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Coker Heaters Performance Improvement

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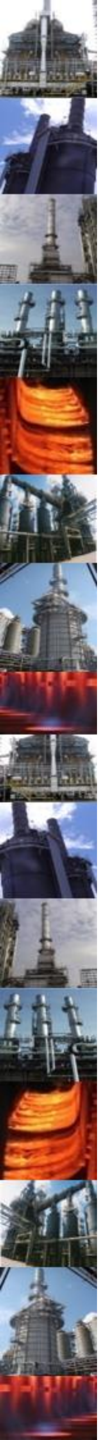
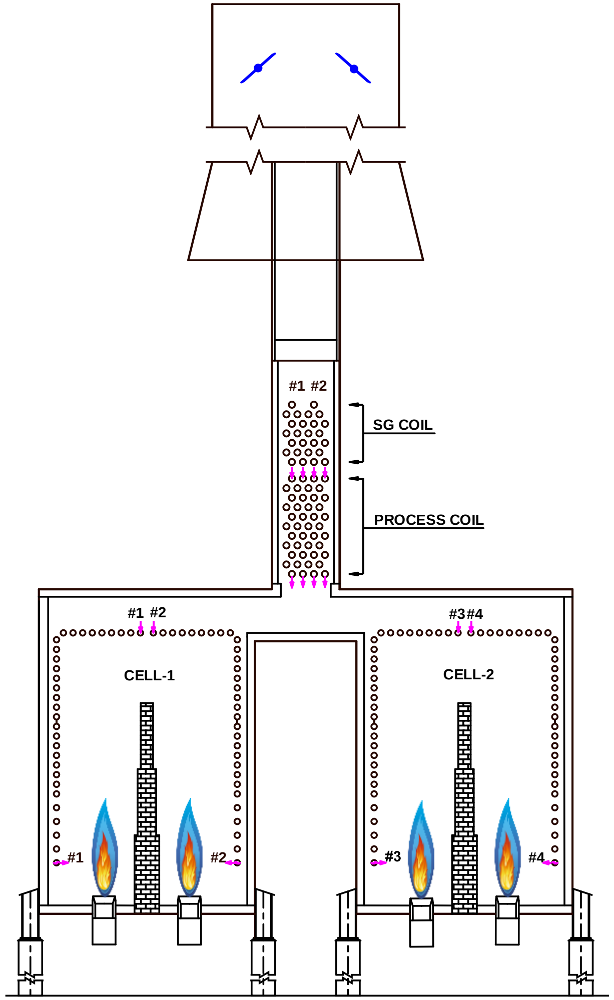


Coker Heaters

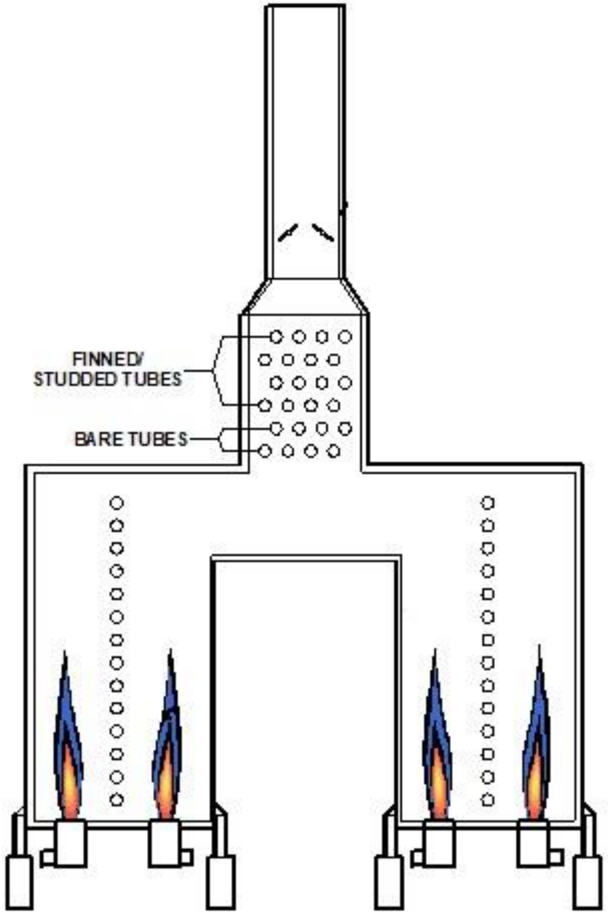
- Most critical heaters in the refineries
- Heart of Delayed Coker Unit (DCU)
- Objective: Process asphalt-like material to higher value products, such as gasoline, diesel fuel, LPG, and petroleum coke
- Charge is rapidly heated to the desired temperature
- Delayed coking is an endothermic reaction with the heater supplying the heat
- Coking in Tubes:
  - Pressure drop goes up
  - High tube metal temperature
- Steam is injected to minimize the cracking until it is in the Coke Drum.
- The rate of coke deposition determine Coker heater run length.

Coker Heater Types

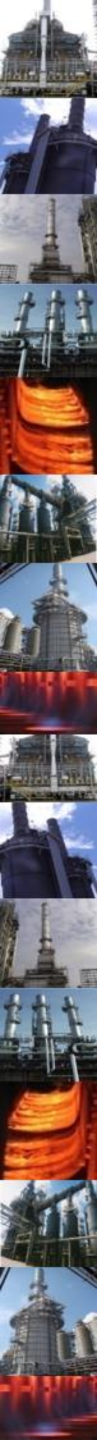
- Horizontal tube cabin heaters
- Single or double fired
- Advantages of double-fired Coker heater over single fired heater
  - Shorter coil
  - Higher heat flux
  - Lower pressure drop
  - Lower residence time
  - More uniform heating of metals



Single Fired



Double Fired



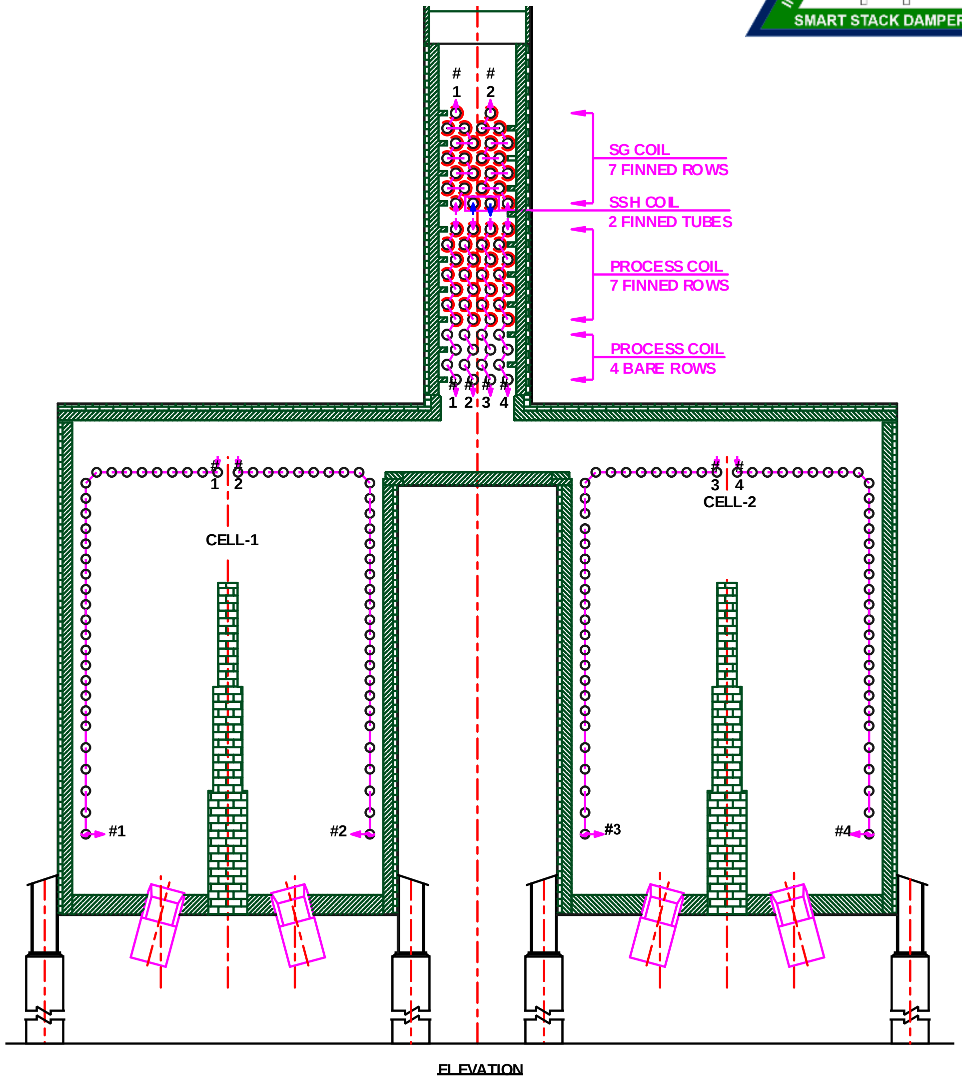
Coker Heater Design Parameters

- Inlet temperature
  - 400-600°F
- Outlet temperature
  - 900-950°F
- Coil Pressure Drop
  - 350-450 Psi (EOR)
- Condensate/Steam Flow Rate
  - 0.5-1 % of heater feed but highly dependent on the flow rate to each pass

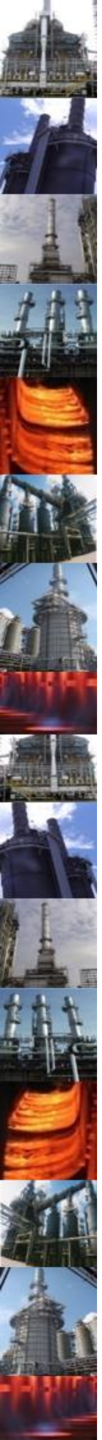
- Average Heat Flux
  - < 9,000 Btu/hr ft^2 (Single Fired)
  - 12,500 – 13,000 Btu/hr ft^2 (Double Fired)
- ❖ Mass velocity-
  - 350-550 lbs/sec ft^2
- ❖ Cold oil velocity
  - around 6-10 ft/s

Lyondell 736 Coker Heater Case Study

Parameters	Units	Value
Total Heat Duty	**MMBtu/hr**	**125.10**
Process Heat Duty	**MMBtu/hr**	**112.0**
Charge Rate	BPD	17,000
Inlet / Outlet Temperature	°F	550 / 950
Inlet / Outlet Pressure	psig	410 / 60
Condensate Flow Rate	lb/hr	1,167
Firing Rate	**MMBtu/hr**	**144**



