

Abstract
Process Economics Program Report 4D
NEW GENERATION OF EPDM ELASTOMERS
(August 1998)

This report, Supplement 4D to PEP Report 4C, *Ethylene Propylene Copolymer and Terpolymer Rubbers*, which was issued in 1990, reviews the technology for producing (ethylene-propylene-diene (EPDM). This report also reviews some cases for producing random ethylene-propylene copolymer (EPM).

EPDM elastomers are produced by three different processes: the solution process, the suspension process (also known as the slurry process), and the gas-phase process. Conventional Ziegler-Natta catalyst systems based on transition metals, such as V and Ti, are commercially used for most of these processes. Currently, metallocene catalyst systems based on Zr, Ti, or Hf also attract the industry's attention for EPDM production. Du Pont/Dow Elastomer, a joint venture between Du Pont and Dow Chemical, has started to produce EPDM by a solution process using Dow's Insite™ metallocene catalyst. The gas-phase process developed by Union Carbide is also recently commercialized. In this report, we evaluate and compare these processes, which use either ethylidene norbornene (ENB) or 1,4-hexadiene (HD) as the nonconjugated diene in the terpolymer, and either Ziegler-Natta or metallocene catalyst systems for polymerization. The processes can be briefly described thus:

- *Solution process for EPDM containing HD by Ziegler-Natta catalyst*—the EPDM(HD) elastomer is made in a process presumably used commercially by Du Pont; the polymer is recovered without steam-stripping.
- *Solution process for EPDM containing ENB by Insite™ metallocene catalyst*—the EPDM(ENB) elastomer is produced in a manner similar to the solution process for EPDM(HD), but this process uses a high polymerization temperature, which allows a high resin concentration in the reactor effluent.
- *Solution process for EPDM containing ENB by Ziegler-Natta catalyst*—the EPDM(ENB) elastomer is produced in a conventional process with steam-stripping to recover the polymer.
- *Gas-phase process for EPDM containing ENB by prepolymerized Ziegler-Natta catalyst*—the EPDM(ENB) elastomer is made in a process presumably similar to the commercial process used by Union Carbide.
- *Suspension process for EPDM containing ENB by Ziegler-Natta catalyst*—the EPDM(ENB) elastomer is produced in excess propylene.

In the EP elastomer industry, it is difficult to differentiate the market share of EPDM elastomers from EPM elastomers. We estimate that EPDM elastomers account for about 80–85% of total worldwide EP elastomer production. The worldwide production capacity for EP elastomers as of July 1998 was estimated at about 2.5 billion lb/yr (1.14 million t/yr). In 1997, the world consumption of EP elastomers was estimated at about 1.59 billion lb/yr (720,000 t/yr).

CONTENTS

GLOSSARY.....	ix
1 INTRODUCTION	1-1
2 SUMMARY.....	2-1
GENERAL ASPECTS.....	2-1
TECHNICAL ASPECTS.....	2-1
Solution Process: EPDM by the Insite™ Metallocene Catalyst.....	2-1
Gas-Phase Process: EPDM by the Prepolymerized Ziegler-Natta Catalyst.....	2-2
Suspension Process: EPDM by the Ziegler-Natta Catalyst.....	2-2
3 INDUSTRY STATUS	3-1
DEMAND FOR EP ELASTOMERS	3-1
SUPPLY OF EP ELASTOMERS	3-2
FORECAST	3-2
4 REVIEW OF TECHNOLOGY	4-1
METALLOCENE CATALYSTS	4-2
CONVENTIONAL ZIEGLER-NATTA CATALYSTS.....	4-5
Slurry Process	4-5
Solution Process.....	4-6
Gas-Phase Process.....	4-8
Fluidized-Bed Reactors and Product Recovery	4-9
Prevention of Agglomeration and Sheeting	4-11
TITANIUM CATALYSTS.....	4-12
COMPOSITIONS OF EPDM ELASTOMERS.....	4-13
5 SOLUTION PROCESS FOR EPDM(ENB) BY INSITE™ METALLOCENE CATALYST	5-1
INTRODUCTION	5-1
PROCESS DESCRIPTION.....	5-1
Polymerization and Product Recovery.....	5-1
Product Finishing	5-2

CONTENTS (Concluded)

5	SOLUTION PROCESS FOR EPDM(ENB) BY INSITE™ METALLOCENE CATALYST (Concluded).....	5-1
	Solvent Recovery.....	5-2
	PROCESS DISCUSSION.....	5-12
	COST ESTIMATES	5-12
	ECONOMIC COMPARISON	5-13
6	GAS-PHASE PROCESS FOR EPDM(ENB) BY CONVENTIONAL ZIEGLER-NATTA CATALYST.....	6-1
	PROCESS DESCRIPTION.....	6-1
	Polymerization and Product Recovery.....	6-1
	Product Finishing	6-2
	Prepolymerized Catalyst Preparation	6-2
	PROCESS DISCUSSION.....	6-13
	COST ESTIMATES	6-13
7	SUSPENSION PROCESS FOR EPDM(ENB) BY CONVENTIONAL ZIEGLER-NATTA CATALYST.....	7-1
	PROCESS DESCRIPTION.....	7-1
	Polymerization	7-1
	Product Recovery	7-1
	Monomers and Solvent Recovery.....	7-2
	Product Drying and Finishing.....	7-2
	PROCESS DISCUSSION.....	7-5
	COST ESTIMATES	7-5
	APPENDIX A: Patent Summary Tables.....	A-1
	APPENDIX B: Design and Cost Bases.....	B-1
	APPENDIX C: Cited References	C-1
	APPENDIX D: Patent References by Company	D-1
	APPENDIX E: Process Flow Diagrams	E-1

