International Aircraft Systems Fire Protection Working Group Meeting

Updated Experimental Investigation of NexGen Burner

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Outline

- ***Project Objective***
- ***Conclusion of Previous Work***
- ***Test Setup and Burner Configuration***
- ***Sensitivity of Burner Calibration to:***
  - ***Fuel Temp. ($60^oF \sim 130^oF$)***
  - ***Air Temp. ($60^oF \sim 140^oF$)***
- ***Fire Test Results: Effect of Air Temp.***
- ***Conclusion and Recommendations***

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**

Previous Approach:

- Sensitivity of burner calibration to burner settings (2011)
- Fire test results from NexGen burner operated at the same calibration setup (2011)
- Comparison of fire test results between NexGen and Gas burner (2012)
- Effect of burner orientation on Fire Test results (2012)

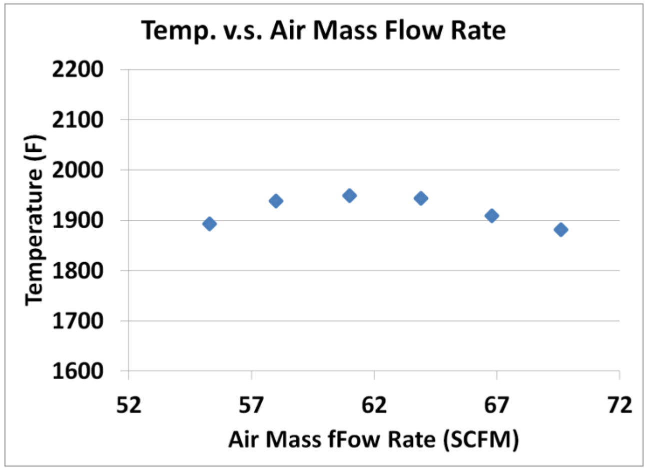
Current Approach:

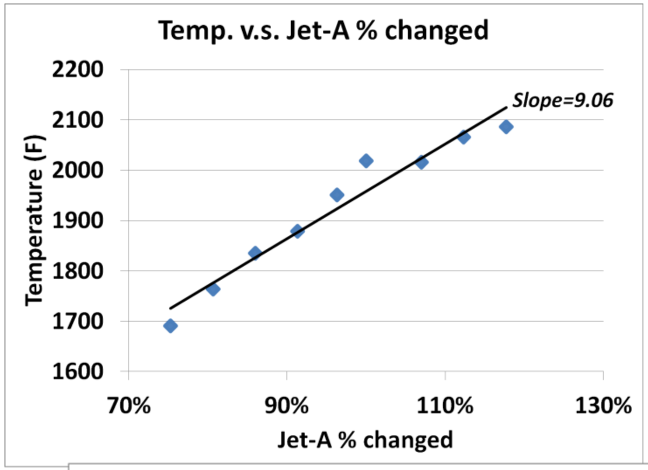
- Sensitivity of burner calibration to fuel or air temperature
- Effect of air temperature on fire test results

Conclusion of Previous Work (1)

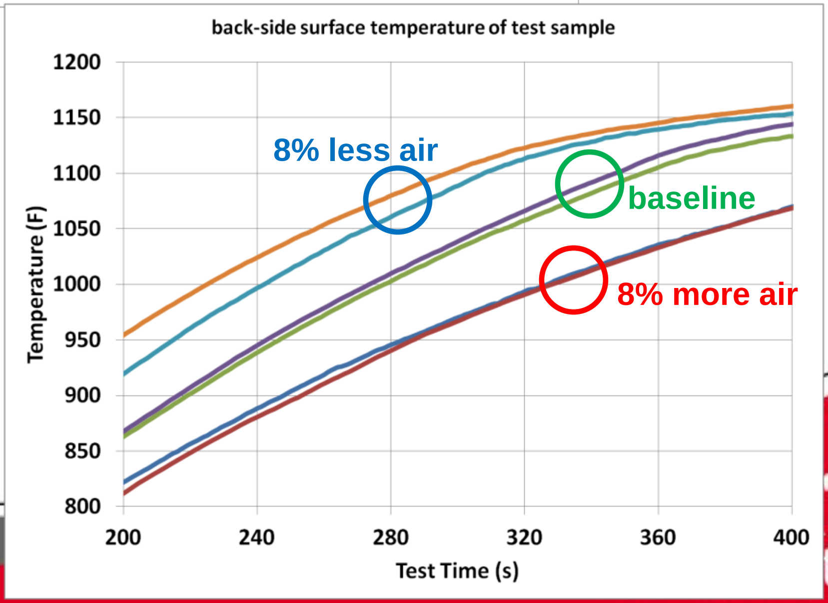
Sensitivity of Burner Calibration and Fire Test result to burner settings

➢NexGen burner calibration is much more sensitive to a change in the fuel flow rate as compared to a change in air flow rate.





