube will be inserted 3 inches into the coupling, resulting in a 12-inch length of draft tube extending beyond the coupling. The coupling is constructed of 4.25-inch inner diameter mild-seam steel tubing that is 4 inches long with an outer diameter of 4.75 inches. Three set-screw holes are 120 degrees apart and are drilled 1 inch in from the edge. These holes will be tapped and set-screws inserted to hold the draft tube in place. The coupling has two mounting brackets welded to the sides for easy mounting and adjustment (figure 3). The back section is made of the same 4-inch inner diameter mild-seam steel tubing as the draft tube. The overall length of the back section is 6 inches, inserted 1 inch into the coupling and welded in place (figure 4). 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 5). 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 6).

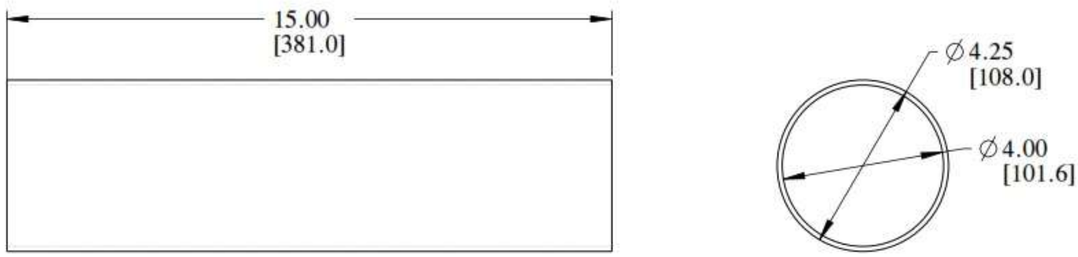

Figure 2. Dimensioned Drawing of the Draft Tube

