Burnthrough Test Method for Aircraft Thermal/Acoustic Insulation:

Alternative Burner Apparatus

Presented to: Materials Working Group

By: Robert I. Ochs

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Outline

- **PHASE I: PROOF OF CONCEPT**
- **PHASE II: CONSTRUCTION AND CALIBRATION OF MULTIPLE BURNERS**
- **PHASE III: DESIGN AND CONSTRUCTION OF A FULLY INDEPENDENT BURNER**

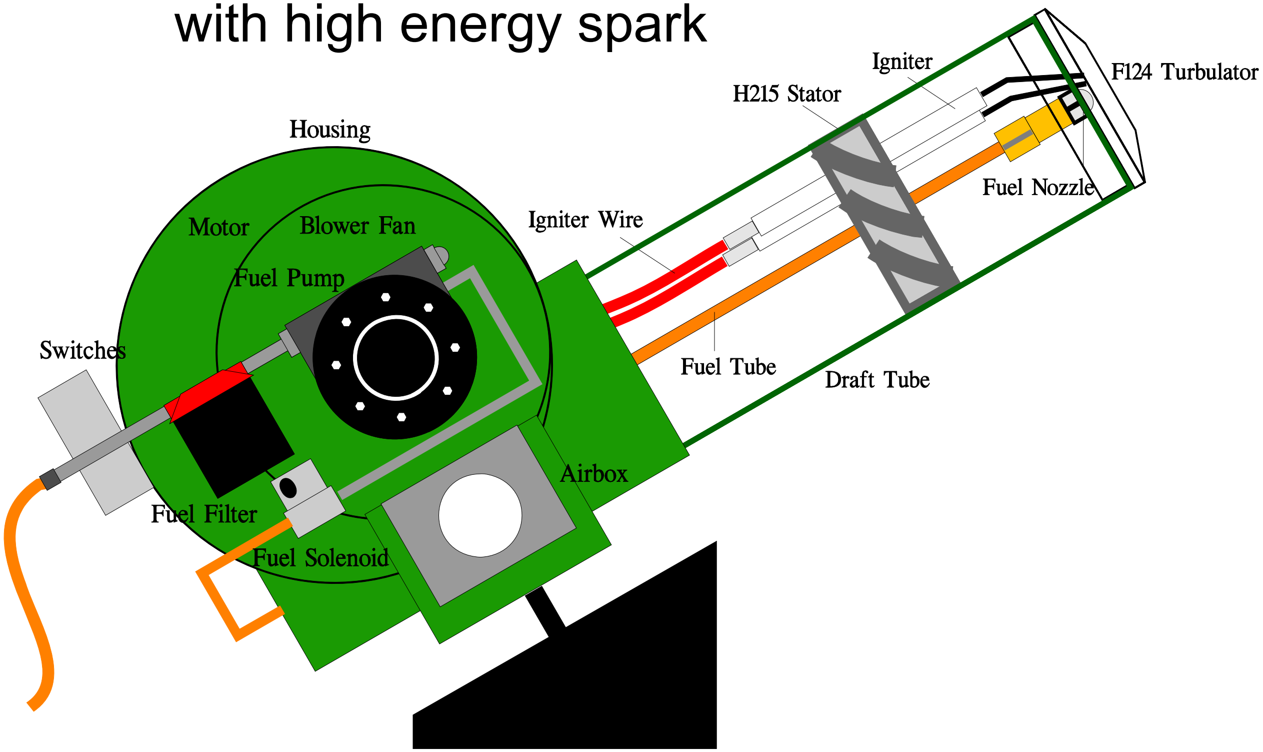
PHASE I: PROOF OF CONCEPT

Motivation

- **Need for new test apparatus**
  - Inconsistencies in burner performance
    - Reproducibility of experiment critical for compliance
    - Burner performance dependent upon several factors
      - Electric motor
        - » Supply voltage differences and fluctuations
        - » Does motor/fan supply constant, steady flow rate of air?
      - Variability in construction
        - » Flange-type burners
        - » Socket-type burners
        - » Differences in blower castings
      - Laboratory conditions
        - » Local air temperature, humidity affect supply air density, fuel to air mass ratio

Operation of Oil Burner

- **Simple design**
  - Turbulent airflow is mixed with fuel spray
  - Air/fuel mixture is ignited with high energy spark

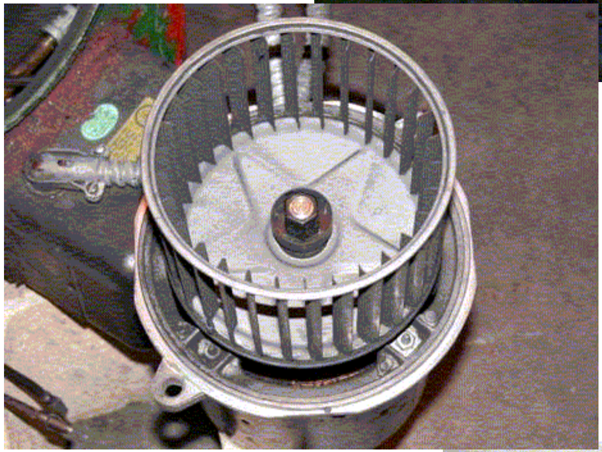


Problems

- **Remove dependence upon electric motor**

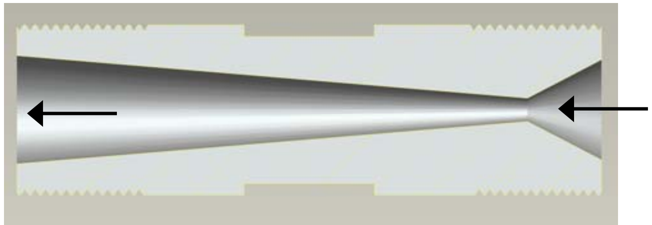
  What does the motor do?

  1. Directs lab air through the blower housing and draft tube towards the sample at a fixed velocity/flow rate
  2. Pressurizes liquid fuel to approx. 100 psi, which is required for Monarch-type fuel nozzles

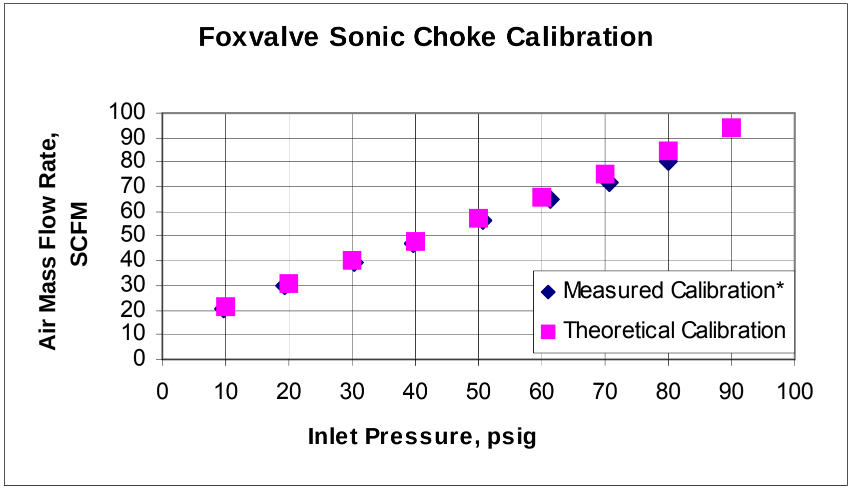


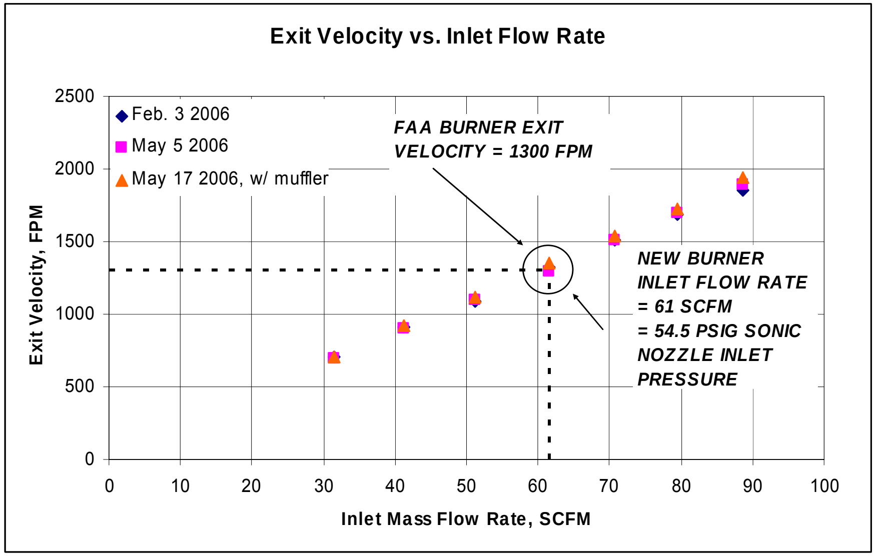
Replacement of Electric Motor

- **Task 1: To supply air to the draft tube at a controllable velocity / flow rate**
- **Solution: Utilize compressed air from laboratory compressor**
  - More control over level of conditioning of supply air
    - Humidity
    - Temperature
    - Pressure
  - Flow can be metered with a sonic choke to deliver a constant mass flow rate of air
    - Mass flow rate will be fixed for choked flow
    - Choked flow for positive pressure conditions can be achieved by maintaining a constant inlet pressure and certain range of backpressures
    - Required parts / instrumentation:
      - » Sonic choke
      - » Precision air pressure regulator (moderate to high flow)
      - » Pressure gauge (0-200 psig) and transducer to measure and record sonic choke inlet pressure
      - » Solenoid valve to remotely operate the compressed air supply
      - » Type-K thermocouple for inlet air temperature



Sonic Nozzle Calibration

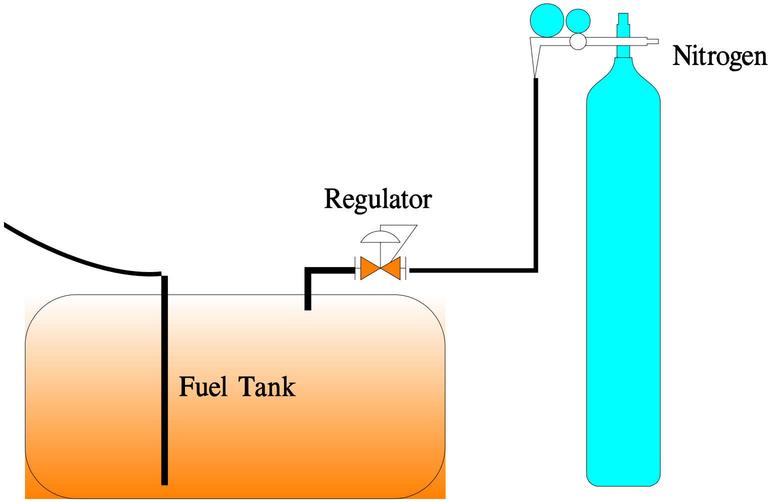




- Theoretical calibration checked with Sierra Instruments, Inc. vortex-shedding mass flow meter
- Exit velocity measured with vane anemometer inserted into the flow at the end of draft tube
- Inline air intake/exhaust low pressure drop muffler used to dampen out high frequency noise, with a negligible change in burner exit velocity
- FAA burner exit velocity = 1300 fpm
- Corresponding new burner inlet flow rate = 61.5 SCFM, provided by a sonic nozzle inlet pressure of 54.5 psig

Replacement of Electric Motor

- **Task 2: To supply the fuel rail / nozzle with fuel (JP-8) at an adjustable pressure**
- **Solution: Construct a pressurized fuel tank**
  - Fill partially with JP-8
  - Pressurize the headspace with compressed N_2 from gas bottle with pressure regulator
  - Required parts / instrumentation:
    - Pressure vessel
    - Pressure gauge and transducer to monitor fuel pressure
    - Bleed valve to reduce pressure
    - Compressed nitrogen and bottle regulator
    - Liquid level sight gauge to monitor fuel level
    - Solenoid valves for remote operation of fuel flow and fuel tank pressurization



Pressurized Fuel Delivery System: Description

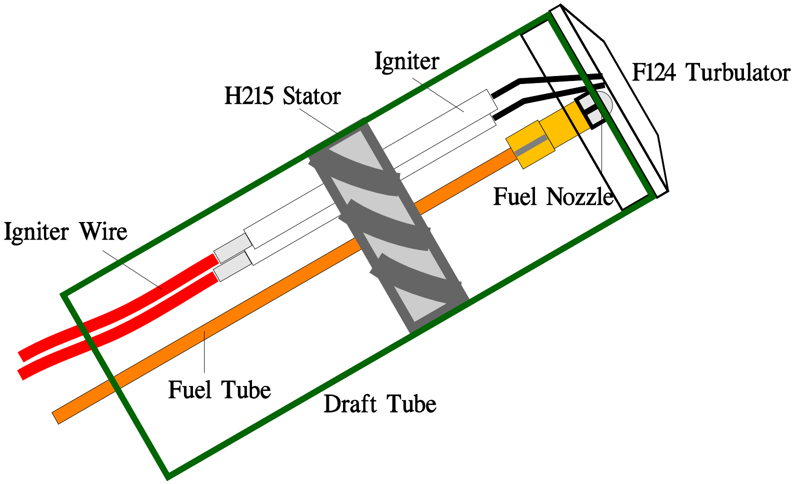
- **Constructed fuel tank out of an old Halon bottle**
  - Welded fittings on top and bottom
  - Mounted upright on stand with front panel for fuel level and tank pressure gauges
  - Solenoid valves and control box for remote operation
  - Coated inner surfaces with fuel tank liner

