Composites Testing Laboratory
CTL TÁSTÁIL TEO.

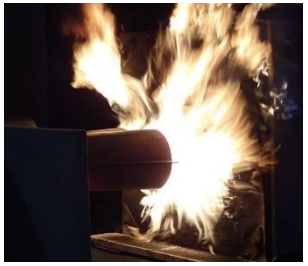
Resonate TESTING LIMITED

Continued evaluation of Carlin and Sonic Burner calibration equivalences

International Aircraft Systems Fire Protection Virtual Forum
2021-04-21







Olivia McAvoy
Resonate Testing

Resonate TESTING LIMITED

ilac-MRA

UKAS TESTING 9373

ISO 9001 SYSTEM CERTIFICATION SGS

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Premise- why are we doing this study?

Premise:

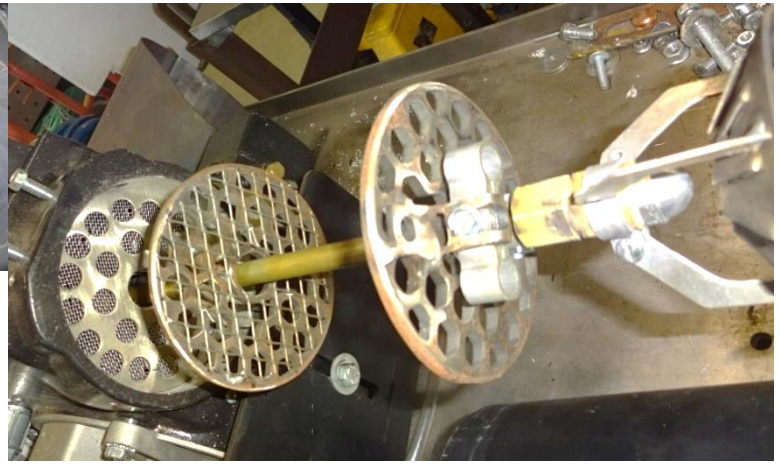
- To build on and add knowledge from previous studies
- Aim to achieve data that is comparable and consistent with other test house facilities/labs
- To give our experience on burner repeatability

Overview:

- Build of Carlin and Sonic burners used (including sonic burner modifications)
- Sonic burner modification
- Equipment used
- Comparison of calibration data for Carlin and Sonic Mod 3
- Comparison of panels tested with Carlin and Sonic Mod 3
- Comparison of temp mapping with Carlin and Sonic Mod 3
- Comparison of all Sonic Mod 3 data so far…
- Conclusions and future work

Carlin 200 CRD

Engineering report 3A



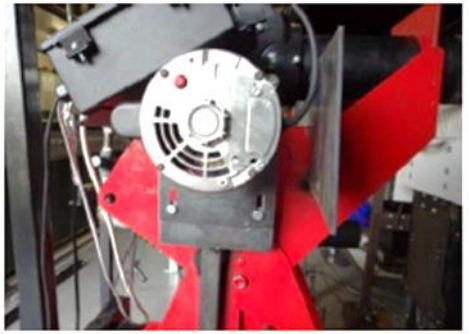
Acceptable Modified Burners:

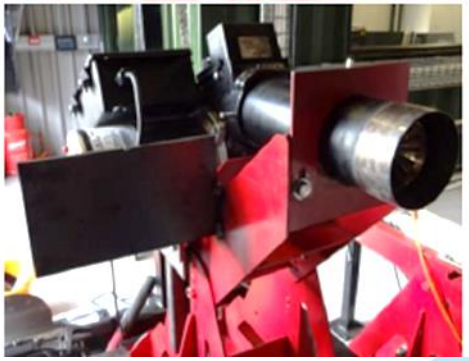
CARLIN 200 CRD, manufactured by the Carlin Company, 912 Silas Deane Highway, Wethersfield, Connecticut 06109, shown in figures 5 and 6, was modified in the following manner to produce a diffused 6-inch (vertical) by 11-inch (horizontal) sized flame with homogeneous temperature gradiant. Note: Carlin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

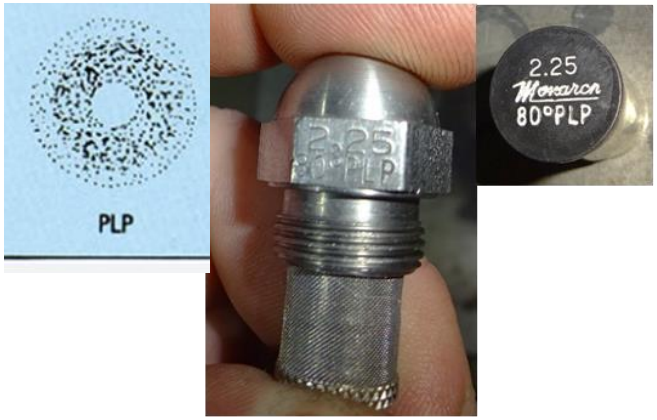
3. A flat-plate disc, approximately 4 inches in diameter and randomly punched with ten 1/2-inch holes, was installed 4 inches aft of the fuel nozzle tip. This provided support and centering of the oil delivery tube.





Innovative R&D- Sonic Burner Modification – Classified as Mod 3

Monarch 80°PLP 2.25 GPH



Muffler foam was removed

Added Carlin type turbulator on fuel nozzle fitting

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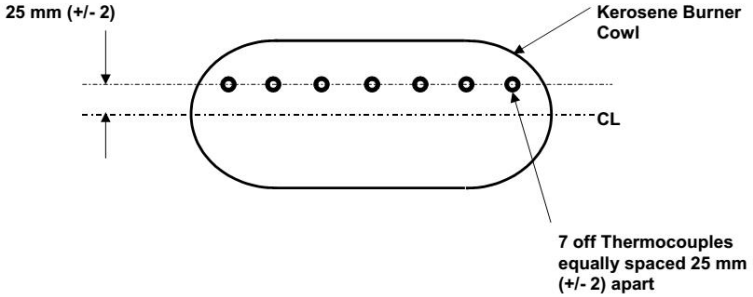
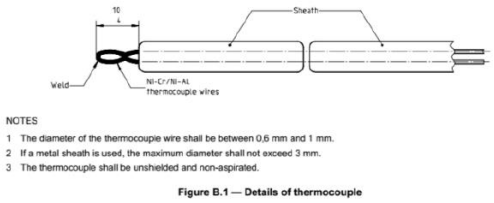
TC Rake – Temperature Calibration



