Updated Experimental Investigation of the NexGen Burner

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Acknowledgments

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- Aeon Brown, Rob Ochs, and other researchers at FAATC for inputs

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Overview

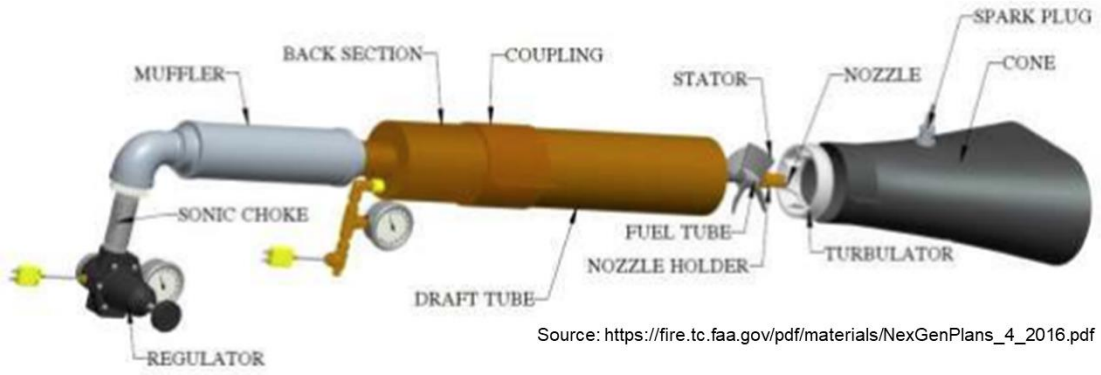
- Research objective:
  - Continued experimentation with NexGen burner configurations to optimize burner performance
    - Desire a heat flux more in line with the requirement (4500 BTU/hr)
- Approach:
  - Obtain temperature and heat flux map of existing configurations
  - Further experiment with different draft tube configurations
    - Types of components and the spacing of those components
    - For all experimental configurations, inputs to the burner (fuel and air pressure) remain constant. The only variable should be the burner configuration itself.
      - Fuel: 115 psi, Air: 50 psig
  - Promising candidates will be selected for full temperature/heat flux mapping and burn-through testing
  - Evaluate additional burner operating conditions (fuel/air inputs) by varying total mass flow

Outline

- Summary of existing burner configurations
- Temperature and heat flux mapping
  - Horizontal and vertical orientations
- Result of further experimentation of draft tube components
- Comparison of burner configurations – calibration results
- Panel testing : burn through results and comparisons
- Effect of total mass flow on burner performance
- Operating conditions for optimal heat flux
- Summary

Starting Configurations – Overview

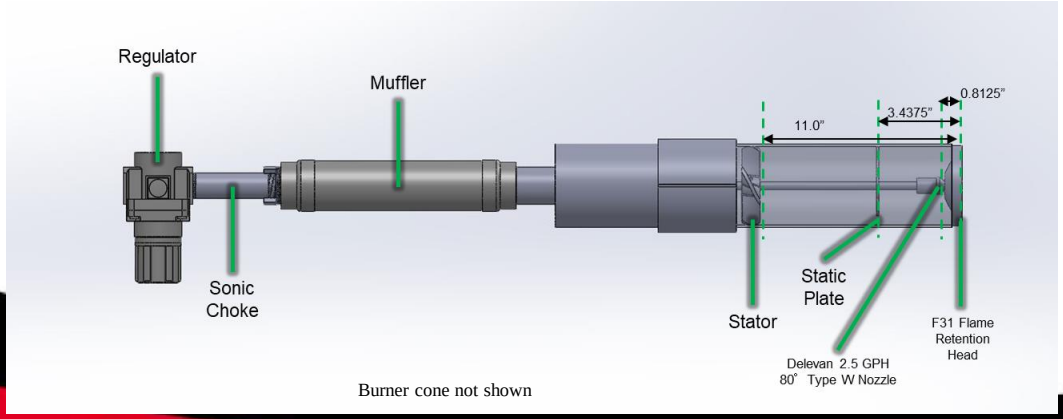
- FAA Configuration
  - NexGen burner plans as currently shown on FAA website



Source: https://fire.tc.faa.gov/pdf/materials/NexGenPlans_4_2016.pdf

At 1.5" above burner centerline:		
Average Temperature (F)	Total Heat Flux (BTU/hr)	
	Average	Peak
2133	6323	6802

- Modified Configuration A
  - Previously developed by experimentation at UC to achieve lower heat flux



At 1.5" above burner centerline:		
Average Temperature (F)	Total Heat Flux (BTU/hr)	
	Average	Peak
2058	5260	5902

Static Plate and F31 Flame Retention Head manufactured by Beckett and purchased from patriot-supply.com. Full link: http://www.patriot-supply.com/products/showitem.cfm/BECKETT_F31, other flame retention head designs are available.

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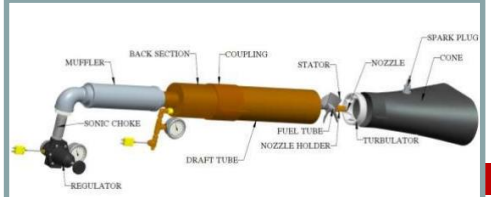
Burner Mapping – Horizontal and Vertical Orientations

Burner Mapping Overview

Desire a more comprehensive look at the temperature and heat flux output of various burner configurations.

