

# Nylon 6 and Nylon 6,6

## Table of Contents

A Report by **NexantThinking™**

Process Evaluation/Research Planning (PERP) Program

PERP Report 2016S3 – Published September 2016

[www.nexantthinking.com](http://www.nexantthinking.com)

Section		Page
1	Executive Summary .....	1
1.1	INTRODUCTION .....	1
1.2	CHEMISTRY .....	1
1.2.1	Nylon 6 .....	1
1.2.2	Nylon 6,6 .....	2
1.3	PRODUCTION TECHNOLOGY OVERVIEW .....	2
1.3.1	Nylon 6 Batch (Autoclave) Process.....	2
1.3.2	Nylon 6 Continuous Process.....	3
1.3.3	Nylon 6,6 Batch (Autoclave) Process.....	4
1.3.4	Nylon 6,6 Continuous Process.....	4
1.3.5	Nylon Compounding.....	5
1.4	PROCESS ECONOMICS.....	5
1.5	MARKET ANALYSIS.....	7
2	Introduction.....	8
3	Chemistry and Technology.....	9
3.1	CHEMISTRY .....	9
3.1.1	Nylon 6 .....	9
3.1.2	Nylon 6,6 .....	13
3.1.3	Importance of Molecular Weight .....	17
3.2	PRODUCTION PROCESSES.....	19
3.2.1	Nylon 6 Batch (Autoclave) Process.....	19
3.2.2	Nylon 6 Continuous Process.....	21
3.2.3	Nylon 6,6 Batch (Autoclave) Process.....	23
3.2.4	Nylon 6,6 Continuous Process .....	25
3.2.5	Nylon Compounding.....	30

4	Current Commercial Technologies Available for License .....	32
4.1	INTRODUCTION .....	32
4.2	LURGI ZIMMER GMBH .....	32
4.2.1	Background .....	32
4.2.2	Technology Features.....	33
4.2.3	Process Description .....	33
4.2.4	Licensees .....	35
4.3	UHDE INVETA-FISCHER .....	36
4.3.1	Background .....	36
4.3.2	Technology Features.....	36
4.3.3	Process Description for Nylon 6 .....	38
4.3.4	Process Description for Nylon 6,6.....	47
4.3.5	Licensees .....	47
5	Technology Developments.....	49
5.1	INTRODUCTION .....	49
5.2	RECENT SELECTED PATENTS.....	49
5.2.1	New Recycling Technologies .....	49
5.2.2	Improvements in Process Design .....	50
5.2.3	Improvements in Quality.....	52
6	Product and End-Use .....	53
6.1	RESINS AND COMPOUNDS .....	53
6.1.1	Resins Properties .....	53
6.1.2	Recycling .....	59
6.1.3	Storage .....	60
6.1.4	Additives and Fillers .....	60
6.1.5	Compounding .....	66
6.2	FABRICATION METHODS .....	67
6.2.1	Injection Molding .....	68
6.2.2	Extrusion .....	68
6.2.3	Blow Molding .....	69
6.2.4	Rotomolding .....	70
6.2.5	Reaction Injection Molding (RIM) .....	70
6.2.6	Assembly Techniques .....	70
6.3	NYLON MAJOR MARKETS .....	70
6.3.1	Automotive .....	73

6.3.2	Electronics and Electrical .....	74
6.3.3	Consumer.....	74
6.3.4	Industrial.....	75
6.3.5	Other Applications.....	75
6.3.6	Alloys.....	75
6.3.7	New Developments in Nylon 6 and 6,6 Products.....	76
7	Process Economics .....	77
7.1	COSTING BASIS .....	77
7.1.1	Investment Basis .....	77
7.1.2	Cost of Production Basis.....	79
7.1.3	Pricing Basis.....	79
7.2	COMPARATIVE ECONOMICS.....	80
7.3	SENSITIVITY ANALYSIS.....	88
7.3.1	Raw Material Sensitivity .....	88
7.3.2	Sensitivity to Scale .....	89
8	Market Analysis .....	91
8.1	GLOBAL .....	91
8.1.1	Global Summary.....	91
8.2	NORTH AMERICA .....	92
8.2.1	Overview .....	92
8.2.2	Demand.....	92
8.2.3	Supply .....	94
8.3	EUROPE .....	96
8.3.1	Overview .....	96
8.3.2	Demand.....	96
8.3.3	Supply .....	97
8.4	CHINA .....	99
8.4.1	Overview .....	99
8.4.2	Demand.....	99
8.4.3	Supply .....	100
8.5	ROW (REST OF WORLD).....	102
8.5.1	Overview .....	102
8.5.2	Demand.....	102
8.5.3	Supply .....	103
9	References .....	104

<b>Appendix</b>		<b>Page</b>
A	Additional Cost of Production Estimates .....	A-1
B	Definitions of Capital Cost Terms Used in Process Economics.....	B-1
C	Definitions of Operating Cost Terms Used in Process Economics .....	C-1
D	PERP Program Title Index (2007 - 2016) .....	D-1

