Improving Shale Oil Crude Heater Performance

Furnace Improvements

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Shale Crudes

- Most of the US refiners are now processing Shale Crudes increasingly
- These are ultra light crudes with high API and low Sulfur
- In reality, pose significant challenges
  - High paraffin content
  - Asphaltene destabilization when mixed with other crudes
  - Filterable solids

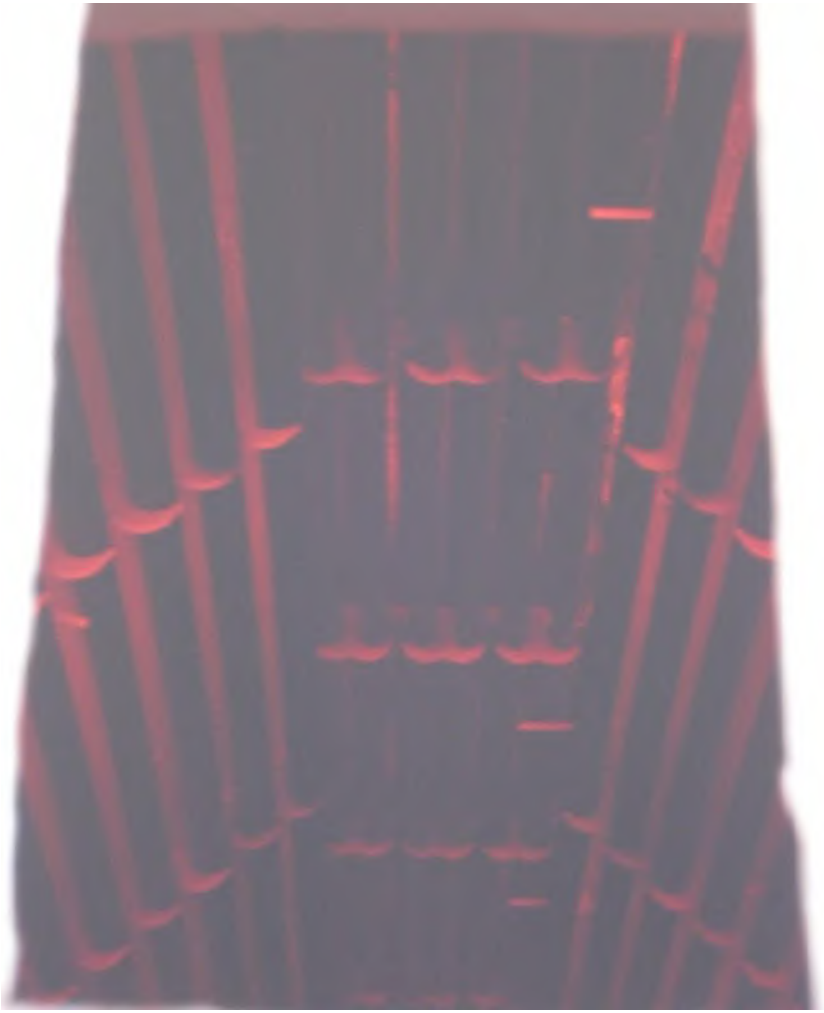
Issues

- One of our Client started processing shale crude in the heater
- Heater run length came down from 5 years to 3 months
- Client started injecting antifoulant in the heater with limited success+
- Antifoulant injection was costing millions of dollar per year
- Client was limited on the outlet temperature could not go up more than 580 °F (304 °C) (design 720 °F (382 °C))

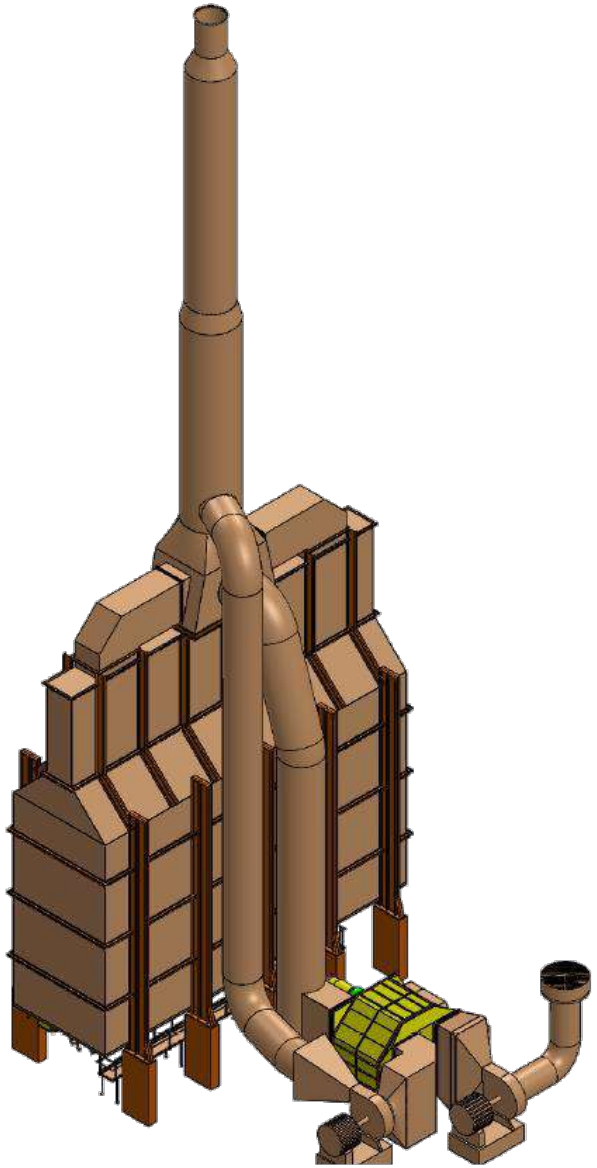
Crude Heater

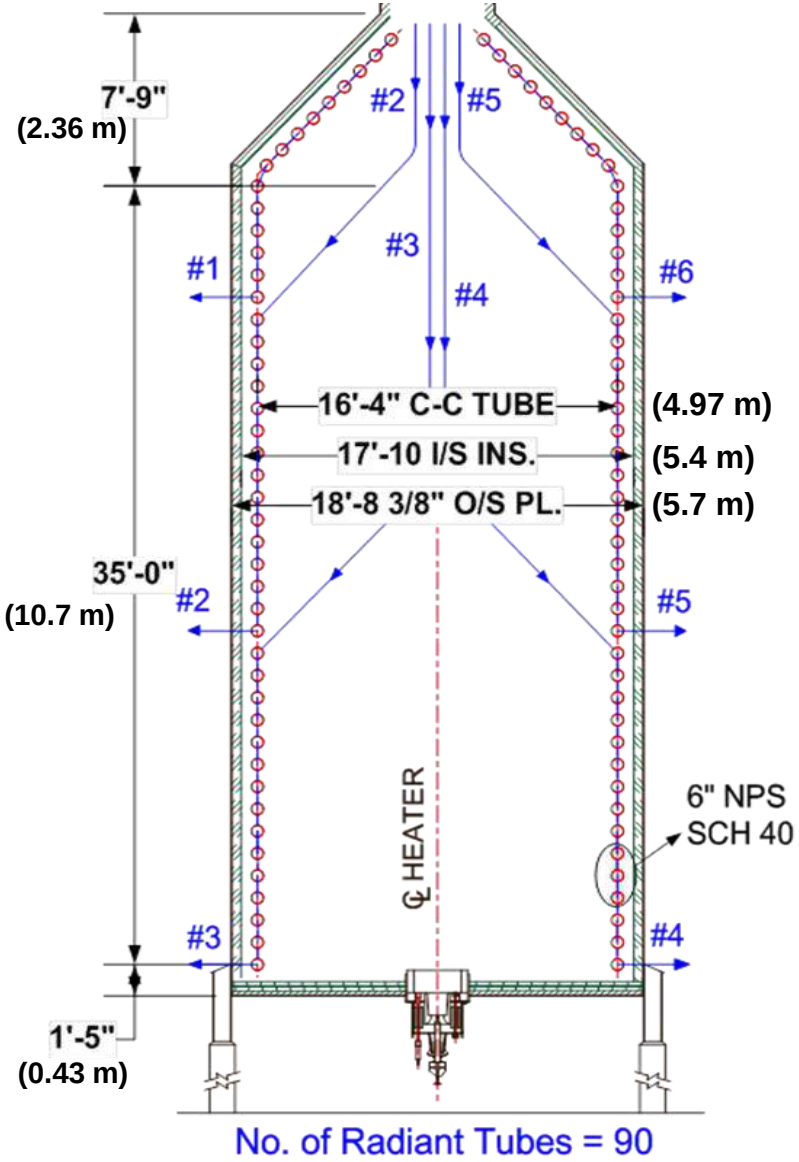
Cabin Type Heater

- Horizontal Tube Radiant & Convection Section
- Gas Fired Low NOx Burners
- Heater Duty = 155.7 MM Btu/hr (45.63 MW)
- Charge Flow rate = 50,376 BPD (8,009 m3/day)
- Temperature (Inlet/Outlet) = 427 / 720 °F (219/ 382 °C)
- Pressure (Inlet/Outlet) = 95 / 35 psig (655 / 241.3 KPa)
- Avg. Flux Density = 12,000 Btu/hr-ft^2 (37,855 W/m^2)
- Floor Heat Flux = 190,164 Btu/hr-ft^2 (599,890 W/m^2)