Pressurized Fuel Delivery System: Performance

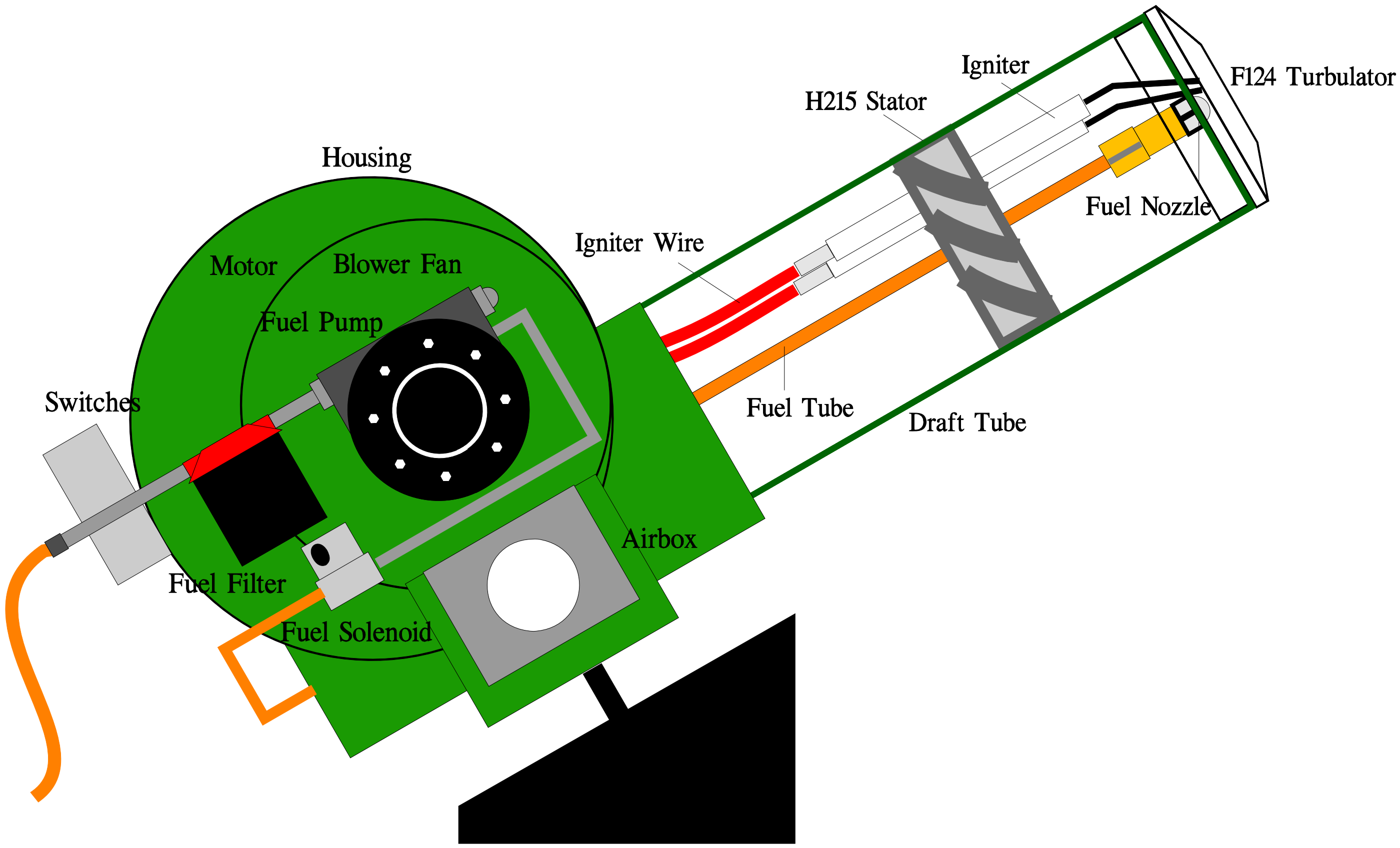
- **Performed fuel flow rate measurements with graduated cylinder and stopwatch**
- **Used a Monarch 6.5 GPH 80° PL type nozzle @ 80 psig, corresponding to a fuel flow rate of 6.0 GPH**

Draft Tube / Ignition

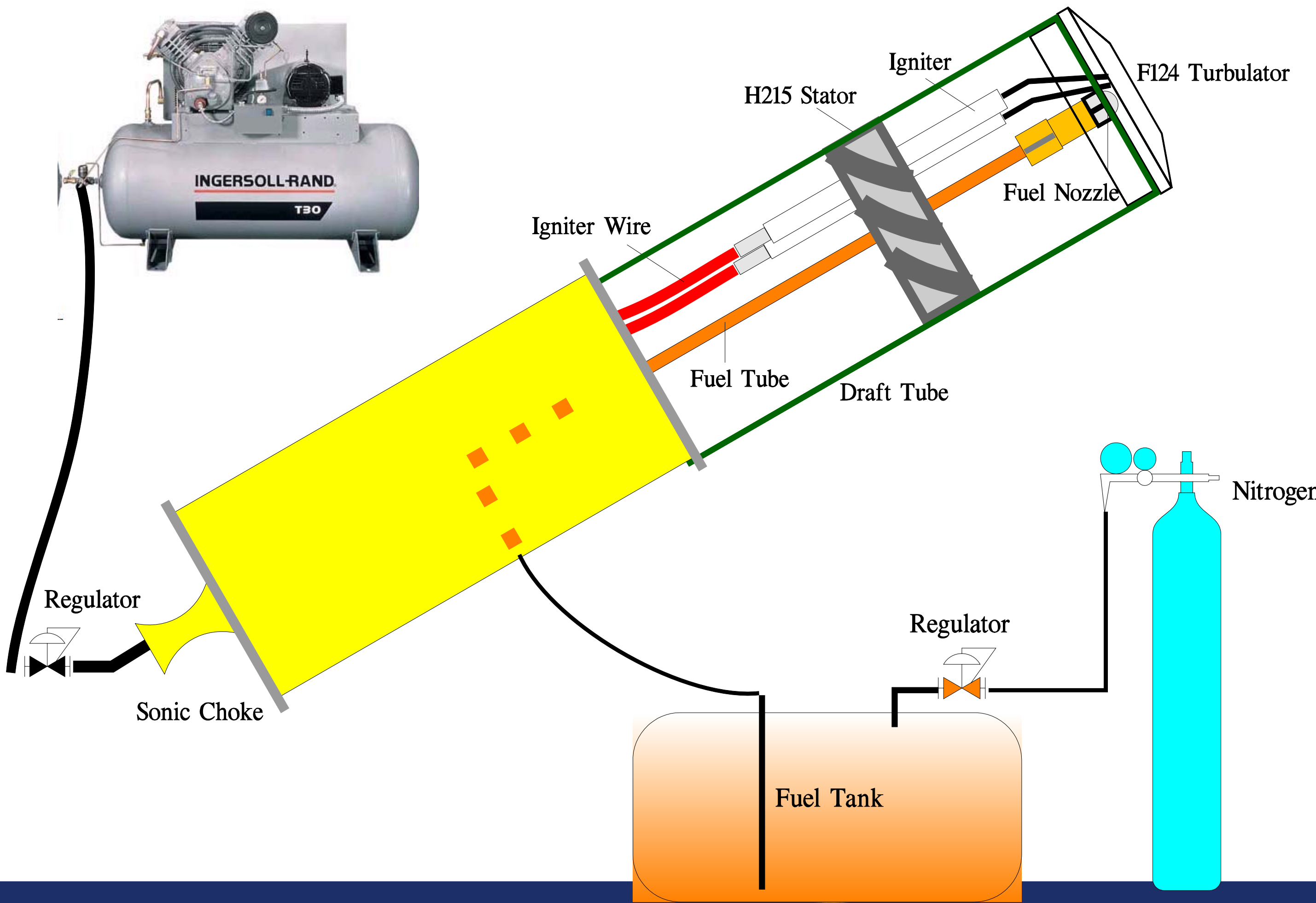
- **Plan to reconstruct a draft tube to similar specifications of original draft tube**
  - Construct out of 4.25” O.D. , 4” ±0.01” steel tubing (mild seam)
  - This size tubing will fit the stator / ignitor assembly from the original burners
    - Use same ignition source
    - Use same end cap (turbulator) as original burner
    - Use cone specified in rule



