International Aircraft Systems Fire Protection Working Group

Liquid Burner Development for Powerplant Fire Test

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Project Objective:

- Develop the operating settings for NexGen burner for powerplant fire tests
  - NexGen burner should **simulate** previously FAA approved liquid 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 2010)
- **Fire test results from NexGen burner operated at the same heat flux and temperatures**
- Derive the NexGen burner settings *future work*
  - Comparison of fire test results from different burners (Park, NexGen and ISO)

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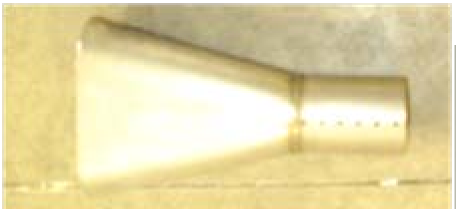
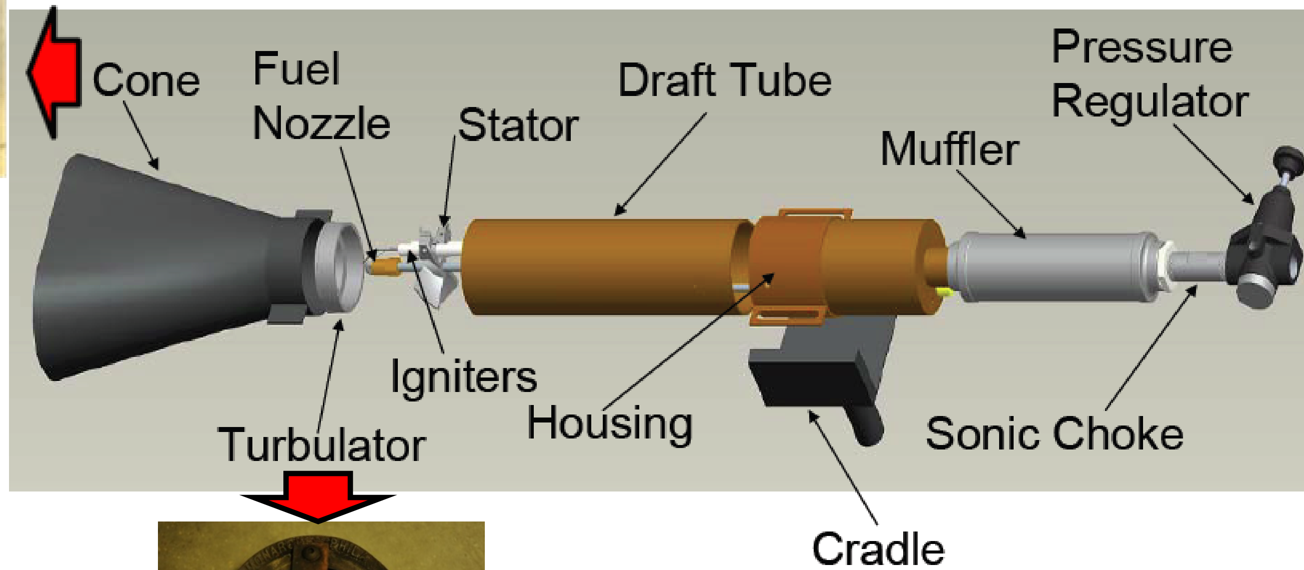
NexGen Burner

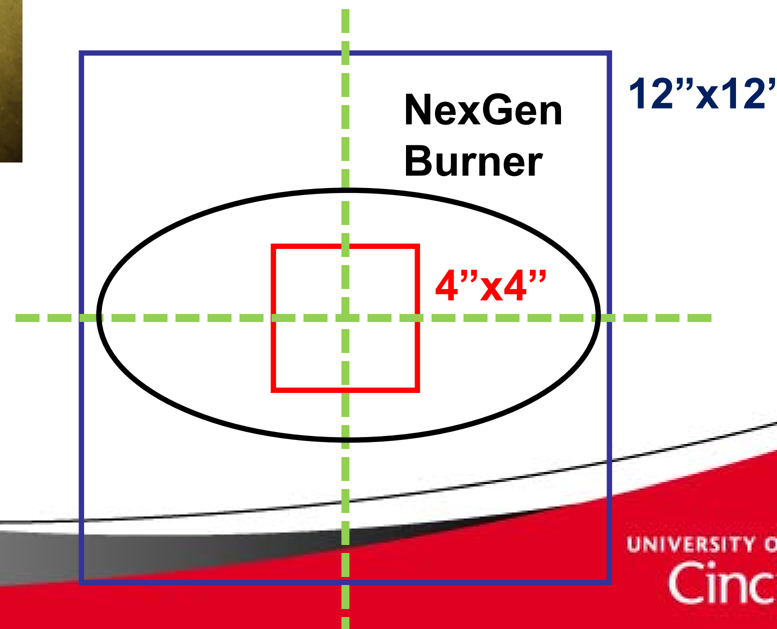
Both fuel and air rate can be accurately metered and controlled



Uninsulated Cone
(Inconel 661)



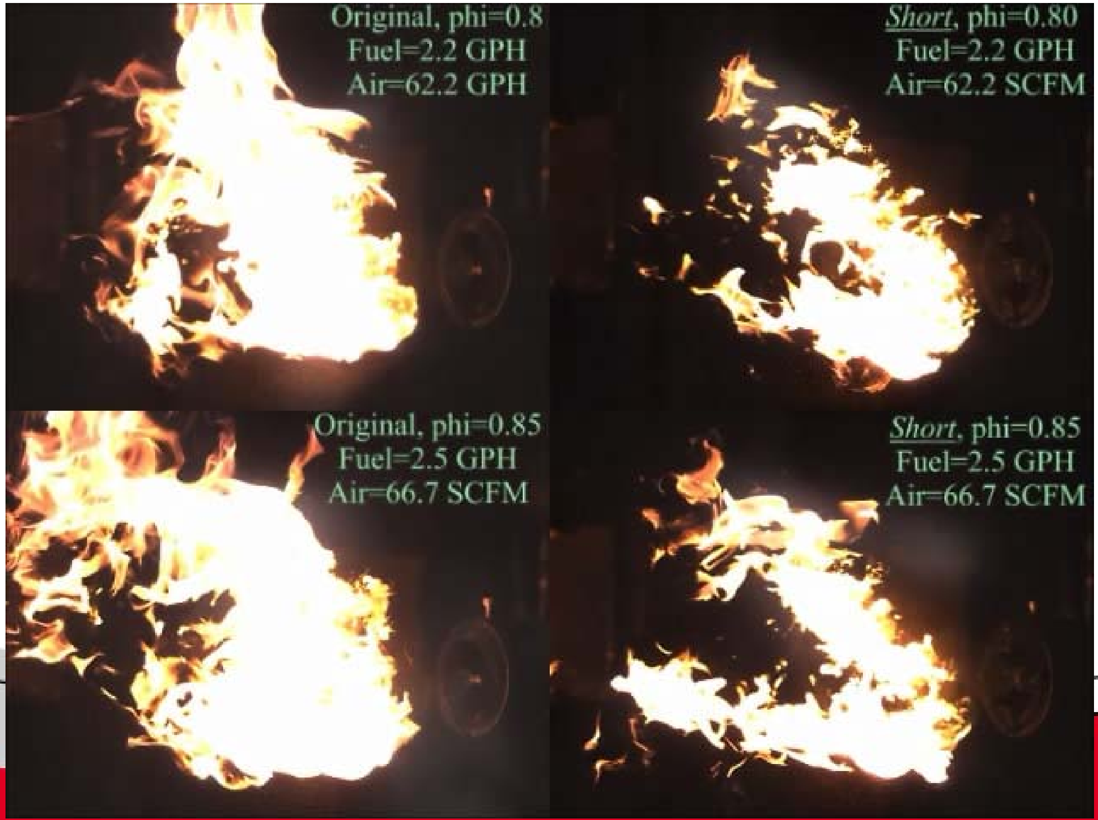
Modified Turbulator
(Four 1”x3/4” tabs)



