KBC NextGen Performance®

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MORE PRODUCTION - LESS RISK!

# Coker Heater Optimization and Heater Fouling

May, 2013

# Introduction

- The fired heater is the main driver in the thermal cracking process we know as delayed coking
- There is a balance between the length of the heater run length (determine due to tube fouling) and the reliability/performance of the coke drums
  - The coke drum should be run as hot as possible – the hotter the better – but this requires a high heater outlet
  - A hotter the heater outlet will cause the heater to foul/coke faster
  - The heater fouling is a controlled event – you control how fast the heater will foul – you control the outlet temperature – but a cold drum and the problems associated with at cold drum are not controlled  and can cause extreme reliability/safety problems
    - Drum foam over
    - Drum hot spots
    - Drum fall outs

# Heater Overview

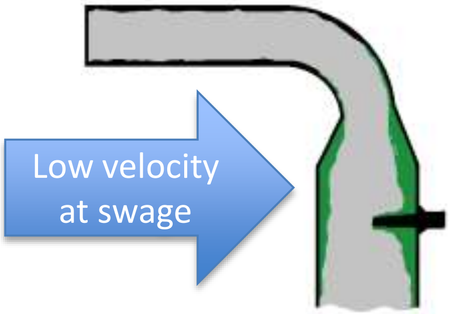
- How velocity steam affect heater operations – how much is enough
- How the coil outlet temperature location and reliability affects the fouling rate
- Heater balancing – how and why
- Transfer line design and maintenance
- Feed rate and fouling rates
- Recycle and external feeds (FCC slurry and other recycle streams) and fouling rates
- Burner design and flame patterns
- Decoking

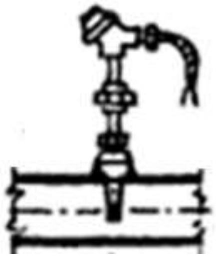
# Velocity Steam– How Much Is Enough

- Design values are between 1 to 2 wt% of the heater feed but this is highly dependent on the flow rates to each pass
- More steam is always better for the heater
  - When to stop
    - Drum velocity limits – too much steam can cause solids carry over from the drum
    - Flash zone section limits – the quality of the heavy gas oil is dependent on the wash zone operation including the vapor velocity in this section of the tower
    - Tower limits – tray jet flood – too much vapor traffic  can be created with excessive heater velocity steam but drum stripping is usually more significant than heater velocity steam
    - Heater removal limits – both cooling requirements and extra pressure drop on a overhead air cooler
    - Sour water limits – heater velocity steam will add to the sour water production from the coker
  - Where to inject the steam and why
    - Pressure drop limits in the heater – more steam will increase DP but not much in the convection section – however the steam is not needed in the convection and is only needed for reducing fouling in the lower radiant section
    - Heater transfer coefficient & tube inside fluid film temperature

# Coil Outlet Temperature

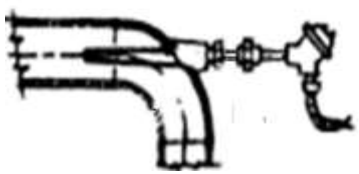
- Location Matters
  - Why is the temperature so critical
    - The actual coil out temperature is not critical but the drum inlet and out temperatures are critical but we control the heater at or near the coil outlet
  - Problem location
    - Locations that see fouling are bad places to put the TIC
    - TW perpendicular to small diameter pipe is a bad location
  - Possible alternate location
    - The 1st elbow in the heater outlet – is the best location
    - Metallurgy or special hardening should be required to prevent erosion
    - Some locations are using the process temperature two to four tubes back in the process



short thermowell

Straight run out of heater



longer thermowell

Badly installed thermowells can significantly effect heater performance

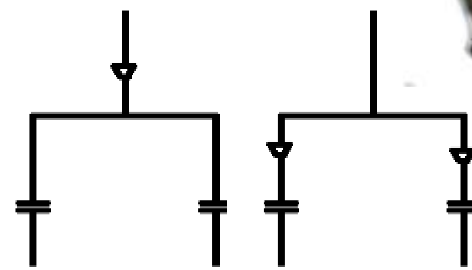
# Thermal Well Location – Temperature Control Locations

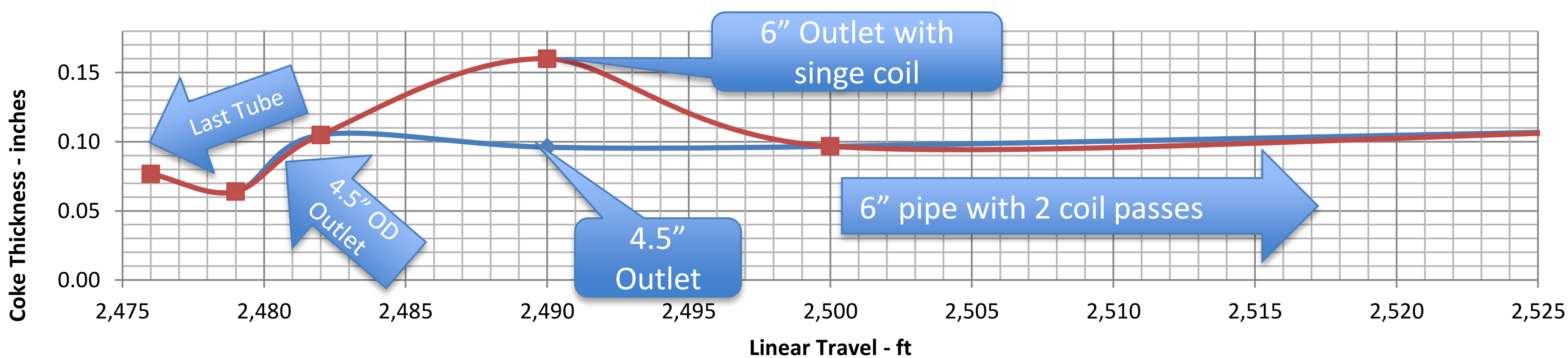
| | Linear Travel -ft | Fluid Temp. ºF |
|---|---|---|
| 14" Drum Inlet | 2,695 | 900 |
| 14"Transfer Line | 2,670 | 901.5 |
| 14" Switch Deck to Drum Inlet Piping | 2,650 | 903.8 |
| 8“ pipe common feed | 2,530 | 912.4 |
| 6“ pipe common feed | 2,500 | 915.5 |
| 4“ Heater Outlet | 2,490 | 917.3 |
| 4“ Heater Outlet | 2,482 | 919.1 |
| 4“ Heater Outlet | 2,479 | 920.5 |
| 4“ Radiant Tube 1 Outlet | 2,476 | 921.3 |
| 4” Radiant Tube 2 Outlet | 2,406 | 917.5 |
| 4” Radiant Tube 3 Outlet | 2,336 | 913.9 |
| 4” Radiant Tube 4 Outlet | 2,266 | 908.4 |
| 4” Radiant Tube 5 Outlet | 2,196 | 901.7 |
| 4” Radiant Tube 6 Outlet | 2,126 | 894.5 |

