

**Abstract**  
**Process Economics Program Report 25C**  
**XYLENE SEPARATION**  
**(March 1998)**

A significant amount of new xylene isomer capacity is being built worldwide, especially for p-xylene, which has experienced sustained demand growth of 7–8% per year. While p-xylene production economics were extremely attractive in 1994–1995, there is now concern about surplus capacity and reduced profitability. Thus, producers are focusing on the need for competitive advantage and operating efficiency. The efficiency and performance of existing xylene separation technologies (crystallization and adsorption) continue to improve, and new technologies are emerging.

This report focuses on the current technological advancements in xylene isomer production and recovery. It also evaluates the production economics for xylene isomers derived from reformate C<sub>8</sub> aromatic fractions combined with xylenes derived from either conventional toluene disproportionation (TDP) or para-selective TDP. Configurations evaluated are:

- p-Xylene and o-xylene production via adsorption/isomerization
- p-Xylene and o-xylene production via crystallization/isomerization
- p-Xylene and m-xylene production via adsorption/isomerization.

The total fixed capital (TFC) costs for the crystallization process are about 45% higher than for the adsorption process. Variable costs are comparable for both adsorption and crystallization, but plant cash costs are higher for crystallization because of the higher capital related direct costs.

For both adsorption and crystallization processes, para-selective TDP has lower TFC because the higher p-xylene content allows the use of smaller equipment than conventional TDP.

Knowledge of technological advances and production cost structures for xylenes enables producers to evaluate industry competition. This report also gives a comprehensive view of the xylene industry structure and a short term supply/demand outlook. The integrated views are important to existing producers as well as those who are evaluating opportunities to enter this market.

## CONTENTS

<b>GLOSSARY</b> .....	xvii
<b>1 INTRODUCTION</b> .....	1-1
<b>2 SUMMARY</b> .....	2-1
<b>COMMERCIAL ASPECTS</b> .....	2-1
Xylene Capacity Expansion.....	2-2
Commercial Xylene Recovery.....	2-2
<b>TECHNICAL ASPECTS</b> .....	2-3
p-Xylene Recovery.....	2-3
Adsorption Processes.....	2-3
Crystallization Processes.....	2-4
m-Xylene Recovery.....	2-4
Xylene Isomerization.....	2-4
<b>ECONOMIC ASPECTS</b> .....	2-5
p-Xylene Recovery.....	2-5
m-Xylene Recovery.....	2-8
<b>3 INDUSTRY STATUS</b> .....	3-1
<b>XYLENE SOURCES</b> .....	3-1
Xylenes from Coproduct Sources .....	3-3
Xylenes from On-Purpose Sources.....	3-4
Toluene Disproportionation.....	3-5
Transalkylation.....	3-5
Isomerization .....	3-6
<b>XYLENE RECOVERY</b> .....	3-6
<b>p-XYLENE SUPPLY/DEMAND</b> .....	3-12
p-Xylene Demand.....	3-12
p-Xylene Supply .....	3-14

## CONTENTS (Continued)

p-Xylene Trade.....	3-15
p-Xylene Supply/Demand Projections.....	3-15
o-XYLENE SUPPLY/DEMAND .....	3-16
o-Xylene Demand.....	3-18
o-Xylene Supply .....	3-18
o-Xylene Trade.....	3-19
o-Xylene Supply/Demand Projections.....	3-19
m-XYLENE SUPPLY/DEMAND .....	3-20
ANNOUNCED NEW CAPACITY .....	3-20
<b>4 FEED AND PRODUCT VALUATIONS.....</b>	<b>4-1</b>
BTX SUPPLY/DEMAND.....	4-1
Benzene Supply/Demand.....	4-2
Toluene Supply/Demand.....	4-4
Mixed Xylenes Supply/Demand .....	4-5
p-Xylene .....	4-6
o-Xylene .....	4-7
BTX SPOT MARKET PRICES .....	4-7
Benzene Price.....	4-8
Toluene and Mixed Xylenes Prices.....	4-9
p-Xylene Price.....	4-10
o-Xylene Price.....	4-11
m-Xylene Price.....	4-12
OCTANE VALUES .....	4-13

