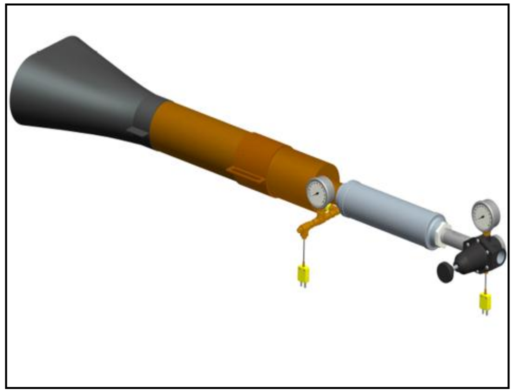
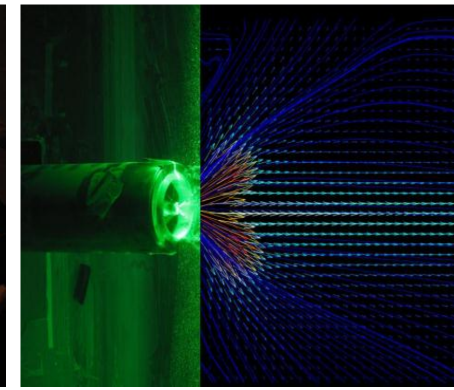
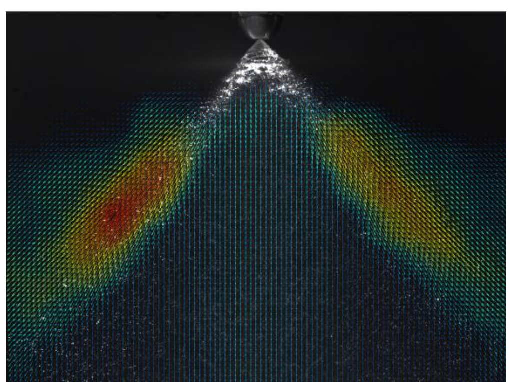
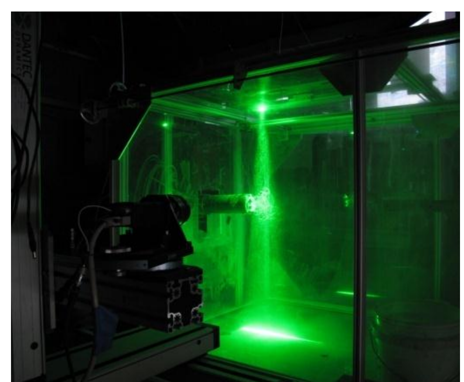
NexGen Burner Comparative Testing

Federal Aviation Administration



Presented to: IAMFTWG, Indianapolis, IN, USA
By: Robert I. Ochs
Date: October 16-17, 2012

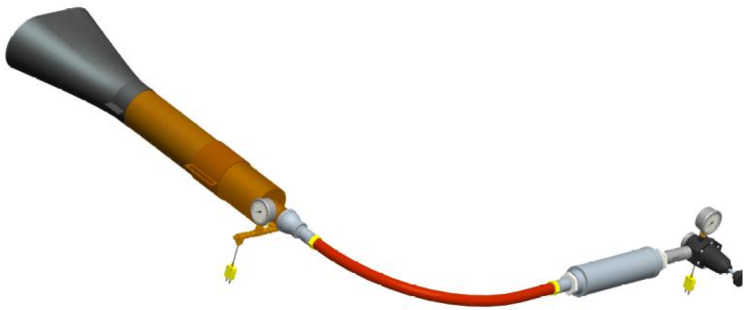




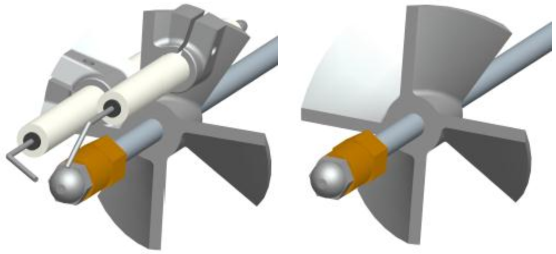

Objectives

- Perform comparative burnthrough testing to determine the effect of various parameters on test results
  - Use picture frame sample holder and PAN material to determine burnthrough performance
- Test results will help to determine which parameters are most critical when specifying the burner in the new workbook

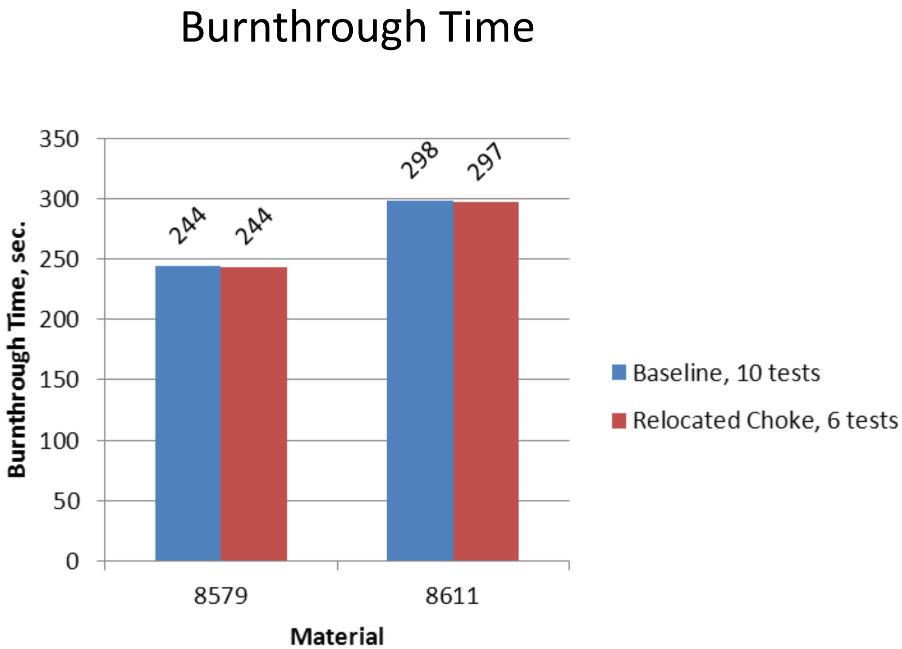
Review from Toulouse

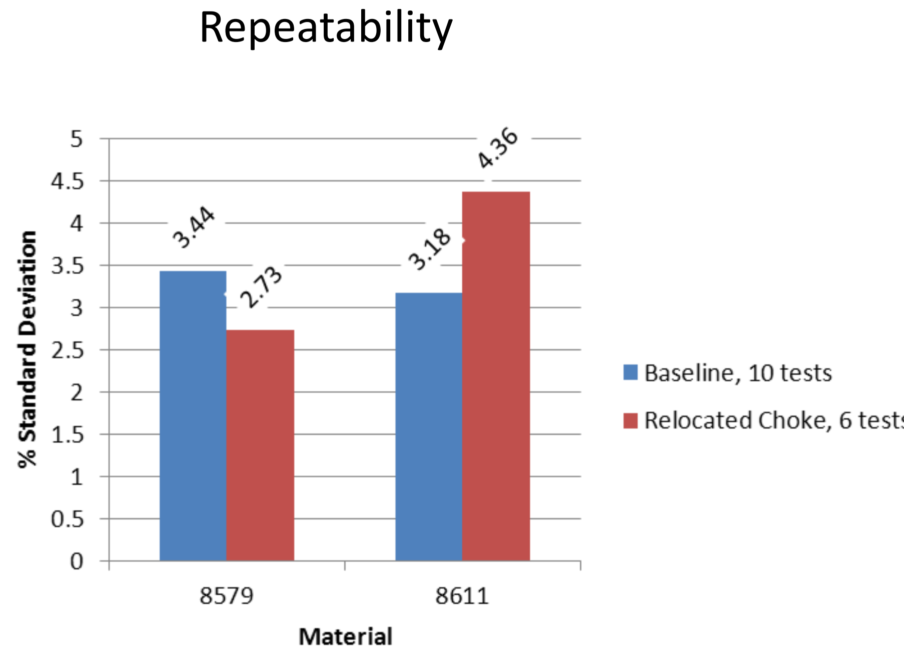
- Comparative BT tests were performed to determine effect of various parameters on BT time
  - Sonic choke location
    - Moving the choke upstream before a 6’ flex hose had little effect on BT
  - Burner cones
    - Cones of different construction and age had an effect on BT times
  - Igniter-less stator
    - Introducing a symmetric stator and removing the igniters significantly increased the BT time
  - Flame retention heads
    - Combined stator-turbulator devices on new OEM oil burners
    - Different FRH’s had different effects on BT times
    - F-22 model showed similar results to current NexGen burner configuration



