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REFCOMM®
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Amec Foster Wheeler- Fired Heater Division

Amec Foster Wheeler Delayed Coker Heater - Best Practices

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Agenda

1. Overview Amec Foster Wheeler in delayed coking
2. Fired Heater best practices
3. Delayed coker heater best practices
4. When it all comes together
5. Questions

Industry recognition and acceptance

- Delayed coker heaters since 1959
- 150 delayed coker heaters
- 86 Terrace Wall delayed coker heaters
- 66 delayed coker heaters in last 10 years
- 12 delayed coker heaters under contract

Delayed coking and the fired heater

- Amec Foster Wheeler has more than half the licensed delayed coking unit market share in the world
- Alignment of the process licensor and the proprietary heater supplier provides the client the focused attention to providing the best heater design to the process requirements
- Amec Foster Wheeler Fired Heater Division has the largest market share of delayed coker heaters in the world with over 150 heaters since 1959
- We are the largest supplier of the highly reliable double fired coker heater with our trademark design the Terrace Wall™ delayed coker heater

Best practices

Fired heaters general

Fired heater DCS monitoring

Data to bring into DCS

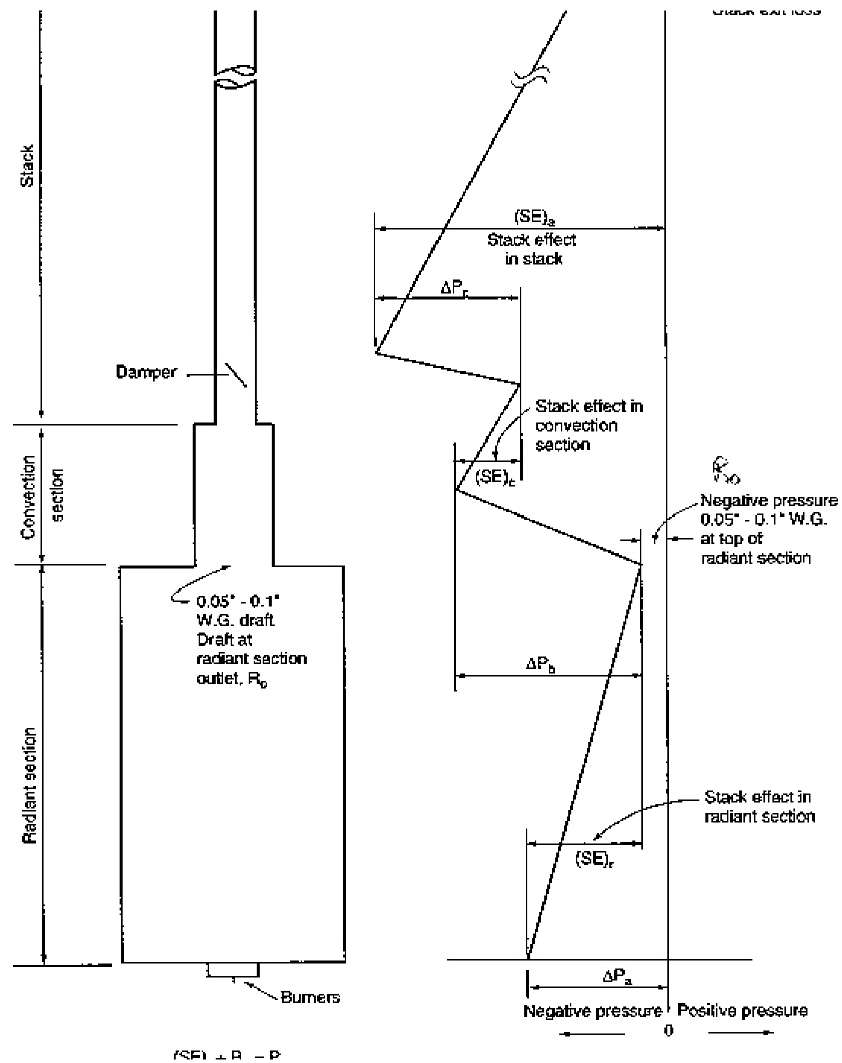
- Arch draft – alarm high as well as low
- Stack damper setting
- Radiant section O_2 readings preferably several in firebox
- Burner pressure-burner test set points
- Combustible analyzers
- Process conditions in/out (and crossover)
- TSTC
- APH
  - Skin TIs
  - Damper settings - fans, bypass, stack
  - Air and flue gas temperatures/pressures

Fired heater best practices

- Proper draft profile
- Excess air / oxygen in flue gas
- Tramp air – air infiltration
- Burner selection
- Convection section monitoring
- Air preheat monitoring

Draft monitoring

- Draft should be measured under the first row of convection tubes
- High draft causes more air leakage and lowers the heater’s efficiency, the higher the draft higher the leakage
- High draft changes the burner flame pattern-longer flames
- High draft can cause a heater to be firing/flue gas limited
- Low draft could mean a positive and dangerous fire box, especially the sight doors