## CONTENTS (Continued)

<b>5 REVIEW OF PROCESSES</b> .....	5-1
AROMATICS COMPLEX OVERVIEW .....	5-
<b>ERROR! BOOKMARK NOT DEFINED.</b>	
XYLENE SEPARATION BY ADSORPTION .....	5-4
Adsorptive Separation Principles .....	5-4
Selectivity .....	5-4
Capacity .....	5-4
Reversibility .....	5-
<b>Error! Bookmark not defined.</b>	
UOP Sorbex® Technology .....	5-
<b>Error! Bookmark not defined.</b>	
p-Xylene Recovery via Parex® Process .....	5-
<b>Error! Bookmark not defined.</b>	
Parex Operation .....	5-5
Parex Performance Improvements .....	5-8
Parex Mechanical Improvements .....	5-8
Parex Feedstock Considerations .....	5-9
m-Xylene Recovery via MX Sorbex Process .....	5-
<b>Error! Bookmark not defined.</b>	
IFP Eluxyl® Process .....	5-
<b>Error! Bookmark not defined.</b>	
Toray Aromax Process .....	5-12
Asahi Chemical Process .....	5-
<b>Error! Bookmark not defined.</b>	
XYLENE SEPARATION BY CRYSTALLIZATION .....	5-14
Crystallization Technology .....	5-14
Early PEP Evaluations .....	5-15
Conventional Crystallization Operation .....	5-16
Recent Advances in Crystallization .....	5-17
Hybrid Crystallization Processes .....	5-
<b>Error! Bookmark not defined.</b>	
Crystallization Processes .....	5-18

Sulzer Chemtech Process .....	5-18
Befs Prokem Process .....	5-
<b>Error! Bookmark not defined.</b>	
UOP/Raytheon/Niro Process Technology Combination .....	5-19

### **CONTENTS (Continued)**

NOVEL XYLENE SEPARATION TECHNOLOGIES .....	5-19
Inclusion Compounds.....	5-19
Membrane Separation.....	5-19
Azeotropic and Extractive Processes.....	5-
<b>Error! Bookmark not defined.</b>	
Other Technologies for Xylene Production .....	5-20
XYLENE ISOMERIZATION.....	5-20
Xylene Isomerization Catalysts and Chemistry .....	5-
<b>Error! Bookmark not defined.</b>	
EB Isomerization .....	5-21
EB Dealkylation .....	5-23
Feedstock Considerations.....	5-23
Commercial Processes .....	5-24
Commercial Status of EB Isomerization .....	5-24
Isomar <sup>®</sup> Process .....	5-25
Octafining <sup>™</sup> Process .....	5-25
Commercial Status of EB Dealkylation .....	5-26
<b>6 p-XYLENE BY PAREX ADSORPTION PROCESS.....</b>	<b>6-1</b>
PROCESS DESCRIPTION .....	6-1
Rerun Section (Section 100) .....	6-5
Parex Section (Section 200).....	6-5
Isomar Section (Section 300).....	6-6
o-Xylene Distillation Section (Section 400) .....	6-7
PROCESS DISCUSSION .....	6-18
Rerun Section.....	6-18