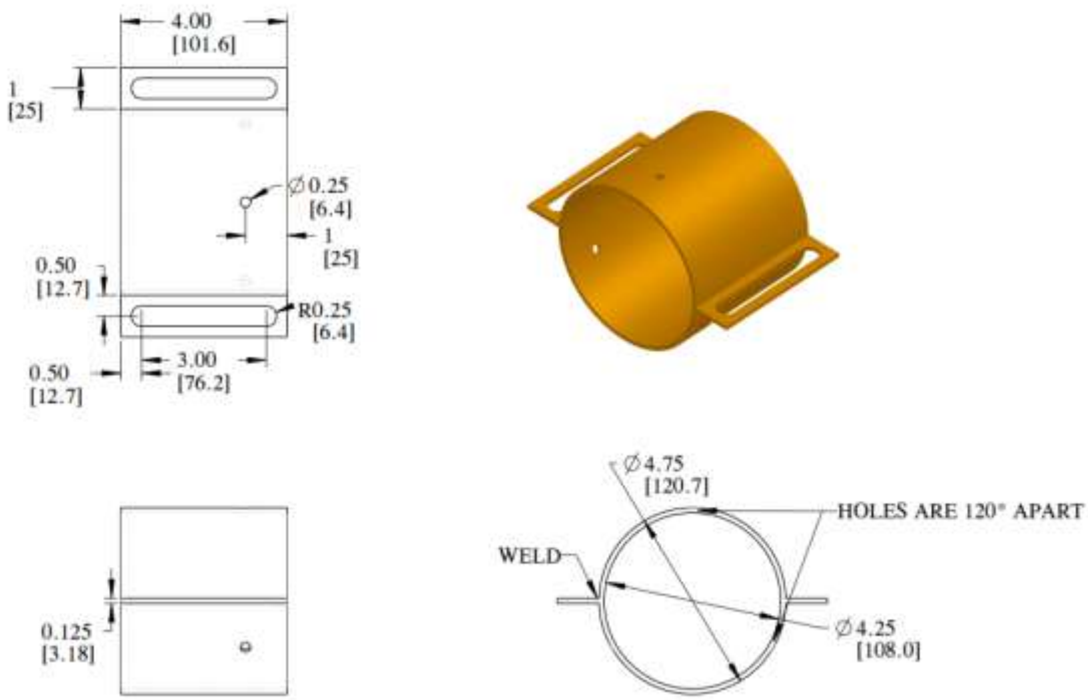

Figure 3. Dimensioned Drawing of the Coupling

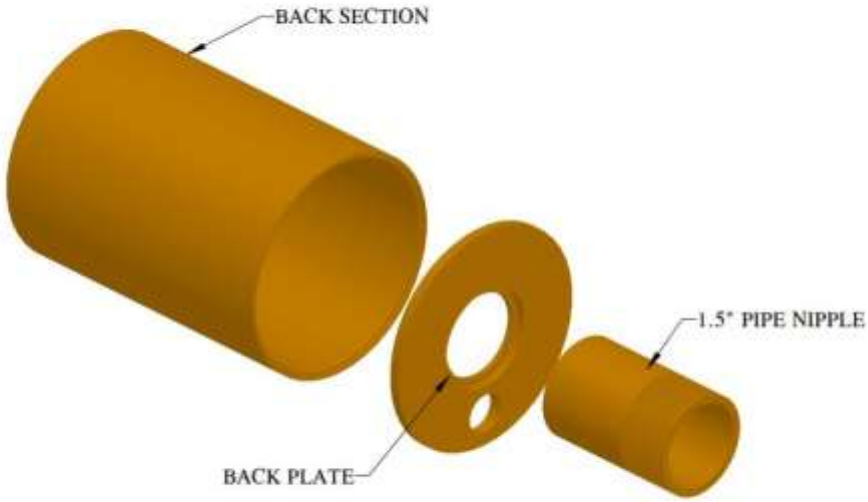

Figure 4. Back Section Components - Exploded View

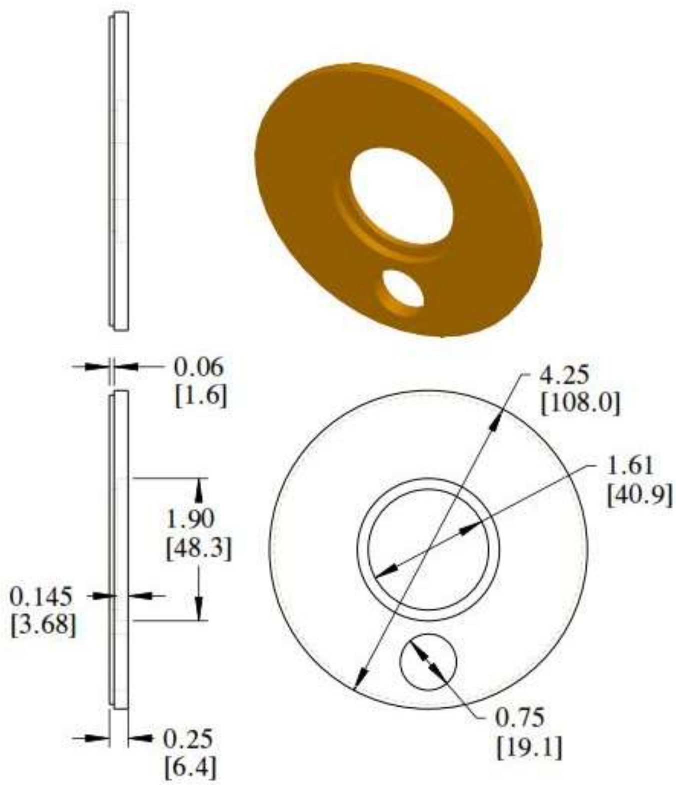

Figure 5. Dimensioned Drawing of the Back Plate

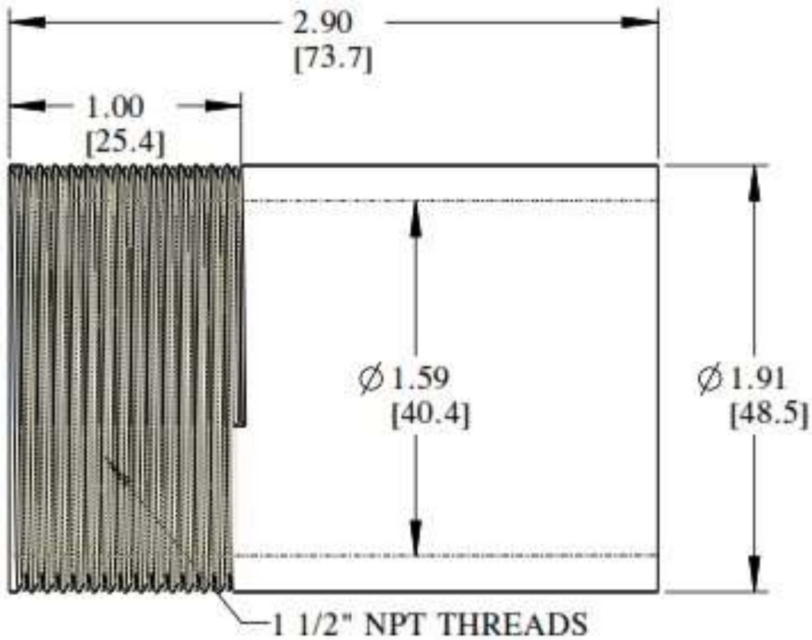

Figure 6. Dimensioned Drawing of the Pipe Nipple

3.2 Combustion Airflow Control

3.2.1 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 7). 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.

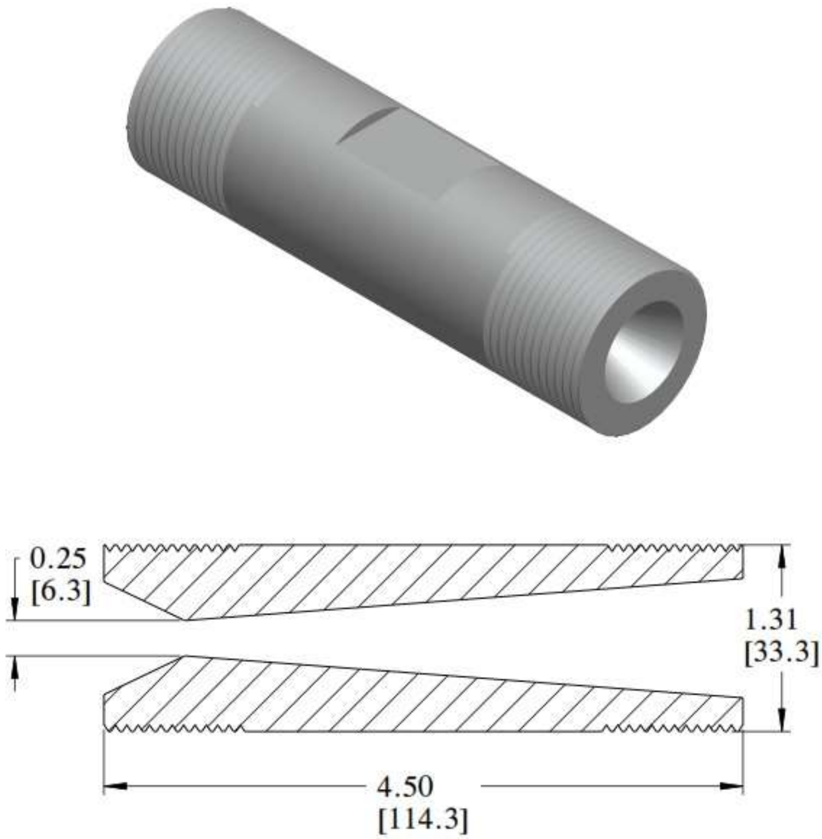

Figure 7. Schematic of the Sonic Nozzle with Cutaway View Showing Converging and Diverging Interior Sections

3.2.2 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). A suitable regulator is available from Grainger, item number 4ZM10 (manufactured by Speedaire) with an adjustment range of 5-125 lbs/in^2. 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.

