International Aircraft Systems Fire Protection Working Group Meeting

Updates of Round Robin Test
&
Temperature Mapping for NexGen and Gas Burners

May 22nd, 2013

Fire Test Center

University of Cincinnati, Cincinnati, U.S.A.

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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**

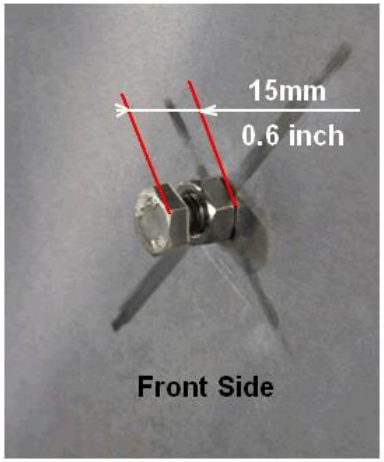
Previous Approach:

- Sensitivity of burner setup on temperature and heat flux calibration (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)
- Fire test results from NexGen burner operated at different orientations (2012)
- Sensitivity of fuel or air temperature on burner calibration (2012)
- Fire test results of the effect of air temperature (2012)

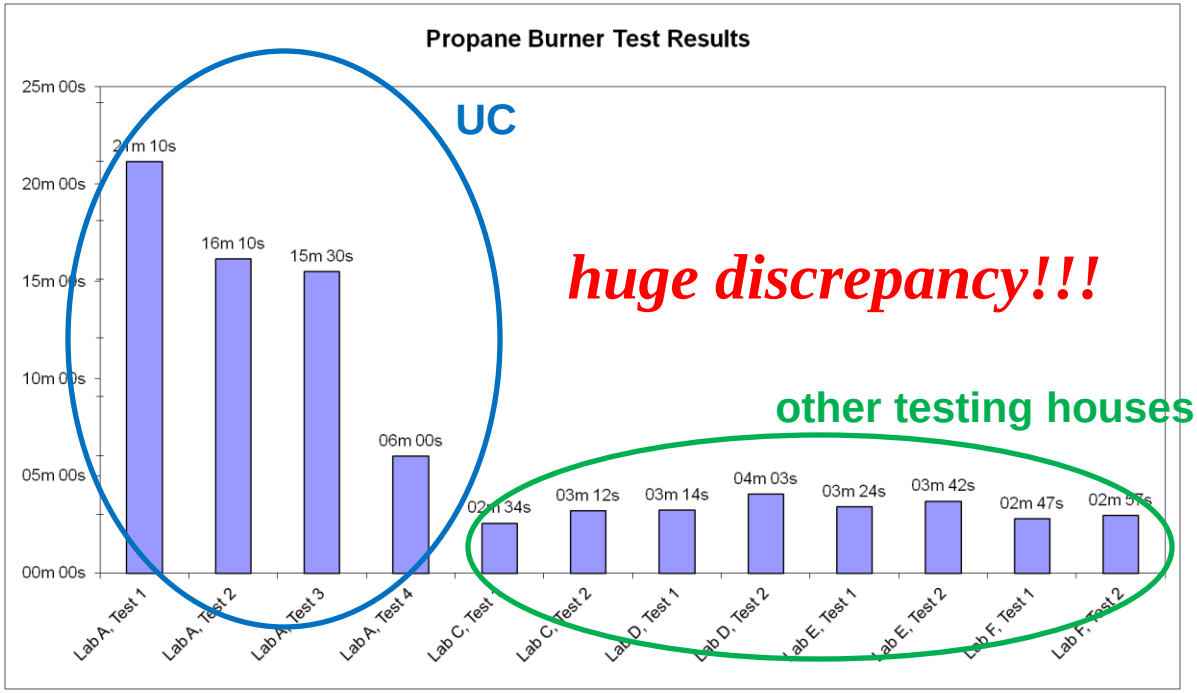
Current Approach:

- ***Updated result and analysis for round-robin fire test (gas burner)***
- ***Temperature mapping for NexGen and gas burners at different orientations***

Introduction of Round Robin Fire Test

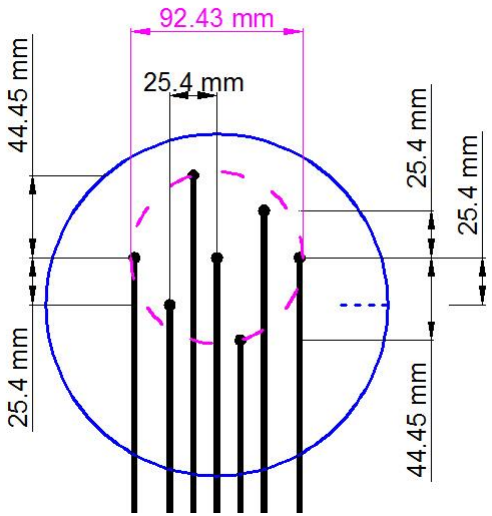


- Burner Orientation: horizontal (with vertical panel)
- 600 mm x 600 mm (24 inch x 24 inch), 2024 aluminum sheet
- 8 mm x 20 mm screw nut in the front side and counter nut in the back side of aluminum sheet
- the vertical distance = undefined on the statement
- the horizontal distance = from the burner exit to the head of bolt

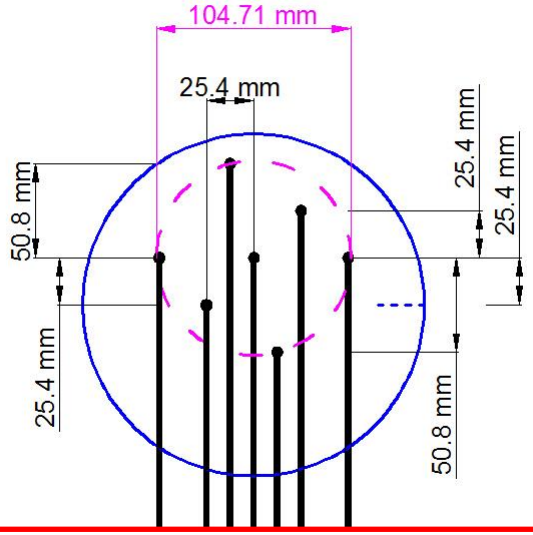


- *Some Possible Causes of Test Discrepancy*
  - calibration pattern (to cover at least 25% burner area as ISO-2685 requests)
  - Standard for avg. flame temp. (ISO-2685 v.s. AC20&AC33)
  - Effect of Alignment (both horizontal and vertical direction)

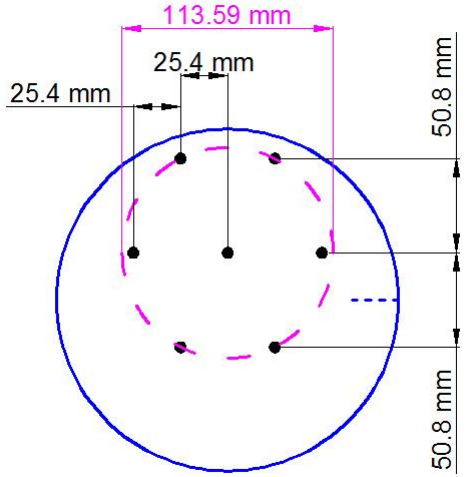
Effect of Calibration Pattern of TCs



Covering a circle with D≈3.64 inch **(37%)**



Covering a circle with D≈4.12 inch **(47%)**



Covering a circle with D≈4.47 inch **(56%)**

Propane (CFM)	Mixing Air (CFM)	Cooling Air (CFM)	Avg. Temp. (F)	Heat Flux (BTU/ft^2-s)	B.T.		
0.43	4.95	6.89	1975.4	9.6	21m10s	ISO	**26%** (Not Shown)
0.44	5.15	7.19	1912.5	9.9	11m30s	ISO	**37%**
0.46	5.15	8.22	1944.7	10.2	7m00s	ISO	**47%**
0.47	5.15	8.56	1923.3	10.1	6m05s	ISO	**56%**

➢The burnthrough time decreases with the increasing covering area of calibration TC pattern with the same calibration standard.