Existing Heater and Radiant Section



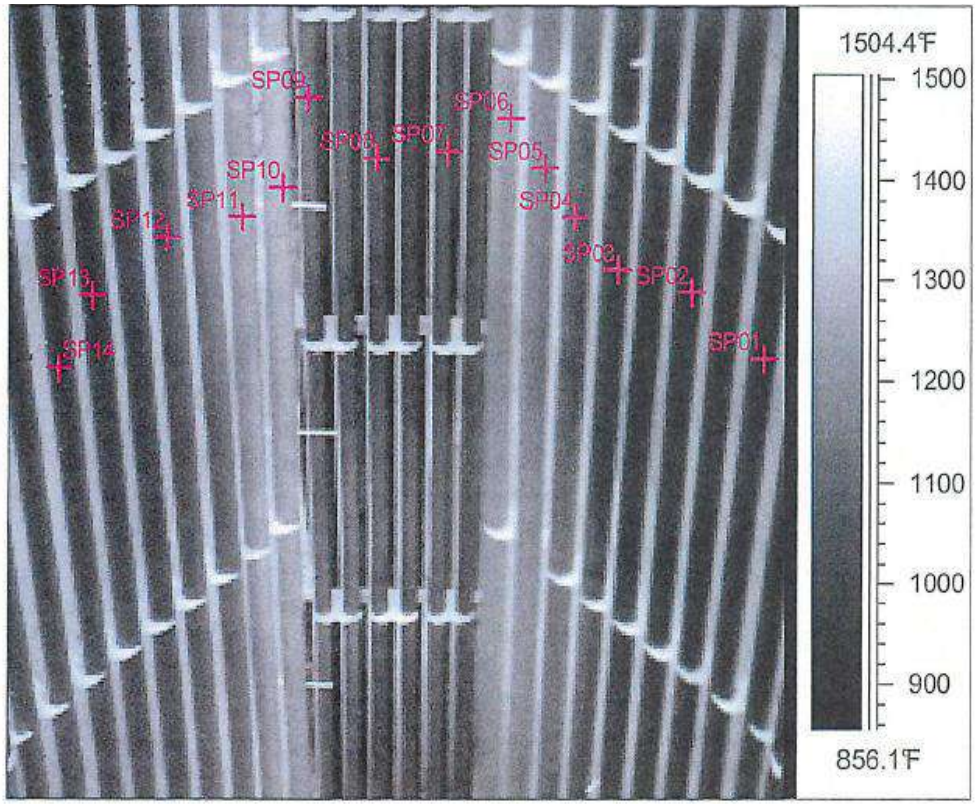


Objective

- Reduce coking rate in the Crude Heater

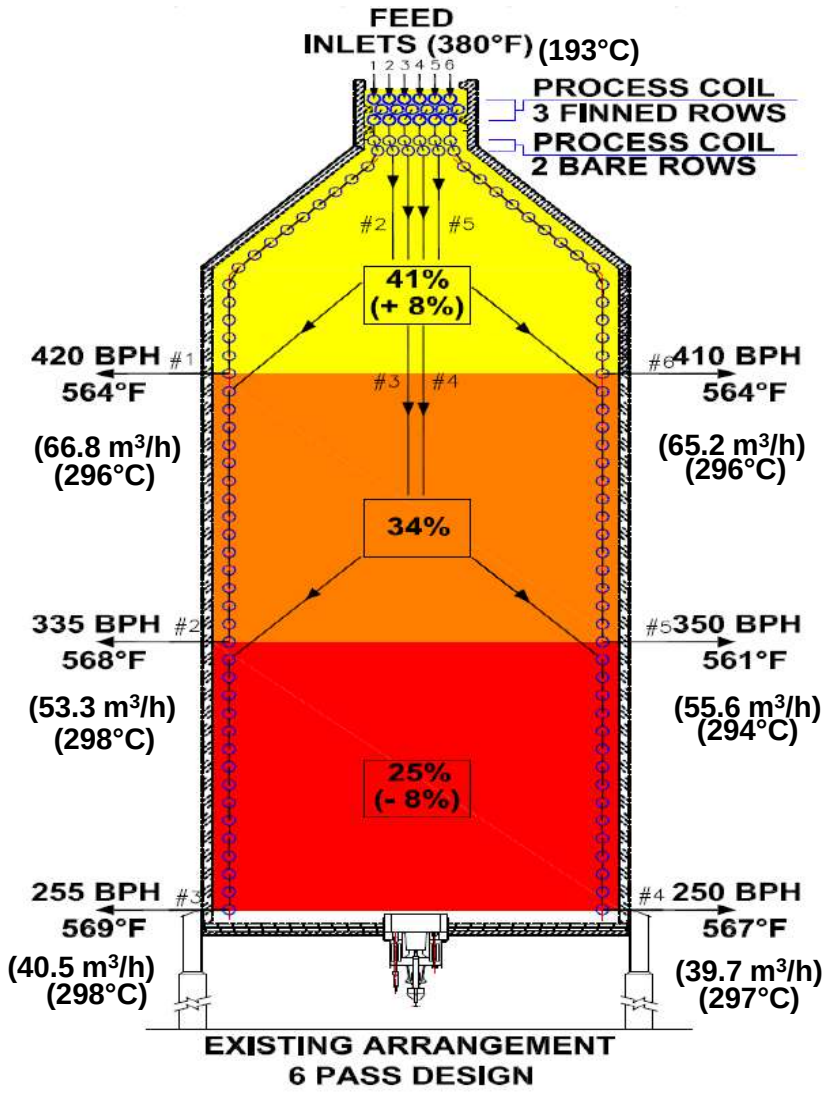
Area of Heater: Roof

Tube Location: South End Roof Tubes



Heat Distribution Pattern

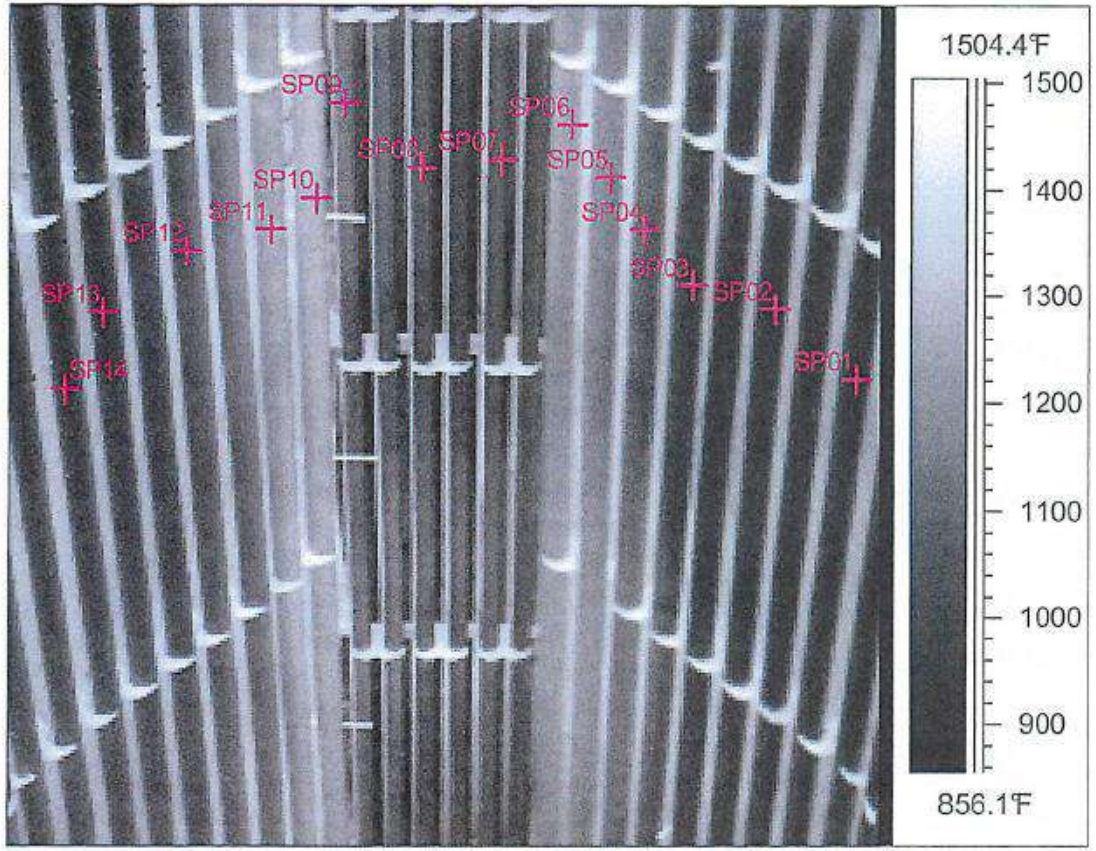
- Top portion was receiving maximum heat
- Heat distribution was not uniform
- Pass imbalance



Tube Temperatures

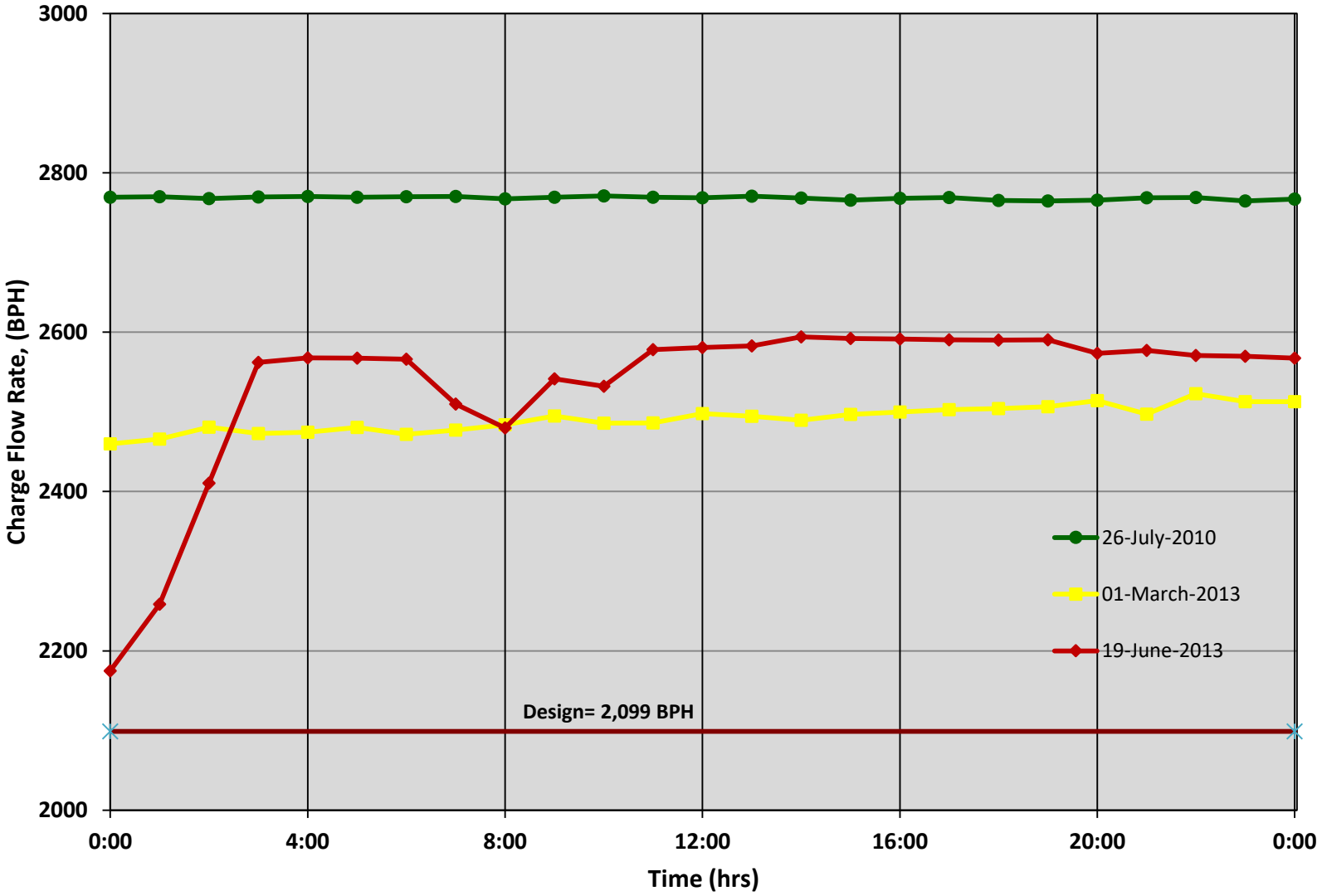
Area of Heater: Roof

Tube Location: South End Roof Tubes

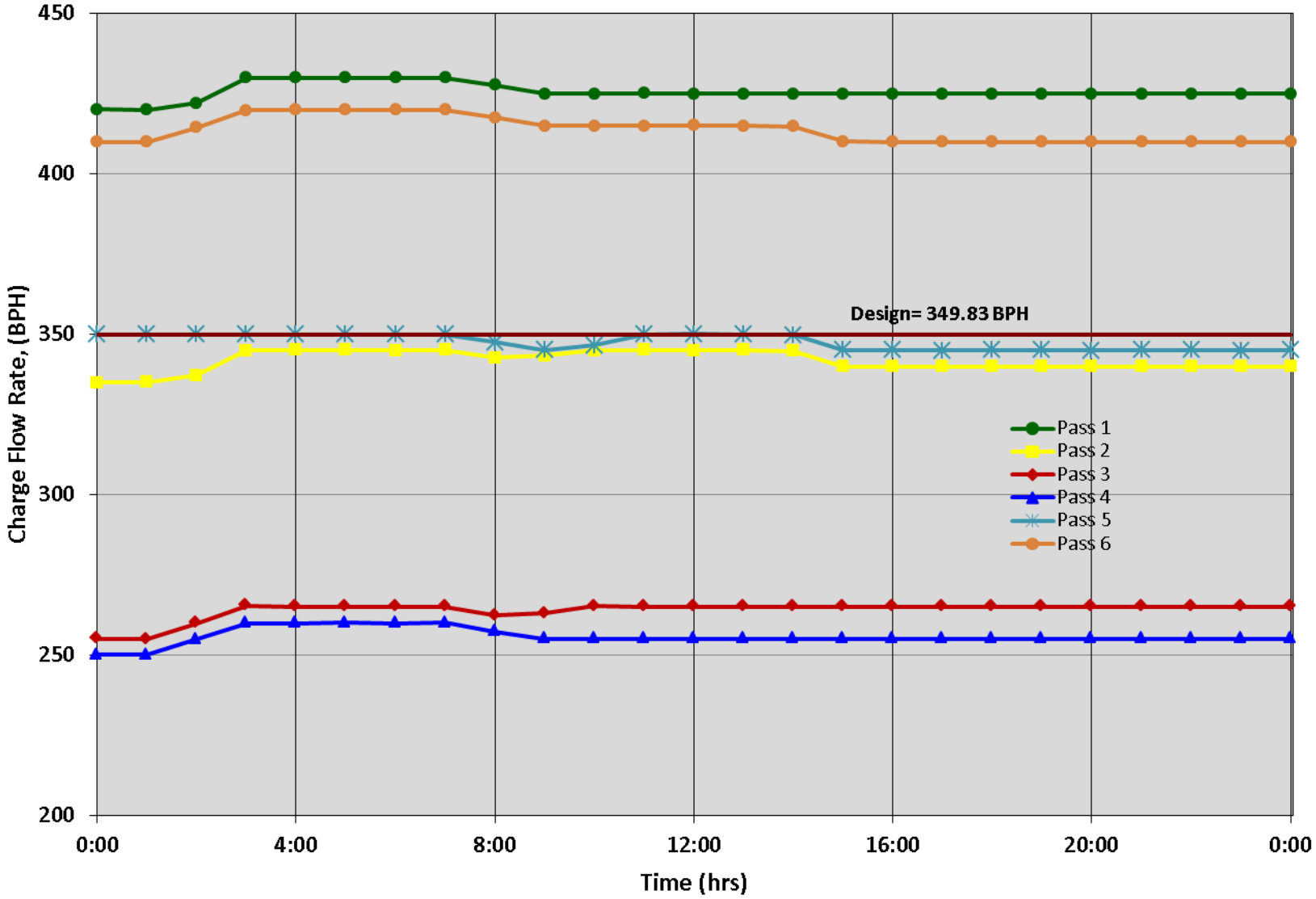


IR Information	Value
SP04	1103.4°F
SP05	1169.7°F
SP06	1232.6°F
SP07	1045.9°F
SP08	1070.9°F
SP09	1168.3°F
SP10	1267.7°F
SP11	1257.2°F
SP12	1039.6°F

