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INITIAL STUDY OF MODIFIED SONIC BURNER FOR POWERPLANT FIRE TESTING AND INNOVATIVE MAPPING TECHNIQUES

2018-10-30

PRESENTED BY: DR. MARY KELLY (RESONATE) AND SIMON HIND (NATIONAL RESEARCH COUNCIL CANADA)

BATTLE OF THE BURNERS

Resonate TESTING LIMITED

ilac-MRA

UKAS TESTING 9373

SYSTEM CERTIFICATION ISO 9001 SGS

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Premise – why are we doing this study?
Presentation overview

Premise

Comparison of existing and new Burners carried out to add to the body of knowledge and increase consistency between labs for powerplant/systems testing aiding in providing direction for future trials.

Presentation overview

- Trial summary
- Equipment used
- Calibration comparison of Carlin and existing Sonic configuration
- Modifications to Sonic
- Calibration comparison of Carlin and Newly modified Sonic Configuration
- Novel mapping techniques to compare the burner flames
- Conclusions and future work

Trial Summary

Date	Trial
16-Jul-18	T1 - Carlin 1
16-Jul-18	T2 - Sonic FAA 1
16-Jul-18	T3 - Sonic FAA 2
16-Jul-18	T4 - Sonic FAA 3
16-Jul-18	T5 - Sonic FAA 4 Temp Map
16-Jul-18	T6 - Sonic FAA 5 Temp Map
16-Jul-18	T7 - Sonic FAA 6
17-Jul-18	T8 - Carlin 2
17-Jul-18	T9 - Carlin Panel 3 pre burn
17-Jul-18	T10 - Carlin Panel 4 post burn
17-Jul-18	T11 - Carlin 5
17-Jul-18	T12 - Carlin 6
17-Jul-18	T13 - Carlin 7
18-Jul-18	T14 - Carlin 8
18-Jul-18	T15 - Sonic Mod 1
18-Jul-18	T16 - Sonic Mod 2
18-Jul-18	T17 - Sonic Mod 3 Temp & BTU/hr Map
19-Jul-18	T18 - Sonic Mod 4 Temp Map
19-Jul-18	T19 - Sonic Mod 5 pre burn
19-Jul-18	T20 - Sonic Mod 6 post burn
19-Jul-18	T21 - Sonic Mod 7 Temp Map
19-Jul-18	T22 - Sonic Mod 8 pre burn
19-Jul-18	T23 - Sonic Mod 9 post burn
19-Jul-18	T24 - Sonic Mod 10 Temp Map
19-Jul-18	T25 - Sonic Mod 11
19-Jul-18	T26 - Sonic Mod 12
19-Jul-18	T27 - Sonic Mod 13 pre BTU/hr Map
19-Jul-18	T28 - Sonic Mod 14 post BTU/hr Map
20-Jul-18	T29 - Sonic Mod 15 Temp Map
20-Jul-18	T30 - Sonic Mod 16 burn
20-Jul-18	T31 - Sonic FAA 7 Temp Map
20-Jul-18	T32 - Sonic FAA 8
20-Jul-18	T33 - Sonic FAA 9
20-Jul-18	T34 - Sonic FAA 10
21-Jul-18	T35 - Carlin 9
21-Jul-18	T36 - Carlin 10
21-Jul-18	T37 - Carlin 11
21-Jul-18	T38 - Carlin 12 pre BTU/hr Map
21-Jul-18	T39 - Carlin 13 post BTU/hr Map
21-Jul-18	T40 - Carlin 14

More than 40 trials conducted over 6 days of testing:

- Carlin x 14
- Sonic FAA Config. x 10
- Sonic Mod. Config. x 16

Including:

- X5 2D temperature map with 11 TC rake
- X2 2D HD temperature map with 11 TC rake
- X3 2D HD temperature map with 21 TC rakes and impingement surface
- X4 BTU/hr maps
- X4 burnthrough tests

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EQUIPMENT AND SETUP

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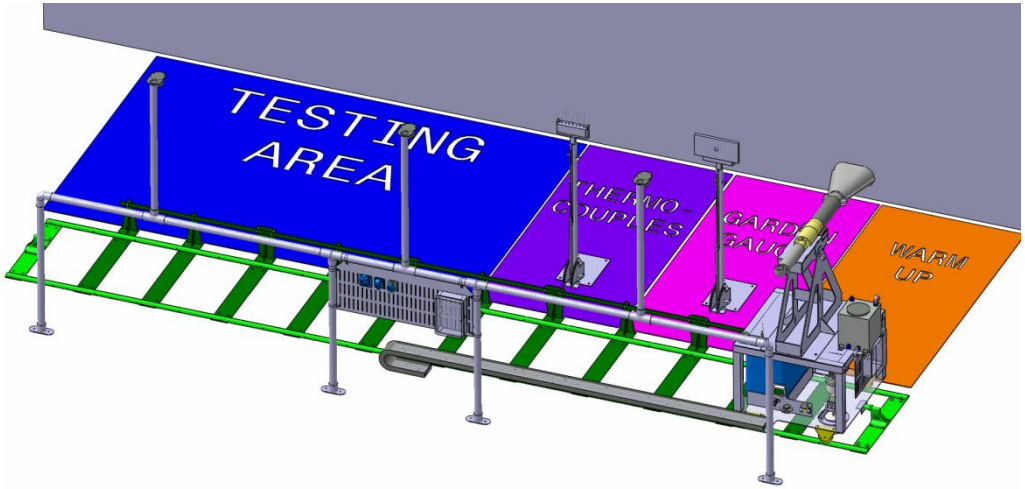
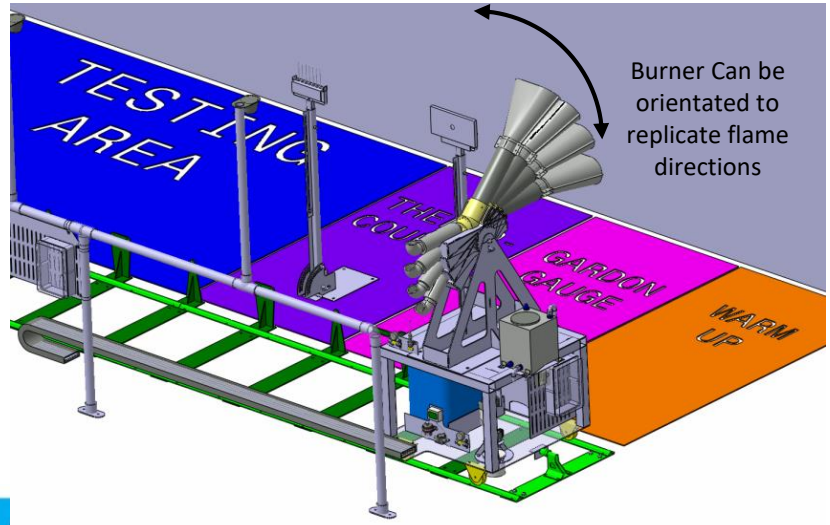
Fire Test Facilities





Automated Burner Control

- The Burner is mounted on a carriage that travels along a 6m rail track. The Carriage is controlled from control room.
- The Track has four separate zones
  - 1. Warm up Area.
  - 2. Heat flux Calibration.
  - 3. Flame Temperature Calibration .
  - 4. Specimen Test area.

- The Test Technician controls the movement burner between stations.
- The data acquisitions is via National Instruments LabVIEW, giving real time display of heat flux and temperature distribution during calibration stages.
- The burner can be positioned at any angle between horizontal and vertical angles as required.

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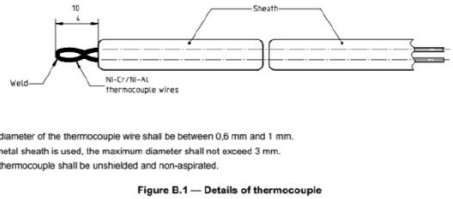
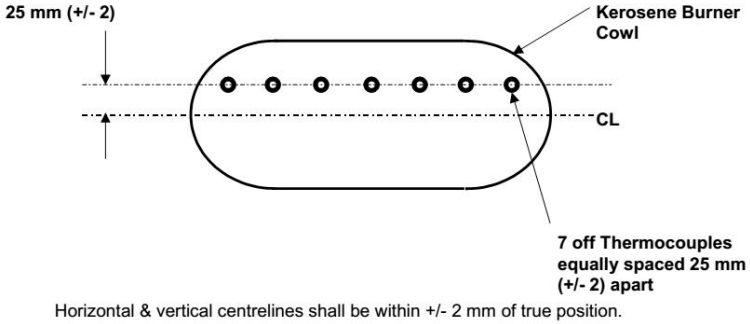
TC Rake – Temperature Calibration



NOTES
1 The diameter of the thermocouple wire shall be between 0,5 mm and 1 mm.
2 If a metal sheath is used, the maximum diameter shall not exceed 3 mm.
3 The thermocouple shall be unshielded and non-aspirated.

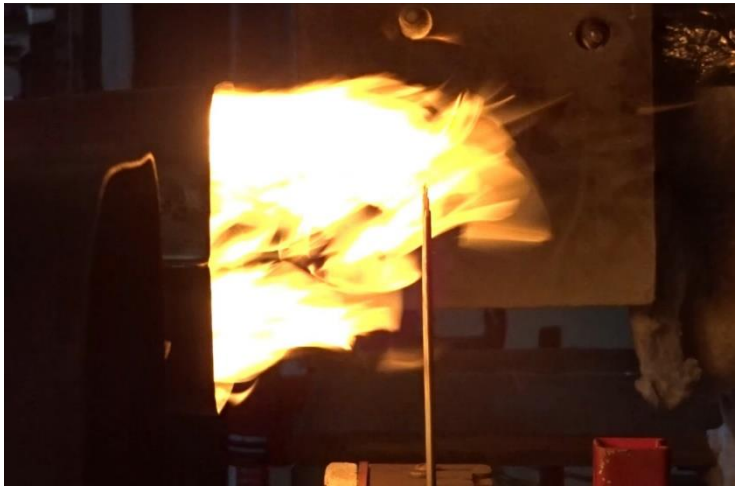
Figure B.1 — Details of thermocouple

Brand New TC's Used



Horizontal & vertical centrelines shall be within +/- 2 mm of true position.

- 7 type K thermocouples
- 1-inch apart (25mm)
- 1-inch above centreline
- 4-inches away from cone
- 3mm external sheath
- 4-6mm exposed tip
- 24 AWG (0.5mm) wire



Compliant with BS EN 60584.1 Pt4 Class 1

375°C to 1000°C ±0.004 . $|t|$ → ± 40°C

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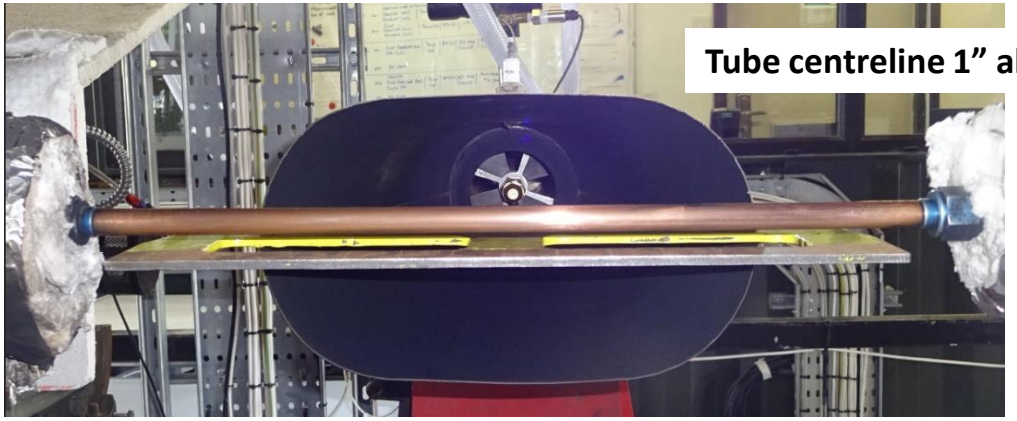
Copper Tube – Heat flux Calibration



Tube centreline 1” above burner cone centreline

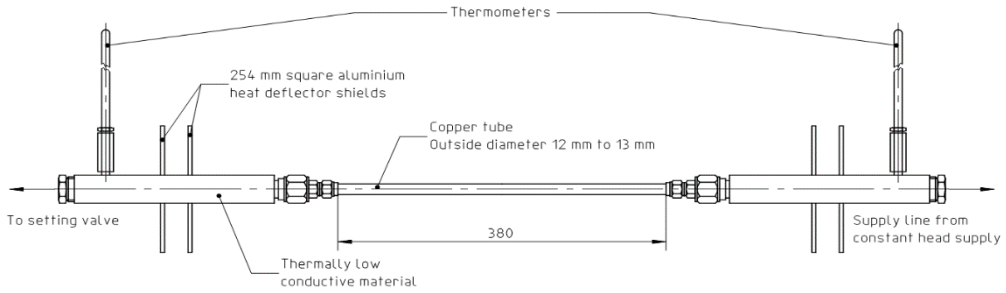
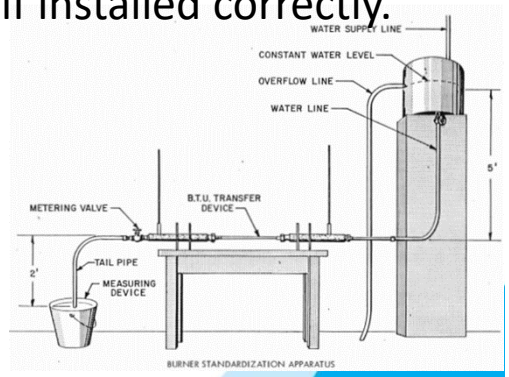


Figure B.4 — Overall view of the mounting of the standard heat flux density measuring tube

RTD’s for temp measurement offer a better solution than Glass bulb thermometers if installed correctly.



- 500 lb/hr, 1 US gallon, 3.8 litre per minute flow water
- 50-71°F input temp,
- minimum of 9°F temperature increase required

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Copper Tube – Heat flux Calibration
The rational approach…..

This makes sense

- Engineering Report 3A
  - A three minute warmup period should be allowed to obtain stable conditions before temperature measurements are recorded. **Note: the three minutes should be conducted away from the heat transfer tube to prevent buildup of carbon.**

- ISO 2685
  - Allow a 3 min warm-up period in order to obtain stable conditions before recording the temperature measurements
  - **NOTE — When warming up the flame, do not expose the heat-transfer tube to the flame; this minimizes carbon build-up on the tube.**

Heat flow Average was calculated over the 3mins beginning once 4500BTU/hr was reached

or

If 4500BTU/hr was not reached 1mins warm up was allowed and 3 mins of data recorded after this

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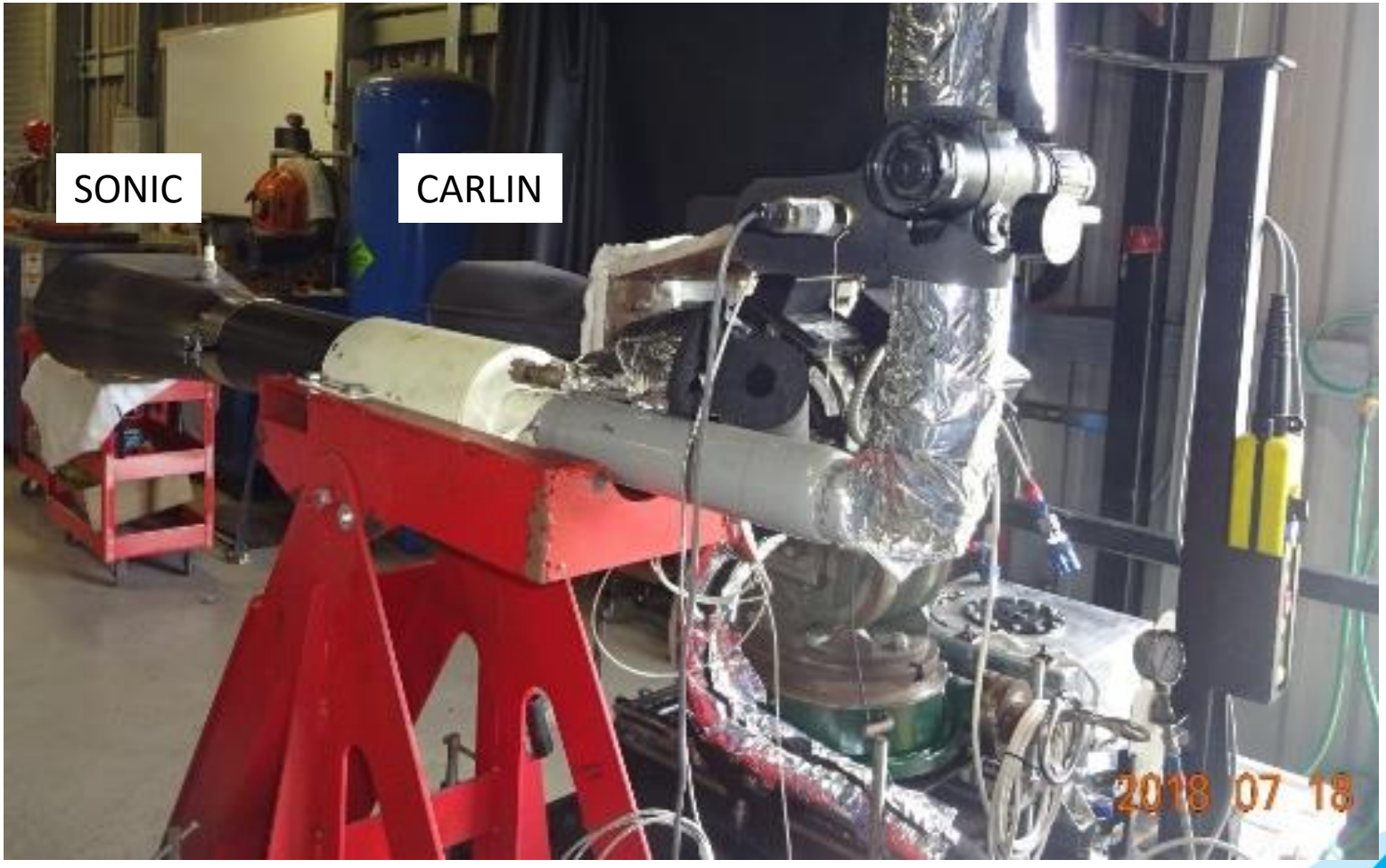
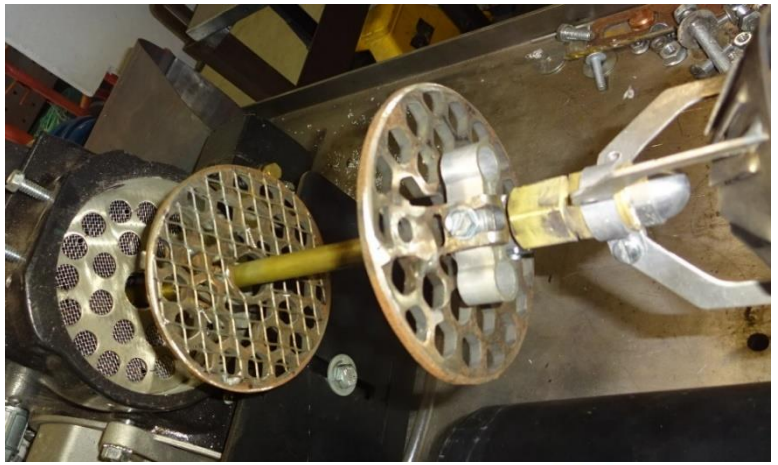
Burners – Carlin and Sonic – Side by Side



Carlin 200 CRD

Engineering report 3A



Acceptable Modified Burners:

CARLIN 200 CRD, manufactured by the Carlin Company, 912 Silas Deane Highway, Wethersfield, Connecticut 06109, shown in figures 5 and 6, was modified in the following manner to produce a diffused 6-inch (vertical) by 11-inch (horizontal) sized flame with homogeneous temperature gradiant. Note: Carlin 200 CRD AS 1055 incorporates these following modifications and may be purchased directly.