	Parex Section .....	6-19
	Isomar Section .....	6-20
	Materials of Construction.....	6-21
	Waste Streams.....	6-21
<b>CONTENTS (Continued)</b>		
	COST ESTIMATES .....	6-23
	Capital Investment.....	6-23
	Production Cost.....	6-24
<b>7</b>	<b>p-XYLENE BY CRYSTALLIZATION PROCESS .....</b>	<b>7-1</b>
	PROCESS DESCRIPTION .....	7-1
	Rerun Section (Section 100).....	7-5
	Crystallization Section (Section 200).....	7-5
	Isomar Section (Section 300).....	7-7
	o-Xylene Distillation Section (Section 400) .....	7-7
	PROCESS DISCUSSION .....	7-18
	Rerun Section.....	7-18
	Crystallization Section .....	7-19
	Isomar Section .....	7-20
	o-Xylene Distillation Section.....	7-21
	Materials of Construction.....	7-21
	Waste Streams.....	7-22
	COST ESTIMATES .....	7-22
	Capital Investment.....	7-22
	Production Cost.....	7-24
<b>8</b>	<b>p-XYLENE AND m-XYLENE BY ADSORPTION PROCESSES.....</b>	<b>8-1</b>
	PROCESS DESCRIPTION .....	8-1
	Rerun Section (Section 100).....	8-5
	Parex Section (Section 200).....	8-5

Isomar Section (Section 300) .....	8-6
MX Sorbex Section (Section 400) .....	8-7
<b>CONTENTS (Concluded)</b>	
<b>PROCESS DISCUSSION</b> .....	<b>8-21</b>
Rerun Section.....	8-21
Parex Section .....	8-22
Isomar Section .....	8-22
MX Sorbex Section.....	8-22
Materials of Construction.....	8-23
Waste Streams.....	8-23
<b>COST ESTIMATES</b> .....	<b>8-25</b>
Capital Investment.....	8-25
Production Cost.....	8-26
<b>APPENDIX A: PATENT SUMMARY TABLES</b> .....	<b>A-1</b>
<b>APPENDIX B: ZEOLITE CATALYSTS AND ADSORBENTS</b> .....	<b>B-1</b>
<b>APPENDIX C: DESIGN AND COST BASES</b> .....	<b>C-1</b>
<b>APPENDIX D: CITED REFERENCES</b> .....	<b>D-1</b>
<b>APPENDIX E: PATENT REFERENCES BY COMPANY</b> .....	<b>E-1</b>
<b>APPENDIX F: PROCESS FLOW DIAGRAMS</b> .....	<b>F-1</b>

## ILLUSTRATIONS

1.1	Xylene Industry Technology Evolution, 1950–1996 .....	1-2
2.1	p-Xylene Recovery Technology Market Share, 1996.....	2-3
2.2	p-Xylene Production Costs on the U.S. Gulf Coast, 1996 (o-Xylene By-Product) .....	2-7
2.3	p-Xylene Spot Prices on the U.S. Gulf Coast, 1991–1996.....	2-8
2.4	p-Xylene Production Costs on the U.S. Gulf Coast, 1996 (m-Xylene By-Product) .....	2-10
3.1	Schematic Diagram of an Olefins/Aromatics Complex .....	3-2
3.2	p-Xylene Recovery Technology Market Share, 1996.....	3-12
3.3	p-Xylene Supply/Demand, 1991–1996.....	3-13
3.4	World p-Xylene Demand, 1991–1996 .....	3-14
3.5	World p-Xylene Supply, 1991–1996.....	3-15
3.6	p-Xylene Supply/Demand Projections, 1996–2001.....	3-16
3.7	o-Xylene Supply/Demand, 1991–1996.....	3-17
3.8	World o-Xylene Demand .....	3-18
3.9	World o-Xylene Capacity, 1991–1996.....	3-19
3.10	o-Xylene Supply/Demand, 1996–2001.....	3-20
3.11	Announced p-Xylene Capacity as of Mid-1997 .....	3-22
4.1	Options for BTX Aromatics Processing.....	4-2
4.2	World Benzene Demand, 1996 .....	4-3
4.3	World Benzene Supply, 1996.....	4-4
4.4	World Toluene Demand, 1996 .....	4-5
4.5	World Mixed Xylenes Demand, 1996.....	4-6
4.6	World p-Xylene Demand, 1996 .....	4-7
4.7	Aromatics Price, 1991–1996 .....	4-8
4.8	Benzene Price, 1970–1996.....	4-9
4.9	Toluene and Xylene Price Versus Regular Unleaded Gasoline Price, 1970–1996.....	4-10
4.10	p-Xylene Price Versus Mixed Xylenes Price, 1970–1996 .....	4-11
4.11	o-Xylene Price Versus Mixed Xylenes Price, 1970–1996 .....	4-12
4.12	Toluene and Mixed Xylenes Spot Market Price, 1991–1996 .....	4-14
5.1	Aromatics Complex Based on Reformate Feedstock .....	5-2