Current Test Apparatus



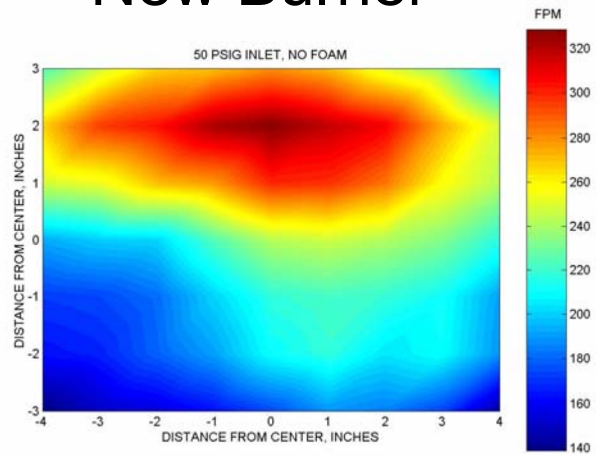
Proposed Replacement Apparatus

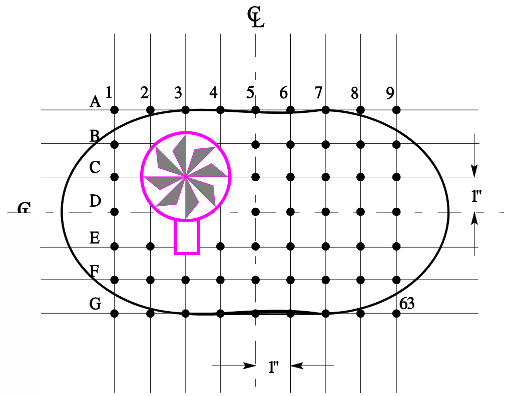


Alternative Burner Apparatus

Velocity Mapping

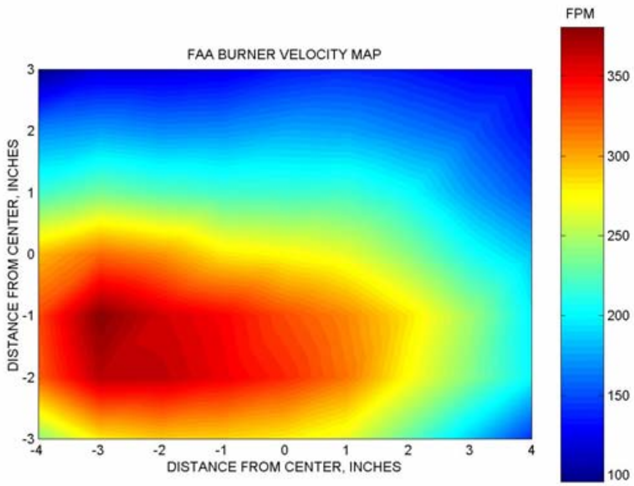
New Burner



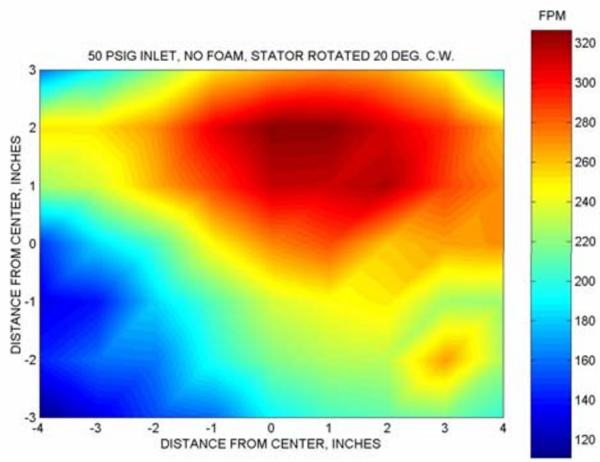


Average Velocity = 227 fpm

FAA Burner

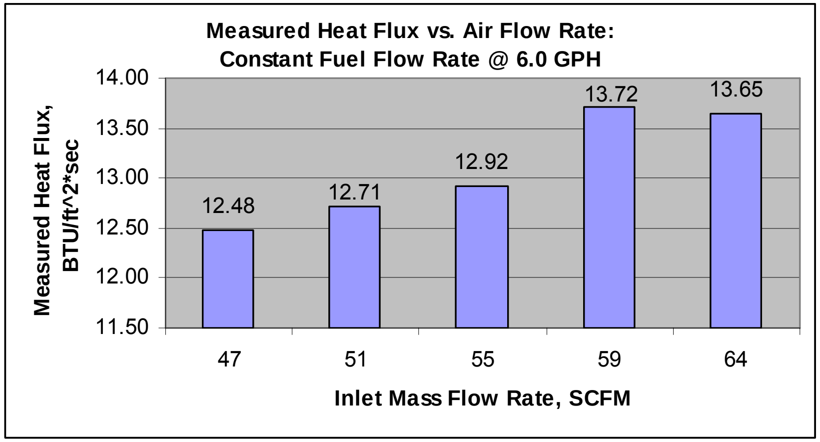


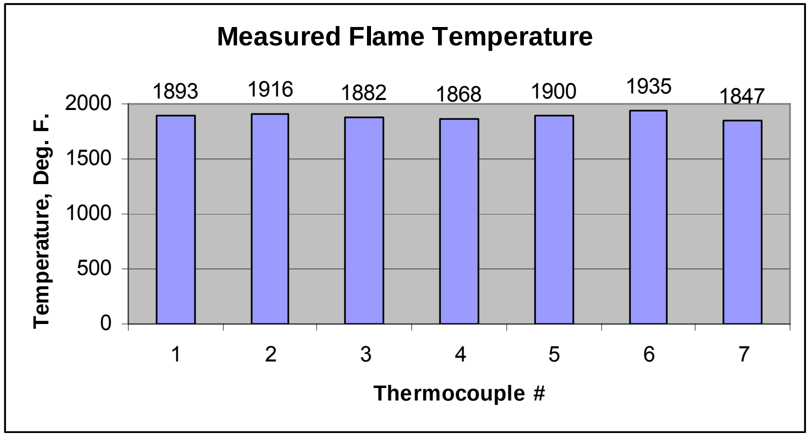
Average Velocity = 231 fpm

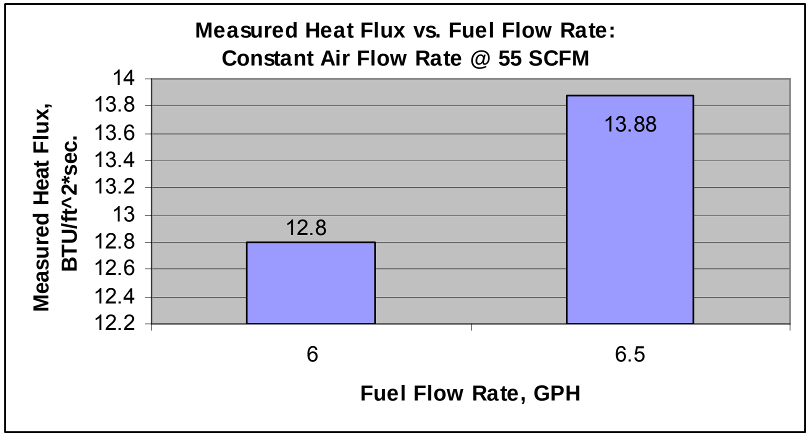


Average Velocity = 231 fpm

Initial Calibration – Heat Flux and Temperatures

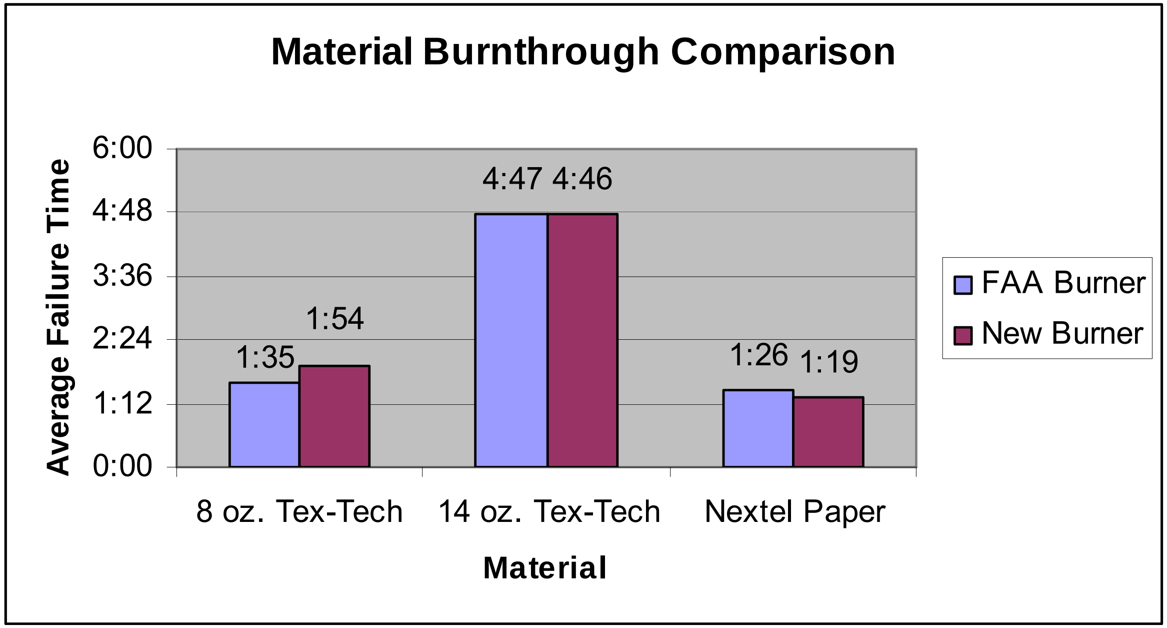






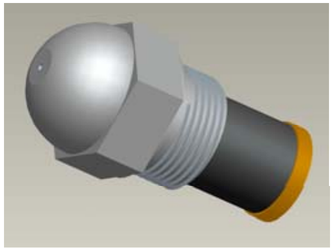
Initial Burnthrough Times

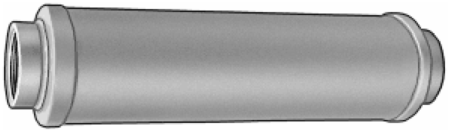
- **3 materials were chosen for comparing burner performance with FAA burner**
  - 8 oz. Tex-Tech (consistent burnthrough times)
  - 14 oz. Tex-Tech (consistent burnthrough times)
  - Nextel Paper (consistent backface heat flux failure times)

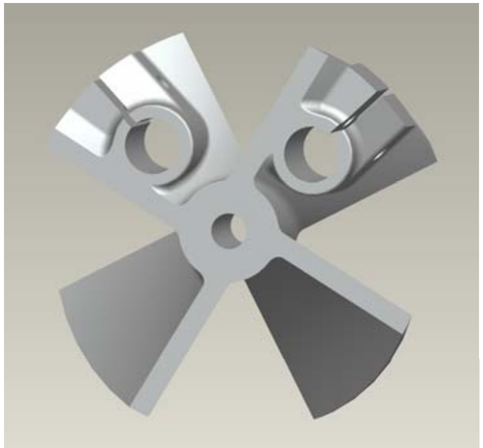


Latest Adjustments and Modifications

- **Tried several different nozzles**
  - 6.0 gph 80° PL (new style)
  - 6.5 gph 80° PL (old style)
  - 5.5 gph 80° PL (old style)
    - Ran all at 6.0 gph by adjusting fuel pressure
    - Found great inconsistencies with 6.0 gph nozzle
    - Found highest measured heat flux with 5.5 gph nozzle at 120 psig
- **Installed in-line muffler to reduce high frequency noise**
- **Installed in-line water cooled aftercooler to maintain a constant temperature airflow**
- **Modified H-215 stator to fit slightly larger diameter tubing**
- **Tried positioning the stator at several different axial locations, found maximum heat flux at 4.0” back from nozzle tip.**
- **Adjustments successful in achieving burner calibration:**
  - Heat flux: approximately 15.4 BTU/ft^2*s
  - Temperatures: all within at most 1900°F ±40°F
- **Now, with a calibrated burner, we can compare burn-through results with burners of other types that are also in calibration**
- **On to RR8**







Round Robin VIII

- **Purpose: to compare laboratory performance of socket-type oil burners with FAA standard**
- **Alternative burner apparatus participated as an informal participant, in order to compare results with the FAA standard, as well as other labs that have burners that are in calibration**
- **Three materials used as standard controls in the experiment:**
  - 8 oz./yd^2 pre-ox PAN, Tex-Tech Industries, b.t. ≈ 90-120 sec.
  - 14 oz./yd^2 pre-ox PAN, Tex-Tech Industries, b.t. ≈ 240-300 sec.
  - Ceramic dot-printed paper, 3M, backface failure ≈ 60-90 sec.

Round Robin VIII Calibration Checklist

Monarch 5.5 80° PL

120 psig

4.0”

n/a

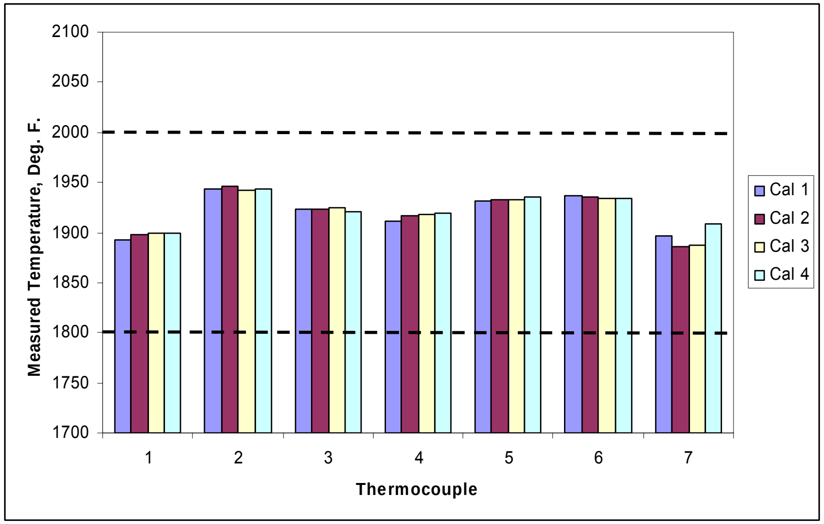
Nozzle type	Approximate pump pressure (psi)	Depth of nozzle recessed from end plane of turbulator (inches)	Distance of igniters protruding end plane of nozzle (inches)	Stator depth from nozzle (inches)	~~Fan size (inches)~~
~~Monarch 6.5 80° PL~~	~~85~~	0.3125	0.15625	~~3.375~~	~~5.25 dia X 3.5 depth~~

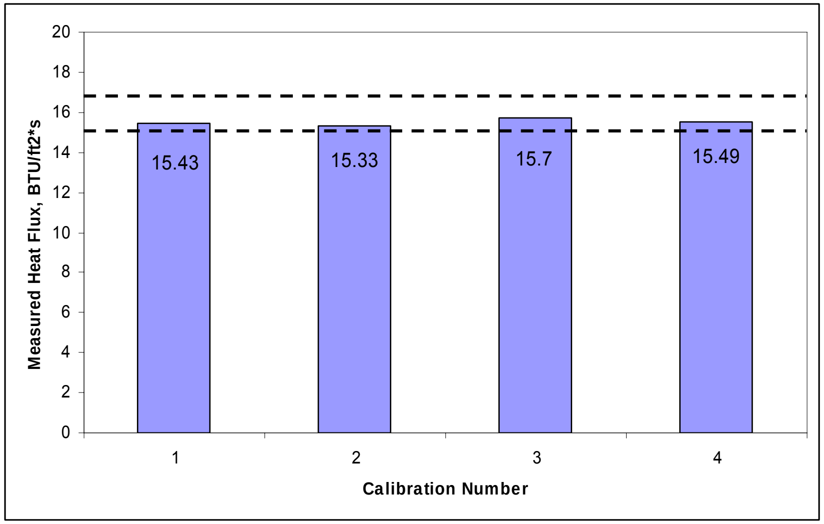
Stator type	Stator orientation	Turbulator type	Turbulator orientation	~~Intake air velocity (ft/min)~~	~~Intake hose length (ft)~~
modified H215	11 o'clock (330° C.W.)	Monarch F124	notch at bottom	2100-2150	~~20~~

