

PHENOL/ACETONE/CUMENE (96/97-2) DECEMBER 1997

CONTENTS	Page
I SUMMARY	1
A. CURRENT COMMERCIAL TECHNOLOGY	1
B. DEVELOPING TECHNOLOGIES	4
C. COMMERCIAL ANALYSIS	6
1. Introduction	6
2. Phenol	7
3. Cumene	11
4. Acetone	12
(a) Demand	12
(b) Supply	14
(c) Supply/Demand Balance	14
II INTRODUCTION	16
A. HISTORICAL ROUTES TO PHENOL	16
B. CURRENT COMMERCIAL TECHNOLOGY	17
1. Cumene Hydroperoxide Route	17
2. DSM Toluene Oxidation Route	18
C. DEVELOPING TECHNOLOGIES	18
1. Mitsui Acetone Recycle Route	18
2. Solutia/BIC N ₂ O Benzene Oxidation Route	19
3. Asahi Cyclohexene Route	19
III CUMENE PRODUCTION TECHNOLOGY	20
A. CHEMISTRY	20
B. SOLID PHOSPHORIC ACID CATALYZED CUMENE PROCESS	22
C. ALUMINUM CHLORIDE CATALYZED CUMENE PROCESS	26
D. ZEOLITE BASED CATALYZED CUMENE PROCESS	29
IV PHENOL AND ACETONE PRODUCTION TECHNOLOGY	35
A. CUMENE BASED PHENOL/ACETONE PROCESS TECHNOLOGY	35
1. Chemistry	35
(a) Cumene Oxidation to Cumene Hydroperoxide	35
(b) Cumene Hydroperoxide Cleavage to Phenol and Acetone	39
2. Process Technology	42
B. MITSUI ACETONE RECYCLE PROCESS	49
C. SOLUTIA NITROUS OXIDE BENZENE OXIDATION PROCESS	53
1. Chemistry	53
2. Reaction Mechanism	55
3. Oxidation Catalysts	56
4. Process Basis	57
5. Process Description	59

PHENOL/ACETONE/CUMENE (96/97-2) DECEMBER 1997

CONTENTS	Page
D. PHENOL FROM TOLUENE	60
1. Benzoic Acid from Toluene	61
2. Phenol from Benzoic Acid	62
(a) Chemistry	62
(b) Process Description	65
E. PHENOL FROM BENZENE VIA HYDROGENATION TO CYCLOHEXENE: THE ASAHI PROCESS	70
F. ACETONE FROM PROPYLENE	74
1. Chemistry	74
2. Process Description	76

V	ECONOMICS	79
	A. ECONOMICS OF CUMENE PRODUCTION	79
	B. ECONOMICS OF PHENOL PRODUCTION	85
	1. Phenol Production via Cumene	85
	2. Phenol Production via Benzene and Propylene	85
	3. Phenol Production via Acetone	89
	4. Phenol Production via Solutia Process	92
	C. ECONOMICS OF ACETONE PRODUCTION	96
VI	COMMERCIAL ANALYSIS	98
	A. INTRODUCTION	98
	B. PHENOL	99
	1. United States	99
	(a) Demand	99
	(1) Phenolic Resins	100
	(2) Bisphenol A	100
	(3) Caprolactam	100
	(4) Other	101
	(b) Supply	101
	(c) Supply/Demand Balance	102
	2. Western Europe	103
	(a) Demand	103
	(1) Phenolic Resins	104
	(2) Bisphenol A	104
	(3) Caprolactam	105
	(4) Other	105
	(b) Supply	105
	(c) Supply/Demand Balance	106
	3. Japan	107
	(a) Demand	107
	(1) Phenolic Resins	108
	(2) Bisphenol A	108

PHENOL/ACETONE/CUMENE (96/97-2) DECEMBER

1997

CONTENTS	Page
(3) Other	108
(b) Supply	109
(c) Supply/Demand Balance	110
4. Other Far East	110
(a) Demand	110
(b) Supply	110
(c) Supply/Demand Balance	112
5. Latin America	112
6. Rest of the World	113

