Coke Drum Flow Distributions

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Coking.com
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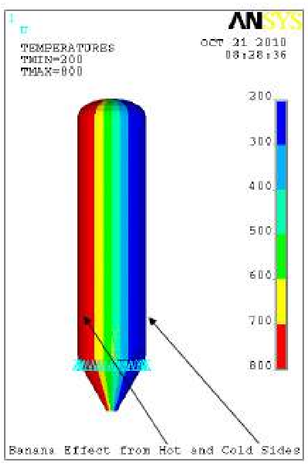
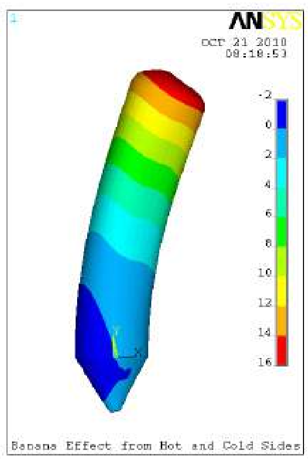
Overview

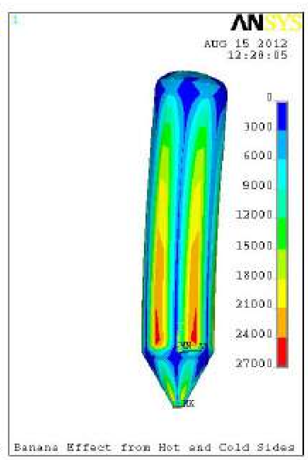
- Coking process – flow behavior
- Simulation methods for coke drum flow behavior
- Simulation Results (Traditional, Side Inlet, Dual Inlet)
- DeltaValve CFD Design
  - Simulation Results
  - In situ measurement results



Contour plot of temperature



Contour plot of deflection



Contour plot of stress

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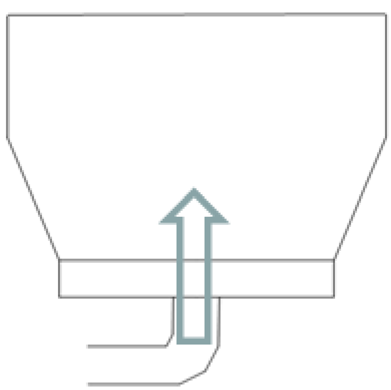
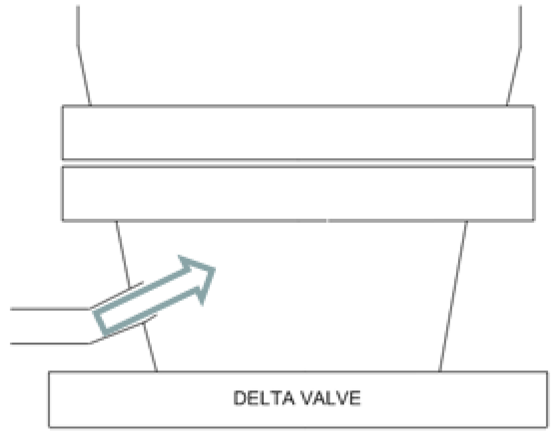
Coke Drum - Inlet Feed

Traditional inlets:

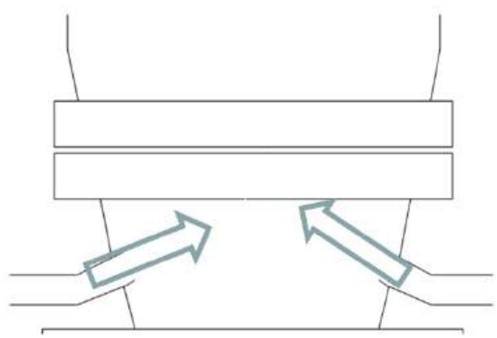


Bottom Feed Entry

- Difficult to remove coke



Side Feed Entry



Dual Side Feed Entry

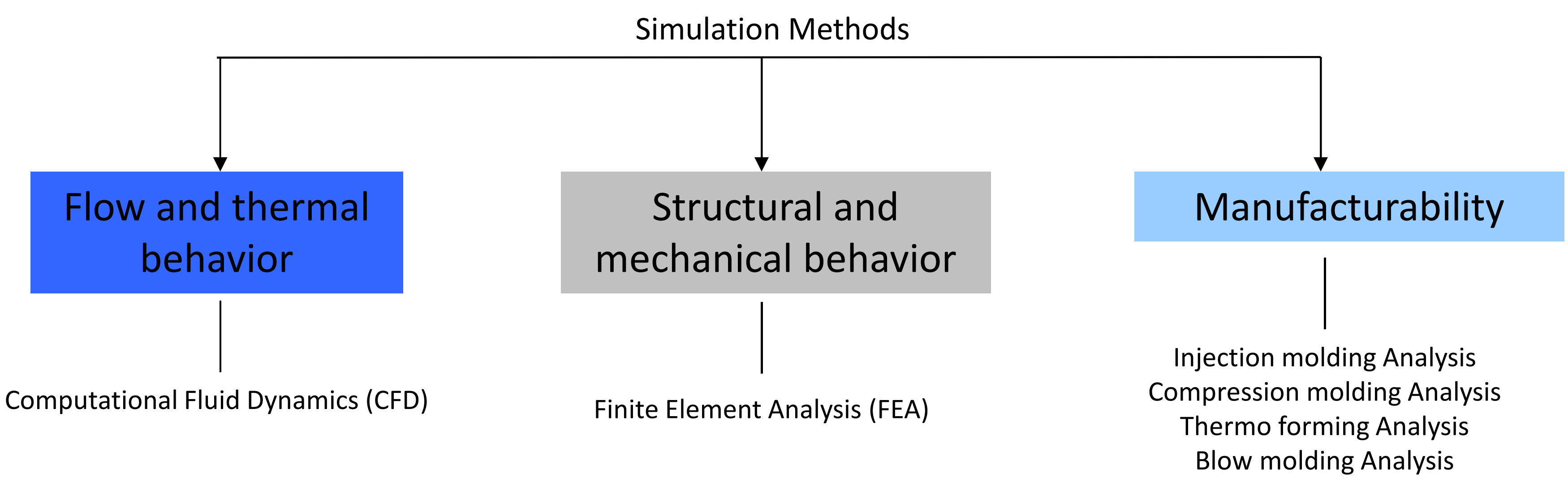
- The inlet feed distribution determines the formation of coke bed
- The coke bed formation in turn determines the flow path of VRC and also the quench water.
- Temperature measurement data suggests quench water flows near the walls of the drum
- This creates greater stress in shell/cladding bond and skirt weld.
- **How do we influence the feed stream distribution in the coke drum?**

Analysis Methods

First principle calculations→ **Lumped parameter estimation →** ***Empirical methods + first principle methods***

Detailed Simulations:

Performance prediction
Details of geometry considered
Based on first principle of conservation of mass, momentum and energy
Complex models, appreciable computational effort.



Flow Analysis Method - Assumptions

The feed stream is a mixture of vapor and liquid.

