FOSTER WHEELER
Fired Heaters

Coker Heater Design
The Heart of the Coking Process

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Foster Wheeler USA Corporation
Fired Heater Division

Coking.com®
MORE PRODUCTION - LESS RISK!

Galveston, TX April 19-23, 2010

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NEW UNITS OPTIONS

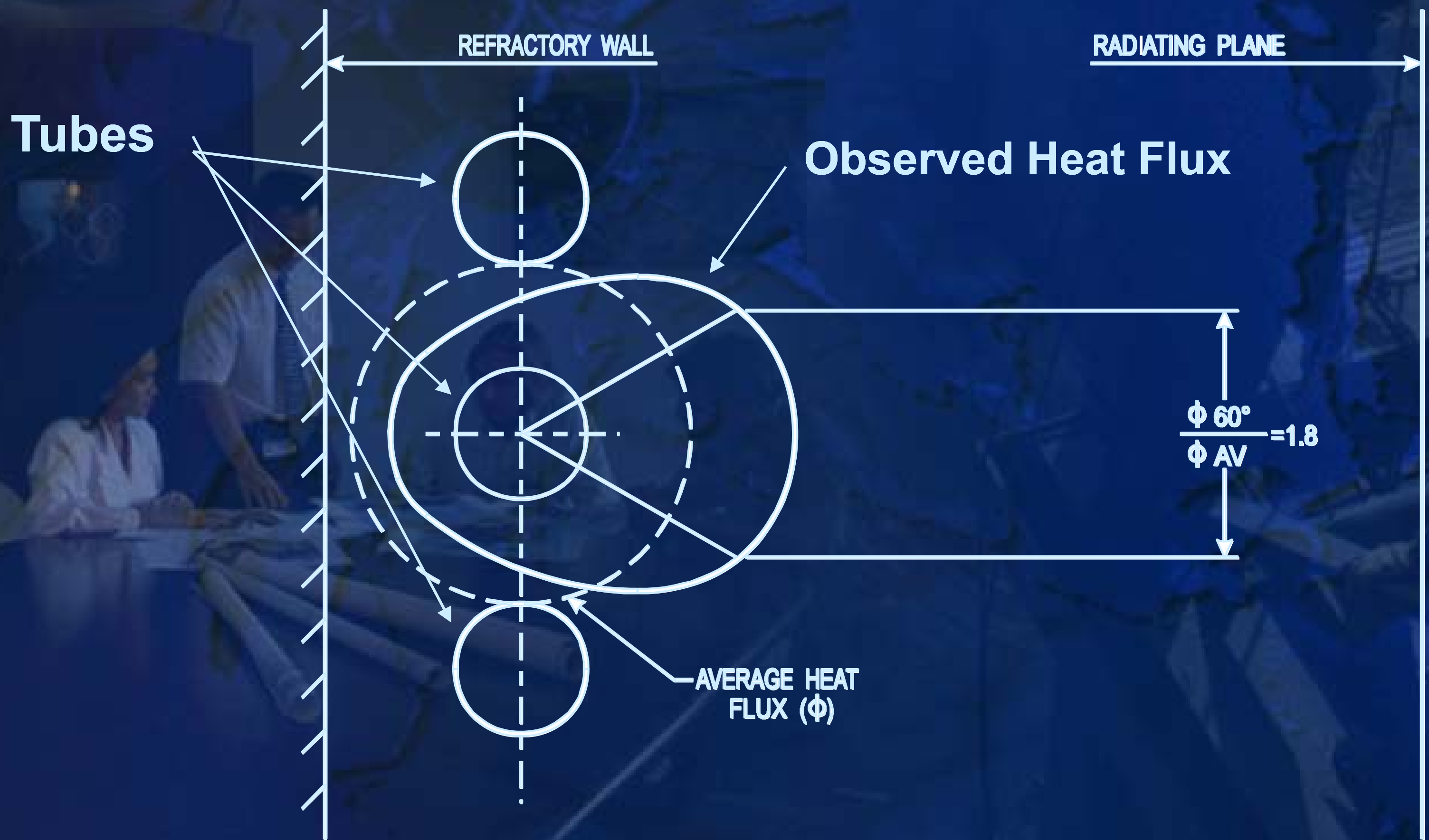
ELLIOTT'S RULES FOR COKER HEATERS

- Individual Pass Control and Firing Ability
- High In-Tube Velocities (6 fps min.)
- Minimum Residence Times
- Optimum Flux and No Mal-distribution
- Constantly Rising Temperature Profile
- Symmetrical Pass Arrangements and Piping
- Steam/Condensate Injection
- Generous Firebox Dimensions

