TechnipFMC

New Technologies in Ethylene Cracking Furnace Design

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TechnipFMC

1. Introduction

TechnipFMC

TechnipFMC in a Snapshot

A unique global leader in oil and gas projects, technologies, systems, and services that will enhance the performance of the world's energy industry

2 Stock Exchange listings – NYSE and Euronext Paris	**21** Vessels
48 Countries in which we operate	**44,000** Employees

Three Major Operating Segments

A comprehensive and flexible offering from concept to project delivery and beyond

Subsea	Onshore/Offshore	Surface
		

Technip Benelux B.V.

Zoetermeer, The Netherlands

- **Technology center for**
  - Ethylene + Hydrogen Technologies
  - SPYRO® (steam cracking simulation software)
  - Fast pyrolysis oil (biomass to oil)
- **Full EPC capabilities**
  - Strong front-end engineering capabilities
  - Advisory / Consulting services
  - Procurement, Expediting, QA/QC
  - Construction, Commissioning, Startup
  - Project Management
- **No. 1 in furnace revamp projects (200+)**
- **Alliances with DOW and Air Products**

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Process Technology Centers Around the World

Supply of ~400 Cracking Furnaces

Liquid Furnaces
GK6®, USC-U® & SU®
> 200 furnaces

Gas Furnaces
SMK™, USC-M®
> 200 furnaces

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2. Cracking Fundamentals

Characteristics

Cracking Furnace

SPYRO® simulation software

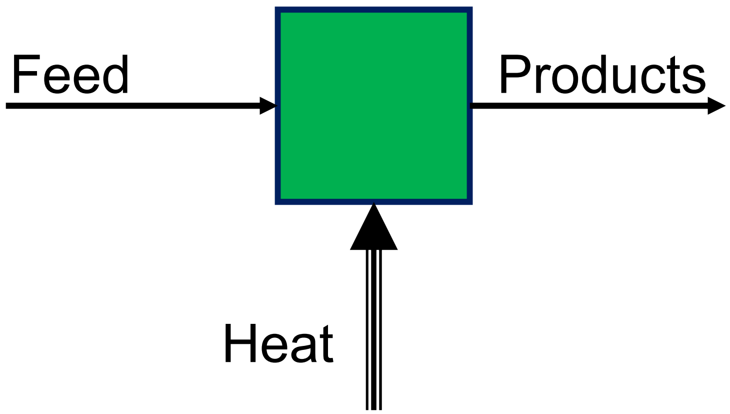
Worldwide Ethylene Capacity

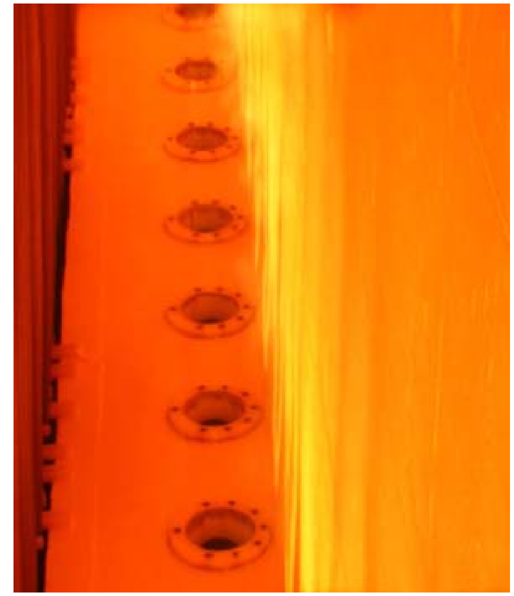
- Current ethylene capacity 165 000 kta (2016)
- 271 steam cracking units in operation
- Plant capacity ranging from 30 to almost 2000 kta
- 54 countries
- Average growing ethylene capacity: 3.9% (recorded over the years)
- Capacity is increased by
  - New grassroots plants
  - Plant expansions

Ethylene is the largest chemical produced worldwide

Characteristics of Olefins Production

- Strongly endothermic process





Ethane

- Absorbed duty: Q ~1.6 MW / ton of feed
- For 1500 kta cracker: fired heat ~ 890 MW

Naphtha

- Absorbed duty: Q ~1.4 MW / ton of feed
- For 1000 kta cracker: fired heat ~ 790 MW

Cracking Reactions - Products

Example – ethane cracking

C_2H_6		$\rightarrow CH_3^* + CH_3^*$	initiation reaction
CH_3^*	$+ C_2H_6$	$\rightarrow CH_4 + C_2H_5^*$	hydrogen abstraction
$C_2H_5^*$		$\rightarrow C_2H_4 + H^*$	propagation
H^*	$+ C_2H_6$	$\rightarrow CH_4 + C_2H_5^*$	
$C_2H_5^*$	$+ C_2H_5^*$	$\rightarrow C_2H_{10}$	termination
H^*	$+ C_2H_5^*$	$\rightarrow C_2H_6$	
H^*	$+ CH_3^*$	$\rightarrow CH_4$	
H^*	$+ H^*$	$\rightarrow H_2$	

Mass, dry%	ethane	Naphtha
Hydrogen	4.1	0.8
Methane	5.0	13.4
Acetylene	0.4	0.3
Ethylene	52.8	27.7
Ethane	32.6	3.8
C3H4’s	0.03	0.6
Propylene	1.2	16.4
Propane	0.2	0.5
sum C4’s	1.9	11.2
sum C5s	0.4	5.9
sum C6’s	0.9	8.1
sum C7’s	0.1	4.1
sum C8’s	0.1	2.2
sum C9’s	0.01	1.4
sum C10’s	0.2	3.4

Cracking - Coke formation

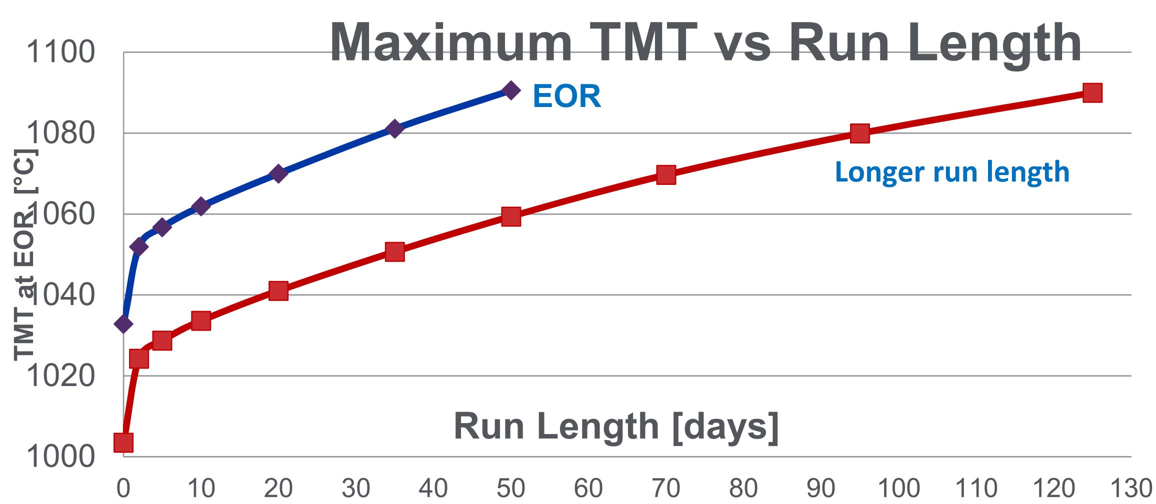
Hydrocarbons → Olefins + other products + <u>coke</u>