## ILLUSTRATIONS (Concluded)

5.2	Parex Simulated Moving Bed Process .....	5-6
5.3	Asahi Process Block Flow Diagram .....	5-13
6.1	p-Xylene by Parex Adsorption Process.....	F-3
6.2	p-Xylene by Parex Adsorption Process Net Production Cost and Product Value as a Function of Heavy Reformate Price .....	6-38
6.3 A	p-Xylene by Parex Adsorption Process—Case A Effect of Operating Level and Plant Capacity on Product Value .....	6-39
6.3 B	p-Xylene by Parex Adsorption Process—Case B Effect of Operating Level and Plant Capacity on Product Value .....	6-40
7.1	p-Xylene by Crystallization Process.....	F-7
7.2	p-Xylene by Crystallization Process Net Production Cost and Product Value as a Function of Heavy Reformate Price .....	7-39
7.3 A	p-Xylene by Crystallization Process—Case A Effect of Operating Level and Plant Capacity on Product Value .....	7-40
7.3 B	p-Xylene by Crystallization Process—Case B Effect of Operating Level and Plant Capacity on Product Value .....	7-41
8.1	p-Xylene and m-Xylene by Adsorption Processes .....	F-11
8.2	p-Xylene and m-Xylene by Adsorption Processes Net Production Cost and Product Value as a Function of Heavy Reformate Price .....	8-41
8.3 A	p-Xylene and m-Xylene by Adsorption Processes—Case A Effect of Operating Level and Plant Capacity on Product Value .....	8-42
8.3 B	p-Xylene and m-Xylene by Adsorption Processes—Case B Effect of Operating Level and Plant Capacity on Product Value .....	8-43

## TABLES

1.1	Properties of Xylene Isomers .....	1-1
2.1	World Xylene Capacity, 1996 .....	2-1
2.2	p-Xylene Capacity in Leading Countries, 1996 .....	2-2
2.3	Summary of Cost Estimates for p-Xylene and o-Xylene Recovery .....	2-6
2.4	Summary of Cost Estimates for p-Xylene and m-Xylene Recovery .....	2-9
3.1	Distribution of Isomers in C <sub>8</sub> Aromatics Fractions .....	3-3
3.2	Estimated Xylene Content of Catalytic Feed and Reformate .....	3-3
3.3	Estimated Yields from Ethylene Manufacture .....	3-4
3.4	On-Purpose Xylene Production Technologies .....	3-4
3.5	Toluene Disproportionation Process Yield Comparison .....	3-5
3.6	p-Xylene Production from Isomerization, 1996 .....	3-6
3.7	Xylene Recovery Technology .....	3-7
3.8	World Xylene Capacity .....	3-8
3.9	Announced Xylene Capacity .....	3-21
4.1	Values of Aromatic Streams, May 1996 .....	4-13
5.1	Properties of Xylene Isomers and Ethylbenzene .....	5-1
5.2	p-Xylene Recovery by Adsorption .....	A-3
5.3	Recovery of Ethylbenzene or Xylene Isomers by Adsorption .....	A-12
5.4	p-Xylene Recovery by Crystallization .....	A-15
5.5	p-Xylene Recovery with Inclusion Compounds .....	A-20
5.6	p-Xylene Recovery by Membrane Separation .....	A-23
5.7	Recovery of C <sub>8</sub> Aromatics by Azeotropic or Extractive Processes .....	A-26
5.8	Miscellaneous p-Xylene Production Processes .....	A-31
5.9	Recovery of m-Xylene by Crystallization or Processes .....	A-34
5.10	Xylene Isomerization—Ethylbenzene Isomerization Catalysts .....	A-35
5.11	Xylene Isomerization—Ethylbenzene Dealkylation Catalysts .....	A-44
5.12	Contaminant Effects and Limits in Parex Process .....	5-10
5.13	Contaminant Effects and Limits in Isomar Process .....	5-24
5.14	EB Isomerization Process Comparison .....	5-25
5.15	Ethylbenzene Dealkylation Process Comparison .....	5-27
6.1	p-Xylene by Parex Adsorption Process Design Basis and Assumptions .....	6-3