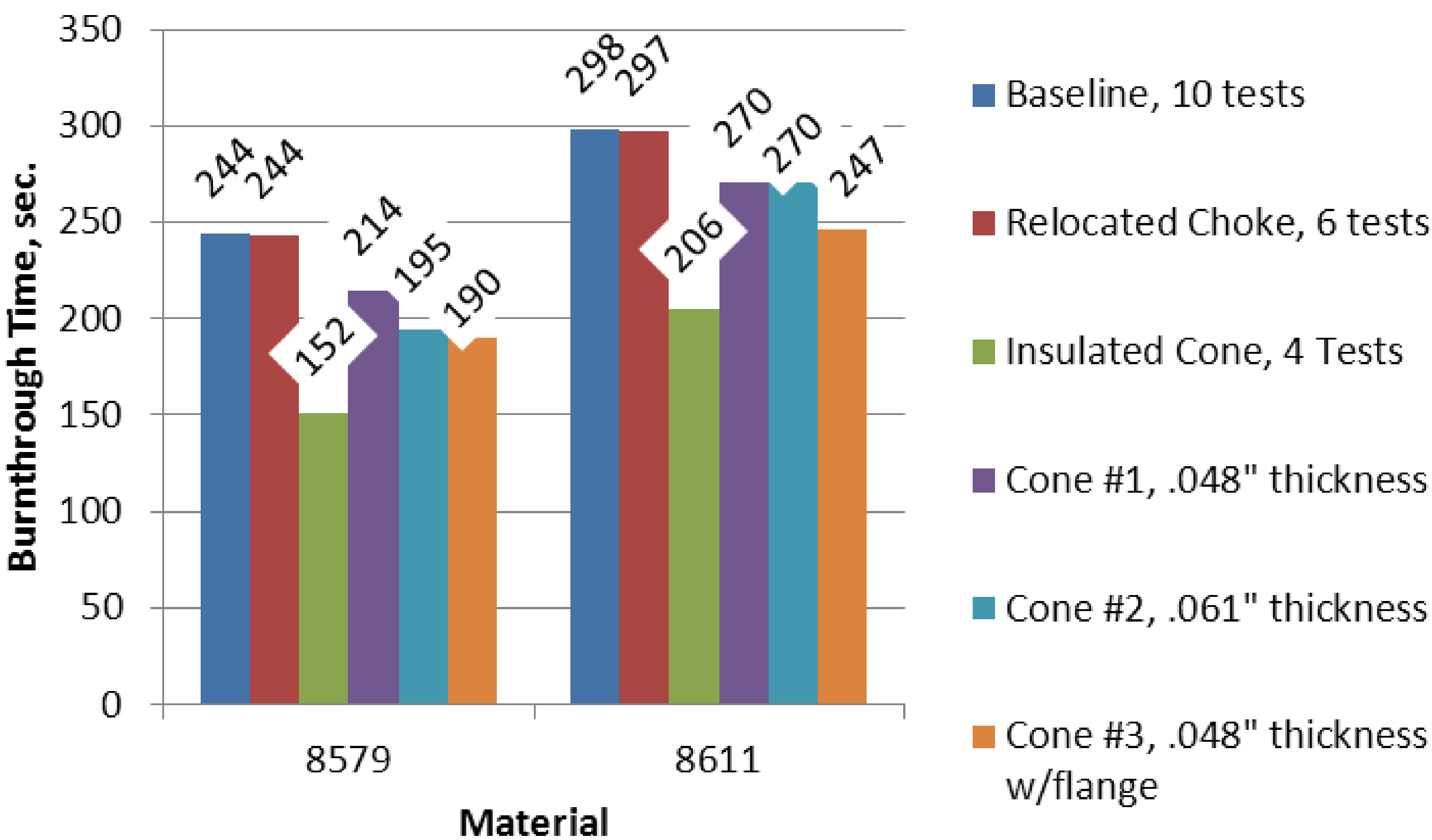



Relocated Sonic Choke

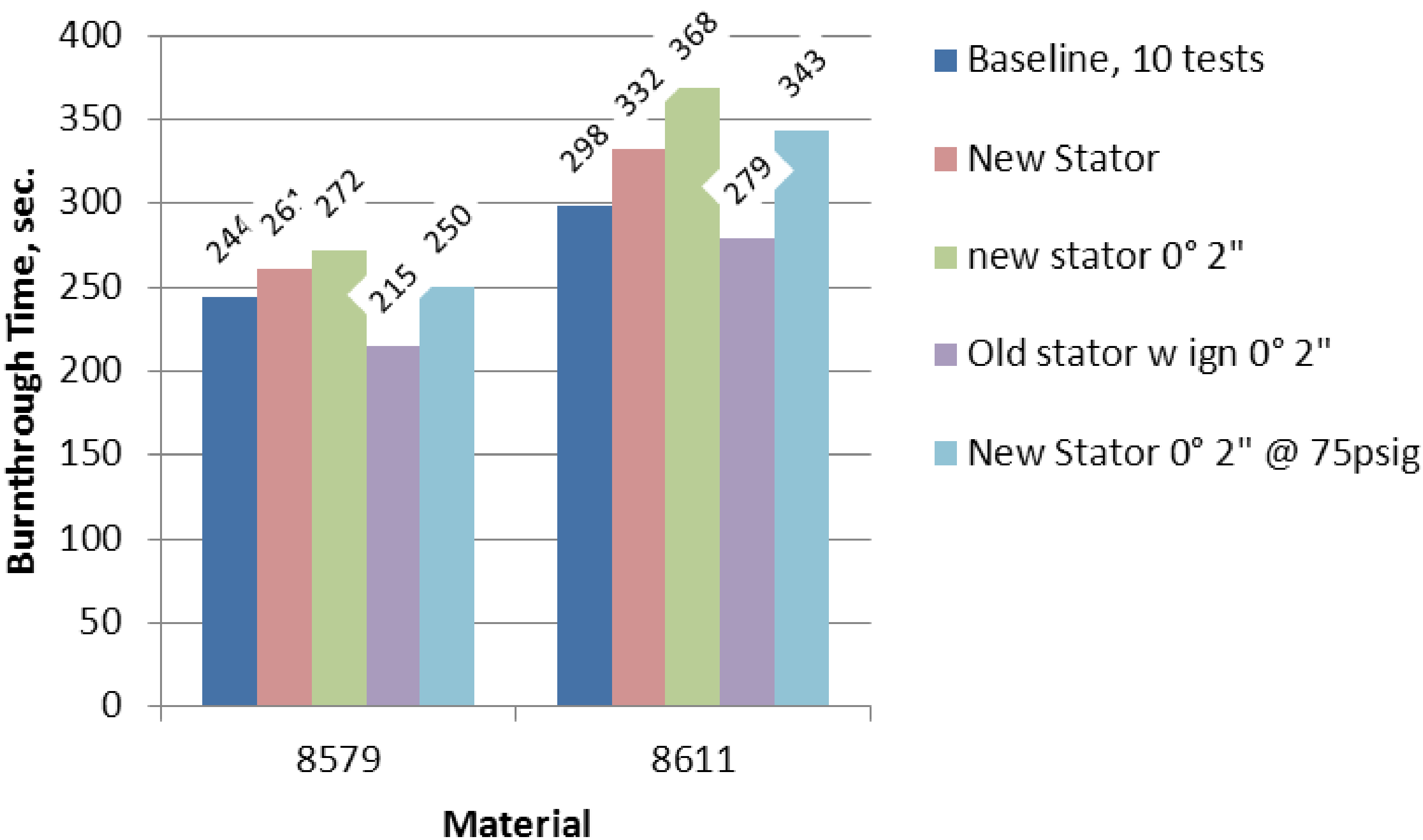




Various New Cones

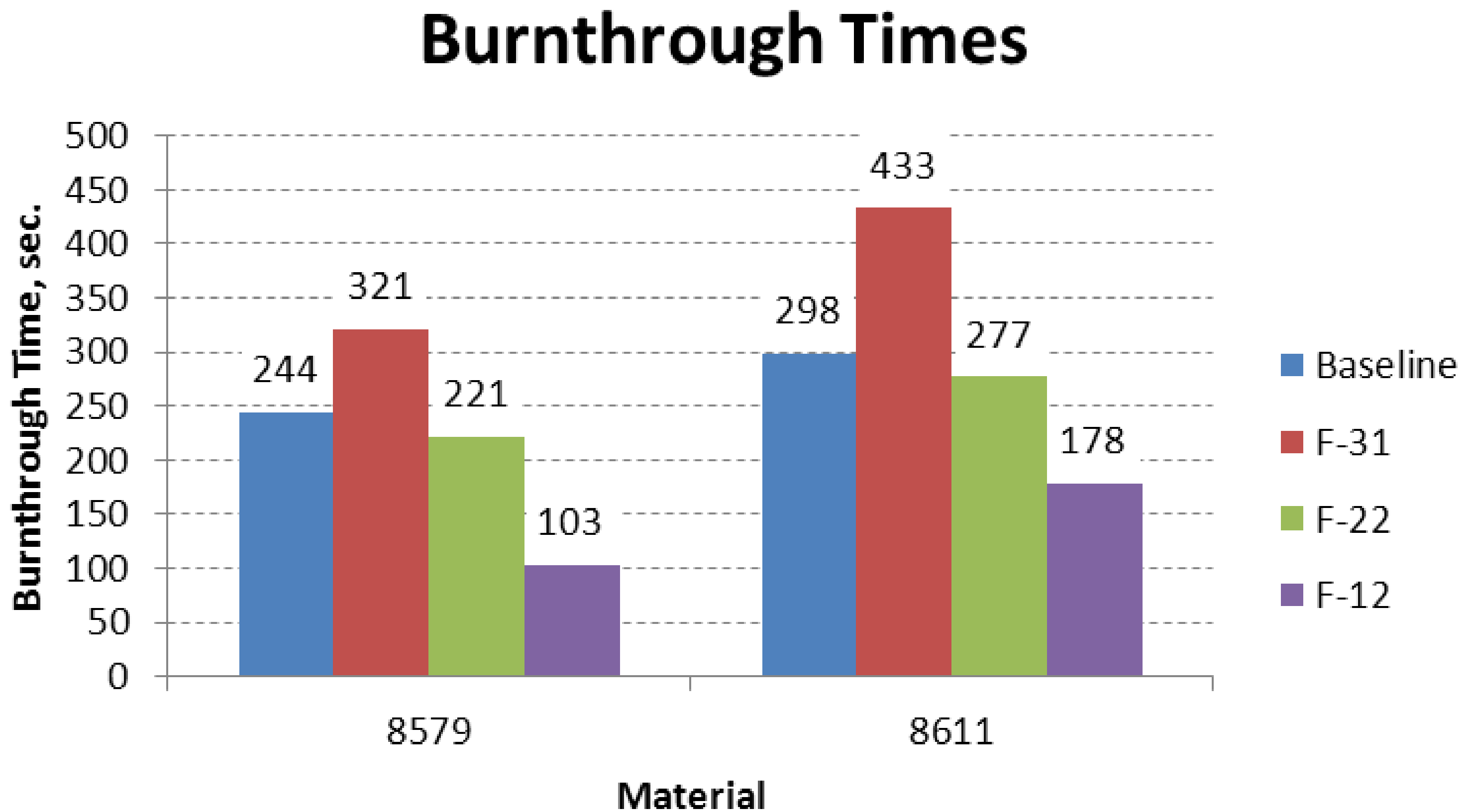


New Stator



Burnthrough Time, sec.
400
350
300
250
200
150
100
50
0
244
26
272
215
250
298
332
368
279
343
8579
8611
Material
Baseline, 10 tests
New Stator
new stator 0° 2"
Old stator w ign 0° 2"
New Stator 0° 2" @ 75psig

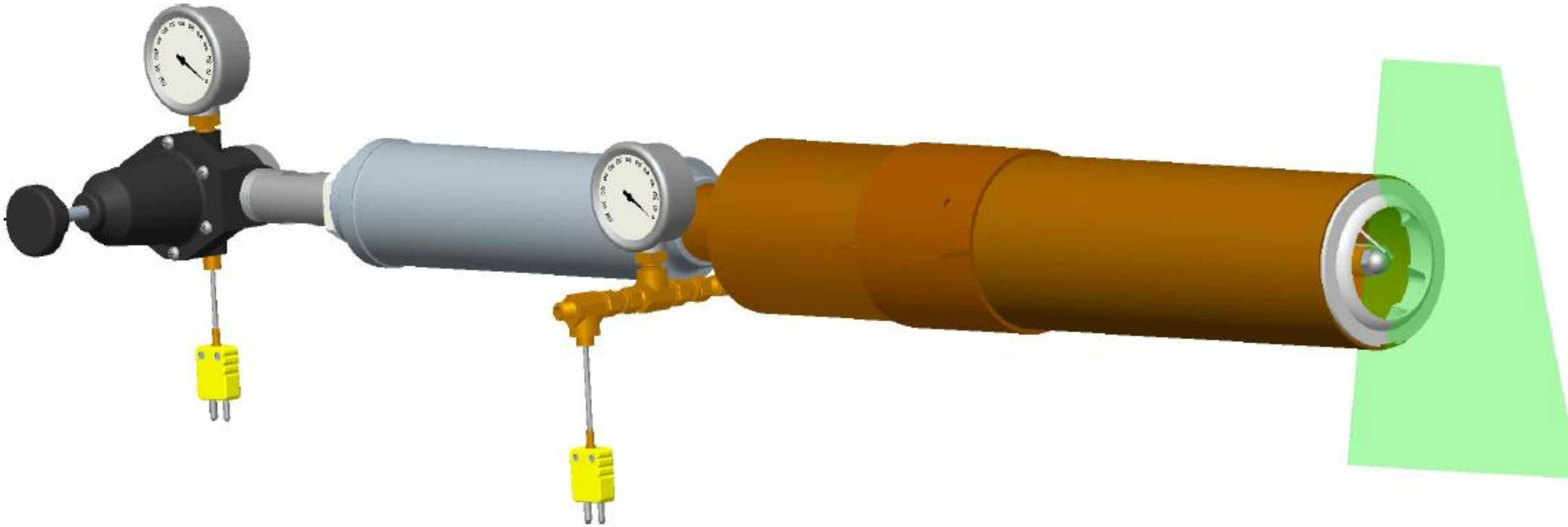
Flame Retention Heads



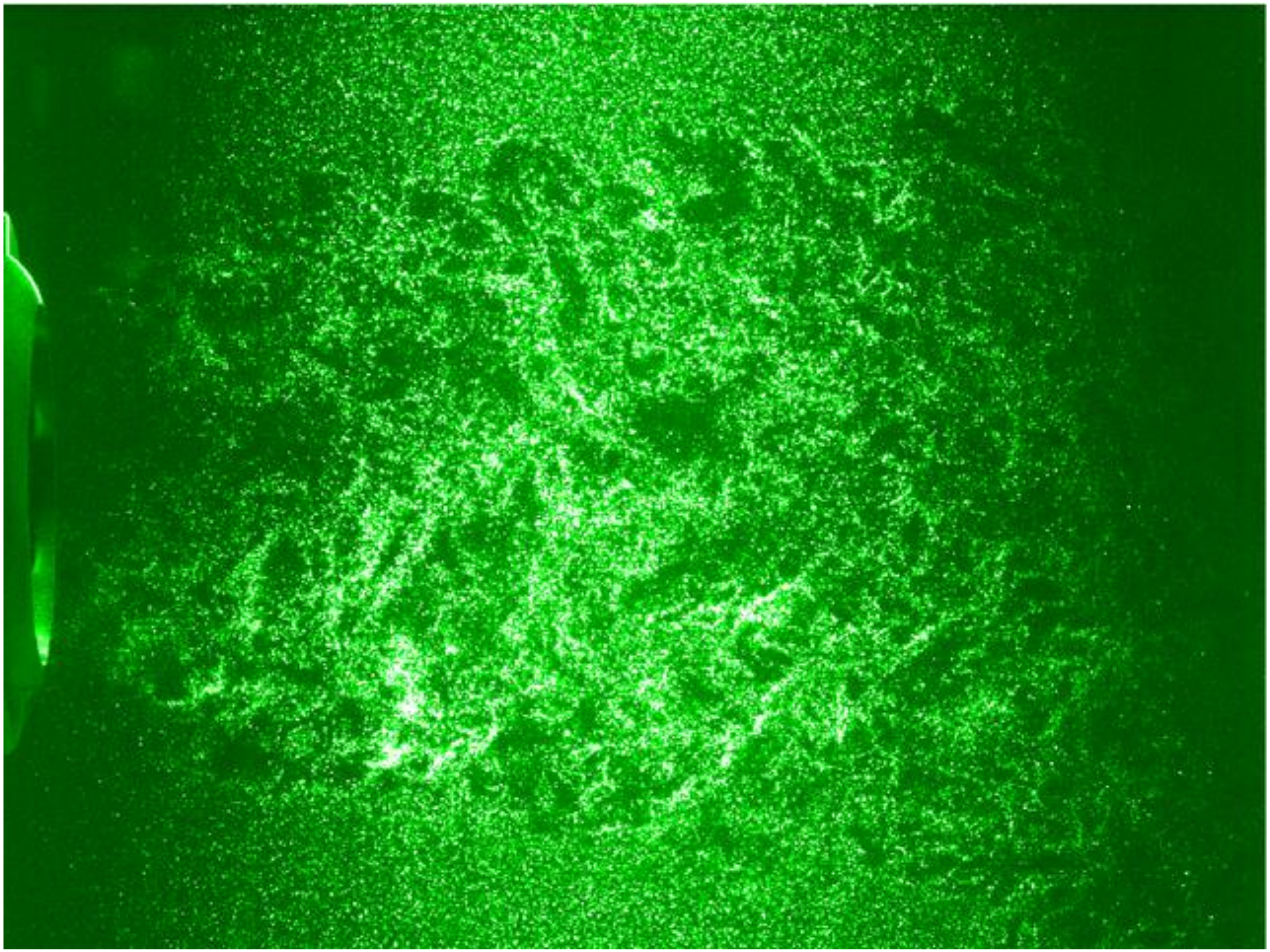
Recent PIV Measurements

- For each new stator and FRH tested on the burnthrough rig, PIV measurements were taken
- PIV: Particle Image Velocimetry
  - Non-intrusive, whole field, fluid flow measurement technique employing a laser light sheet, digital cameras, synchronized timer and acquisition and analysis software

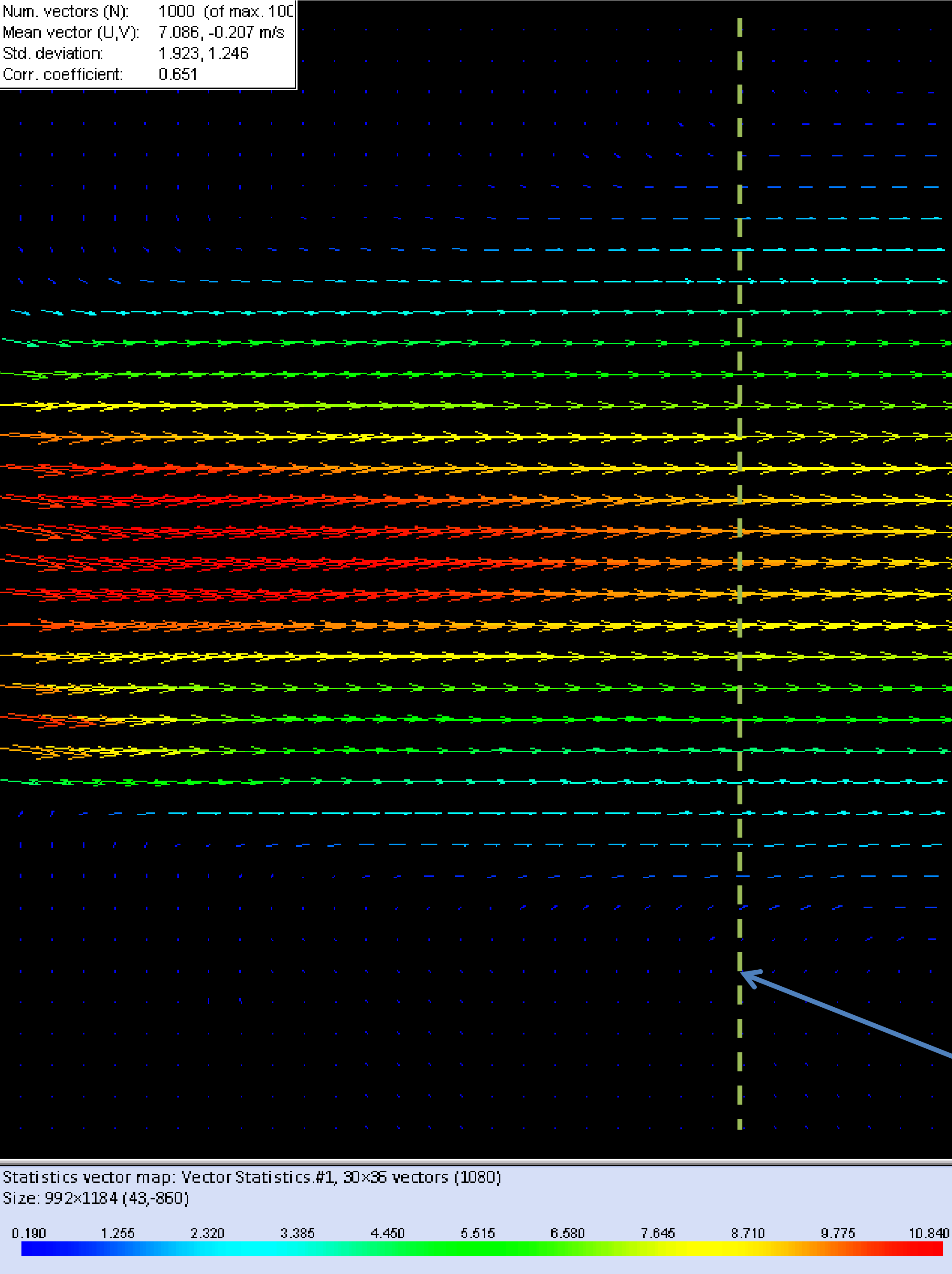
PIV Imaging Plane

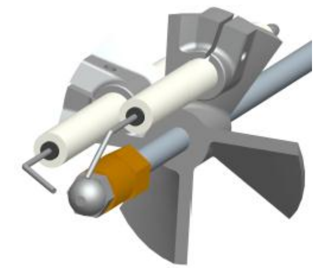


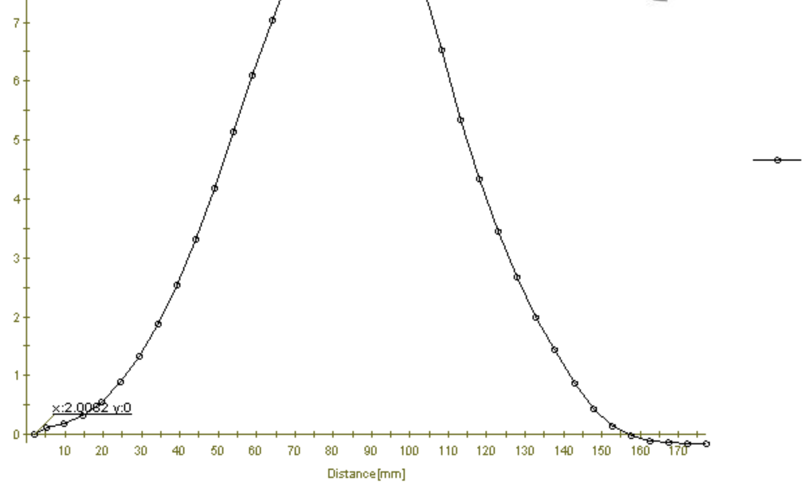
PIV Image Plane



Old Stator, with Turbulator, -35° 4”
Peak U = 9.49 m/s (Baseline)



