FAA 7th Triennial International Fire & Cabin Safety Research Conference
December 2nd~5th, 2013

Elementary Experimental Study of the Burner Used in FAA Fire Test: NexGen Burner

December 5th. 2013

Fire Test Center
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Agenda

- Fire Test Regulations for Powerplant & NexGen Burner
- Impact of Turbulator Configuration
- Impact of TC Size
- Impact of Fuel Flow Rate
- Impact of Air Flow Rate
- Impact of Air Temp.
- Fire Test Results by Different Burner Orientation
- Temperature Mappings of NexGen Burner
- Conclusions and Recommendations

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FAA Fire Test Regulations for Power Plant

		AC20-135, AC33.17-1A	ISO2685: 1998
Flame Temperature Calibration	**TC Type**	Bare Junction, Type K	Bare Junction, Type K
	TC Size (sheath dia)	1/16 – 1/8 inch	< 3 mm (0.120 inch)
	TC Wire Size	AWG 22 (0.025 inch) – AWG 30 (0.010 inch)	0.6 – 1 mm (0.025 – 0.040 inch)
	Individual TC Temperature	2000 ± 150 ^{o}F	1100 ± 80 ^{o}C (2012 ± 144 ^{o}F)
	Average of all TCs	≥ 2000 ^{o}F	N/A
Heat Flux Calibration	**Measurement Device**	½" O.D. copper tube; Calorimeter (optional)	½" O. D. copper tube
	Heat Flux Requirement	≥ 9.3 BTU/ft^2-s	116 ± 10 kW/m^2 (10.2 ± 0.9 BTU/ft^2-s)

- **Recommended burners: stated in FAA powerplant report 3A**

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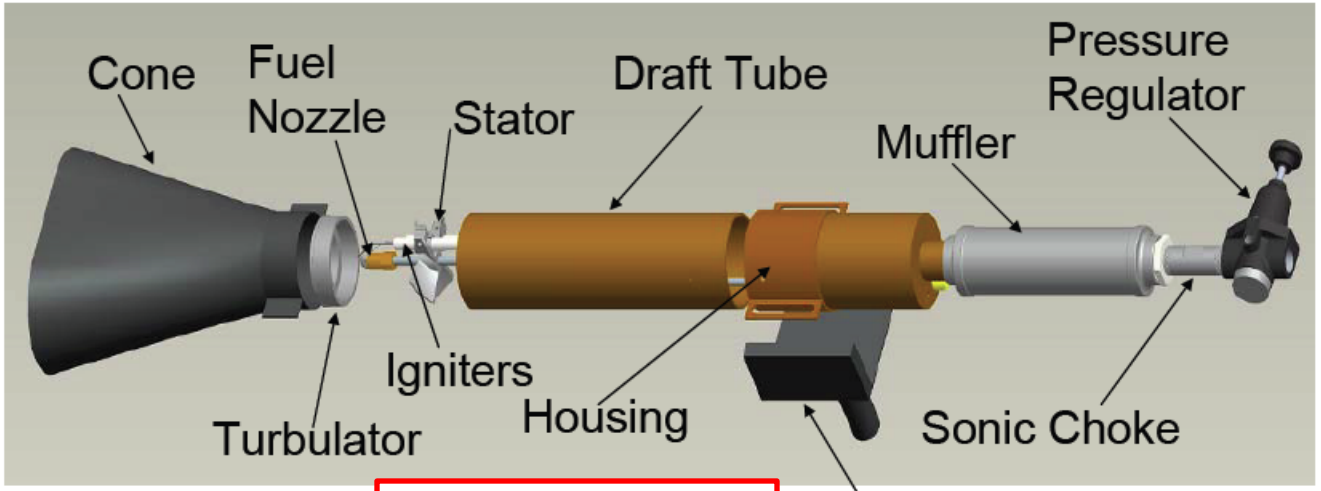
NexGen Burner

Background of NexGen Burner:

- Kerosene burners listed in FAA Powerplant report 3A are out of production
- These burners do not have provisions to control and meter air flow rate
- NexGen burner was designed to replace old kerosene burners
- NexGen burner has independent air and fuel flow rate controls, and air flow rate is controlled and metered by pressure setting at sonic choke
- ***NexGen burner should be robust and repeatable to provide consistent fire test results***