Range of control temperatures depending on location of TW

Actual Outlet

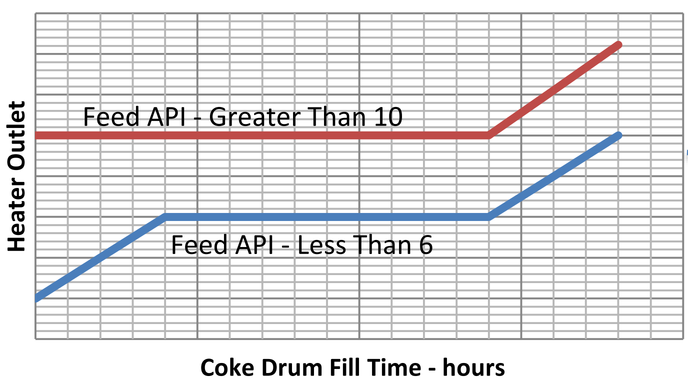
Where the line swages up is a small but important detail

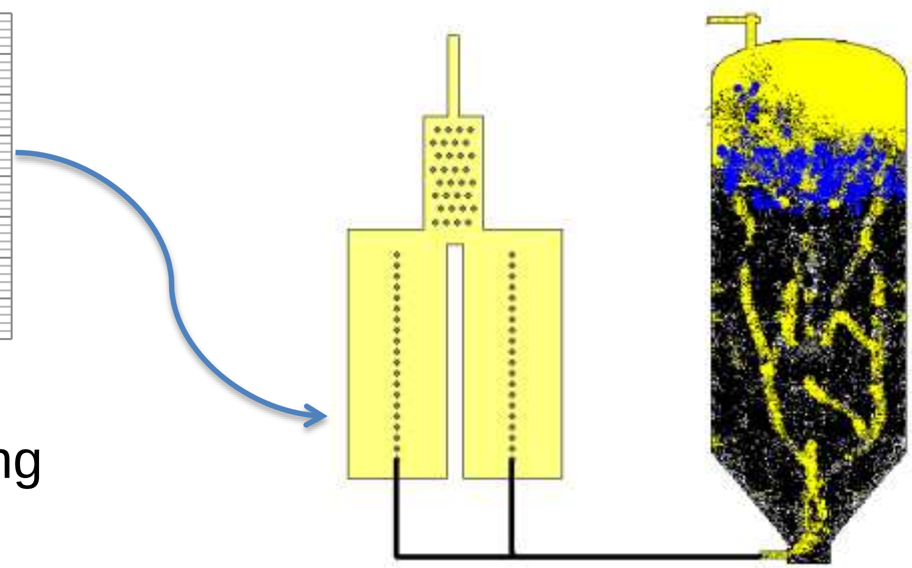




# Heater Ramping

- What temperature should the heater be set for or how much is enough
  - What should set the target => the coke drum operations
    - Coke VCM
    - Foaming in the drum
  - Heater ramping – can be a good option to address poor coke drum temperature issues
  - How does feed quality influence the required coil outlet temperature
    - More paraffinic feed which crack more will require more heat



Heater ramping

# Heater balancing – How & Why

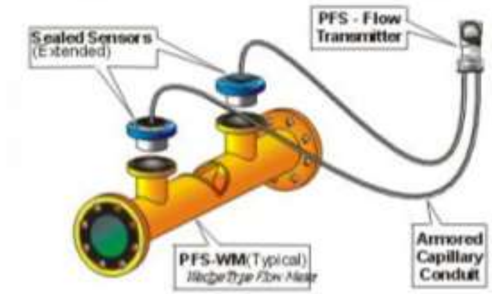
- We live in a imperfect world – the heater passes will not coke/foul evenly
  - Flow meter (both feed and velocity steam) can be off or reading incorrectly, which will cause differences in the rate of fouling
  - TIC can be off or reading incorrectly
  - Control valves can stick or be tuned differently
- Which piece of equipment are you going to trust
  - Each location will be different and will depend on the equipment installed – equipment that you know is unreliable should be replaced or fixed especially if it is causing the heater to be mismanaged

*If you cannot measure it – then you cannot manage it*

- Biasing a heater pass too early can make the heater foul faster
  - Adjusting the heater to have even heat distribution or balancing must be done at the start of run – there is a difference between balancing and biasing a heater
  - Biasing a pass to get a longer run should only happen at the end of the run
    - This is done when one pass has fouled faster but the other passes are not as bad – biasing the flow to that pass with an increased steam rate will help extend the run
    - This causes the other passes to foul faster while slowing down the fouling in the higher tube skin pass
    - Outlet temperatures can be adjust as well but can deliver insufficient heat to the coke drum if too much heat is removed from the pass being adjusted

# Heater Balancing

- Better ideas for better control
  - Get the flow meters (pass feed and steam) working well – this might require changing out the old orifice plate design for something more advanced
  - Inspect (optical pyrometer or thermal scan) to balance heater – if the flow to the heater are correct then on a clean heater each fire box should have the same heat requirements or the same heat flux. Measure the tube supports as well as the tubes to verify the heat flux.
  - If you think the gas meters are good but the feed meters are bad the adjust the feed meters to so that each box has the same fuel gas flow.
  - The coil outlet temperatures should always be the same – the outlet temperatures are the last thing you want to adjust

