FAA NexGen Burner Update

A Review of Completed Work

Presented to: International Aircraft Materials Fire Test Working Group, Niagara Falls, NY

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Date: Tuesday, June 17, 2008

Outline

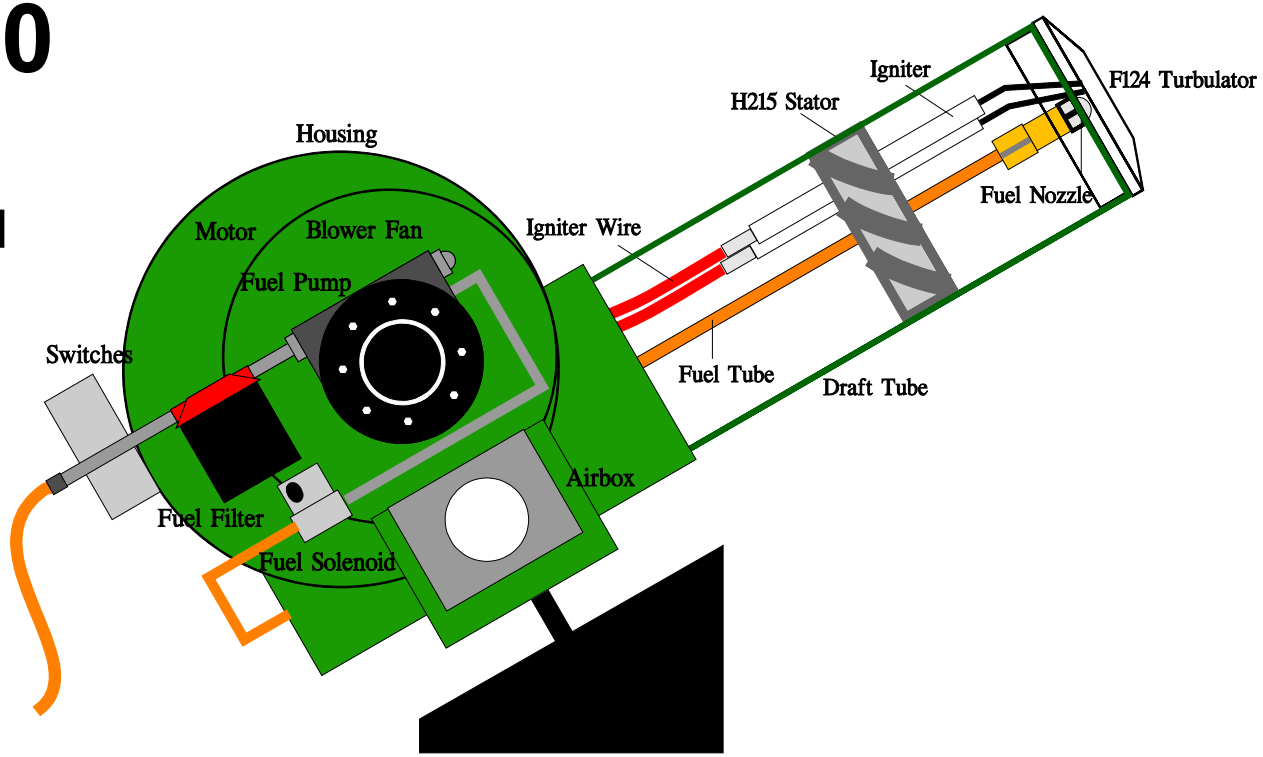
- Objective, and why we built a next generation burner
- How to build a next generation burner
- How to test a next generation burner
- Recent findings with the next generation burner
- Future work with the next generation burner

Motivation

- **To develop a burner that can be considered equivalent to the burner specified in 14 CFR 25, Appendix F, part VII**
  - Specified burner is the Park DPL 3400
  - The equivalent burner should:
    - be constructed from readily available materials
    - rely on similar operating principles
    - provide a flame with similar characteristics to the specified burner
    - provide material burnthrough times and backside heat flux measurements similar to the specified burner
  - The primary motivator for this work was to fulfill the industry's need for an equivalent burner in order to meet the deadline for the thermal acoustic insulation burnthrough rule
  - The next generation (NexGen) burner will be tested for the seat test, cargo liner test, and powerplant firewall and hose assembly test.

Park DPL 3400

- **Standard household oil burner**
  - Manufacturer: Park Electric Motor of Atlantic City, NJ
  - Model: DPL 3400
  - Fuel Nozzle: Monarch 6.0 gph 80° PL hollow cone
- **Same oil burner specified for testing of:**
  - Aircraft Seats
  - Aircraft Cargo compartment liners
  - Aircraft powerplant hose assemblies

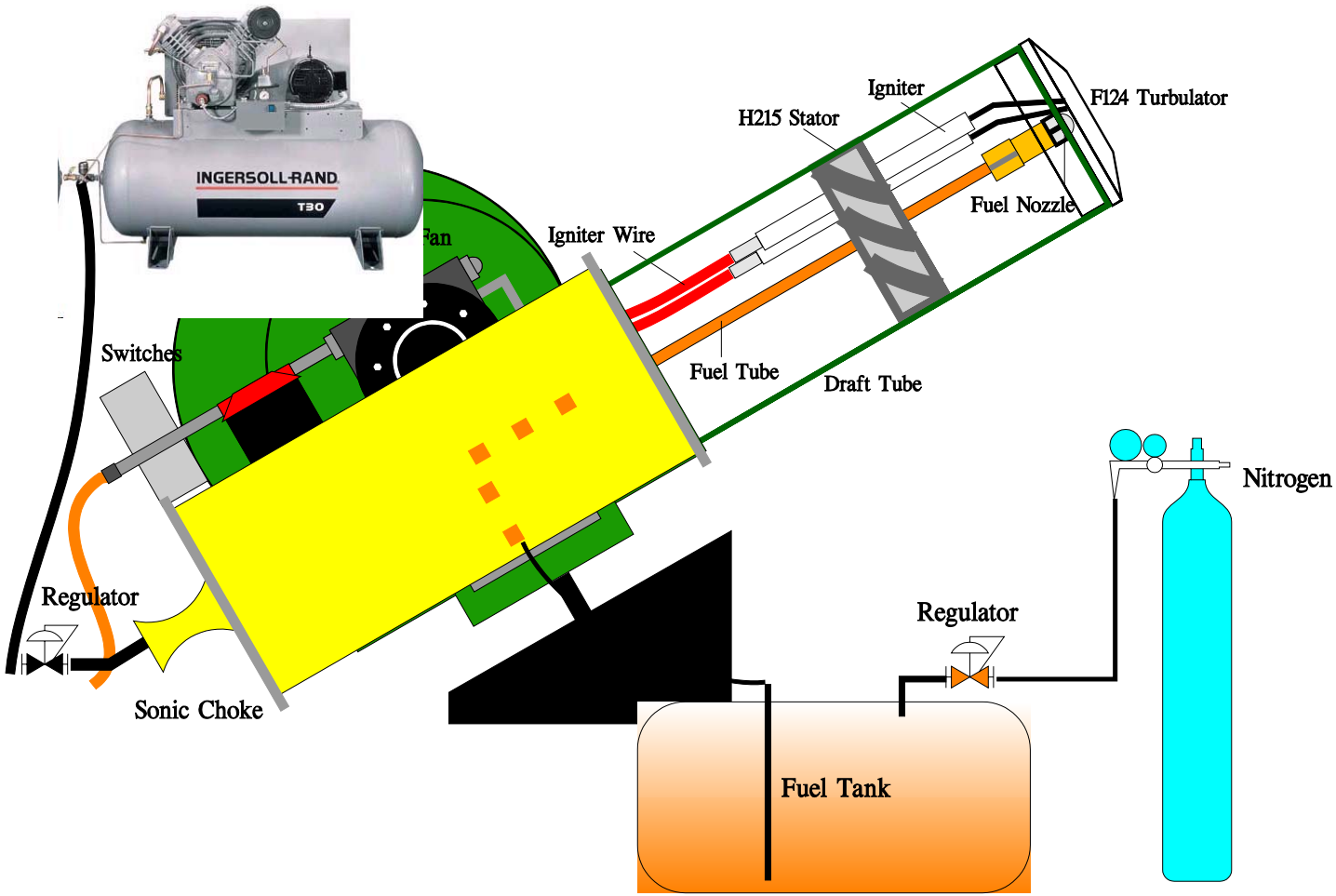


Burner Issues

- **Critical Discoveries:**
  - Burner housing differences:
    - Model DPL3400 found to have 2 different housings
      - Flanged style connection
      - Socket style connection
    - Each style has different dimensions
    - This has an effect on calibration and burnthrough times
  - Fuel nozzle differences:
    - Model F-80 found to have differences
      - Slotted style
      - Hex-head style
    - These differences affect the spray, changing the calibration and burnthrough measurements
    - Slotted style are no longer produced
  - Park Oil Burner ceased production
    - Burner housings are no longer produced
    - Other components can be purchased
  - Difficulties in calibration procedure
- **These issues present the need for an equivalent test apparatus**
  - Rulemaking has been delayed due to these issues
  - An equivalent burner is desired immediately
  - The burner should be free of these issues, and should have an increased level of accuracy
  - The development of a next-generation burner has been divided into phases:
    - Phase I: Proof of Concept
    - Phase II: Delivery of several next-generation burners
    - Phase III: Fundamental analysis and development of a fully independent burner

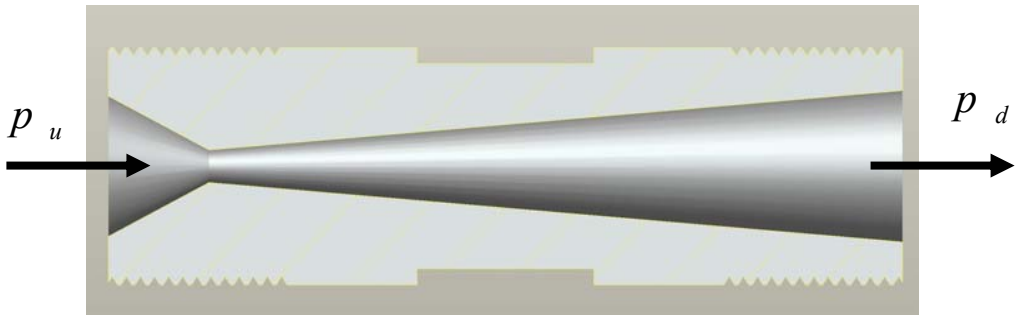
Concept

- **Early research with the Park DPL 3400 found that fluctuations in burner properties had a significant effect on test results**
  - Air
    - Velocity
    - Temperature
    - Density
    - Mass flow rate
  - Fuel
    - Flow rate
    - Pressure
    - Temperature
- **An increased level of control was desired for the NexGen burner in order to decrease the variability in the inlet parameters, ultimately leading to an increase in the consistency of the burner output**

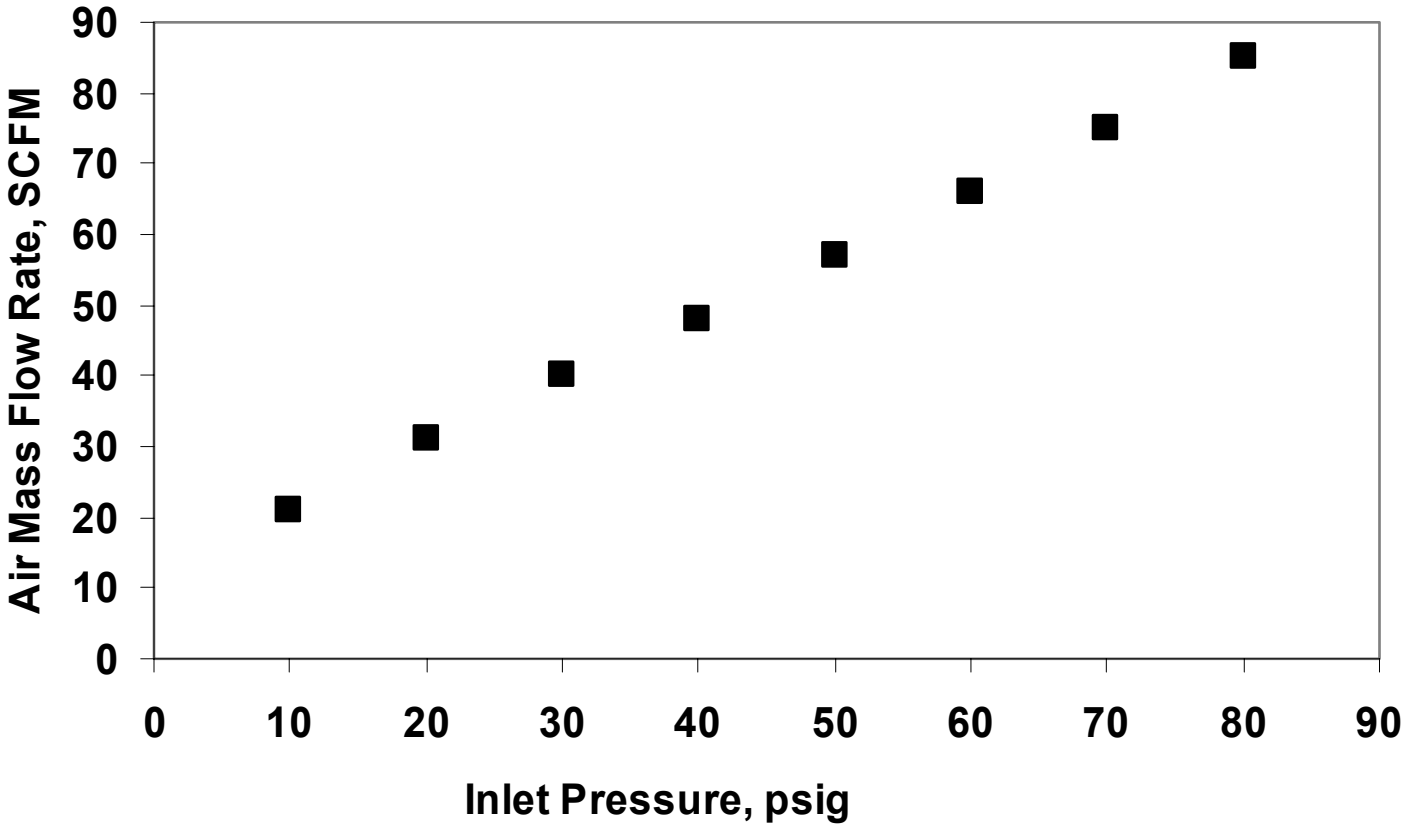

INGERSOLL-RAND
T30
Fan
Igniter
H215 Stator
F124 Turbulator
Fuel Nozzle
Igniter Wire
Switches
Fuel Tube
Draft Tube
Nitrogen
Regulator
Regulator
Sonic Choke
Fuel Tank

NexGen Components – Air Delivery

- **Critical Flow Venturi (Sonic Choke)**
  - Applied fluid dynamics
    - Converging-Diverging nozzle theory derived from:
      - Continuity (conservation of mass)
      - Equation of State (ideal gas)
      - Isentropic Flow Relations (2nd Law of Thermodynamics – Reversible Flow)
    - Flow is motivated by a pressure difference between the upstream converging section and the downstream diverging section
    - Increasing the pressure ratio (P_U/P_D) increases the mass flow rate through the nozzle
    - At a certain pressure ratio, the gas velocity at the throat will be equal to the speed of sound, Mach 1
    - Further increases in the pressure ratio will not increase the mass flow rate, and the flow is said to be choked
  - A sonic choke can be used for the NexGen burner to accurately regulate the mass flow rate of burner inlet air
    - Pressure ratio (P_U/P_D) is controlled by placing a precision air pressure regulator fed by a compressed air line immediately upstream of the converging section
    - The choke will be designed such that choked flow will occur at 80 SCFM, which is the same mass flow rate specified for the Park DPL 3400
      - 80 SCFM will be the maximum mass flow rate allowable by this choke, but a steady mass flow rate less than 80 SCFM can be achieved by decreasing the pressure ratio
  - The details of the sonic choke chosen for the NexGen burner are
    - Fox Valve, Inc. of Dover, NJ
    - p/n 612021-8
    - Design point – 80 SCFM at 75 psig inlet pressure
    - Construction – 1” pipe, 304 stainless steel, male NPT ends

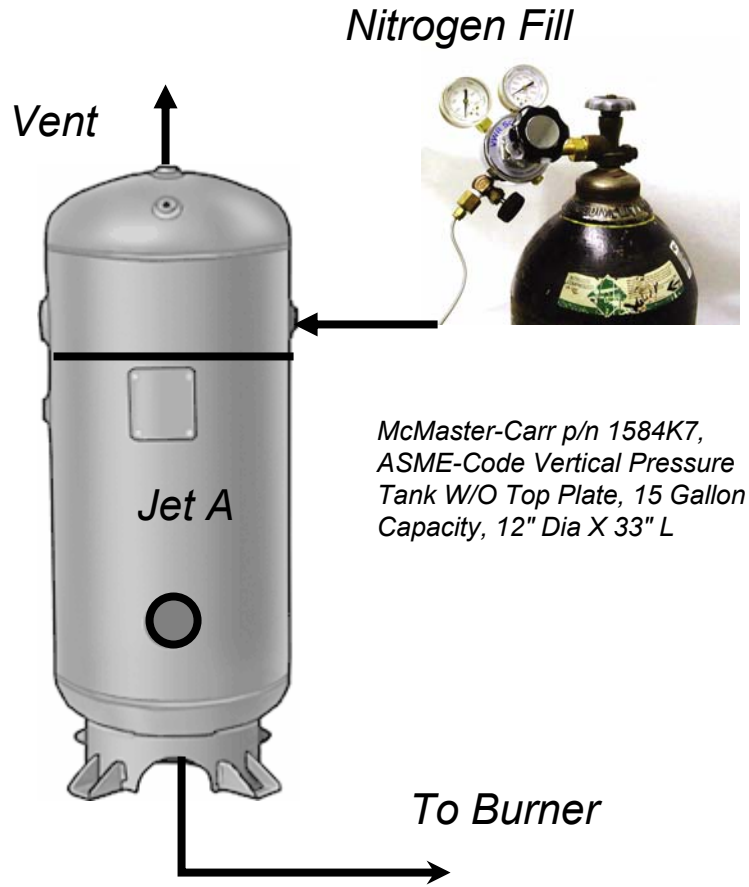


Sonic Choke Calibration



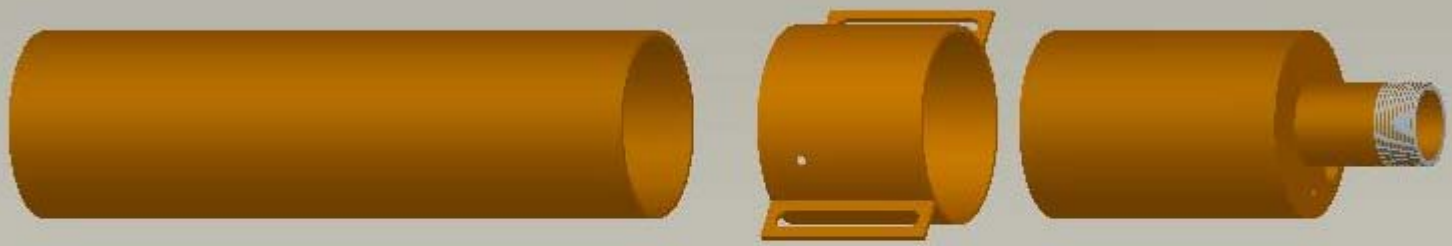
NexGen Components – Fuel Delivery

- **Fuel will be provided by a pressurized fuel tank**
  - Headspace gas pressure controlled with a precision regulator
  - Fuel pressure can be measured at the back of the burner for an accurate reading nearest to the fuel nozzle
  - Fuel flow rate is more stable with the pressurized fuel tank when compared to the fuel pump on the DPL 3400
  - **Note: equivalent results have been obtained using a mechanical fuel pump to achieve the same pressure*



McMaster-Carr p/n 1584K7, ASME-Code Vertical Pressure Tank W/O Top Plate, 15 Gallon Capacity, 12" Dia X 33" L

NexGen Burner Housing

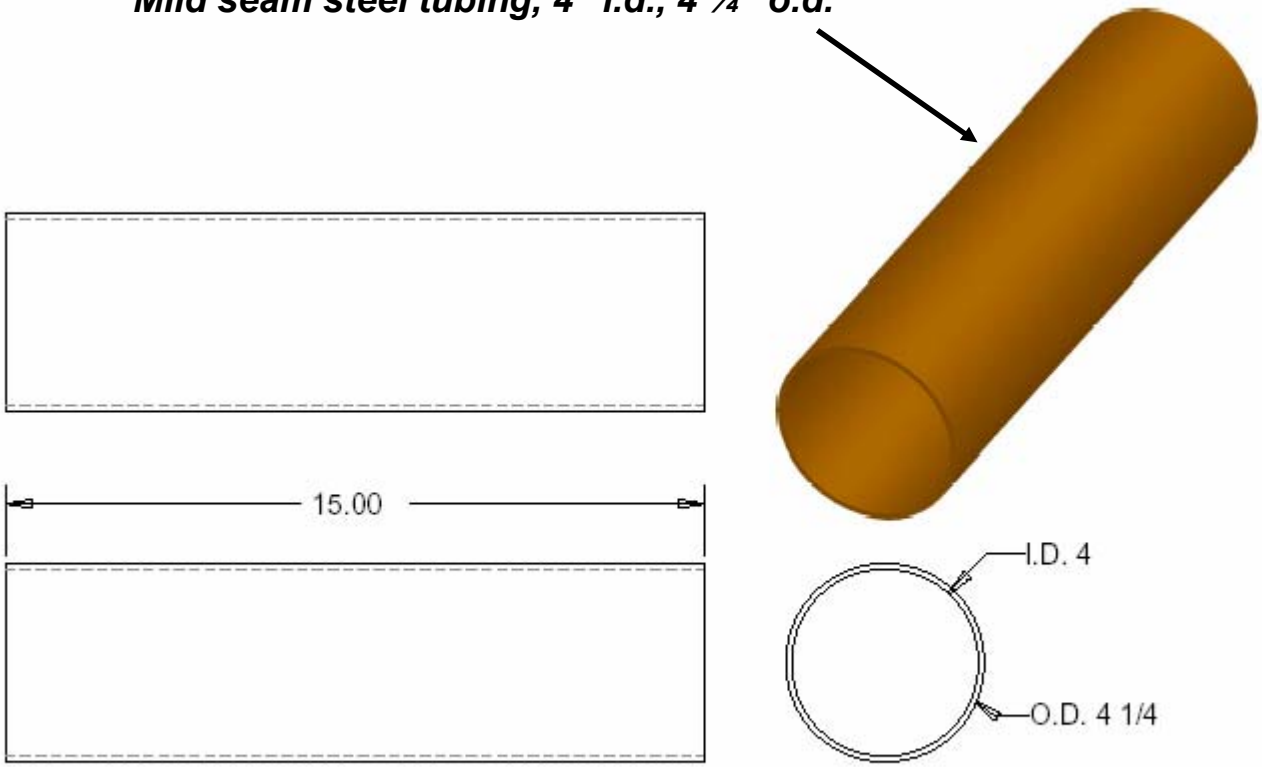


Draft Tube *Coupling* *Back Section*

Draft Tube

ALL DIMENSIONS ARE INCHES

Mild seam steel tubing, 4" i.d., 4 ¼" o.d.