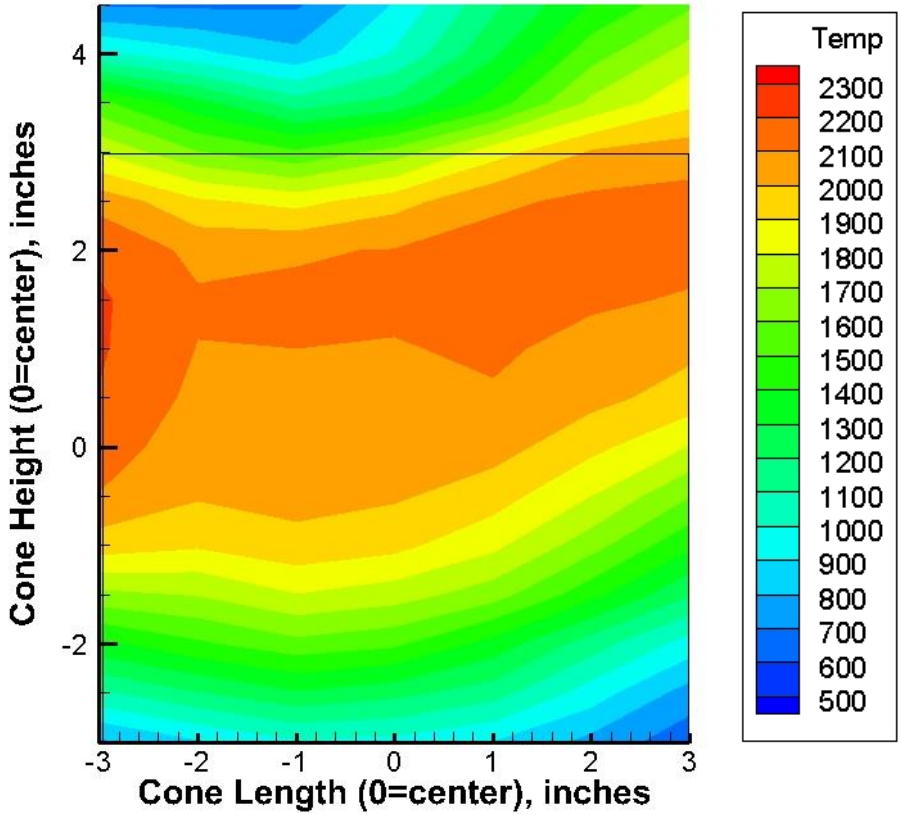
- Mapping is conducted using both horizontal and vertically operated burners
- Temperature is recorded in 0.5” increments
  - Using 1/16” Type K Exposed Bead TCs
- Heat Flux is recorded in 1.5” increments
  - Heat Flux is allowed to rise for 30 seconds before recording starts
  - Heat Flux is time averaged over the full typical 3 minute calibration period
  - Peak Heat Flux is also reported
  - Using RTDs for temperature measurement

Burner next to Heat Flux tube



FAA Configuration

FAA Config - Horizontal



Height (inches)	Average Temperature (F)	Total Heat Flux (BTU/hr)	
		Average	Peak
4.5	1018	2764	2977
4	1195		
3.5	1469		
3	1785	5040	5336
2.5	2022		
2	2123		
1.5	2133	6323	6802
1	2101		
0.5	2072		
0	2011	5538	5930
-0.5	1930		
-1	1807		
-1.5	1602	3614	3824
-2	1344		
-2.5	1093		
-3	845	1764	1910

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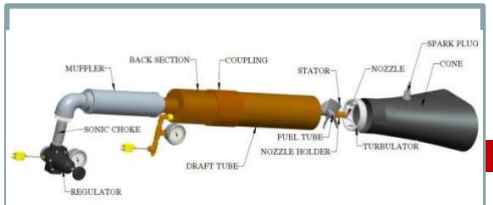
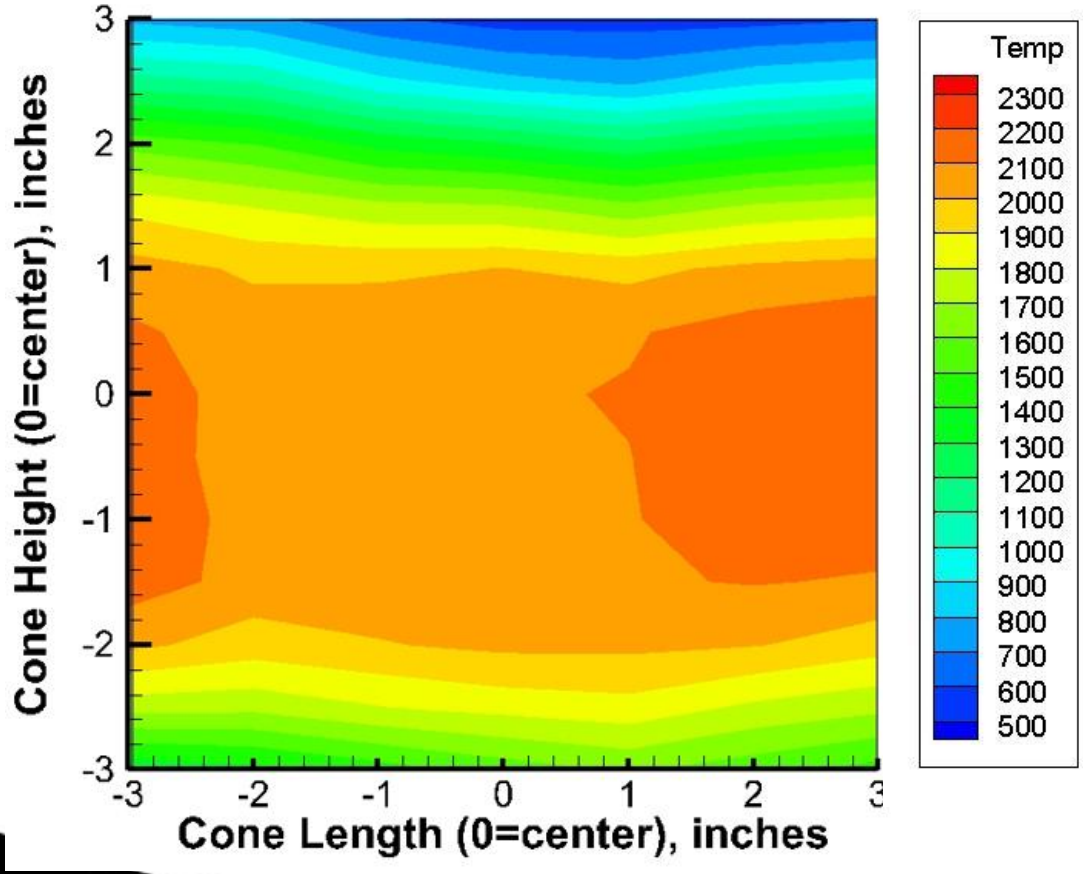
FAA Config - Vertical



FAA Configuration



Height (inches)	Average Temperature (F)	Total Heat Flux (BTU/hr)	
		Average	Peak
3	626	2016	2106
2.5	937		
2	1380		
1.5	1744	4690	5063
1	2009		
0.5	2101		
0	2115	5809	6359
-0.5	2110		
-1	2108		
-1.5	2094	4912	5420
-2	1995		
-2.5	1785		
-3	1473	2998	3158