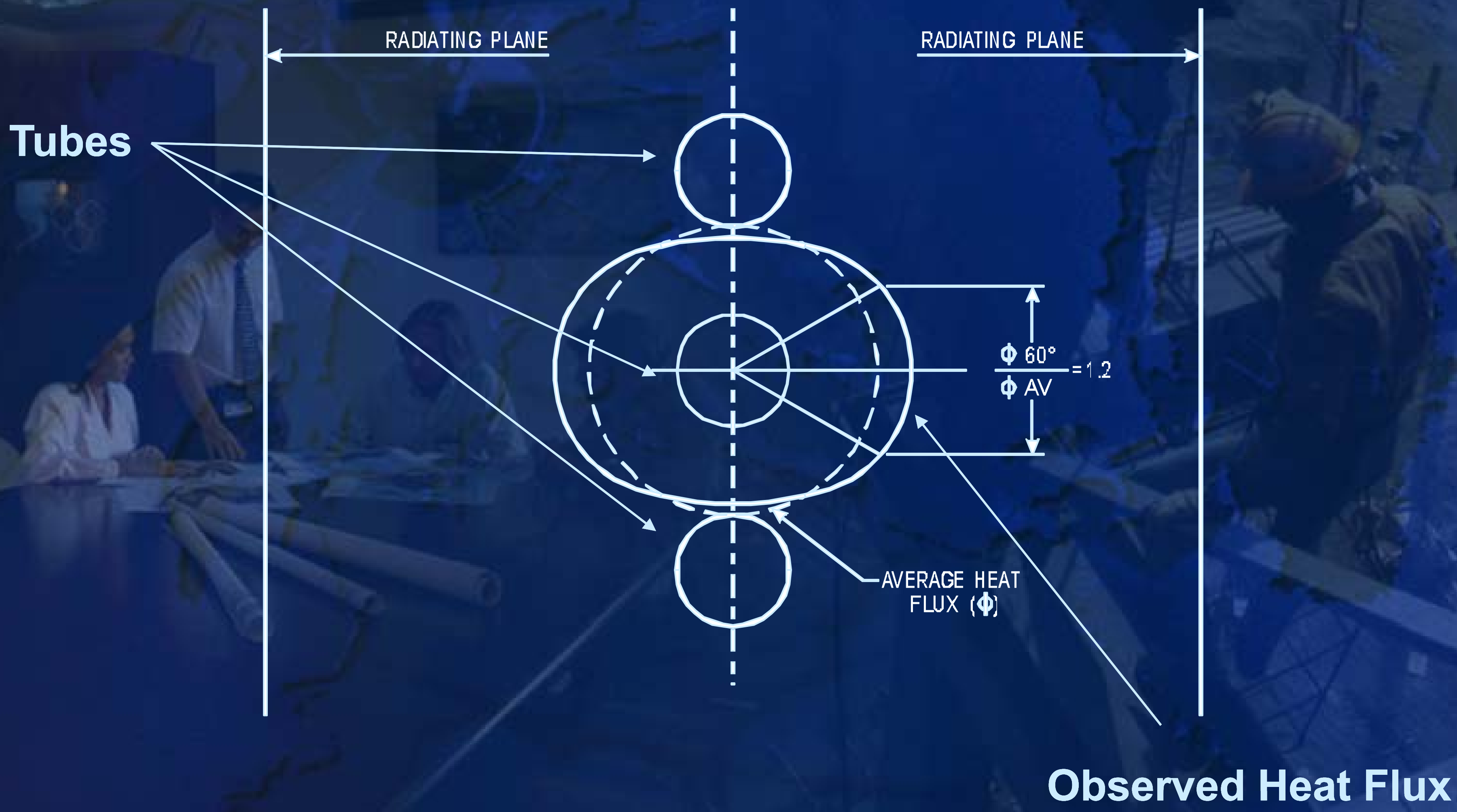
SINGLE VERSED DOUBLE FIRED

- Same Peak Heat Flux
- Same TMT Limit
- Double Fired –2/3 the Radiant Surface
- Double Fired- More Volume in Radiant Section
- Double Fired- Higher Velocity For Same ΔP
- Double Fired- More Uniform Heat Flux
- Double Fired-Handles Difficult Feeds Better

CIRCUMFERENTIAL HEAT FLUX DISTRIBUTION - SINGLE FIRED TUBES

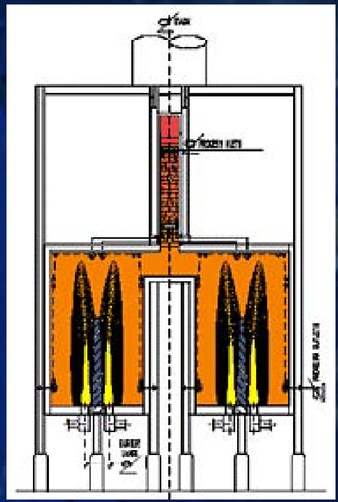


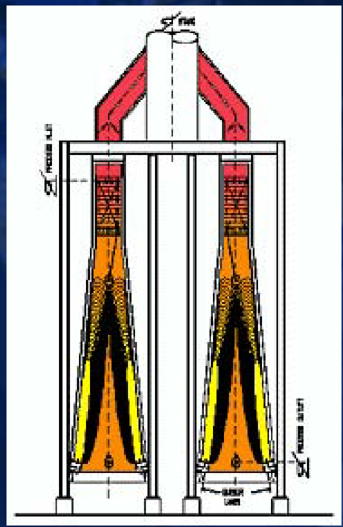
CIRCUMFERENTIAL HEAT FLUX DISTRIBUTION - DOUBLE FIRED TUBES



Heater Design Complete

WHAT MORE IS THERE TO CONSIDER?





DETAIL CONSIDERATIONS

- Velocity Medium Injection/Locations
- Single vs. Multiple Design Temperatures
- Single vs. Multiple Design Pressures
- Tube Metallurgy/Diameter/Thickness
- Plug Headers/Wrought/Cast Fittings
- Radiant Header Boxes
- Pigging/Spalling/Steam Air Decoking
- Burner Selection/Layout
- Radiant Tube Supports
- Modularization

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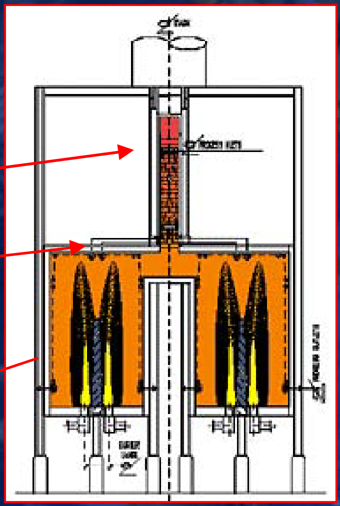
STEAM/CONDENSATE INJECTION/LOCATIONS