➢ Fire test results show clear impact of air flow rate on test results even though calibration was not very sensitive to air flow rate

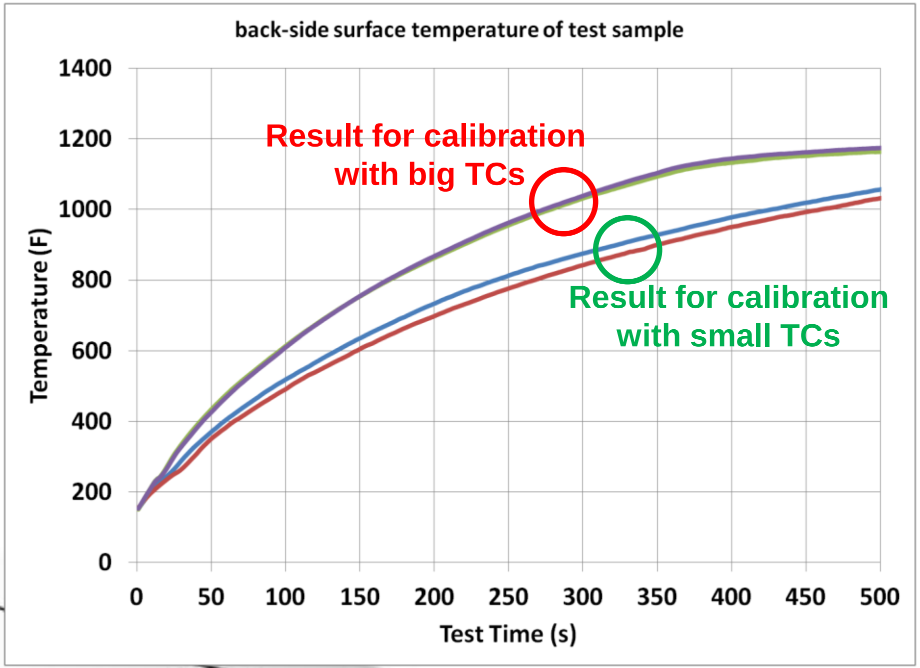


Conclusion of Previous Work (2)

Sensitivity of Burner Calibration and Fire Test result to thermocouple size

➢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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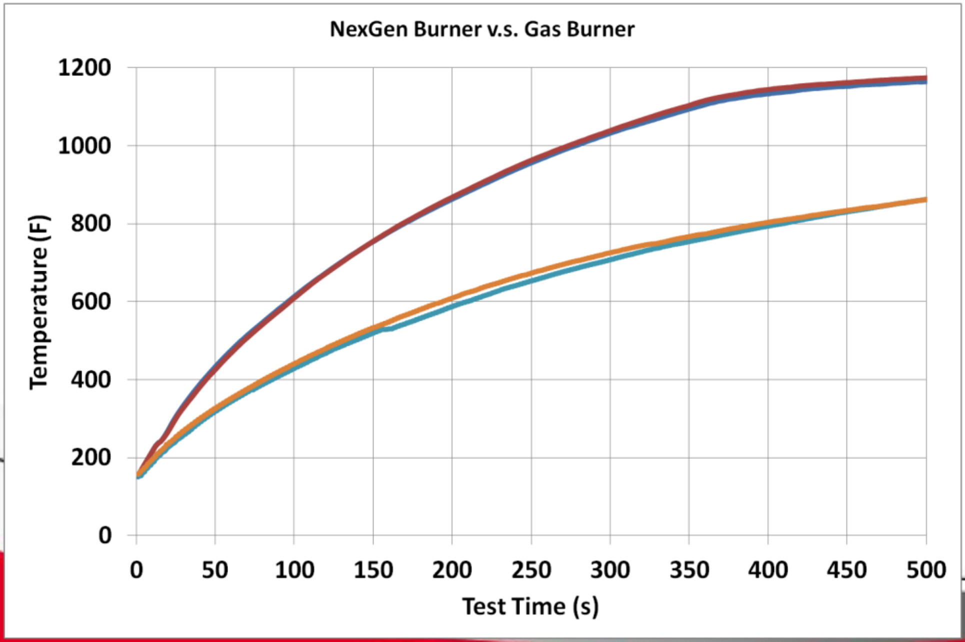
Conclusion of Previous Work (3)