❖TC pattern and heat flux gauge are placed1 inch offset for all the cases account for the buoyancy
❖The burner is placed at 3” away from the head of bolt and aligned with the panel center

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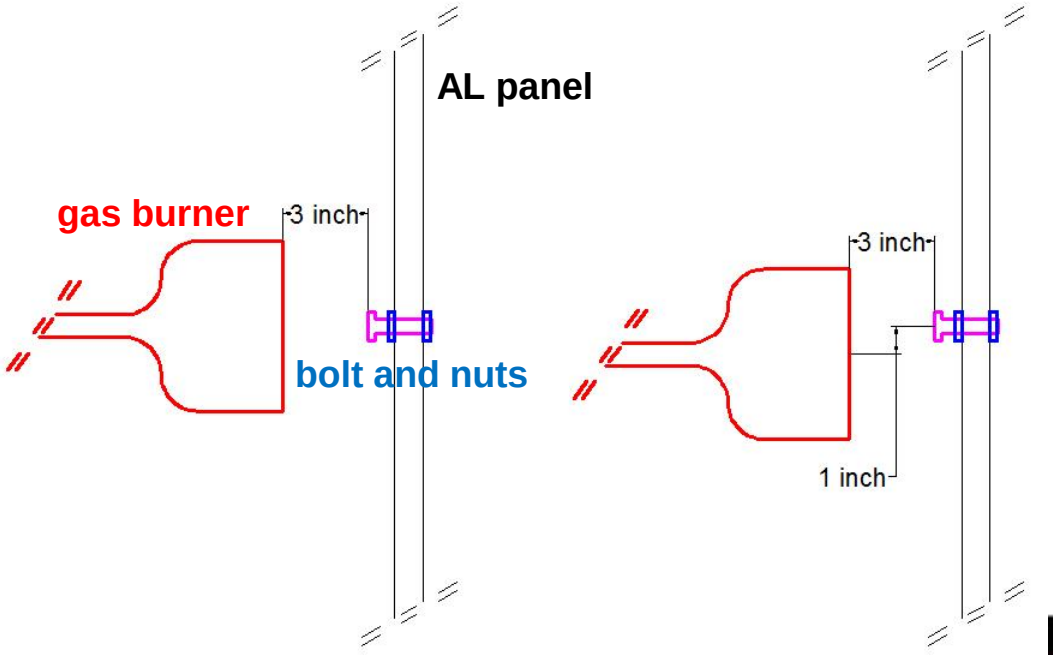
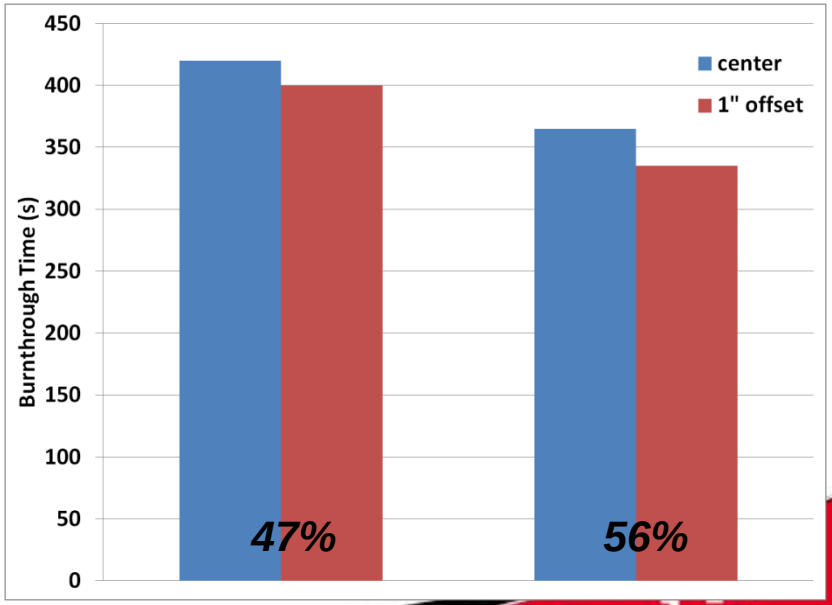
Effect of Vertical Alignment of Test Sample

Propane (CFM)	Mixing Air (CFM)	Cooling Air (CFM)	Avg. Temp. (F)	Heat Flux (BTU/ft^2-s)	B.T.	V. alignment	standard	
0.46	5.15	8.22	1944.7	10.2	7m00s	center	ISO	47%
0.46	5.15	8.22	1932.5	10.2	6m40s	1” offset	ISO	47%
0.47	5.15	8.56	1923.3	10.1	6m05s	Center	ISO	56%
0.47	5.15	8.22	1936.4	10.3	5m35s	1” offset	ISO	56%

➢While the center of propane burner is placed 1 inch (25.4 mm) lower than the center of bolt, the burnthrough time becomes shorter around 20~30 seconds for the both tested configurations.





❖The Burner is placed at 3” away from the head of bolt for all cases

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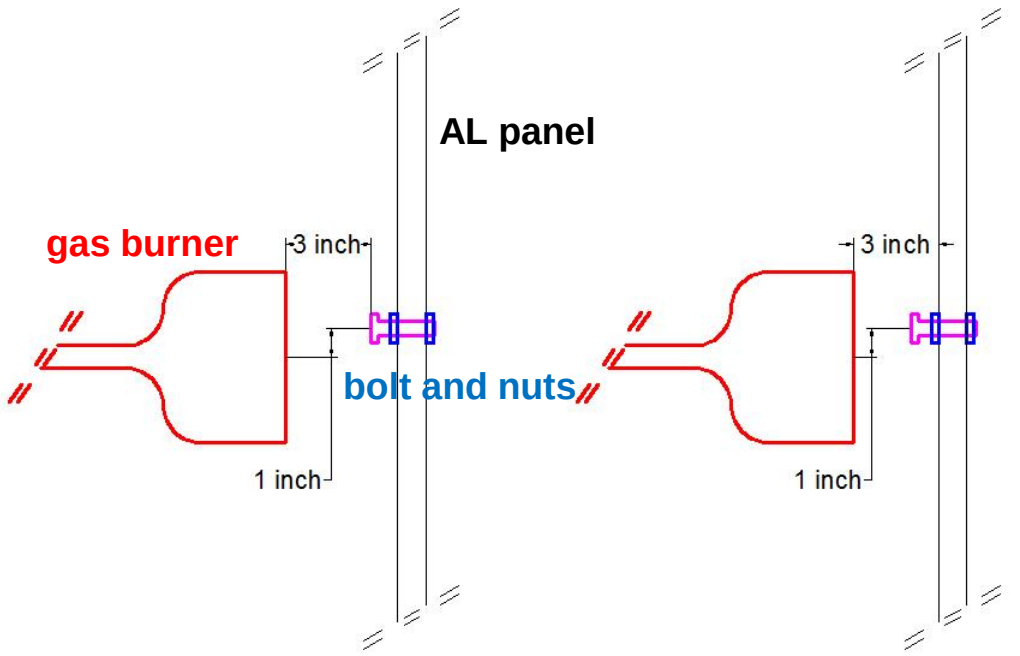
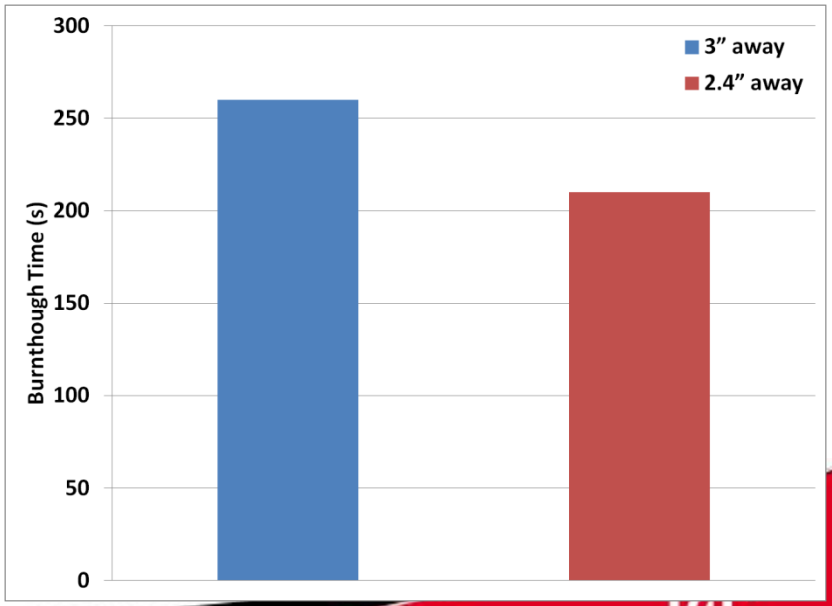
Effect of Horizontal Alignment of Test Sample