Corresponding exit velocity = 1300 fpm

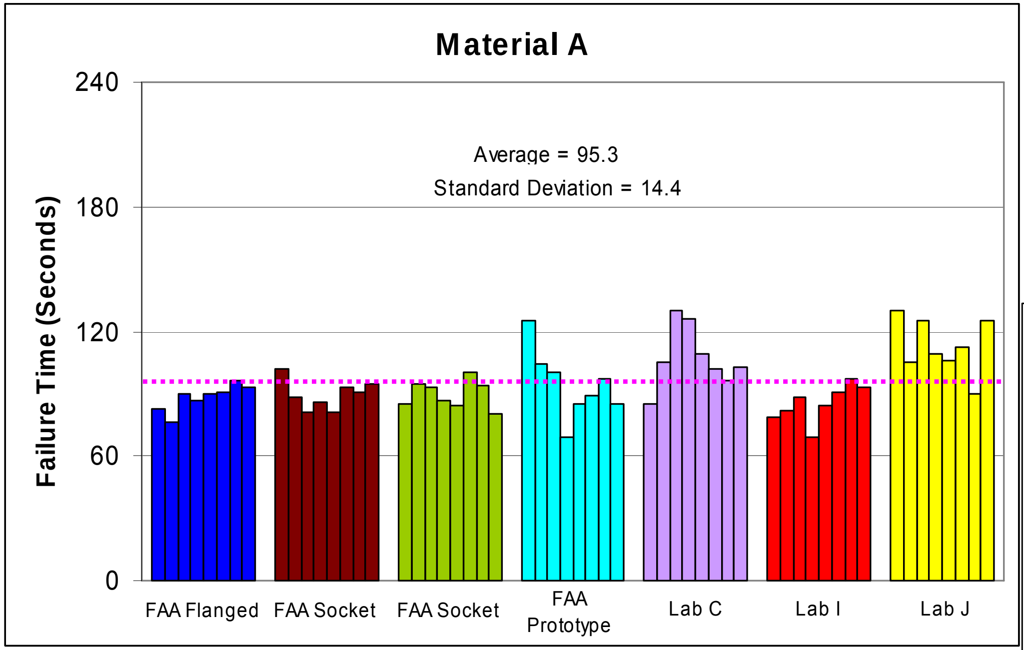
n/a

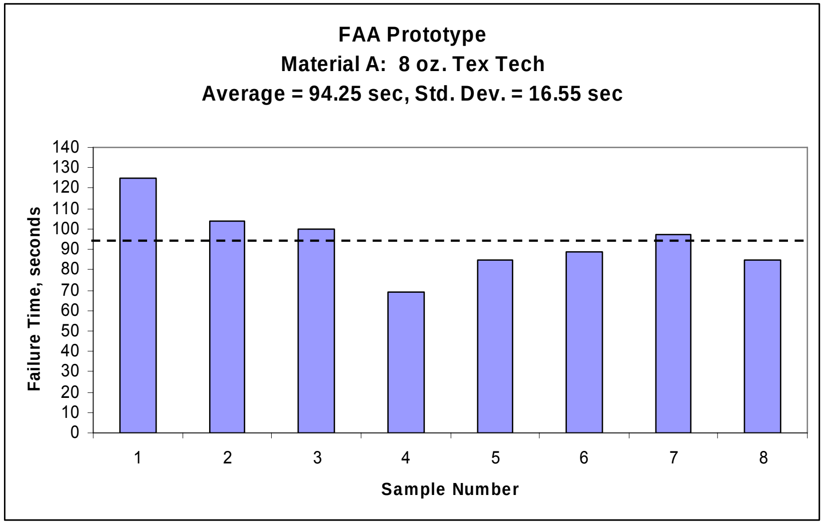
Round Robin VIII Calibrations

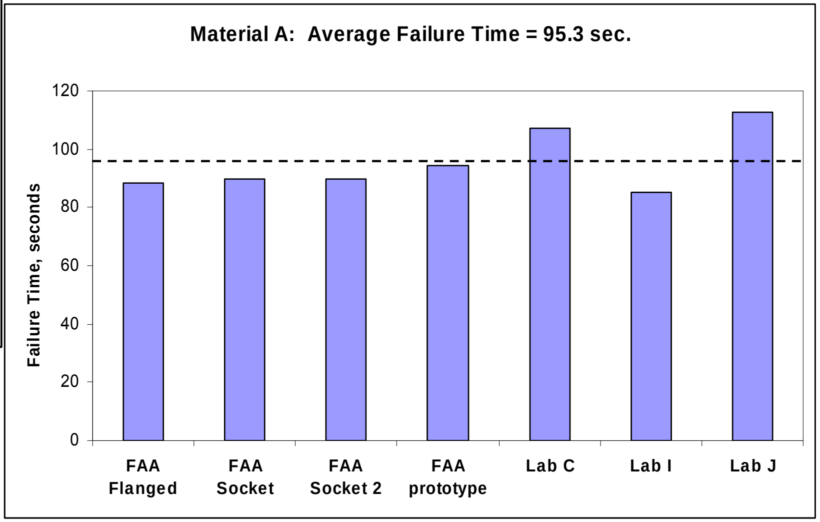




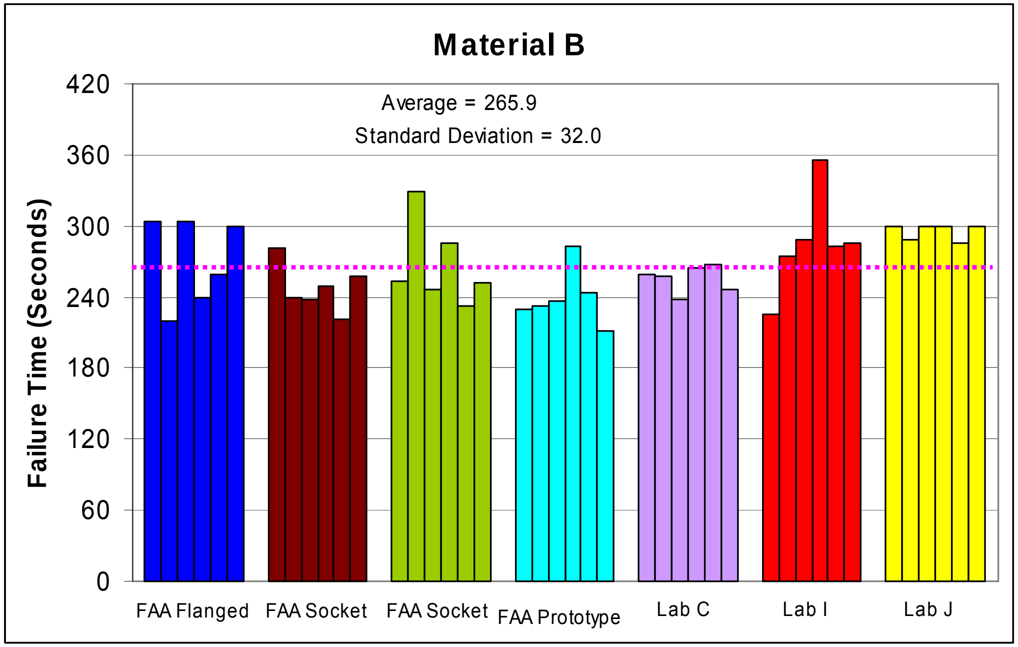
Round Robin VIII Results: Material A

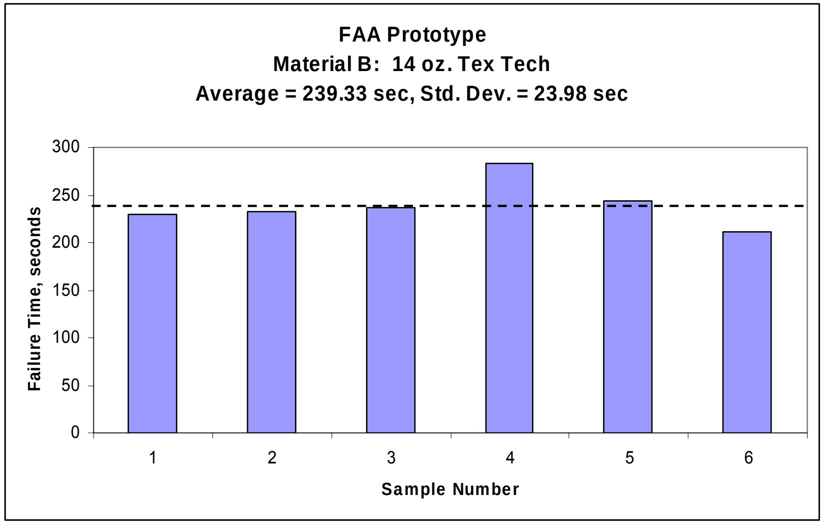


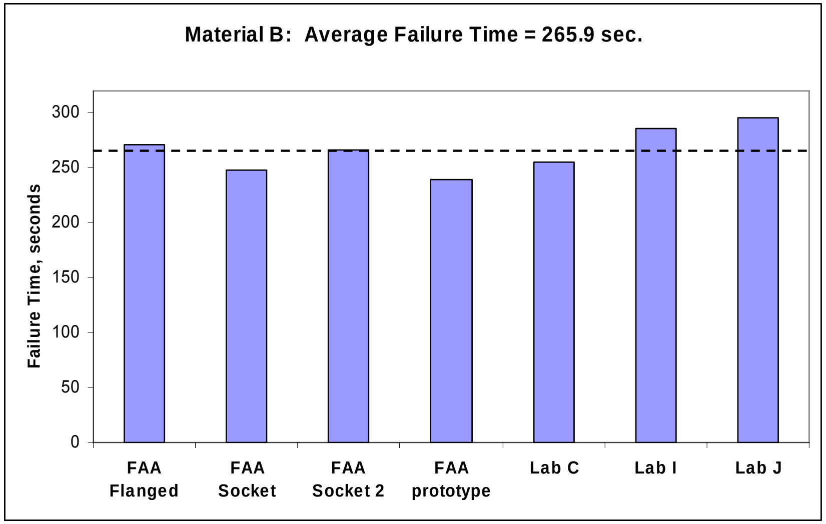




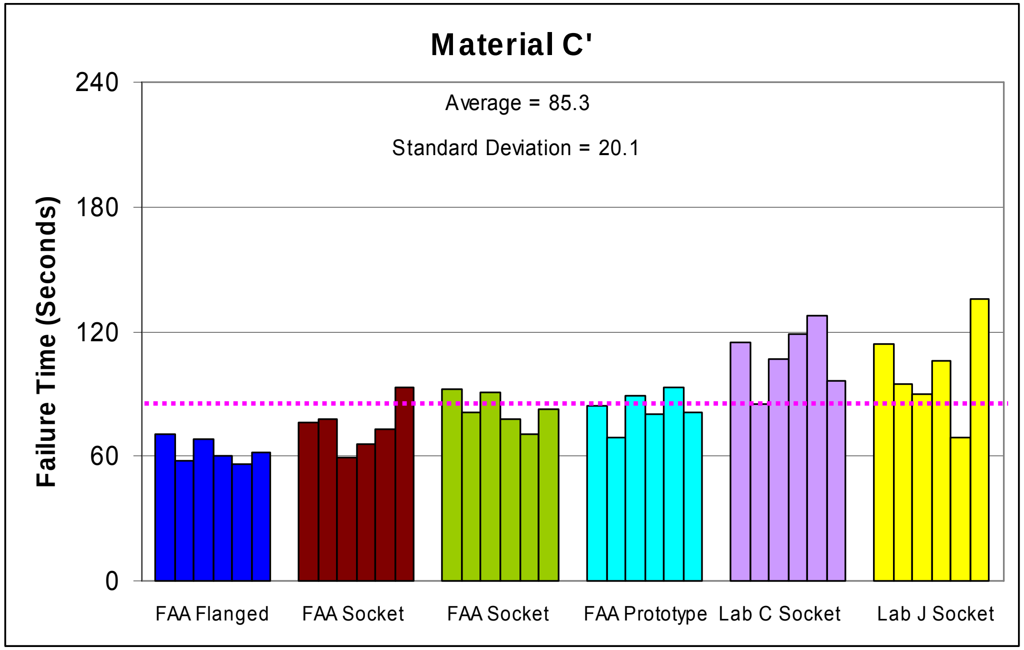
Round Robin VIII Results: Material B

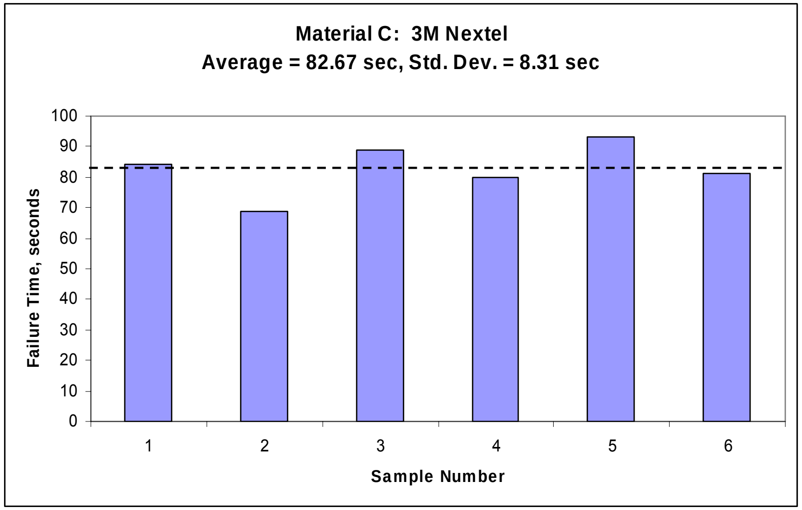


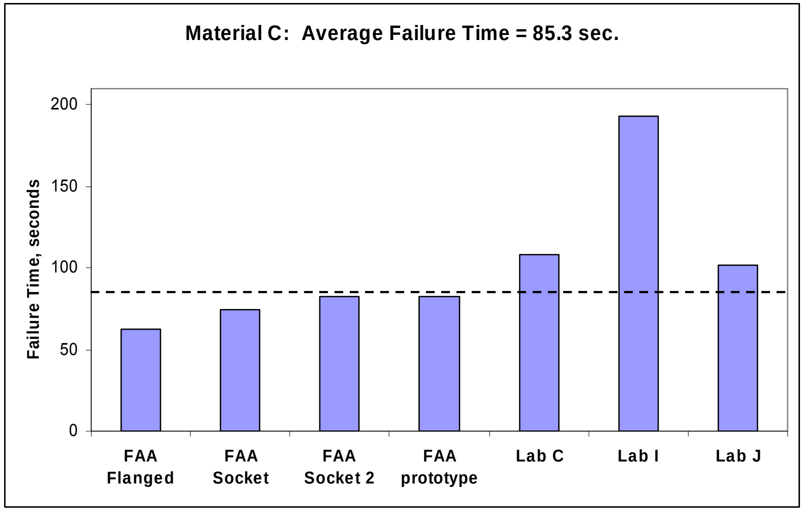




Round Robin VIII Results: Material C







Round Robin VIII Summary

FAA prototype burner results were in good agreement with the FAA standard and the other RR8 participants

PHASE II: CONSTRUCTION AND CALIBRATION OF MULTIPLE BURNERS

Objectives

1. **Construct and calibrate ten (10) identical burners**
   - Modify the current “prototype” design slightly in order to improve the ease of adjustment and operation
2. **Use calibration materials (yet to be determined) in order to closely match the performance of each new burner with the performance of the FAA standard**
3. **Loan/distribute burners to participating labs to verify performance**

