

*Novel Desulfurization Technologies*  
00/01S8

*October 2002*

## TABLE OF CONTENTS

SECTION	DESCRIPTION	PAGE
<b>I</b>	<b>EXECUTIVE SUMMARY</b>	1
	A. INTRODUCTION	1
	1. Background	1
	B. DESULFURIZATION TECHNOLOGY	2
	1. Conventional Desulfurization Technology	2
	2. New Developments in FCC Naphtha Desulfurization	4
	(a) Gasoline Component Blending	4
	(b) Requirements for New Technology	6
	C. DEEP GASOLINE DESULFURIZATION TECHNOLOGIES	8
	1. General Considerations	8
	D. COMMERCIAL ANALYSIS	10
	1. Background	10
	E. ECONOMIC ANALYSIS	11
	1. Background and Assumptions	11
	2. Results	12
	F. CONCLUSIONS	14
<b>II</b>	<b>INTRODUCTION</b>	15
	A. BACKGROUND	15
	1. General Introduction	15
	2. Desulfurization Processes	15
	B. TERMINOLOGY	17
	C. BASIS OF REPORT	18
	1. Desulfurization Technologies	18
	2. Product Quality	18
	3. Economics	19
<b>III</b>	<b>DESULFURIZATION TECHNOLOGY</b>	20
	A. CONVENTIONAL HYDRODESULFURIZATION	20
	1. Process Description	20
	2. Hydrotreating Reactions	21
	B. CATALYSTS FOR CONVENTIONAL HYDRODESULFURIZATION	24
	C. NEW DEVELOPMENTS IN FCC NAPHTHA DESULFURIZATION	25
	1. Gasoline	25
	(a) Quality Requirements	25
	(b) Gasoline Component Blending	25
	2. Requirements for New Technology	27
	D. PRETREATMENT OF FCC FEEDSTOCK VERSUS POST TREATMENT OF FCC NAPHTHA	29

<b>SECTION</b>	<b>DESCRIPTION</b>	<b>PAGE</b>
<b>IV</b>	<b>DEEP GASOLINE DESULFURIZATION TECHNOLOGIES</b>	<b>30</b>
A.	INTRODUCTION	30
B.	GENERAL CONSIDERATIONS	31
C.	EXXONMOBIL'S OCTGAIN PROCESS	34
	1. Process Technology	34
	2. Current Implementation Status	36
D.	EXXONMOBIL'S SCANFINING PROCESS	37
	1. Process Technology	37
	2. Current Implementation Status	39
E.	AXENS' PRIME G+ PROCESS	40
	1. Introduction	40
	2. Selective Hydrogenation	41
	3. Fractionation	41
	4. Dual Catalyst HDS	41
	5. Overall Process	42
	6. Current Implementation Status	42
F.	PHILLIPS PETROLEUM CORPORATION'S S ZORB PROCESS	43
	1. Process Technology	43
	2. Current Implementation Status	45
G.	UOP's ISAL PROCESS	46
	1. Process Technology	46
	2. Current Implementation Status	48
H.	CATALYTIC DISTILLATION TECHNOLOGIES' CDHYDRO, CDHDS AND CDHDS+ PROCESSES	49
	1. Introduction	49
	2. CDHydro	49
	3. CDHDS	51
	4. CDHDS+	52
	5. Overall Comparison	52
	6. Current Implementation Status	53
I.	BP'S OATS PROCESS	54
	1. Process Technology	54
	2. Treatment of Full Range FCC Naphtha	56
	3. Treatment of MCN and HCN Only	56
	4. Treatment of MCN Fraction Only	56
	5. Overall Process	57
	6. Current Implementation Status	57
J.	Conclusion	58

<b>SECTION</b>	<b>DESCRIPTION</b>	<b>PAGE</b>
<b>V</b>	<b>COMMERCIAL ANALYSIS</b>	59
	A. INTRODUCTION	59
	B. GASOLINE QUALITY	60
	1. Quality Issues	60
	(a) Sulfur	60
	(b) Olefins	60
	(c) Oxygenates	60
	(d) Benzene and Aromatics	61
	(e) Reid Vapor Pressure	61
	2. United States	63
	3. Western Europe	64
	(a) Gasoline Quality	64
	4. Gasoline Standards in Other Countries	65
	C. GASOLINE MARKET CHARACTERISTICS AND DEMAND	67
	1. Overall Gasoline Market Outlook	67
	2. North America	69
	3. Western Europe	69
	4. Africa and Asia	70
<b>VI</b>	<b>ECONOMIC ANALYSIS</b>	71
	A. BACKGROUND AND ASSUMPTIONS	71
	B. ECONOMIC ANALYSIS	73
	1. Introduction	73
	C. CONCLUSIONS	78
<b>VII</b>	<b>REFERENCES</b>	80
<b>VIII</b>	<b>APPENDIX I</b>	82

