The State of Delayed Coking

A strong foundation & legacy
A technology for today
A technology for the future

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**Presentation Agenda**

- **Delayed coking a strong foundation & legacy**
  - Changes in bottom of the barrel processing
  - 60+ years of ThruPlus® Delayed Coking

- **Delayed coking a technology for today**
  - Superior safety & emissions controls
  - Superior stream factor performance
  - Ever increasing coke drum longevity
  - Dependable yields

- **Delayed coking a technology for the future**
  - What’s next
DELAYED COKING

A STRONG FOUNDATION & LEGACY

Image Sources Bechtel Image Library, US National Archives
1862 - 1932
Emergence of refining industry

Primary bottom of the barrel technologies
Atmospheric / Vacuum Distillation (1862-1913)
Thermal Cracking (1913-1932)

1932 - 1942
Beginnings of bottom of the barrel processing

Primary bottom of the barrel technologies
Coking

1942 - 1960
Development of fluid catalytic cracking → gasoline from bottom of the barrel feedstocks
Emergence of Middle East as source of crude oil (Tapline)

Primary bottom of the barrel technologies
Delayed Coking
1960 – mid 1970s
Bottom of the barrel solutions for diesel via hydrocracking
Emergence of other bottom of the barrel technologies

Primary bottom of the barrel technologies
- Delayed Coking

mid 1970s - 2010
Increased bottom of the barrel processing driven by changes in crude feedstock quality; Canadian oilsands upgrading; 1980: Saudi Arabia surpasses USA to become largest oil producer

Primary and newer bottom of the barrel technologies
- Delayed Coking
- Resid Hydrocracking

2010+
Tight oil reshapes bottom of the barrel processing; higher fleet fuel economy dampens refined product demand; North America shifts to processing domestic crude vs. imports with high utilization; Europe/Asia experience capacity rationalization due to decreased margins; Middle East shifts downstream

Primary and newer bottom of the barrel technologies
- Delayed Coking
- Resid Hydrocracking
- Slurry Hydrocracking
60+ years of ThruPlus® Delayed Coking

1950-1954
Conoco begins operating Ponca City USA Delayed Coker

1960

1964-1966
World's first modular Sands Minisands, including a B Grade Delayed Coker

mid 1960s
Skirt-structure designed for Dar'ex USA Delayed Coker

1960s
Sloped Wall design provides a rigid structure mitigating operational vibration when a coke drum is unheaded
1967
- First Oil & Upgrading facility by Bechtel in Canada
- Bechtel-designed Fuel Coker

1969
- Startup of Humber UK and Petrocokes Japan Premium Cokers

1970
- Early-mid 1970s Coke Drum correlations developed by in-house pilot runs

1970s
- Pilot Plant construction and operation at Ponca City, USA
- Conoco becomes one of the world's largest producers of Premium Coke by continuously investing in product quality and consistency improvements

1970s
- Mid-late 1970s Database of five major crude pilot runs developed, forming the basis for our yield prediction and furnace design models. Correlations allow for lowest natural recycle in the industry (< 5%)
- Mid-late 1970s Furnace models predicting fouling, coking factor, and pressure drop developed

1980
- Late 1980s Conoco introduces the world's first commercial delayed coking technology into the USA.
- Refinery in US 4213846

1980s
- First use of coke production in the Humber refinery
- Conoco becomes one of the world's largest producers of Premium Coke by continuously investing in product quality and consistency improvements
60+ years of ThruPlus

1983
First Switchdeck with vapor and transfer lines on the same manifold and First Drill Derrick platforms implemented to facilitate ease of maintenance. Fines Settling Basin design refined for optimum PM control

1984 - 1985
Distillate Recycle™ patented to increase furnace run lengths, improve coke quality and eliminate natural recycle
- US 4455219
- US 4518487

1985
Flash Zone Gas Oil System patented to facilitate Zero Natural Recycle™ operation and reduce coke formation in fuel grade cokers
- US 4549934