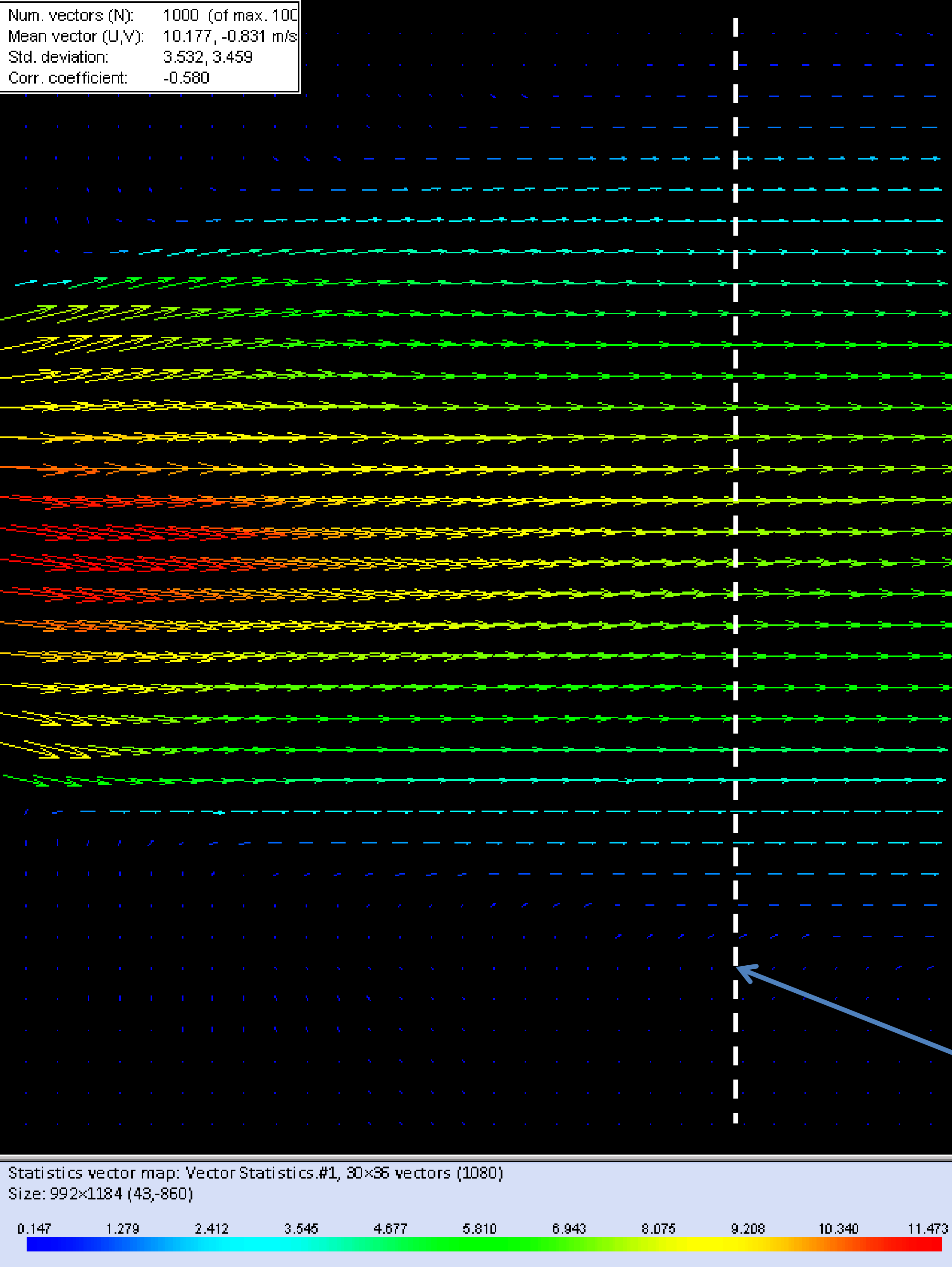


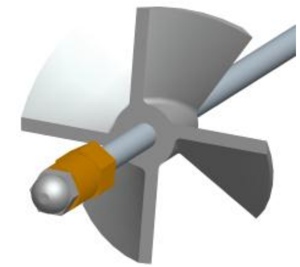


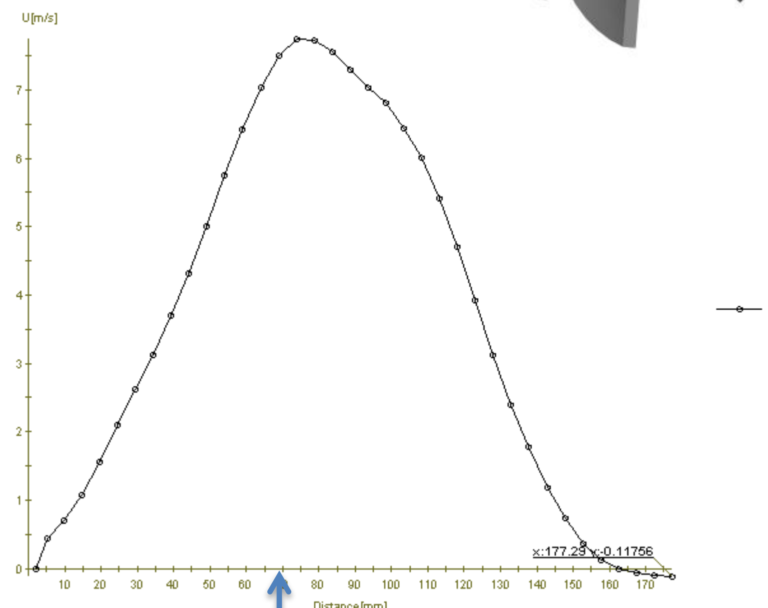
5” from turbulator exit

Federal Aviation Administration

New Stator, with Turbulator, -35° 4”
Peak U = 7.7 m/s



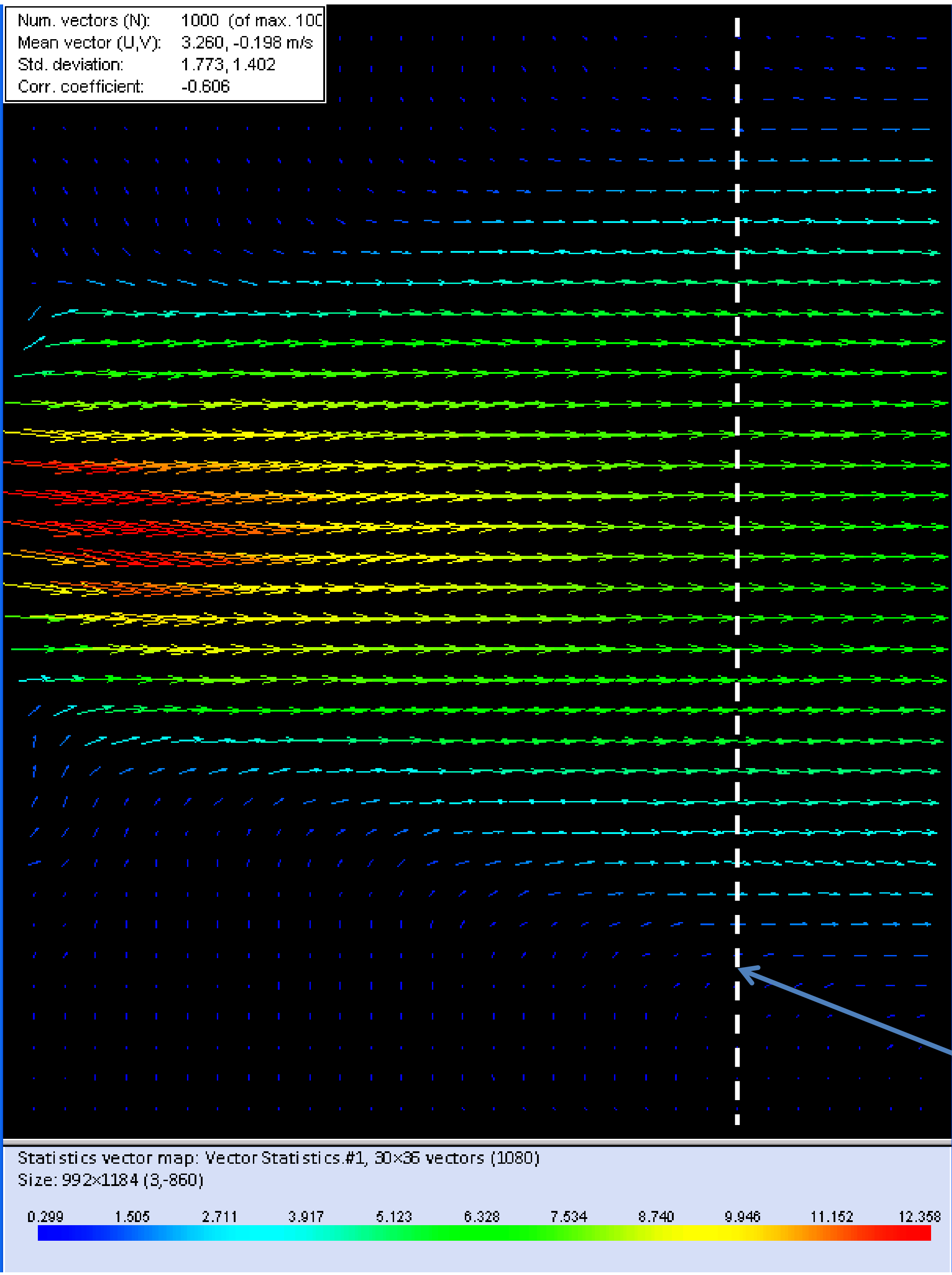


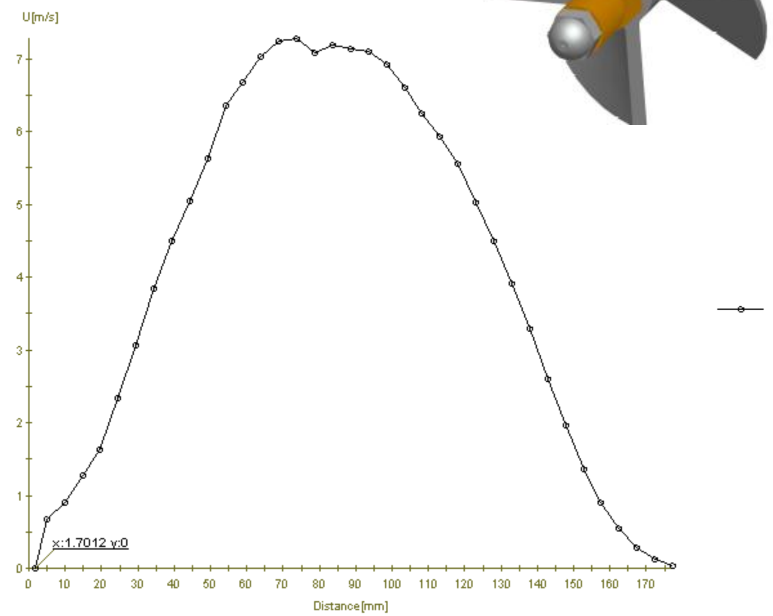


5” from turbulator exit

Federal Aviation Administration

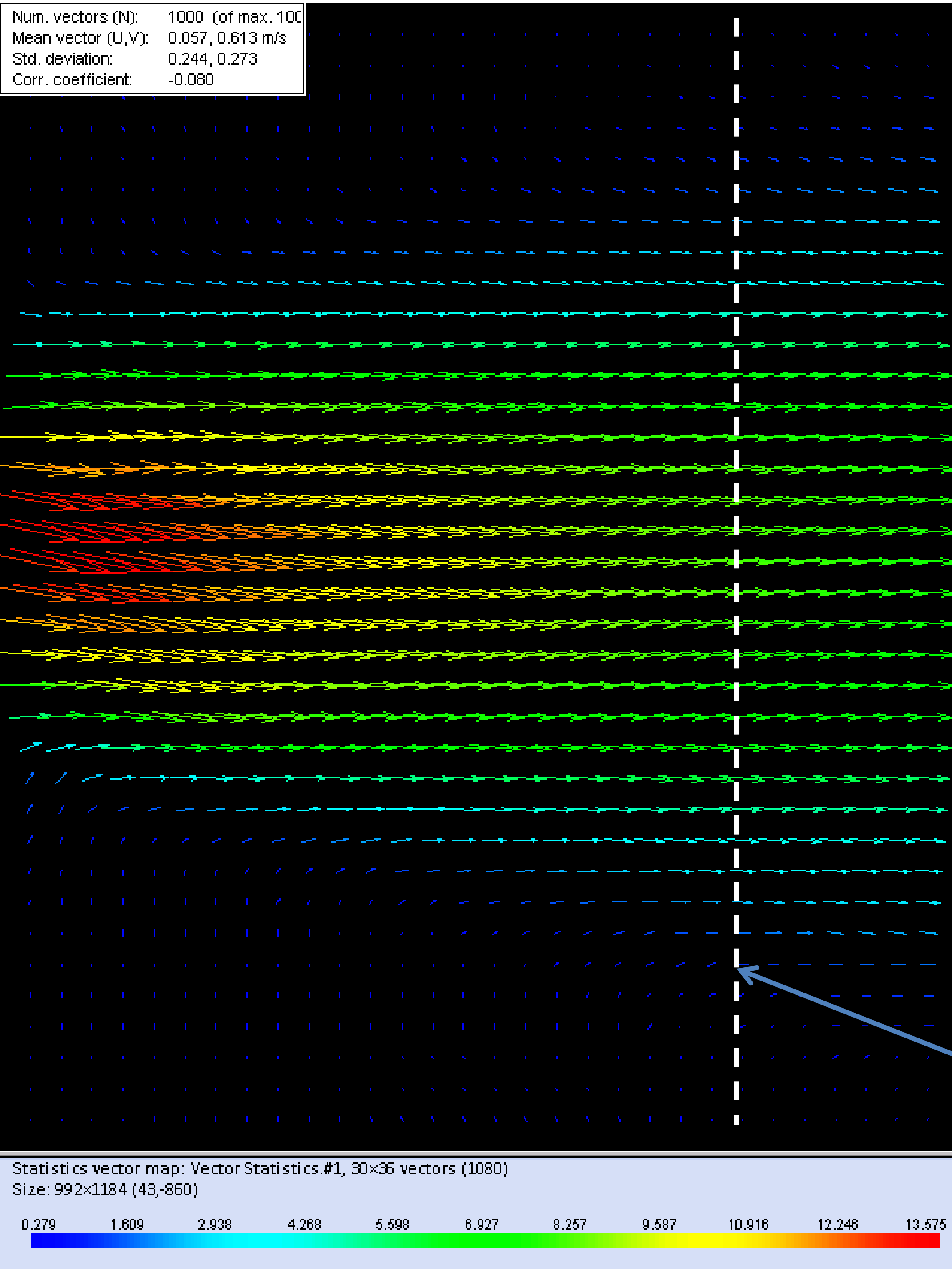
New Stator, with Turbulator, 0° 2”
Peak U = 7.3 m/s