NexGen Burner

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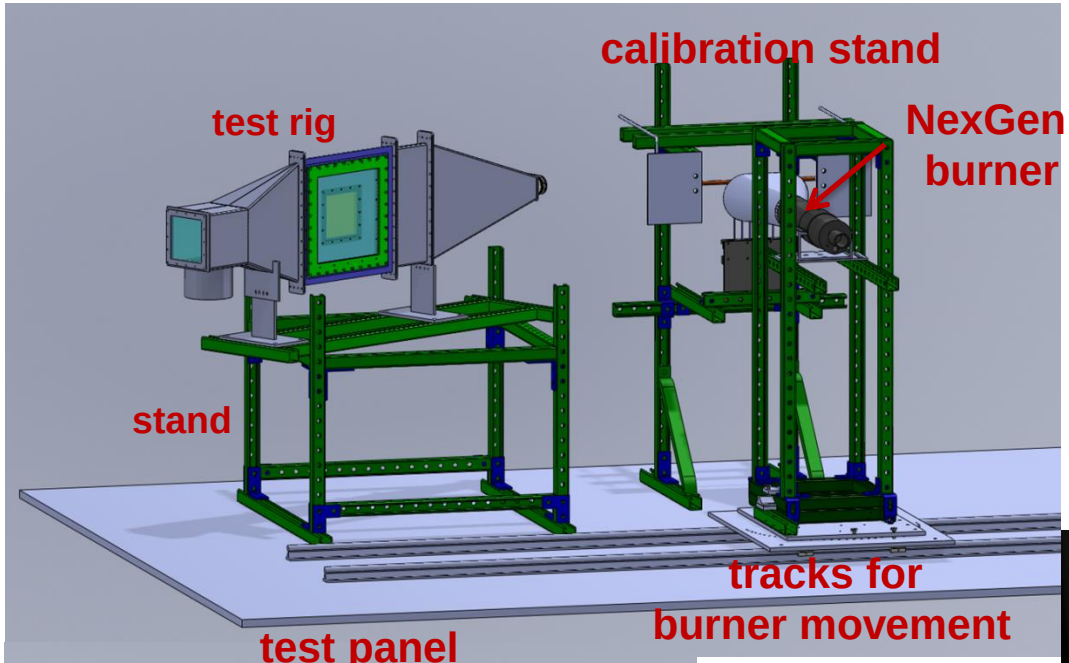
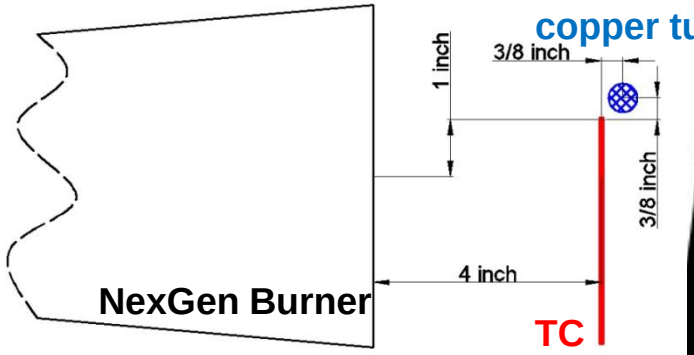
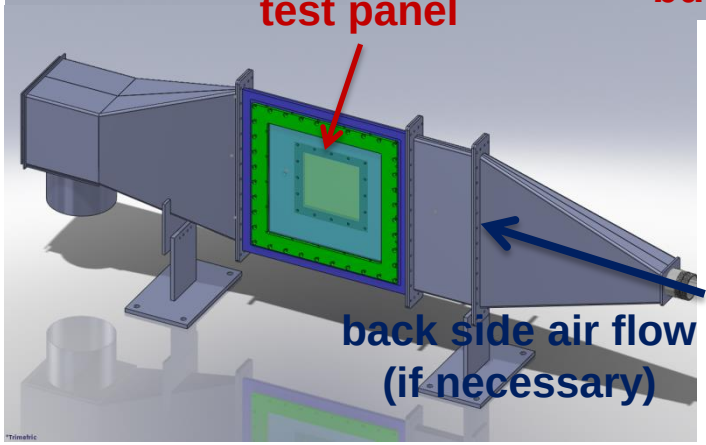
Fire Test Setup and Calibration Stand



flame temperature and heat flux calibrations are conducted simultaneously





test panels in this work:

