International Aircraft Systems Fire Protection Working Group Meeting

Liquid Burner Development for Powerplant Fire Test- NexGen Burner, Gas Burner Comparison; Operating Orientation of NexGen Burner

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University of Cincinnati
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Project Objective:

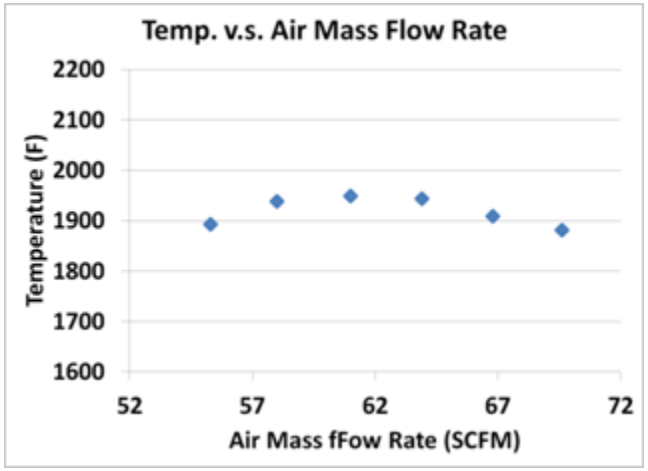
- Develop the operating settings for NexGen burner for powerplant fire tests
  - NexGen burner should **simulate** previously FAA approved oil burners
  - NexGen burner should be **robust and repeatable**

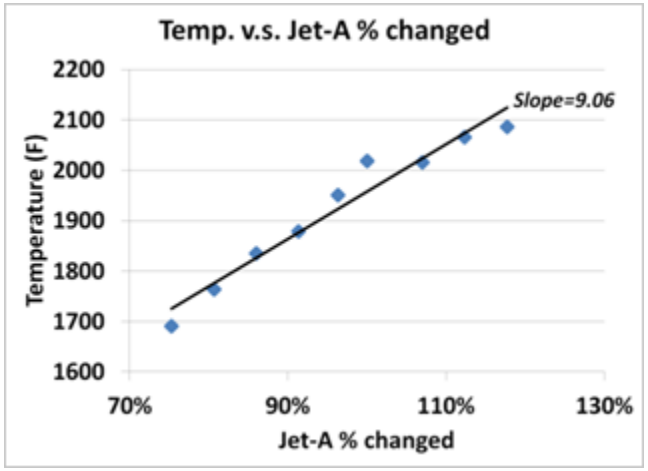
Approach:

- Sensitivity of NexGen burner setup on burner temperature and heat flux calibration (International Aircraft Systems Fire Protection Working Group, May 2011)
- Fire test results from NexGen burner operated at the same heat flux and temperatures (International Aircraft Systems Fire Protection Working Group, November 2011)
- Comparison of fire test results between NexGen and Gas burner
- Fire test results from NexGen burner operated at different orientations
- Derive the NexGen burner settings *(future work)*

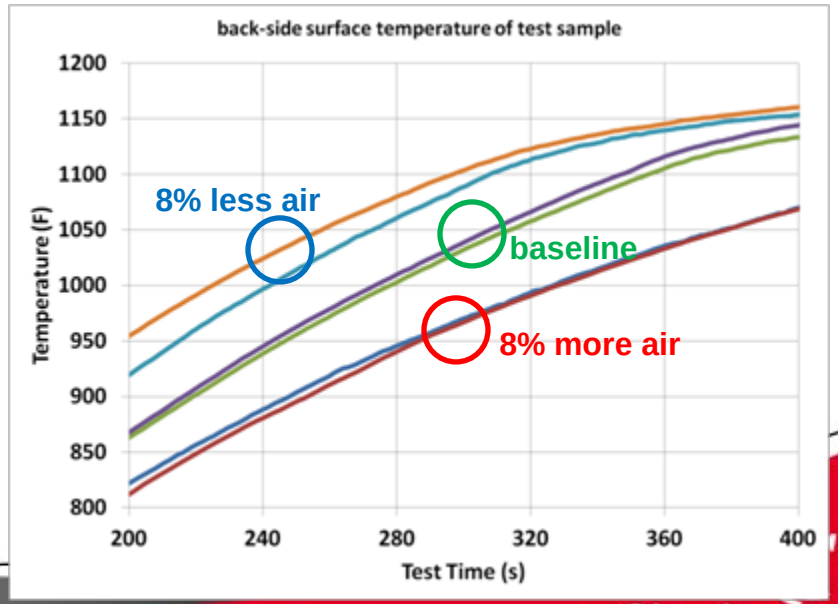
Conclusion of previous works (1)

➢For calibration purpose, NexGen burner is much more sensitive to a change in the fuel flow rate as opposed to a change on air flow rate.





➢ Even though the calibration of the NexGen burner was not sensitive to change in air flow rate, tests conducted on samples indicated that air flow had an impact on damage induced by the burner



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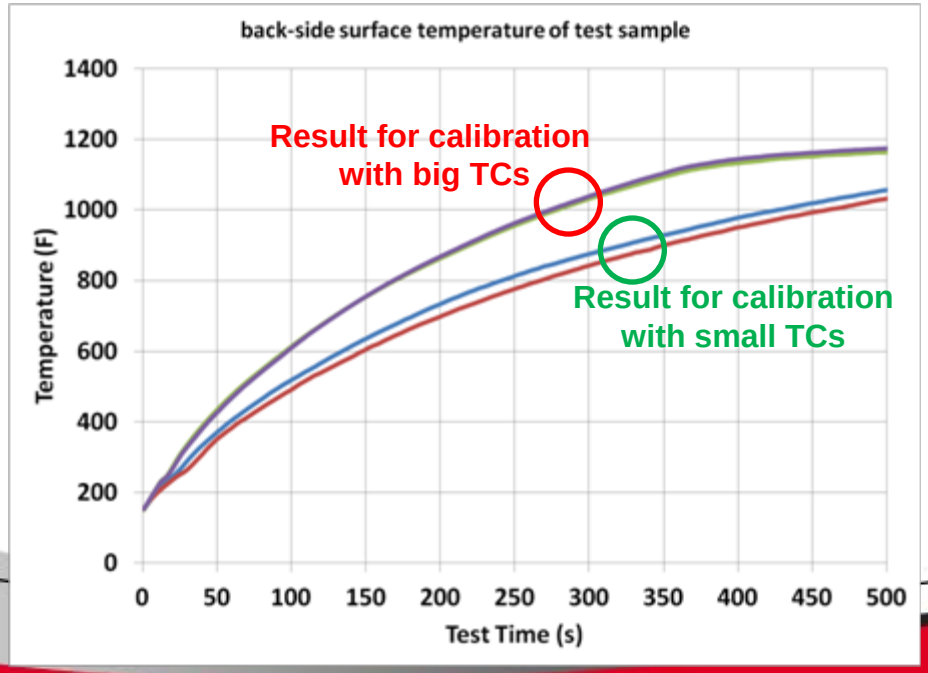
Conclusion of previous works (2)

- Thermocouple size does affect the temperature calibration data, as well as the result of fire test.
  - Smaller thermocouples read the higher measured temperature.
  - Test sample tested with flame calibrated by smaller thermocouple survived longer .

