Ethylene Middle East Technology Conference

EMET CONFERENCE

KBR Olefins Technologies

Providing Key Flexibility with Optimum Design to Ensure Profitability

Outline

- Introduction to KBR and KBR Technologies
- The need for flexibility:
  - Feedstock
  - Product slate
- SCORE™ technology gives ability to process various feedstocks at optimal conditions
- K-COT™ technology gives an alternative for higher propylene-to-ethylene ratio
- Integration of K-COT™ and steam cracking
- K-PRO™ provides an innovative and lower cost option for on-purpose propylene production

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KBR at a Glance

Revenue

Full year 2017

$4.2 bn

Headquarters

Houston,
Texas

Employees

~ 35,000

Global Presence

80+
Countries

KBR is a global provider of differentiated professional services and technologies across the asset and program life cycle within the Government Services and Hydrocarbons sectors

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KBR Segments

KBR

TECHNOLOGY

Proprietary technologies focused on the monetization of hydrocarbons including oil refining; ethylene and petrochemicals; gasification; as well as fertilizers including ammonia, nitric acid and phosphoric acid, and inorganic salts

HYDROCARBONS SERVICES

Differentiated EPC; maintenance services (via Brown & Root Industrial Services); program management and consulting services for onshore oil and gas; LNG (liquefaction and regasification)/GTL; oil refining; petrochemicals; chemicals; fertilizers; biofuels; offshore oil and gas (shallow-water, deep-water, subsea); and floating solutions (FPU, FPSO, FLNG & FSRU)

GOVERNMENT SERVICES

Global capabilities that cover the full life-cycle of defense, space, aviation and other government programs and missions including research and development, systems engineering, test and evaluation, program management, operations, maintenance and field logistics

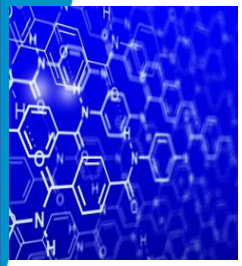
KBR Technology Portfolio

Refining

- ROSE®
- VCC™
- FCC, MAXOFIN™, MAXDIESEL™
- Hydroprocessing
- Advanced Distillation
- K-SAAT™, MAX-ISOM™, NExOCTANE™
- Aromatics Extraction

Olefins

- SCORE™
- K-COT™
- K-PRO™

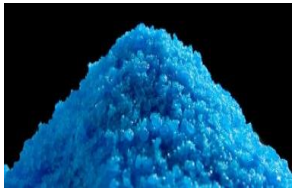


Chemicals

- Phenol/Acetone, BPA
- PCMAX™
- PVC
- Acetic Acid
- Vinyl Acetate Monomer
- NExETHERS™
- Aromatic Transalkylation

Ammonia and Syngas

- Ammonia
- Weatherly Nitric Acid
- Weatherly Ammonium Nitrate, UAN
- Syngas, Coal Gasification



Inorganic Chemicals

Ecoplanning Evaporation & Crystallization

- Purified Phosphoric Acid
- Fly Ash Crystallization
- Metal Sulfates recovery

Plinke Acid Treatment

- High concentration separation and recovery
- Nitration of Benzene

All Markets

Proprietary Equipment & Catalysts

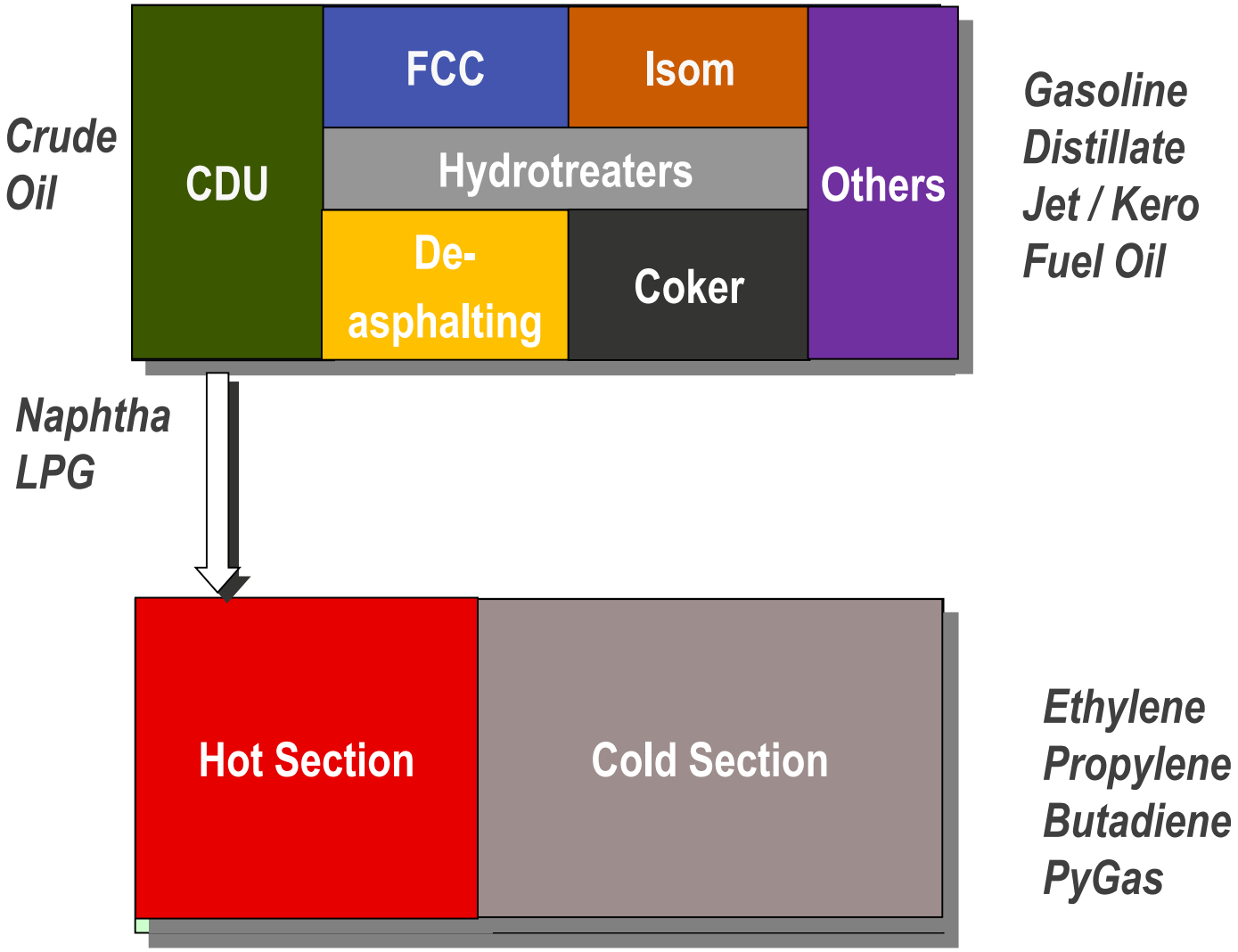
- Internals
- Specialized Service
- Proprietary Design
- Proprietary Catalysts