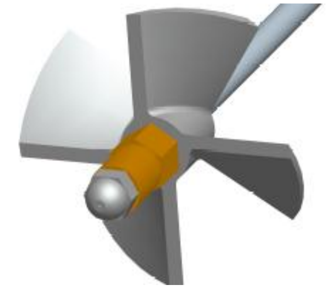
5” from turbulator exit

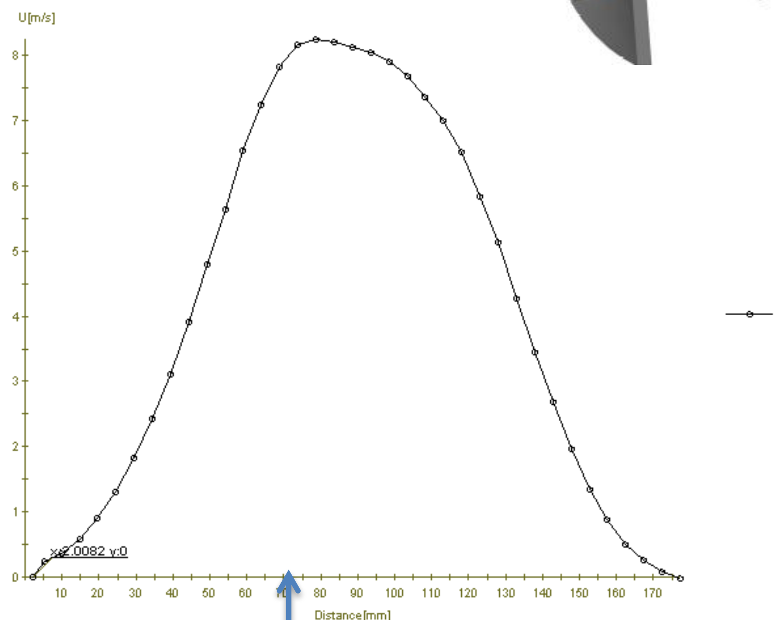
Federal Aviation Administration



New Stator, with Turbulator, 0° 2”, 75 psig

Peak U = 8.2 m/s

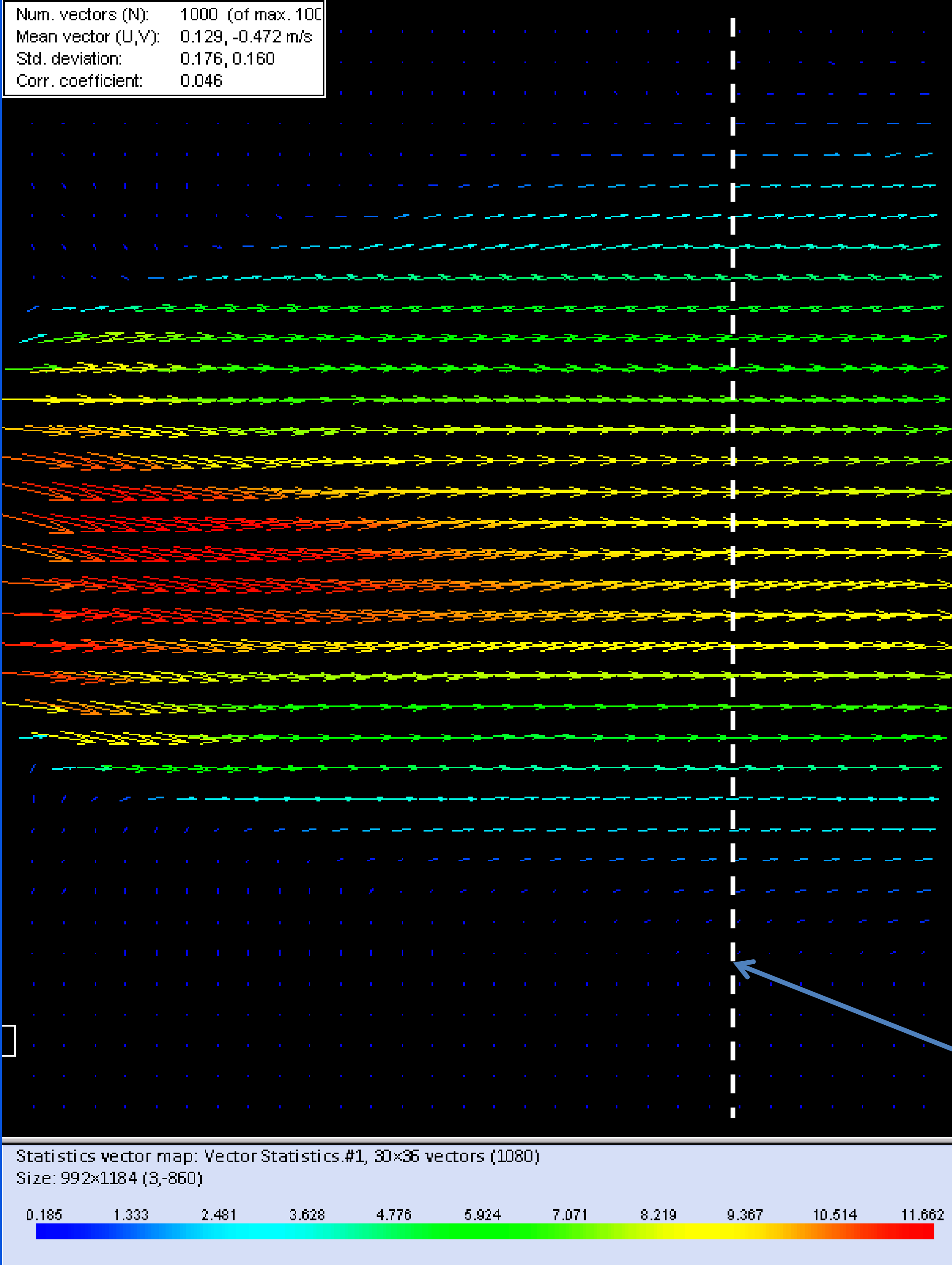


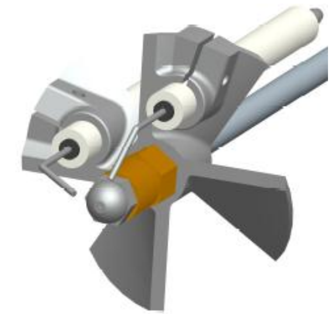


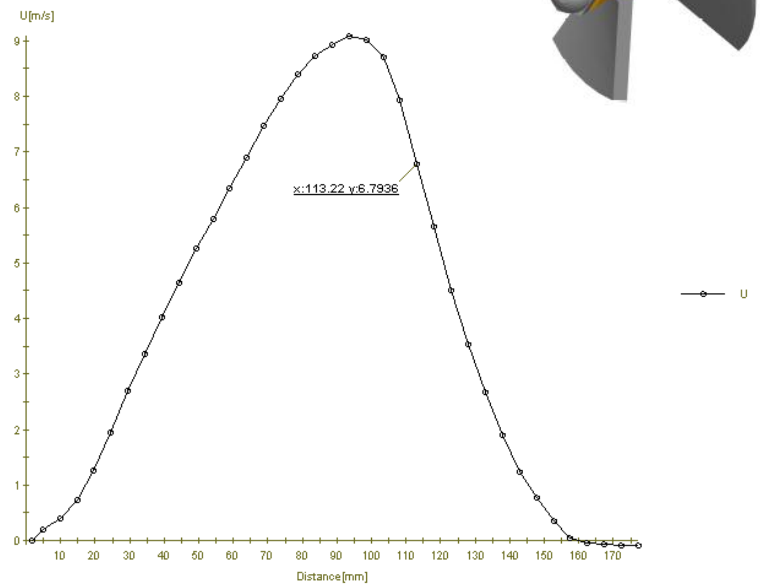
5” from turbulator exit

Old Stator, with Turbulator, 0° 2”