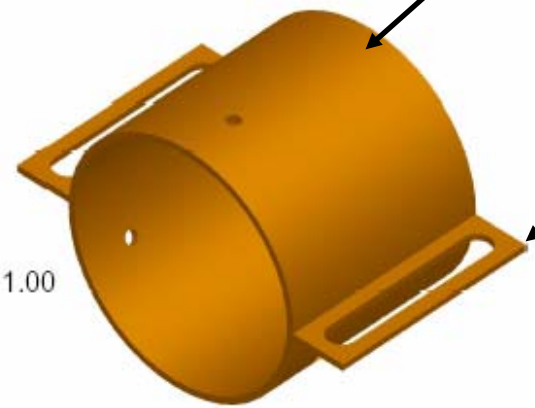


Coupling

ALL DIMENSIONS ARE INCHES

Mild seam steel tubing, 4 ¼" i.d., 4 ¾" o.d

Steel plate, 1/8" thickness



Back Section

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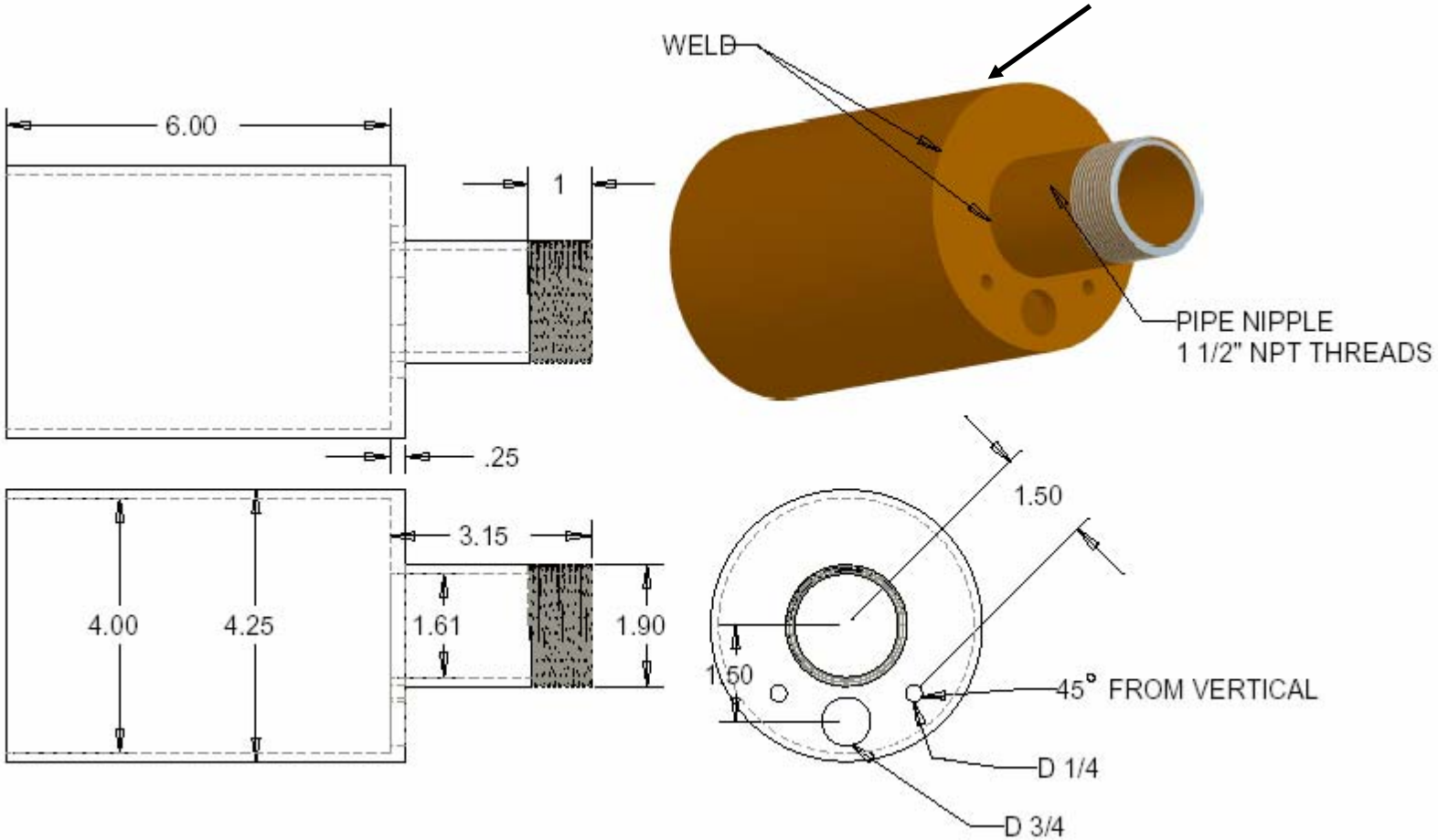
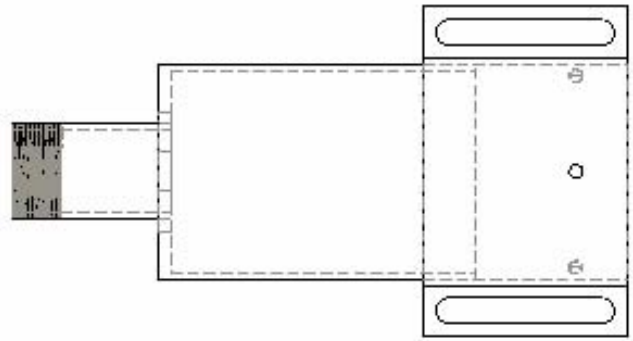
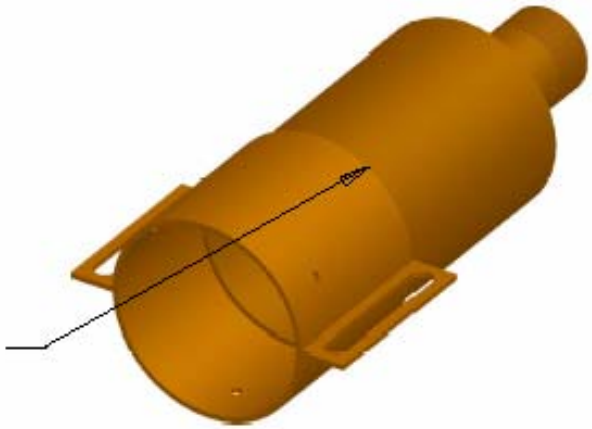
Mild seam steel tubing, 4" i.d., 4 ¼" o.d.

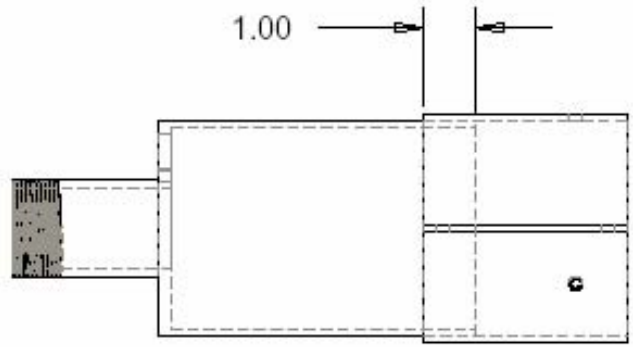


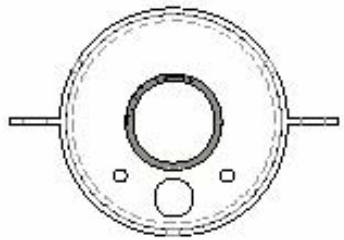
Assembled Back Section and Coupling

ALL DIMENSIONS ARE INCHES





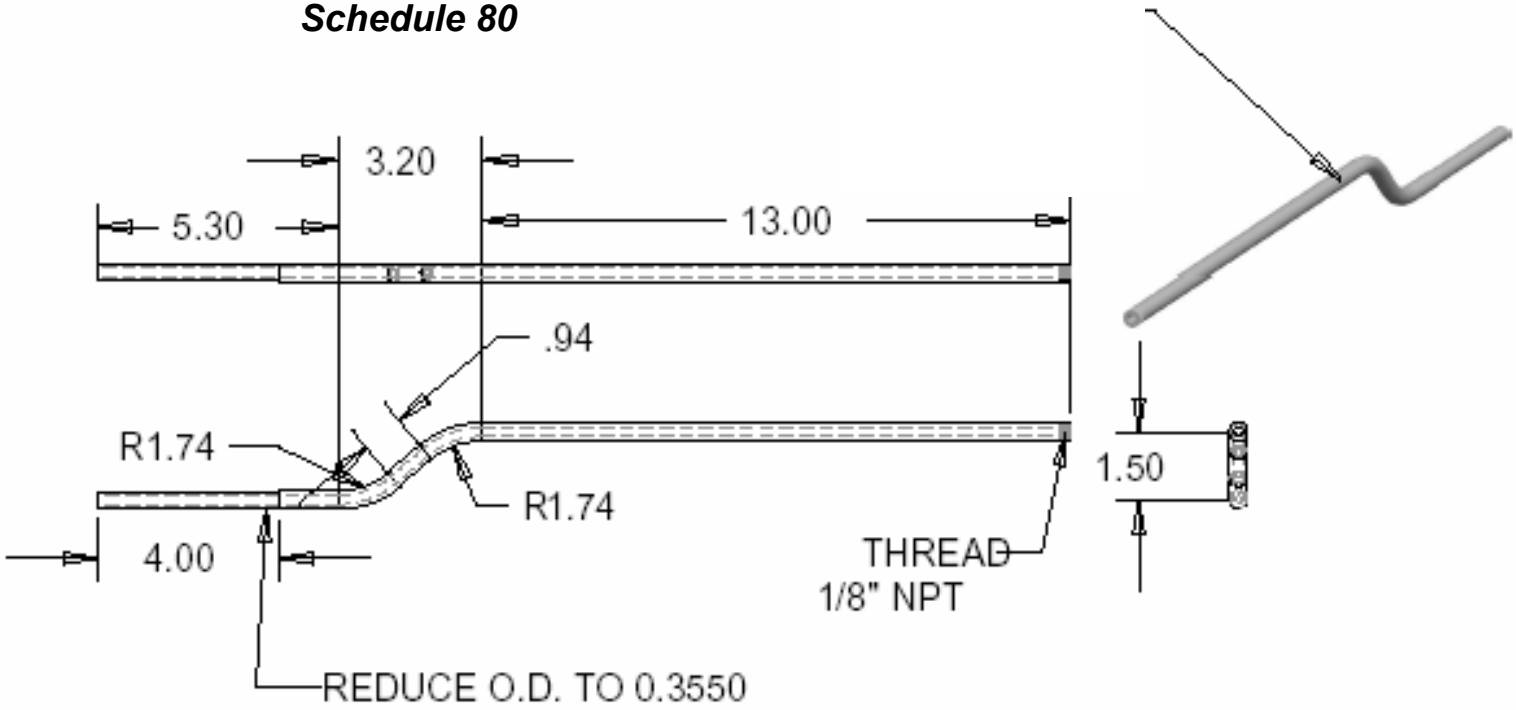




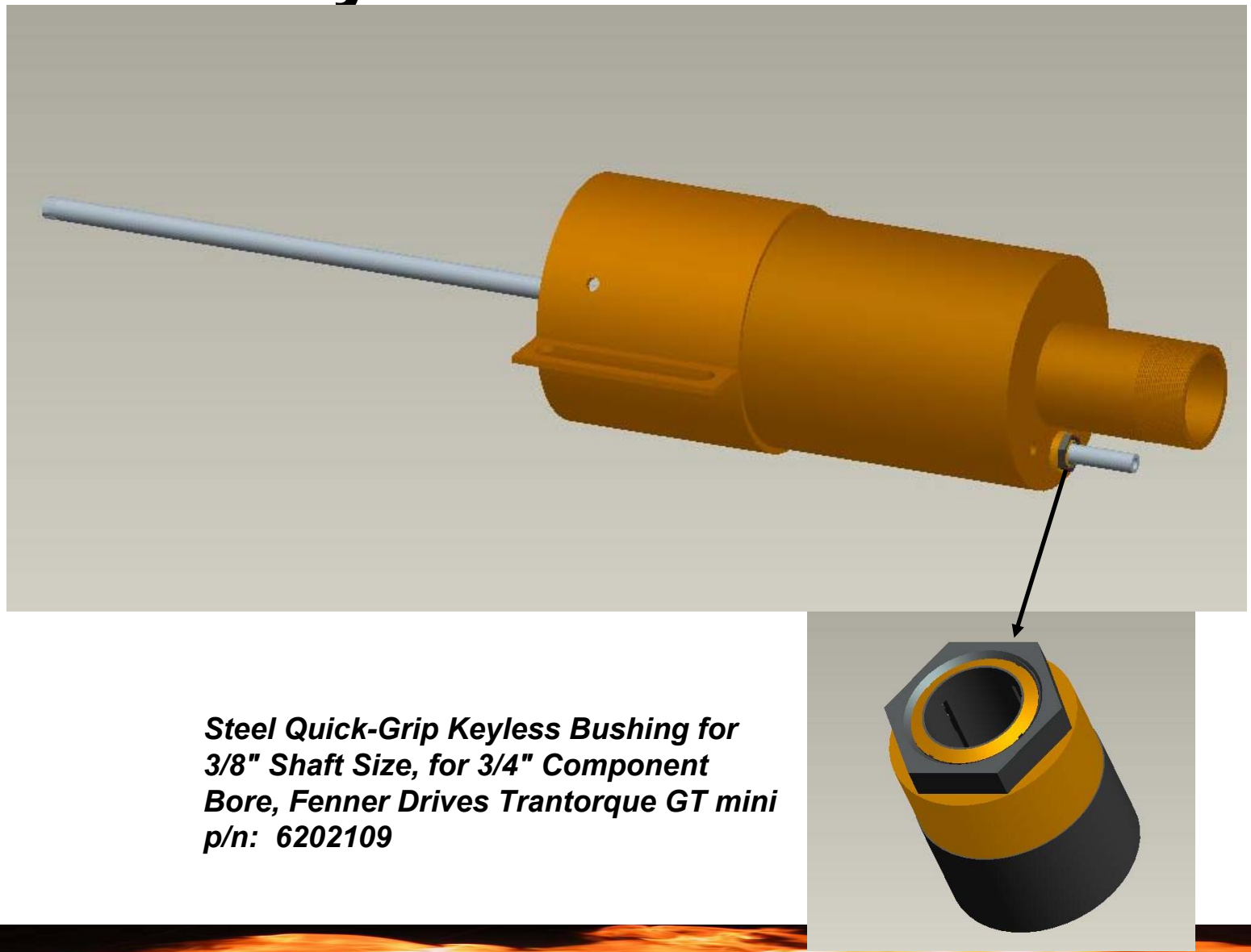
Fuel Tube

ALL DIMENSIONS ARE INCHES

Thick-Wall Steel Seamless Pipe 1/8" Pipe Size
Schedule 80



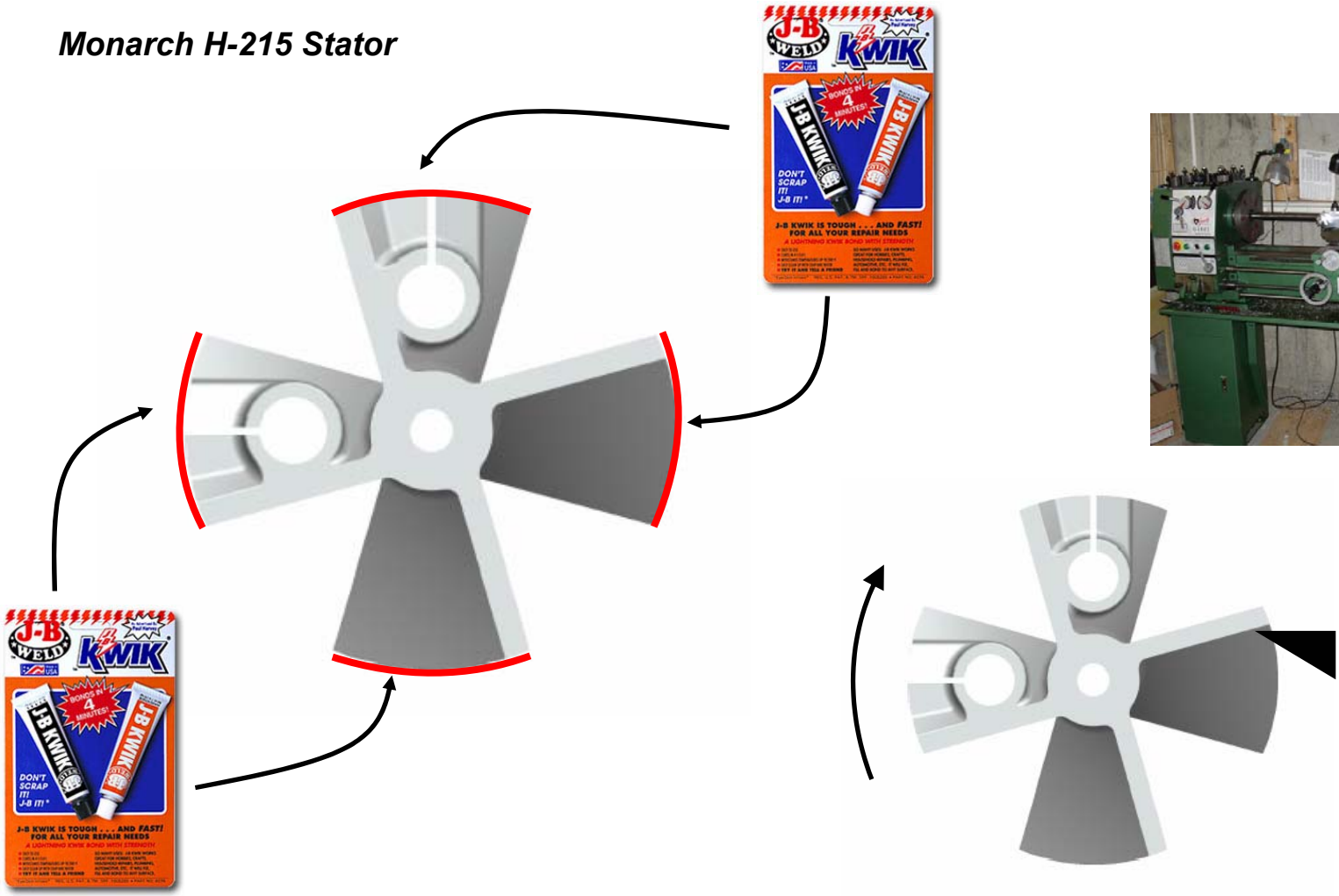
Assembly



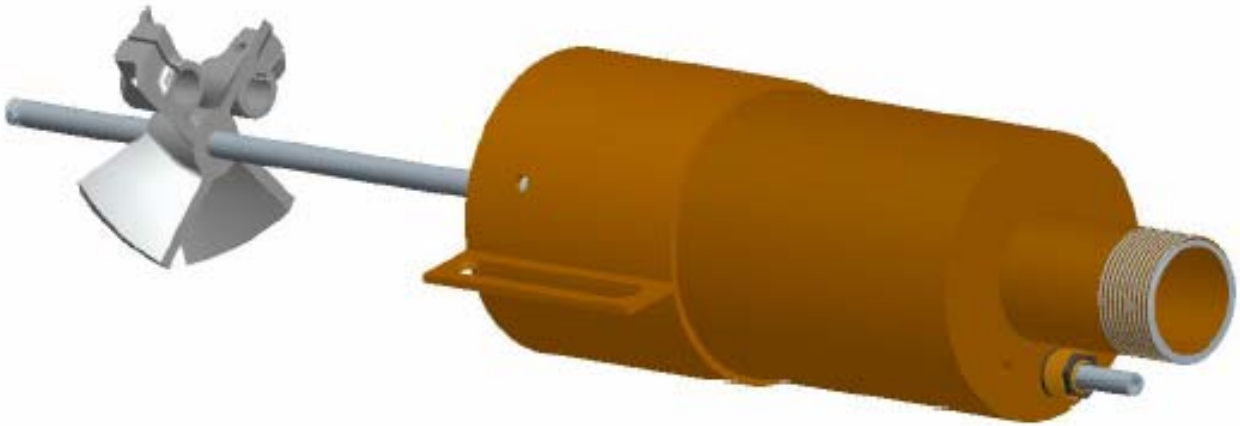
Steel Quick-Grip Keyless Bushing for 3/8" Shaft Size, for 3/4" Component Bore, Fenner Drives Trantorque GT mini p/n: 6202109