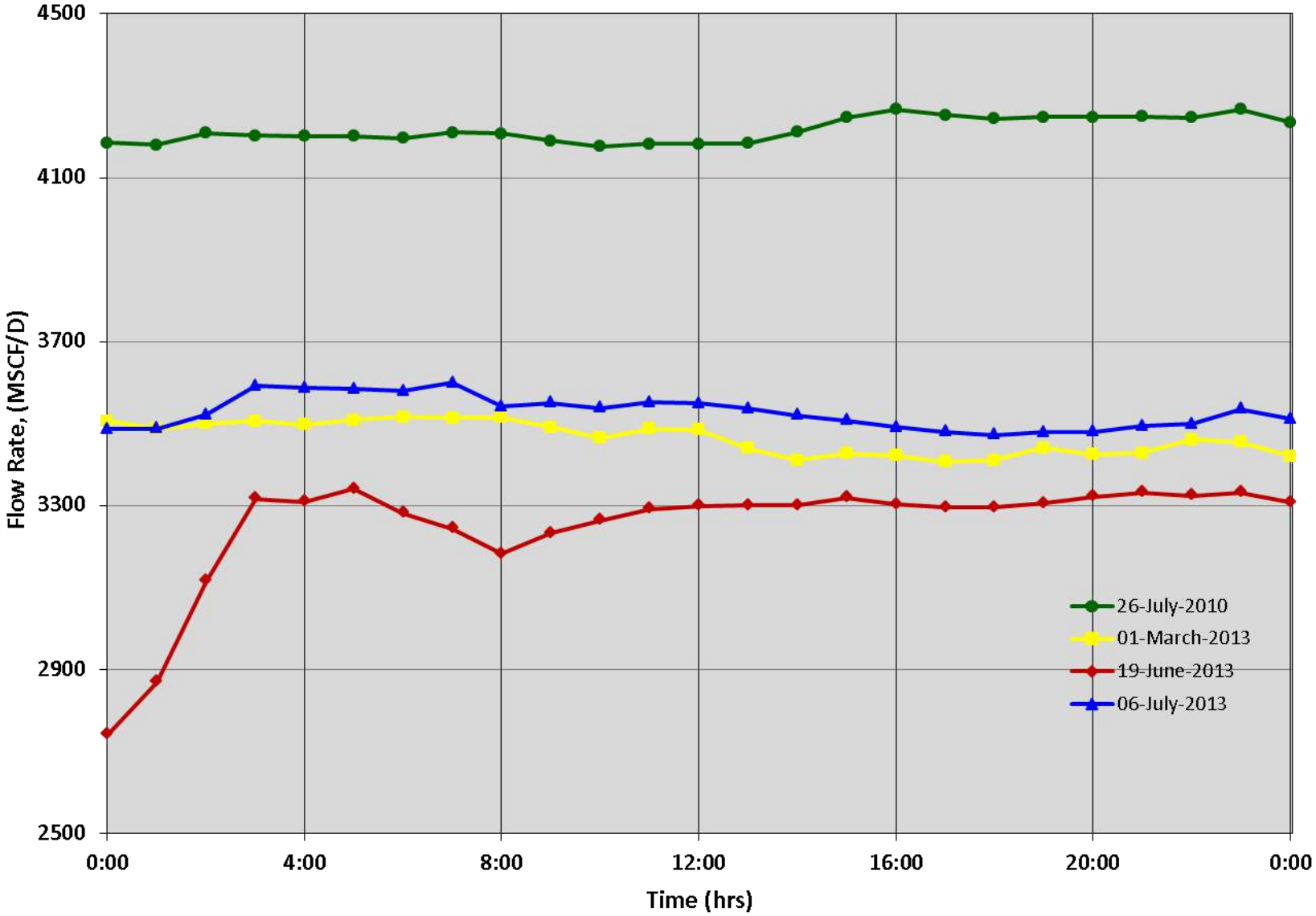
Charge Flow Rate



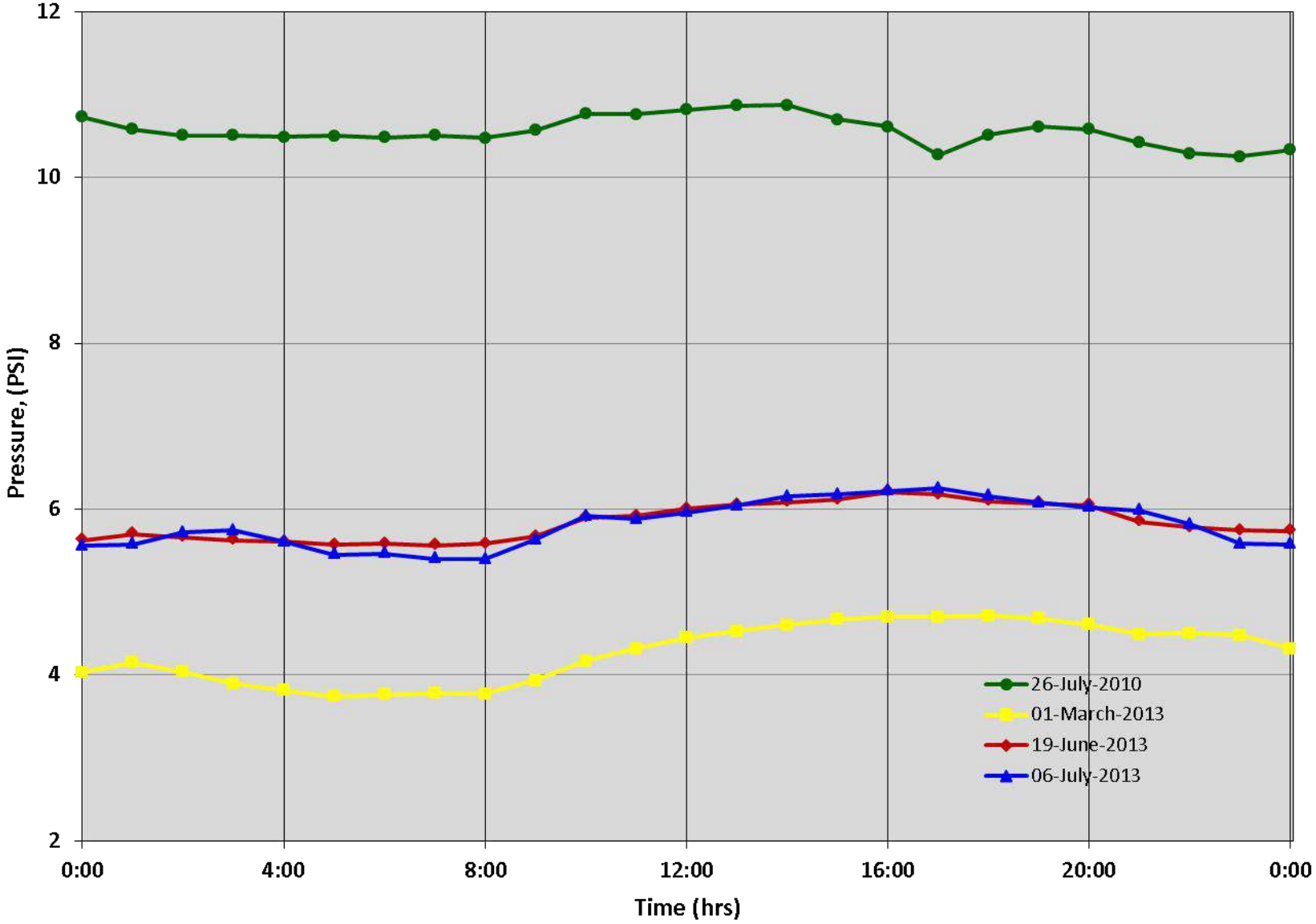
Flow Rate Comparison b/w 6 Passes 07/06/13