Peak U = 9.1 m/s



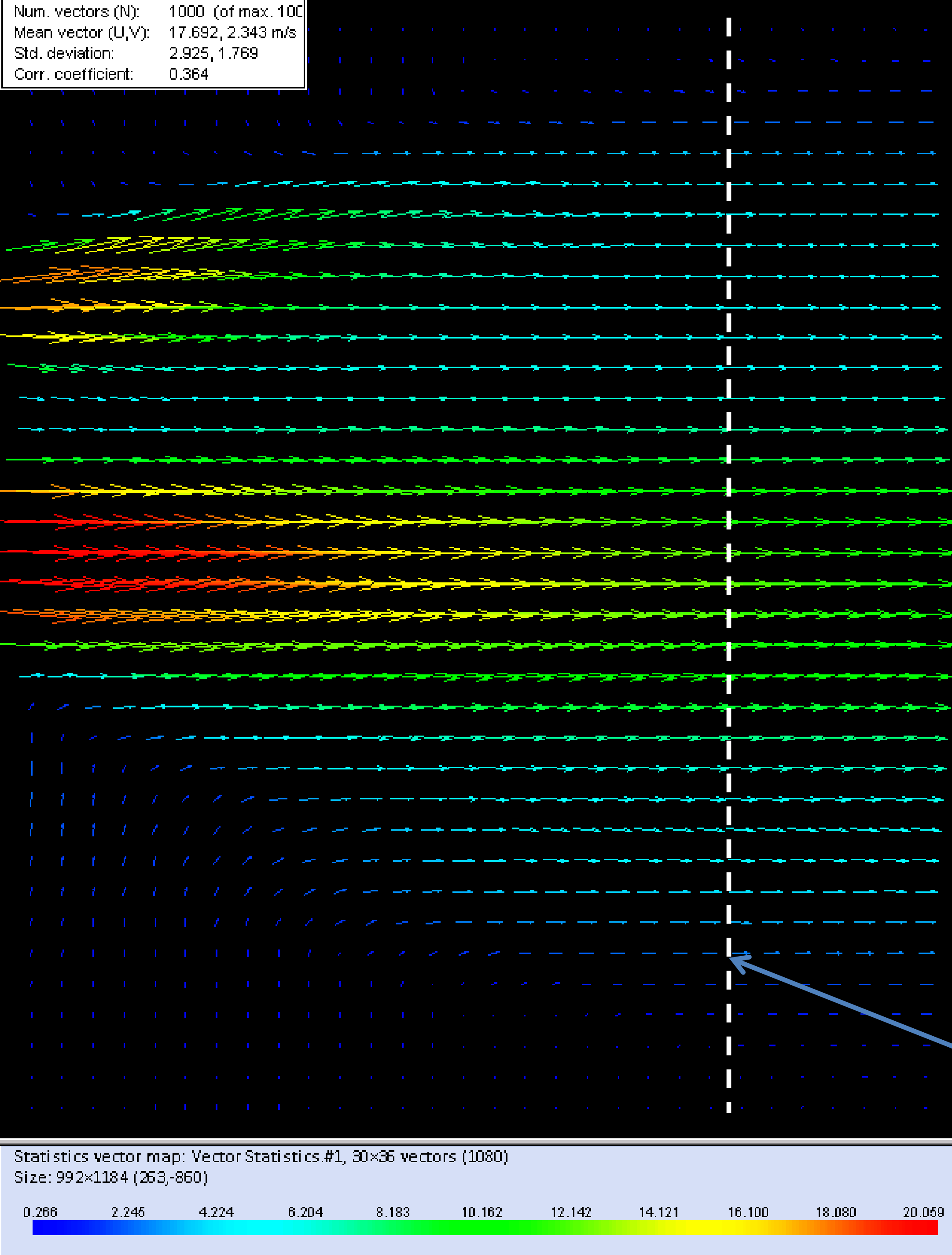


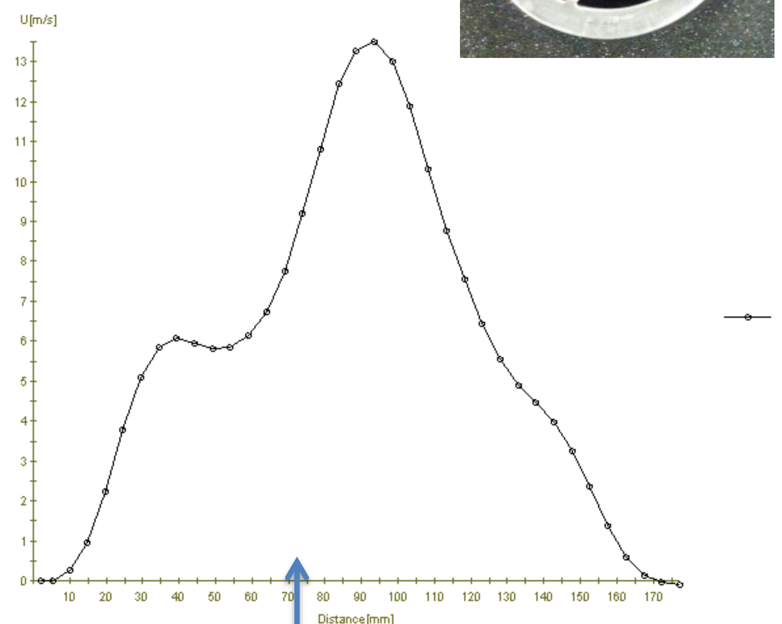


5” from turbulator exit

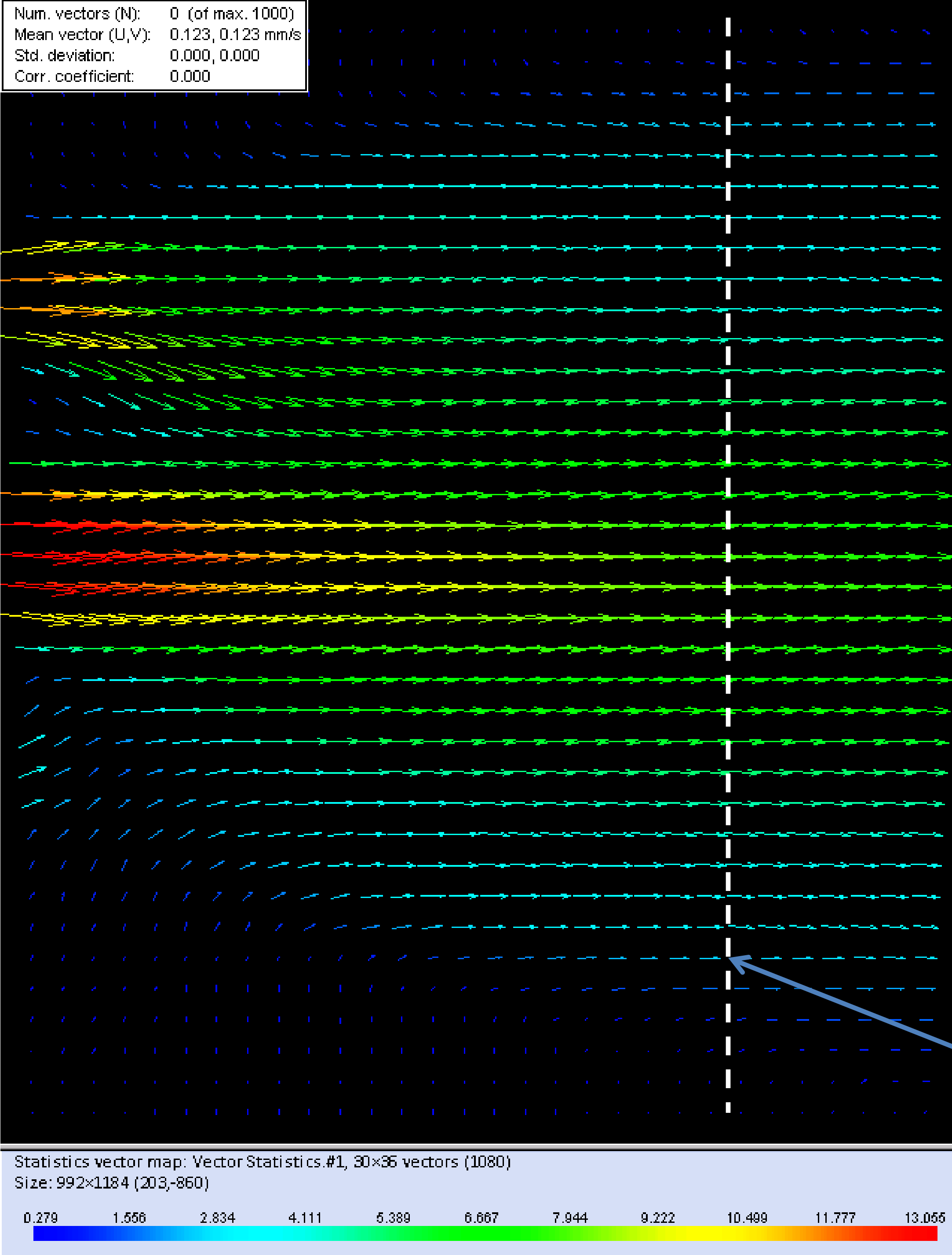
Federal Aviation Administration

F-12 Flame Retention Head
Peak U = 13.5 m/s



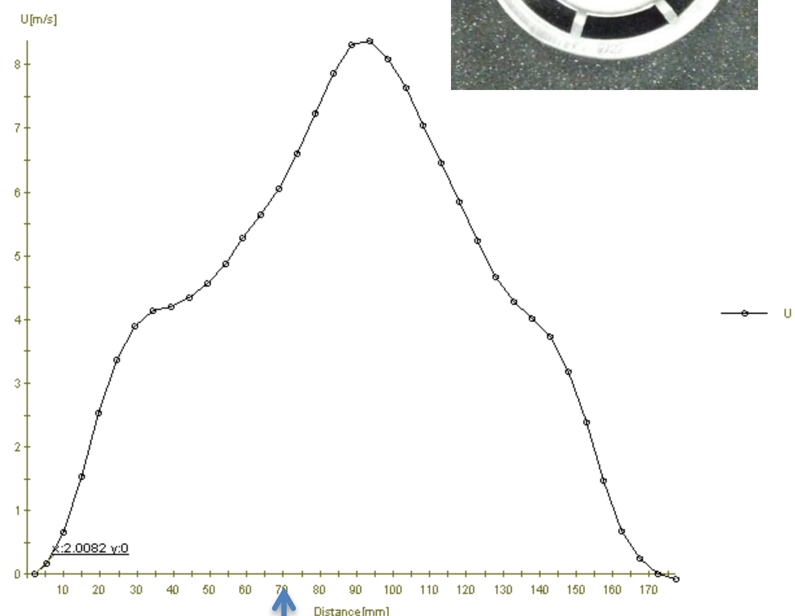


5” from turbulator exit



F-22 Flame Retention Head

Peak U = 8.4 m/s

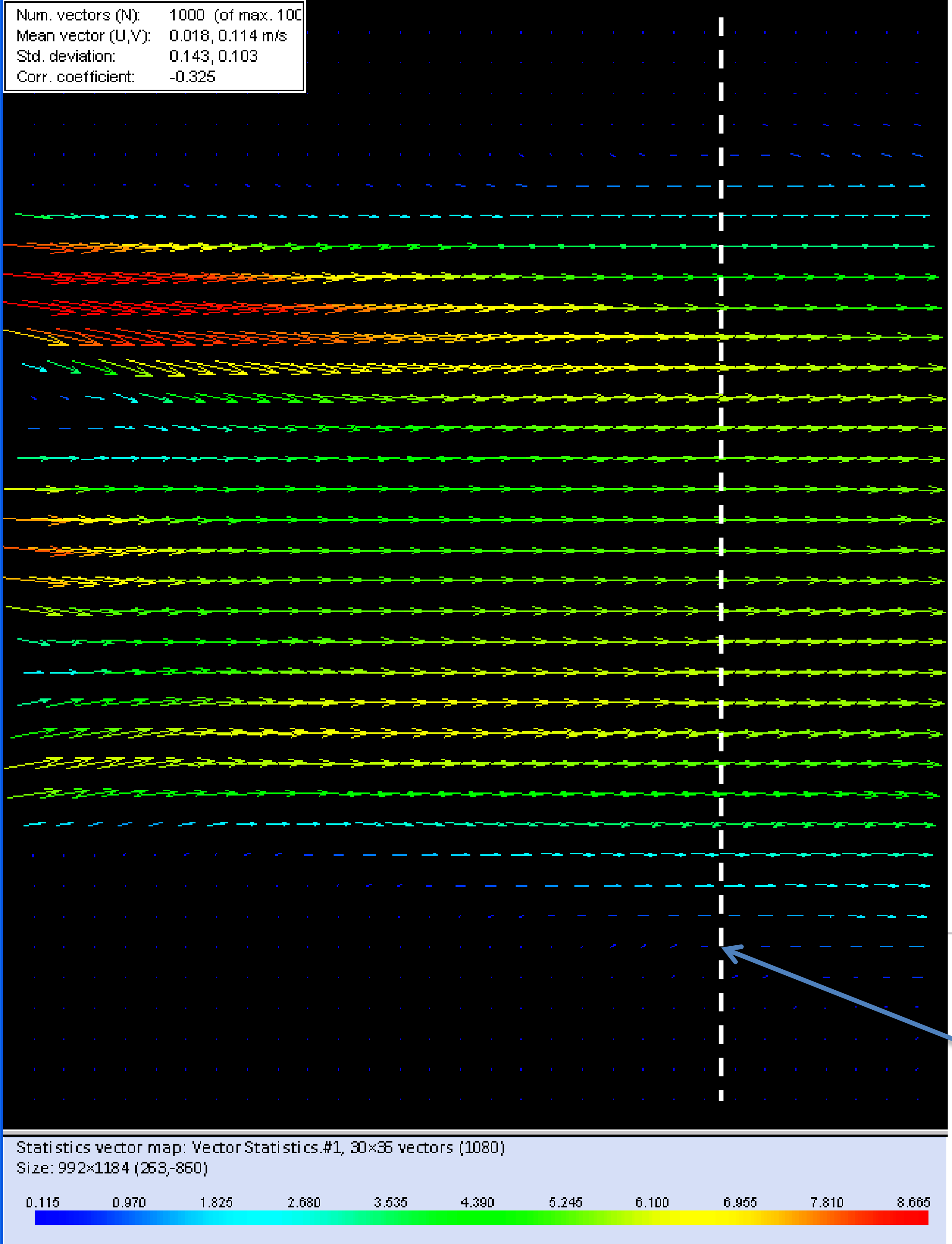


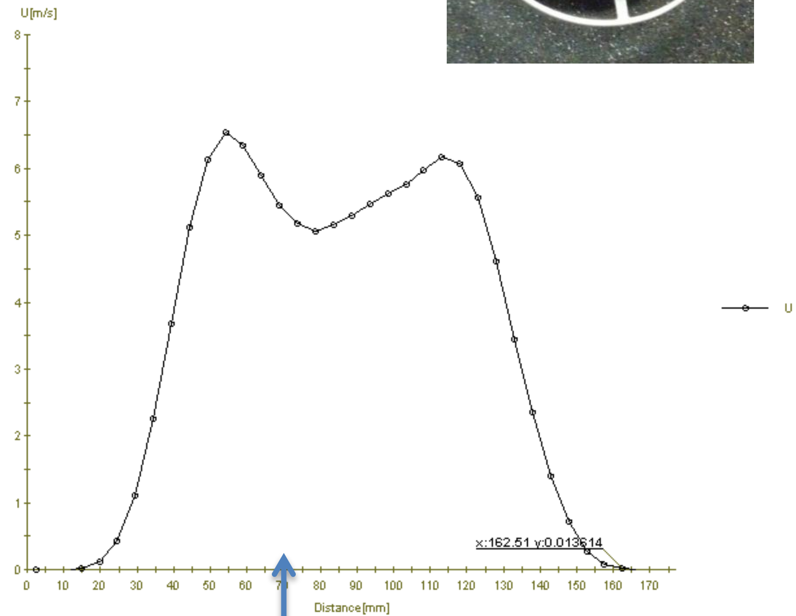
5” from turbulator exit

Federal Aviation Administration

F-31 Flame Retention Head

Peak U = 6.5 m/s

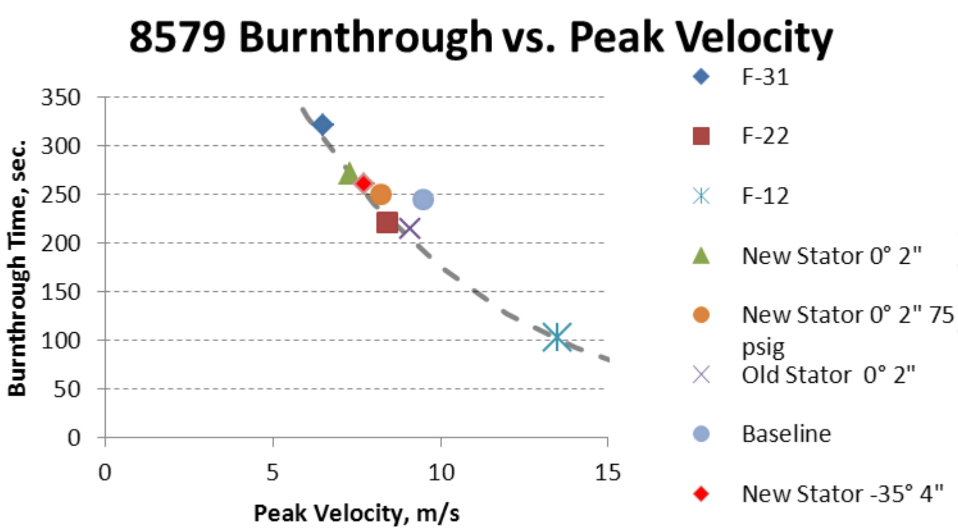


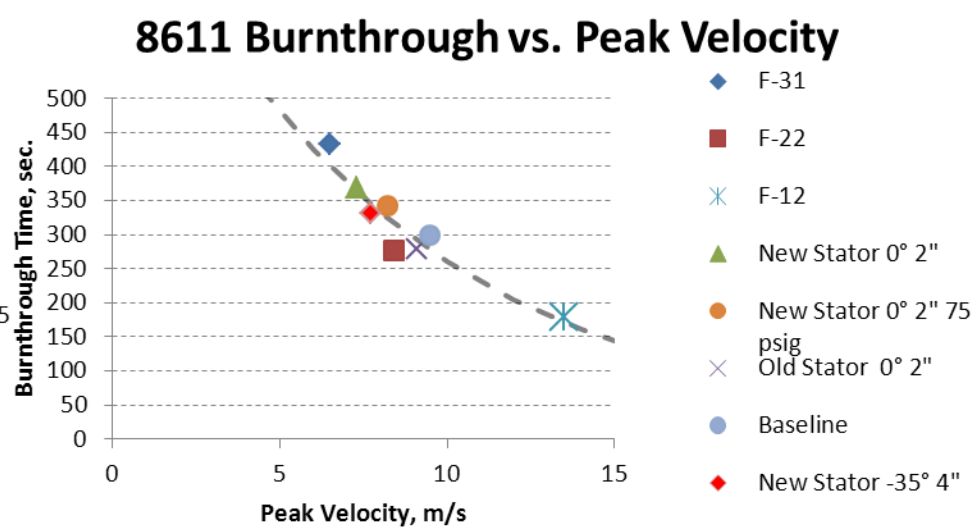


5” from turbulator exit

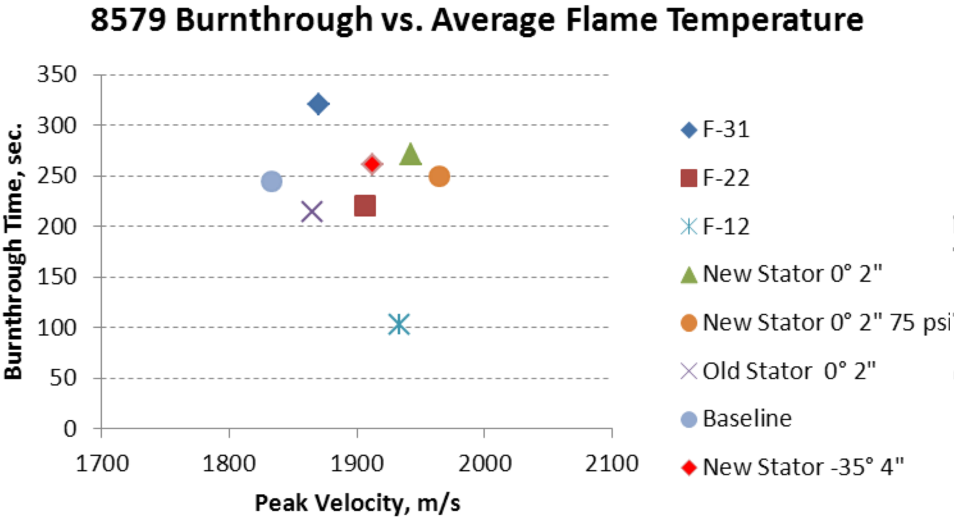
Federal Aviation Administration

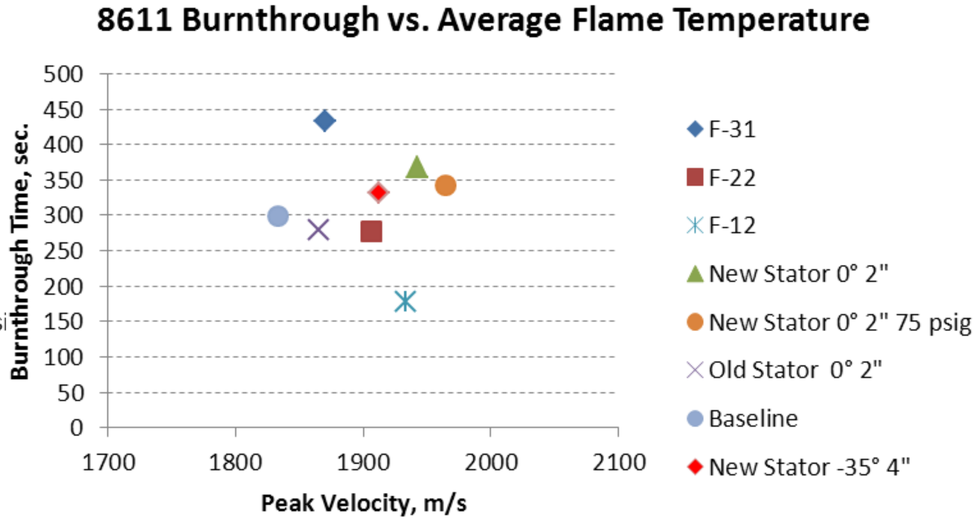
Burnthrough vs. Peak Velocity





Burnthrough vs. Average Flame Temperature



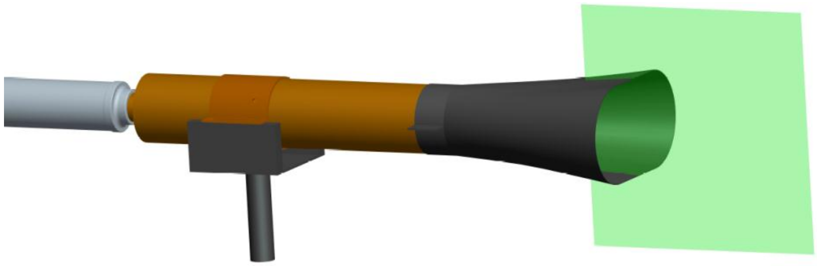


Burnthrough vs. Peak Velocity – Summary

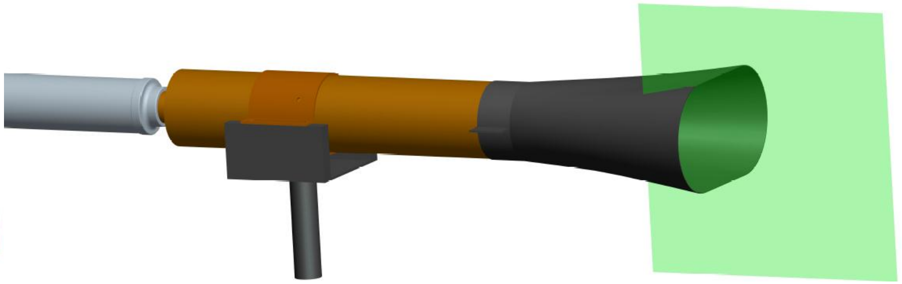
- A strong dependence between peak velocity and material burnthrough was found
  - The higher the peak velocity, the quicker the burnthrough
- Despite having the same sonic choke-controlled mass flow rate of air into the burner, the stator & turbulator or FRH can shape the velocity profile and change the burnthrough time
- No correlation was found between burnthrough time and average flame temperature

Cone Exit Flow

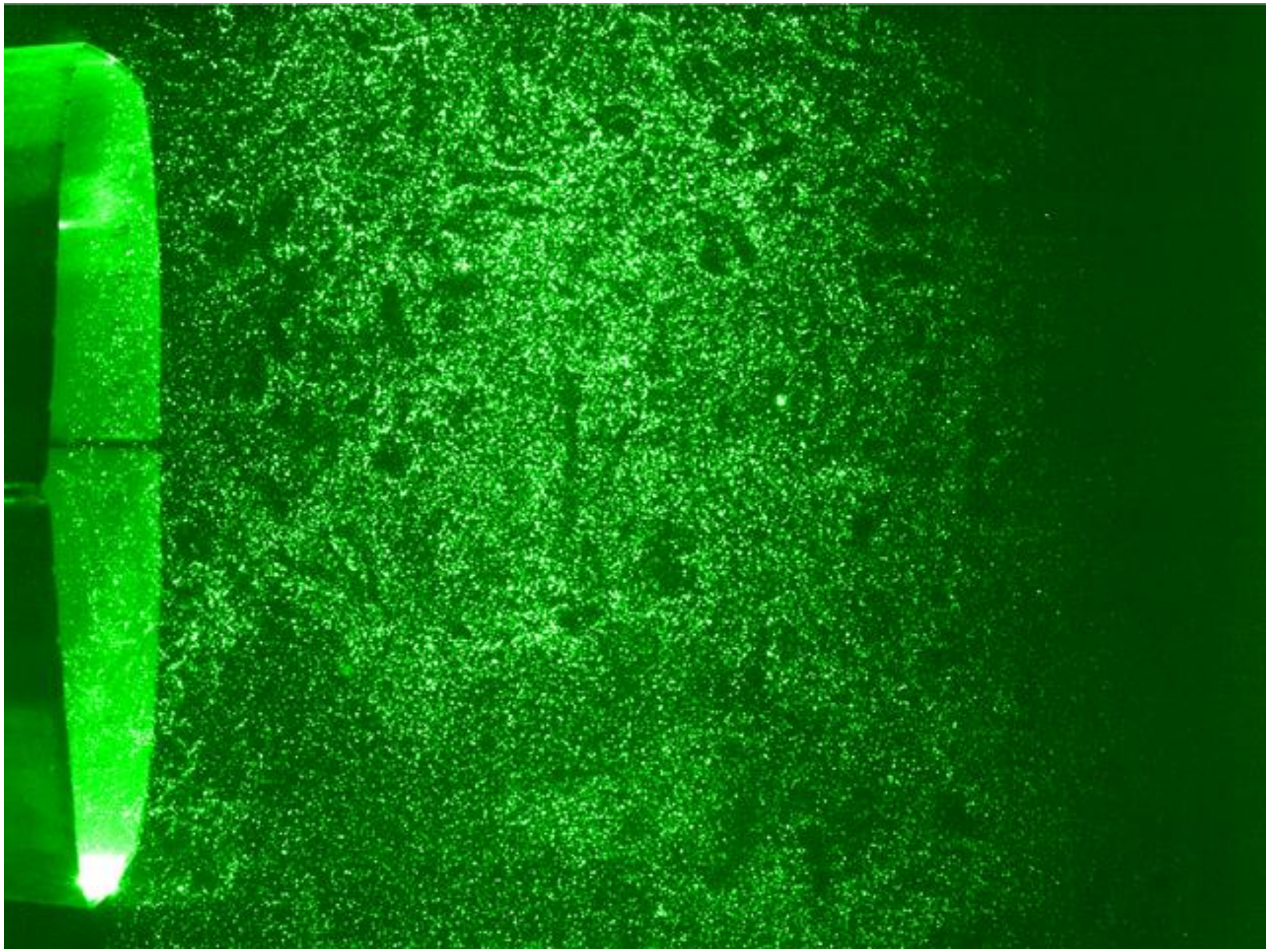
On Cone Centerline



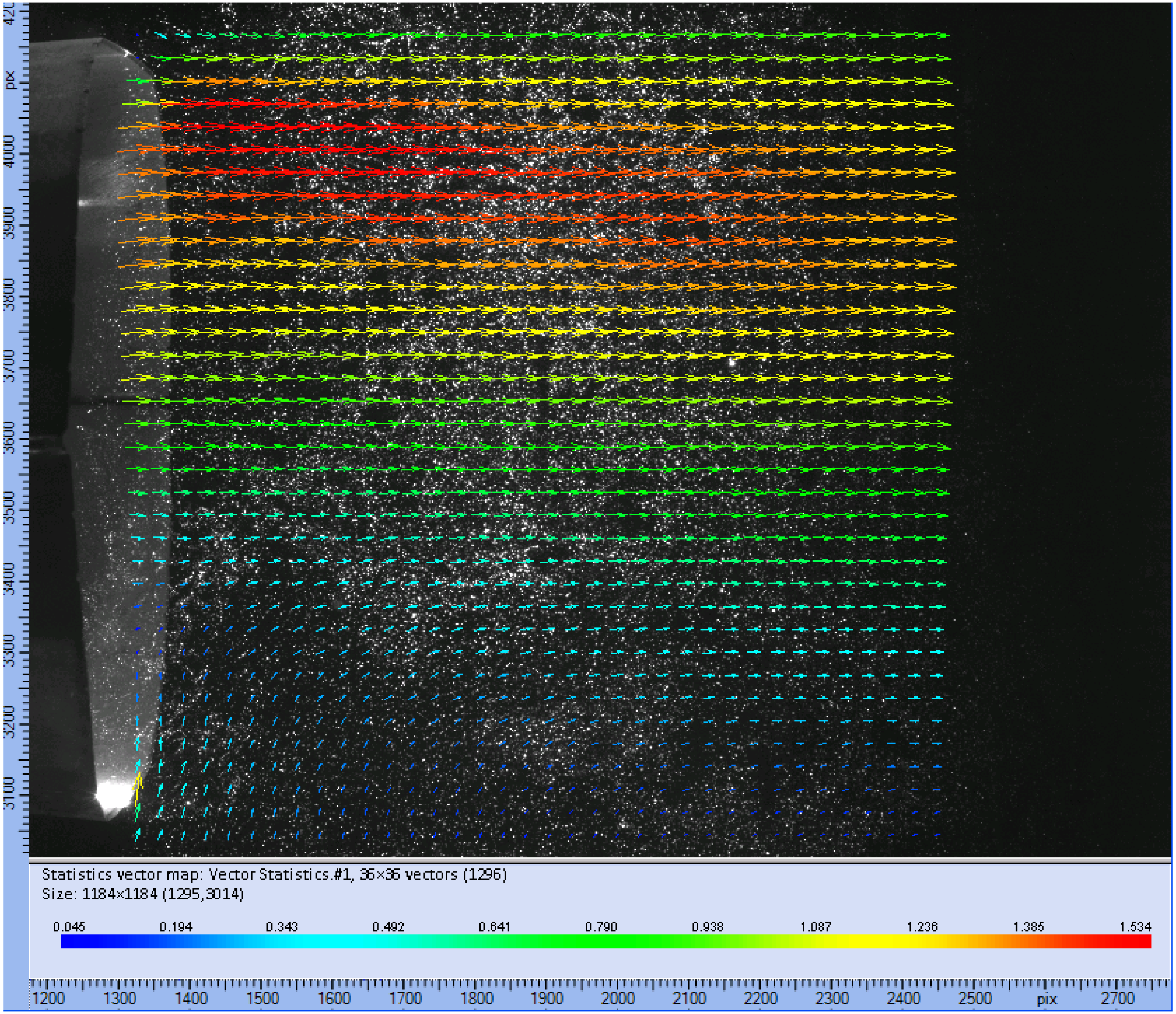
Centerline -3”



