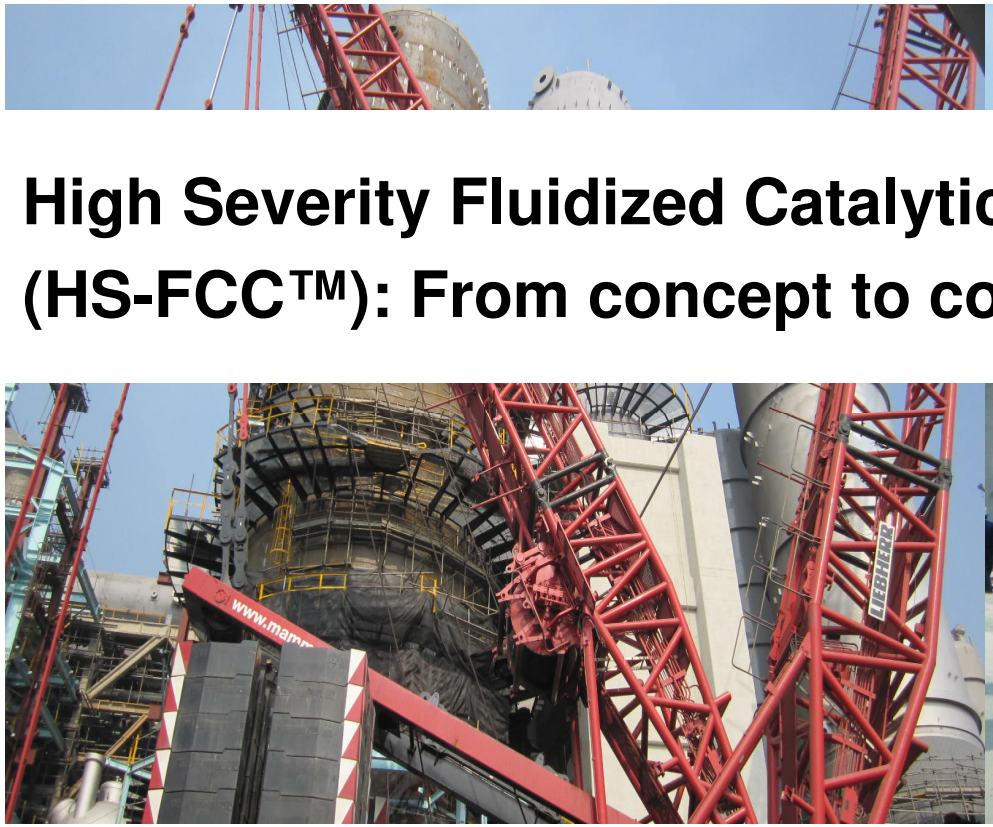

High Severity Fluidized Catalytic Cracking (HS-FCC™): From concept to commercialization

Alexander MALLER and Eusebius GBORDZOE
Technip Stone & Webster Process Technology

April 2016

REFCOMM GALVESTON MAY 2-6 2016

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Evolving Family of FCC Technologies

- **FCC – Gasoline production from VGO**
- **RFCC – Gasoline production from Resid**
  - ZSM-5 added to both FCC & RFCC for Petrochemicals
- **DCC – Petrochemical production from VGO**
- **R2P™: Resid to Propylene – Petrochemical and fuels production from Resid**
  - Direct & Indirect recycles
- **HS-FCC™: High Severity FCC – Petrochemical production from VGO and Resid**

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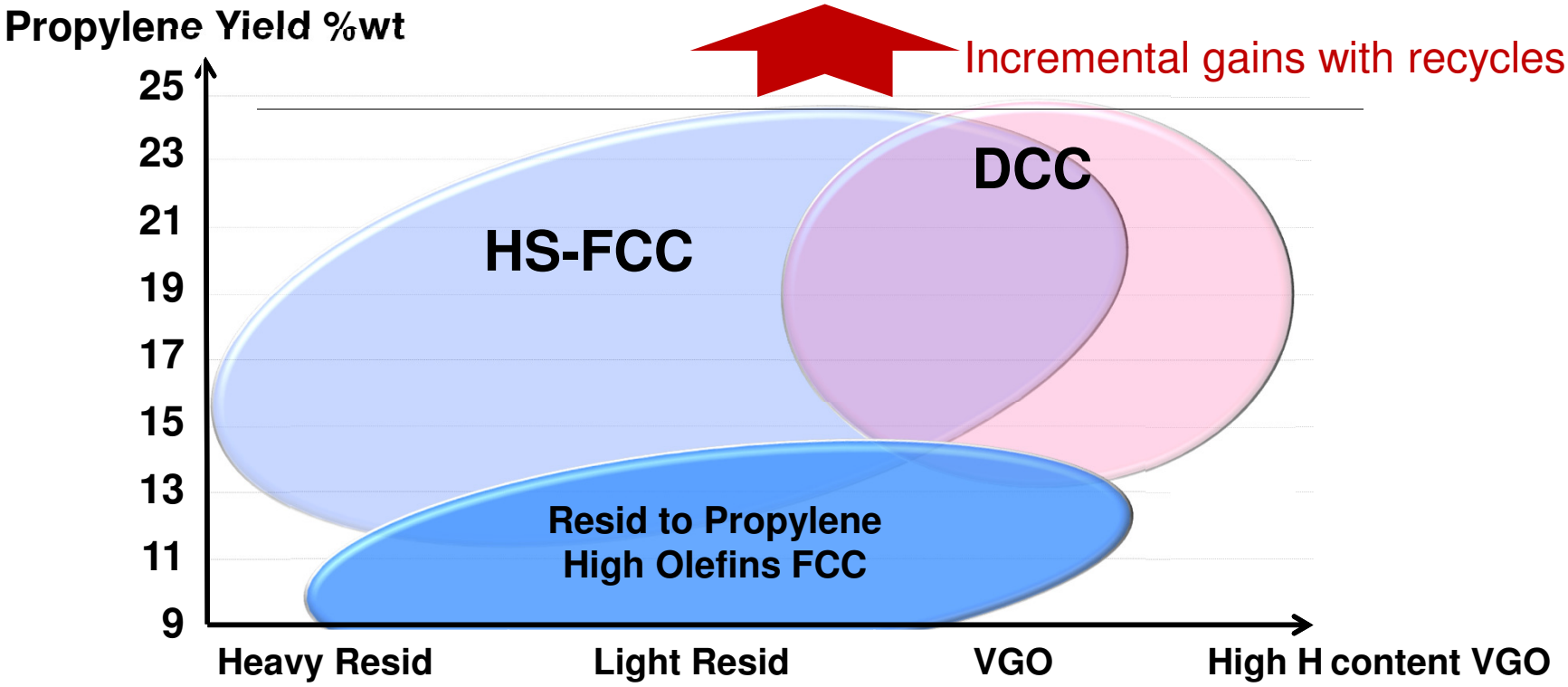
Catalytic Cracking Technologies