Temperature=890 F and Pressure =15 psig			SI	Units
Vapor density	0.339	lb/ft3	5.44	Kg/m3
Vapor viscosity	1.10E-02	cp	1.10E-05	Pa.s
Liquid density	49.37	lb/ft3	792.49	Kg/m3
Liquid viscosity	0.894	cp	8.94E-04	Pa.s

Typical feed stream composition
(based on plant data)

The feed stream is a mixture of vapor and liquid; using the above fluid properties and a vapor weight fraction of 36.91% the feed stream properties are computed.

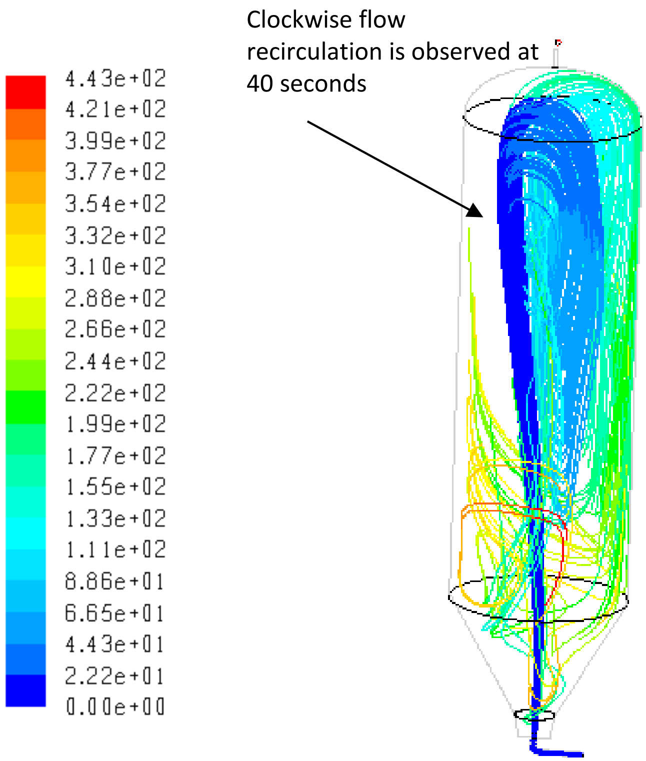
SES computed process conditions using above data			
Volume fraction of gas	0.98		
Average feed stream density	14.57	Kg/m3	
Average feed stream viscosity	2.90E-05	Pa.s	

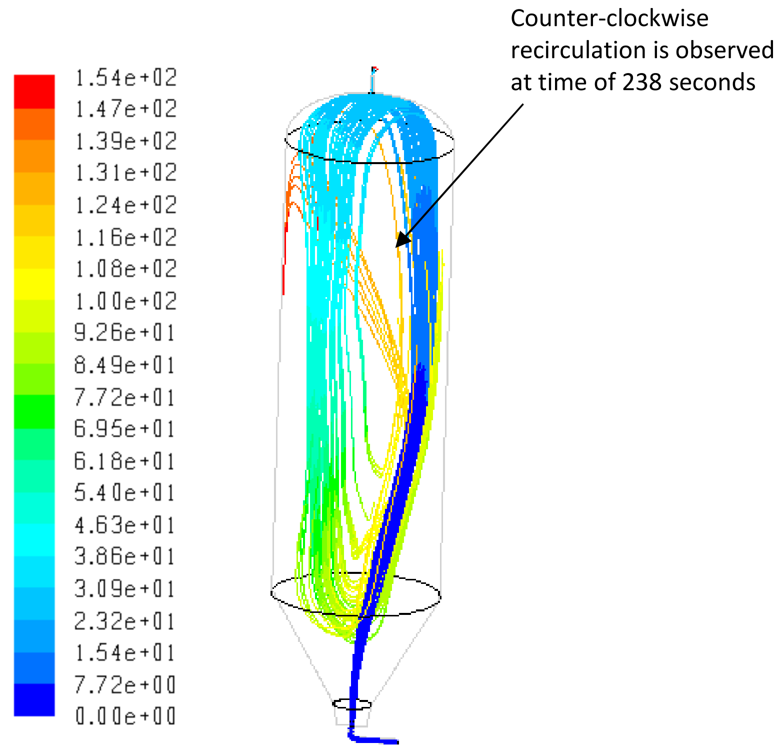
RESULTS

Results

Traditional Bottom Center Feed Nozzle

The simulations represent the beginning of the coking process when VRC vapor is injected into an empty drum





Flow path lines colored with residence time (seconds)

Flow at the top reverses direction with time.

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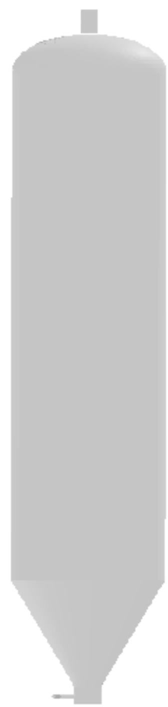
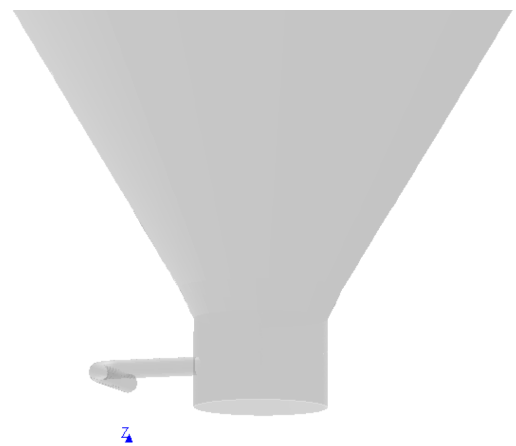
Results – Single Side Entry Inlet

Flow analysis results for the coke drum with single side entry inlet

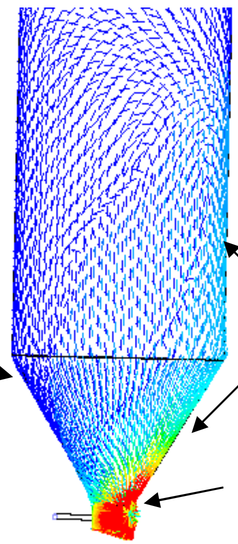


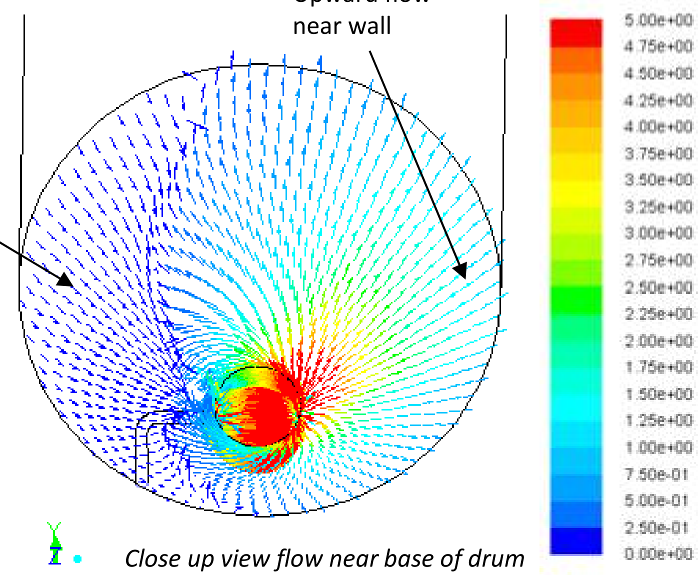


Close up view of single entry inlet

Results – Single Side Entry Inlet

Flow behavior at 40 seconds from the start is depicted below.