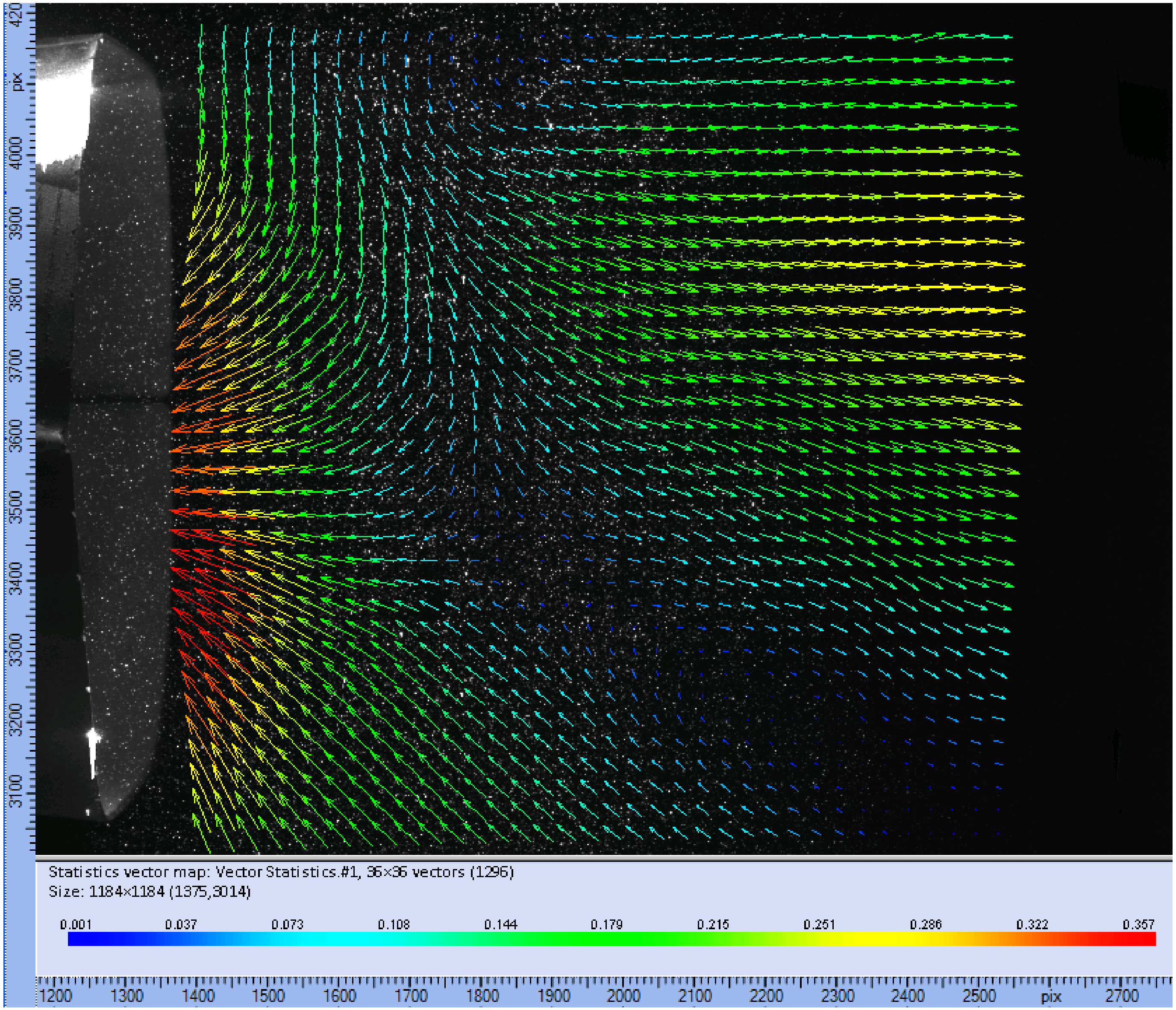
Raw PIV Data



Centerline Flow Plane (thermocouple #4)

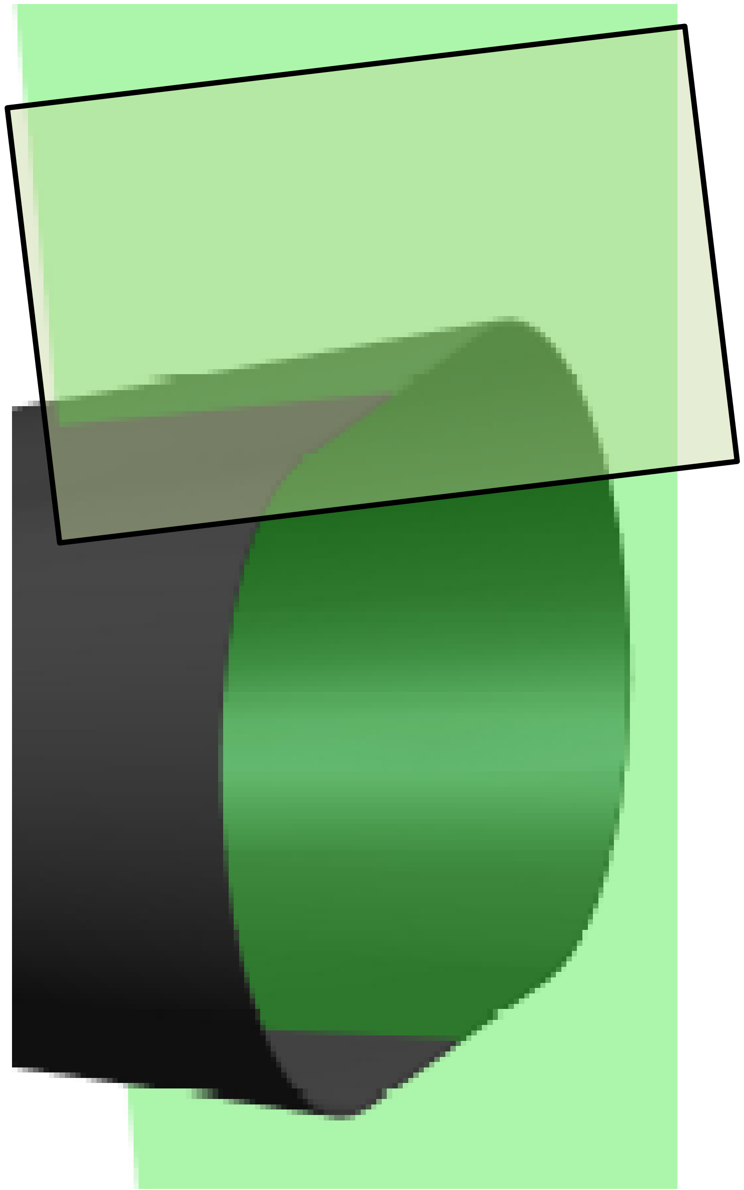


Centerline -3” Flow Plane (thermocouple #1)

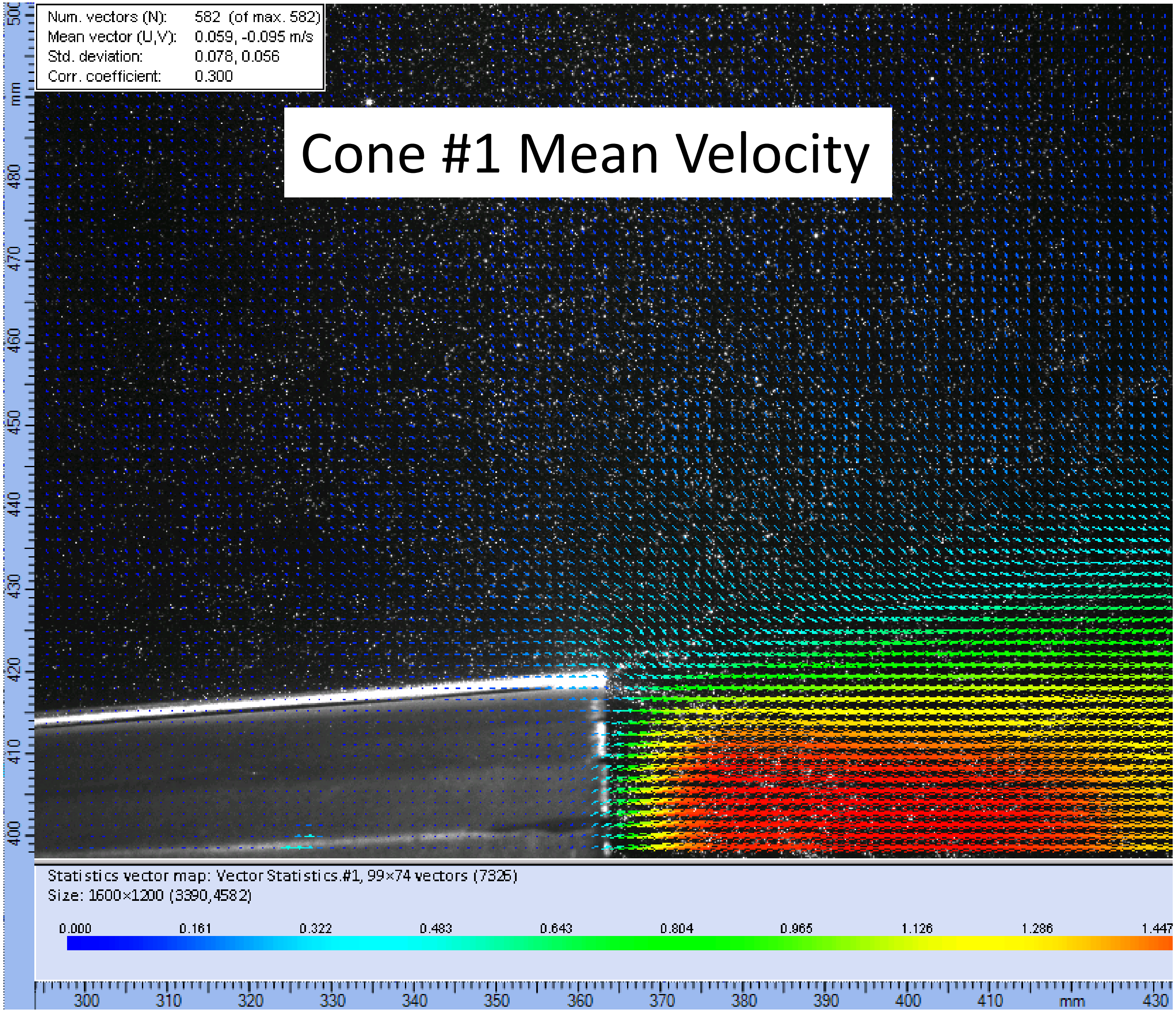


Cone Exit Flow - Summary

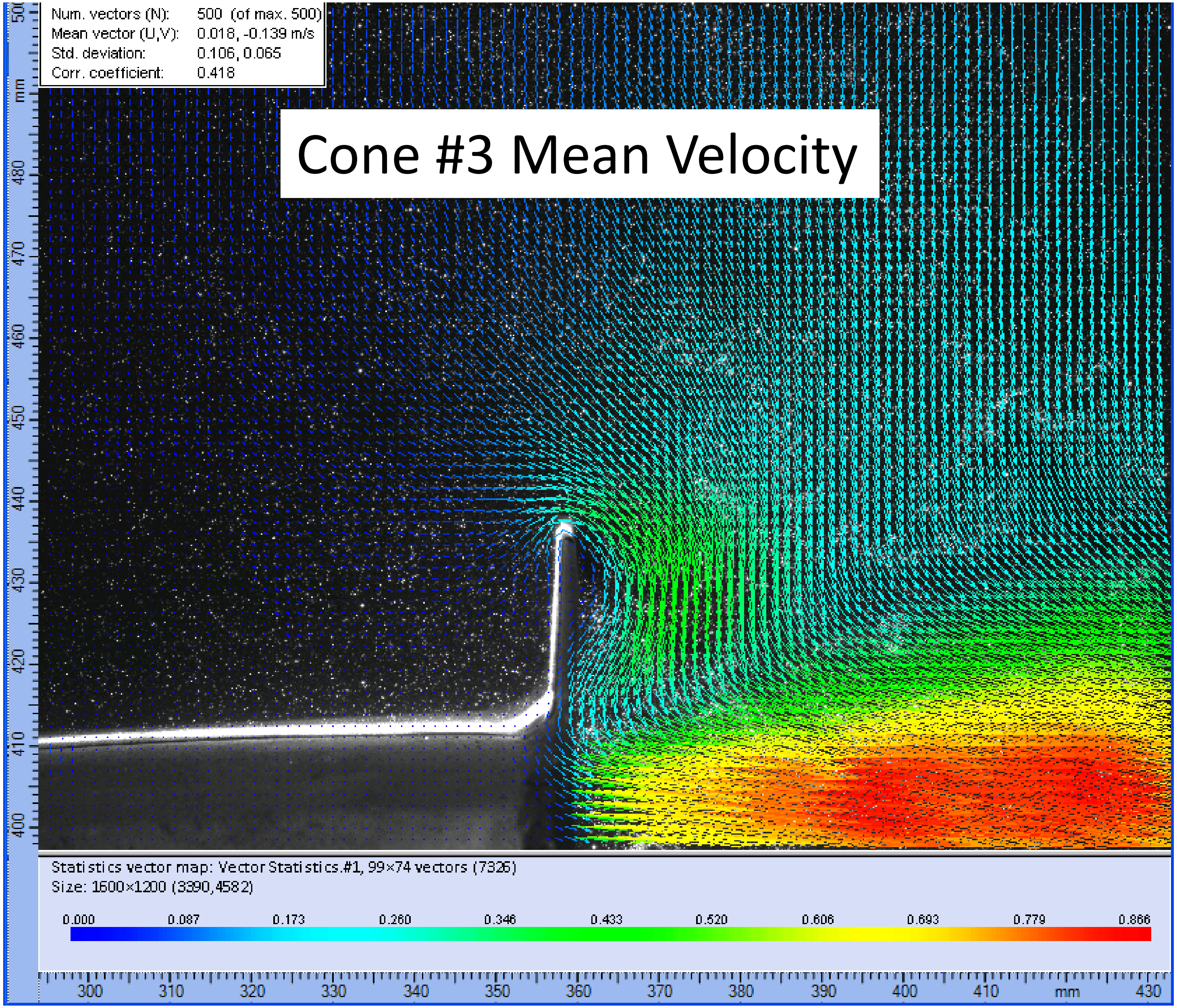
- Airflow out of the cone is not fully developed
- The flow in the plane of thermocouple #4 is drastically different than the flow in the plane of thermocouple #1
- The reverse flow and low velocity flow in the C-3" plane are the most likely cause of the soot formation on thermocouple #1