- **Amount**
  - **1% wt Steam or Condensate**
- **Location**
  - **Prior to Convection Section**
  - **Crossover Piping**
  - **Just Prior to where Cracking Starts**
- **When to Relocate the Injection Point?**
  - **Pressure Drop issues Only**
- **Turndown**



TURNDOWN-
VELOCITY INJECTION MEDIUM

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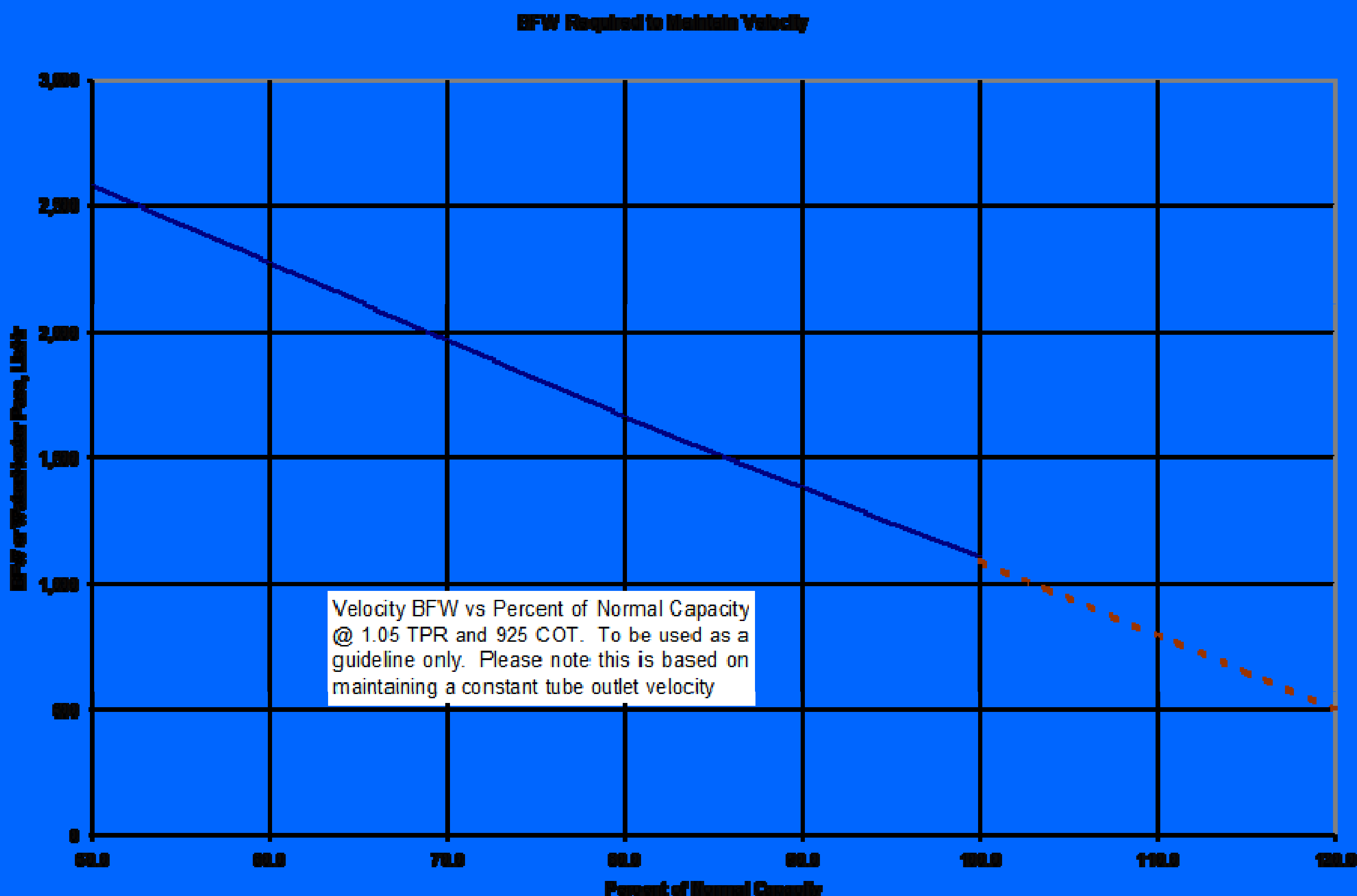

Each heater should have a velocity injection medium curve developed for the feedstock to be processed in the tube size installed

VARYING DESIGN TEMPERATURES

- **PROS - Lower Convection Design Temperature**
  - Thinner tubes
  - Possible different metallurgies
  - Possible different fin metallurgies
  - Less costly
- **CONS -Lower Convection Design Temperature**
  - Limits operating conditions at EOR
  - Limits Spalling Flexibility (increase time)
  - Fin losses and Thermal Efficiency losses
  - Shorter run lengths
  - Operational revenue lost

VARYING DESIGN PRESSURES

- **PROS- Lower Radiant Design Pressure**
  - Thinner tubes
  - Less costly
- **CONS - Lower Radiant Design Pressure**
  - Limiting operating conditions at EOR
  - Can not handle Blocked-in Conditions
  - Shorter run lengths on opportunity crudes
  - Operational revenue lost

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TUBE DESIGN CONDITIONS

- Metallurgy 9Cr-1Mo vs. 347SS
  - API Limits 1300°F for 9Cr-1Mo vs. 1500°F for SS
  - SS Tubes have better spalling ability on organic fouling due to thermal expansion properties
  - SS Tubes are more prone to erosion in return bends
  - 9Cr has proven to be successful in operation on various feed stocks including high S, high minerals, and high TAN
  - SS Tubes must watch for chlorides in injection medium and sulfur in fuels and feeds for corrosion attack