- AL 6061
- 12 inch x 12 inch
- 1/4” in thick
- TCs were mounted on the back side of surface
- no back side air flow

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Impact of Turbulator (calibration)

Back Side **Front Side**

original, w/o tab

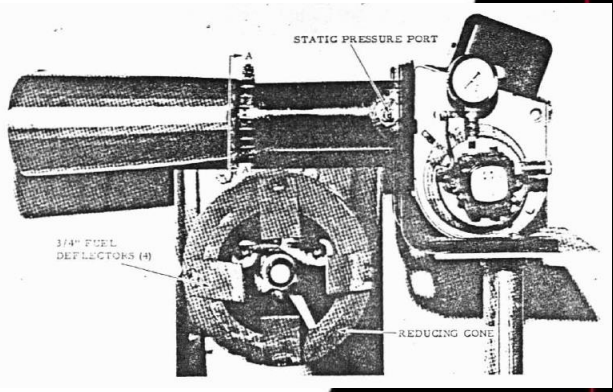
Short Tabs (1”x3/4”)

Long Tabs (1 1/8”x3/4”)

NexGen Burner w/o cone
Original v.s. Modified
Turbulator

Record: 3000 fps/ Playback: 15 fps

Tab	TC	Jet-A (GPH)	Air (SCFM)	A/F	T_avg (F)	T_max (F) / T_min (F)	Heat Flux (BTU/ft^2-s)
NA	1/8”	3.01	61.2	13.2	2015	2131 / 1928	11.4
Short	1/8”	2.86	61.2	14.1	2011	2095 / 1884	10.5
Long	1/8”	2.44	55.2	14.9	2007	2063 / 1916	9.7



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- Use of “tabs” requires less fuel to satisfy temperature requirement
- Burner performance is sensitive to the details of turbulator’s geometry and configuration

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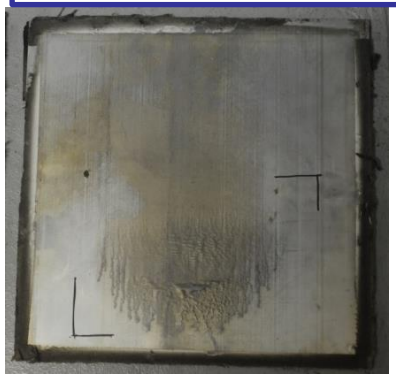
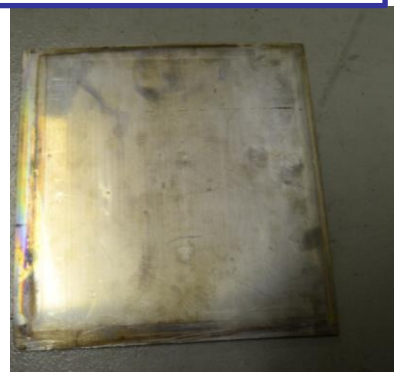
Impact of TC size

	Fuel (GPH)	Air (SCFM)	Temp. (F)	Heat Flux (BTU/ft^2-s)	B. T.
small TCs	2.14	60.4	1908	9.0	15m0s
big TCs	2.25	62.2	1920	9.5	11m30s

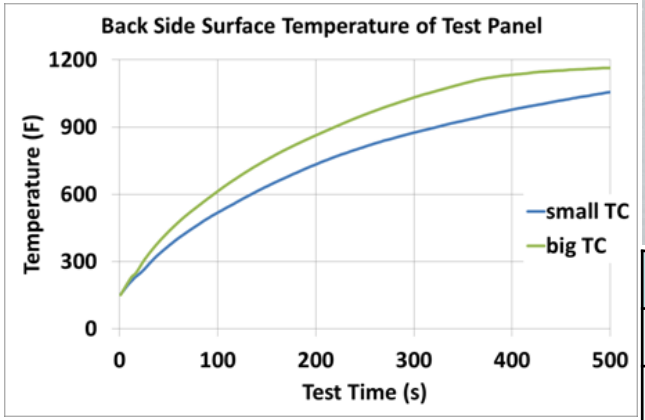
Front Side of Test Panel (after 10 mins)