HS-FCC, a new member of the family

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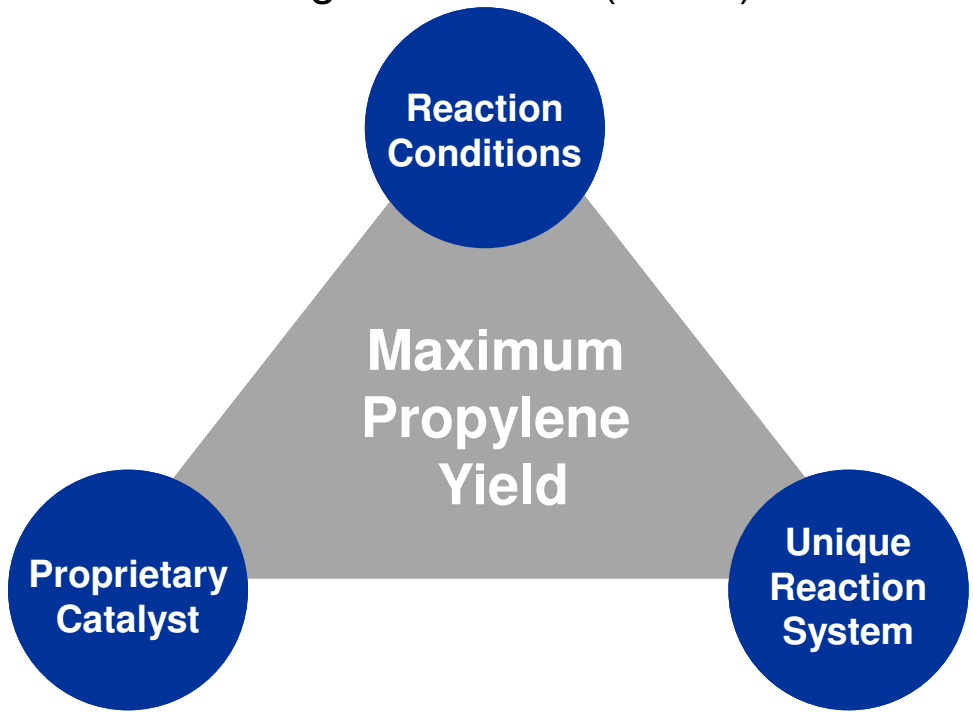
HS-FCC™ Technology – Key features

High ROT (580-620°C)
Ultra short contact time (0.5-1s)
High C/O Ratio (25-30)