- Coke coats the inside surface of radiant tubes
- Pressure drop increases
  - Reduce yield
- TMT increases, limiting furnace runlength (availability)
- Increase energy consumption
- Increase carburization

(reduce coil lifetime)

Cracking - Coke formation

- Coking mechanism:
  - Catalytic (Ni, Fe)
  - Free radical
  - Condensation



Cracking – Coil failure mechanism

Carburisation

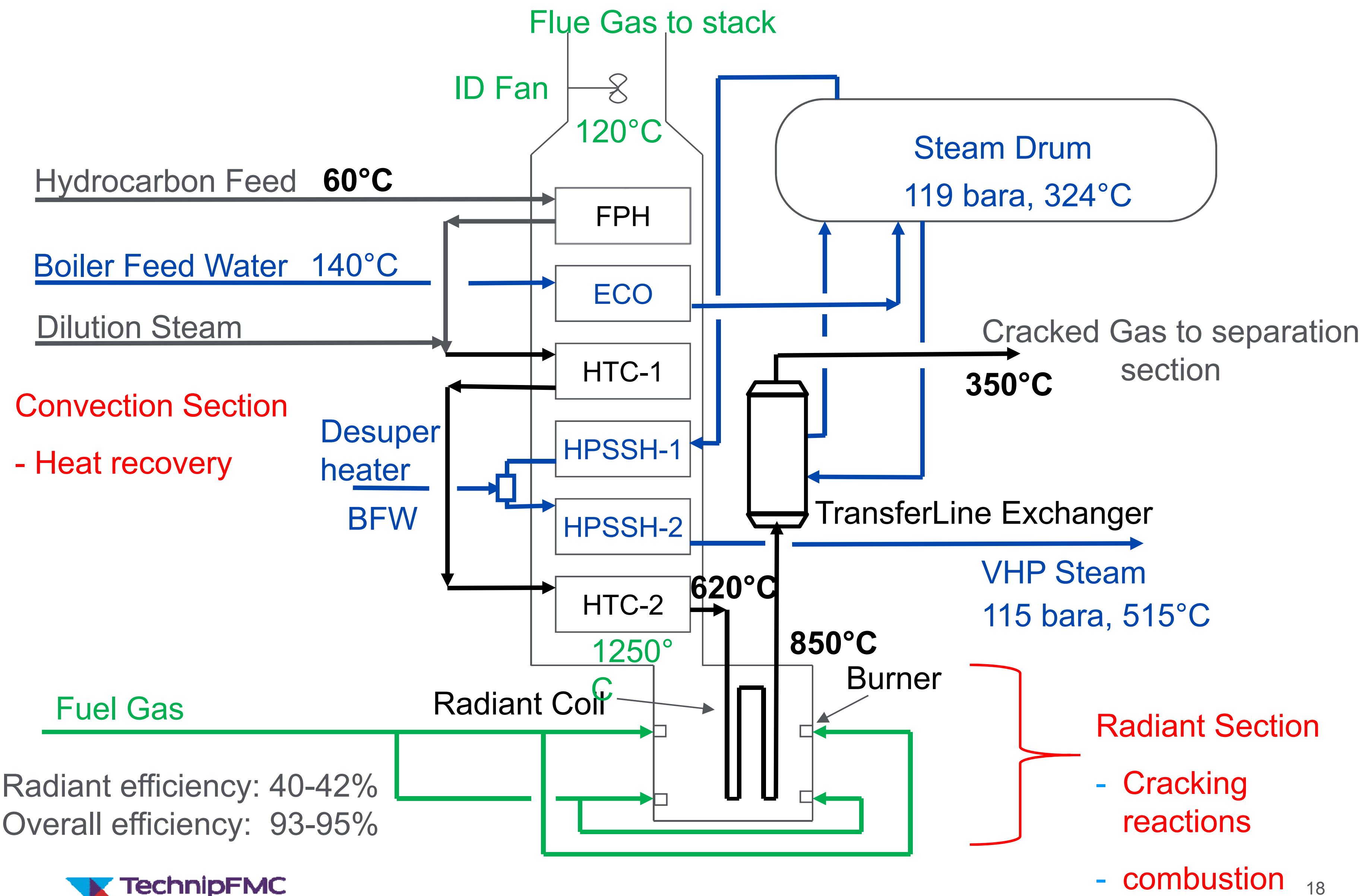
- Internal Carbide formation in carbonaceous atmospheres at high temperatures (>900°)
- Effects tube characteristics by impact on creep properties, ductility, thermal fatique, thermal expansion coefficient

