

Polyurethanes

Table of Contents

A Report by NexantThinking™

Process Evaluation/Research Planning (PERP) Program

PERP Report 2014S1– Published October 2014

www.nexantthinking.com

Section	Page
1 Executive Summary	1
1.1 HISTORY AND BACKGROUND	1
1.2 POLYURETHANE BUSINESS DEVELOPMENTS	6
1.3 STRATEGIC AND BUSINESS CONSIDERATIONS	6
1.4 POLYURETHANES ADDITIVES	7
1.5 POLYURETHANE PROCESS	8
1.5.1 Process Description	8
1.5.2 Summary of Cost Estimates	8
1.6 COMMERCIAL OVERVIEW	9
1.7 GLOBAL MARKET OVERVIEW	9
2 Introduction	11
2.1 HISTORY AND BACKGROUND	11
2.2 POLYURETHANE BUSINESS DEVELOPMENTS	17
2.2.1 BASF	17
2.2.2 Huntsman	17
2.2.3 Bayer MaterialScience	18
2.2.4 Dow	18
2.3 HIGH LEVEL CHEMISTRY (POLYOL AND DI-ISOCYANATE)	19
2.3.1 Diisocyanate	19
2.3.2 Polyol	19
2.4 POLYURETHANE PROCESSING EQUIPMENT SUPPLIERS	21
2.5 STRATEGIC AND BUSINESS CONSIDERATIONS	22
2.6 PHYSICAL AND THERMODYNAMIC PROPERTIES	23
2.7 HEALTH HAZARDS	23
2.7.1 Toluene Diisocyanate (TDI)	23

2.7.2	Methylene Diphenyl Diisocyanate (MDI)	23
2.7.3	Polyols	24
2.8	STORAGE AND TRANSPORTATION	24
3	Polyurethane Feedstocks	25
3.1	POLYURETHANES CHEMISTRY	25
3.1.1	Di-Isocyanates	25
3.2	POLYOLS	28
3.2.1	Polyether Polyols	28
3.2.2	Polyester Polyols	31
3.2.3	Polyols from Renewable Sources	31
4	Polyurethanes Production	37
4.1	POLYURETHANES ADDITIVES	37
4.1.1	Catalysts	37
4.1.2	Cross-linkage Agent and Chain Extenders	39
4.1.3	Blowing Agents	39
4.1.4	Surfactant	40
4.1.5	Flame Retardants	41
4.1.6	Coloring Materials	41
4.1.7	Fillers	41
4.2	PROCESS DESCRIPTION	42
4.3	POLYURETHANES FORMULATION	44
5	Patent Analysis	46
5.1	FLEXIBLE POLYURETHANE FOAM	46
5.1.1	Pace of Filing	46
5.1.2	Patent Priority by Country	46
5.1.3	Patent Activity by Assignee	47
5.1.4	Top Forward Citation	47
5.2	RIGID POLYURETHANE FOAM	49
5.2.1	Pace of Filing	49
5.2.2	Patent Priority by Country	49
5.2.3	Patent Activity by Assignee	50
5.2.4	Top Forward Citation	50
5.3	POLYURETHANE COATINGS	52
5.3.1	Pace of Filing	52
5.3.2	Patent Priority by Country	52