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TUBE DESIGN CONDITIONS

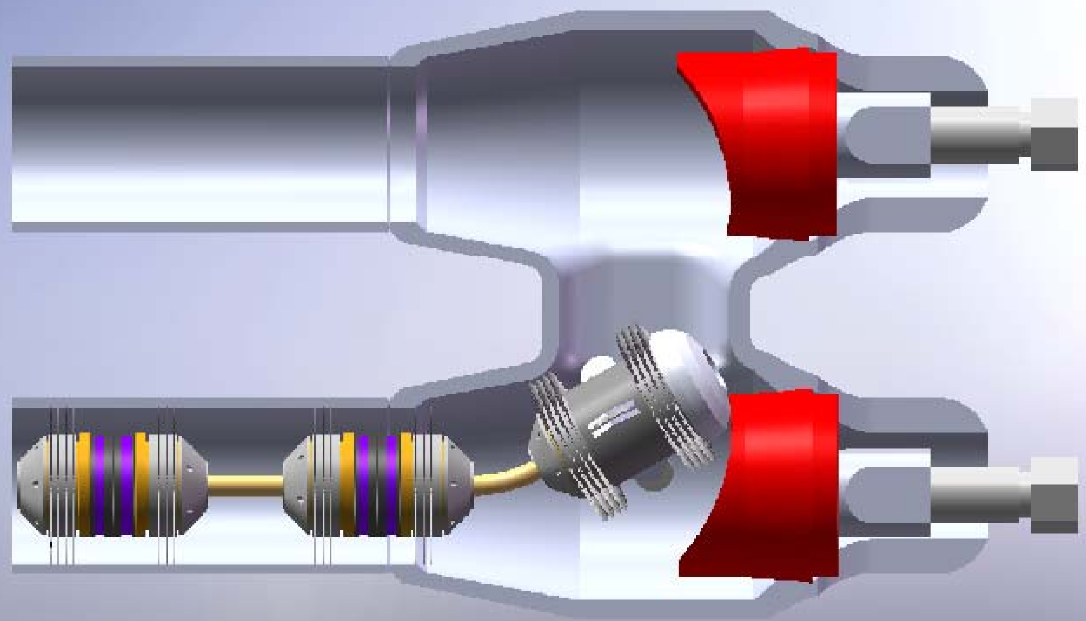
- **Diameter-Single Diameter in Radiant**
  - **Elliott's Rule on High Velocity – Diameter Increase Reduces the Inside Heat Transfer Coefficient and Raises Film Temperature**
  - **More ΔP is Seen with a Single Tube Diameter**
- **Thickness-Single Thickness Throughout**
  - **Allows Higher EOR conditions, Off-Design Operations like Spalling and Recovery from Emergencies like Blocked In Conditions**
- **Ultimately Longer Run Lengths and Tube Life are possible**

PLUG HEADERS

- Plug Headers Cons
  - Leak
  - Maintenance Problems
  - Require Header Boxes
- Plug Header Pros
  - Can Pay for Themselves with One Use
  - Are Useful for New Coker Unit Owners
  - New Contoured Plug Designs for Pigging
  - Can Now be Smart Pigged

CONTOURED PLUG HEADER

SMART PIGS



Plug headers as pictured will allow for Quest Integrity Group's FTIS intelligent pig inspection process

Courtesy of Quest Integrity Group

RETURN BEND DESIGN-RADIANT

- **WROUGHT FITTINGS**
  - Typically Supplied in a Thicker Schedule than the Tube
  - The Reduced ID Causes Additional Acceleration and Additional Erosion on the Return Bends
- **CAST FITTINGS**
  - Supplied with the Extra Thickness on the OD for Enhanced Erosion Resistance
  - Maintains the Same ID as the Tube to Limit Acceleration Related Erosion Effects
- **INTERNAL SURFACING**
  - Primarily Used on the External 'Swing Elbow' for Erosion Prevention
  - Patented for Use Inside the Heater- Believe it is of Limited Use

CAST RETURN BENDS

RADIANT HEADER BOXES

- **PROS**
  - **Allow Lower Design Temperatures on Fittings**
  - **Easier to Remove and Replace than Large End Panels**
  - **No Confined Space Entry to Exam or Repair Return Bends**
  - **End Panel Option Allows Easy Access to Exam Return Bends on a ‘Pit Stop’ Turnaround**
  - **Required for Plug Header Designs**
- **CONS**
  - **Requires More Tube Length (not effective area)**
  - **Requires More Plot Length**
  - **Additional Cost**