Creep ductility exhaustion

- Each cycle small amount of creep until creep ductility reached

radiant coil has a limited lifetime

Cracking Furnace layout



Radiant efficiency: 40-42%
Overall efficiency: 93-95%

Cracking Furnace layout

Fluegas ID Fan

Steam Drum

TransferLine exchanger

Convection Section

Quench Oil Fitting

Radiant wall burners

Radiant box
- radiant coils

Bottom burners

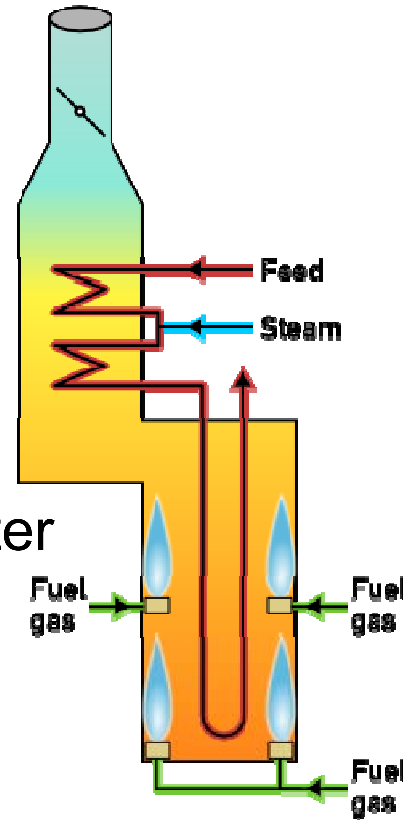
Furnace before Modernization

New Radiant Coil in Transport

Lifting New Radiant Coil

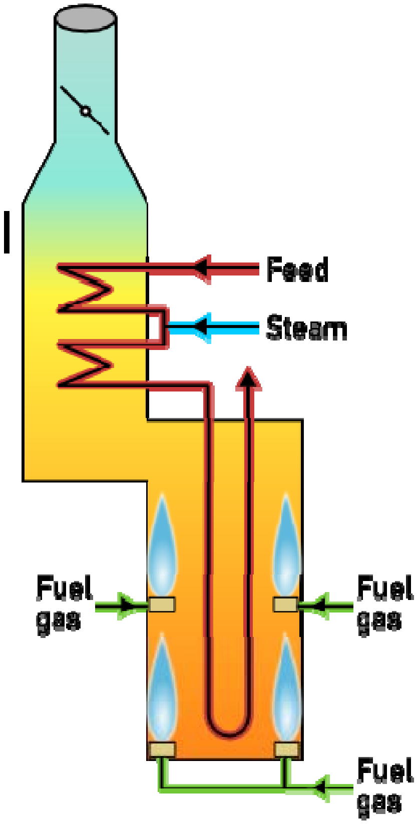
Facts / Parameter ranges

- Cracking reaction is non catalytic and not selective
- Cracking reaction is highly endothermic
- Inlet temperature: 550-700°C
- Outlet temperature: 750-900°C
- Selectivity sensitive for residence time, lower is better
- Selectivity sensitive for pressure, lower is better
- Furnace outlet pressure at TLE: 0,5 – 1,5 barg
- Dilution steam is required; ratio between 0,25 – 1,0
- Radiant coil material: 25/35 and 35/45



Facts / Limitations

- Coking rate
  - Coke layer increases TMT
  - Coke layer increases pressure drop over radiant coil
- Run length determined by:
  - Maximum allowable TMT (Outlet tube)
  - Coil pressure drop (critical flow venturi stays critical)
- Run length, typically 40-75 days
- Decoke with steam/air after EOR; 1-3 days duration
- Operation modes: SOR, MOR, EOR, Hot standby to fractionator, Hot standby to decoke system, Decoke



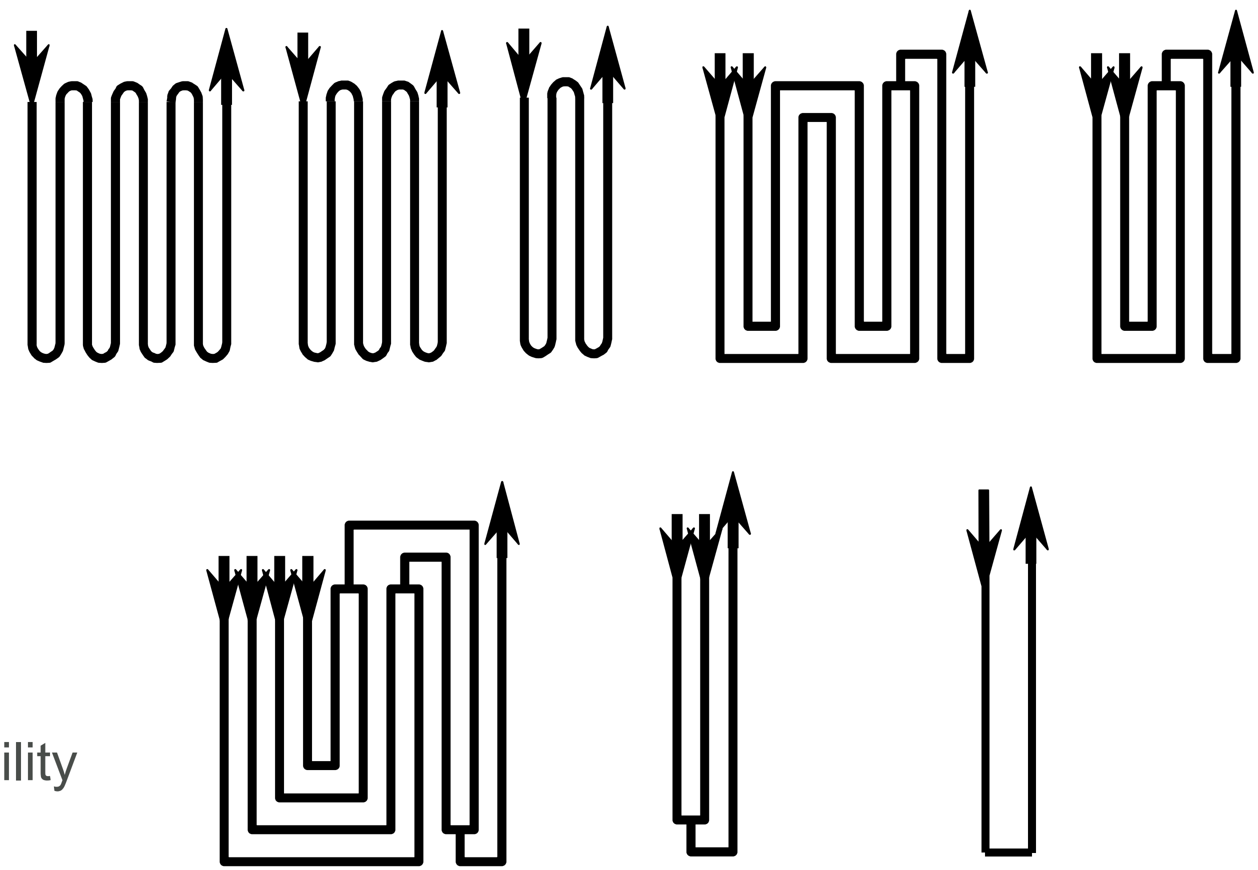
The Magic of Cracking

Optimization of:

- Coil selection
- Coil sizing

against:

- Yields
- Runlength
- Feedstock flexibility
- Operating cost
- Investment cost



- **SPYRO® steam cracking simulation software is used by most cracking furnace operators**