Existing Coker Heater



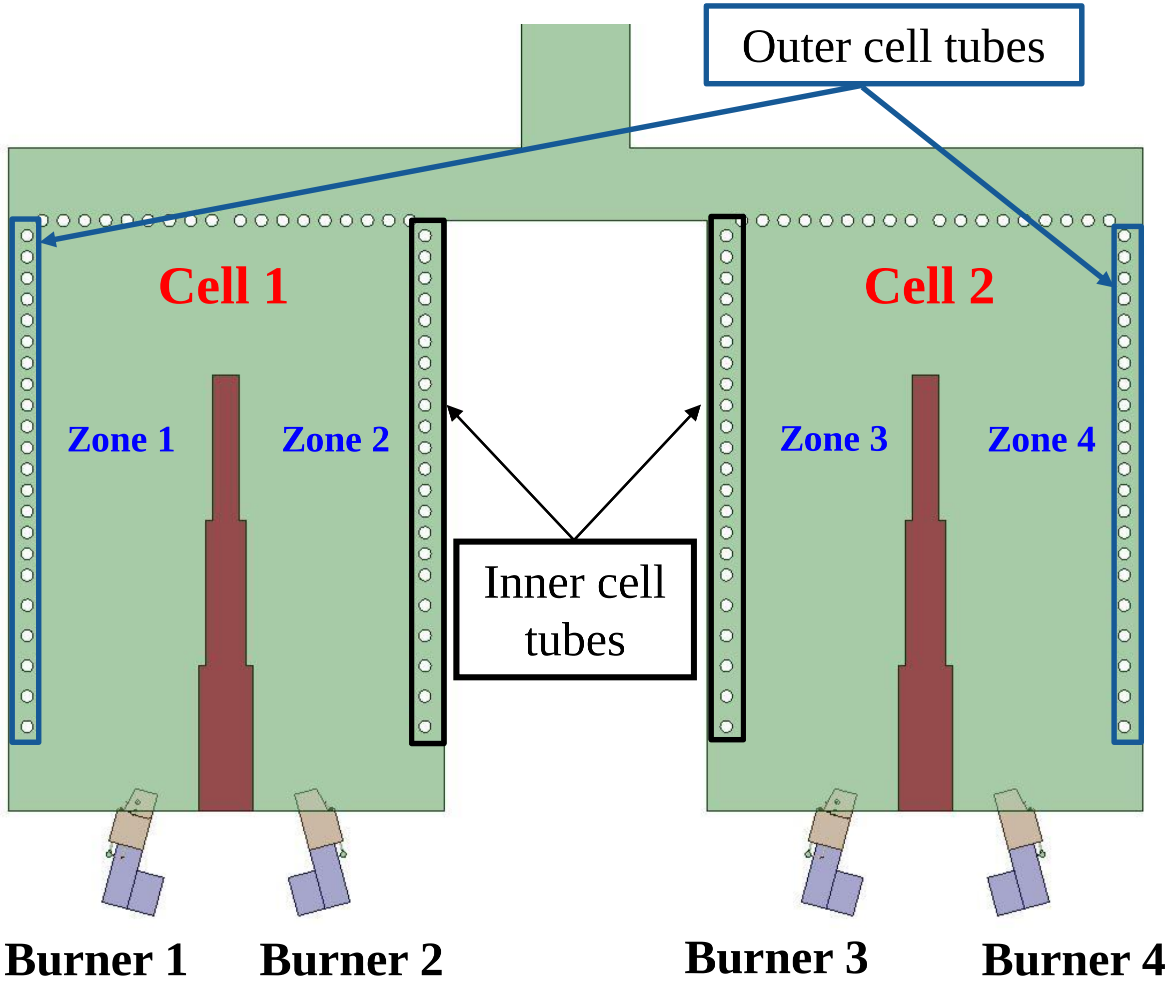
Lyondell 736 Coker Heater Issues

- Coking
  - Frequent decoking requirement (every year)
  - Short tube life around 5.7 years only- Increase to 14 years
- Overheating and flame impingement on roof tubes
  - Longer flame lengths
  - Low roof tubes elevation
  - Tube failures
- Stack
  - Draft at arch -0.3” WC to -0.5” WC
  - Poor flame patterns
- Tramp Air
  - Leakage of tramp air into the heater due to higher draft operation

Existing Heater Design Observation

- Flue gas temperature leaving radiant section –1,620°F
- The flue gas mass velocity in convection section is 0.5 lb./sec.ft^2
- The flue gas convection exit temperature is 800°F from process coil
- There are 48 burners arranged in 4 rows in both cells.
- Coker heaters are designed for a higher average radiant heat flux of 10,000 Btu/hr.ft^2.
- Calculated charge mass velocity is only 295 lbs./sec.ft^2 (SOR case)
  - This is very low for the Coker heaters.
  - The typical recommended Coker heater mass velocity is in the range of 350-450 lbs./sec.ft^2.
  - Minimum Cold oil velocity in Coker heaters is 6 ft/sec.
- The draft mentioned at burners is only 0.3 inch WC
- The ultralow NOx burners currently installed have very long flames

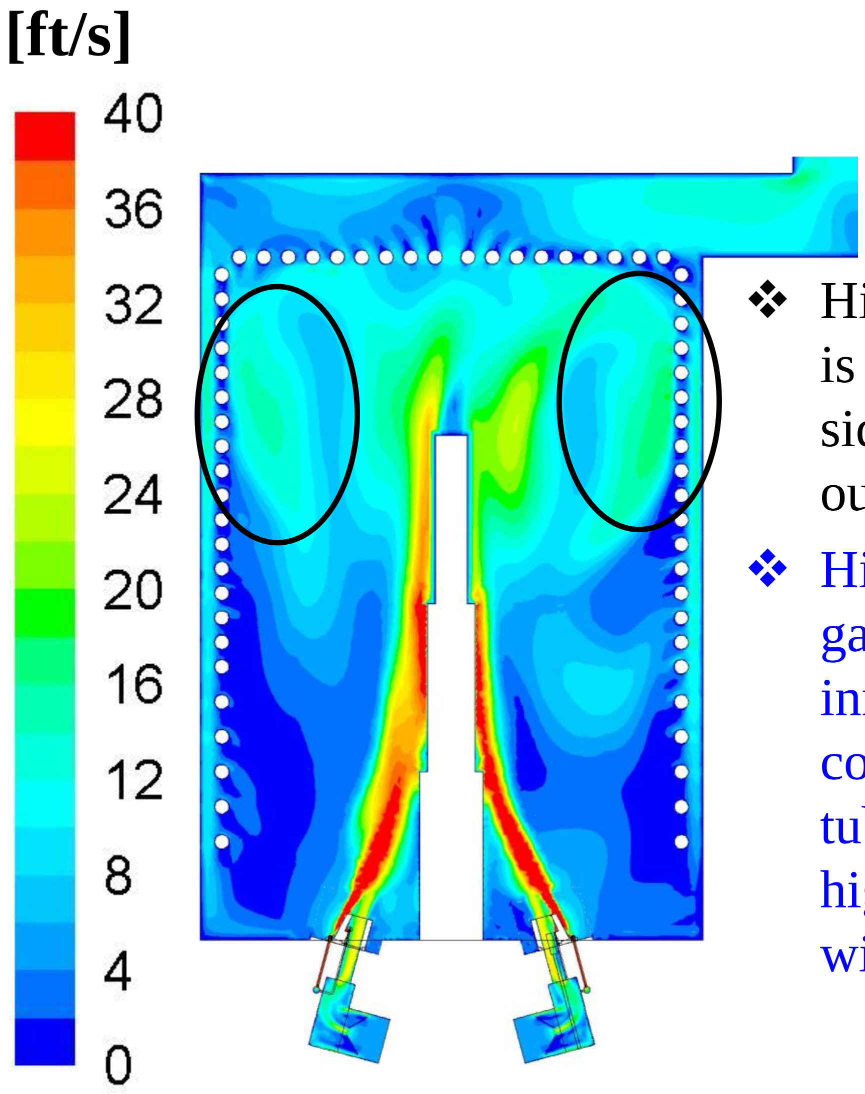
Existing Design Geometry for CFD



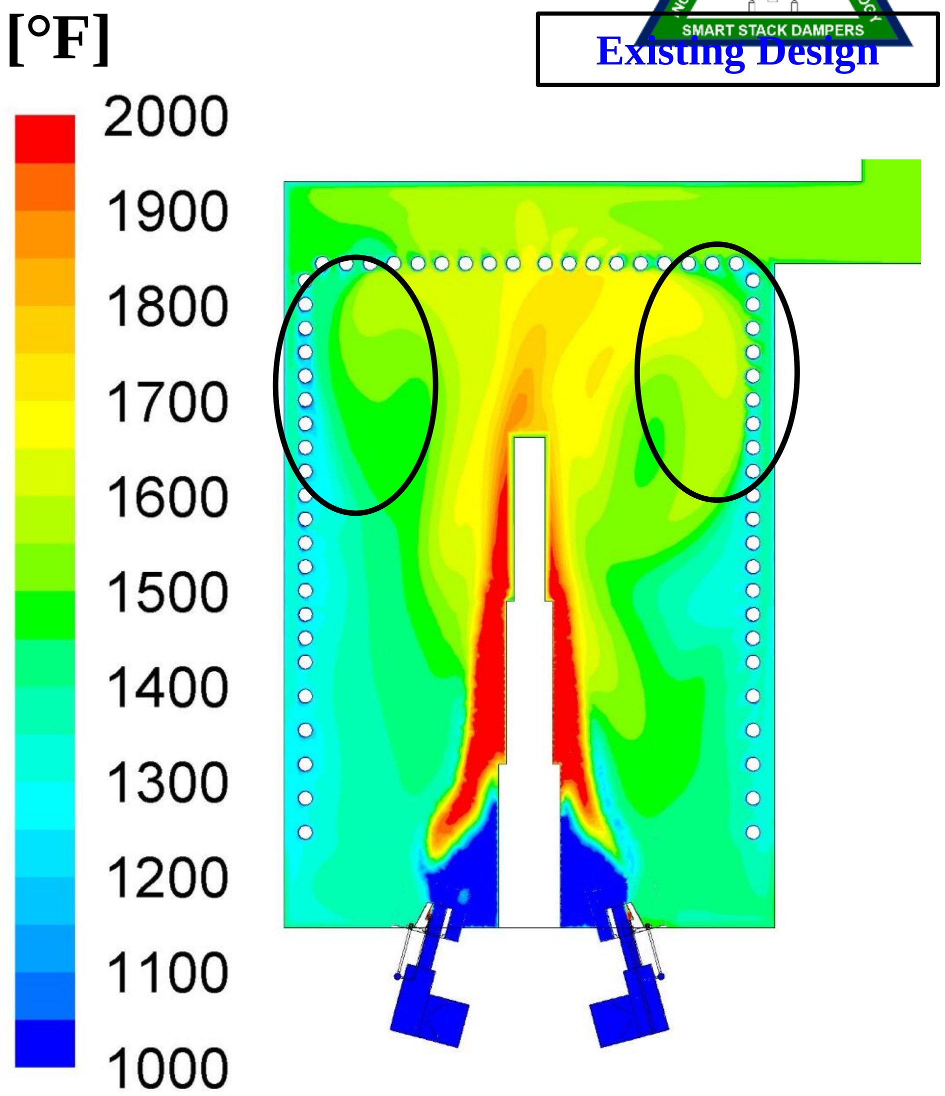
- No. of burners in CFD model: 4
- Design heat release per burner: 3.0 MMBtu/hr
  - Fuel flow rate per burner: 154.7 lb/hr
  - Air flow rate per burner: 2,928 lb/hr