1990
Combination Coke Cutting patented to allow for drilling and cutting one bit. World’s first implementation in Lake Charles USA
- Delayed Coker
- US 4923021

mid 1990s
Spill Models developed to reduce pit-pad

mid - late 1980s
Zero Natural Recycle™ concept developed to reduce fuel grade coke production and increase distillate yields

1992
Isotropic Coke manufacture patented to allow for production of high coefficient of thermal expansion graphite for nuclear reactors
- US 5092982

1997
Frac heat removal
- US 5824189

1997
Flash Filtration design that allows for
- US 5645747
60+ years of ThruPlus® Delayed Coking

- **early 2000s**
  - **Modified Double Fired**
    - Furnace design developed to provide the same even heat flux of a conventional double fired furnace, but at a lower cost.
- **2001**
  - **Reinforced return bend**
    - Furnace design patented to increase operator safety and tube longevity when exposed to online spalling. US 6187147
  - **Semi-automatic top unheading**
    - Device developed to increase operator safety. US 6228225
- **2004**
  - **Semi-manual bottom unheading**
    - Design patented to make manual unheading safer by maintaining coke drum gasket seal while bolts are removed. US 6808602
- **2008**
  - **Delayed Coking Econo**
    - Developed to inform refinery operating differentiators translate into operational improvements.
- **mid 2000s - 2014**
  - **VOC reduction concept**
    - Developed to reduce coke drum unheading pressure to less than 20 psig. Patent Pending

- **1998**
  - **Improved anode coke production**
    - Implemented by switching from roll-crushing to a feeder-breaker crusher.
  - **MRC**
    - Starts up Melaka Malaysia Delayed Coker in Zero Natural Recycle™ operation.
- **2005**
  - **Staggered tube furnace**
    - Design patented to reduce pressure drop and residence time, reducing coke formation and increasing onstream time. US 6852294, US 7524411
- **2005**
  - **Cyclone filtration**
    - Gas oil patented effectively etched out efficiently eliminating coke scales. Implemented in Venezuela. US 6919093, US 7476275
60+ years of ThruPlus®

Mid 2000s
Crane runway girder system developed to allow for flexible bridge crane rail alignment

2005-2009
Clone imitation of flash zone patented as a more cost-effective solution than the original disc design. Design patented at Hamaca Upgrader Venezuela 20017 5295

2011
Gas Oil additive concept patented to increase furnace run lengths in fuel and anode grade coker furnaces
**US 7922896**

Gas Oil system developed to allow Heavy Coker Gas Oil to be used as Hydrocracker feedstock
**US 8535516**

2011
Bechtel purchases ConocoPhillips ThruPlus® fuel and anode-grade delayed coking technology, and in the process forms Bechtel Hydrocarbon Technology Solutions, dedicated to technology licensing and specialty consulting services

2014
Dual purpose spalling / pigging system developed to increase furnace uptime
**Patent Pending**

2014
Near-zero VOC emissions closed blowdown system
**Patent Pending** (US20140262724 A1)

2020

DELAYED COKING

A TECHNOLOGY FOR TODAY
# Good Coker Design Today is Safe

## FEATURES REQUIRED TODAY

- Automated coke drum unheading valves with dual-entry technology
- Remote, automated coke cutting
- Furnace tubes designed for feed pump shutoff
- Design, procedures and interlocks for safe coke drum switching
- Common switch and unheading deck

## SAFETY BENEFIT

- Removes the operator from coke drum unheading & reduces hot spots in the coke drum → less blowouts
- Eliminates operator personnel at coke cutting
- Eliminates installation of pressure safety valve on furnace outlet, that when plugged could facilitate tube rupture
- Proactively mitigates the causes of coke drum switching incidences through superior design and operator training
- Provides unhindered access, improved communication and superior egress
Good Coker Design Emissions Today are Low

Overall Refinery VOC emissions - Delayed Coking emissions can be a smaller contributor if designed and operated properly.
Coker VOC Emissions Can be Kept Low Today with A Proper Design Coker Low Pressure Closed Blowdown System