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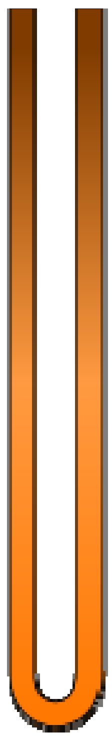
Radiant coil - metallurgy



GK6

GK6 radiant coil - typical

- Two pass
- Outlet tube highest temperatures
  - Highest process temperature
  - Coke formation

Tube	1	2
Material	**25Cr35NiNb** Micro-alloy	**35Cr45NiNb** Micro-alloy
DT	1080 °C	1115 °C
DP 100.000 hrs 10.000 hrs	 3.9 barg 4.9 barg	 3.5 barg 4.6 barg

Radiant coil - Development

Cracking furnaces

- 165 000 kta, +3.9% yearly
- Radiant coil
  - Expensive
  - Limited lifetime – consumables

Looking for

- Lower carburization rate – increase coil lifetime
- Lower coking rate – increase runlength, fewer coils

Developments

- Additives (DMDS)
- Cr-oxide forming alloys
- Al-oxide forming alloys
- Ceramics
- Finned / riffled tubes
- Coatings
- Multi lane
- SFT – enhanced heat transfer
- ....

3. Latest Applied Technologies in Furnace Design

Multi lane radiant coils

Swirl Flow Tube®

Large Scale Vortex® Burner

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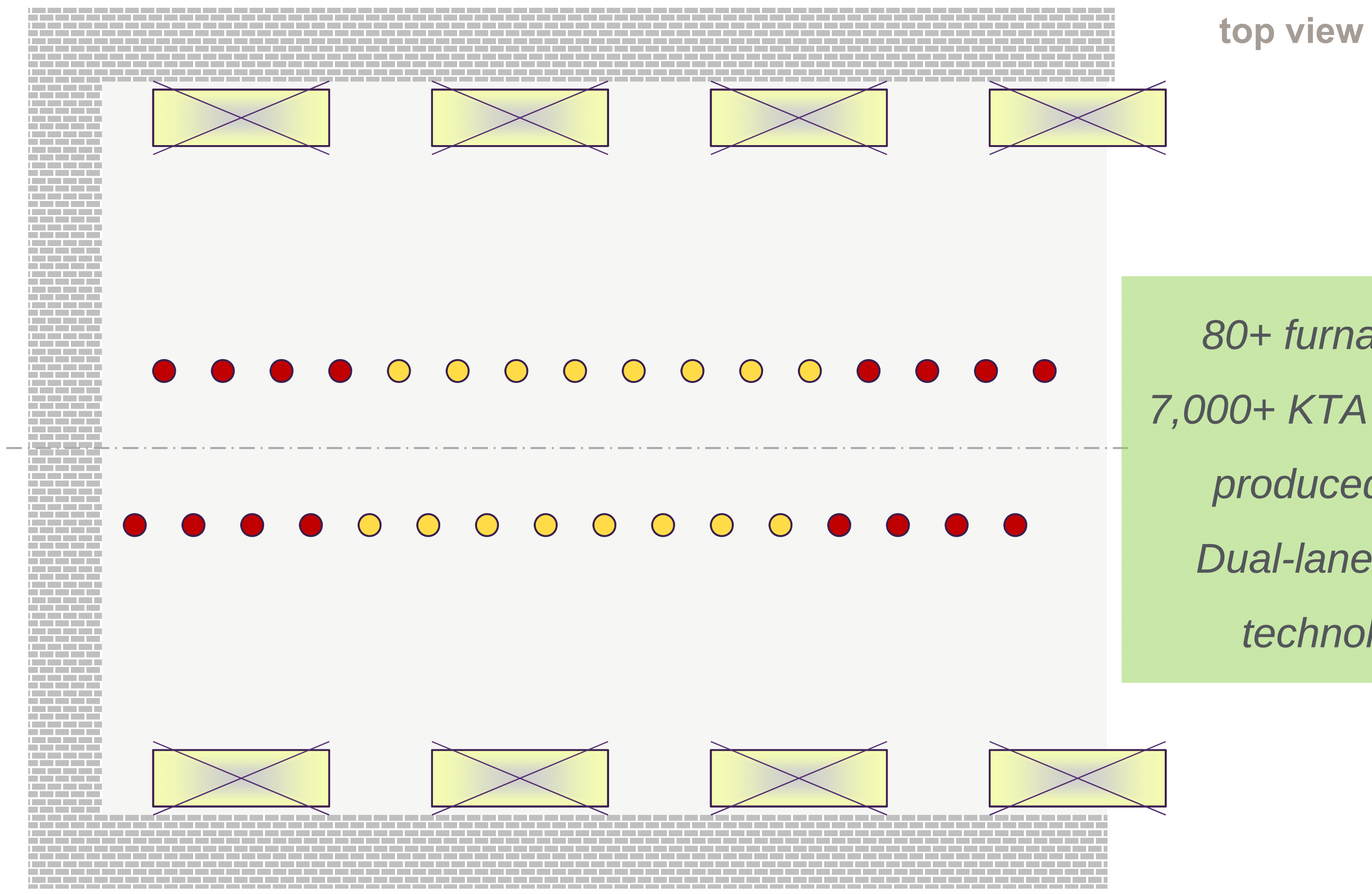
Dual-lane GK6®