Automation and Process Technologies

- InSite℠ Performance Advisory
- Adv Simulation, OTS, APC, RTO
- Operations Assurance Solutions
- Technical Services

Proprietary Technologies

Conventional Refinery and Steam Cracker



Flexibility is Key for Olefins Profitability

- Typical project justification uses anticipated feed, product and utilities pricing
- 20 year project life

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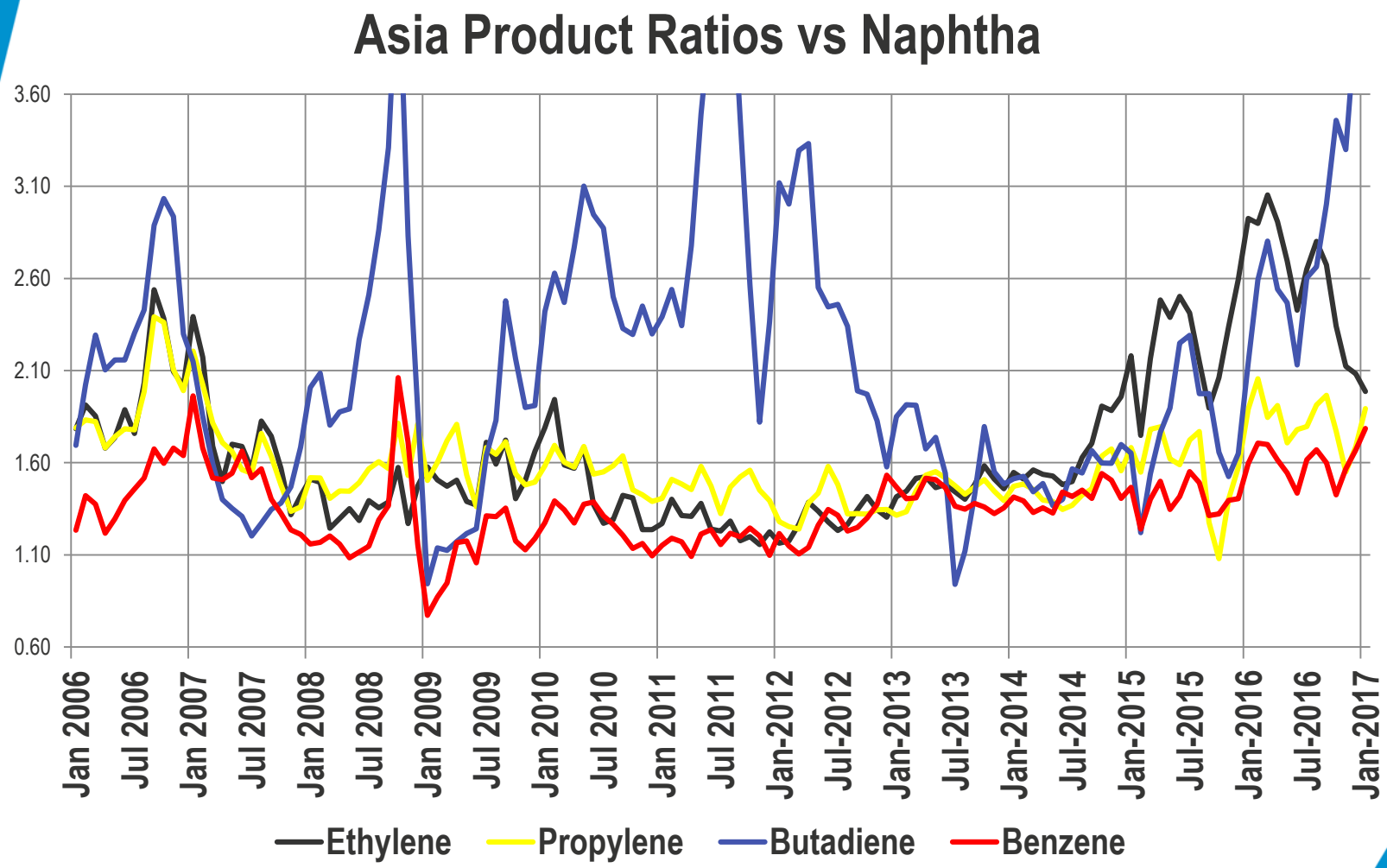
Historical Prices