Stator

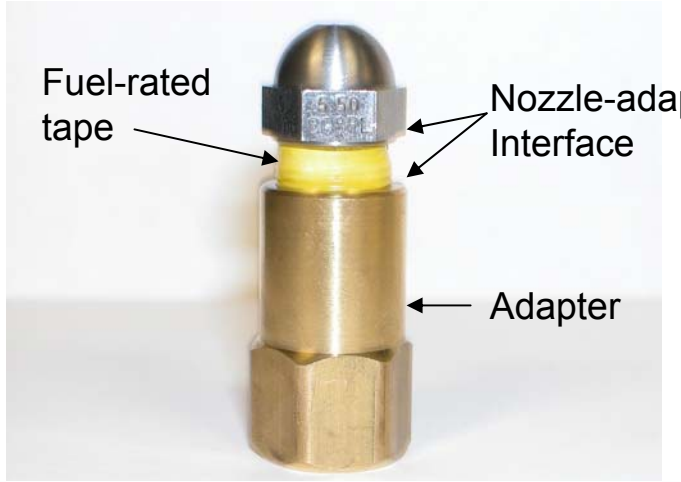
Monarch H-215 Stator



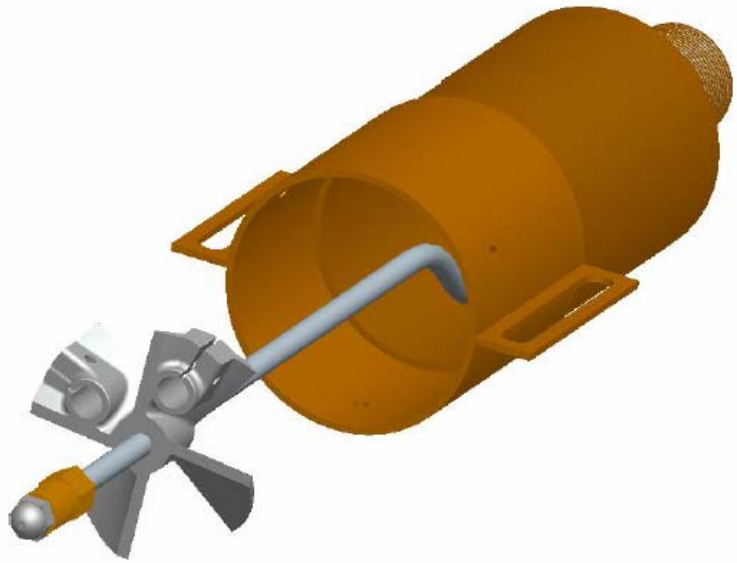
Assembly



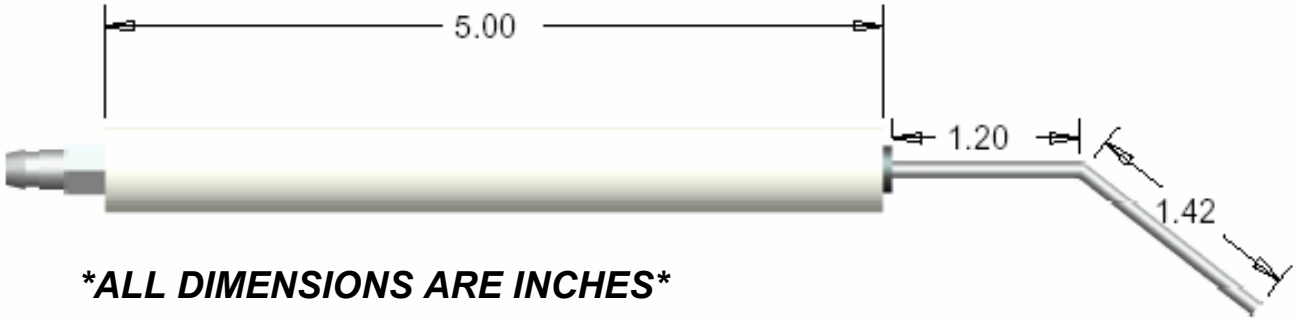
Fuel Nozzle



- **Monarch 5.5 GPH 80° PL hollow cone nozzle**
- **Standard female nozzle adapter, brass, 1/8” NPT**
- **Fuel rated thread tape used to prevent fuel leakage**



Igniters

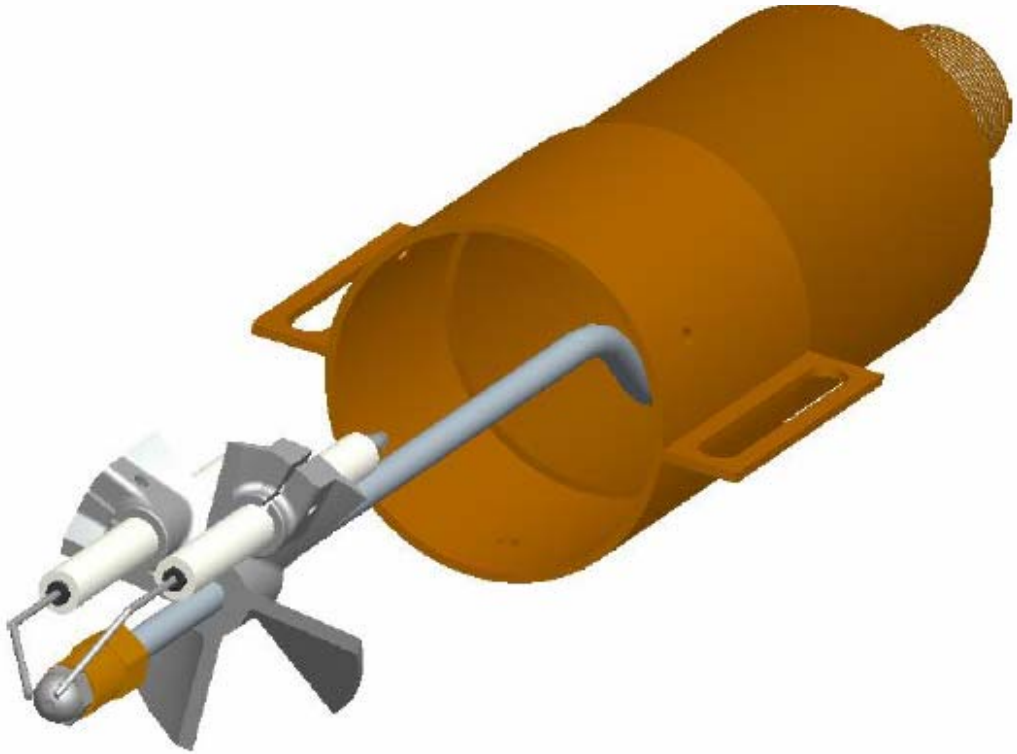


ALL DIMENSIONS ARE INCHES

Insulator length 5”

Insulator diameter 0.5”

Electrode diameter 0.1”



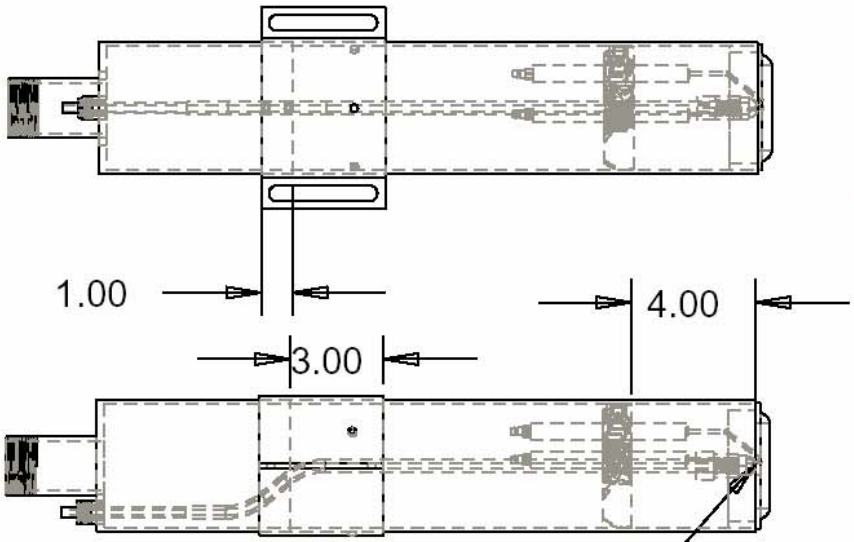
Igniter Wires

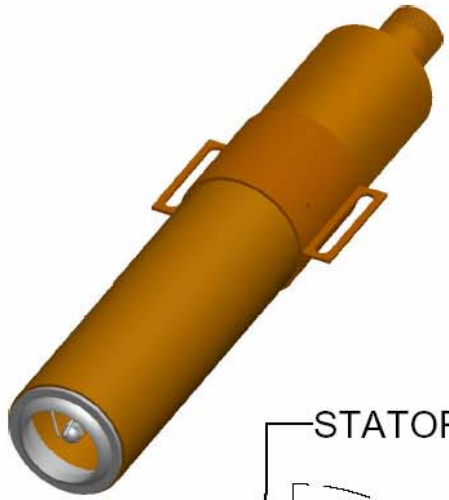
Turbulator

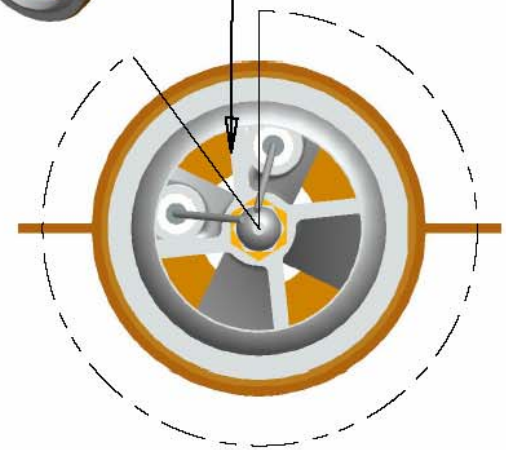
- **Monarch F-124 4 x 2 ¾” turbulator**

Assembled NexGen Burner Housing

ALL DIMENSIONS ARE INCHES



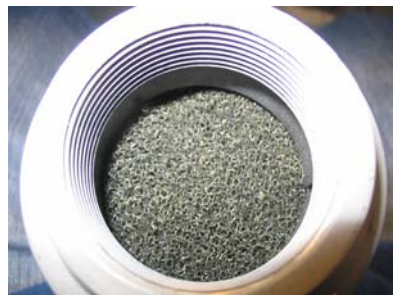




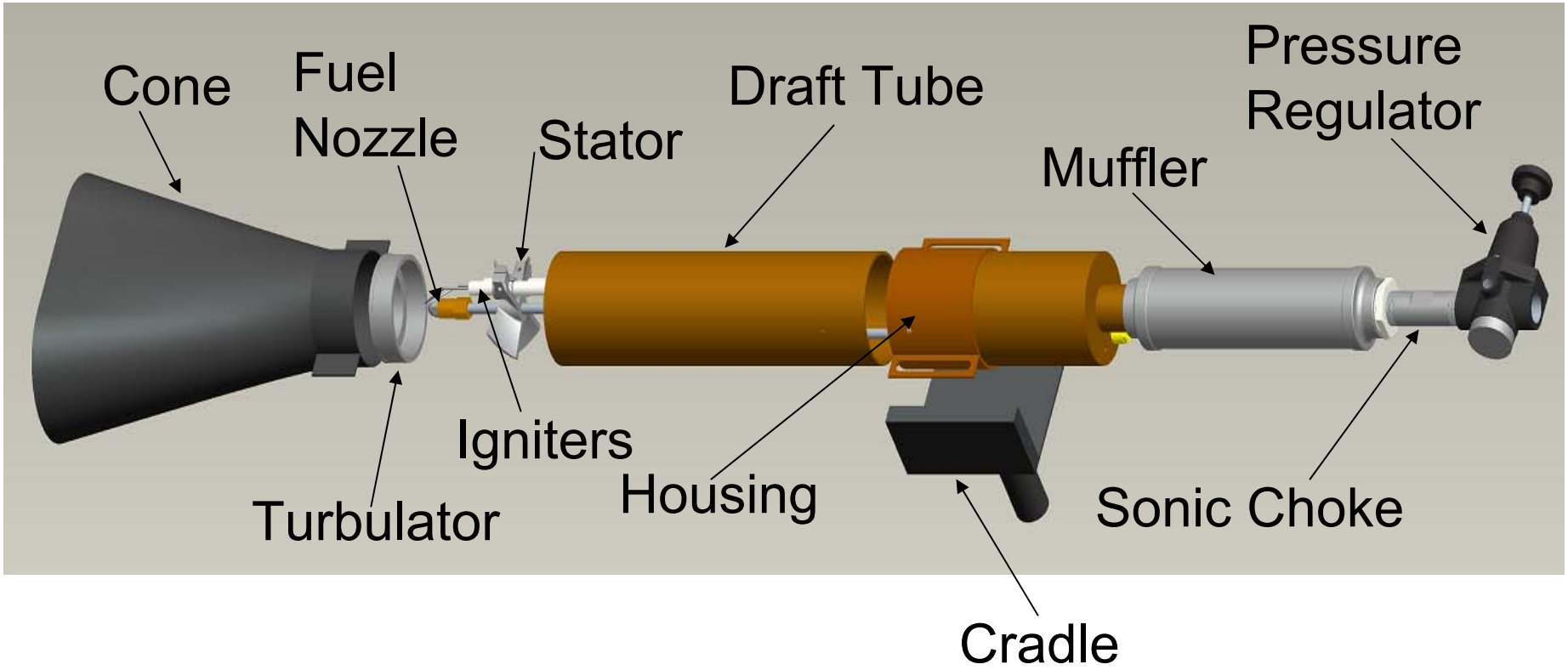
NOZZLE DEPTH 5/16"
IGNITOR DEPTH 5/32"
STATOR DEPTH 4 5/16"
FROM TURB EXIT PLANE

Regulator and Muffler

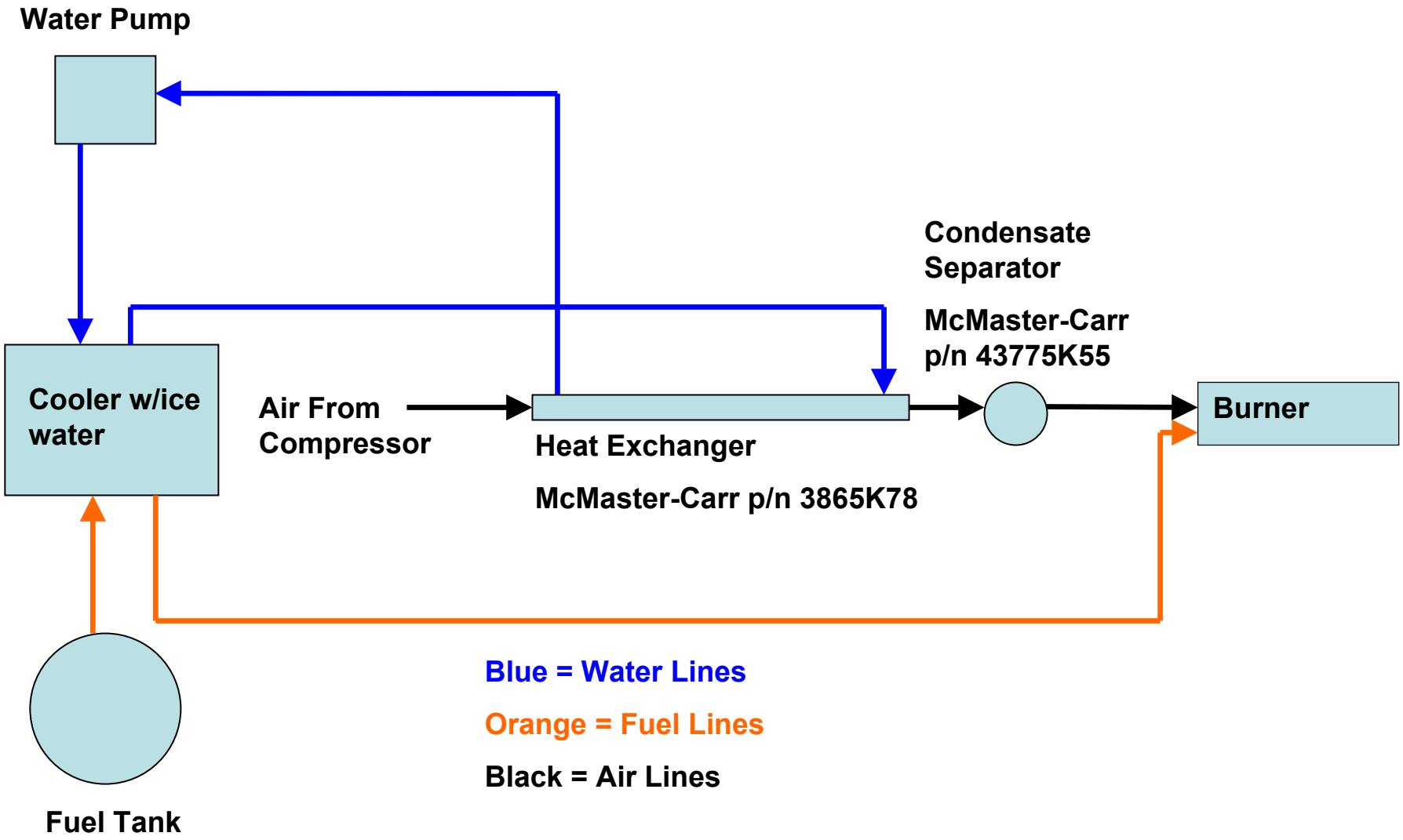
- **Air Pressure Regulator**
  - ARO Ingersoll Rand high flow general purpose regulator, p/n 27364-000
- **Muffler**
  - Heavy duty inline muffler, McMaster-Carr p/n 5889K73
  - Can use a foam insert to further reduce the burner noise
    - Reticulated foam, typically used for explosion protection in military fuel tanks, is an ideal solution
    - Foam can be cut into a 12” long x 2 ½” diameter cylinder to fit inside the muffler
    - Foam insert has no effect on burner output