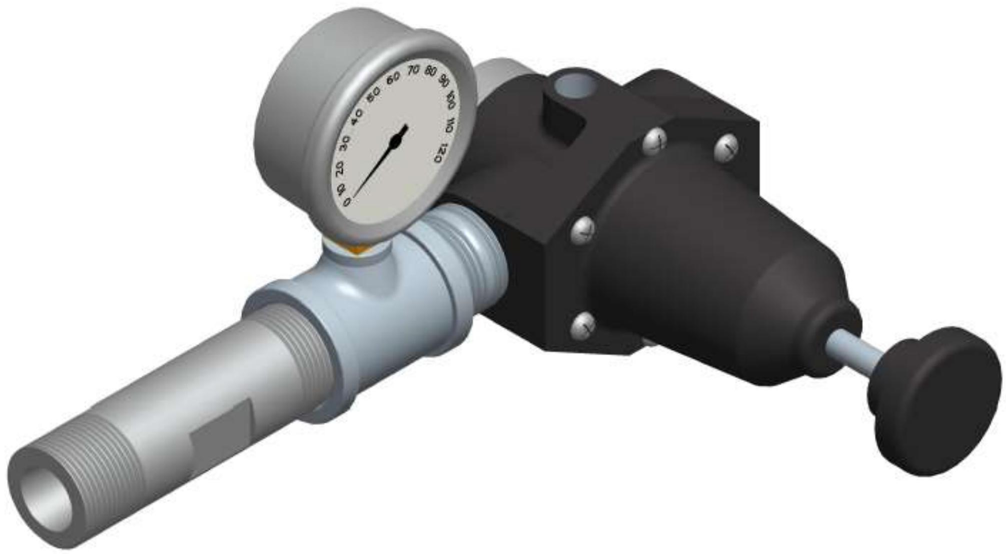

Figure 8. Schematic of Air Pressure Regulator with Sonic Nozzle Attached

3.2.3 Air Pressure Gauge

Correct air pressure at the inlet of the sonic choke is critical for establishing the proper mass flow of air through the sonic orifice. The pressure measuring device should be located nearest the point at which airflow enters the sonic choke. The pressure measuring device may be connected to the port on the pressure regulator when using either of the specified models from section 3.2.2. Otherwise, a 1-inch NPT tee-fitting connected directly to the inlet side of the sonic choke is a suitable point of air pressure measurement should the regulator be located upstream from the sonic choke, or an unspecified air pressure regulator is used (figure 8). The burner flame is highly sensitive to any fluctuations in the mass flow of air through the sonic orifice. The pressure measuring device must have NIST (or equivalent) traceable certification with an accuracy of $\pm$ 2% or less. Pressure transducers or 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 measuring device 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 4053K23 with a 0-60 psi pressure range.

3.2.4 Muffler

An airflow muffler is used to reduce the high frequency noise created by the air expanding from the sonic nozzle throat. The 2.625-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 9). 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 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 or less. 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 via a 1.5-inch NPT female to 1.5-inch NPT male, 90-degree, Schedule 40 standard-wall steel street elbow.

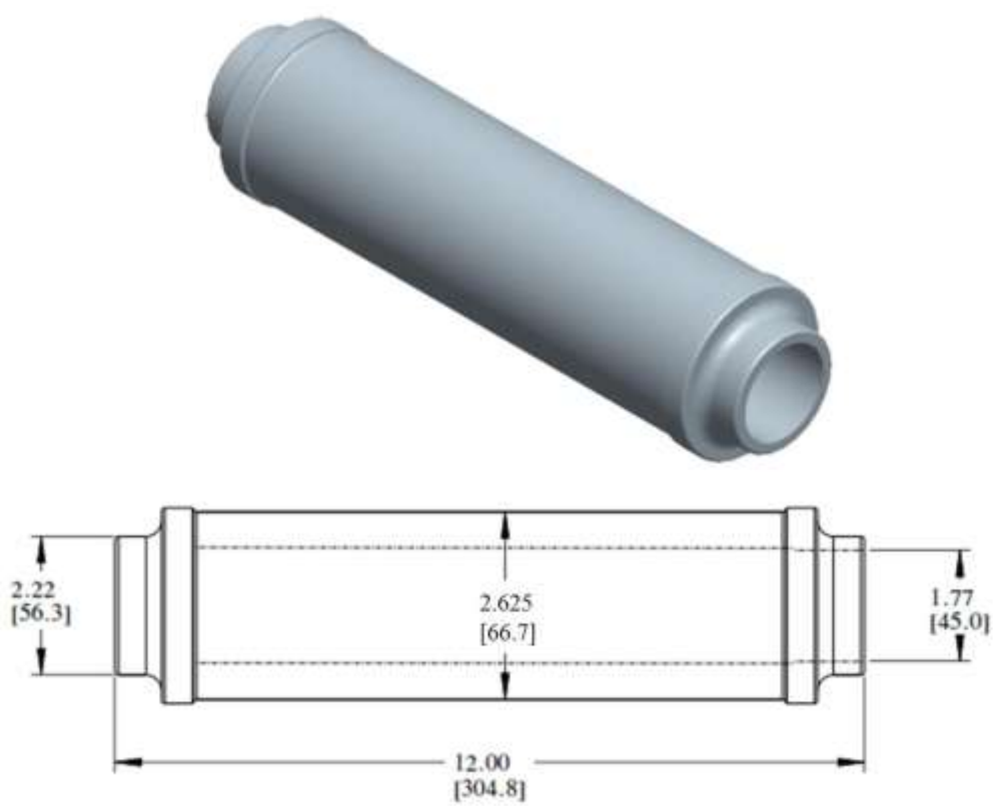

Figure 9. Schematic of the Muffler

3.2.5 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 document.

3.3 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

3.3.1 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 10). A suitable stator is supplied by Marlin Engineering, part number ME1513-3.

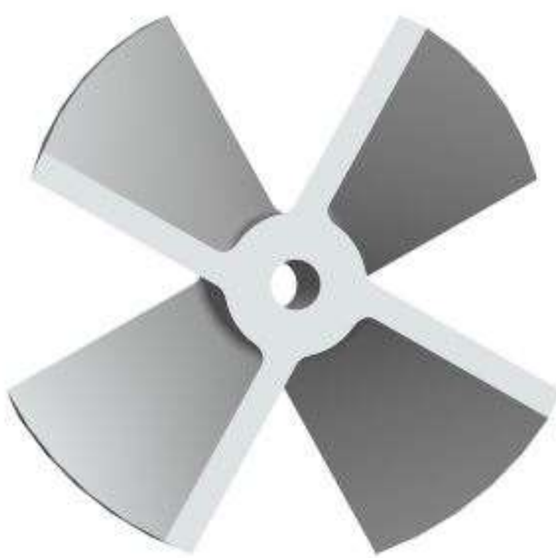

Figure 10. Stator

3.3.2 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 11). A suitable turbulator is supplied by Marlin Engineering, part number ME1512-1.

Figure 11. Turbulator, Front and Back

3.3.3 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 12). The turbulator is placed on the end of the draft tube with the notch located at the six o'clock position (figure 13). The typical configuration positions the face of the stator approximately 2.6875 inches from the exit plane of the turbulator (figure 14). Instructions for the exact positioning of the stator and turbulator can be found in the Preparation of Apparatus section of the particular test method being conducted.