5.3.3	Patent Activity by Assignee	53
5.3.4	Top Forward Citation	53
5.4	POLYURETHANE ADHESIVE	54
5.4.1	Pace of Filing	54
5.4.2	Patent Priority by Country	55
5.4.3	Patent Activity by Assignee	56
5.4.4	Top Forward Citation	56
5.5	POLYURETHANE SEALANTS	57
5.5.1	Pace of Filing	57
5.5.2	Patent Priority by Country	58
5.5.3	Patent Activity by Assignee	58
5.5.4	Top Forward Citation	59
5.6	POLYURETHANE ELASTOMERS	59
5.6.1	Pace of Filing	59
5.6.2	Patent Priority by Country	59
5.6.3	Patent Activity by Assignee	60
5.6.4	Top Forward Citation	61
6	Fabricated Polyurethane Economics	63
6.1	COSTING BASIS	63
6.1.1	Investment Basis	63
6.1.2	Pricing Basis	63
6.1.3	Cost of Production Basis	64
6.2	FABRICATED POLYURETHANE PRODUCTS	65
6.2.1	Cost of Producing Faced Roofing Panels	65
6.2.2	Cost Production of Flexible Molded Car Seats	68
6.2.3	Cost Production of Flexible Slabstock Foam for Mattresses	70
6.2.4	Cost of production of Polyurethane Furniture Topcoat	72
6.3	SENSITIVITY ANALYSIS	74
6.3.1	Pricing	74
6.3.2	Isocyanates	75
6.3.3	Polyols	76
7	Commercial Overview	77
7.1	END-USES FOR POLYURETHANES	77
7.1.1	Flexible Polyurethane Foams	77
7.1.2	Rigid Polyurethane Foam	78

7.1.3	Coating, Adhesives, Sealants, and Elastomers (CASE)	80
7.1.4	Spandex Fibers	80
7.1.5	Thermoplastic Polyurethane (TPU)	81
7.1.6	Reaction Injection Molding (RIM)	82
7.1.7	Waterborne Polyurethane Dispersions (PUDs)	82
7.2	GLOBAL POLYURETHANE MARKET OVERVIEW	82
7.2.1	North America	84
7.2.2	Western Europe	85
7.2.3	Asia.....	86
7.2.4	Rest of World.....	86
8	Glossary	88
9	References	89

Appendix	Page
A	Definitions of Capital Cost Terms Used in Process Economics..... A-1
B	Definitions of Operating Cost Terms Used in Process Economics B-1
C	PERP Program Title Index (2005 - 2014) C-1

Figure	Page
1.1 Polyurethane Value Chain.....	1
1.2 Polyurethane Chemistry	2
1.3 Polyurethane System House Participation	3
1.4 BASF's Urethane System House Locations.....	3
1.5 Polyurethane Manufacturing – Typical Layout Process Map.....	8
1.6 USGC Cost of Production Comparison.....	9
1.7 Global Polyurethane Demand by End-Use, 2013	10
1.8 Global Polyurethane Demand	10
2.1 Polyurethane Value Chain.....	11
2.2 Polyurethane Chemistry	12
2.3 Polyurethane System House Participation	14
2.4 BASF's Urethane System House Locations.....	14
4.1 Polyurethane Manufacturing – Typical Layout Process Map.....	42
5.1 Patent Filing Pace for Flexible Polyurethane	46
5.2 Granted Patents by Country/Region	47
5.3 Patent Filing Pace for Rigid Polyurethane Foam	49
5.4 Granted Patents by Country/Region	49
5.5 Patent Filing Pace for Polyurethane Coatings	52
5.6 Granted Patents by Country/Region	52
5.7 Patent Filing Pace for Polyurethane Adhesives	55
5.8 Granted Patents by Country/Region	55
5.9 Patent Filing Pace for Polyurethane Sealants.....	57
5.10 Granted Patents by Country/Region	58
5.11 Patent Filing Pace for Polyurethane Elastomers.....	59
5.12 Granted Patents by Country/Region	60
6.1 Rigid Faced Roofing Panel Production Line	67
6.2 Flexible Molded Car Seat Production Line.....	68
6.3 Flexible Mattress Slabstock Foam Production Line	70
6.4 Polyurethane Wood Topcoat Production Line.....	72
6.5 USGC Cost of Production Comparison.....	74
6.6 Historical Isocyanate and Polyol Pricing	75
6.7 Cost of Production - Sensitivity to Isocyanate Pricing.....	75
6.8 Cost of Production - Sensitivity to Polyol Pricing	76
7.1 Flexible Polyurethane Foam Applications	78