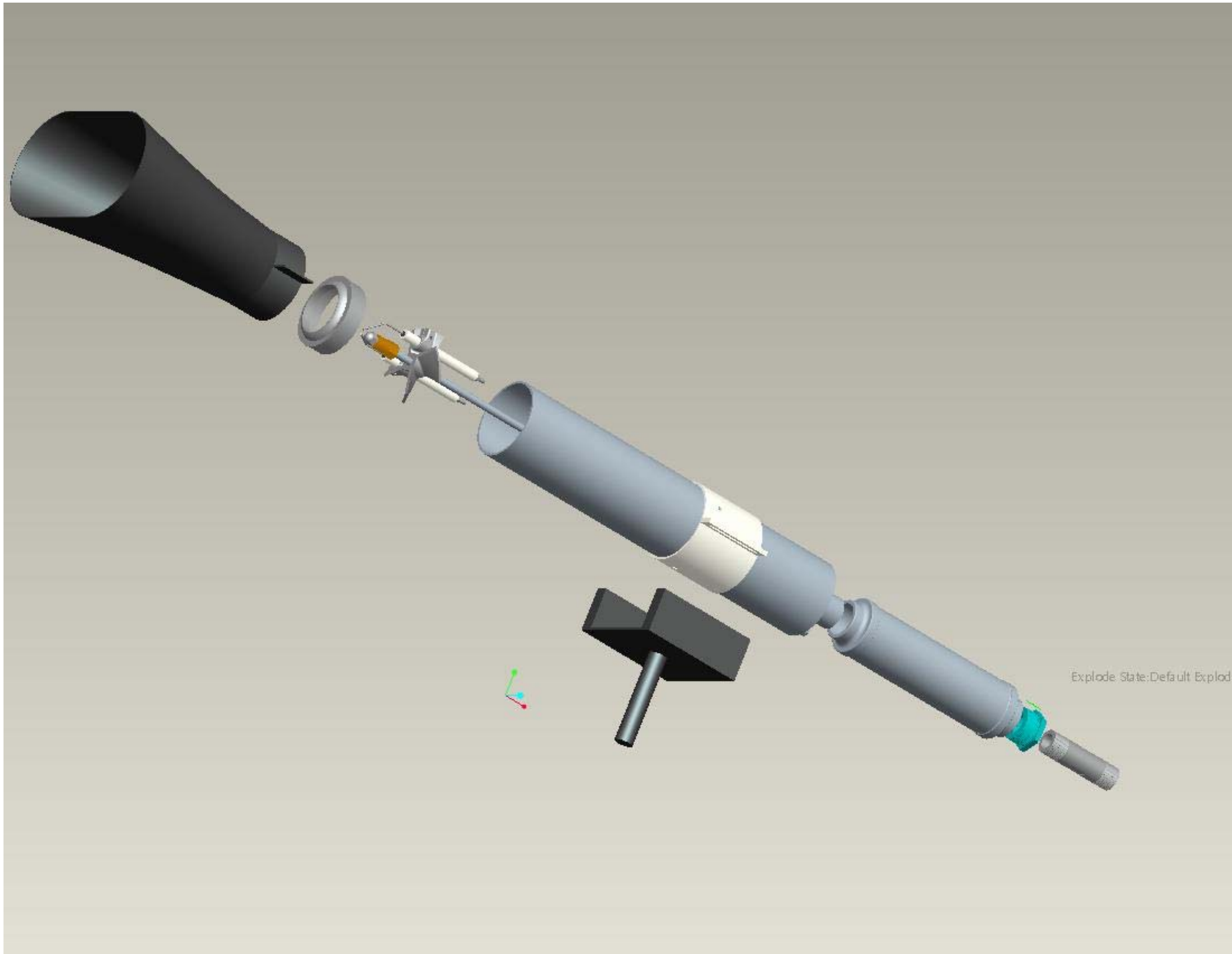
Design

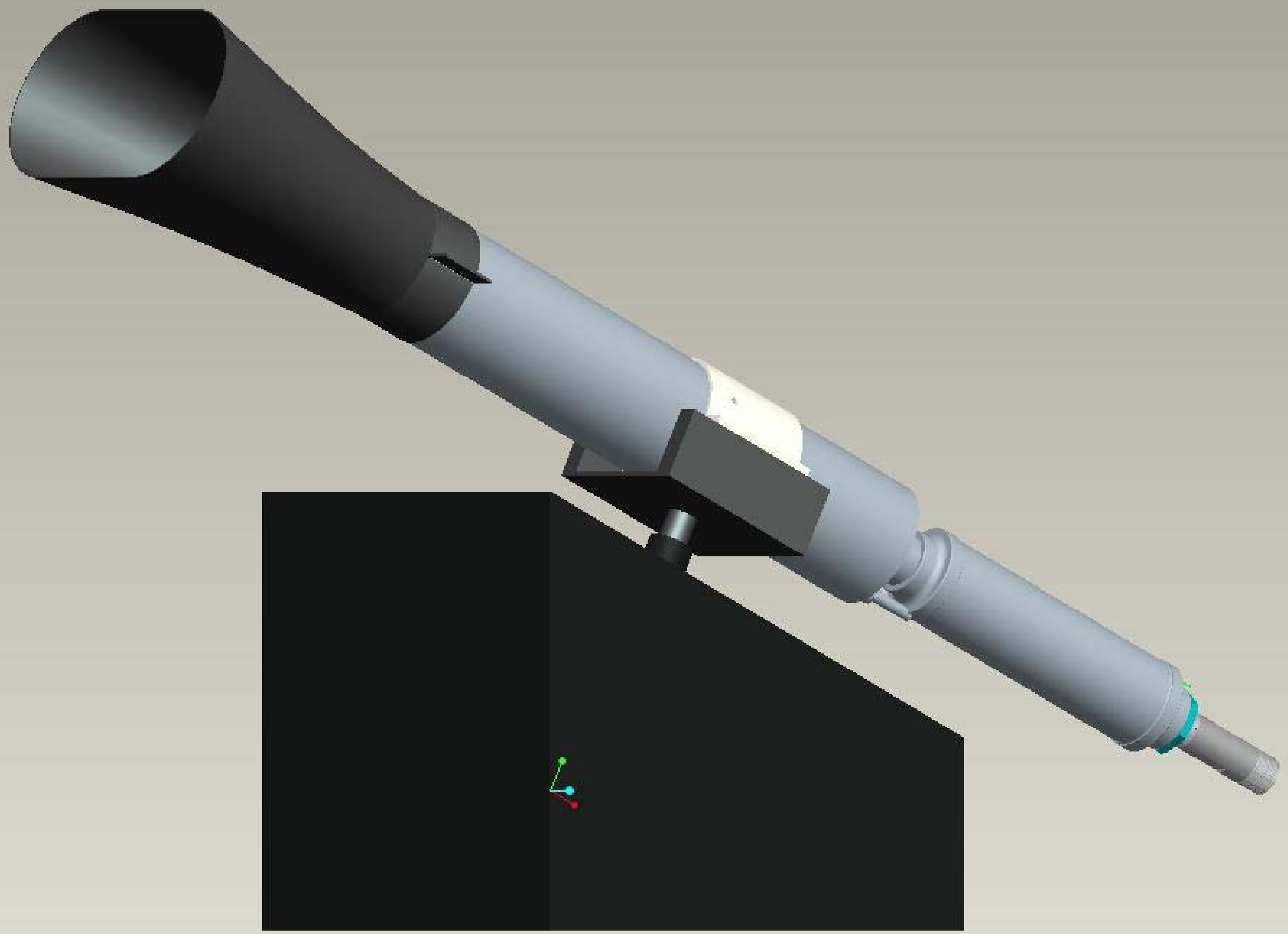
Parts:

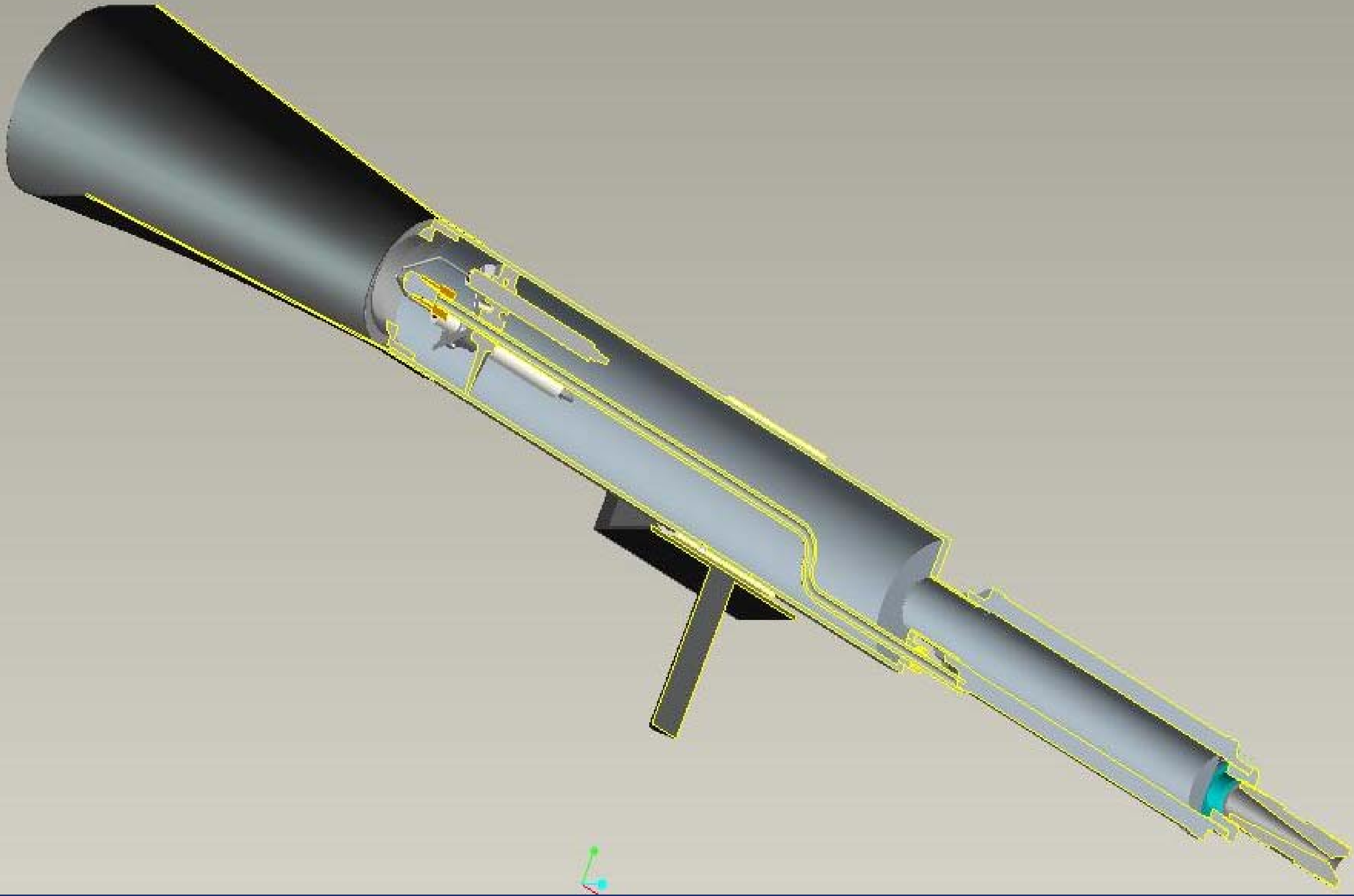
1. ARO Air Pressure Regulator
2. 0-100 psig pressure gauge
3. Fox Valve Development Corporation 1” sonic choke
4. 1” to 1 ½” NPT bushing
5. 1 ½” high flow, low pressure drop air intake muffler
6. 1 ½” NPT nipple
7. Burner tubing
   – Back section
   – Coupling
   – Draft tube
8. Burner mount
9. Fuel rail
10. Keyless bushing for fuel rail mounting
11. Modified H215 stator
12. Igniters
13. Igniter wire
14. Igniter box
15. Nozzle adapter, standard
16. 5.5 GPH, 80° PL Monarch nozzle (old-style)
17. F124 “Turbulator” end-cap

Required for operation:

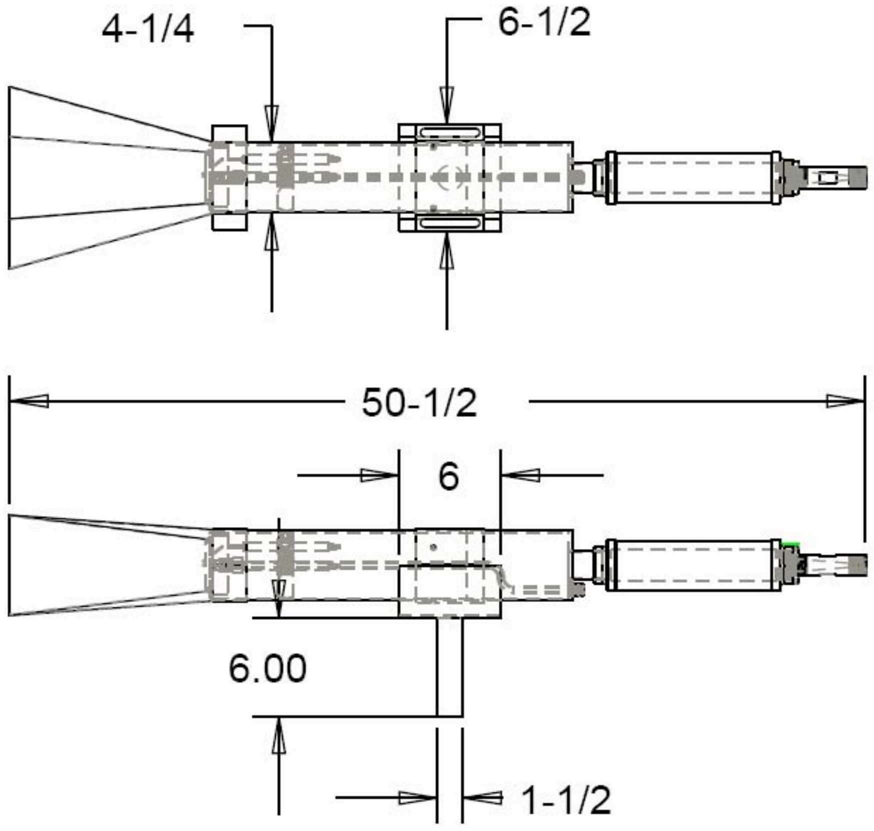
1. Compressed air supply (approx 60 psig, 60 scfm)
2. Temperature control for compressed air
3. Fuel supply (pressurized fuel system capable of 120 psig supply pressure)
4. 30° base stand
5. Calibration and test rigs
6. Burner cone