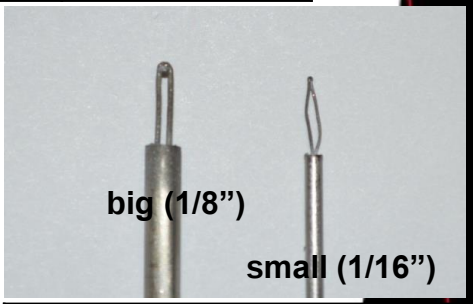


flame calibrated by ***big TC***



flame calibrated by ***small TC***





K-type TC- big, AWG24	
bead size	0.033 inch
wire size	0.020 inch

K-type TC- small, AWG28	
bead size	0.020 inch
wire size	0.012 inch

- **TC size and TC wire size can affect calibration and fire test result**
- **Using small TCs, calibration requirements achieved by using less fuel flow rate, resulting in longer burnthrough time**
- **Tolerance for TC sizes in specifications should be made narrower to ensure consistent results**

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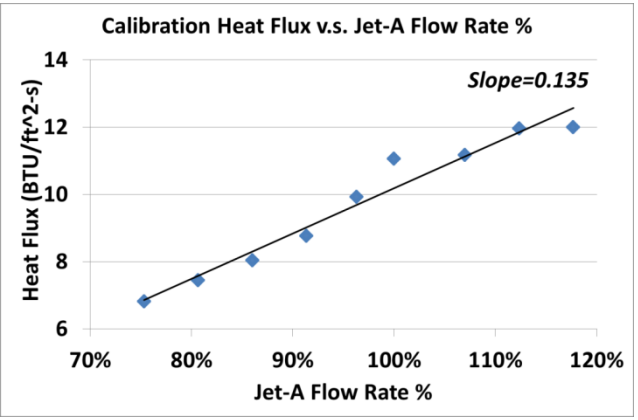
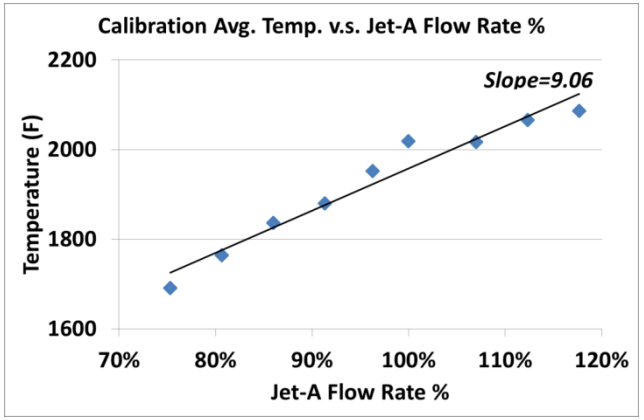
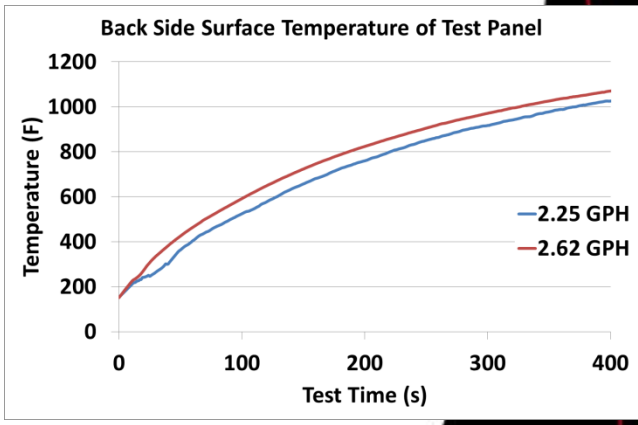
Impact of Fuel Flow Rate

	test conditions		calibration data		
	Fuel (GPH)	Air (SCFM)	Temp. (F)	Heat Flux (BTU/ft^2-s)	B. T.
2.25 GPH	**2.25**	67.6	1920	9.5	15m0s
2.62 GPH	**2.62**	66.7	2013	11.5	10m10s







- **Calibration data and fire test result are both quite sensitive to the change of fuel flow rate.**
- **Fuel flow rate and it's tolerance should be specified in the regulations.**