<b>FIGURES</b>		<b>PAGE</b>
Figure I.B.1	Typical Naphtha Hydrosulfurization Process	3
Figure I.B.2	Typical Composition of Gasoline	5
Figure I.B.3	Octane Loss vs Sulfur Level in Hydrotreated FCC Naphtha Using Conventional HDS Unit	6
Figure I.C.1	Typical Composition of FCC Naphtha Cuts	8
Figure I.D.1	Maximum Permitted Sulfur Levels in Gasoline	10
Figure I.E.1	Technology Competitiveness - Low Sulfur Feedstock	12
Figure I.E.2	Technology Competitiveness - High Sulfur Feedstock	13
Figure II.B.1	Simplified Flow Diagram of a Typical Complex Refinery	17
Figure II.C.1	Maximum Gasoline Sulfur Levels	19
Figure III.A.1	Typical Naphtha Hydrosulfurization Process	21
Figure III.C.1	Typical Composition of Gasoline	26
Figure III.C.2	Octane Loss vs Sulfur Level in Hydrotreated FCC Naphtha Using Conventional HDS Unit	27
Figure IV.B.1	Composition of FCC Naphtha Cuts	31
Figure IV.C.1	ExxonMobil's OCTGAIN	34
Figure IV.D.1	ExxonMobil's SCANfining	37
Figure IV.E.1	Axens/IFP's PRIME G+	40
Figure IV.F.1	Phillips Petroleum Corp.'s S ZORB	43
Figure IV.F.2	Example of S ZORB Chemistry	44
Figure IV.G.1	UOP's ISAL	46
Figure IV.H.1	CDTECH's CDHydro & CDHDS	50
Figure IV.I.1	bp's OATS	55
Figure V.C.1	Major Gasoline Trade Flows, 2010	68
Figure V.C.2	Gasoline and Diesel Demand in Western Europe	69
Figure VI.B.1	Impact of Desulfurization on Octane Number By Process	74
Figure VI.B.2	Assumed Product Yield by Process	75
Figure VI.B.3	Impact of FCC Naphtha Desulfurization on Gasoline Pool Revenues	76
Figure VI.B.4	Technology Competitiveness – Low Sulfur Feedstock	77
Figure VI.B.5	Technology Competitiveness – High Sulfur Feedstock	77

<b>TABLES</b>	<b>PAGE</b>	
Table I.B.1	Effect of Changes in Operational Parameters on Product Qualities	2
Table I.B.2	Typical Composition of Gasoline Produced by a Complex Refinery in Western Europe	5
Table I.C.1	Processes Considered in this Report and Their Key Features	9
Table I.E.1	Gasoline Specifications Used in Economic Analysis	11
Table I.E.2	Number of Operational units	13
Table III.A.1	Effect of Changes in Operational Parameters on Product Quality	23
Table III.C.1	Typical Composition of Gasoline Produced by a Complex Refinery in Western Europe	26
Table IV.B.1	Potential Octane Loss Due to Olefin Saturation in FCC Naphtha	32
Table IV.C.1	Comparison between HDS and OCTGAIN Product Qualities	36
Table IV.C.2	Typical Operating Parameters for OCTGAIN Process	36
Table IV.D.1	SCANfining Sulfur Removal	38
Table IV.D.2	Reduction in Octane Loss by Heavy Mercaptan Removal	38
Table IV.G.1	Comparison of Product Quality After Conventional HDS and ISAL Process	48
Table IV.H.1	Estimated Performance Data for CDTech Processes	52
Table IV.H.2	CDTech FCC Gasoline Commercial Experience	53
Table IV.I.1	Quality of OATS Treated MCN+HCN Fractions of FCC Naphtha	56
Table IV.J.1	Processes Summary	58
Table V.B.1	Effect of Gasoline Quality on Emissions of Passenger Cars	62
Table V.B.2	United States EPA: Tier II Gasoline Sulfur Overview Sulfur Levels	64
Table V.B.3	European Gasoline Specifications	65
Table V.B.4	Sulfur Levels Permitted in Gasoline, ppm	66
Table V.C.1	Worldwide Gasoline Regional Supply/Demand	67
Table V.C.2	Gasoline Price Projections	68
Table VI.A.1	Gasoline Specifications Used in Economic Analysis	71
Table VI.A.2	Product Pricing Assumptions	72
Table VI.B.1	FCC Naphtha Feedstock and Product Characteristics By Process	73