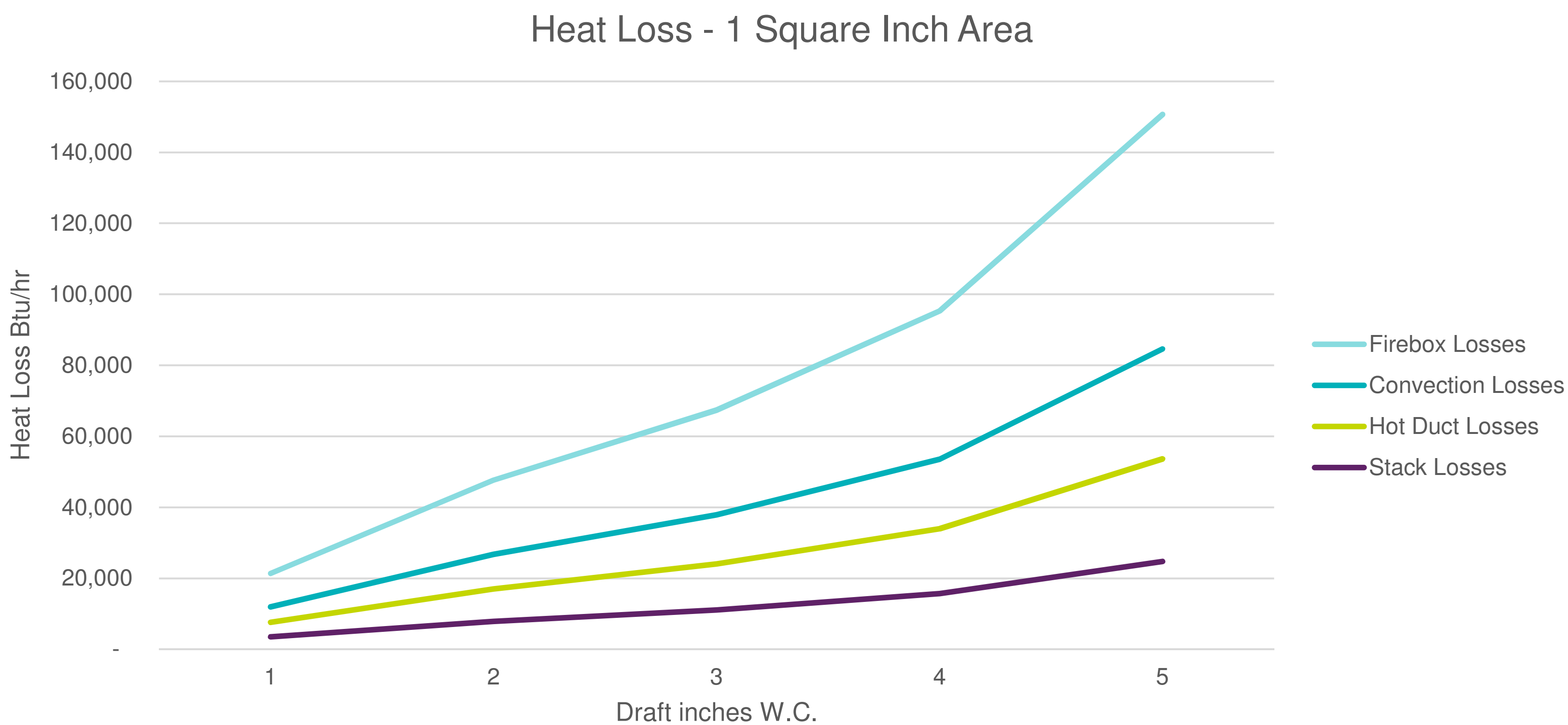


Oxygen monitoring

- Fired heaters are designed for 10-25% excess air that translates to 2-5% oxygen in the flue gases
- First the O_2 must be measured in the radiant section and not the stack- air infiltration will distort the true reading
- Higher O_2 transfers duty to the convection section and raises the crossover temperature from convection to radiant section.
- At higher capacities, it can be a benefit to unload the radiant flux
- It lowers the bridgewall temperature which reduces fouling/coking tendencies
- Higher O_2 causes higher firing of the burners
- If the burners are near their operating limits higher O_2 will increase flame stability issues

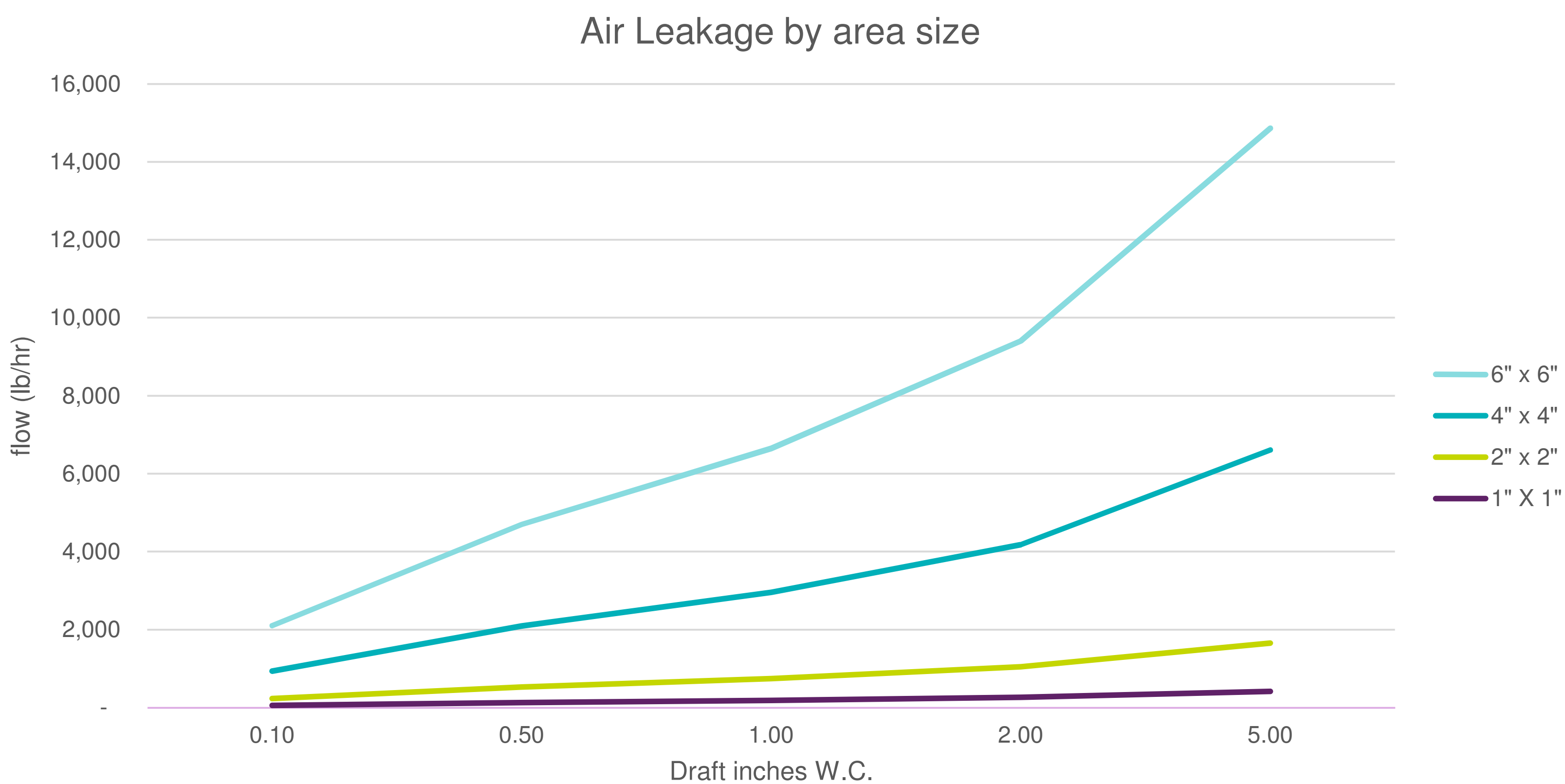
Tramp air infiltration - oxygen readings

- Air infiltration causes erroneous O_2 readings that after safe operation of the heater.
- Air infiltration causes efficiency losses.



Tramp air infiltration - fan loadings

- Tramp air can load up ID fans and impact abilities to meet capacity requirements



Burner selection

- Sizing and spacing requirements of API standards
- Type selected for the heater geometry, draft, fuel & combustion air conditions
- Emissions require extensive coordination with burner vendors
- A distinct flame pattern is usually desired by the heater designer- height and spread of the flame
- Burner testing to verify above, it also sets high and low pressure alarm points for proper monitoring

Poor burner pattern

- Draft too high or too low?
- O_2 too high or too low?
- Burner registers opened or closed?
- Burner tips plugged?
- Considerably different fuels?
- High fuel pressure?
- Flame impingement?
- Burners shut off?
- Air preheat temperature?