TCs used for calibration	Test Conditions		Calibration Data	
	Fuel (GPH)	Air (SCFM)	Temp. (F)	Heat Flux (BTU/ft^2-s)
small TCs	2.14	60.4	1907.9	9.0
big TCs	2.25	62.2	1919.6	9.4



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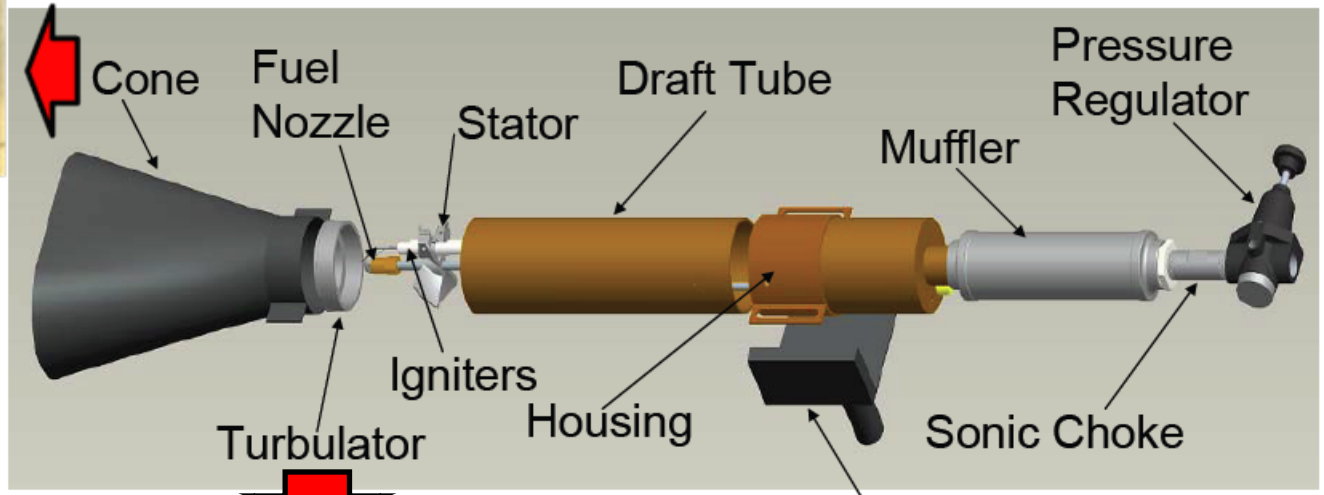
NexGen burner

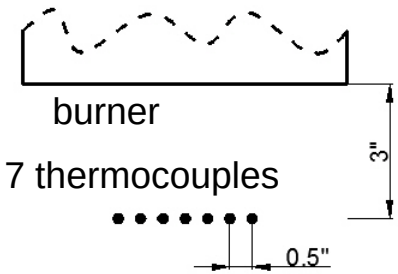
Both fuel and air rate can be accurately metered and controlled

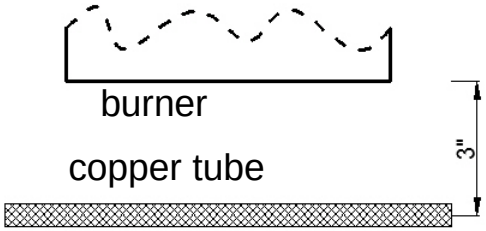
Uninsulated Cone
(Inconel 661)

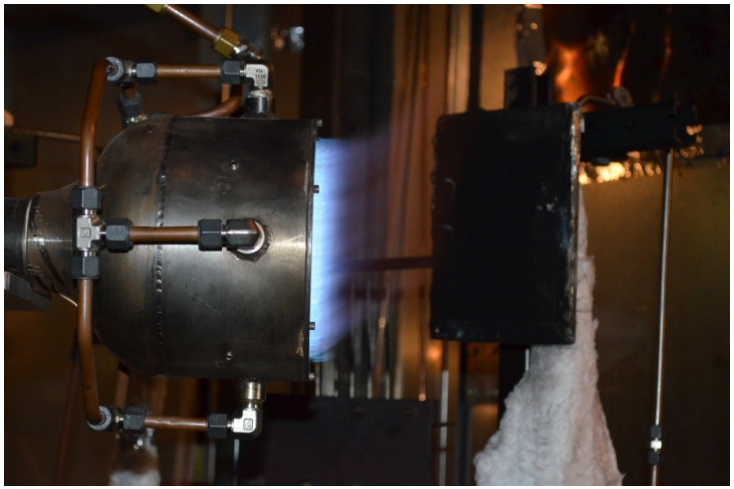


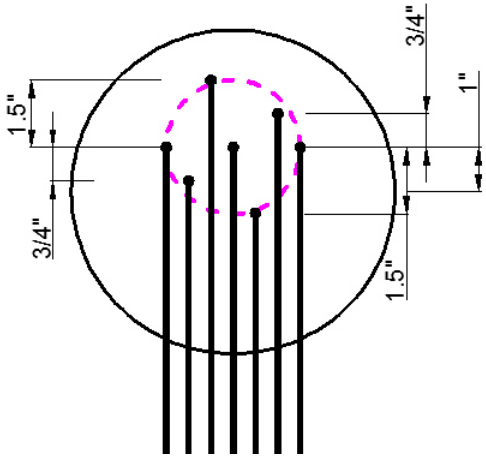
Modified Turbulator
(Four 1”x3/4” tabs)