1. An 80 fuel nozzle rated at 2.25 gal/hr. and pressure adjusted to deliver 2.04 gal/hr. at 97 psig was installed.

2. The retention and throttle rings plus the support and forward extension were removed.

3. A flat-plate disc, approximately 4 inches in diameter and randomly punched with ten 1/2-inch holes, was installed 4 inches aft of the fuel nozzle tip. This provided support and centering of the oil delivery tube.

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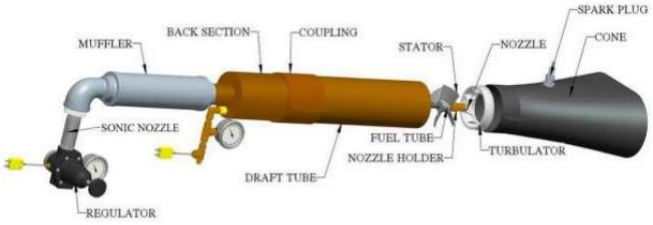
Sonic – FAA (Existing)



FAA FIRE TEST HANDBOOK - Chapter 7 configuration
Supplier by Marlin Engineering

Fuel Nozzle
FAATC data from presentations (as late as 2017):
2.0 gph 80°B Delevan nozzle, 100 psi fuel, 40/50 psi air
FAATC config Resonate used for this test:
2.0 gph <u>80°W</u> manufacturer nozzle, 100 psi fuel, 50 psi air

Ignitorless stator
Muffler foam retained with wire
Turbulator – no flame retention head

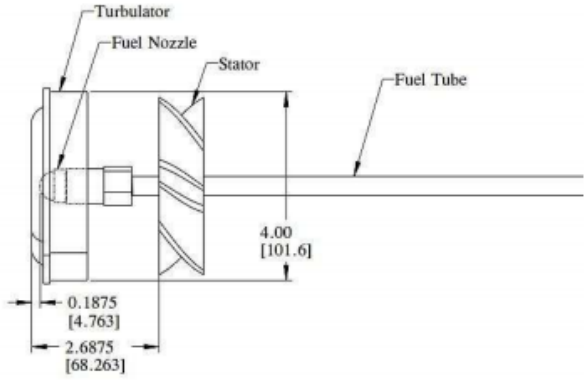


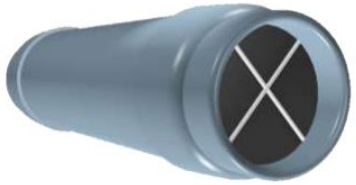
Figure 7-S-17. Typical Configuration of the Stator and Turbulator

supplied by Marlin Engineering, part number ME1513-3.

Figure 7-S-13. Stator

supplied by Marlin Engineering, part number ME1512-1.

Figure 7-S-14. Turbulator, Front View and Back View



12. Safety Wire Affixed to inside of the Muffler for Restrainin

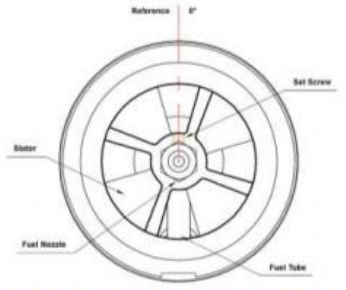


Figure 7-S-29 Stator Axial Position (looking into draft tube)

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Seat Burner Settings

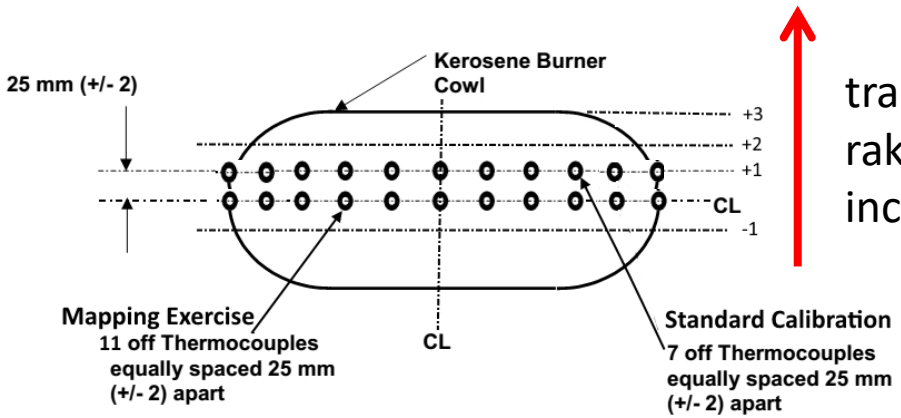
- **Fuel Nozzle:** Delavan 2.0 gal/hr 80° spray pattern W "all purpose"
  Face of FRH to nozzle tip: 1-1/8"
- **Fuel nozzle adapter to static plate: 2-3/8"**
- **Static Plate Angle: centerline of igniters at 0°**
  - Looking into the cone of the burner from above, the centerline between the igniters will be at 0° on the burner reference plane
- **Fuel pressure: 108 psi (+/- 4 psi)**
  - Pressure used as a starting point when checking fuel flow rate
- **Air pressure: 45 psi**
- **Air Temperature: 40-60°F**
- **Fuel Temperature: 32-52°F**

- **Internal settings identical to the cargo sonic**

Development of Burner Settings

- **Began with manufacturer's recommend settings for placement of static plate and igniters**
- **Air pressure**
  - 30 40, 50, psi tested initially
  - 45 psi produced the most repeatable results which were consistent with Park burner results
  - Same air pressure used on cargo burner
- **Nozzles**
  - Delavan B (solid spray pattern)
  - Delavan A (hollow spray pattern)
  - Delavan W (all purpose spray pattern)
  - W nozzle selected based on cargo and seat burner test results

11 TC Map – 1” vertical Increments & 1” TC spacing



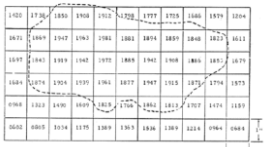
transitioning rake with 1” increments.

Horizontal & vertical centrelines shall be within +/- 2 mm of true position.

FIGURE 2 - FLAME TEMPERATURE MEASUREMENT POSITIONS FOR KEROSENE BURNER

Flame temperature mapping

- Engineering Report 3A CARLIN 200 CRD



Burner Map looking into the Burner [°F] - Max Values

	TC 1	TC 2	TC 3	TC 4	TC 5	TC 6	TC 7	TC 8	TC 9	TC 10	TC 11	AVERAGE Central 7 TC's
Level 6	1420.0	1738.0	1850.0	1908.0	1912.0	1798.0	1777.0	1725.0	1686.0	1579.0	1204.0	1808.0
Level 5	1671.0	1869.0	1947.0	1963.0	1981.0	1881.0	1894.0	1859.0	1848.0	1823.0	1611.0	1910.4
Level 4	1697.0	1843.0	1919.0	1942.0	1972.0	1885.0	1942.0	1908.0	1886.0	1852.0	1679.0	1922.0
Level 3	1634.0	1874.0	1904.0	1936.0	1961.0	1877.0	1947.0	1915.0	1871.0	1794.0	1573.0	1915.9
Level 2	968.0	1323.0	1490.0	1609.0	1825.0	1766.0	1862.0	1813.0	1707.0	1474.0	1159.0	1724.6
Level 1	602.0	805.0	1034.0	1175.0	1389.0	1363.0	1536.0	1389.0	1214.0	964.0	684.0	1300.0

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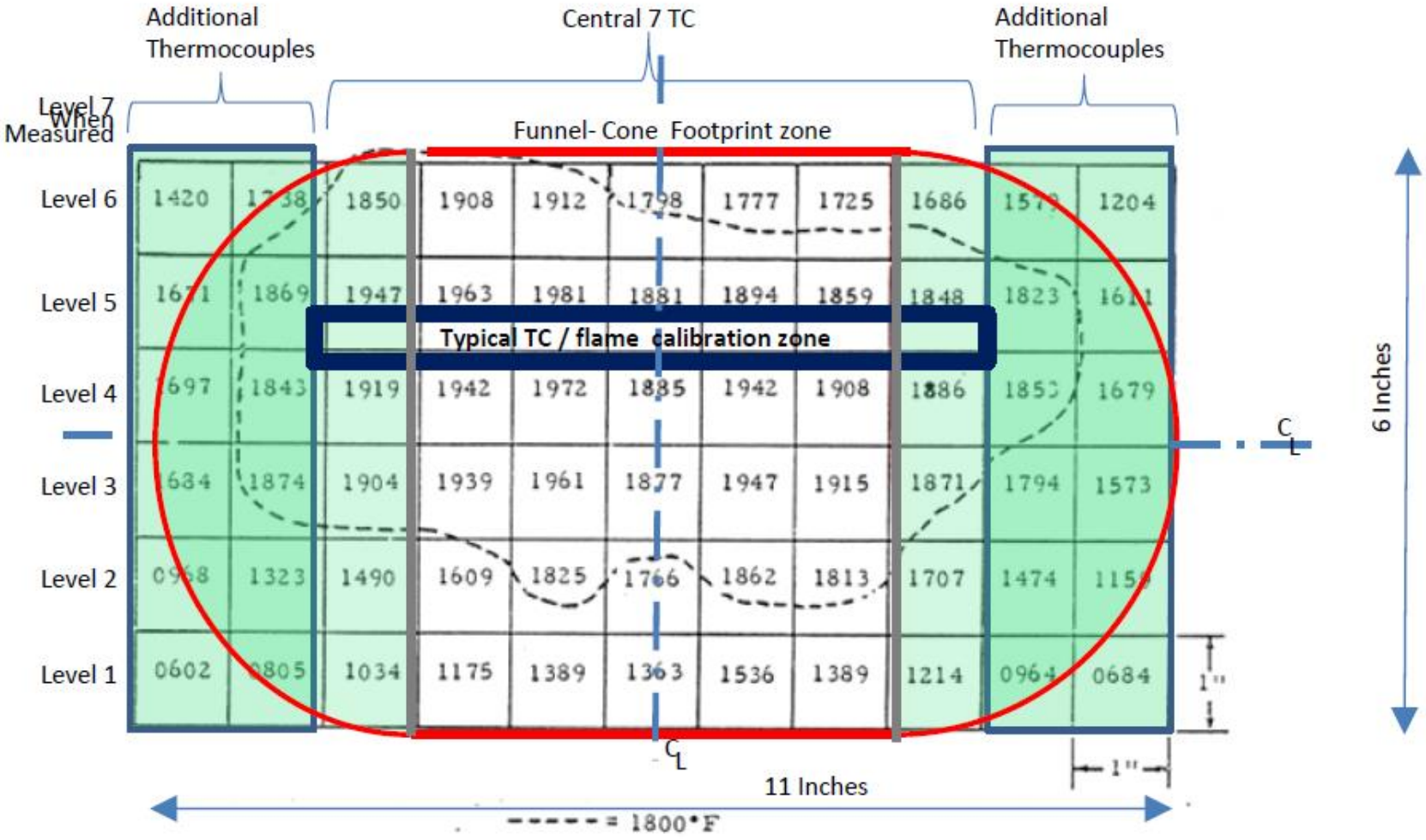

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CARLIN CALIBRATION DATA

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SYSTEM CERTIFICATION ISO 9001 SGS

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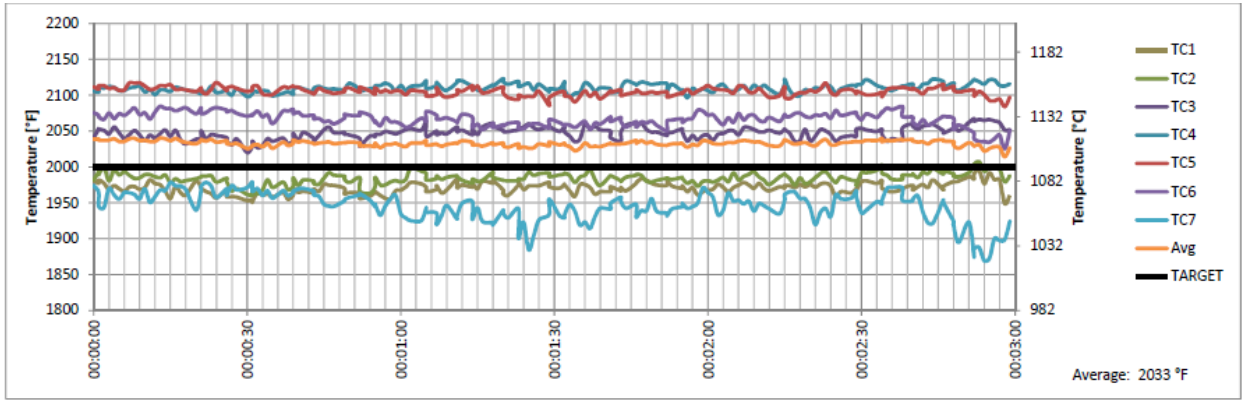
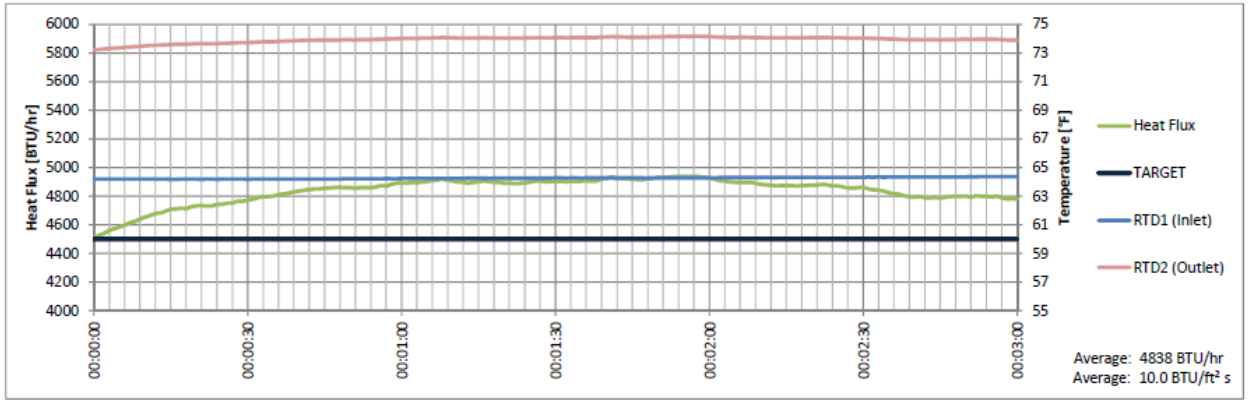
Baseline Calibration Data (T1 - Carlin 1)
Conservative Certification Test Point





	Temp (°F)	Heat Flux (BTU/hr)
Avg	2033	4836
Min	1869	4509
Max	2123	4938

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Baseline Assessment – Calibration Data for Carlin

- T8 – Carlin 2
- Standard 2D temperature map using 11 TC rake
- Standard TC calibration taken at level 4.5 with average = 2033°F (see previous slide)

Burner Map

Test	Date/Time
Carlin MAP Burn1	17/07/2018 10:42:48.100 AM

Burner Map looking into the Burner [°F] - Max Values

	TC 1	TC 2	TC 3	TC 4	TC 5	TC 6	TC 7	TC 8	TC 9	TC 10	TC 11	AVERAGE Central 7 TC's
Level 7	1845.3	1923.1	1951.1	1922.5	1970.7	1971.0	1901.7	1871.4	1695.3	1434.4	1108.6	1897.7
Level 6	1862.8	1937.7	1959.4	1926.6	1987.4	1994.2	1943.9	1884.7	1720.1	1500.0	1150.3	1916.6
Level 5	1917.5	1993.2	2008.6	2004.6	2077.6	2121.8	2111.6	2074.3	1958.9	1828.4	1380.9	2051.1
Level 4	1767.2	1907.1	1890.2	1866.8	2017.0	2110.0	2111.6	2035.8	1894.4	1657.1	1304.3	1989.4
Level 3	1261.9	1535.7	1612.3	1439.7	1671.5	1881.9	1921.0	1846.3	1627.8	1419.6	1027.7	1714.3
Level 2	670.6	1004.1	1172.4	960.0	1101.2	1351.6	1455.3	1364.6	1157.2	905.6	588.2	1223.2
Level 1	380.9	547.1	688.2	561.1	625.8	750.0	863.2	811.1	643.7	461.7	381.9	706.1

Burner Map looking into the Burner [°F] - Average Values

	TC 1	TC 2	TC 3	TC 4	TC 5	TC 6	TC 7	TC 8	TC 9	TC 10	TC 11	AVERAGE Central 7 TC's
Level 7	1829.6	1916.7	1948.2	1906.4	1957.6	1953.5	1877.2	1850.2	1666.9	1418.3	1086.9	1880.0
Level 6	1841.1	1924.5	1951.1	1910.7	1967.7	1961.3	1899.8	1854.8	1671.2	1452.7	1089.3	1888.1
Level 5	1900.2	1970.0	1996.0	1995.1	2062.4	2108.7	2102.3	2052.0	1927.8	1755.5	1311.3	2034.9
Level 4	1701.7	1863.9	1856.1	1823.0	1985.9	2087.9	2095.7	2009.6	1866.2	1625.1	1250.1	1960.6
Level 3	1189.8	1486.8	1548.1	1374.6	1622.1	1828.4	1881.6	1787.1	1563.4	1352.0	953.9	1657.9
Level 2	647.4	967.1	1147.5	931.3	1068.1	1311.8	1398.3	1322.8	1097.9	867.8	557.6	1182.5
Level 1	358.5	520.6	666.1	541.1	570.0	710.2	809.6	750.1	596.2	431.9	359.2	663.3