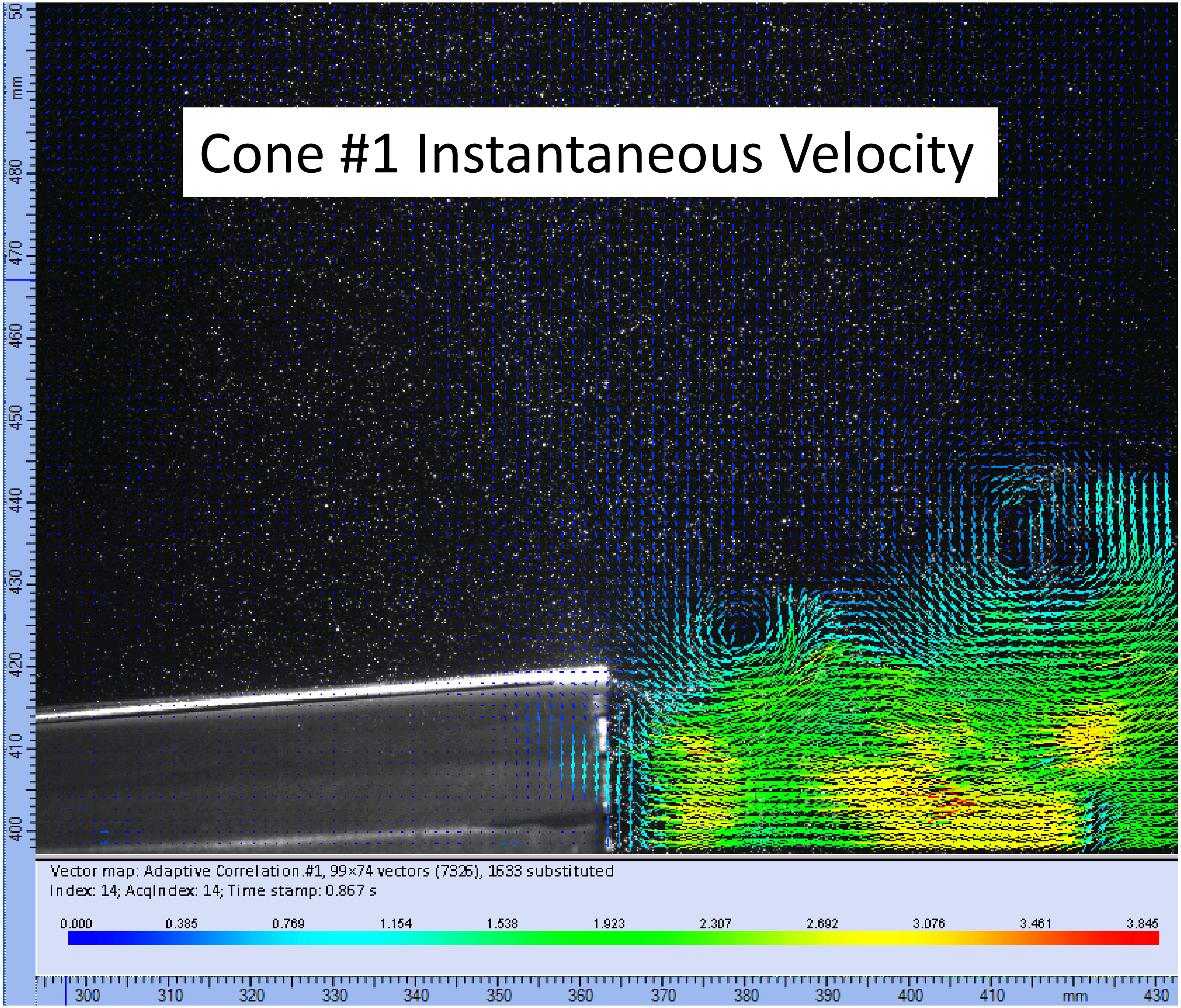
Cone #1 Mean Velocity



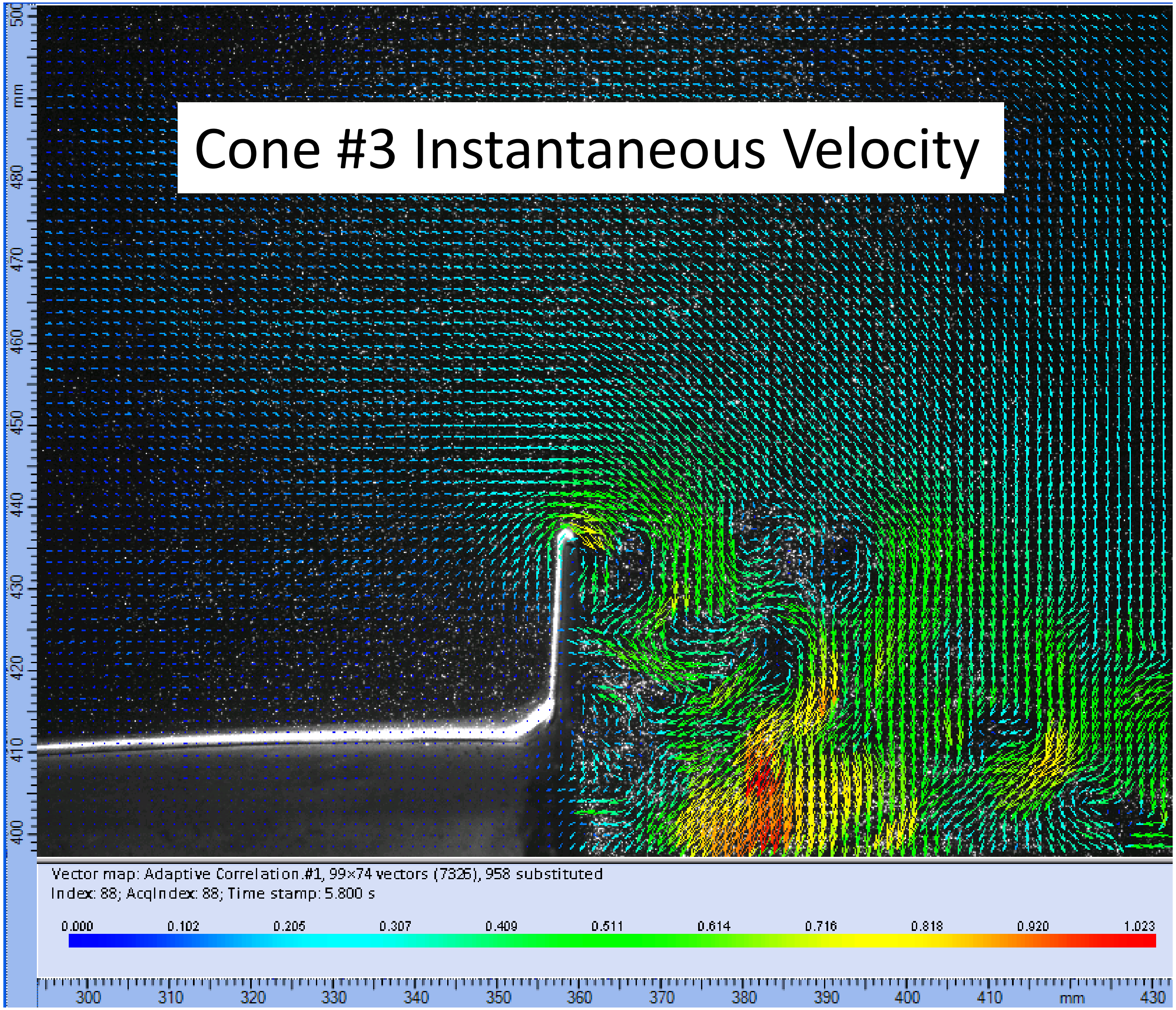
Cone #3 Mean Velocity



Cone #1 Instantaneous Velocity



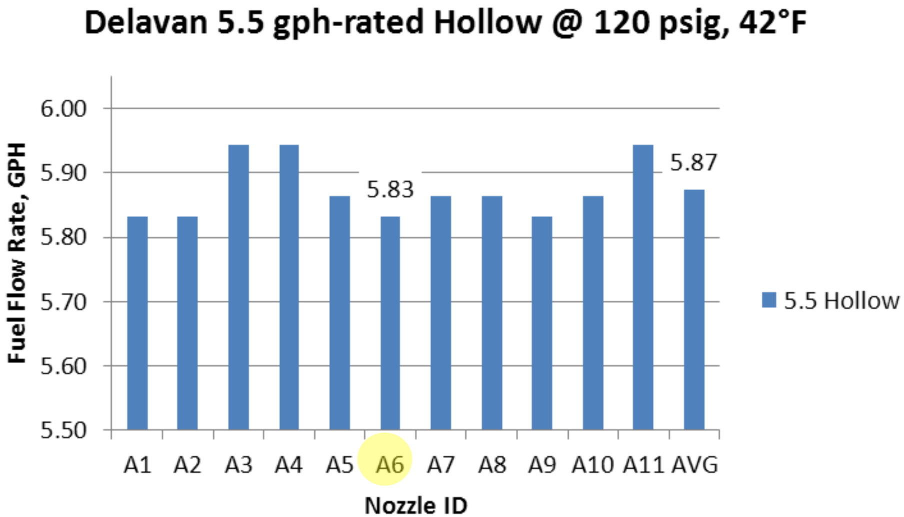
Cone #3 Instantaneous Velocity



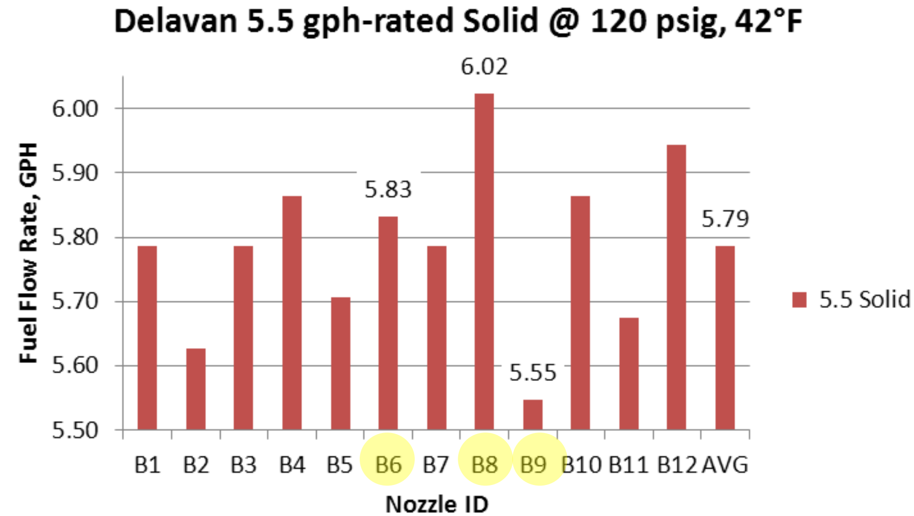
External Cone Flow - Summary

- Mean velocity field measurements
  - Normal cone draws in air from surrounding environment
  - Flange seems to interrupt the flow from the surrounding environment into the cone exit flow
- Instantaneous velocity field measurements
  - Shear flow on edge of cone exit flow causes mixing with surrounding air
  - Flange seems to create wake vortices, increasing turbulence and mixing with surrounding air
    - This increased turbulence may explain quicker burnthrough times for cone #3 – higher turbulent intensity may cause faster mechanical rupture of PAN material

Delavan 5.5 gph-rated nozzles

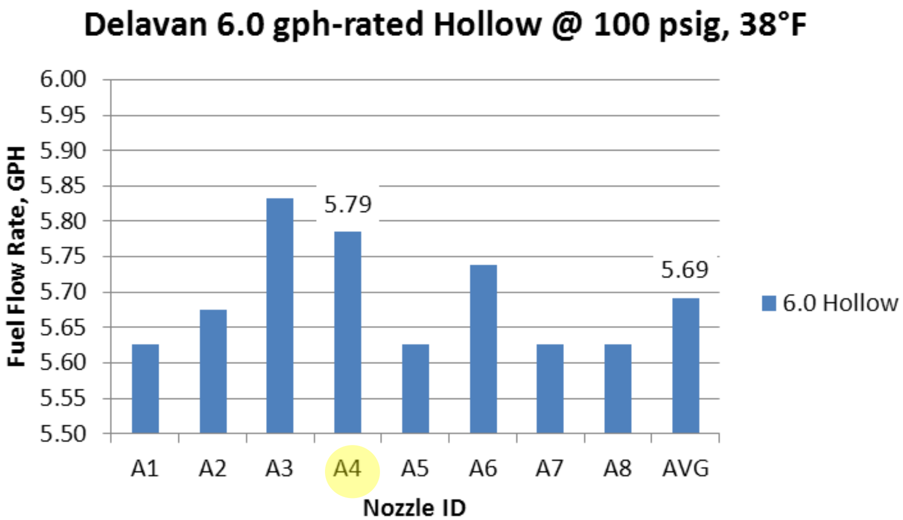


AVG	5.87
SD	0.05
%SD	0.79

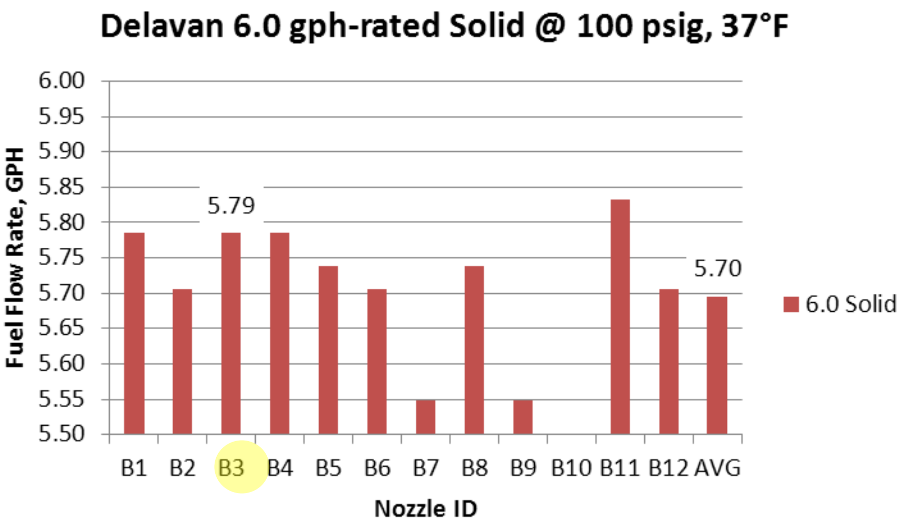


AVG	5.79
SD	0.13
%SD	2.31

- B8 vs. B9 @ 120 psig – effect of fuel flow rate
- B8 @ 120 psig vs. B9 @ 140 psig – effect of fuel pressure
- B8 @ 102 psig vs. B9 @ 120 psig – effect of fuel pressure
- B6 vs. A6 @ 120 psig – effect of spray pattern



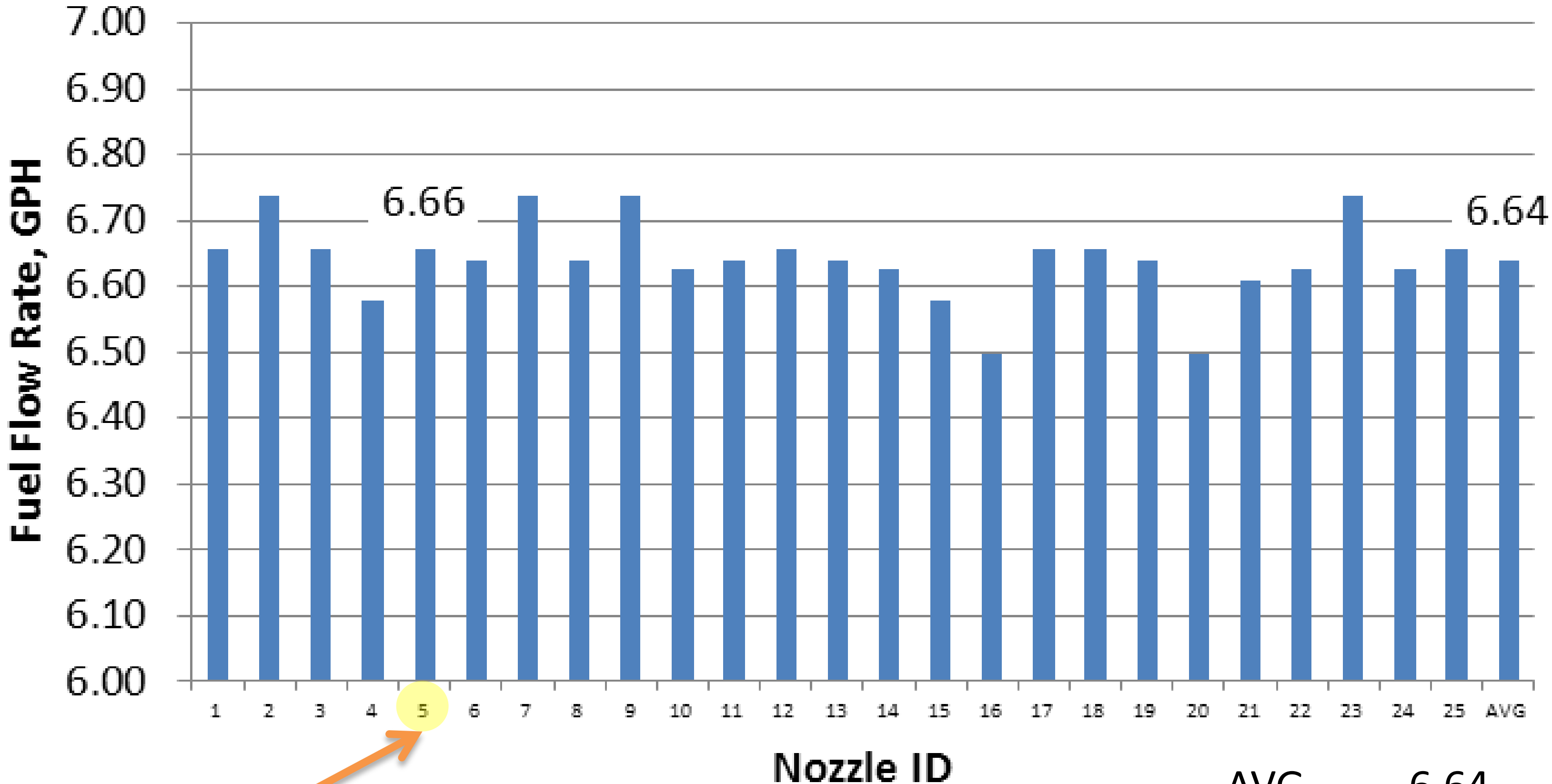
AVG	5.69
SD	0.08
%SD	1.36



AVG	5.70
SD	0.11
%SD	2.00

- B3 vs. A4 @ 108 psig, effect of spray pattern
- 5.5 B8 @ 120 psig vs. 6.0 B3 @ 108 psig, effect of nozzle rating