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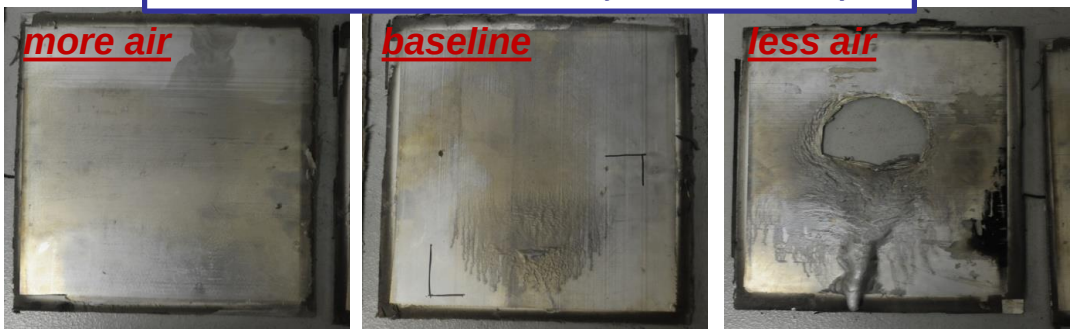
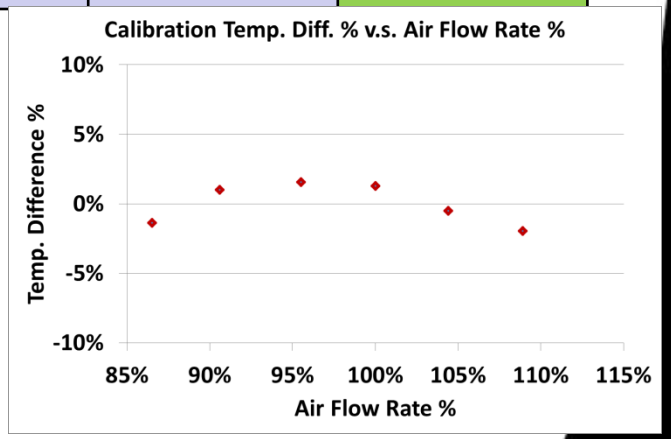
Impact of Air Flow Rate

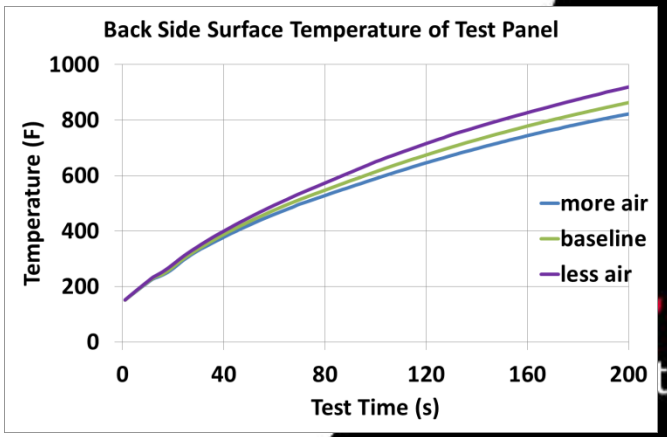
	test conditions		calibration data		
	Fuel (GPH)	Air (SCFM)	Temp. (F)	Heat Flux (BTU/ft^2-s)	B. T.
more air	2.25	**67.6**	1920	9.4	15m0s
baseline case	2.25	**62.2**	1920	9.5	11m30s
less air	2.25	**57.7**	1937	9.5	10m0s

Front Side of Test Panel (after 10 mins)





- Air flow rate did not have significant impact on calibration
- Burn through times increased with increasing air flow rates
- **The air flow rate and it's tolerance should be specified in the regulations.**