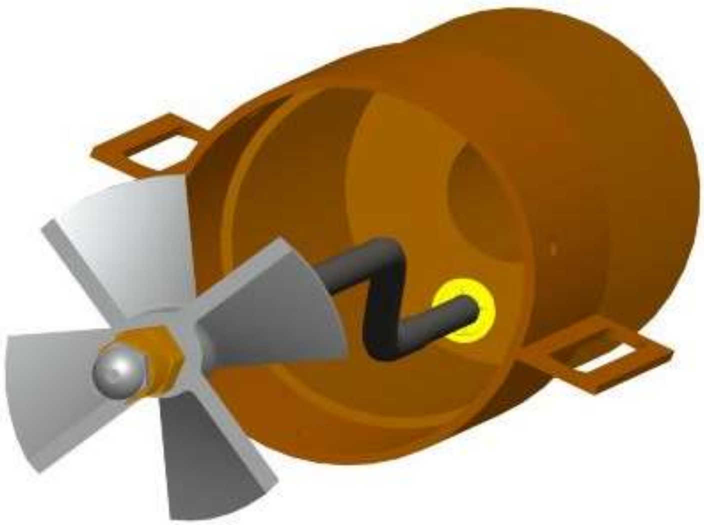

Figure 12. Location of the Stator on the Fuel Tube

Figure 13. Position of Turbulator at the end of the Draft Tube

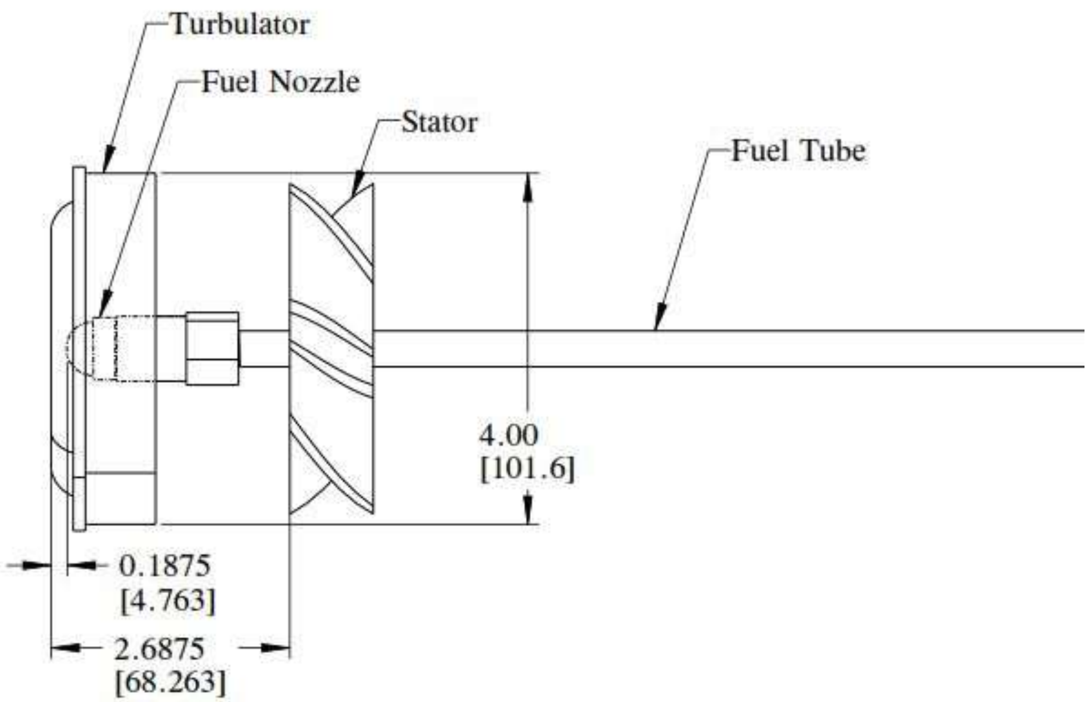

Figure 14. Typical Configuration of the Stator and Turbulator

3.4 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 15). 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 35 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 or pressure transducer. A high pressure translucent tube can be used for indicating the fuel level in the tank.