Flue Gas Flow and Temperature Profile

Existing Design

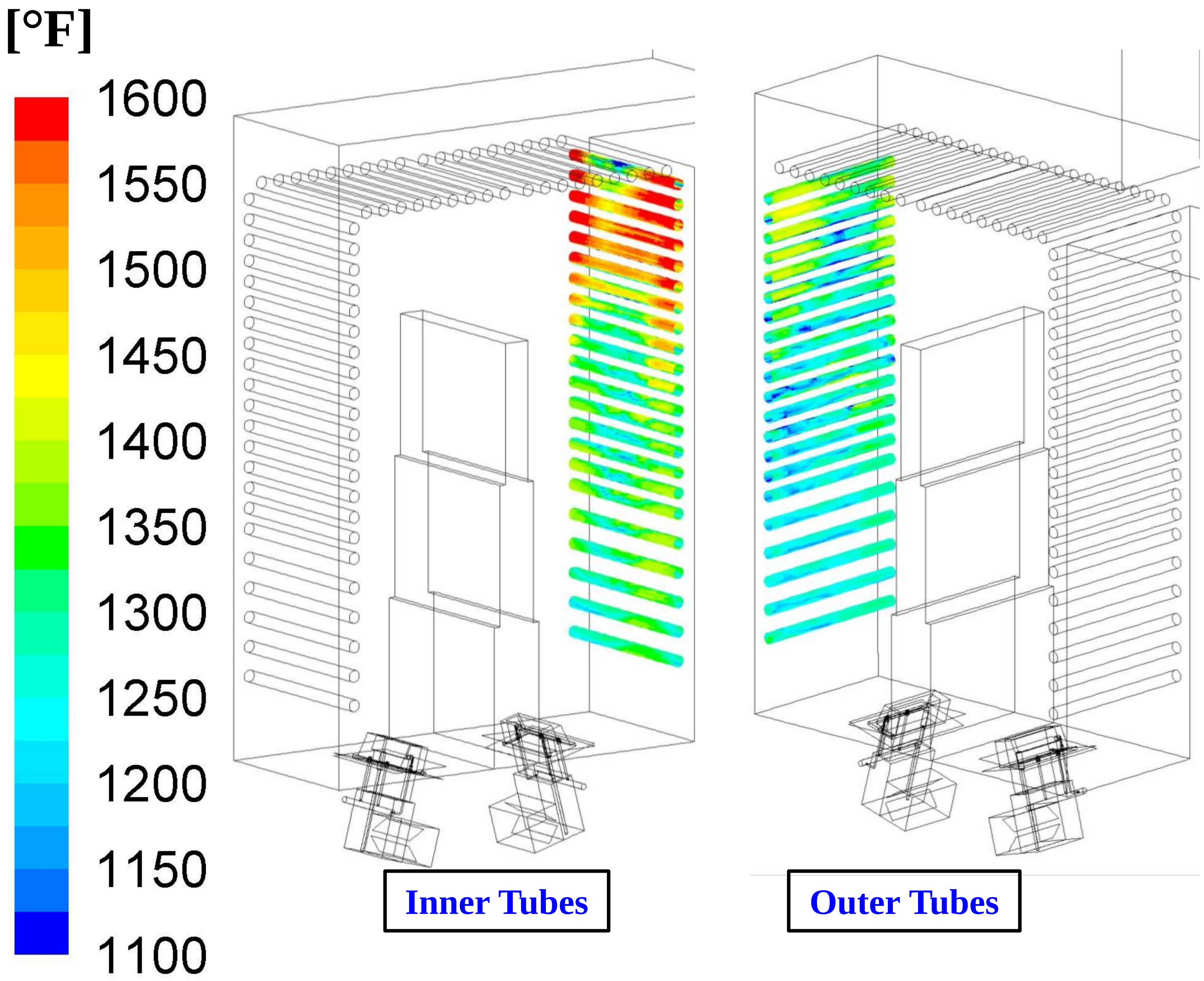


- Higher velocity flue gas is observed on the inner side as compared to the outer side
- Higher temperature flue gas is observed near the inner cell tubes as compared to the outer cell tubes. This indicates higher heat exchange with the inner cell tubes.



Firing rate for all burners is same: 3 MMBtu/hr

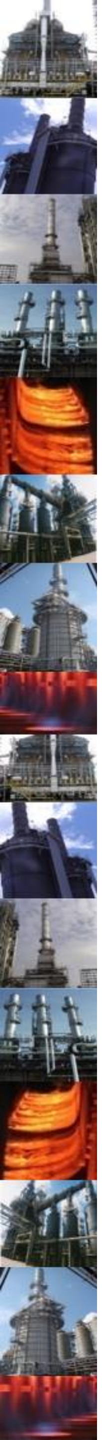
Flue Gas Temperature around Tubes

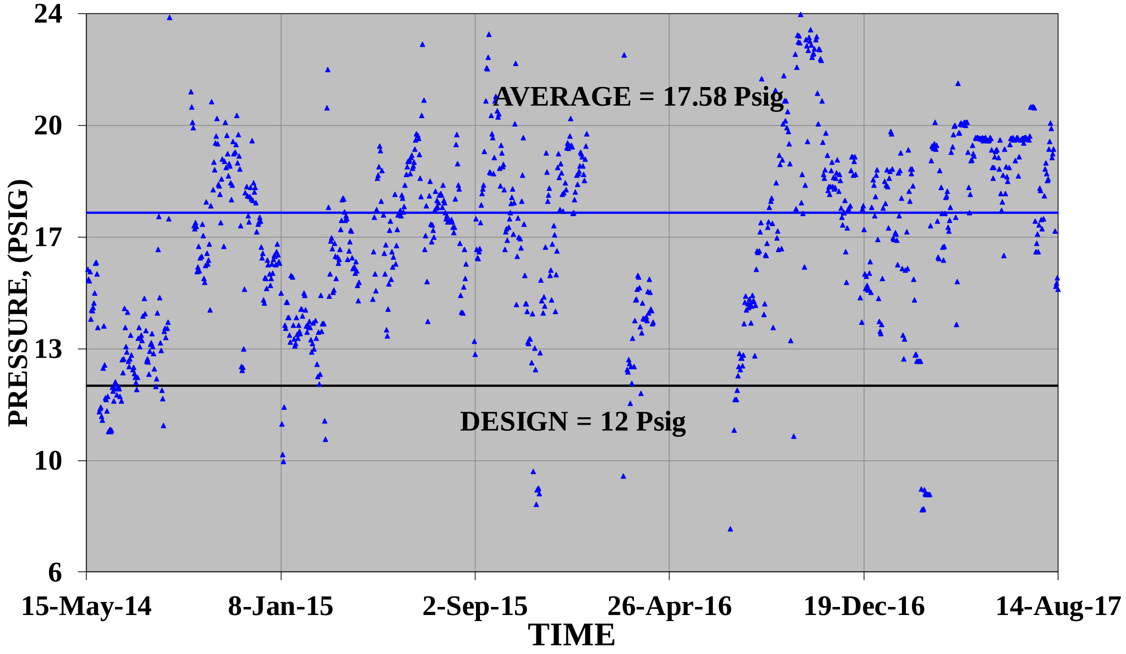


Existing Design

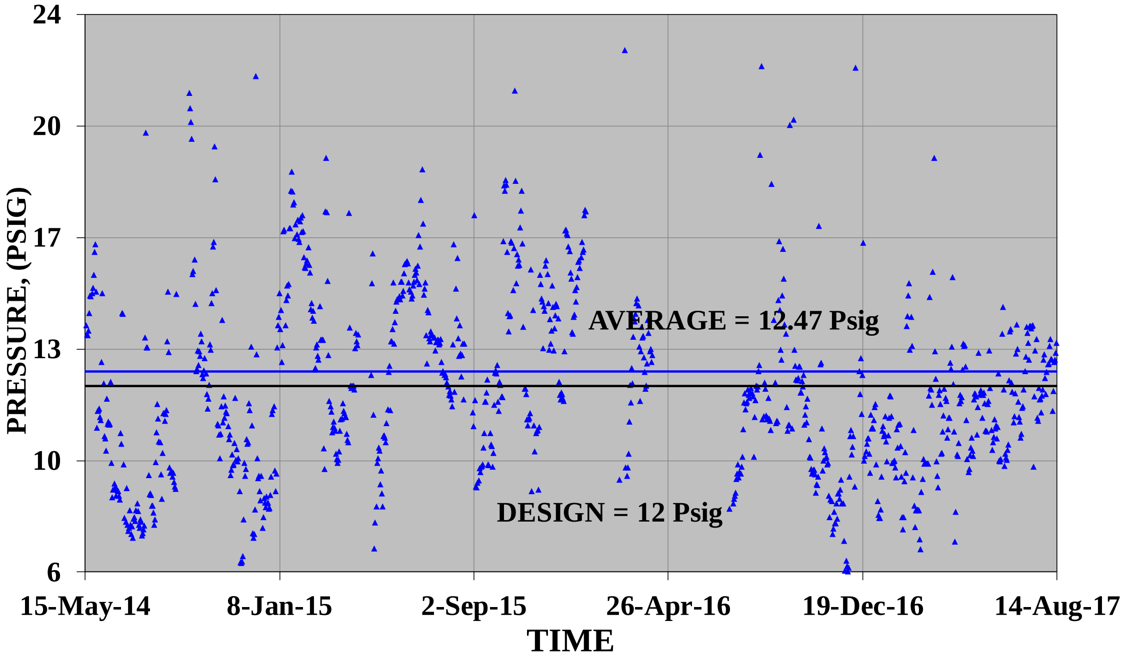
❖ Flue gas temperatures around inner cell tubes and outer cell tubes are significantly different. This is due to the inclination of flow towards the convection section.

