Next Generation Fire Test Burner for Powerplant Fire Testing Applications

International Aircraft Systems Fire Protection Working Group
Dresden, Germany
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Fire Safety Branch
http://www.fire.tc.faa.gov

Background

- **Numerous FAR's mandate fire protection in aircraft powerplant fire zones**
  - Parts 23, 25, 27, 29, 33…
  - FAR Part 1 Section 1.1 – Definitions and Abbreviations
    - Fireproof--
      - (1) With respect to materials and parts used to confine fire in a designated fire zone, means the capacity to withstand at least as well as steel in dimensions appropriate for the purpose for which they are used, the heat produced when there is a severe fire of extended duration in that zone;
      - (2) With respect to other materials and parts, means the capacity to withstand the heat associated with fire at least as well as steel in dimensions appropriate for the purpose for which they are used.
    - Fire resistant--
      - (1) With respect to sheet or structural members means the capacity to withstand the heat associated with fire at least as well as aluminum alloy in dimensions appropriate for the purpose for which they are used; and
      - (2) With respect to fluid-carrying lines, fluid system parts, wiring, air ducts, fittings, and powerplant controls, means the capacity to perform the intended functions under the heat and other conditions likely to occur when there is a fire at the place concerned.
  - No definition of test method, apparatus, or criteria
  - Advisory material has been used to define these test parameters

Background

- **Advisory Circulars and FAA Reports:**
  - Power Plant Engineering Report No. 3A, Standard Fire Test Apparatus and Procedure (For Flexible Hose Assemblies), Revised March 1978
    - Acceptable fire test burners listed in Appendix III:
      - Lennox OB-32 (not available)
      - Carlin 200 CRD (not available)
      - Stewart-Warner HPR 250 (not available)
      - Stewart-Warner FR-600 (not available)
  - AC 20-135, Powerplant Installation and Propulsion System Component Fire Protection Test Methods, Standards, and Criteria, 2/6/90
    - Acceptable fire test burners listed in sec. 6c:
      - Those listed in Appendix III of Powerplant Report 3A
      - SAE 401 Burner adjusted to 9.3 BTU/ft^2s (propane fueled burner)
      - Propane and oxy-acetylene torch-standard and diverging nozzles (for small components)

Background

- **Advisory Circulars and FAA Reports (cont.):**
  - FAA Aircraft Materials Fire Test Handbook (4/2000)
    - Chapter 11 specifies the oil burners listed above, plus
      - Park DPL 3400 (not available)
    - Chapter 12 specifies the oil burners above, including the Park DPL 3400
      - Chapter 12 Supplement, section 12.3.1 states:
        - » SAE AS401B Propane Burner is also acceptable provided the temperature profile and heat flux density conform to the specified requirements
  - AC 33.17-1A, Engine Fire Protection, 8/3/09
    - References Powerplant Report 3A and AC 20-135 for acceptable burners

- **All of these specified oil burners are no longer commercially available**

Background

- **Industry is left with the propane burner, which can be obtained and is typically preferred due to it's consistency and ease of use**
  – Intent of regulations is to provide protection against an *engine* fire, with flames from aviation flammable fluids such as oil, jet fuel and hydraulic, not a propane flame
  – Propane and engine flammable fluid flames, despite having similar measured temperatures and heat flux, are fundamentally different
  – Propane will provide a less severe flame than an engine flammable fluid flame, due to the transparency of the propane flame vs. the opacity of engine flammable fluid flame
    - As test components approach the flame temperature, they begin to re-radiate due to the high surface temperature
    - Heat is lost readily from the hot surface through the transparent propane flame
    - Heat is not lost through the opaque engine flammable fluid flame

Background (cont.)

- **This difference has been recognized by the authorities**
- **FAA Tech Center Fire Safety Branch has been tasked by Transport Airplane Directorate to develop burner performance standards for the next-generation fire test burner for powerplant fire testing**
  - New burner should be much easier to calibrate, provide more consistent results, and be readily available for industry use.

Current Status

Powerplants User Survey

Used to gain insight into current calibration/ operating conditions. Additionally, requested test data will help to initially set NextGen burner settings.

Round Robin Testing

This initial round robin testing, along with the test data requested in the survey will aid in the initial setting of operating parameters of NextGen Burner.

Setting of NextGen Burner Parameters

Utilizing the test data obtained from Oil/ Propane burner testing, NextGen burner parameters will be set. Testing will be conducted to compare NextGen with Oil/Propane burners.

Additional Round Robin/ NextGen Testing

Additional round robin testing with more advanced components will be conducted and compared with NextGen burner performance to help refine NextGen burner settings.

Report Publication

An FAA report will be published detailing the NextGen burner settings and performance characteristics. This report will also detail testing and calibration guidelines/procedures for the NextGen burner.

Revision of AC 20-135

Once a powerplants test method utilizing the NextGen burner has been defined and standardized, a revision of AC 20-135 and other regulatory material will be able to proceed.

Participating Labs

- **Materials were sent to 8 different labs (9 burners) for comparative testing**
  – 1 lab utilizing a Blue Angel burner
    - Set up with same tube, stator and turbulator as Park
  – 2 labs utilizing Park burner
  – 2 labs utilizing Carlin burner
  – 4 labs utilizing Sonic burner
- **1 lab utilizing both Park and Sonic**
    - In large test cell (~1000 m^3)
    - In small test cell (~100 m^3)

Materials Tested

- **Slug Calorimeter**
  - 10″x10″ copper panel with thermal absorptive coating on front face and thermocouple on back face to determine heat flux ($Q=mC_p\Delta T$). Panel was mounted on a 24″x24″ steel plate.
  - Copper slug exposed to burner flame for a period of 10-20 seconds.
  - Repeated 3x with sufficient time for full cooling of all materials (burner, thermocouples copper panel, etc) between each test.

Materials Tested

- **1/8″ thick, 24″x24″ 2024 Aluminum Sheet**
  - Burnthrough time recorded and reported
  - Repeated 3x
- **Double-layered TexTech felt (to be mounted in a 24″x24″ opening)**
  - Burnthrough time recorded and reported
  - Repeated 3x

Sonic Burner Parts/Setup

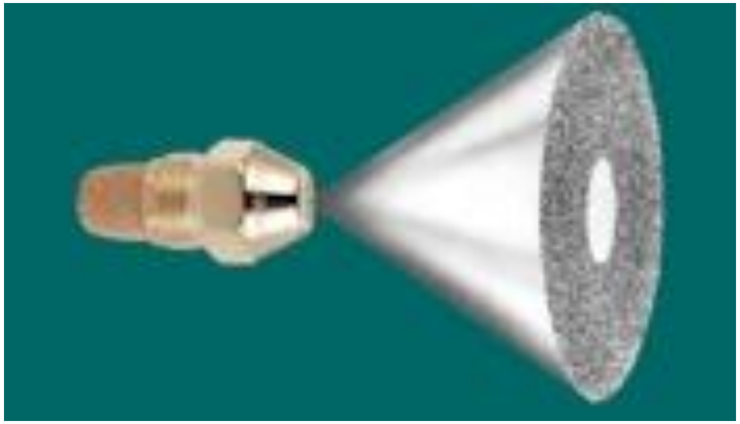
- Modified draft tube
- Spacer tube
- Static plate
- Beckett model F31 flame retention head (FRH)
- Delavan 2.5 gal/hr 80° W style fuel nozzle
- Burner cone

Fuel Nozzle

- **Delevan 2.5 gal/hr rated W style fuel nozzles using a semi-solid spray pattern**

- **Once installed in the burner, the nozzles are to be flow checked, and fuel flow adjusted to 2.5 gal/hr (+/- 0.1 gal/hr)**

- **All labs are advised to adjust the burner fuel pressure to achieve a fuel flow rate to as close to 2.5 gal/hr as possible**



Fuel Flowrate Check

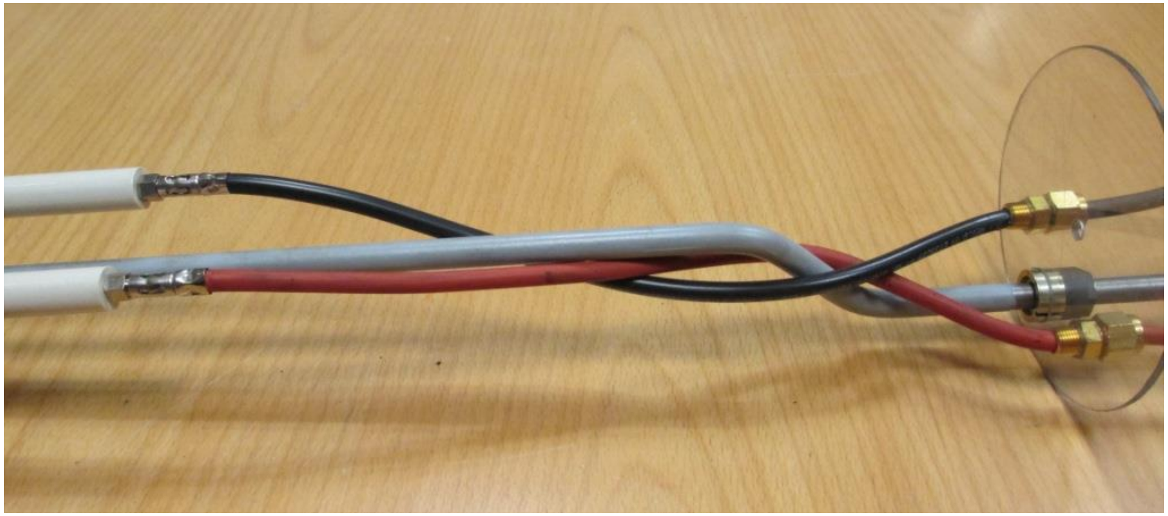
- To properly check the fuel flow, a clear Tygon tube must be slipped over the end of the fuel nozzle once it is installed in the burner. A collection container AND graduated cylinder can be used to collect the fuel. First ensure that the igniters are off, and begin fuel flow through the Tygon tube into a collection container. Once a steady stream is flowing, simultaneously move the Tygon tubing into the graduated cylinder, and also start the timing device. It is recommended that fuel be collected for a 1-minute period.