**TABLES (Continued)**

6.2 A	p-Xylene by Parex Adsorption Process Case A—Heavy Reformate/TDP Xylene Feed Stream Flows .....	6-8
6.2 B	p-Xylene by Parex Adsorption Process Case B—Heavy Reformate/MSTDP Xylene Feed Stream Flows .....	6-9
6.3 A	p-Xylene by Parex Adsorption Process Case A—Heavy Reformate/TDP Xylene Feed Major Equipment .....	6-10
6.3 B	p-Xylene by Parex Adsorption Process Case B—Heavy Reformate/MSTDP Xylene Feed Major Equipment .....	6-13
6.4 A	p-Xylene by Parex Adsorption Process Case A—Heavy Reformate/TDP Xylene Feed Utilities Summary .....	6-16
6.4 B	p-Xylene by Parex Adsorption Process Case B—Heavy Reformate/MSTDP Xylene Feed Utilities Summary .....	6-17
6.5	p-Xylene by Parex Adsorption Process Waste Streams Summary .....	6-22
6.6 A	p-Xylene by Parex Adsorption Process Case A—Heavy Reformate/TDP Xylene Feed Total Capital Investment.....	6-26
6.6 B	p-Xylene by Parex Adsorption Process Case B—Heavy Reformate/MSTDP Xylene Feed Total Capital Investment.....	6-27
6.7 A	p-Xylene by Parex Adsorption Process Case A—Heavy Reformate/TDP Xylene Feed Capital Investment by Section.....	6-28
6.7 B	p-Xylene by Parex Adsorption Process Case B—Heavy Reformate/MSTDP Xylene Feed Capital Investment by Section.....	6-30
6.8 A	p-Xylene by Parex Adsorption Process Case A—Heavy Reformate/TDP Xylene Feed Production Costs.....	6-32
6.8 B	p-Xylene by Parex Adsorption Process Case B—Heavy Reformate/MSTDP Xylene Feed Production Costs.....	6-34
6.9 A	p-Xylene by Parex Adsorption Process Case A—Heavy Reformate/TDP Xylene Feed Direct Costs by Section.....	6-36

## TABLES (Continued)

6.9 B	p-Xylene by Parex Adsorption Process Case B—Heavy Reformate/MSTDP Xylene Feed Direct Costs by Section .....	6-37
7.1	p-Xylene by Crystallization Process Design Basis and Assumptions .....	7-3
7.2 A	p-Xylene by Crystallization Process Case A—Heavy Reformate/TDP Xylene Feed Stream Flows .....	7-8
7.2 B	p-Xylene by Crystallization Process Case B—Heavy Reformate/MSTDP Xylene Feed Stream Flows .....	7-9
7.3 A	p-Xylene by Crystallization Process Case A—Heavy Reformate/TDP Xylene Feed Major Equipment .....	7-10
7.3 B	p-Xylene by Crystallization Process Case B—Heavy Reformate/MSTDP Xylene Feed Major Equipment .....	7-13
7.4 A	p-Xylene by Crystallization Process Case A—Heavy Reformate/TDP Xylene Feed Utilities Summary .....	7-16
7.4 B	p-Xylene by Crystallization Process Case B—Heavy Reformate/MSTDP Xylene Feed Utilities Summary .....	7-17
7.5	p-Xylene by Crystallization Process Waste Streams Summary .....	7-22
7.6 A	p-Xylene by Crystallization Process Case A—Heavy Reformate/TDP Xylene Feed Total Capital Investment.....	7-26
7.6 B	p-Xylene by Crystallization Process Case B—Heavy Reformate/MSTDP Xylene Feed Total Capital Investment.....	7-27
7.7 A	p-Xylene by Crystallization Process Case A—Heavy Reformate/TDP Xylene Feed Capital Investment by Section.....	7-28
7.7 B	p-Xylene by Crystallization Process Case B—Heavy Reformate/MSTDP Xylene Feed Capital Investment by Section.....	7-30
7.8 A	p-Xylene by Crystallization Process Case A—Heavy Reformate/TDP Xylene Feed Production Costs.....	7-32