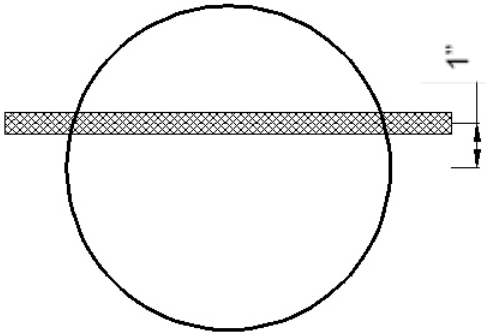
Gas burner

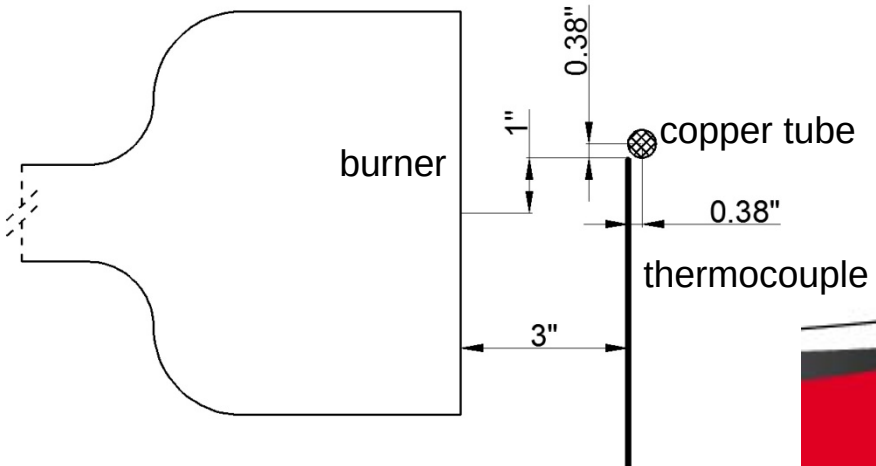












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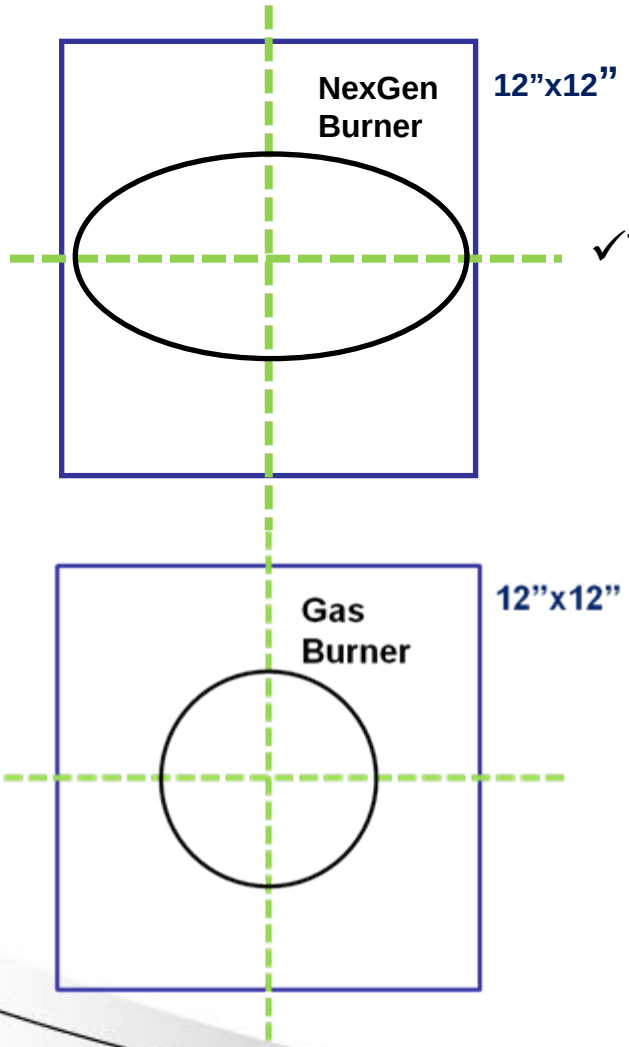
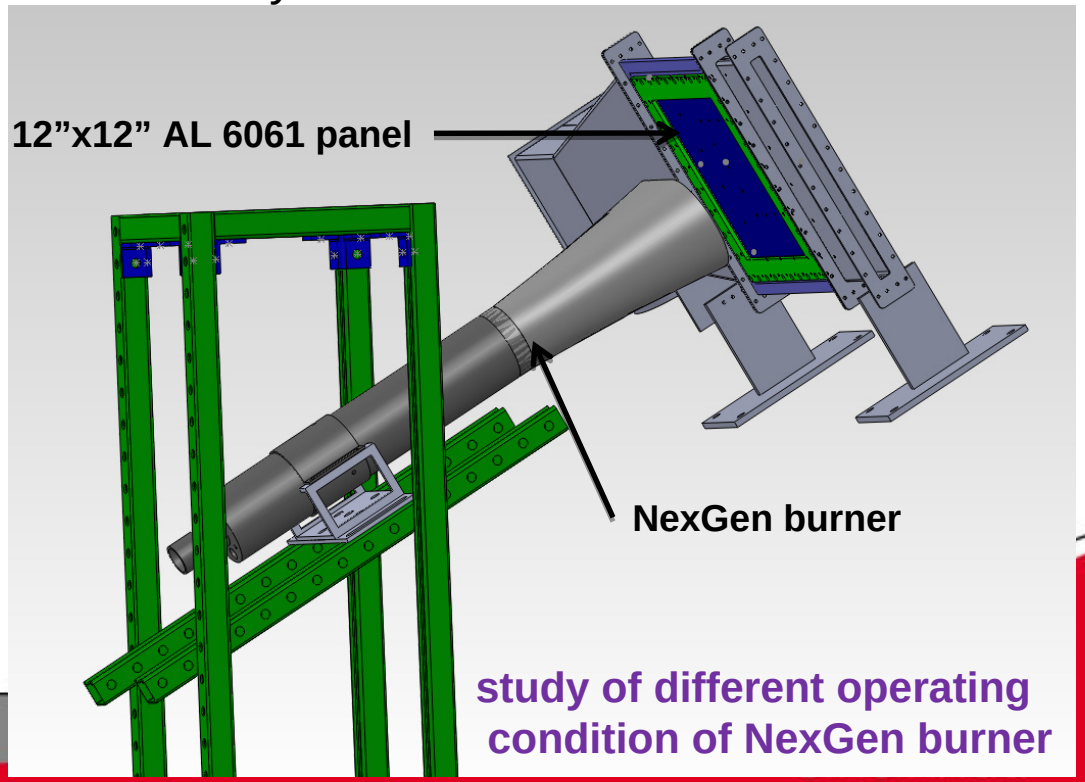
Current Study