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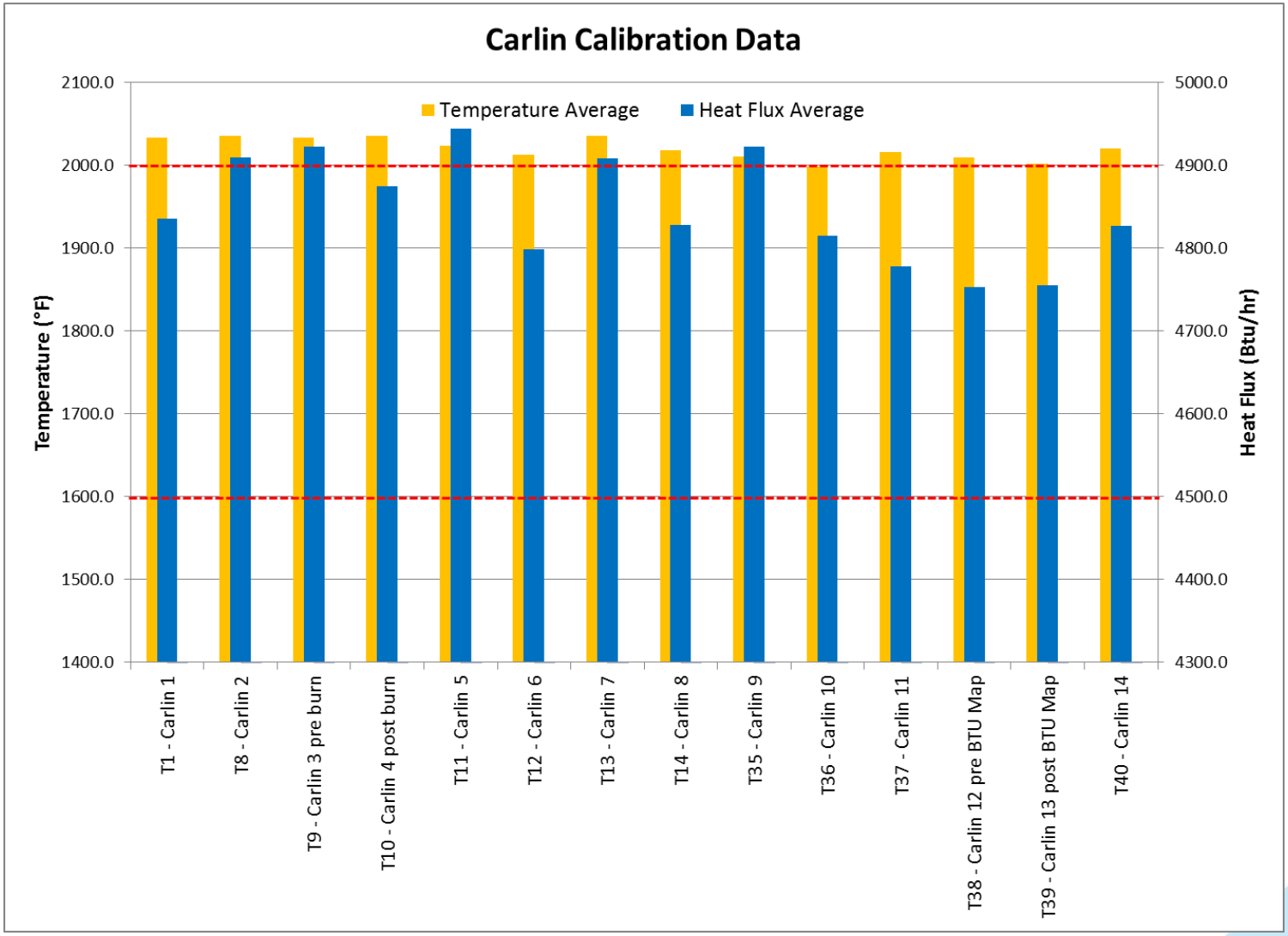
Summary of Carlin Calibration Data



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SONIC FAA CALIBRATION DATA

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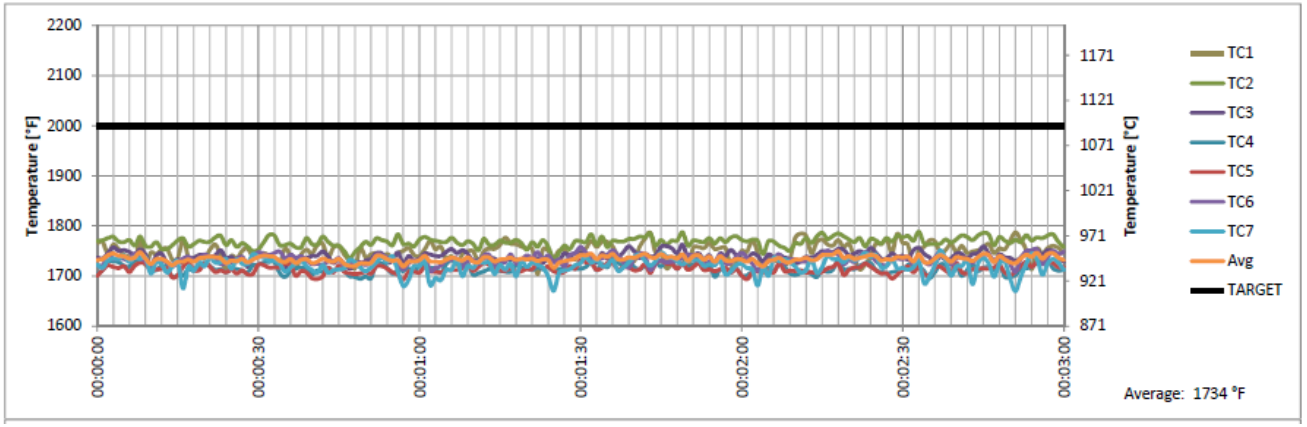
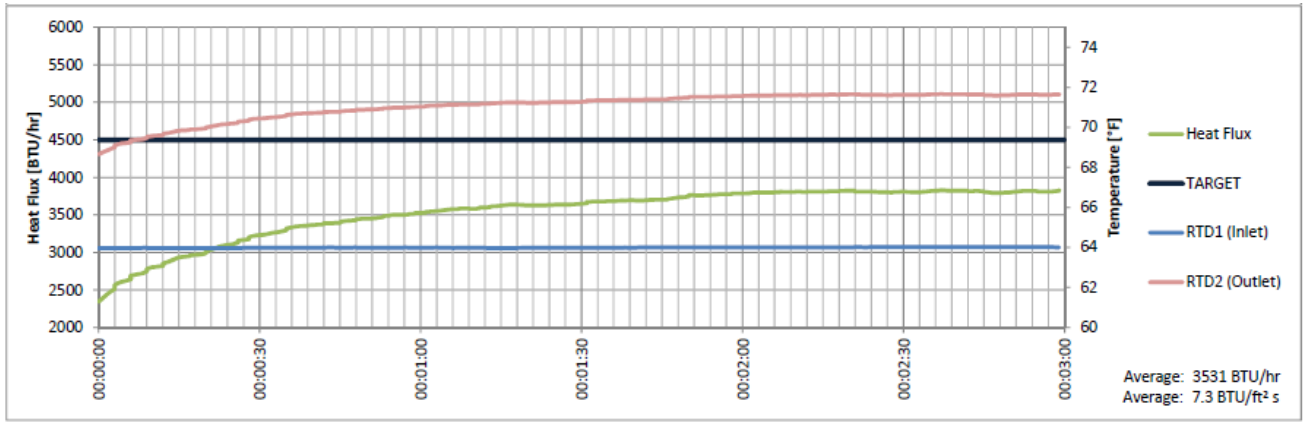
Calibration Data for Sonic FAA Configuration (T5 – Sonic FAA 4 Temp. Map)

- Fuel P = 100 psi, Air P = 50 psi





	Temp (°F)	Heat Flux (BTU/hr)
Avg	1734	3531
Min	1670	2342
Max	1788	3832

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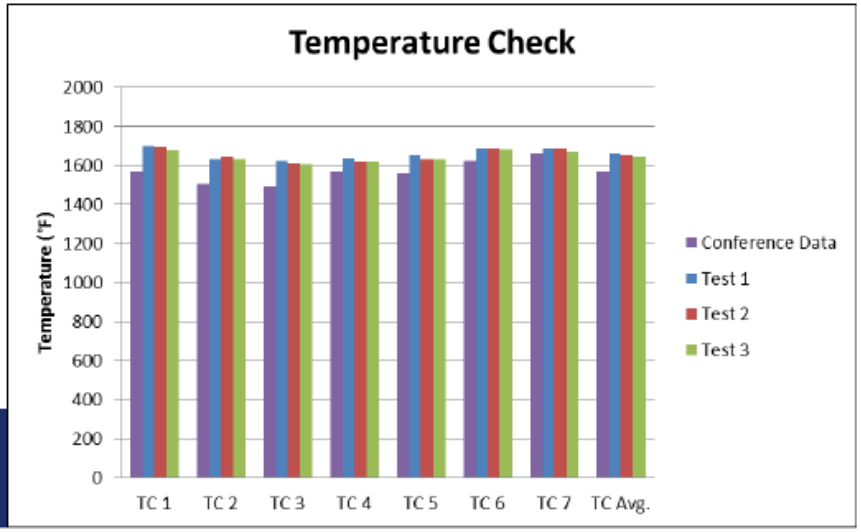
Next Generation Fire Test Burner For Powerplant Fire Testing Applications – Summer, Rehn, Nov17

Burner Settings

- Nozzle: 80° B 2.0 gph
- Flow-checked 2.00 gph @ 102 psi
- Air Pressure: 50 psi
- Copper Tube Heat Flux (3 test average): 5111.3 Btu/hr
- Temperature check (first 3 tests with brand new 1/8" exposed-bead thermocouples



Powerplants Fire Test Development
November 1, 2017

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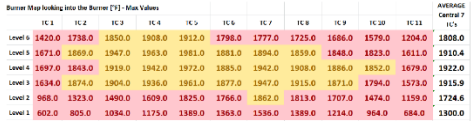
Calibration Data for Sonic (FAA Configuration)

- T5 – Sonic FAA 4 Temp Map
- Standard 2D temperature map using 11 TC rake
- Standard TC calibration taken at level 4.5 with average = 1734°F (see previous slide)

Flame temperature mapping
- Engineering Report 3A CARLIN 200 CRD



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Burner Map

Test	Date/Time
Sonic MAP Burn4	16/07/2018 02:40:33.373 PM

Burner Map looking into the Burner [°F] - Max Values

	TC 1	TC 2	TC 3	TC 4	TC 5	TC 6	TC 7	TC 8	TC 9	TC 10	TC 11	AVERAGE Central 7 TC's
Level 7	1542.6	1798.6	1849.3	1855.9	1848.9	1828.1	1841.5	1840.1	1807.4	1728.7	1456.7	1838.8
Level 6	1576.9	1800.3	1848.5	1860.8	1853.1	1831.9	1839.5	1843.0	1812.9	1774.7	1519.1	1841.4
Level 5	1367.9	1664.9	1770.4	1805.5	1797.3	1775.8	1793.2	1813.4	1775.1	1733.2	1554.6	1790.1
Level 4	1224.9	1593.6	1720.5	1753.7	1745.3	1717.2	1729.4	1736.0	1708.3	1656.3	1414.7	1730.1
Level 3	908.2	1271.5	1525.8	1660.4	1692.7	1673.5	1661.9	1635.6	1558.7	1420.8	1176.0	1629.8
Level 2	673.3	947.7	1206.3	1339.6	1459.4	1443.6	1454.3	1361.2	1202.2	1000.6	769.7	1352.4
Level 1	509.2	662.8	858.3	1002.5	1059.0	1058.4	1091.3	948.0	787.6	641.8	544.6	972.1

Burner Map looking into the Burner [°F] - Average Values

	TC 1	TC 2	TC 3	TC 4	TC 5	TC 6	TC 7	TC 8	TC 9	TC 10	TC 11	AVERAGE Central 7 TC's
Level 7	1499.7	1760.9	1825.1	1814.2	1788.9	1767.4	1772.1	1795.1	1778.8	1679.9	1389.4	1791.7
Level 6	1476.0	1726.4	1817.8	1844.6	1833.6	1811.6	1817.0	1823.7	1793.0	1731.5	1458.1	1820.2
Level 5	1292.0	1600.0	1738.1	1788.3	1781.7	1760.0	1774.6	1781.2	1750.8	1685.2	1448.1	1767.8
Level 4	1117.1	1471.6	1652.2	1726.3	1730.0	1701.9	1710.8	1715.6	1686.6	1612.7	1371.3	1703.4
Level 3	838.1	1200.5	1468.7	1623.6	1670.6	1640.1	1638.2	1604.7	1513.2	1365.8	1080.4	1594.1
Level 2	608.0	885.4	1143.5	1308.0	1403.7	1387.4	1398.8	1303.1	1121.3	933.0	734.6	1295.1
Level 1	482.0	622.4	784.1	879.6	953.5	953.4	976.4	847.6	712.8	597.2	519.6	872.5

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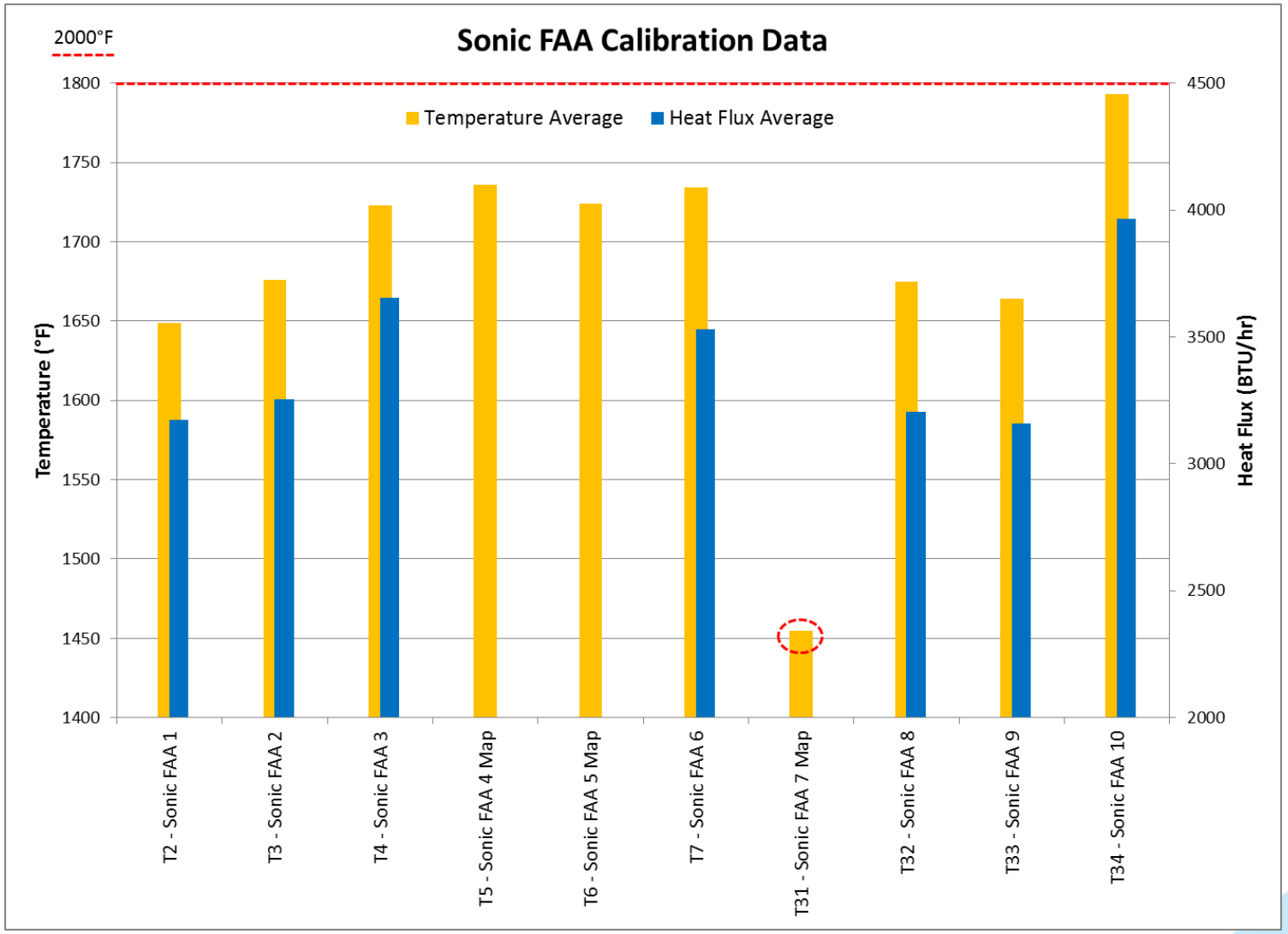
Summary of Sonic FAA Calibration Data



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MODIFIED SONIC CALIBRATION DATA

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Innovative R&D – Sonic Burner Modification

- Objective: Produce temperature and heat flux output data which demonstrate the modified Sonic burner can replicate Carlin conditions - i.e. Sonic can be calibrated according to AC20-135 guidance using the same equipment to produce similar results to a traditional oil burner.

- Details of modification
  - Removed foam from muffler – poor fit and would get compressed in tube
  - Changed nozzle from Delavan 80°W 2.0 GPH to Danfoss 80°H 2.0 GPH
  - Added Carlin type turbulator (attached to fuel nozzle fitting with rod moved fully forward) – reached higher levels of combustion – similar effect to FAA flame retention head
- Standard calibration data incl: 7 TC rake, Cu tube, standard 2D temp map
- Panel burnthrough tests
- Initial repeatability trials

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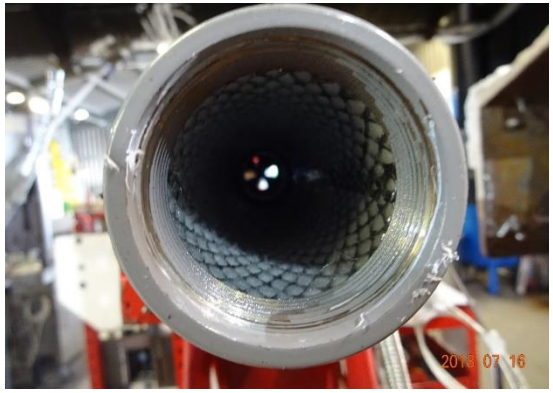
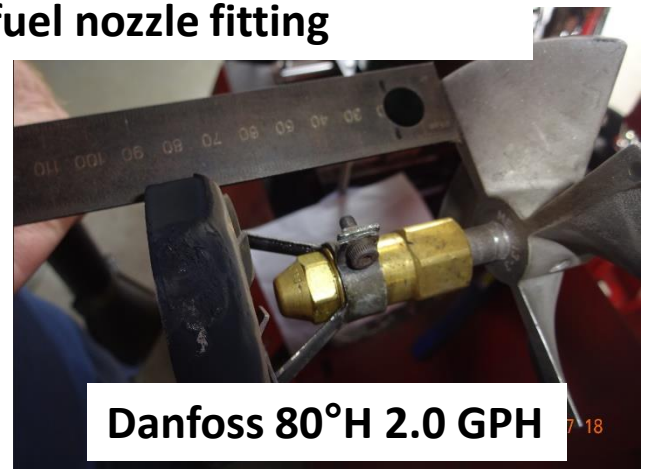
Sonic Mod - internals