7.	Summary	114
C.	CUMENE	120
1.	United States	120
	(a) Demand	120
	(b) Supply	120
	(c) Supply/Demand Balance	121
2.	Western Europe	121
	(a) Demand	121
	(b) Supply	121
	(c) Supply/Demand Balance	122
3.	Japan	123
	(a) Demand	123
	(b) Supply	123
	(c) Supply/Demand Balance	124
4.	East Asia	125
	(a) Demand	125
	(b) Supply	125
	(c) Supply/Demand Balance	125
5.	Latin America	126
	(a) Demand	126
	(b) Supply	126
	(c) Supply/Demand Balance	127
6.	Rest of the World	128
	(a) Demand	128
	(b) Supply	128
7.	Summary	128
D.	ACETONE	132
1.	Demand	132
	(a) Methyl Methacrylate	132
	(b) Bisphenol A	133
	(c) Solvents	133
	(d) Other Uses	133
2.	Supply	135
3.	Supply/Demand Balance	136
	REFERENCES	138

PHENOL/ACETONE/CUMENE (96/97-2) DECEMBER 1997

TABLES

	Page
Table I.A.1 U.S. Gulf Coast Cumene Production Economic Comparison, 1st Qtr 1996	2
Table I.A.2 U.S. Gulf Coast Phenol Production Economic Comparison: Cumene Route, 1st Qtr 1997	3
Table I.A.3 U.S. Gulf Coast Acetone Production Economic Summary, 1st Qtr 1997	4
Table I.B.1 U.S. Gulf Coast Phenol Production Economic Comparison of Developing Technologies, 1st Qtr 1997	6
Table I.C.1 Global Phenol Demand by Region, 1990-2010	8
Table I.C.2 Global Phenol Capacity by Region, 1993-2010	9
Table I.C.3 Global Cumene Demand by Region, 1993-2010	11
Table I.C.4 Global Cumene Capacity by Region, 1993-2010	12
Table I.C.5 Acetone Demand by Major Region, 1990-2010	13
Table I.C.6 Global Acetone Capacity in Major Producing Regions, 1990-2010	14
Table I.C.7 Global Acetone Supply/Demand Balance, 1990-2010	15
Table III.A.1 Benzene Feedstock Specifications	21
Table III.A.2 Propylene Feedstock Specifications	22
Table III.B.1 Typical Cumene Specifications for Chlorination Grade Phenol Manufacture	26
Table IV.A.1 Typical Acetone Product Specifications	46
Table IV.A.2 Typical Phenol Product Specifications	48
Table IV.C.1 Effect of Catalyst Water Vapor Treatment on Benzene Conversion	56
Table IV.C.2 Various Operating Conditions for N ₂ O Oxidation of Benzene to Phenol	58
Table IV.C.3 Process Parameters for N ₂ O Oxidation of Benzene to Phenol	59
Table IV.D.1 Toluene Oxidation Reactor Design Bases	67
Table V.A.1 U.S. Gulf Coast Cumene Production Economics Comparison, 1st Qtr 1997	80
Table V.A.2 Cost Estimate of Cumene Production via Benzene/Propylene Transalkylation, Phosphoric Acid Catalyst	82
Table V.A.3 Cost Estimate of Cumene Production via Benzene/Propylene Transalkylation, Aluminum Chloride Catalyst	83
Table V.A.4 Cost Estimate of Cumene Production via Benzene/Propylene Transalkylation, Zeolite Catalyst	85
Table V.B.1 Cost Estimate of Phenol Production via Cumene	86
Table V.B.2 Cost Estimate of Phenol Production from Benzene and Propylene, Phosphoric Acid Catalyst	87
Table V.B.3 Cost Estimate of Phenol Production from Benzene and Propylene, Zeolite Catalyst	88
Table V.B.4 Cost Estimate of Phenol Production via Mitsui Process with Acetone Recycle	90
Table V.B.5 Cost Estimate of Phenol Production from Benzene (Solutia)	93