Conclusions from previous work (1)

Turbulator with four 1”x 3/4” tabs creates better and more stable air/fuel mixing and provides:

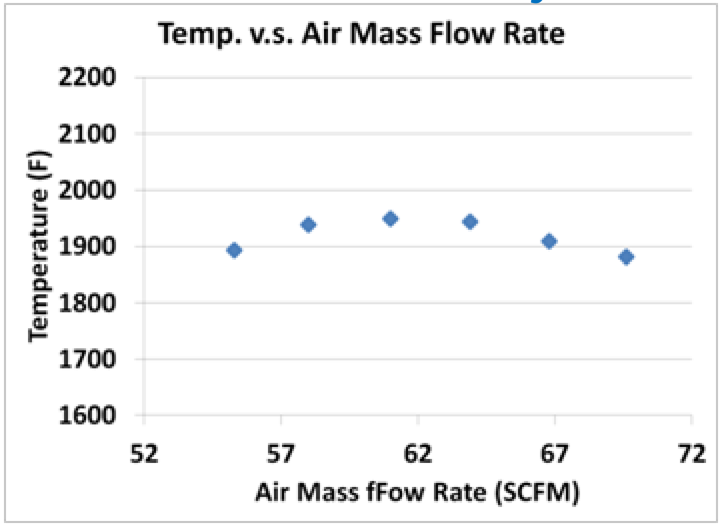
- Higher and more uniform flame temperatures
- More repeatable flames
- We recommend these tabs to be added to NexGen burner design

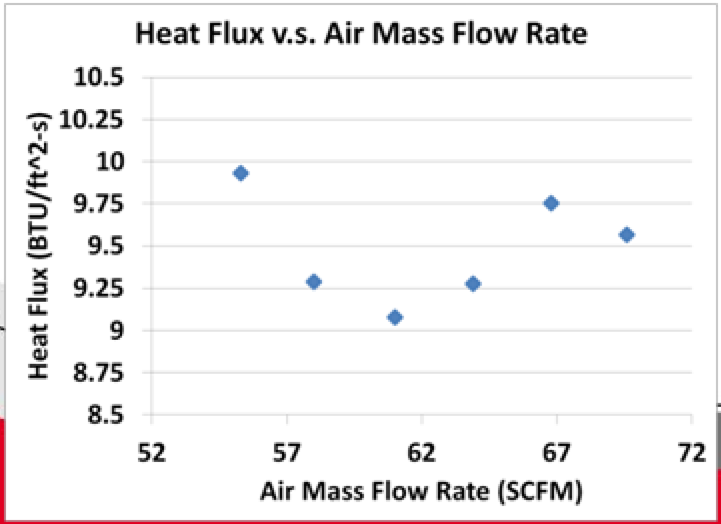


Conclusions from previous work (2)

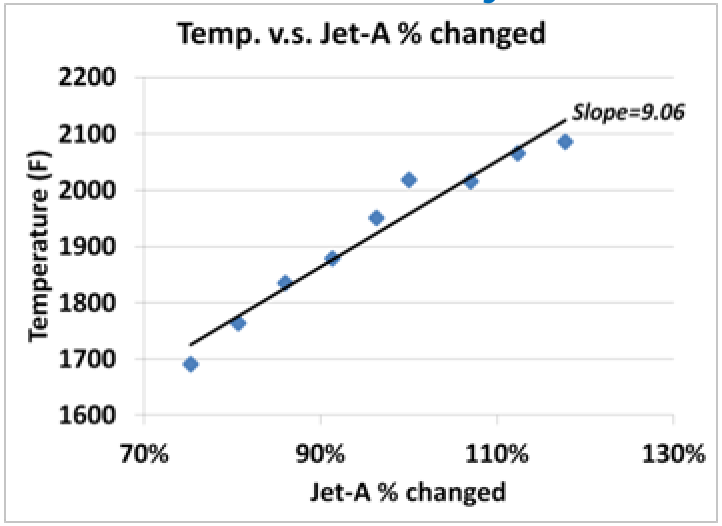
Burner flame temperature and heat flux is very sensitive to the fuel flow rate, but not as sensitive to the air flow rate