80+ furnaces &
7,000+ KTA ethylene
produced with
Dual-lane GK6®
technology

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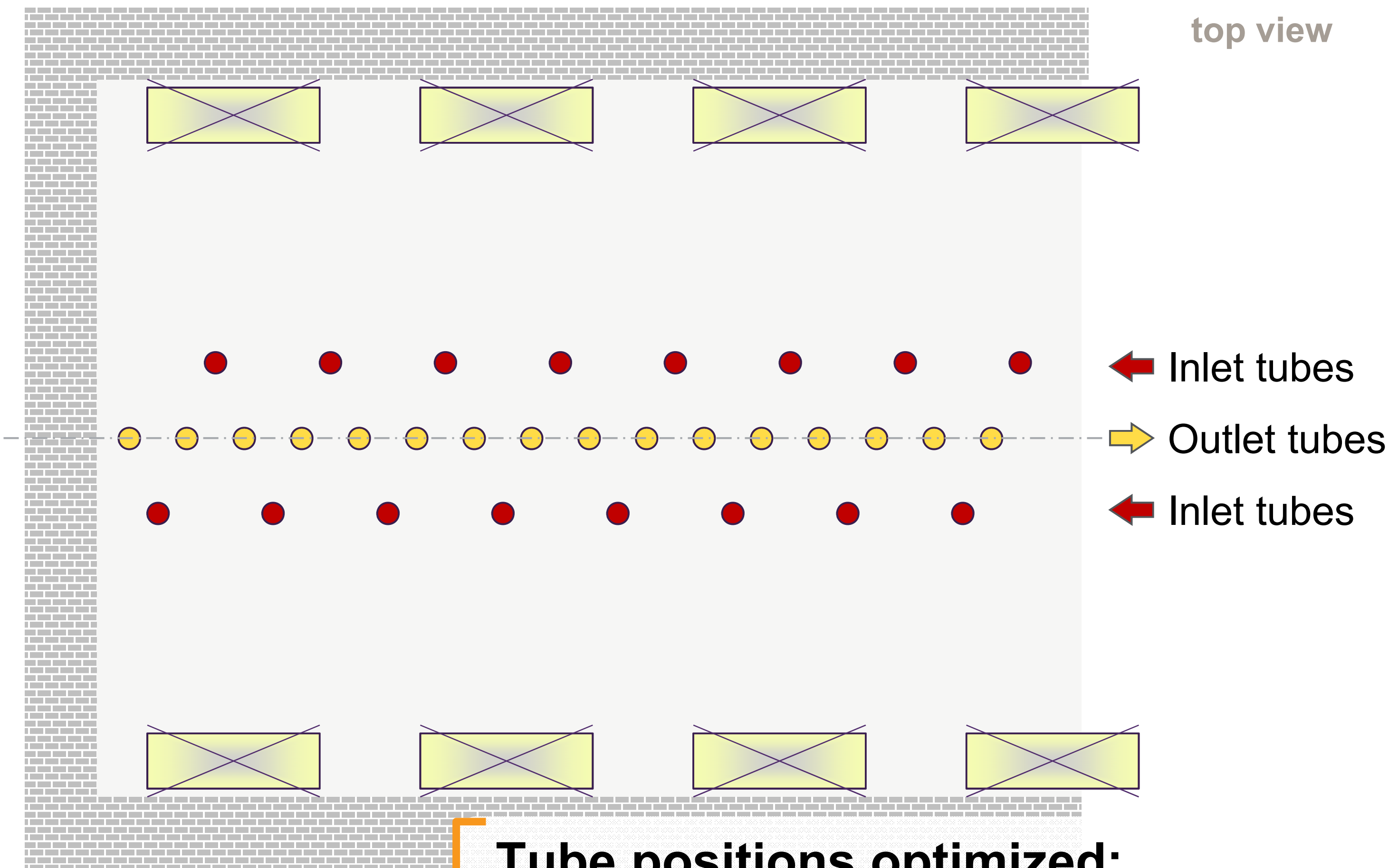
Triple-lane GK6®



Tube positions optimized:
Outlet tubes to the center lane
Inlet tubes to the outside lanes

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Triple-lane Features & Advantages

Inlet tubes at outside, facing burners & refractory

→ Heat is shifted to inlet tubes

Outlet tubes at inside, away from direct radiant sources

Uniform circumferential radiation combined with large tube-tube spacing

→ Reduced Peak to Average Heat-flux on outlet tube

Large tube-tube spacing

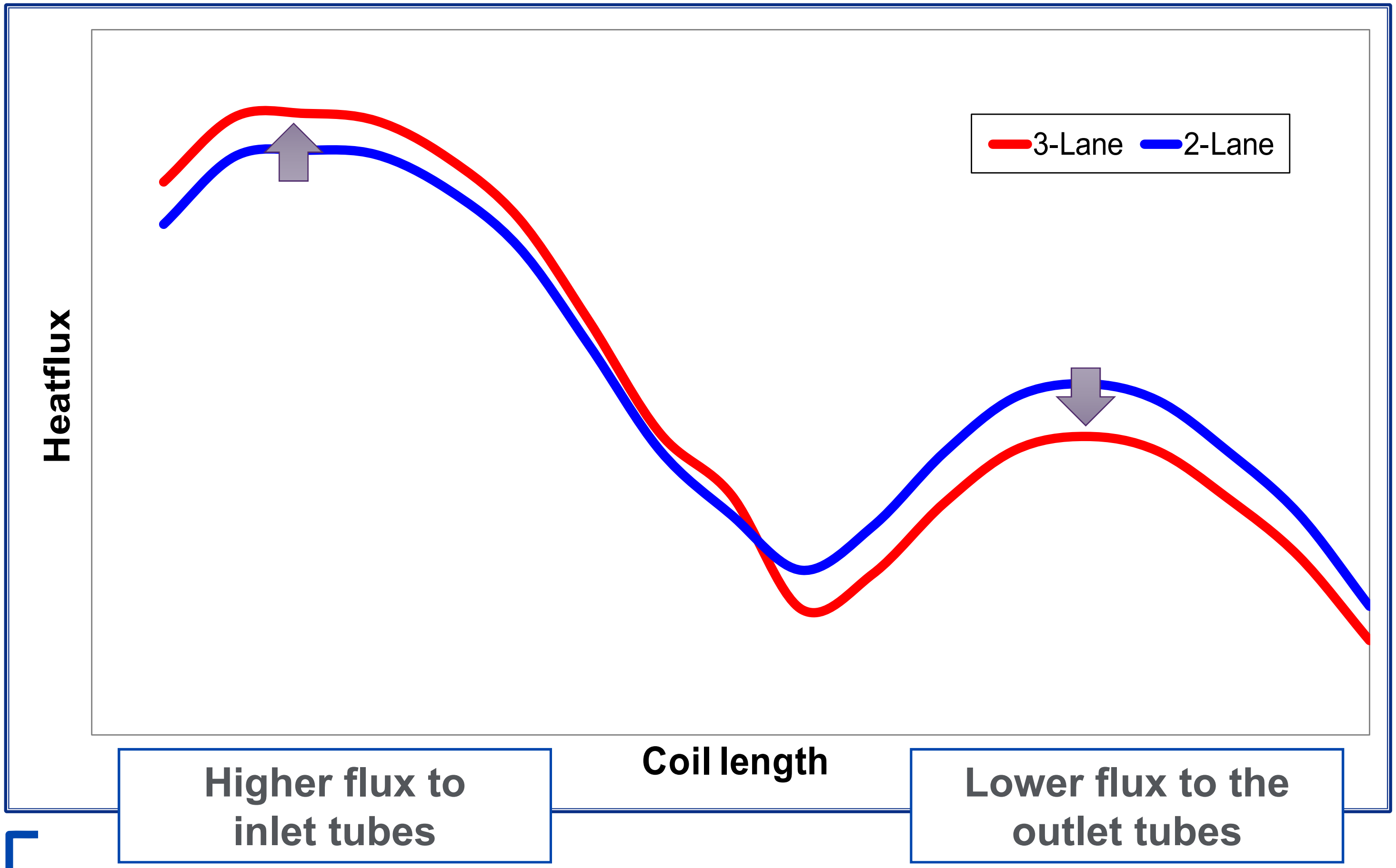
Same amount of tubes in 3 lanes vs in 2 lanes