Fuel Flowrate Check (con't)

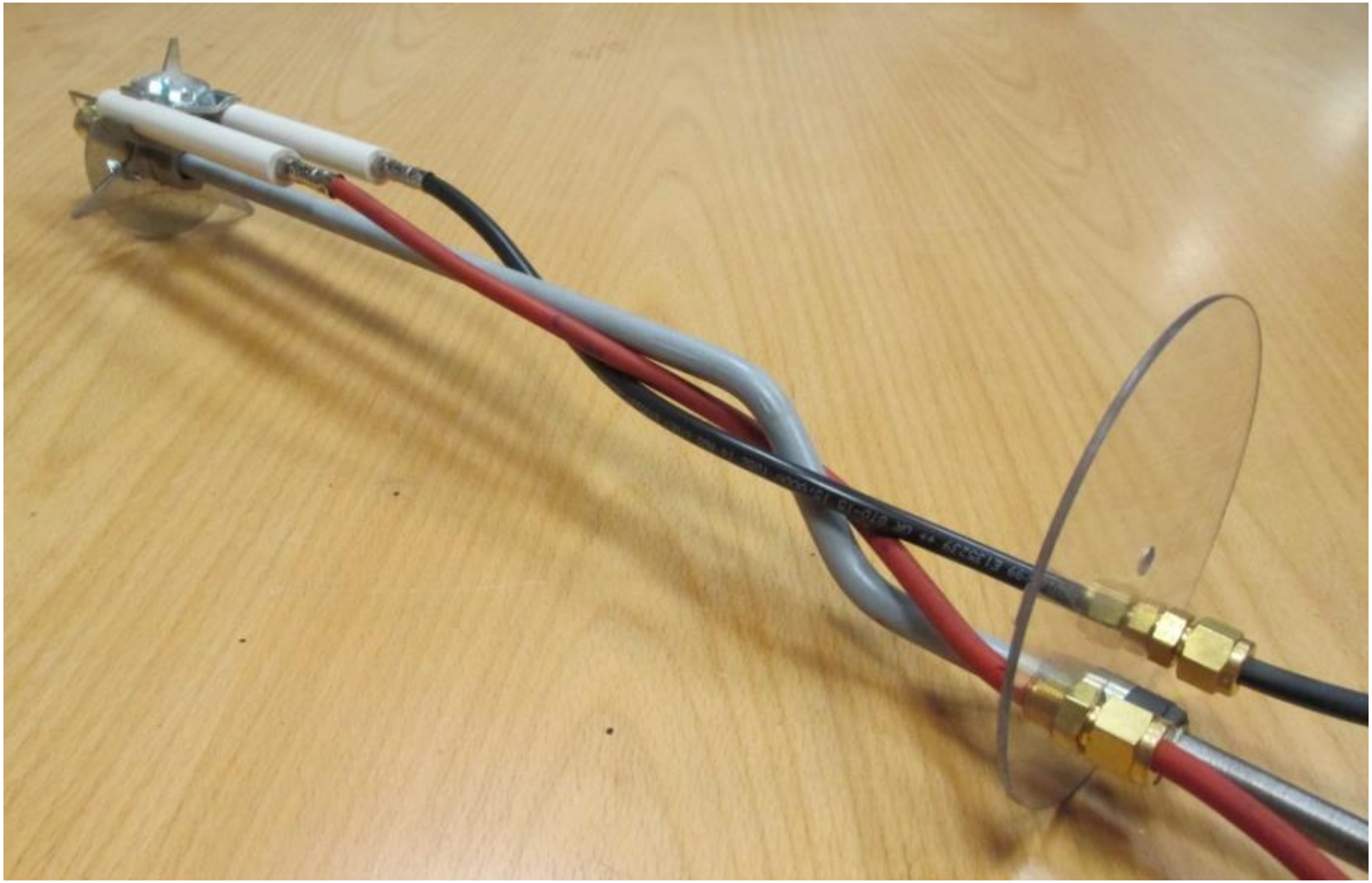
- **At the 1-minute point, quickly divert the Tygon tube away from the graduated cylinder, back into the collection container, to ensure that only 1 minute of fuel is collected. Carefully measure the collected fuel and convert this to gallons/hour. The fuel flow rate must be within 2.5 gal/hr (+/- 0.1 gal/hr). If it is not within this range, adjust the fuel pressure accordingly and repeat the process.**

Ignition Wires

- Wires should be positioned exactly as shown in picture below to keep them wrapped tightly around the fuel rail, and minimize disrupting the flow of air in the draft tube
- It is important to ensure each wire crosses over or under the other wire or fuel rod as shown
- Pull wires tight to eliminate any slack
- Wire lengths (tip of metal wire terminal to rear of draft tube)
  - Red: 12.5”
  - Black: 12.5”

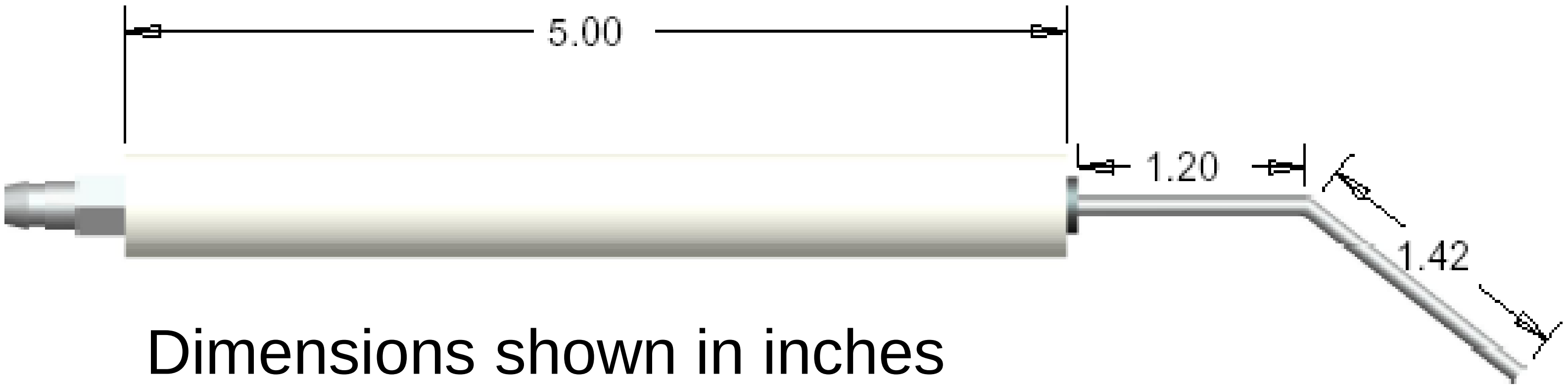


New Ignition Wire Routing Method



Igniters

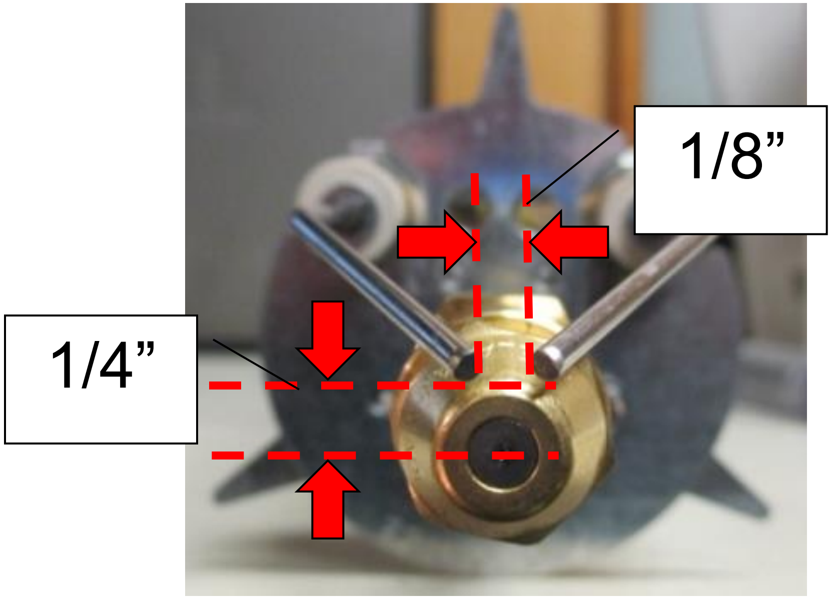
- **Igniter dimensions should be approximately the same as those shown in the pictures below**

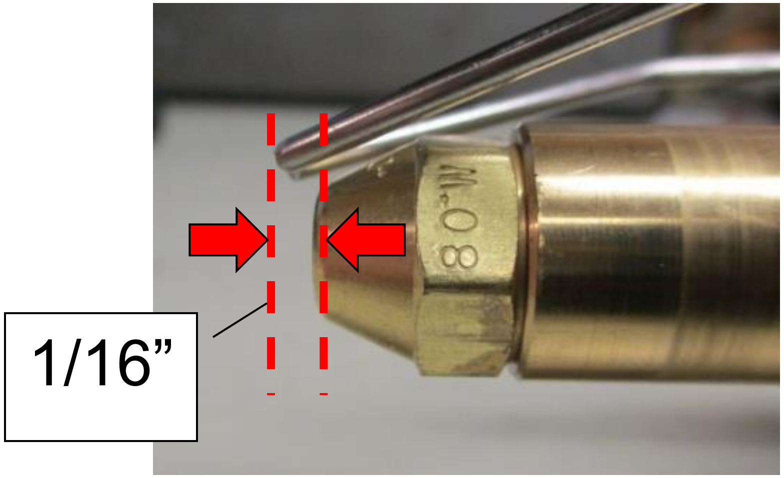


Dimensions shown in inches

Standardized Igniter Position

- **Gap between igniters**
  - 1/8”
- **Nozzle center to igniters**
  - ¼”
- **Nozzle face to igniter tips**
  - 1/16”





