

TECHNOLOGY & COSTS**TECHNOECONOMICS - ENERGY & CHEMICALS****Thermoplastic Polyurethanes (TPUs)**

Table of Contents

A Report by **Nexant, Inc.**

TECH Report 2018S2 – Published June 2018

www.nexantsubscriptions.com**Contents**

1	Executive Summary	1
1.1	Introduction.....	1
1.2	Background on Thermoplastic Polyurethanes (TPUs)	1
1.3	Chemistry	2
1.4	Process Technology	3
1.4.1	Thermoplastic Polyurethanes	3
1.5	Economics.....	4
1.6	End Uses.....	6
1.7	Global Market Analysis	6
2	Introduction	8
2.1	Background on Thermoplastic Polyurethanes (TPUs)	8
2.2	Overview of Thermoplastic Elastomers (TPEs).....	14
2.2.1	Background.....	14
2.2.2	Properties and Performance: Definitions.....	18
2.2.3	Definition of TPE Polymers.....	19
3	Technology	25
3.1	Chemistry	25
3.2	Process Technology	28
3.2.1	Thermoplastic Polyurethanes	28
3.2.2	Polyester Polyols.....	31
3.3	Use of Natural Polyols	34
3.4	Trends in Technology	35
4	Process Economics.....	37
4.1	Cost Basis	37
4.2	Basis	37
4.3	Investment.....	38
4.4	Pricing Basis.....	39
4.5	Economics.....	40
4.6	Raw Material Cost Sensitivity – Effect of Back Integration	55

5	Commercial Analysis.....	56
5.1	End Uses.....	56
5.1.1	Extrusion Applications.....	57
5.1.2	Solution and Adhesives.....	58
5.1.3	Injection and Other Types of Molding	58
5.1.4	Other Applications.....	60
5.2	Global Market Analysis	60
5.2.1	Demand	60
5.2.2	Supply.....	62
6	Glossary.....	65

Appendices

A	Cost of Production Tables.....	67
B	Definitions of Capital Cost Terms Used in Process Economics.....	79
C	Definitions of Operating Cost Terms Used in Process Economics	84
D	TECH Program Title Index (2008 - 2018).....	88

Figures

Figure 1	Thermoplastic Polyurethane Morphology.....	1
Figure 2	TPU Bridges the Gap between Rubber and Plastics.....	2
Figure 3	Polyester and Polyether TPUs	2
Figure 4	Ester-TPU: Cost Comparison of Twin Screw Reactive Extrusion Equipment.....	5
Figure 5	Ether-TPU: Cost Comparison of Twin Screw Reactive Extrusion Equipment.....	5
Figure 6	Global TPU Demand by Region	7
Figure 7	Global TPU Demand by End-Use, 2017	7
Figure 8	Thermoplastic Polyurethane Morphology.....	8
Figure 9	TPU Bridges the Gap between Rubber and Plastics.....	9
Figure 10	Tear Resistance of Thermoplastic Elastomers.....	11
Figure 11	Taber Abrasion Resistance Comparison	12
Figure 12	Elastomer Industry Growth, 1938-2018	15
Figure 13	Phase Arrangement in Crystalline Block Copolymers	16
Figure 14	Phase Arrangements of Polymer/Elastomer Blends.....	17
Figure 15	Thermoplastic Elastomers – Performance Regimes	22
Figure 16	TPE Performance Regimes.....	23
Figure 17	Thermoplastic Polyurethane Morphology.....	25
Figure 18	Polyester and Polyether TPUs	26
Figure 19	TPU Prepolymer Manufacturing Processes	29
Figure 20	TPU Manufacture via the "One-Shot" Process.....	30
Figure 21	Polyester Polyol Preparation Section.....	32
Figure 22	1,4-Butanediol Recovery Section	33
Figure 23	Ester-TPU: Cost Comparison of Twin Screw Reactive Extrusion Equipment (USGC, Q1 2018)	42
Figure 24	Ester-TPU: Cost Comparison of Twin Screw Reactive Extrusion Equipment (Coastal China, Q1 2018).....	42
Figure 25	Ether-TPU: Cost Comparison of Twin Screw Reactive Extrusion Equipment (USGC, Q1 2018)	43
Figure 26	Ether-TPU: Cost Comparison of Twin Screw Reactive Extrusion Equipment (Coastal China, Q1 2018).....	43
Figure 27	Comparison of Ester-TPU and Ether-TPU Production Costs by Line Size.....	44
Figure 28	Effect of Changes in 1,4 Butanediol Adipate Price on TPU Economics	55
Figure 29	Effect of Changes in MDI Price on TPU Economics.....	55
Figure 30	Global TPU Demand by Region	61
Figure 31	Global TPU Demand by End-Use, 2017	61