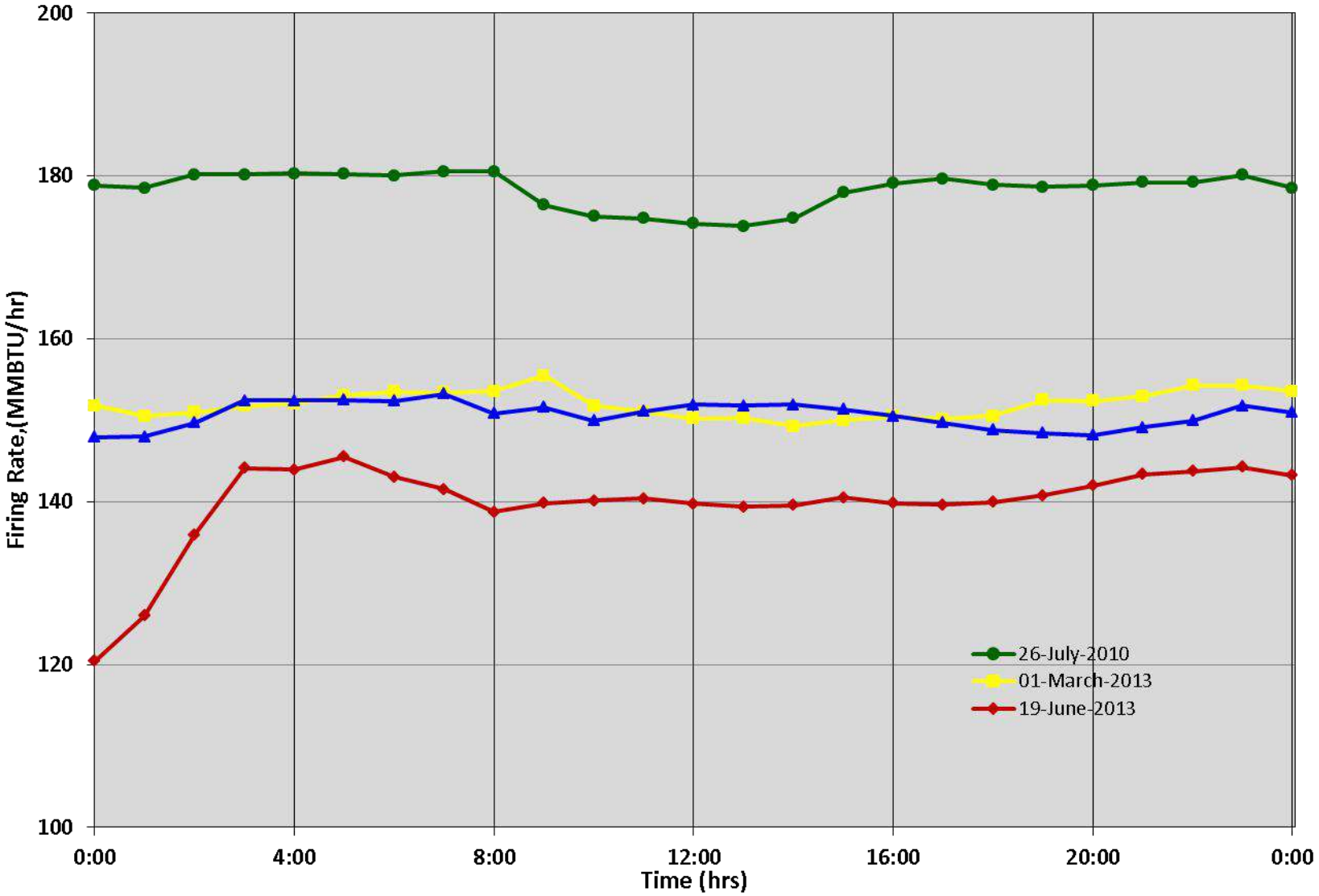
Compensated FG Flowrate To Burner



Fuel Gas Pressure at Burner



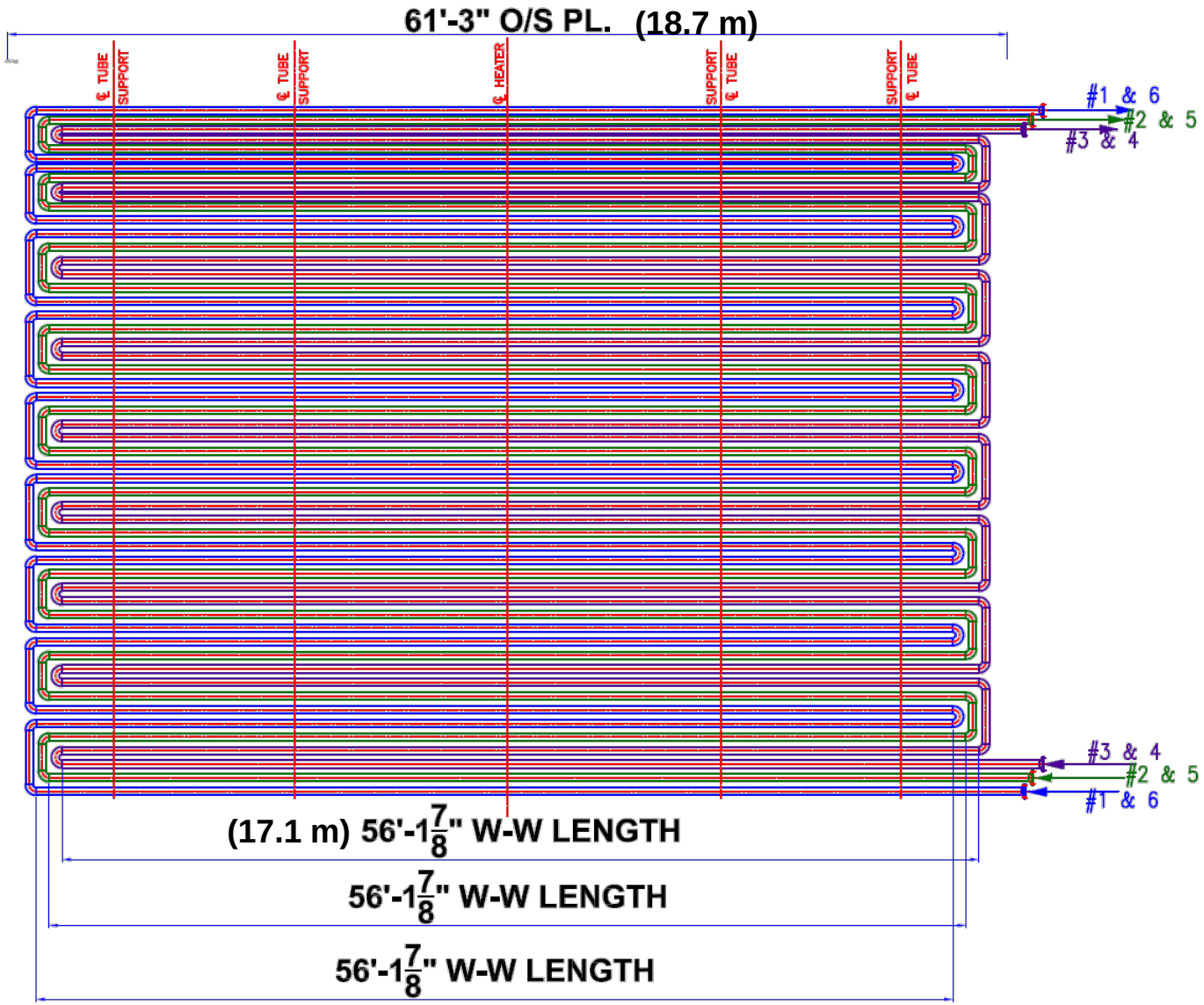
Firing Rate


200
180
160
140
120
100
Firing Rate,(MMBTU/hr)
0:00
4:00
8:00
12:00
16:00
20:00
0:00
Time (hrs)
26-July-2010
01-March-2013
19-June-2013

Non uniform heat distribution

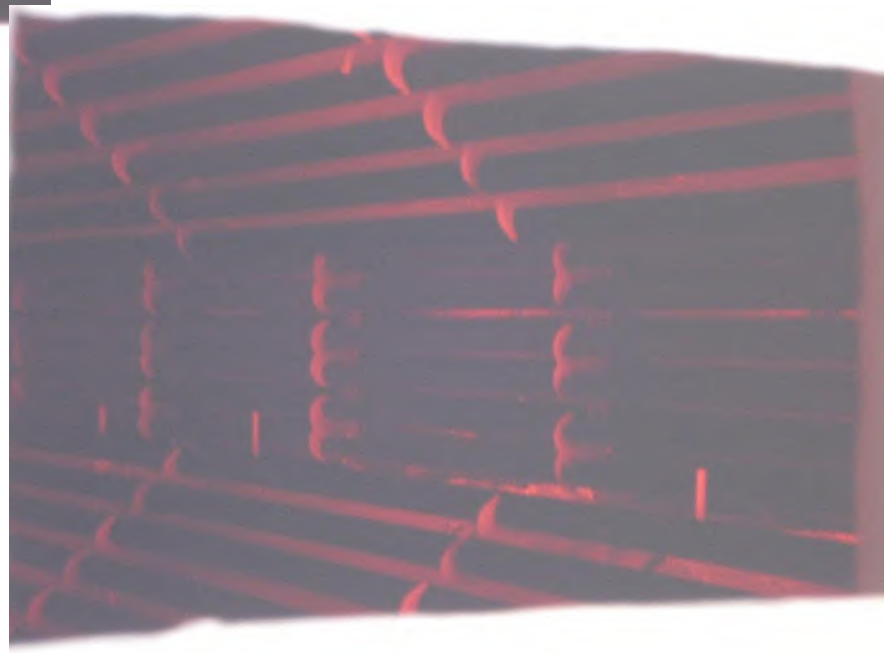
- FIS recommended nesting of radiant coils to ensure uniform heat distribution
- All passes receive equal amount of heat
- Uniform flow and outlet temperature of each pass

Nested Coil

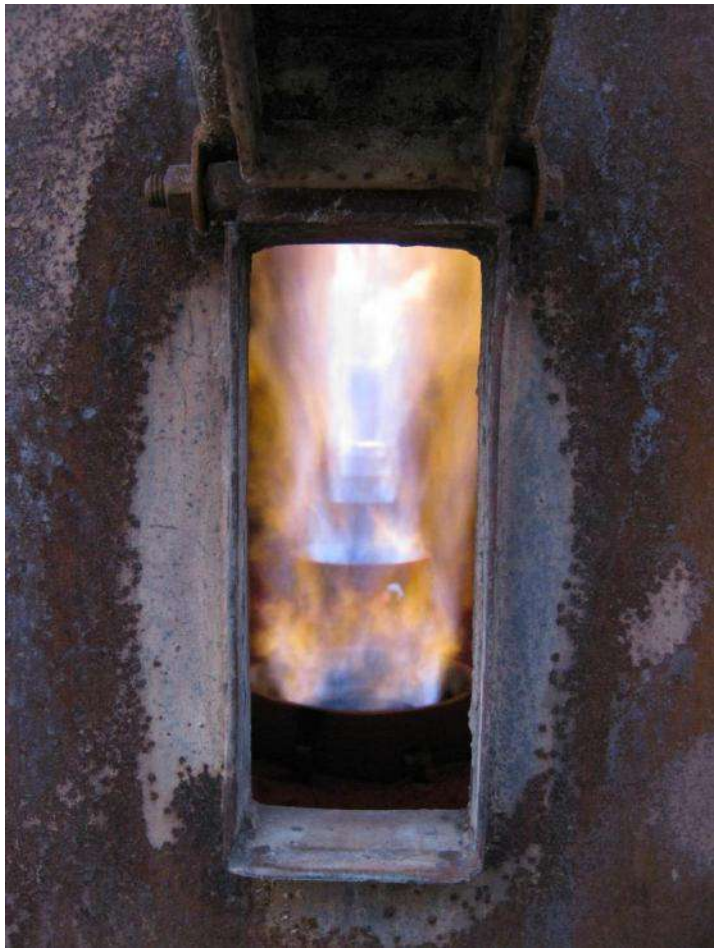

61'-3" O/S PL. (18.7 m)
℄ TUBE
SUPPORT
℄ TUBE
SUPPORT
℄ HEATER
SUPPORT
℄ TUBE
SUPPORT
℄ TUBE
#1 & 6
#2 & 5
#3 & 4
#3 & 4
#2 & 5
#1 & 6
(17.1 m) 56'-1 7/8" W-W LENGTH
56'-1 7/8" W-W LENGTH
56'-1 7/8" W-W LENGTH

Radiant Coil

- Low Mass Flux in the Radiant Coil
  - Existing radiant coil is 6 inch (152 mm) (4 inch (102 mm) in convection)
  - Reduce radiant tube coil from 6 inch (152 mm) to 5 inch (127 mm)
  - Increase mass velocity from 155 to 228 lb/sec ft^2 (757 to 1,113 kg/sec-m^2)
- Coil pressure drop
  - Existing -53 psi (365.4 Kpa)
  - With 5 inch (127 mm) coil- 83 psi (572.3 Kpa)
- Coil size can be optimized to the max pressure drop available in the system



Glowing tube supports at the arch



Burner Flames

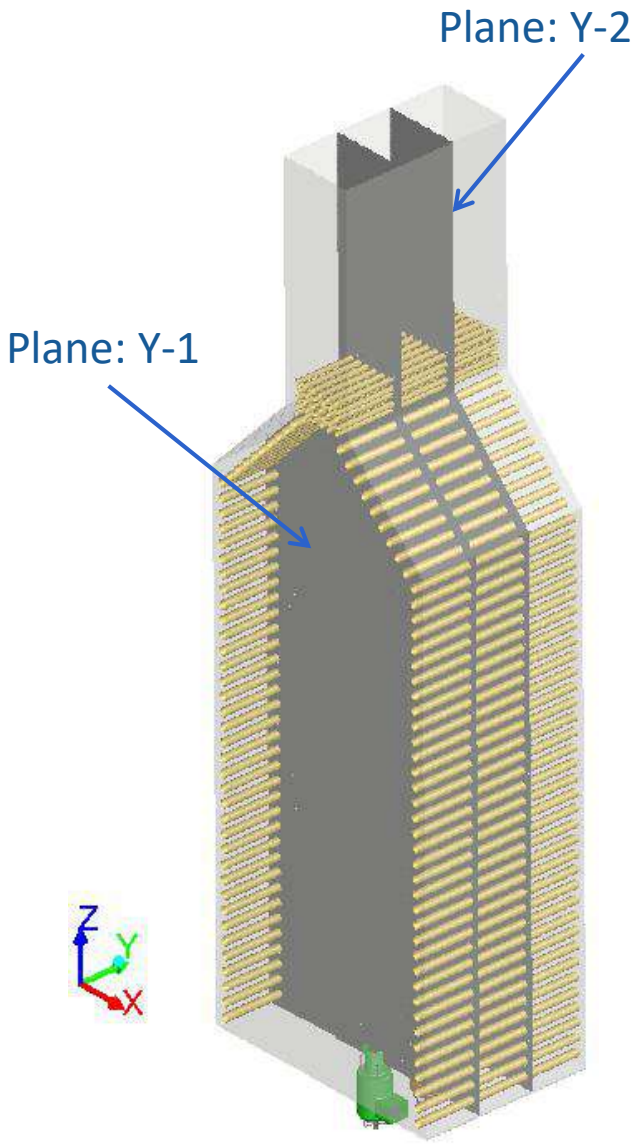
CFD Modeling

- CFD modeling has been utilized to analyze the
  - Flue gas flow patterns,
  - Flame characteristics,
  - Heat flux distribution and
  - Tube metal temperature profile in the heater