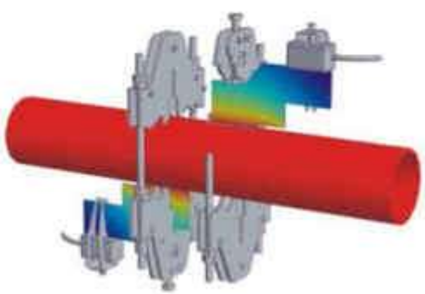



**Wedge Meter**

- Better reliability - large diaphragm pressure taps
- Similar accuracy to an orifice plate
- Fewer solid plugging issues

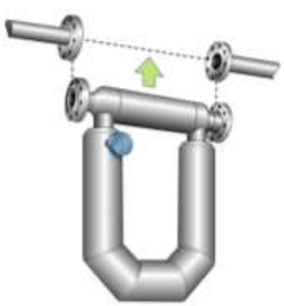
**Sonic or Ultrasonic Meter**

- New technology very low maintenance and good reliability
- No obstruction in flow path
- Pressure drop equal to an equivalent length of straight pipe
- Unaffected by changes in temperature, density or viscosity
- Corrosion/erosion -resistant
- Accuracy about 1% of flow rate



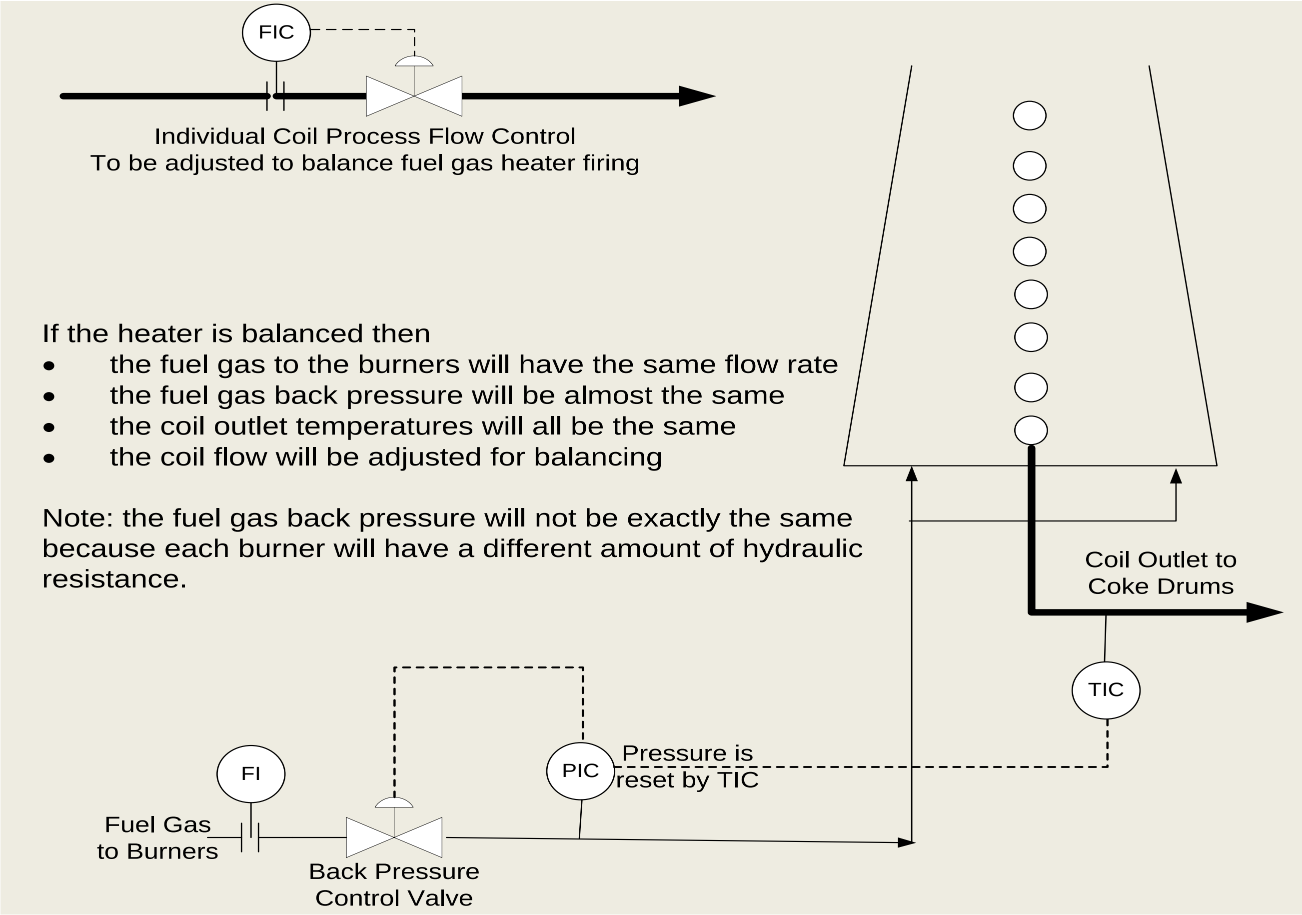
**Coriolis Meter**

- New technology some maintenance and startup issues
- Good reliability
- Excellent accuracy- better than +/-0.1% with an turndown rate more than 100:1. The Coriolis meter can also be used to measure the fluid density.



Micro Motion ELITE© Coriolis Sensor

# Heater Balancing




Heater balancing should not be necessary except that the feed flow meters are not working correctly