Muffler foam was removed



Added Carlin type turbulator on fuel nozzle fitting



Danfoss 80°H 2.0 GPH

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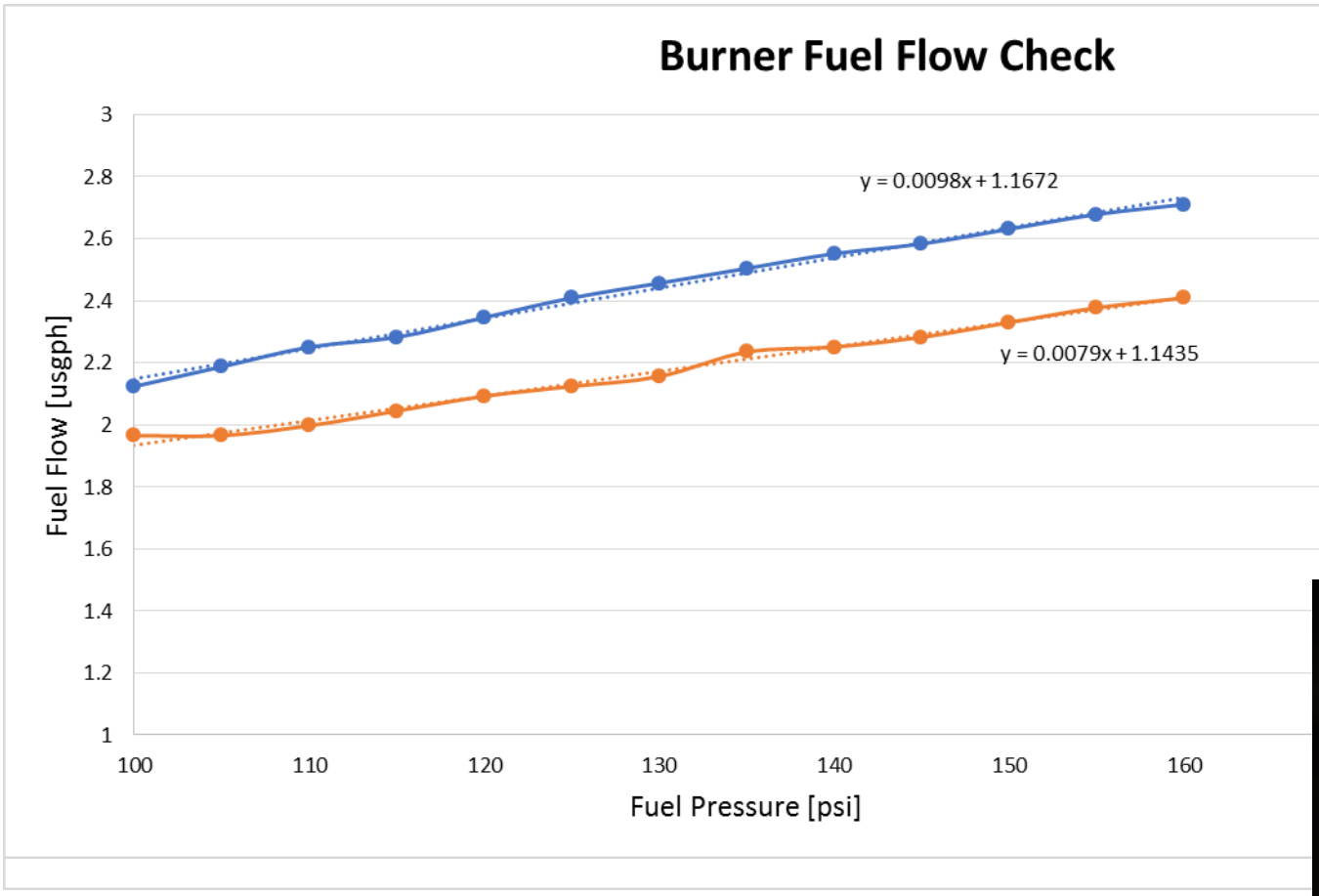
Fuel Flow Check – Based on FAA Procedure



Carlin 2.25 80°PLP
Sonic 2.0 80°H
Linear (Carlin 2.25 80°PLP)
Linear (Sonic 2.0 80°H)

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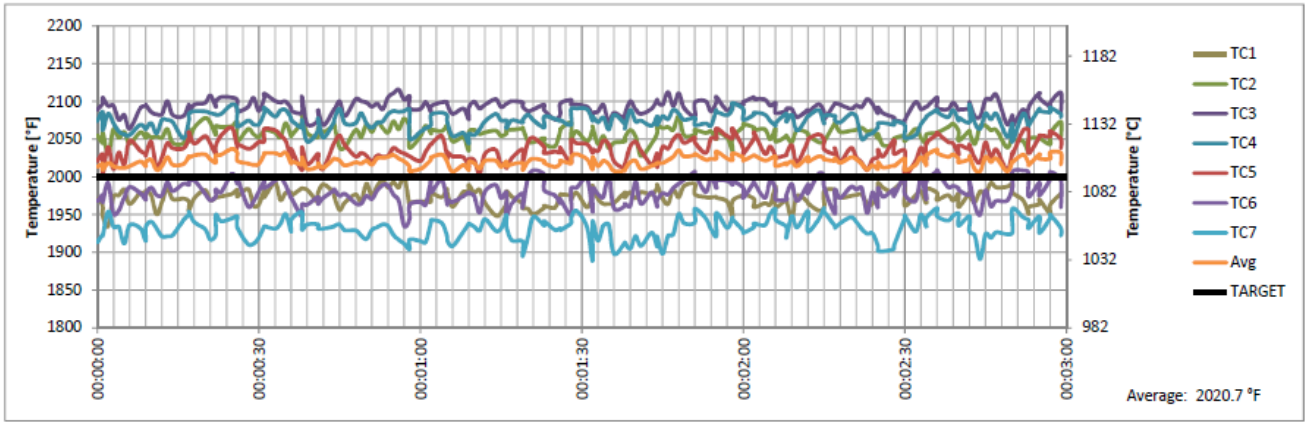
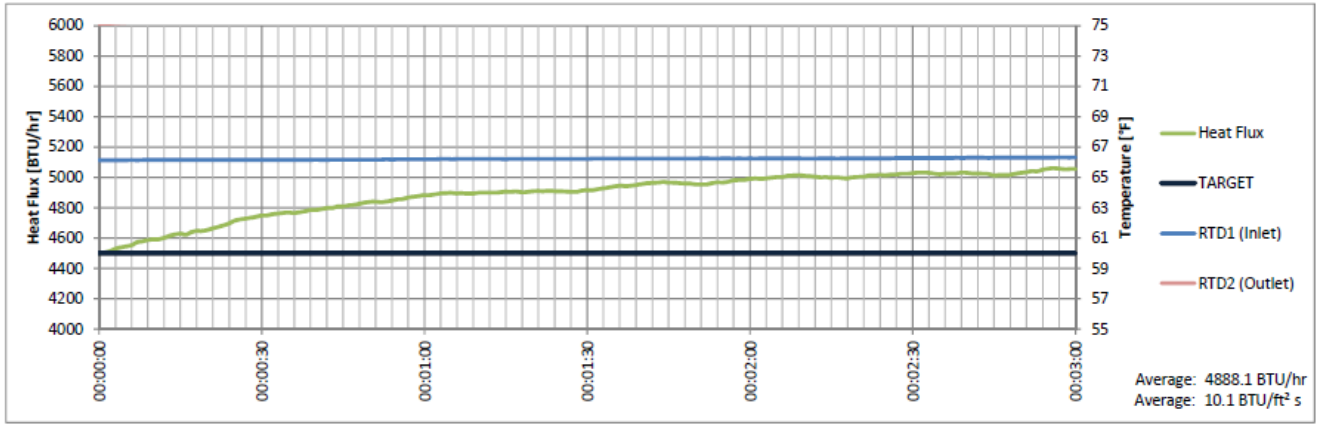
Calibration Data for Sonic Mod Configuration (T15 – Sonic Mod 1)

- Fuel P = 143 psi, Air P = 54.5 psi





	Temp (°F)	Heat Flux (BTU/hr)
Avg	2021	4888
Min	1889	4501
Max	2116	5061

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Calibration Data for Sonic (Mod Configuration)

- T17 – Sonic Mod 3 Temp & BTU/hr Map
- Standard 2D temperature map using 11 TC rake
- Standard TC calibration taken at level 4.5 with average = 2021°F (see previous slide)

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Burner Map

Test	Date/Time
Sonic ModV3 Burn6 Map	18/07/2018 11:24:19.245 AM

Burner Map looking into the Burner [°F] - Max Values

	TC 1	TC 2	TC 3	TC 4	TC 5	TC 6	TC 7	TC 8	TC 9	TC 10	TC 11	AVERAGE Central 7 TC's
Level 7	1683.8	1862.8	1978.6	2081.6	2133.9	2109.8	2095.5	2035.7	1944.0	1863.1	1440.5	2054.1
Level 6	1700.1	1877.5	2000.2	2102.2	2155.9	2117.2	2102.5	2037.8	1952.8	1877.0	1483.3	2067.0
Level 5	1712.1	1891.9	2017.1	2130.0	2165.6	2119.8	2100.2	2013.8	1959.8	1900.7	1547.1	2072.3
Level 4	1538.4	1812.3	1959.0	2048.1	2097.2	2039.2	1993.1	1919.9	1900.3	1895.3	1528.7	1993.8
Level 3	1334.5	1710.1	1829.8	1842.4	1803.3	1768.5	1745.8	1719.7	1764.5	1804.1	1411.7	1782.0
Level 2	1013.8	1502.0	1579.5	1393.4	1269.1	1288.7	1317.0	1326.3	1421.0	1476.2	1087.0	1370.7
Level 1	584.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Burner Map looking into the Burner [°F] - Average Values

	TC 1	TC 2	TC 3	TC 4	TC 5	TC 6	TC 7	TC 8	TC 9	TC 10	TC 11	AVERAGE Central 7 TC's
Level 7	1572.8	1793.3	1905.4	1971.3	2000.1	1986.5	1961.3	1908.9	1862.6	1779.8	1376.2	1942.3
Level 6	1627.8	1848.7	1970.4	2069.5	2121.6	2104.0	2092.3	2024.9	1940.8	1812.4	1403.7	2046.2
Level 5	1679.5	1866.4	1993.1	2107.2	2155.1	2109.1	2083.3	1999.7	1931.8	1860.4	1485.1	2054.2
Level 4	1500.0	1782.7	1929.1	2020.2	2052.6	1997.8	1959.1	1876.4	1861.9	1855.0	1474.5	1956.7
Level 3	1260.9	1665.3	1791.6	1777.7	1746.0	1697.7	1703.9	1666.7	1716.8	1748.6	1344.3	1728.6
Level 2	937.4	1424.6	1529.3	1361.3	1229.1	1203.3	1274.3	1266.0	1349.2	1385.2	1018.3	1316.1
Level 1	542.2	886.5	1004.9	860.9	725.7	673.2	773.7	775.8	792.4	769.2	533.2	800.9

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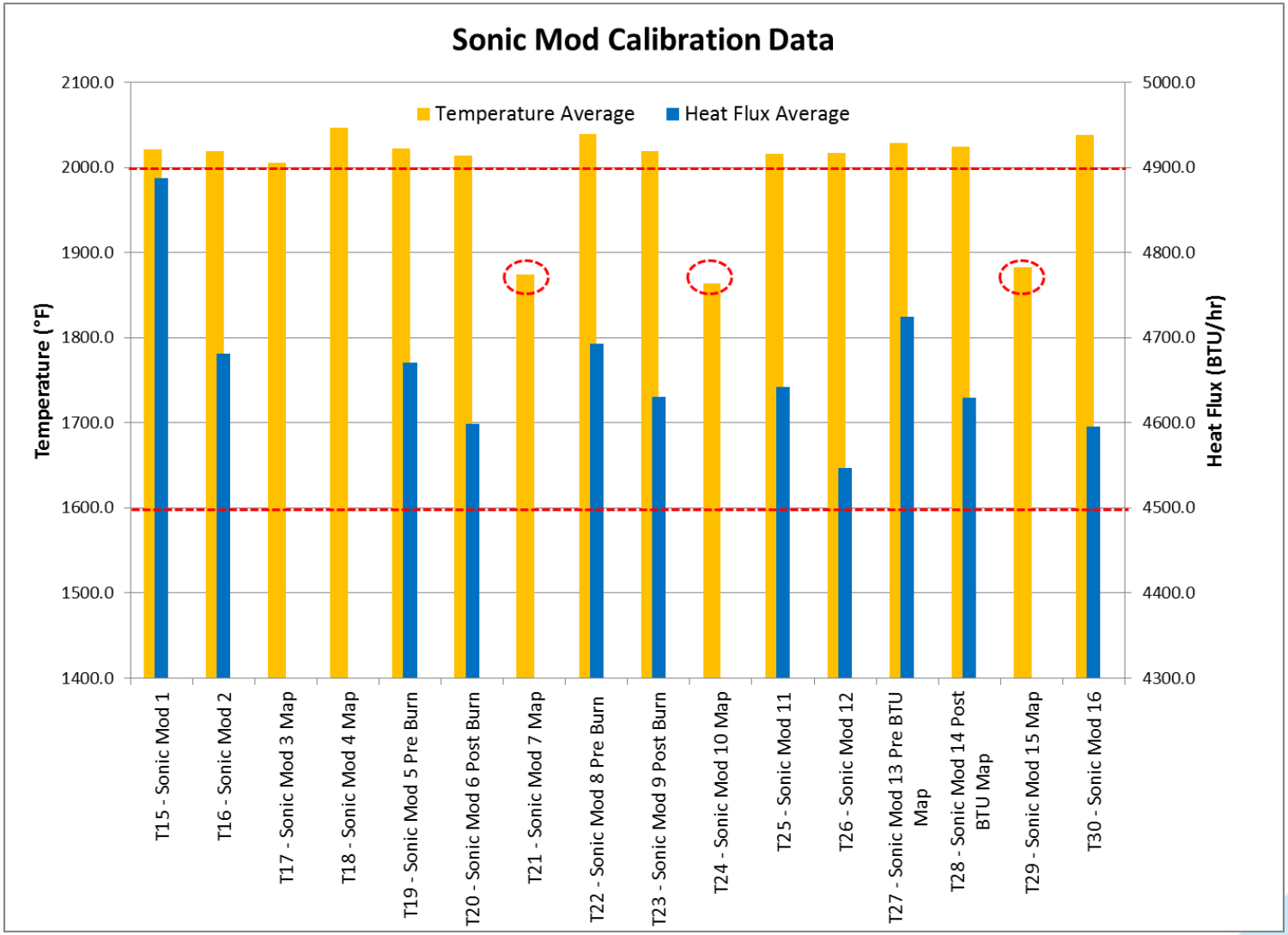
Summary of Sonic Mod Calibration Data



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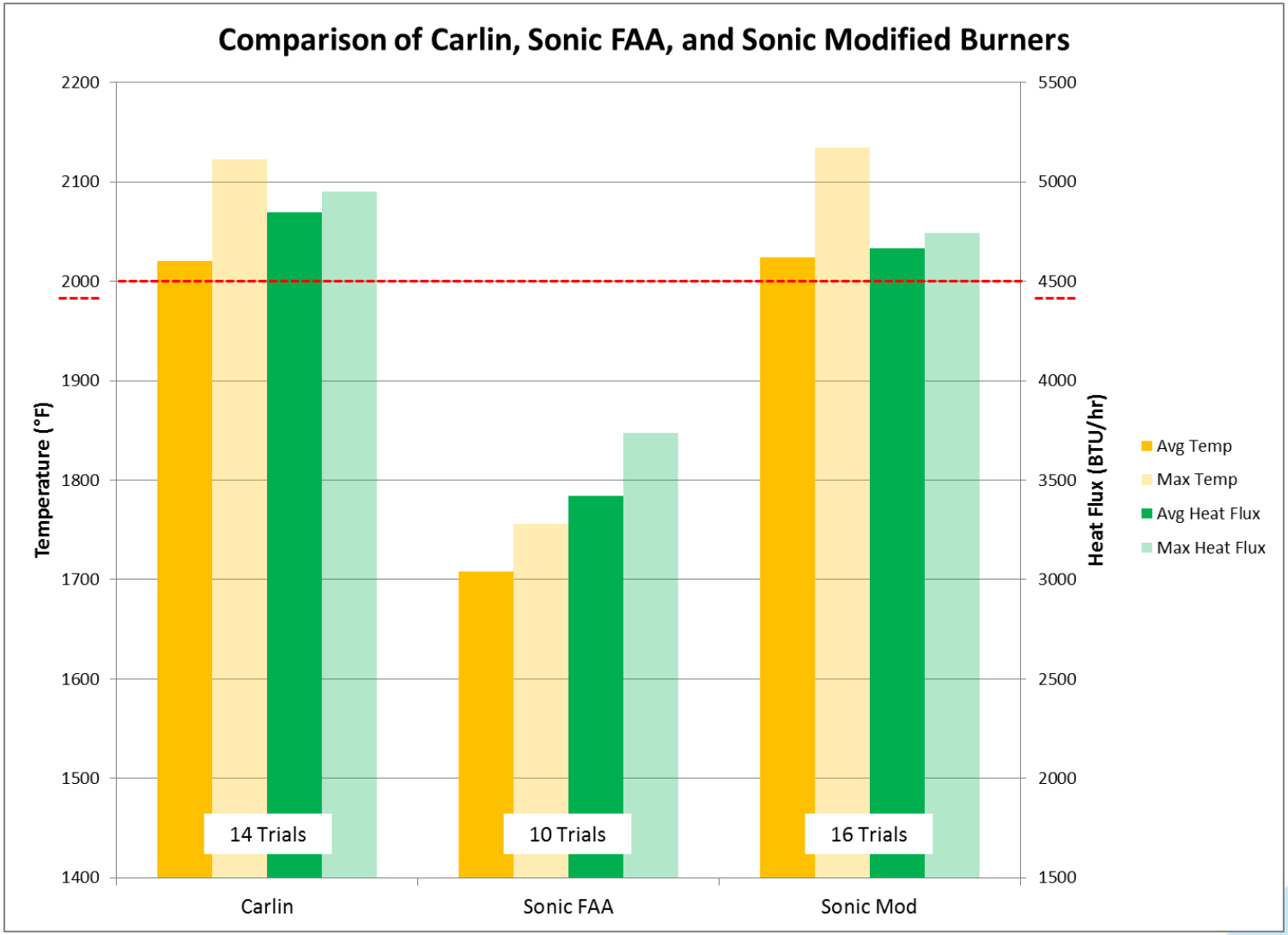
Summary of All Burner Calibration Data



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ALUMINIUM PANEL BURNTHROUGH DATA

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Burnthrough Data for Carlin

- Carlin panel burnthrough #1 (1/8 inch thick 2024-T3 ALCLAD AMS QQ-A-250/5)
- T9 - Carlin Panel 3 (**2:23 second burnthrough time**)

Carlin Burn1 Panel - pre	T9 - Carlin 3 pre burn	2033.5	2122.7	4922.4	5015.2	39
Carlin Burn1 Panel - post	T10 - Carlin 4 post burn	2035.4	2124.4	4875.0	4972.4	41

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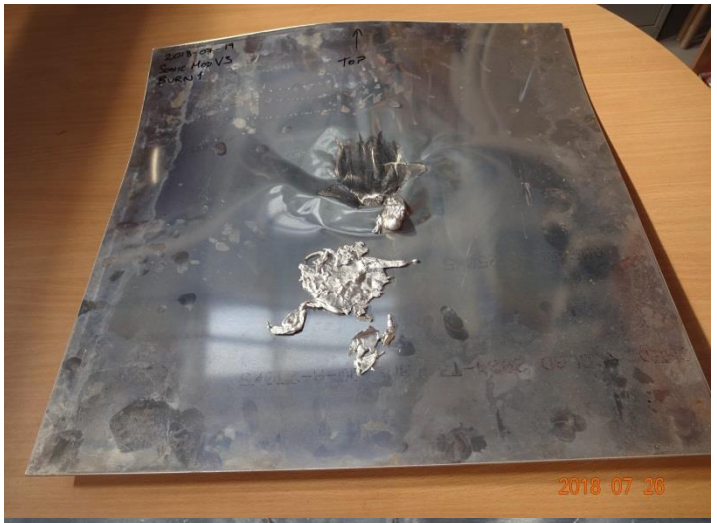
Sonic Mod Burnthrough

- Sonic Mod burnthrough #1 (1/8 inch thick 2024-T3 ALCLAD AMS QQ-A-250/5)
- T19 - Sonic Mod 5 (**3:16 second burnthrough time**)