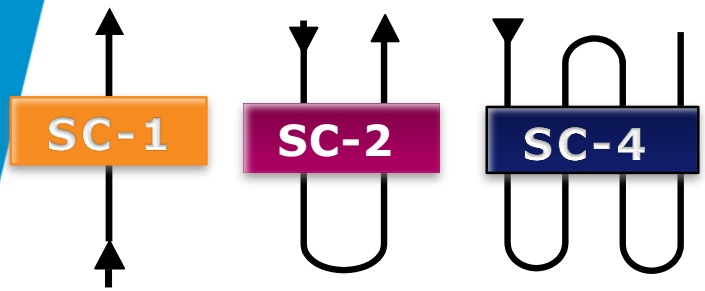


Flexibility is Key for Olefins Profitability

- Typical project justification uses anticipated feed, product and utilities pricing
- 20 year project life
- **Actual experience is that these continuously fluctuate**
- **Thus, FLEXIBILITY is the key to maintaining plant profitability throughout the project life time**

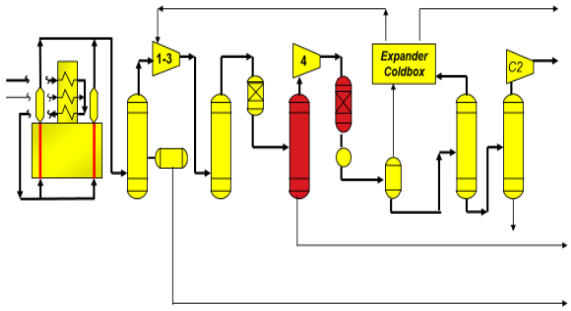
SCORE™ Ethylene Technology

Selective Cracking

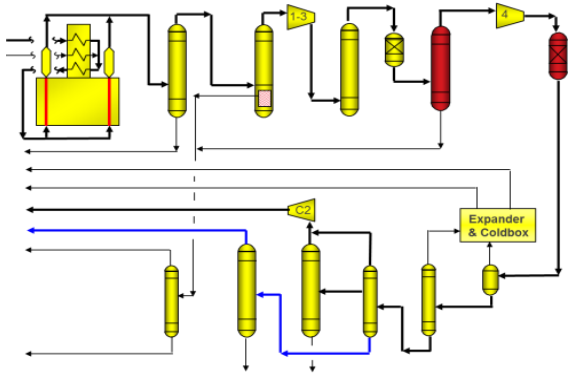


Coil Type	Residence Time (sec)	SCORE	Competitors
Four pass	0.4	SC-4	Yes
Two pass	0.2	SC-2	Yes
One pass	0.1	SC-1	No