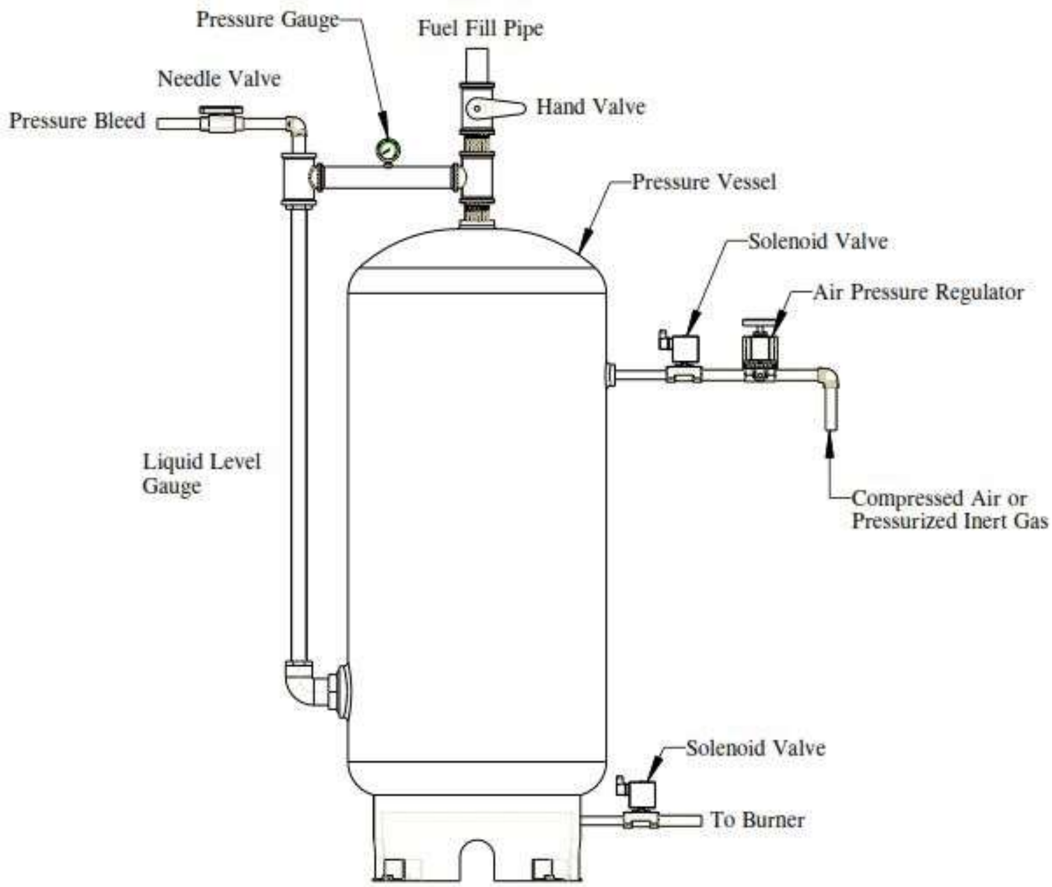

Figure 15. Schematic of Pressurized Fuel Tank System

3.4.1 Fuel Pressure Gauge

A suitable pressure gauge must be used to monitor the fuel system pressure, which is critical for establishing the proper flow of fuel through the fuel nozzle. The pressure measuring device must have NIST (or equivalent) traceable certification with an accuracy of $\pm$ 2% or less. Pressure transducers or 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 measuring device 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

3.4.2 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.

3.4.3 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 16). 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 1/8-inch female NPT fitting is attached to the back end of the fuel tube to connect the pressurized fuel system to the fuel tube.

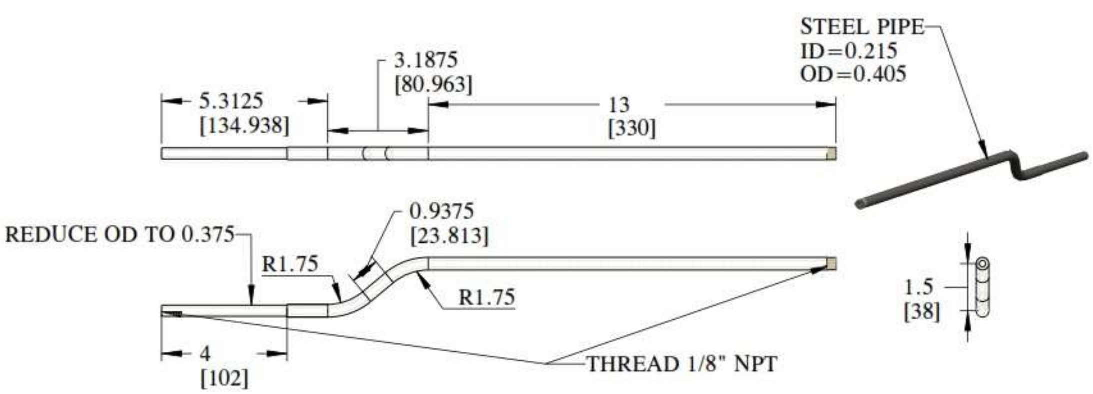

Figure 16. Schematic of the Fuel Tube

3.4.4 Fuel Nozzle

The fuel nozzle for the NexGen burner should be an 80-degree, solid conical spray pattern, oil burner nozzle. The nozzle flow rate will depend on the test method. The rated flow rate provided by the manufacturer is achieved when applying a 100 lb/in^2 pressure of water to the nozzle. The actual flow rate of fuel from the nozzle may differ slightly than the rated flow. 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, solid spray pattern (B-type) fuel nozzle has been found suitable for this application. A suggested nozzle flow rating can be found in the particular test method for which the burner is being used.

3.4.5 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 17).

Figure 17. Fuel Nozzle and Brass Adapter

3.4.6 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.

3.5 Ignition System

The fuel/air charge will be ignited by a high-voltage arc produced by a spark plug positioned in the top of the combustion cone in the vicinity of the fuel spray nozzle. The high-voltage is supplied by an alternating current (AC)-powered transformer, which produces a direct current (DC) spark.

3.5.1 Ignition Transformer

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.

3.5.2 Spark Plug

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 18). 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.

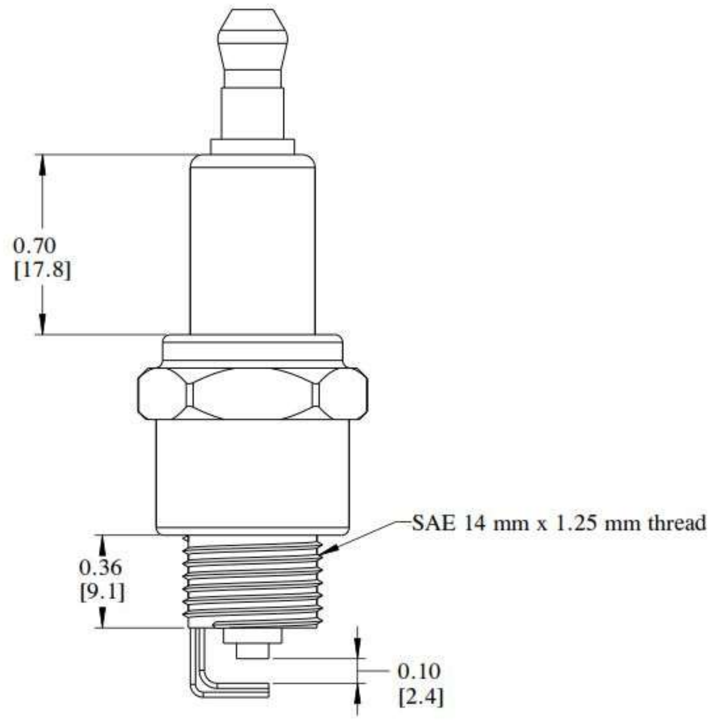

Figure 18. Dimensioned Drawing of a Spark Plug

3.6 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 19. The cooling system can be constructed from an insulated cooler or a chest freezer with temperature control capability. The fuel travels through coiled copper tubing in the cooling bath and out to the burner. The air is cooled in a heat exchanger, such as McMaster-Carr part number 43865K78, which has cooling fluid traveling through the outer shell, removing heat from the air. The cooling fluid 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 flow rate 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. Uninsulated or long fuel/inlet air supply lines can create difficulties in maintaining proper fuel/inlet air temperatures.