Propane (CFM)	Mixing Air (CFM)	Cooling Air (CFM)	Avg. Temp. (F)	Heat Flux (BTU/ft^2-s)	B.T.	H. alignment	standard	
0.54	5.15	8.56	2004.7	11.2	4m20s	3” away	FAA	56%
0.54	5.15	8.56	2015.7	10.8	3m30s	2.4” away	FAA	56%

➢While the burner is placed 3 inch (76.2 mm) away from the test sample instead of that from the head of bolt, the burnthrough time would decrease by around 1 minute.



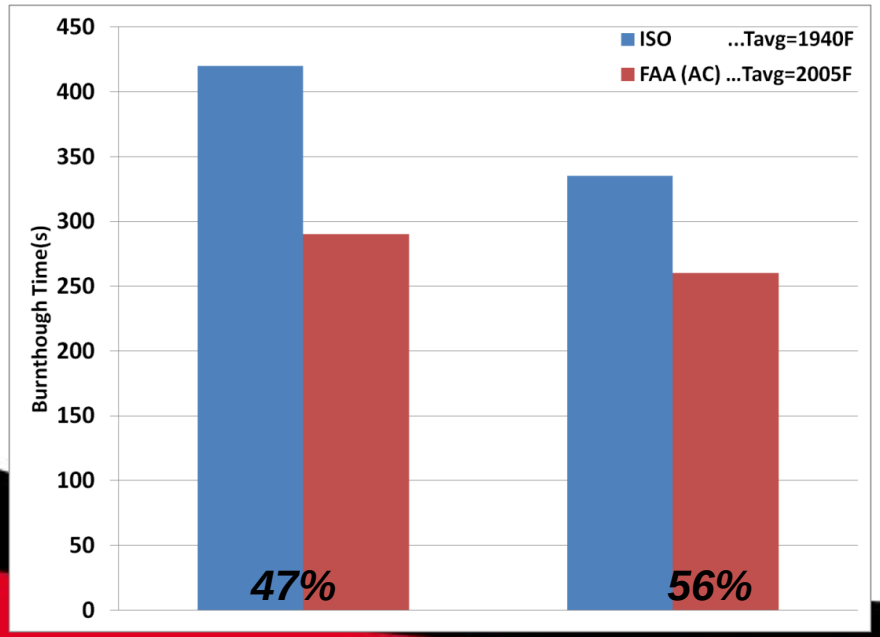


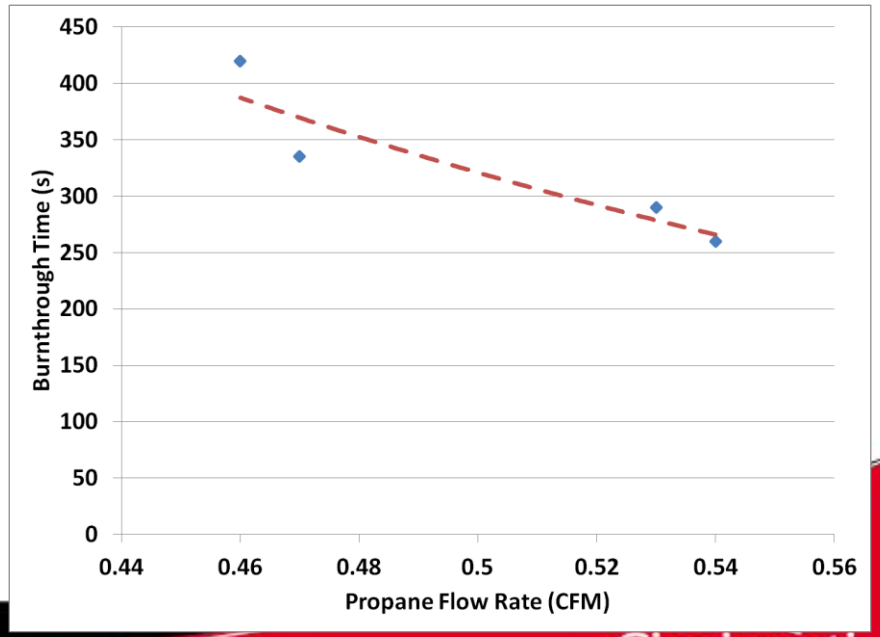
❖The Burner is aligned 1” lower than the center of bolts

Effect of Calibration Standard of Fire Test

Propane (CFM)	Mixing Air (CFM)	Cooling Air (CFM)	**Avg. Temp. (F)**	Heat Flux (BTU/ft^2-s)	**B.T.**	V. alignment	**guidance**	
0.46	5.15	8.22	**1944.7**	10.2	**7m00s**	center	**ISO**	47%
0.53	5.15	8.56	**2009.8**	10.9	**4m50s**	center	**FAA**	47%
0.47	5.15	8.22	**1936.4**	10.3	**5m35s**	offset	**ISO**	56%
0.54	5.15	8.56	**2004.7**	11.2	**4m20s**	offset	**FAA**	56%

➢Due to the additional flame average temperature requirement (T_{avg}.≥2000 ºF, *AC33-17-1*), the fire test results following FAA standard show the burnthrough time is much shorter than those following ISO standard. The burnthrough time could be shortened up to 2 minutes.





❖The Burner is placed at 3” away from the head of bolt for all cases

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Advised Test Conditions from ISO-2685:1992

Propane (CFM)	Mixing Air (CFM)	Cooling Air (CFM)	Avg. Temp. (F)	**Heat Flux (BTU/ft^2-s)**	**B.T.**	
0.59	5.15	7.59		**11.7**	**3m30s**	***ISO-2685:1992***

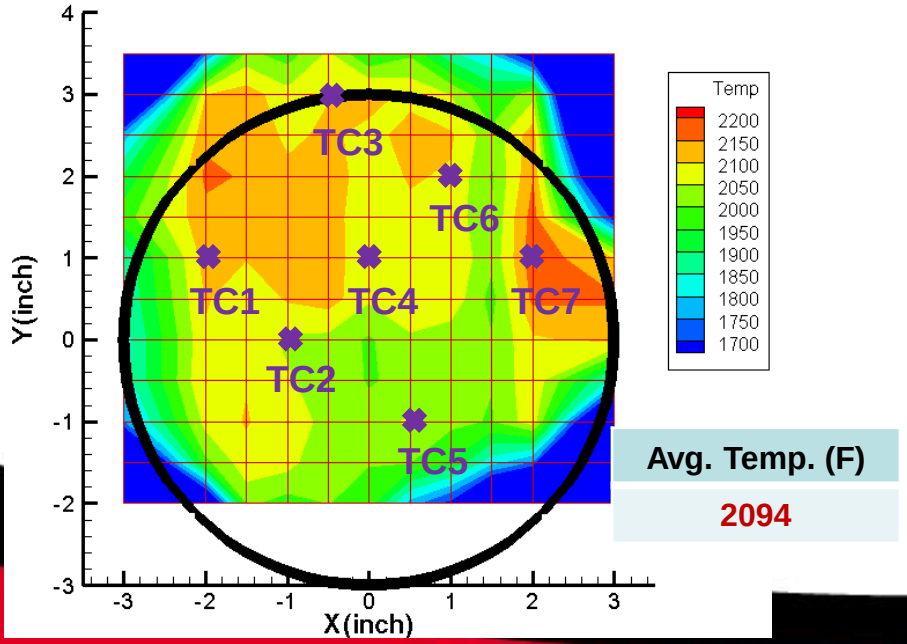
Table A.1 — Typical settings for fire integrity testing