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

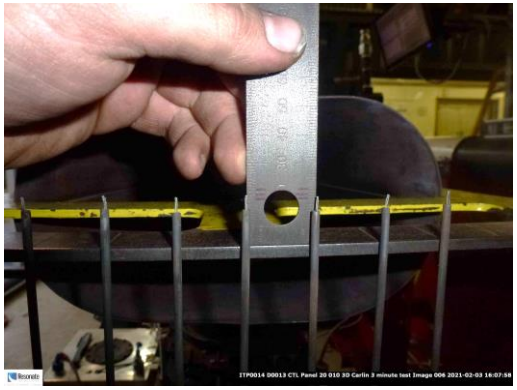


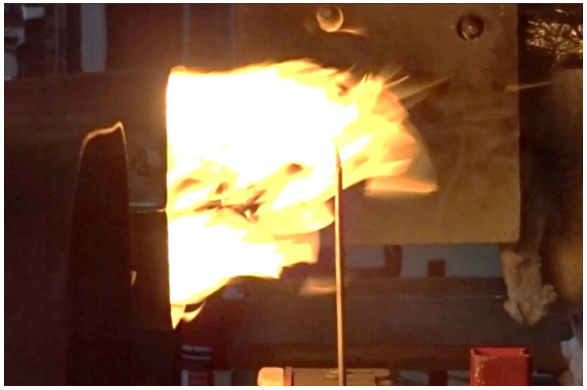
NOTES

1 The diameter of the thermocouple wire shall be between 0,6 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

- 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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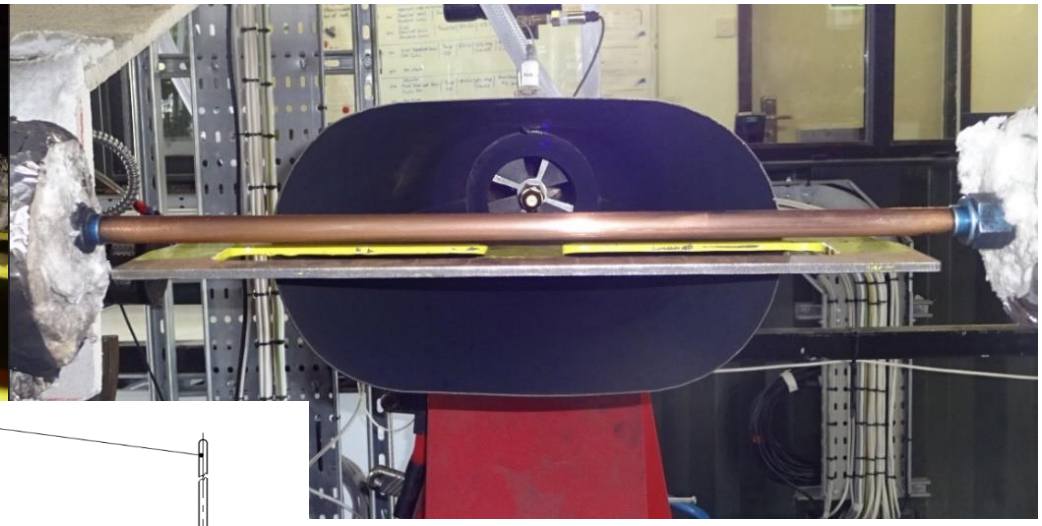
Copper Tube – Heat flux Calibration

Tube centreline 1” above burner cone centreline



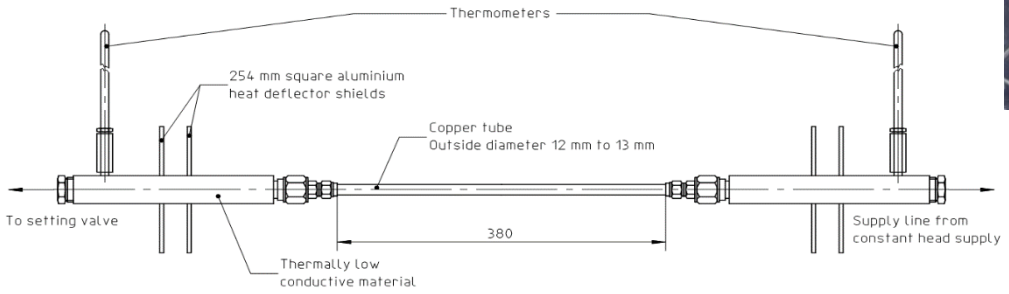


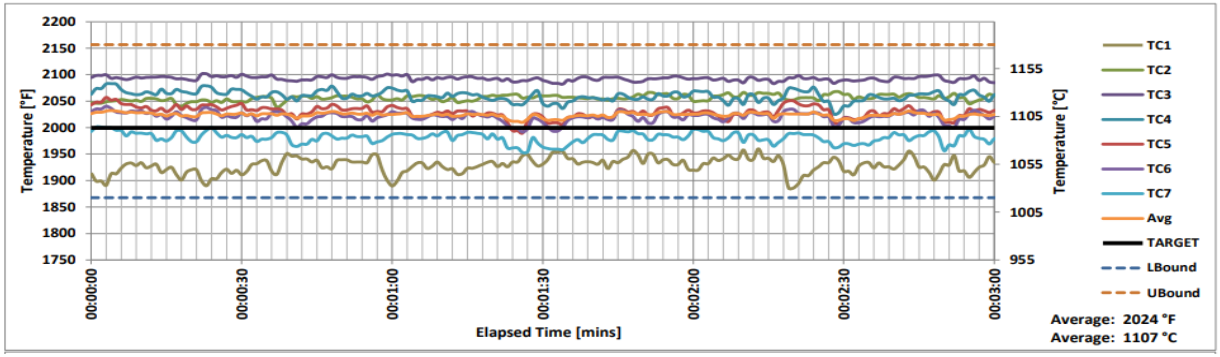
Figure B.4 — Overall view of the mounting of the standard heat flux density measuring tube

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
- Din 1/10 sensor, ±0.03°C accuracy

Carlin vs Sonic Burner trials- Flame Temperature Comparison

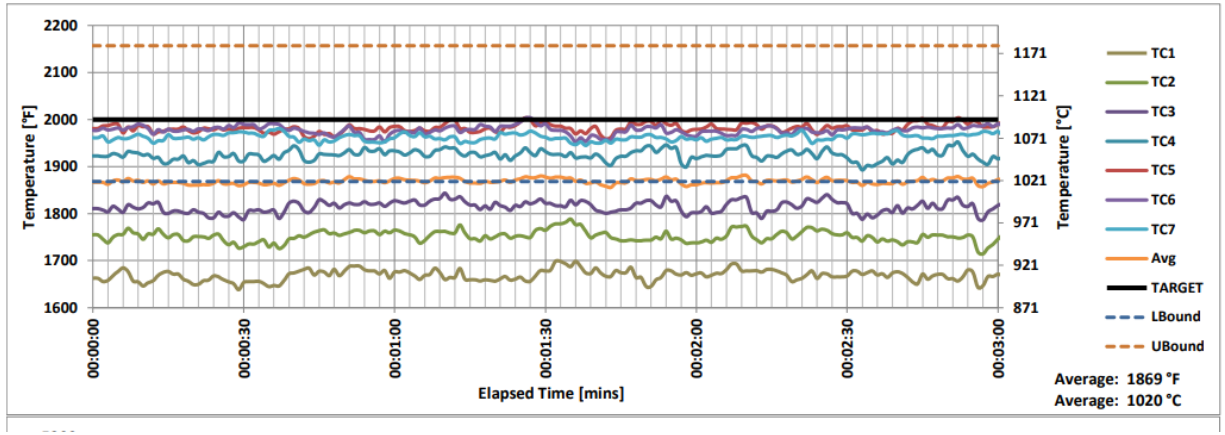
ITP0014 D0014 Carlin burner fuel pressure ~95psi