Fuel Gas Pressure





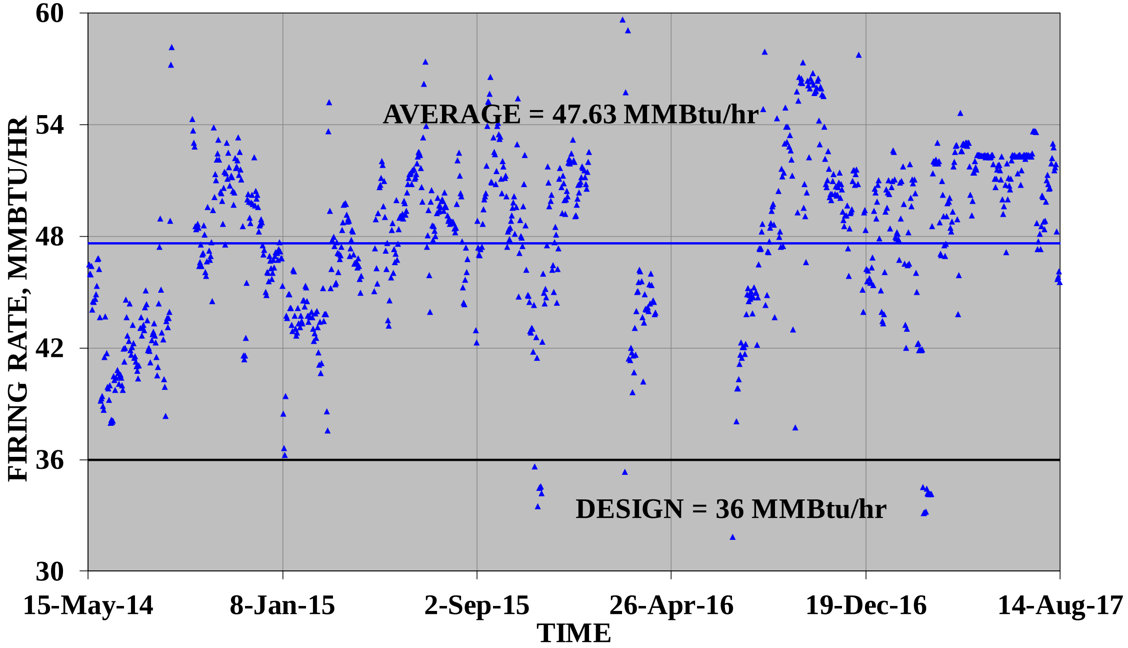
West Outer Cell

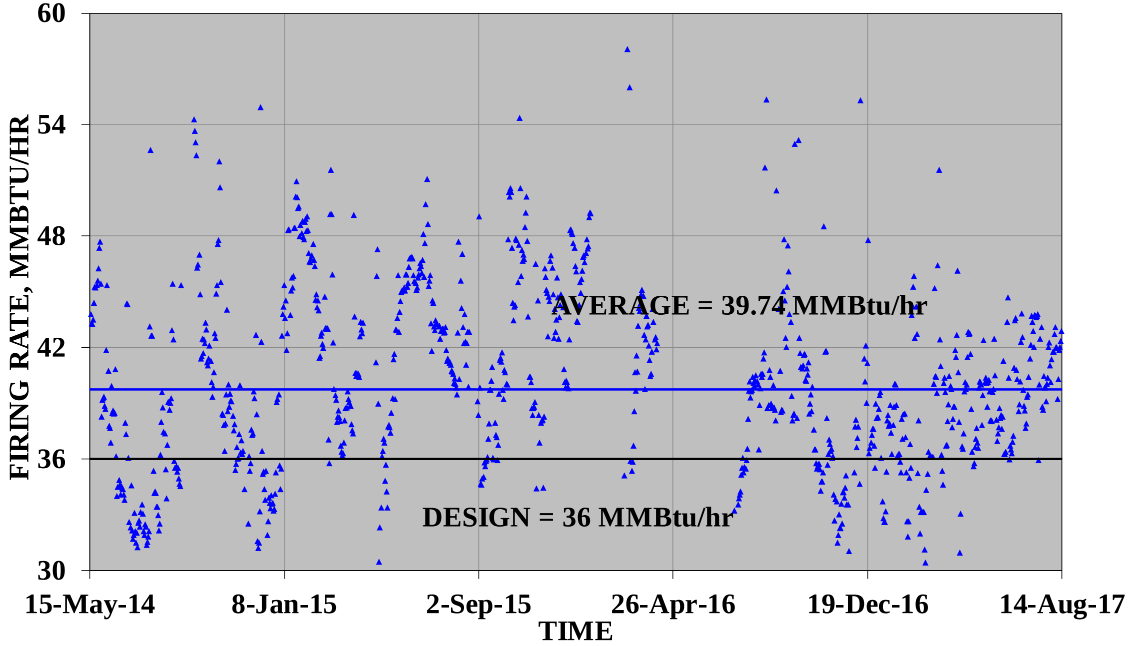


West Center Cell

Fuel gas pressure in the outer cell is almost 40% higher than the fuel gas pressure in the inner cells.

Firing Rate based on Fuel Gas Pressure





West Outer Cell

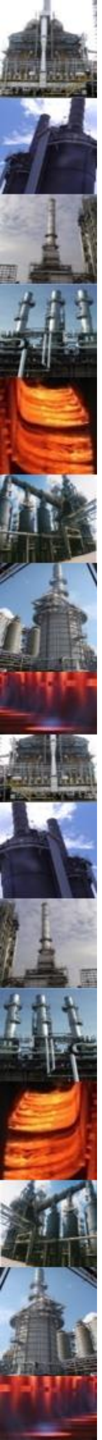
West Center Cell

Fuel gas flow in the outer cell is almost 20% higher than the fuel gas flow in inner cell.

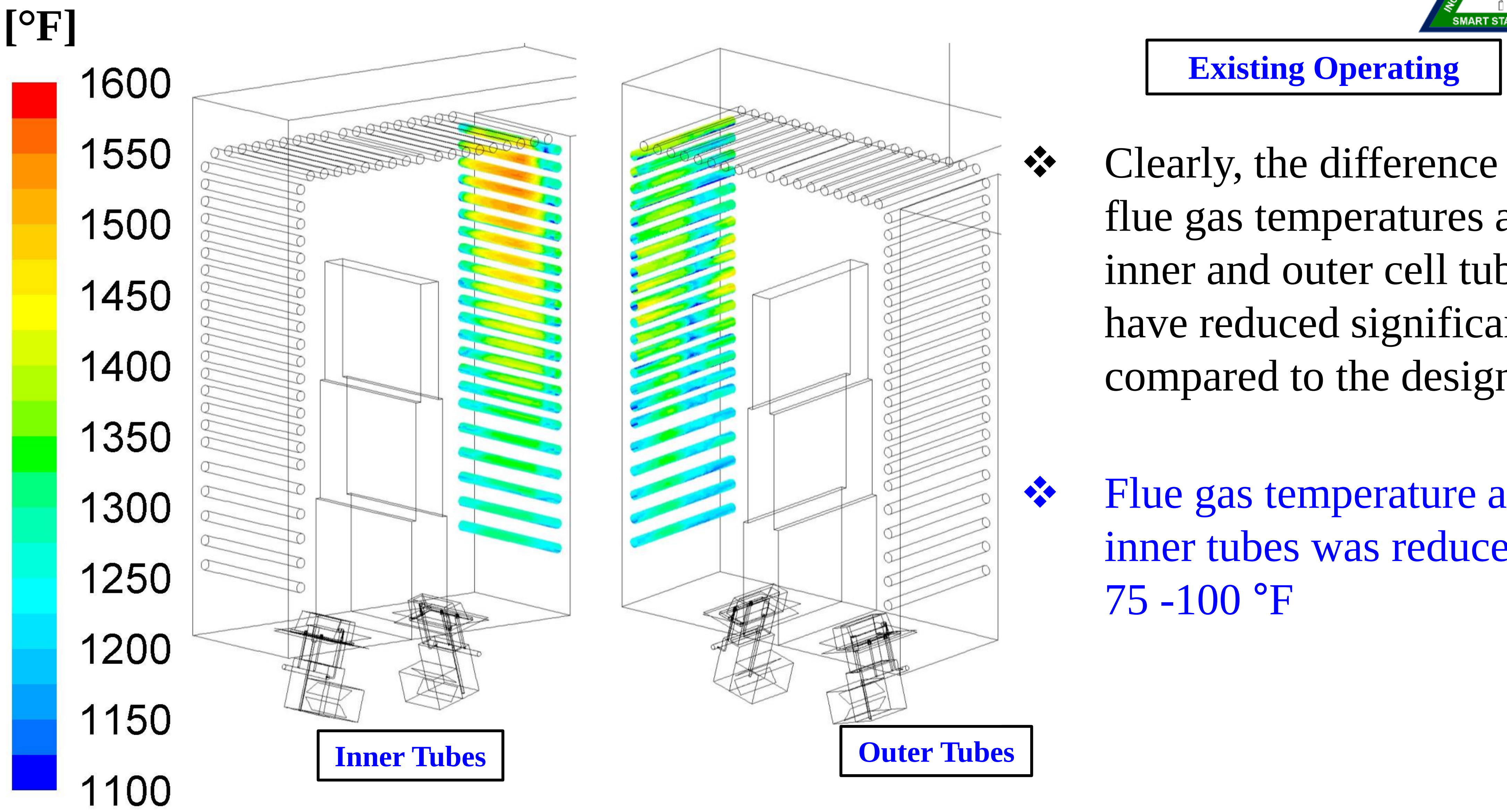
Existing Heater Operating Observation

- Current operating pressure drop is 210 psi (lower by 140 psi)
- Heater outlet temperature is 915°F (lower by 35 F)
- The flue gas approach temperature to Coker feed is 250-300°F, which is very high
- Total firing rate in the heater is 18% higher than the design firing rate.