Sonic ModV3 Burn1 Panel PRE	T19 - Sonic Mod 5 Pre Burn	2022.0	2130.9	4670.1	4759.2	0	88.999
Sonic ModV3 Burn1 Panel POST	T20 - Sonic Mod 6 Post Burn	2013.8	2118.9	4598.8	4664.6	0	105

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Sonic Mod Burnthrough

- Sonic Mod burnthrough #2 (1/8 inch thick 2024-T3 ALCLAD AMS QQ-A-250/5)
- T22 - Sonic Mod 8 (**3:14 second burnthrough time**)

Sonic ModV3 Burn2 Panel PRE	T22 - Sonic Mod 8 Pre Burn	2039.9	2141.2	4693.3	4786.6	0	93.003
Sonic ModV3 Burn2 Panel POST	T23 - Sonic Mod 9 Post Burn	2019.2	2128.7	4630.2	4746.8	0	155

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Sonic Mod Burnthrough

- Sonic Mod burnthrough #3 (1/8 inch thick 2024-T3 ALCLAD AMS QQ-A-250/5)
- T30 - Sonic Mod 16 (**2:10 second burnthrough time**)

Sonic ModV3 Burn4 BTU Map PRE	T27 - Sonic Mod 13 Pre BTU Map	2029.1	2144.3	4724.2	4734.0	0.0	109.0
Sonic ModV3 Burn4 BTU Map POST	T28 - Sonic Mod 14 Post BTU Map	2024.4	2130.4	4629.9	4638.8	0.0	153.0

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Burn Times for 1/8 in. Thick Aluminum

Burn #	Burner / Config.	Pre-Test Avg. Temp. (°F)	Pre-Test Avg. Heat Flux (BTU/hr)	Post-Test Avg. Temp. (°F)	Post-Test Avg. Heat Flux (BTU/hr)	Burn - Through Time (m:ss)
1 – T9	Carlin Baseline July 17	2033	4922 0:39 to 4500	2035	4875 0:41 to 4500	2:23
2 – T19	Sonic Mod. P_f=147, P_a=61.5 July 19	2022	4670 1:29 to 4500	2014	4599 1:45 to 4500	3:16
3 – T22	Sonic Mod. P_f=147, P_a=61.5 July 19	2040	4693 1:33 to 4500	2019	4630 2:35 to 4500	3:14
4 – T30	Sonic Mod. P_f=147, P_a=61.5 July 20	2039	4685 2:13 to 4500	2030	4662 2:42 to 4500	2:10

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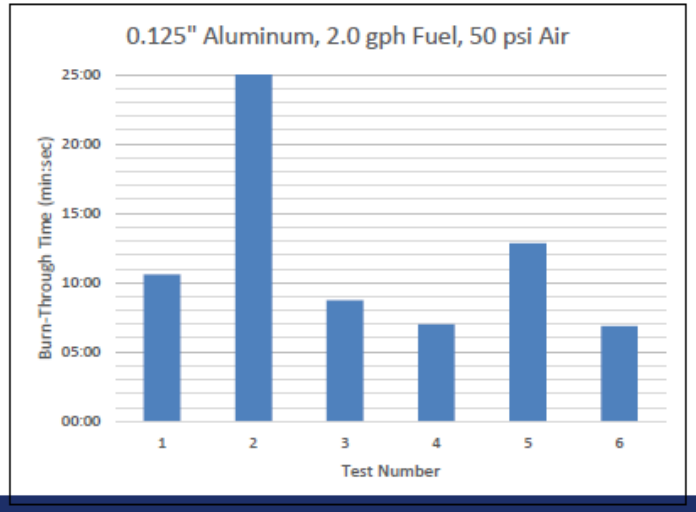
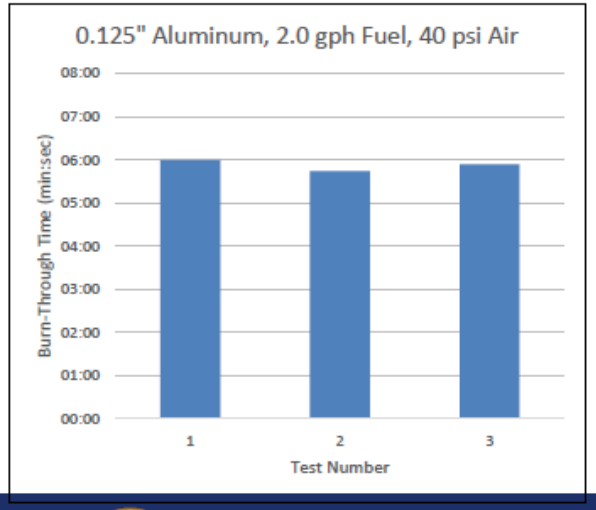
Next Generation Fire Test Burner For Powerplant Fire Testing Applications – Summer, Rehn, Nov17

Aluminum Tests

- 0.125” 2024-T3 Aluminum
- No repeatability with 50 psi air pressure
- Very repeatable with 40 psi air pressure





Powerplants Fire Test Development
November 1, 2017

Federal Aviation Administration

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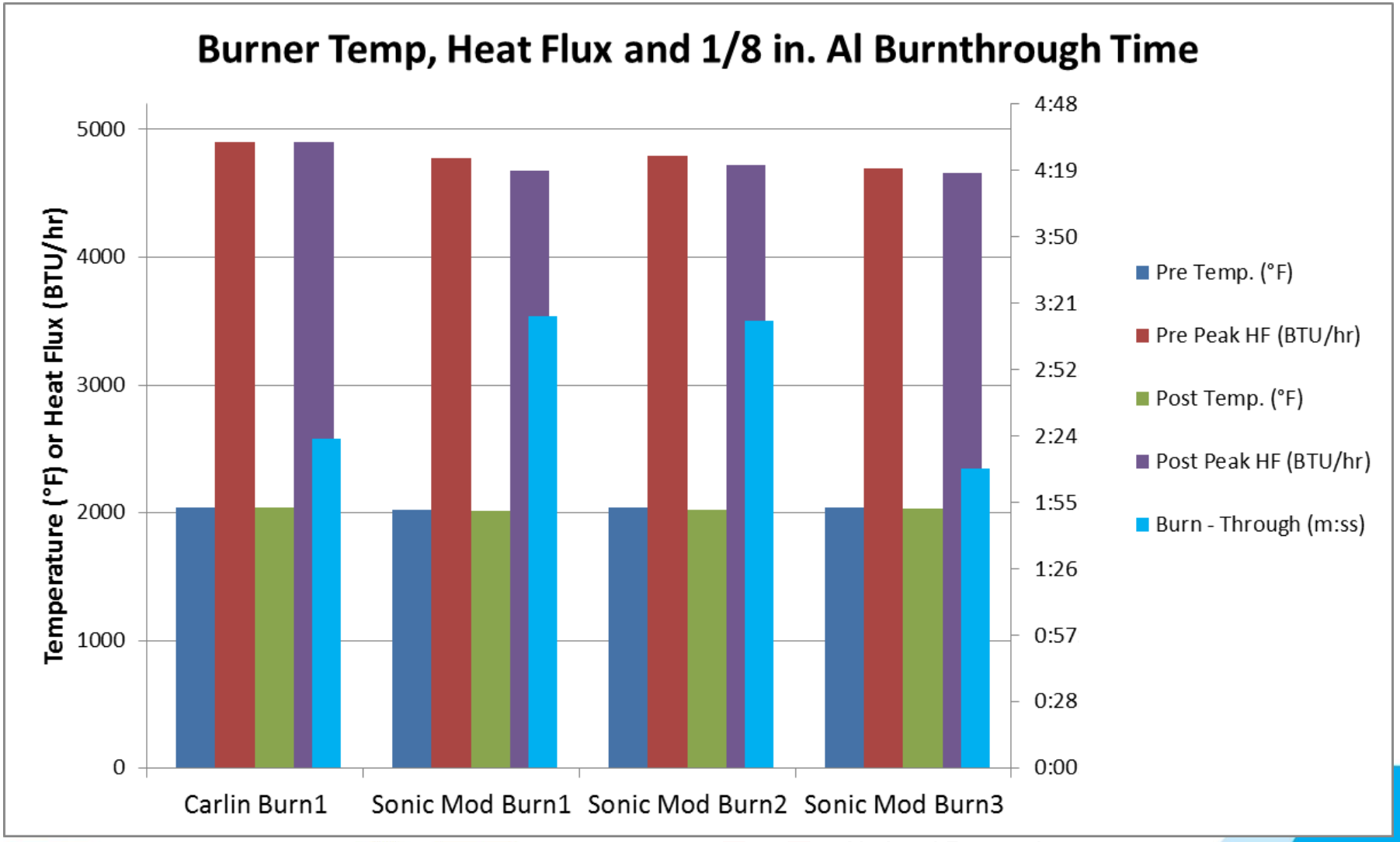
Summary of Burnthrough Times



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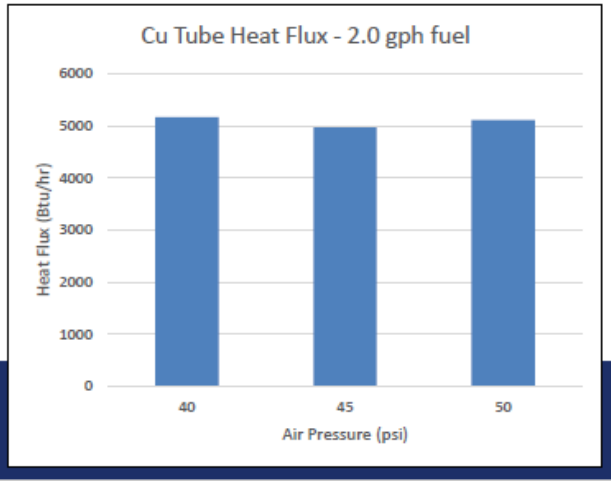
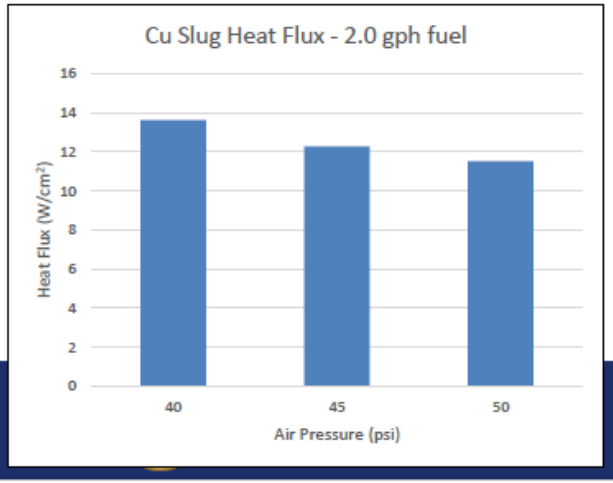
Next Generation Fire Test Burner For Powerplant Fire Testing Applications – Summer, Rehn, Nov17

Air Pressure Comparison

- 50 psi air had highest temperatures in previous testing
- Copper tube heat flux was relatively constant
- 40 psi air had highest copper slug heat flux
- Copper slug correlated best to aluminum burn-through times





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NOVEL MAPPING TECHNIQUES

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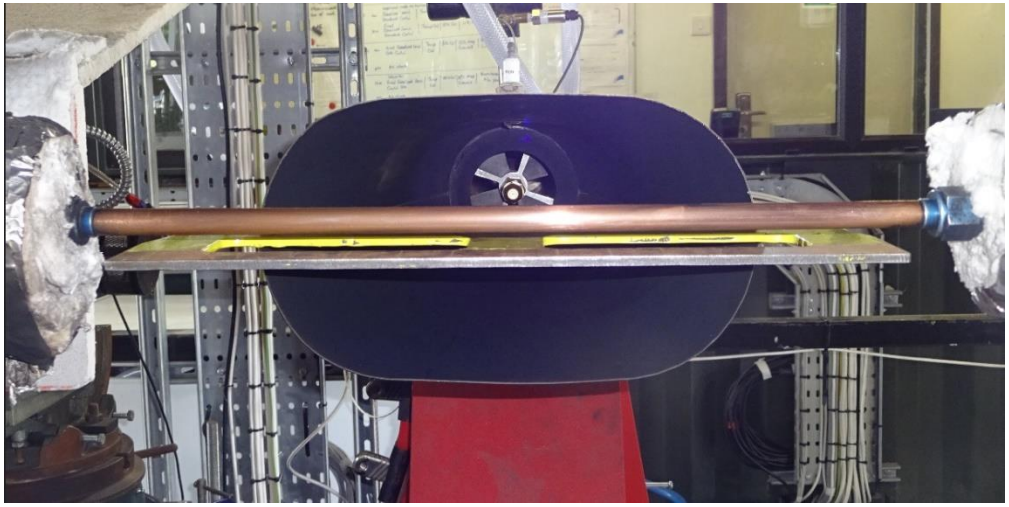
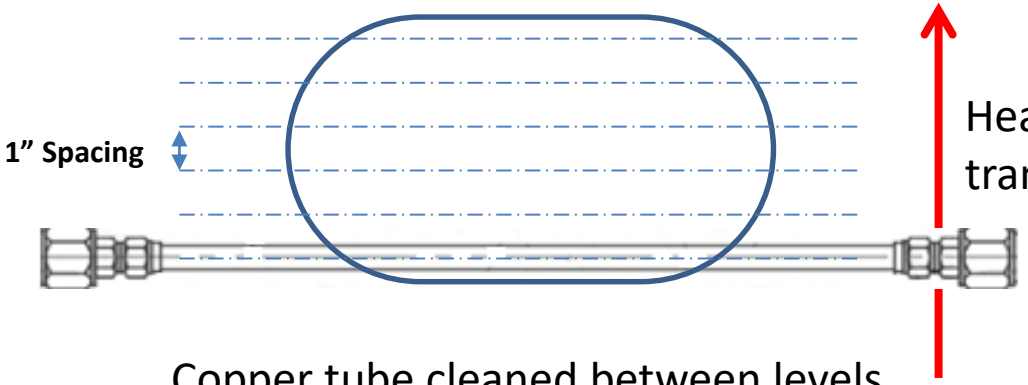
Heat Flux (BTU/hr) Map – 1” vertical Increments



Burner BTU Map looking into the Burner [BTU/hr] - Average Values

Level 6 - 5.5 inch	3448.3
Level 5 - 4.5 inch	4452.0
Level 4 - 3.5 inch	4733.5
Level 3 - 2.5 inch	3833.7
Level 2 - 1.5 inch	2211.4
Level 1 - 0.5 inch	800.6

At each level : 1mins warm up was allowed and 3 mins of data recorded after this



Heat flux Mapping: Copper tube transitioned in 1” increments vertically

Copper tube cleaned between levels

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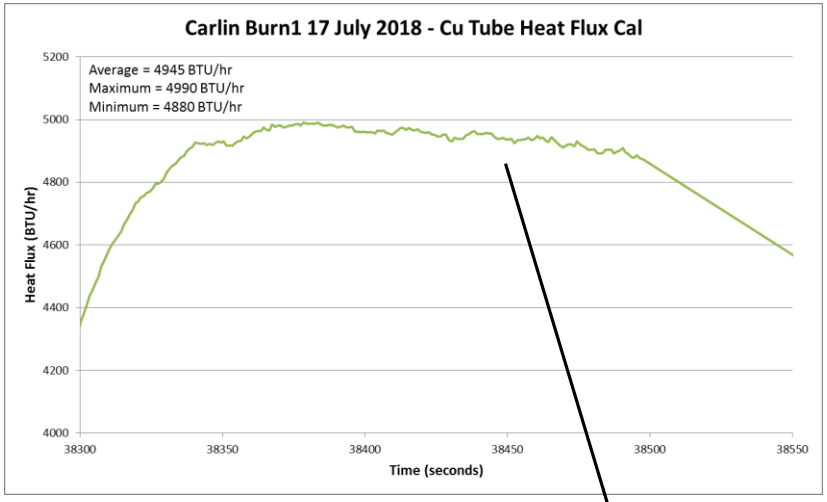
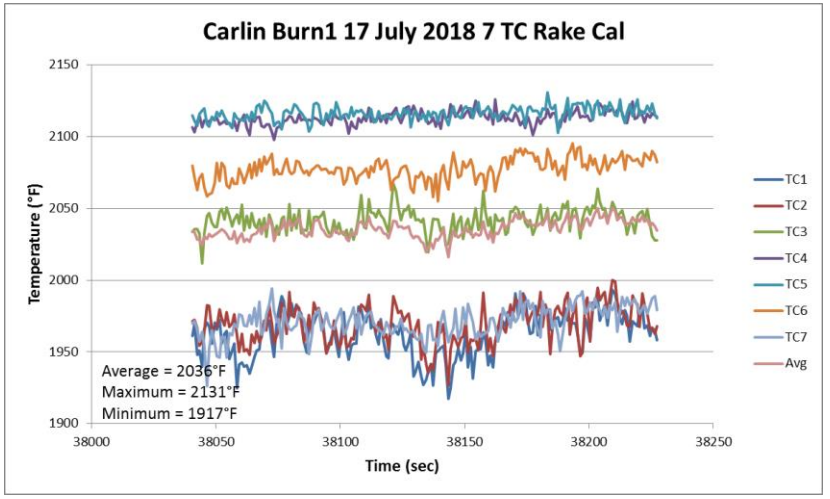
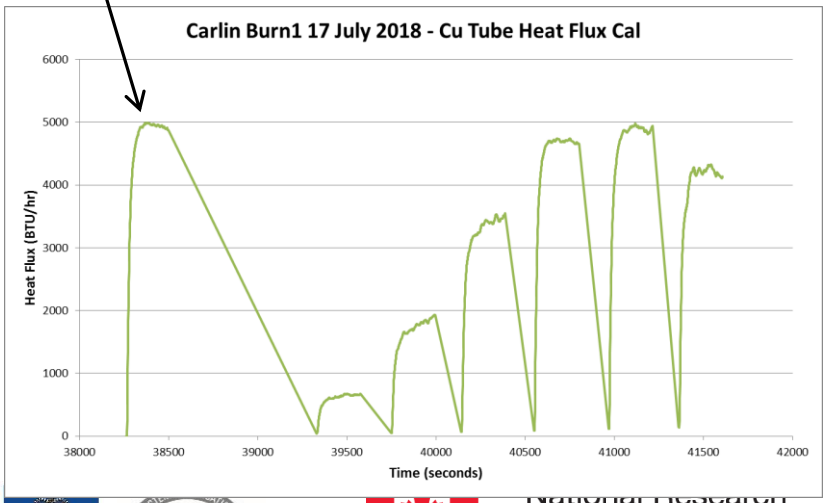
BTU/hr Mapping Technique (T8 - Carlin 2)