Fuel flow rate: 2.1 usgph

	Temperature (°F)
Average	2024
Min	1860
Max	2102

ITP0014 D0015 Sonic burner fuel pressure ~ 152psi, air pressure ~78psi

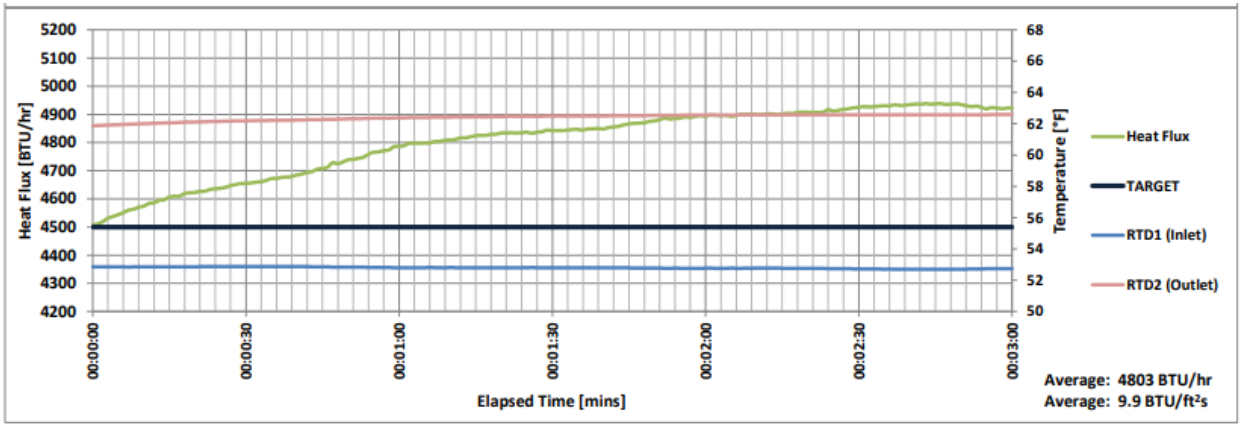


Fuel flow rate: 2.7 usgph

	Temperature (°F)
Average	1869
Min	1500
Max	2004

Carlin vs Sonic Burner trials- Heat Flux Comparison

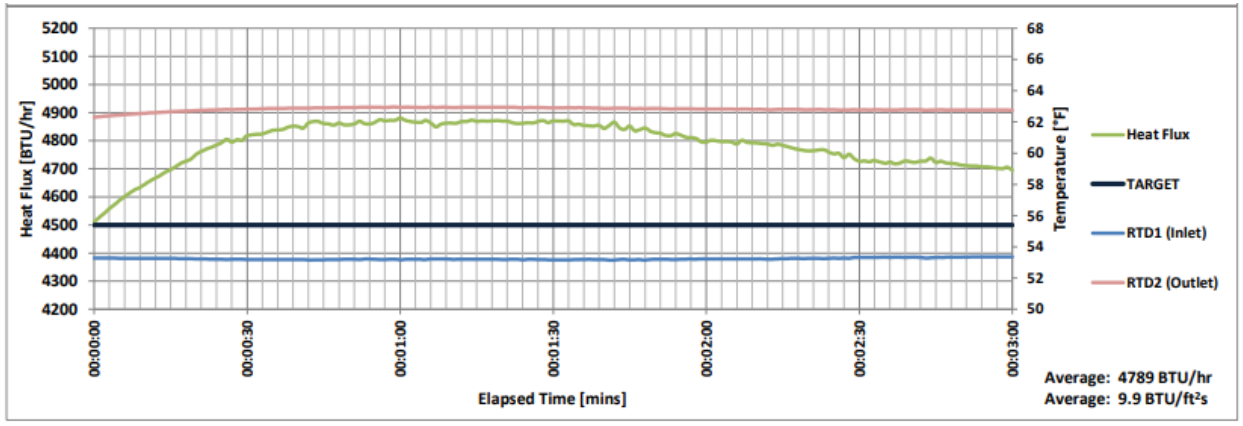
ITP0014 D0014 Carlin burner fuel pressure ~95psi



Fuel flow rate: 2.1 usgph

	Heat Flux (BTU/hr)
Average	4803
Min	4506
Max	4961

ITP0014 D0015 Sonic burner fuel pressure ~ 152psi, air pressure ~78psi



Fuel flow rate: 2.7 usgph

	Heat Flux (BTU/hr)
Average	4789
Min	4511
Max	4880

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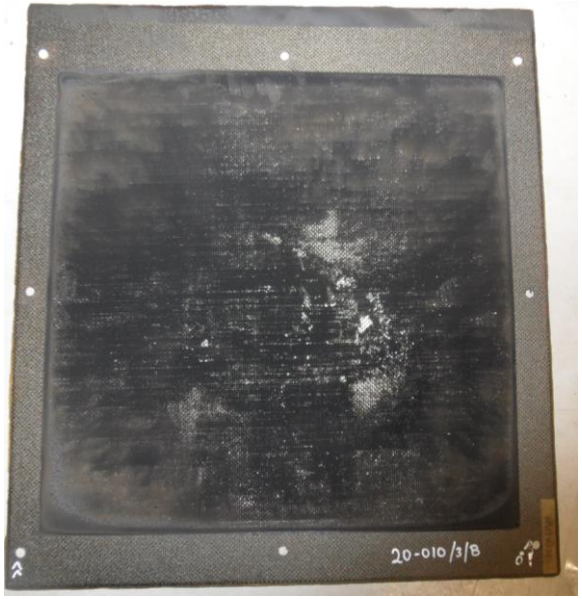
Panel burn preliminary Result

Panels returned assessment to CTL
Awaiting further material analysis

Carlin

UUT Serial Number: 20-010/3/C
Test duration: 1 minute
Flare up on UUT ~ 5 seconds after test start
Burning at edges of UUT
Bubbling on aft face
Outgassing on aft face ~ 45 seconds after test start