SCORE™



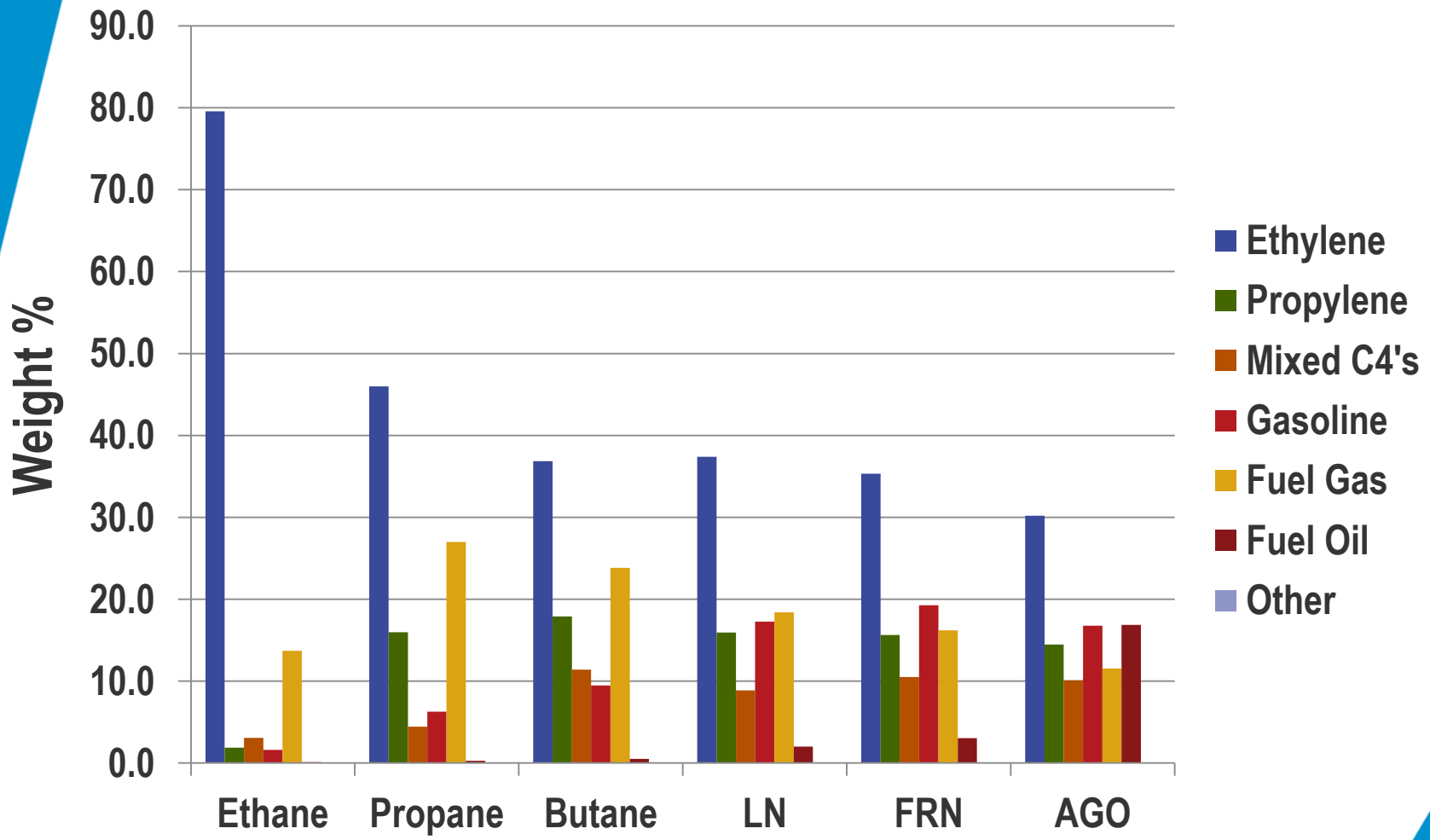
Deethanizer-first



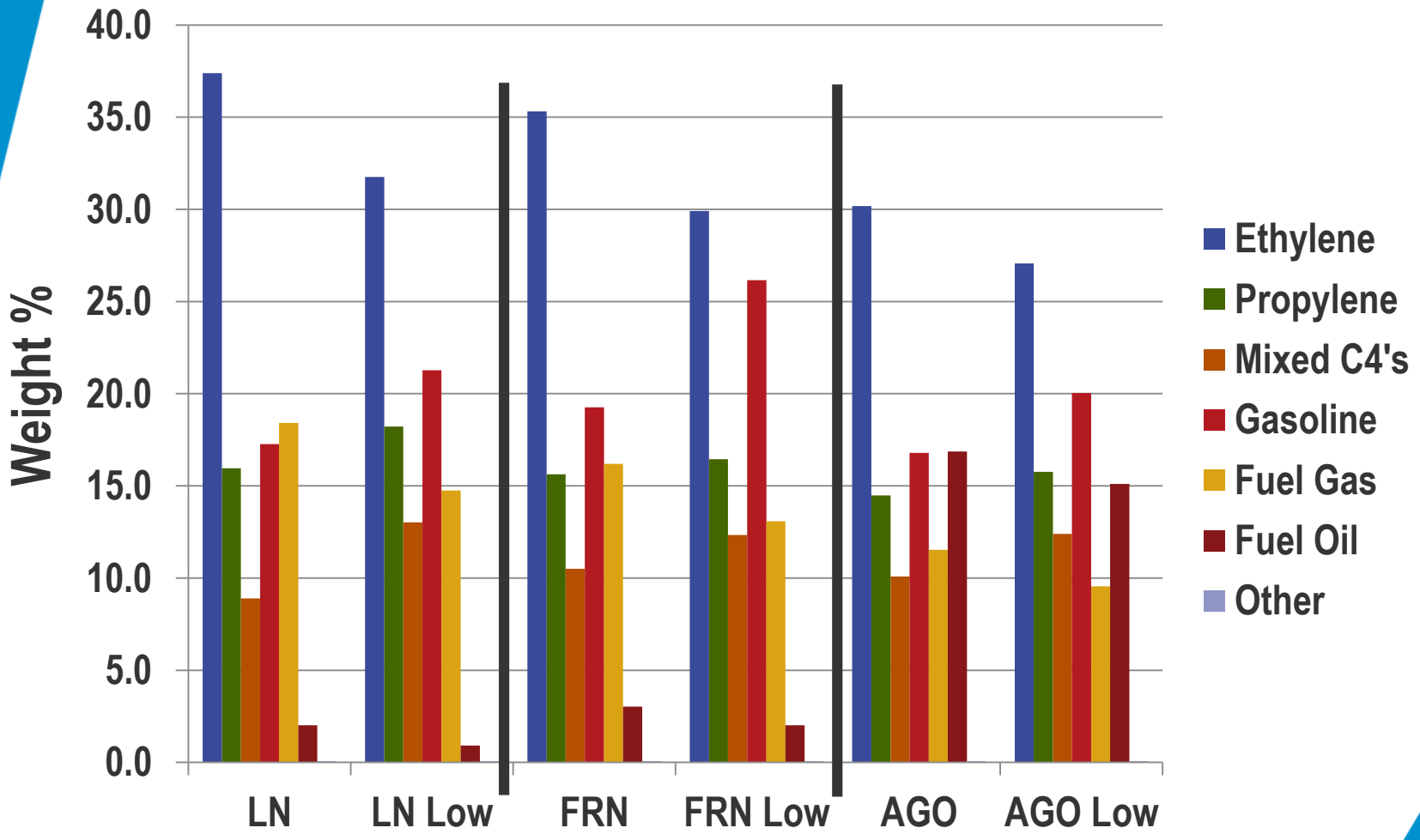
Depropanizer-first

Optimum REcovery

Typical Steam Cracking Yields



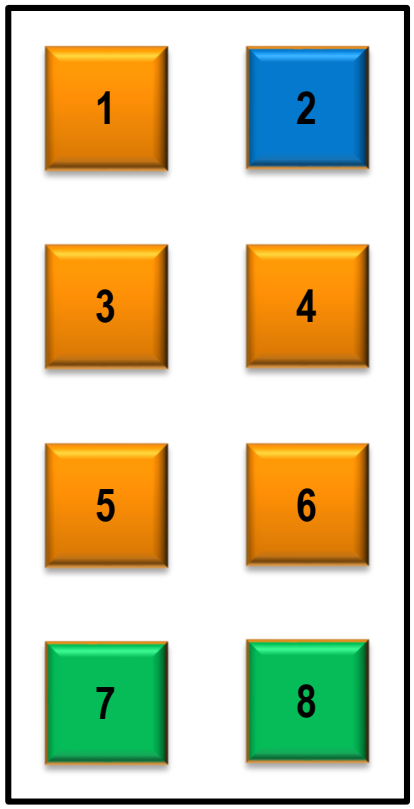
Cracking Severity Impact on Steam Cracking Yields