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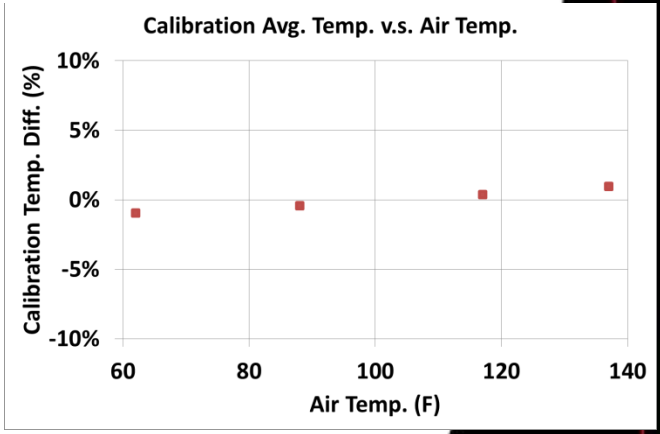
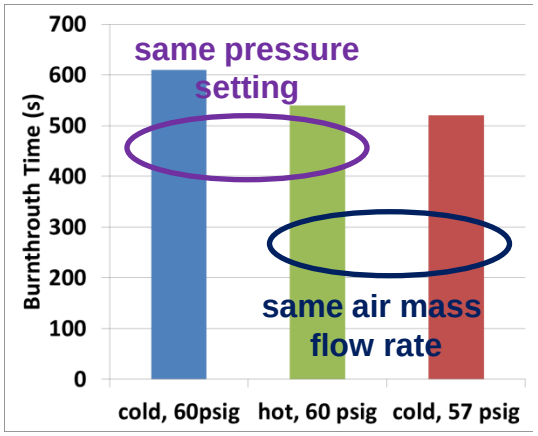
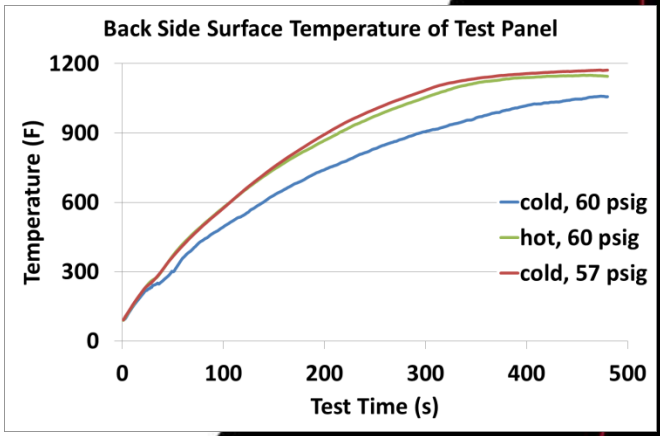
Impact of Air Temperature

	test conditions			calibration data		
	Fuel (GPH)	Pressure, Air (psig)	Air Temp. (F)	Temp. (F)	Heat Flux (BTU/ft^2-s)	B. T.
cold air, 60 psig	2.62	**60**	**82**	2013	11.5	10m10s
hot air, 60 psig	2.62	**60**	**134**	2009	11.5	9m0s
cold air, 57 psig	2.62	**57**	**81**	2006	11.5	8m40s

- **Only pressure setting of sonic choke might not be enough to ensure the repeatability of fire test.**
- **Air mass flow rate depends on the air temperature (air density) and pressure setting of sonic choke (volume flow rate).**
- **Burnthrough time is observed to depend on the air mass flow rate even for different inlet temperature. Air mass flow rate should be specified in the regulations.**







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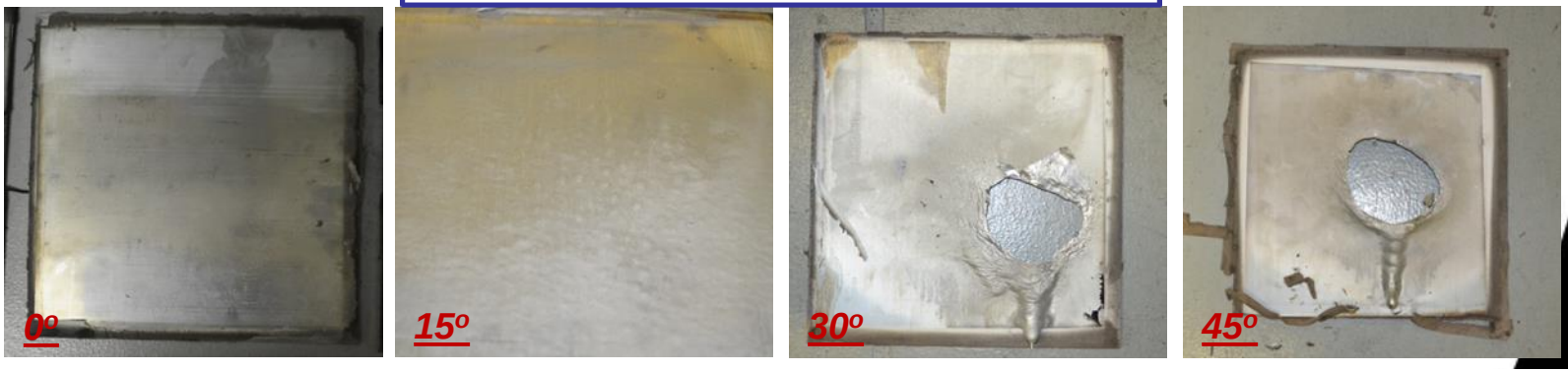
Impact of Burner Orientation