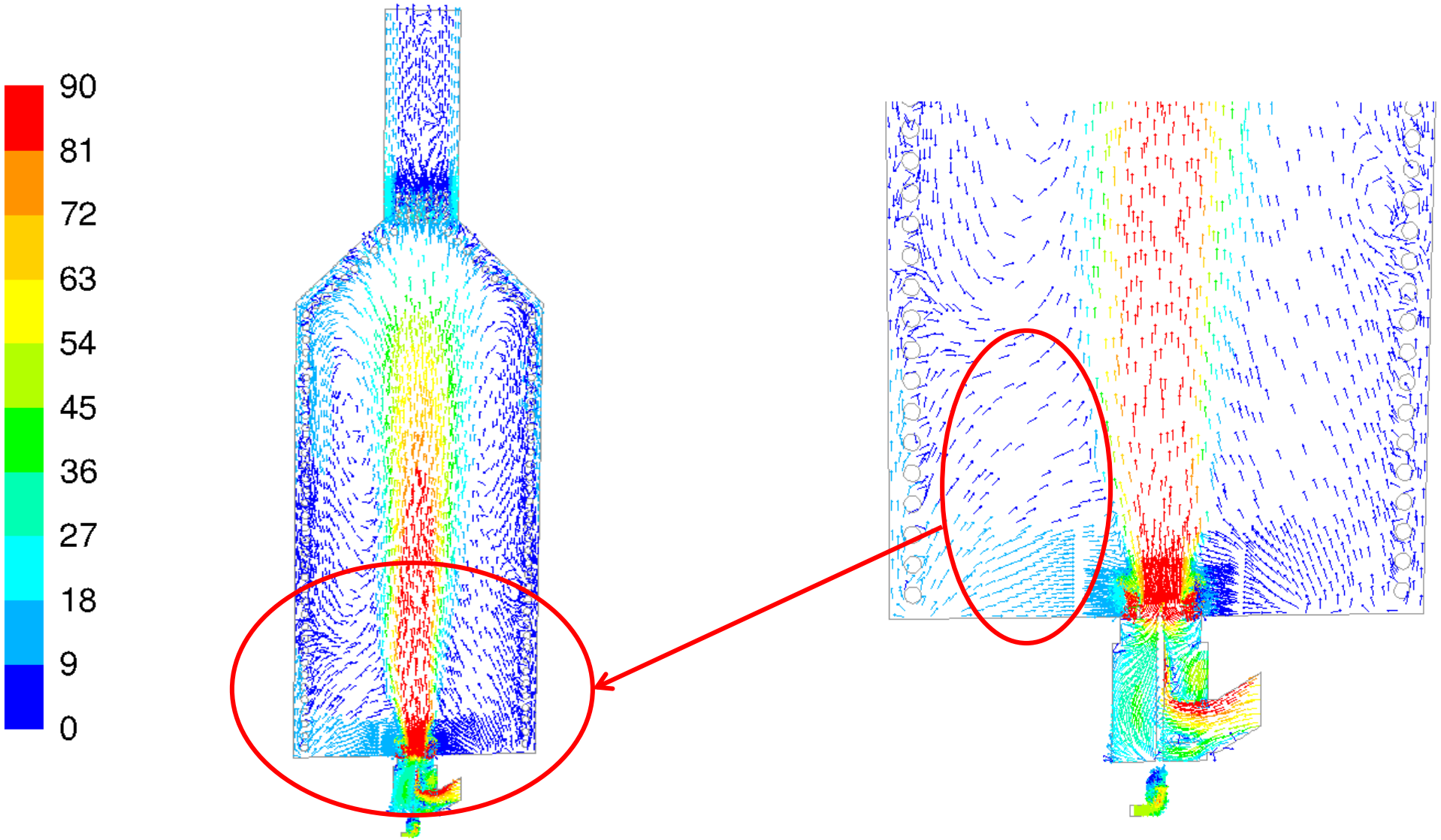
- Non-premixed Probability Density Function combustion model along with Discrete Ordinate radiation models are used

Results

- Two burners are considered for modeling
- Vertical planes passing through each burner are used to analyze the results
  - Velocity Vectors
  - Temperature contours

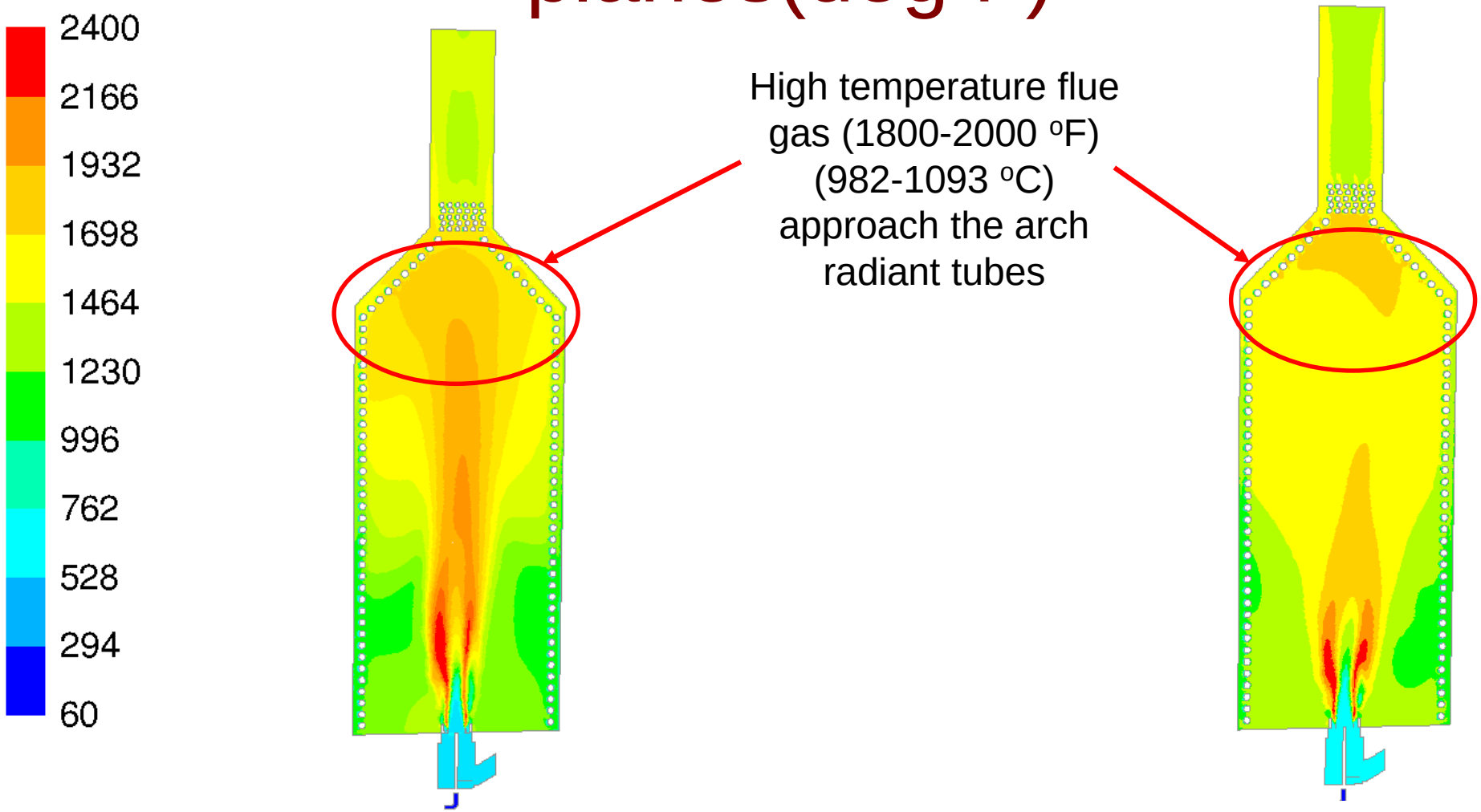


Velocity Vectors at plane Y-1 (ft/s)



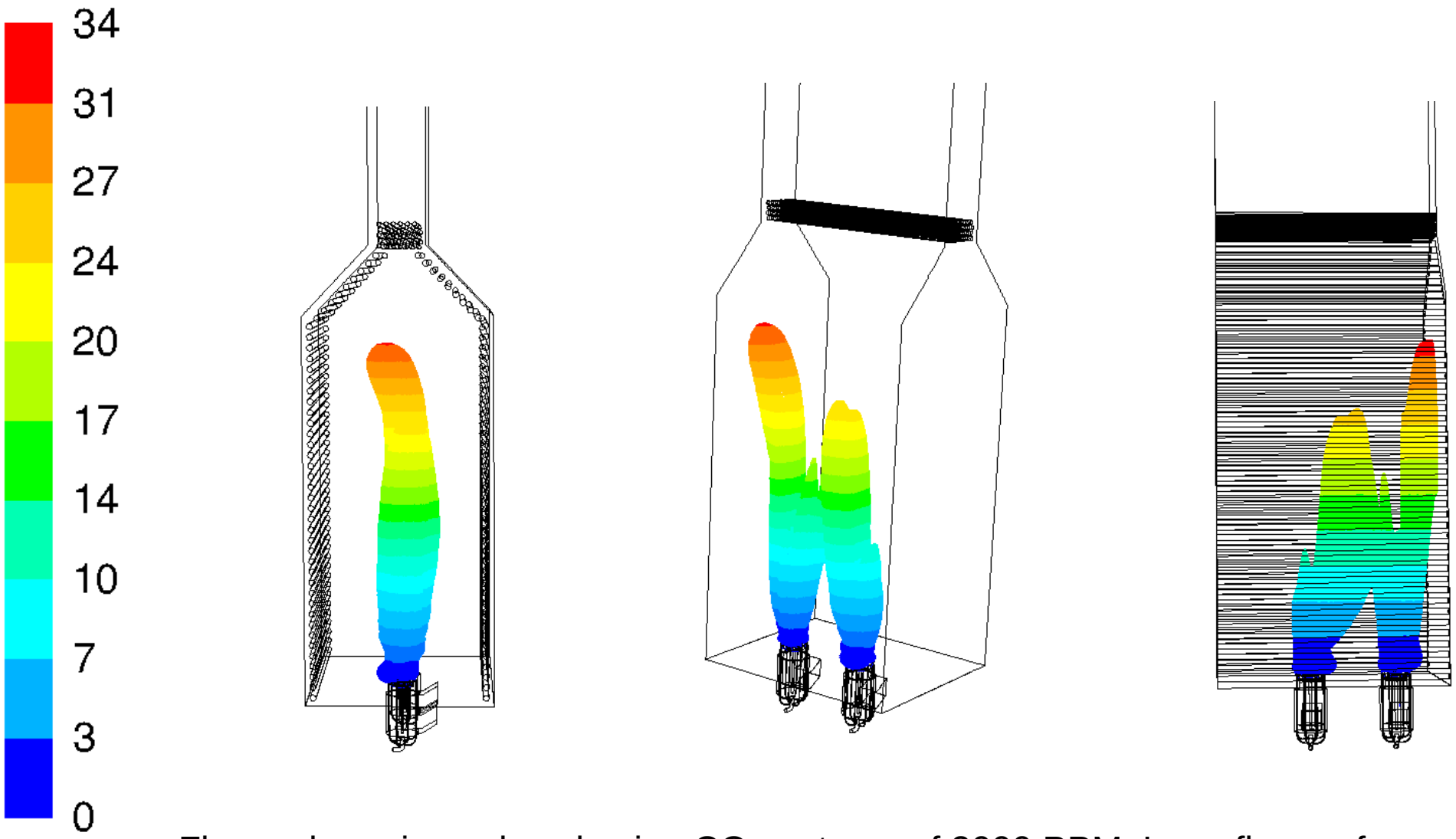
Velocity vectors show flue gas of high velocity exists till top of the heater

Temperature Contours at Y planes(deg F)



