
WORLDWIDE REFINERY PROCESSING REVIEW

Monitoring Technology Development and Competition in One Single Source

Second Quarter 2020

Catalytic Reforming



HYDROCARBON PUBLISHING COMPANY

Translating Knowledge into Profitability®

P.O. Box 815, Paoli, PA 19301-0815 (U.S.A.)

Phone: (610) 408-0117

Review@Hydrocarbonpublishing.com

WORLDWIDE REFINERY PROCESSING REVIEW

Monitoring Technology Development and Competition in a Single Source

Second Quarter 2020

Catalytic Reforming

<http://www.hydrocarbonpublishing.com>

WORLDWIDE REFINERY PROCESSING REVIEW is published by Hydrocarbon Publishing Co. every quarter. Copyright 2007-2020. All rights reserved. No part of this publication may be reproduced, stored in a retrieval system or transmitted in any form or translated into any language or by any means—electronic, mechanical, photocopying, recording or otherwise—without prior written permission of Hydrocarbon Publishing Company. P.O. Box 815, Paoli, PA 19301-0815 (USA). Tel: (610) 408-0117. E-mail: review@hydrocarbonpublishing.com

1Q, 2Q, 3Q, 4Q...(the) first, second, third, and fourth quarters, respectively	K	thousand
AAA American Automobile Association (US)	kL.....	kiloliter
ANS Alaskan North Slope crude	lb.....	pound(s)
API..... American Petroleum Institute (US)	METI	Ministry of Economy, Trade and Industry (Japan)
ARA..... Antwerp, Rotterdam, Amsterdam	MM	million
ASTM American Society for Testing & Materials	MOU.....	memorandum of understanding
b or bbl..... barrel(s)	mpg.....	miles per gallon
B billion	mt.....	metric ton
boe barrel(s) of oil equivalent	MW.....	megawatt
CA California	N.A.	not applicable or not available
CAA..... Clean Air Act (US)	NAAQS	national ambient air quality standards
CARB California Air Resources Board	NESCAUM.....	Northeast States for Coordinated Air Use Management
cf..... cubic foot, cubic feet	NG	natural gas
cfr..... cost and freight	NGL.....	natural gas liquid
cif..... cost, insurance, and freight	NPRA	National Petrochemical & Refiners Association (US)
Concawe Conservation of Clean Air and Water Europe	NWE.....	Northwest Europe
CIS..... Commonwealth of Independent States	NYMEX	New York Mercantile Exchange (US)
CNG..... compressed natural gas	OECD	Organization for Economic Cooperation & Development
cst..... centistoke	OPEC.....	Organization of the Petroleum Exporting Countries
d..... day	OSHA	Occupational, Safety and Health Administration (US)
DOE..... Department of Energy	PC	petrochemical(s)
EEC European Economic Community	PM	particulate matter
EIA..... US Energy Information Administration	RBOB	RFG before oxygenate blending
EPA US Environmental Protection Agency	RFG	reformulated gasoline
EPC(M)..... engineering, procurement, and construction (management)	RMT.....	refining, marketing, and transportation
EU15..... 15 original EU members	RVP	Reid vapor pressure
EU25..... EU15 and the 10 new members admitted in May 2004	SCAQMD	South Coast Air Quality Management District (California)
EUROPIA..... European Petroleum Industry Association (Brussels)	VLCC	very large crude carrier
FCV fuel cell vehicle	WTI	West Texas Intermediate
fd..... free delivered	y	year
FEED front-end engineering design	¢.....	US cent(s)
fob..... free on board	€.....	EU euro(s)
gal..... gallon	£.....	UK pound(s)
GTL gas to liquid(s)	\$.....	US dollar(s)
h..... hour	¥.....	Japanese yen
H1 or H2 first or second half of the year		
ICE..... Int'l Commodity Exchange (UK—formerly Int'l Petroleum Exchange)		
IEA Int'l Energy Agency (Paris-based)		
IPAA..... Independent Petr. Assoc. of America		
IPO..... initial public offering		
j.v..... joint venture		
LPG liquefied petroleum gas		