SCORE™ Furnace Flexibility

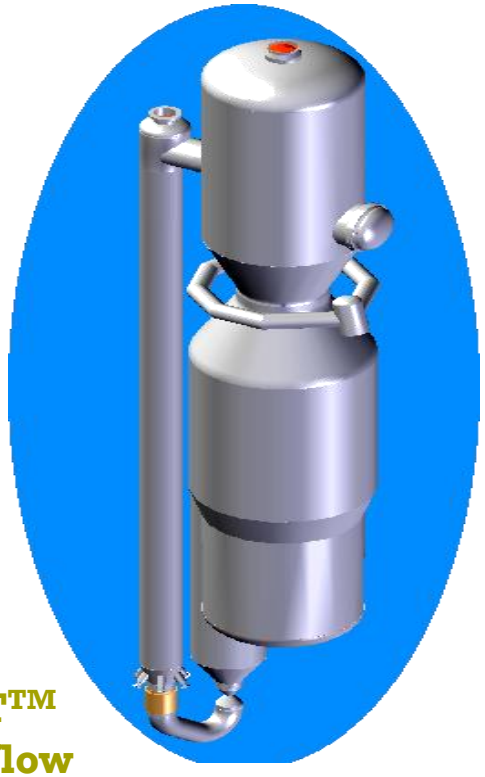
Multi-Feed (Hybrid) Cracking

SCORE™ Furnaces
• Large Capacity
• Single Cabin Firebox
• 8 individually flow controlled passes
• Number of Feeds only limited by inlet piping arrangement
• Each Feed can be cracked at optimum conditions: - Temperature - S:HC Ratio



Flexibility of 8 mini furnaces within a single firebox

KBR Catalytic Olefins Technology (K-COT)™

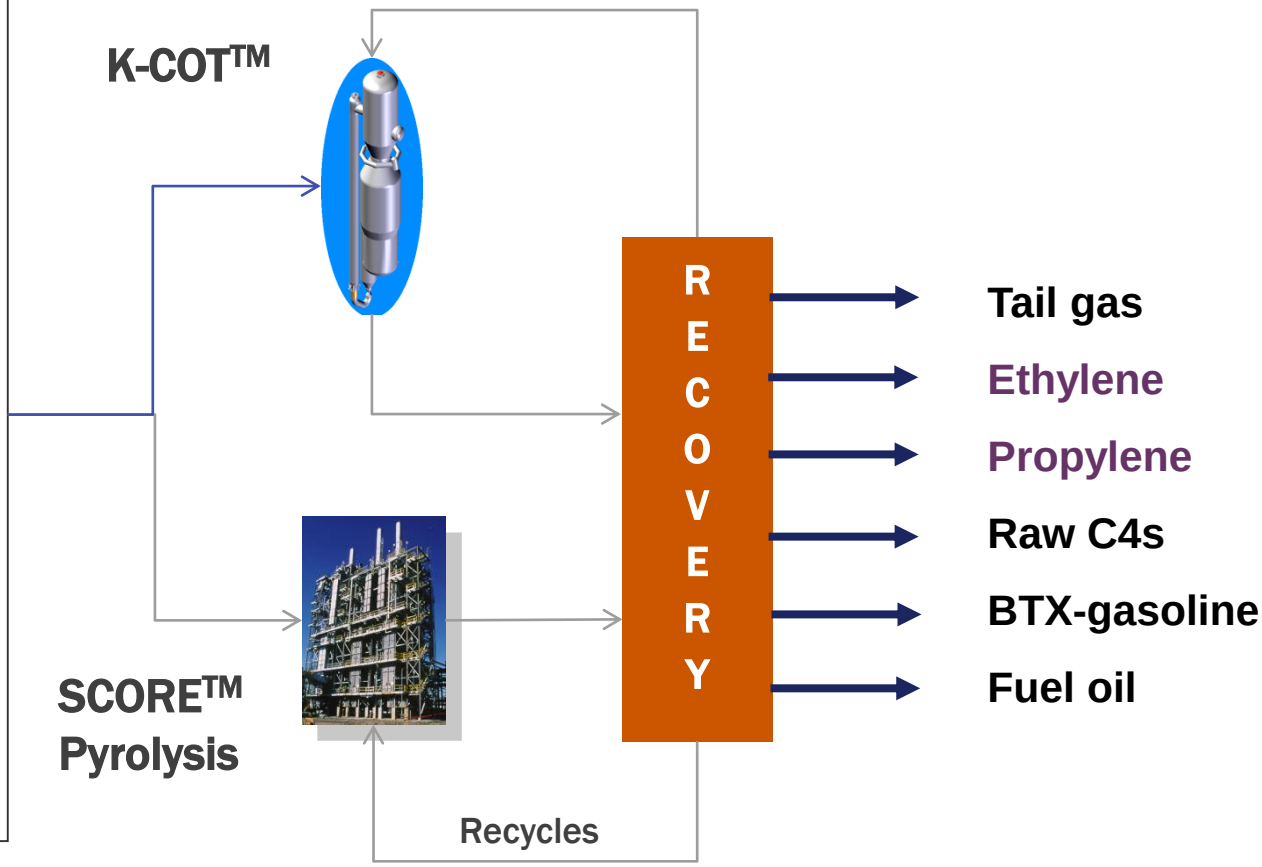


K-COT™ Orthoflow FCC Converter

- **Olefinic, Paraffinic** or **mixed** feeds
- High propylene yields with ethylene and aromatic-rich gasoline by-products
- Typical P/E = 2 (olefinic) or 1 (paraffinic)
- Proven FCC-based technology
- Tailored ZSM-5 catalyst maximizes propylene yield
- Simple operation
- Wide feed flexibility