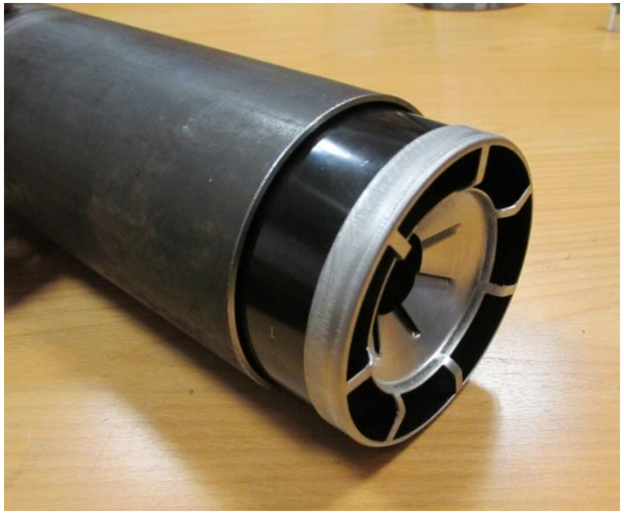
Draft Tube Assembly

- **Top: Modified draft tube with machined groove (left), to allow for spacer sleeve and FRH**

- **Bottom: Spacer sleeve fits into draft tube to ensure static plate and fuel rod are centered in draft tube**

Draft Tube Assembly

- **Top: FRH is press fit onto the spacer sleeve**
- **Bottom: The FRH and spacer sleeve assembly is pressed into the burner draft tube until the face of the FRH and end of the draft tube are flush**

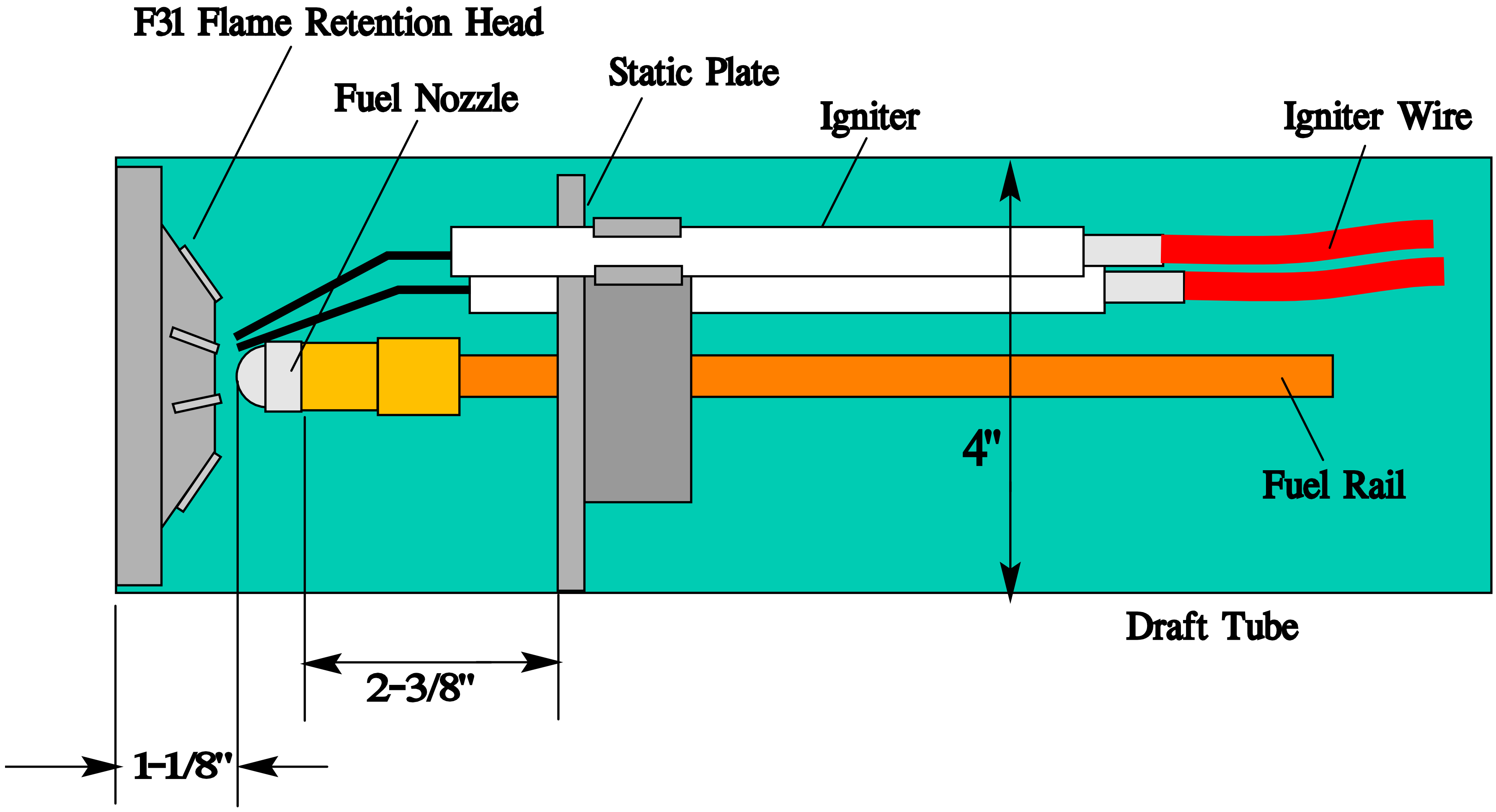


Burner Installation

- It is possible for the static plate to catch on the spacer tube inside the draft tube while assembling the burner

- The draft tube assembly should be assembled with care to prevent damaging or dislodging the static plate