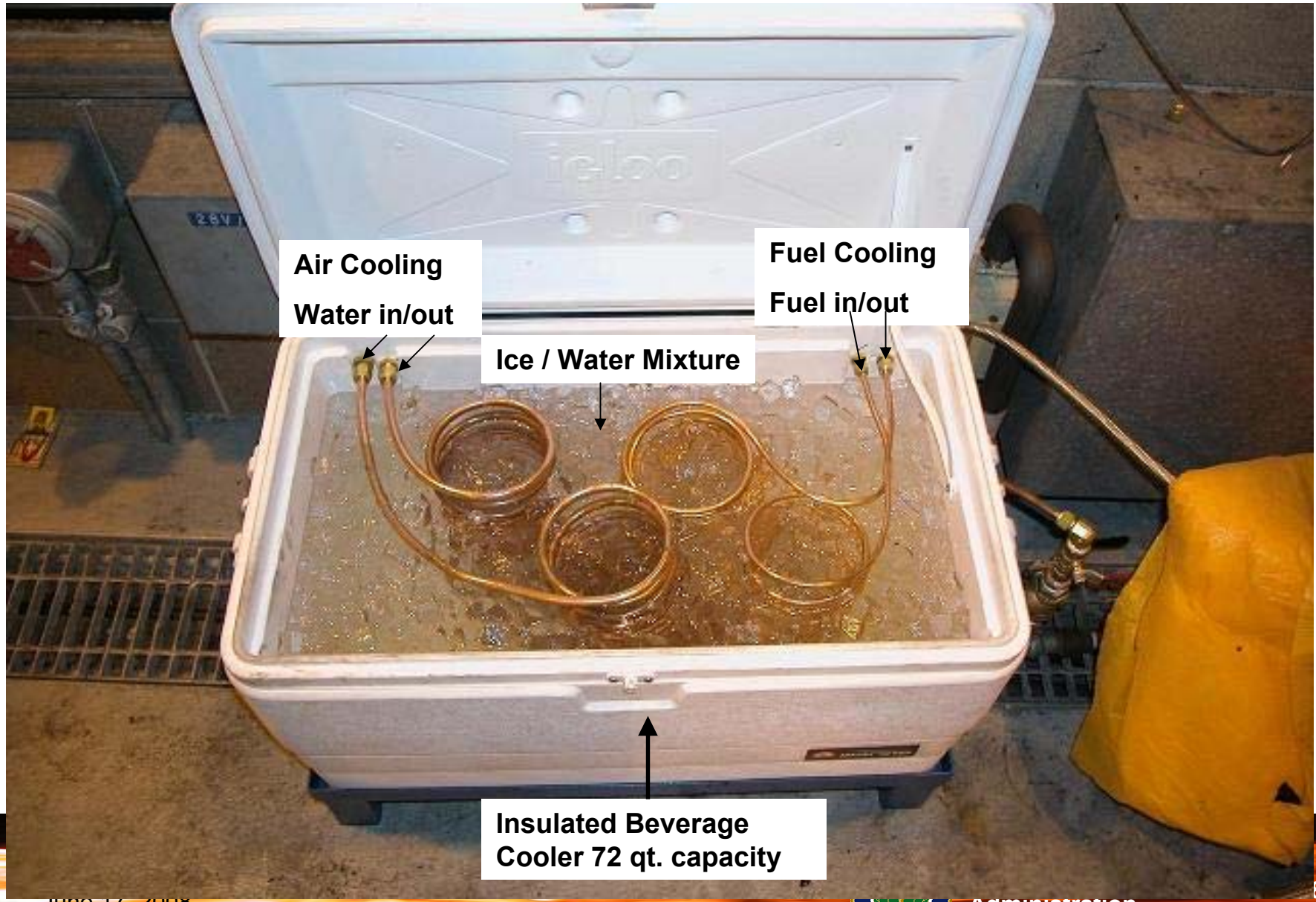
NexGen Burner

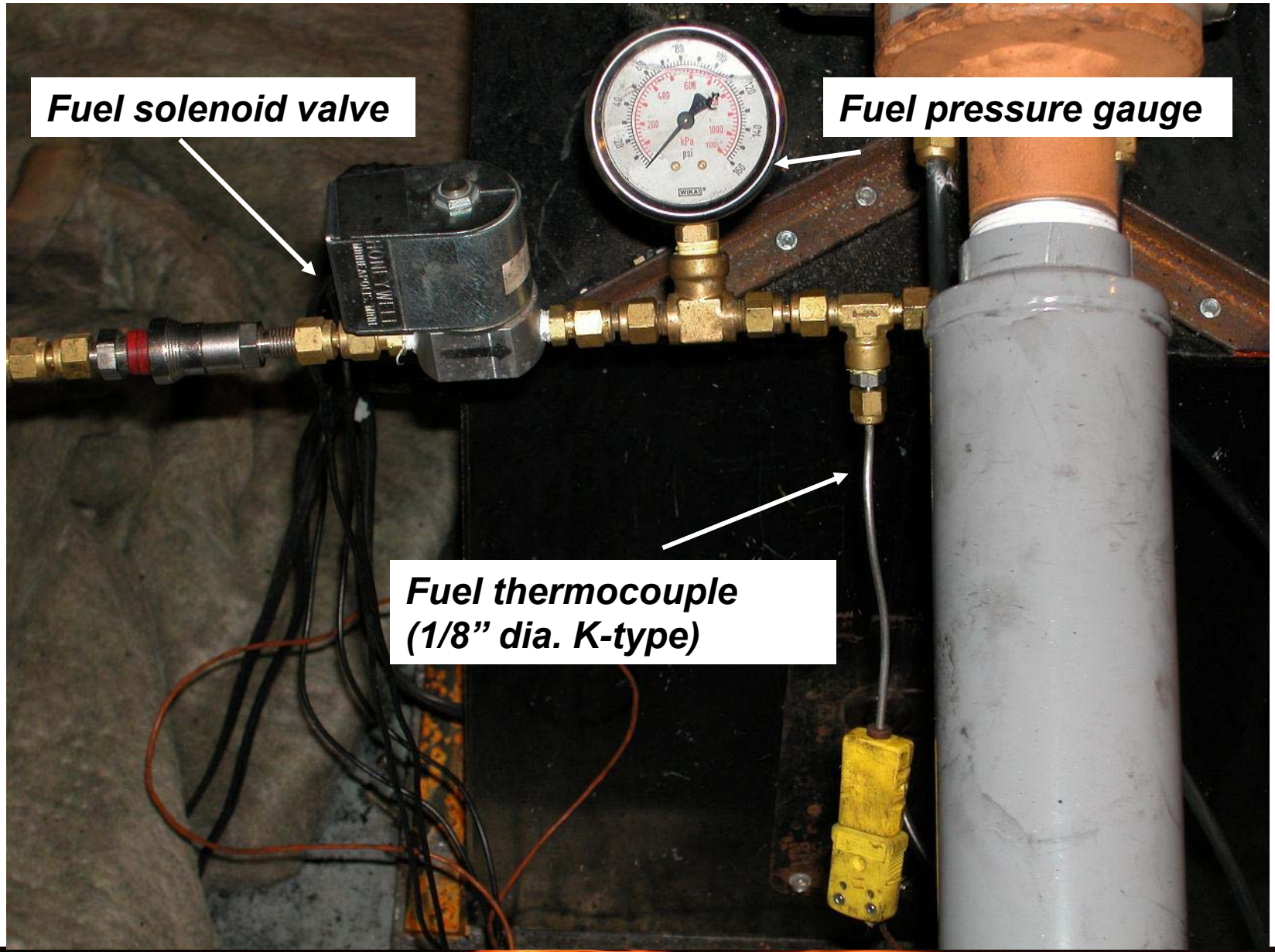


Heat Exchange System



Ice Bath

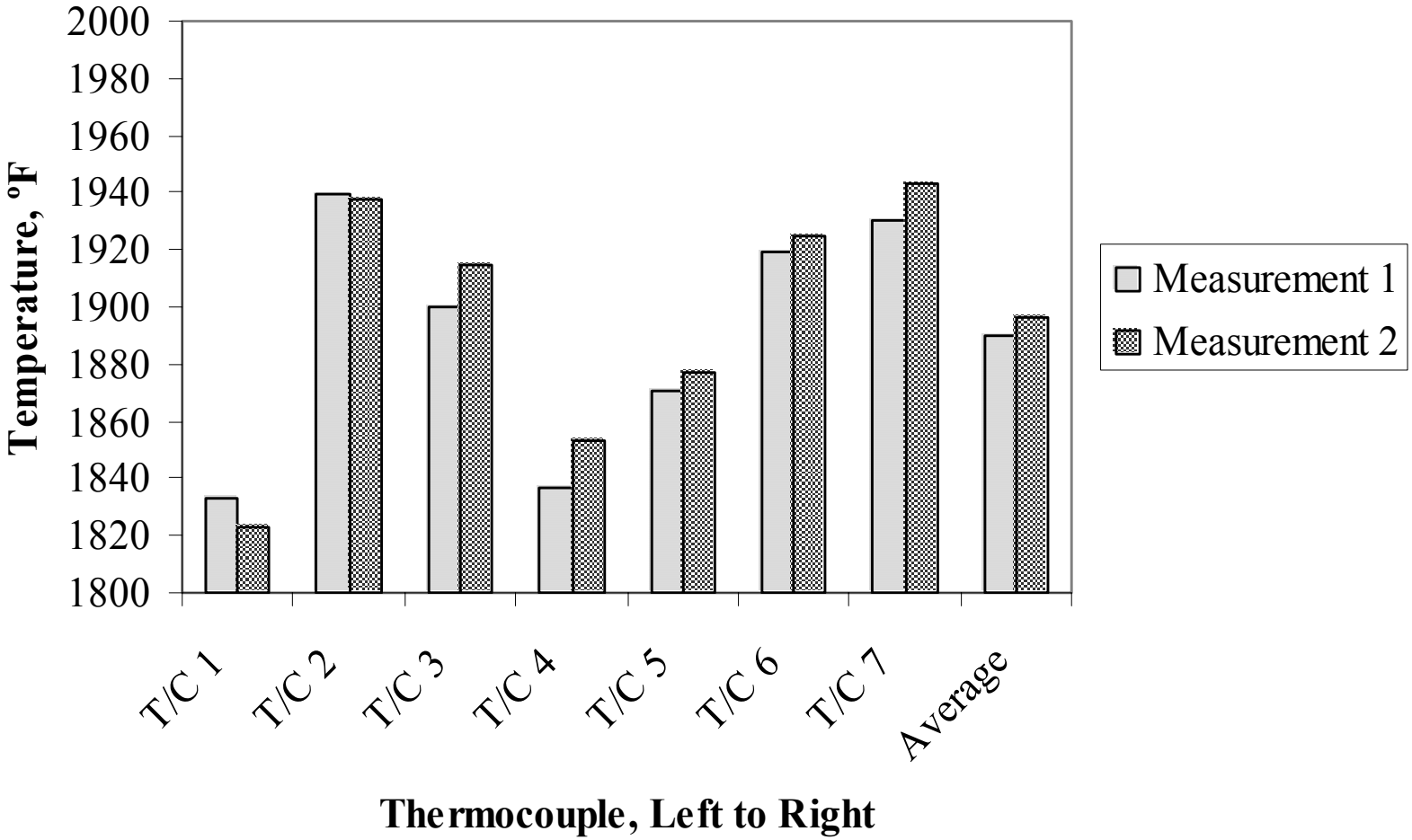

Air Cooling
Water in/out
Fuel Cooling
Fuel in/out
Ice / Water Mixture
Insulated Beverage
Cooler 72 qt. capacity


Fuel solenoid valve
Fuel pressure gauge
Fuel thermocouple
(1/8” dia. K-type)

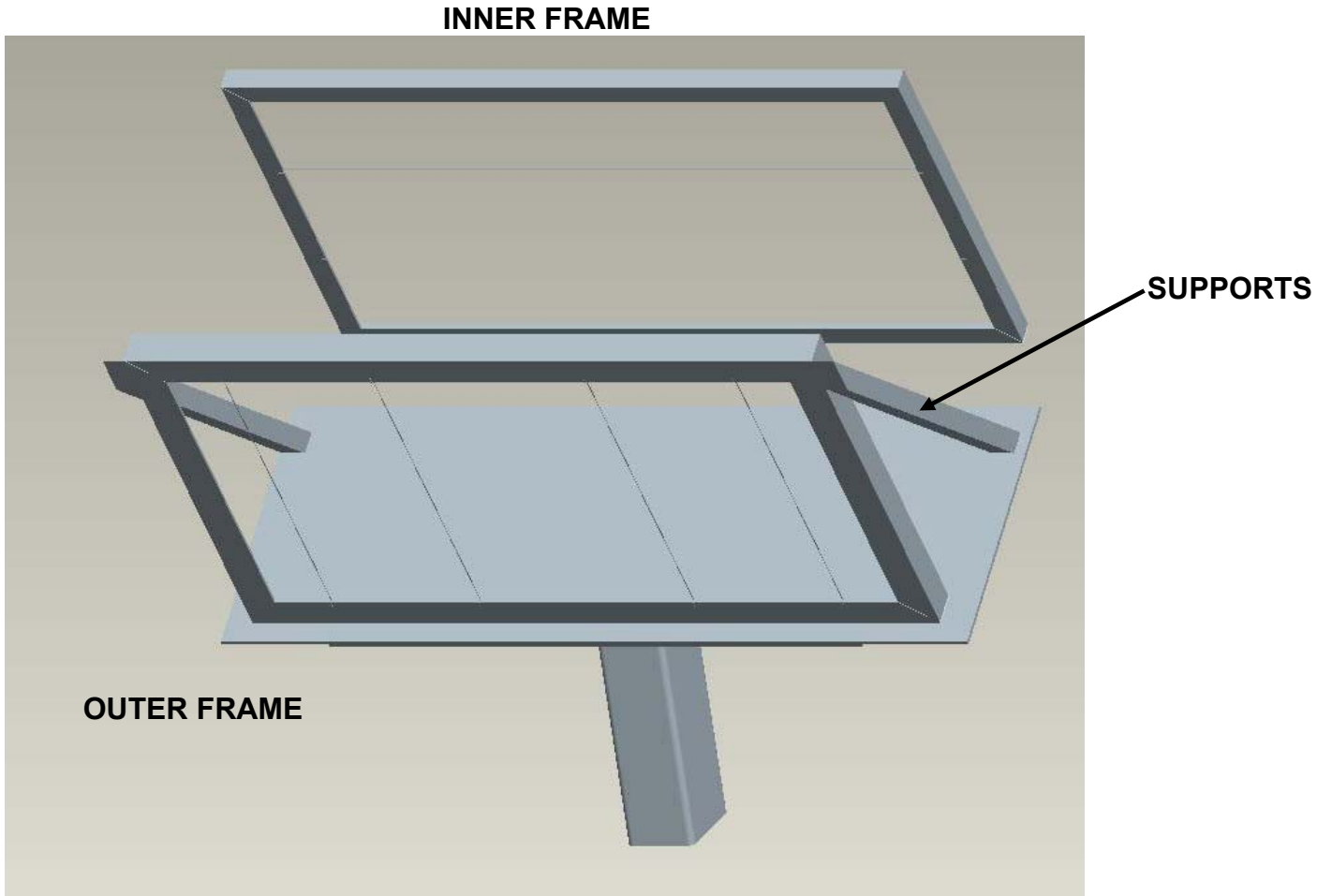
Burner Operational Parameters

- **Fuel**
  - Type: JP8, Jet A or equivalent
  - Nozzle: Monarch 5.5 gph 80°PL
  - Pressure: 120 psig (±2 psig)
  - Temperature: 42°F (±10°F)
  - Flowrate: 6.0 gph (±0.3 gph)
- **Air**
  - Pressure: 60 psig (±2 psig)
  - Temperature: 50°F (±10°F)

Flame Temperature Measurement



Picture Frame Blanket Holder



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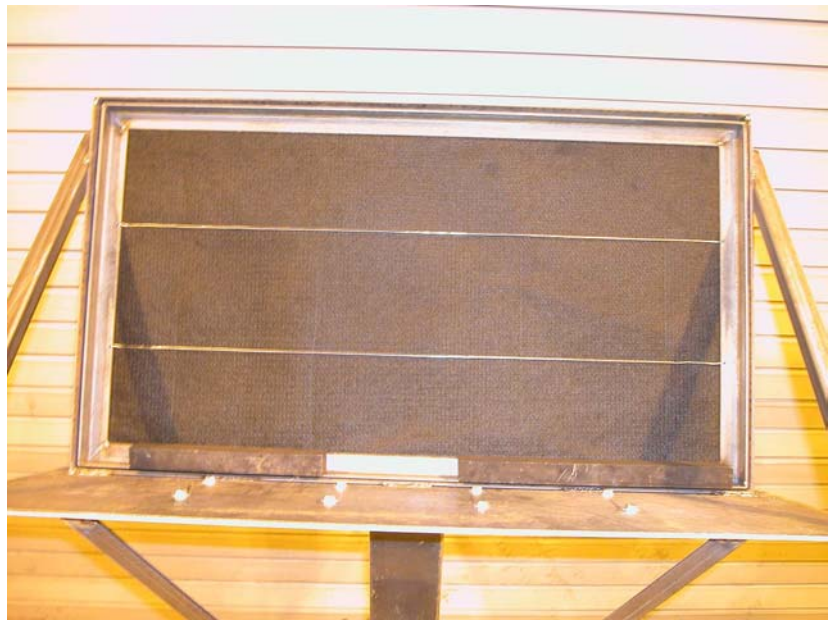
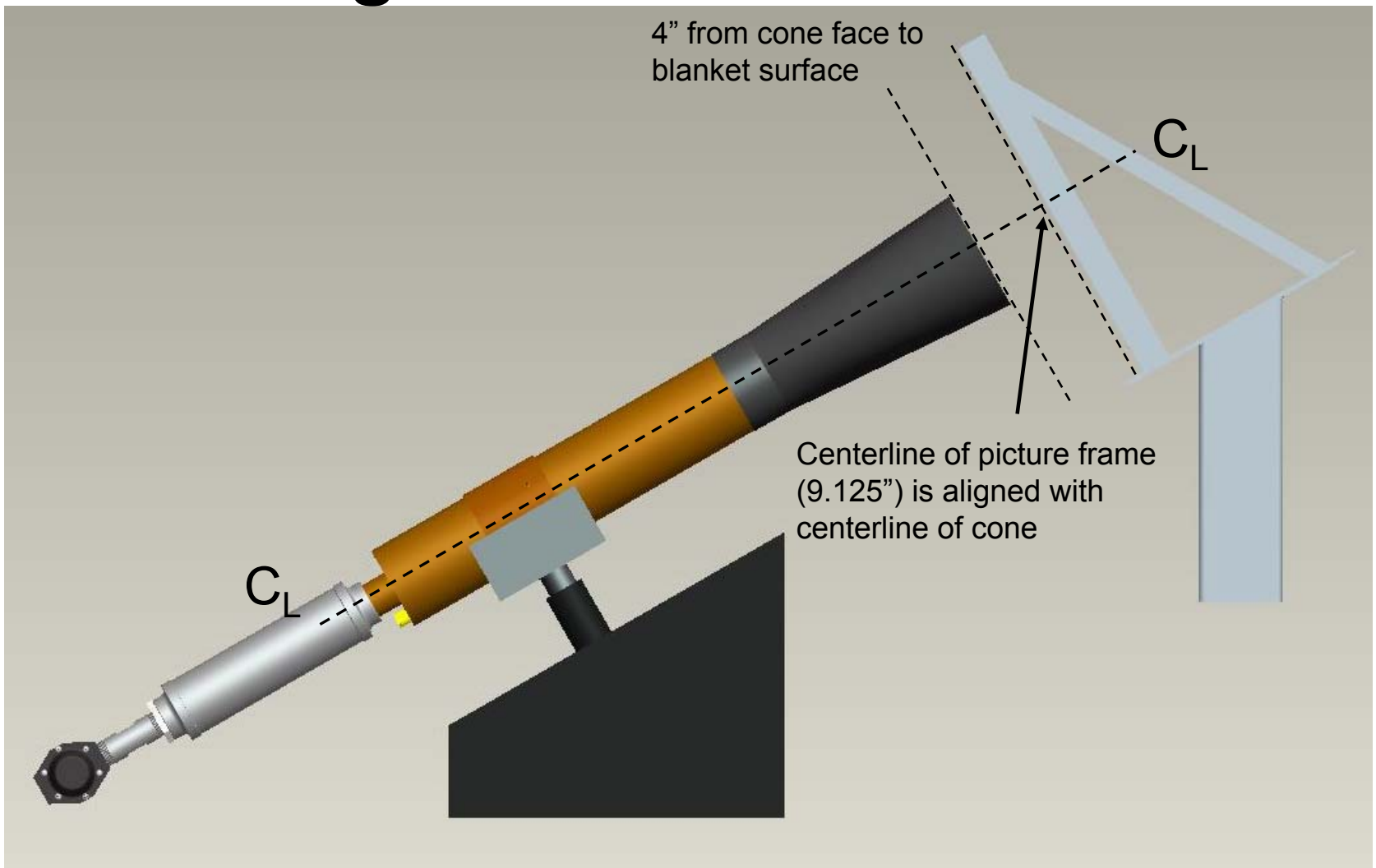


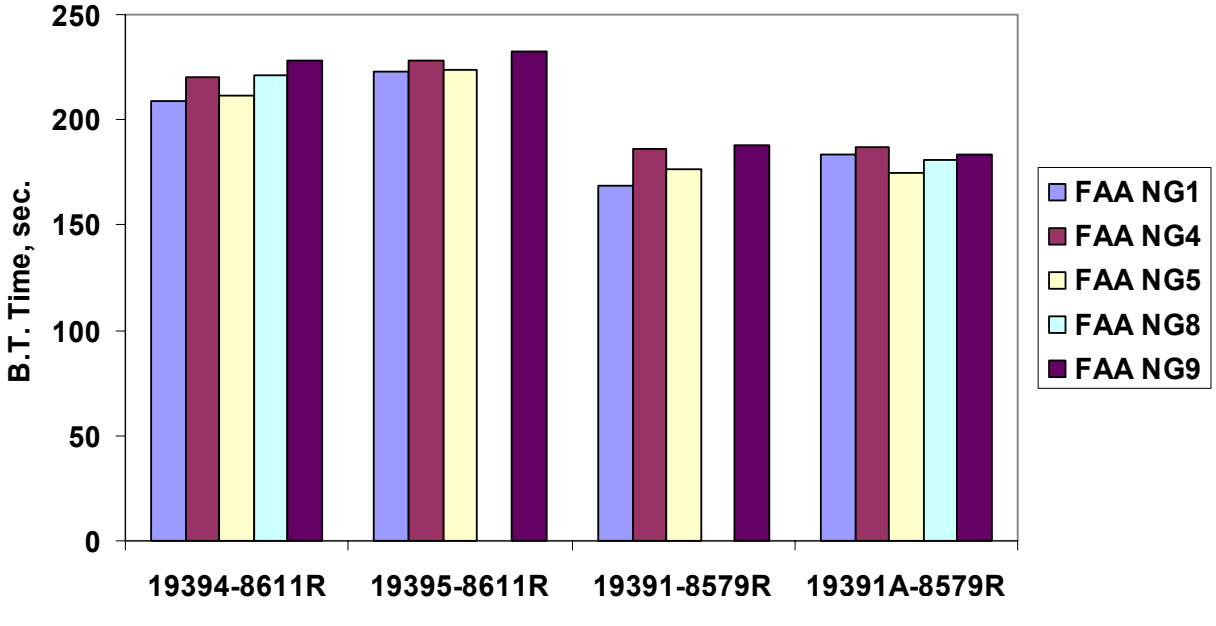
Frame Alignment



Testing on the Picture Frame

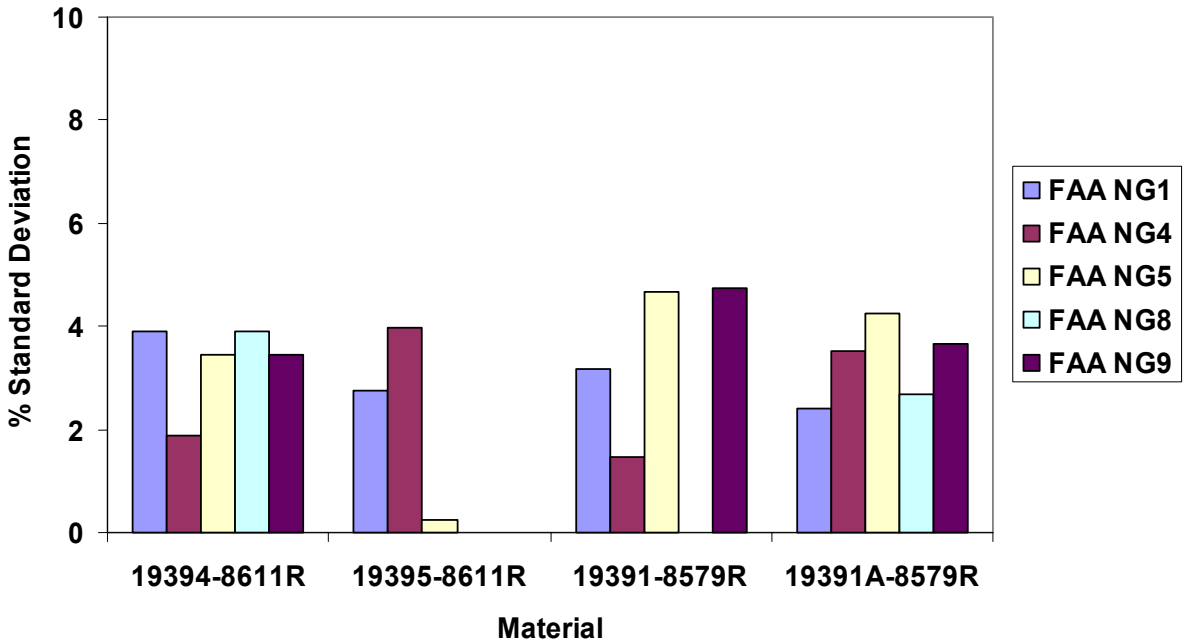
- **Tex Tech Polyacrylonitrile material**
  - 8579R: ~9 oz/yd^2, burnthrough typically around 180 sec.
  - 8611R: ~16 oz/yd^2, burnthrough typically around 225 sec.
  - 3M Nextel dot paper: 4 min heat flux ~ 2.8 BTU/ft^2*s