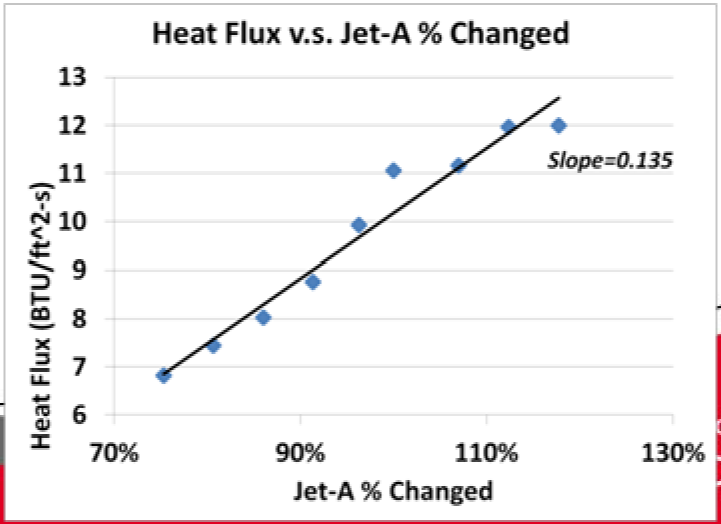
Air Sensitivity





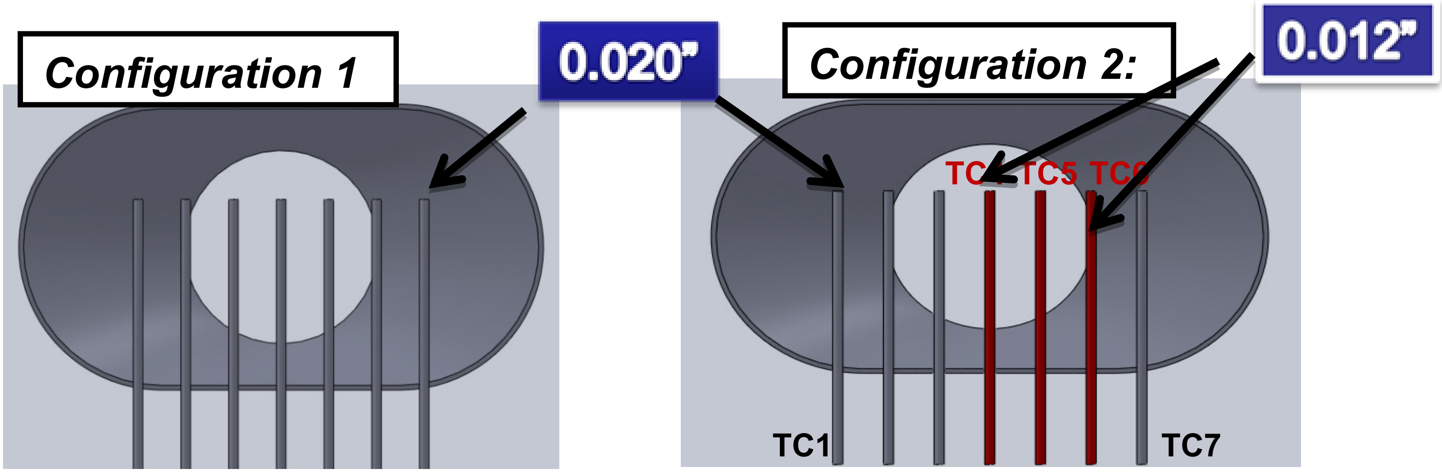
Fuel Sensitivity

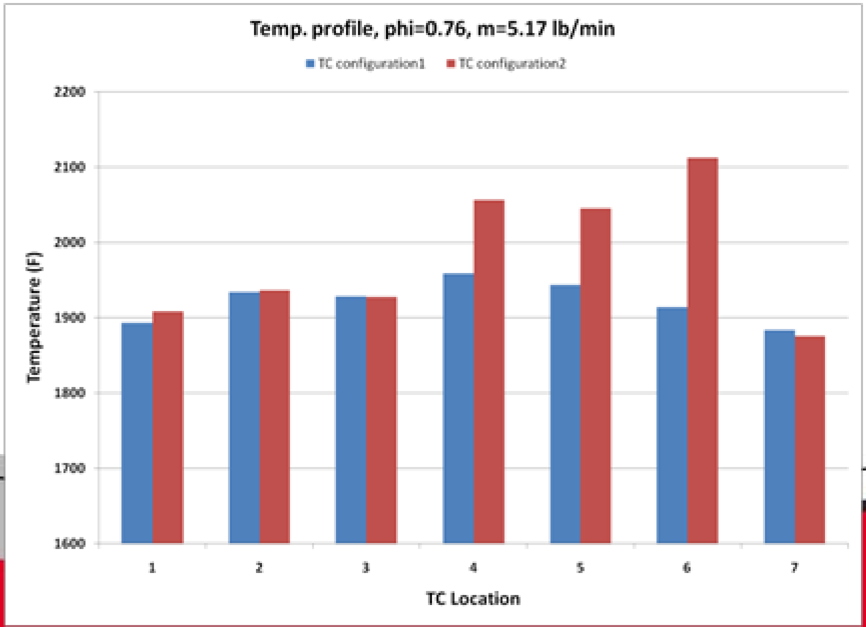




Conclusions from previous work (3)