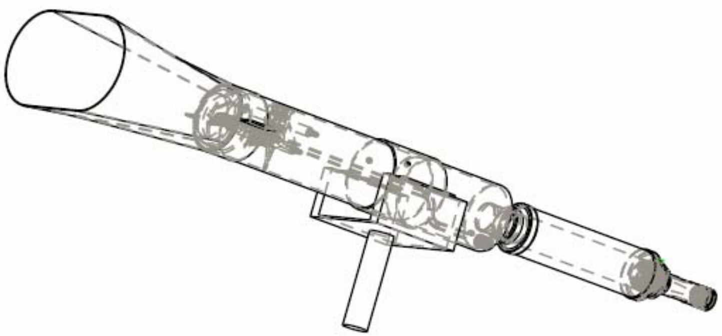






Dimensions are in inches

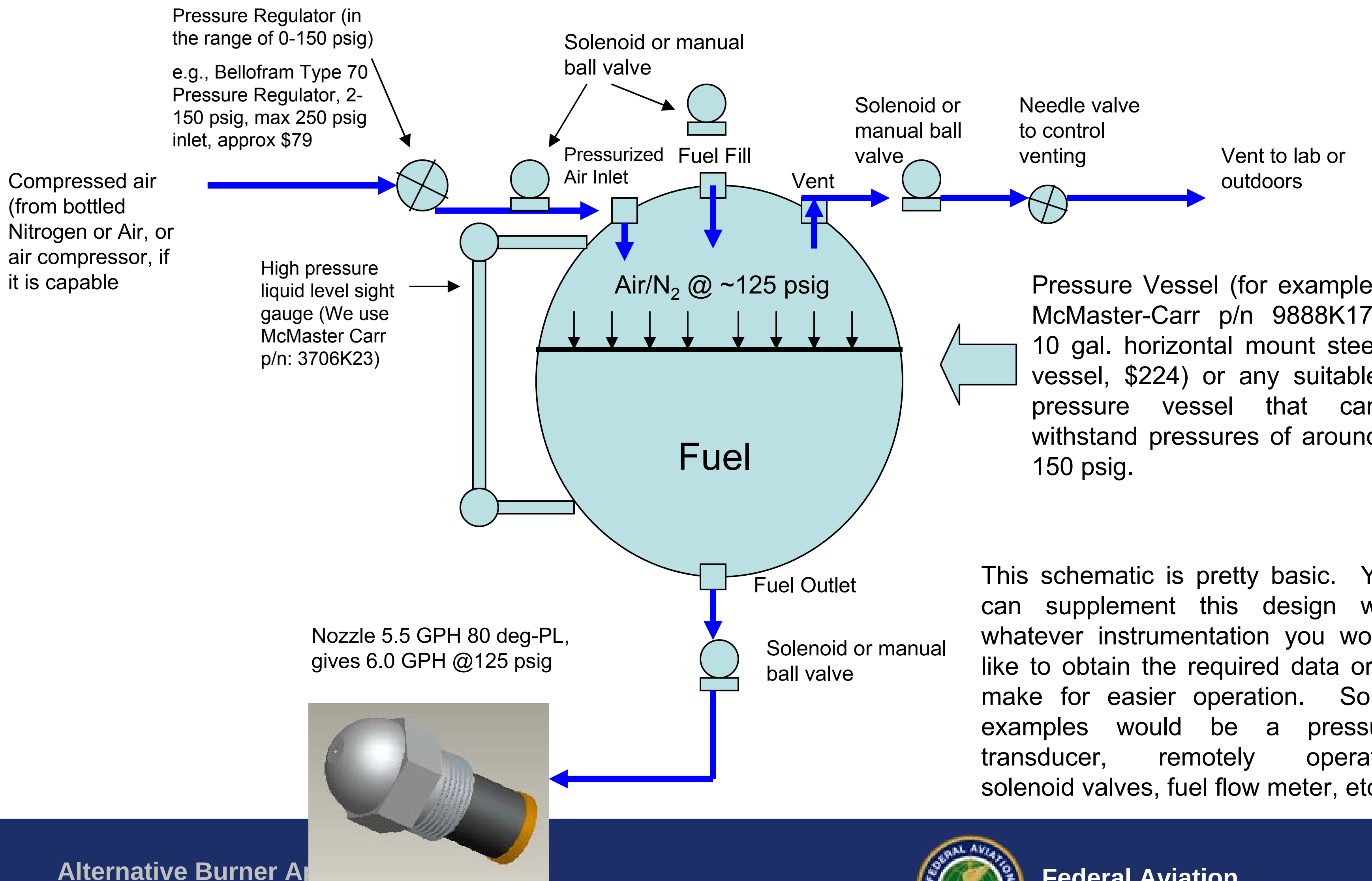




Compressed Air Supply

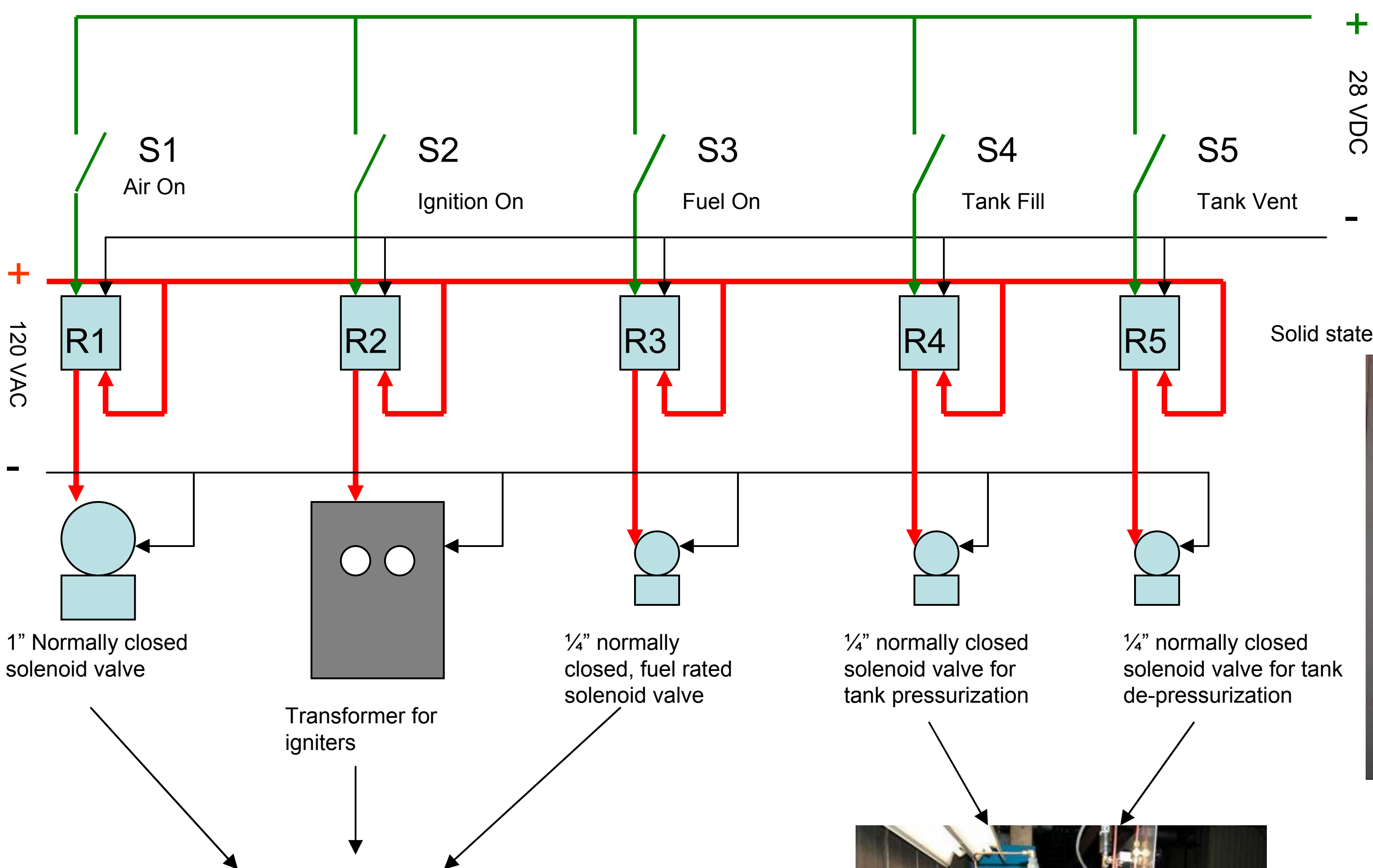
- **Compressor minimum requirements:**
  - Constant line pressure of at least 60 psig
  - Mass flow rate of 62 SCFM (standard cubic feet per minute)
  - Burner comes supplied with a pressure regulator upstream of the sonic orifice. To connect the burner to your compressed air supply, a 1” air line will be required
- **Regulator has 1” NPT female connection. A flexible air line will make connections easier, we use a steel braided 1” flex-line.**
- **Before receiving the burner, it may be wise to measure the temperature of your airflow as a function of time while your compressor is running, for a time duration about equal to that of a burnthrough test. This will tell you if you will have fluctuations in air temperature during a test. The temperature should be standard ambient (approx 70-75 deg. F.) If the fluctuations are significant (greater than 10°F), it is recommended to install an in-line water cooled heat exchanger to dampen out temperature fluctuations. We use McMaster Carr p/n 43865K78 (www.mcmaster.com) with a condensate separator, McMaster Carr p/n 43775K55**

Pressurized Fuel System

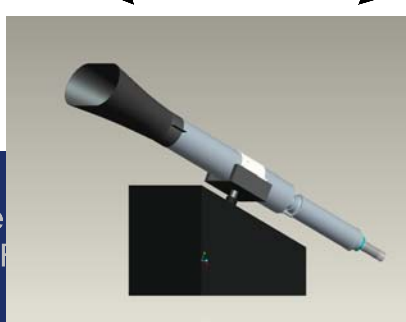


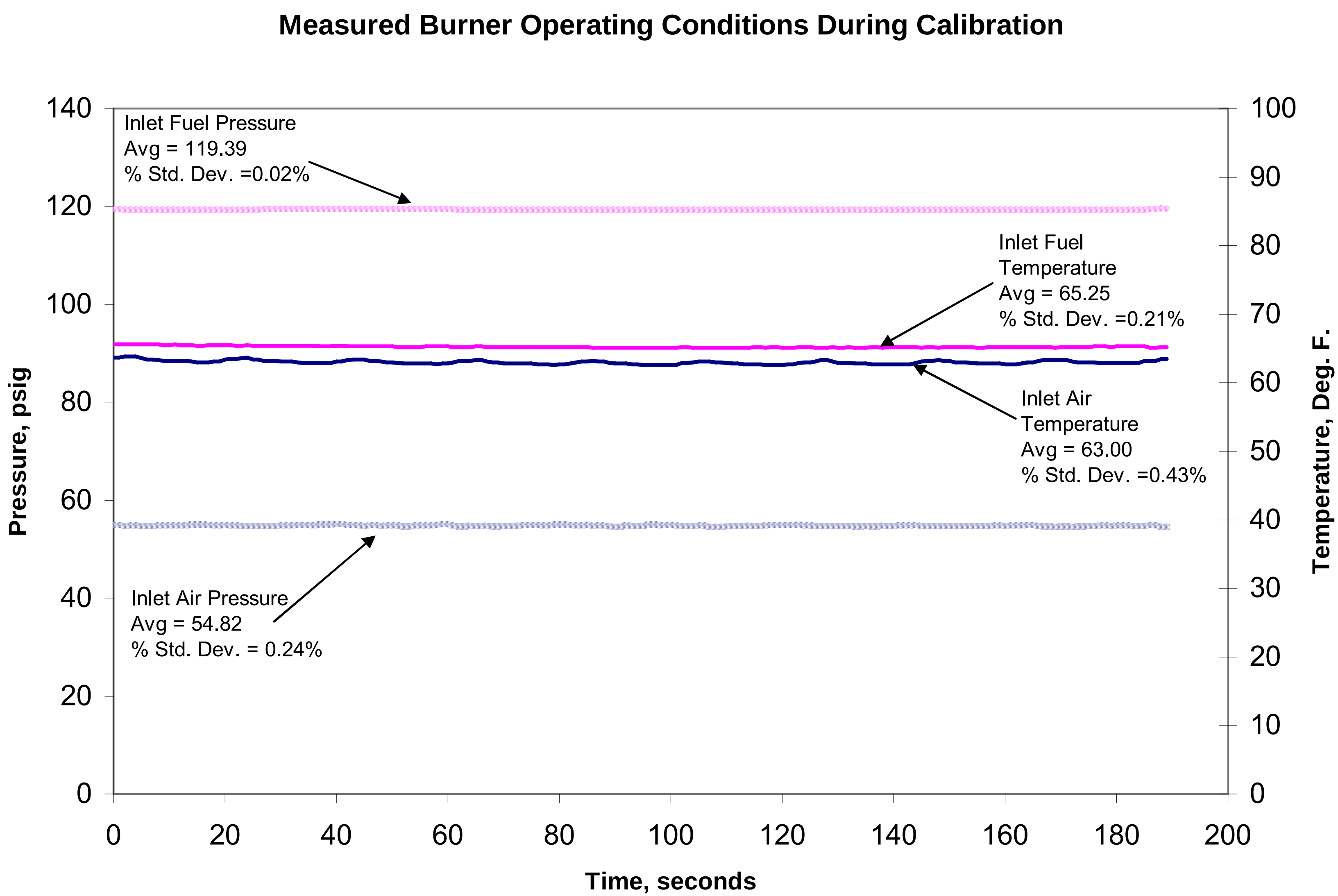
This schematic is pretty basic. You can supplement this design with whatever instrumentation you would like to obtain the required data or to make for easier operation. Some examples would be a pressure transducer, remotely operated solenoid valves, fuel flow meter, etc.