2Q 2020 Review

Catalytic Reforming

1. CATALYTIC REFORMING	1
1.1 MARKET/TECHNOLOGY TRENDS & OPPORTUNITIES.....	1
1.1.1 <i>Introduction</i>	1
1.1.2 <i>Market Conditions and Outlook</i>	2
1.1.2.1 Global Transportation Fuel Specifications.....	3
1.1.2.2 Refined Product Supply and Demand	5
1.1.2.2.1 Gasoline.....	6
1.1.2.2.1.1 US.....	9
1.1.2.2.1.2 South America.....	10
1.1.2.2.1.3 Europe.....	10
1.1.2.2.1.4 Russia	11
1.1.2.2.1.5 Asia-Pacific	12
1.1.2.2.2 Rise of Aromatics (BTX)	13
1.1.2.2.2.1 Supply and Demand	14
1.1.2.2.2.2 New Capacity Additions	16
1.1.2.3 Hydrogen Demand	19
1.1.2.4 Catalytic Reforming Installed Capacity.....	19
1.1.2.5 New Construction and Expansion	20
1.1.3 <i>Technology Competition, Directions, and Future Prospects</i>	20
1.1.3.1 Process and Catalyst Advancements.....	21
1.1.3.1.1 Process and Hardware Improvements	21
1.1.3.1.2 Mitigation of Corrosion and Fouling by Chlorides.....	23
1.1.3.1.3 Catalyst Innovations	25
1.1.3.2 Trends in R&D	26
1.1.4 <i>Conclusion</i>	29
1.2 STATE-OF-THE-ART TECHNOLOGY	29
1.2.1 <i>Introduction</i>	29
1.2.2 <i>Commercial Process Technology</i>	30
1.2.2.1 Axens	31
1.2.2.1.1 Semi-regenerative	31
1.2.2.1.2 Octanizing (CCR)	33
1.2.2.1.3 Aromizing (CCR)	35
1.2.2.1.4 Dualforming/Dualforming Plus	36
1.2.2.2 Chevron Phillips Chemical	38
1.2.2.3 Honeywell UOP.....	39
1.2.2.3.1 Platforming	40
1.2.2.3.2 CCR Platforming.....	40
1.2.2.3.3 RZ Platforming	44
1.2.2.3.4 CycleMax.....	45
1.2.2.3.5 Chlorsorb	47
1.2.2.4 New Gas Technologies-Synthesis	48
1.2.2.5 Zeosit	50
1.2.2.6 Summary of Commercial Process Technology	52
1.2.3 <i>Commercial Catalysts</i>	55
1.2.3.1 Axens	57
1.2.3.1.1 CCR Catalysts	58
1.2.3.1.2 Fixed-bed Catalysts.....	59
1.2.3.2 Honeywell UOP.....	61
1.2.3.2.1 CCR Catalysts	61
1.2.3.2.2 Fixed-bed Catalysts.....	65
1.2.3.3 Sinopec	67
1.2.3.3.1 CCR Catalysts	68