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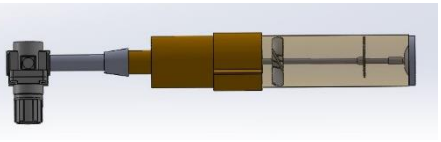
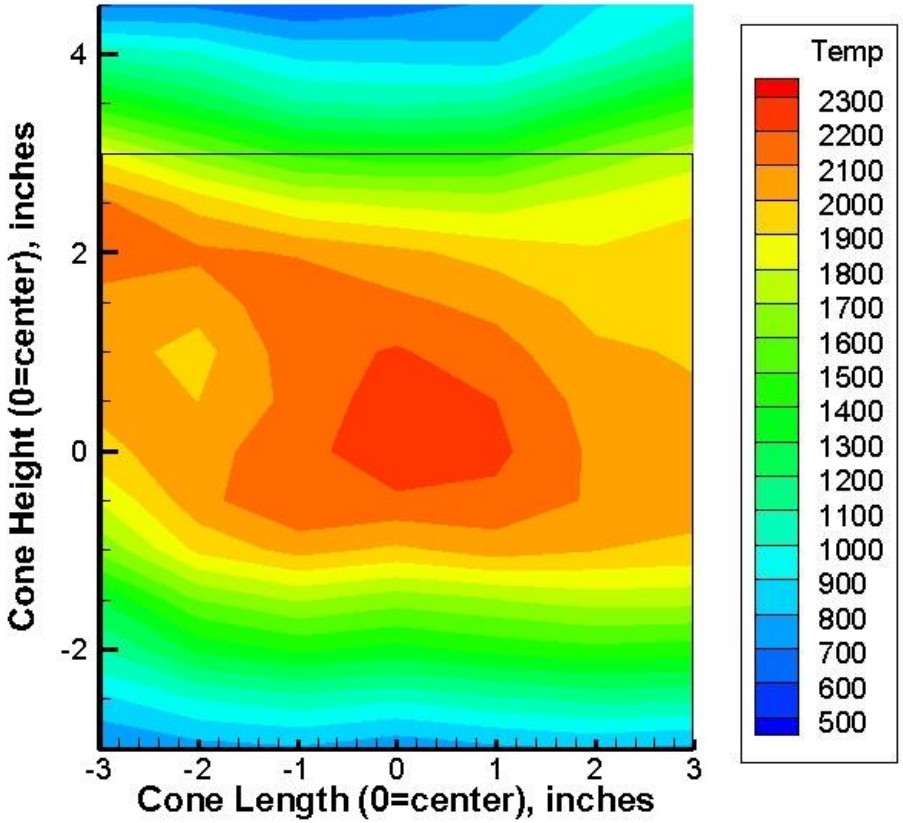


Modified Configuration A

Modified Config A - Horizontal



Height (inches)	Average Temperature (F)	Total Heat Flux (BTU/hr)	
		Average	Peak
4.5	742	2089	2197
4	971		
3.5	1260		
3	1603	4576	4850
2.5	1879		
2	2030		
1.5	2058	5260	5902
1	2075		
0.5	2099		
0	2116	4903	5352
-0.5	2081		
-1	1941		
-1.5	1633	3570	3761
-2	1366		
-2.5	1043		
-3	755	1575	1711

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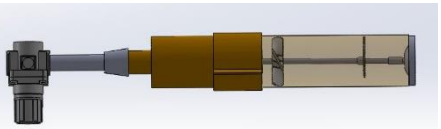
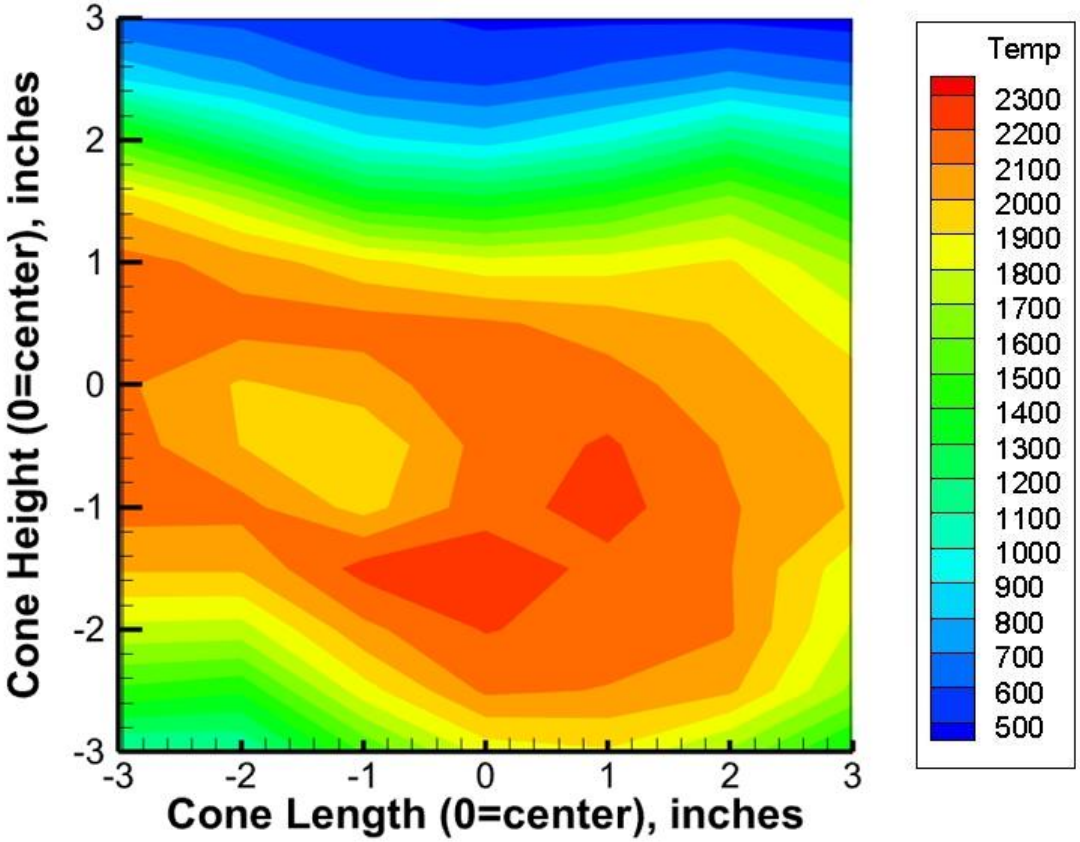