# Transfer Line Design & Maintenance

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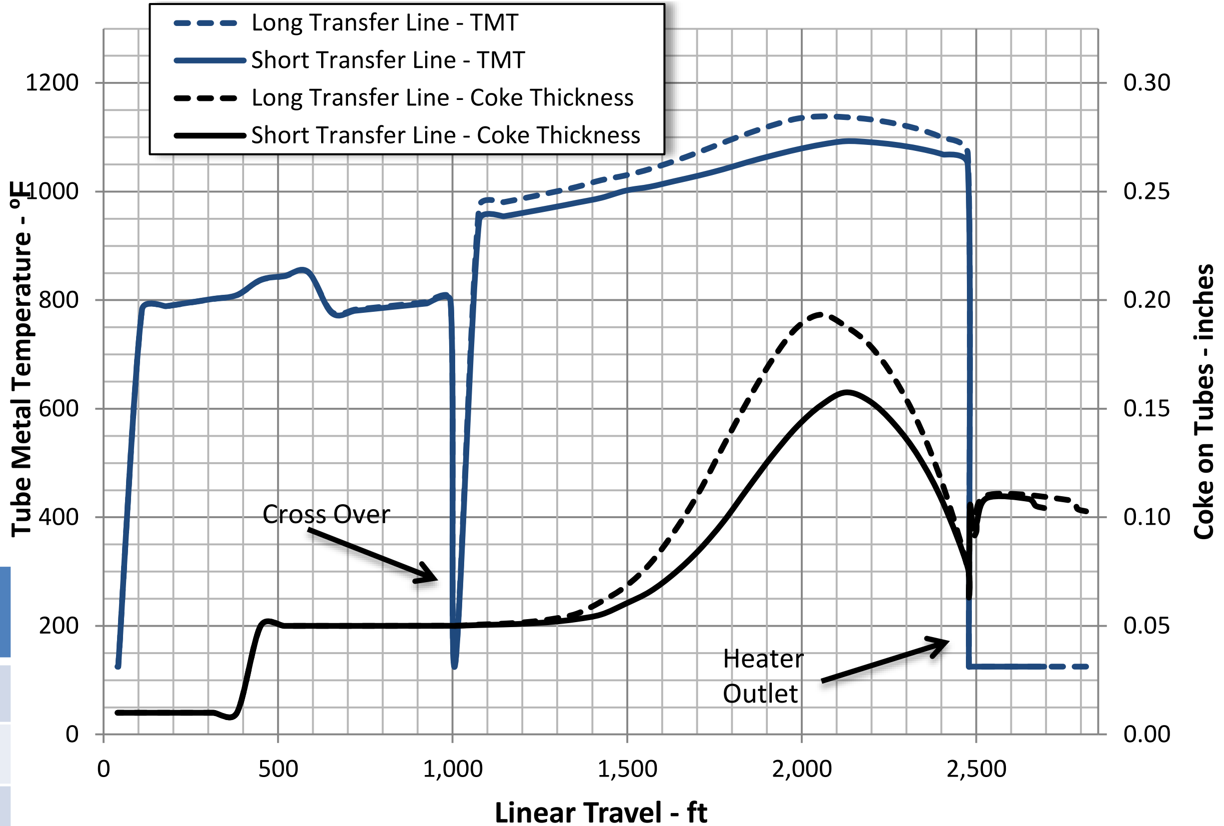
- The transfer line affects the heater operation by the pressure drop associated with the transfer line hydraulics and the added reaction volume
- The diameter usually is not that significant it is the length and number of fittings or flow path in the outlet piping to the coke drums that causes the hydraulics and reacting volume

During a turnaround the outlet piping from the heater to the coker drum inlet should be cleaned out.

| Case | Duty BTU/Hr | Out psig | In psig |
|---|---|---|---|
| Short 14" Transfer Line | 109.1 | 86.3 | 332.1 |
| Long 14" Transfer Line | 117.1 | 93.6 | 356.2 |
| Short 12" Transfer Line | 109.0 | 89.5 | 333.9 |



# General Transfer Line Operations

- Locations in a transfer line that can cause problems
  - Line size changes – asphaltene will settle out on the pipe when the velocity changes in the transfer line
  - Changes in flow direction  - flow patterns in the transfer piping can cause low velocity zones due to Eddy current patterns
  - Erosion at the outlet – spalling will cause erosion problems in not only return bends in the heater but also in the outlet of the heater i.e. the first elbow of the outlet.  The high erosion area needs reinforcing of the pipe.  This extra wall thickness needs to be applied to the outside of the tube/pipe so that the line can be easily pigged.
  - Smart or few cleanout locations – clean out flanges are critical but should be done as needed.
  - Designing or modifying a transfer line – KISS principle.  Too many bends, valves and fittings can add significantly to the pressure drop in the transfer line
- How to fix problems with a problematic transfer line.
  - More steam
  - Simplify the piping/transfer line – a larger line may help but is not a guarantee