	Gas	Mixing air	Cooling air
Flow rate	1 m^3/h	8,9 m^3/h	12,7 m^3/h
Differential pressure	45 mmH_2O	435 mmH_2O	300 mmH_2O

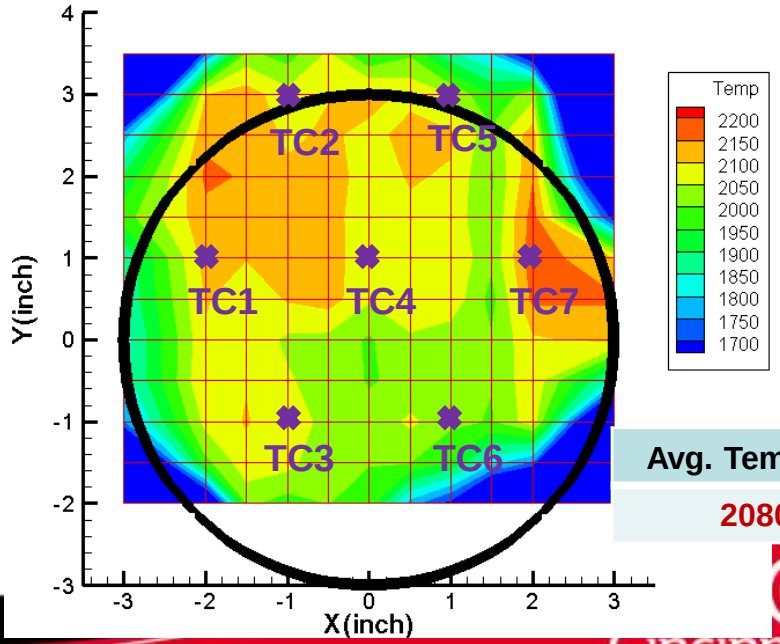
NOTE — The above values may need adjusting to achieve the characteristics of the standard flame (see 2.2).

- The heat flux and temp. might over spec. of calibration standard.

ISO-2685 Standard
- Temp.: 1100±80 °C (individual)
  1868~2156 °F
- H. F.: 116±10 kW/m^2
  9.3~11.1 BTU/ft^2-s



Avg. Temp. (F)
2094



Avg. Temp. (F)
2080

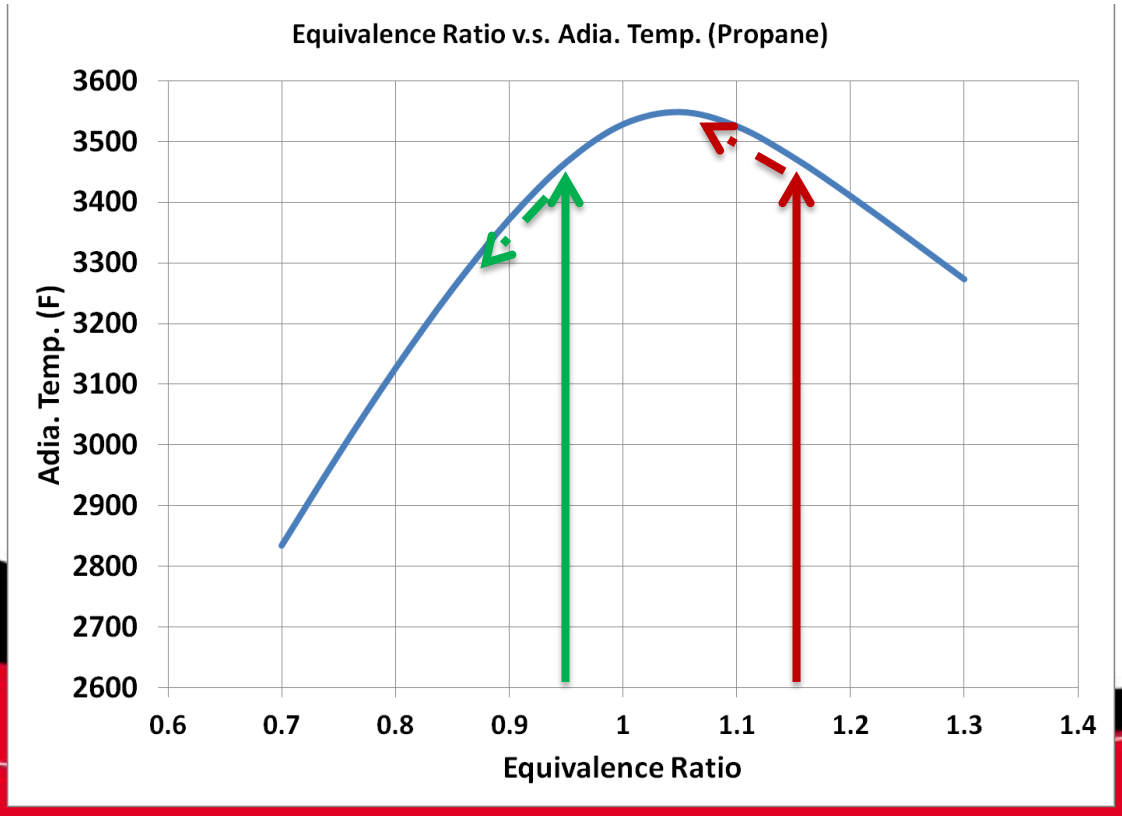
❖The Burner is placed at 3” away from the head of bolt and aligned 1” above the center of bolts

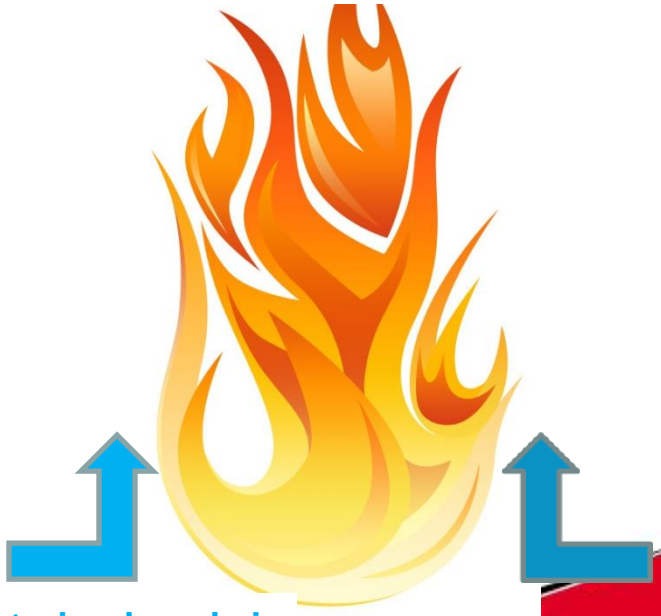
Dilution Effect on Burner Performance

	Propane (CFM)	Mixing Air (CFM)	Cooling Air (CFM)	Eq. Ratio	B.T.
UC	0.54	5.15	8.56	**0.95**	**4m20s**
ISO (1992)	0.59	5.15	7.59	**1.14**	**3m30s**

20% shorter life !!!