PHENOL/ACETONE/CUMENE (96/97-2) DECEMBER

1997

TABLES

	Page
Table V.C.1 U.S. Gulf Coast Acetone Production Economics Summary, 1st Qtr 1997	96
Table V.C.2 Cost Estimate of Acetone Production via IPA Dehydration	97
Table VI.B.1 U.S. Phenol Demand by Application, 1997	99
Table VI.B.2 U.S. Phenol Demand by End Use, 1990-2010	100
Table VI.B.3 U.S. Synthetic Phenol Capacity, 1997	102
Table VI.B.4 U.S. Phenol Supply/Demand Balance, 1993-2010	103
Table VI.B.5 West European Phenol Demand by Application, 1997	103
Table VI.B.6 West European Phenol Demand by End Use, 1990-2010	104
Table VI.B.7 West European Phenol Capacity, 1997	106
Table VI.B.8 West European Phenol Supply/Demand Balance, 1993-2010	107
Table VI.B.9 Japanese Phenol Demand by Application, 1997	107
Table VI.B.10 Japanese Phenol Demand by End Use, 1990-2010	108
Table VI.B.11 Japanese Phenol Capacity, 1997	109
Table VI.B.12 Japanese Phenol Supply/Demand Balance, 1993-2010	110
Table VI.B.13 East Asian Phenol Capacity, 1997	111
Table VI.B.14 East Asian Phenol Supply/Demand Balance, 1993-2010	112
Table VI.B.15 Latin American Phenol Supply/Demand Balance, 1993-2010	113
Table VI.B.16 Phenol Capacity, Rest of the World, 1997	114
Table VI.B.17 Global Phenol Demand by Region, 1990-2010	116
Table VI.B.18 Global Phenol Capacity by Region, 1993-2010	118
Table VI.C.1 U.S. Cumene Capacity, 1997	120
Table VI.C.2 U.S. Cumene Supply/Demand Balance, 1993-2010	121
Table VI.C.3 West European Cumene Capacity, 1997	122
Table VI.C.4 West European Cumene Supply/Demand Balance, 1993-2010	123
Table VI.C.5 Japanese Cumene Capacity, 1997	124
Table VI.C.6 Japanese Cumene Supply/Demand Balance, 1993-2010	124
Table VI.C.7 East Asian Cumene Capacity, 1997	125
Table VI.C.8 East Asian Cumene Supply/Demand Balance, 1993-2010	126
Table VI.C.9 Latin American Cumene Capacity, 1997	127
Table VI.C.10 Latin American Cumene Supply/Demand Balance, 1993-2010	127
Table VI.C.11 Rest of the World Cumene Capacity, 1997	128
Table VI.C.12 Global Cumene Demand by Region, 1993-2010	130
Table VI.C.13 Global Cumene Capacity by Region, 1993-2010	132
Table VI.D.1 Acetone Demand by Major Region, 1990-2010	135
Table VI.D.2 Acetone Capacity in Major Producing Regions, 1990-2010	136
Table VI.D.3 Global Acetone Supply/Demand Balance, 1990-2010	137

FIGURES

	Page
Figure I.C.1 Global Phenol Net Trade by Region, 1996	10
Figure III.B.1 Phosphoric Acid Catalyst, UOP Cumene Synthesis	

1997**FIGURES**

	Page
Figure III.C.1	Solutia/Kellogg Cumene Synthesis and Purification 27
Figure III.D.1	UOP's Qmax Process: Zeolite Catalyst 30
Figure III.D.2	CDTech CDCumene Process, Zeolite Catalyst 31
Figure IV.A.1	Phenol from Cumene Oxidation and Cleavage 43
Figure IV.A.2	Phenol from Cumene: Phenol/Cumene Recovery and AMS Hydrogenation 47
Figure IV.B.1	Mitsui Process: Hydrogenation of Acetone to Isopropanol 50
Figure IV.B.2	Simplified Flow Diagram of Mitsui Process: Isopropanol to Propylene 51
Figure IV.C.1	Simplified Flow Diagram of Solutia Process: Benzene to Phenol 54
Figure IV.D.1	Phenol via Toluene: Benzoic Acid Synthesis and Purification Area 66
Figure IV.D.2	Phenol via Toluene: Liquid Phase Phenol Synthesis and Purification 69
Figure IV.E.1	Phenol via Benzene Hydrogenation to Cyclohexene 73
Figure IV.F.1	Acetone from Propylene via IPA 78
Figure V.A.1	Sensitivity of Cumene Production Cost to Benzene and Propylene Price, Zeolite Catalyst 81
Figure V.B.1	Sensitivity of Phenol Production Cost to Acetone Price in Conventional and Mitsui Processes 91
Figure V.B.2	Sensitivity of Phenol Production Cost to N ₂ O Price in Conventional and Solutia Processes 95
Figure VI.B.1	Global Phenol Demand by Region, 1997 115
Figure VI.B.2	Global Phenol Capacity by Region, 1997 117
Figure VI.B.3	Global Phenol Net Trade by Region, 1996 119
Figure VI.C.1	Global Cumene Demand by Region, 1997 129
Figure VI.C.2	Global Cumene Capacity by Region, 1997 131
Figure VI.D.1	Acetone Consumption in Major Regions, 1997 134