For the same flame, temperature indicated by smaller TCs was around 100 F higher



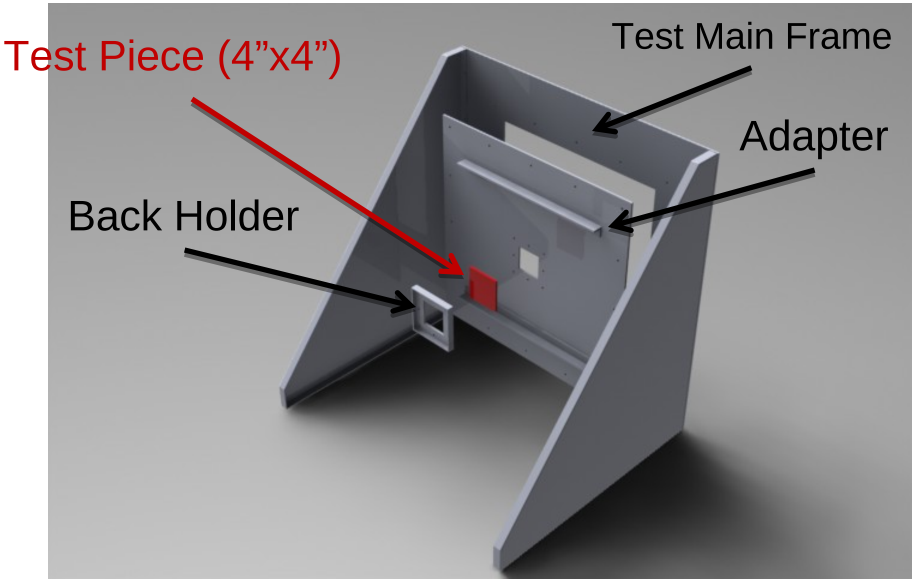


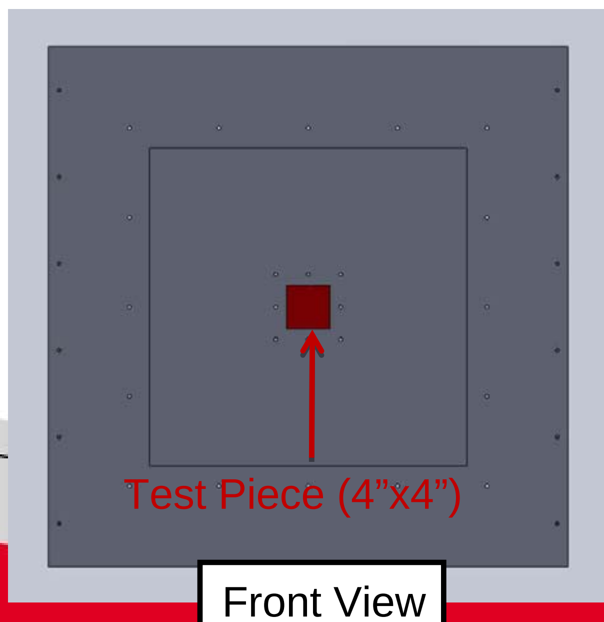
Current Study

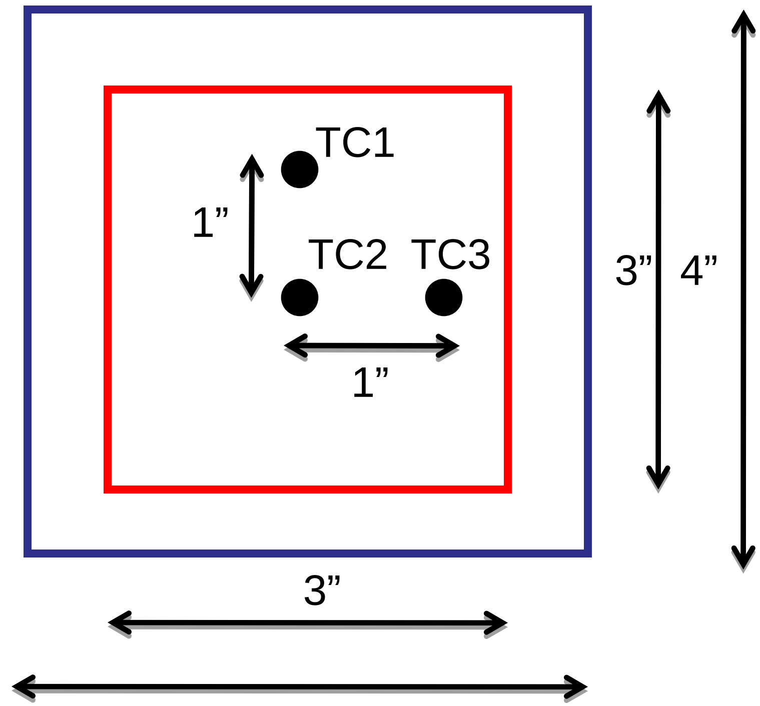
- Fire tests using burner settings with the same measured temperature and heat flux
  - Different air flow rate
  - Different thermocouple size

- Test samples and methods
  - Small size Sample (4”x4”x1/4” AL6061) and
    Large size Sample (12”x12”x1/4” AL6061)
  - Back side TCs to monitor the temperature history and post-test inspection

Test Rig #1 and TC Locations for 4"x4" Sample

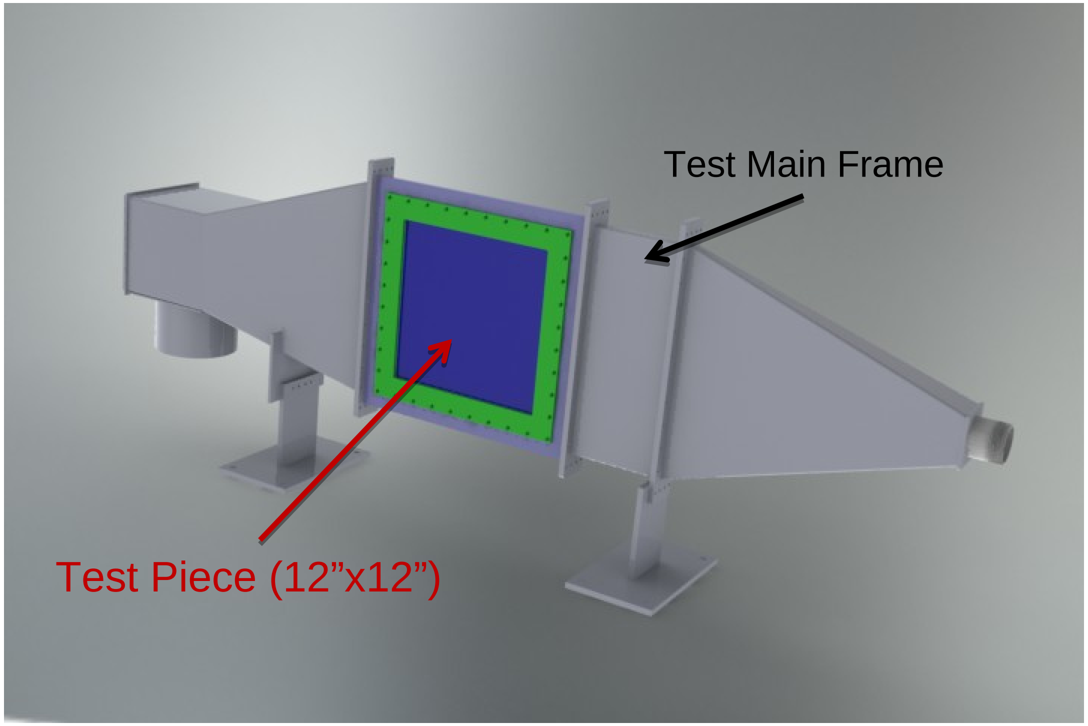


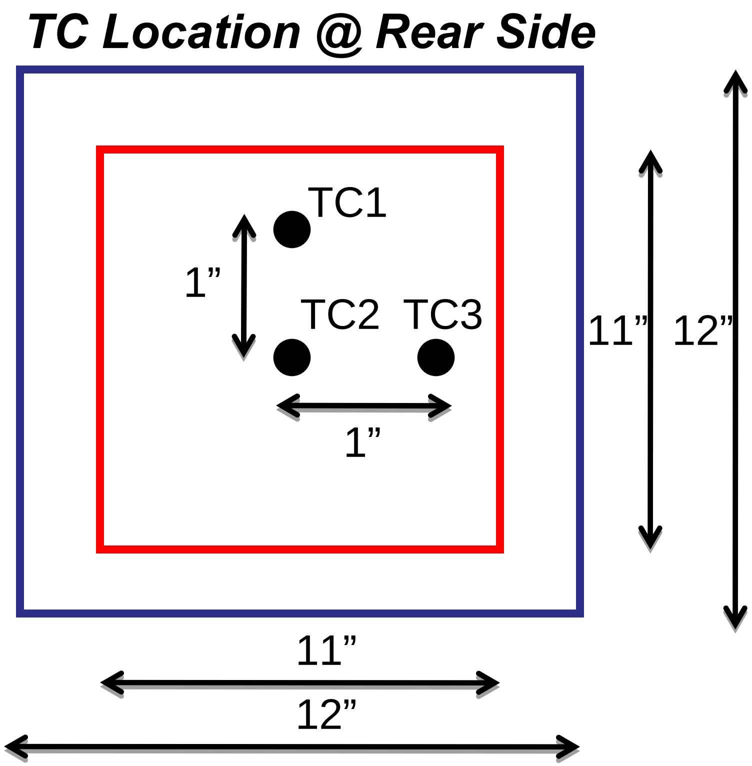




- ✓Test Sample: 4"x4"
- ✓Exposure Area: 3"x3"