- ✓ Fire Test for same temperature calibration
  - ➢Different burners: NexGen burner v.s. gas burner (horizontal placement)
  - ➢Different operating orientations of NexGen burner

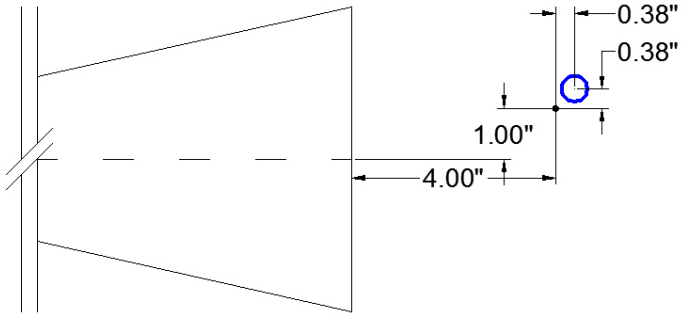


- ✓Test samples and Methods
  - ➢12”x12”x1/4”, AL 6061
  - ➢back side thermocouples to monitor the surface temperature history

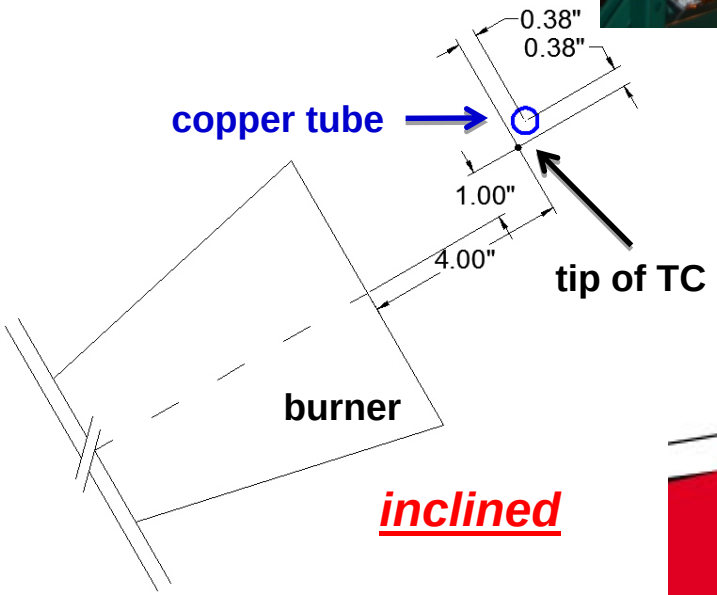


study of different operating condition of NexGen burner

Test Setup and Burner Orientation



horizontal



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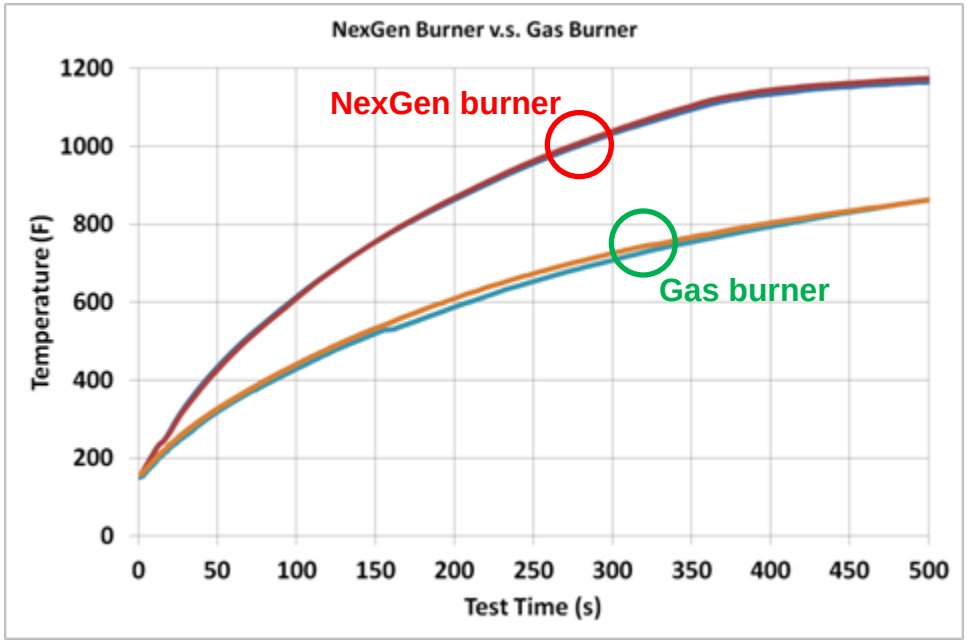
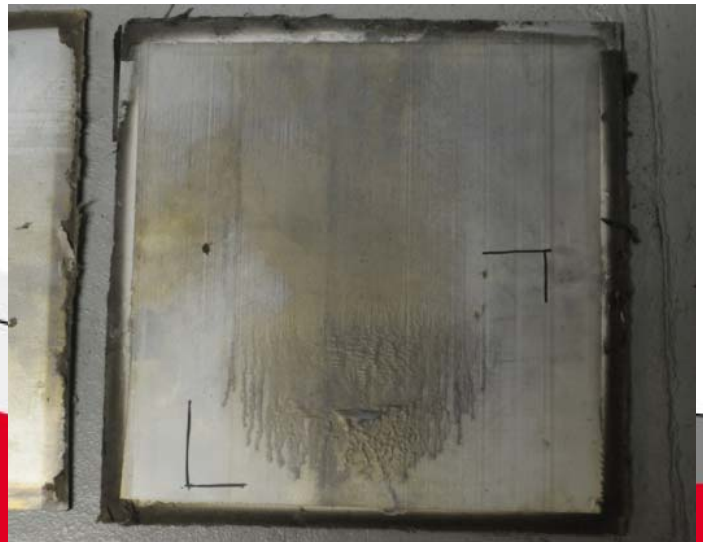
Burner Calibration Data (Diff. Burner)

	Test Conditions		Calibration Data		Burnthought Time
	Fuel	Air	Temp. (F)	Heat Flux (BTU/ft^2-s)	
NexGen-1st	2.25 GPH	62.2 SCFM	1919.8	9.5	11.5 min
NexGen-2nd			1919.6	9.4	terminated at 10 min
Gas-1st	0.45 SCFM	4.95+7.43 SCFM (mixing+cooling air)	1914.9	8.8	≥20 min
Gas-2nd			1916.5	8.9	≥20 min
*Ambient Temp.=70~80 F, w/o forced convection					