Overall Impact

Improved heat flux profile & decreased maximum TMT

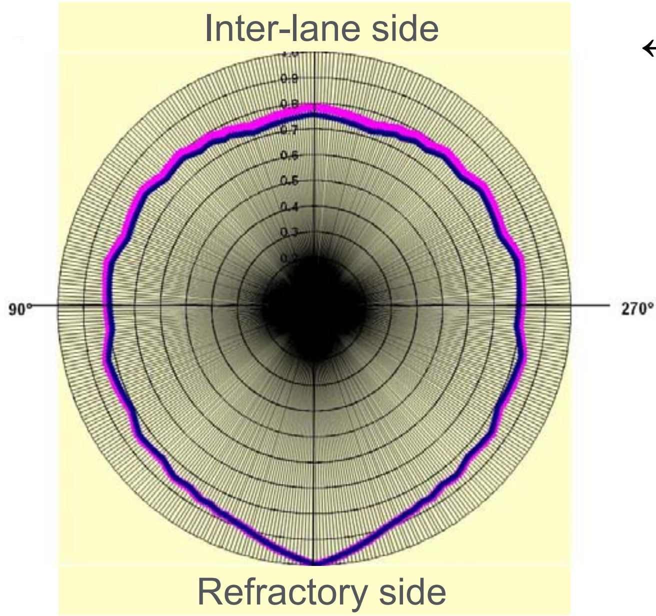
Improved performance

Biasing heat flux towards inlet tubes



Improved thermal utilization of radiant coil

Improved Circumferential Temperature Distribution Outlet Tubes

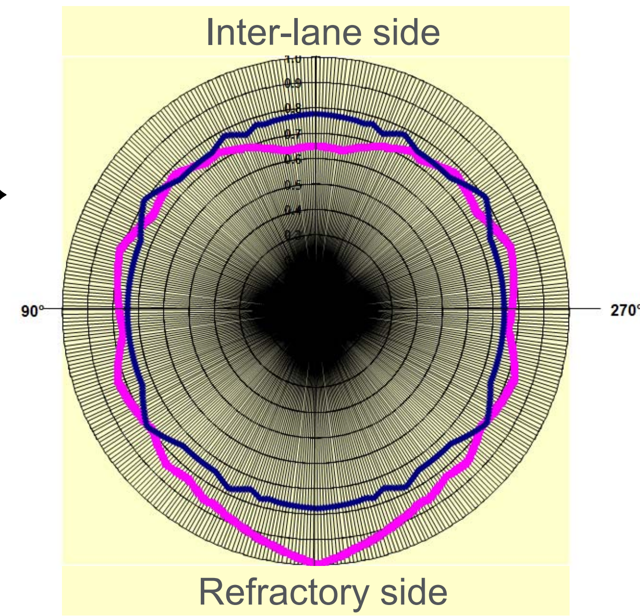


← **Dual-Lane**

- All tubes peak at refractory side
- All tubes dip at inter-lane side

Inlet
Outlet

Triple-Lane →



- Inlets peak at refractory side