Convection section monitoring

- 150ºF (85℃) approach temperature (flue gas out to process in) is a rule of thumb design benchmark
  - More means a fouled convection
  - Steam generation lowers this slightly
- Draft across the convection section should be ~0.3-0.5” 7.5-12.5mm) WC
  - Higher if fouling in convection tube’s extended surface
  - Or if increased flue gas flow rate due to high O2/ air leakage
- Check crossover temperatures between passes for fouling or blockage
- Thermally scan convection wall for refractory damage
- Measure draft under first row of tubes instead of radiant arch

Air preheat system monitoring

- APH systems may have steam-air preheat coils, cold air bypass ducts, skin TI's & fan dampers to monitor and control heater efficiency
- Steam-air coils assist in cold weather conditions to keep APH surfaces above dew point temperatures- monitor with the skin TIs
- Cold air bypasses can also assist in cold weather but should normally be closed- loss of efficiency and impacts ID fan operations
- Operations with the cold air bypass opened causes higher burner firing due to colder air and more volume in ID fan due to warmer and more flue gas
- Pressure drop across APH systems can occur – it is best to benchmark the pressure profile on start up
- Thermally scan ducts for refractory damage should be planned prior to any shutdown

Best practices

Delayed coker heaters

Delayed coker heater best practices

- Srini's rules for coker heater design
- Single- and double-fired designs
- Oil firing – India market
- Vintage versus current practices

Srini's rules for coker heater design

- Individual pass control and firing required
- High cold oil velocities- 6-7 fps (1.8 m/s) minimum
- Generous fire box dimensions
- Proper velocity medium injection rate
- Minimum residence times above the cracking temperature
- Optimum heat flux with no mal-distribution
- Constantly rising temperature profile (no dead zones)
- Symmetrical pass arrangement and connected piping

Uniform heat flux= long runs

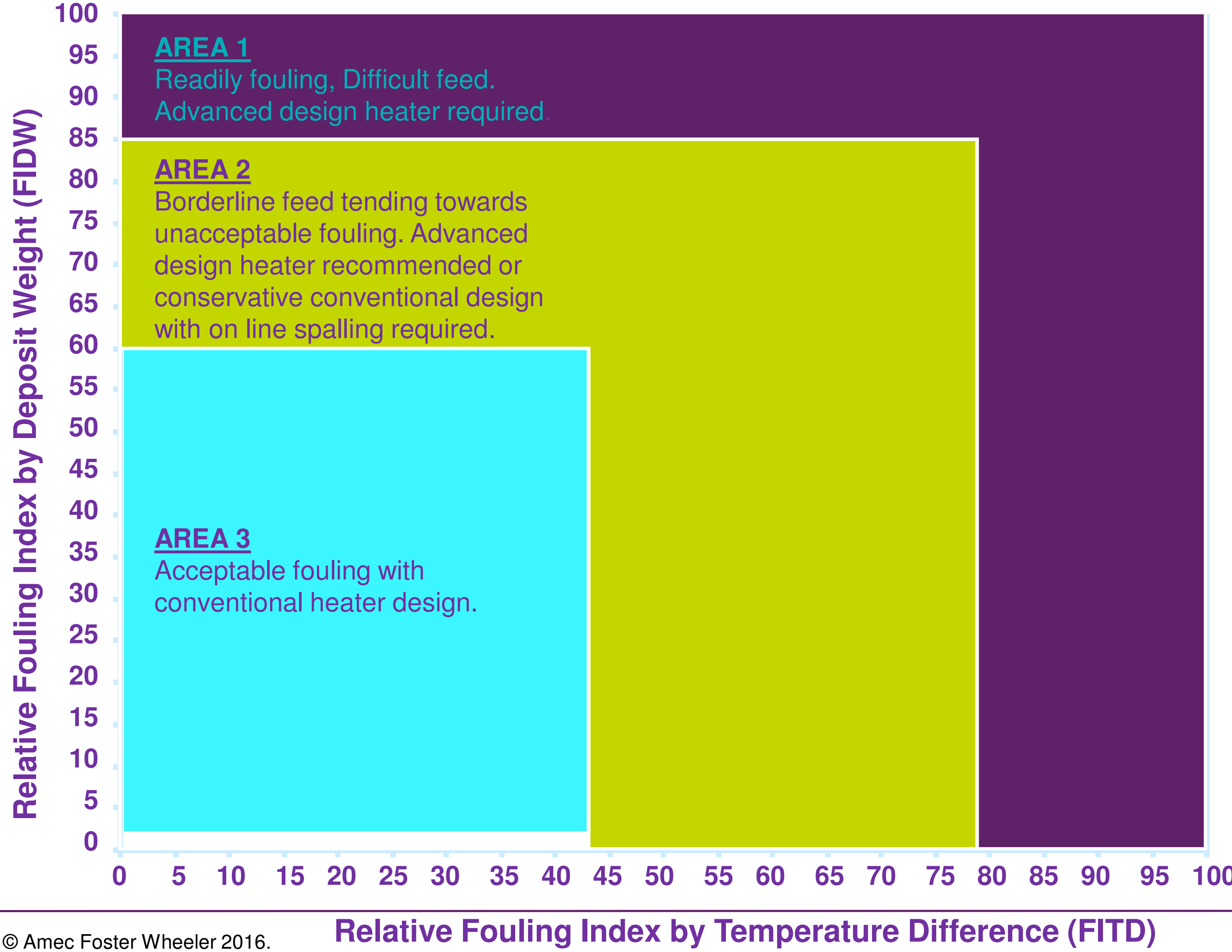
Cold oil velocity= velocity at 60F

Individual pass control and firing

- DCU heaters are controlled differently than refinery heaters - the flow rate per pass is set and the firing is adjusted for the critical outlet conditions
- Completely isolated passes allow for different operations on each pass without impacting adjacent passes to meet the outlet conditions
- In normal operation, a faster coking pass can be adjusted to continue operations until a spall can be planned
- For proper spalling operations this isolation is the key - it allows a high degree of firing control and TMT control to get a good spall
- There is an negative economic impact on plant operations if multiple passes must be removed for a spalling operation

Amec Foster Wheeler has designed this way for decades and continues to design in this fashion whether a single- or double-fired coker heater