- The entrained cool air could make the flame becoming hotter and more severe while the burner's operating condition is fuel rich.
- Even the same theoretic flame temperature, the fuel richer test condition is more severe than the fuel leaner test condition.





entrained cool air
(dilution effect)

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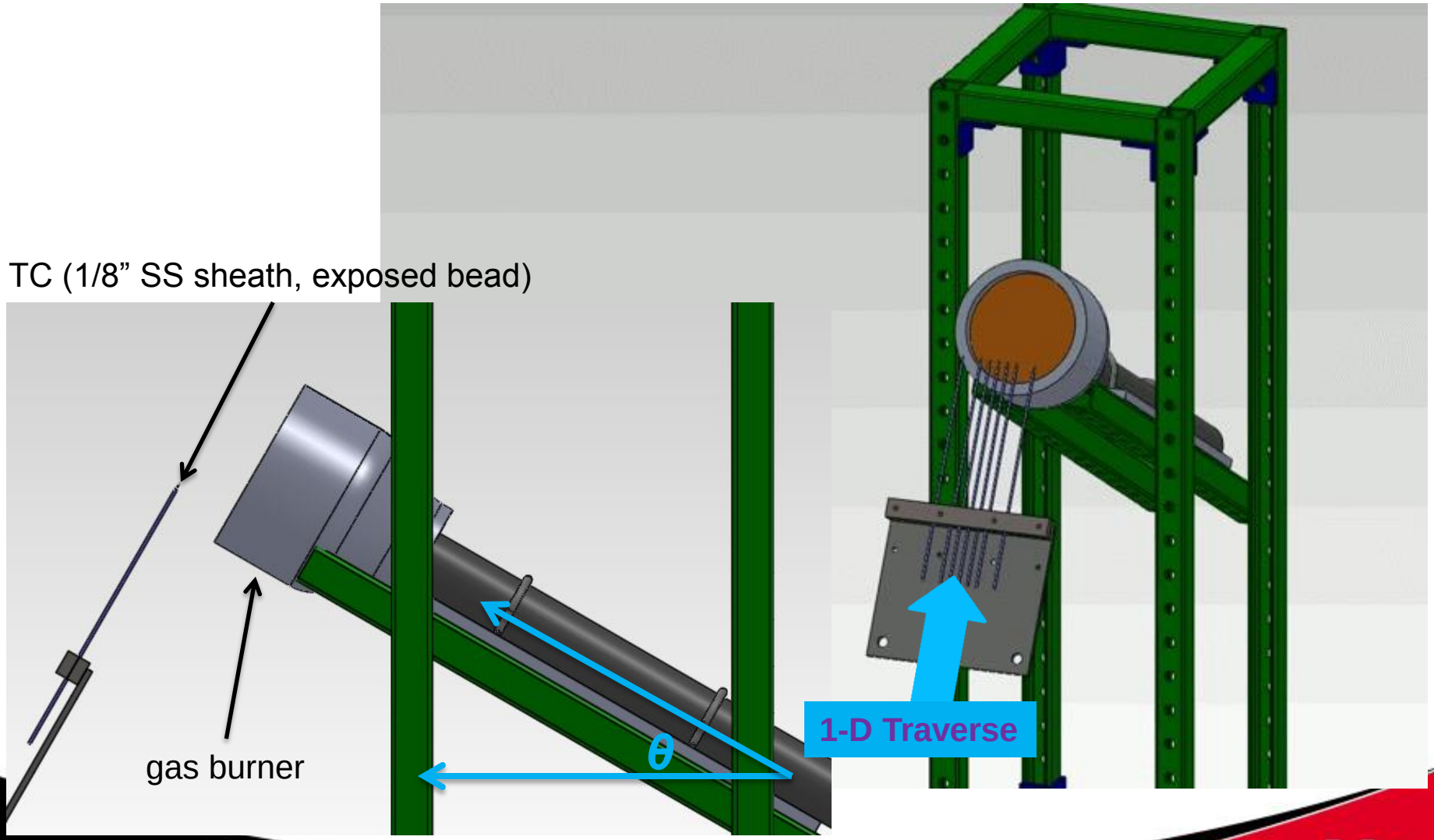
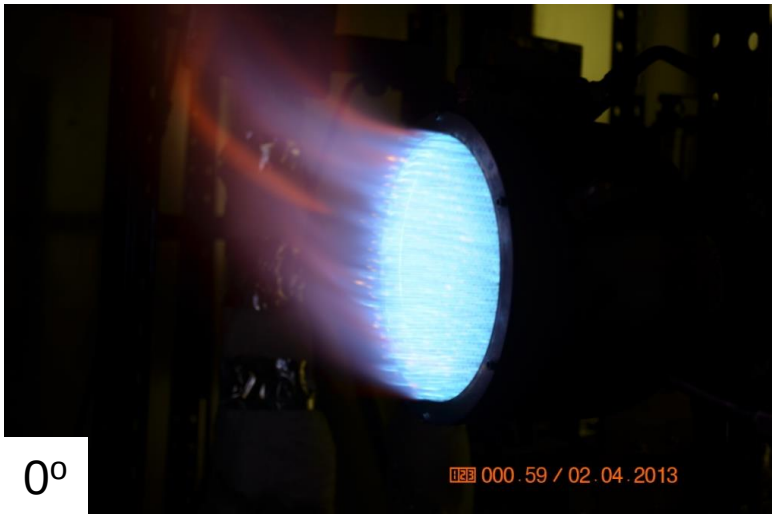
- *Conclusion*
  - The calibration pattern of TCs is a critical factor of fire test result
  - Both alignment issues have impact on the test result, although the impact is less than that of TC pattern.
  - The flame following the additional statement from FAA guidance (AC33.17-1), the minimum flame temp.≥2000 ^{o}F, will provide a more severe test condition and shorten the burnthrough time.
  - The burnthrough time is observed to be inversely proportional to the input amount of propane flow rate.

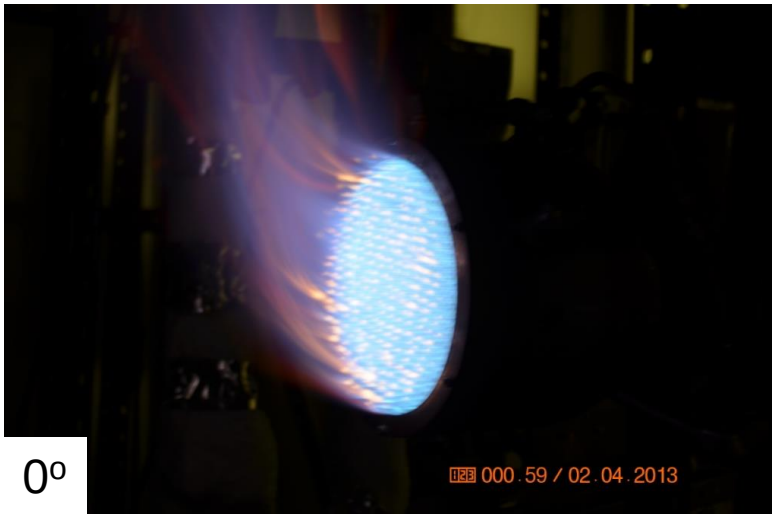
- *Recommendation*
  - The requirement might should be stated more specific than current statement in ISO document, as ”over at least 25% of burner area”.
  - Due to the relationship between the burnthrough time and the input amount of fuel, the fuel flow rate for gas burner should be reported and monitored among fire test houses.
  - The equivalence ratio has a clear impact on the performance of burner, so the air flow rate should be also reported and monitored.