## TABLES (Continued)

7.8 B	p-Xylene by Crystallization Process Case B—Heavy Reformate/MSTDP Xylene Feed Production Costs .....	7-34
7.9 A	p-Xylene by Crystallization Process Case A—Heavy Reformate/TDP Xylene Feed Direct Costs by Section .....	7-36
7.9 B	p-Xylene by Crystallization Process Case B—Heavy Reformate/MSTDP Xylene Feed Direct Costs by Section .....	7-37
7.10	Production Cost Comparison at Base Capacity .....	7-38
8.1	p-Xylene and m-Xylene by Adsorption Processes Design Basis and Assumptions .....	8-3
8.2 A	p-Xylene and m-Xylene by Adsorption Processes Case A—Heavy Reformate/TDP Xylene Feed Stream Flows .....	8-9
8.2 B	p-Xylene and m-Xylene by Adsorption Processes Case B—Heavy Reformate/MSTDP Xylene Feed Stream Flows .....	8-11
8.3 A	p-Xylene and m-Xylene by Adsorption Processes Case A—Heavy Reformate/TDP Xylene Feed Major Equipment .....	8-13
8.3 B	p-Xylene and m-Xylene by Adsorption Processes Case B—Heavy Reformate/MSTDP Xylene Feed Major Equipment .....	8-16
8.4 A	p-Xylene and m-Xylene by Adsorption Processes Case A—Heavy Reformate/TDP Xylene Feed Utilities Summary .....	8-19
8.4 B	p-Xylene and m-Xylene by Adsorption Processes Case B—Heavy Reformate/MSTDP Xylene Feed Utilities Summary .....	8-20
8.5	p-Xylene and m-Xylene by Adsorption Processes Waste Streams Summary .....	8-24
8.6 A	p-Xylene and m-Xylene by Adsorption Processes Case A—Heavy Reformate/TDP Xylene Feed Total Capital Investment .....	8-28
8.6 B	p-Xylene and m-Xylene by Adsorption Processes Case B—Heavy Reformate/MSTDP Xylene Feed Total Capital Investment .....	8-29
8.7 A	p-Xylene and m-Xylene by Adsorption Processes Case A—Heavy Reformate/TDP Xylene Feed Capital Investment by Section .....	8-30

**TABLES (Concluded)**

8.7 B	p-Xylene and m-Xylene by Adsorption Processes Case B—Heavy Reformate/MSTDP Xylene Feed Capital Investment by Section.....	8-32
8.8 A	p-Xylene and m-Xylene by Adsorption Processes Case A—Heavy Reformate/TDP Xylene Feed Production Costs.....	8-34
8.8 B	p-Xylene and m-Xylene by Adsorption Processes Case B—Heavy Reformate/MSTDP Xylene Feed Production Costs.....	8-36
8.9 A	p-Xylene and m-Xylene by Adsorption Processes Case A—Heavy Reformate/TDP Xylene Feed Direct Costs by Section.....	8-38
8.9 B	p-Xylene and m-Xylene by Adsorption Processes Case B—Heavy Reformate/MSTDP Xylene Feed Direct Costs by Section.....	8-39
8.10	Production Cost Comparison at Base Capacity.....	8-40