Parameters	Units	West Outer Cell	West Center Cell	East center Cell	East Outer Cell
Design Firing Rate	MMBtu/hr	36.0			
Average Firing Rate	MMBtu/hr	47.3	39.2	37.9	45.1
Firing Rate for CFD model	MMBtu/hr	3.0	2.3	2.3	3.0



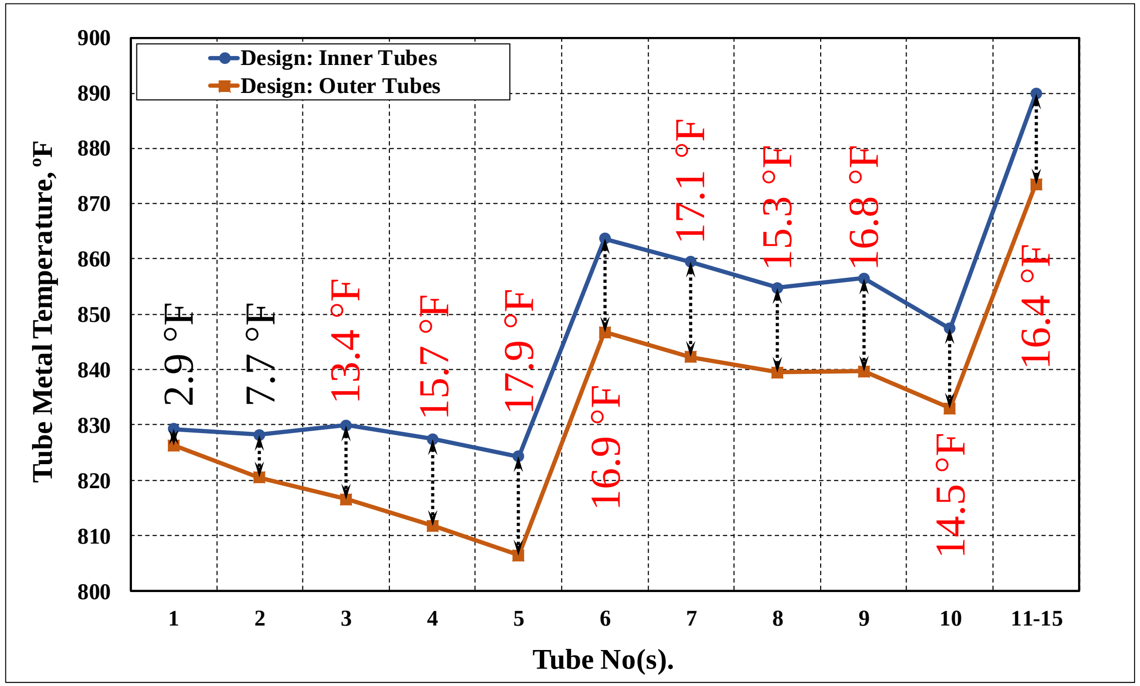
Flue Gas Temperature around Tubes



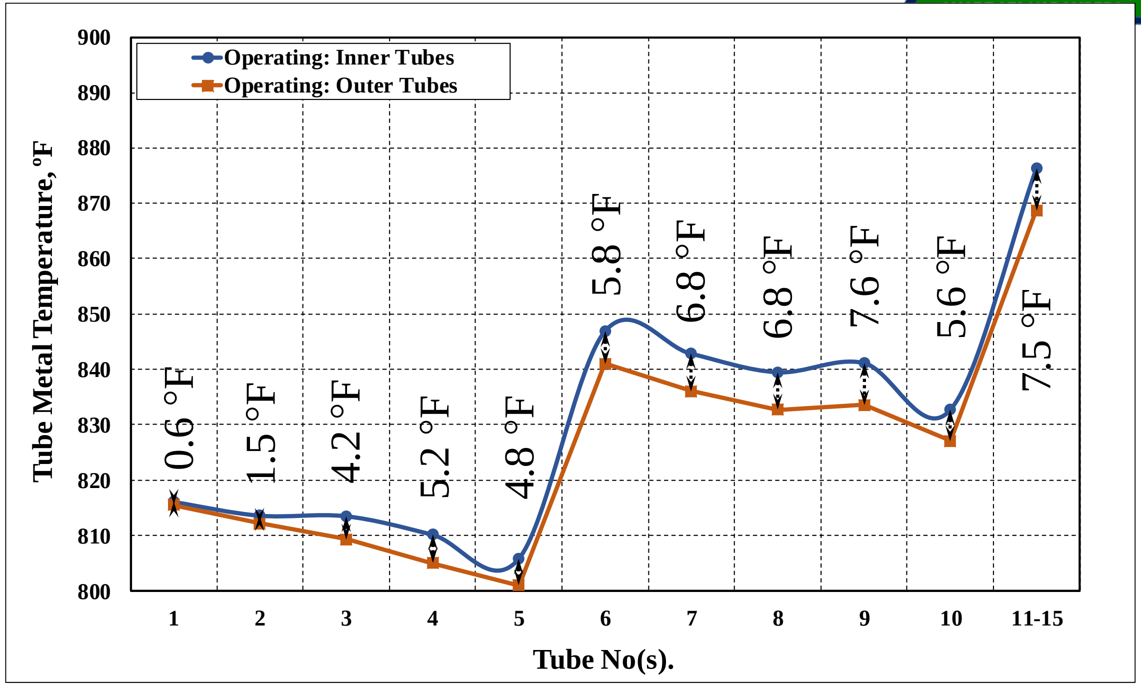
- ❖ Clearly, the difference in flue gas temperatures around inner and outer cell tubes have reduced significantly as compared to the design case

- ❖ Flue gas temperature around inner tubes was reduced by 75 -100 °F

TMT Comparison with Existing Design

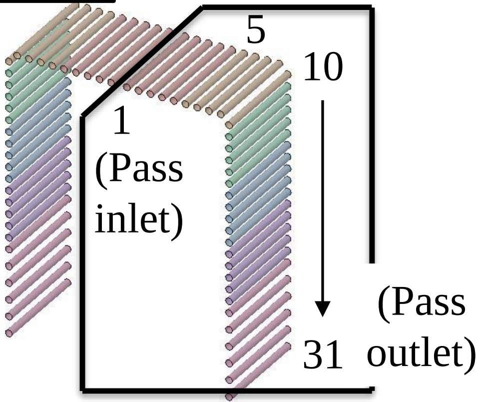


Existing Design

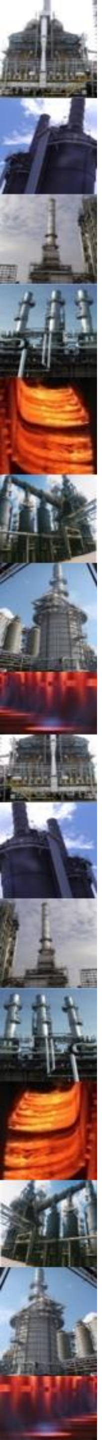


Existing Operating

TMT difference between the inner and outer tubes has decreased for each of the tubes for the operating case where inner cell burners fire 20% lower than the outer cell burners.

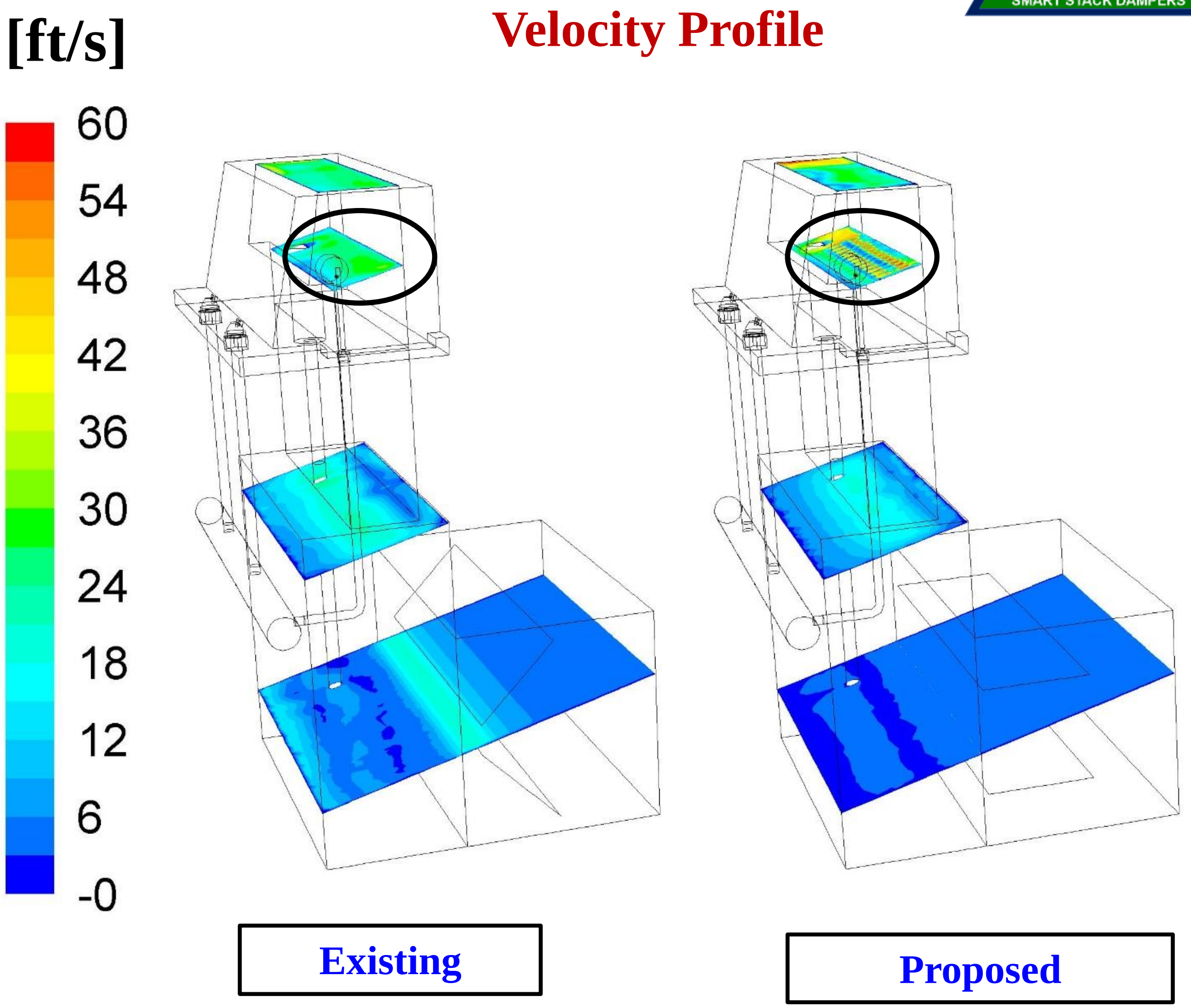


Comparison is done only for roof tubes and few tubes in the top section of the heater