Back Surface Temp. History



NexGen burner, 10 mins surface damaged



Gas burner, 20 mins undamaged

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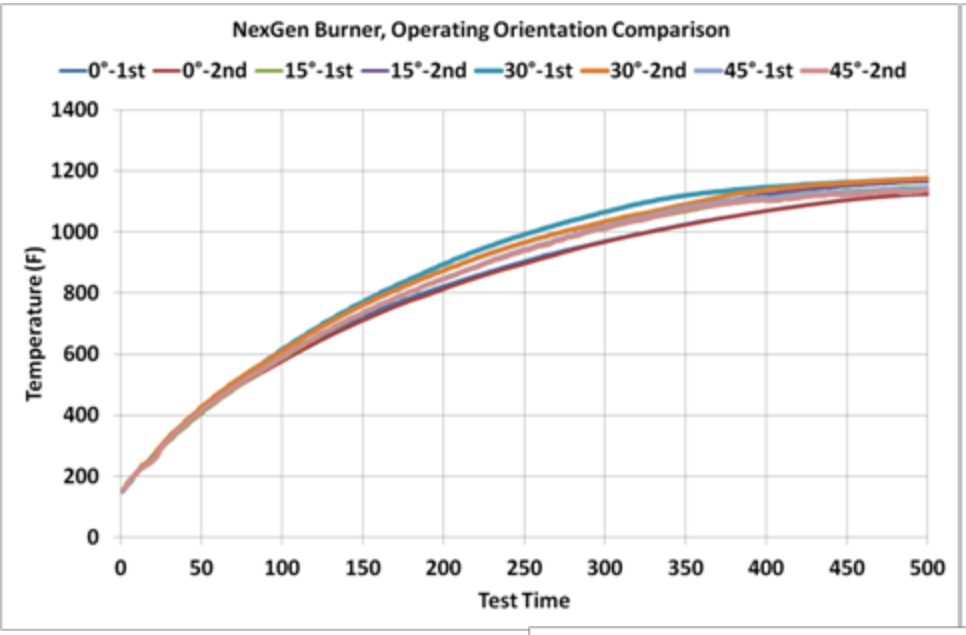
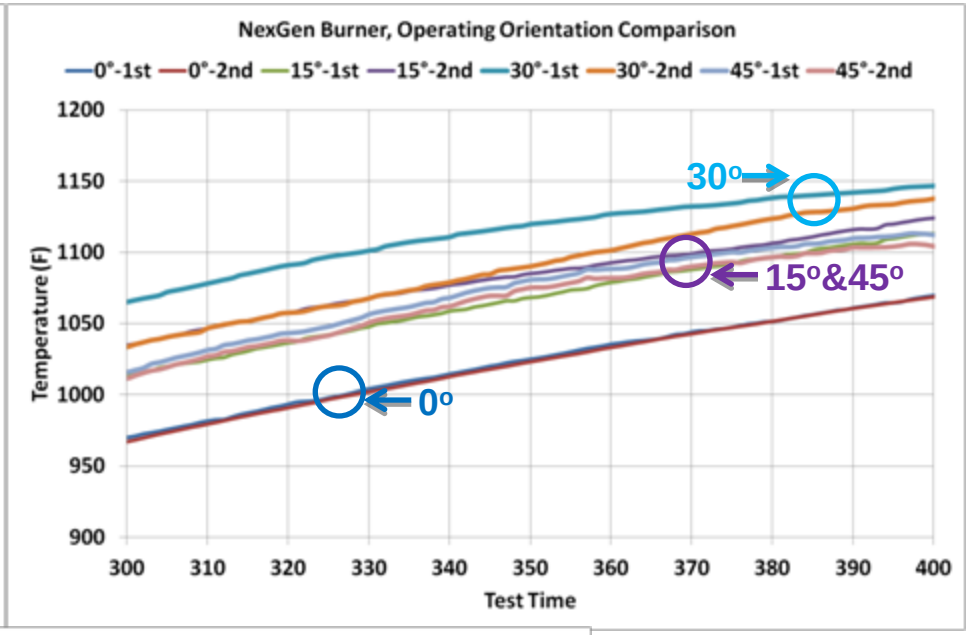
Burner Calibration Data (Diff. Orientation)

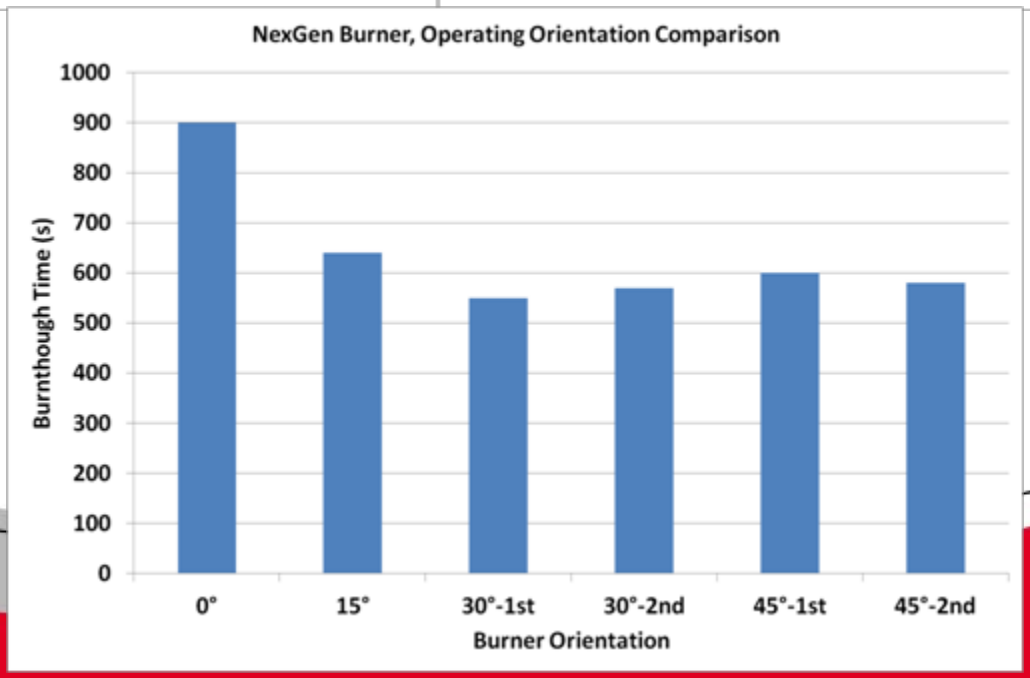
Test Conditions				Calibration Data		Burnthought Time
Test #	Fuel (GPH)	Air (SCFM)	Φ	Temp. (F)	Heat Flux (BTU/ft^2-s)	
0°-1st	2.25	67.6	0.76	1919.6	9.4	**15m**
0°-2nd				1919.8	9.4	-
15°-1st	2.36	66.7	0.81	1922.4	10.3	**10m40s**
15°-2nd				1920.7	10.4	-
30°-1st	2.55	66.7	0.87	1928.1	11.0	**9m10s**
30°-2nd				1930.0	11.1	**9m30s**
45°-1st	2.61	66.7	0.89	1928.6	11.4	**10m**
45°-2nd				1920.1	11.5	**9m40s**