Everloy 6.0 gph-rated Hollow @ 100 psig, 50°F

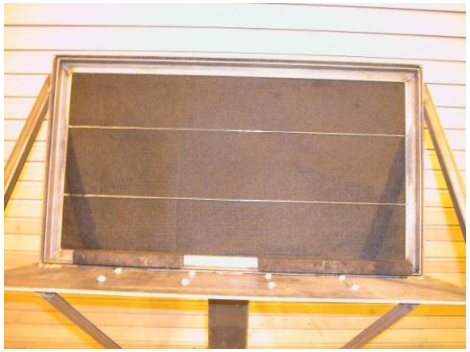


Reduced pressure to 85 psig,
obtained 380 mL/min = 6.02 gph

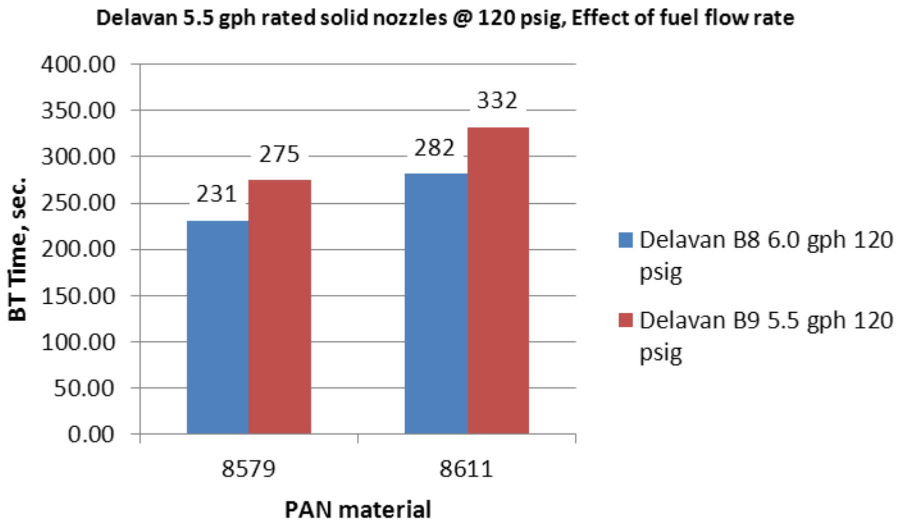
AVG	6.64
SD	0.06
%SD	0.92

Comparative BT Testing

- PAN material BT tests used for comparison
  - 8579 9 oz/yd^2
  - 8611 16 oz/yd^2
- Each material was tested 4 times for each configuration

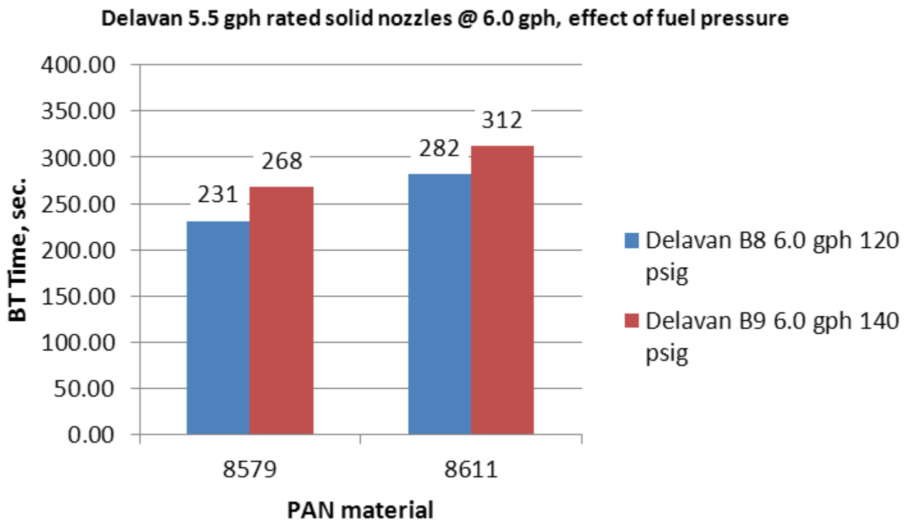



5.5 gph rated B8 vs. B9 @ 120 psig – effect of fuel flow rate



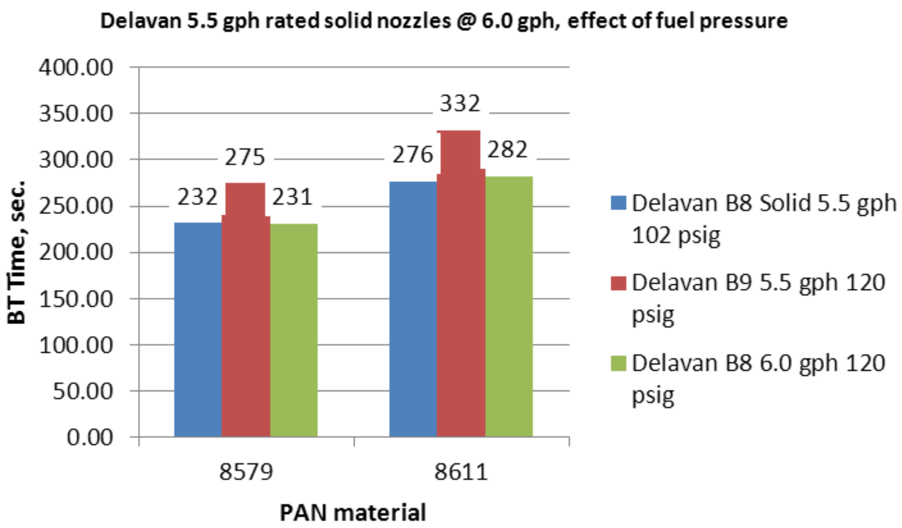
- Both nozzles are 5.5 gph rated @ 100 psig
- When applied with 120 psig, B8 flows 6.0 gph while B9 flows 5.5 gph
- The nozzle that flows the higher flow rate has the faster BT time on both materials
- Suggests that fuel flow rate has an effect on BT time

5.5 gph rated B8 @ 120 psig vs. B9 @ 140 psig – effect of fuel pressure



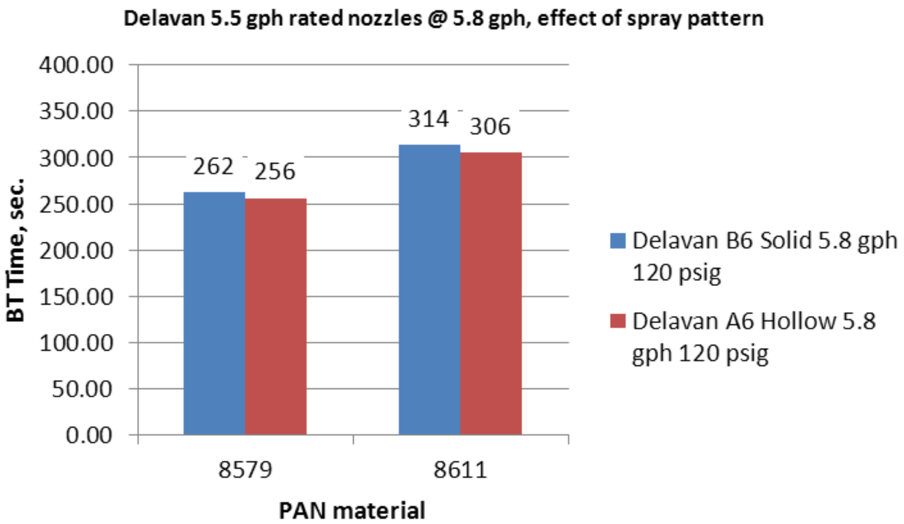
- Both nozzles are flowing 6.0 gph
- B8 requires 120 psig for 6.0 while B9 requires 140 psig
- Despite achieving the same flow rate (6.0 gph), nozzle B9 still does not burn through in the same time as B8 at 6.0 gph
- This suggests that if a nozzle does not achieve it's rated flow rate, it does not suffice to increase the pressure to achieve the desired fuel flow rate

5.5 gph rated B8 @ 102 psig vs. B9 @ 120 psig 5.5 gph – effect of fuel pressure



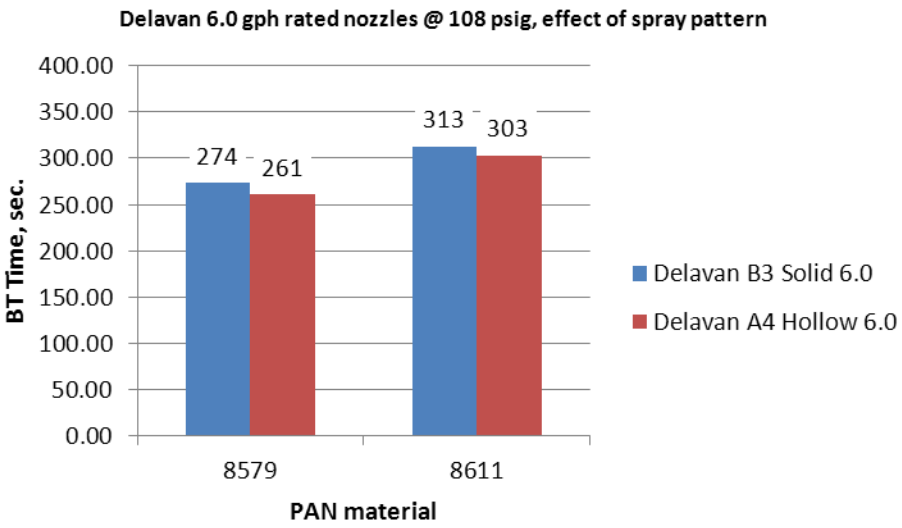
- Both nozzles are flowing 5.5 gph
- B8 requires 102 psig for 5.5 gph while B9 requires 120 psig
- Despite achieving the same flow rate (5.5 gph), nozzle B9 still does not burn through in the same time as B8 at 5.5 gph
- When comparing B8 @ 120 psig (6.0 gph) and @ 102 psig (5.5 gph), there is little difference in BT time
- Suggests that something else may be causing B8 to have this BT time

5.5 gph rated B6 vs. A6 @ 120 psig – effect of spray pattern



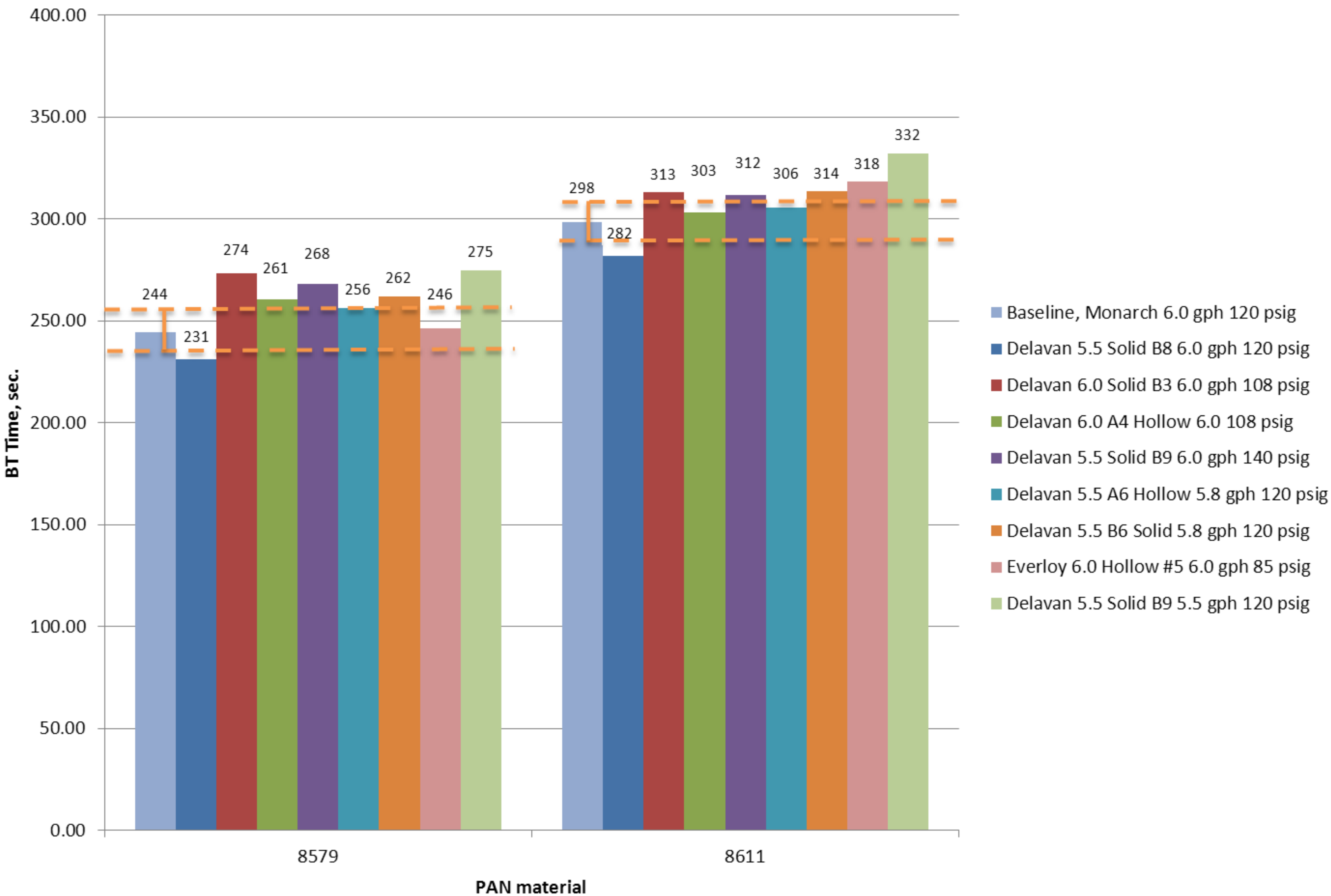
- Both nozzles are flowing 5.8 gph
- Both nozzles have similar BT times for both materials
- Suggests that spray pattern has little effect on BT time

6.0 gph rated B3 vs. A4 @ 108 psig, effect of spray pattern



- Both nozzles are flowing 6.0 gph
- Both nozzles have similar BT times for both materials
- Suggests that spray pattern has little effect on BT time
  - Nozzle to nozzle differences may be the cause of the discrepancy

All Nozzles compared to Monarch 5.5 gph 80 Hollow Baseline

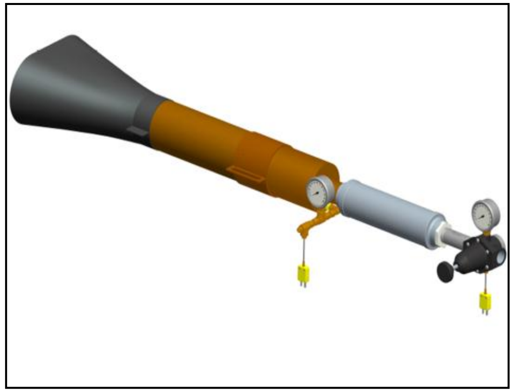


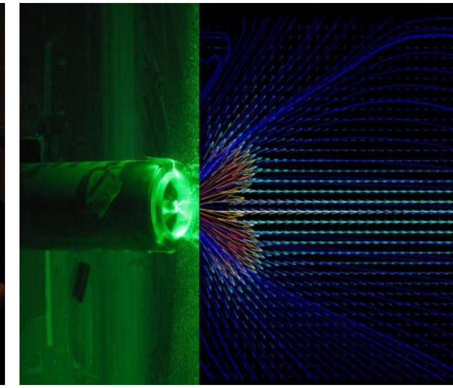
Summary – Nozzle Comparison

- The spray nozzles tested compare reasonably well with baseline Monarch nozzle
  - Some are within 1 standard deviation, the rest are within 2 standard deviations of baseline
- Nozzles that flow 5.8 gph @ 120 psig compare well with those that flow 6.0 gph
  - Further evidence for the 6.0 ± 0.2 gph tolerance
  - The nozzle that flows 5.5 gph @ 120 psig does not compare with the rest
- Specification of fuel flow rate is not adequate for describing fuel spray
  - Fuel pressure and nozzle rating should be specified, as well as spray type should be specified
  - Other factors that were not measured in this test series may have an impact on test results
    - Spray asymmetry
    - Droplet size

Next Steps

- Continue nozzle evaluation
  - Other Everloy nozzles
- Define settings for FRH F-22 that are equivalent to current NexGen settings
- Develop “optimal” burner settings
  - FRH
  - Nozzle
  - Cone
- Establish baseline for all BT labs
  - Have an abundance of PAN material for picture frame testing
  - Labs with NexGen or Park and picture frame blanket holder that want to participate will be provided material for data generation



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