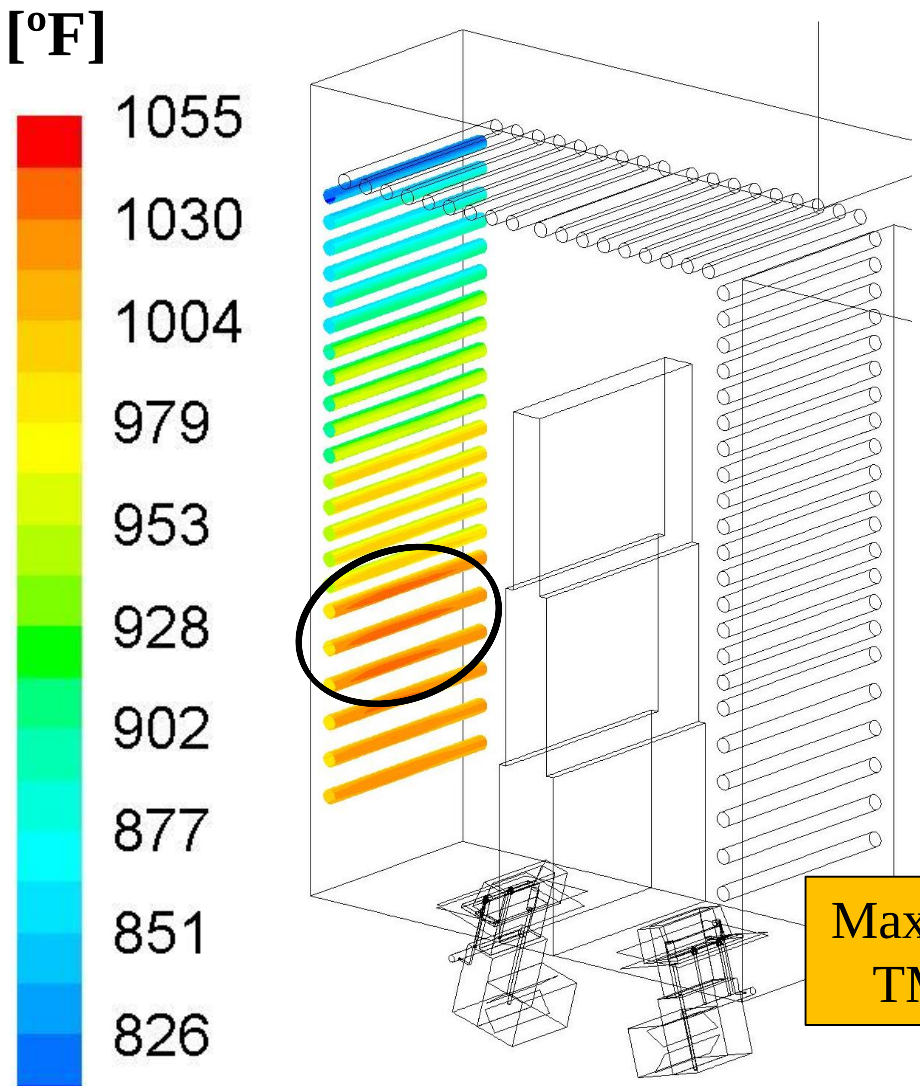


Burners Modification

- Existing burners were not utilizing the full heater floor draft available as well as full fuel gas pressure available at the tips.
- To improve the flame pattern and heat distribution in the radiant section, a pressure drop plate was installed at the burner throat
- This increases the air side pressure drop, improves the fuel air mixing and gives a better flame pattern



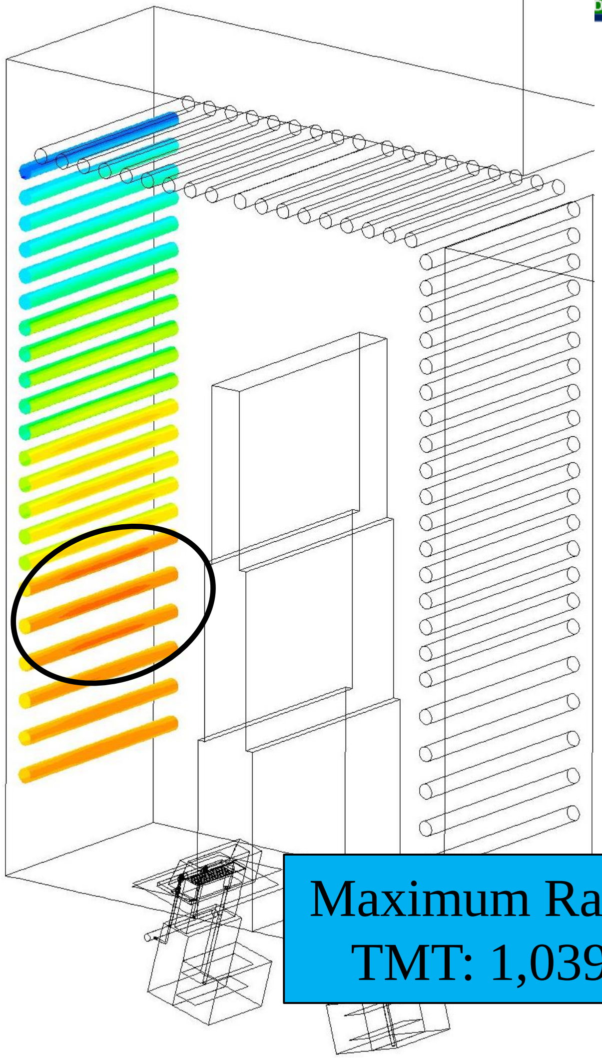
Radiant TMT profile- Outer Tubes



Maximum Radiant TMT: 1,044 ºF

Existing

Reduction in TMT is observed on these radiant tubes with burner modification



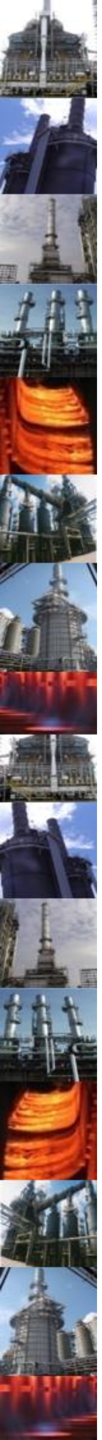
Maximum Radiant TMT: 1,039 ºF

Burner Modification

Radiant Re-Tubing Proposed Options

<table>
<tr><th></th><th>Tube Details</th><th>Total No. of Radiant Tubes</th><th>Material</th></tr>
<tr><td>Existing</td><td>3.5” NPS Sch 80</td><td>62</td><td>9 Cr-1Mo Material</td></tr>
<tr><td>Proposed Option-1</td><td rowspan="2">4” OD, 0.4” MWT</td><td rowspan="3">66</td><td>9 Cr-1Mo Material</td></tr>
<tr><td>Proposed Option-2</td><td>SS347H Material</td></tr>
<tr><td>Proposed Option-3
(Finalized Option)</td><td>4.25” OD, 0.5” MWT</td><td>9 Cr-1Mo Material</td></tr>
</table>

- Upgrading the tube material to SS-347H increases spalling temperature to 1,300°F. SS347H tubes can be operated up to 1,500°F design tube metal temperature
- The arch tubes for all the proposed options are shifted closer to arch refractory.



Radiant Coil Re-Tubing

Existing Design

- No. of radiant tubes: 62 per cell
- Tube size: 3.5” NPS Sch 80
- Tube length: 60 ft 9 inches
- Heat transfer area: 7,770 ft^2
- Tube material: A335 Gr. P9
- Tube are approaching end of life
- Low roof tubes elevation
- High radiant TMT

Final Proposed Design

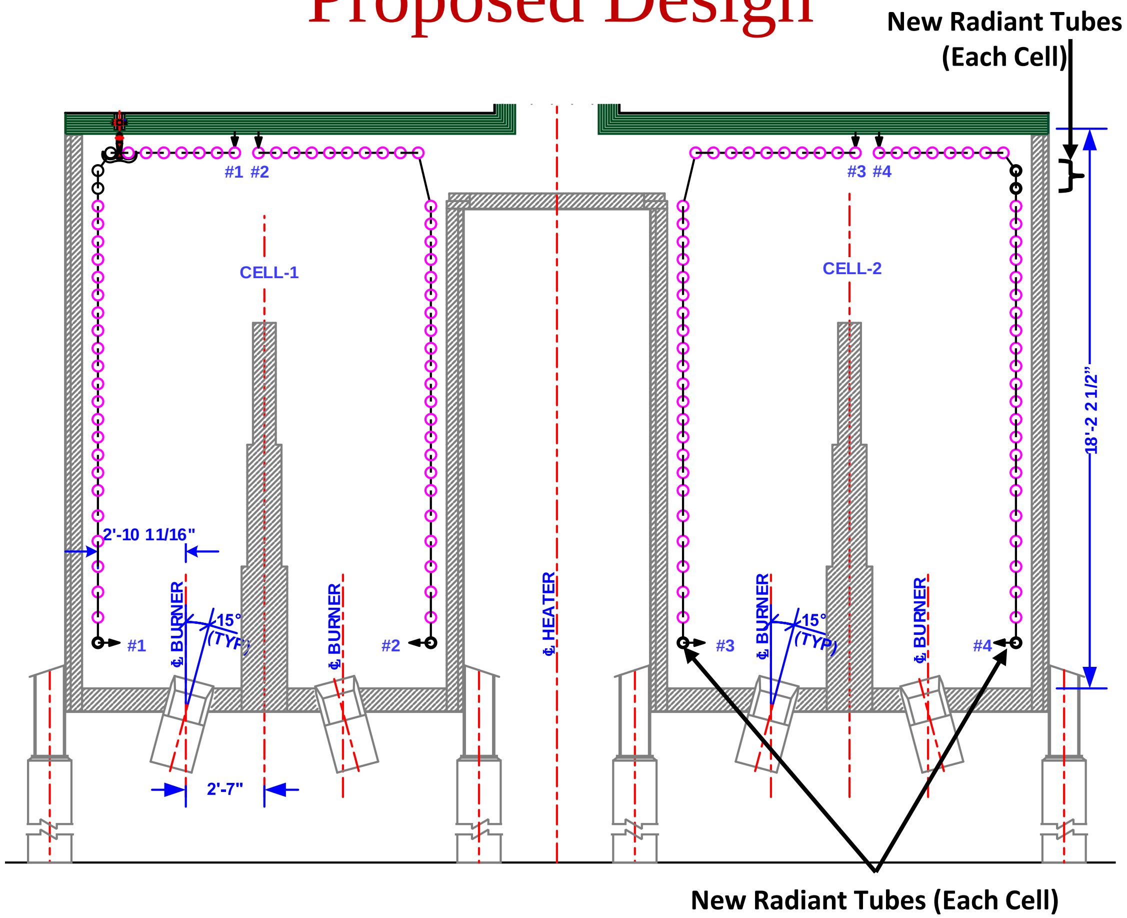
- Total radiant tubes: 66 per cell
  - Addition of 4 new radiant tubes
  - 2 tubes installed at outlet and 2 at roof
- Tube size: 4.25” OD, 0.5” MWT
- Heat transfer area: 8,922 ft^2
- Tube material: A213 Gr.T9
- Roof tubes will be shifted closer to arch by 16”

Radiant Heat transfer Area increased by 15% in the heater.