Schematic of Temp Mapping. (Gas burner as example)





0º



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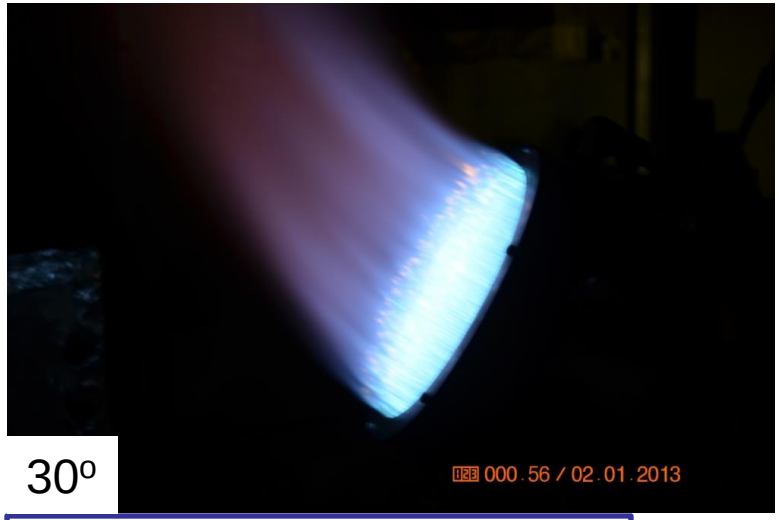


30º

30º

- Propane= 0.60 CFM (1.01 m^3/h)
- Mixing Air= 5.12 CFM (8.7 m^3/h)
- Cooling Air= 7.59 CFM (12.9 m^3/h)
- Φ= 1.15

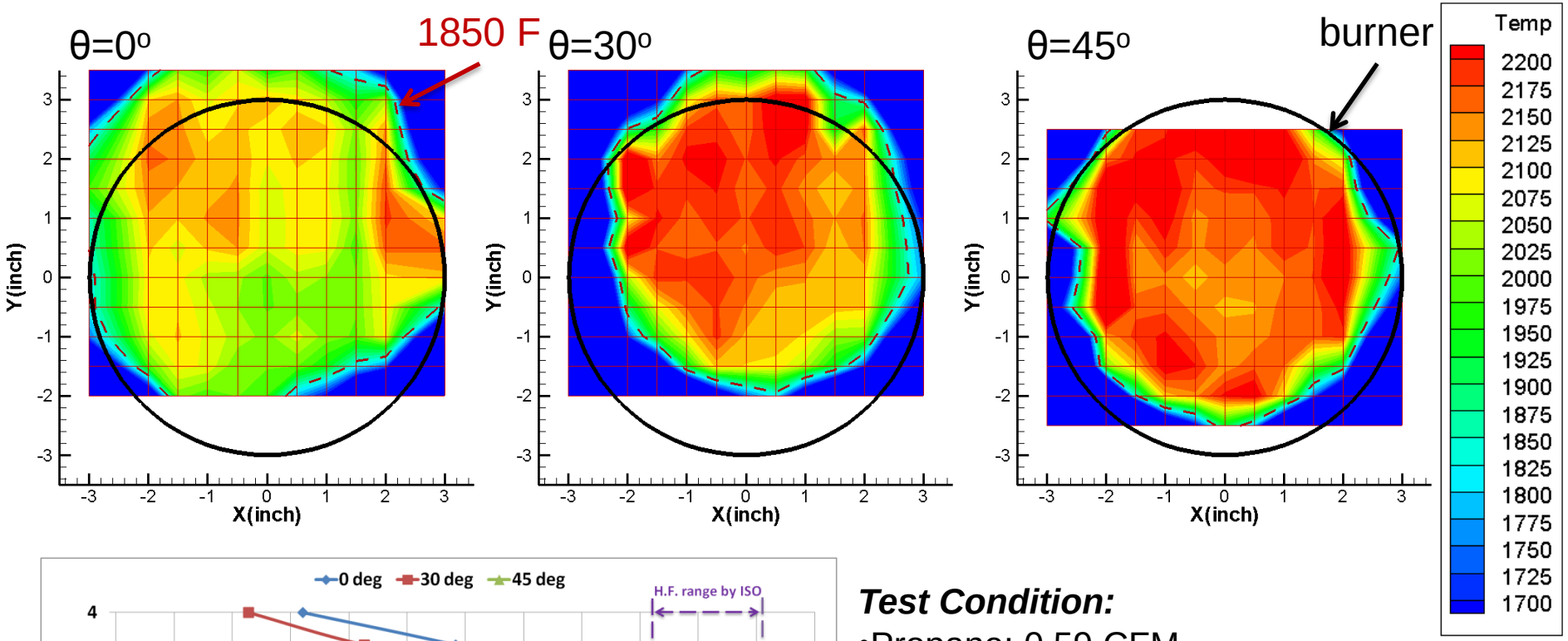
20 % less flow rate

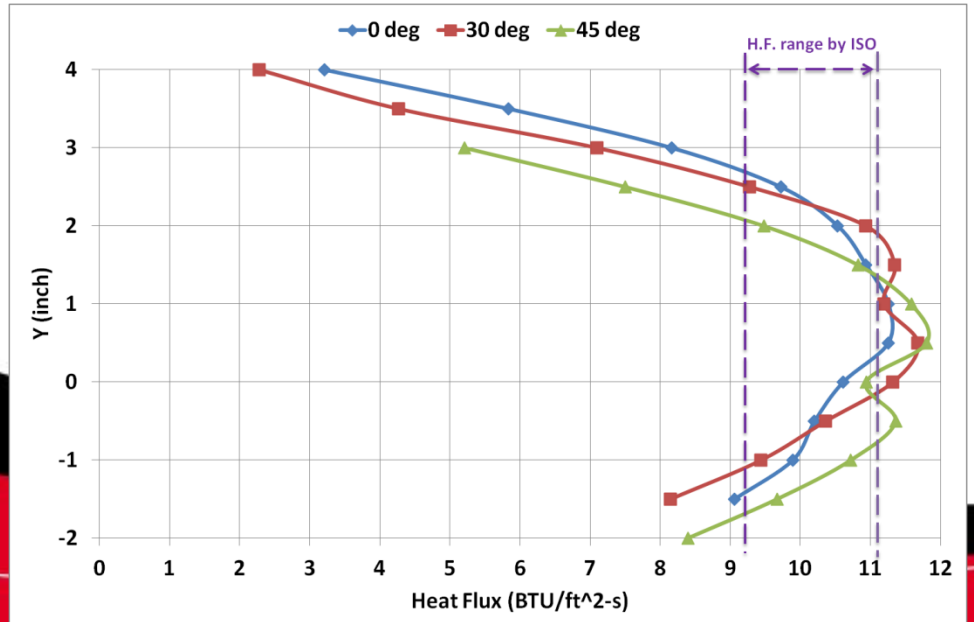
- Propane=0.47 CFM (0.80m^3/h)
- Mixing Air=3.88 CFM (6.6 m^3/h)
- Cooling Air=6.00 CFM (10.2 m^3/h)
- Φ= 1.16

ISO-2685:1992

- The flame shape of gas burner is very influenced by the total mass flow rate and the burner orientation.