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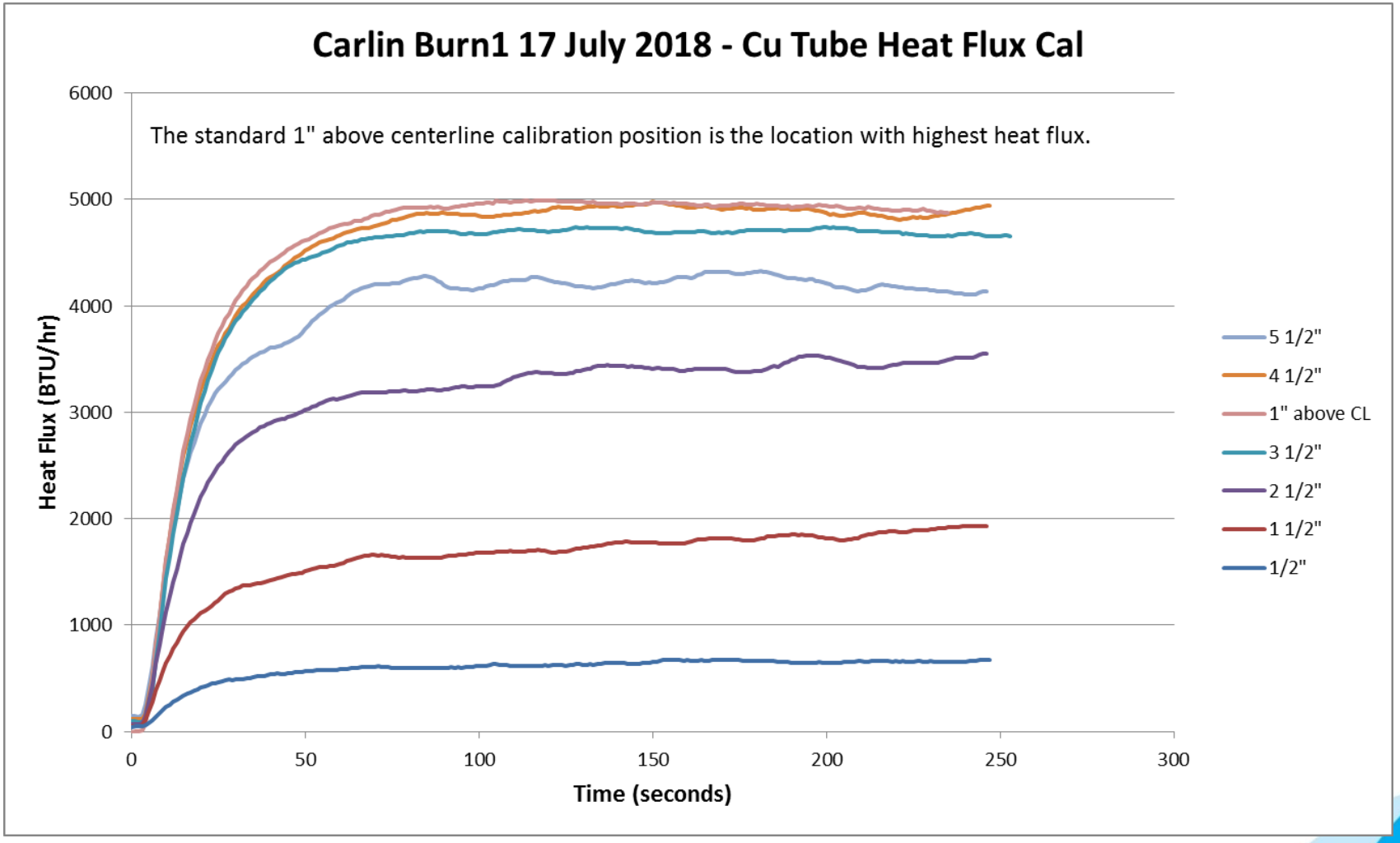
BTU/hr Mapping Technique (T8 - Carlin 2)



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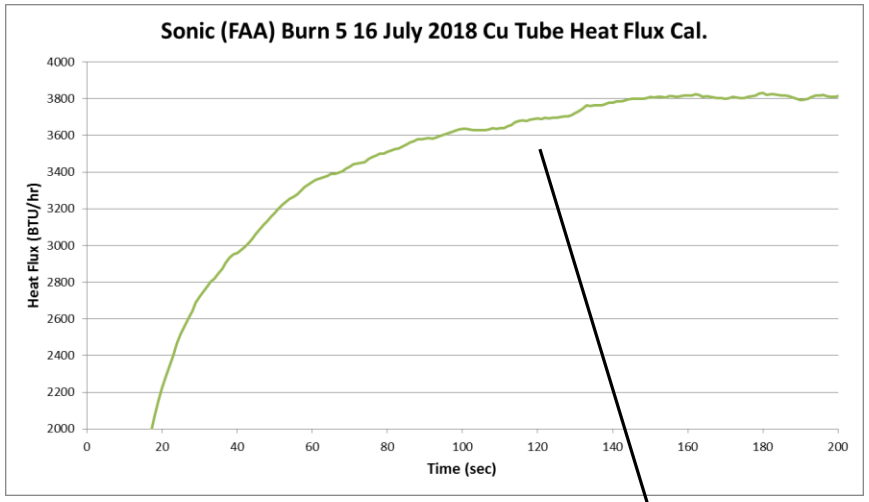
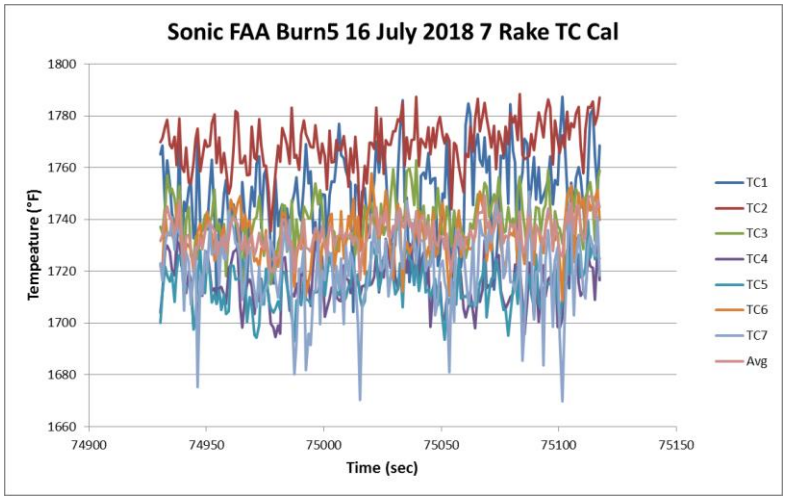
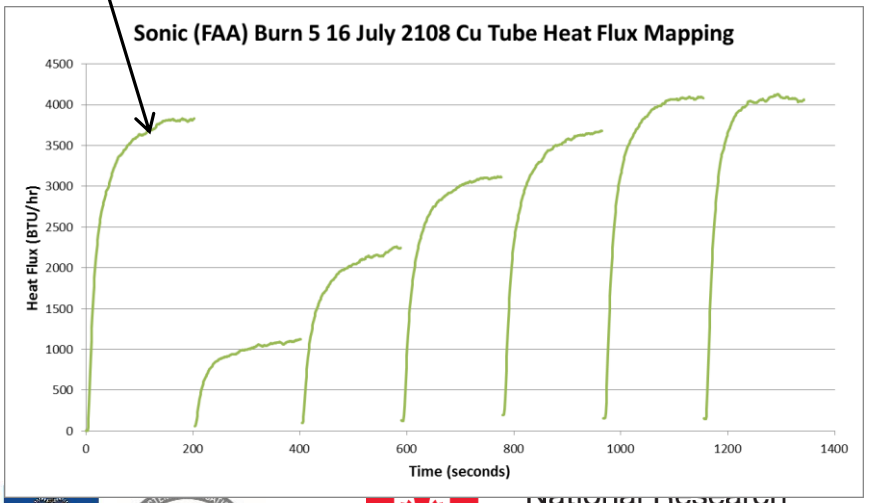
BTU/hr Mapping Technique (T7 – Sonic FAA 6)







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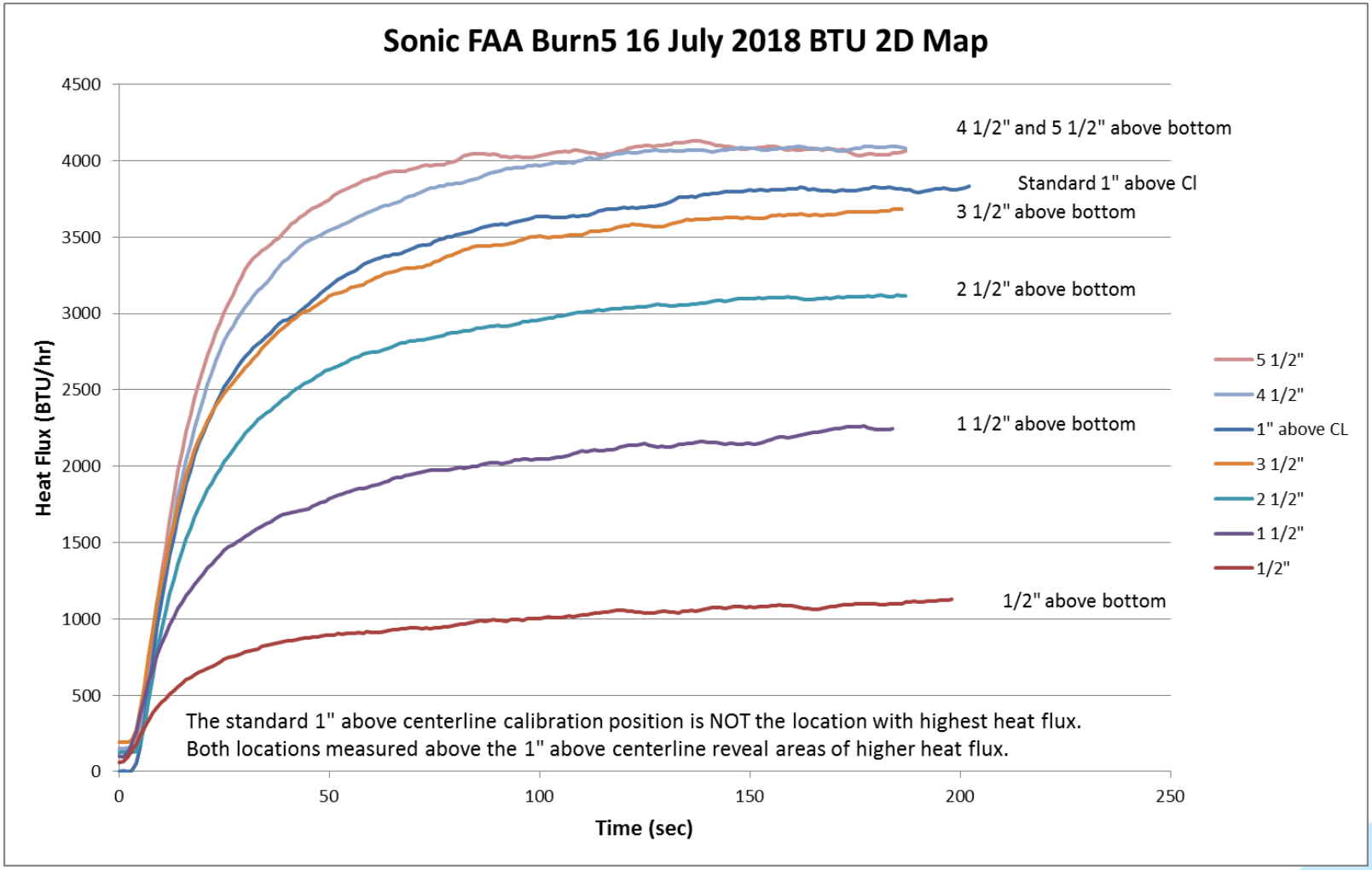
BTU/hr Mapping Technique (T7 – Sonic FAA 6)



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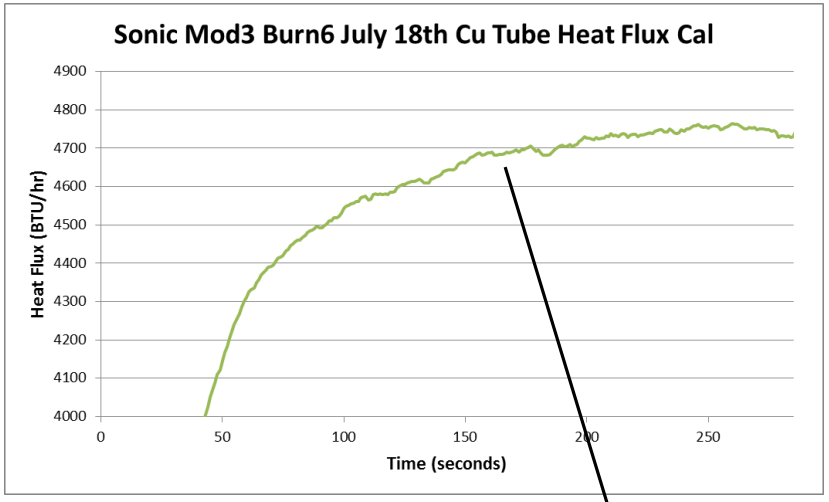
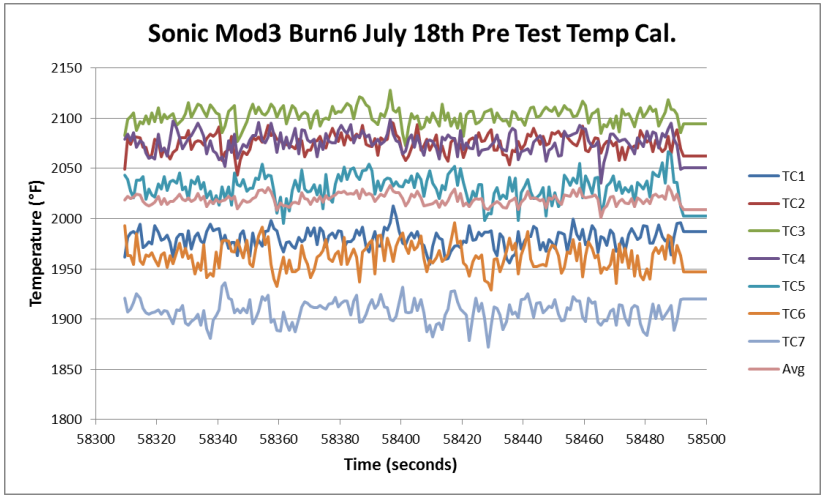
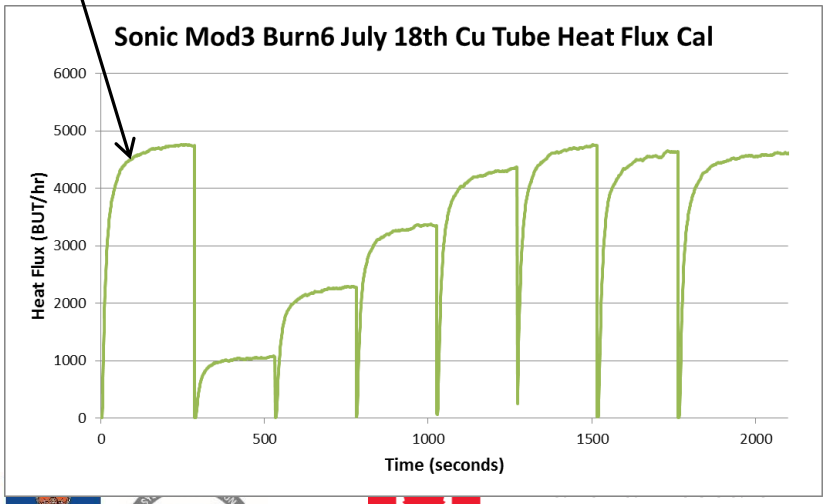
BTU/hr Mapping Technique (T17 – Sonic Mod 3)







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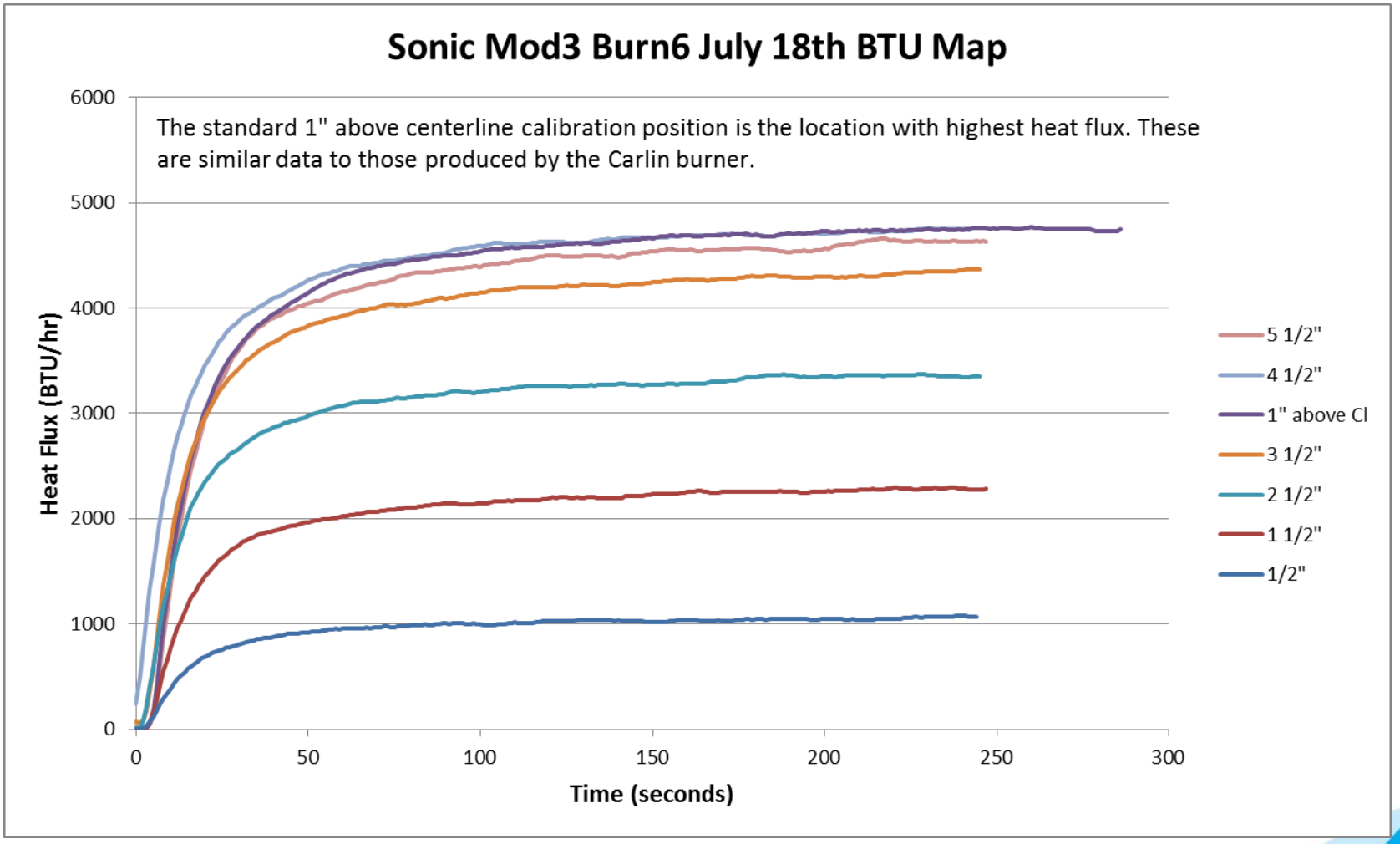
BTU/hr Mapping Technique (T17 – Sonic Mod 3)