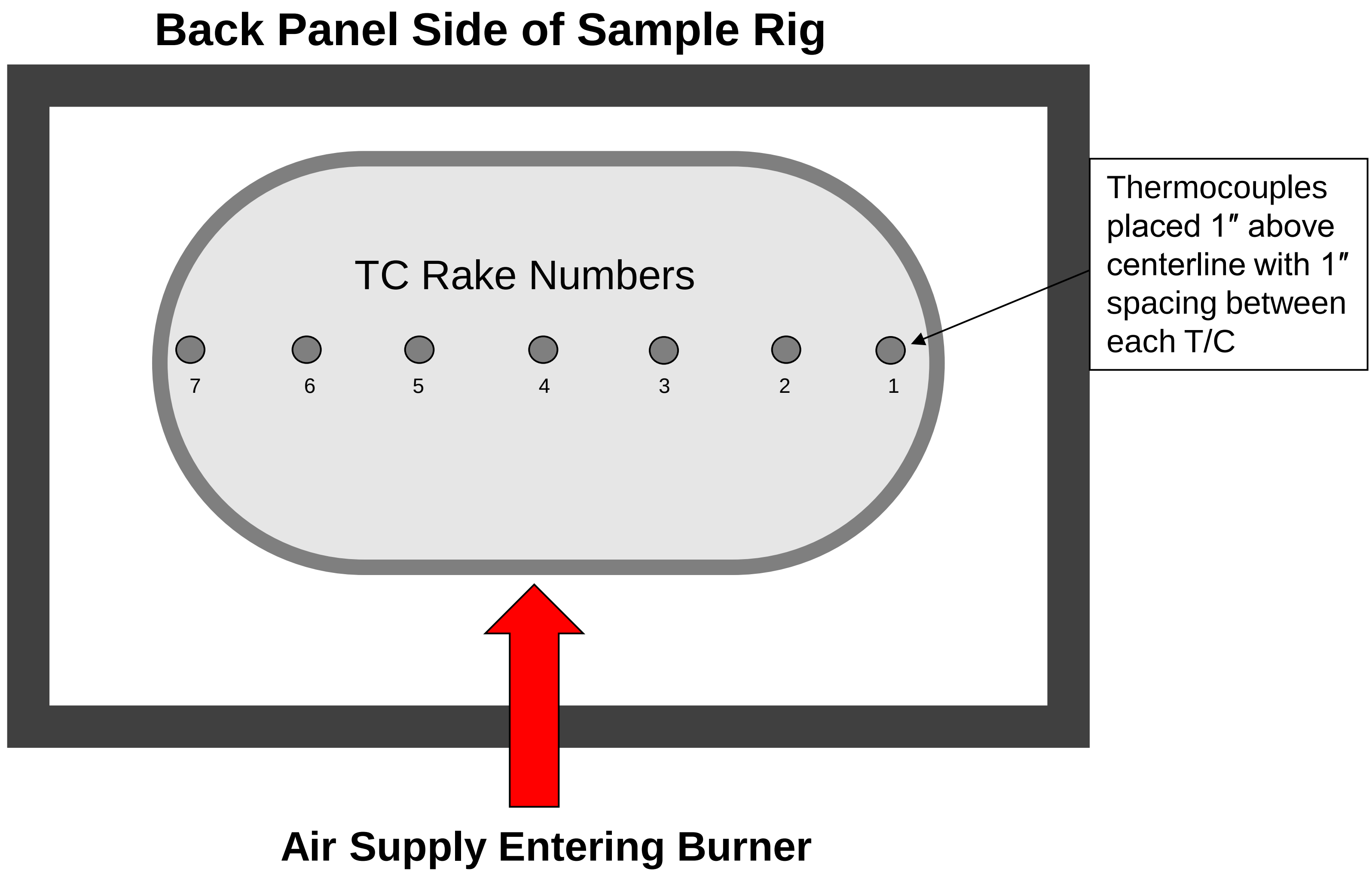
Burner Settings



Sonic Burner Settings

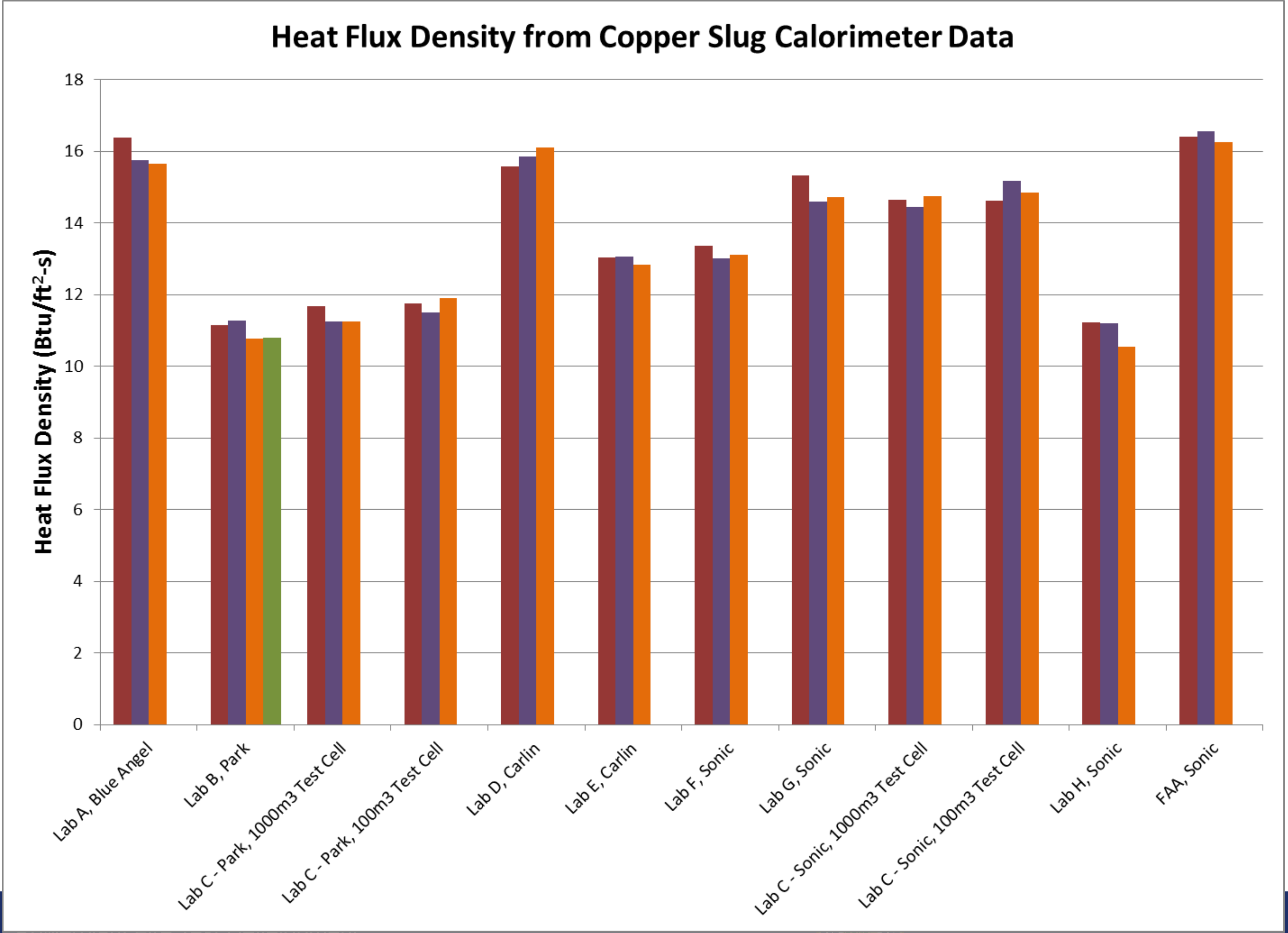
- **Face of FRH to nozzle tip: 1-1/8”**
- **Fuel nozzle adapter to static plate: 2-3/8”**
- **Static Plate Angle: centerline of igniters at 0°**
  - Looking into the cone of the burner from above, the centerline between the igniters will be at 0° on the burner reference plane
  - Fuel pressure: 100 psi +/- 5 psi
    - Note: This pressure is to be used as a starting point when flow checking the fuel flow rate. Actual pressure used during testing should be that found from the fuel flowrate check
- **Air pressure: 50 psi**
- **Air Temperature: 50º ± 10ºF**
- **Fuel Temperature: 42º ± 10ºF**