Comparison of NexGen Burner and Gas burner (Horizontal)

	Test Conditions		Calibration Data		Burnthrough 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**
Gas-1st	0.45 SCFM	4.95 (mixing)+ 7.43(cooling) SCFM	1914.9	8.8	**≥20 min**
Gas-2nd			1916.5	8.9	**≥20 min**
*Ambient Temp.=70~80 F, w/o forced convection					



➢Gas burner does provide more favorable test condition at horizontal orientation, as compared to NexGen burner.

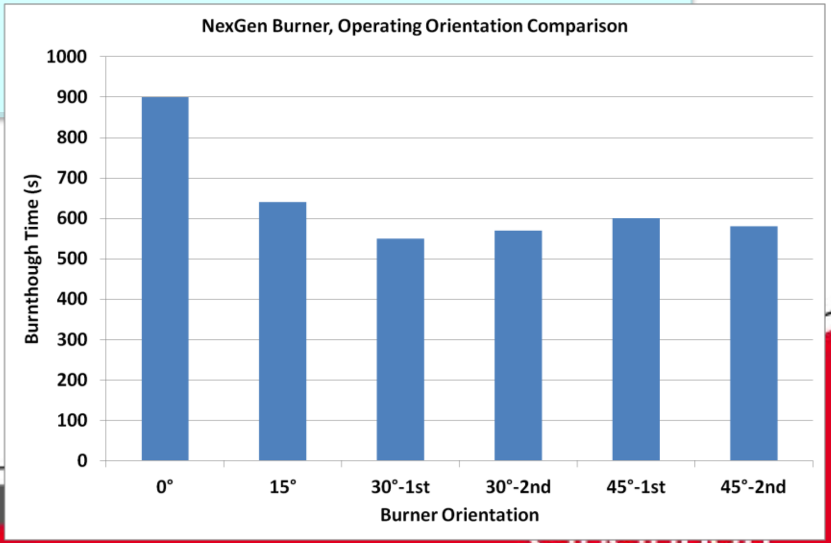
Conclusion of Previous Works (4)

Effect of Burner Orientation on Fire Test Result

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

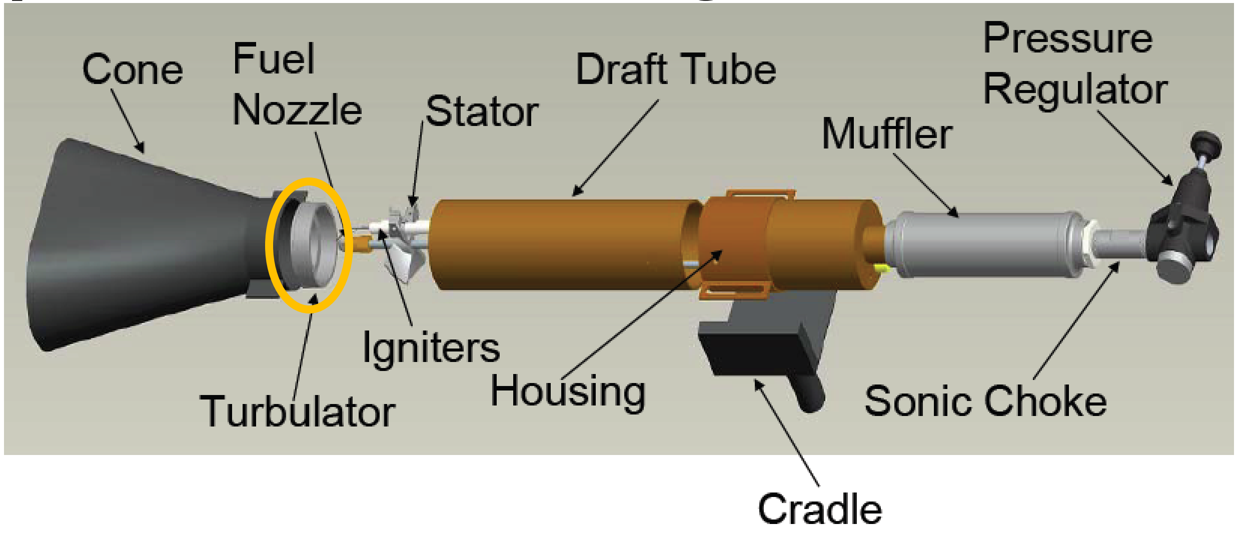
*Ambient Temp.=70~80 F, w/o forced convection
*ϕ: equivalent ratio