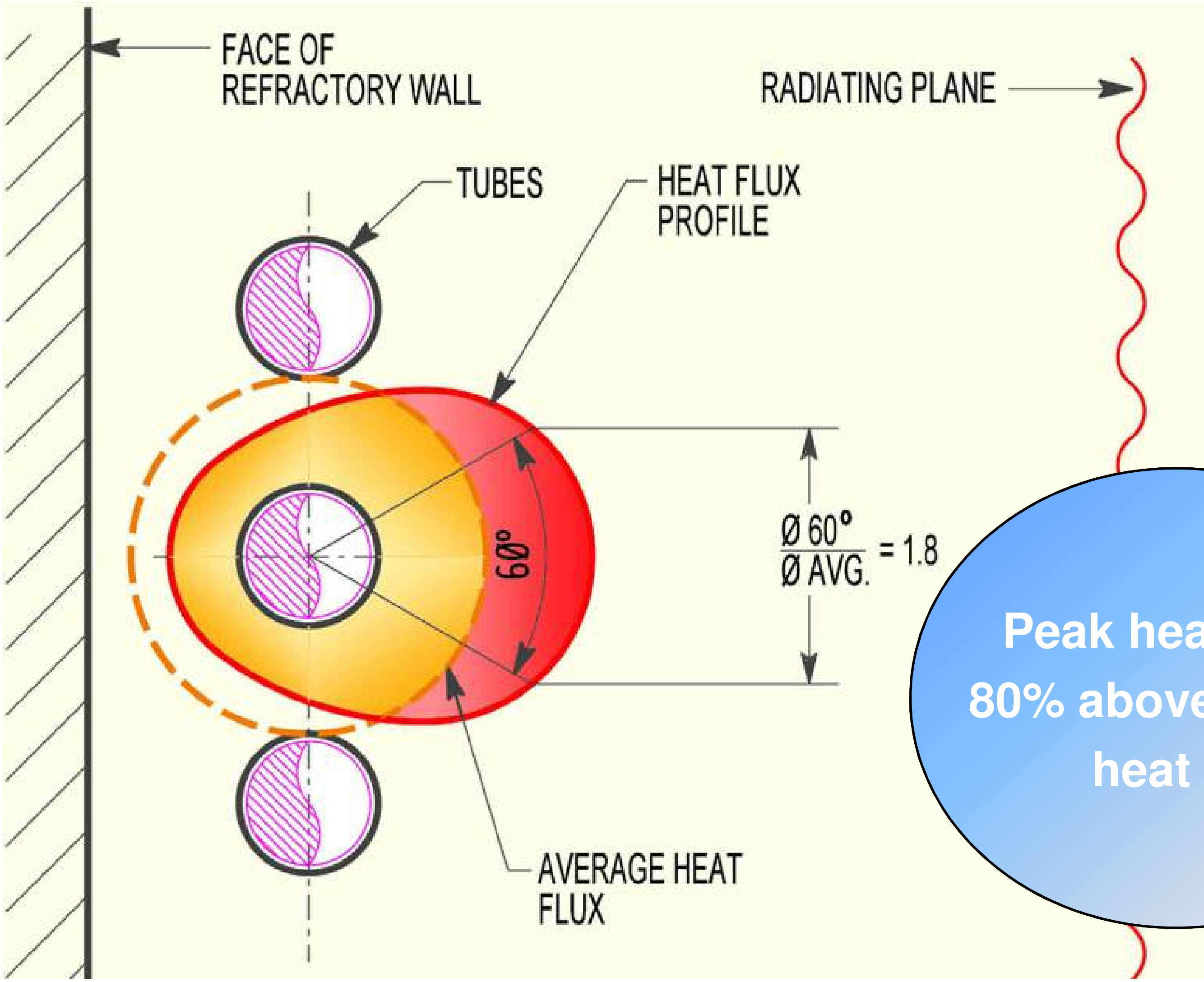
Single- versus double-fired design



Single- versus double-firing

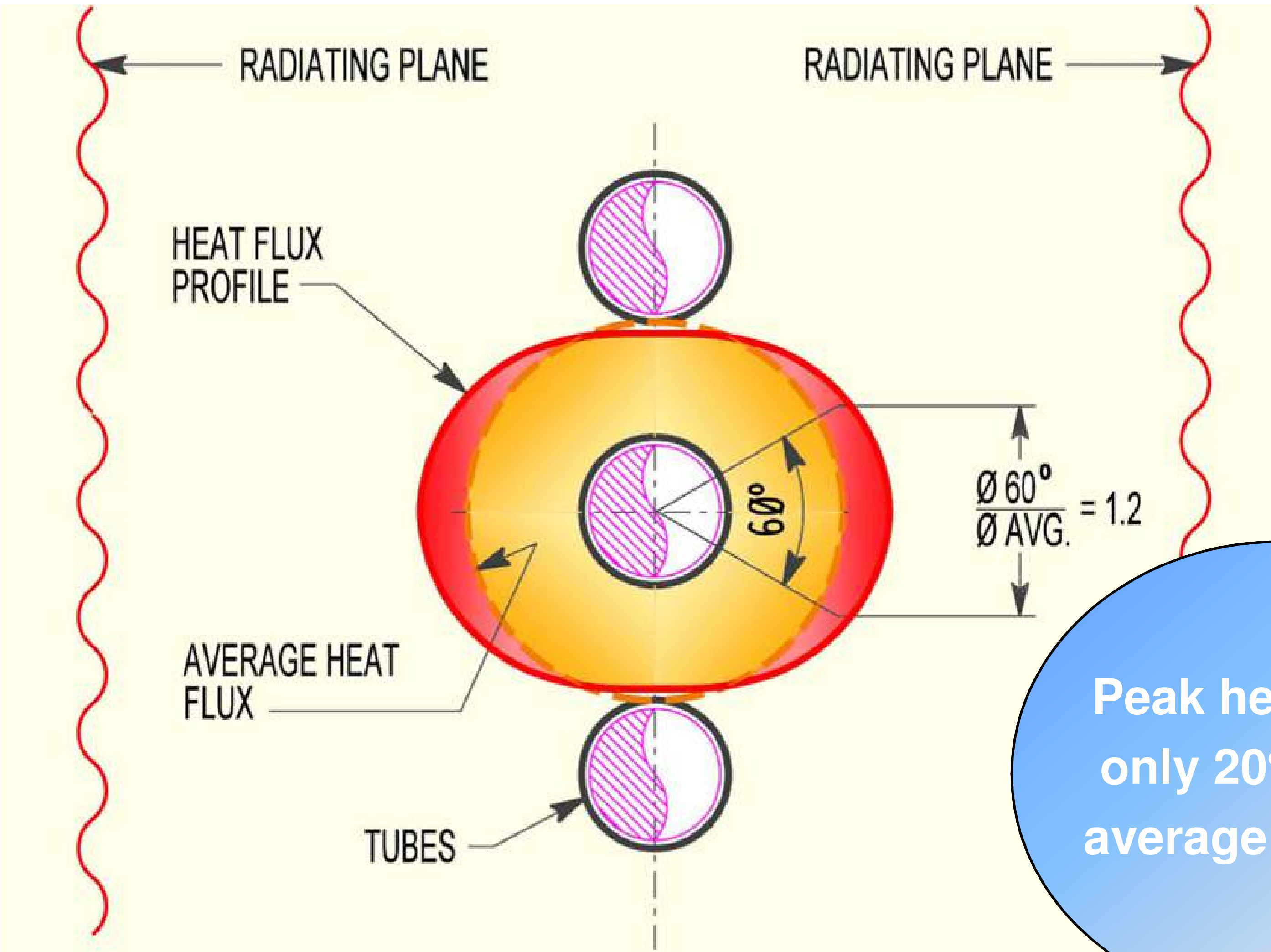
- As seen there are overlaps with conservative single fired designs and double fired designs
- Oil firing requires a single fired design as there are burner selection and operation issues on double fired designs due to the sizes
- A single fired design can achieve good run lengths with:
  - Generous firebox dimensions
  - Proper flux and COV selection
  - Optimum burner sizing and spacing
  - Attention to sootblower design
  - Proper APH system selection
- Double firing can be used in all cases following Srini’s rules