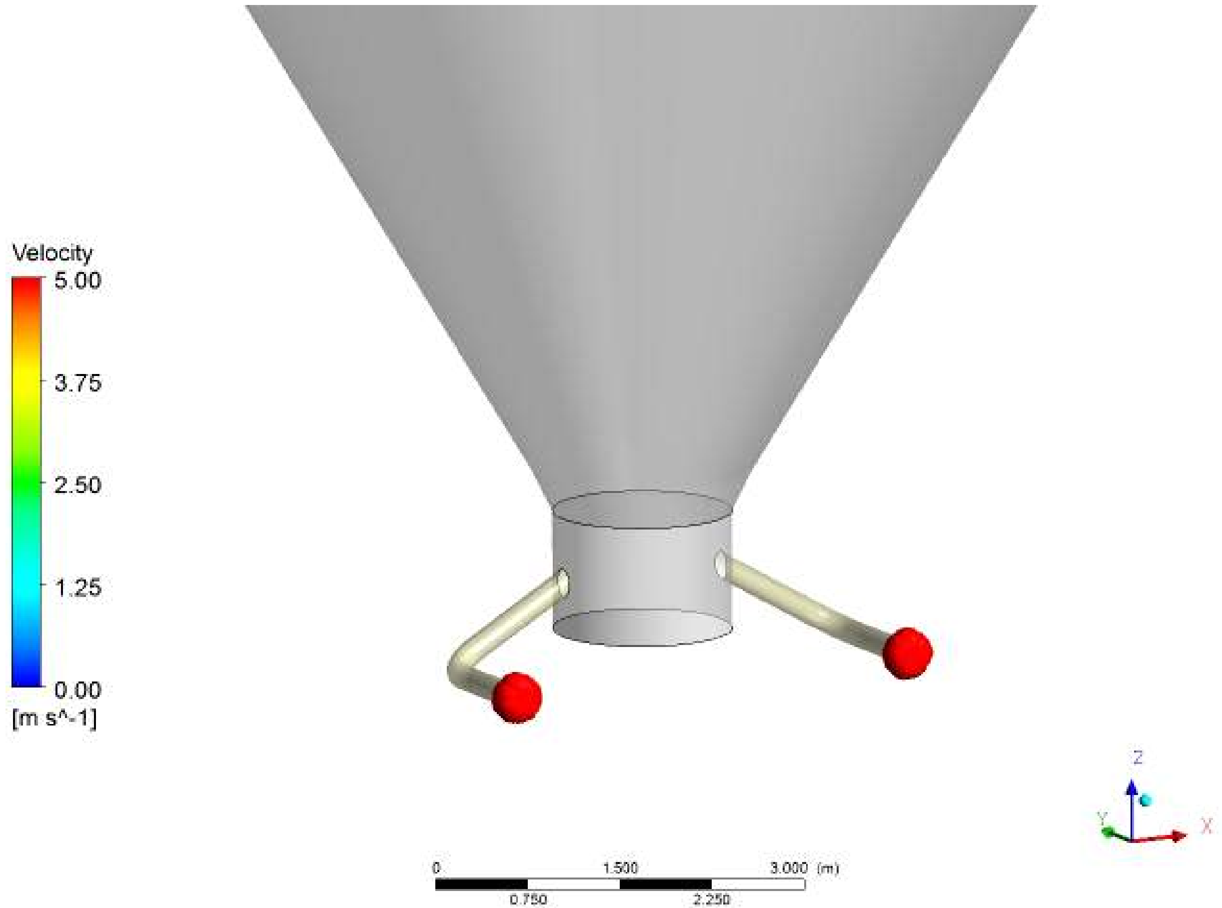


Close up view flow near base of drum

Velocity vectors colored with speed (m/s) Red
color denotes speed of 5m/s or higher

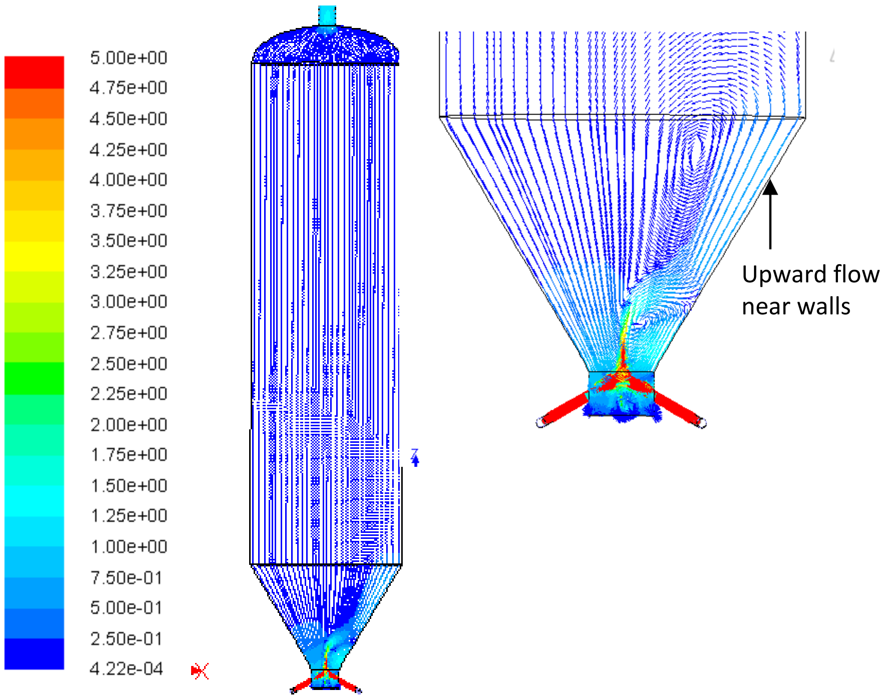
The analysis shows upward as well as downward flow at the walls of the coke drum.