Rare earth free catalyst
Low acid site density
Patented formula

Downflow reactor
Tempest ™ Separator
Technip FIT

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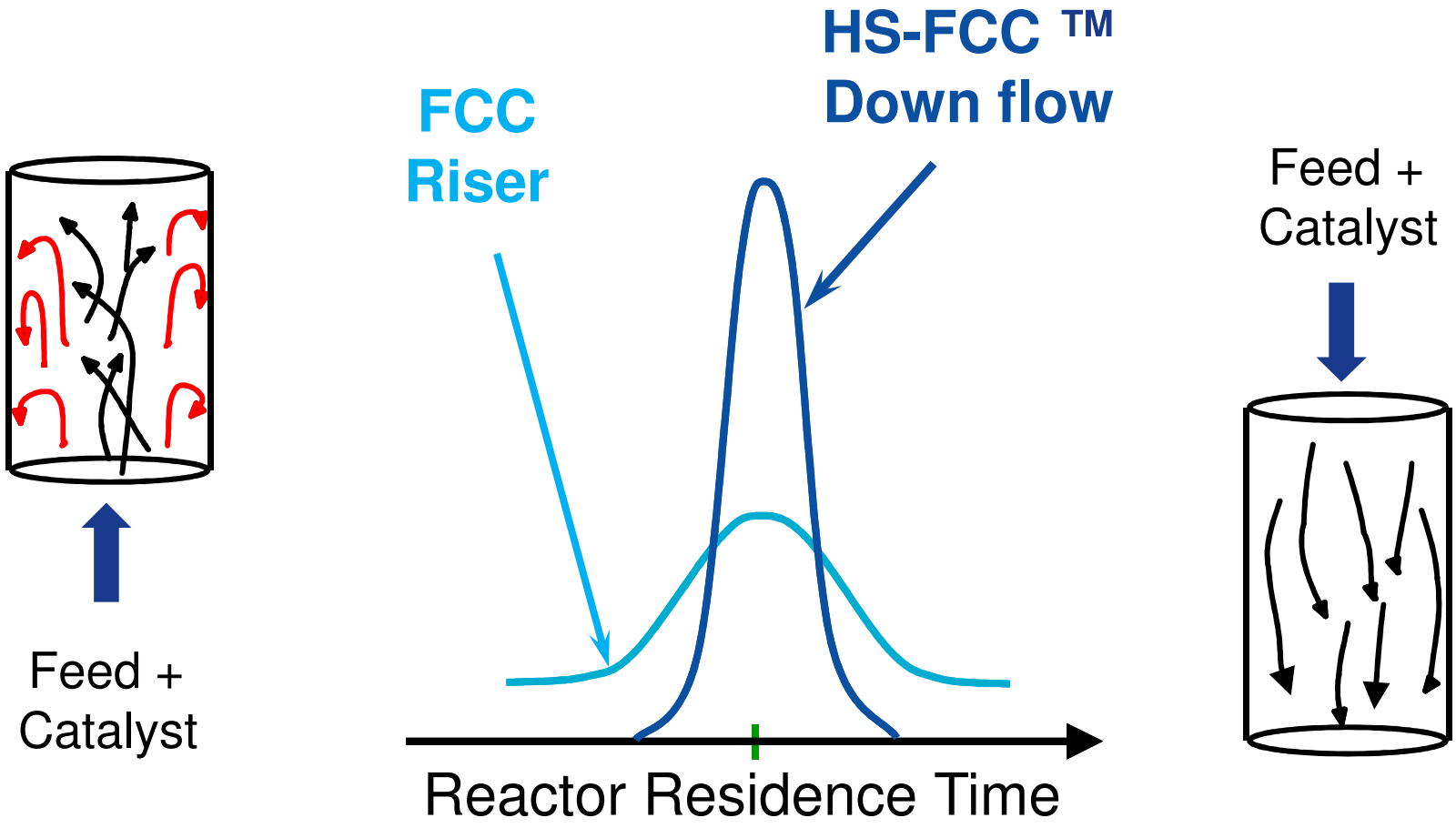
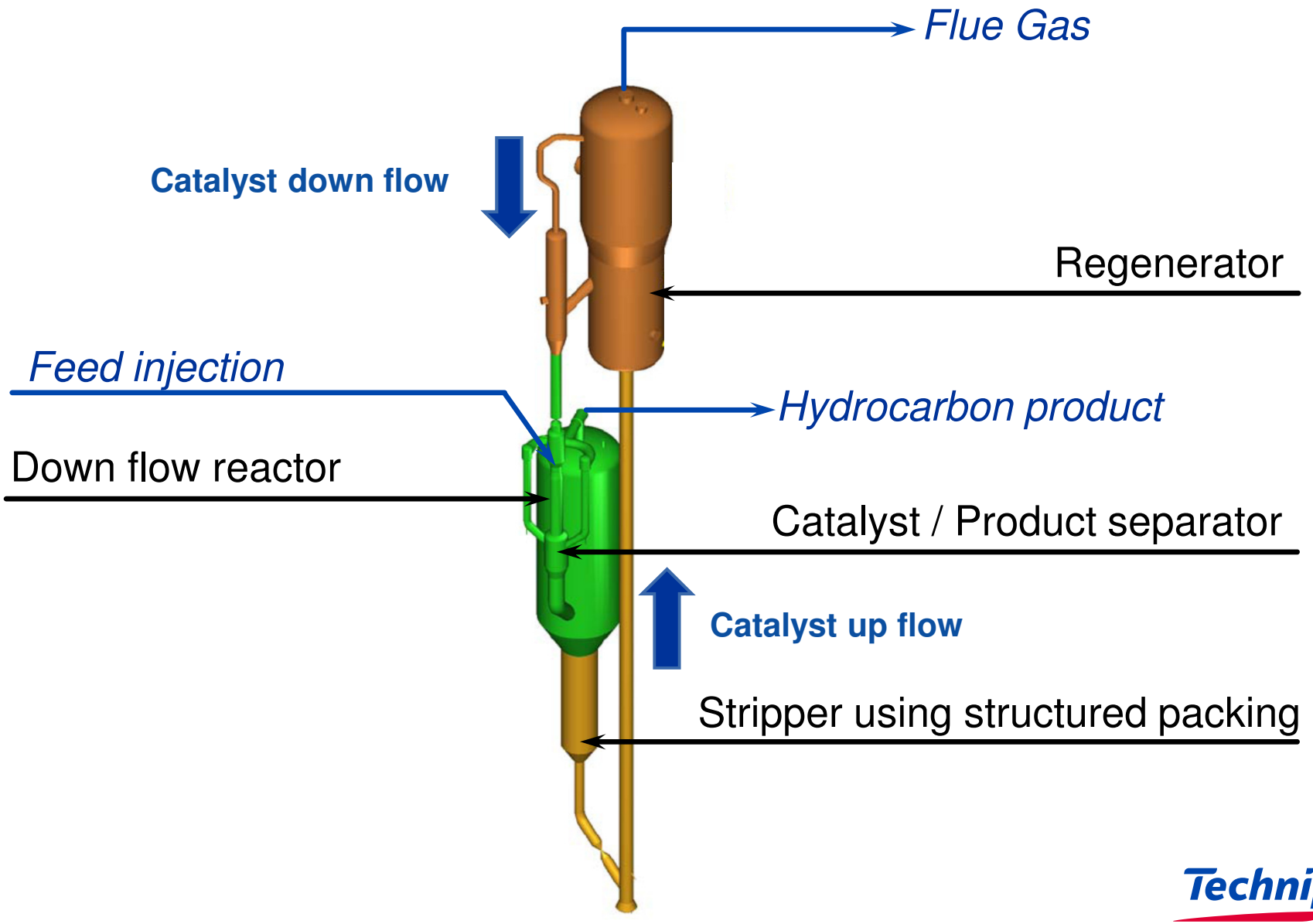
Selectivity by Short Contact Time