Test Rig #2 and TC Locations for 12”x12” Sample





- ✓Test Sample: 12”x12”
- ✓Exposure Area: 11”x11”

Test Conditions and Calibration Data (Small Sample)

Small		Test Conditions		Calibration Data		Burnthrough Time
	Test #	Fuel (GPH)	Air (SCFM)	Temp. (F)	Heat Flux (BTU/ft^2-s)	min
Fuel Leaner Case (ϕ=0.74)	#1	2.20	67.6	1936.1	9.2	-
	#2			1951.4	9.3	-
Baseline Case (ϕ=0.80)	#3	2.25	64	1949.6	9.1	-
	#4			1923.8	9.0	-
Fuel Richer Case (ϕ=0.87)	#5	2.25	58.6	1951.3	9.3	17
	#6			1921.1	9.0	17
***Ambient Temp.=80~90 F, w/o forced convection**				***1935±20***	***9.2±0.2***	

All tests were terminated at 17 min

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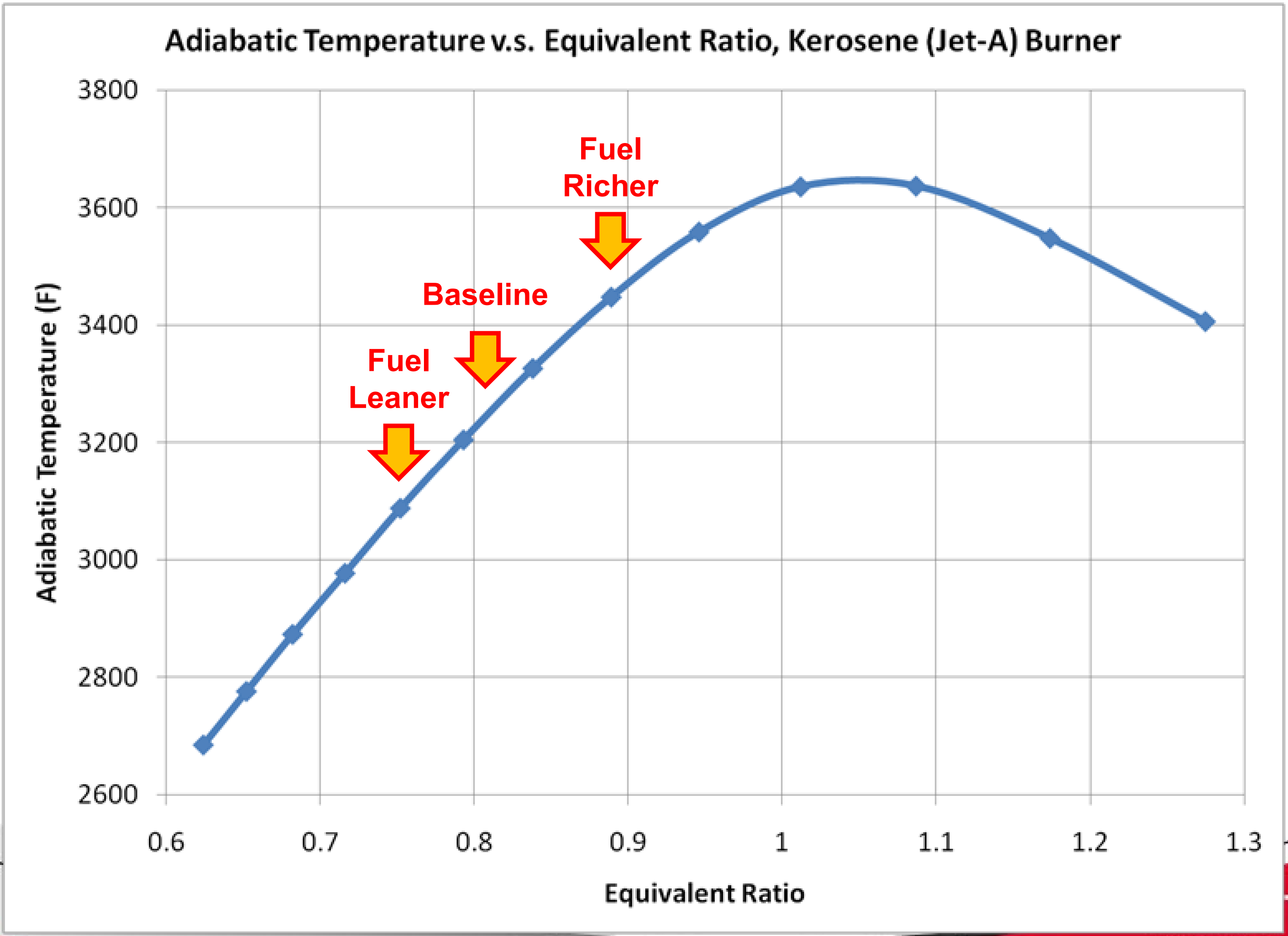
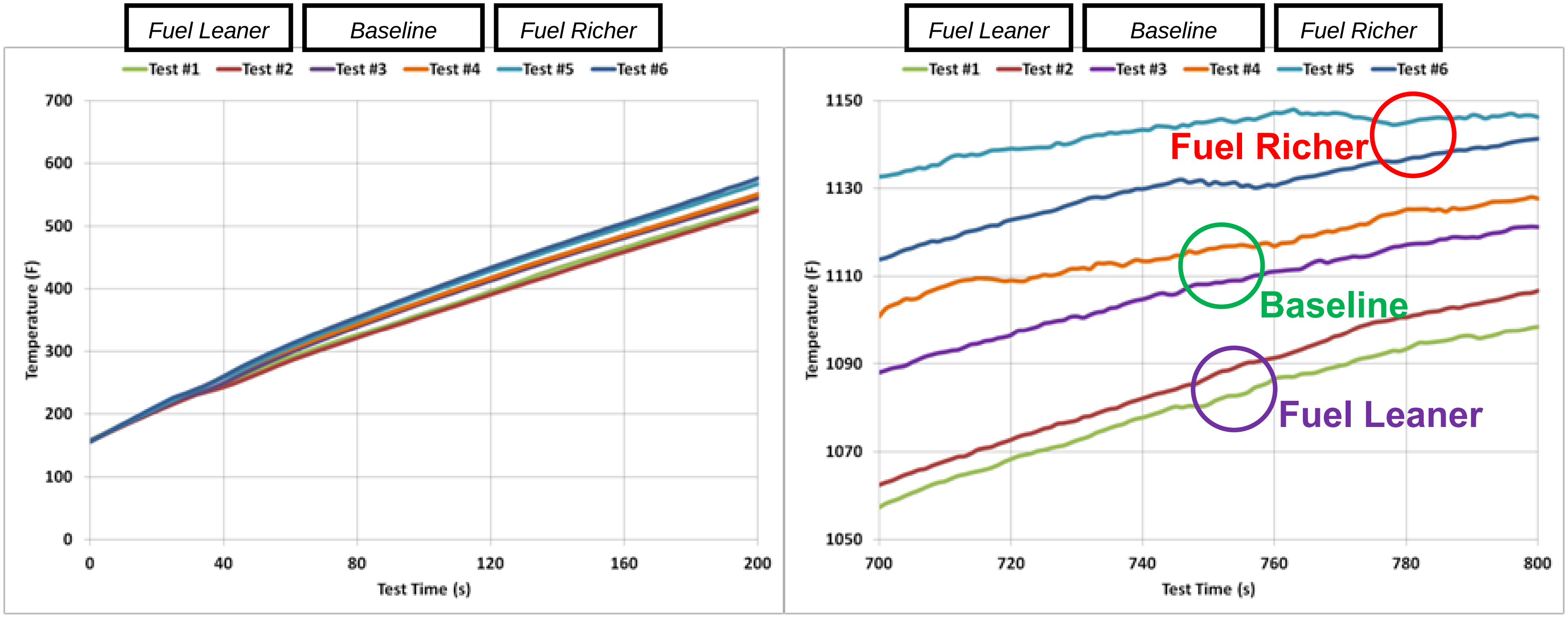
Test Conditions and Calibration Data