Temp., Heat Flux Mapping: Gas Burner





Test Condition:

- Propane: 0.59 CFM
- Mixing Air: 5.15 CFM
- Cooling Air: 7.59 CFM

ISO-2685:1992

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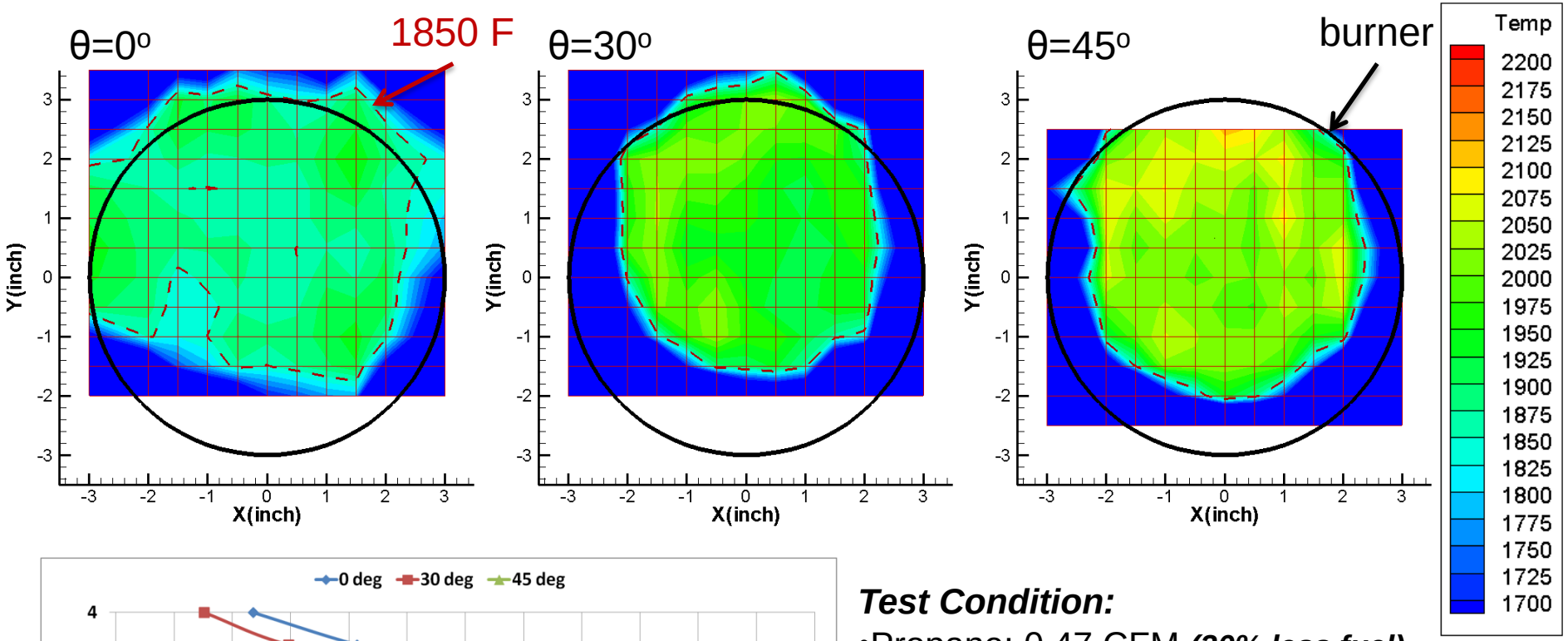
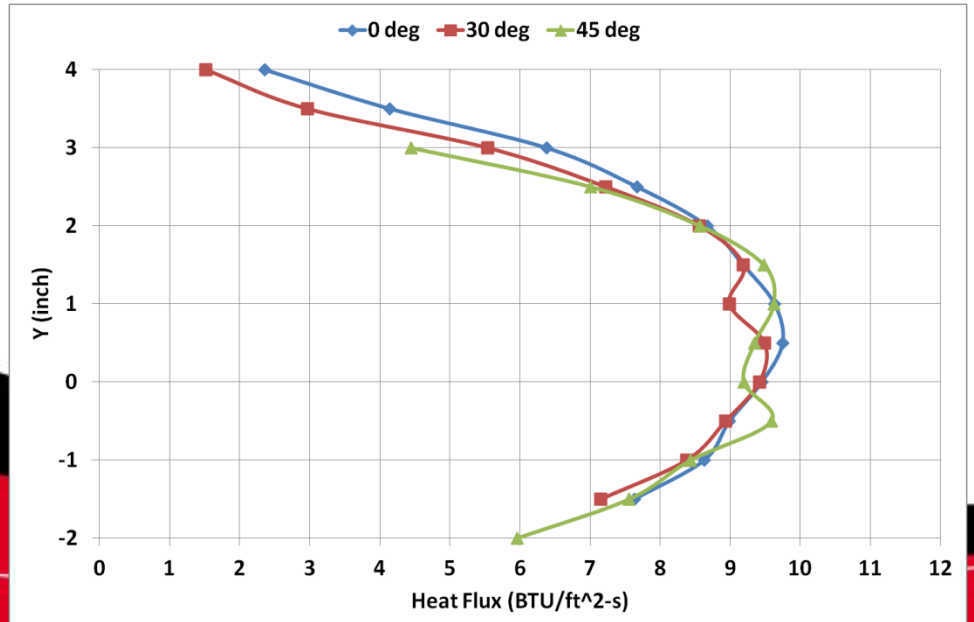
Temp., Heat Flux Mapping: Gas Burner





Test Condition:

- Propane: 0.47 CFM ***(20% less fuel)***
- Mixing Air: 5.15 CFM
- Cooling Air: 7.59 CFM

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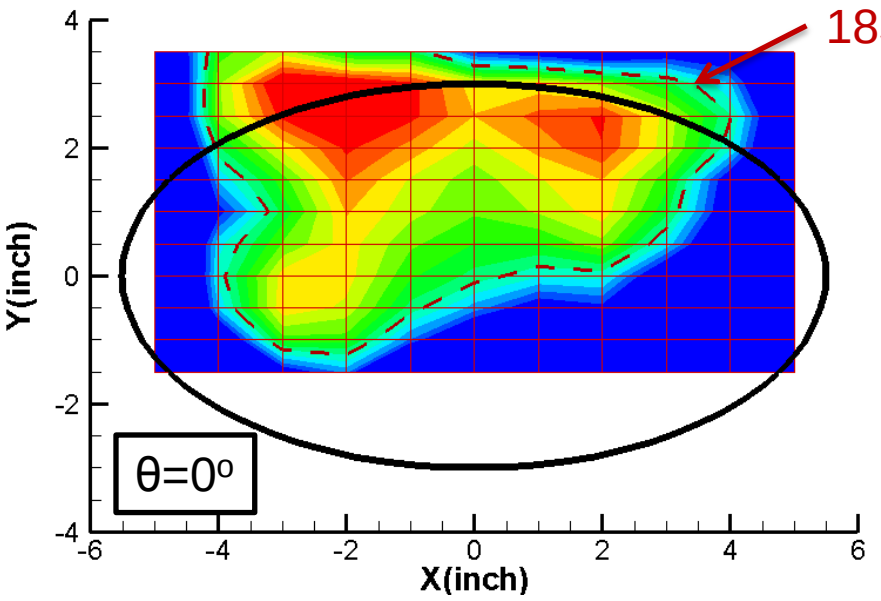
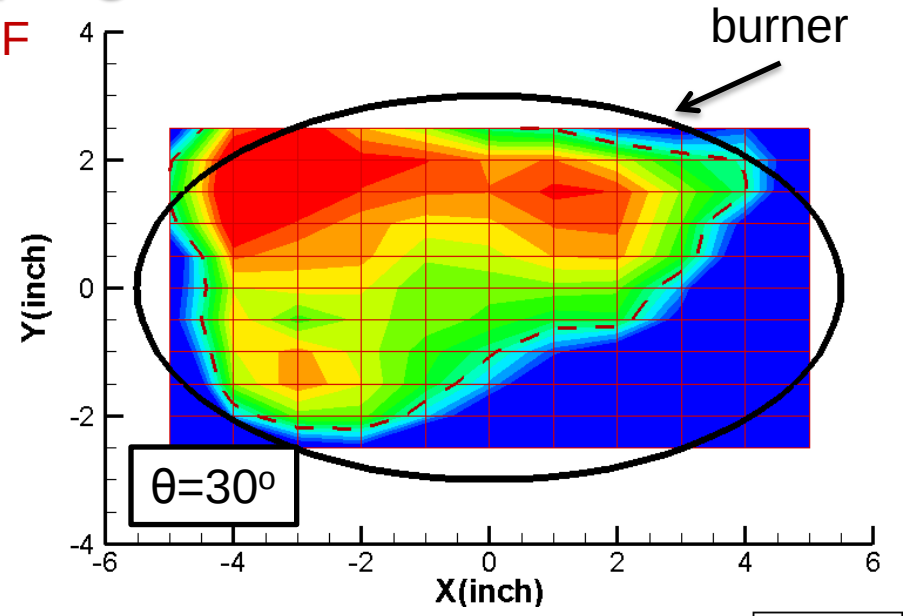
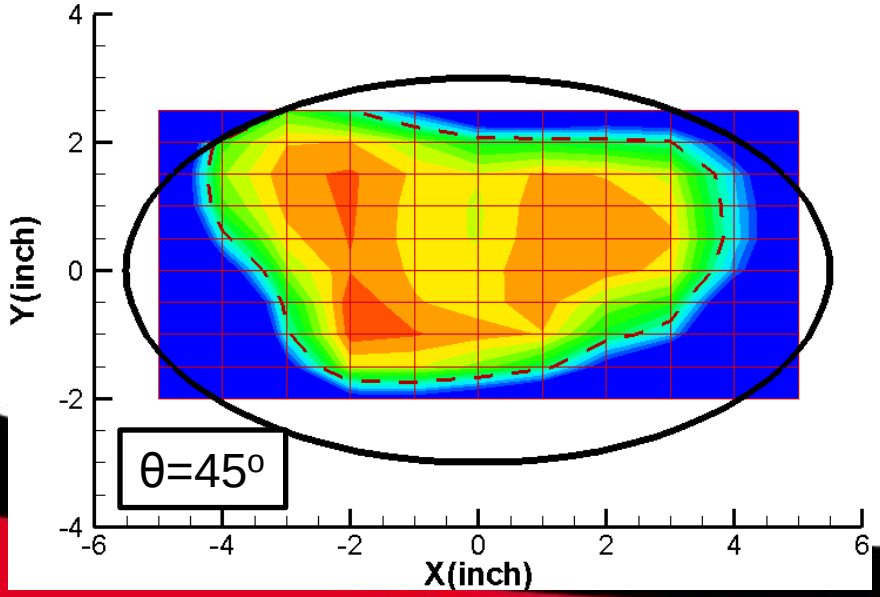
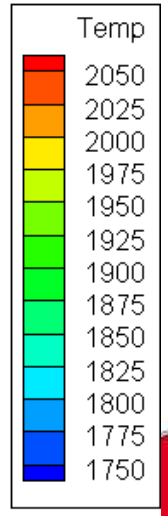
Temp., Heat Flux Mapping: NexGen Burner