HS-FCC™ Schematics



HS-FCC™ – Technology Development

3 DFRs to minimize scale-up risk

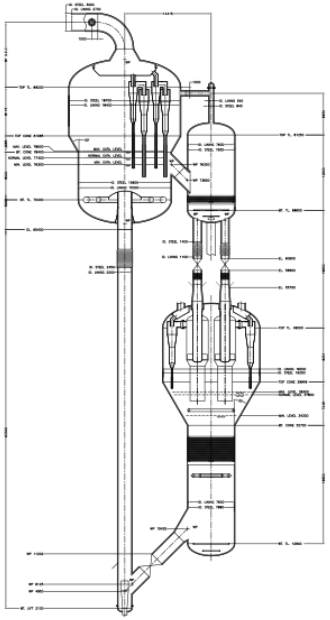
Small step

Successful scale-up

x300

X100

X8.5



1996-2001	2001-2004	2007- 2013	2014
0.1 BPSD pilot at KFUPM Saudi Arabia	30 BPSD Demonstration plant in Ras Tanura, KSA	3,000 BPSD Semi-commercial unit in Mizushima, Japan	76,000 BPSD Commercial unit

Comparative Typical Operating Conditions

	Conv. FCC	HP FCC	DCC	HS-FCC™
ROT	530°C (986°F)	550°C (1022°F)	580°C (1076°F)	600°C+ (1112°F+)
Contact time	2 - 5 s	2 - 5 s	10 s	0.5 - 1 s
C/O	5	10	15	25
Recycle	None	LCN	LCN	None

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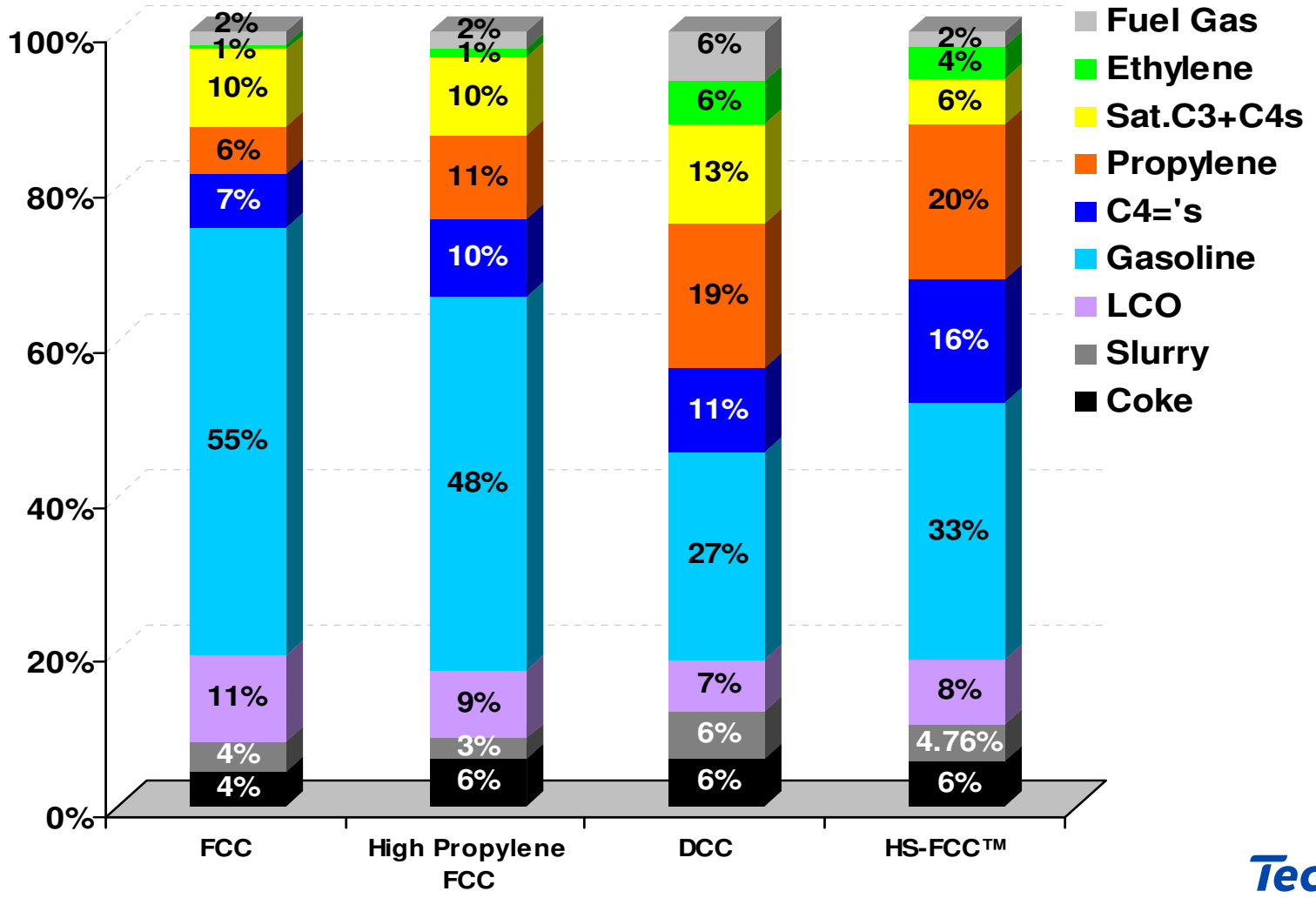
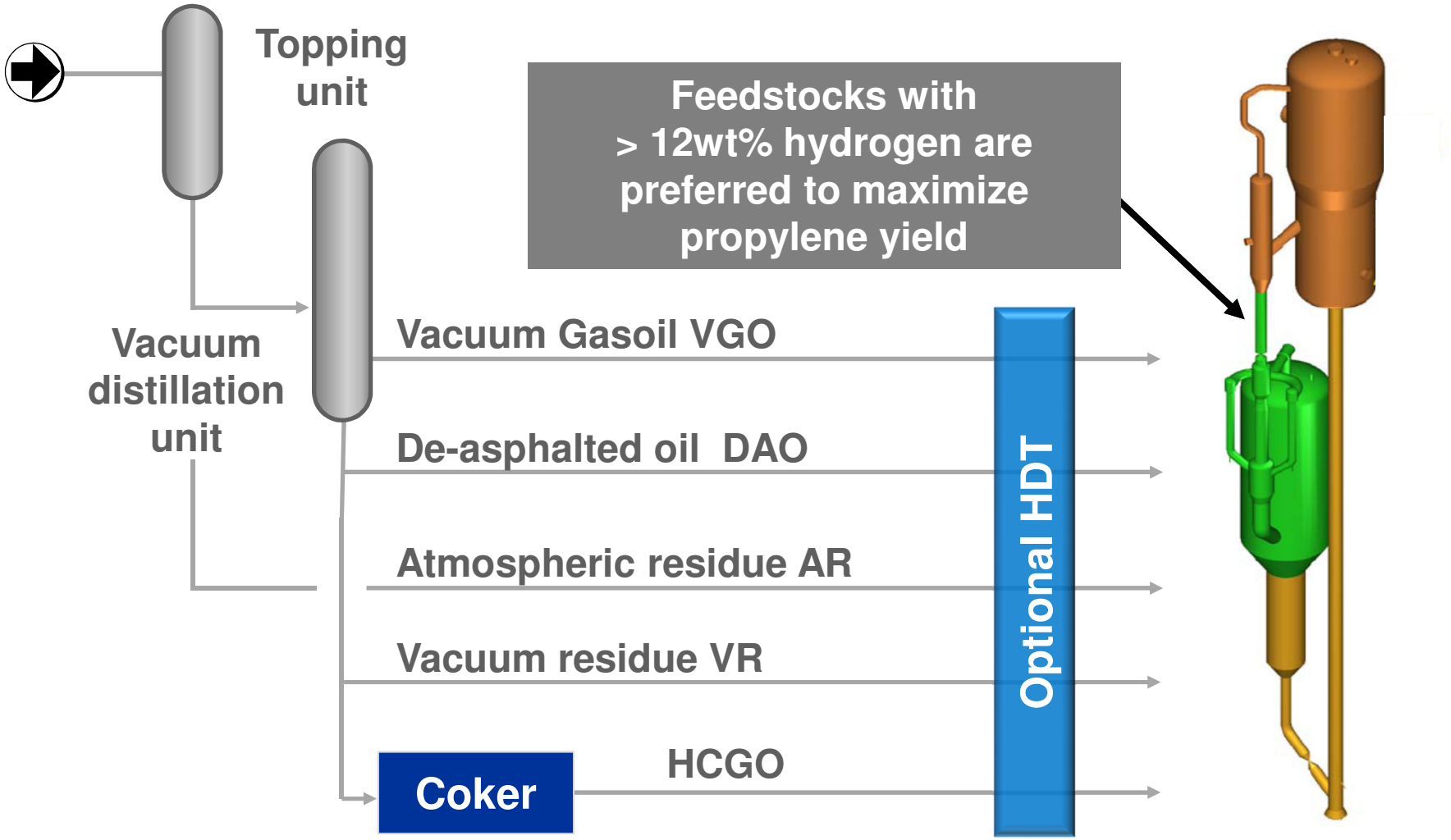
Comparative Yields (Hydrotreated VGO)