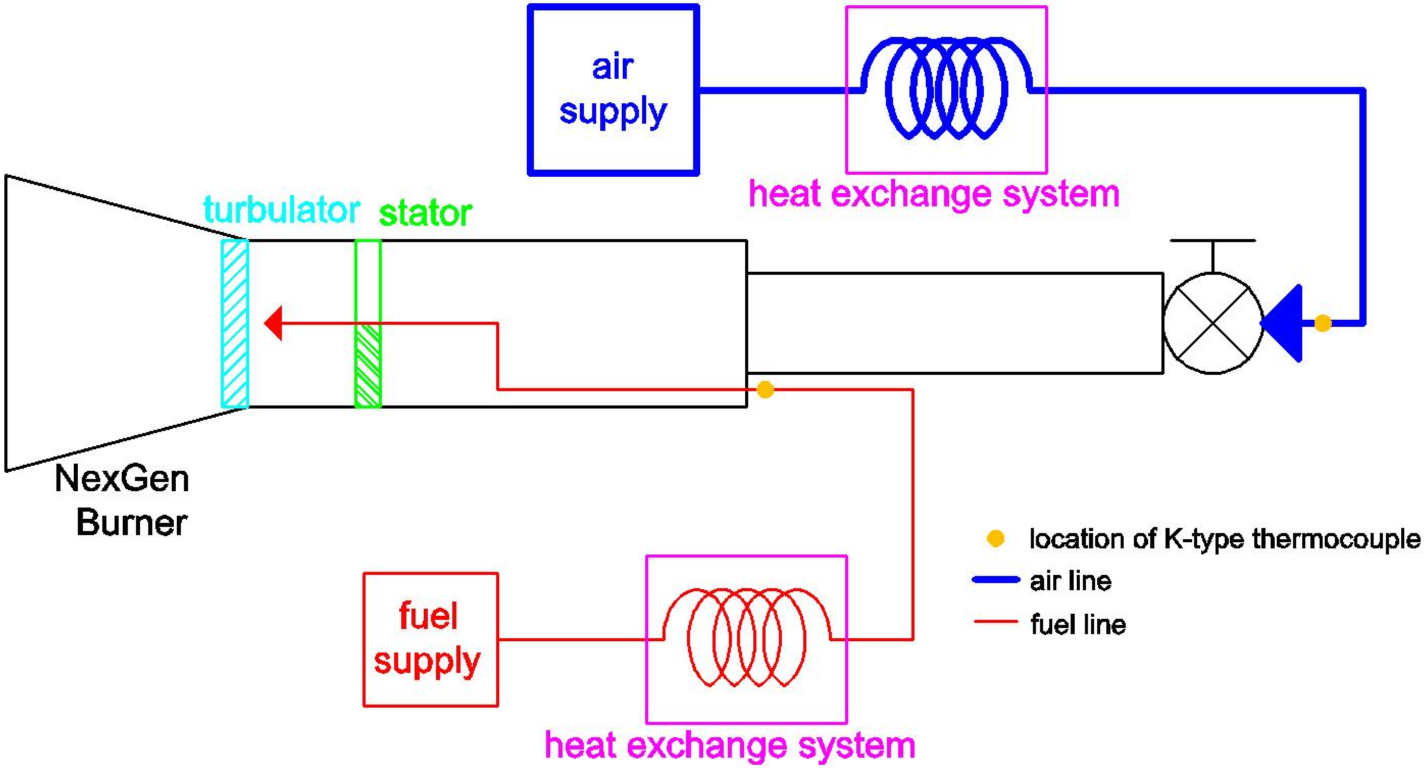
- The burnthrough time reduces as burner inclination angle is increased