Results – Dual Side Entry Inlets

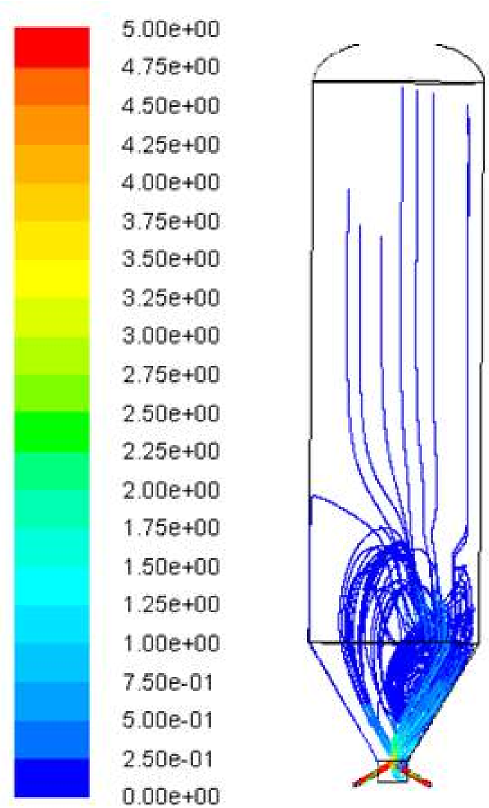


Results – Dual Side Entry Inlets

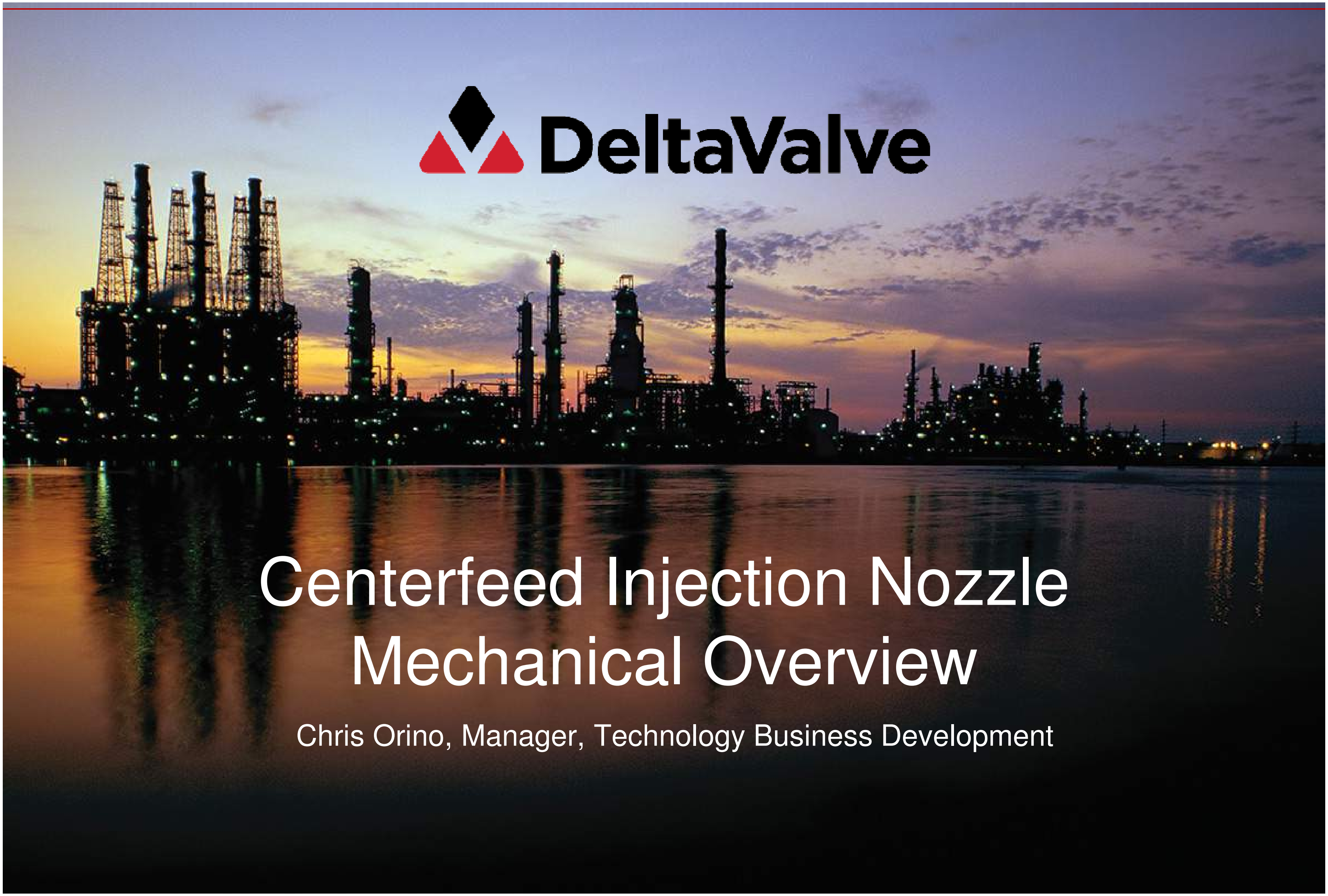
Flow behavior at 40 seconds from the start is depicted below.



Velocity vectors colored with speed (m/s) Red color denotes speed of 5m/s or higher



The analysis shows that even though the geometric arrangement of inlets is symmetric the flow inside the coke drum is not symmetric. The opposing jets of incoming flow generate flow instabilities that cause the flow to be biased towards one side. Upward flow at the walls of the coke drum is observed. The biasing of the flow and upward flow at the walls can result in localized hot spots and/or channeling.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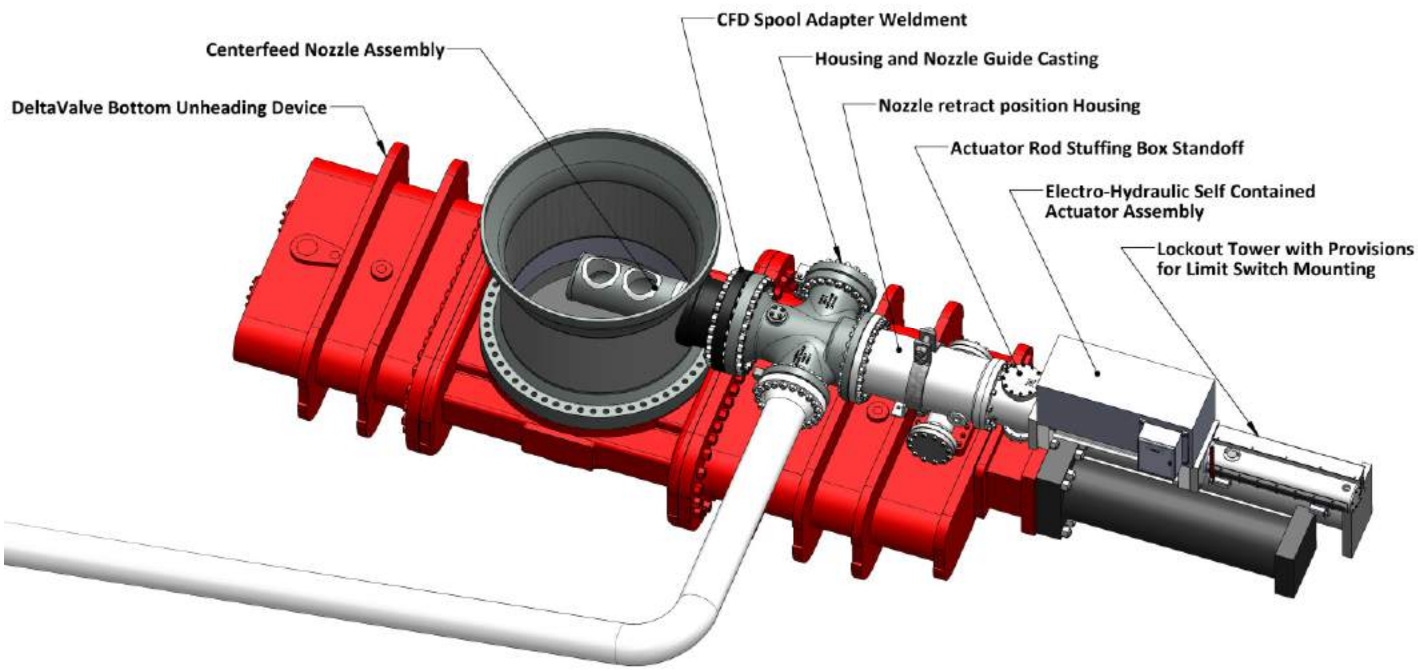
Centerfeed Injection Nozzle
Mechanical Overview
Chris Orino, Manager, Technology Business Development