Yields, wt %



HS-FCC™ Feed Sources



Semi-Commercial HS-FCC™ Unit

- **JX refinery: 400,000 BPSD**
- **Location: Mizushima, Japan**
- **3,000 BPSD HS-FCC™ unit**
- **Operating Period: 2011-2014**
- **Objectives Met**
  - Confirmed yields
  - Demonstrated operability & reliability
  - Confirmed scale-up criteria
  - Validated benefits of HS-FCC™ technology

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HS-FCC™ Operation

	VGO + 80 % HC Btm (Feb.2012)	100% HDT VGO (Nov.2011)	VGO + 50% DAO (Aug.2012)	VGO + 90% AR (Feb.2014)
Feed SG	0.845	0.879	0.891	0.902
Reactor T, ºC	575	595	580	600
C/O, wt/wt	25	25	25	25
Conv, w%	93.2	83.7	83.0	84.8
Light Olefins, w%	39	34	31	35
C2=	4	4	3	5
C3=	19	17	15	17
C4=	16	13	13	13
C5-220 Gasoline, w%	35	34	34	32
RON	98.5	98.1	98.1	98.5

Catalyst formulation fine tuned over time.

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HS-FCC™ Commercial Design Parameters

	JX Mizushima	Licensee A
Capacity, BPSD	3 000	76 000
# of DFR	1	3
Feed source	HDT AR	HDT AR + VR + VGO
Feed SpGr	0.923	0.914
Feed CCR, wt%	3.9	3.7
ROT, DegC	600	610
Contact time, ms	500	700
C/O	25	25
Yields: C3=, wt%	18.1	17.5
Yields: C4='s, wt%	15.4	15.6
Yields: Gaso., wt%	34.0	31.2
Yields: Coke, wt%	8.6	8.0

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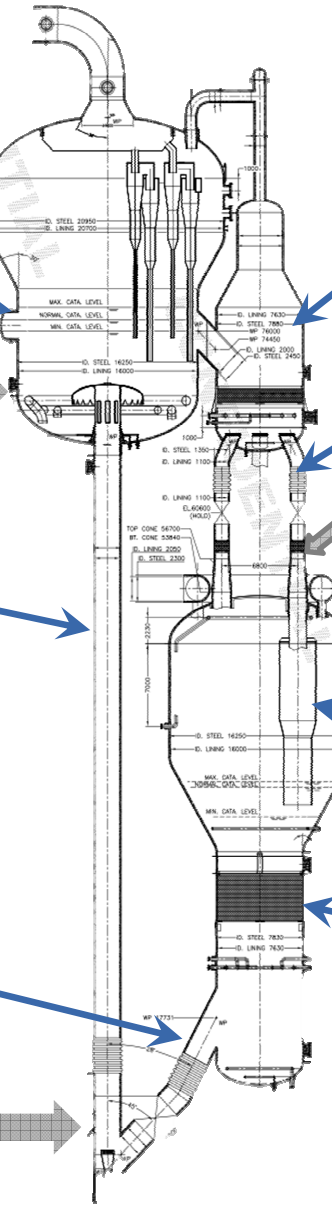
Commercial Unit Configuration