# Heater Coil Tube Diameter

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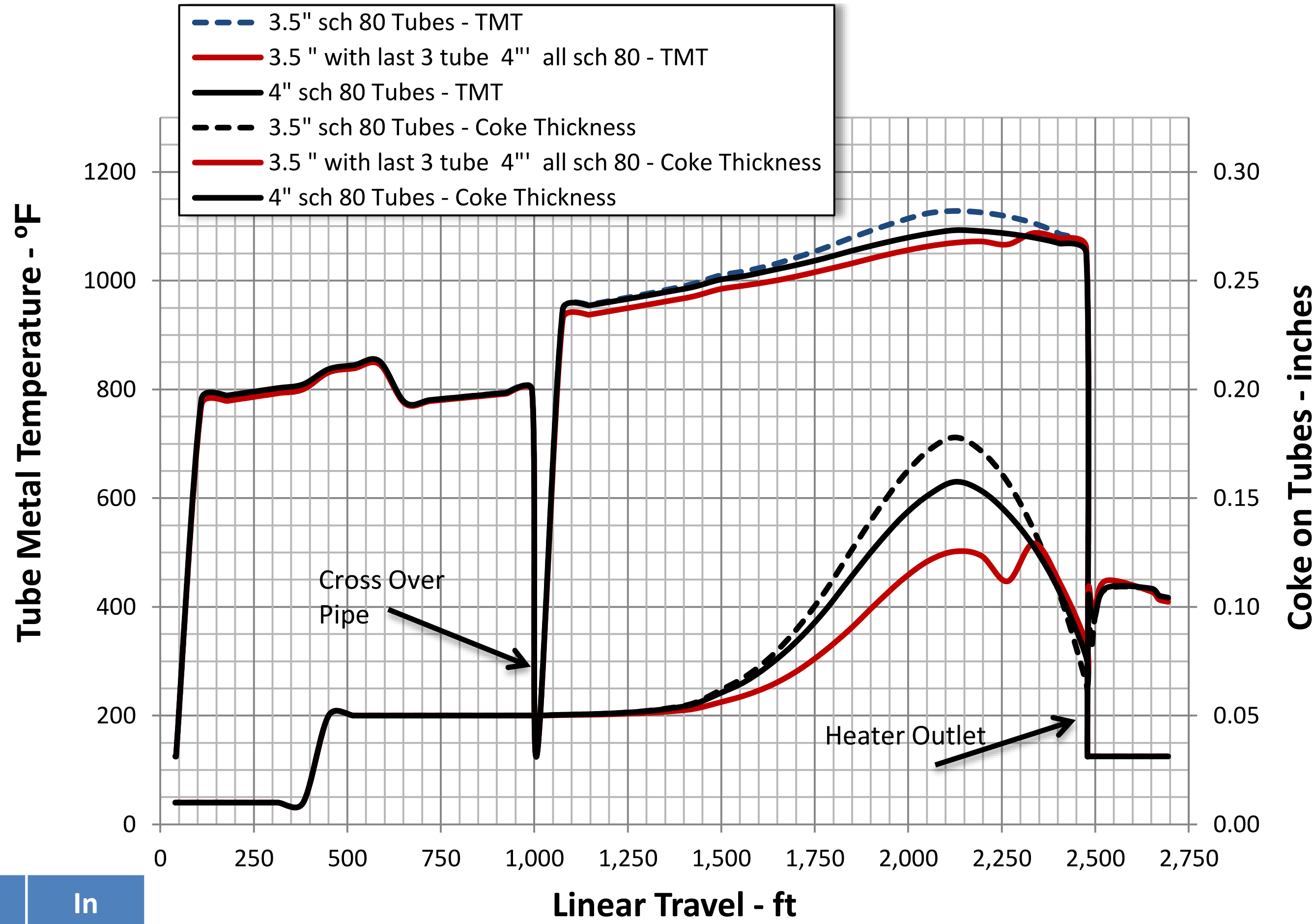
- There is some flexibility on the coil diameter but generally 3 to 4 NPS is used
- Smaller tubes may not be the best solution for reducing fouling
- If done correctly enlarging the last few tubes can be a good solution but is highly dependent on the feed quality and operation condition – change any of these factor and this could make this tube arrangement worse

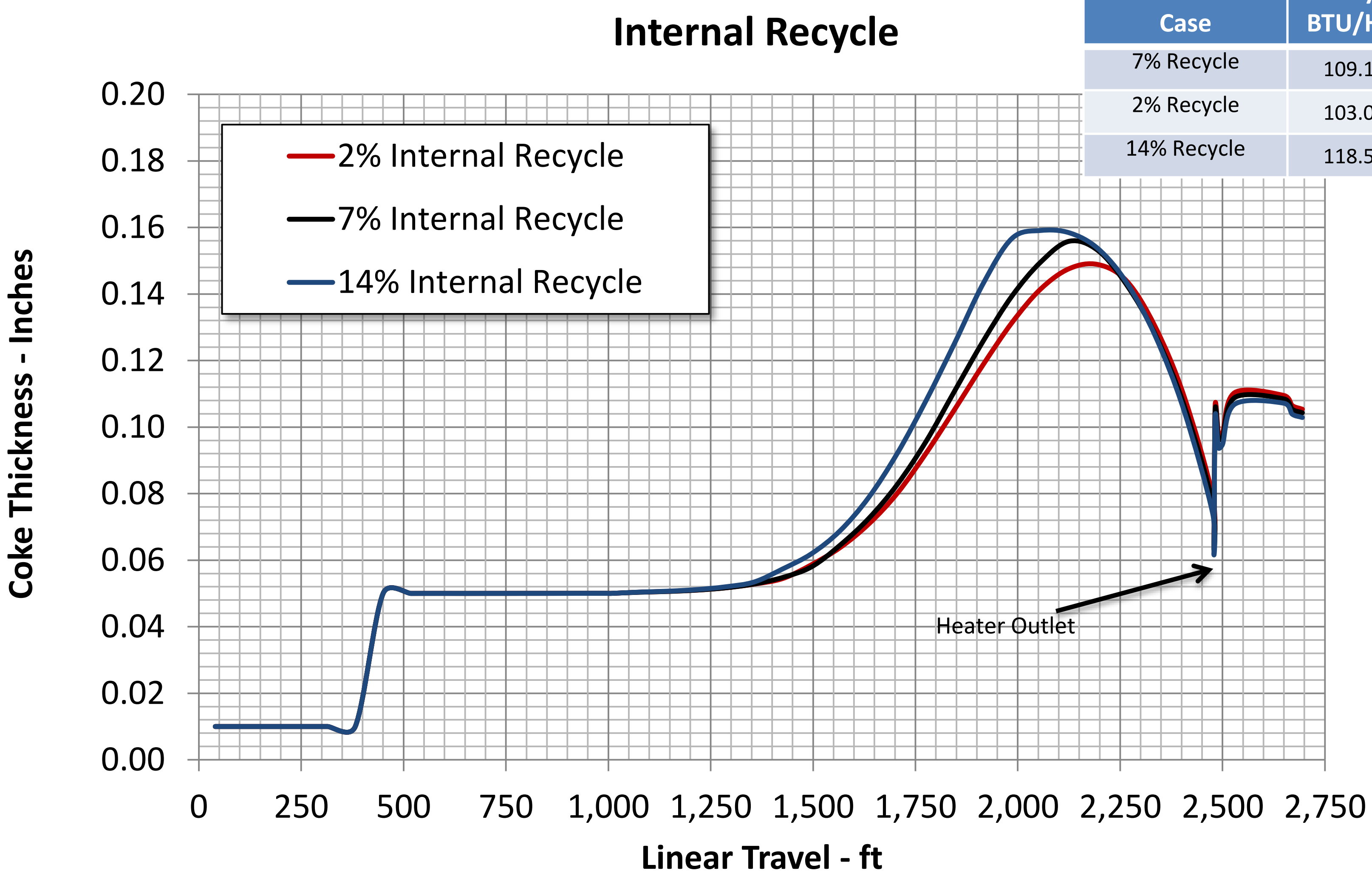



| Case | Duty BTU/Hr | Out psig | In psig |
|---|---|---|---|
| 4 " sch 80 | 109.1 | 86.3 | 332.1 |
| 3.5" sch 80 | 110.4 | 104 | 491.8 |
| 3.5 sch 80 with last 3 tubes 4" sch 80 | 106.6 | 86.7 | 438.5 |