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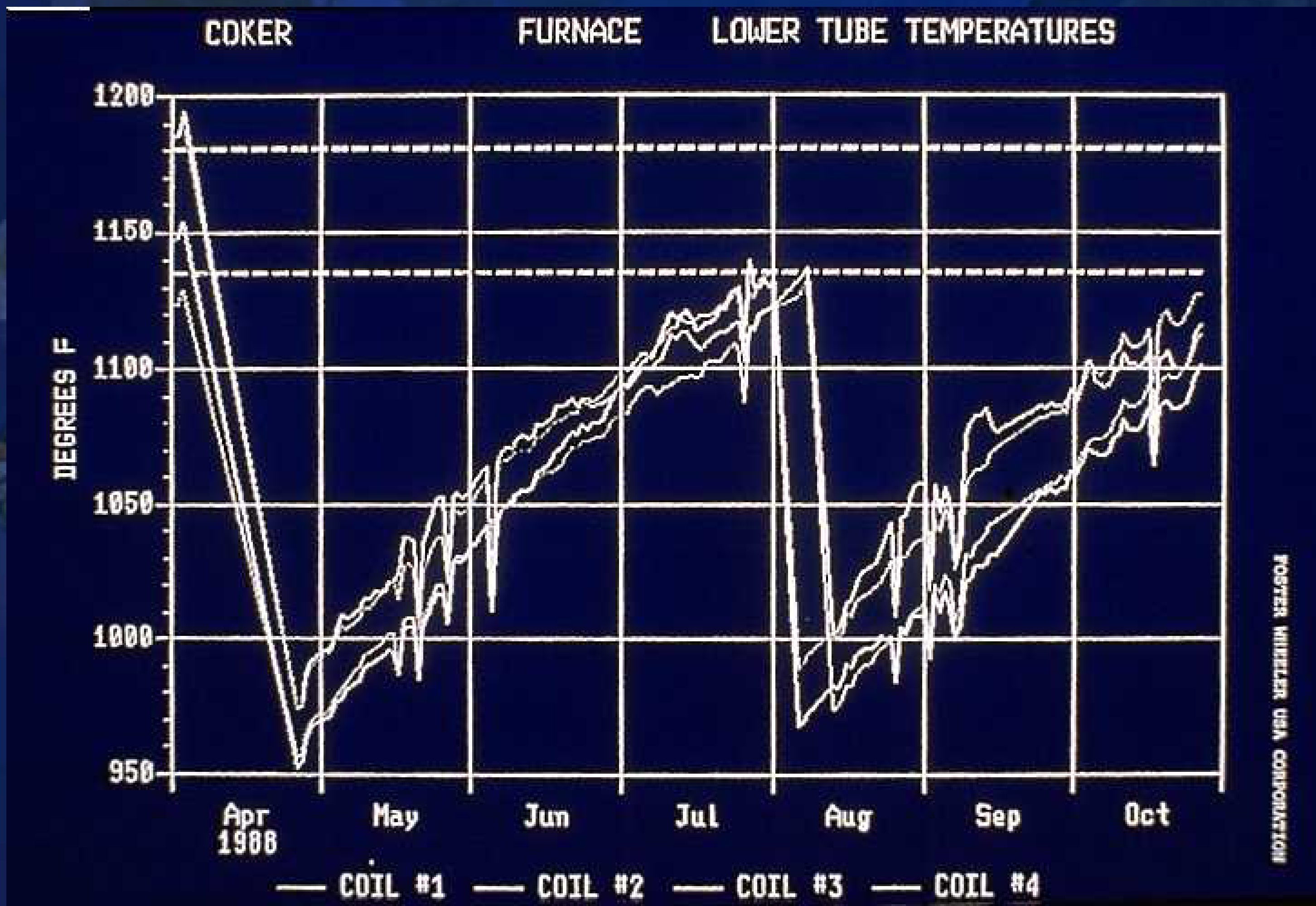
RADIANT HEADER BOXES

PIGGING/SPALLING/DECOKING

In General, the Refiner Should Determine Early in the Project with DCU Licensor the Desired Decoking Method(s) so Provisions Can be Made in the Heater Design and Heater Piping Layout

- On-Line Spalling and Pigging
- Off-line Spalling and Pigging
- Organic Fouling – Spalling and Pigging Compatible
- Inorganic Fouling- Pigging Only

SPALLING CHART



Pigging System (DDT Pigging)

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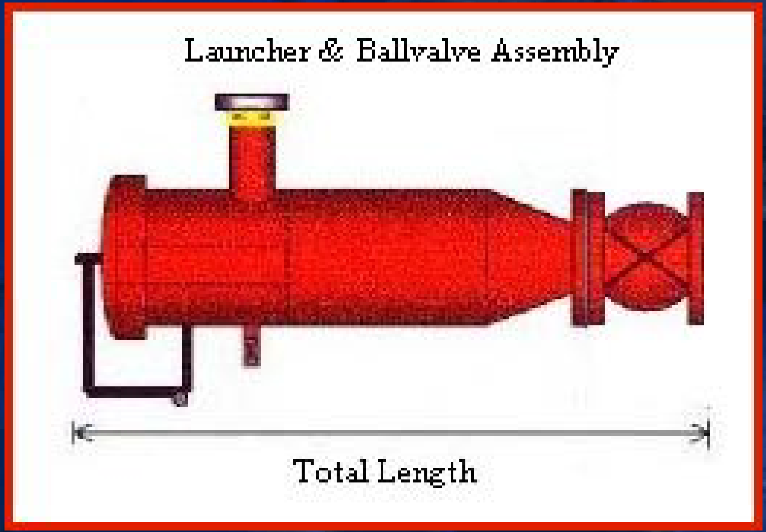

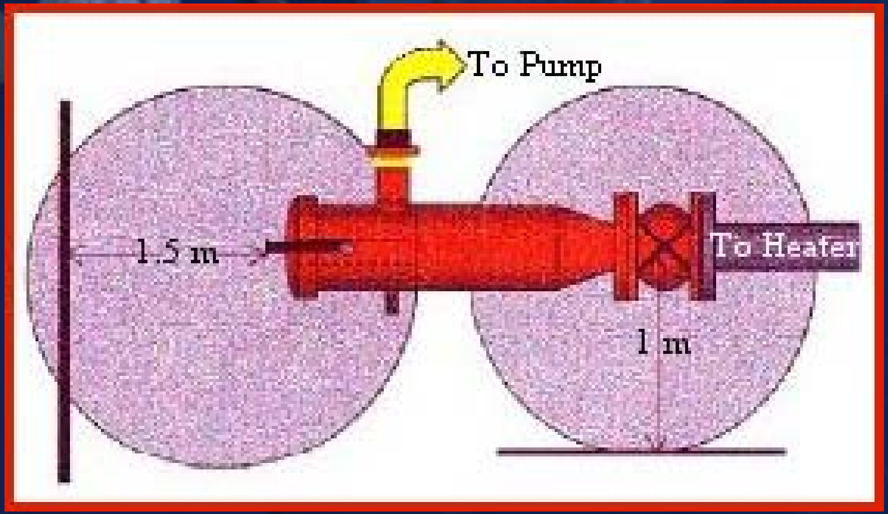

<u>Length</u>
4" Assembly - 56"
6" Assembly - 66 3/4"
8" Assembly - 68 3/4"

Courtesy of Decoking Descaling Technology Inc.