*Ambient Temp.=70~80 F, w/o forced convection
*ϕ: equivalent ratio
*" 0°-2nd"&" 15°-2nd" were terminated at 10 minutes for post inspection

Back Surface Temp. History (Diff. Orientation)







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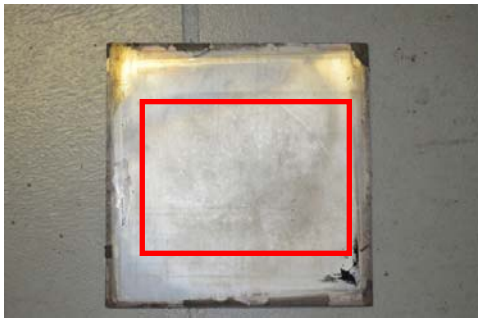
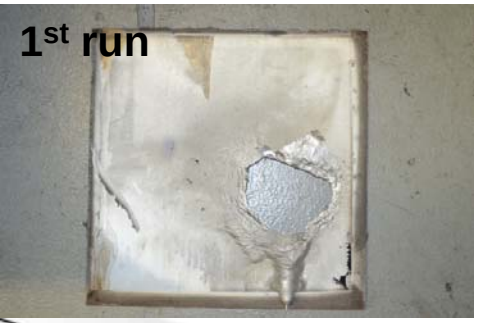
Post-Test Inspection

0°, 10 mins, undamaged

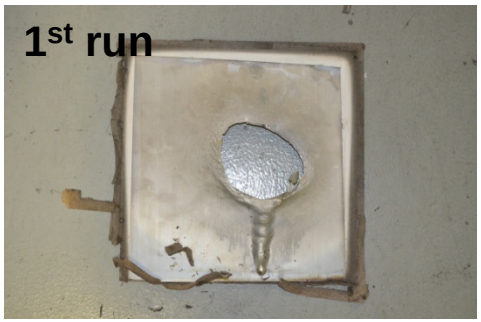
15°, 10 mins, surface damaged

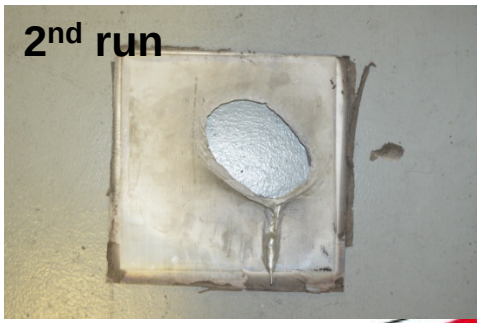


30°, 9m10s& 9m30s surface melted



45°, 10m& 9m40s surface melted





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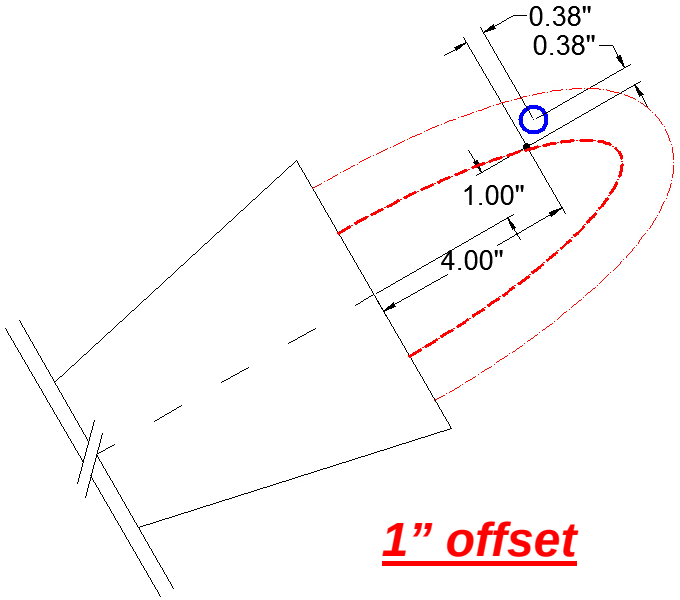
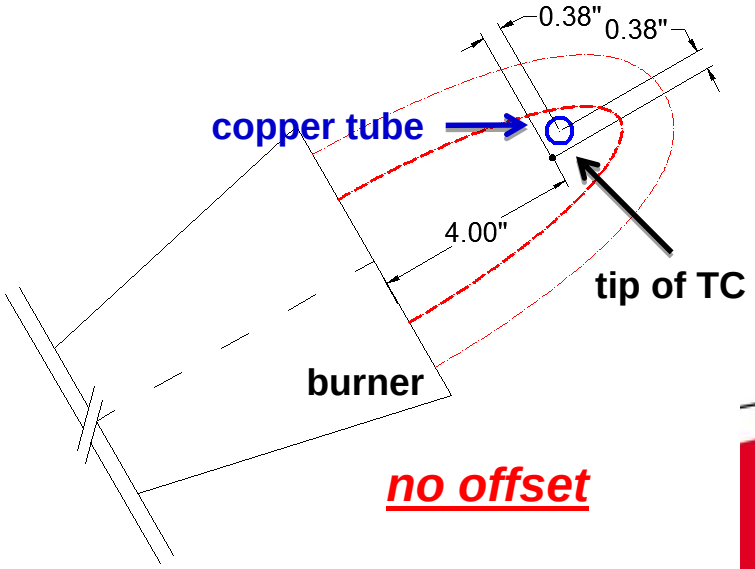
Burner Calibration Data (45º, Offset)

Test Conditions				Calibration Data		Burnthrough Time
Test #	Fuel (GPH)	Air (SCFM)	Φ	Temp. (F)	Heat Flux (BTU/ft^2-s)	
1" offset-1st	2.61	66.7	0.89	1928.6	11.4	10m
1" offset-2nd				1920.1	11.5	9m40s
no offset-1st	2.52	66.7	0.86	1912.1	11.1	12m30s
no offset-2nd				1916.2	11.2	12m10s