Mechanical overview

- Centerfeed Assembly Overview
- Component identification and materials of construction
  - Drum spool
  - Retractable Nozzle
  - Main housing
  - Bonnet
  - Electric actuator
- Principals of Operation – extending nozzle
  - Forward thrust Belleville spring
  - Dynamic seat
  - Static seat
- Principals of Operation – retracted nozzle

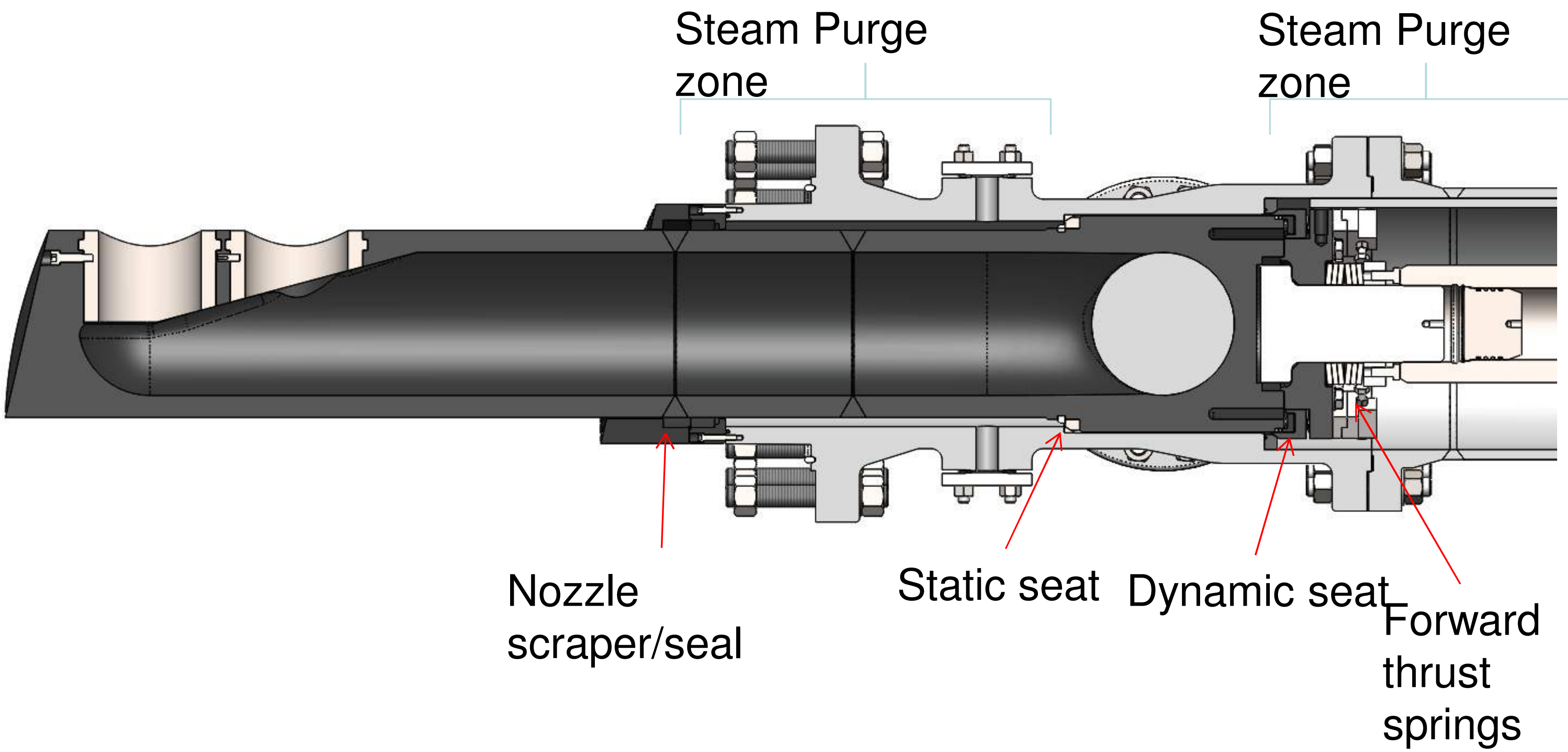
Mechanical overview

- Centerfeed Assembly Overview



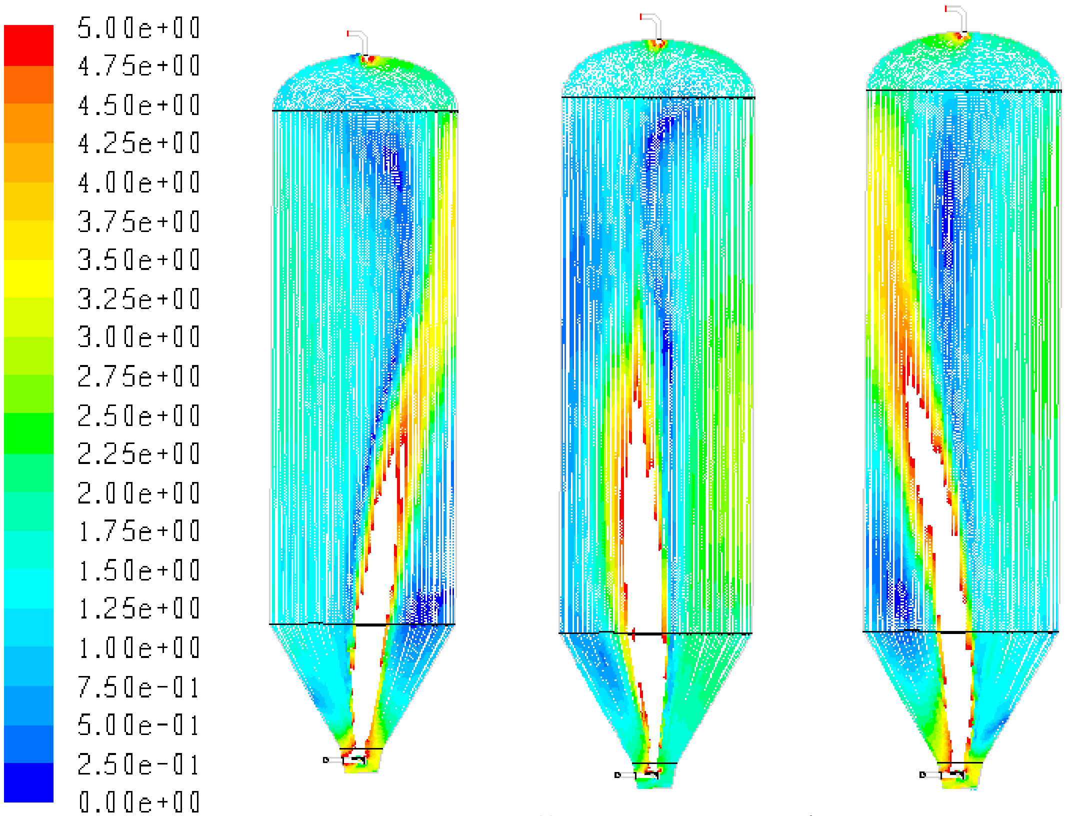
Mechanical overview

- Principals of Operation – Nozzle Extended



Results – Center Feed Nozzle

The simulations represent the beginning of the coking process when VRC vapor is injected into an empty drum