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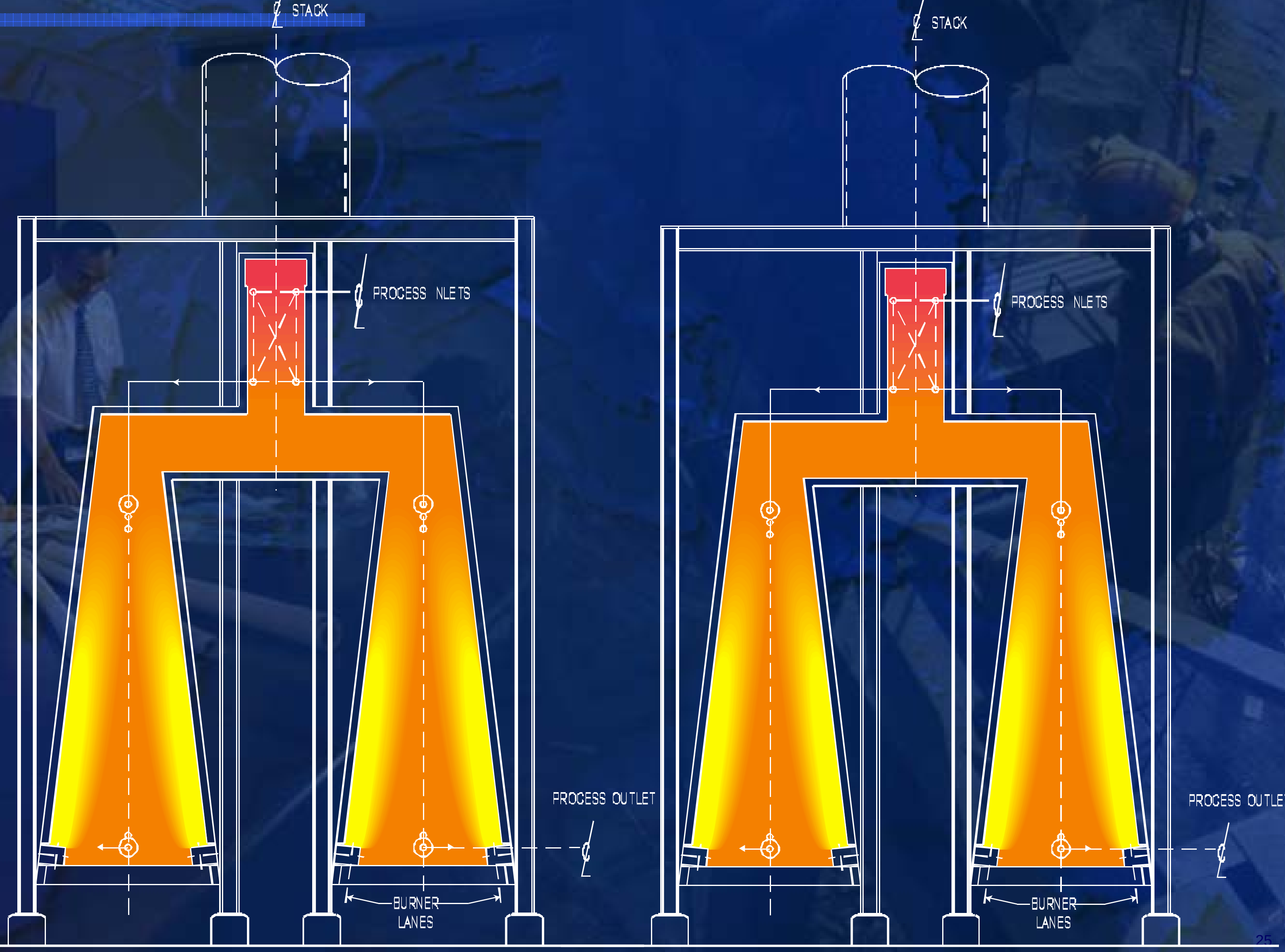
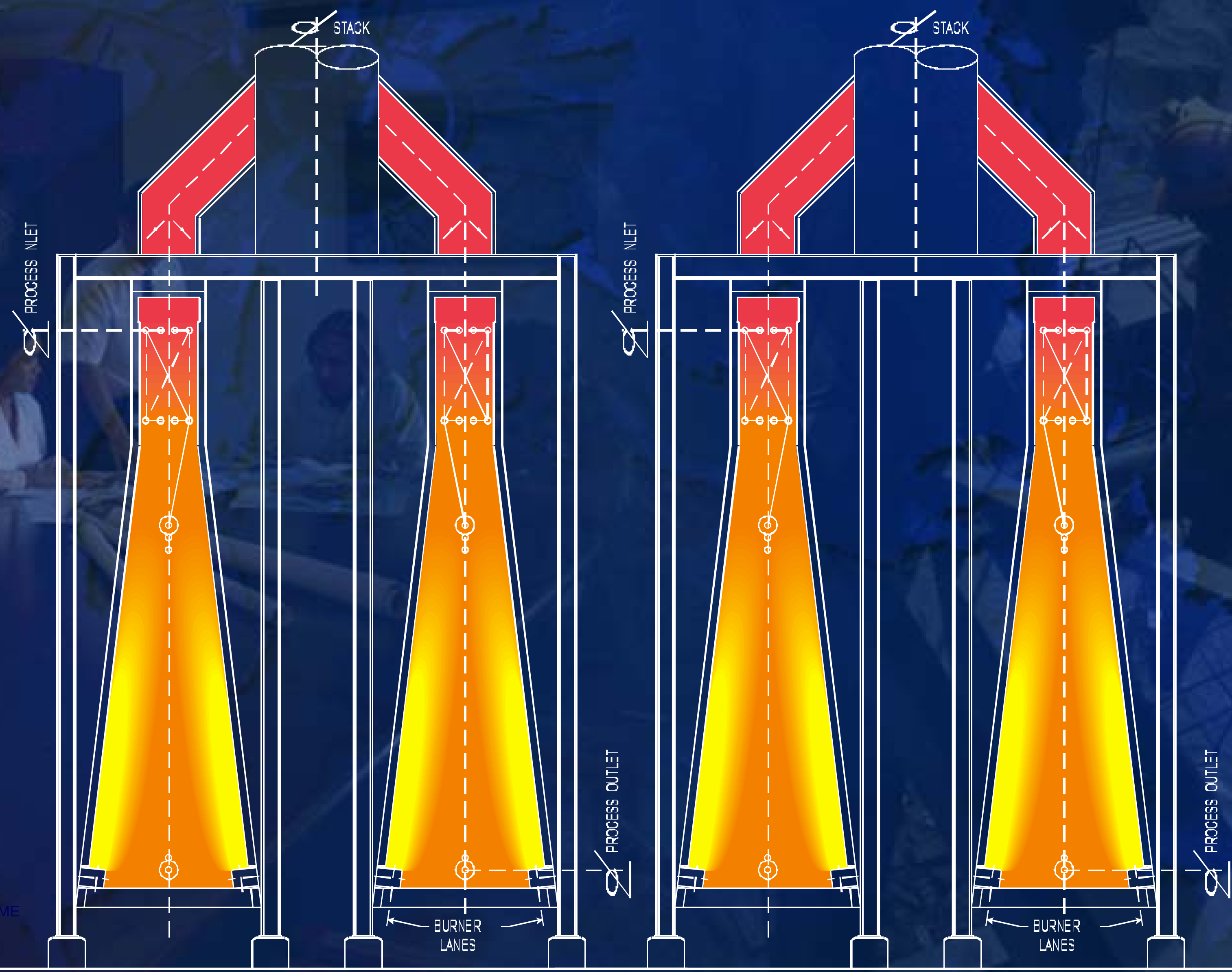
ON-LINE PIGGING-PAIR OF PASSES