Controls

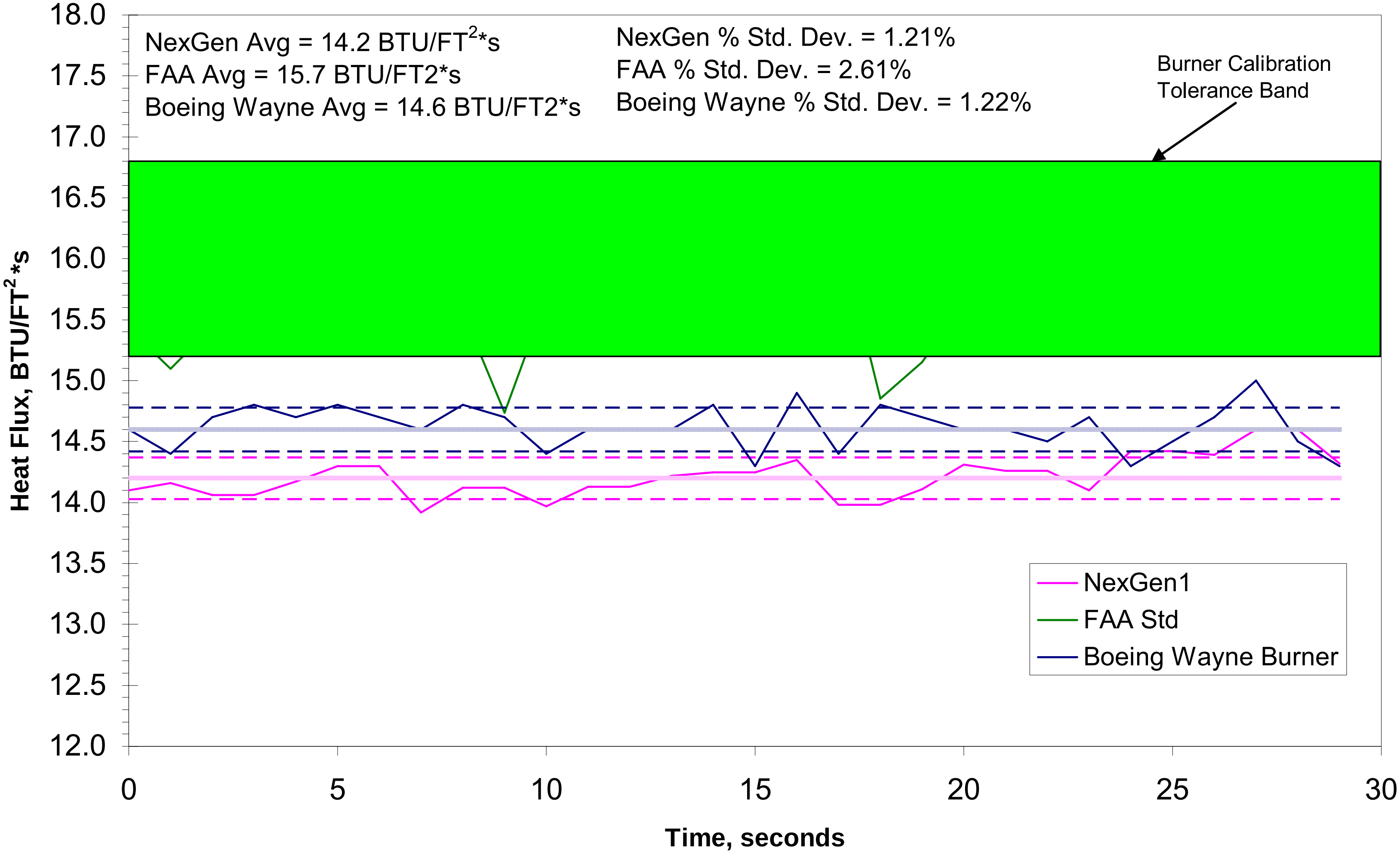


Control Box

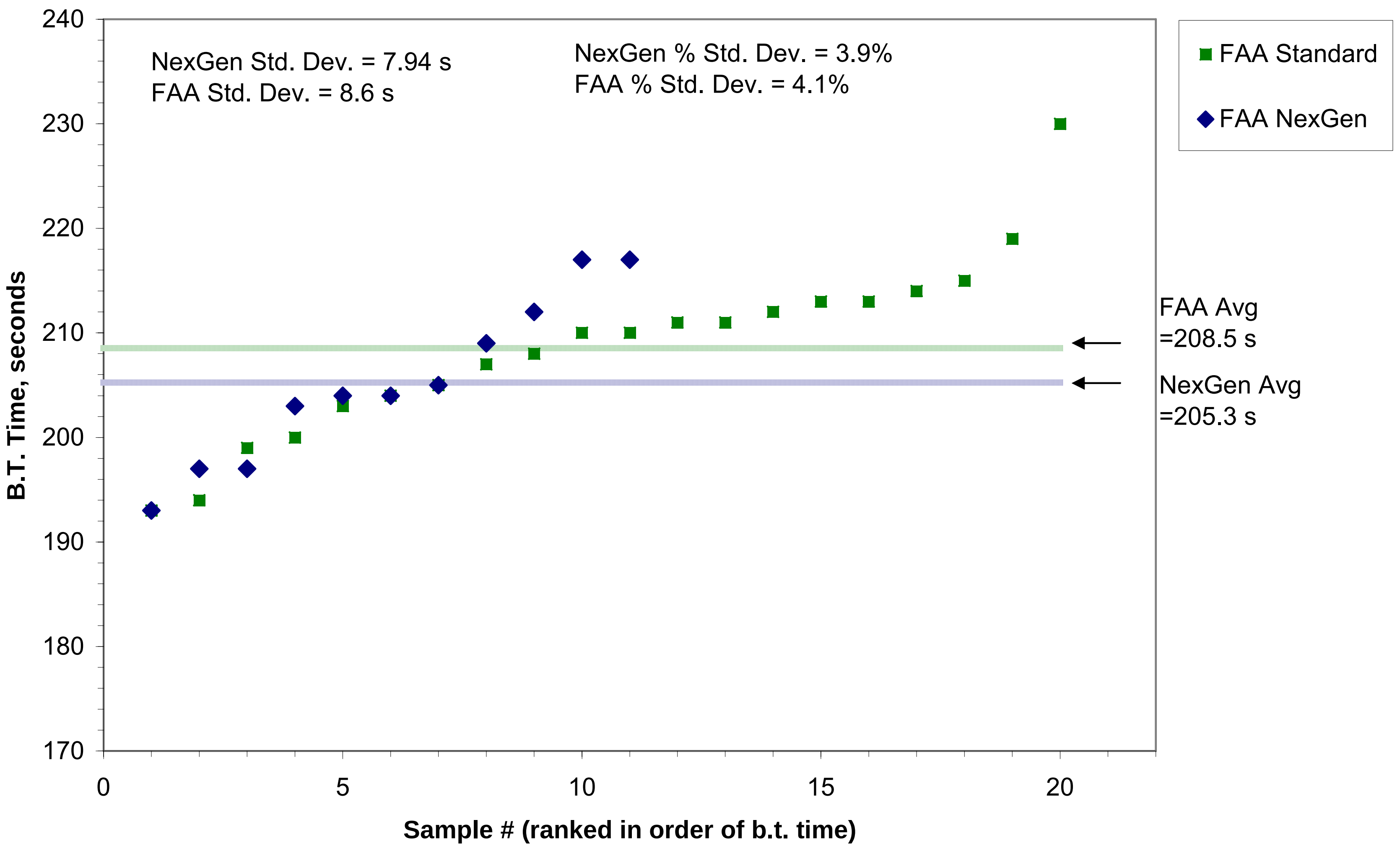


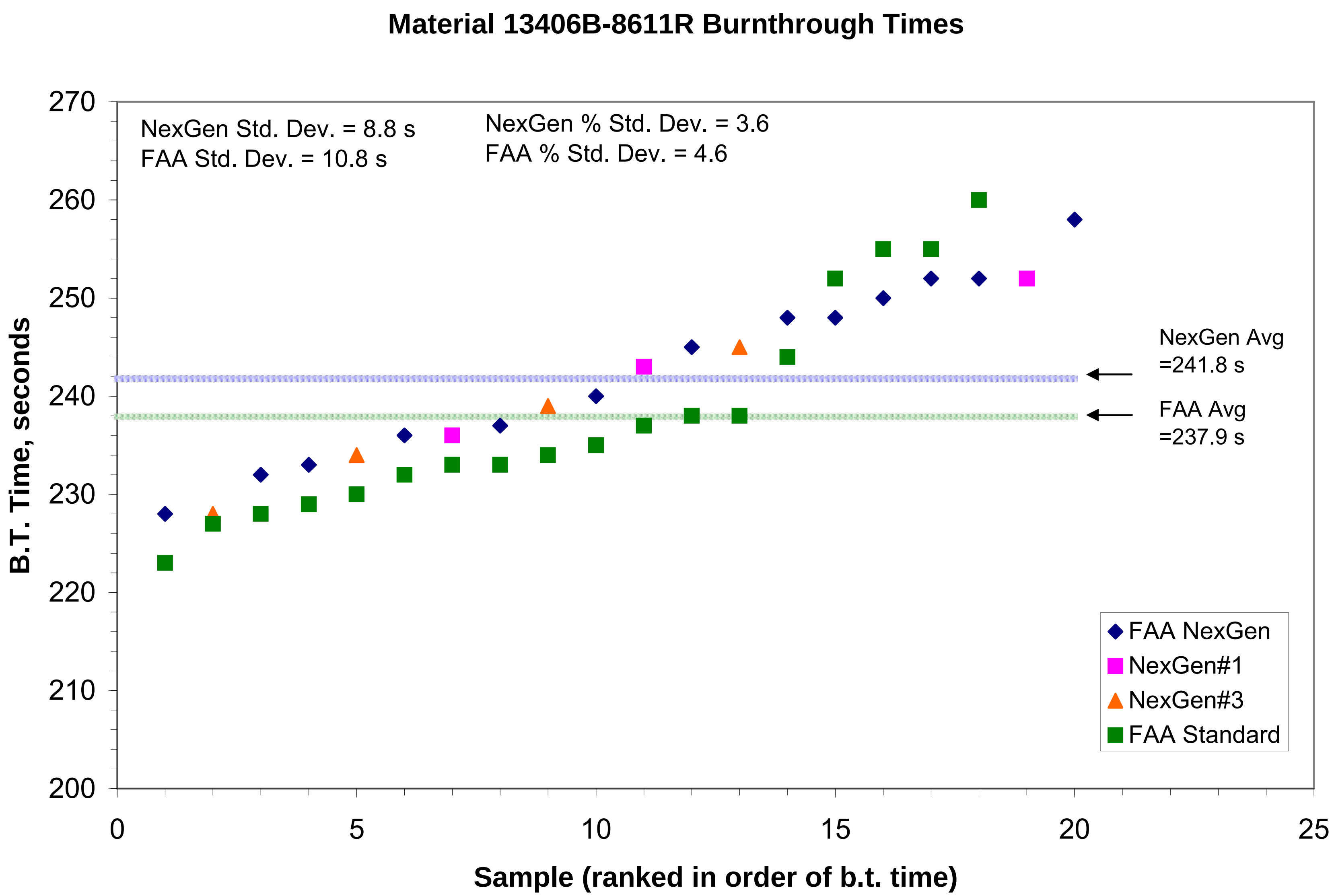

Measured Burner Operating Conditions During Calibration
Inlet Fuel Pressure
Avg = 119.39
% Std. Dev. =0.02%
Inlet Fuel
Temperature
Avg = 65.25
% Std. Dev. =0.21%
Inlet Air
Temperature
Avg = 63.00
% Std. Dev. =0.43%
Inlet Air Pressure
Avg = 54.82
% Std. Dev. = 0.24%
Pressure, psig
Temperature, Deg. F.
Time, seconds
0
20
40
60
80
100
120
140
10
30
50
70
90
160
180
200