Single fired heaters



Peak heat flux is 80% above average heat flux

Double fired heaters



Peak heat flux is only 20% above average heat flux

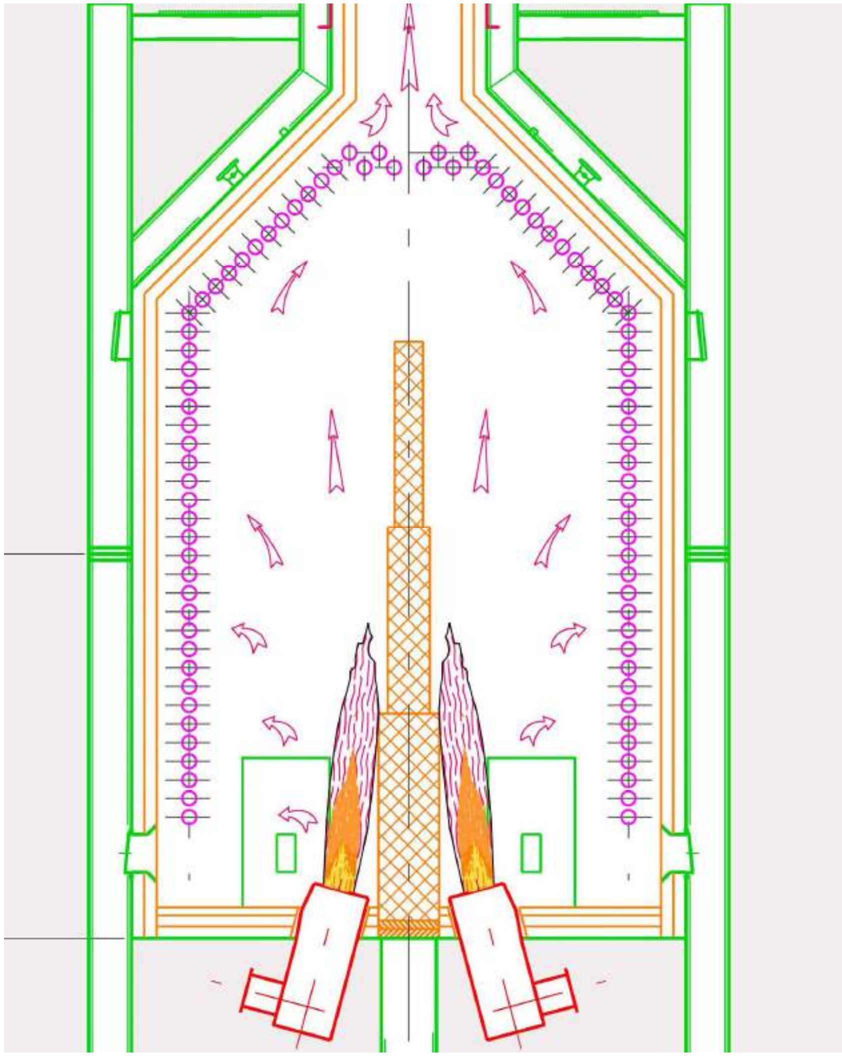
Indian Delayed Coker Heater

- Due to the oil firing requirements in most plants - only single-fired delayed coker heaters are provided
- As indicated in the previous graph- conservative single fired designs can provide good and reasonable run lengths
- Generous firebox sizing and optimum heat flux with no maldistribution are key design rules for these heaters
- This ‘classic’ delayed coker heater design has been improved upon over the years and incorporated in recent heaters
- Bridgewalls included in radiant sections for individual pass firing
- Set up for on-line spalling and off line pigging

A comparison of vintage versus current practices follows

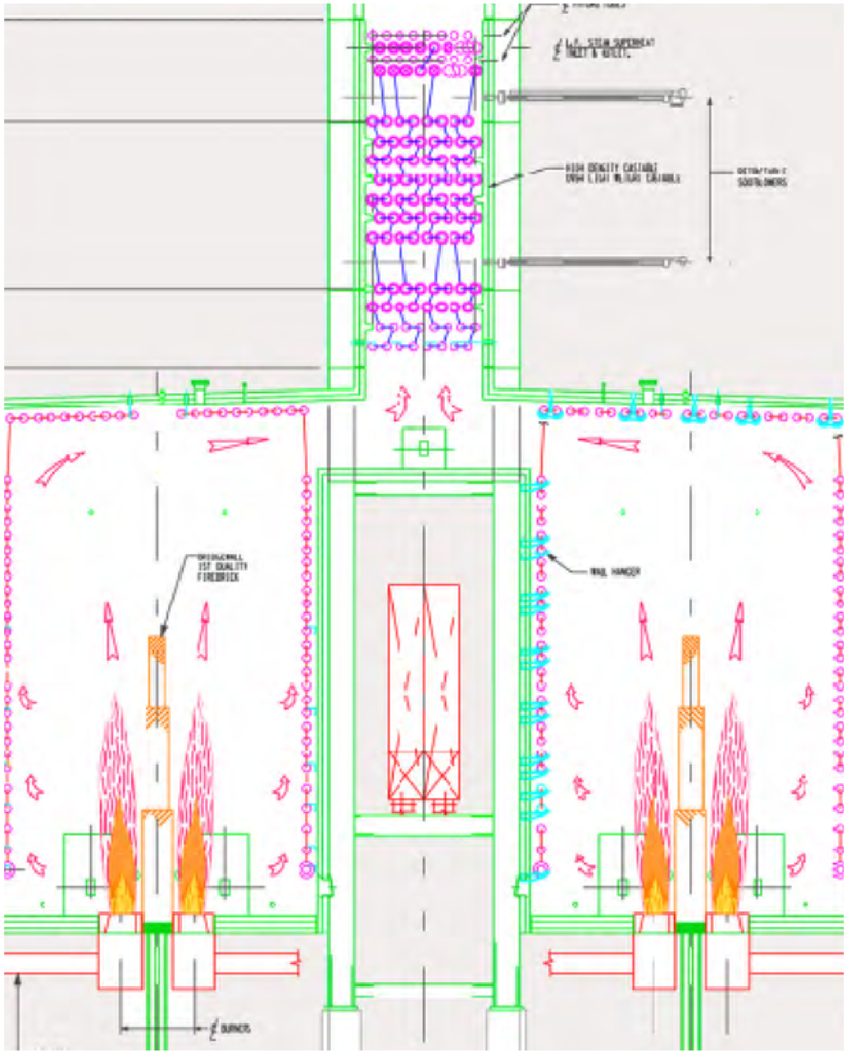
Vintage single-fired coker heater

- Single fired with bridgewall
- Roof tubes - sometimes double row
- Mule ears both ends - in header boxes
- Angled burner firing
- Multiple tube diameters in radiant section
- 6 fps (1.8 mps) COV
- Oil & gas firing