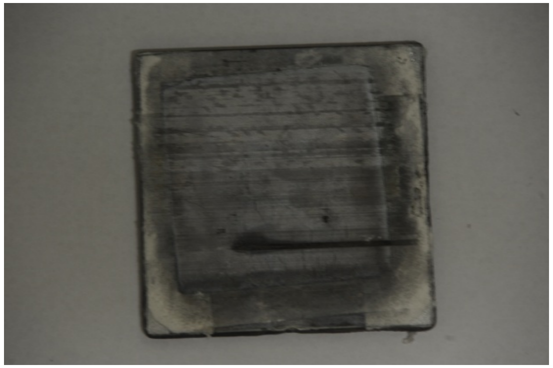


Test Results: Small Sample

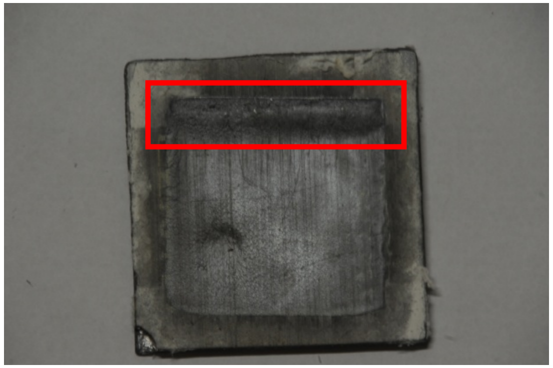


Test Results: Small Sample (after 17mins)

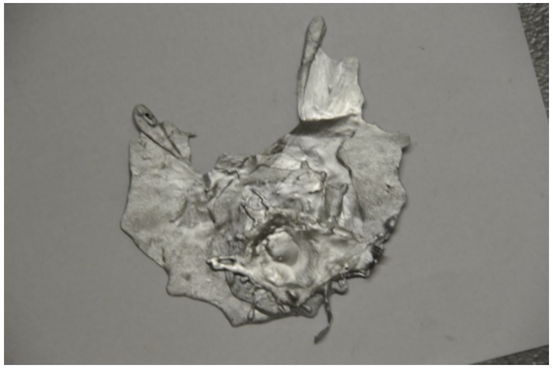
Φ=0.74 (undamaged)



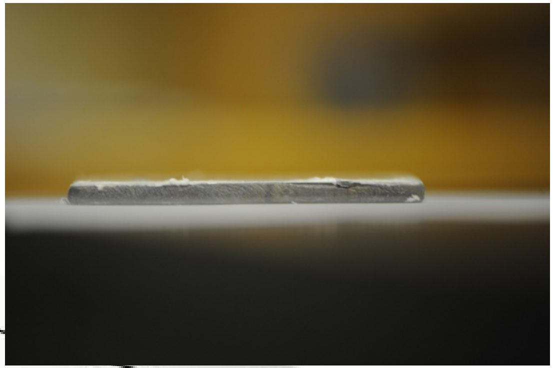
Φ=0.80 (surface melted)



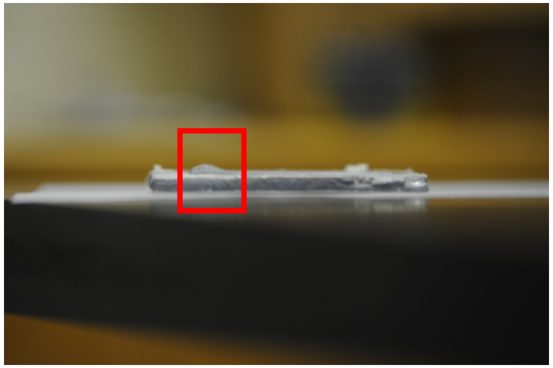
Φ=0.87 (burned though @ 17 min)



