

**Abstract**  
**Process Economics Program Report No. 159B**  
**SPECIALTY PLASTIC FILMS**  
**(July 1993)**

This report is a supplement to PEP Report 159A on specialty plastic films. The previous report covered the technologies and economics for the production of agricultural films, microporous films, fluoropolymer films, polycarbonate film, and polyimide film. The present report covers the following specialty films:

- Polyester (PET) film for magnetic media
- Polyethylene 2,6-naphthalate (PEN)
- Metallized polyester (M-PET), and metallized and oriented polypropylene (M-OPP) films by
  - The resistance-heated boat method
  - The electron beam heating method
- Biaxially oriented monolayer and coextruded nylon (BON) films by
  - The double-bubble blowing process
  - The chill-roll casting process
- Polyetherimide (PEI)
- Polyetheretherketone (PEEK)
- Polyarylate (PAR)
- Liquid crystal polymer (LCP)
- Polyethersulfone (PES)
- Polyphenylene sulfide (PPS).

Besides the technical and economic aspects, the report also discusses the market status and future prospects for these films. It consolidates the market data, technology data, and production cost estimates into one convenient-to-use volume. For those who are in market research, polymer development, application, or manufacture of advanced plastic films, the report will serve as a very valuable information source.

## CONTENTS

<b>1 INTRODUCTION</b>	1-1
<b>2 SUMMARY</b>	2-1
SCOPE	2-1
COMMERCIAL ASPECTS	2-1
ECONOMIC ASPECTS	2-2
TECHNICAL ASPECTS	2-5
Chill-Roll Casting and Biaxial Orientation Process	2-5
Double-Bubble Blowing Process	2-5
Metallizing by the Resistance-Heated Boat Method	2-5
Metallizing by the Electron Beam Heating Method	2-6
<b>3 INDUSTRY STATUS</b>	3-1
POLYESTER FILM FOR MAGNETIC MEDIA	3-1
POLYETHYLENE 2,6-NAPHTHALATE (PEN) FILM	3-4
METALLIZED FILMS	3-4
BIAXIALLY ORIENTED NYLON FILM	3-5
HIGH-PERFORMANCE FILMS	3-5
Properties	3-6
Consumption and Prices	3-7
PEI Film	3-7
PEEK Film	3-7
PAR Film	3-7
LCP Film	3-8
PES Film	3-8
PPS Film	3-8
<b>4 POLYETHYLENE TEREPHTHALATE (PET) FILM FOR MAGNETIC MEDIA</b>	4-1
CHEMISTRY	4-1
Transesterification System	4-1
Direct Esterification System	4-2
PET RESIN PROPERTIES	4-3
PET FILM PROPERTIES	4-3

## CONTENTS (Continued)

<b>4 POLYETHYLENE TEREPHTHALATE (PET) FILM FOR MAGNETIC MEDIA (Concluded)</b>	
PET FILM SURFACE TREATMENTS	4-5
PET FILM APPLICATIONS	4-5
PATENTS	4-8
Polymer Composition Modifications	4-8
Inorganic Additives	4-8
Organic Additives	4-8
Surface Coatings	4-8
Production Procedures	4-8
DESIGN AND ESTIMATE BASES	4-9
PROCESS DESCRIPTION	4-10
Film Casting (100)	4-10
MD Stretching (200)	4-11
Transverse Stretching (300)	4-11
Trim and Windup (400)	4-11
Scrap Reclaiming (500)	4-11
Slitting (600)	4-11
PROCESS DISCUSSION	4-16
COST ESTIMATES	4-16
Capital Costs	4-16
Production Costs	4-17
Discussion of Costs	4-18
<b>5 POLYETHYLENE 2,6-NAPHTHALATE (PEN) FILM</b>	<b>5-1</b>
CHEMISTRY	5-1
Transesterification	5-1
Direct Esterification	5-2
MONOMER PRODUCTION	5-3
Monomer Process Technology	5-3
Monomer Economics	5-4