KBR Advanced Flexible Olefins Process

Fresh Feeds:
- Ethane
- LPG
- Mixed Refinery C4s
- Straight-run Naphtha
- Cracked Naphtha (FCC, Coker, Visbreaker)
- Raffinate from Aromatics Complex
- Gasoil/HGO/VGO/ Unconverted Oil
- By-products from FT/MTO/MTP facilities
- Oxygenates
- Other low value olefinic streams

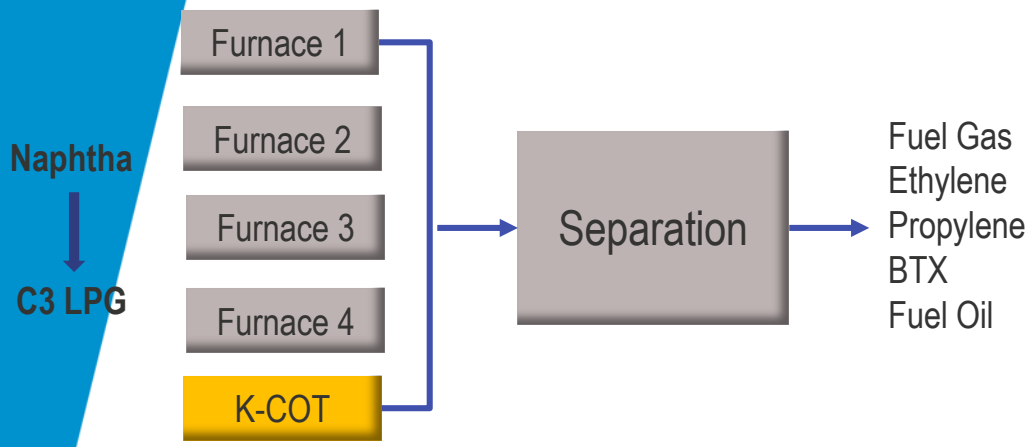


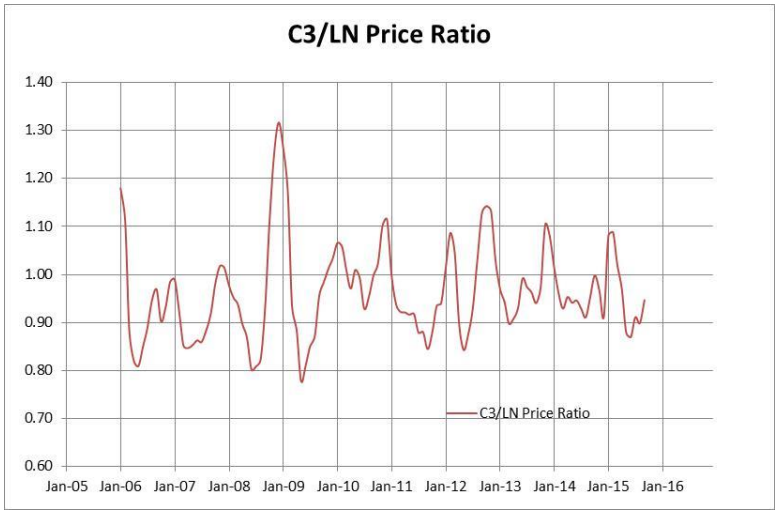
- Highest flexibility on feed side
- Highest flexibility on product side