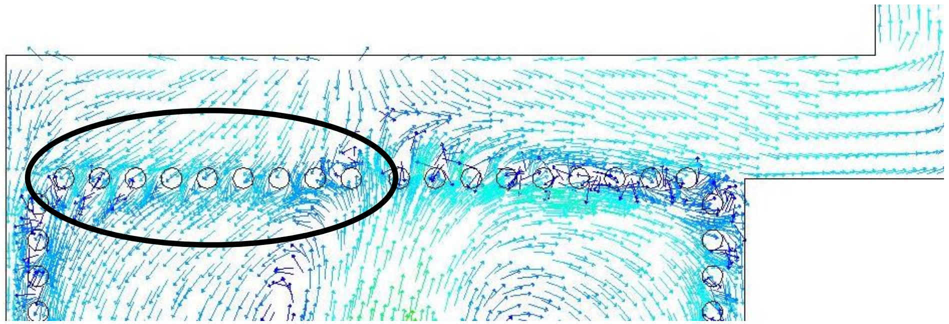
Raising of Roof Tubes

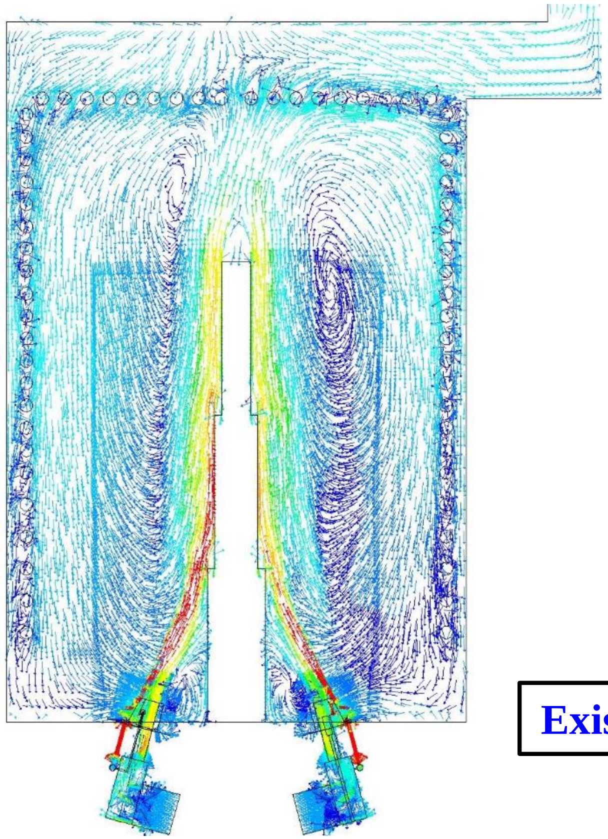
- The ultralow NOx burners currently installed have very long flames
- The burner to roof tubes distance barely meets the minimum distance between burner and roof tubes specified by API-560
- The existing radiant tubes at the roof will be shifted up towards the arch, such that the tubes are backed by the refractory to reduce flame impingement on the tubes
- This will move the roof tubes out of the flue gas path to the convection section

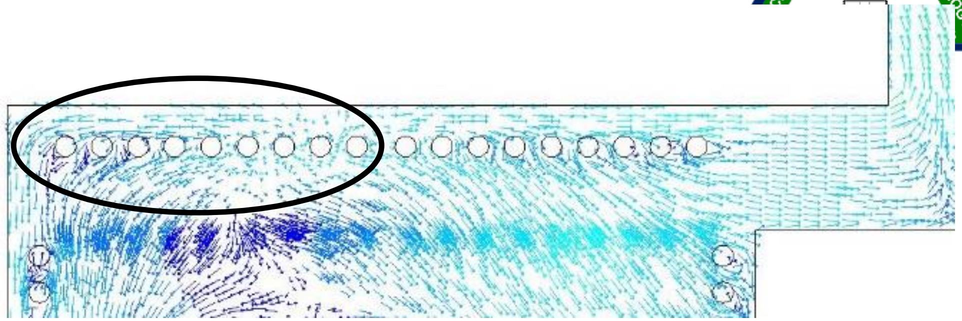
Proposed Design

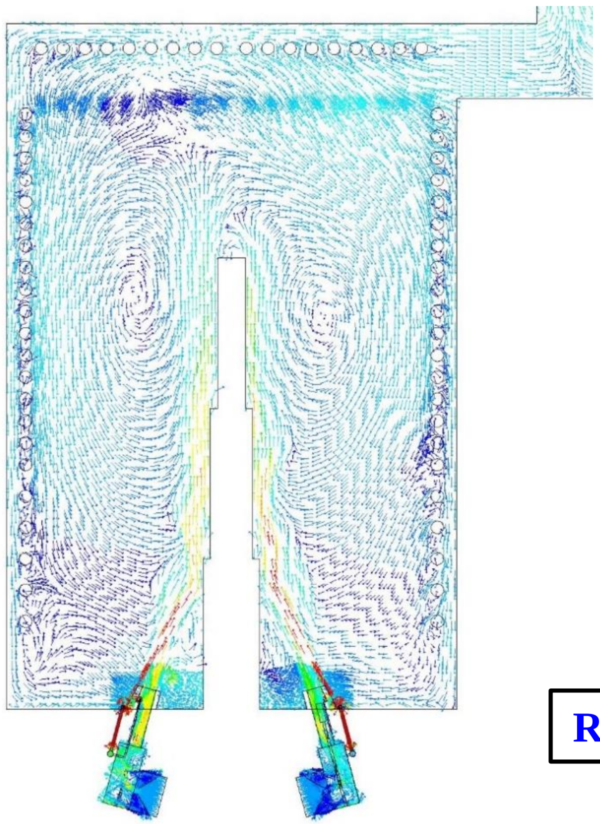


Flue Gas Velocity Vectors









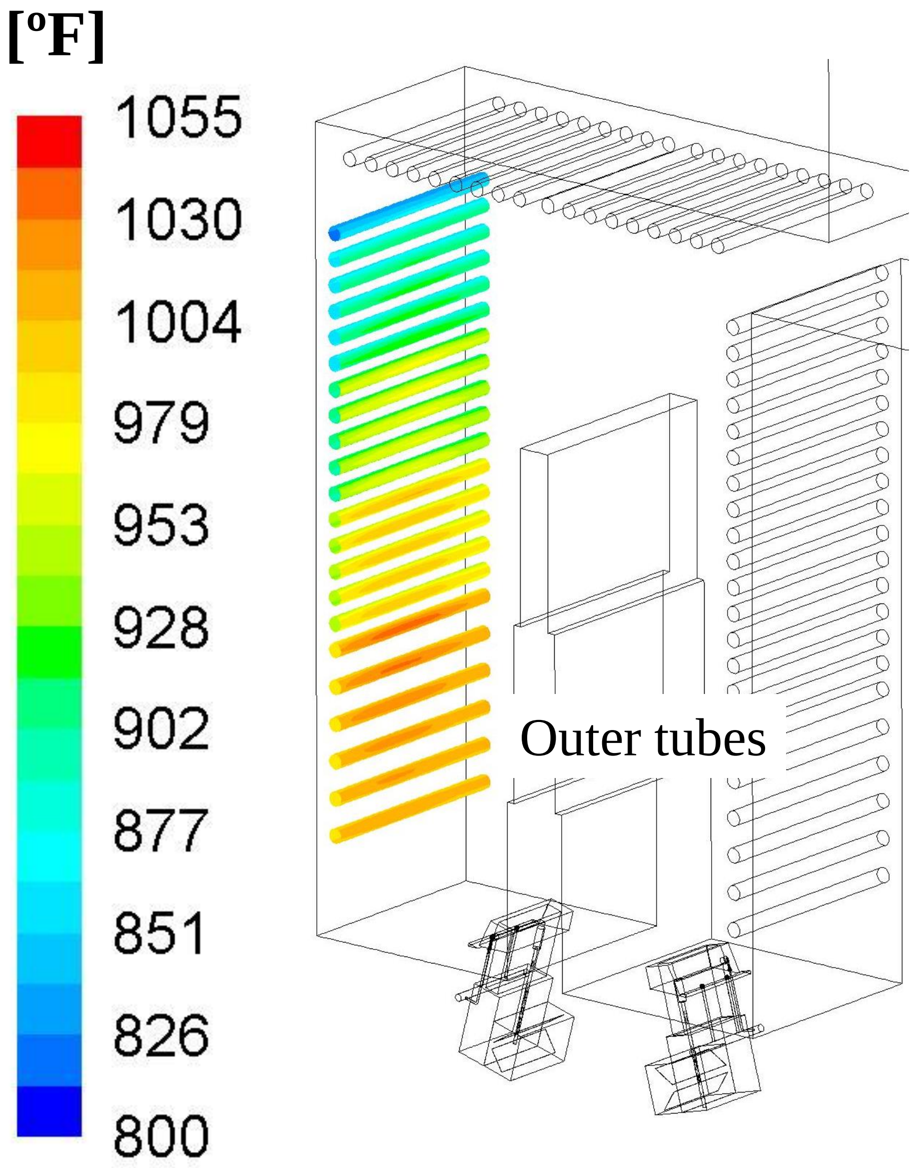
Recirculation around roof tubes has reduced for raised tubes case

Longer flue gas recirculation path is observed in the proposed case with raised roof tubes