Velocity distribution at different time instants (indicating oscillation of plume)

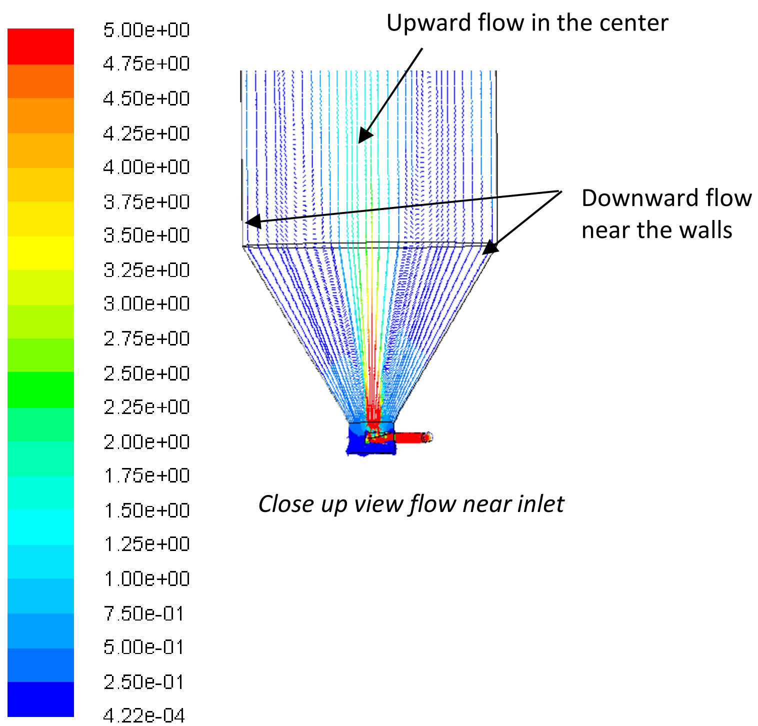
The loss factor associated with this configuration is 4.7 (as compared to 3.7 for the traditional nozzle). This results in 13% lower flow rate as compared to the traditional nozzle under the same supply pressure.

Velocity (m/s)

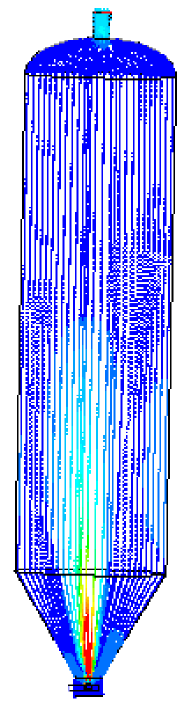
Red color denotes velocity of 5 m/s and the white areas next to red denotes regions of velocity higher than 5 m/s

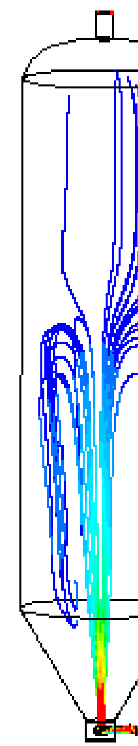
Results – DV New Concept Nozzle

Flow behavior at 40 seconds from the start is depicted below.



Close up view flow near inlet





Velocity vectors colored with speed (m/s).
Red color denotes speed of 5m/s or higher

The analysis shows the formation of a well centered plume of incoming VRC inside the coke drum. Upward flow in the center of the coke drum and downward flow near the walls is observed; impingement of flow on the walls (leading to possible hot spots or channeling) is not observed.

Courtesy of DeltaValve (DV) Oil and Gas Systems Division, CurtissWright Flow Control Corporation

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Increased Reliability

Several improvements reported after installing Center Feed Device (CFD):

- Improved top head safety by minimizing blowouts and geysers
- Minimized pressure spikes during quench cycle
- Reduced local hot-spots
- Overall reduction in vibration of the drum
- Maximized coke-drum life and minimized down-time and repairs (Reduced stresses in the drum wall, resulting in increased drum life, and a reduction in drum damage such as cracks, rippling, and the "banana effect".)

The average financial costs from lost production from a pair of coke drums ranges from $50,000 per day to $100,000 per day, an average repair can take 5 to 7 days.

The reduced number of shutdowns and repairs after installing CFD has resulted in savings of several $M.

The cost to replace a pair of coke drums is several $M. The extension in life of coke drum due to the CFD has also resulted in several $M savings.

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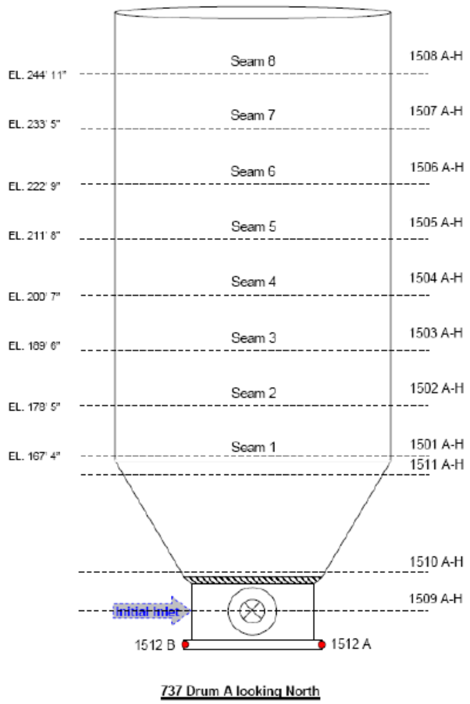
Retractable Center Feed Device