Current single-fired units – oil firing

- No roof tubes
- Straight up burner firing
- Single size radiant tubes
- Contoured plug headers – one end
- Heavy back wall return bends – one end
- Bridgewalls for individual pass firing
- COV 6 fps (1.8 mps) minimum
- Oil or gas burner firing



Velocity injection

Vintage units

- Steam used as medium
- Injection rate - 1-2% by weight
- Injection sites
  - Inlet
  - Crossover
  - ~4th tube from outlet

Current units

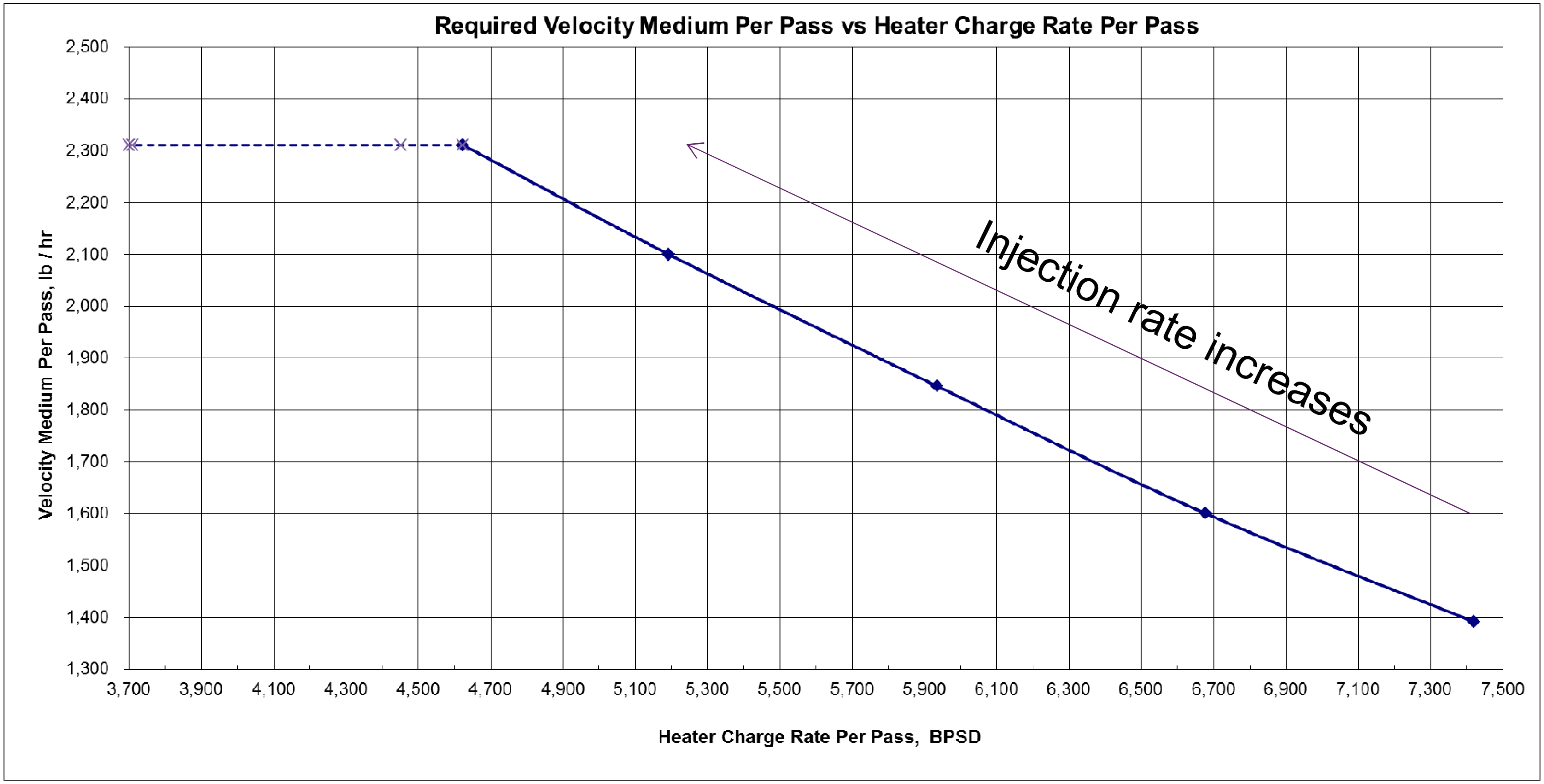
- Steam or condensate medium
- Condensate preferred as its use in spalling operations provides better spalls
- Injection rate - variable versus capacity - curve is provided
- Injection sites
  - Inlet
  - Crossover

Velocity injection

- Velocity mediums - steam or condensate are determined by the licensor and are unique for each heater design
- Velocity medium rates have gone from 1-2% to a variable rate used currently – dependent on % of design capacity
- The licensor should provide an appropriate curve of the velocity medium injection rates and this should be programmed into the control system
- Injection sites for the medium where at inlet, crossover and in the radiant section; all injection medium now is injected before the convection section and a crossover connection is provided and rarely used; the radiant connection has been eliminated
- This same medium can be used for on-line spalling which leads to condensate being preferred in many case
- With high inlet pressures condensate may be required if HP steam is not available

Velocity medium injection rate vs feed rate

50% ← 100%



Tube design

Vintage units

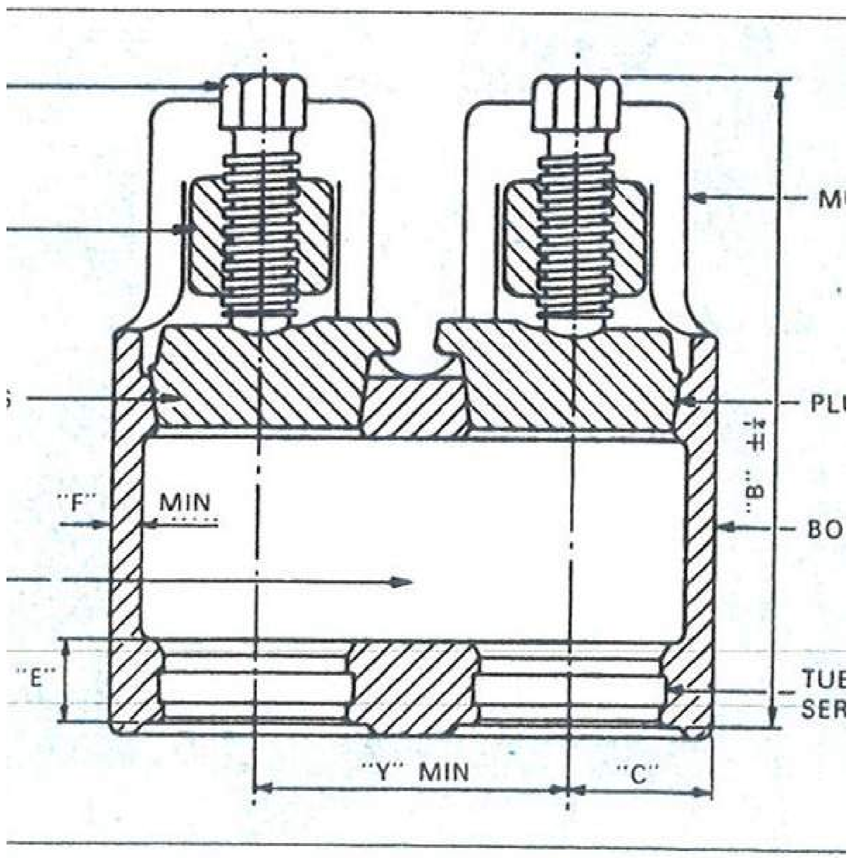
- 5Cr or 9Cr
- Calculated TMT with a margin - ~1200F (650C)
- Pump shut off pressure ~500-600 psig (35-42 kg/cm2)
- Pipe schedule thicknesses