## CONTENTS (Continued)

<b>5 POLYETHYLENE 2,6-NAPHTHALATE (PEN) FILM (Concluded)</b>	
PEN POLYMER PRODUCTION	5-8
Polymer Technology	5-8
Polymer Economics	5-8
Process Description	5-8
Transesterification	5-10
Polymerization	5-10
Process Discussion	5-10
Cost Estimates	5-15
PEN FILM PRODUCTION	5-21
Film Technology	5-21
Patents	5-21
Film Properties	5-21
Film Economics	5-22
Capital Costs	5-22
Production Costs	5-22
<b>6 METALLIZED POLYETHYLENE TEREPHTHALATE AND POLYPROPYLENE FILMS</b>	6-1
REVIEW OF PROCESS TECHNOLOGIES	6-1
Resistance-Heated Boat Method	6-1
Electron Beam Heating Method	6-3
Magnetron Sputtering Method	6-4
PATENTS	6-5
ESTIMATE BASES	6-6
PROCESS DESCRIPTION	6-7
PROCESS DISCUSSION	6-8
COST ESTIMATES	6-9
Capital Costs	6-9
Resistance-Heated Boat Method	6-9
Electron Beam Heating Method	6-10
Production Costs	6-19
Resistance-Heated Boat Method	6-19
Electron Beam Heating Method	6-20
DISCUSSION OF COSTS	6-20

## CONTENTS (Continued)

<b>7</b>	<b>BIAXIALLY ORIENTED MONOLAYER AND COEXTRUDED NYLON 6 FILMS</b>	7-1
	FILM PROPERTIES	7-1
	REVIEW OF PROCESS TECHNOLOGIES	7-3
	Polymer Crystallinity and Properties	7-3
	Biaxial Orientation	7-5
	Film Production Processes	7-5
	Double-Bubble Blowing Process	7-5
	Chill-Roll Casting and Tentering Process	7-7
	Patents	7-8
	ESTIMATE BASES	7-8
	PROCESS DESCRIPTION	7-12
	Double-Bubble Blowing Process	7-12
	Chill-Roll Casting and Simultaneous Stretching Process	7-13
	PROCESS DISCUSSION	7-13
	COST ESTIMATES	7-15
	Capital Costs	7-15
	Production Costs	7-16
	DISCUSSION OF COSTS	7-17
<b>8</b>	<b>HIGH-PERFORMANCE FILMS FROM HIGH-TEMPERATURE POLYMERS</b>	8-1
	POLYMER PRODUCTION COST ESTIMATES	8-1
	Polyetherimide (PEI) Resin	8-2
	Polyetheretherketone (PEEK) Resin	8-3
	Polyarylate (PAR) Resin	8-3
	Polyethersulfone (PES) Resin	8-4
	Liquid Crystal Polymer (LCP) Resin	8-5
	Polyphenylene Sulfide (PPS) Resin	8-6
	PATENTS	8-19
	Ketone-Based Polymers	8-19
	Polyarylate and Polyphenylene Sulfide	8-20
	Nitrogen Containing and Liquid Crystal Polymers	8-20
	REVIEW OF DESIGN AND ESTIMATE BASES	8-21

## CONTENTS (Concluded)

<b>8 HIGH-PERFORMANCE FILMS FROM HIGH-TEMPERATURE POLYMERS (Concluded)</b>	
FILM PRODUCTION COST ESTIMATES	8-22
Capital Costs	8-22
Production Costs	8-22
Polyetherimide (PEI) Film	8-22
Polyetheretherketone (PEEK) Film	8-23
Polyarylate (PAR) Film	8-23
Liquid Crystal Polymer (LCP) Film	8-24
Polyethersulfone (PES) Film	8-24
Polyphenylene Sulfide (PPS) Film	8-25
DISCUSSION OF COSTS	8-26
<b>APPENDIX A: PATENT SUMMARY TABLES</b>	A-1
<b>APPENDIX B: DESIGN AND COST BASES</b>	B-1
<b>APPENDIX C: CITED REFERENCES</b>	C-1
<b>APPENDIX D: PATENT REFERENCES BY COMPANY</b>	D-1
<b>APPENDIX E: PROCESS FLOW DIAGRAMS</b>	E-1