NexGen Burner Test Results



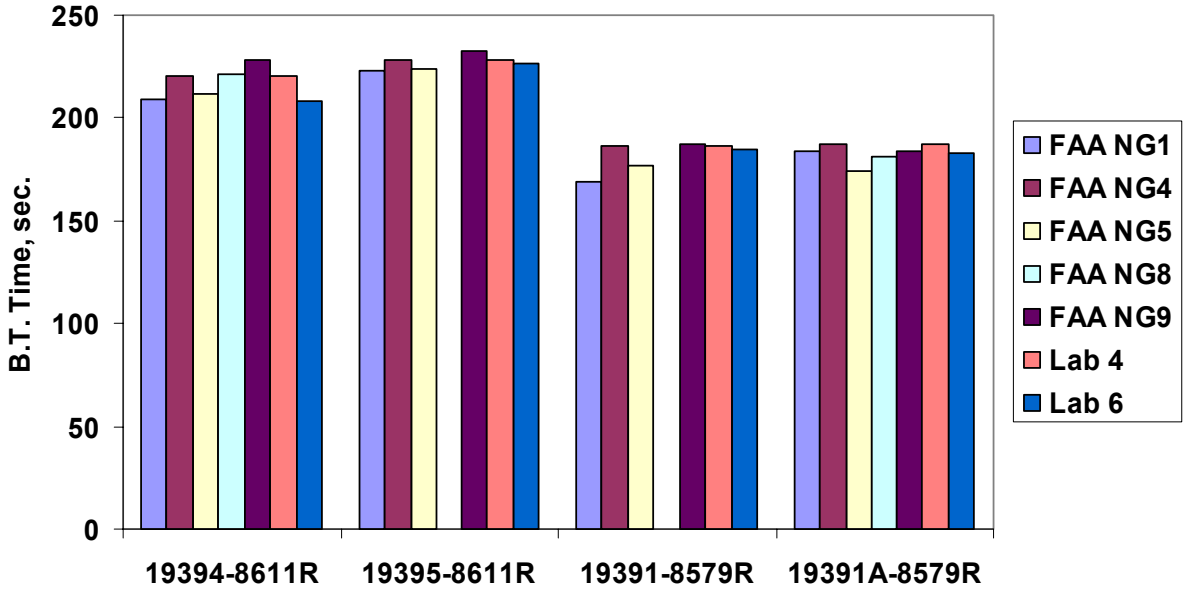
- 5 burners tested at FAATC on with PAN material on picture frame blanket holder
- Very good agreement was found between five different burners

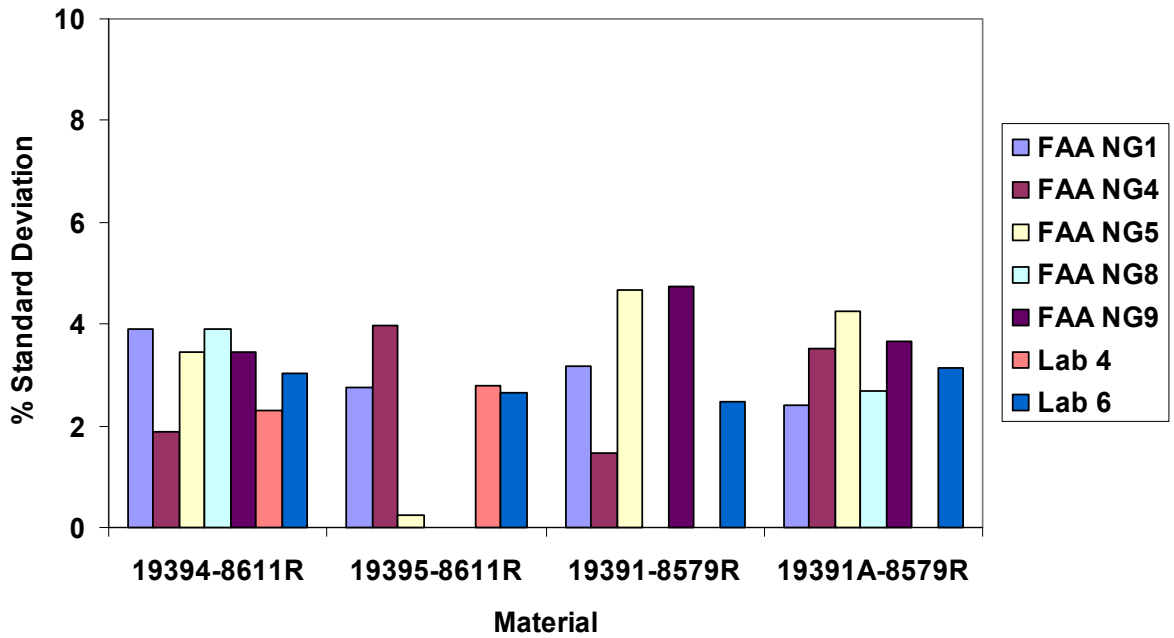
- Relative standard deviation is used to determine the consistency or repeatability of a burner/material
- Good repeatability was found for all materials and burners (less than 5%)



Comparative Results

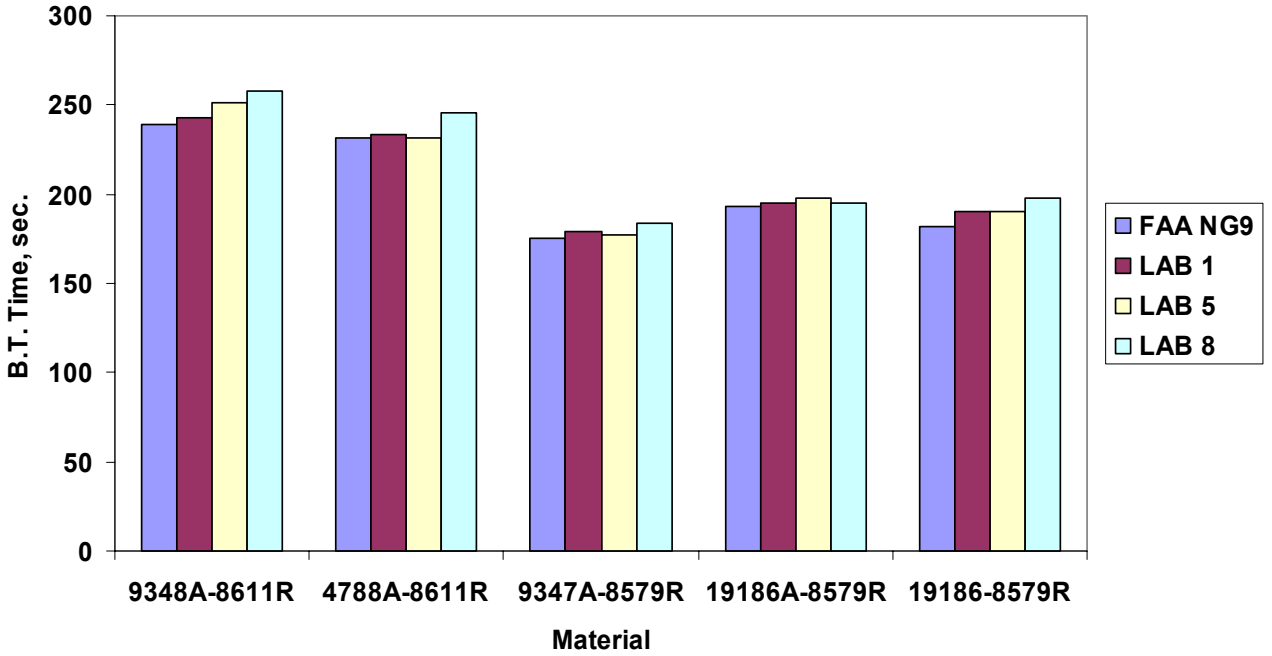
- NexGen burners were shipped out to participating laboratories in order to determine the repeatability of the test results in various environments
- 2 U.S. Labs and 3 European Labs (and 1 South American lab on the way)
- Materials were shipped with burners so that all materials tested came from the same production lot
- Labs
  - NG1-> Lab 1
  - NG4-> Lab 4
  - NG5-> Lab 5
  - NG6-> Lab 6
  - NG8-> Lab 8
- Very good agreement was found between labs 4 and 6 and the rest of the NexGen's tested at the FAATC
- Labs 4 and 6 were also found to have good repeatability
- Labs 4 and 6 were approved by their respective A.C.O.'s to perform certification tests according to the rule
- This round of testing exhausted the supply of materials, and new rolls were ordered

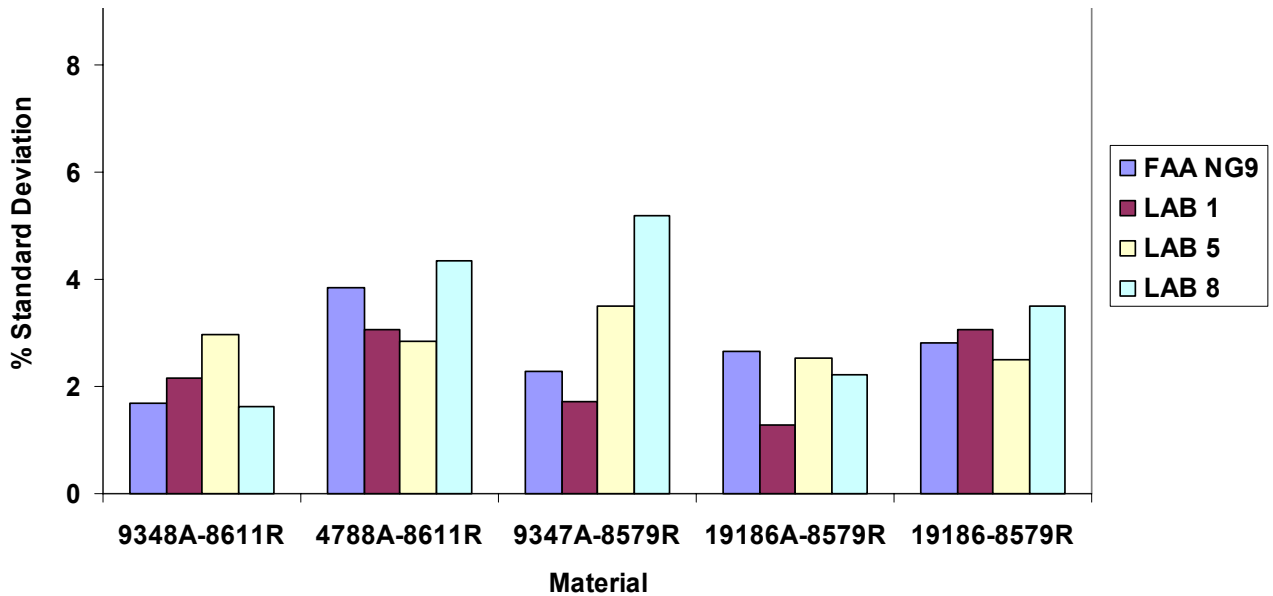




Comparative Results II

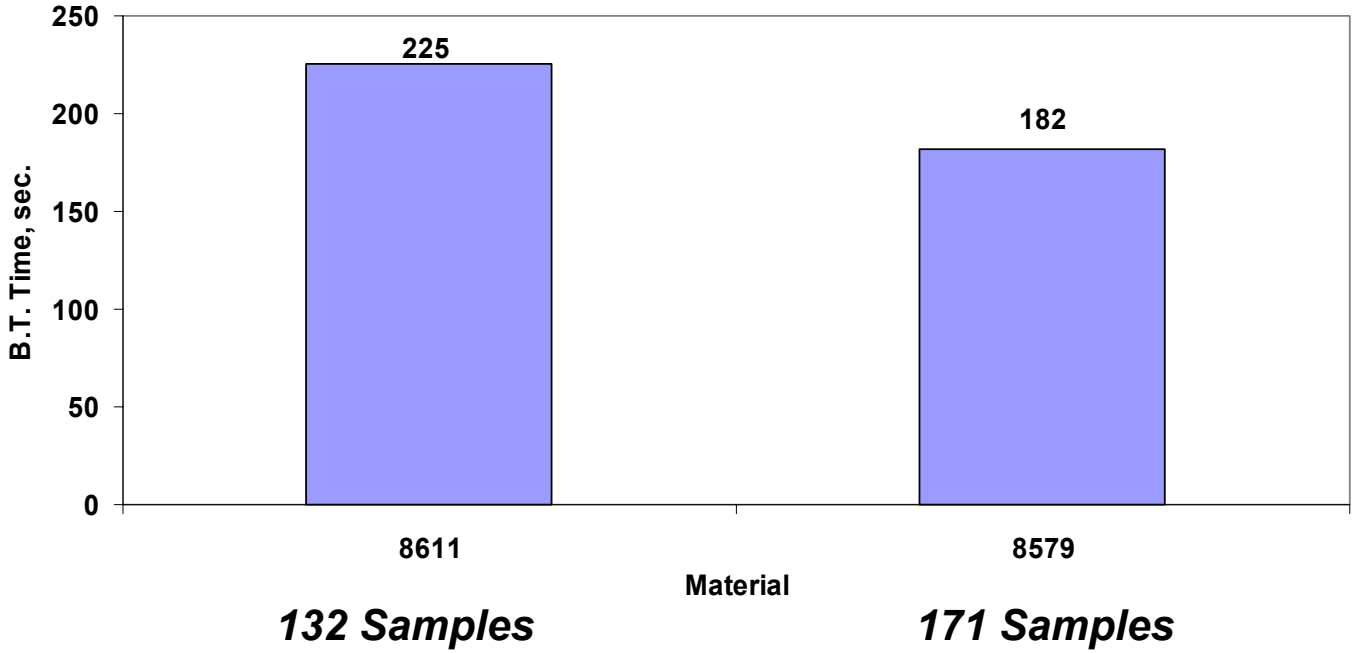
- In this round of testing, 5 different rolls of the two PAN materials were tested
- Very good agreement was found between each of the burners at various locations
- Good repeatability was found for each material/burner, with most relative standard deviations at or below 5%

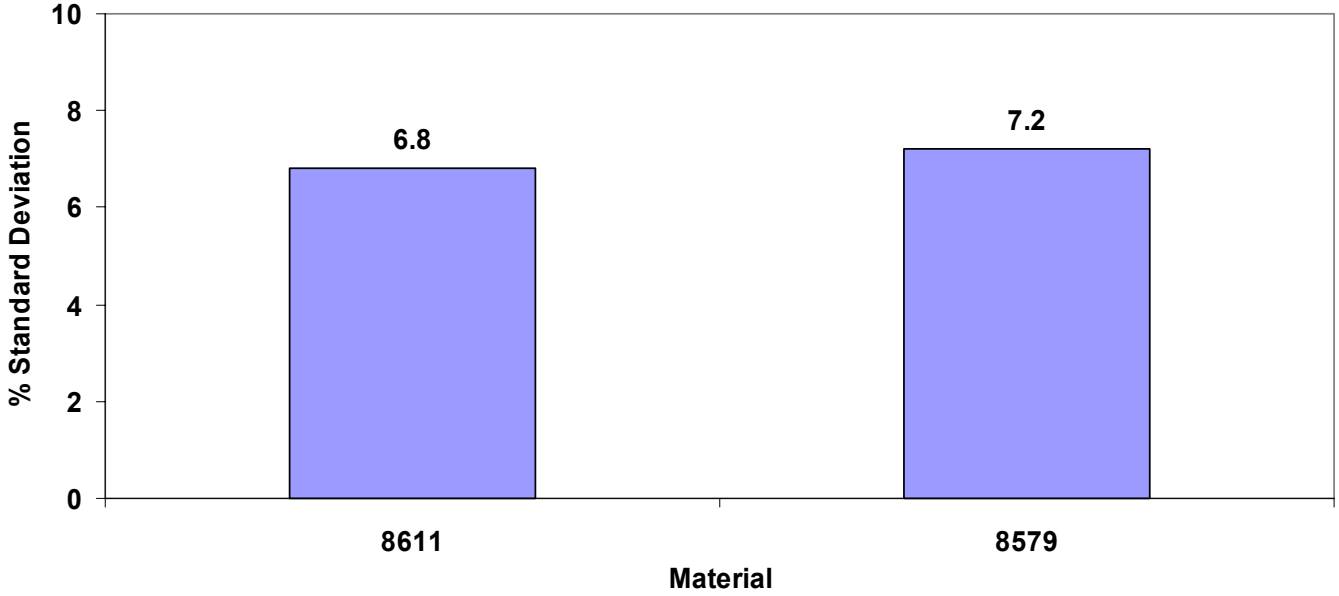




Analysis of All Data

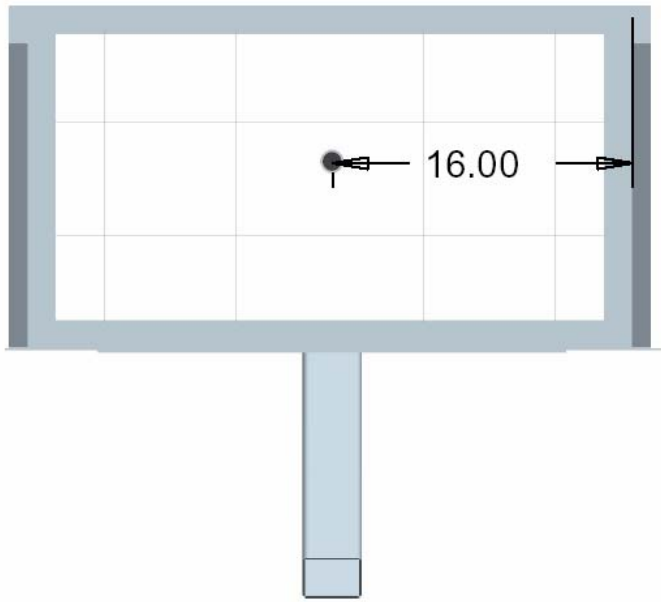
- In order to understand the statistical variation in the PAN material and test method, we can take the average and standard deviation of all picture frame tests every performed
- Data is from all tests – with various degrees of conditioning, including all experimental and trial and error tests
- Data indicates that overall, including all possible influences, the combined effect of the test method and the material amounts to a repeatability of about 7%
- Data shows that regardless of which roll of material is tested, average burnthrough times can be found within a very good standard deviation

