

CHEMSYSTEMS PERP PROGRAM

Nylon 6 and Nylon 6,6

PERP 07/08S6

January 2009



44 South Broadway, White Plains, New York 10601, USA
Tel: +1 914 609 0300 Fax: +1 914 609 0399

This Report was prepared by Nexant, Inc ("Nexant") and is part of the ChemSystems Online® suite. Except where specifically stated otherwise in this Report, the information contained herein is prepared on the basis of information that is publicly available, and contains no confidential third party technical information to the best knowledge of Nexant. Aforesaid information has not been independently verified or otherwise examined to determine its accuracy, completeness, or financial feasibility. Neither NEXANT, Subscriber nor any person acting on behalf of either assumes any liabilities with respect to the use of or for damages resulting from the use of any information contained in this Report. Nexant does not represent or warrant that any assumed conditions will come to pass.

The Report is submitted on the understanding that the Subscriber will maintain the contents confidential except for the Subscriber's internal use. The Report should not be reproduced, distributed, or used without first obtaining prior written consent by Nexant. Each Subscriber agrees to use reasonable effort to protect the confidential nature of the Report.

Copyright © by Nexant Inc. 2009. All rights reserved.

Contents

Section	Page
1 Summary	1
1.1 INTRODUCTION	1
1.2 CHEMISTRY	2
1.2.1 Nylon 6.....	2
1.2.2 Nylon 6,6.....	4
1.3 PRODUCTION PROCESSES.....	5
1.3.1 Nylon 6 Batch Process.....	5
1.3.2 Nylon 6 Continuous Process.....	6
1.3.3 Nylon 6,6 Batch Process.....	7
1.3.4 Nylon 6,6 Continuous Process.....	8
1.4 NYLON MAJOR MARKETS.....	11
1.5 ECONOMICS	13
1.6 COMMERCIAL ANALYSIS.....	15
1.6.1 North America	15
1.6.2 Europe.....	17
1.6.3 China.....	19
2 Introduction	22
3 Chemistry and Technology	24
3.1 CHEMISTRY	24
3.1.1 Nylon 6.....	24
3.1.2 Raw Materials of Nylon 6 Production	25
3.1.3 Nylon 6,6.....	26
3.1.4 Raw Materials of Nylon 6,6 Production	27
3.2 PRODUCTION PROCESSES.....	30
3.2.1 Nylon 6 Batch Process.....	30
3.2.2 Nylon 6 Continuous Process.....	32
3.2.3 Nylon 6,6 Batch Process.....	34
3.2.4 Nylon 6,6 Continuous Process.....	36

4	Current Commercial Technologies	42
4.1	INTRODUCTION	42
4.2	LURGI ZIMMER GmbH	42
4.2.1	Background	42
4.2.2	Technology Features	42
4.2.3	Process Description	43
4.2.4	Licensee	45
4.3	UHDE INVENTA-FISCHER	47
4.3.1	Background	47
4.3.2	Technology Features	47
4.3.3	Process Description for Nylon 6	49
4.3.4	Process Description for Nylon 6,6	55
4.3.5	Licensees	55
5	Technology Developments	57
5.1	INTRODUCTION	57
5.2	SELECTED RECENT PATENTS	57
5.2.1	New Recycling Technologies	57
5.2.2	Improvements in Process Design	58
5.2.3	Improvements in Quality	60
6	Product and End-Use	62
6.1	RESINS AND COMPOUNDS	62
6.1.1	Resins Properties	62
6.1.2	Recycling	71
6.1.3	Storage	71
6.1.4	Additives and Fillers	72
6.1.5	Compounding	79
6.2	FABRICATION METHODS	80
6.2.1	Injection Molding	81
6.2.2	Extrusion	82
6.2.3	Blow Molding	83
6.2.4	Rotomolding	84

6.2.5	Reaction Injection Molding (RIM)	84
6.2.6	Assembly Techniques	84
6.3	NYLON MAJOR MARKETS	85
6.3.1	Automotive	87
6.3.2	Electronics and Electrical	88
6.3.3	Consumer	89
6.3.4	Industrial	89
6.3.5	Other Applications	90
6.3.6	Alloys	90
6.3.7	New Developments in Nylon 6 and 6,6 Products	91
7	Economic Analysis	92
7.1	BASIS	92
7.1.1	Pricing Basis	92
7.1.2	Investment Basis	92
7.1.3	Cost of Production Basis	93
7.2	COMPARATIVE ECONOMICS	94
7.2.1	Investment	94
7.2.2	Production Costs	95
7.2.3	Raw Material Sensitivity	102
7.2.4	Sensitivity to Scale	103
8	Market Analysis	110
8.1	NORTH AMERICA	110
8.1.1	Overview	110
8.1.2	Demand	110
8.1.3	Supply	112
8.2	EUROPE	115
8.2.1	Overview	115
8.2.2	Demand	115
8.2.3	Supply	117
8.3	JAPAN	119
8.3.1	Overview	119

8.3.2	Demand	119
8.3.3	Supply	121
8.4	CHINA	123
8.4.1	Overview	123
8.4.2	Demand	123
8.4.3	Supply	126
8.5	GLOBAL	127
8.5.1	Global Summary	127
9	Reference	129
10	Glossary	132

Appendix		Page
A	Elements of Nexant's <i>ChemSystems</i> Capital Cost Estimates.....	A-1
B	Supporting Cost of Production Estimates	B-1
C	PERP Title Index	C-1