Test Setup and Burner Configuration

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



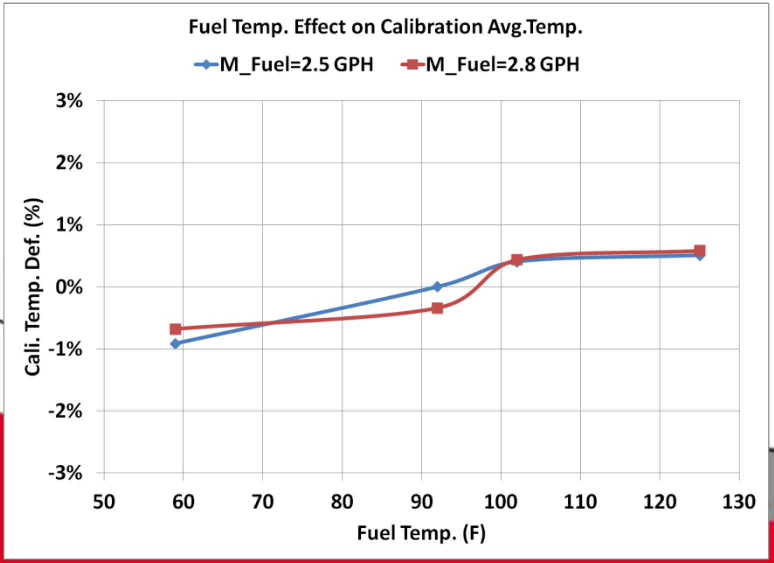


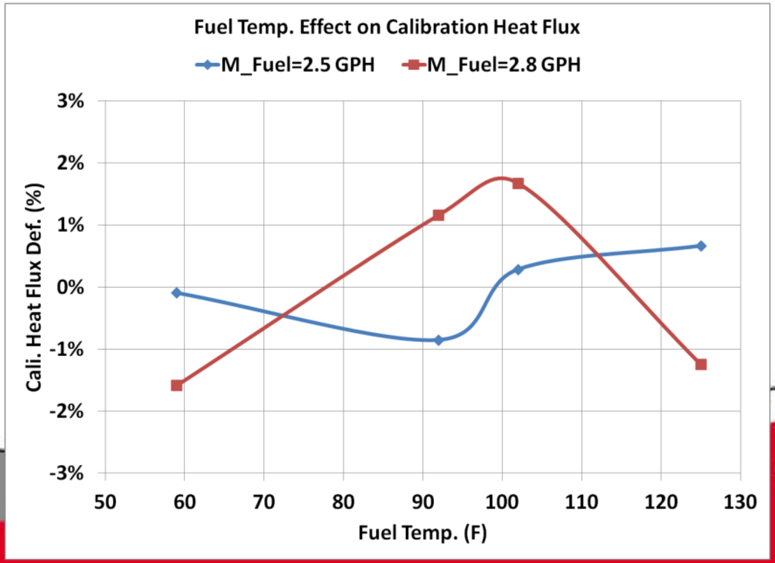
Sensitivity of Fuel Temp.

T_fuel (F)		M_fuel (GPH)	Calib_Temp. (F)		Calib_H.F. (BTU/ ft^2-s)	
57~61	59	2.51	1954	-0.91%	10.53	-0.09%
89~94	92		1972	0.00%	10.45	-0.85%
101~104	102		1980	0.41%	10.57	0.28%
124~125	125		1982	0.51%	10.61	0.66%
			1972 (Avg.)	←	10.54 (Avg.)	←

T_fuel (F)		M_fuel (GPH)	Calib_Temp. (F)		Calib_H.F. (BTU/ ft^2-s)	
57~61	59	2.78	2044	-0.68%	11.48	-1.59%
89~94	92		2051	-0.34%	11.80	1.16%
101~104	102		2067	0.44%	11.86	1.67%
124~125	125		2070	0.58%	11.52	-1.24%
			2058 (Avg.)	←	11.67 (Avg.)	←

- P=60 psig (pressure setting at pressure regulator)