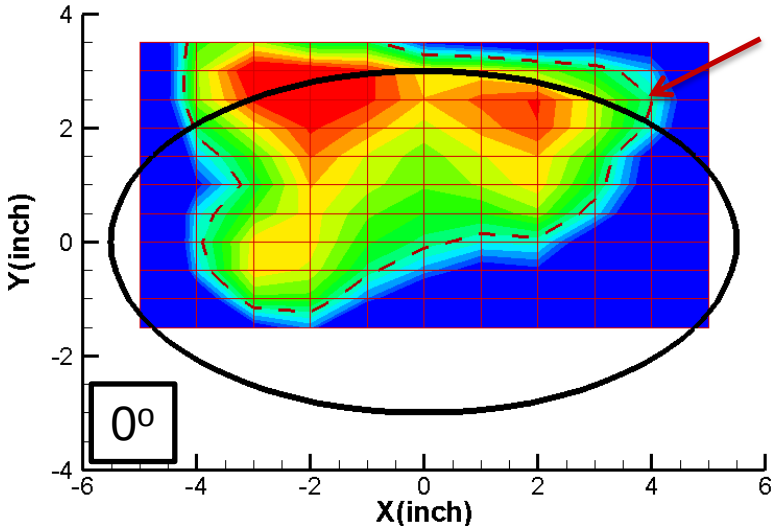
	test conditions		calibration data		
	Fuel (GPH)	Air (SCFM)	Temp. (F)	Heat Flux (BTU/ft^2-s)	B. T.
0º (horizontal)	2.25	67.6	1920	9.4	15m0s
15º	2.36	66.7	1922	10.3	10m40s
30º	2.55	66.7	1928	11.0	9m10s
45º	2.61	66.7	1929	11.4	10m0s

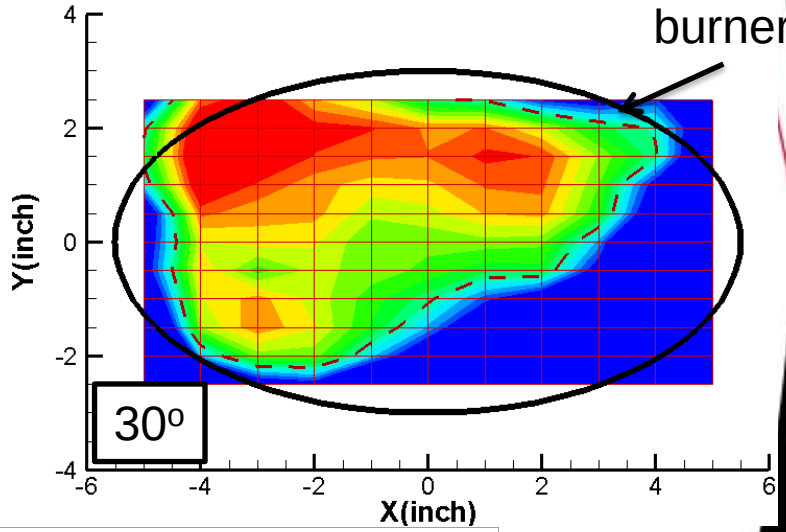
Front Side of Test Panel (after 10 mins)