Current units

- 9 Cr-1Mo
- Maximum temperature of material - 1300F (705C)
- Pump shut off pressure ~800-900 psig (55-65 kg/cm2)
- Minimum wall tubing specified thicknesses

Mule ear plug headers - vintage designs

- ► Plug headers both ends of the tube
- ► Contained in radiant header boxes
- ► Rolled joint attachment to the tubes
- ► Leaked but allowed mechanical cleaning access to the tube ID



le-ear" top construction. The Key type 1900 retu
t popular fitting being widely applied for general

Contour plug header – current designs

- Plug headers one or both ends of the tube
- Contained in radiant header boxes
- Welded joint attachment to the tubes
- Leakage minimizes but allowed mechanical cleaning access to the tube ID - used when fully coked off

Return bends

- Current design has heavy wall cast return bends on one end of the tube
- Cast returns are selected to maintain the tube ID throughout the bend
- Intermediate vintage return bends used heavier sch. thickness but caused higher velocities with smaller ID

Radiant header boxes - a continued feature

- Plug headers *require* header boxes
- Return bends in header boxes operate at fluid temperature – not at tube TMT a benefit for the erosive nature of spalling
- The lower temperatures translate to higher stresses in the material since the return bends are still designed for firebox conditions
- A new Amec Foster Wheeler patent to cover SS tubes in the firebox but the more erosion/wear resistant 9Cr-1Mo return bends in header boxes

Decoking methods

Vintage

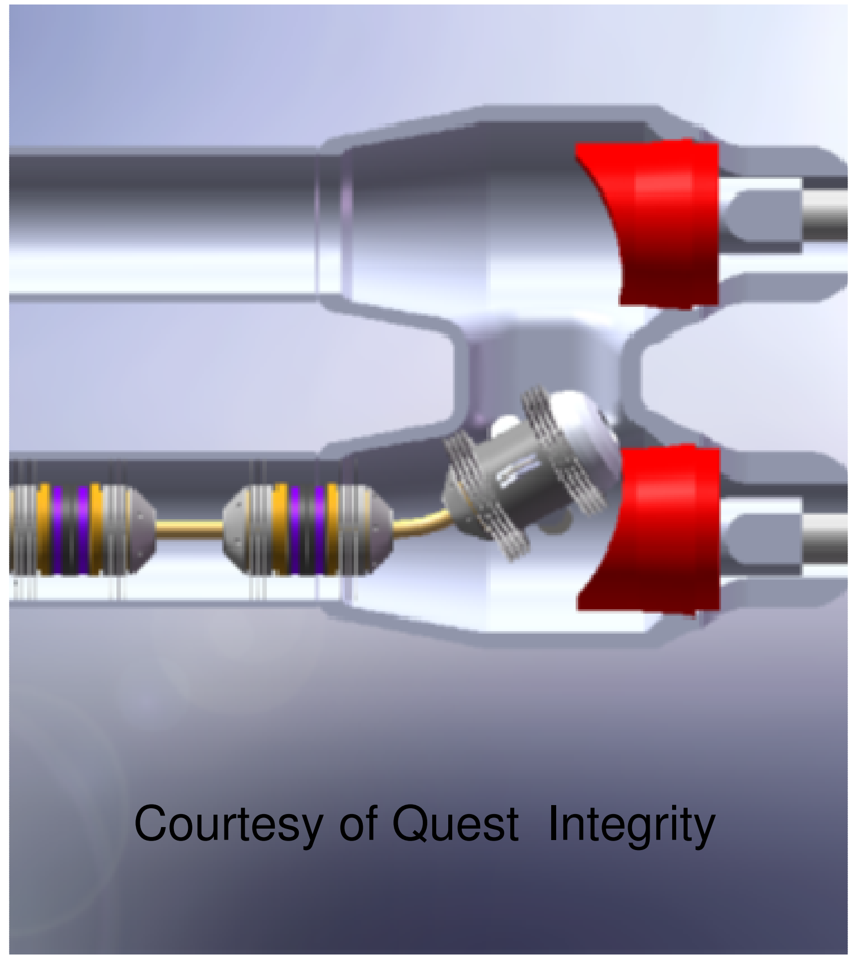
- Steam-air decoking
  - Off line execution by owner's staff
- Mechanical
  - Off line execution by owner or outside contractor

Current

- Spalling
  - On line by owner's staff
- Pigging
  - Off line by contractors
- Steam air
  - Off line by owner
- Mechanical
  - Off line by owner or outside contractor