face to burber



Test Conditions:

- Fuel=2.6 GPH (room temp.)
- Air=60 psig (room temp.)

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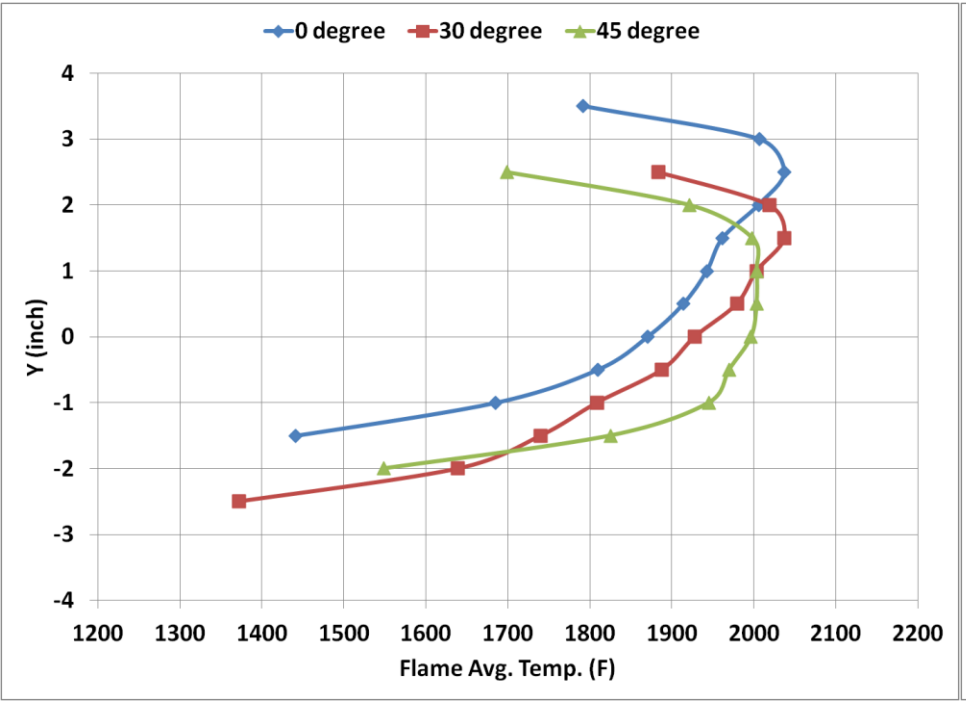
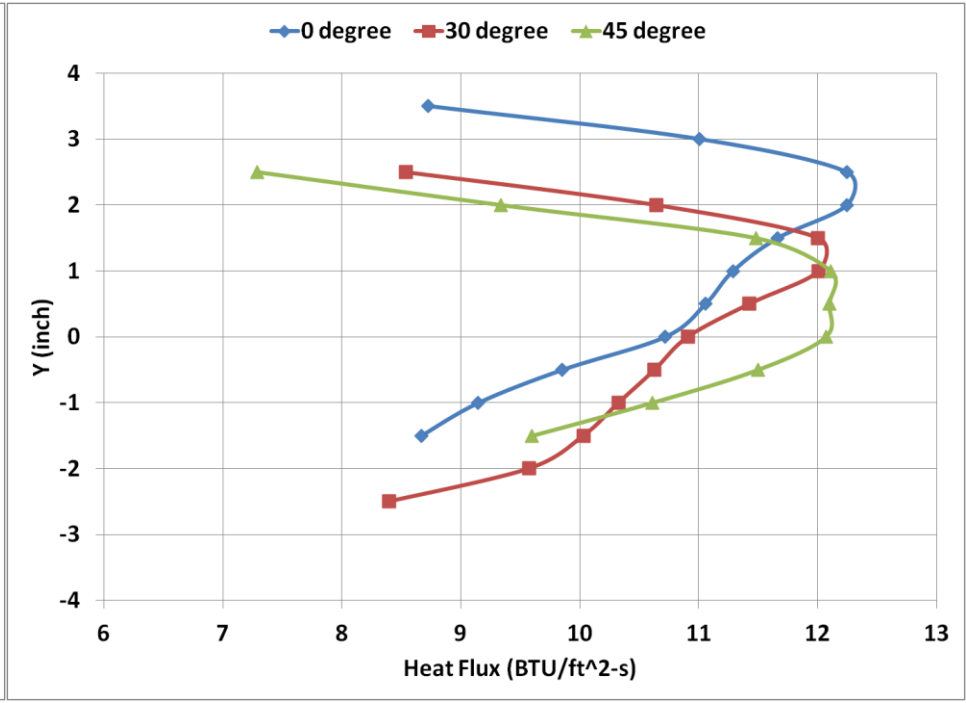
Temp., Heat Flux Mapping: NexGen Burner





Avg. Temp. obtained by the central 7 TCs

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- *Conclusion*
  - For both NexGen and gas burners, the profile of flame is influenced by the orientation of burner setup, even the fuel and air flows are the same.
  - The more inclined (facing up) burner setup, the flame is more concentrative, compact and uniform.
  - The hottest region of NexGen burner with horizontal setup is around 2 inch above the centerline of burner.

- *Recommendation*
  - In order to narrow down the discrepancy of test result in the future, the mean and tolerance of fuel and air mass flows should be specified for different burner orientation in the new fire test standard.
  - The heat flux and temperature calibration device should be located at different location with different burner orientation.