7.2	Rigid Polyurethane Foam Applications	79
7.3	Global Polyurethane Demand	83
7.4	Global Polyurethane Demand by End-Use, 2013	84
7.5	North American Polyurethane Demand By End-Use, 2013	85
7.6	West European Polyurethane Demand by End-Use, 2013.....	85
7.7	Asian Polyurethane Demand by End-Use, 2013	86
7.8	Rest of World Polyurethane Demand by End-Use, 2013.....	87

Table	Page
1.1 Strategic/Business Considerations	6
1.2 SWOT Analysis	7
1.3 Additives Summary Table	7
2.1 Raw Material Trade Names.....	13
2.2 Properties and Uses of Polyether Polyols	19
2.3 Typical Input Requirements for Selected Polyurethanes	20
2.4 Polyurethanes Equipment Supplier List (Exemplary).....	21
2.5 Strategic/Business Considerations	22
2.6 SWOT Analysis	22
2.7 Physical and Thermodynamic Properties of Isocyanates	23
2.8 Properties of Selected Polyether Polyols	23
3.1 Properties of Common Starters for Polyurethane Polyols	30
4.1 Additives Summary Table	37
4.2 List of Some Tertiary-amine Catalysts	38
4.3 Some Commercially Available Organo-Metallic Catalyst.....	38
4.4 Chain-Extending Agents, Cross-Linking Agents and Curing Agents	39
4.5 List of Blowing Agents	40
4.6 Structure Ranges of Silicone Surfactants for Polyurethanes Foam.....	40
4.7 Generic polyurethane foam, Slab formulation, Part by Weight.....	44
4.8 Combustion-modified High Resilience (HR) Foam Formulation, Parts by Weight.....	44
4.9 Formulation for Rigid Foam.....	45
4.10 Generic Castable Elastomer Formulation for Rollers.....	45
4.11 Typical Polyurethane Powder Coating Composition	45
5.1 Top Assignees for Flexible Polyurethane Foam	47
5.2 Top Forward Citation Analysis - Flexible Polyurethane	48
5.3 Top Assignee for Rigid Polyurethane Foam	50
5.4 Top Forward Citation Analysis - Rigid Polyurethane Foam	51
5.5 Top Assignee for Polyurethane Coatings.....	53
5.6 Top Forward Citation Analysis - Polyurethane Coatings	53
5.7 Top Assignee for Polyurethane Adhesives	56
5.8 Top Forward Citation Analysis - Polyurethane Adhesive.....	56
5.9 Top Assignee for Polyurethane Sealants.....	58
5.10 Top Forward Citation Analysis - Polyurethane Sealants.....	59
5.11 Top Assignee for Polyurethane Elastomer.....	60

5.12	Top Forward Citation Analysis - Polyurethane Elastomers.....	61
6.1	Prices of Raw Materials, Utilities, and Labor.....	64
6.2	Cost of Production Estimate for: Rigid Foamed Polyurethane Faced Roofing Panels	66
6.3	Cost of Production Estimate for: Flexible Molded Polyurethane Car Seat	69
6.4	Cost of Production Estimate for: Flexible Polyurethane Foam for Mattresses	71
6.5	Cost of Production Estimate for Polyurethane Wood Topcoat, USGC	73
7.1	Flexible Polyurethane Foam Applications	77
7.2	Rigid Polyurethane Foam Applications	79
7.3	Coating, Adhesive, Sealant and Elastomers (CASE) Applications	80
7.4	Spandex Applications.....	81
7.5	TPU Property Advantages and Applications by Polyol	81
7.6	Key TPU Attributes by End-Use Market.....	82
7.7	Regional Polyurethane Demand	83

Nexant Thinking™

PERP PROGRAM



www.nexantthinking.com

The NexantThinking™ Process Evaluation/Research Planning (PERP) program is recognized globally as the industry standard source for information relevant to the chemical process and refining industries. PERP reports are available as a subscription program or on a single report basis.

Contact Details:

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

New York: Heidi Junker Coleman, Global Programs Support Manager
Phone: + 1-914-609-0381, e-mail: hcoleman@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. 2015. All Rights Reserved.