→ **Optimization based on market conditions**

Hybrid Configuration for Ultimate Feed Flexibility

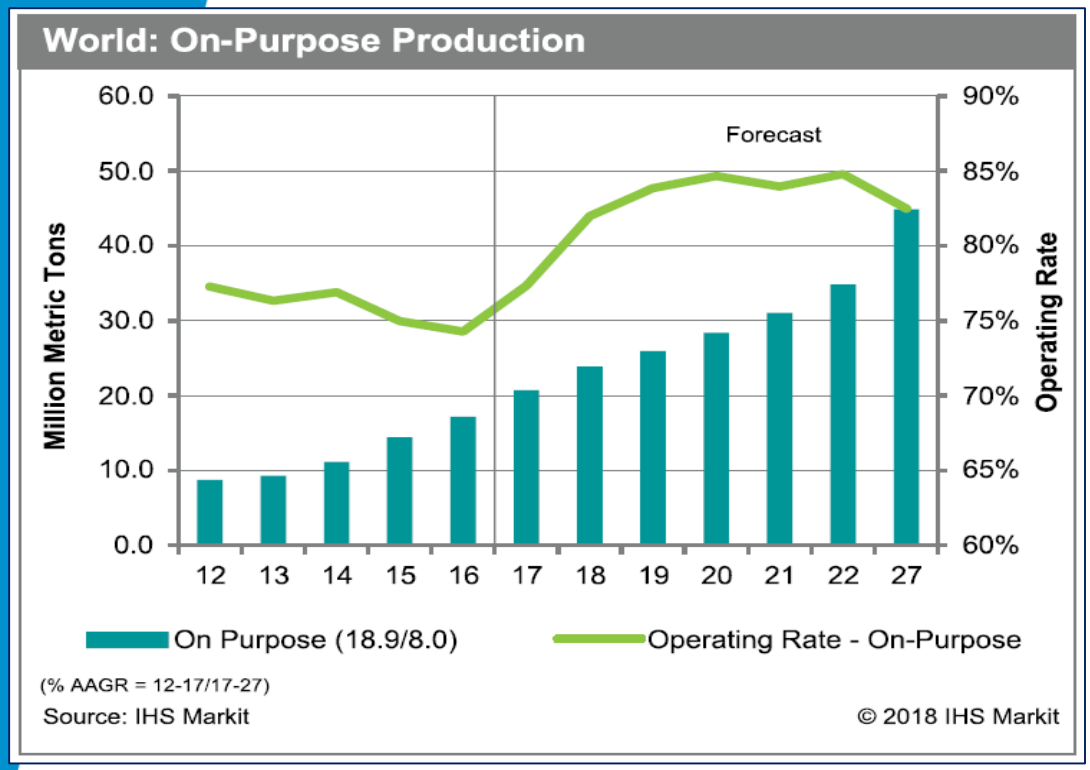
Propane Flexibility





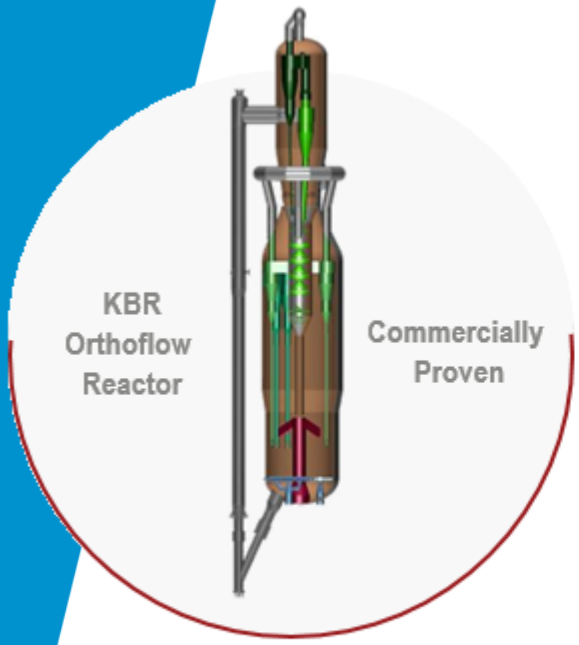
- Goal: Lower Feedstock Costs while keeping downstream PE and PP plants fully loaded (→ constant P/E ratio)
- Conventional Cracker: ability to swap in C3 LPG limited to 25% → Benefit @ C3/LN 0.9 = $29/ton ethylene
- K-COT: able to swap in 75%! → Benefit @ C3/LN 0.9 = $93/ton ethylene (i.e. $74/ton ethylene more benefit)

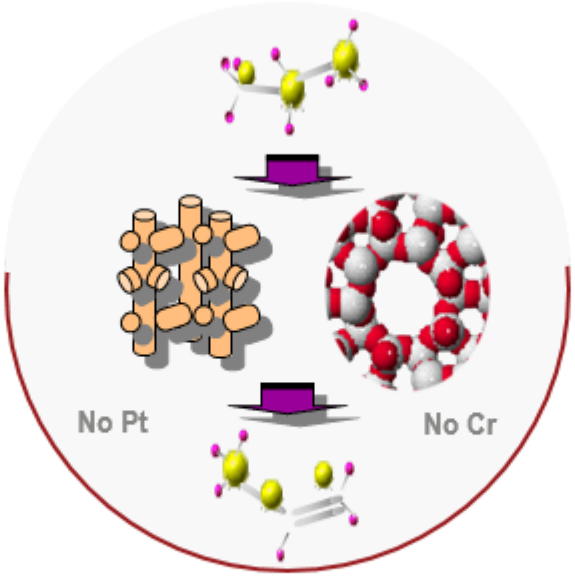
On-purpose Propylene Demand

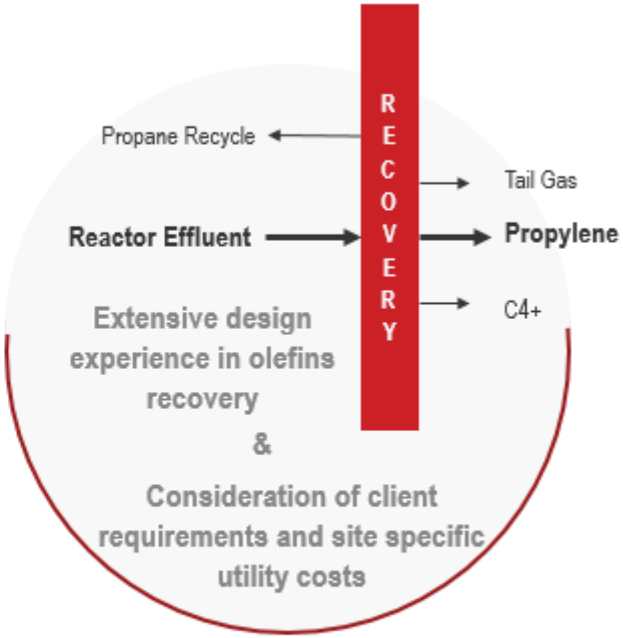


- **25 MMTA in 10 years**
- **4-6 world scale PDH plants per year**
- China, India , SE Asia (demand & import independence) plus availability of LPG imports
- US, Middle East (feedstock advantage)
- Everywhere where there is a need or benefit to having on-site on-purpose propylene production for further growth or integration