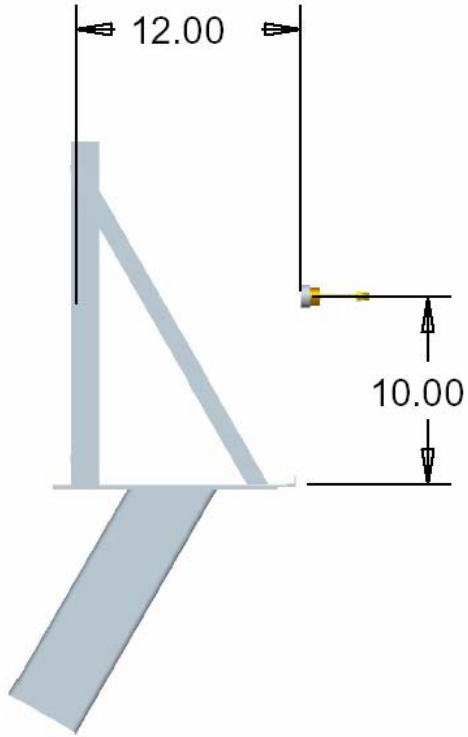




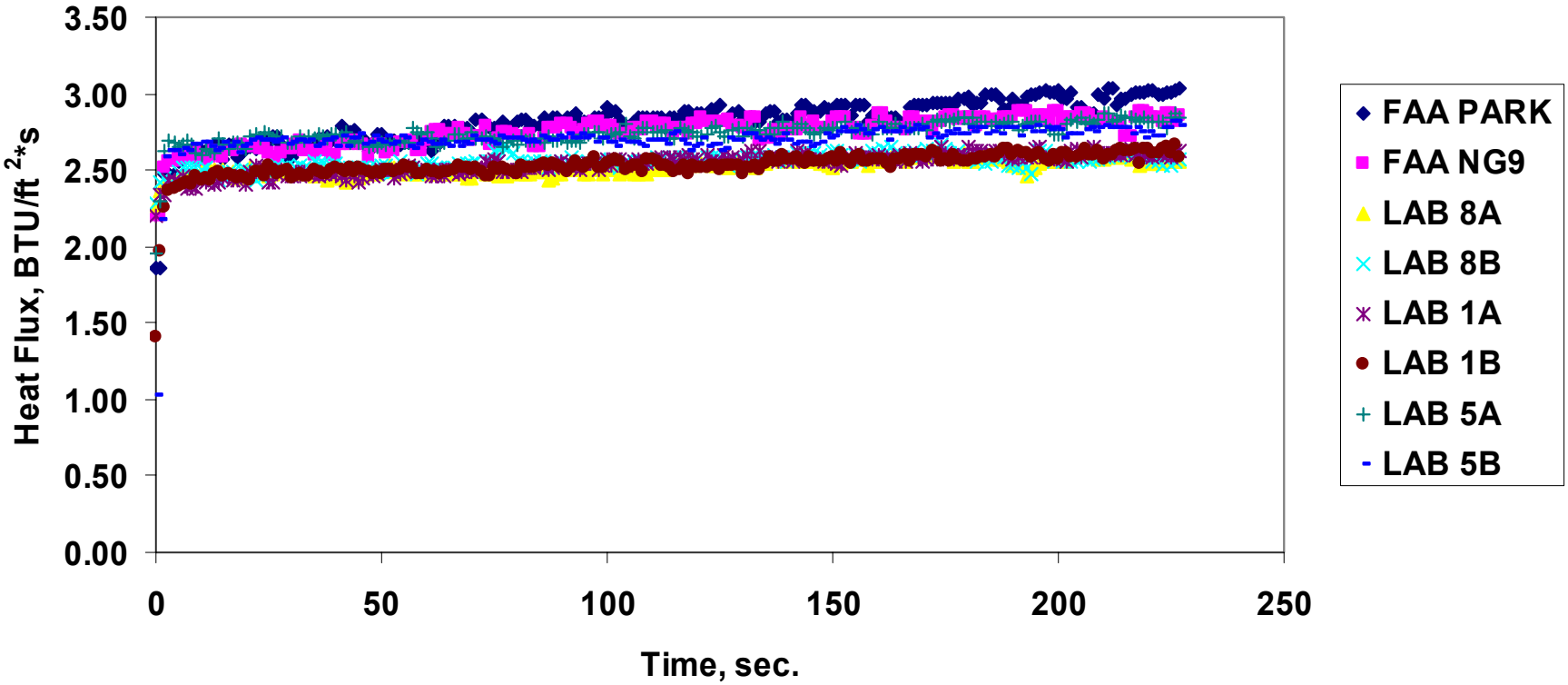
Recent Work with NexGen Burners

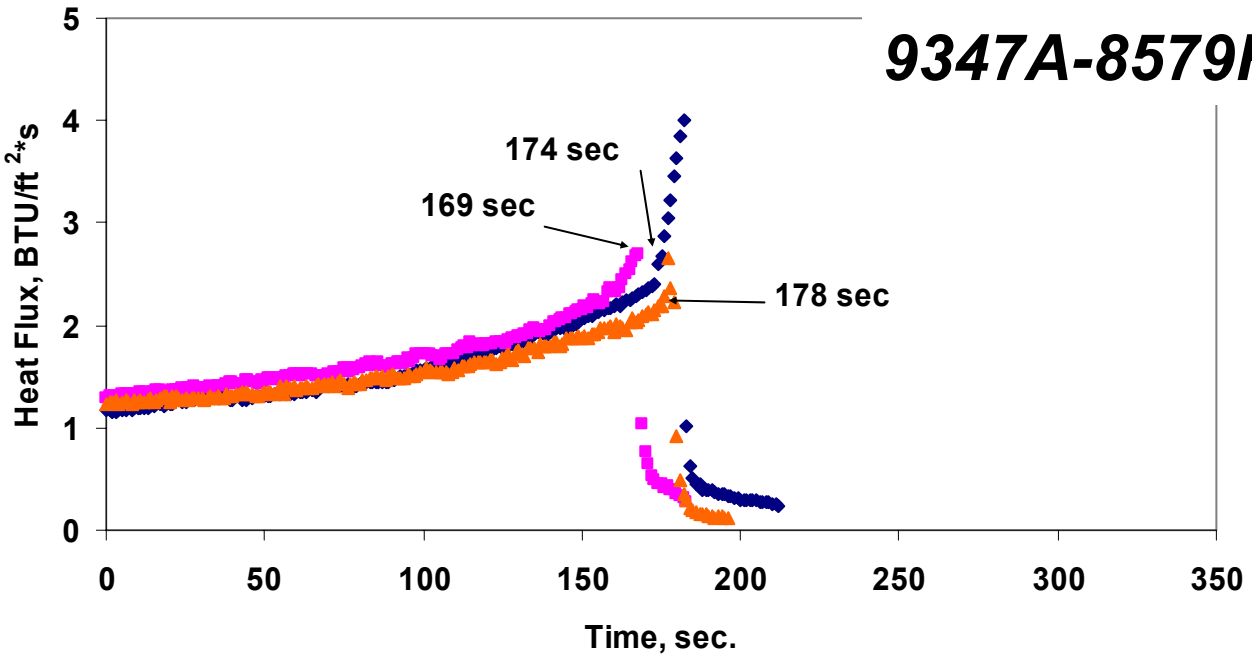
- It was decided to also test a flame barrier type material on the picture frame in order to get a backside heat flux measurement
- Heat flux measurements may be able to give us information about the surrounding environment
- The same calorimeter was used for all data collected
- The material chosen was 3M Nextel dot paper, single sheet, no insulation or film

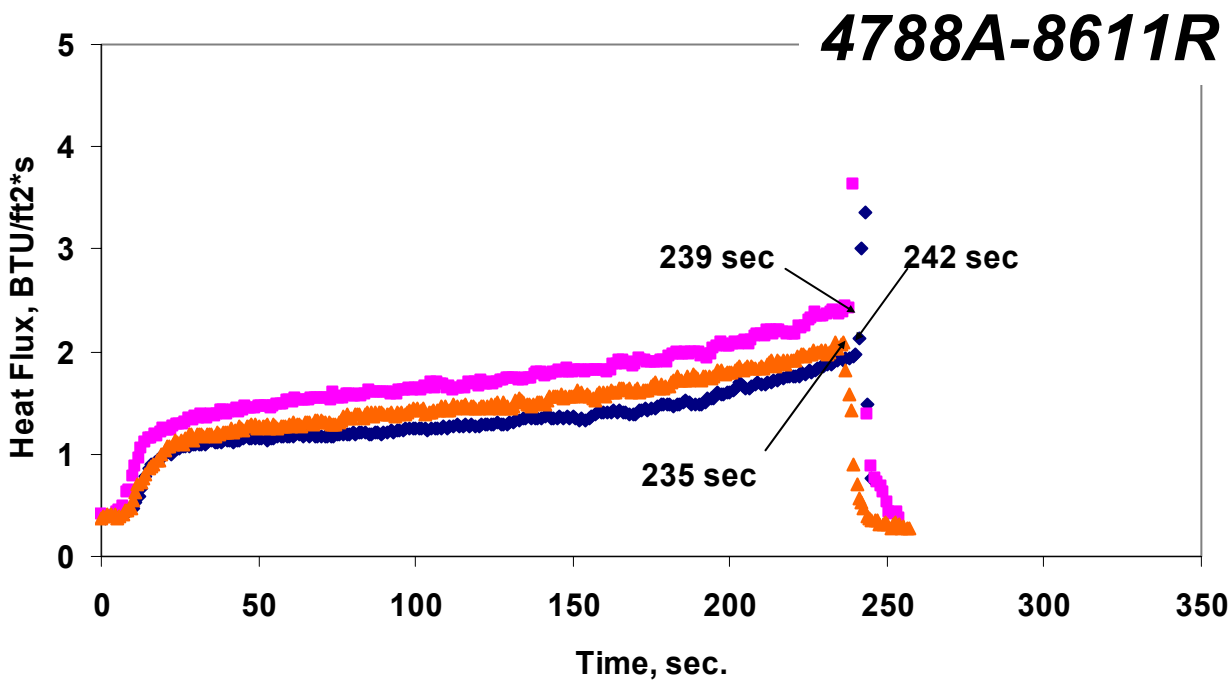




Backside Heat Flux Results




9347A-8579R
Heat Flux, BTU/ft 2*s
Time, sec.
174 sec
169 sec
178 sec
LAB 8 - 2B
LAB 5 - 4A
LAB 1 - 10B
0
1
2
3
4
5
0
50
100
150
200
250
300
350

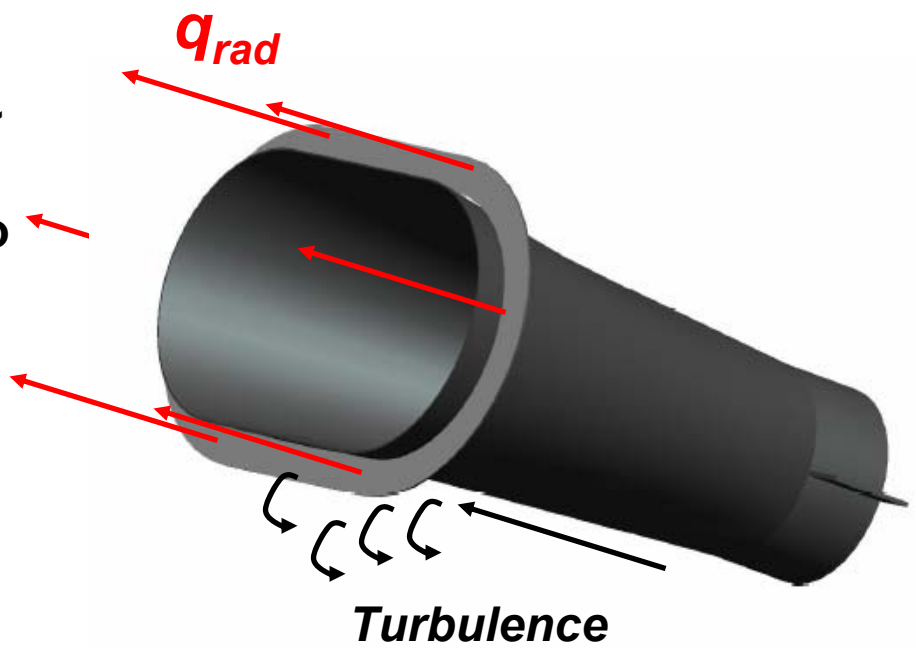

4788A-8611R
Heat Flux, BTU/ft2*s
Time, sec.
239 sec
242 sec
235 sec
LAB 8 - 167A
LAB 5 - 166A
LAB 1 - 169A
0
1
2
3
4
5
0
50
100
150
200
250
300
350

Heat Flux Measurements

- **3M Nextel tests:**
  - Using the same calorimeter and same material at various labs, slightly different heat flux measurements were obtained
  - This may be due to different environments in which the measurements were made
  - More work needs to be done to determine the cause of this discrepancy
- **PAN tests**
  - For both 8579 and 8611, burnthrough was found to occur between 2.0 and 2.5 BTU/ft^{2}s
  - Similar heat flux curves were obtained for each material at all labs

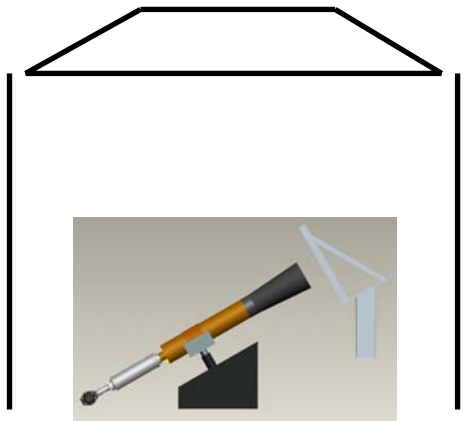
Burner Cone Tests

- **A quick comparison test was made with two different cones**
- **A significant difference was found between the two tests (~ 30 sec.)**
- **The critical parameters need to be determined**
  - Exit plane shape
  - Material thickness
  - Effect of the exterior strengthening ring
    - Flame re-radiation
    - Increasing turbulence / enhancing mixing
  - Degree of tempering
  - Soot coating / emissivity



Room Size Tests

- During the last round robin testing in Europe, consideration was given to the influence of the room size on test results
- Of the three labs tested, all three had varying room sizes and wall coatings (soot, etc.)
- An experiment was thought up to test this by building partitions around the burner and performing identical tests

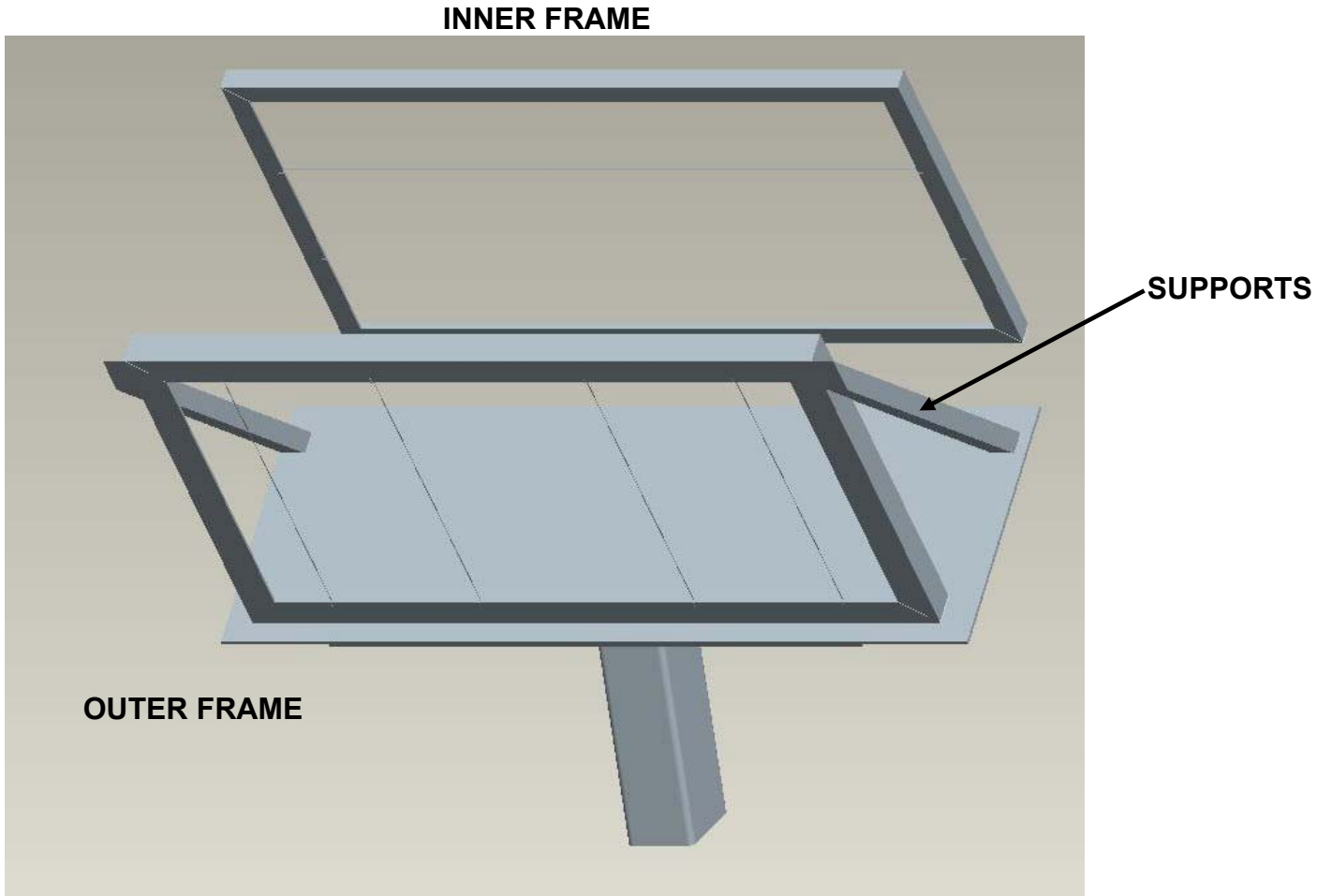


Summary – NexGen Burner Development

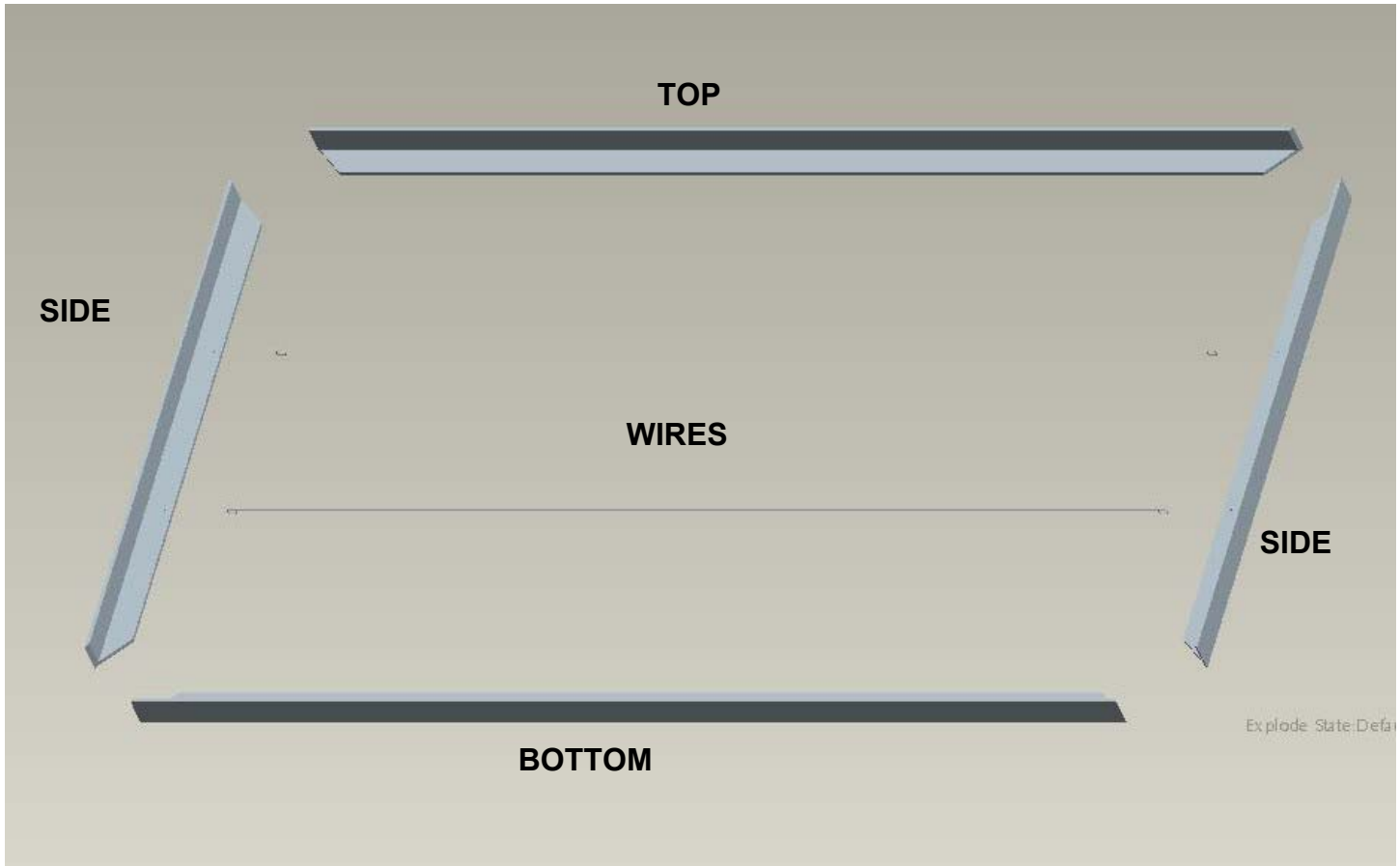
- **A next generation burner has been designed, tested, and found to be equivalent to the Park DPL 3400**
- **The NexGen burner has been found to perform properly at various laboratories under varying conditions**
- **Several laboratories with NexGen burners have been approved by Aircraft Certification Officials to perform certification tests**
- **Comprehensive instructions are now available to build and test a NexGen burner**
- **Future work to be completed includes:**
  - Determination of exact cause of small variation in heat flux readings (room size, environmental factors, etc.)
  - Determination of effect of various cones on test results