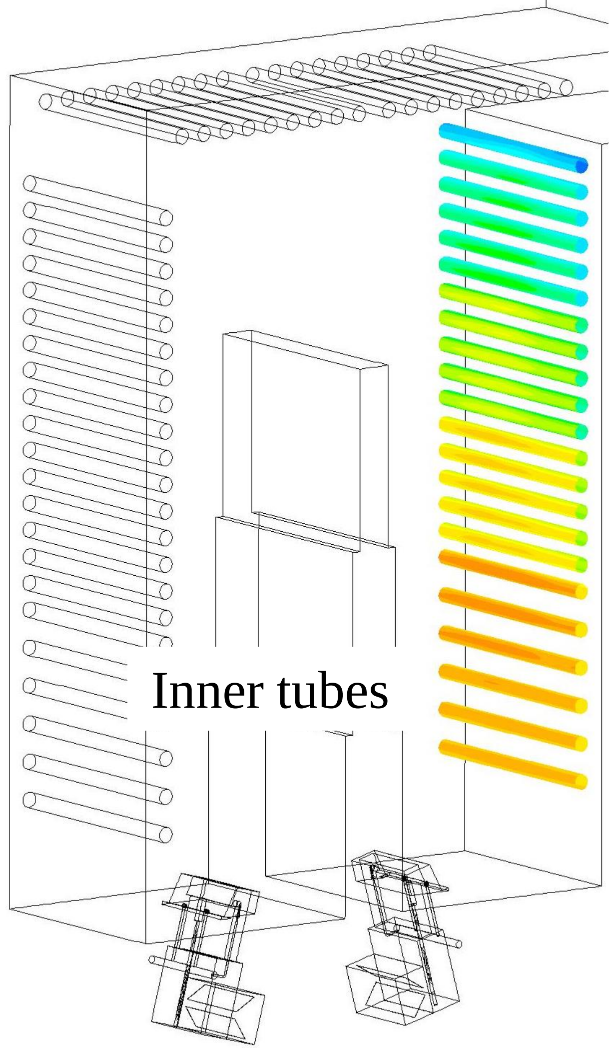
Existing

Raised Tubes

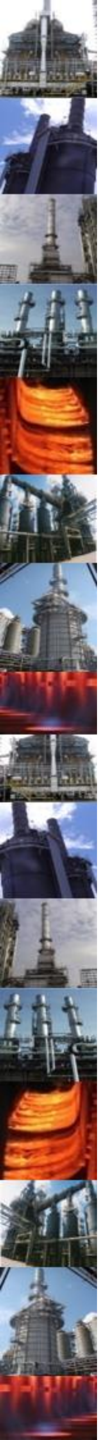
Radiant TMT profile



TMT profiles for inner and outer tubes are almost identical. Slight reduction in maximum TMT



Raised Tubes



Proposed Design Advantages

- Radiant heat flux is reduced from 9,648 Btu/hr.ft^2 to 8,723 Btu/hr.ft^2
- The additional area provided increase the heater capacity and enable to fire harder
- Fluid mass velocity increased from 296 lb/sec.ft^2 to 347 lb/sec.ft^2, leading to lower coke formation

❖ Radiant coil pressure drop within allowable limits (350 psi)

  - Calculated pressure drop in proposed design is ~20% higher than existing

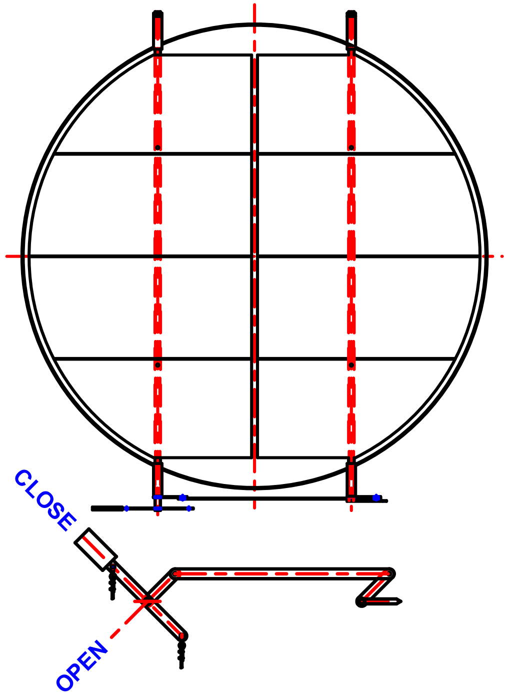
Existing vs Proposed Operating SOR Cases

Parameters	Units	West Heater SOR Case	
		Existing	Proposed
Total Heat Duty	MMBtu/hr	94.41	94.51
Process Heat Duty	MMBtu/hr	82.83	83.18
Charge Flow Rate	lb/hr	284,683	284,683
Outlet Temperature	°F	915.2	915.2
Coil Pressure Drop	**psi**	**213.8**	**251.8**
Bridge Wall Temperature	°F	1,447	1,416
Radiant Heat Duty	MMBtu/hr	62.63	63.81
Radiant Heat Transfer Area	ft^2	7,770	8,922
Average / Maximum Radiant Heat flux	$Btu/hr/ft^2$	8,060 / 14,991	7,152 / 11,587
Fluid Mass Velocity in Radiant Section	**$lb/sec/ft^2$**	**320.3**	**375.2**
Radiant Coil Pressure Drop	**psi**	**186.4**	**226.5**
Maximum Radiant Tube Metal Temp.	**°F**	**966.4**	**981.6**

Stack Damper Replacement

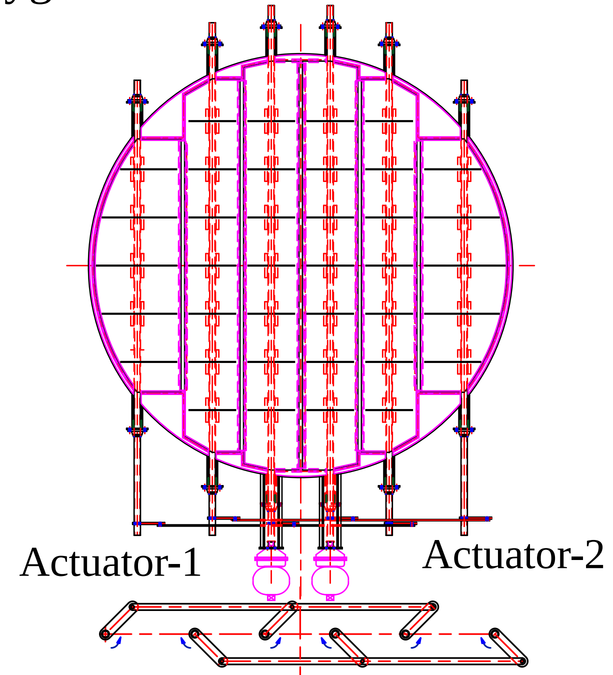
Existing

- Stack is oversized
- Two blade Damper
- Pneumatically operated
- Heater is operating at ~ (-0.3) to (-0.5) in WC
- Unable to provide accurate draft control



Proposed Smart Stack Damper

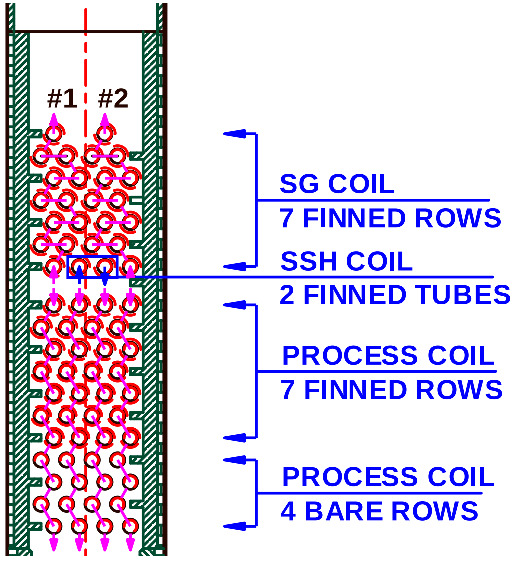
- ❖ New Damper with 6 blades and two actuators
- ❖ Two actuators link the alternate blades
- ❖ Better controlling characteristics
- ❖ Allow more pressure drop in stack
- ❖ Maintain proper draft at reduced heater loads
- ❖ Excess oxygen in firebox will be reduced



Convection Tubes

Existing Design

- 44 tubes with 3.5” NPS Sch 80
- Tube Pitch - 8”(H) x 8”(D)
- Tube Material – A335 Gr.P9
- Fin Details – 0.75/1” ht. x 0.06” thk x 2/3/4 FPI.



Proposed (Not Executed)

❖ Increased heat transfer area, higher efficiency

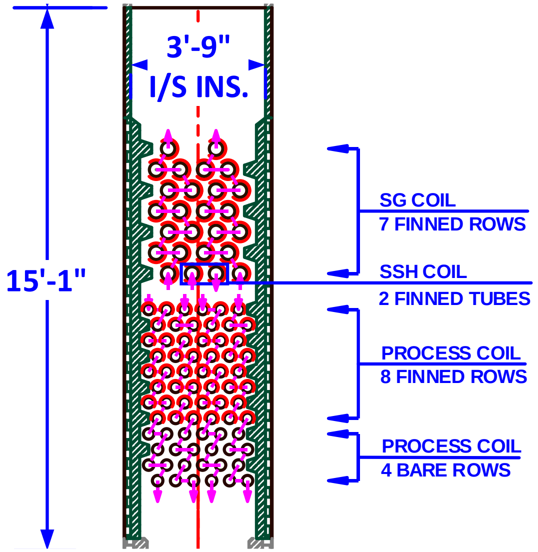
❖ Flue gas approach temperature reduced by 170°F

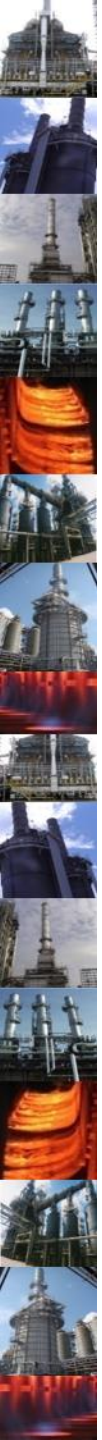
❖ Higher fluid mass velocity of 355 lb/sec-ft^2 to prevent coking

❖ Higher fin configuration for waste heat recovery section to recover more heat

❖ Firing rate reduced to 135.7 MMBtu/hr

- 72 tubes with 3” NPS Sch 40
- Tube Pitch - 6”(H) x 6”(D)
- Tube Material – A335 Gr. T9
- Fin Details – 0.5/0.75” ht. x 0.06” thk x 5 FPI.





Thank You

- We hope you will find our presentation helpful and informative
- Questions and comments are welcome