*Ambient Temp.=70~80 F, w/o forced convection
*ϕ: equivalent ratio



1" offset



no offset

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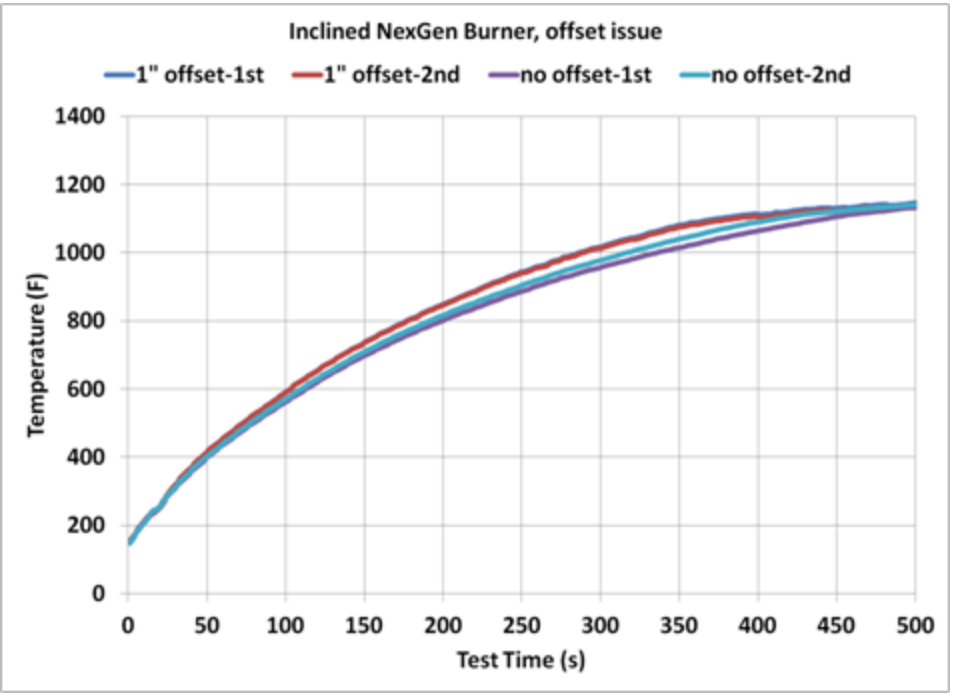
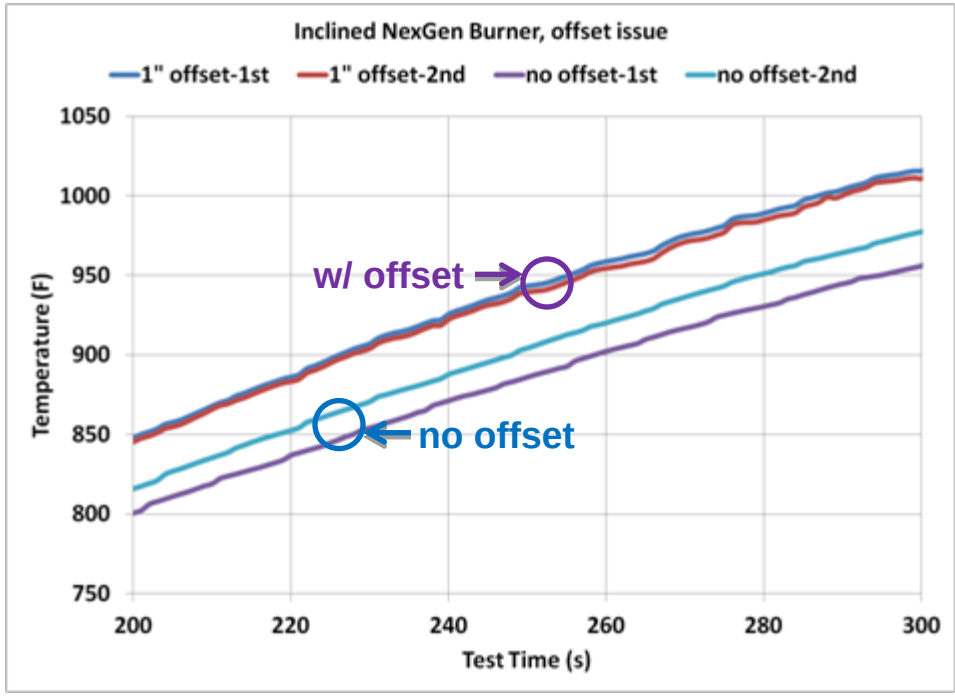
Back Surface Temp. History (45º, Offset)





Conclusion

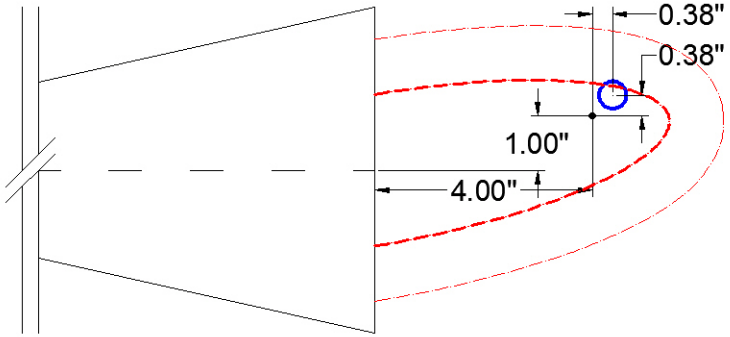
✓For horizontal orientation, the damage induced by the propane burner is less severe than the NexGen burner

✓Tests were conducted with the NexGen burner oriented at different angles, while maintaining similar temperature calibration