Pigging- developed for inorganic fouling

Pig



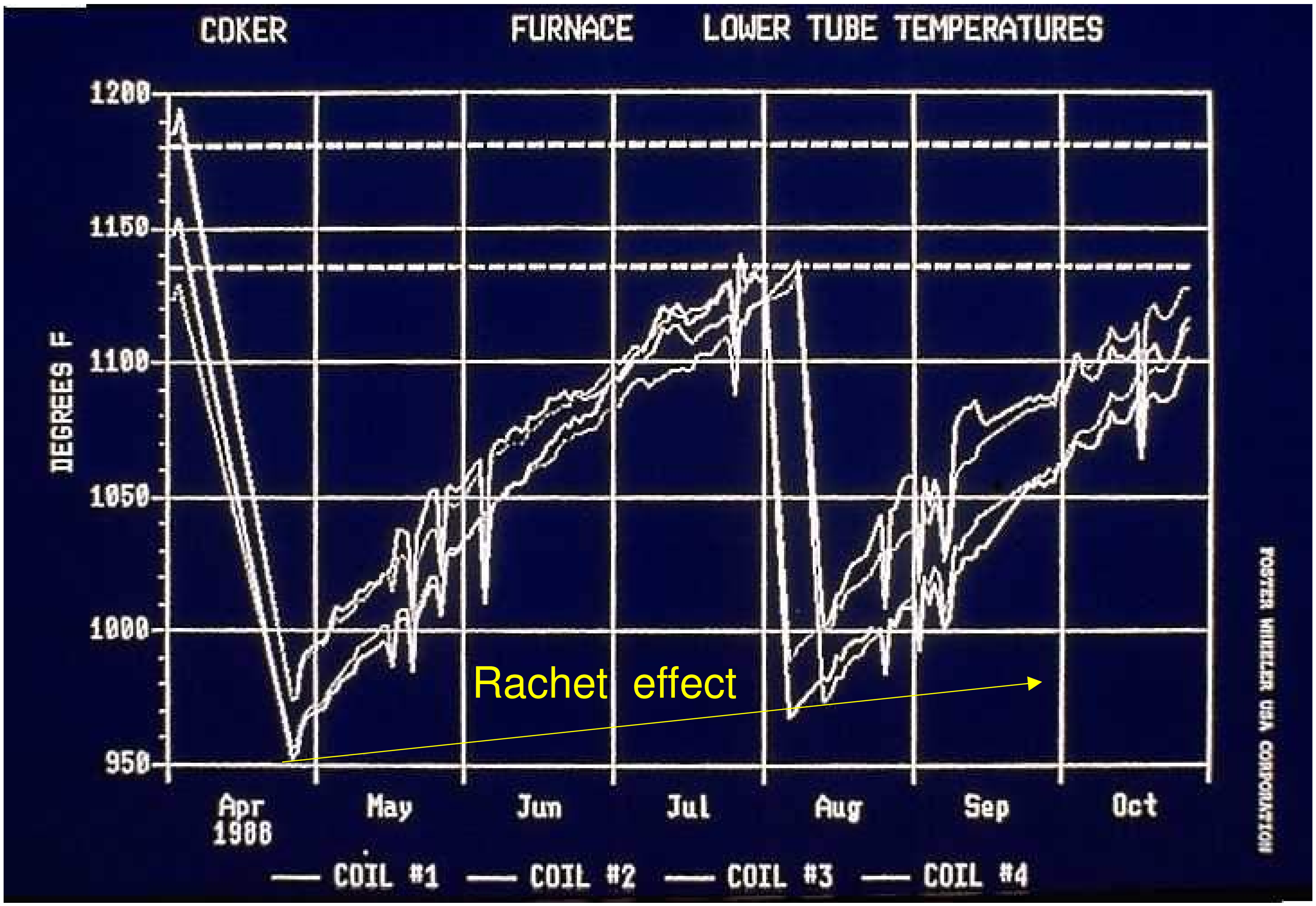
Smart pigging capability

Spalling

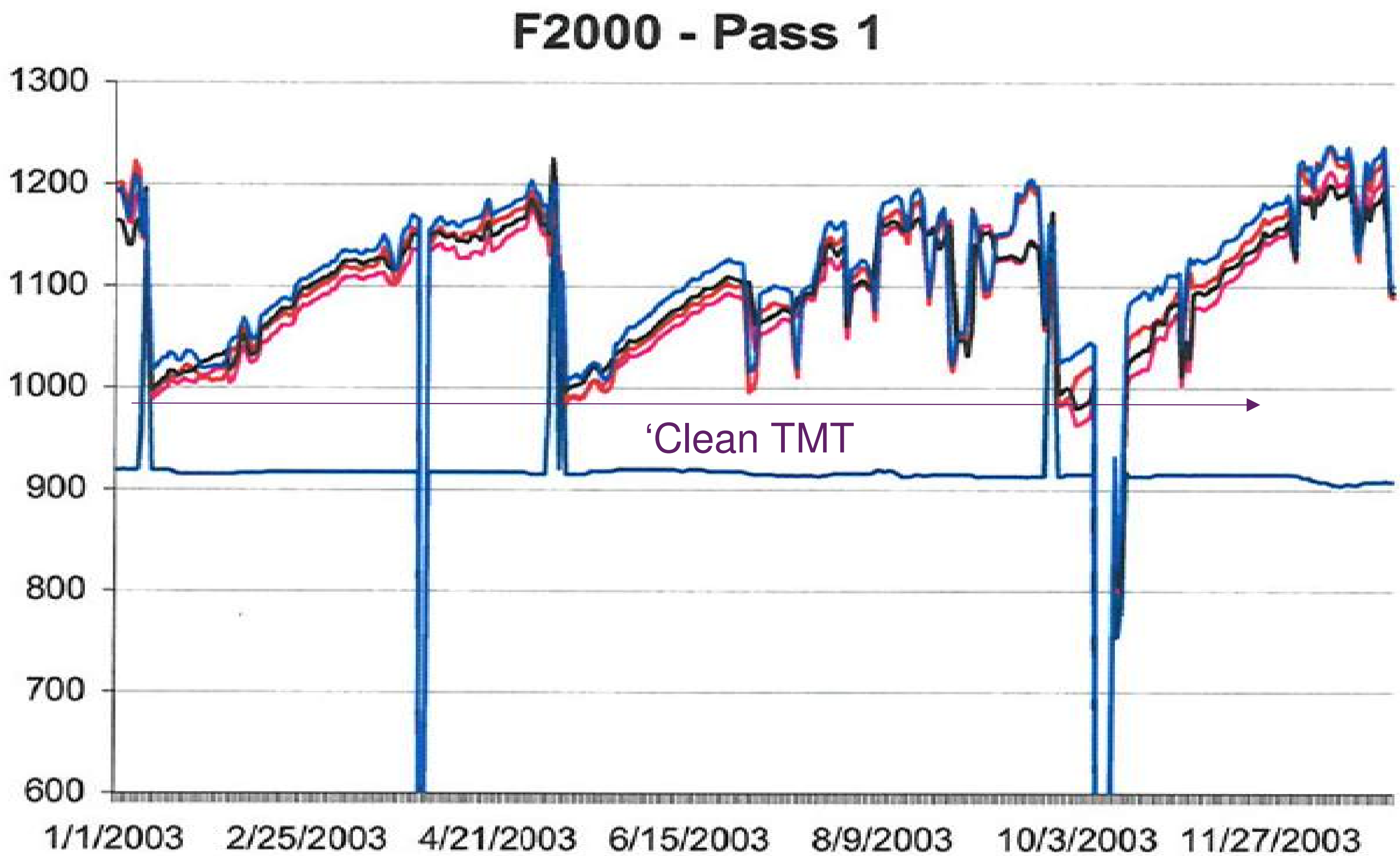
Steam/condensate sparging with thermal cycling

- Spalling was a patented process developed in the 1980s
- Spalling is a reliable method for organic fouling removal on-line with the right procedure
- Spalling relies on temperature cycling of the tubes to be effective
- It is an on-line operation so the effluent must be handled by the process downstream of the heater
- Spalling does not require the heater to be cool to perform
- It is most effective when the heater is set up with individual passes for isolation and separate burners for each pass for firing control
- Spalling can be performed by properly trained plant personnel

On-line spalling – single-fired



Online spalling double-fired



Best practices

Terrace Wall™
Delayed Coker Heater
As presented in
Bahrain Refcomm
Conference 2015

When it all comes together!

SATORP Coker Heater presentation Bahrain meeting

- Terrace Wall coker heater 1 year run without spalling
- Running at design rates and recycle
  - Design COV (cold oil velocity)
  - Design velocity medium injection rate
  - Design crossover temperature
- Feed stock same as design basis
  - Fluid properties per design
  - Residence time and cracking as design
- Coker off gas fuel same as design basis
  - Burners firing at normal rates
  - Burners firing at shop test conditions

Q&A

Thank you!

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