Sonic



UUT Serial Number: 20-010/3/B
Test duration: 1 minute
Flare up on UUT ~ 5 seconds after test start
Burning at edges of UUT
Bubbling on aft face
Outgassing on aft face ~ 43 seconds after test start
After burn for ~1 second after flame removed from UUT

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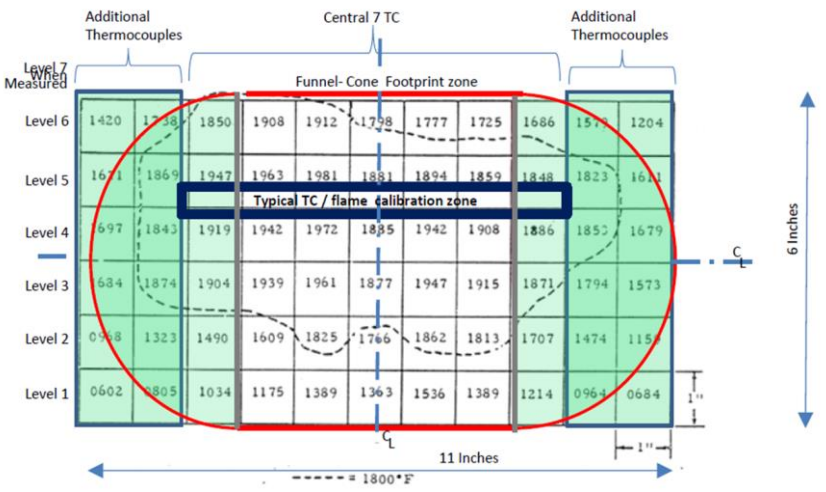
11 TC Map – 1” vertical Increments & 1” TC spacing



transitioning rake with 1” increments.

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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Baseline Assessment – 1” Map- Carlin Trials

Date: 2019-04-03
Fuel: 125 psi

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 6	1813.8	2051.9	2108.9	2118.5	2080.4	1941.2	2016.3	2099.5	2022.2	1774.0	1344.7	2055.3
Level 5	1778.4	1995.9	2167.8	2220.3	2189.1	2210.3	2229.1	2209.7	2092.5	1824.0	1337.8	2188.4
Level 4	1258.8	1538.0	1812.6	2036.2	2056.1	2144.6	2176.6	2076.7	1979.7	1710.6	1187.9	2040.4
Level 3	708.5	1072.2	1379.6	1497.3	1435.0	1566.0	1717.6	1734.7	1665.7	1423.4	906.7	1570.8
Level 2	384.6	564.5	784.6	882.5	826.1	889.2	1083.3	1129.0	1048.3	788.5	491.0	949.0
Level 1	363.1	409.9	433.7	485.5	488.1	522.4	593.7	591.4	550.6	449.5	361.7	523.6

Date: 2020-09-22
Fuel: 95 psi

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	1648.2	1958.8	2103.8	2129.6	2130.8	2154.0	2135.3	2103.6	2069.2	1888.0	1560.3	2118.0
Level 5	1726.5	1984.0	2115.1	2192.9	2214.3	2221.1	2201.1	2205.2	2165.4	2009.1	1769.2	2187.9
Level 4	1631.6	1835.1	1895.3	1894.5	1930.8	1955.9	2006.6	2087.1	2121.0	1985.3	1770.3	1984.4
Level 3	1314.0	1459.9	1447.1	1374.2	1428.8	1550.1	1760.7	1908.4	1947.4	1751.2	1461.7	1631.0
Level 2	711.3	864.7	823.2	742.9	809.1	1031.2	1338.9	1495.3	1472.1	1285.7	1051.2	1101.8
Level 1	296.7	346.3	355.3	320.9	376.2	515.7	717.5	882.5	913.3	681.8	533.5	583.0

Baseline Assessment – 1” Map- Sonic Trials

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

Sonic Mod 3 trial 29
Fuel pressure: 125psi
Air pressure: 60psi

	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	1639.5	1693.3	1733.2	1806.6	1892.9	2001.9	1990.4	2004.0	1968.7	1782.3	1639.6	1914.0
Level 6	1645.6	1704.6	1728.1	1793.7	1899.7	2007.5	1987.7	2014.8	2010.2	1857.5	1714.4	1920.3
Level 5	1592.1	1619.3	1626.1	1717.2	1825.4	1940.9	1958.7	1989.0	1990.2	1850.1	1759.7	1863.9
Level 4	1421.3	1385.8	1347.1	1422.9	1537.2	1664.1	1658.3	1728.6	1748.4	1742.2	1672.0	1586.7
Level 3	1102.9	1171.2	1130.7	1120.3	1178.6	1233.6	1226.7	1252.5	1398.4	1475.3	1397.2	1220.1
Level 2	734.4	866.8	869.4	801.2	833.9	862.1	842.2	913.4	1048.5	1080.2	976.0	881.5
Level 1	492.9	562.5	579.2	531.6	539.3	527.7	523.0	560.2	634.0	651.3	601.1	556.5

Sonic Mod 3 trial 30
Fuel pressure: 145psi
Air pressure: 56psi

Level 7	1692.7	1770.1	1820.1	1894.2	1971.3	2064.8	2004.5	2013.7	2057.6	1873.1	1717.1	1975.2
Level 6	1708.4	1764.7	1828.1	1915.0	1977.3	2067.2	2010.1	2004.3	2050.8	1903.6	1818.6	1979.0
Level 5	1628.0	1624.4	1698.2	1821.7	1939.1	2015.9	1999.7	2002.5	2032.8	1912.0	1794.7	1930.0
Level 4	1355.1	1382.6	1361.8	1449.6	1611.5	1737.9	1804.1	1814.4	1820.3	1742.6	1669.1	1657.1
Level 3	1015.0	1083.5	1054.3	1077.8	1167.9	1259.7	1281.2	1247.4	1289.9	1378.0	1384.0	1196.9
Level 2	716.7	838.9	849.8	764.4	784.3	865.7	844.2	857.5	1026.0	1101.7	995.7	856.0
Level 1	392.9	463.3	494.0	510.9	521.7	534.8	517.8	530.7	578.1	569.8	528.2	526.9