Closed Blowdown System
Steam / Non condensibles are recovered

At Coke Drum
2 psig (14 kPag)
~100% Water
negligible levels of VOC

At Blowdown Settling Drum
Hydrocarbons recycled to fractionator for reprocessing

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Good Coker Design Today Means 98+% On-Stream Factors and 7+ Years Between Turnarounds Capability

First Turnaround Cycle

Years between turnaround


40,000 bpsd feed throughput

120,000 bpsd feed throughput
Good Coker Design Today Means Ever Increasing Coke Drum Longevity

The Coke drums can possibly be greater than 10% of the total capital investment of a Delayed Coker

Why should refiners have to replace this crucial piece of equipment regularly?

Good coke drum design today should result in 25+ years of useable life (at 16 hours or less coking cycles) before needing replacement
What Major Things Contribute Today to Coke Drum Longevity?

- Metallurgy specifications exceeding ASTM requirements
- Real world measured strain data + proprietary drum correlations for optimum diameter and steel plate selection
- Uniform wall thickness from cone to above coke bed elevation eliminates local stress concentration
- < 4 circumferential welds to minimize sites for crack initiation
- Proper construction inspection
- Tangential mount skirts to ensure that both drum and skirt have similar heat profiles throughout the cycle and Proper operation
Good Coker Design Today Has Dependable Product Yields

A typical hydrocracker-based refinery receives 20-30% of its net diesel and all of its petroleum coke from the Delayed Coker. How can a refinery planner ensure that the licensor product yields are right?

- Coke (100%)
- Diesel
- 350 - 650°F (177 - 343°C)
- Naphtha
- C₄-

Delayed Coker Contribution (vol. %)

- 30-40%
- 20 - 30%
- 100%
Predicting accurate coking yields is more than merely having a set of textbook equations!
It's about understanding coke morphology at the microscopic level!
Countless laboratory cases and pilot data! and real world operating data are needed!
Good Coker Design Test Run Product Yield Variance Should Contain Less Than 1% Error.

### PERCENT ERROR

-1.00 | -0.75 | -0.50 | -0.25 | 0.00 | 0.25 | 0.50 | 0.75 | 1.00

-0.56% | LIGHT ENDS

C₄ -

-0.67% | NAPHTHA

C₅ - 350°F (177°C)

0.71% | DIESEL

350 - 650°F (177 - 343°C)

0.79% | HEAVY ENDS

650°F + (343°C+)

-0.69% | PETROLEUM COKE
DELAYED COKING A TECHNOLOGY FOR THE FUTURE

What’s next?
<table>
<thead>
<tr>
<th>INNOVATION</th>
<th>BENEFIT</th>
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<tbody>
<tr>
<td>Online spalling / pigging systems</td>
<td>Patent-pending process to increase furnace uptime by allowing operators to online pig (scrape) a furnace (no furnace shutdown)</td>
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<td>Near-zero VOC emissions systems</td>
<td>Specialized Closed Blowdown system design to again further reduce VOC emissions when unheading a coke drum</td>
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<td>Improved coker furnace draft systems</td>
<td>Allows for exclusive forced draft operation (no natural draft requirement) to minimize stack sizing and ensure a focused flame pattern</td>
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INNOVATION

- ThruPlus® ELECTROPOWER Nuclear Delayed Coking process
- Artificial intelligence system coupled with UAS to reduce operator interface in the Delayed Coker
- Rotating cylinder coke drum system

BENEFIT

- Integration of Bechtel’s industry-leading Nuclear technology know-how for very fast cycle times and city-wide power generation capability
- Eliminate operations personnel near the process (FAA license filed April 6, 2015 as part of VPD initiative)
- Ability to change out coke drums with the coker on-line
Summary

DELAYED COKING A STRONG FOUNDATION & LEGACY

DELAYED COKING A TECHNOLOGY FOR TODAY

DELAYED COKING A TECHNOLOGY FOR THE FUTURE