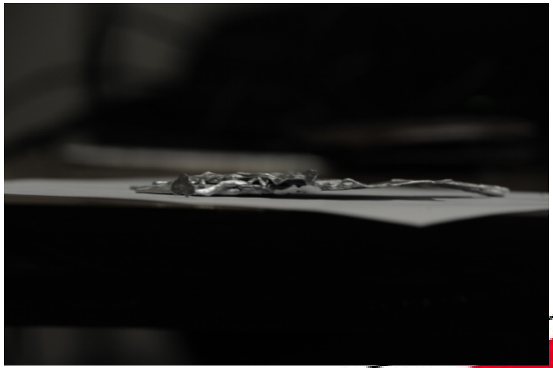
Φ=0.74



Φ=0.80



Φ=0.87



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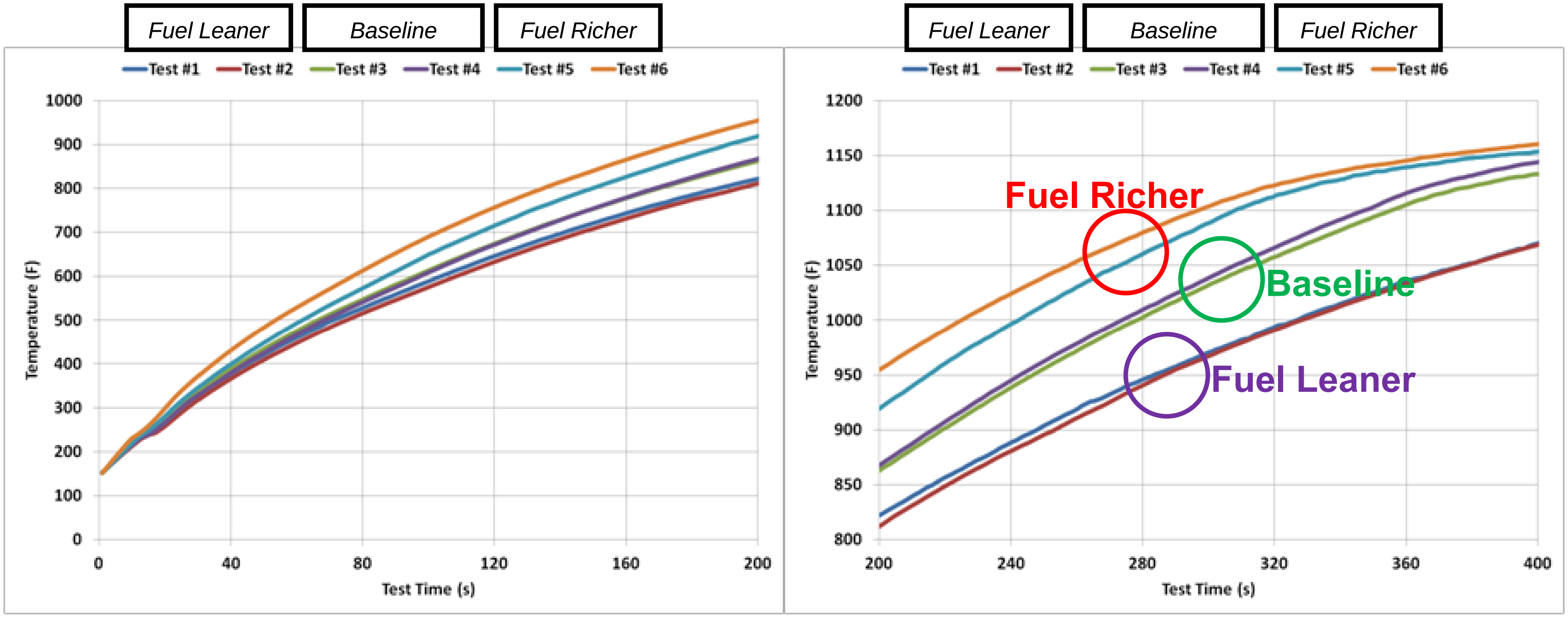
Test Conditions and Calibration Data (Large Sample)

Large		Test Conditions		Calibration Data		Burnthrough Time
	Test #	Fuel (GPH)	Air (SCFM)	Temp. (F)	Heat Flux (BTU/ft^2-s)	Min
Fuel Leaner Case (ϕ=0.76)	#1	2.25	67.6	1919.6	9.4	15
	#2			1919.8	9.4	-
Baseline Case (ϕ=0.82)	#3	2.25	62.2	1919.8	9.5	11.5
	#4			1919.6	9.4	-
Fuel Richer Case (ϕ=0.88)	#5	2.25	57.7	1937.3	9.5	10
	#6			1926.3	9.5	10
****Ambient Temp.=80~90 F, w/o forced convection***				***1930±15***	***9.4±0.1***	

Tests 1, 3, 5, 6 conducted up to burn through
Tests 2, 4 terminated at 10 min

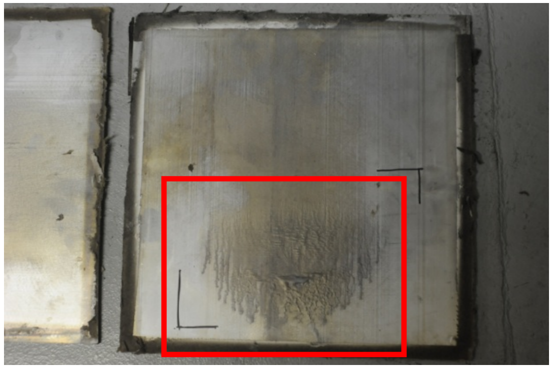
Test Results: Large Sample

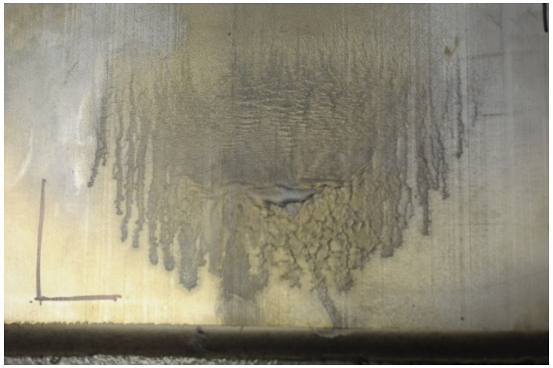


Test Results: Large Sample (after 10mins)

Φ=0.76 (undamaged)

Φ=0.82 (surface melted)





Φ=0.88 (burned though)

Burnthough

@ 15 mins

@ 11.5 mins

@ 10 mins

Test Conditions and Calibration Data (Diff. TCs)

Large		Test Conditions		Calibration Data		Burnthrough Time
	Test #	Fuel (GPH)	Air (SCFM)	Temp. (F)	Heat Flux (BTU/ft^2-s)	Min
Small TCs (ϕ=0.8:baseline)	#1	2.14	60.4	1907.9	9.0	-
	#2			1918.8	9.0	-
Big TCs (ϕ=0.82:baseline)	#3	2.25	62.2	1919.8	9.5	11.5
	#4			1919.6	9.4	-
****Ambient Temp.=80~90 F, w/o forced convection***						

Thermocouple Dimension Information

	Bead (inch)	**Wire (inch)**
Big	**0.033**	**0.020 (AWG 24)**
Small	**0.020**	**0.012 (AWG 28)**