- Inlet gradient similar to dual-lane

Outlet tube circumferential heat distribution very uniform

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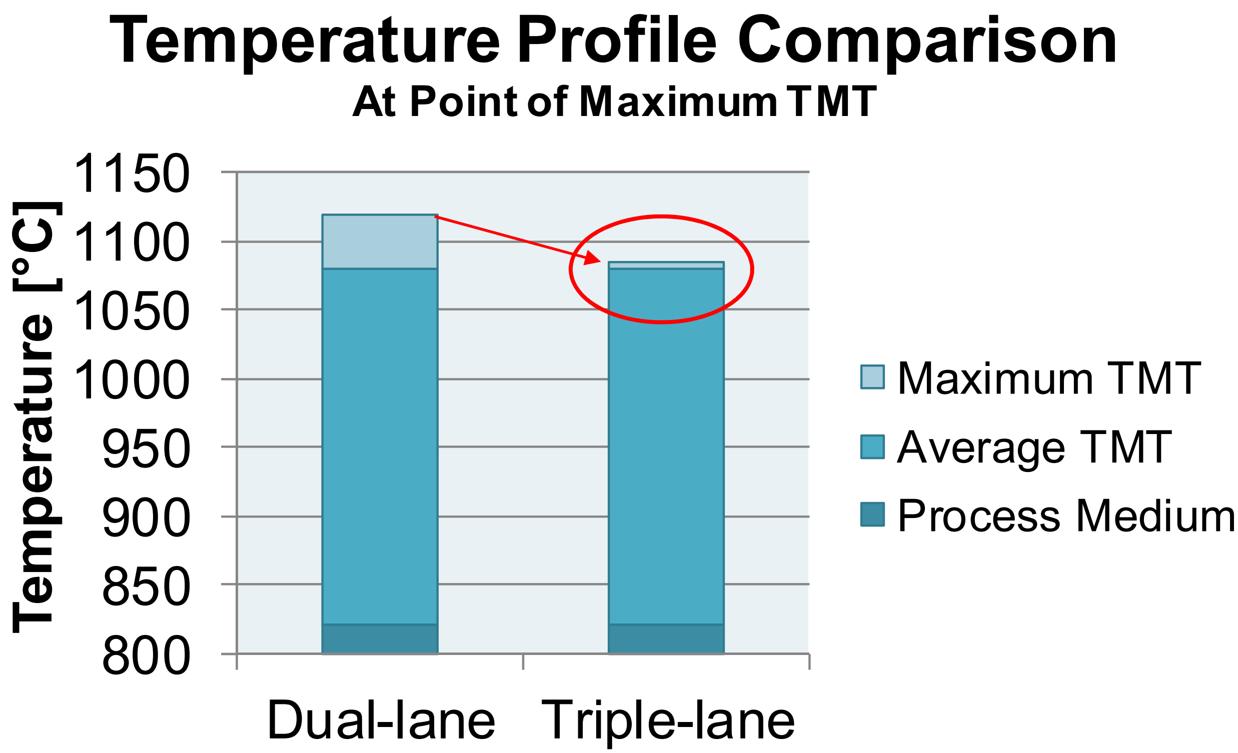
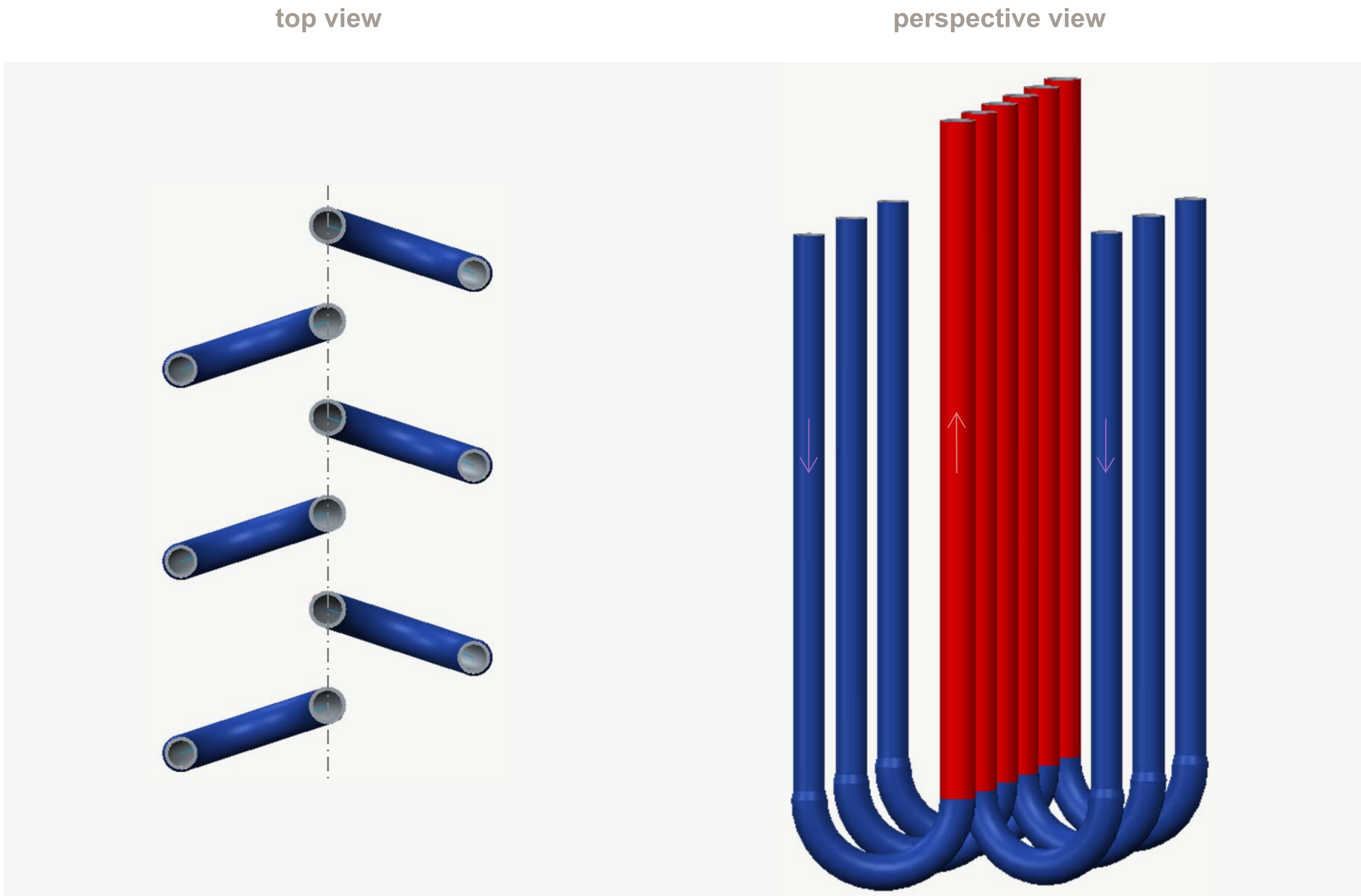
Maximum Tube Metal Temperature



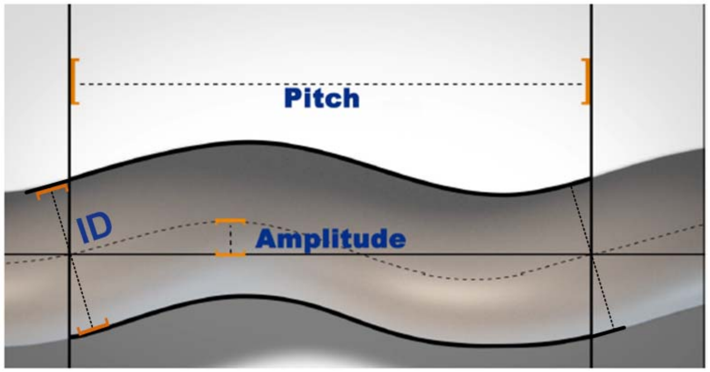
Maximum TMT reduced

Triple-lane 1-1 “U” Coil:

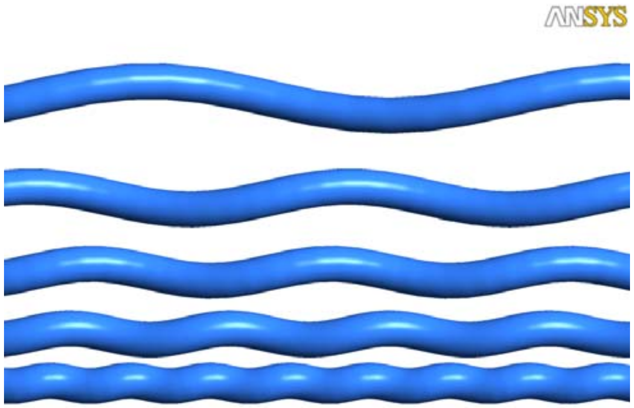


Swirl Flow Tube®

- Round tube
- Helical geometry
- Full line of sight
- No obstructions
- Improved heat transfer