KBR K-PRO™ Propane Dehydrogenation (PDH) Technology



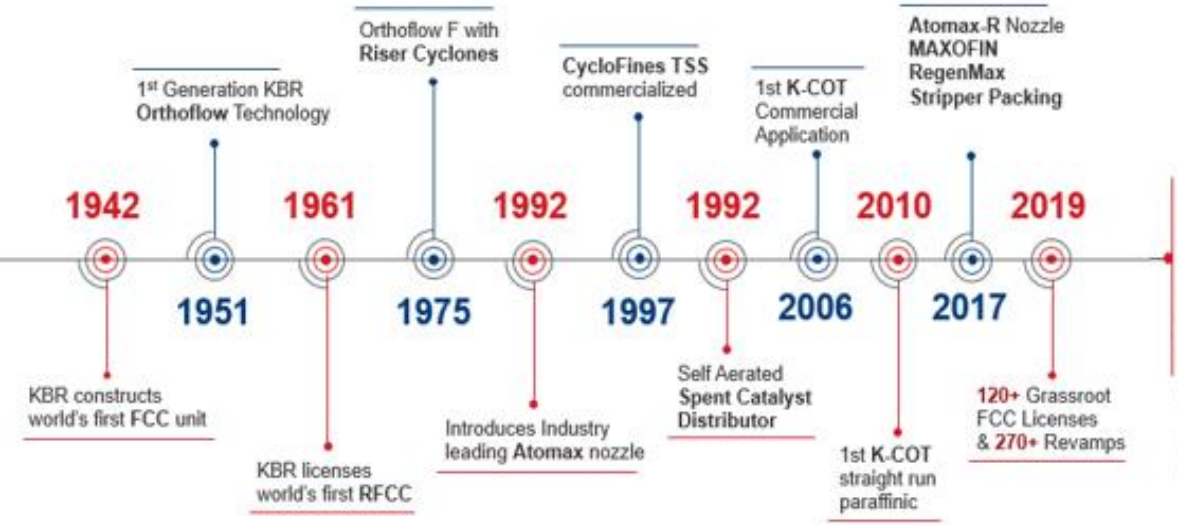




PROVEN REACTOR + **PROPRIETARY CATALYST** + **PROPYLENE RECOVERY**

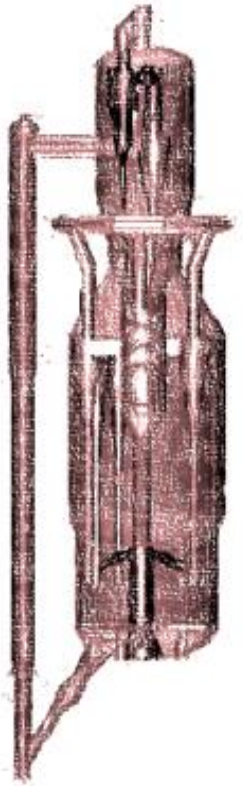
K-PRO™ – Innovation based on Commercially Proven Technology

K-PRO™ Technology is based on the commercially proven K-COT™ technology and KBR's extended experience in FCC reactor design



Proven Innovation!

KBR has been on the forefront of **FCC technology** from the beginning and has consistently delivered leading-edge high performing technology to its customers **for over 70 years**.



KBR K-PRO™ is based on over 70 years of innovation and improvements

Catalyst Innovation that Enhance K-PRO™ Performance

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PDH Technologies Comparison Overview

	Other Commercial Technologies			KBR
	PDH Technology 1	PDH Technology 2	PDH Technology 3	K-PRO™
Reactor Type Regeneration	Moving Bed Continuous CCR	Fixed Bed Cyclic (in-situ)	Fixed Bed Cyclic (in-situ)	**Orthoflow FCC Continuous**
Comments	4 stacked radial flow reactors with inter-reactor heaters along with Continuous Catalyst Regeneration (CCR)	3-10 fixed bed reactors cycling between on-line, steam purge, hot air/reheat, evacuation/vacuum, reduction, back to on-line	Tubular fixed bed reactor/furnace design similar to Steam Methane Reforming (SMR) technology, 2 reactors in parallel alternating between on-line and regeneration	**Commercially proven KBR Catalytic Olefins Technology (K-COT™) reactor, including inherent continuous catalyst regeneration and heat input**
Catalyst	Pt-Sn on Alumina	Chromium Oxide (Chromia) on Alumina	Pt-Sn on Zn-Ca Aluminate	**Proprietary (non-Chromium, non-precious metals/Pt)**
Conversion, %	30 - 40	45	30 - 40	**45**
Selectivity, wt.%	85.5 - 88	87	80 - 90	**87 - 90**
Reactor Pressure (bara)	1.4	0.5	5.0-6.0	**1.5**

KBR EXCELS

Why K-PRO™ – Our Value to You

CAPEX

- 20-30% lower capital investment

OPEX

- 10-20% lower operational cost

PRODUCTION

- Simple robust operations ensure reliability and higher on-stream time

OTHER BENEFITS

- Safe and environmentally friendly
- High performing catalyst
- Outperforms competition

K-PRO™ offers significant benefits compared to other commercially available technologies

Conclusion

- Ever changing feedstock and product pricing and ability to adapt greatly impacts profitability
- SCORE™ provides ability to operate with different feedstocks at optimal conditions for each individual feedstock
- K-COT™ gives a high feedstock flexibility with higher propylene to ethylene product ratio
- K-PRO™ is an innovative, lower cost option for on-purpose propylene production based on proven process technology

KBR fulfills the demand for innovative olefins technologies which provide flexibility leading to increased profitability

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Questions

www.kbr.com/technologies