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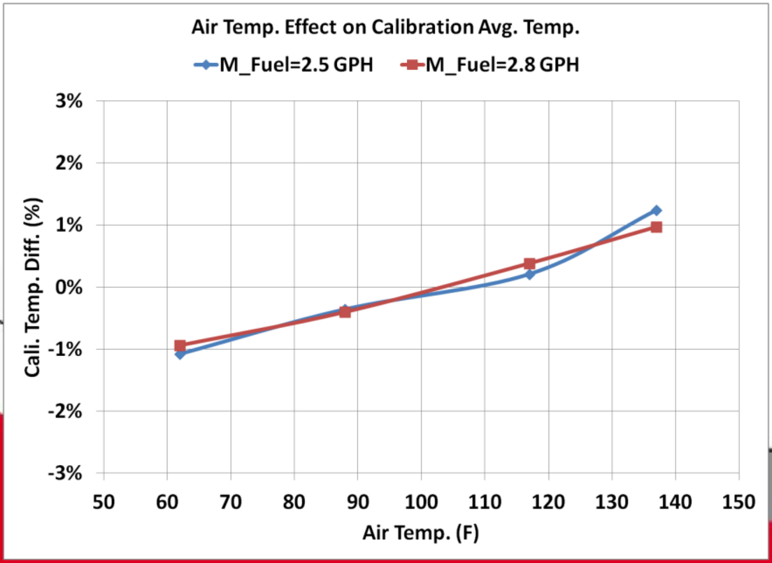
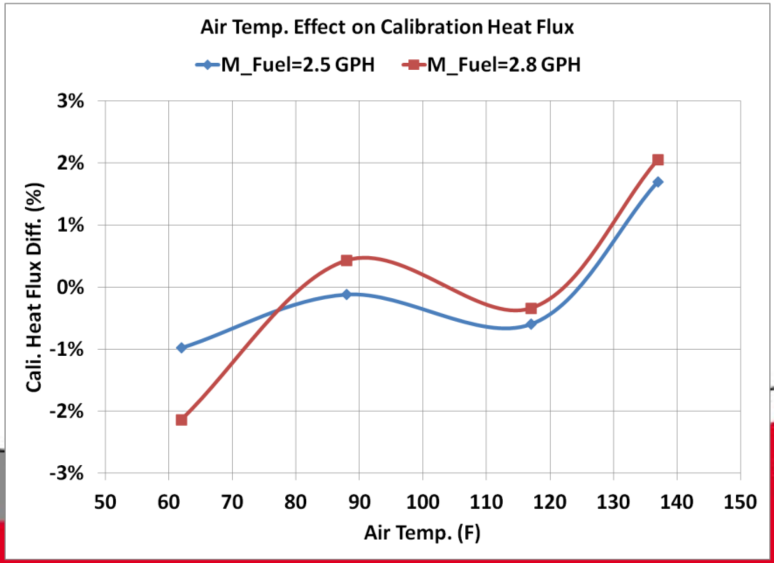
Sensitivity of Air Temp.

T_air (F)		M_fuel (GPH)	Cali._Temp (F)		Cali._H.F. (BTU/ ft^2-s)	
61~64	62	2.51	1918	-1.08%	10.35	-0.98%
85~90	88		1932	-0.36%	10.44	-0.12%
114~120	117		1943	0.21%	10.39	-0.60%
133~139	137		1963	1.24%	10.63	1.70%
			1939	←	10.45	←

T_air (F)		M_fuel (GPH)	Cali._Temp (F)		Cali._H.F. (BTU/ ft^2-s)	
61~64	62	2.78	2020	-0.94%	11.43	-2.14%
85~90	88		2031	-0.40%	11.73	0.43%
114~120	117		2047	0.38%	11.64	-0.34%
133~139	137		2059	0.97%	11.92	2.05%
			2039	←	11.68	←

- P=60 psig (pressure setting at pressure regulator)