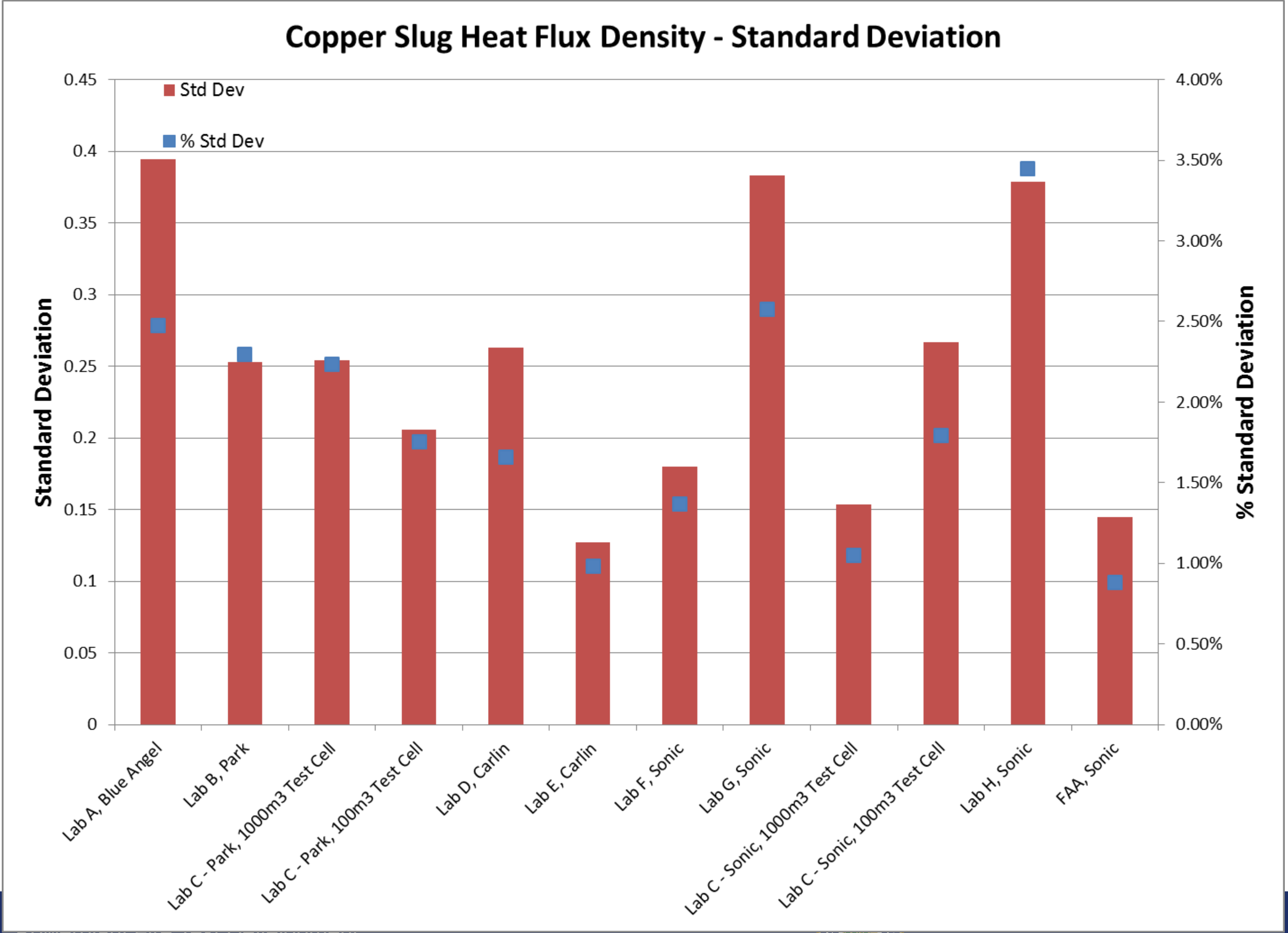
View from in front of Burner Cone

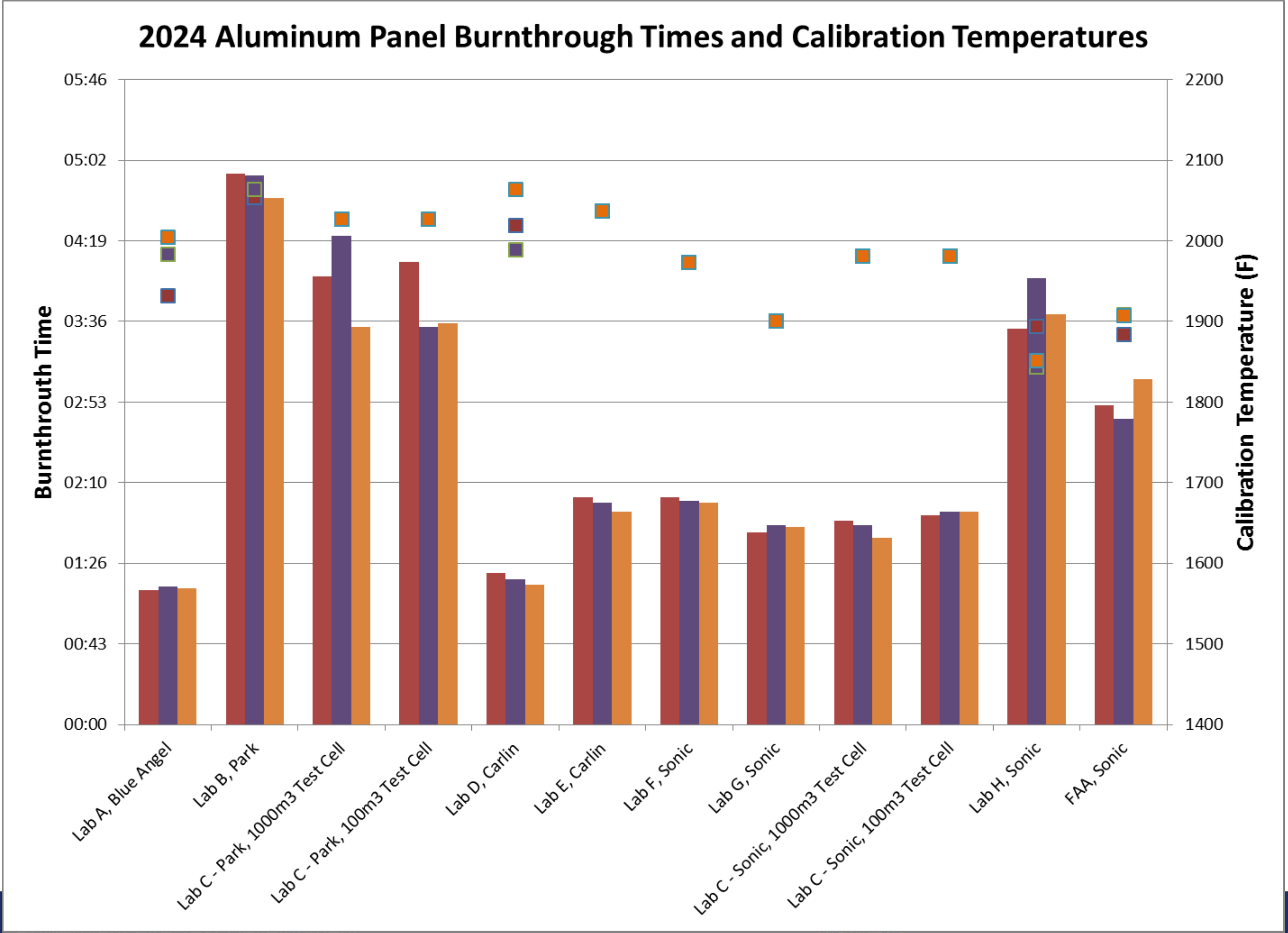


Calibration

- All labs will calibrate using 1/8”, exposed bead, Type K, stainless steel sheathed thermocouples for calibration
- Labs utilizing the Sonic Burner are not expected to necessarily achieve the calibration temperatures or heat fluxes, but rather are calibrating the fuel/air temperature and pressure input to the burner. Temperature and heat flux calibration data should be recorded and reported however.
- Labs utilizing burners other than the Sonic Burner, should calibrate to a minimum average of 2000°F, with each thermocouple reading 2000°F ± 150°F. In addition, the burner should provide a heat flux density of at least 9.3 BTU/ft^2-s or 4500 BTU/hr as per AC 20-135.
- Changing or deviating from provided burner settings to achieve higher or more uniform calibration temperatures is not recommended
- Three separate calibration runs should be recorded
- Each calibration should include a 2-minute warm-up of the burner, a 1-minute thermocouple flame soak, and a 30-second data collection period of flame temperature. This should be followed by the heat flux calibration.


Heat Flux Density from Copper Slug Calorimeter Data
Heat Flux Density (Btu/ft2-s)
18
16
14
12
10
8
6
4
2
0
Lab A, Blue Angel
Lab B, Park
Lab C - Park, 1000m3 Test Cell
Lab C - Park, 100m3 Test Cell
Lab D, Carlin
Lab E, Carlin
Lab F, Sonic
Lab G, Sonic
Lab C - Sonic, 1000m3 Test Cell
Lab C - Sonic, 100m3 Test Cell
Lab H, Sonic
FAA, Sonic


Copper Slug Heat Flux Density - Standard Deviation
Std Dev
% Std Dev
Standard Deviation
% Standard Deviation
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.00%
0.50%
1.00%
1.50%
2.00%
2.50%
3.00%
3.50%
4.00%
Lab A, Blue Angel
Lab B, Park
Lab C - Park, 1000m3 Test Cell
Lab C - Park, 100m3 Test Cell
Lab D, Carlin
Lab E, Carlin
Lab F, Sonic
Lab G, Sonic
Lab C - Sonic, 1000m3 Test Cell
Lab C - Sonic, 100m3 Test Cell
Lab H, Sonic
FAA, Sonic


2024 Aluminum Panel Burnthrough Times and Calibration Temperatures
Burnthrouth Time
Calibration Temperature (F)
05:46
05:02
04:19
03:36
02:53
02:10
01:26
00:43
00:00
2200
2100
2000
1900
1800
1700
1600
1500
1400
Lab A, Blue Angel
Lab B, Park
Lab C - Park, 1000m3 Test Cell
Lab C - Park, 100m3 Test Cell
Lab D, Carlin
Lab E, Carlin
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Lab G, Sonic
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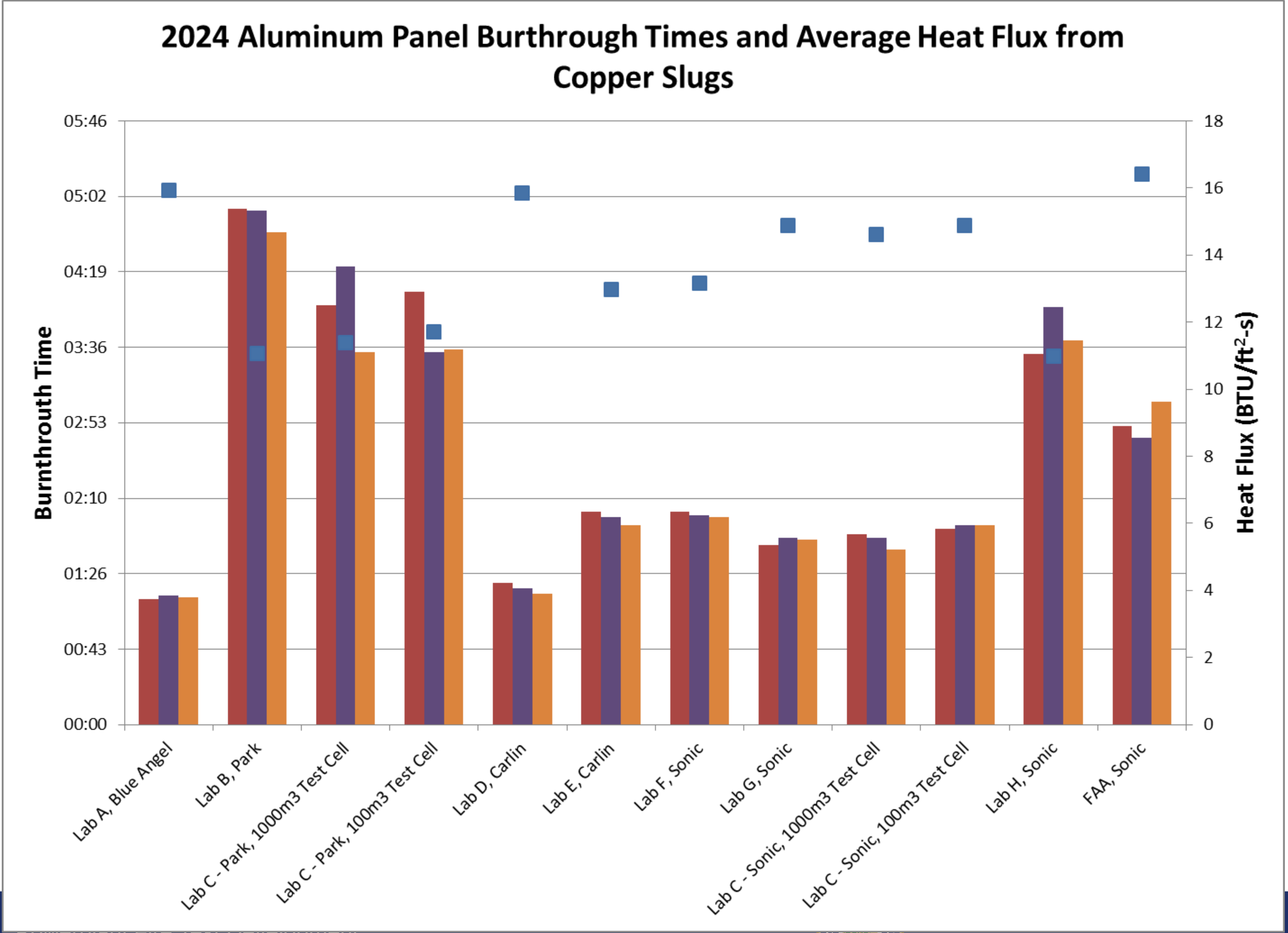
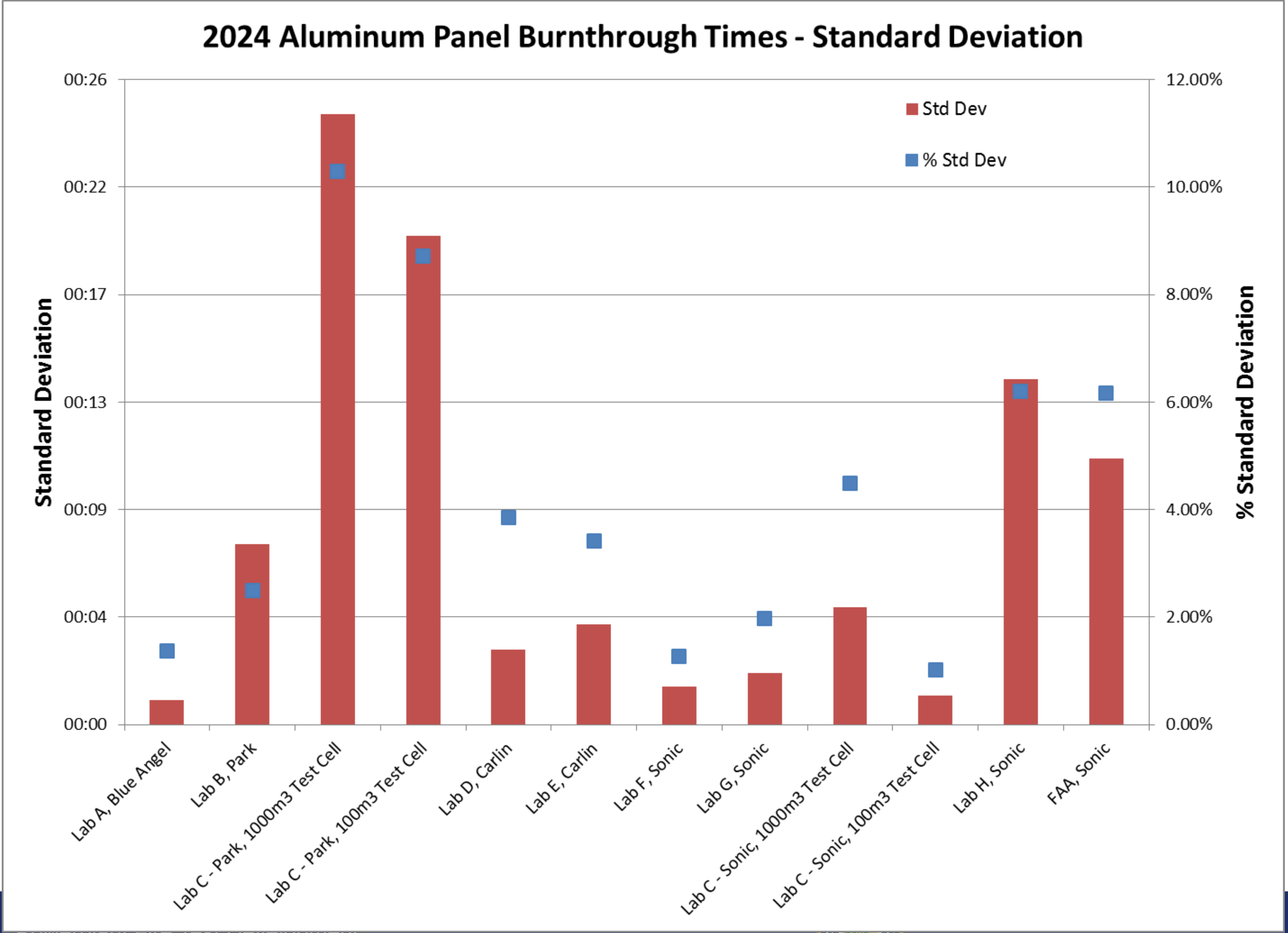