# Recycle & External Oils

- .

| Case | Duty BTU/Hr | Out psig | In psig |
|---|---|---|---|
| 7% Recycle | 109.1 | 86.3 | 332.1 |
| 2% Recycle | 103.0 | 81.5 | 312.1 |
| 14% Recycle | 118.5 | 93.3 | 361.8 |



# Lighter Oil Recycle – i.e. Distillate Recycle

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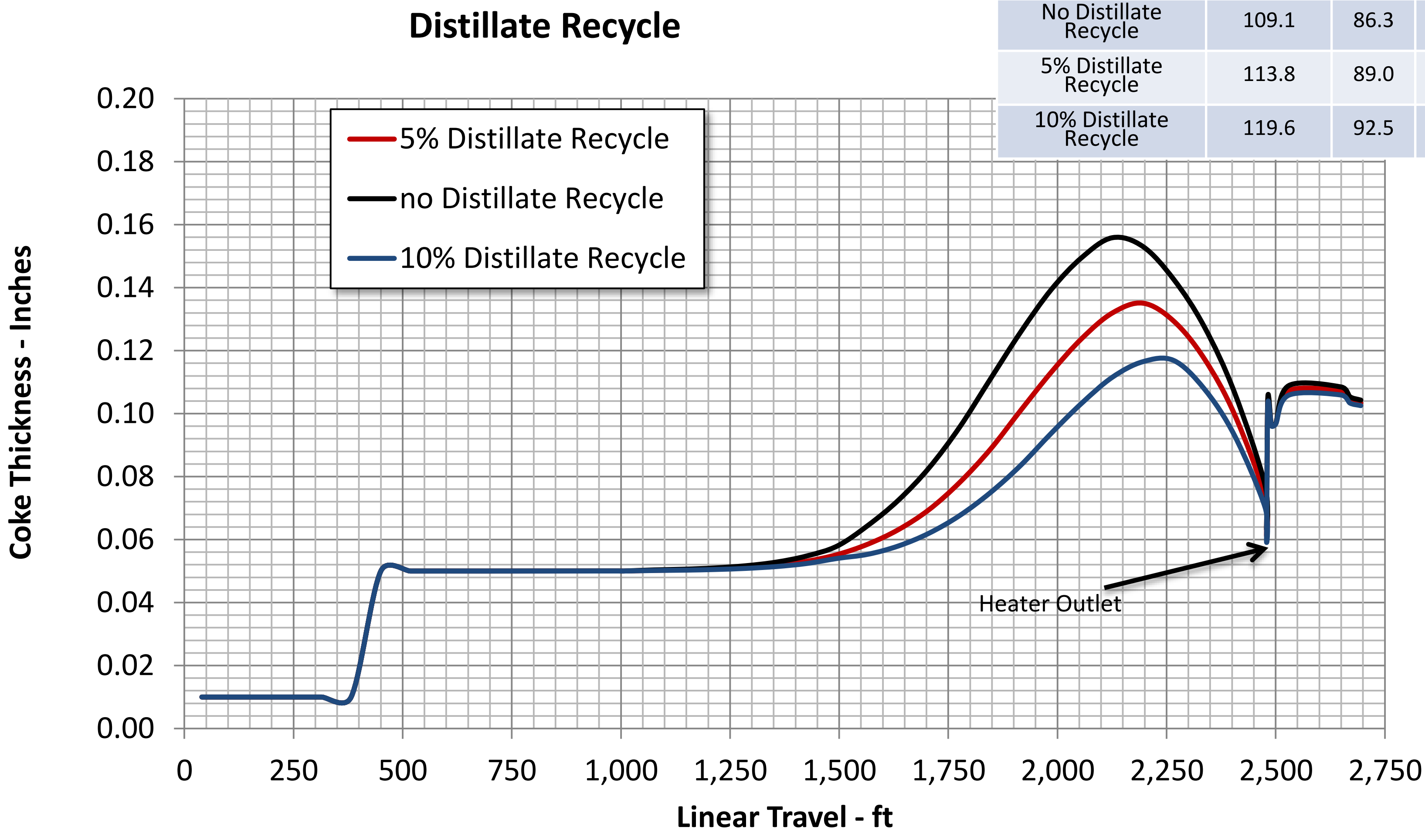
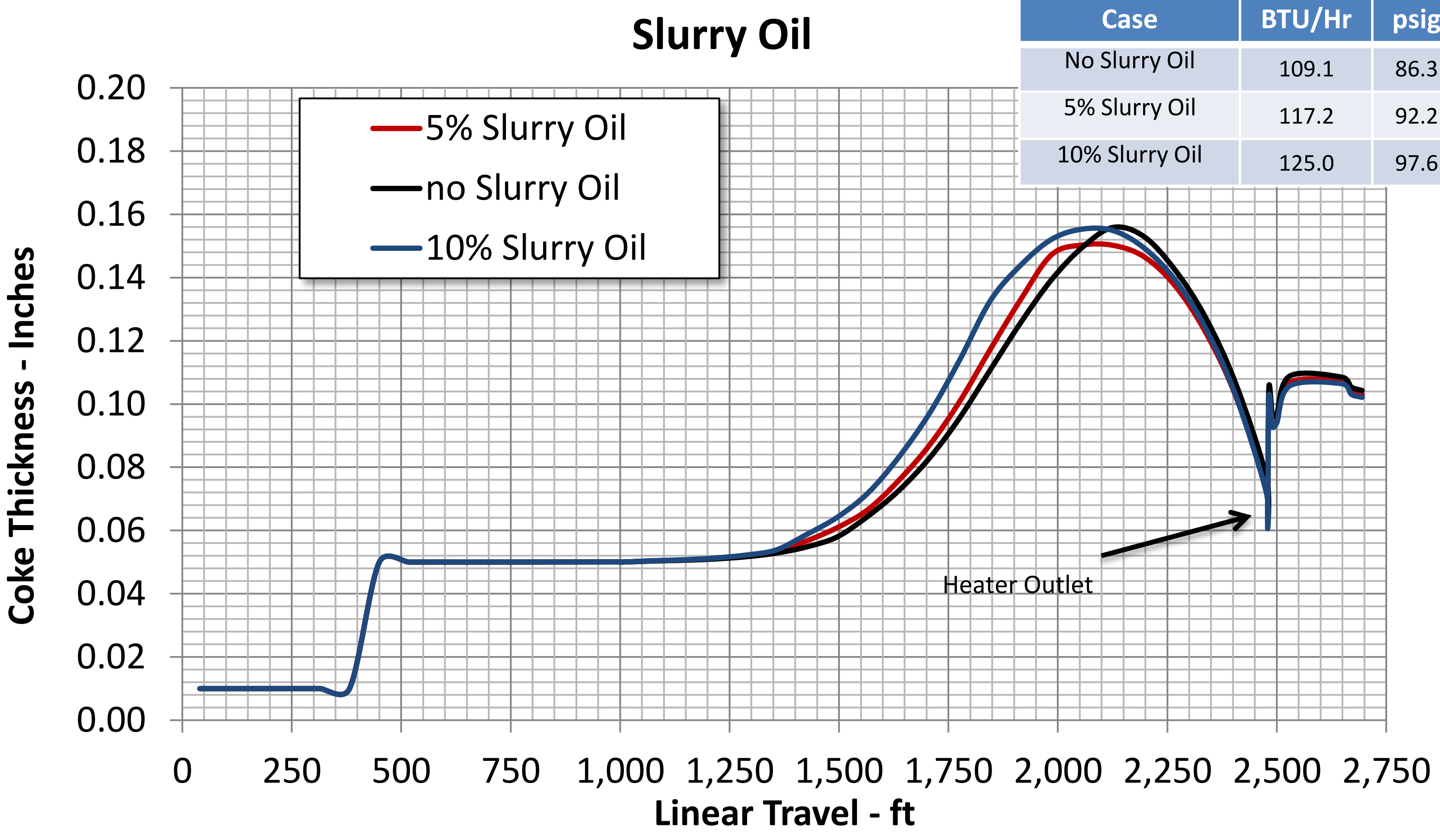
| Case | Duty BTU/Hr | Out psig | In psig |
|---|---|---|---|
| No Distillate Recycle | 109.1 | 86.3 | 332.1 |
| 5% Distillate Recycle | 113.8 | 89.0 | 340.0 |
| 10% Distillate Recycle | 119.6 | 92.5 | 353.9 |