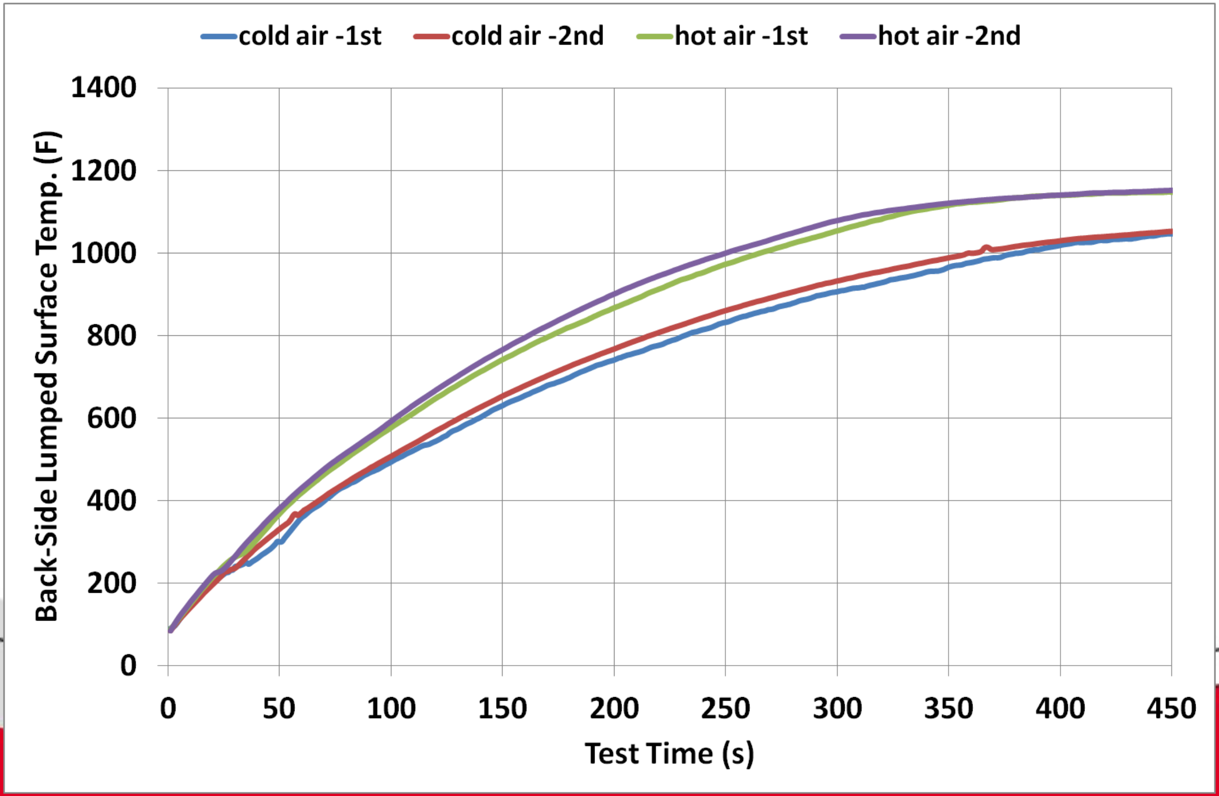




Fire Test Results v.s. Air Temp.

	Air temp. (F)	Fuel (GPH)	P, Air (psig)	calibration data		burnthrough time
				avg. temp. (F)	heat flux (BTU/ft^2-s)	
cold air -1st	82	2.62	60	2013	11.46	10m10s
cold air -2nd	78	2.62	60	2008	11.37	10m0s
hot air -1st	134	2.62	60	2009	11.52	9m0s
hot air -2nd	140	2.62	60	2021	11.58	8m30s

- 10% increase in (absolute) air temperature reduced burnthrough time by 80s (300K->330K, 80°F->135°F)



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Theory behind Experimental Results (1)

Air Mass Flow for Choked Flow → $\dot{m} = CA\sqrt{k\rho P\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}} \propto \sqrt{\rho P}$

Ideal Gas Law → $P = \rho RT$ → $\rho = {}^{P}/_{RT}$

From Above Two Eq.s → $\dot{m} = {}^{P}/_{\sqrt{T}}$

m	**mass flow rate**
C	**Discharge coefficient**
A	**cross area**
k	**Cp/Cv**
ρ	**density**
P	**pressure**