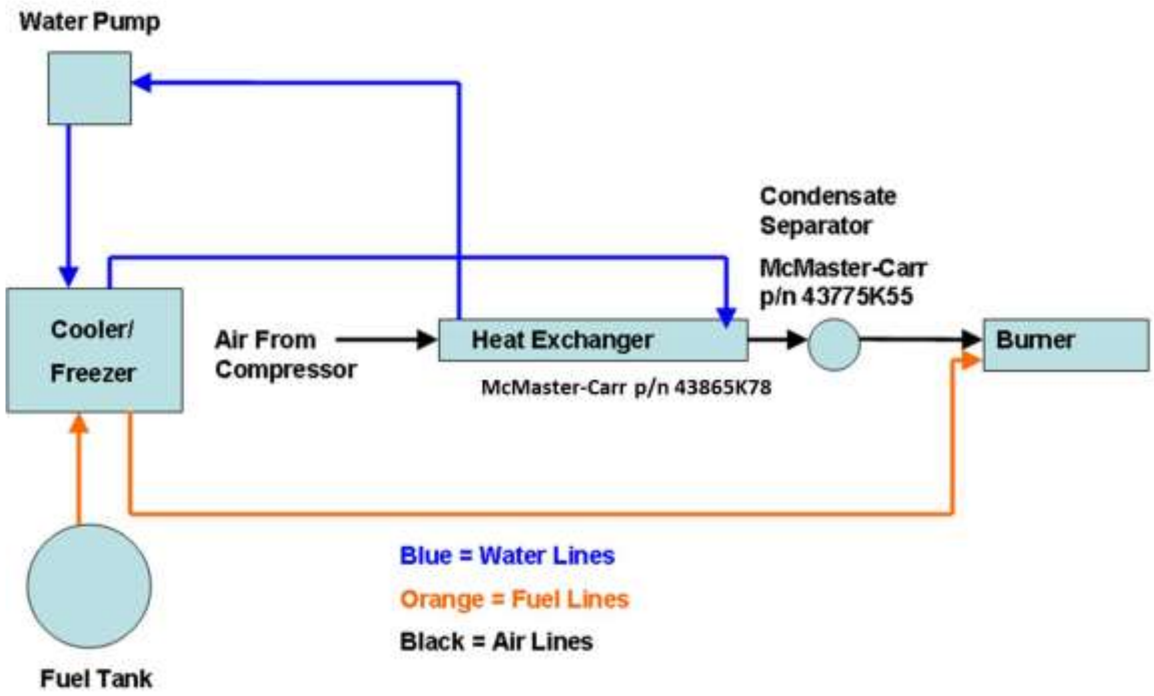

Figure 19. Schematic of Air/Fuel Heat Exchange System

3.7 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 20 and figure 21 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 exit plane dimensions to ensure they remain within the specified tolerances.