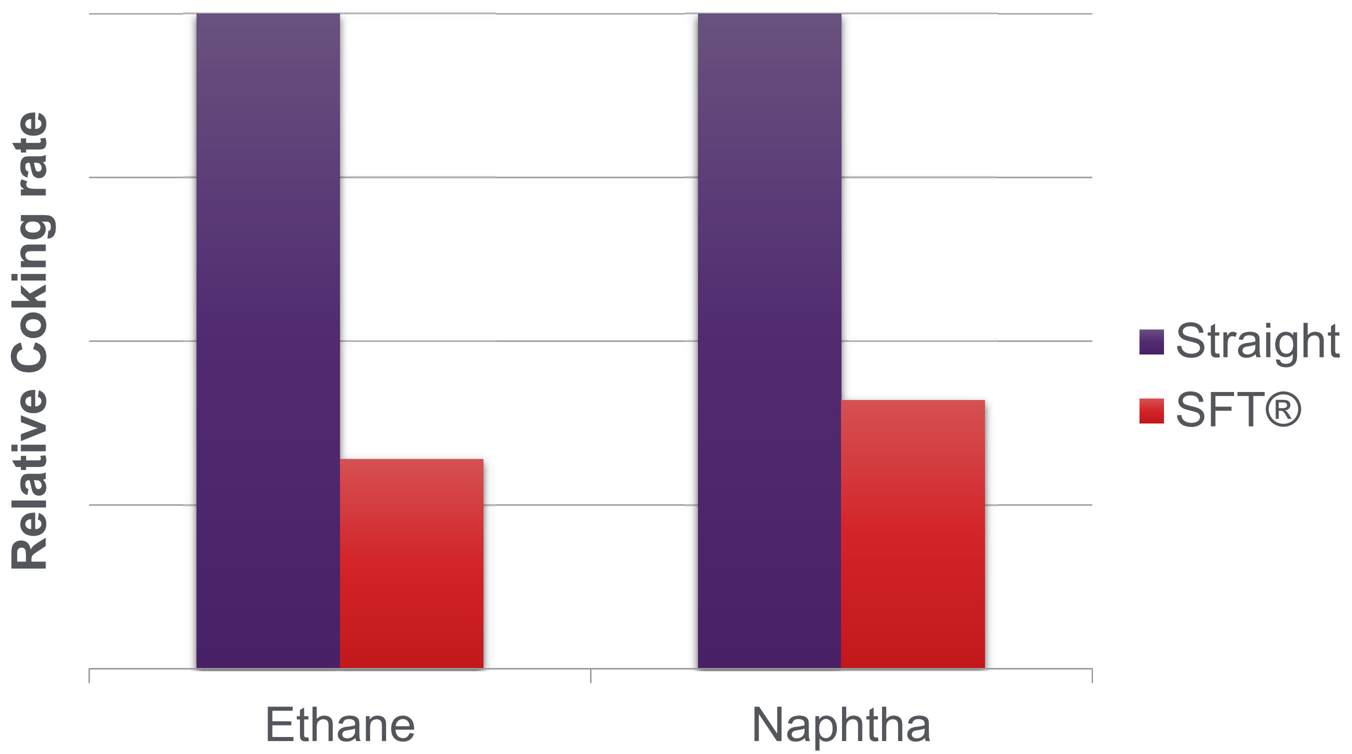


* Veryan Medical Limited: BioMimics 3DTM



Helical tubes of different amplitudes and pitches

Relative Coking Rates



Substantially lower coking rates observed due to

- **Lower wall temperature**
- **Increased turbulence**

Footnotes:

(1) Data from Pilot Steam Cracker of Universiteit Gent

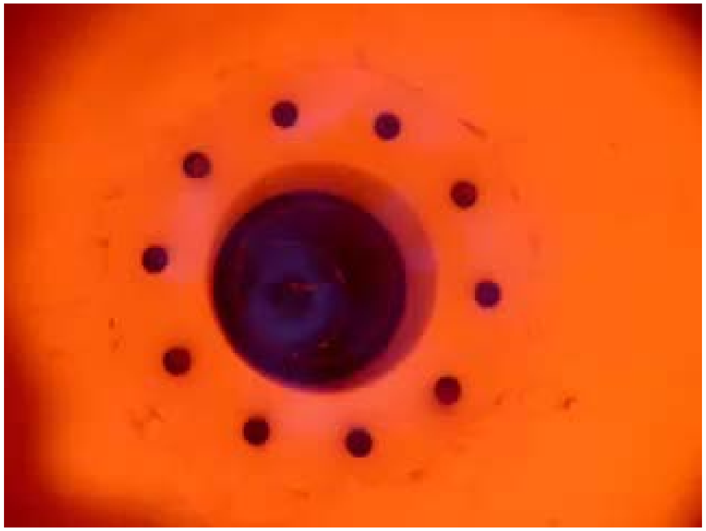
Requirements for Ultra Low NOx burners

- NOx emission in the range 50 … 100 mg/Nm3
- Safety: Burner shall be stable for all operating conditions
- Stable flame and no flame impingement
- Uniform heat flux profile resulting in uniform tube wall temperatures
- Optimized firebox efficiency
- Burner shall be suitable for revamp and new furnace design
- Ability to operate at a high firing intensity
- Low maintenance costs
- Sound pressure level <76 dB(A) @ 1 m.

The LSV burner meets these requirements

LSV ® burner overview

- Simple robust design
- Uses a combination of techniques to prevent NOx formation
- Proven ultra low NOx performance
- Designed to have optimized heat release profile for the most optimal furnace design
- Suitable for furnace revamp and grass root furnace designs



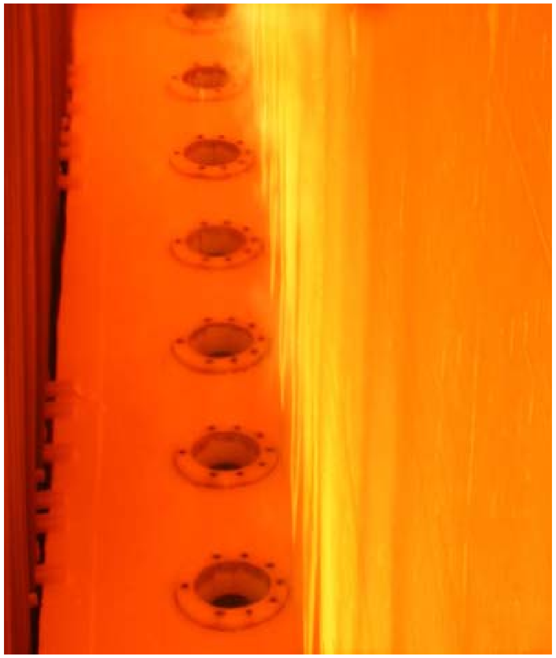
Operational Experience

LSV design data

Excess air	%	7 – 15
Flue Gas Temp (box temp)	°C	1030-1360
Combustion Air Temp	°C	Ambient-470
NOx Emission @ 3 % O2	***ppmv***	***25 – 50***

Operational Experience

- Excellent flame patterns and flame stability
- Very good heat distribution on coils
- High firebox efficiency
- Low NOx emission
- Proven design, trouble free operation
- Reported low maintenance cost
- Manufacturing by TechnipFMC



More than 1000 LSV burners have been applied