# Slurry Oil Feed

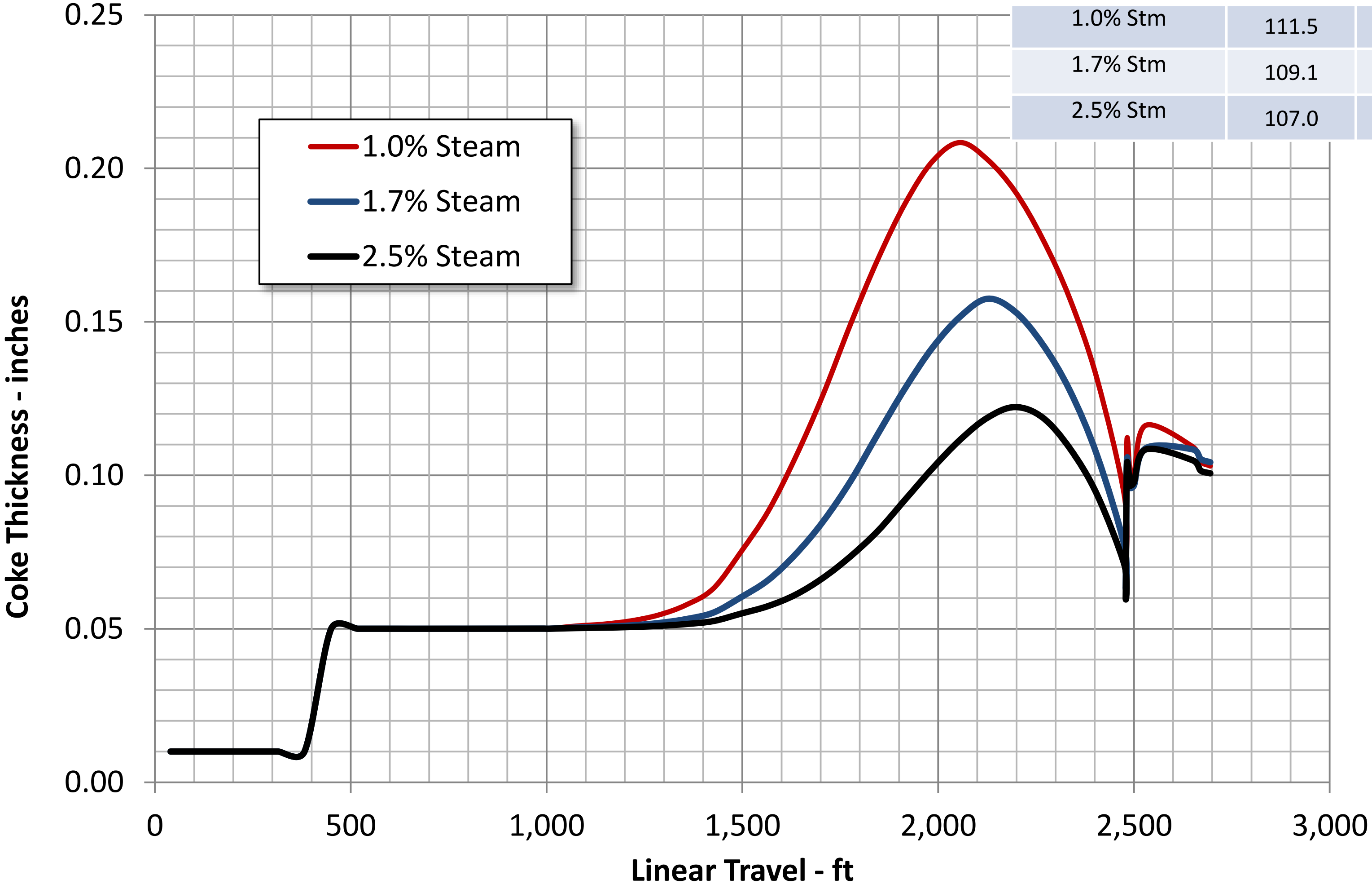
| Case | Duty BTU/Hr | Out psig | In psig |
|---|---|---|---|
| No Slurry Oil | 109.1 | 86.3 | 332.1 |
| 5% Slurry Oil | 117.2 | 92.2 | 354.8 |
| 10% Slurry Oil | 125.0 | 97.6 | 378.3 |