Modified Configuration A

Modified Config A – Vertical



Height (inches)	Average Temperature (F)	Total Heat Flux (BTU/hr)	
		Average	Peak
3	510	1809	1852
2.5	696		
2	1101		
1.5	1565	4882	5141
1	1917		
0.5	2071		
0	2065	5038	6412
-0.5	2069		
-1	2106		
-1.5	2092	4458	5108
-2	1980		
-2.5	1809		
-3	1493	2920	3032

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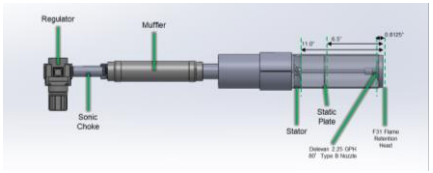
Result of Continued Burner Experimentation

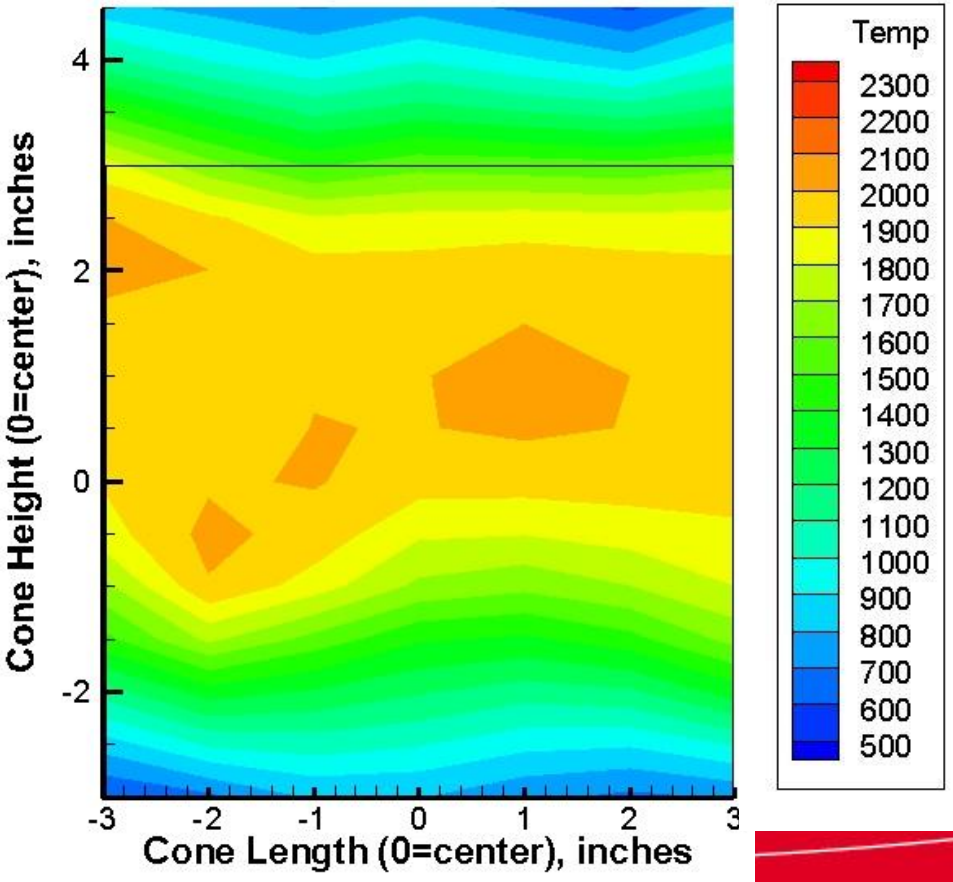


Modified Configuration B

- Continued experimentation with draft tube components and spacing yielded a new configuration with slightly more optimal heat flux
- Two key changes from 'Modified Configuration A':

  -Static Plate depth increased to 6.5" (from downstream end of Flame Retention Head)

  -Nozzle (typically 2.5 GPH 80° Type W) replaced with Delevan 2.25 GPH 80° Type B



Height (inches)	Average Temperature (F)	Total Heat Flux (BTU/hr)	
		Average	Peak
4.5	720	2013	2135
4	960		
3.5	1260		
3	1600	4301	4392
2.5	1867		
2	1963		
1.5	1975	5118	5546
1	1972		
0.5	1972		
0	1955	4726	4980
-0.5	1885		
-1	1758		
-1.5	1520	3408	3541
-2	1237		
-2.5	965		
-3	711	1420	1534