Figure	Page
1.1 Nylon 6 and Nylon 6,6 USGC Production Costs .....	6
1.2 Global Nylon Consumption by End-Use, 2015.....	7
3.1 Primary Commercial Caprolactam Production Routes .....	11
3.2 Polyamide 6,6 Value Chain .....	14
3.3 Commercial Adipic Acid Process Technologies.....	16
3.4 Nylon 6 Viscosity Ranges and Applications .....	18
3.5 Nylon 6 Batch Polymerization Process .....	20
3.6 Nylon 6 Continuous Polymerization Process .....	22
3.7 Nylon 6,6 Batch Polymerization Processes .....	24
3.8 Nylon 6,6 Continuous Process: Salt Preparation .....	26
3.9 Nylon 6,6 Continuous Process: Polymerization .....	28
3.10 Plant for Compounding Filled Nylons.....	31
4.1 Lurgi Zimmer Continuous Nylon 6 Process.....	34
4.2 Uhde Inventa-Fischer Nylon 6 Single-Stage Polymerization Process .....	39
4.3 Uhde Inventa-Fischer Nylon 6 Two-Stage Polymerization Process .....	41
4.4 Uhde Inventa-Fischer's Internal Design of the Extraction Column .....	42
4.5 Block-Flow Diagram of Nylon 6 Re-feeding Processes .....	43
4.6 Block-Flow Diagram of the Re-Polymerization Process .....	45
4.7 Block-Flow Diagram of the OMDP® Oligomer Degradation Process .....	46
6.1 Modifications in Polyamides Properties to Fill Market Needs .....	62
7.1 Nylon 6 and Nylon 6,6 USGC Production Costs .....	81
7.2 West European Nylon 6 and Nylon 6,6 Production Costs .....	87
7.3 Chinese Nylon 6 and Nylon 6,6 Production Costs .....	87
7.4 Effect of Caprolactam Cost on Nylon 6 Resin Economics .....	88
7.5 Effect of HMDA Cost on Nylon 6,6 Resin Economics .....	89
7.6 Cost and Scale Comparisons of USGC Nylon 6 and Nylon 6,6 Continuous Polymerization Processes .....	90
8.1 Global Nylon Consumption by End-Use, 2015.....	91
8.2 North America Nylon 6,6 Demand by End-Use, 2015 .....	93
8.3 North American Nylon 6 Demand by End-Use, 2015.....	94
8.4 Europe Nylon 6 Demand by End-Use, 2015 .....	97
8.5 Europe Nylon 6,6 Demand by End-Use, 2015 .....	97
8.6 China Nylon 6 ETP Demand by End-Use, 2015 .....	100
8.7 China Nylon 6,6 ETP Demand by End-Use, 2015 .....	100

Table	Page
1.1 Nylon 6 and Nylon 6,6 USGC Production Costs .....	6
4.1 Lurgi Zimmer Nylon Plants and Projects, 2000-2015 .....	36
4.2 Important Features of Single-Stage and Two-Stage Polymerization Processes .....	37
4.3 Uhde Inventa-Fischer Nylon Plants and Projects, 2000-2015 .....	48
6.1 Nylon 6 Strengths and Weaknesses .....	54
6.2 Nylon 6,6 Strengths and Weaknesses .....	54
6.3 Typical Properties of Nylon 6 and Nylon 6,6 .....	55
6.4 Chemical Resistance of Engineering Thermoplastics.....	59
6.5 Typical Grades of Nylon 6 and Nylon 6,6.....	61
6.6 Selected Properties of Dry, Filled/Reinforced Nylon 6,6 .....	64
6.7 Properties of Nanocomposite Nylon 6, High Cycle Nylon 6 and 35% Mineral Reinforced Nylon 6 .....	65
6.8 Strengths and Weaknesses of Nylon/Polymer Blends.....	66
6.9 Major Applications for Nylon 6 by Fabrication Process.....	68
6.10 Typical Temperatures (°C) for Nylon Extrusion.....	69
6.11 Nylon 6 and Nylon 6,6 End-Use by Major Market.....	72
6.12 Market Requirements of Nylon 6 and Nylon 6,6 .....	73
6.13 Nylon Alloys (Representative List) .....	76
7.1 USGC Nylon 6 and Nylon 6,6 Capital Cost Estimates.....	78
7.2 USGC Talc-Filled Nylon 6,6 Capital Cost Estimates.....	78
7.3 Price and Utilities Basis.....	80
7.4 Nylon 6 and Nylon 6,6 USGC Production Costs .....	80
7.5 Cost of Production Estimate for: Nylon 6 Process: Batch Process .....	82
7.6 Cost of Production Estimate for: Nylon 6,6 Process: Batch Process .....	83
7.7 Cost of Production Estimate for: Nylon 6 Process: Continuous Process .....	84
7.8 Cost of Production Estimate for: Nylon 6,6 Process: Continuous Process .....	85
7.9 Cost of Production Estimate for: Talc-Filled Nylon 6,6 Process: Compounding, 92mm Twin Screw Extruder .....	86
7.10 Cost and Scale Comparisons of Nylon 6 and Nylon 6,6 Continuous Polymerization Processes.....	90

8.1	Global Nylon 6 & 6,6 Demand Forecast.....	92
8.2	North America Nylon 6 & 6,6 Demand Forecast.....	92
8.3	North American Nylon 6 and Nylon 6,6 Capacity, 2015.....	95
8.4	Europe Nylon 6 & 6,6 Demand Forecast .....	96
8.5	Nylon 6 and Nylon 6,6 Capacity in Europe, 2015 .....	98
8.6	China Nylon 6 & 6,6 Demand Forecast.....	99
8.7	Nylon 6 and Nylon 6,6 Capacity in China, 2015.....	101
8.8	ROW Nylon 6 & 6,6 Demand Forecast .....	102
8.9	Nylon 6 and Nylon 6,6 Capacity in ROW, 2015 .....	103

# Nexant Thinking™

## Process Evaluation/Research Planning



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](http://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. 2016. All Rights Reserved.