K-Type, bare bead, ¼" inch exposed wire

****AC 20-135:***
thermocouple wire: AWG 20~30 (0.0100~0.0253 inch)

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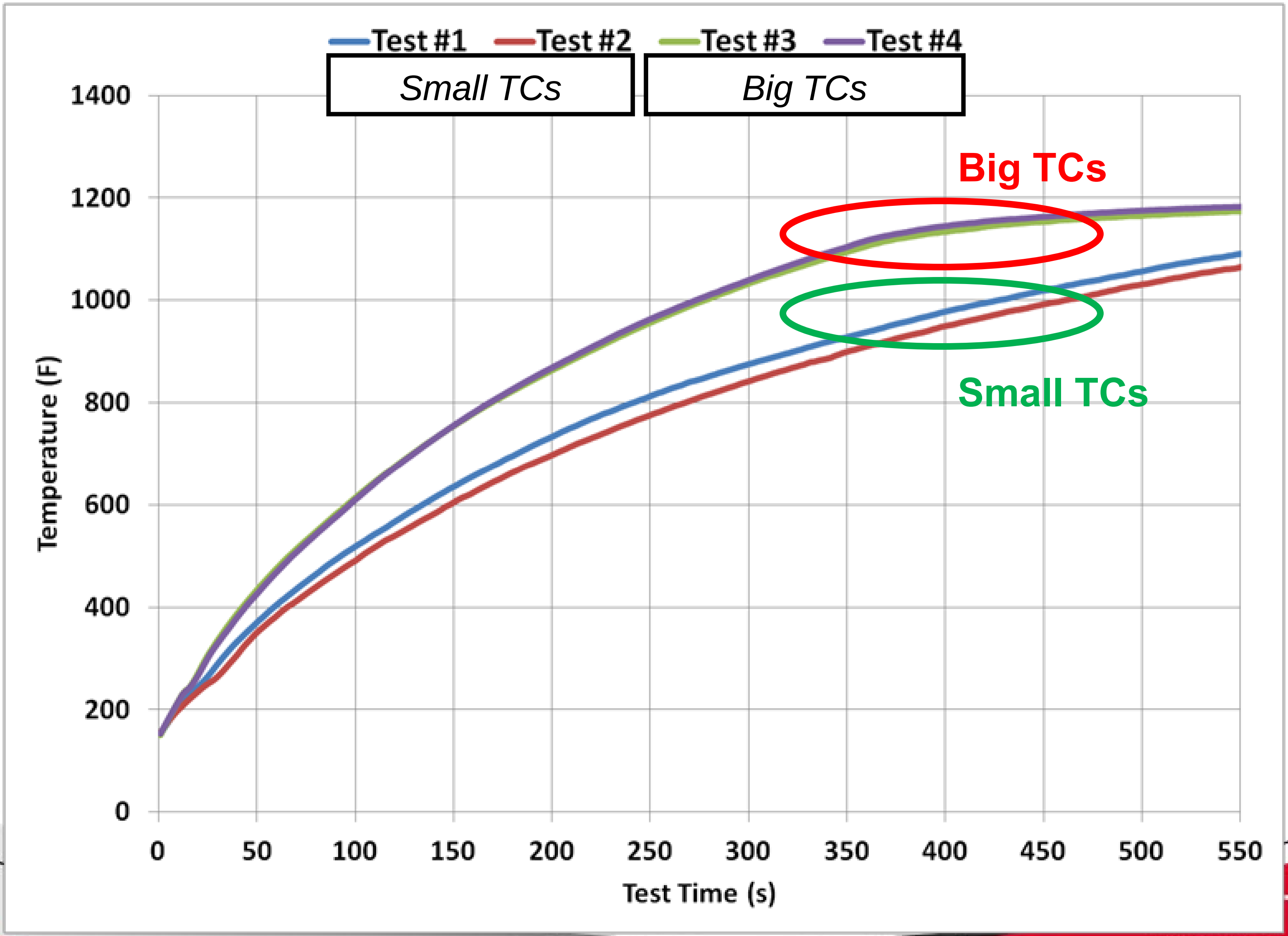
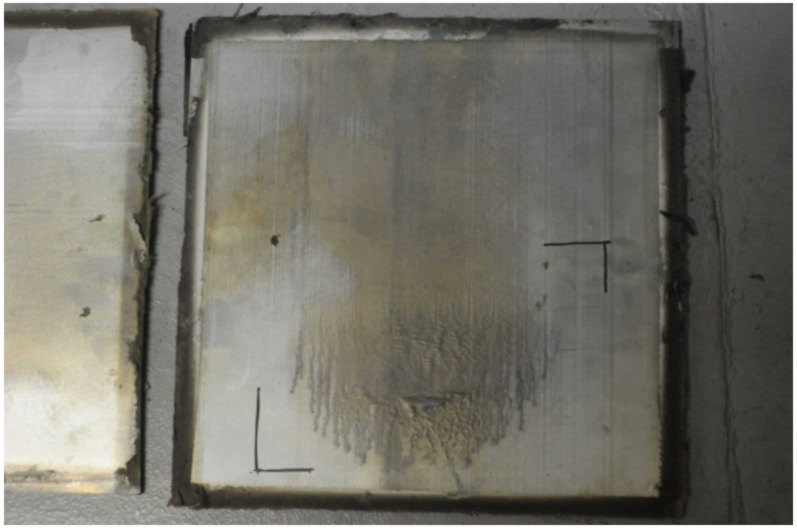
Test Results – Different TCs

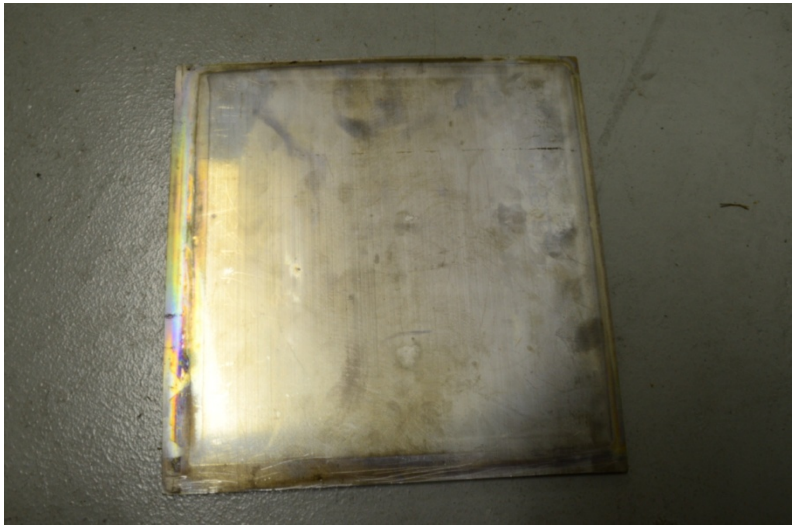


Test Results_Diff. TCs(after 10mins)

Big TCs, (surface melted)



Small TCs, (undamaged)



Burnthough

@ 11.5 mins

Survive

until 15 mins

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Conclusion

- Tests were conducted at flames with different air/fuel ratios but the same heat flux and temperature calibrations:
  - More damage was observed for the fuel richer test condition as compared to the fuel leaner condition.

- Small test samples had less damage as compared to the large test samples.

- Tests results are sensitive to TC sizes in calibration process:
  - The temperature measured by small TCs could reach target temperature at lesser fuel flow rate resulting in lower heat flux.
  - Test sample could survive longer under the flame calibrated by small TCs.

Recommendations

- Both air and fuel flow rates for a liquid burner should be precisely controlled and metered

- Current Fire Test guidelines do not require reporting the fuel and air flow rates. For future tests we recommend
  - Fuel and air flow rates to be documented
  - Guidelines should include precise air and fuel flow rate settings

- The range of recommended thermcouple size should be made narrower to limit the effect of different thermocouple sizes

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