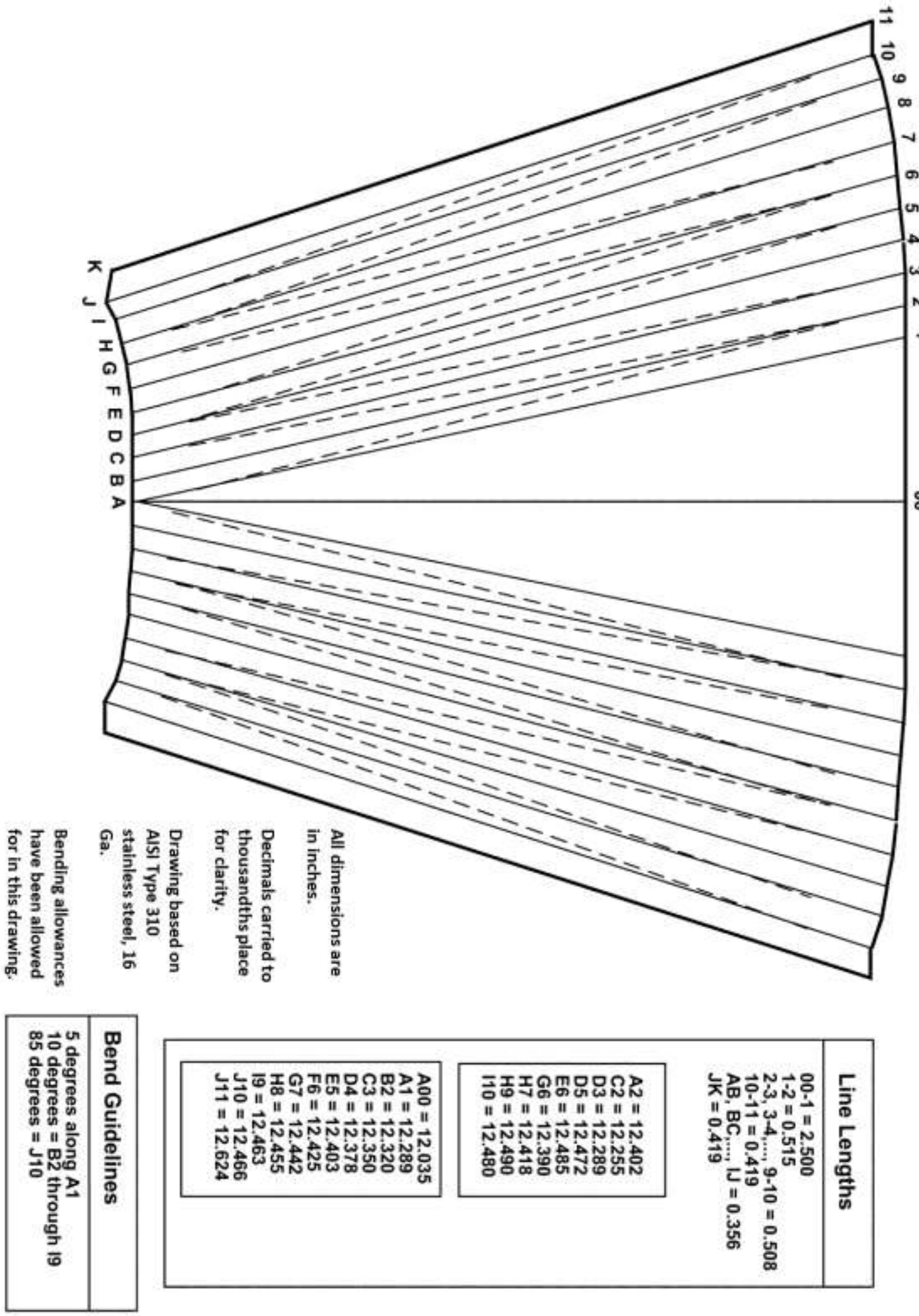

Figure 20. Burner Cone Layout and Bending Pattern

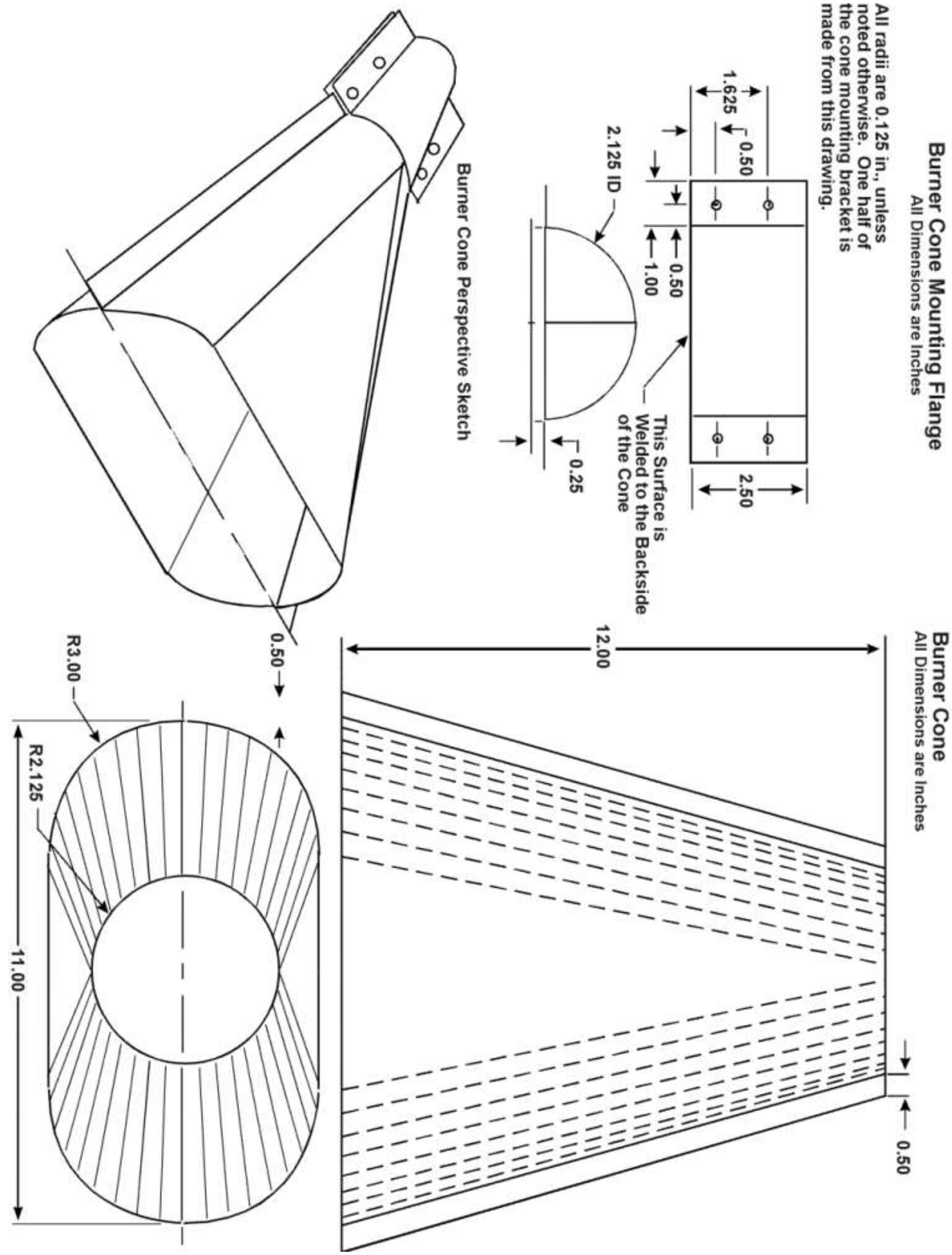

Figure 21. Burner Cone Details

3.7.1 Threaded Boss for Spark Plug

A 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 22). The threaded boss must be welded to the top side of the burner extension cone for acceptance of the spark plug used to ignite the fuel charge (figure 23).