Tables

Table 1	Ester-TPU: USGC Cost Comparison of Twin Screw Reactive Extrusion Equipment.....	4
Table 2	Ether-TPU: Cost Comparison of USGC Twin Screw Reactive Extrusion Equipment	4
Table 3	TPU Property Advantages and Applications by Polyol	6
Table 4	Benefits and Drawbacks of Various TPUs	9
Table 5	Thermoplastic Polyurethane Physical Properties.....	11
Table 6	Modified Thermoplastic Polyurethane Physical Properties.....	13
Table 7	Effect of Annealing (Curing) on TPU Properties.....	14
Table 8	Hard Polymer/Elastomer Blend Combinations	17
Table 9	Comparison of TPU Properties versus Selected Competing Materials	21
Table 10	Intermaterial Substitution Competitive Grid.....	23
Table 11	Functional Determinants of Rubber Products	24
Table 12	Commonly Used TPU Raw Materials	28
Table 13	Reactive Twin Screw Extruder Capital Cost Estimates for TPU Production.....	38
Table 14	Reactive Twin Screw Extruder Capital Cost Estimates for TPU Production.....	39
Table 15	Price and Utilities Basis.....	39
Table 16	Ester-TPU: USGC Cost Comparison of Twin Screw Reactive Extrusion Equipment.....	40
Table 17	Ester-TPU: Cost Comparison of Coastal China Twin Screw Reactive Extrusion Equipment	40
Table 18	Ether-TPU: Cost Comparison of USGC Twin Screw Reactive Extrusion Equipment	41
Table 19	Ether-TPU: Cost Comparison Of Coastal China Twin Screw Reactive Extrusion Equipment	41
Table 20	Cost of Production Estimate for: Ester TPU Process: Reactive Extrusion - 40 mm Twin Screw.....	45
Table 21	Cost of Production Estimate for: Ester TPU Process: Reactive Extrusion – 58 mm Twin Screw.....	46
Table 22	Cost of Production Estimate for: Ester TPU Process: Reactive Extrusion – 70 mm Twin Screw.....	47
Table 23	Cost of Production Estimate for: Ester TPU Process: Reactive Extrusion – 92 mm Twin Screw.....	48
Table 24	Cost of Production Estimate for: Ester TPU Process: Reactive Extrusion – 133 mm Twin Screw	49
Table 25	Cost of Production Estimate for: Ether TPU Process: Reactive Extrusion – 40 mm Twin Screw.....	50
Table 26	Cost of Production Estimate for: Ether TPU Process: Reactive Extrusion – 58 mm Twin Screw.....	51
Table 27	Cost of Production Estimate for: Ether TPU Process: Reactive Extrusion – 70 mm Twin Screw.....	52
Table 28	Cost of Production Estimate for: Ether TPU Process: Reactive Extrusion – 92 mm Twin Screw.....	53
Table 29	Cost of Production Estimate for: Ether TPU Process: Reactive Extrusion – 133 mm Twin Screw	54
Table 30	TPU Property Advantages and Applications by Polyol	56
Table 31	Key TPU Attributes by End-Use Market.....	57

Table 32	Engineering Thermoplastic Polyurethane Resin Types, Properties, and Applications	59
Table 33	Global TPU Capacity, 2017	62
Table 34	Cost of Production Estimate for: Ester TPU Process: Reactive Extrusion - 40 mm Twin Screw, China	67
Table 35	Cost of Production Estimate for: Ester TPU Process: Reactive Extrusion - 58 mm Twin Screw, China	68
Table 36	Cost of Production Estimate for: Ester TPU Process: Reactive Extrusion - 70 mm Twin Screw, China	69
Table 37	Cost of Production Estimate for: Ester TPU Process: Reactive Extrusion - 92 mm Twin Screw, China	70
Table 38	Cost of Production Estimate for: Ester TPU Process: Reactive Extrusion - 133 mm Twin Screw, China	71
Table 39	Cost of Production Estimate for: Ether TPU Process: Reactive Extrusion – 40 mm Twin Screw, China	72
Table 40	Cost of Production Estimate for: Ether TPU Process: Reactive Extrusion – 58 mm Twin Screw, China	73
Table 41	Cost of Production Estimate for: Ether TPU Process: Reactive Extrusion – 70 mm Twin Screw, China	74
Table 42	Cost of Production Estimate for: Ether TPU Process: Reactive Extrusion – 92 mm Twin Screw, China	75
Table 43	Cost of Production Estimate for: Ether TPU Process: Reactive Extrusion – 133 mm Twin Screw, China	76
Table 44	Cost of Production Estimate for: Polyester Polyol (1,4 Butanediol Adipate Polyol) Process: Batch, USGC	77
Table 45	Cost of Production Estimate for: Polyester Polyol (1,4 Butanediol Adipate Polyol) Process: Batch, China	78

Nexant Inc.

TECHNOLOGY AND COSTS **Technoeconomics –** **Energy & Chemicals (TECH)**

The Nexant Subscriptions' Technoeconomics – Energy & Chemicals (TECH) program is recognized globally as the industry standard source for information relevant to the chemical process and refining industries. TECH reports are available as a subscription program or on a single report basis.

Contact Details:

Americas:

Marcos Nogueira Cesar, Vice President, Global Products, E&CA: Nexant Subscriptions
Phone: + 1-914-609-0324, e-mail: mcesar@nexant.com

Erica Hill, Client Services Coordinator, E&CA-Products
Phone: + 1-914-609-0386, e-mail: ehill@nexant.com

EMEA:

Anna Ibbotson, Director, Nexant Subscriptions
Phone: +44-207-950-1528, aibbotson@nexant.com

Asia:

Chommanad Thammanayakatip, Managing Consultant, Energy & Chemicals Advisory
Phone: +66-2793-4606, email: chommanadt@nexant.com

Nexant, Inc. (www.nexant.com) is a leading management consultancy to the global energy, chemical, and related industries. For over 38 years, Nexant has helped clients increase business value through assistance in all aspects of business strategy, including business intelligence, project feasibility and implementation, operational improvement, portfolio planning, and growth through M&A activities. Nexant has its main offices in San Francisco (California), White Plains (New York), and London (UK), and satellite offices worldwide.

Copyright © by Nexant Inc. 2018. All Rights Reserved.