2024 Aluminum Panel Burthrough Times and Average Heat Flux from Copper Slugs
Burnthrouth Time
Heat Flux (BTU/ft2-s)
05:46
05:02
04:19
03:36
02:53
02:10
01:26
00:43
00:00
18
16
14
12
10
8
6
4
2
0
Lab A, Blue Angel
Lab B, Park
Lab C - Park, 1000m3 Test Cell
Lab C - Park, 100m3 Test Cell
Lab D, Carlin
Lab E, Carlin
Lab F, Sonic
Lab G, Sonic
Lab C - Sonic, 1000m3 Test Cell
Lab C - Sonic, 100m3 Test Cell
Lab H, Sonic
FAA, Sonic


2024 Aluminum Panel Burnthrough Times - Standard Deviation
Standard Deviation
% Standard Deviation
00:26
00:22
00:17
00:13
00:09
00:04
00:00
12.00%
10.00%
8.00%
6.00%
4.00%
2.00%
0.00%
Std Dev
% Std Dev
Lab A, Blue Angel
Lab B, Park
Lab C - Park, 1000m3 Test Cell
Lab C - Park, 100m3 Test Cell
Lab D, Carlin
Lab E, Carlin
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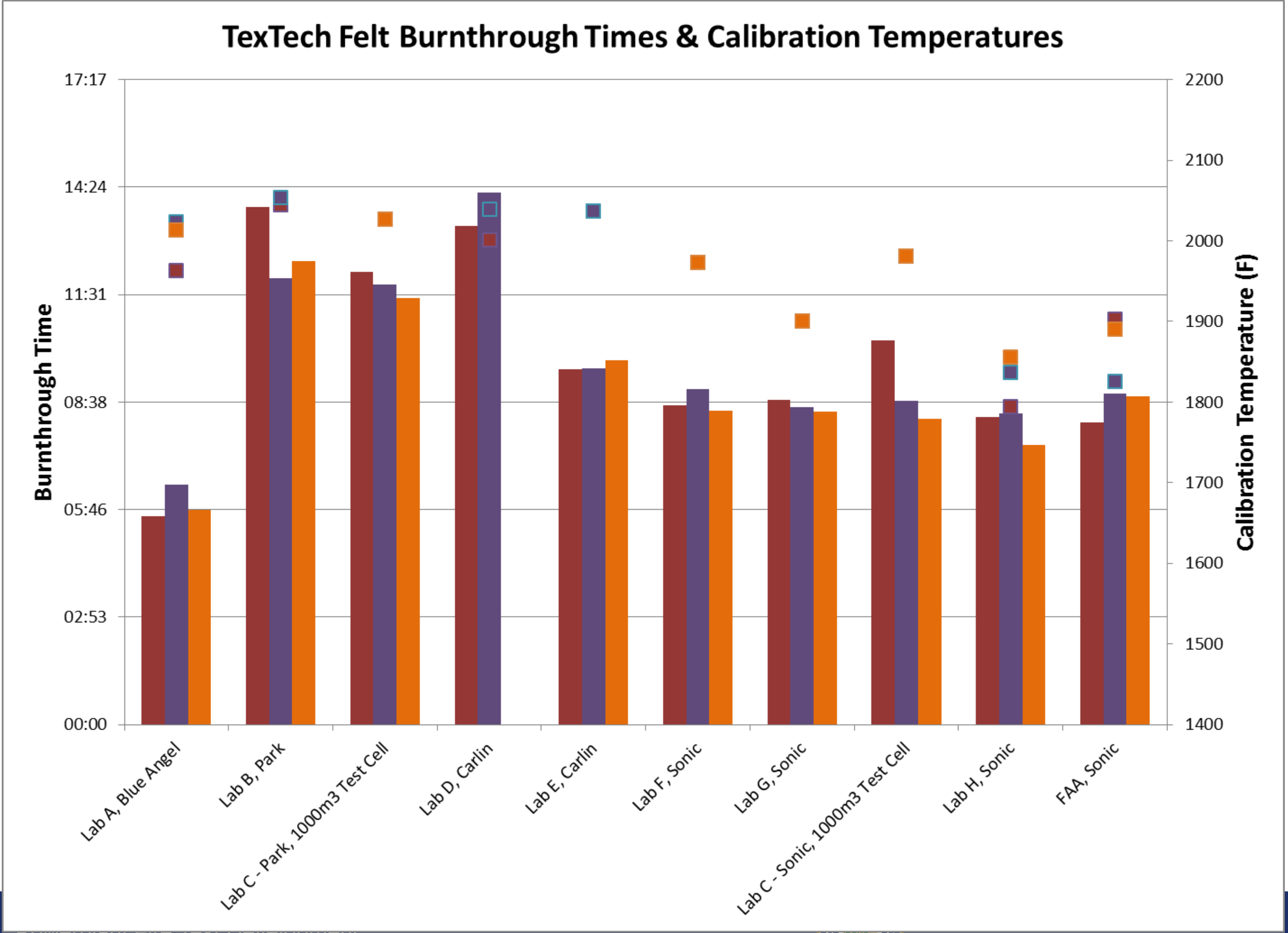
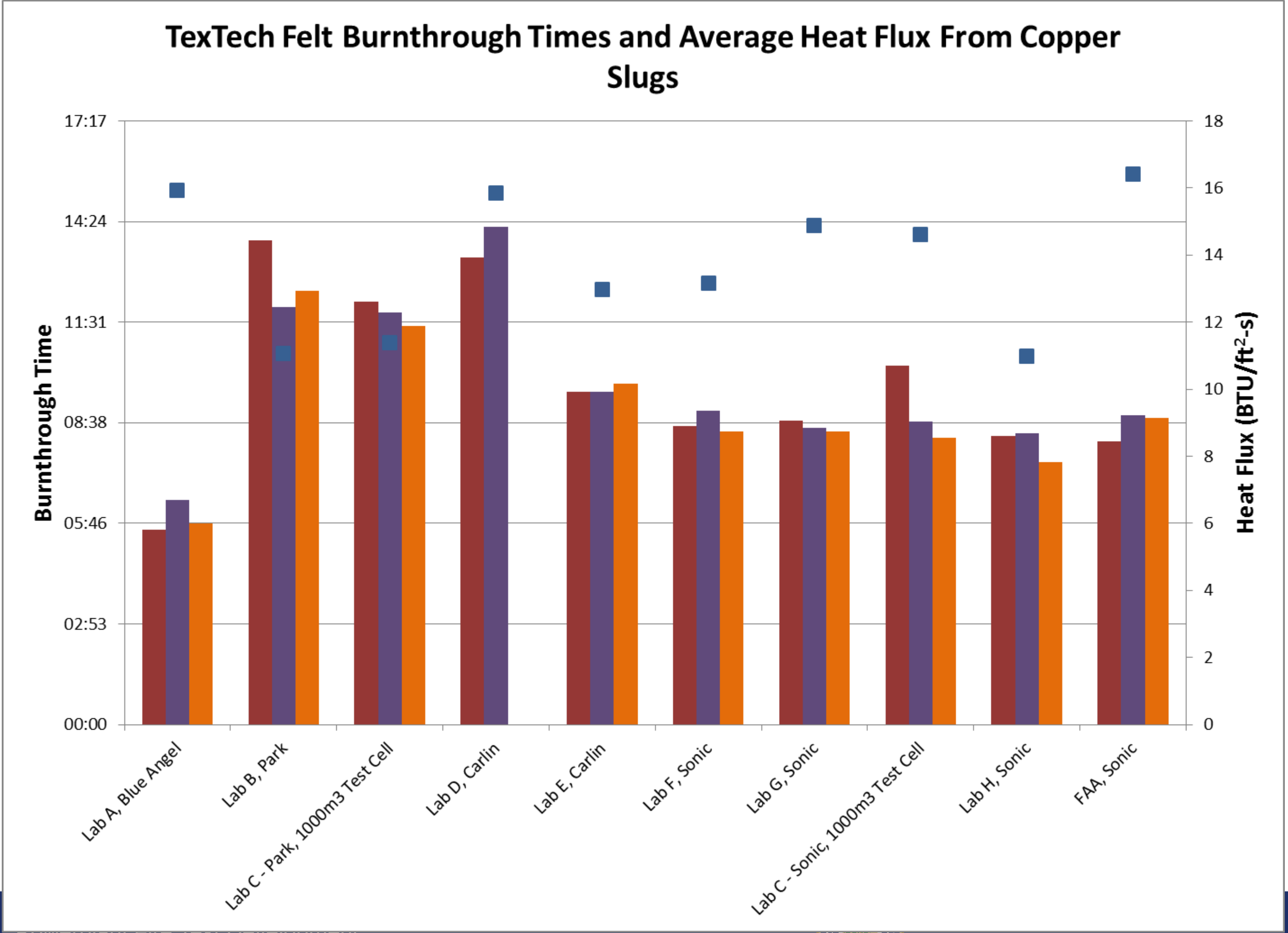
Lab G, Sonic
Lab C - Sonic, 1000m3 Test Cell
Lab C - Sonic, 100m3 Test Cell
Lab H, Sonic
FAA, Sonic