Appendix – Picture Frame Drawings

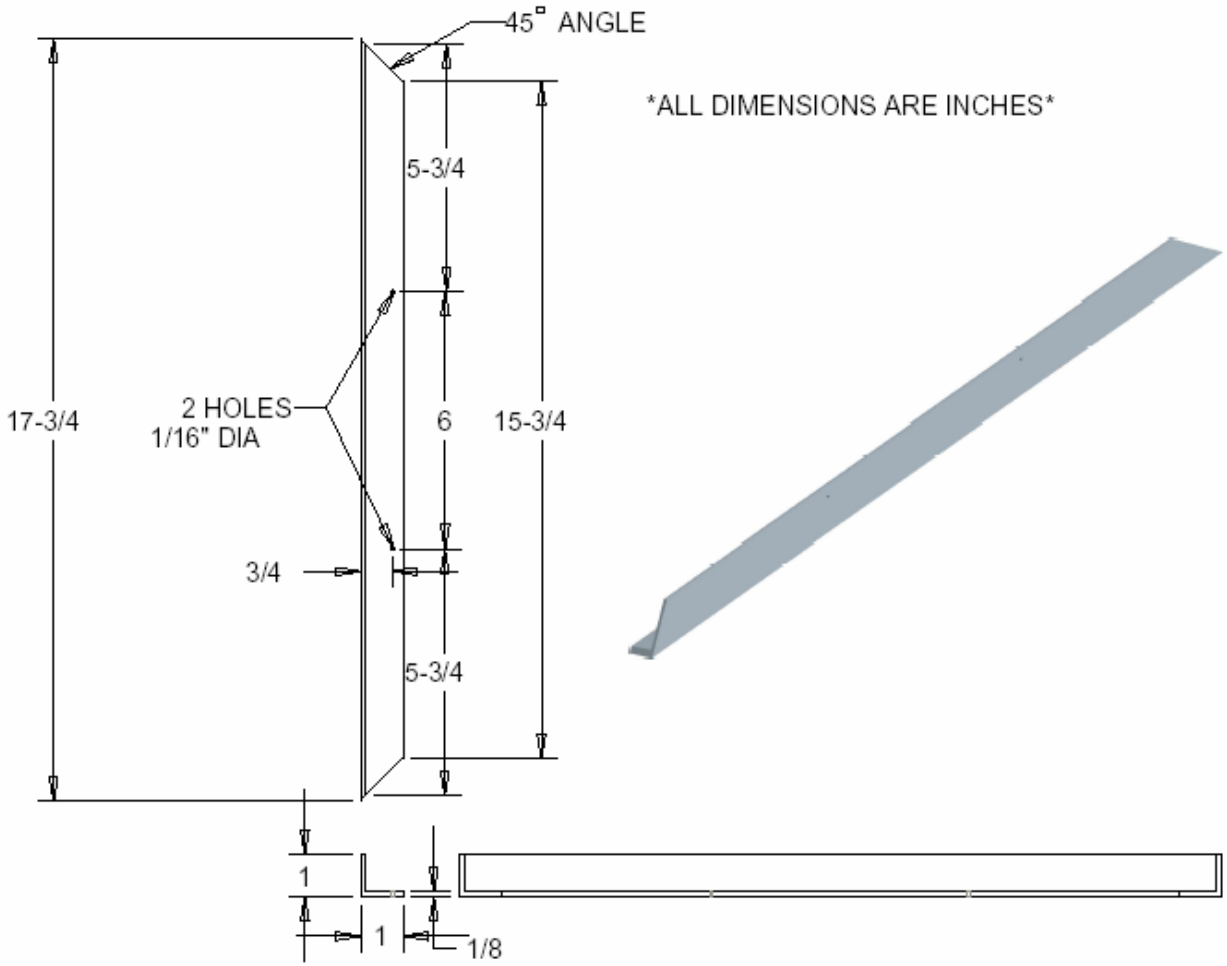
Picture Frame – Component View



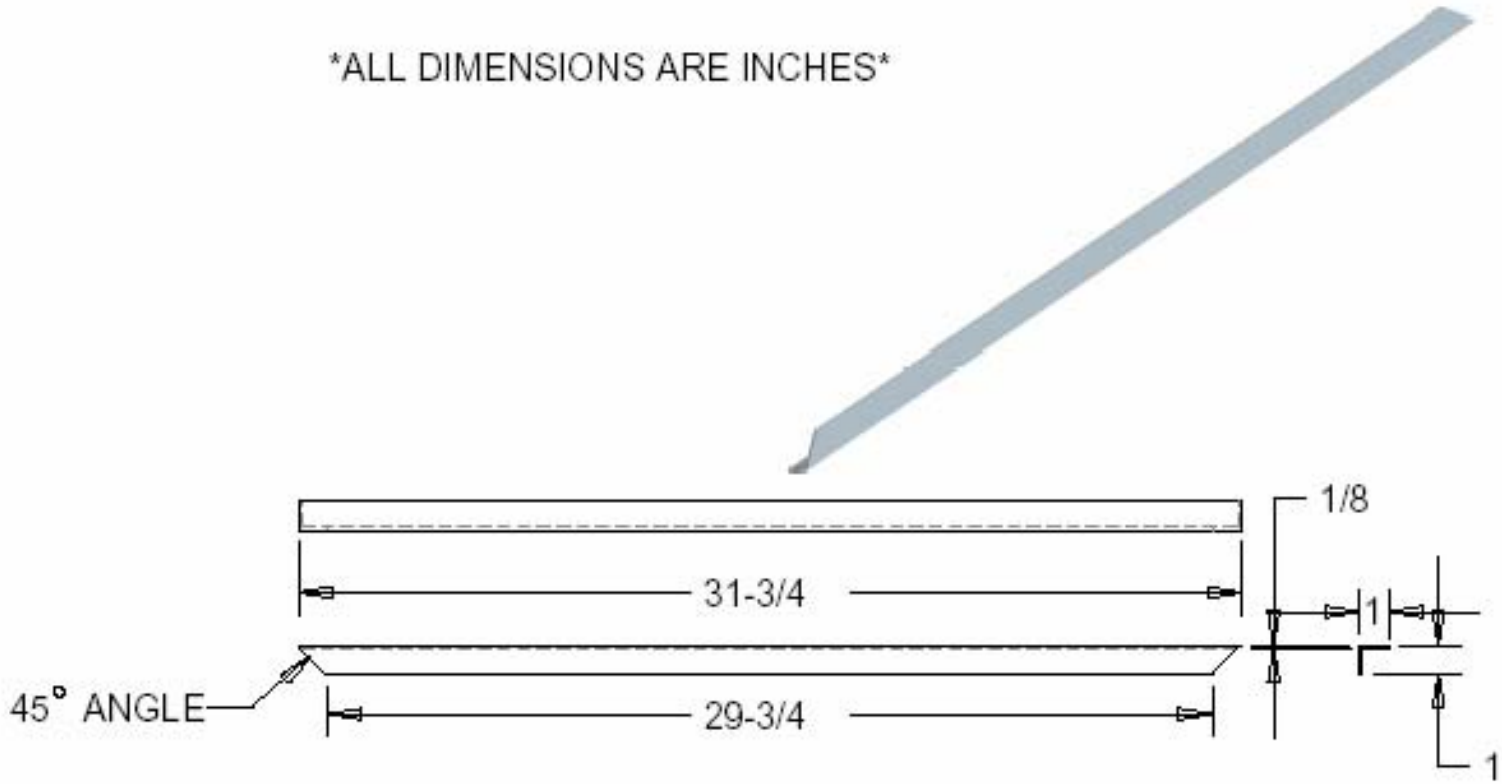
Inner Frame – Exploded View



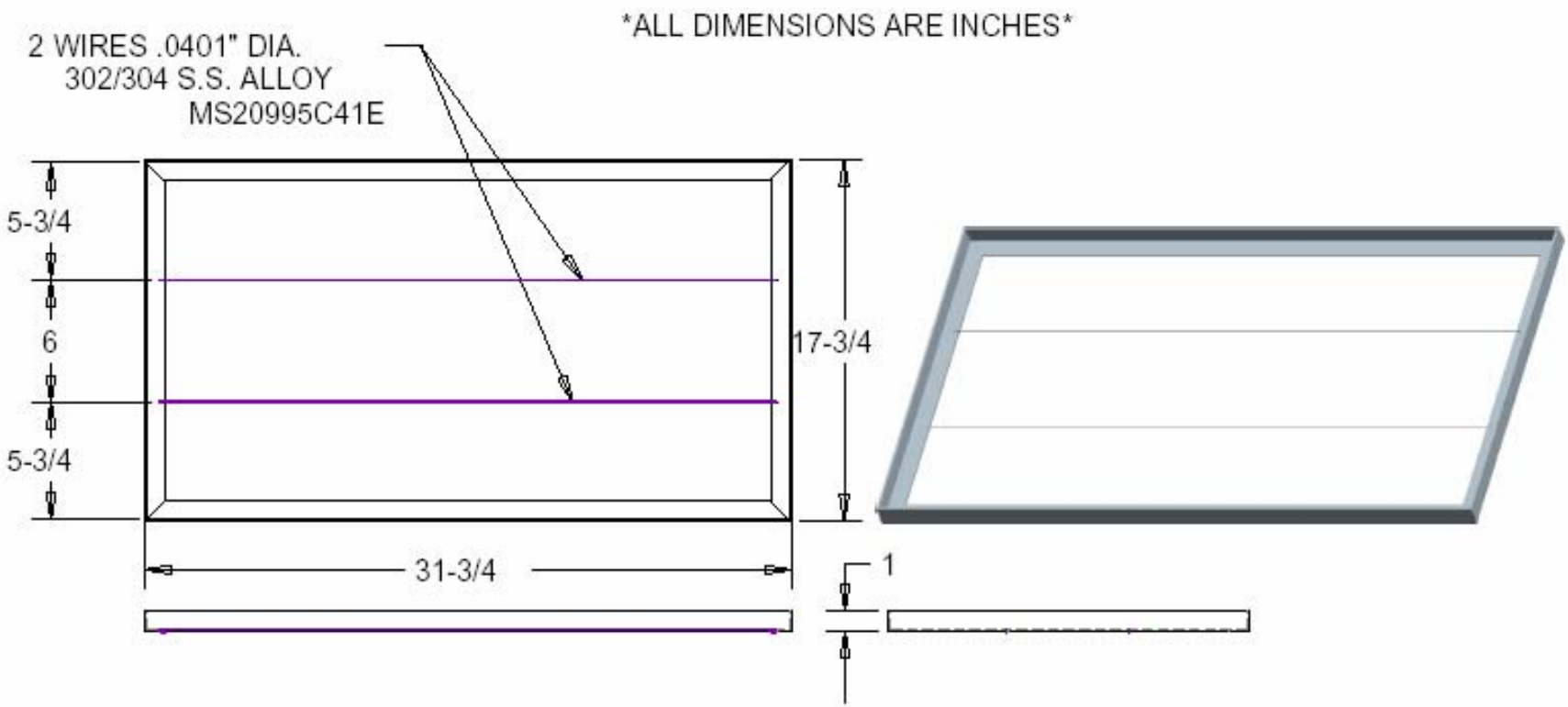
Inner Frame Components – Sides



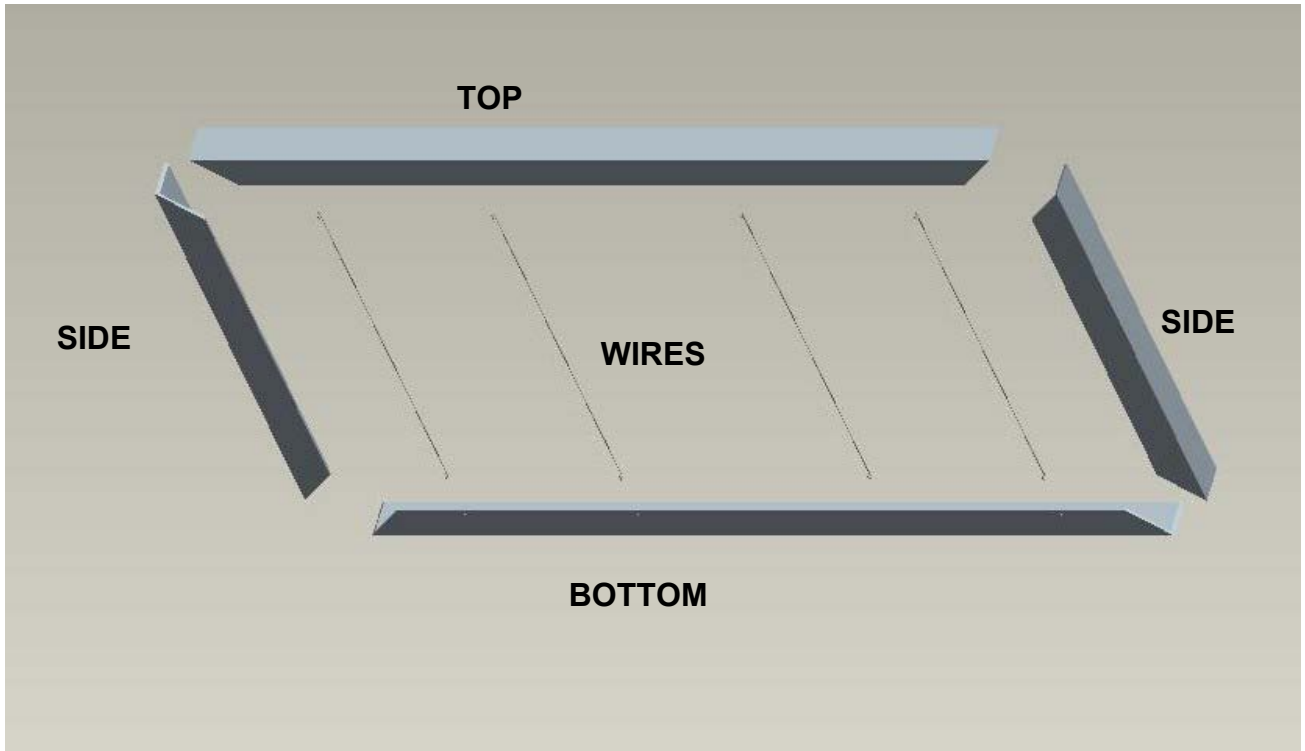
Inner Frame Components – Top & Bottom



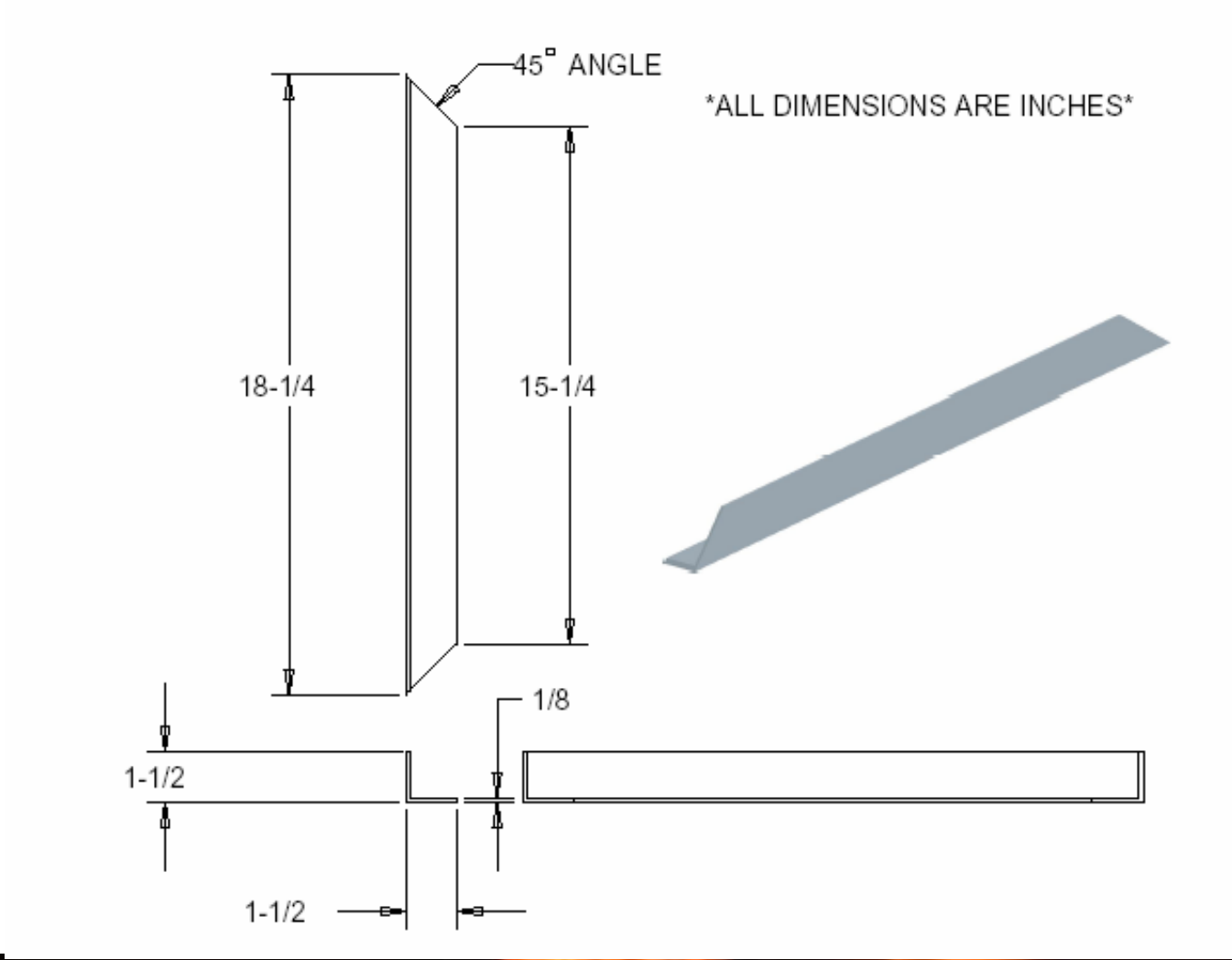
Inner Frame - Assembled



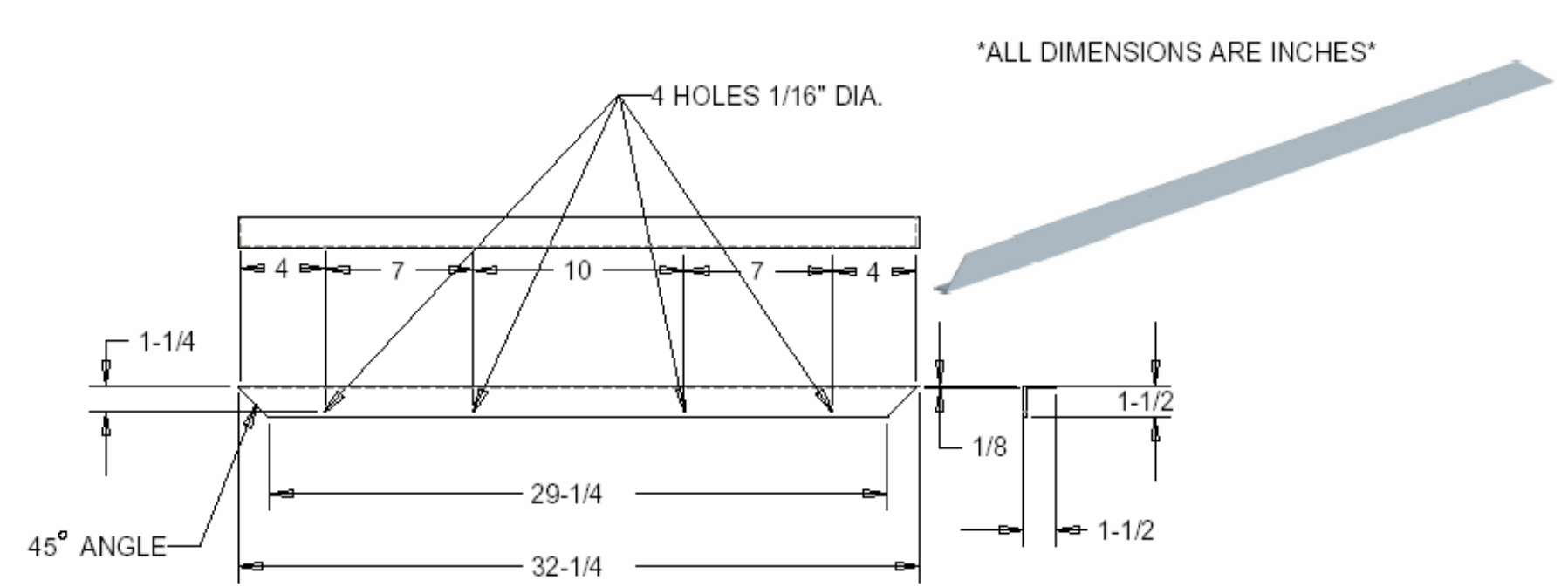
Outer Frame – Exploded View



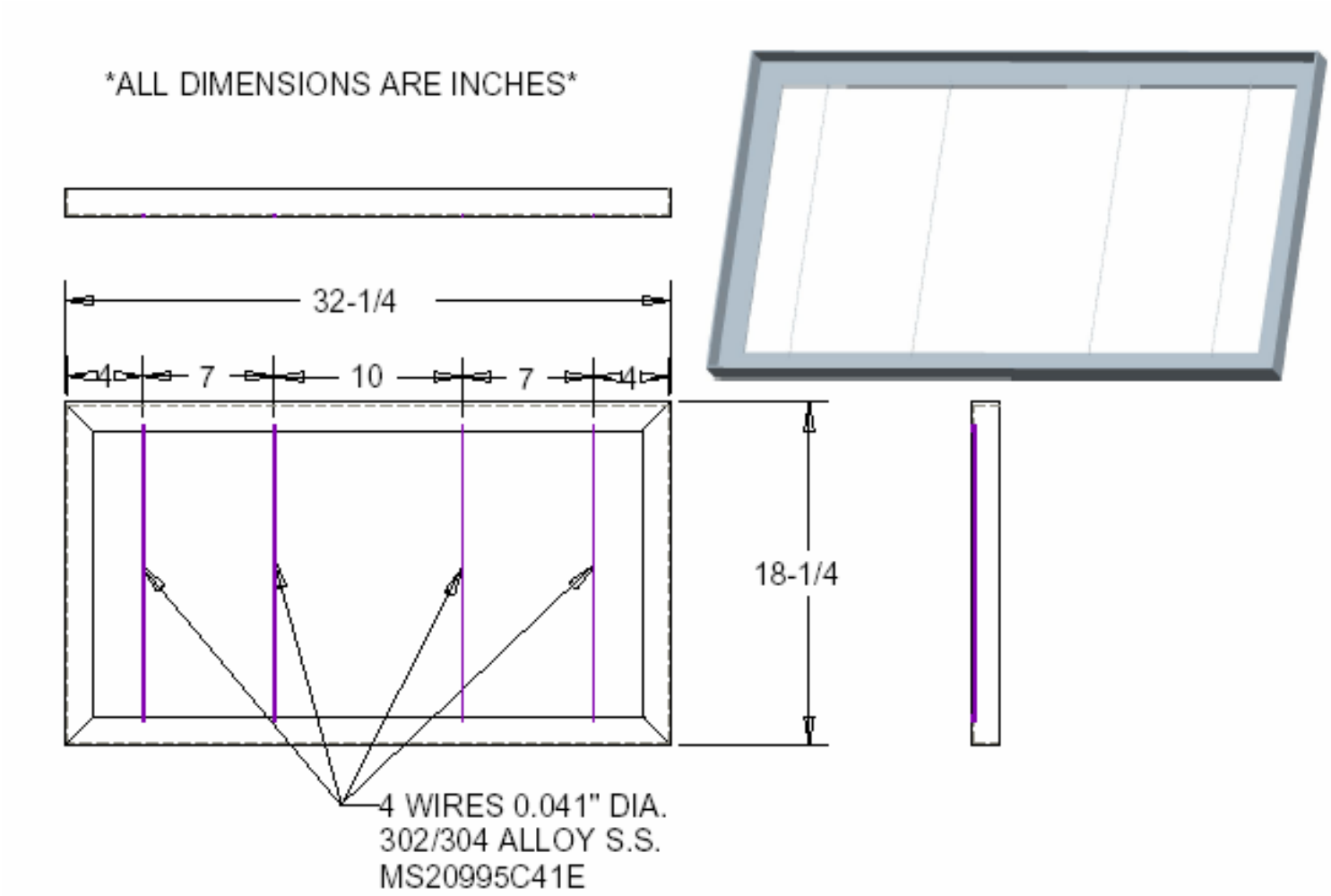
Outer Frame Components - Sides



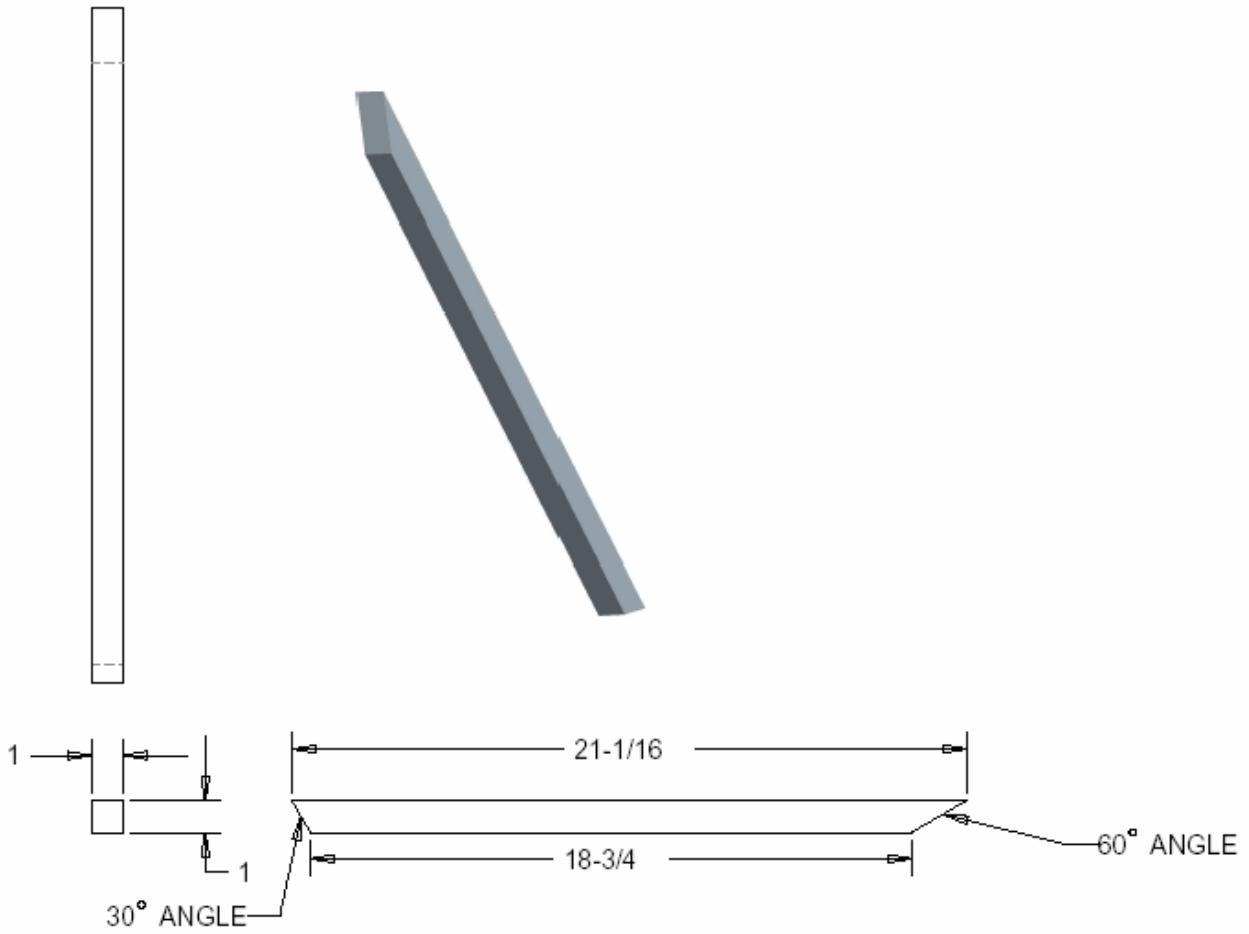
Outer Frame Components – Top & Bottom



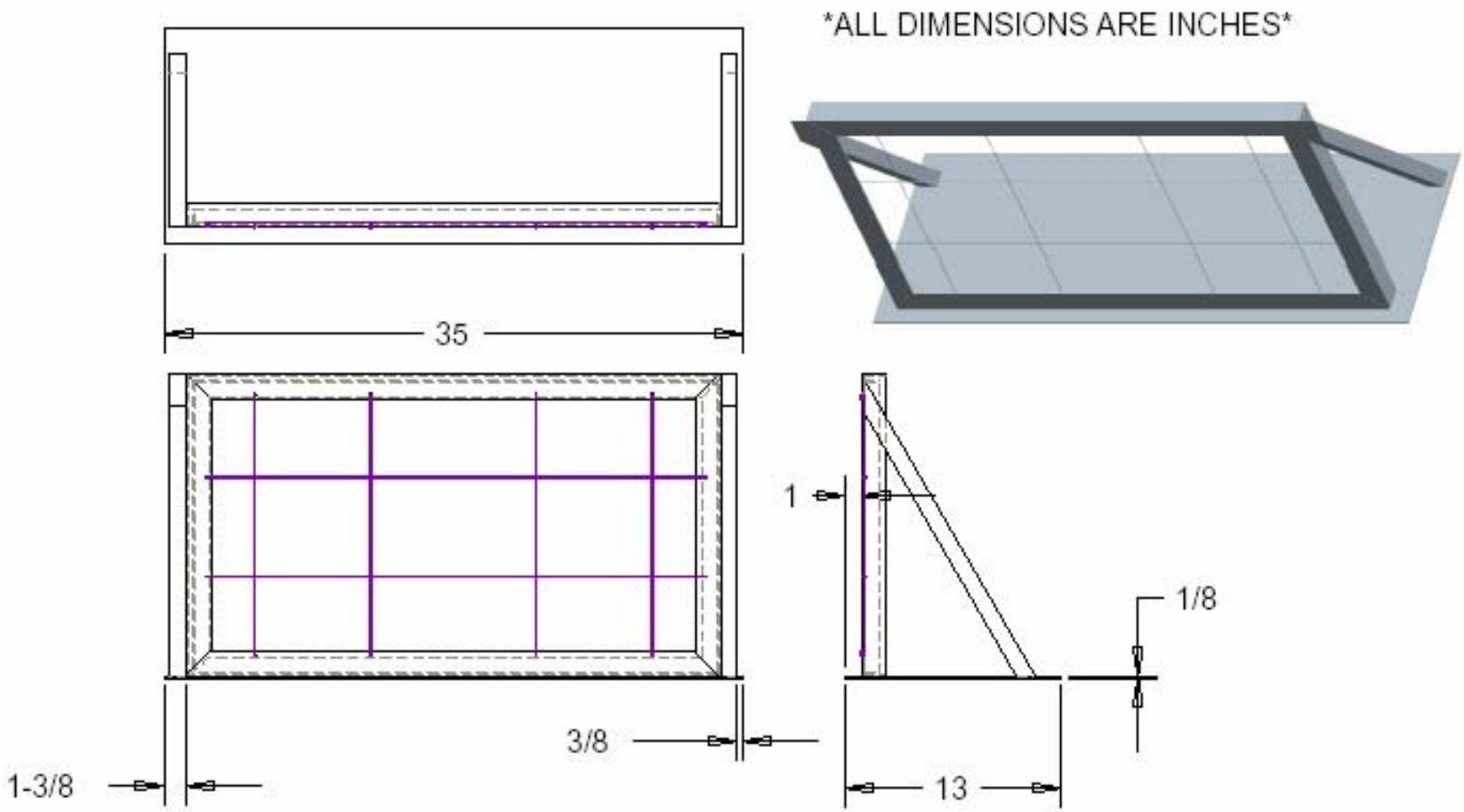
Outer Frame - Assembled



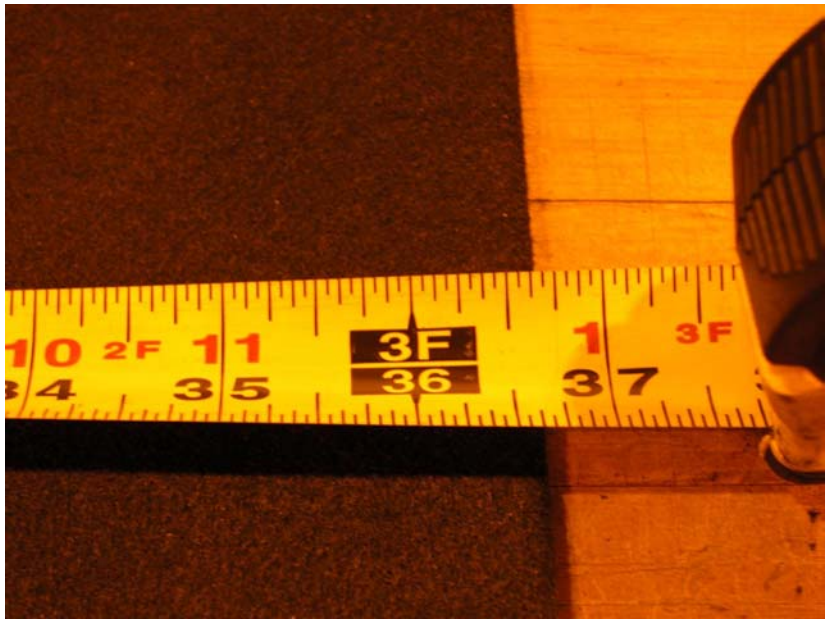
Supports



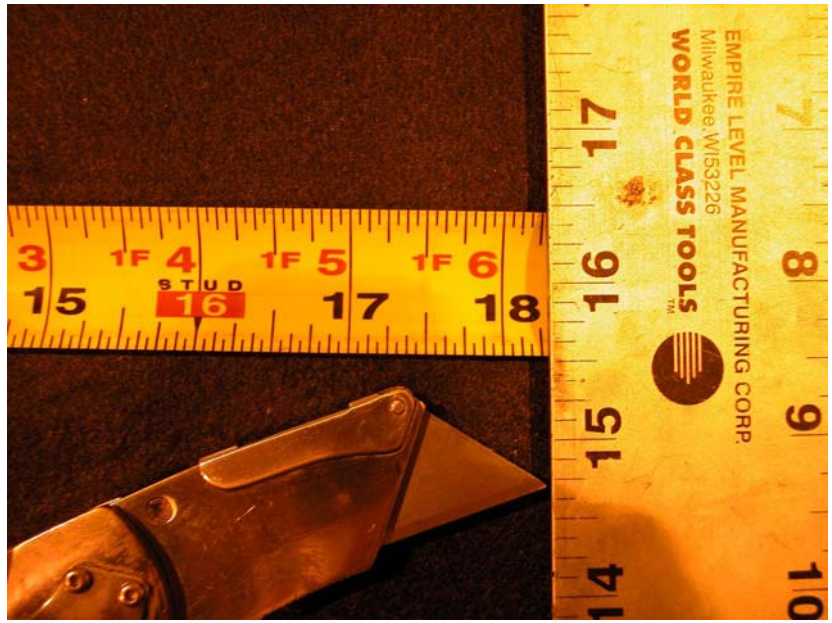
Frame Assembly



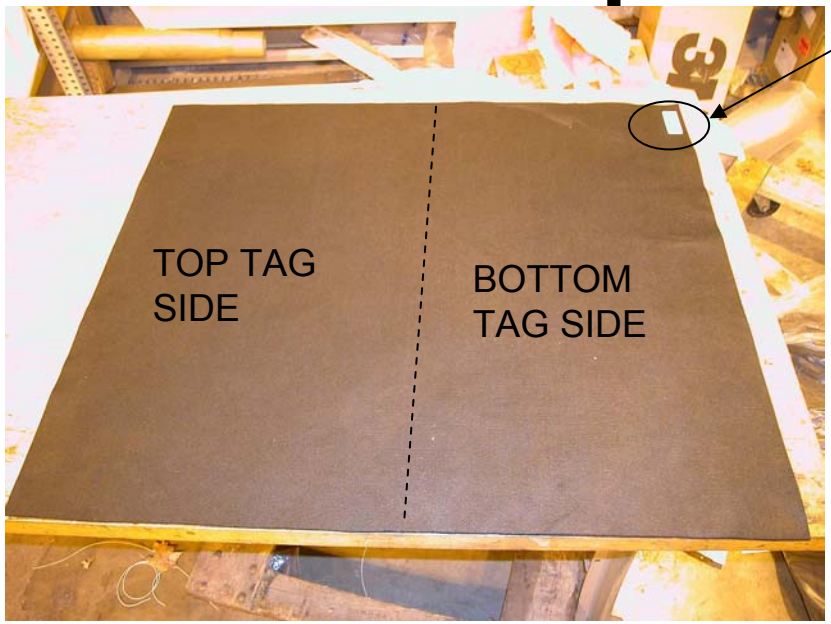
Blanket Preparation



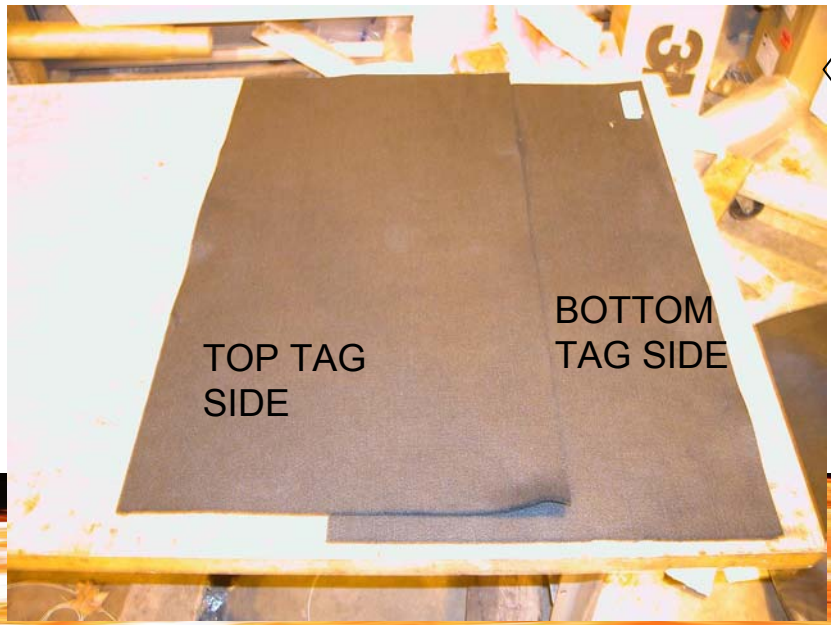
Most blankets are 36”L x 32”W, but some may be longer, like 36 ½”. Just divide the length in 2 and cut there – 18 ¼” in this case.