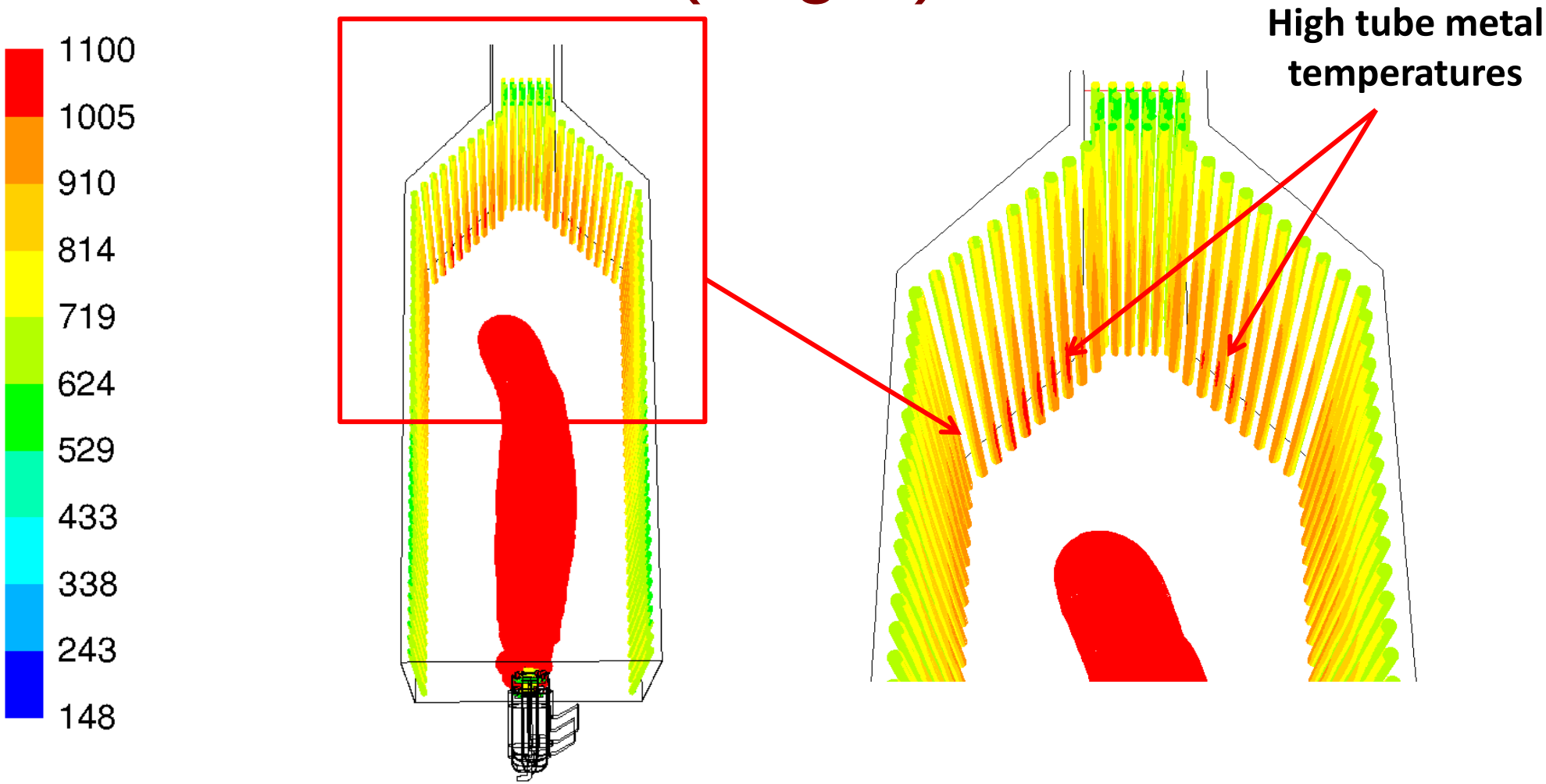
Temperature contours show the top region of heater is much hotter as compared to the lower region

Flame Colored by Height (ft)



Flame shape is analyzed using CO contours of 2000 PPM. Long flame of 30’ height exists in the heater. This also causes high TMT for arch tubes.

Radiant Tubes Temperature Contours (deg F)



Tube metal temperature of radiant tubes at arch is high ~1100 ^{o}F (593 ^{o}C), due to long flame.

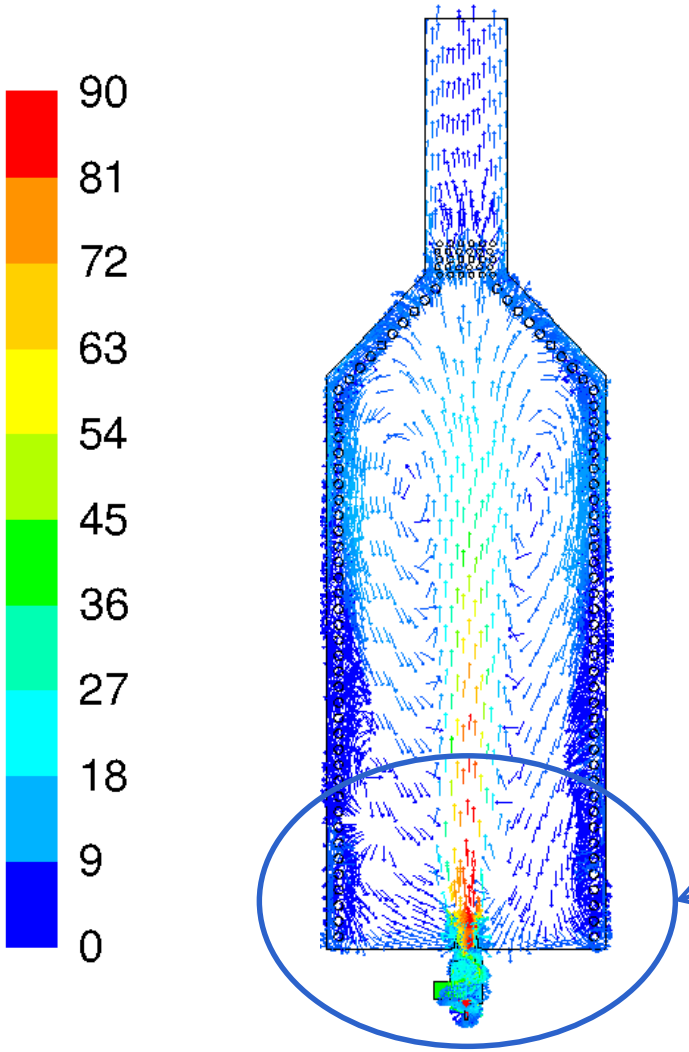
Comments: Existing Case

- CFD modeling results captured the flue gas flow pattern to show long recirculation loop exists with high flue gas temperature approaching the arch radiant tubes
- Long flames of height ~30’ (9.14 m) which also causes high TMT for arch radiant tubes
- The heat flux distribution also showed that the top heater section has higher heat transfer as compared to the lower section of the heater
- Proposed design modification was then evaluated to check the performance improvement of the heater

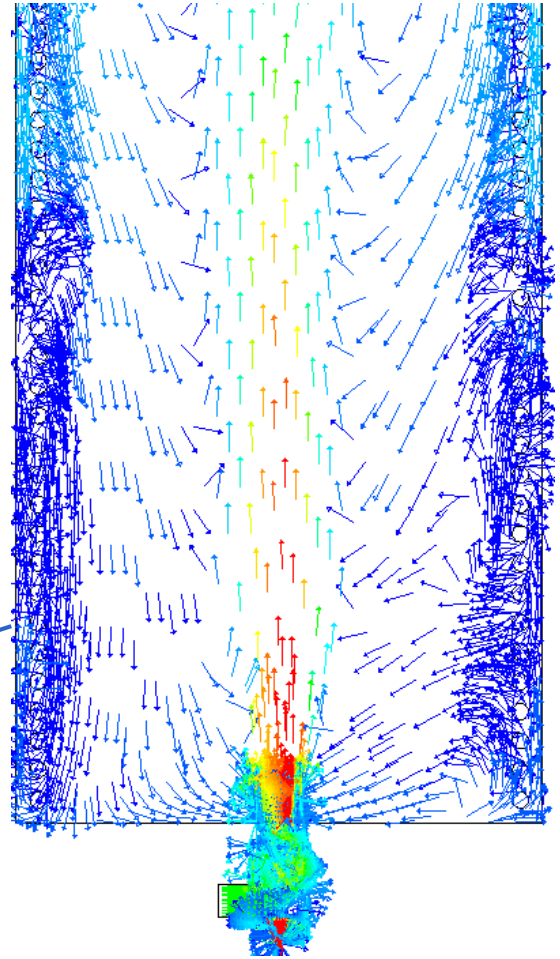
Proposed Options

- FIS recommended installation of New Ultra Low Nox Burners to bring the heat down in the box.
- Forced draft
- Preheated air
- Nox emission lower than 45 ppmvd
- Fuel gas firing

Velocity vectors at Y-1 Section(ft/s)

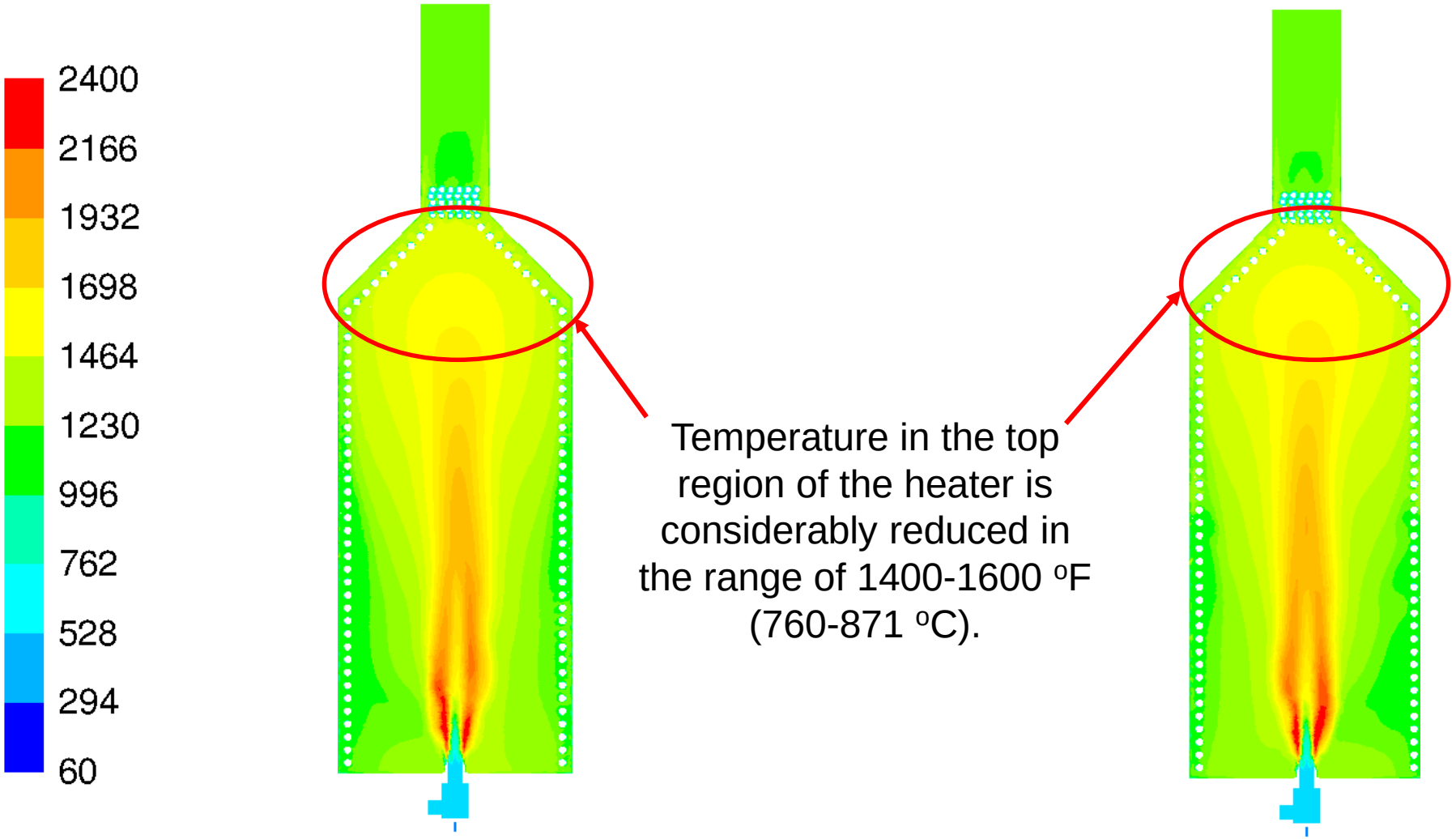


The velocity vectors show high velocity region exists till the center of the heater. The velocity of flue gas approaching the arch radiant tubes is decreased.