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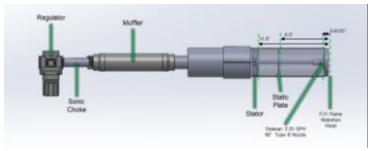
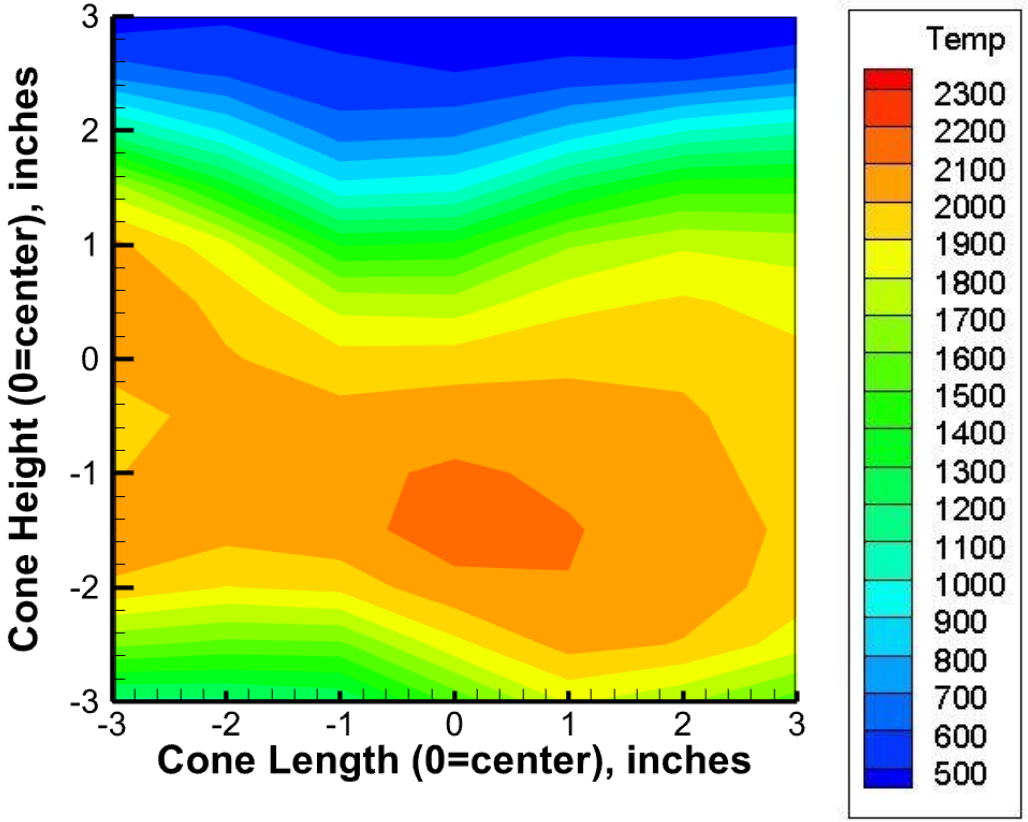


Modified Configuration B

Modified Config B - Vertical



Height (inches)	Average Temperature (F)	Total Heat Flux (BTU/hr)	
		Average	Peak
3	429	1392	1435
2.5	564		
2	890		
1.5	1316	3685	3799
1	1701		
0.5	1887		
0	1973	4604	5041
-0.5	2013		
-1	2046		
-1.5	2071	4372	4912
-2	1999		
-2.5	1788		
-3	1453	2778	2844

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Comparison of Calibration Results

-FAA Configuration

-Modified Config A

-Modified Config B

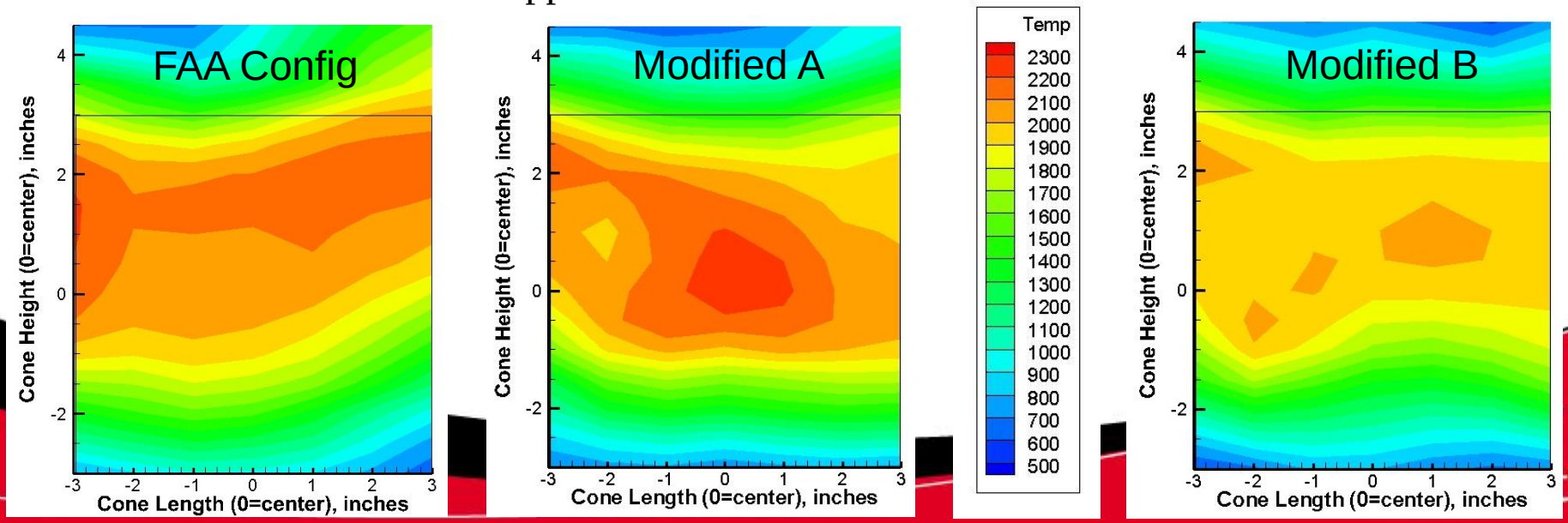
Result Comparisons – Horizontal Burner

At typical calibration height of 1.5” above centerline:

	Temperature (F)	Heat Flux (avg) (BTU/hr)	Heat Flux (peak) (BTU/hr)
FAA Config	2133	6323	6802
Modified A	2058	5260	5902
Modified B	1975*	5118	5546

*Calibration TCs were worn out. When replaced with new TCs, temperature above 2000 F is achieved.