## ILLUSTRATIONS

4.1	Applications of Polyester Films	4-7
4.2	Polyester Film for Magnetic Media Process Flow Diagram	E-3
4.3	Polyester Film for Magnetic Media Effect of Plant Capacity on Plant Investment	4-24
4.4	Polyester Film for Magnetic Media Effect of Operating Level on Product Value	4-25
5.1	Polyethylene 2,6-Naphthalate (PEN) from Dimethyl 2,6-Naphthalenedicarboxylate Process Flow Diagram	E-7
5.2	PEN Film Effect of PEN Price and Plant Capacity on Film Product Value	5-26
6.1	Metallizing by Resistance-Heated Boat	6-2
6.2	Metallizing by Electron Beam Heating	6-4
6.3	Metallizing by Sputtering	6-5
6.4	Metallized PET and OPP Films by the Resistance-Heated Boat Method Process Flow Diagram	E-9
6.5	Metallized PET and OPP Films by the Electron Beam Heating Method Process Flow Diagram	E-11
6.6	Metallizing of PET and OPP Films by the Resistance-Heated Boat Method Effect of Plant Capacity on Capital Investment	6-30
6.7	Metallizing of PET and OPP Films by the Electron Beam Heating Method Effect of Plant Capacity on Capital Investment	6-31
6.8	Metallizing of PET and OPP Films by the Resistance-Heated Boat Method Effect of Plant Capacity on Product Value	6-32
6.9	Metallizing of PET and OPP Films by the Electron Beam Heating Method Effect of Plant Capacity on Product Value	6-33
7.1	Double-Bubble Blowing Process	7-6
7.2	Film Tenting Frame	7-7
7.3	Example of Extruders Arrangement for Coextrusion in the Bubble-Blowing Process	7-14

## **ILLUSTRATIONS (Concluded)**

7.4	Biaxially Oriented Nylon Films Effect of Plant Capacity on Capital Investment	7-26
7.5	Biaxially Oriented Nylon Films Effect of Plant Capacity on Product Value	7-27
8.1	Total Fixed Capital Investment of High-Performance Films Versus Plant Capacity	8-39
8.2	Product Values of Developmental High-Performance Films Versus Plant Capacity	8-40



## TABLES

2.1	Summary of Conversion Costs for All Films	2-3
2.2	Summary of Economics for Polyester and Polyethylene 2,6-Naphthalate Films	2-7
2.3	Summary of Economics for Metallized Polyester and Oriented Polypropylene Films	2-8
2.4	Summary of Economics for Biaxially Oriented Monolayer and Coextruded Nylon 6 Films	2-9
2.5	Summary of Economics for High-Performance Developmental Films	2-10
3.1	U.S. Producers of PET Film	3-3
3.2	Comparison of Barrier Properties of Metallized Films	3-4
3.3	Comparison of Properties of High-Performance Polymer Films	3-6
4.1	Properties of Film Grade PET Resin	4-3
4.2	Properties of PET Film	4-4
4.3	Effect of Stretching on PET Film Properties	4-5
4.4	Polyester Film Thicknesses for Magnetic Media	4-6
4.5	Polyester Films from Polyethylene Terephthalate Patent Summary	A-3
4.6	Polyester Film for Magnetic Media Design and Estimate Bases	4-9
4.7	Polyester Film for Magnetic Media Stream Flows	4-12
4.8	Polyester Film for Magnetic Media Major Equipment	4-13
4.9	Polyester Film for Magnetic Media Utilities Summary	4-15
4.10	Polyester Film for Magnetic Media Total Capital Investment	4-19
4.11	Polyester Film for Magnetic Media Capital Investment by Section	4-20

## TABLES (Continued)

4.12	Polyester Film for Magnetic Media Production Costs	4-22
5.1	DM-2,6-NDC from 2-Methylnaphthalene Production Costs	5-6
5.2	PEN from DM-2,6-NDC Design and Estimate Bases	5-9
5.3	PEN from DM-2,6-NDC Stream Flows	5-11
5.4	PEN from DM-2,6-NDC Major Equipment	5-12
5.5	PEN from DM-2,6-NDC Utilities Summary	5-14
5.6	PEN from DM-2,6-NDC Total Capital Investment	5-17
5.7	PEN from DM-2,6-NDC Capital Investment by Section	5-18
5.8	PEN from DM-2,6-NDC Production Costs	5-19
5.9	Polyethylene 2,6-Naphthalate (PEN) Film Patent Summary	A-14
5.10	Comparison of Typical Properties of PEN and PET Films	5-22
5.11	PEN Film Production Costs	5-24
6.1	Metallized PET and OPP Films Patent Summary	A-17
6.2	Metallizing of PET and OPP Films by the Resistance-Heated Boat Method Design and Estimate Bases	6-6
6.3	Metallizing of PET and OPP Films by Electron Beam Heating Design and Estimate Bases	6-7
6.4	Metallized PET Film by the Resistance-Heated Boat Method Major Equipment	6-11