TI plots elevation 1510 – Above inlet in cone section on original drum

Chris Orino, Manager, Technology Business Development

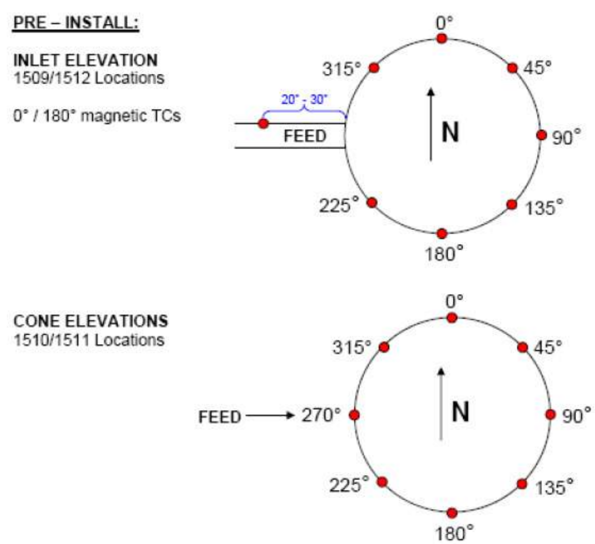
Center Feed Injection Field Testing

Vertical Thermocouple Locations

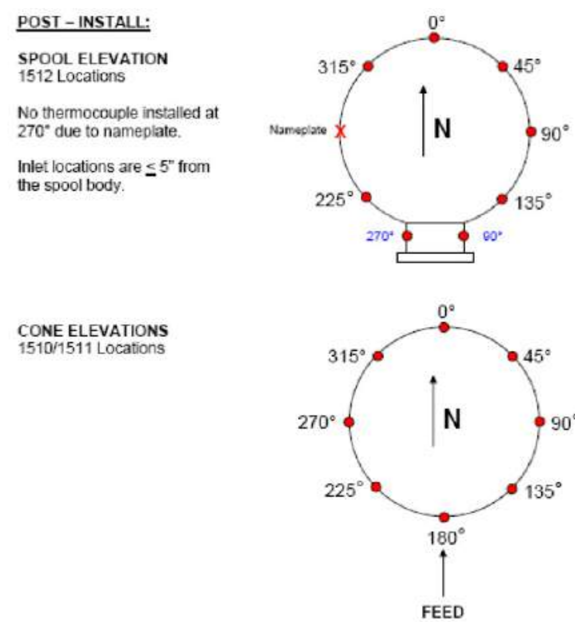


Radial Thermocouple Locations and Feed Inlet Orientation

Pre CFD Spool Installation



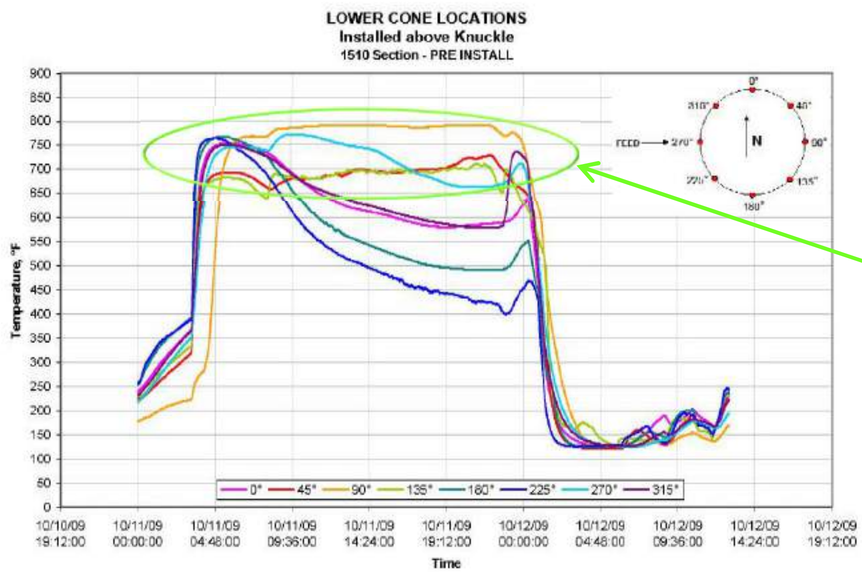
Post CFD Spool Installation



1510 Elevation TI Plot Discussion and Analysis

Discussion -1510 Elevation - No CFD Installed

TI plots elevation 1510 – Above inlet in cone section on original drum



- TI's opposite of feed line, and the 2 adjacent TI locations (45º (red), 90º (orange), and 135º (green)) are relatively constant between 800ºF and 700ºF throughout entire cycle.
- TI location 270º (light blue line) directly above inlet also remains high throughout cycle.
    - The high temperature readings at these TI locations indicate flow channeling is occurring throughout cycle, preventing coke build up on walls from occurring at these TI locations, resulting in direct heating of the drum walls

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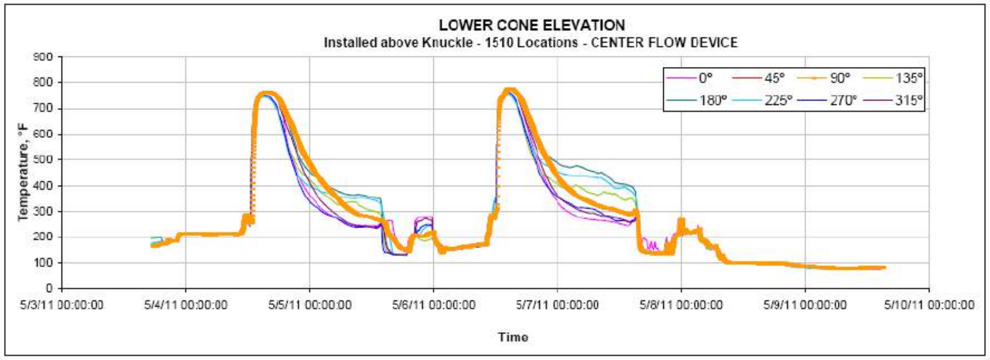
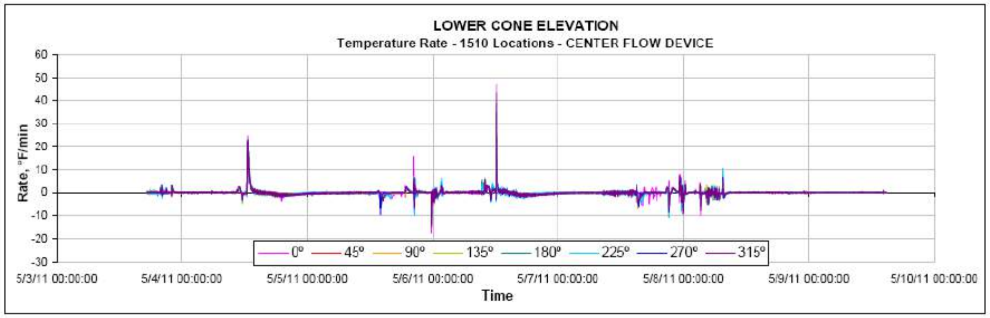
1510 Elevation TI Plot Discussion and Analysis