# Velocity Steam

More velocity steam is always better

| Case | Duty BTU/Hr | Out psig | In psig |
|---|---|---|---|
| 1.0% Stm | 111.5 | 86.8 | 306.9 |
| 1.7% Stm | 109.1 | 86.3 | 332.1 |
| 2.5% Stm | 107.0 | 93.2 | 365.5 |



# Heater Design and Operations

## Design & Operating Parameters – Tube Metallurgy

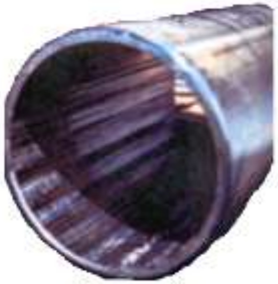
- Tube metallurgy – 9 Chrome vs. SS
  - 347 SS Sch 80 tubes design temperature limit is much higher ~1400ºF
  - The higher temperature limit may not be possible if you spall because of the coke thickness at temperature higher than 1300ºF
  - The coefficient of expansion is much greater than 9 Chrome, which can be good for spalling but can cause problems with uneven tube growth or shrinkage and keeping the tubes from moving off their supports
  - SS can significantly reduce scale on the outside of the tube
- External tube ceramic coating
  - Effective in reducing scale
  - Can shift the heat load away from high heat flux and high tube wall temperature zones
  - Will slightly increase firing rates

SS tubes are a good replacement for 9 Chrome but some of the perceived benefits of longer runs may not be possible due to excessively thick coke in the coil and the difficulty this presents for spalling

# Decoking

- Steam-Air Decoking
  - ✓ Difficult  and labor intensive – must watch air/steam ratio to prevent overheating the tubes with accelerated combustion
  - ✓ Not practices as much
  - ✓ Requires a heater/unit shut down
  - ✓ Can cause damage to the tubes if the tubes are overheated – carburization of tubes
  - ✓ Requires some spalling to remove the bulk of the coke before the actual air burn

- Pigging or mechanical coke removal
  - ✓ Very easy for operations – contracted work
  - ✓ Requires heater/unit shut down
  - ✓ Can work inside heater box simultaneously (but not common)
  - ✓ Can damage the tube if the pig metal studs are improperly used
    - Tungsten carbide has a Brinell hardness of 600-800
    - Most furnace tube materials, will have a Brinell hardness of 150-225



- Online Spalling
  - ✓ Can be difficult initially – operation needs to walk through the process carefully – detailed MOC
  - ✓ Does not require unit shutdown
  - ✓ Every effective in removing coke in the lower radiant section of the heater – not effective for removing inorganic solids in the convection section of the heater
  - ✓ Risk of plugging the coil if the spall is done too aggressively and/or if there is too much coke in the tubes – ¼ to $^{1}/_{2}$ " is a good maximum thickness
  - ✓ Return bend in the heater and 90º bend directly outside the heater need to be thicker to prevent erosion from spalling coke

General practice is to online spall and pig decoke when the opportunity arises

# Heater Design and Operations

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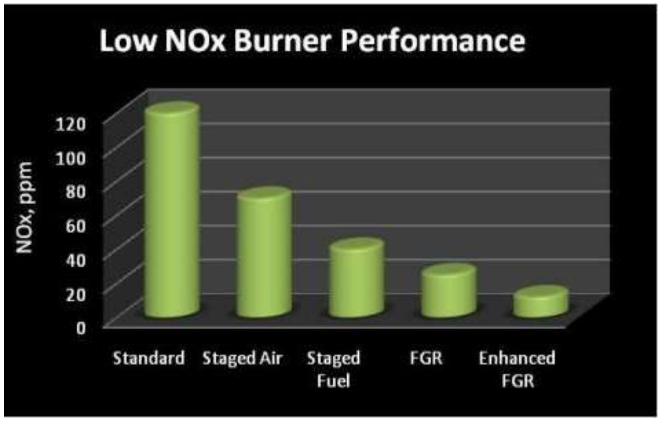
## Design & Operating Parameters – Firebox

- Flame impingement will rapidly foul the affected area
- Ultralow $NO_x$ burners have very small fuel orifices at the burner tip and will plug with time
  - ✓ The fuel should be filtered with a fuel gas coalescer
  - ✓ The fuel gas line from the coalescer to the burners should SS
  - ✓ Steam trace the fuel gas line – especially in cold climates
- In a retrofit the box height needs to be reviewed - ultralow $NO_x$ burner extend the flame and can cause flame impingement




Flame impingement can rapidly foul the heater coil

# Heater Design and Operations

Design & Operating Parameters – Firebox Oxygen Control

- $O_2$ levels can be controlled too closely (less than 3%) – run higher $O_2$ (greater than 5%) will help reduce fouling by lowering the tube wall temperature
  - Higher $O_2$ will shifts heat to convection section and reduces radiant flux rates
  - Higher $O_2$ will lower peak by lowering the tube wall temperature
  - Increasing the $O_2$ from ~3% to ~8% will lower the tube wall temperature by ~75ºF
  - Multiple $O_2$ analyzers are needed in a typical fire box
- Air preheat systems
  - Good way to improve efficiency but are costly
  - Startup procedures need to be well thought out with air preheat systems – generally start with the on natural draft 1st

Because of the severe coking issue in a delayed coker heater the $O_2$ levels should be relaxed to 5% to 8%

# Questions & Answer

- KBC Advanced Technologies is continuously developing our technology, improving our skills and evolving our tools.

- *"Our science and technology strive to explain how complex problems behave. As engineers we use this science and technology to create models to explain and control the world around us – but our models have limits  - the real world is very complex."*

QUESTIONS?