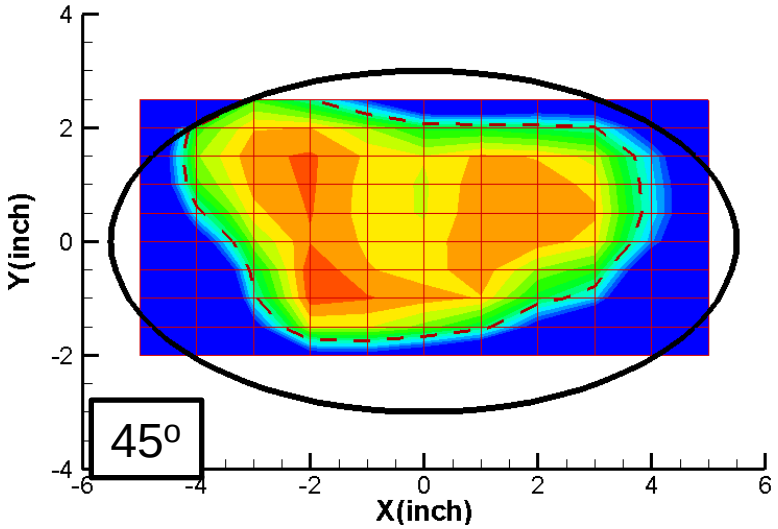


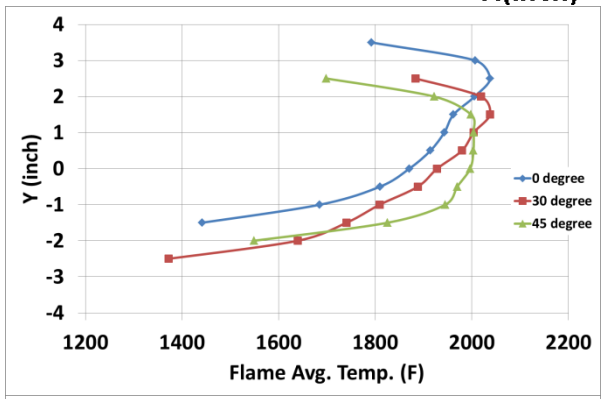
- **Calibration location was maintained at 1 inch above burner centerline.**
- **As inclination angle increased, higher fuel flow rate was needed to maintain similar calibration temperature. Heat flux increased with increasing fuel flow rate.**
- **Burner performance is observed to change with orientation. Air and fuel mass flow rates should be specified for different orientation angles.**

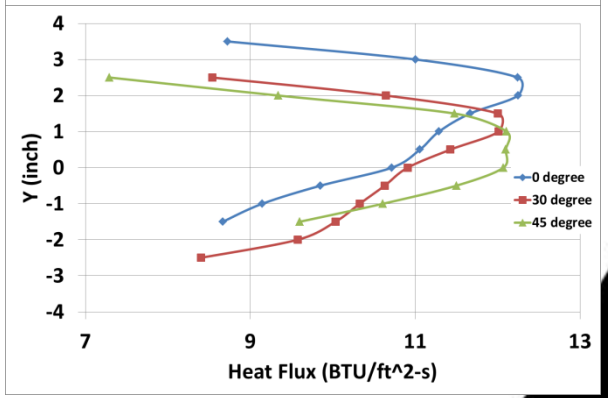
Temperature Mappings of NexGen Burner











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Conclusions and Recommendations

1. Adding the tabs could improve the efficiency of NexGen Burner and improve the uniformity of flame.

2. Using the smaller TCs, a similar flame temperature could be reached by less fuel flow rate and a longer burnthrough time was observed by conducting fire test.
   - The accepted range of TC size should be more narrow than the current guidance to ensure the fire test result could be more consistent.

3. NexGen burner's performance is very sensitive to fuel flow rate change.
   - The fuel flow rate should be monitored and reported for fire tests. and the tolerance of fuel flow rate should be specified in the guidance.

4. Even though the air flow rate does not affect the calibration results of NexGen burner, but it has a clear impact on fire test results.
   - The air mass flow rate also should be monitored and reported for fire tests, and it's tolerance should be regulated as well.

5. The air temperature could influence the air mass flow rate for constant pressure setting of sonic choke
   - The range of air supply temperature should be specified in the guidance.
   - The air mass flow rate should be monitored during the fire test.

6. As the inclination of NexGen burner increased, the flame becomes more concentrated, compact and uniform. The damage of test sample is also more severe from observation.
   - The fuel/ air flow rate settings might need to be stated according to the different burner orientation.

Acknowledgement

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

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