Zoomed view

Temperature contours at Y planes (deg F)

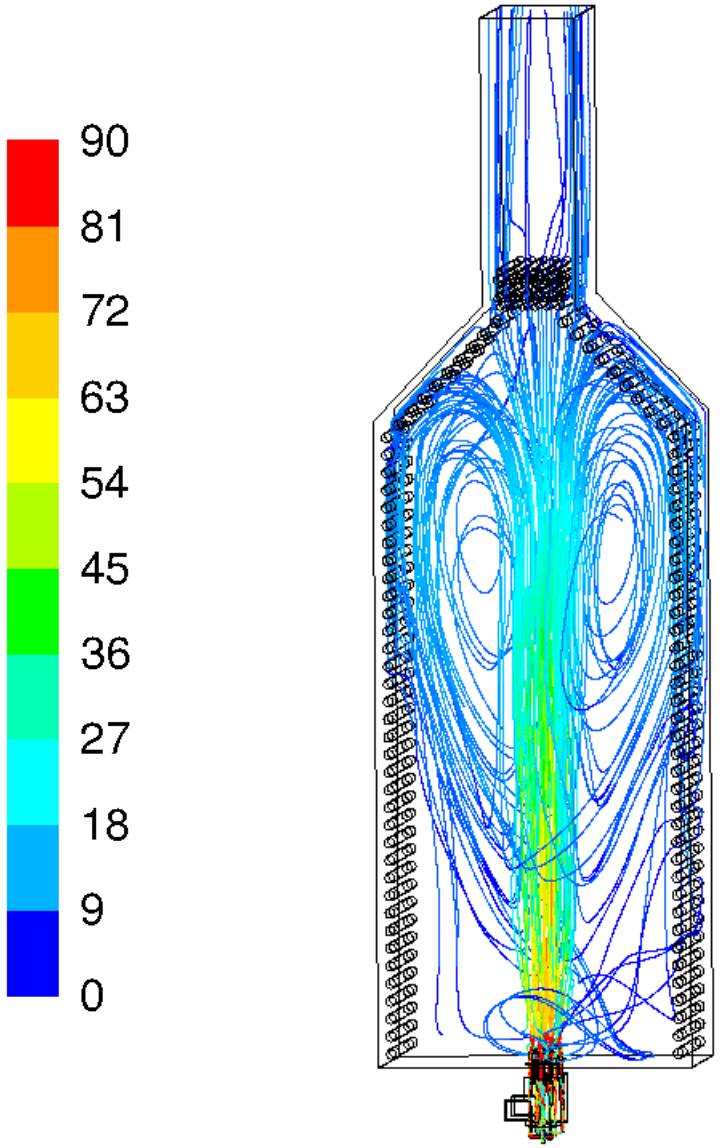


Temperature in the top region of the heater is considerably reduced in the range of 1400-1600 ºF (760-871 ºC).

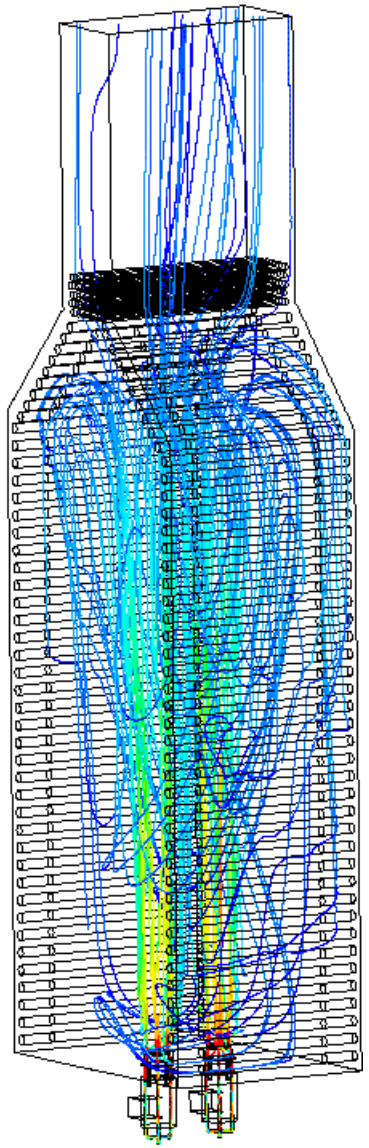
Plane: Y-1

Plane: Y-2

Path lines colored by velocity (ft/s)

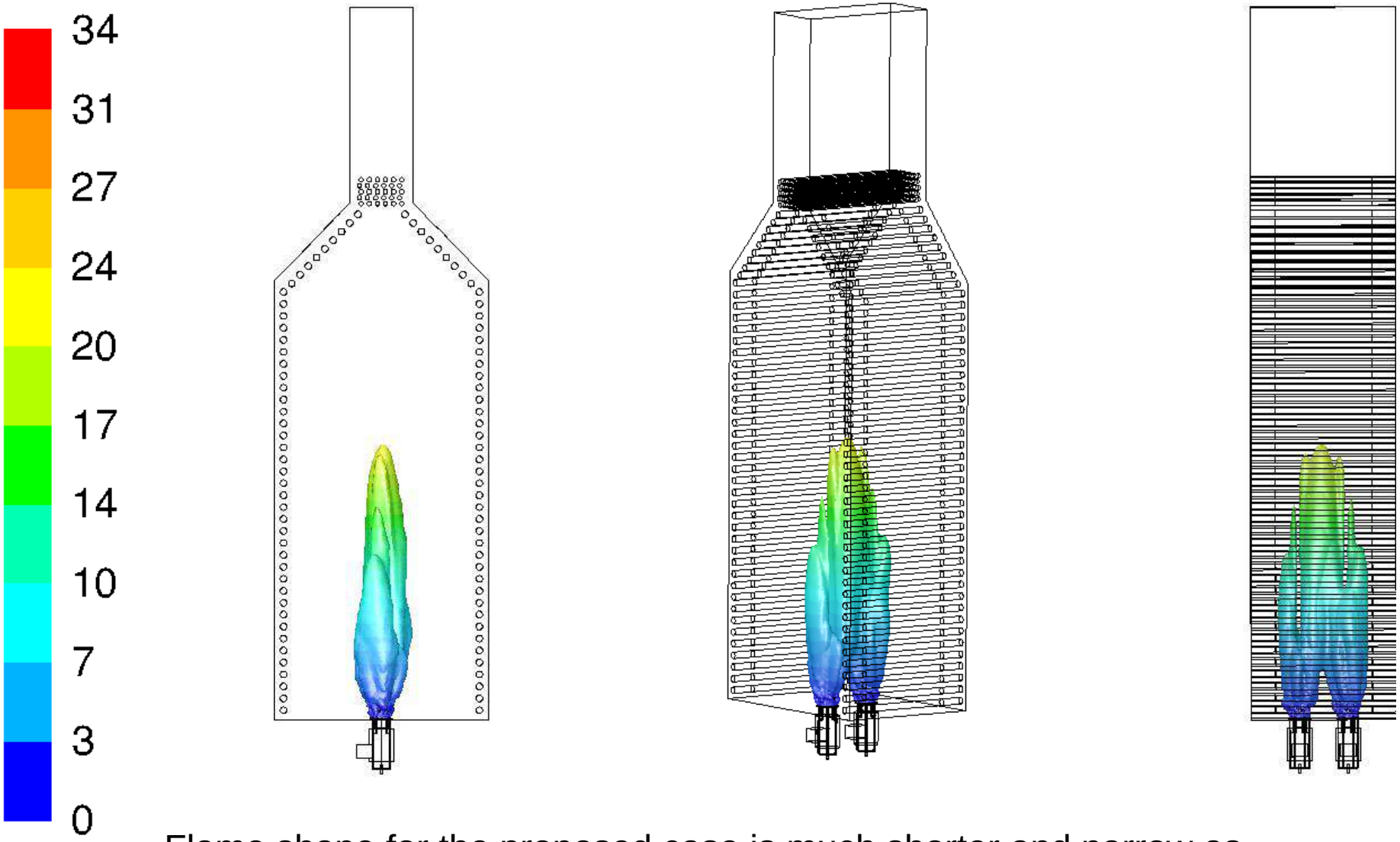


Flue gas recirculation patterns shows, symmetric flow pattern on either side of the heater, with reduced velocity around the radiant tubes.



Path lines released from burner fuel tip

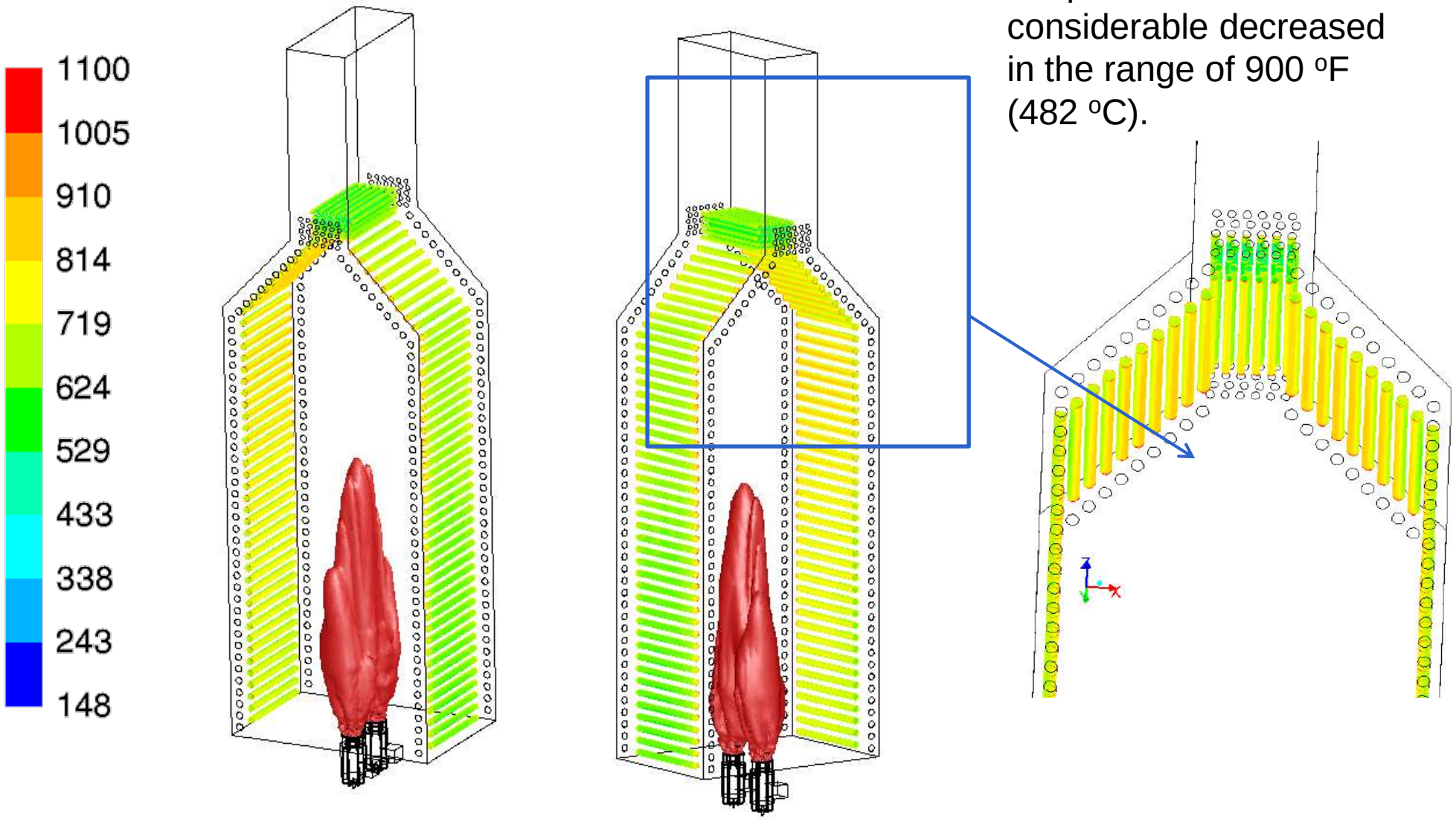
Flame colored by height (ft)