Discussion -1510 Elevation - CFD Installed

TI plots elevation 1510 – Above inlet in cone section on original drum



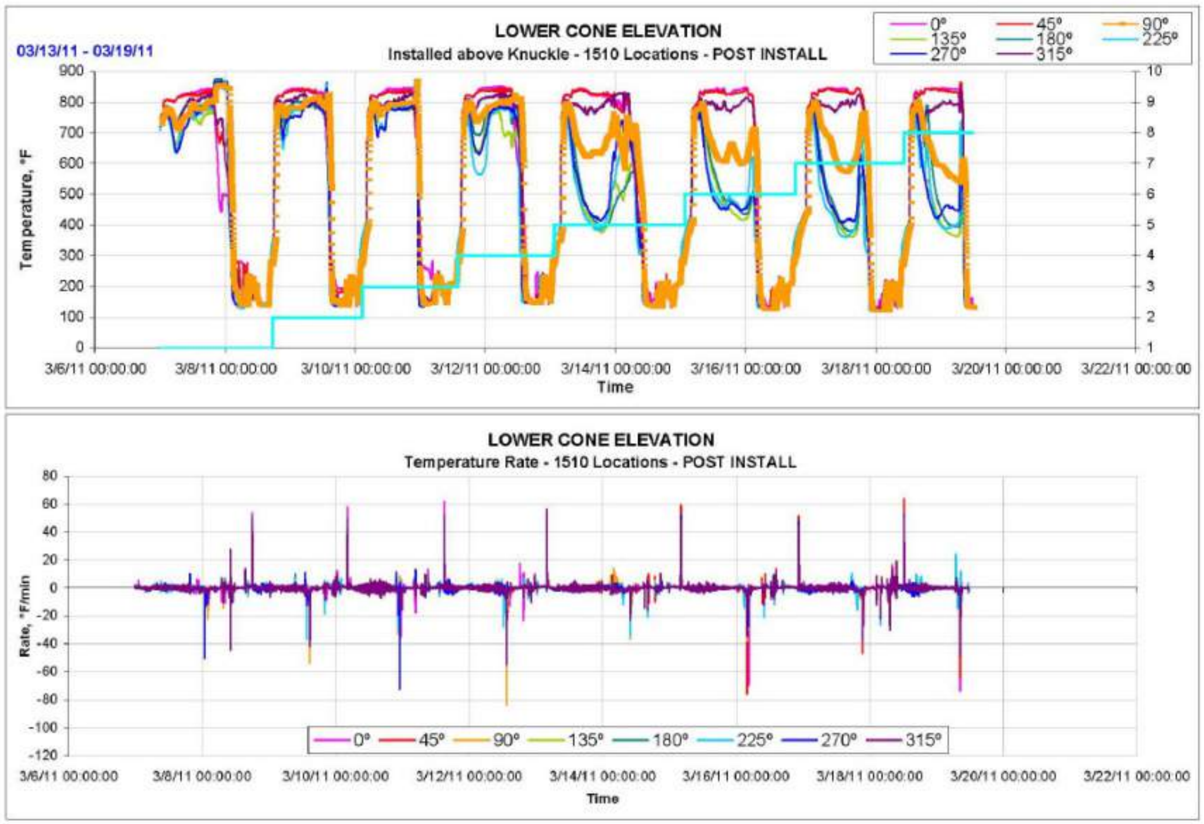


- After center-feed is installed all TI positions track very close to each other, within 100ºF
- After initial feed starts, all TI's increase to a maximum temperature of 750ºF, but shortly after all TI's track downward together.
  - This indicates no flow channeling is occurring along the wall, allowing an insulating layer of coke build up on drum wall
- At the time of quench the temperatures of the TI's are in the 200ºF to 400ºF range
  - Because of the lower temperatures just before quench, the rate of temperature change is dramatically reduced
  - Lower rates of temperature change directly relate to lower stresses in the drum wall.

TI plots elevation 1510 –Above inlet in cone section on original drum

Pre installation of Center Feed

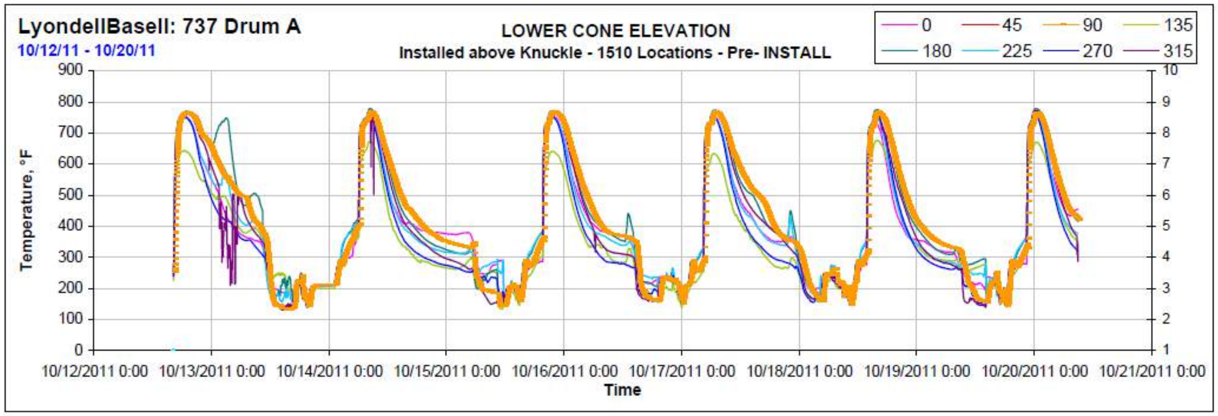
- TI opposite (or on either side) of feed line remains near 800F
- TI's adjacent to inlet show large temperature differential form TI opposite feed line in some cycles (some cases show 400F less)
- At time of quench multiple TI's at or near 800F
- Rate of temperature change at time of quench approaches -80F deg/min

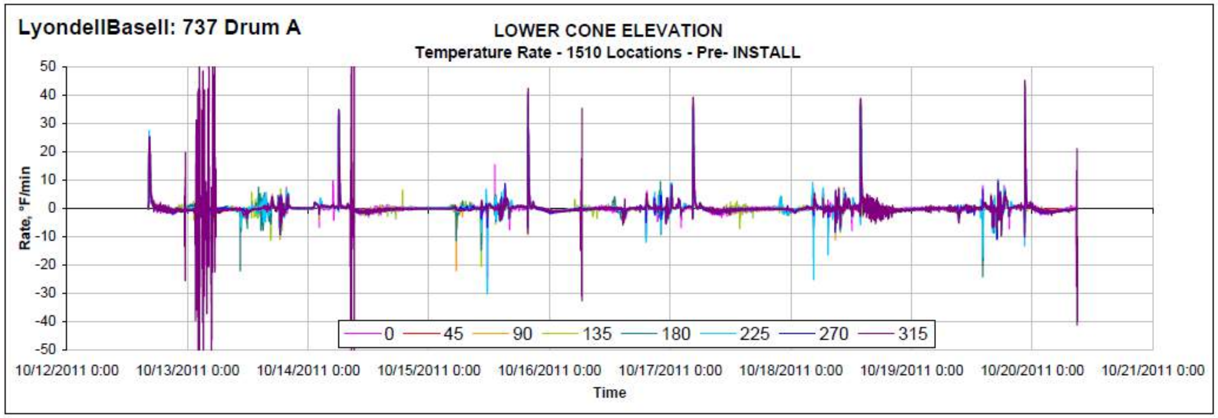


TI plots elevation 1510 –Above inlet in cone section on original drum

Post installation of Center Feed

- TI in most cases all within 50F or each other
- TI's all track downward from beginning of cycle to end.
- TI's at quench show temperature of 300F to 400F
- Because of lower temperatures at time of quench, rate of temperature change dramatically lower (-80F deg/min compared to -40F deg/min)
- Reduction in rate of temperature change = significant reduction in stress in drum wall





Thank You

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