Sonic Mod 3 trial 31
Fuel pressure: 150psi
Air pressure: 65psi

Level 7	1665.4	1782.5	1813.6	1857.1	1941.7	2074.8	2068.6	2073.5	2022.6	1811.7	1622.0	1978.8
Level 6	1698.5	1797.2	1818.9	1881.1	1961.9	2076.6	2065.5	2079.0	2102.4	1913.5	1790.2	1997.9
Level 5	1708.3	1752.1	1777.3	1842.4	1950.3	2056.4	2051.2	2067.2	2095.6	1931.7	1795.0	1977.2
Level 4	1533.4	1548.7	1534.3	1591.6	1681.9	1795.9	1858.5	1888.1	1928.4	1836.0	1744.0	1754.1
Level 3	1150.0	1282.0	1214.6	1173.1	1254.5	1347.6	1393.1	1419.0	1536.3	1617.8	1508.9	1334.0
Level 2	746.3	927.5	951.6	866.1	828.8	853.5	926.2	939.7	1168.4	1209.9	1091.4	933.5
Level 1	439.2	534.6	549.6	515.0	506.7	512.3	513.9	577.9	674.4	701.4	666.3	550.0

Sonic Mod 3 trial 32
Fuel pressure: 152psi
Air pressure: 78psi

Level 7	1509.3	1706.5	1739.8	1780.5	1888.1	1996.8	2060.1	2052.8	1996.2	1755.1	1496.3	1930.6
Level 6	1610.8	1724.7	1748.7	1812.4	1928.5	2017.7	2091.3	2127.2	2098.4	1904.6	1730.7	1974.9
Level 5	1637.4	1735.5	1778.0	1834.2	1943.7	2025.6	2081.2	2114.9	2101.9	1911.5	1765.6	1982.8
Level 4	1580.6	1609.5	1579.7	1629.1	1746.4	1838.6	1890.8	1936.3	1970.8	1879.8	1769.4	1798.8
Level 3	1267.2	1423.6	1307.8	1245.2	1333.9	1438.2	1483.4	1543.2	1728.5	1698.7	1569.6	1440.0
Level 2	806.8	1053.4	1035.9	909.1	861.5	941.4	975.8	1087.7	1347.1	1386.4	1202.7	1022.6
Level 1	404.6	561.8	612.7	512.9	485.5	464.1	510.6	605.5	782.4	747.1	631.8	567.7

Previous 1” Map- Sonic Trials-

Round 3
FP: 145
AP: 56

Burner Map looking into the Burner [°F] - Max Values NO BOARD

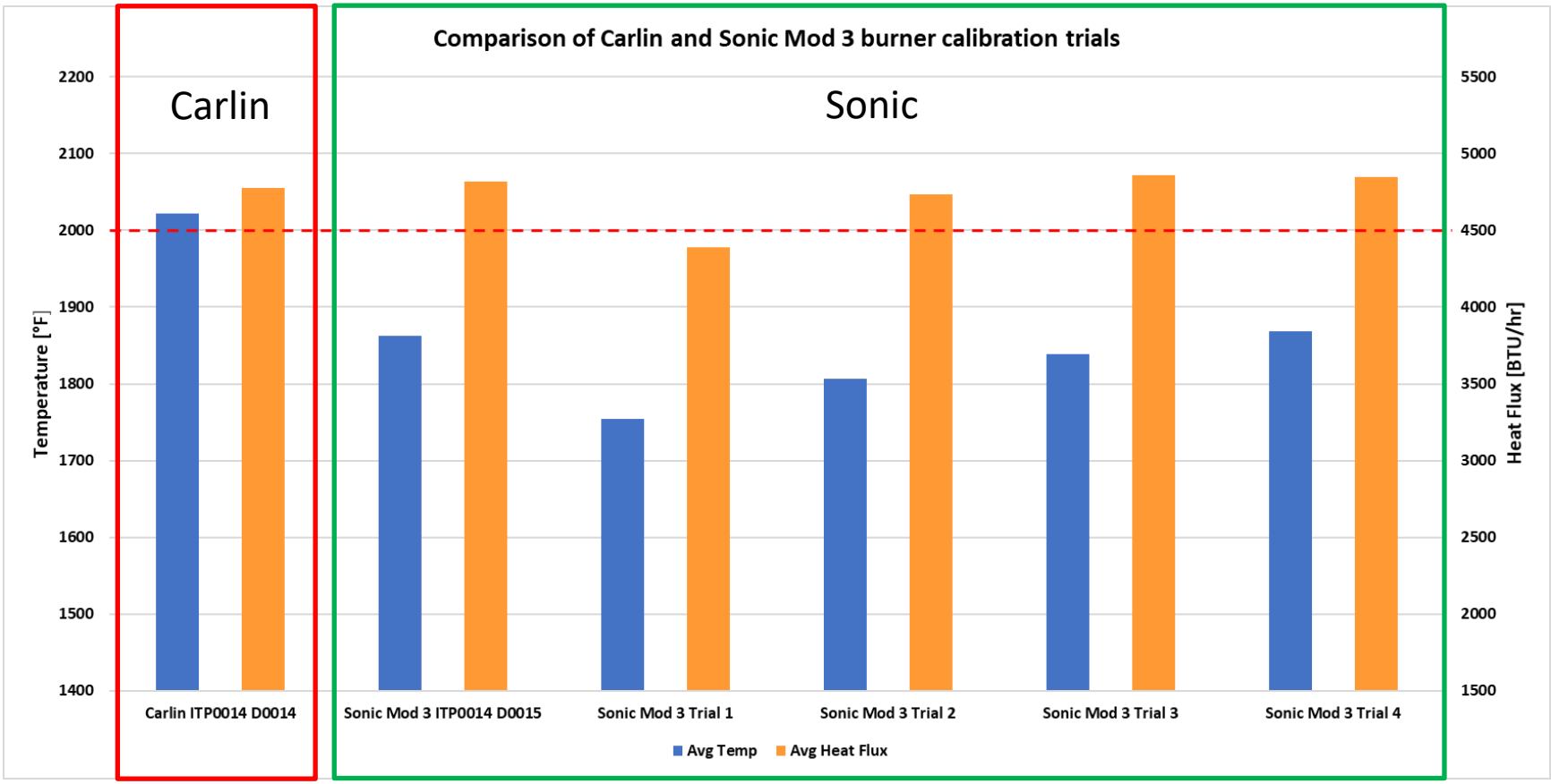
	TC 1	TC 2	TC 3	TC 4	TC 5	TC 6	TC 7	TC 8	TC 9	TC 10	TC 11	AVERAGE Central 7 TC's
Level 6	1469.5	1519.4	1603.6	1755.1	1956.9	2057.9	2099.8	2092.2	2101.0	1951.4	1786.7	1952.4
Level 5	1210.4	1261.1	1376.4	1650.2	1943.8	2161.5	2241.3	2219.1	2168.4	1980.2	1863.9	1965.8
Level 4	868.2	996.8	1138.7	1416.5	1831.3	2126.1	2240.0	2214.4	2129.7	1873.1	1705.4	1870.9
Level 3	607.2	679.8	802.6	1024.8	1417.7	1733.6	1975.8	1993.7	1917.4	1611.9	1383.3	1552.2
Level 2	448.2	527.7	593.9	711.8	1024.5	1334.4	1501.0	1478.8	1409.6	1121.3	895.4	1150.6
Level 1	340.6	394.2	435.7	461.7	596.1	741.5	871.0	834.9	742.2	588.5	448.1	669.0