Flue Gas outlet

Withdrawal well (WW)

Regenerated Catalyst Standpipe (RCSP)

Regenerator

Regeneration air inlet

Feed inlet

Spent catalyst lift line

Hydrocarbons outlet

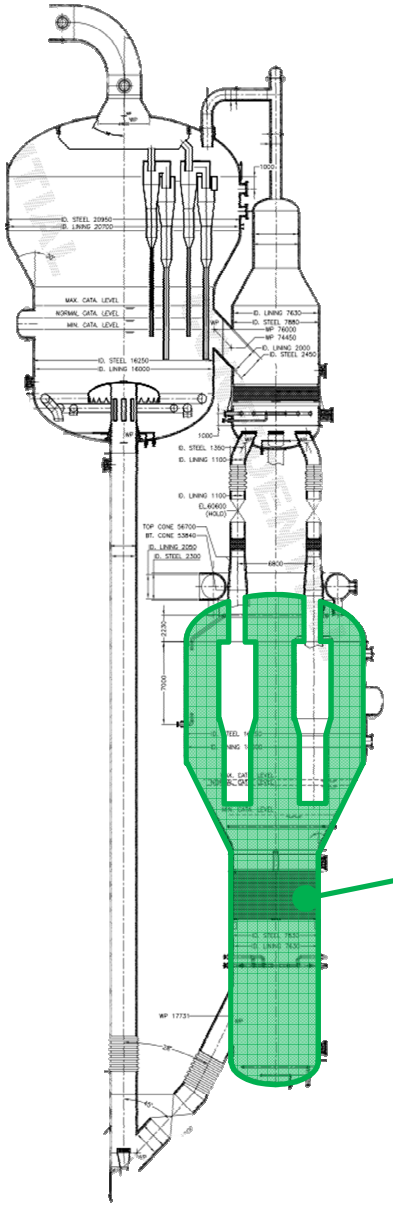
Downflow reactors (DFR) and Tempest Separator

Spent Catalyst Standpipe (SCSP)

Disengager/Stripper

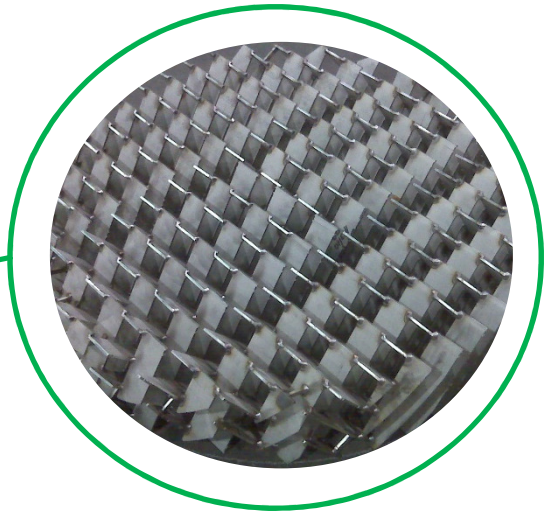
Lift air inlet

Commercial Unit Features

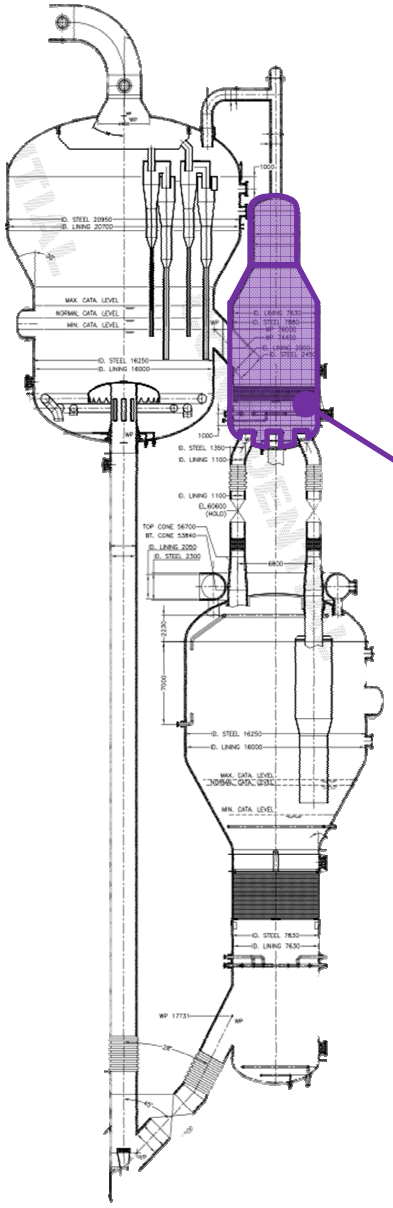


Disengager/Stripper:

Stripper packing

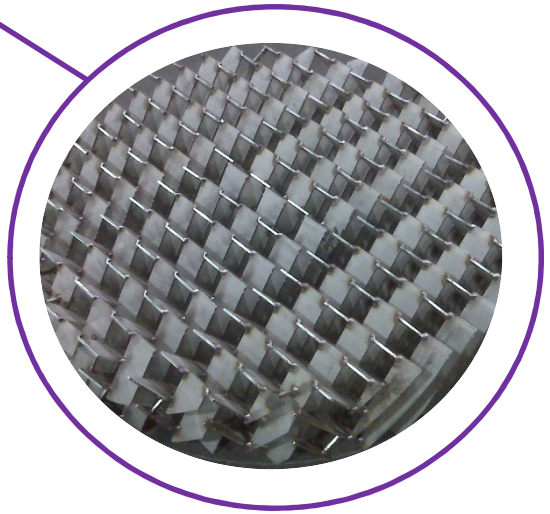


Commercial Unit Features

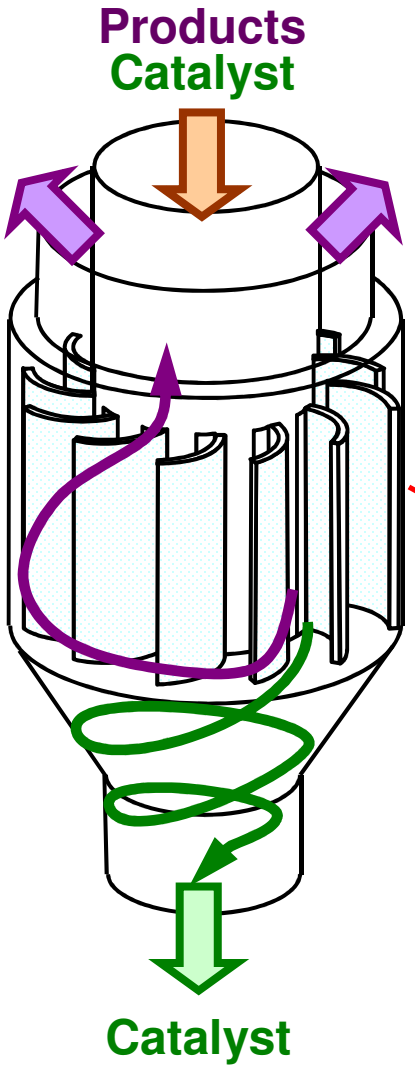


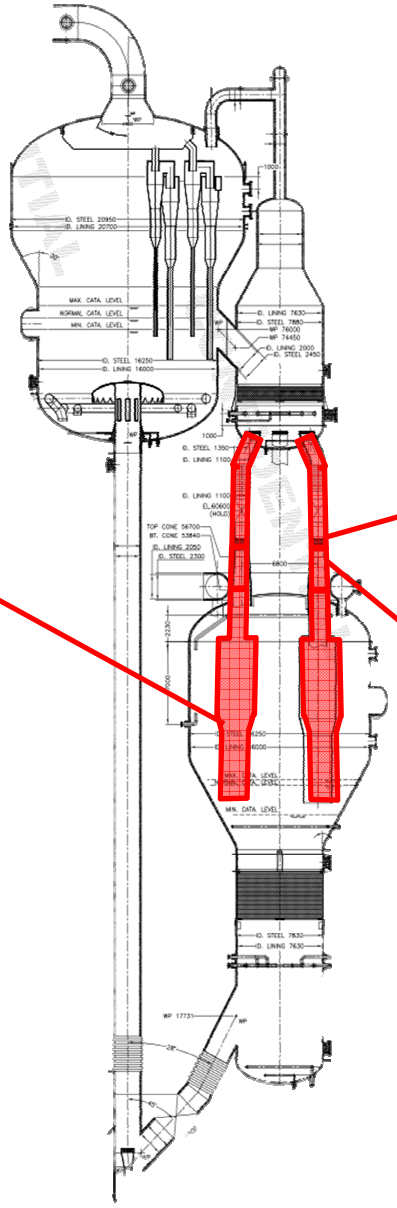
Withdrawal well:

Packing



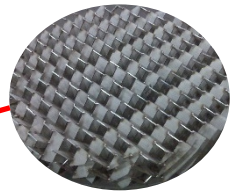
Commercial Unit Features





Downflow reactors:

- Packing
- Impact-type feed injectors
- Tempest™ separator



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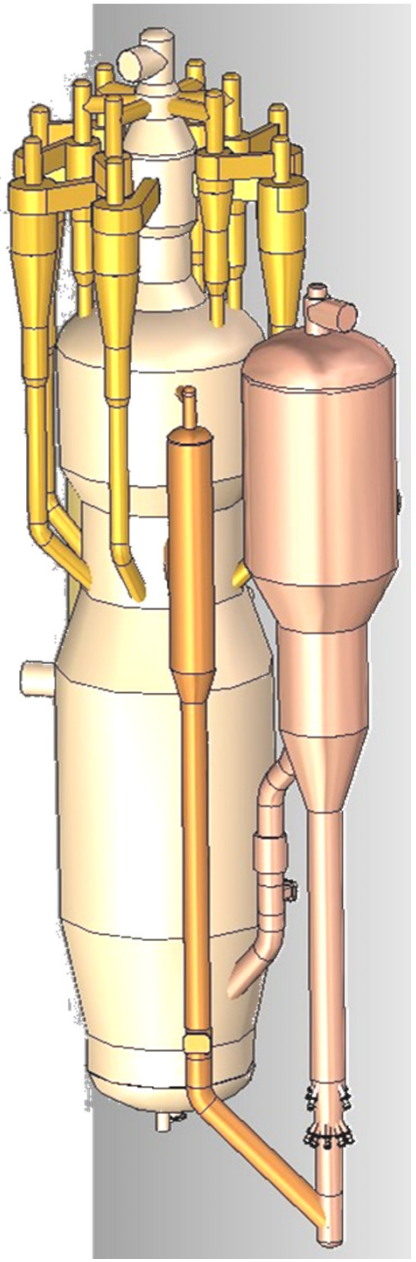
HS-FCC™ RETROFIT Study

- **Objective**
  - Maximum increase in propylene production with minimum investment
- **Technip S&W R2R selected for initial study**
  - Two stage regeneration
  - Processing Resid
  - Catalyst cooler
- **Feedstock Types HS-FCC Downer Reactor**
  - HT-VGO
  - Full range Naphtha