1.2.3.3.2 Fixed-bed Catalysts	68
1.2.3.4 Comparison of Commercially Available Catalysts	69
1.2.4 Additional Catalyst and Adsorbent Technology	70
1.2.4.1 Avantium	70
1.2.4.2 Axens	71
1.2.4.3 Clariant	72
1.2.4.4 Honeywell UOP	72
1.2.4.5 Johnson Matthey	73
1.2.5 Comparison of Commercially Available Advanced Control and Optimization Systems	75
1.3 PLANT OPERATIONS AND PRACTICES	79
1.3.1 Feedstock Management	79
1.3.1.1 Product Slate and Feed Type	79
1.3.1.2 Feedrate Considerations.....	80
1.3.1.3 Sulfur Management	81
1.3.1.4 Iron	82
1.3.1.5 Nitrogen.....	83
1.3.1.6 Mercury	84
1.3.2 Operational Challenges and Mitigation Strategies	84
1.3.2.1 Problems Encountered when Processing Non-straight Run Naphthas.....	84
1.3.2.2 Chloride, Water, and Fouling Monitoring and Control	87
1.3.2.3 Red Oil in the Reformer	89
1.3.2.4 High Temperature Hydrogen Attack (HTHA)	90
1.3.2.5 Problems in the Catalyst Circulation Loop	90
1.3.2.6 Preventing Failure in Reactor Internals	91
1.3.2.7 Carbon Monoxide in Reformer Net Gas.....	92
1.3.2.8 High Regenerator Dust Collector Pressure Drop	93
1.3.2.9 Low-coke Reformer Operation	94
1.3.2.10 Feed/Effluent Heat Exchanger Fouling	96
1.3.2.11 Ball Valve Performance Problems and Replacement	97
1.3.2.12 Detection and Prevention of Lift Line Erosion.....	98
1.3.3 Catalyst Management.....	98
1.3.3.1 Catalyst Changeouts: Justification and Procedures	98
1.3.3.2 Tracking Coke on Catalyst	100
1.3.3.3 Separating Useable Catalyst Pills from Fines	101
1.3.3.4 Using Pre-reduced and Pre-sulfided Catalyst	101
1.3.3.5 Platinum Losses from Reforming Catalyst	102
1.3.3.6 Catalyst Modeling for Improved Unit Performance.....	103
1.3.3.7 Catalyst Improvements for Extending Semi-regenerative Reformer Cycle Length.....	103
1.3.3.8 In-situ Regeneration and its Importance for Reclamation.....	104
1.3.3.9 Using Trimetallic Catalysts	105
1.3.3.10 Oxygen Concentration for Platinum Redistribution	106
1.3.3.11 Changing Catalyst Suppliers	106
1.3.3.12 CCR Catalyst Platinum Agglomeration.....	108
1.3.3.13 Catalyst Reduction Hydrogen Quality.....	108
1.3.3.14 Regenerating CCR Catalyst with High Carbon Content.....	109
1.3.3.15 CCR Heel Catalyst Contamination	110
1.3.4 Process Control, Modeling, and Monitoring.....	111
1.3.4.1 Model-based Inferential Properties.....	111
1.3.4.2 Advanced Process Control in Catalytic Reforming Units.....	112
1.3.4.3 Online Measuring Tools: NMR Spectroscopy and Gas Chromatography.....	113
1.3.4.4 Reformer Feed and Product Analysis.....	114
1.3.4.5 Monitoring Recycle Hydrogen H₂O Levels	115
1.3.5 Product Slate	116
1.3.5.1 Reformate Benzene and Aromatics Reduction.....	116
1.3.5.2 Maximizing Hydrogen Production	118
1.3.5.3 Aromatics Production in Catalytic Reforming.....	118

1.3.5.4	Flexibility in Naphtha Conversion for Integration with Petrochemical Plants.....	119
1.3.5.5	Chloride Removal from Reformer Products	120
1.3.6	Revamp Strategies.....	121
1.3.6.1	Revamping Fixed-bed Units to CCR Reformers or Hybrid Units	122
1.3.6.2	Revamping Semi-regenerative Reformers to Low-pressure Operations.....	123
1.3.6.3	Revamping a CCR Unit with an Atmospheric Regenerator for Low-coke Operation.....	123
1.3.7	Improving Energy Efficiency and Reducing CO₂ Emissions.....	124
1.3.7.1	Reformer Heat Exchanger Types	125
1.3.7.1.1	Welded Plate	126
1.3.7.1.2	Twisted Tube	129
1.3.7.1.3	Rod Baffle	129
1.3.7.2	Fired Heater Capacity and Efficiency.....	129
1.3.7.2.1	General Strategies	129
1.3.7.2.2	CCR Reformer Furnace Upgrade.....	130
1.3.7.2.3	Ceramic Refractory Coating.....	130
1.3.7.2.4	Rebalancing Heat Load among Furnaces for CCR Platforming	132
1.4	REFINING R&D ALERT!	133
1.4.1	Introduction.....	133
1.4.2	Product Selective Cat Reforming	135
1.4.2.1	Aromatics.....	135
1.4.2.1.1	Patents	135
1.4.2.1.2	Research	139
1.4.2.2	Reformate.....	140
1.4.2.3	Hydrogen	141
1.4.3	General Catalyst Improvements	141
1.4.3.1	Composition	141
1.4.3.1.1	Patents	141
1.4.3.1.2	Research	142
1.4.3.2	Preparation Methods	142
1.4.3.3	Other.....	144
1.4.4	General Process and Hardware Improvements.....	145
1.4.4.1	Feed Treatment	145
1.4.4.2	Product Treatment	146
1.4.4.3	Equipment	147
1.4.4.4	Energy Efficiency.....	150
1.4.4.5	Process Monitoring, Modeling and Optimization.....	152
1.4.4.5.1	Patents	152
1.4.4.5.2	Research	154
1.4.4.6	Other.....	156
1.5	WORLDWIDE INSTALLED CAPACITY.....	157
1.6	CONSTRUCTION.....	158
1.6.1	Recent Construction Activity	158
1.6.2	Completed Construction Projects.....	162
1.7	REFERENCES	167