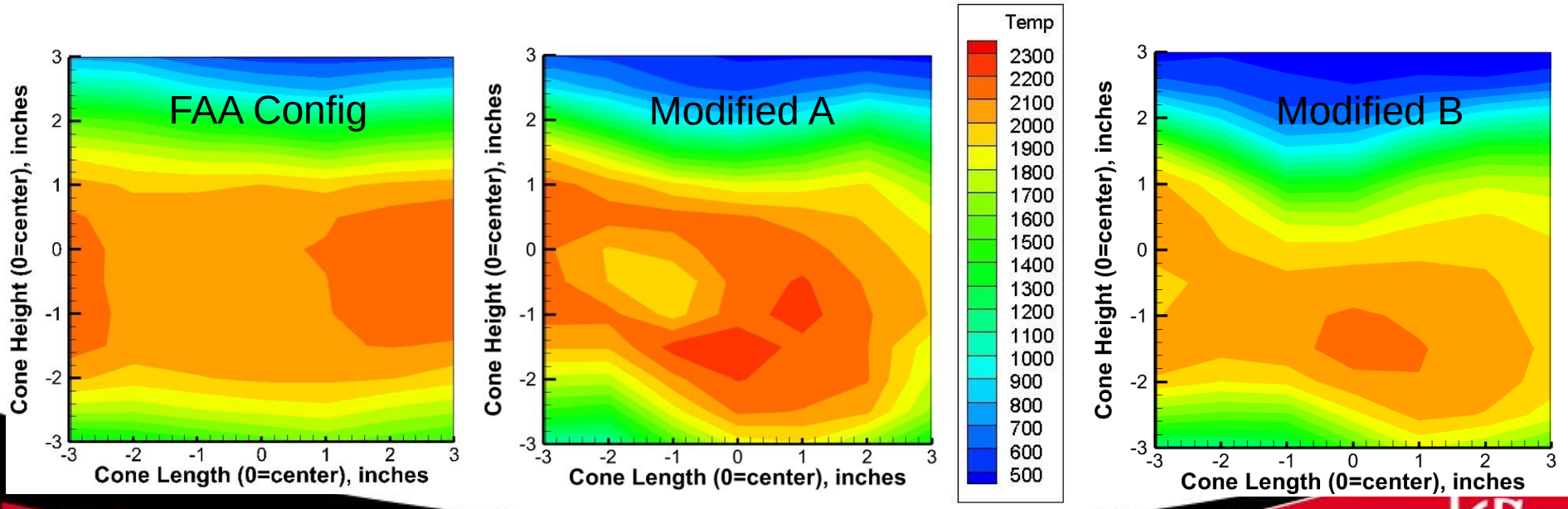
‘Modified Configuration B’ demonstrates lowest heat flux of all configurations tested (at same fuel / air input of 115 / 50 psi, respectively). Temperature distribution also appears most uniform.



Result Comparisons – Vertical Burner

At centerline of burner cone (vertically oriented):

	Temperature (F)	Heat Flux (avg) (BTU/hr)	Heat Flux (peak) (BTU/hr)
FAA Config	2115	5809	6359
Modified A	2065	5038	6412
Modified B	1973	4604	5041



Burn Through Panel Testing

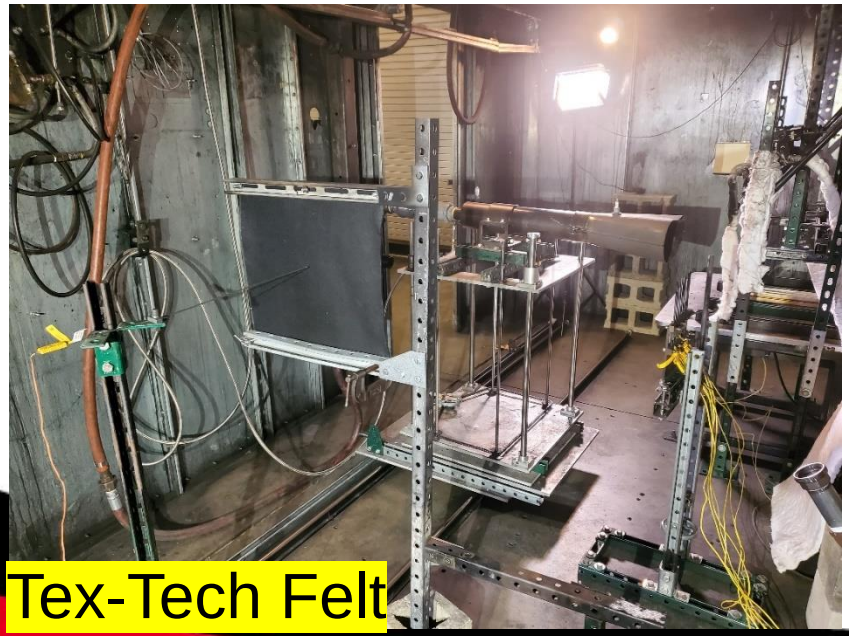
Panel Testing Overview

- Materials:

  -24x24” aluminum panel with screw and nut located at panel centerline

  -19x19” Tex-Tech felt panel (material availability did not allow for 24x24”)

  -1/8” TC measuring backside air temperature intended to aid burn-through detection
- Cone centerline located 1.5” below panel centerline
- Each result is an average of multiple trials



Burn Through Test Result

Aluminum Panel:

	Temperature (F)	Heat Flux (avg) (BTU/hr)	Heat Flux (peak) (BTU/hr)	Bolt Drop Time
FAA Config	2120	6100	6623	1m39s
Modified A	2105	5604	6282	1m34s
Modified B	2021	5061	5450	1m53s

- Burn through times indicate Modified B burner configuration slightly less severe than others.

Tex-Tech Felt Panel:

	Temperature (F)	Heat Flux (avg) (BTU/hr)	Heat Flux (peak) (BTU/hr)	Burn Through Time
FAA Config	2025	5930	6797	6m30s
Modified A	2037	5497	6607	7m18s
Modified B	1945	4805	5358	7m25s

- Burn through times indicate both configurations using FRH + static plate + stator slightly less severe than the configuration using turbulator + stator.

Additional Burn Through Testing

- Prior calibrations and burn-through results obtained using constant burner inputs (fuel and air settings)
- Set all configurations to equivalent temperature and compare heat flux and burn-through performance

@ equivalent operating conditions

	Temperature (F)	Heat Flux (avg) (BTU/hr)	Heat Flux (peak) (BTU/hr)	Bolt Drop Time	Eq. Ratio
FAA Config	2120	6100	6623	1m39s	0.96
Modified A	2105	5604	6282	1m34s	0.96
Modified B	2021	5061	5450	1m53s	0.85

@ ~equivalent temperatures

	Temperature (F)	Heat Flux (avg) (BTU/hr)	Heat Flux (peak) (BTU/hr)	Bolt Drop Time	Eq. Ratio
FAA Config	2022	5672	5931	3m26s	0.84
Modified A	2008	5030	5441	2m20s	0.83
Modified B	2021	5061	5450	1m53s	0.85

Effect of Total Mass Flow

Calculate Flow Conditions

- Picked selection of flow conditions, holding equivalence ratio constant at 1, to observe the effect of total mass flow rate:

For the 2.5 GPH Nozzle (FAA & Modified A Configs)				
Air Pressure psig	Air Mass Flow pph	Fuel Pressure psi	Fuel Mass Flow pph	Eq Ratio
40	212.4	78.0	14.4	1
41	217.0	82.8	14.8	1
42	221.6	87.5	15.1	1
43	226.3	92.3	15.4	1
44	230.9	97.1	15.7	1
45	235.5	101.9	16.0	1
46	240.1	106.6	16.3	1
47	244.8	111.4	16.7	1
48	249.4	116.2	17.0	1
49	254.0	121.0	17.3	1
50	258.6	125.7	17.6	1
51	263.3	130.5	17.9	1
52	267.9	135.3	18.2	1
53	272.5	140.1	18.5	1
54	277.1	144.8	18.9	1
55	281.8	149.6	19.2	1
56	286.4	154.4	19.5	1
57	291.0	159.2	19.8	1
58	295.7	164.0	20.1	1
59	300.3	168.7	20.4	1
60	304.9	173.5	20.7	1

For the 2.25 GPH Nozzle (Modified B Config)				
Air Pressure psig	Air Mass Flow pph	Fuel Pressure psi	Fuel Mass Flow pph	Eq Ratio
40	212.4	107.2	14.4	1
41	217.0	113.0	14.8	1
42	221.6	118.8	15.1	1
43	226.3	124.6	15.4	1
44	230.9	130.4	15.7	1
45	235.5	136.2	16.0	1
46	240.1	142.0	16.3	1
47	244.8	147.8	16.7	1
48	249.4	153.6	17.0	1
49	254.0	159.4	17.3	1
50	258.6	165.2	17.6	1
51	263.3	171.0	17.9	1
52	267.9	176.8	18.2	1
53	272.5	182.6	18.5	1
54	277.1	188.4	18.9	1
55	281.8	194.2	19.2	1
56	286.4	200.0	19.5	1
57	291.0	205.8	19.8	1
58	295.7	211.5	20.1	1
59	300.3	217.3	20.4	1
60	304.9	223.1	20.7	1

Effect of Total Mass Flow – Horizontal Burner

- Evaluate calibration performance of the various configurations over a range of operating conditions by varying the total mass flow into the burner
- At 1.5” above burner centerline:

Burner Configuration	Air Pressure (psig)	Fuel Pressure (psi)	Eq. Ratio	Total Mass Flow (pph)	Temperature (F)	Heat Flux (avg) (BTU/hr)	Heat Flux (peak) (BTU/hr)
FAA	40	78	1	227	1975	4964	5256
FAA	45	102	1	252	2082	5723	6228
FAA	50	126	1	276	2177	6432	7125
FAA	55	150	1	301	2223	6779	7531

Burner Configuration	Air Pressure (psig)	Fuel Pressure (psi)	Eq. Ratio	Total Mass Flow (pph)	Temperature (F)	Heat Flux (avg) (BTU/hr)	Heat Flux (peak) (BTU/hr)
Modified A	40	78	1	227	2020	4652	5319
Modified A	45	102	1	252	2107	5208	5900
Modified A	50	126	1	276	2166	5676	6495
Modified A	55	150	1	301	2197	5961	6748

Burner Configuration	Air Pressure (psig)	Fuel Pressure (psi)	Eq. Ratio	Total Mass Flow (pph)	Temperature (F)	Heat Flux (avg) (BTU/hr)	Heat Flux (peak) (BTU/hr)
Modified B	40	107	1	227	2005	4212	4791
Modified B	45	136	1	252	2058	4741	5329
Modified B	50	165	1	276	2070	5117	5619

Effect of Total Mass Flow – Vertical Burner

- Vary the total mass flow into the burner and observe the effects on calibration result
- At burner centerline (vertically oriented):

Burner Configuration	Air Pressure (psig)	Fuel Pressure (psi)	Eq. Ratio	Total Mass Flow (pph)	Temperature (F)	Heat Flux (avg) (BTU/hr)	Heat Flux (peak) (BTU/hr)
FAA	40	78	1	227	2038	4769	5184
FAA	45	102	1	252	2132	5031	5488
FAA	50	126	1	276	2187	5199	5774
FAA	55	150	1	301	2182	5458	5893

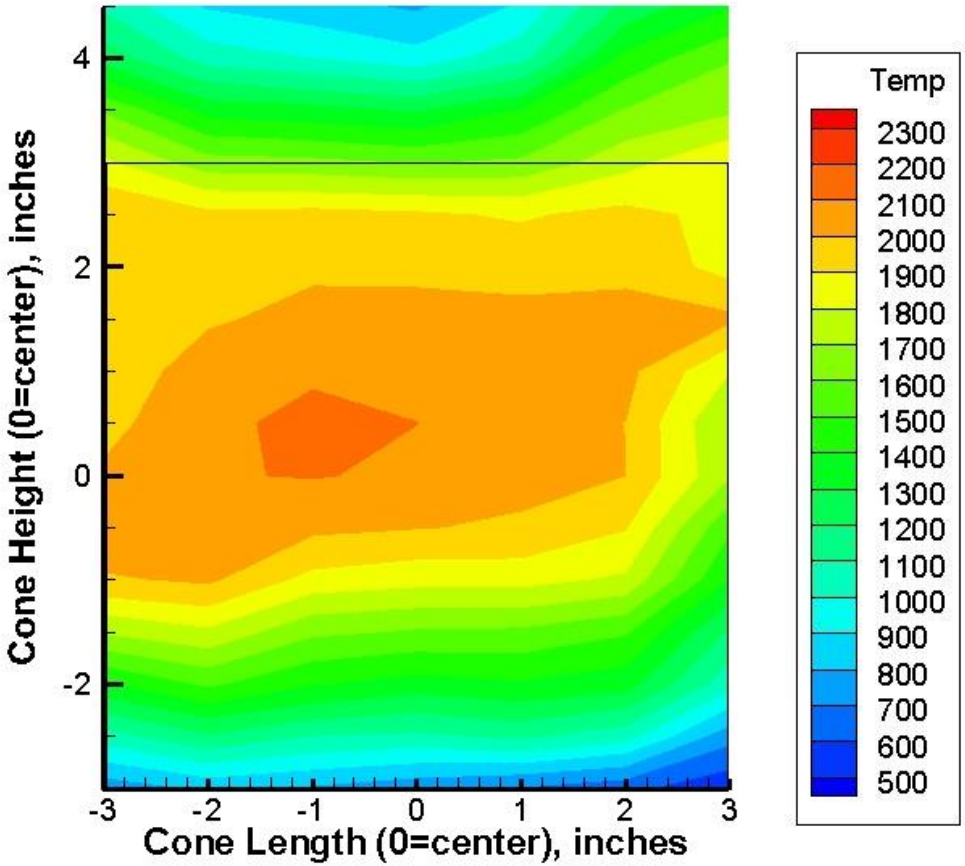
Burner Configuration	Air Pressure (psig)	Fuel Pressure (psi)	Eq. Ratio	Total Mass Flow (pph)	Temperature (F)	Heat Flux (avg) (BTU/hr)	Heat Flux (peak) (BTU/hr)
Modified A	40	78	1	227	1995	4308	5080
Modified A	45	102	1	252	2031	4691	5471
Modified A	50	126	1	276	2065	4914	5741
Modified A	55	150	1	301	2116	5241	6167