unchanged dP + T increasing from 300K to 330K =air mass flow rate drops 5%

300K=27°C=80°F
330K=57°C=134°F

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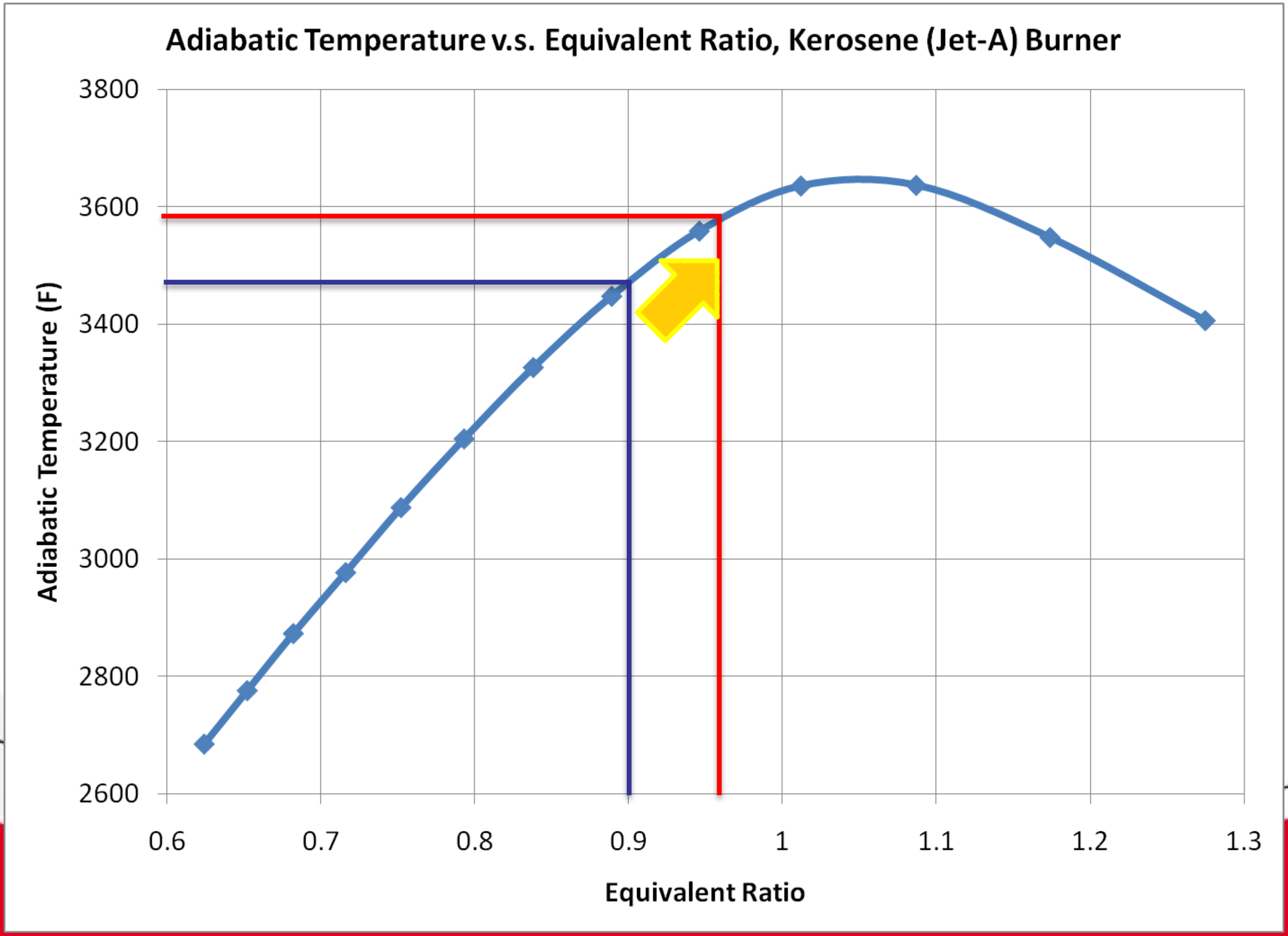
Theory behind Experimental Results (2)

- 5% of air mass flow rate drop could shift the equivalent ratio from 0.9 to 0.95, and increase the adiabatic temperature up to 100ºF.
- Even the NexGen burner is an opened-flame system, the real flame temperature still could be expected to increase a non-neglected value.



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Conclusions

- ❖ Fuel and air temperature do not have a significant impact on burner calibration
  - ✓ Under the range of investigated fuel and air temperature, all of data are within 2% difference of mean value.

- ❖ For the same pressure setting, air temperature has a significant impact on the fire test result
  - ✓For a constant pressure setting on the sonic choke, air flow rate decreases with increasing temperature
  - ✓The decrease in air flow rate results in an increase in the real flame temperature
  - ✓Burnthrough time is inversely proportional to the air temperature, i.e. higher air temperature results in the shorter burnthrough time

Recommendation

• Fire test houses should report and monitor the air temperature during fire testing to minimize the discrepancy of fire test results.

• For the sonic choke, air mass flow rate is proportional to $P/\sqrt{T}$, so this quantity needs to be monitored

Acknowledgement

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