Round 2
Fuel: 125
Air: 60

Burner Map looking into the Burner [°F] - Max Values No Board

	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	1701.2	1846.0	1980.0	2071.1	2066.5	2107.0	2133.4	2072.0	1949.8	1855.4	1719.7	2054.2
Level 6	1726.9	1865.2	1991.9	2069.5	2068.3	2091.1	2124.6	2079.2	1954.9	1876.8	1773.2	2054.2
Level 5	1867.2	1905.6	1977.4	2033.0	2033.9	2083.5	2102.6	2044.8	1971.6	1895.9	1809.7	2035.3
Level 4	1839.1	1802.5	1745.1	1725.6	1763.0	1828.2	1792.1	1716.7	1766.8	1819.1	1751.3	1762.5
Level 3	1585.1	1637.1	1476.3	1393.8	1363.2	1486.1	1424.7	1399.9	1566.4	1600.5	1467.0	1444.3
Level 2	1073.9	1164.2	1083.8	857.5	846.3	913.5	818.5	821.9	1039.0	1164.5	1085.5	911.5
Level 1	534.9	601.4	569.8	459.7	414.1	405.1	428.6	414.0	554.0	627.8	558.7	463.6

Summary of Burner Calibration Data



Fuel: 95	Fuel: 152 Air: 78	Fuel: 125 Air: 60	Fuel: 145 Air: 56	Fuel: 150 Air: 65	Fuel: 152 Air: 78

Pressures in psi

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Summary Table of Data

Burn #	Burner / Config.	Fuel and Air Pressure (psi)	Pre-Test Avg. Temp. (°F)	Pre-Test Avg. Heat Flux (BTU/hr)	Post-Test Avg. Temp. (°F)	Post-Test Avg. Heat Flux (BTU/hr)
Carlin Panel #1	Carlin	FP: 95 AP: N/A	2024	4803	2020	4748
Sonic Panel #1	Sonic Mod 3	FP: 152 AP: 78	1869	4789	1857	4849
Sonic Trial 29	Sonic Mod 3	FP: 125 AP: 60	1759	4341	1748	4435
Sonic Trial 30	Sonic Mod 3	FP: 145 AP: 56	1808	4740	1805	4728
Sonic Trial 31	Sonic Mod 3	FP: 150 AP: 65	1825	4828	1852	4891
Sonic Trial 32	Sonic Mod 3	FP: 152 AP: 78	1867	4852	1871	4842

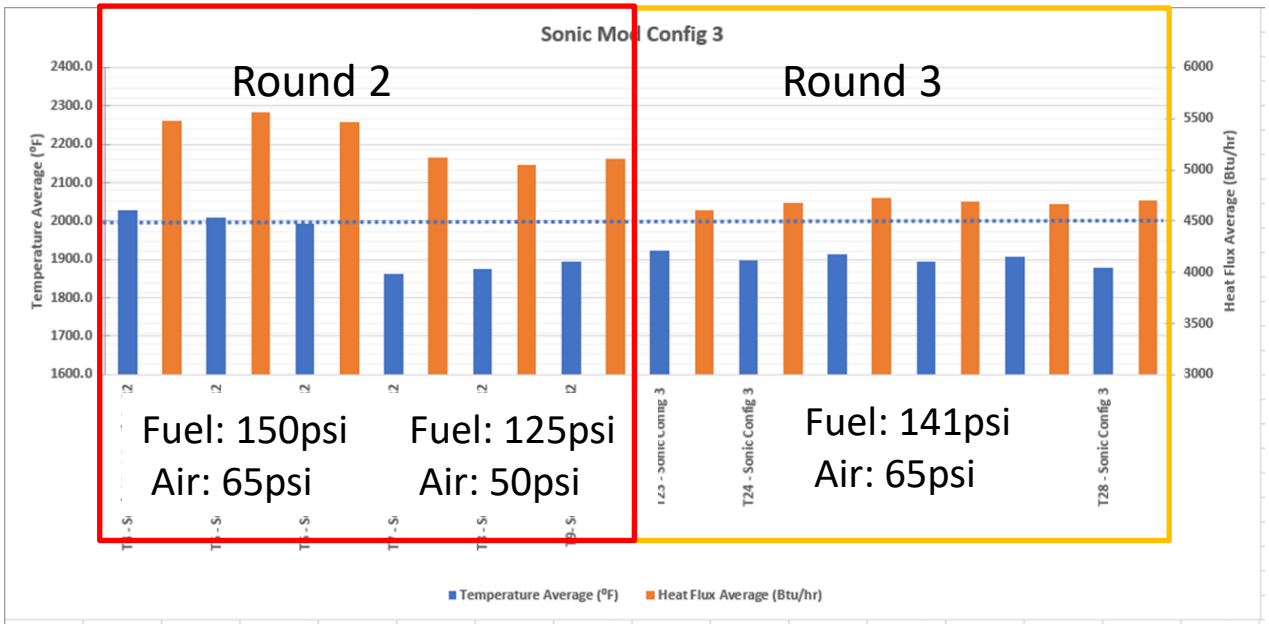
Previous Sonic Mod 3 Burner Rounds

Round 2

02-May-19	T4 - Sonic Mod Config3 - R2
03-May-19	T5 - Sonic Mod Config3 - R2
03-May-19	T6 - Sonic Mod Config3 - R2
03-May-19	T4 - Sonic Mod Config3 - R2
02-May-19	T5 - Sonic Mod Config3 - R2
03-May-19	T6 - Sonic Mod Config3 - R2

Round 3

07 August 2019	T23 - Sonic MOD NEW Config3 – R3
07 August 2019	T24 - Sonic MOD NEW Config3 – R3
07 August 2019	T25 - Sonic MOD NEW Config3 – R3
07 August 2019	T26 - Sonic MOD NEW Config3 – R3
07 August 2019	T27 - Sonic MOD NEW Config3 – R3
07 August 2019	T28 - Sonic MOD NEW Config3 – R3