ON-LINE PIGGING INDIVIDUAL PASSES



BURNER SELECTION

- Elliott's Rule on Individual Pass Control Impacts to Burner Selection and Firing
- Burner Flames Stabilized on a Bridgewall and only to Provide Heat for One Pass
- Planar Heat Flux Provides Uniform Heat Flux to Tube - Along the Tube Length as Well as Up the Radiant Coil
- Higher Burner Count Spreads the Flames and also Reduces Flame Length so Heat Flux is at the Process Outlet Where Desired
- Generous Firebox Dimensions Provide a Better Recirculation of the Flue Gases for More Uniform Bridgewall Temperature

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WITHOUT PASS CONTROL

Flames are not Stabilized on a Wall and not Uniform in Flux

One Burner for 2 Passes are not Individually Controllable.

Not able to individually spall

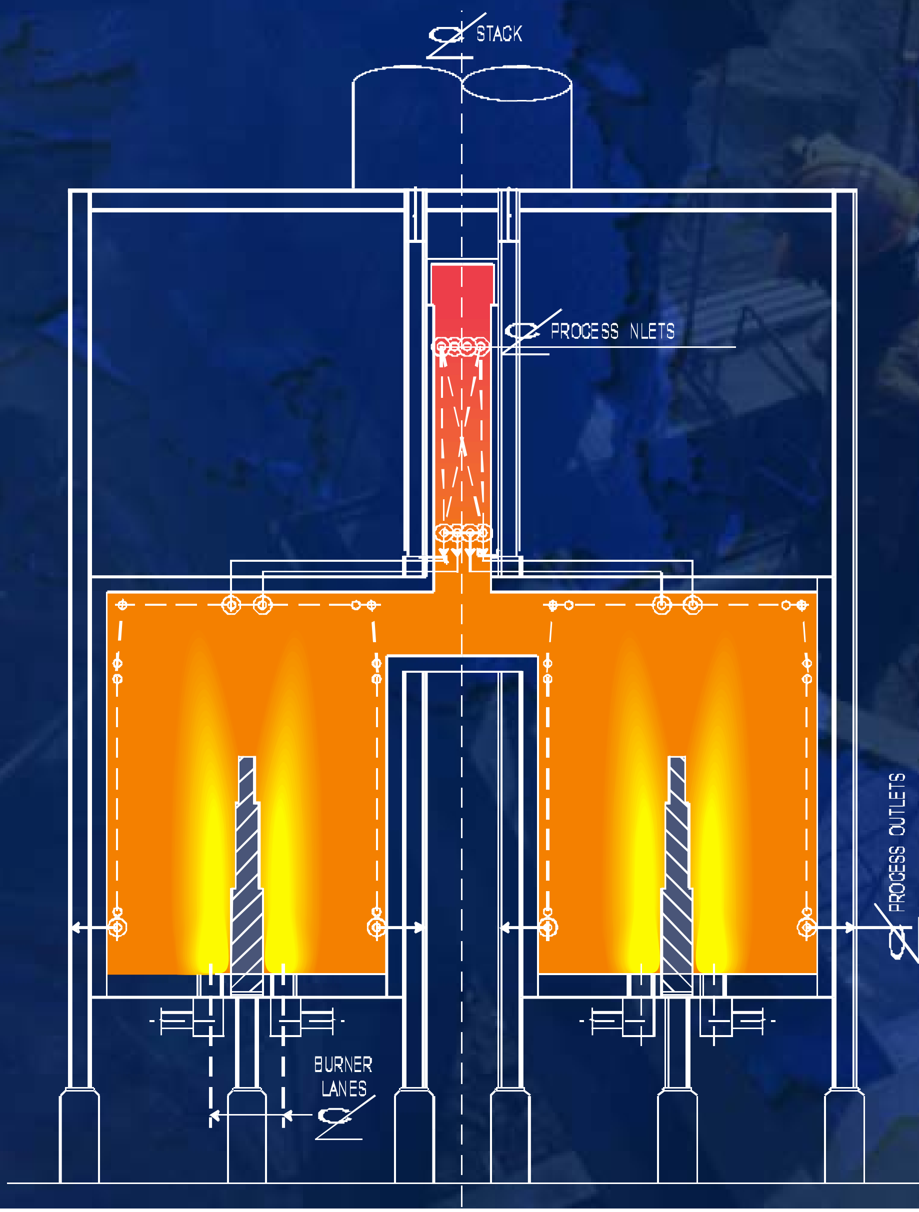
FILENAME

DELAYED COKER CHARGE HEATER

Flames stabilized on the Bridgewall for longitudinal and vertical uniform Flux

Individual pass and firing control.

On line spalling is possible.



UNIFORM HEAT FLUX FIREBOX

More burners keep flames low in the firebox and spread the flames laterally

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RADIANT TUBE SUPPORTS OPTIONS

- Top supported
  - Tubes will loose contact to support as the support grows downward
- Bottom supported
  - Tubes maintain contact to support as support expands upward
- Replaceable with tube removal less costly upfront but requires cutting tubes
- Replaceable WITHOUT tube removal more costly upfront but prevents cutting tubes

MODULARIZATION

- **Extent of Shop Fabrication is One of the Most Important Price Differentiators**
- **Maximum Modularization has Numerous Connotations**
- **Full Understanding of the Degree of Pre-Fabrication is Crucial for a Proper Evaluation and Understanding of TIC**
- **Typically Field Work is a Multiple (X times) of the Equivalent Work Performed in a Shop**

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PANEL SUPPLY

Least Costly Modularization
Supplied With or Without Refractory

MODULARIZATION

Over land shipment

Refractory Usually Shop Installed

MODULARIZATION

Ship/Barge Shipment

Radiant Cell Fully Assembled

EXISTING UNIT OPTIONS

- More Capacity
- Higher Efficiency
- Longer Run Length
- New Process Conditions

GENERAL COMMENT

- Many old heaters (of any service) were designed for conditions far from what is encountered today
- Coker Heaters have the worst impact from this.
  - Crudes are heavier than original design
  - Burners were shorter and narrower
  - Throughput has been pushed
  - Design not set up for modern spalling and pigging operations
- Many new ideas may work uniquely and very well in certain applications but poorly in others applications.

EXTERNAL PRE-HEAT

- Heat Exchanger Pre-heat can Unload the Coker Heater Firing for Additional Capacity
- However, Increasing the Crossover Temperature is not Always a Good Idea