ILLUSTRATIONS

4.1	Sketch of a Fluidized-Bed Reactor	4-10
5.1	Solution Process for EPDM(ENB) by Insite™ Metallocene Catalyst.....	E-3
5.2	Solution Process for EPDM(ENB) by Insite™ Metallocene Catalyst: Effect of Operating Level and Plant Capacity on Product Value	5-25
6.1	Gas-Phase Process for EPDM(ENB) by Conventional Ziegler-Natta Catalyst	E-7
6.2	Gas-Phase Process for EPDM(ENB) by Conventional Ziegler-Natta Catalyst: Effect of Operating Level and Plant Capacity on Product Value	6-18
7.1	Suspension Process for EPDM(ENB) by Conventional Ziegler-Natta Catalyst.....	E-11
7.2	Suspension Process for EPDM EPDM(ENB) by Conventional Ziegler-Natta Catalyst: Effect of Operating Level and Plant Capacity on Product Value	7-12

TABLES

2.1	Solution Process for EPDM(ENB) by Insite™ Metallocene Catalyst: Design Bases	2-4
2.2	Gas-Phase Process for EPDM(ENB) by Prepolymerized Ziegler-Natta Catalyst: Design Bases	2-5
2.3	Suspension Process for EPDM(ENB) by Ziegler-Natta Catalyst: Design Bases	2-6
2.4	Economic Comparison of Three EPDM(ENB) Processes.....	2-7
2.5	Economic Comparison of Three EPDM Solution Processes	2-8
3.1	Consumption of EP Elastomers by Major Regions	3-1
3.2	Major U.S. EPDM Producers.....	3-3
3.3	Major European EPDM Producers	3-4
3.4	Major Japanese EPDM Producers	3-5
3.5	Major EPDM Producers in Other Regions	3-6
3.6	Global Production Capacity of Major Producers	3-7
4.1	Metallocenes for EPDM.....	4-3
4.2	Homogeneous Vanadium Catalyst Systems for Slurry Processes	4-5
4.3	Vanadium Catalyst Systems for Solution Processes	4-7
4.4	Characteristics of a Fluidized-Bed Reactor	4-9
4.5	Review of Technology for EPDM Production Patent Summary.....	A-3
4.6	Review of Technology for EPDM Compositions Patent Summary.....	A-17
5.1	Solution Process for EPDM(ENB) by Insite™ Metallocene Catalyst: Design Bases	5-3
5.2	Solution Process for EPDM(ENB) by Insite™ Metallocene Catalyst: Stream Flows	5-4
5.3	Solution Process for EPDM(ENB) by Insite™ Metallocene Catalyst: Major Equipment	5-8
5.4	Solution Process for EPDM(ENB) by Insite™ Metallocene Catalyst: Utilities Summary	5-11
5.5	Solution Process for EPDM(ENB) by Insite™ Metallocene Catalyst: Total Capital Investment.....	5-15

TABLES (Concluded)

5.6	Solution Process for EPDM(ENB) by Insite™ Metallocene Catalyst: Capital Investment by Section.....	5-16
5.7	Solution Process for EPDM(ENB) by Insite™ Metallocene Catalyst: Production Costs.....	5-17
5.8	Solution Process for EPDM(HD) by Conventional Ziegler-Natta Catalyst: Total Capital Investment.....	5-19
5.9	Solution Process for EPDM(HD) by Conventional Ziegler-Natta Catalyst: Production Costs.....	5-20
5.10	Solution Process for EPDM(ENB) by Conventional Ziegler-Natta Catalyst: Total Capital Investment.....	5-22
5.11	Solution Process for EPDM(ENB) by Conventional Ziegler-Natta Catalyst: Production Costs.....	5-23
6.1	Gas-Phase Process for EPDM(ENB) by Conventional Ziegler-Natta Catalyst: Design Bases.....	6-4
6.2	Gas-Phase Process for EPDM(ENB) by Conventional Ziegler-Natta Catalyst: Stream Flows.....	6-5
6.3	Gas-Phase Process for EPDM(ENB) by Conventional Ziegler-Natta Catalyst: Major Equipment.....	6-9
6.4	Gas-Phase Process for EPDM(ENB) by Conventional Ziegler-Natta Catalyst: Utilities Summary.....	6-12
6.5	Gas-Phase Process for EPDM(ENB) by Conventional Ziegler-Natta Catalyst: Total Capital Investment.....	6-14
6.6	Gas-Phase Process for EPDM(ENB) by Conventional Ziegler-Natta Catalyst: Capital Investment by Section.....	6-15
6.7	Gas-Phase Process for EPDM(ENB) by Conventional Ziegler-Natta Catalyst: Production Costs.....	6-16
7.1	Suspension Process for EPDM(ENB) by Conventional Ziegler-Natta Catalyst: Design Bases.....	7-3
7.2	Suspension Process for EPDM(ENB) by Conventional Ziegler-Natta Catalyst: Utilities Summary.....	7-4
7.3	Suspension Process for EPDM(ENB) by Conventional Ziegler-Natta Catalyst: Total Capital Investment.....	7-6
7.4	Suspension Process for EPDM(ENB) by Conventional Ziegler-Natta Catalyst: Capital Investment by Section.....	7-7
7.5	Suspension Process for EPDM(ENB) by Conventional Ziegler-Natta Catalyst: Production Costs.....	7-9
7.6	Economic Comparison of EPDM Processes.....	7-11