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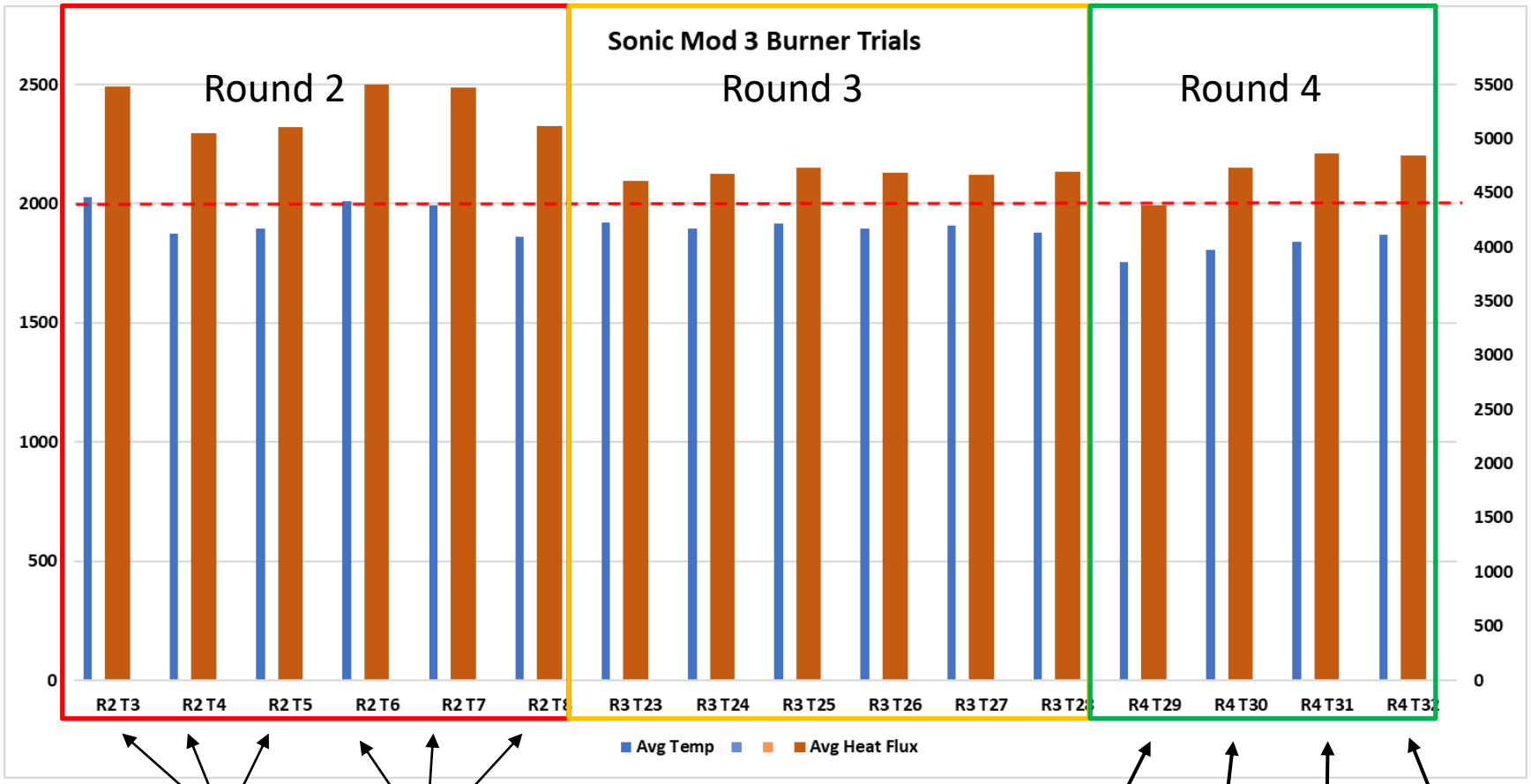
Comparison of data from all trials – Sonic Mod 3