Burner Configuration	Air Pressure (psig)	Fuel Pressure (psi)	Eq. Ratio	Total Mass Flow (pph)	Temperature (F)	Heat Flux (avg) (BTU/hr)	Heat Flux (peak) (BTU/hr)
Modified B	40	107	1	227	1958	4604	5041
Modified B	45	136	1	252	2019	4484	5216
Modified B	50	165	1	276	2044	4705	5434

Operating Conditions for Optimal Heat Flux

Modified Config B, New Burner Inputs, Horizontal

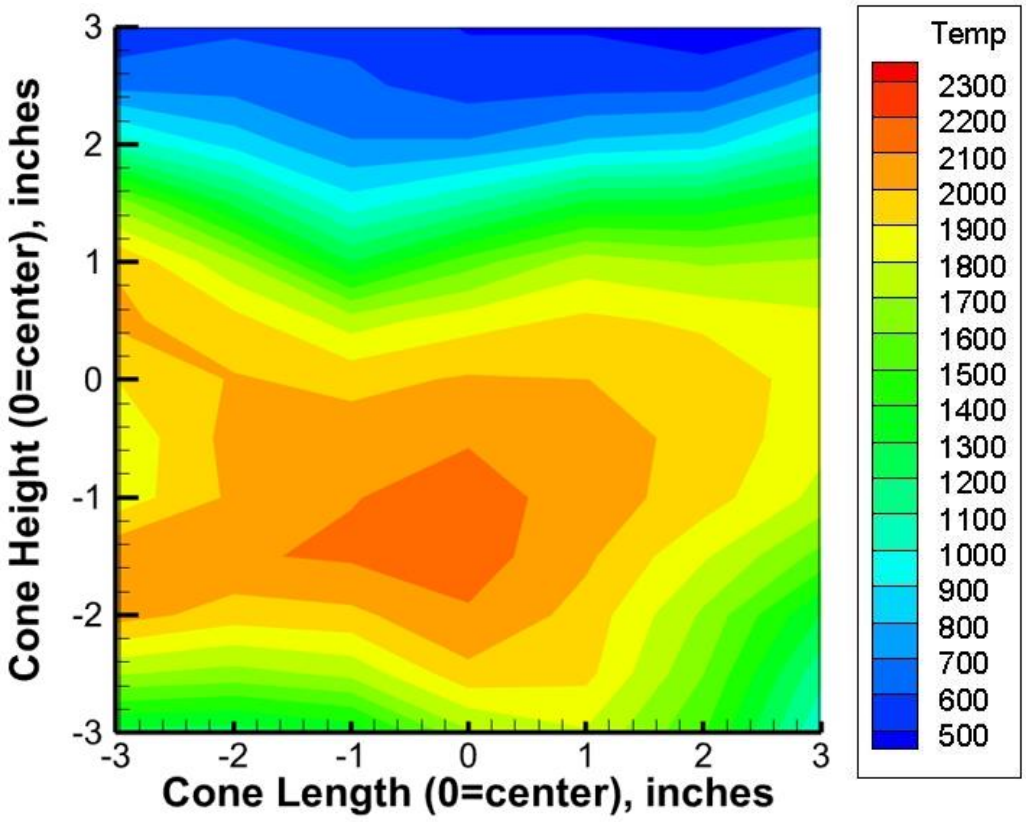
- 'Modified B' Config operated at Air = 40 psi and Fuel = 107 psi demonstrated an average heat flux below the minimum requirement at typical calibration height. Full burner map desired.



Height (inches)	Average Temperature (F)	Total Heat Flux (BTU/hr)	
		Average	Peak
4.5	1010	2940	3133
4	1190		
3.5	1460		
3	1713	4325	4631
2.5	1923		
2	1961		
1.5	2010	4249	4857
1	2006		
0.5	2002		
0	2008	4050	4595
-0.5	1950		
-1	1818		
-1.5	1565	3134	3284
-2	1348		
-2.5	1058		
-3	702	1395	1511

Modified Config B, New Burner Inputs, Vertical

- Air = 40 psi and Fuel = 107 psi. Full vertically oriented burner map taken for comparison.



Height (inches)	Average Temperature (F)	Total Heat Flux (BTU/hr)	
		Average	Peak
3	513	1579	1624
2.5	629		
2	878		
1.5	1300	3771	4019
1	1674		
0.5	1885		
0	1958	4142	4863
-0.5	1977		
-1	1982		
-1.5	1976	3667	4188
-2	1857		
-2.5	1676		
-3	1404	2394	2450

Summary

- Desire to achieve with the NexGen burner a heat flux that is more in line with the requirement of 4500 BTU/hr
- Draft tube components and spacing were varied iteratively to create novel configurations
- Comparisons of calibration results, burner temperature and heat flux maps, and panel burn through testing were made
- A new configuration, ‘Modified B’ was found to achieve the lowest peak and average total heat flux of the candidates, in both horizontal and vertical orientations
- Burn through testing indicates ‘Modified B’ to be the least severe of the configurations tested
- Total mass flow was varied to determine burner performance over a range of operating conditions
- In some cases, the average total heat flux of ‘Modified B’ burner configuration may be below minimum requirement of 4500 BTU/hr. However, total mass flow can be increased to bring heat flux to desired value.

Thank You

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