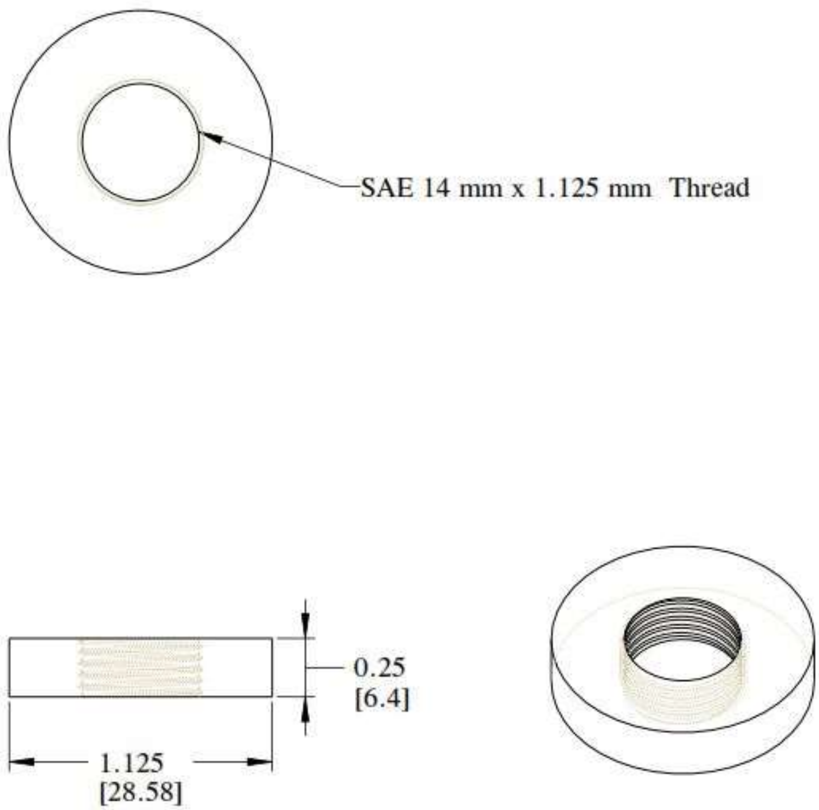

Figure 22. Threaded Boss

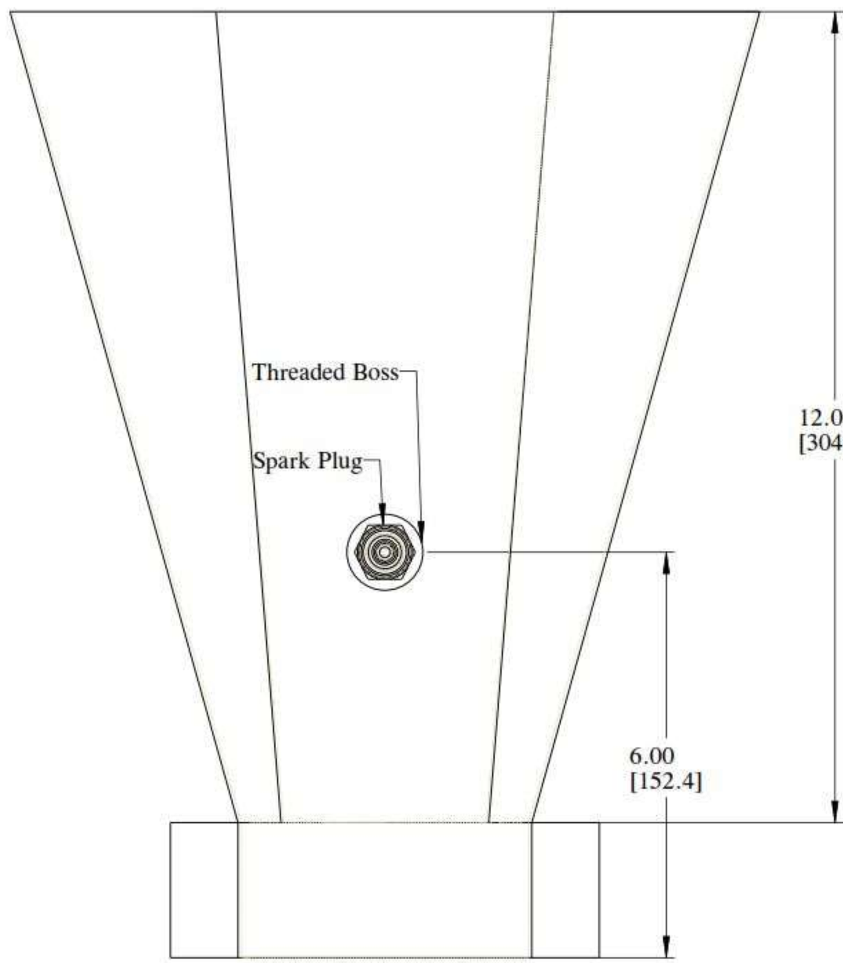

Figure 23. Location for Welding Threaded Boss to Cone

4 Measurement of Adjustable Burner Parameters

4.1 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 24.

4.2 Air Pressure

The sonic choke inlet pressure is measured with a suitable pressure transducer or gauge mounted just upstream of the sonic choke. The transducer or 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).

4.3 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.

4.4 Fuel Pressure

The burner fuel pressure is measured with a suitable pressure transducer or 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.

4.5 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 fuel temperature.

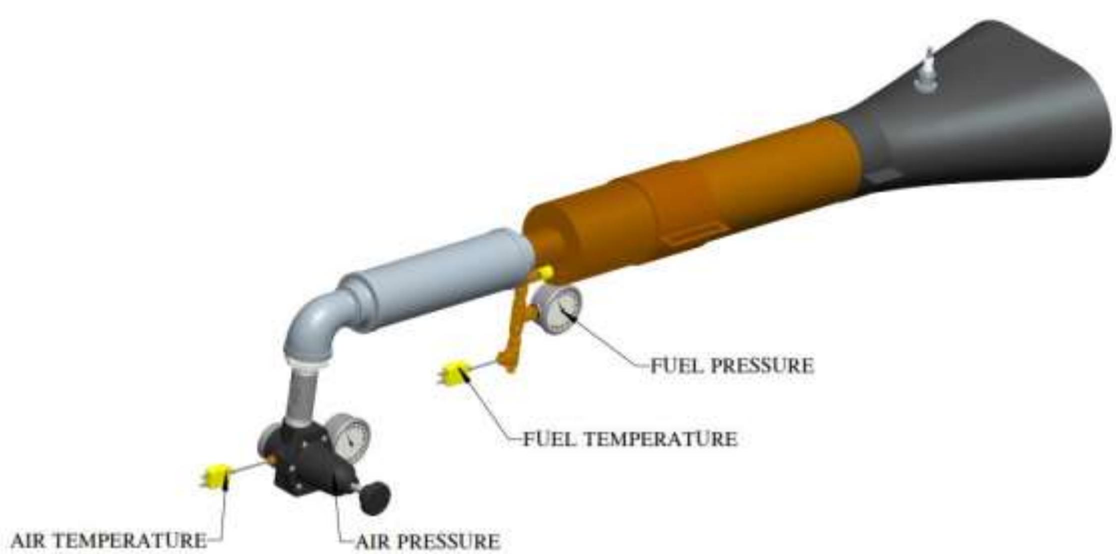

Figure 24. Burner Schematic Showing Inlet Measurement Locations

5 Measurement of Burner Output

5.1 Burner Flame Consistency Validation

The objective of the burner flame consistency validation is to ensure the burner is producing the required flame output, in order to subject the test samples to the proper flame intensity. The NexGen burner is specialized equipment, using precision components that are assembled in a very specific configuration. This level of accuracy is a departure from previous burners, in which the internal components and configuration were not as tightly controlled. For this reason, previous burners used for flammability testing required time-consuming calibration procedures to help ensure the multitude of possible burner configurations were still producing the required flame intensity. With the NexGen burner, there is more reliance on the internal components and precise configuration to produce the correct flame output, thereby minimizing lengthy calibration procedures.

5.2 Thermocouple Degradation

The thermocouples used for measuring the burner flame temperature have been known to degrade over time. This is due to the transient nature of the burner flame, which produces rapid increases and decreases in temperature during measurement. These instantaneous fluctuations in temperature cause a reduction in the sensitivity of the instrument, resulting in a lower indicated reading. The difficulty with this degradation process is that it occurs gradually over a period of time, and currently there are no recommended guidelines for replacing the instruments after a specific number of exposure hours. This occurrence can often lead to suspicion that the burner is malfunctioning, thereby triggering unnecessary adjustment of the burner equipment to compensate for the erroneous low temperature readings.