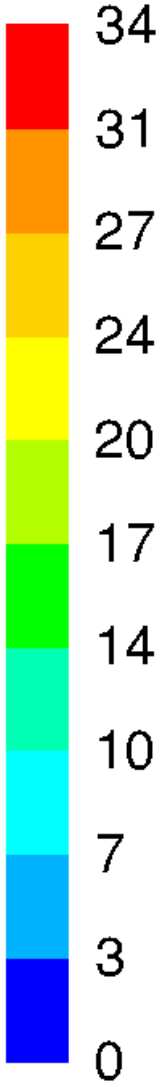
Flame shape for the proposed case is much shorter and narrow as compared to the flame for the existing case. Flame height is ~18’ (5.5 m)

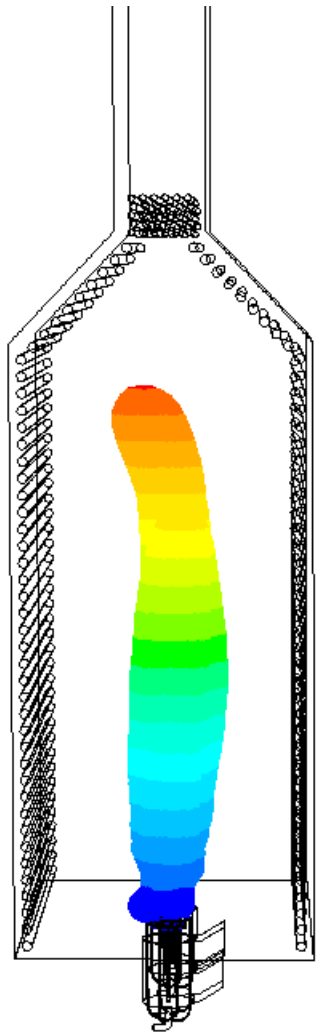
Radiant Tubes Temperature Contours (deg F)

Arch radiant tubes temperature is considerable decreased in the range of 900 ^{o}F (482 ^{o}C).



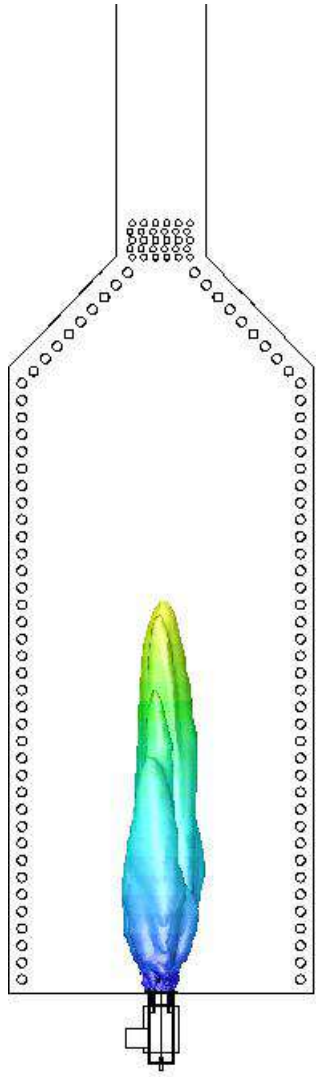
Flame colored by height (ft)





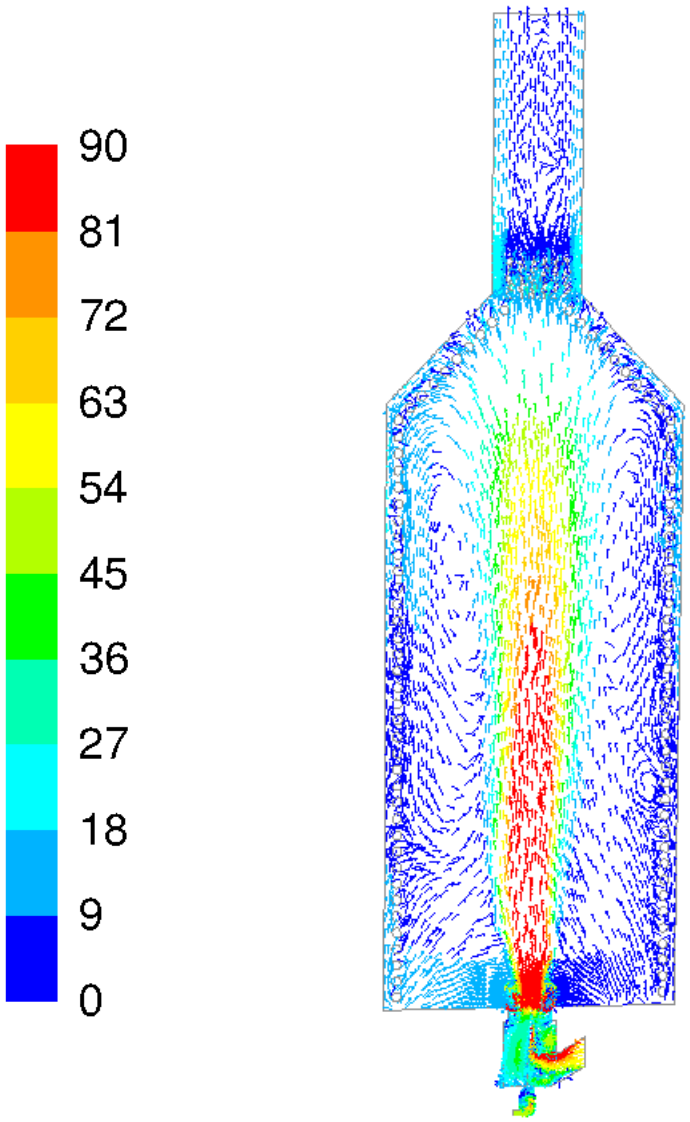
Base Case

This comparison clearly shows the flame for proposed option is shorter and narrow for better heat flux distribution in the heater.



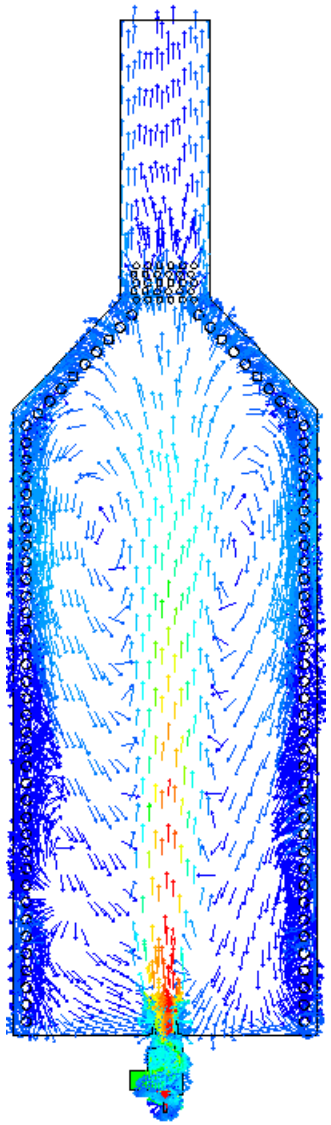
Proposed Design

Velocity Vectors at Vertical Section(ft/s)



Existing Case

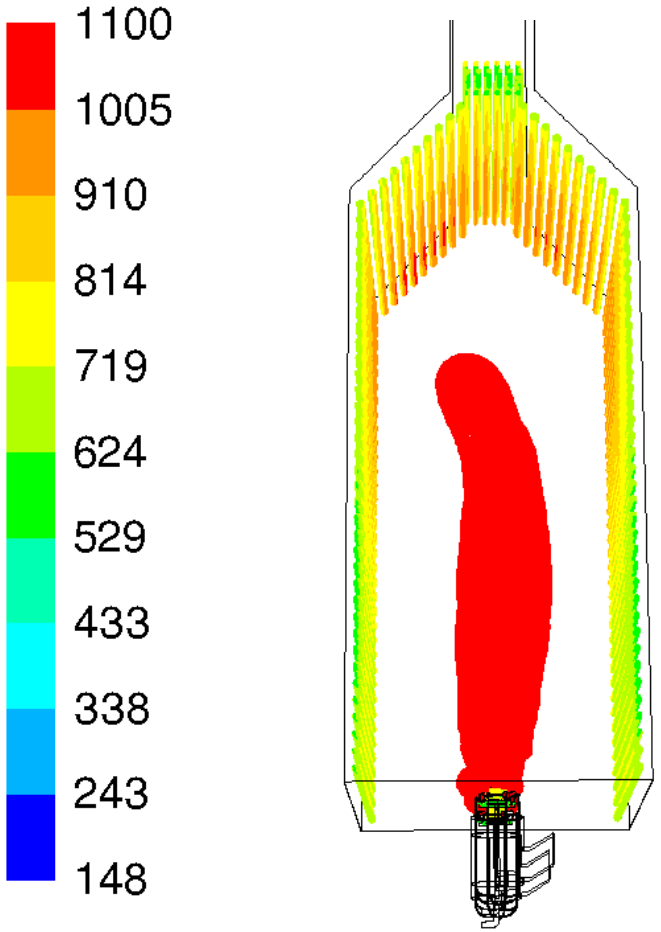
In the proposed option high velocity flue gas exists till half section of the heater. The velocity of flue gas around the arch radiant tubes is also decreased.



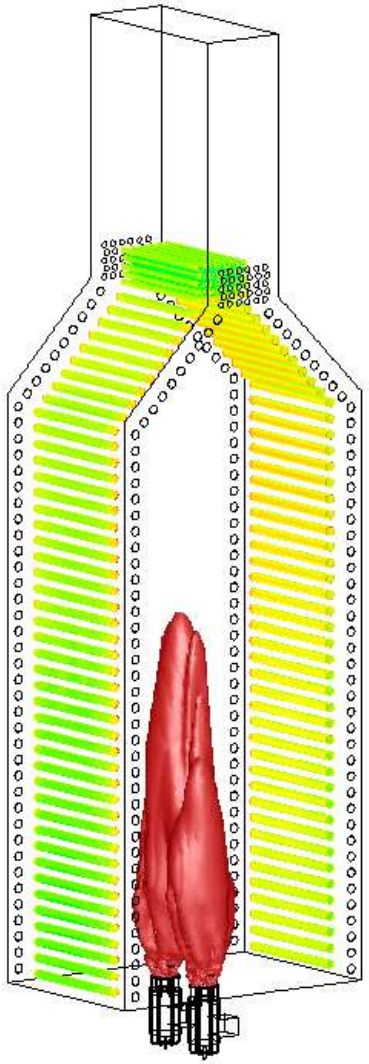
Proposed Option

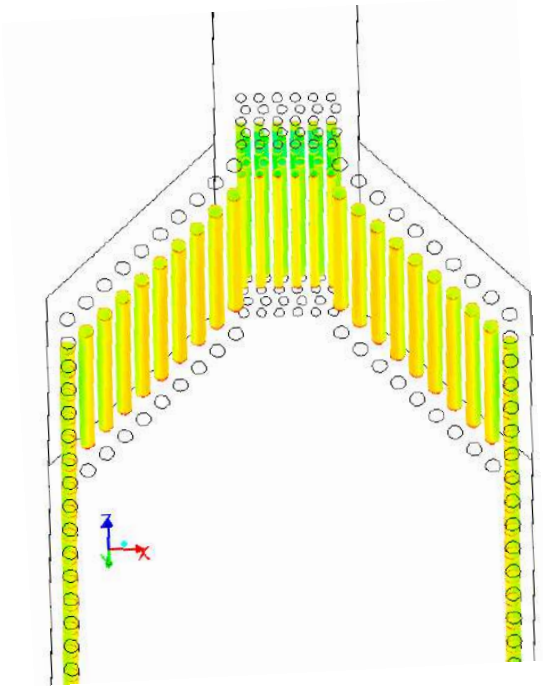
Radiant Tubes Temperature Contours (deg F)

High TMT spots on arch radiant tubes are completely eliminated in the proposed option.



Existing Case





Proposed Option

Comments: Proposed Option

- CFD results for the proposed option show
  - Improved flue gas flow pattern
  - Shorter and narrow flame
  - Better temperature distribution in the heater
  - More even heat flux distribution in the heater

Summary

- The heater was commissioned in January 2014.
- Client is extremely happy with the heater performance.
- The run length increased from 3 months to 2 years+ (estimated based on temperature rise)
- The heater is running at more than 110% capacity
- Client has contacted FIS to see if we can increase the capacity of this heater even further.