  - If the Process Flow Rate Increase does not Off-set the Longer Residence Time Above Cracking Temperature, More or Quicker Coking May Occur
  - If the Crossover Temperature is Increased too High, There is Risk of Convection (Shock) Row Cracking and Coking Occurring
- It is Suggested a Full Review of the Heater Design and Process Conditions be Performed for these Situations.

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LoNOx BURNER ADDITIONS

- Many Old Heaters were Designed for Different Conditions than they are Operated on today, Burners are No Exception.
- New LoNOx Burners Require Larger Spacing than Old Burners; A Burner for Burner Hole Change out is not Possible in Most all Cases.
- Old Short Fireboxes do not Accommodate New Longer Burner Flames without Impacting the Coker Heater Operation.
- A Combined Review of the Process and the Heater Design is Needed for Adding LoNOx Burners.

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APH-AIR PREHEAT ADDITIONS

- Similarly to External Pre-heat, APH modifies the Radiant Section Heat Recovery.
  - Reduced Flue Gas Flow Changes the Crossover Temperature
  - Radiant Flux is Increases Accordingly
  - Radiant Bridgewall Temperature is Increased
  - Burner Firing is Lower
- Again a Combined Process and Heater Review is Needed to Continue the Previously Achieved Coking Run Lengths.

CERAMIC COATINGS

- Can be Used on New Units too, but what is ‘Design Basis’? The Coating working or it not working?
- Coatings are Used on Tubes and/or the Refractory to ‘Re-shape’ the Heat Flux Profile as Claimed
- Papers have been Presented Promoting the Successes, However the Results are not universal and the Coating has a Finite Life Before Recoating is Required.
- Some of the Success can be Attributed to the Cleanliness of the Tubes Needed for Applying the Coating.

INTERNAL COATINGS

- Alonizing was Promoted in the Past to Retard Internal Coke Build up. Fabrication Issues Prevented the Coating from Having Much Success in Industry.
- New Internal ‘Nano’ Coatings are Entering the Market with Recent Installation for Testing
- Chemicals for Injection are on the Market and Again Papers Presented on their Merits
- All these Uses Should be Properly Explored with Clear Expectations Identified from the Onset by Both Parties.

TUBE METALLURGY

- Although Mentioned in New Units Section, this Option is more Applicable for Existing Units Use. Stainless Tubes are the Typical Alternate Tube Material Due to:
  - Thinner Tubes can Reduce ΔP or Increase Flow rate
  - Spalling can be More Effective/Quicker
  - Tube Metal Temperatures can be increased (Longer Run Lengths Possible)
- Just Remember the Previously Mentioned Limitations of its use

OTHER IDEAS ON COKER HEATERS

- Film Cracking
- Upflow in Radiant Section
- Split Flow
- Flue Gas Recirculation into radiant section (not to burners for NOx reduction)
- Double Row of Double Fired Tubes

JUST BECAUSE THE COIL IS SIZED, THE DESIGN OF THE COKER HEATER IS FAR FROM COMPLETE

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