Blanket Preparation



Tag indicates the “bottom” blanket, and also is the backside – not facing the flame.



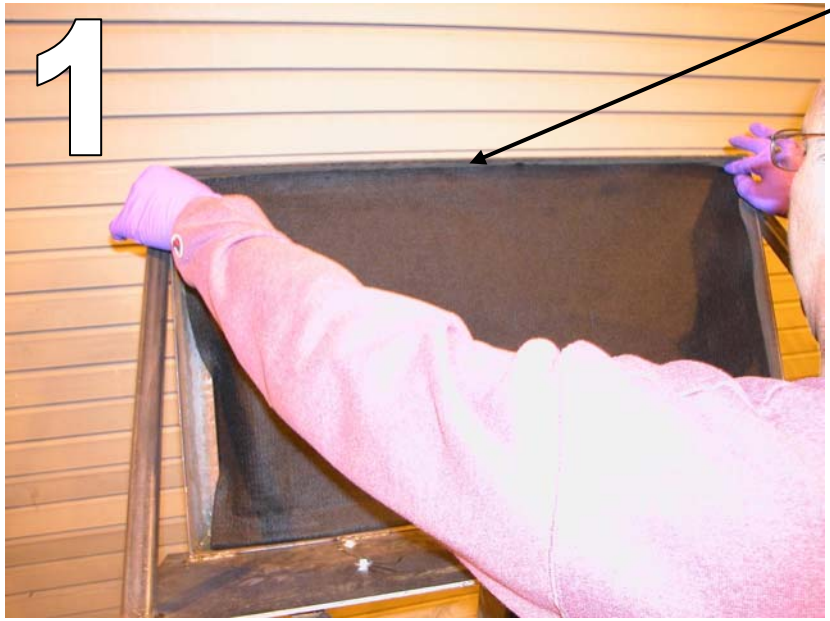
On the top blanket, cut edge is installed on the bottom of the frame. On the bottom blanket, the tag gets installed on the bottom of the frame.

View From Back

Blanket Installation

Start from the top, align the top edge of the blanket with the inner top edge of the frame

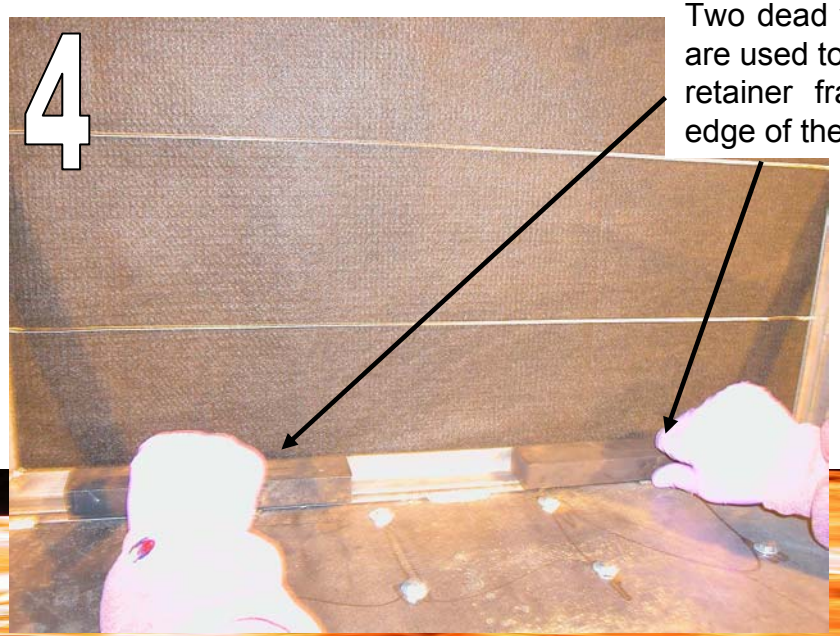
Holding the top in place, work the blanket into the holder from left to right



Blanket Installation

Roll the retainer frame in from the bottom to the top

Two dead weights, about 5 lbs each, are used to put additional force on the retainer frame to keep the bottom edge of the blanket from shrinking up.



Finished Installation, Front and Back

If sample is too small, use two more 5 lb. bars on the vertical members of the inner frame to restrain the sample