Fuel: 150
Air: 65

Fuel: 125
Air: 50

Fuel: 141
Air: 65

Fuel: 125
Air: 60

Fuel: 145
Air: 56

Fuel: 150
Air: 65

Fuel: 152
Air: 78

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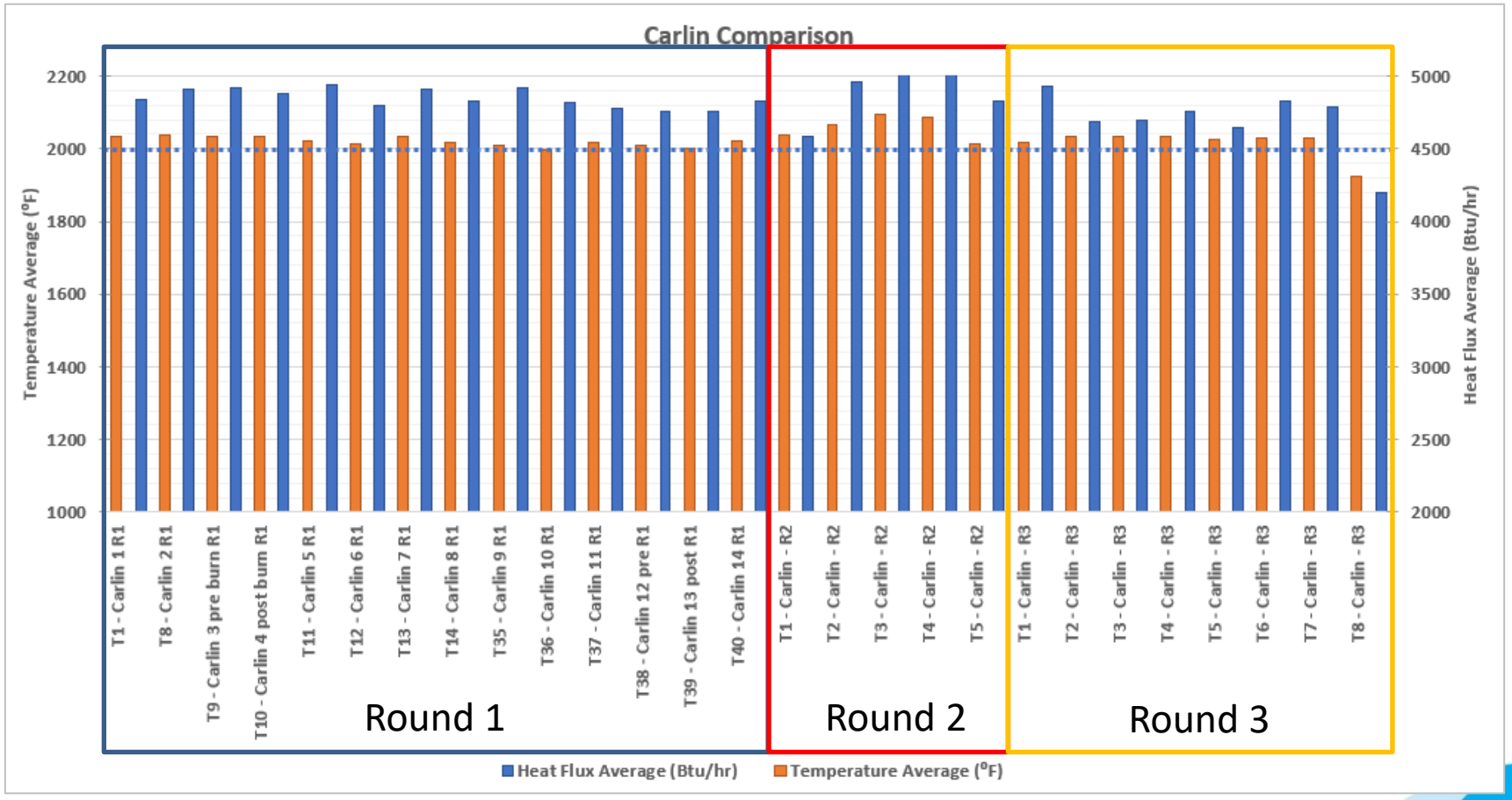
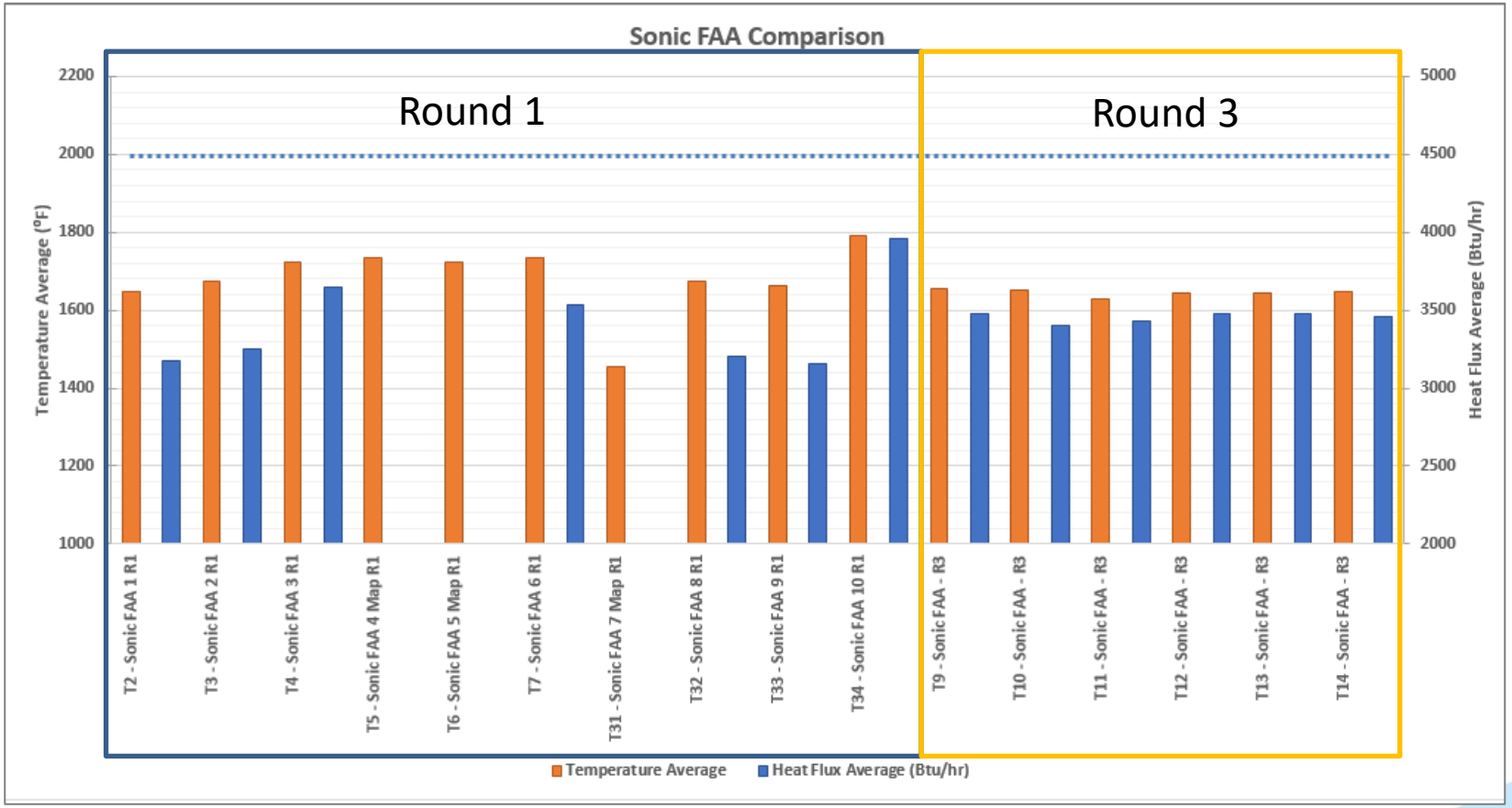
Summary of Carlin Calibration Data

Fuel pressure ranging from 80 psi to 120psi



Summary of Sonic Config 1 [FAA]

Fuel: 100psi Air: 50psi



Main Observations

- From our studies so far, it has been difficult to replicate the flame calibrations that readily achievable with the Carlin burner. This is particularly true for the flame temperature.
- With a significantly higher fuel pressure, in comparison to the Carlin burner, the Sonic burner struggles to reach flame temperature. In all but two trials, it failed to reach a minimum average of 2000°F.
- The Sonic burner uses approximately 21% more fuel than the Carlin when trying to achieve the 2000°F. This fuel is not being fully combusted and therefore is failing to make the flame hotter and which causes heavy sooting.
- The question also remains: what is happening the unburnt fuel? Is it being deposited on to the UUT and causing burn on when the burner is removed?
- Trials run so far show that there is difficulty reproducing the flame calibration parameters even when similar fuel and air pressure inputs are provided. This is true for various modifications of the sonic burner.
- When comparing the burner maps produced by each burner, the sonic map often leans to the right-hand side, there is a 'hot spot' in the flame. The carlin burner allows for adjustment of the turbulator orientation and this in turn allows for the swirl pattern of the flame to be changed in order to increase fuel and air mixing and allowing the flame to 'fill' the burner cone. The Sonic burner does not allow for that adjustment at the moment.

Future Work

- Continue to work on the Sonic burner modification, possibly to be able to adjust the turbulator so swirl can be added to the flame. This could provide a more uniform flame and burner map and may allow for flame temperature calibration to be achieved.
- Continue to work on Sonic burner repeatability
- Continue to work with different Sonic burner modifications with the aim to achieve a burner configuration that can provide a ‘standard flame’ and equivalent damage to the test item
- Conduct more tests on composite panels, with further material assessments from CTL to ascertain equivalent damage
- Work with other labs/test house facilities to share and build on knowledge

Thank you for listening

Questions…

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