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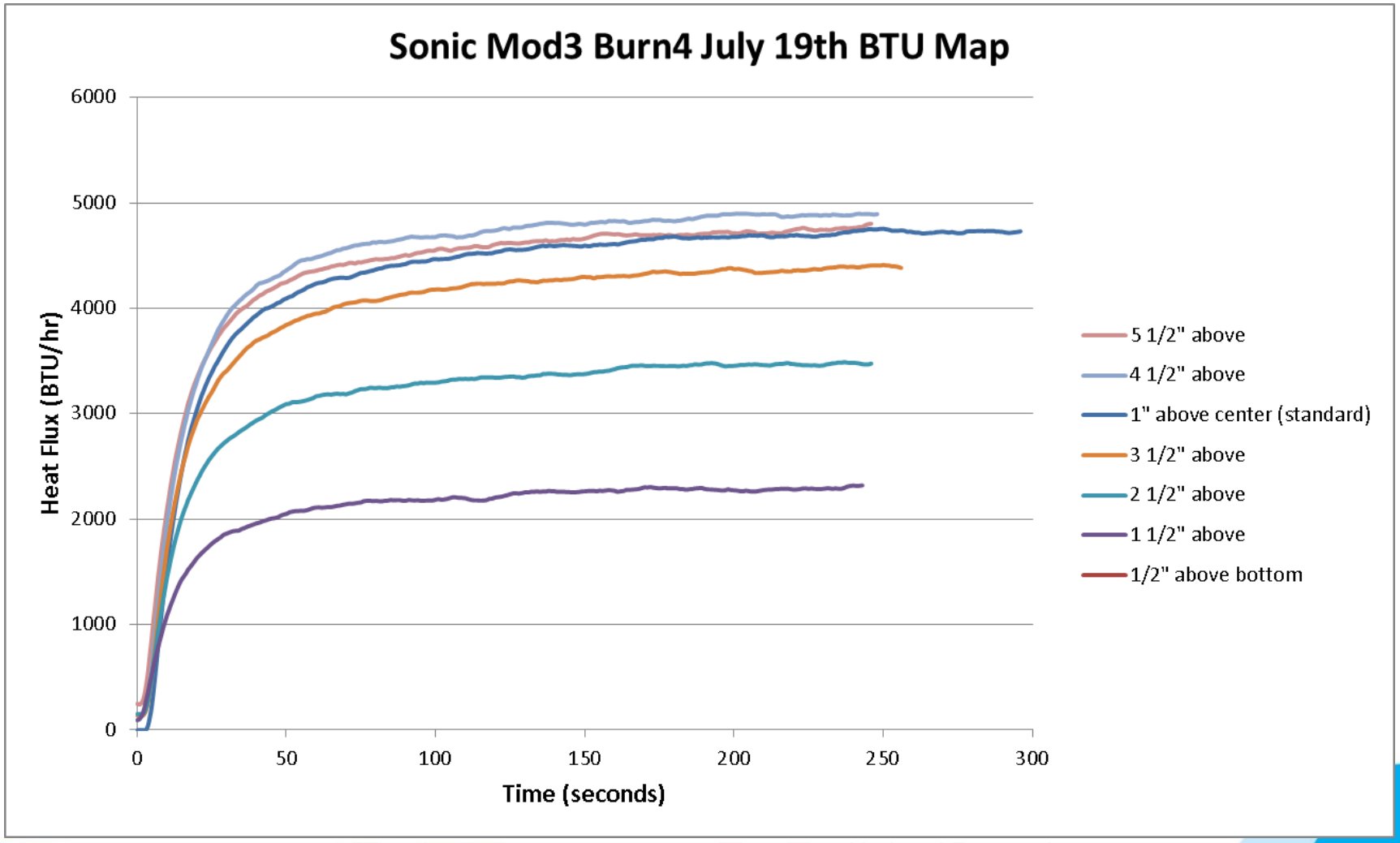
BTU/hr Mapping Technique (T27 – Sonic Mod 3)



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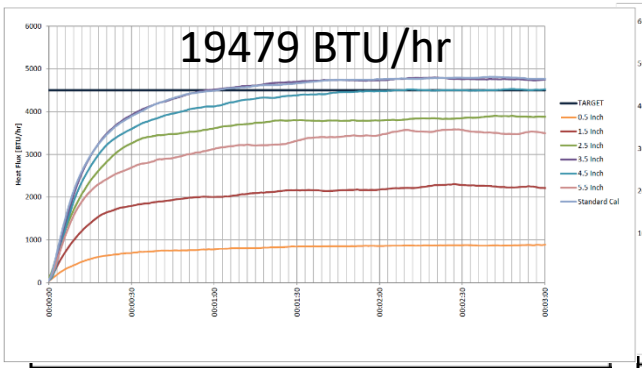
BTU/hr Mapping Summary

T8 - Carlin 2



Carlin Burn 2b BTU Map

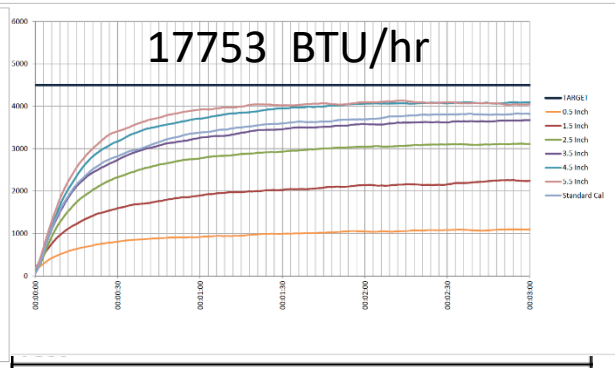
Burner BTU Map looking into the Burner [BTU/hr] - Peak Values

Level 6 - 5.5 inch	3585.2
Level 5 - 4.5 inch	4530.0
Level 4 - 3.5 inch	4800.1
Level 3 - 2.5 inch	3901.3
Level 2 - 1.5 inch	2304.1
Level 1 - 0.5 inch	885.9

Burner BTU Map looking into the Burner [BTU/hr] - Average Values

Level 6 - 5.5 inch	3448.3
Level 5 - 4.5 inch	4452.0
Level 4 - 3.5 inch	4733.5
Level 3 - 2.5 inch	3833.7
Level 2 - 1.5 inch	2211.4
Level 1 - 0.5 inch	800.6

T7 – Sonic FAA 6



Sonic - FAA Burn 5 BTUmap

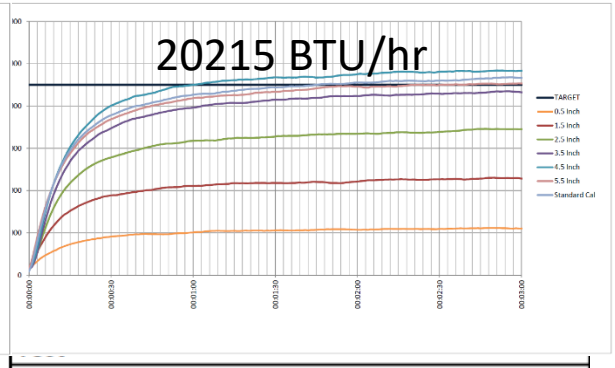
Burner BTU Map looking into the Burner [BTU/hr] - Peak Values

Level 6 - 5.5 inch	4131.9
Level 5 - 4.5 inch	4095.4
Level 4 - 3.5 inch	3673.6
Level 3 - 2.5 inch	3119.1
Level 2 - 1.5 inch	2260.9
Level 1 - 0.5 inch	1098.4

Burner BTU Map looking into the Burner [BTU/hr] - Average Values

Level 6 - 5.5 inch	4052.6
Level 5 - 4.5 inch	4001.0
Level 4 - 3.5 inch	3541.2
Level 3 - 2.5 inch	3011.6
Level 2 - 1.5 inch	2106.9
Level 1 - 0.5 inch	1040.0

T27 – Sonic Mod 3



Sonic ModV3 Burn4 BTU Map

Burner BTU Map looking into the Burner [BTU/hr] - Peak Values

Level 6 - 5.5 inch	4536.6
Level 5 - 4.5 inch	4841.0
Level 4 - 3.5 inch	4350.6
Level 3 - 2.5 inch	3459.5
Level 2 - 1.5 inch	2304.6
Level 1 - 0.5 inch	1115.4

Burner BTU Map looking into the Burner [BTU/hr] - Average Values

Level 6 - 5.5 inch	4462.6
Level 5 - 4.5 inch	4778.4
Level 4 - 3.5 inch	4261.2
Level 3 - 2.5 inch	3380.5
Level 2 - 1.5 inch	2242.3
Level 1 - 0.5 inch	1090.3

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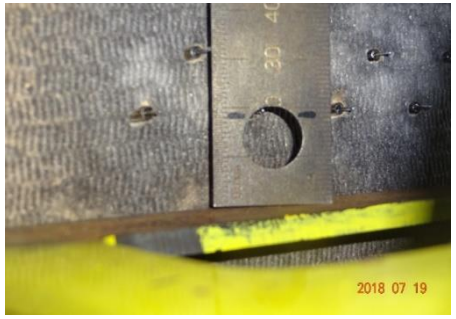
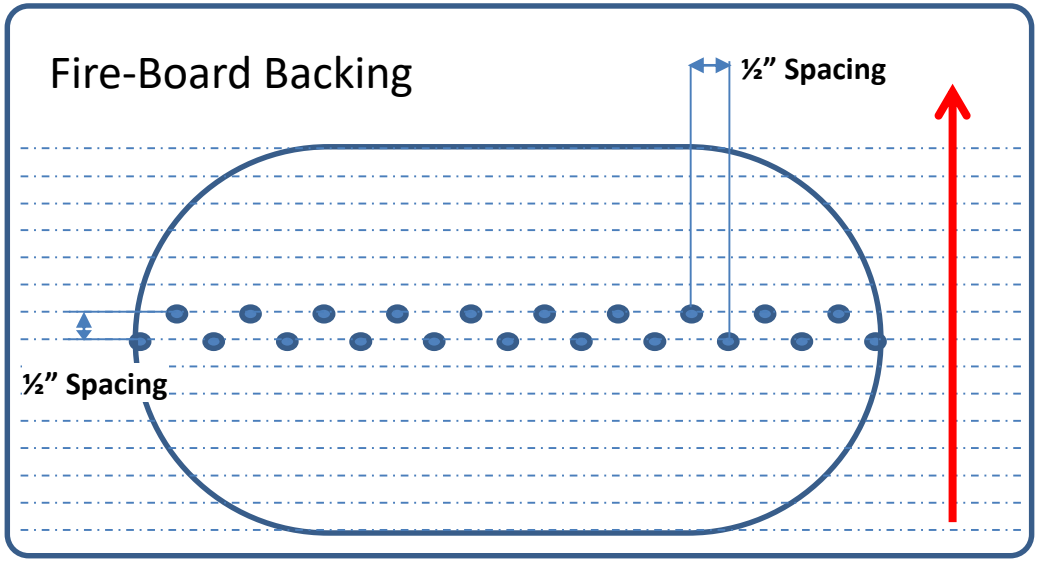
21 TC Map – ½” vertical Increments & ½” TC spacing offset





Higher Definition Mapping:

- 2 lines of thermocouples transitioned in ½” increments vertically
- TC’s orientated Horizontally
- Brand New TC’s used (Never burned)

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HD Temp Mapping (T18 Sonic Mod 4)

Test		Date/Time
Sonic Modv3 MAP Burn1		19/07/2018 09:47:41.478 AM

Burner Map looking into the Burner [°F] - Max Values

	TC 1	TC 2	TC 3	TC 4	TC 5	TC 6	TC 7	TC 8	TC 9	TC 10	TC 11	AVERAGE Central 7 TC's
Level 11	1759.3	1909.0	2034.8	2130.5	2172.5	2133.8	2103.1	2042.0	1960.9	1895.5	1492.3	2082.5
Level 10	1774.3	1936.6	2050.1	2141.4	2186.4	2149.2	2109.3	2043.1	1959.7	1913.6	1574.6	2091.3
Level 9	1757.5	1935.4	2050.9	2149.0	2194.1	2146.6	2106.5	2022.8	1955.4	1916.5	1624.2	2089.3
Level 8	1712.0	1915.2	2039.1	2136.1	2181.5	2117.8	2079.3	1982.3	1923.3	1910.9	1591.7	2065.6
Level 7	1615.1	1867.4	1991.1	2071.1	2105.5	2030.2	1975.2	1910.7	1906.3	1891.8	1549.1	1998.6
Level 6	1493.1	1815.4	1938.5	1989.3	2007.1	1920.0	1883.9	1833.6	1829.4	1874.6	1562.6	1914.5
Level 5	1434.5	1783.8	1870.2	1840.2	1822.7	1770.1	1810.9	1743.5	1774.9	1795.2	1394.2	1804.6
Level 4	1301.5	1716.7	1744.9	1615.7	1599.0	1541.2	1588.6	1612.9	1638.3	1668.9	1247.5	1620.1
Level 3	1142.6	1567.2	1620.2	1422.0	1314.1	1296.3	1334.4	1367.1	1444.2	1441.9	1029.2	1399.8
Level 2	955.7	1323.0	1398.6	1191.5	1063.1	1030.8	1090.7	1104.9	1175.4	1128.6	769.7	1150.7
Level 1	679.9	1010.0	1043.2	911.5	788.1	746.9	836.9	829.0	838.5	761.0	531.0	856.3

- 2D HD temperature map using 11 TC rake with ½” increments
- No fire board behind
- Sonic ModV3 Burn1 Map 19 July 2018
- Level 8 is 1” above burner exit cone C_L = 2066°F avg.

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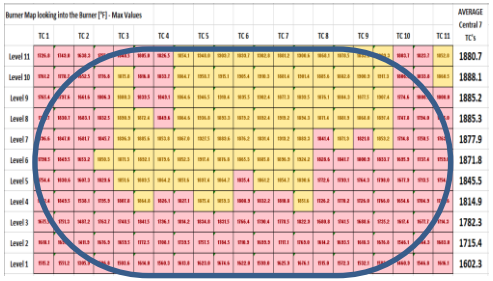
HD Temp Mapping with Impingement (T21 Sonic Mod 7)

- 2D HD temperature map using 21 TC rake and ½” increments
- Fire Board behind
- Sonic ModV3 Burn2 Map 19 July 2018
- Level 8 (top) is 1” above burner exit cone C_L = 1874°F avg.
- Why low?



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Burner Map

Test	Date/Time
Sonic ModV3 MAP Burn 2	19/07/2018 02:30:40.501 PM

Burner Map looking into the Burner [°F] - Average Values

	TC 1	TC 2	TC 3	TC 4	TC 5	TC 6	TC 7	TC 8	TC 9	TC 10	TC 11	AVERAGE Central 7 TC's
		1740.0	1744.5	1797.2	1843.8	1901.1	1895.1	1886.6	1863.6	1898.8	1815.2	1864.6
Level 11	1712.0	1619.6	1843.9	1819.5	1942.9	1892.5	1872.2	1862.6	1886.1	1793.1	1838.3	1874.3
		1761.6	1763.1	1808.4	1856.6	1901.3	1896.0	1891.4	1875.0	1905.8	1813.9	1871.4
Level 10	1739.3	1640.9	1860.9	1828.4	1943.6	1889.4	1874.7	1875.8	1887.0	1786.0	1824.9	1880.0
		1782.5	1788.0	1821.5	1850.4	1899.3	1895.6	1892.2	1876.9	1895.6	1791.6	1872.6
Level 9	1753.9	1653.6	1871.2	1838.7	1933.4	1881.1	1870.5	1869.0	1867.9	1755.6	1789.0	1876.0
		1811.5	1816.3	1841.4	1856.3	1885.4	1884.4	1887.0	1874.0	1883.4	1774.4	1871.4
Level 8	1774.5	1668.8	1883.4	1842.0	1925.1	1871.4	1896.1	1849.4	1848.9	1732.8	1768.8	1873.8
		1824.9	1825.2	1869.9	1847.6	1877.4	1877.5	1883.4	1855.7	1845.6	1735.2	1868.6
Level 7	1774.4	1655.7	1874.9	1839.8	1909.5	1862.4	1907.8	1830.4	1814.1	1695.6	1751.9	1862.7
		1834.5	1831.6	1875.2	1836.5	1865.0	1865.3	1901.0	1828.0	1816.2	1718.9	1861.8
Level 6	1767.2	1634.2	1861.8	1856.9	1902.1	1847.4	1880.6	1803.2	1780.2	1678.1	1747.8	1847.5
		1816.1	1817.7	1877.4	1832.9	1854.8	1848.5	1878.4	1788.3	1780.6	1703.8	1846.7
Level 5	1737.8	1589.0	1834.3	1847.4	1882.0	1826.2	1841.6	1760.8	1749.7	1665.7	1748.1	1820.3
		1778.7	1785.5	1852.7	1812.3	1843.3	1809.3	1837.5	1750.4	1750.5	1694.0	1817.6
Level 4	1691.4	1523.8	1784.2	1809.6	1851.9	1793.7	1794.4	1705.8	1707.1	1640.9	1734.6	1778.1
		1725.3	1726.4	1806.9	1774.6	1807.9	1754.2	1801.2	1725.8	1723.1	1664.0	1778.4
Level 3	1647.7	1459.0	1711.1	1756.7	1800.3	1748.1	1756.3	1665.0	1677.1	1598.3	1702.6	1730.6
		1671.1	1660.1	1753.7	1713.6	1751.8	1667.2	1726.0	1641.8	1656.9	1616.9	1709.0
Level 2	1600.9	1390.8	1634.5	1691.4	1728.4	1693.9	1685.2	1577.9	1599.5	1532.0	1666.2	1658.7
		1535.4	1496.5	1600.2	1577.2	1644.8	1554.1	1627.0	1541.3	1553.3	1516.9	1590.8
Level 1	1499.5	1290.6	1491.3	1544.6	1594.0	1588.1	1588.4	1473.6	1500.9	1414.9	1577.2	1540.1

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HD Temp Mapping with Impingement (T24 Sonic Mod 10)

- Innovative 2D HD temperature map using 21 TC rake located in impingement board
- Sonic ModV3 Burn3 Map 19 July 2018
- Level 8 (top) is 1” above burner exit cone C_L = 1864°F avg.