## TABLES (Continued)

6.5	Metallized PET Film by the Resistance-Heated Boat Method Utilities Summary	6-12
6.6	Metallized PET Film by the Resistance-Heated Boat Method Total Capital Investment	6-13
6.7	Metallized PET Film by the Resistance-Heated Boat Method Capital Investment by Section	6-14
6.8	Metallized PET Film by the Electron Beam Heating Method Major Equipment	6-15
6.9	Metallized PET Film by the Electron Beam Heating Method Utilities Summary	6-16
6.10	Metallized PET Film by the Electron Beam Heating Method Total Capital Investment	6-17
6.11	Metallized PET Film by the Electron Beam Heating Method Capital Investment by Section	6-18
6.12	Metallized PET Film by the Resistance-Heated Boat Method Production Costs	6-22
6.13	Metallized OPP Film by the Resistance-Heated Boat Method Production Costs	6-24
6.14	Metallized PET Film by the Electron Beam Heating Method Production Costs	6-26
6.15	Metallized OPP Film by the Electron Beam Heating Method Production Costs	6-28
7.1	Properties of Unoriented Nylon 6 and Nylon 6,6 Films	7-2
7.2	Comparison of the Properties of Oriented and Unoriented Nylon Films	7-3
7.3	Properties of Nylon Film Resins	7-4
7.4	Biaxially Oriented Nylon (BON) Film Patent Summary	A-19
7.5	Biaxially Oriented Nylon 6-Based Films by the Double-Bubble Blowing Process Design and Estimate Bases	7-10
7.6	Biaxially Oriented Nylon 6-Based Films by the Chill-Roll Casting and Simultaneous Stretching Process Design and Estimate Bases	7-11

## TABLES (Continued)

7.7	Biaxially Oriented Nylon 6 Film by the Double-Bubble Blowing Process Production Costs	7-18
7.8	Coextruded Nylon 6-Based Film by the Double-Bubble Blowing Process Production Costs	7-20
7.9	Biaxially Oriented Nylon 6 Film by the Chill-Roll Casting and Simultaneous Stretching Process Production Costs	7-22
7.10	Coextruded Nylon 6-Based Film by the Chill-Roll Casting and Simultaneous Stretching Process Production Costs	7-24
8.1	Polyetherimide from Phthalic Anhydride, Bisphenol A, and m-Phenylene Diamine Production Costs	8-7
8.2	Polyetherketone from Hydroquinone and 4,4i-Methylene Dianiline (MDA) Production Costs	8-9
8.3	Polyarylate from Bisphenol A and Iso- and Terephthalic Acids Via Bpa Diacetate Production Costs	8-11
8.4	Polyethersulfone from 4,4i-Dichlorodiphenyl Sulfone Production Costs	8-13
8.5	Liquid Crystal Polymer from p-HBA, Terephthalic Acid, and 4,4i-DHDP Production Costs	8-15
8.6	Polyphenylene Sulfide from 1,4-Dichlorobenzene and Sodium Hydrosulfide (Batch) Production Costs	8-17
8.7	High-Performance Films from High-Temperature Polymers Patent Summary	A-24
8.8	High-Performance Films Design and Estimate Bases	8-21
8.9	Polyetherimide Film from Polyetherimide Resin Production Costs	8-27
8.10	Polyetheretherketone Film from Polyetheretherketone Resin Production Costs	8-29

## TABLES (Concluded)

8.11	Polyarylate Film from Polyarylate Resin Production Costs	8-31
8.12	Liquid Crystal Film from Liquid Crystal Resin Production Costs	8-33
8.13	Polyethersulfone Film from Polyethersulfone Resin Production Costs	8-35
8.14	Polyphenylene Sulfide Film from Polyphenylene Sulfide Resin Production Costs	8-37