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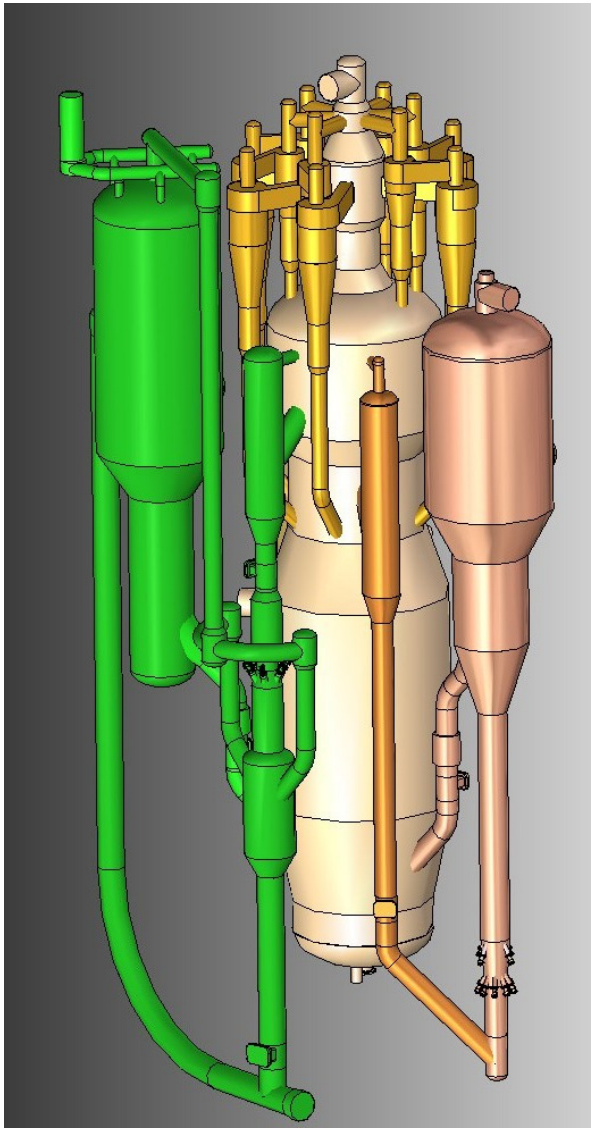
HS-FCCT™ RETROFIT Example

What was determined?

- HS-FCC reactor capacity
- Required regenerator modifications
- Verified pressure balance
- Verified heat balance
- Mechanical design confirmed



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HS-FCC RETROFIT Study Results

	RFCC Base Case	RFCC with HT-VGO HS-FCC
Feed Conditions		
Riser Feed Rate, BPD	70,319	65,000
Riser Feed API	20.80	20.80
Riser Feed Con Carbon, wt%	3.90	3.90
HS-FCC Feed Rate, BPD	--	25,000
HS-FCC Feed API	--	26.4
HS-FCC Feed Con Carbon, wt%	--	0.15
Key Product Yields	Wt%	Wt%
Total H2-C2s	4.74	4.65
C3=	4.82	10.18
C4=	6.34	10.68
Total C3-C4s	17.18	27.44
Gasoline (C5-430 F)	47.98	44.23
Operating Conditions:		
Riser Outlet Temp, F	957	957
Riser Feed Preheat, F	381	381
Riser C/O	5.58	6.17
HS-FCC outlet Temp, F	--	1112
HS-FCC Feed Preheat, F	--	650
HS-FCC C/O	--	15
Catalyst Cooler Duty, MMBTU/Hr	111	0

Conclusion

HS-FCC™ Technology:

- **Turns FCC upside down to achieve higher selectivity cracking**
  - Utilizing high severity-ROT, Cat/oil and catalyst formulation
- **Uses already commercially proven FCC technology hardware**
- **Retrofit of existing FCC Units with HS-FCC™ feasible**
  - Additional retrofit studies in progress
- **Offers refinery/petrochemicals integration opportunities for greater profits**
- **Demonstrated on VGO and resid feedstock in a semi-commercial plant**

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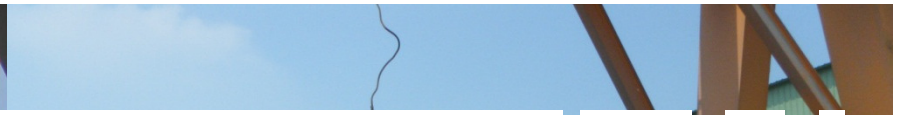
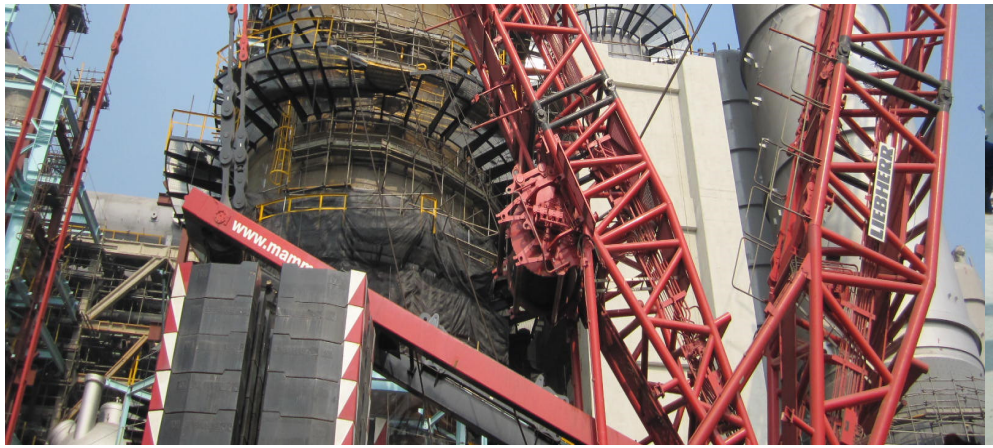


Thank you



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