TexTech Felt Burnthrough Times & Calibration Temperatures
Burnthrough Time
Calibration Temperature (F)
17:17
14:24
11:31
08:38
05:46
02:53
00:00
2200
2100
2000
1900
1800
1700
1600
1500
1400
Lab A, Blue Angel
Lab B, Park
Lab C - Park, 1000m3 Test Cell
Lab D, Carlin
Lab E, Carlin
Lab F, Sonic
Lab G, Sonic
Lab C - Sonic, 1000m3 Test Cell
Lab H, Sonic
FAA, Sonic


TexTech Felt Burnthrough Times and Average Heat Flux From Copper Slugs
Burnthrough Time
Heat Flux (BTU/ft2-s)
17:17
14:24
11:31
08:38
05:46
02:53
00:00
18
16
14
12
10
8
6
4
2
0
Lab A, Blue Angel
Lab B, Park
Lab C - Park, 1000m3 Test Cell
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Lab G, Sonic
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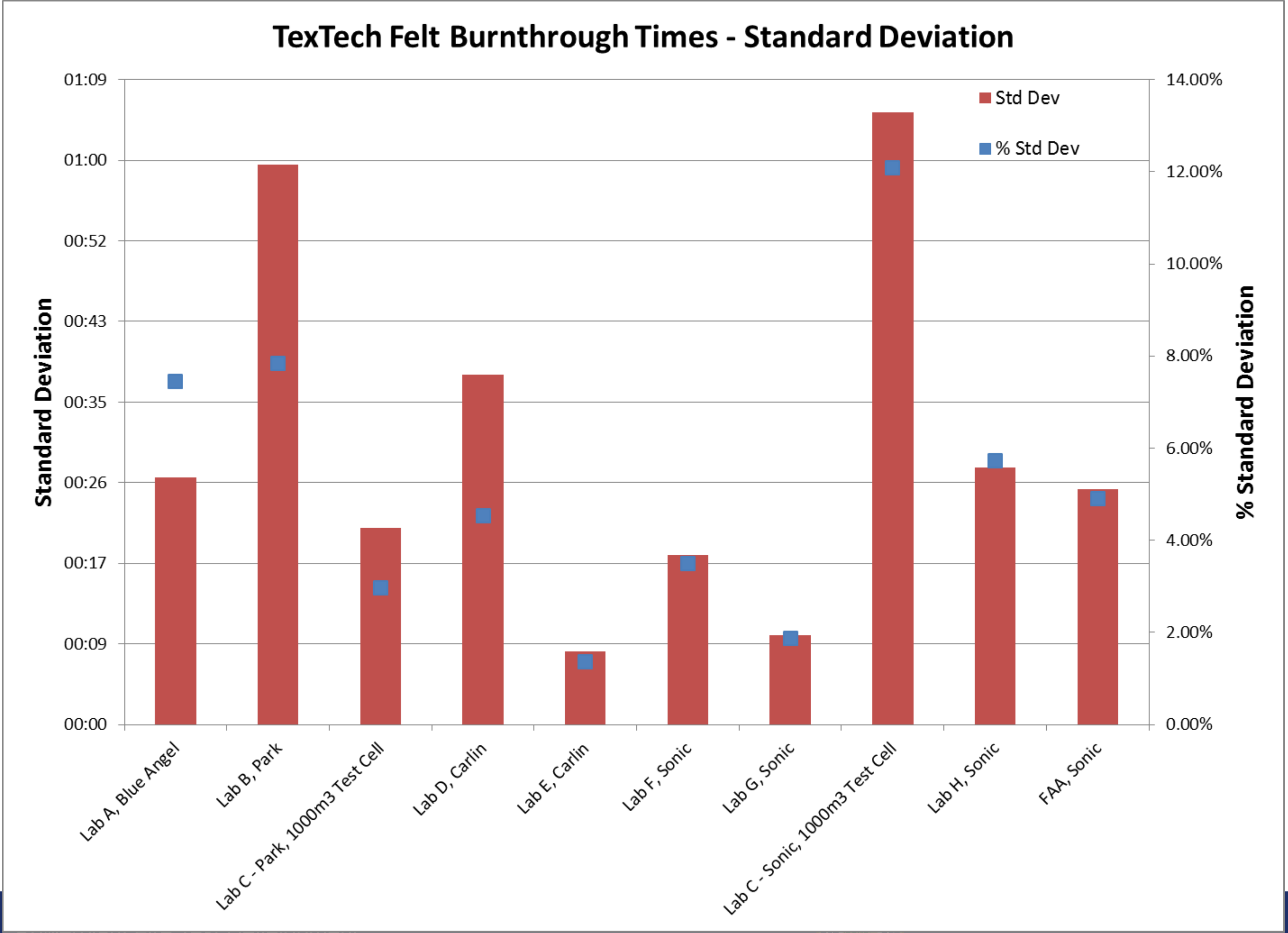
Lab H, Sonic
FAA, Sonic