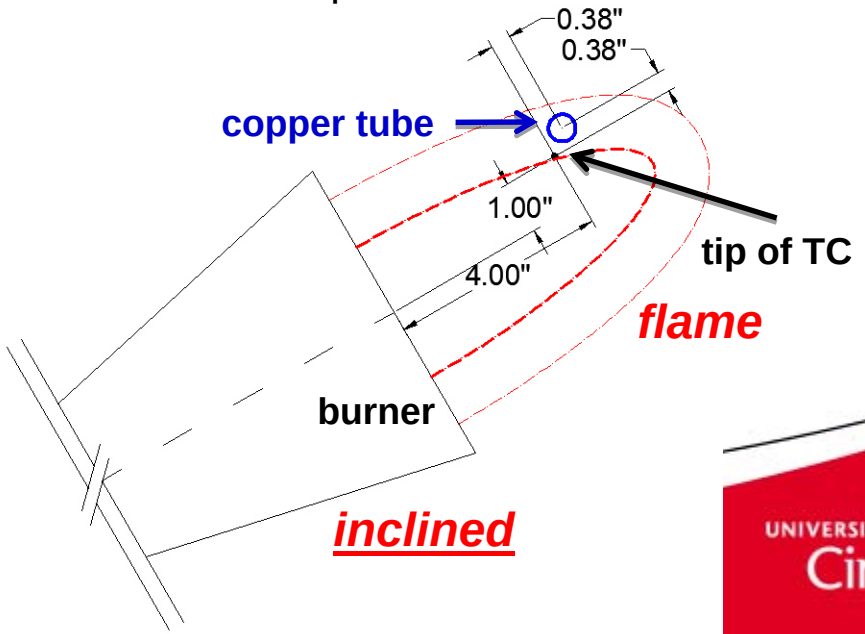
- ➢More damage and shorter burnthrough time were observed for inclined orientation, as compared to horizontal orientation

✓For inclined burner orientation the effect of buoyancy on the flame is reduced

- ➢Due to less buoyancy, the hot zone at inclined orientation remains closer to burner centerline
- ➢Higher fuel flow rate needed to achieve same temperature when the calibration location was offset from burner centerline



horizontal



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Recommendation

• For inclined burner orientation, the offset distance between tip of thermocouple and centerline of burner needs to be defined

• Fire test houses should report the location of the calibration devices, both distance from burner exit and offset from burner centerline, for inclined burner orientation

Future Work

•Mapping the temperature distribution for inclined NexGen burner.

Acknowledgement

The presented work was supported by a grant from the FAA technical center.

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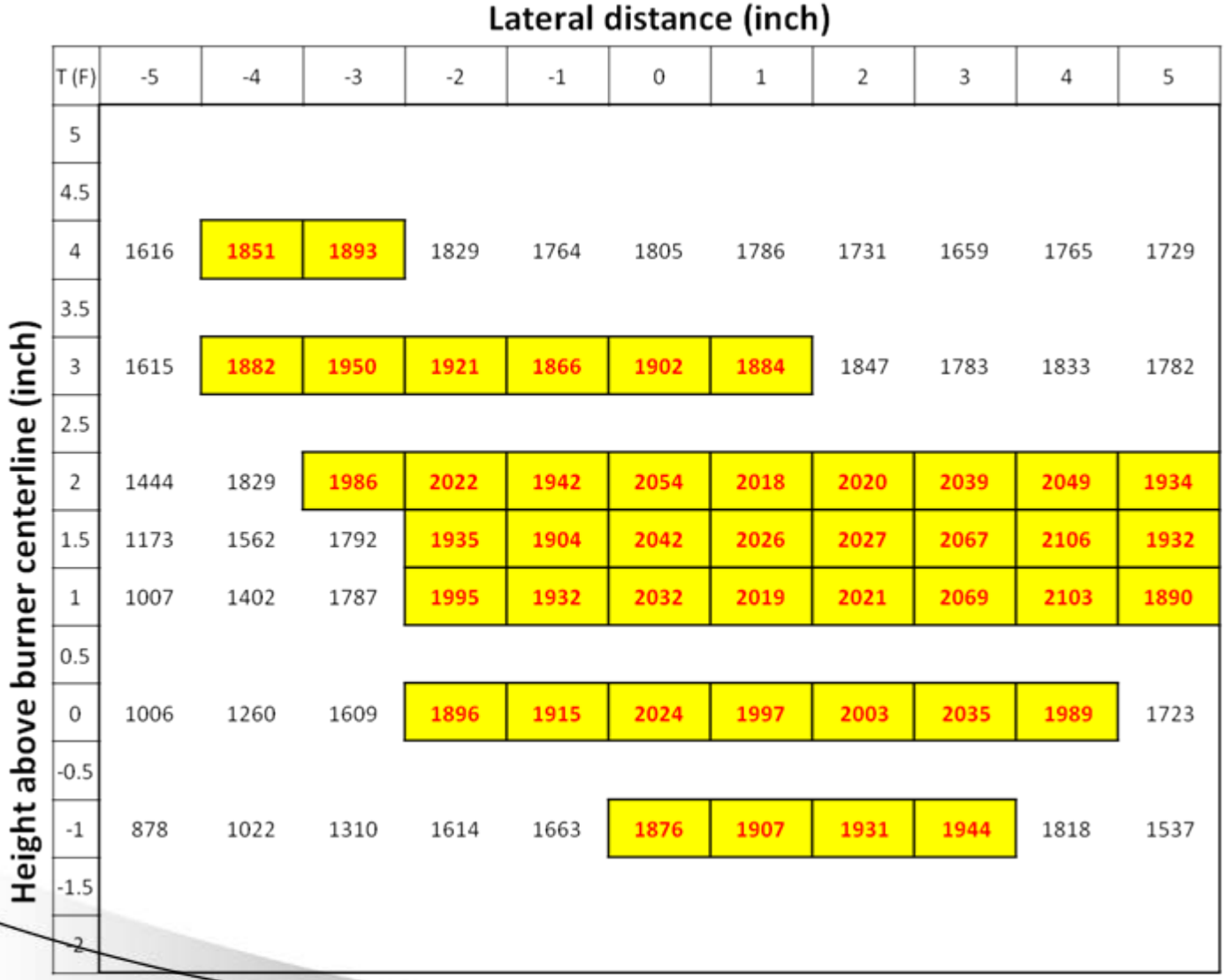
Appendix: temp. mapping



T (F)	-5	-4	-3	-2	-1	0	1	2	3	4	5
5											
4.5											
4	1616	1851	1893	1829	1764	1805	1786	1731	1659	1765	1729
3.5											
3	1615	1882	1950	1921	1866	1902	1884	1847	1783	1833	1782
2.5											
2	1444	1829	1986	2022	1942	2054	2018	2020	2039	2049	1934
1.5	1173	1562	1792	1935	1904	2042	2026	2027	2067	2106	1932
1	1007	1402	1787	1995	1932	2032	2019	2021	2069	2103	1890
0.5											
0	1006	1260	1609	1896	1915	2024	1997	2003	2035	1989	1723
-0.5											
-1	878	1022	1310	1614	1663	1876	1907	1931	1944	1818	1537
-1.5											
2											

- Temperature mapping by horizontal operating orientation of NexGen burner.
- mapping plane is 4 inch away from the exit of burner.