CB&I / Clariant
CATOFIN® Technology For
On Purpose Propylene

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CB&I
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- Cracker Feedstock Trends
- Effects on Propylene Production
- On-Purpose Technology Solutions
- Future Trends and Innovations
Cushing, OK WTI FOB vs Henry Hub Natural Gas
Spot Price History

Source: EIA

- Cushing, OK WTI FOB
- Henry Hub Natural Gas
...are Lightening Global Cracker Feedstocks

2005
- Naphtha: 55%
- Ethane: 27%
- Propane: 7%
- Butane: 4%
- Others: 2%
- Gas Oil: 5%

2010
- Naphtha: 50%
- Ethane: 33%
- Propane: 8%
- Butane: 4%
- Others: 2%
- Gas Oil: 3%

2015
- Naphtha: 45%
- Ethane: 35%
- Propane: 9%
- Butane: 5%
- Others: 3%
- Gas Oil: 3%
Cracker Feedstock Determines Product Slate

MT of Product

- Ethane
- Propane
- Butane
- Light Naphtha

Categories:
- Ethylene
- Propylene
- Crude C4s
- Pygas
- Other
• Global utilization moving towards peak in 2015-2016

• Asia leading the way in capacity additions
• Cracker co-product capacity growth relatively flat
• Refinery FCC units represent the other conventional source of propylene
  – Flat gasoline demand growth a constraint there
Ethylene, Propylene & Butadiene Prices, USGC Spot (Jan-07 – Oct-14)

Source ICIS Pricing
Propane/Propylene Pricing (Jan 97 - Oct 14)

Source ICIS Pricing
Propylene Growth Regions and Usage Patterns

Announced Propane Dehydrogenation Production Capacity of Propylene

Source: Wood Mackenzie Chemical Market Service

Propylene End Markets

Propylene – PDH is necessary to fill propylene demand gap globally; China will import large volumes of propane from the US to make propylene

Source: Wood Mackenzie
Commercial Routes to Propylene

Steam Cracker

FCC

MTO

Propylene

Traditional Technologies

New Technologies

Propane Dehydrogenation PDH

Olefins Conversion Technology OCT
- 20% of the global propylene market by 2016
Propylene Selectivity Comparison

“By-product” Technologies

“On-purpose” Technologies

% Propylene Yield

Ethane  Naphtha  FCC  MTO  PDH  OCT
What is CATOFIN® Technology?

- Proven technology platform licensed by CB&I for single-stage, fixed bed dehydrogenation of paraffins

- CATOFIN for propane and isobutane dehydrogenation
  - Propane to Propylene (C₃ CATOFIN)
  - Isobutane to Isobutylene (iC₄ CATOFIN)
  - Propane + Isobutane Co-processing

- CATADIENE for n-butane dehydrogenation
  - n-Butane to Butadiene and Butylenes
  - N-Butane + Isobutane Co-processing

- Catalyst supplied by Clariant
Why CATOFIN® Propane Dehydrogenation (PDH)?

- CATOFIN technology is a high selectivity process for propylene production
  - propane $\rightarrow$ propylene + hydrogen
  - $<$ 1.15 ton propane required per ton propylene
- Fixed bed reactor system
- Largest single train capacities (up to 850 kta)
- Highest reliability (> 97%)
- 14 CATOFIN units licensed to date
  - Several operating units are integrated with polypropylene
  - Total propylene capacity: $>$ 7000 kta
▪ Low CAPEX design
  – Optimal for areas of the world where low-cost energy is available
  – Heat-pumped product splitter
  – Common waste heat boiler for hot exhaust streams

▪ Low OPEX design
  – Patented “Low-energy Scheme”
  – Optimization of energy use around product compressor and reboilers
  – Optimization of air heating
  – Best application for high energy cost regions
Continuous CATOFIN® Improvements

- Latest CATOFIN catalyst “breakthrough” in commercial operation with Heat Generating Material or HGM
- 2 – 3% increase in olefin selectivity
- 5 – 10% energy savings
- Up to $10 million profit boost over conventional catalyst units

*Improves return on investment*
Latest Start-up of a CATOFIN® PDH Plant

- Latest PDH plant started up in China in August-September of 2014

- Second CATOFIN PDH plant to start in China (first plant started up in November 2013)

- Design based on the low OPEX flowsheet

- Incorporates Heat Generating Material

- Plant has achieved the design capacity
Six PDH plants in operation

Two plants in China
  • Designed for 600 kta
  • Both plants operating at or above design capacity

Only PDH plant in operation in North America is a CATOFIN plant – operating well above the design capacity (designed for 500 kta)

Two plants in operation in Saudi Arabia at well above the design capacity (design capacity of 455 kta)

One plant in operation in Belgium
Higher selectivity of the process with the implementation of HGM

Large design capacities are possible to take advantage of the economy of scale

CATOFIN technology improved flowsheets meet local utility constraints at various locations around the world

CATOFIN productivity and profitability maximized with latest improvements

Unmatched commercial experience