30-second Sample of Heat Flux Measurements

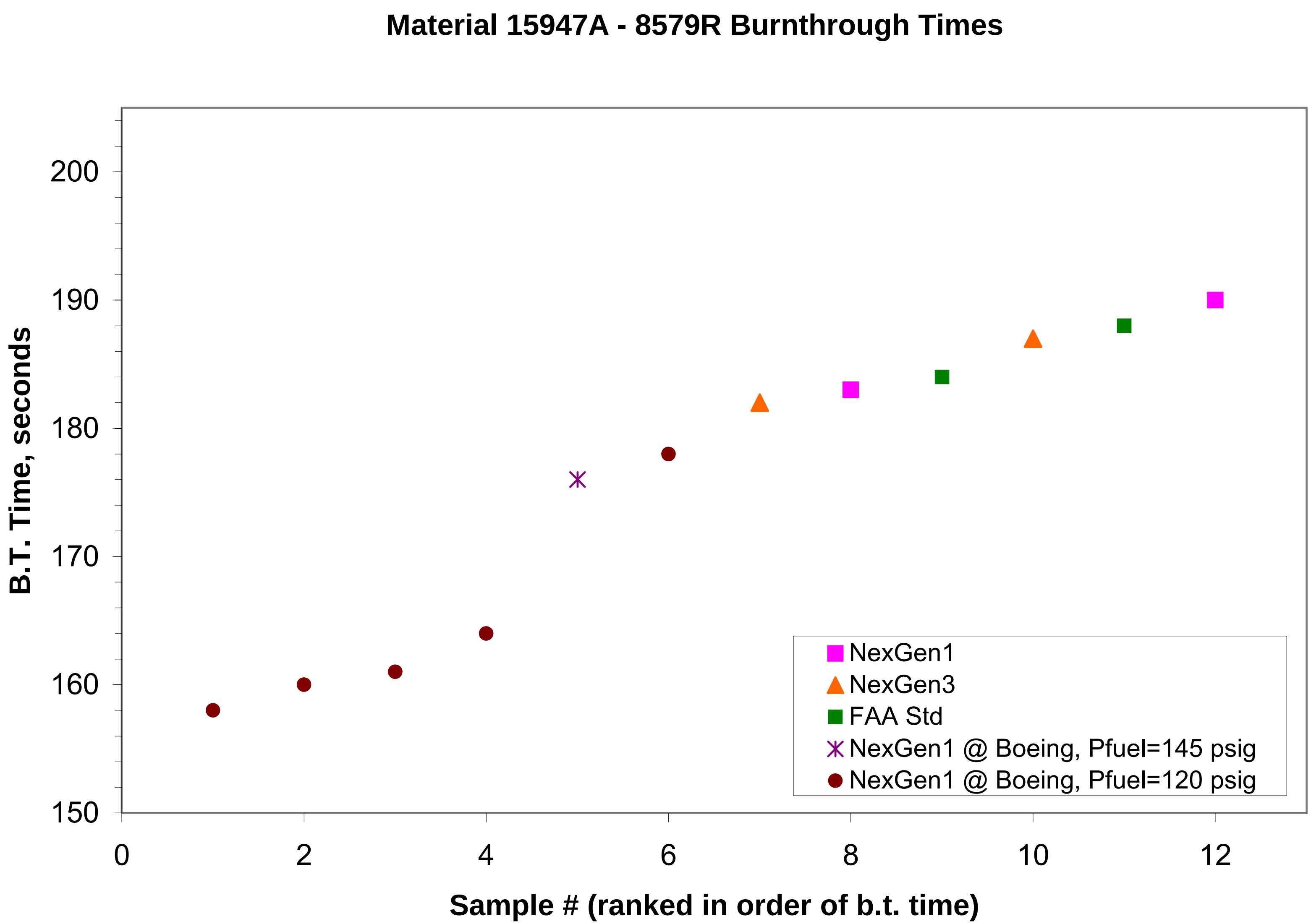


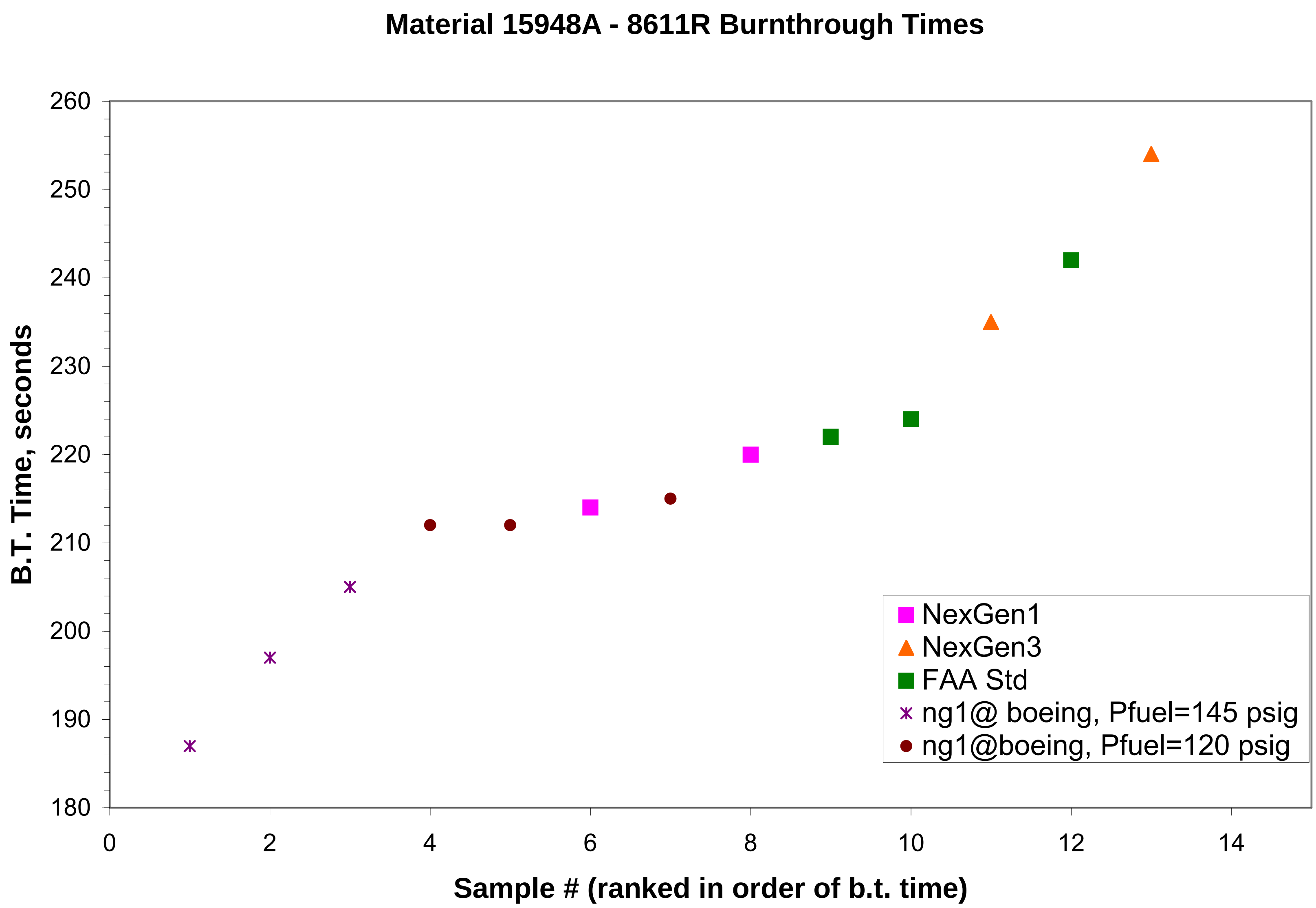
Material 13408A-8579R Burnthrough Times



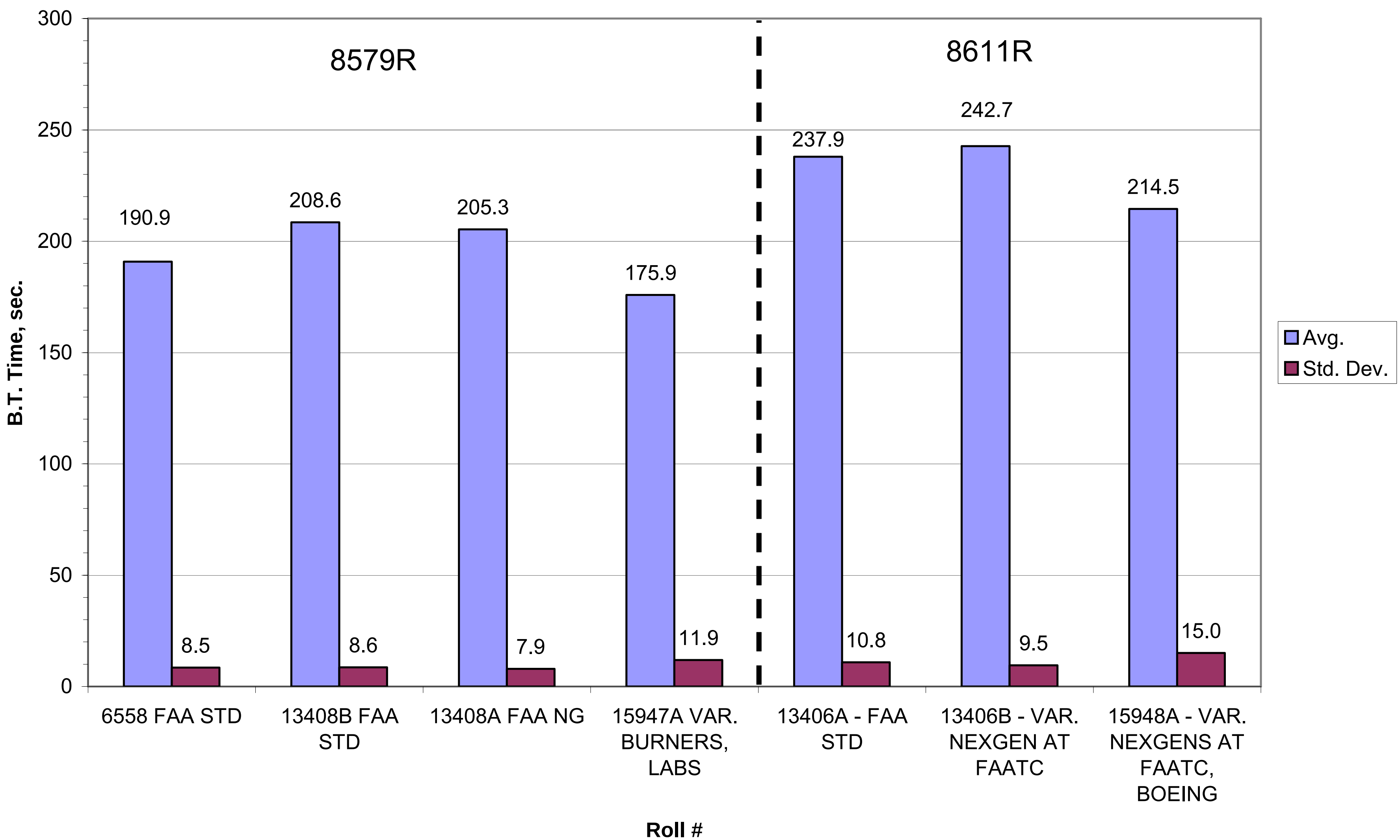


Material 13406B-8611R Burnthrough Times
NexGen Std. Dev. = 8.8 s
FAA Std. Dev. = 10.8 s
NexGen % Std. Dev. = 3.6
FAA % Std. Dev. = 4.6
NexGen Avg =241.8 s
FAA Avg =237.9 s
B.T. Time, seconds
270
260
250
240
230
220
210
200
0
5
10
15
20
25
Sample (ranked in order of b.t. time)
FAA NexGen
NexGen#1
NexGen#3
FAA Standard

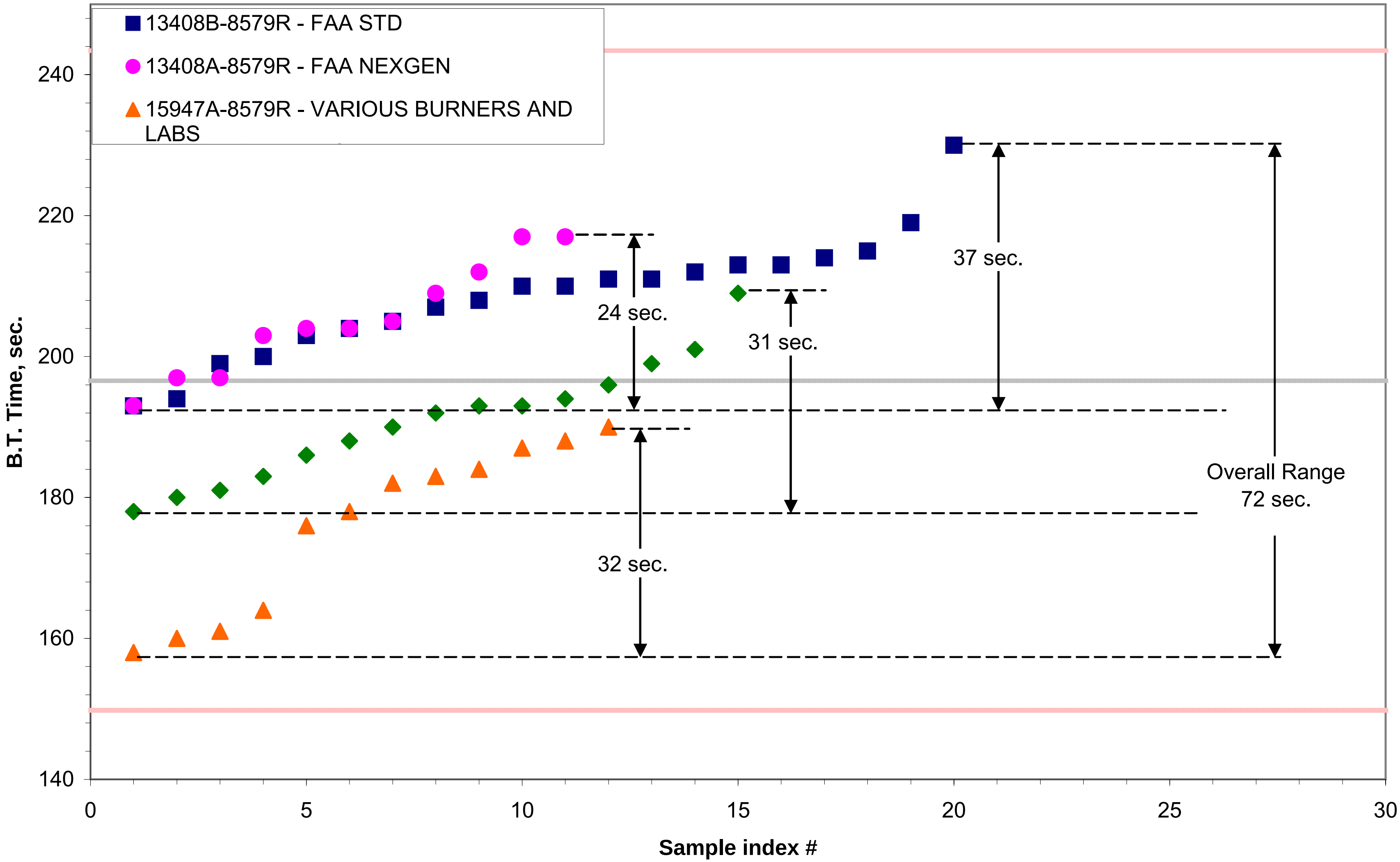

Material 15947A - 8579R Burnthrough Times
B.T. Time, seconds
200
190
180
170
160
150
0
2
4
6
8
10
12
Sample # (ranked in order of b.t. time)
NexGen1
NexGen3
FAA Std
NexGen1 @ Boeing, Pfuel=145 psig
NexGen1 @ Boeing, Pfuel=120 psig

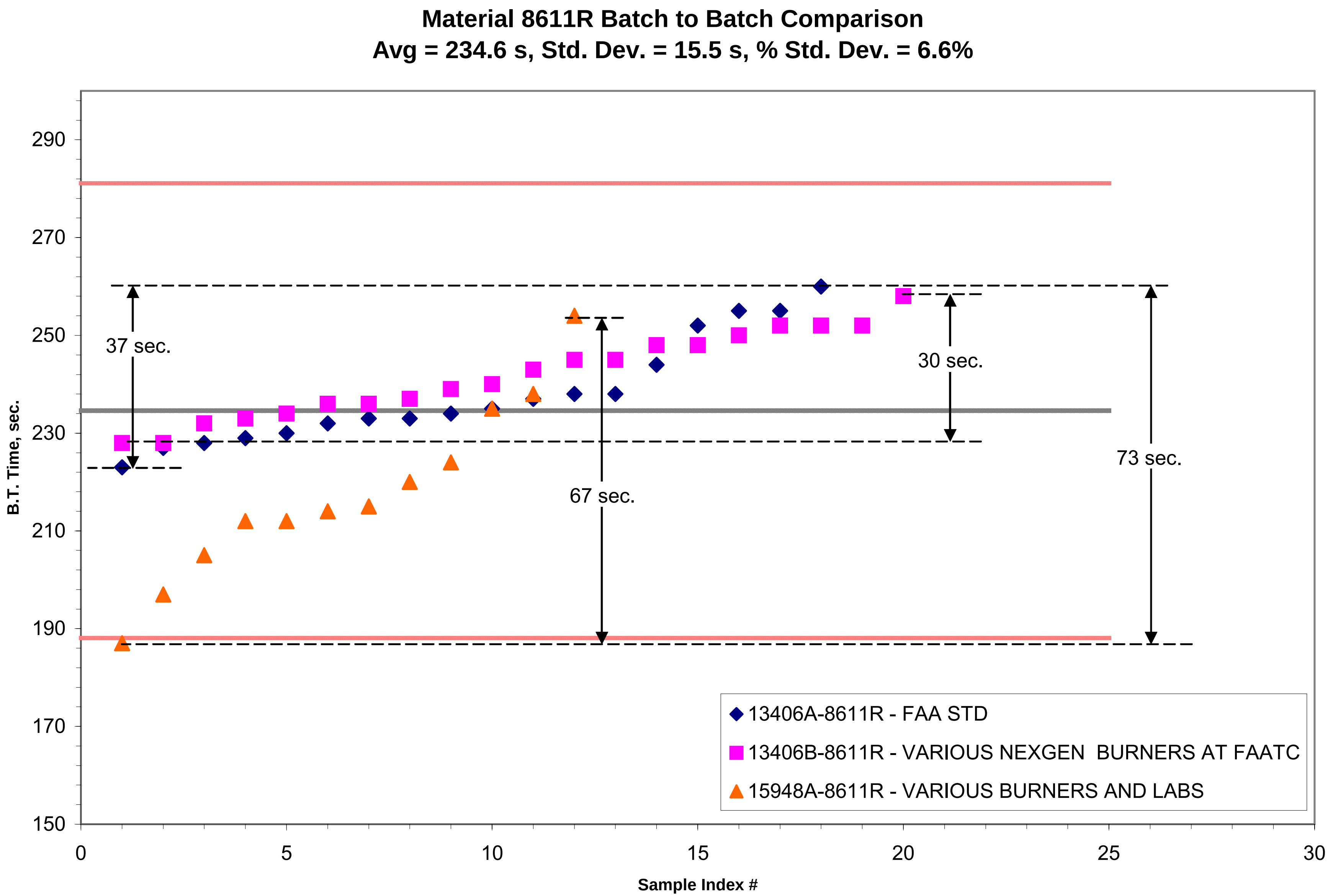

Material 15948A - 8611R Burnthrough Times
B.T. Time, seconds
260
250
240
230
220
210
200
190
180
0
2
4
6
8
10
12
14
Sample # (ranked in order of b.t. time)
NexGen1
NexGen3
FAA Std
ng1@ boeing, Pfuel=145 psig
ng1@boeing, Pfuel=120 psig

Avg. Material B.T. Times



Material 8579R Batch to Batch Comparison
Avg = 196 s, Std. Dev. = 15.6 s, % Std. Dev. = 7.9%




Material 8611R Batch to Batch Comparison
Avg = 234.6 s, Std. Dev. = 15.5 s, % Std. Dev. = 6.6%
B.T. Time, sec.
290
270
250
230
210
190
170
150
0
5
10
15
20
25
30
Sample Index #
37 sec.
67 sec.
30 sec.
73 sec.
13406A-8611R - FAA STD
13406B-8611R - VARIOUS NEXGEN BURNERS AT FAATC
15948A-8611R - VARIOUS BURNERS AND LABS

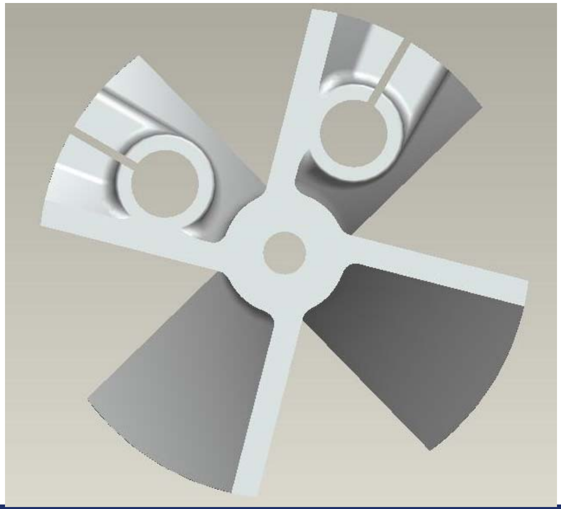
Current Status

- To date, 4 burners have been tested and are ready for use
- One burner (NexGen#1) has been sent to the Boeing group
- One burner (NexGen#3) has been sent to the Airbus group
- Technical center personnel are visiting each lab upon burner arrival, to assist in preparing the burner for use

PHASE III: DESIGN AND CONSTRUCTION OF A FULLY INDEPENDENT BURNER

Design and “mapping” of stators

- **It has recently been discovered that modifying the H215 stators can provide higher heat fluxes and better burner performance**
- **By “mapping” these stators we can produce our own stator that will not need modification**
- **Careful measurements taken from the stator can be used by design software to create a digital stator using parametric relations**
- **The digital stator can be then be manufactured and tested**
  - CNC machining
  - Rapid prototyping (stereo lithography or fused-deposition modeling) and casting



Objectives

To design a burner:

1. **capable of simulating the performance of the FAA standard**
2. **that closely replicates the behavior of a post-crash pool fire and it's effects on an aircraft fuselage**
3. **that is independent of the previous designs and parts that are discontinued or hard to obtain**
   - Leave behind the design of burners that were intended to supply heat to homes efficiently and inexpensively
   - Design a burner utilizing principles of combustion and heat transfer and state of the art research in areas such as industrial combustion, gas turbines, etc.
4. **that is capable of a higher level of precision, as well as tighter tolerances for repeatability and reproducibility**
   - Start with a fundamental analysis of the processes occurring during burnthrough testing, and definitively identify and prioritize those which have the greatest effect on burnthrough time or heat flux failure
   - Use what is learned to design a burner that can have tighter control over these key processes

Questions, Comments, Concerns, Input?

Contact:

Robert I. Ochs

DOT/FAA Tech Center

BLDG 287

Atlantic City Int'l Airport, NJ 08405

robert.ctr.ochs@faa.gov