Burner Map

Test		Date/Time
Sonic Modv3 MAP Burn3		19/07/2018 11:28:58.206 AM

Burner Map looking into the Burner [°F] - Average Values

	TC 1	TC 2	TC 3	TC 4	TC 5	TC 6	TC 7	TC 8	TC 9	TC 10	TC 11	AVERAGE Central 7 TC's
		1738.8	1749.4	1864.8	1869.7	1912.5	1923.7	1946.2	1907.7	1905.4	1815.5	1904.1
Level 11	1711.3	1666.6	1837.7	1891.0	1933.3	1885.0	1948.9	1898.2	1899.3	1782.6	1798.3	1899.0
		1766.4	1777.8	1868.8	1876.3	1905.6	1923.6	1949.6	1906.9	1891.5	1787.4	1905.1
Level 10	1738.2	1685.6	1850.6	1896.1	1925.1	1880.4	1948.0	1886.7	1876.5	1746.2	1766.7	1894.7
		1797.2	1805.4	1873.2	1870.0	1893.0	1916.2	1948.5	1892.5	1861.8	1749.7	1898.9
Level 9	1756.5	1693.4	1858.0	1891.3	1909.0	1871.6	1937.7	1861.4	1843.8	1708.7	1746.7	1881.8
		1806.1	1810.6	1857.1	1858.6	1878.7	1913.3	1933.7	1869.2	1832.5	1730.8	1885.1
Level 8	1758.9	1693.0	1853.3	1876.8	1898.6	1861.6	1917.9	1829.9	1810.4	1690.8	1739.7	1864.1
		1808.8	1811.2	1847.6	1849.4	1865.6	1897.9	1912.5	1832.6	1794.2	1709.0	1867.6
Level 7	1737.8	1672.3	1836.9	1863.1	1880.0	1838.8	1884.0	1778.4	1764.4	1664.4	1733.2	1835.1
		1786.3	1794.2	1823.7	1841.0	1854.8	1881.1	1879.0	1793.1	1761.6	1695.7	1845.5
Level 6	1691.0	1623.1	1792.4	1801.3	1863.1	1816.6	1841.6	1734.2	1730.6	1650.1	1730.0	1797.1
		1748.6	1757.5	1790.2	1819.5	1832.3	1846.6	1833.2	1749.7	1735.0	1694.0	1811.9
Level 5	1644.1	1564.9	1732.6	1733.3	1828.4	1786.7	1790.7	1686.6	1696.1	1632.9	1714.7	1750.6
		1698.2	1703.1	1744.6	1778.7	1797.3	1805.8	1784.2	1714.6	1715.0	1679.8	1770.9
Level 4	1606.2	1514.4	1668.8	1673.9	1780.3	1747.9	1746.8	1649.6	1666.4	1608.1	1698.5	1704.8
		1652.6	1642.6	1692.9	1741.9	1773.4	1778.2	1750.4	1684.2	1686.9	1662.0	1736.8
Level 3	1580.4	1486.0	1616.3	1629.6	1752.5	1717.9	1721.4	1614.4	1637.2	1587.2	1683.8	1669.9
		1600.7	1569.5	1617.0	1676.7	1729.9	1740.2	1697.1	1659.3	1659.9	1640.0	1686.7
Level 2	1545.6	1442.9	1551.6	1559.9	1693.2	1677.9	1666.0	1587.0	1620.2	1568.2	1660.3	1622.2
		1559.1	1510.0	1547.0	1598.6	1678.1	1704.0	1648.5	1621.2	1630.4	1622.3	1632.9
Level 1	1510.3	1411.6	1514.9	1502.4	1641.7	1637.9	1610.4	1552.3	1594.7	1547.0	1616.9	1579.2

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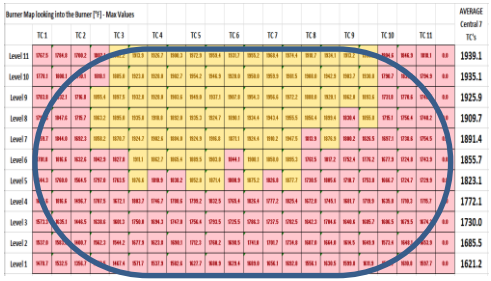
HD Temp Mapping with Impingement (T29 Sonic Mod 15)

- Innovative 2D HD temperature map using 21 TC rake located in impingement board
- Sonic ModV3 Burn1 Map 20 July 2018
- Level 8 (top) is 1” above burner exit cone C_L = 1882°F avg.



Burner Map

Test	Date/Time
Sonic Modv3 MAP Burn1	20/07/2018 05:27:50.186 AM

Burner Map looking into the Burner [°F] - Average Values

	TC 1	TC 2	TC 3	TC 4	TC 5	TC 6	TC 7	TC 8	TC 9	TC 10	TC 11	AVERAGE Central 7 TC's
		1761.4	1775.6	1898.1	1891.4	1946.5	1942.5	1963.8	1924.2	1920.6	1830.4	1927.8
Level 11	1742.8	1678.6	1868.8	1919.0	1960.2	1924.2	1959.6	1906.6	1899.9	1787.3	1791.3	1919.8
		1787.4	1801.8	1907.9	1888.9	1934.7	1934.1	1960.8	1918.1	1898.5	1796.7	1924.1
Level 10	1757.6	1693.2	1876.3	1915.8	1943.6	1907.9	1949.0	1889.0	1872.5	1750.3	1758.5	1907.7
		1811.8	1831.0	1919.8	1886.6	1928.0	1934.6	1957.8	1907.7	1874.1	1758.1	1922.4
Level 9	1771.3	1706.0	1885.5	1914.8	1935.8	1897.5	1943.5	1873.1	1851.1	1719.6	1735.6	1900.2
		1828.2	1844.2	1923.0	1879.3	1915.1	1924.8	1948.9	1890.1	1845.2	1734.7	1913.5
Level 8	1765.9	1699.1	1877.3	1904.0	1921.0	1884.8	1928.1	1844.6	1817.1	1695.6	1734.9	1882.4
		1824.1	1841.9	1914.8	1866.9	1898.1	1913.6	1931.9	1858.2	1808.0	1726.3	1897.2
Level 7	1738.9	1673.8	1855.9	1885.3	1905.4	1862.8	1895.7	1802.3	1779.1	1683.4	1736.2	1855.2
		1790.7	1819.6	1897.3	1850.2	1878.0	1880.5	1878.0	1797.1	1758.3	1715.9	1863.5
Level 6	1679.5	1612.5	1809.2	1850.2	1871.0	1822.4	1838.5	1740.6	1733.4	1667.9	1732.6	1809.3
		1730.4	1766.0	1852.8	1821.7	1853.9	1851.4	1850.2	1771.7	1738.1	1710.2	1833.6
Level 5	1627.0	1542.8	1734.3	1795.6	1839.0	1789.8	1803.4	1705.6	1702.6	1651.8	1720.4	1767.2
		1663.0	1687.6	1796.0	1777.1	1817.9	1801.5	1795.3	1726.8	1711.2	1696.3	1785.8
Level 4	1590.0	1480.3	1651.5	1728.4	1786.8	1747.7	1751.6	1653.3	1667.3	1623.1	1697.2	1712.4
		1618.1	1623.6	1733.8	1728.4	1779.5	1769.1	1765.7	1692.6	1675.7	1665.8	1744.8
Level 3	1557.5	1438.1	1588.3	1670.1	1742.5	1717.2	1723.9	1622.8	1631.4	1586.8	1665.2	1670.9
		1562.1	1531.9	1643.1	1654.3	1720.1	1709.4	1717.2	1651.9	1638.9	1635.4	1682.7
Level 2	1518.1	1392.9	1518.9	1595.9	1678.4	1668.8	1683.2	1586.7	1603.5	1563.0	1638.3	1619.3
		1507.5	1450.0	1547.0	1564.2	1651.1	1651.0	1670.7	1605.7	1591.1	1593.6	1614.9
Level 1	1463.8	1339.5	1453.3	1521.6	1596.3	1609.3	1632.1	1538.8	1567.7	1523.0	1576.6	1559.9

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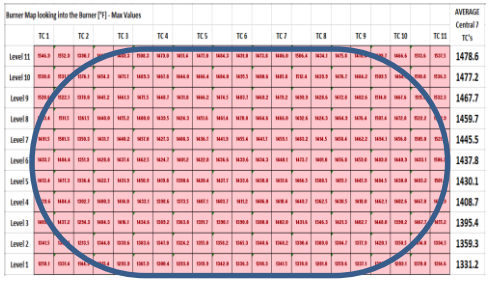
HD Temp Mapping with Impingement (T31 Sonic FAA 7)

- Innovative 2D HD temperature map using 21 TC rake located in impingement board
- Sonic FAA Map Burn2 20 July 2018
- Level 8 (top) is 1” above burner exit cone C_L = 1454°F avg.



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Burner Map

Test	Date/Time
Sonic FAA MAP Burn2	20/07/2018 08:56:39.021 AM

Burner Map looking into the Burner [°F] - Max Values

	TC 1	TC 2	TC 3	TC 4	TC 5	TC 6	TC 7	TC 8	TC 9	TC 10	TC 11	AVERAGE Central 7 TC's
		1552.9	1462.7	1508.3	1451.4	1484.3	1473.8	1506.4	1475.8	1508.7	1513.6	1483.3
Level 11	1546.9	1390.7	1489.3	1479.0	1477.0	1491.0	1486.0	1434.1	1476.4	1466.6	1537.5	1476.1
		1531.3	1454.3	1489.3	1444.0	1484.0	1480.6	1512.4	1476.7	1509.5	1510.8	1481.2
Level 10	1530.8	1376.1	1471.7	1467.8	1466.4	1495.5	1485.8	1439.9	1484.2	1468.1	1536.3	1473.0
		1522.1	1445.2	1475.5	1431.8	1474.5	1469.2	1499.9	1472.8	1514.0	1515.8	1470.6
Level 9	1520.6	1378.0	1461.3	1448.7	1466.2	1483.7	1479.2	1428.6	1482.6	1467.6	1532.3	1464.3
		1511.5	1440.0	1480.0	1424.3	1461.4	1464.6	1492.6	1464.9	1507.4	1522.2	1464.6
Level 8	1503.4	1361.5	1455.2	1439.5	1451.6	1470.8	1466.0	1424.3	1476.4	1472.8	1542.9	1454.8
		1501.3	1431.7	1457.0	1408.3	1441.9	1441.7	1483.2	1458.4	1494.1	1505.0	1448.4
Level 7	1491.5	1350.3	1440.2	1427.3	1436.7	1455.4	1459.1	1414.5	1462.2	1456.8	1527.0	1442.2
		1484.4	1428.8	1462.5	1401.2	1436.6	1434.3	1473.7	1456.8	1489.8	1493.1	1444.2
Level 6	1493.7	1351.9	1437.4	1424.7	1422.8	1439.6	1440.1	1401.0	1459.8	1440.9	1506.9	1432.2
		1477.3	1422.7	1450.9	1390.6	1427.7	1430.8	1466.5	1455.1	1484.5	1483.2	1436.9
Level 5	1472.4	1336.6	1431.9	1419.8	1420.4	1433.6	1431.6	1388.5	1445.9	1430.0	1501.4	1424.5
		1484.4	1400.3	1433.1	1373.5	1403.7	1406.0	1449.7	1430.5	1462.1	1467.0	1416.1
Level 4	1429.6	1302.7	1414.0	1398.6	1407.1	1411.2	1410.4	1362.5	1418.0	1402.6	1472.9	1403.1
		1437.2	1404.3	1434.6	1363.8	1390.1	1380.8	1431.6	1421.3	1448.0	1467.7	1403.7
Level 3	1409.0	1294.3	1416.1	1389.2	1391.7	1390.8	1402.0	1346.3	1402.7	1390.2	1455.2	1391.3
		1385.5	1344.8	1383.6	1324.2	1358.2	1348.6	1390.4	1384.7	1420.1	1414.0	1364.9
Level 2	1341.5	1213.5	1339.6	1347.0	1355.0	1365.3	1368.2	1309.0	1377.9	1350.5	1394.5	1351.7
		1331.4	1313.4	1365.9	1293.8	1342.0	1318.3	1378.0	1359.6	1381.4	1370.0	1342.9
Level 1	1258.1	1144.9	1293.9	1300.4	1319.9	1336.3	1341.5	1281.8	1337.1	1289.1	1314.6	1315.8

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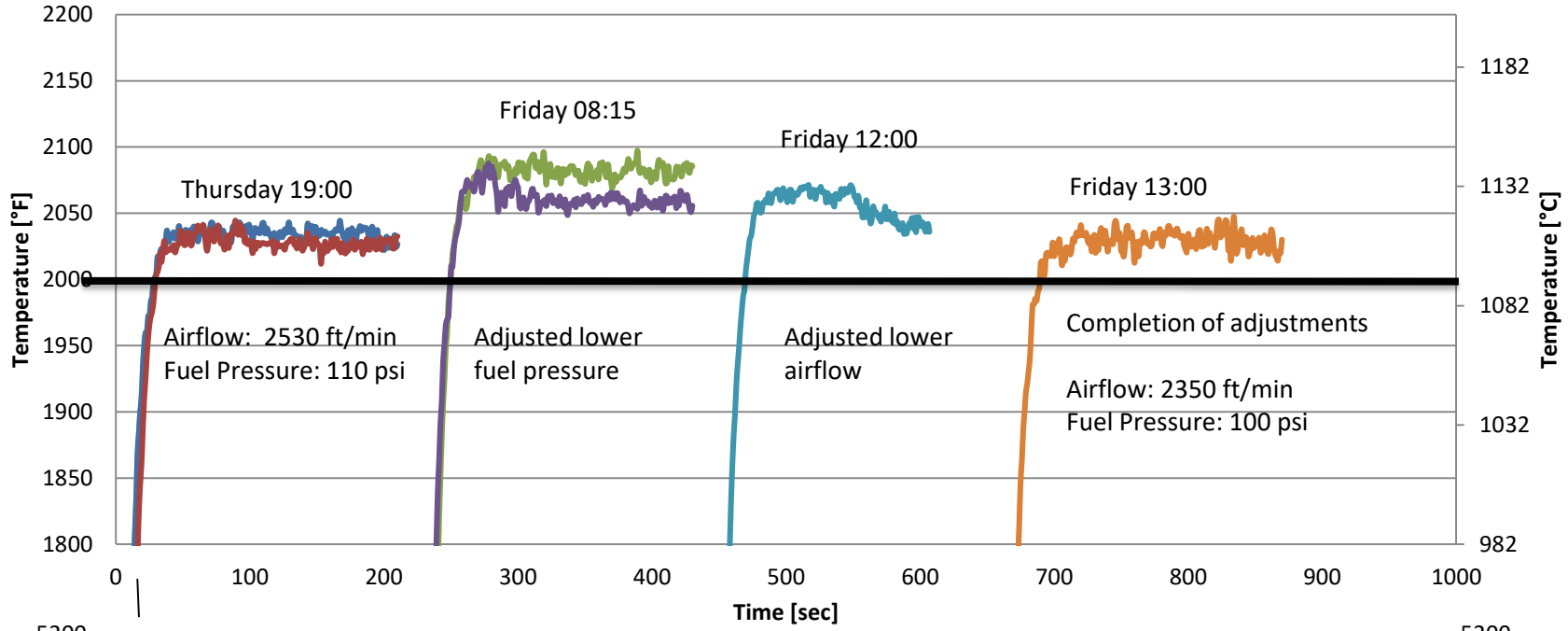
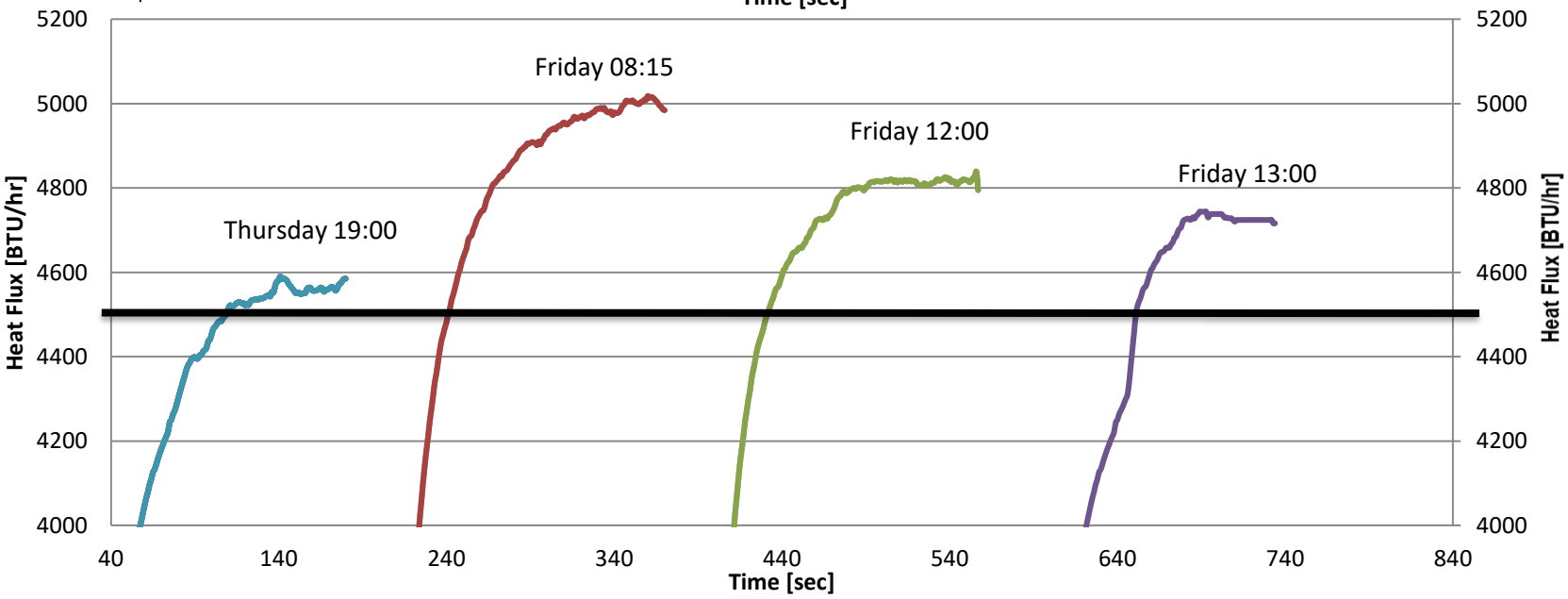
Difficulty with Carlin - factors: air P, density, temp?

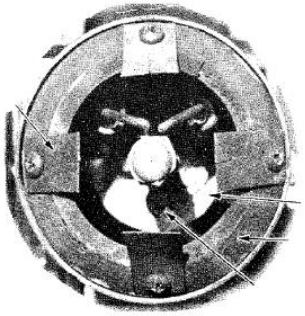


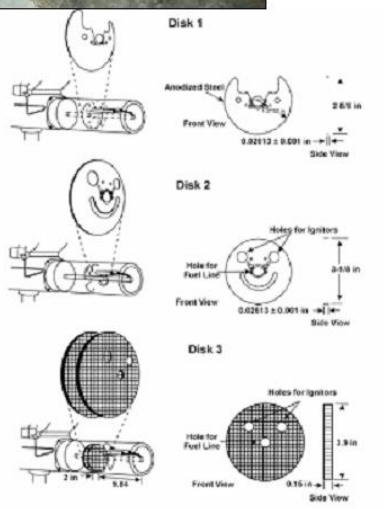


“FAA Fire Test Burner Apparatus Description – Feb 7, 2012, Singapore, Robert Ochs.”

Lessons Learned Over the Years

- Not all burners are created equal
- Configuration of burner components can drastically alter flame
- Burner air flow can have a significant effect on test results, especially for lighter weight materials
- It’s an oil burner, not precision lab equipment!





Summary of Main Observations

- Sonic can be modified from current configuration to achieve traditional burner like output
  - Similar to work FAATC conducted with flame retention head (2.5 gph vs. 2.0 gph and varying fuel and air pressures)
  - Can calibrate sonic burner according to current AC20-135 guidance and equipment
  - Potentially simplifies any guidance appendix (AC20-135) for use of Sonic burner – upcoming SAE A22/FAA task
  - Does not take advantage of the expected Sonic burner repeatability – but have we seen this?
- Tools developed to achieve greater understanding of burner outputs
  - 2D HD temperature maps
    - with and without impingement surface
  - BTU mapping
  - All to better qualify burner flames for comparison during any research effort
    - Ensure that we know where the hottest part of the flame is and the highest energy and relate that to calibration sensor location.
- For any given burner setup we might be able to establish useful expectations in terms of time to 4500 BTU/hr and peak value – will likely rely on more data than simply average.
- Do not draw major conclusions from shallow data sets. We always need to assess the significance of our data. This is particularly important when talking about repeatability or reliability.

Future Work: Considerations for Next Year's Triennial Conference

- Alu strip idea – electrical cond. – takes out difficult burnthrough assessment and is cheaper
- Composite panels?
- Other labs – variability
- Consider fuel types
- Consider application of other tools
- Repeatability data/statistical analysis
- Numerical tools to predict flame dynamics
- Understanding individual burner limitations and sources of variability
- Sensitivity study of burner parameters – could potentially further simplify set up
- Studying the modified Sonic Burner with off-the-shelf parts

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