TexTech Felt Burnthrough Times - Standard Deviation
Std Dev
% Std Dev
Standard Deviation
% Standard Deviation
01:09
01:00
00:52
00:43
00:35
00:26
00:17
00:09
00:00
14.00%
12.00%
10.00%
8.00%
6.00%
4.00%
2.00%
0.00%
Lab A, Blue Angel
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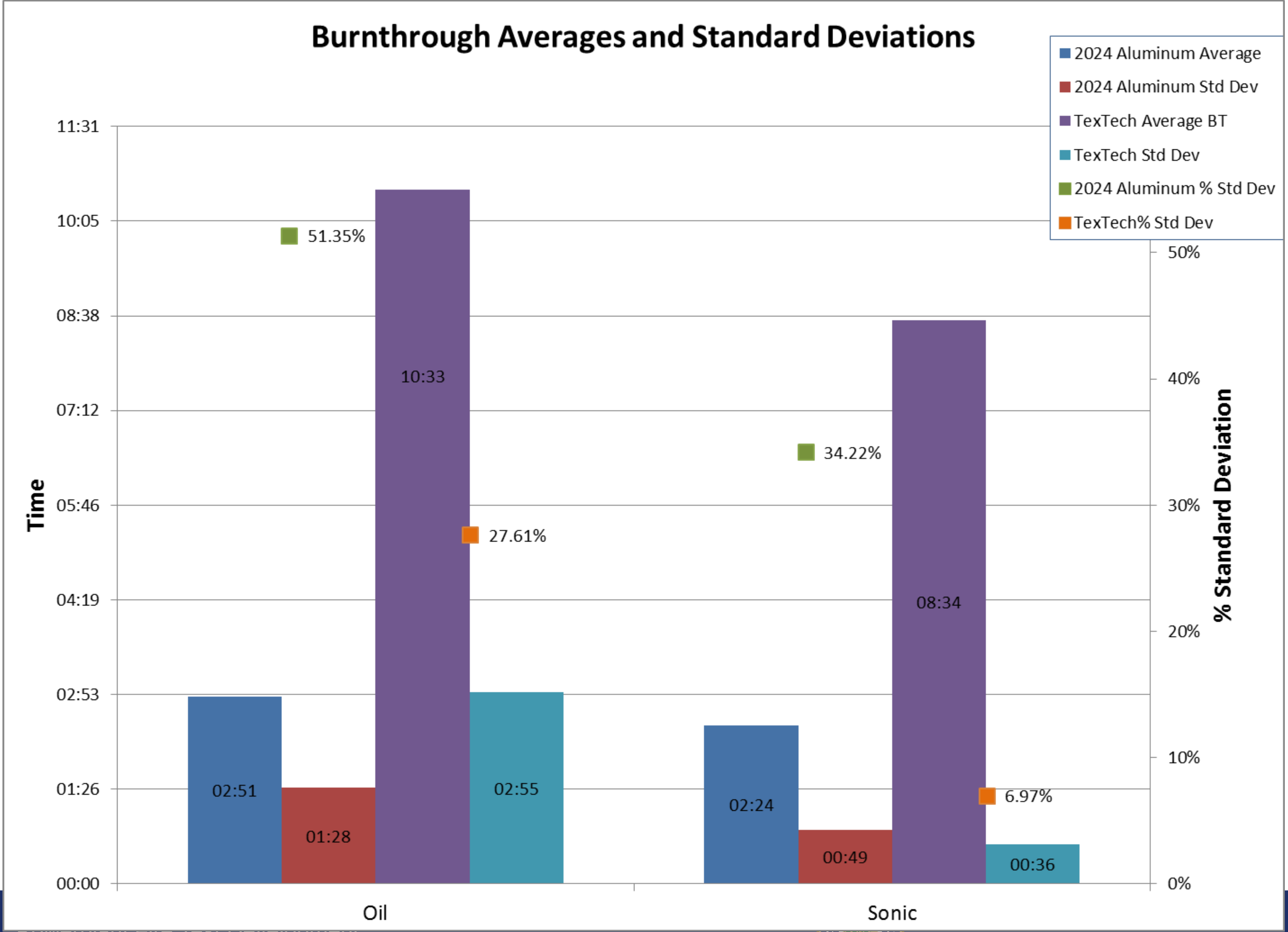
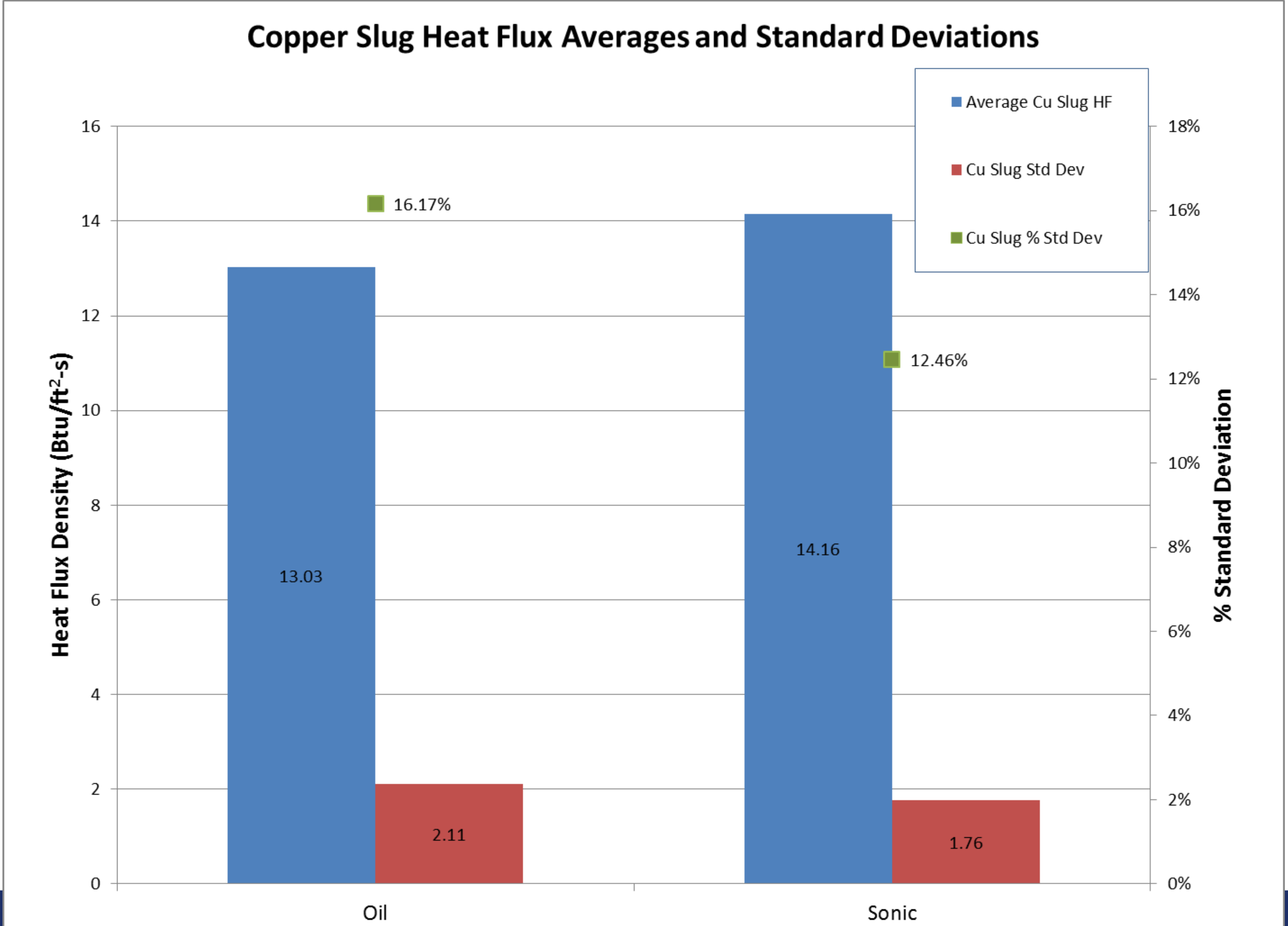
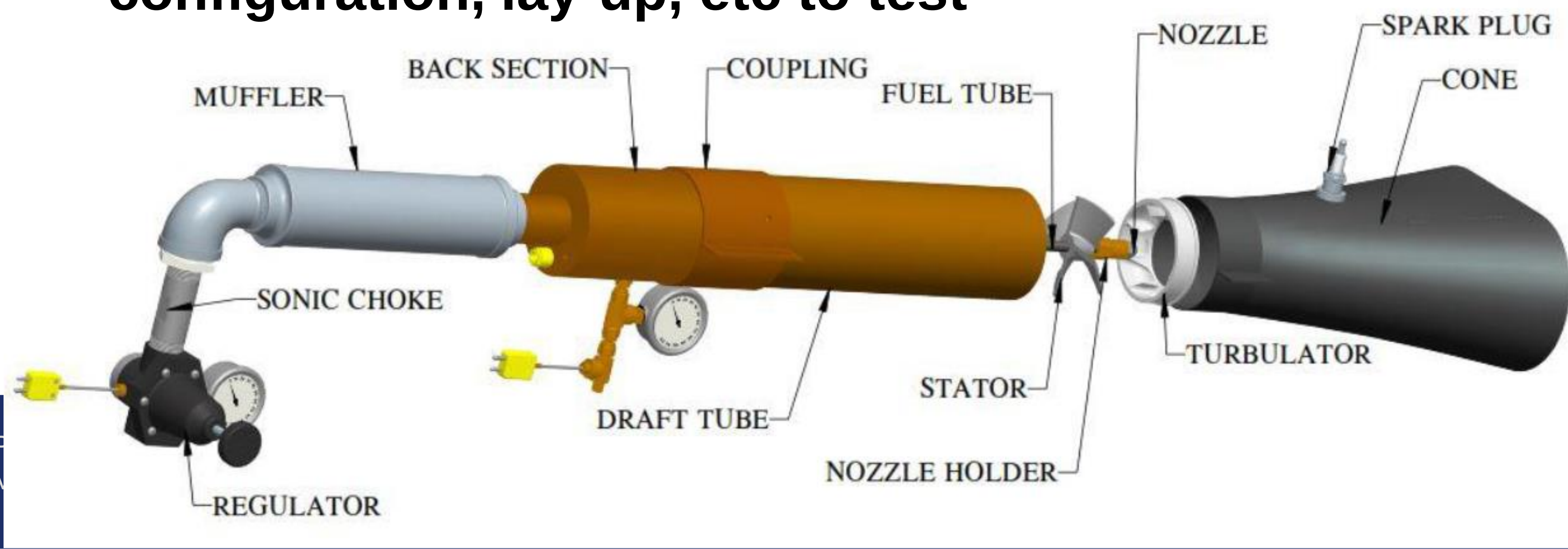

Burnthrough Averages and Standard Deviations
2024 Aluminum Average
2024 Aluminum Std Dev
TexTech Average BT
TexTech Std Dev
2024 Aluminum % Std Dev
TexTech% Std Dev
Time
% Standard Deviation
11:31
10:05
08:38
07:12
05:46
04:19
02:53
01:26
00:00
50%
40%
30%
20%
10%
0%
51.35%
10:33
27.61%
02:51
01:28
02:55
34.22%
08:34
02:24
00:49
6.97%
00:36
Oil
Sonic


Copper Slug Heat Flux Averages and Standard Deviations
Average Cu Slug HF
Cu Slug Std Dev
Cu Slug % Std Dev
Heat Flux Density (Btu/ft2-s)
% Standard Deviation
16
14
12
10
8
6
4
2
0
18%
16%
14%
12%
10%
8%
6%
4%
2%
0%
16.17%
12.46%
13.03
14.16
2.11
1.76
Oil
Sonic

Current Status – Testing

- **Reconfiguring burner to current Materials configuration – ignitor-less stator**
  - Will repeat testing on materials to ensure repeatability, consistency with previous tests
- **Building up to be able to conduct composite (and other) testing under vibration**
- **Need recommendations on composite suppliers, configuration, lay-up, etc to test**



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Current Status – AC 20-135

- **A sub-group had been formed with the goal of developing proposed rewording of AC20-135 in a parallel effort with NexGen burner development.**
  – Testing requirements (i.e. when/how to vibrate sample, orientation of sample, etc) and testing equipment (i.e. thermocouple type, heat transfer calibration device, etc) will be addressed.
  – Actual burner operation and calibration will be left open subject to burner development.
- **After initial sub-group meetings, it became evident that a more formal involvement from FAA was required and it was suggested that a proposal be submitted to the FAA from industry with the request that a formal group chartered for this task.**

Current Status – AC 20-135 (cont.)

- Dirk Kearsley (BAE Systems) has drafted this request and has submitted to FAA (6/2014).
- Work is currently underway to form an internal FAA group of experts and interested parties to develop a plan of action.
- Internal FAA group is holding some initial meetings to decide the best course forward.
- Resulting chartered group will likely be managed through the existing Systems Fire Protection Working Group and Powerplants Fire Test Task Group

Questions

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