Figure	Page
1.1 Nylon 6 and Nylon 6,6 Production Costs	14
1.2 North America Nylon 6 ETP Demand by End-Use, 2007	16
1.3 North America Nylon 6,6 ETP Demand by End-Use, 2007	17
1.4 Europe Nylon 6 ETP Demand by End-Use, 2007	18
1.5 Europe Nylon 6,6 ETP Demand by End-Use, 2007	19
1.6 China Nylon 6 ETP Demand by End-Use, 2007	20
1.7 China Nylon 6,6 ETP Demand by End-Use, 2007	21
3.1 Nylon 6 Viscosity Ranges and Applications	29
3.2 Nylon 6 Batch Polymerization Process.....	31
3.3 Nylon 6 Continuous Polymerization Process	33
3.4 Nylon 6,6 Batch Polymerization Processes	35
3.5 Nylon 6,6 Continuous Process: Salt Polymerization	38
3.6 Nylon 6,6 Continuous Process: Polymerization	39
4.1 Lurgi Zimmer Continuous Nylon 6 Process	44
4.2 Uhde Inventa-Fischer's Nylon 6 Single-Stage Polymerization Process.....	49
4.3 Uhde Inventa-Fischer's Nylon 6 Two-Stage Polymerization Process.....	50
4.4 Uhde Inventa-Fischer's Internal Design of the Extraction Column	52
4.5 Uhde Inventa-Fischer's Nylon 6 Re-feeding Process.....	53
4.6 Block-Flow Diagram of the Re-Polymerization Process.....	54
6.1 Modifications in Polyamides Properties to Fill Market Needs.....	73
7.1 Nylon 6 and Nylon 6,6 Production Costs	96
7.2 Effect of Caprolactam Cost on Nylon 6 Resin Economics.....	102
7.3 Effect of HMDA Cost on Nylon 6,6 Resin Economics	103
7.4 Cost and Scale Comparisons of Nylon 6 and Nylon 6,6 Continuous Polymerization Processes.....	109
8.1 North America Nylon 6 ETP Demand by End-Use, 2007	111
8.2 North America Nylon 6,6 ETP Demand by End-Use, 2007	112
8.3 Europe Nylon 6 ETP Demand by End-Use, 2007	116
8.4 Europe Nylon 6,6 ETP Demand by End-Use, 2007	117
8.5 Japan Nylon 6 ETP Demand by End-Use, 2007	120

8.6	Japan Nylon 6,6 ETP Demand by End-Use, 2007	121
8.7	China Nylon 6 ETP Demand by End-Use, 2007	124
8.8	China Nylon 6,6 ETP Demand by End-Use, 2007	125
8.9	Global Nylon Consumption by End-Use, 2007	127
8.10	Global Nylon Consumption by End-Use, 2000-2007	128

Table	Page
1.1 Nylon 6 and Nylon 6,6 End-Use by Major Market	12
1.2 Nylon 6 and Nylon 6,6 Production Costs	13
1.3 North America Nylon 6 ETP Demand Forecast	15
1.4 North America Nylon 6,6 ETP Demand Forecast	16
1.5 Europe Nylon 6 ETP Demand by End-Use, 2007	17
1.6 Europe Nylon 6,6 ETP Demand by End-Use, 2007	18
1.7 China Nylon 6 ETP Demand by End-Use, 2007	20
1.8 China Nylon 6,6 ETP Demand by End-Use, 2007	21
4.1 Lurgi Zimmer Nylon Plants and Projects, 2000-2009	46
4.2 Important Features of Single-Stage and Two-Stage Polymerization Processes	48
4.3 Uhde Inventa-Fischer Nylon Plants and Projects, 2000-2007	56
6.1 Nylon 6 Strengths and Weaknesses	64
6.2 Nylon 6,6 Strengths and Weaknesses	64
6.3 Typical Properties of Nylon 6 and Nylon 6,6	65
6.4 Chemical Resistance of Engineering Thermoplastics.....	71
6.5 Typical Grades of Nylon 6 and Nylon 6,6	74
6.6 Selected Properties of Dry, Filled/Reinforced Nylon 6,6	77
6.7 Properties of Nanocomposite Nylon 6, High Cycle Nylon 6 and 35% Mineral Reinforced Nylon 6	77
6.8 Strengths and Weaknesses of Nylon/Polymer Blends	79
6.9 Major Applications for Nylon 6 by Fabrication Process	81
6.10 Typical Temperatures (°C) for Nylon Extrusion	83
6.11 Nylon 6 and Nylon 6,6 End-Use by Major Market	86
6.12 Market Requirements of Nylon 6 and Nylon 6,6	87
6.13 Nylon Alloys (Representative List)	90
7.1 Price and Utilities Basis	92
7.2 USGC Nylon 6 and Nylon 6,6 Capital Cost Estimates.....	95
7.3 Nylon 6 and Nylon 6,6 Production Costs	96
7.4 Cost of Production Estimate for: Nylon 6 Process: Batch Process.....	98

7.5	Cost of Production Estimate for: Nylon 6,6 Process: Batch Process.....	99
7.6	Cost of Production Estimate for: Nylon 6 Process: Continuous Process.....	100
7.7	Cost of Production Estimate for: Nylon 6,6 Continuous Process	101
7.8	Cost of Production Estimate for: Nylon 6 Process: Continuous Process, 60 KTA Capacity	104
7.9	Cost of Production Estimate for: Nylon 6 Process: Continuous Process, 100 KTA Capacity	105
7.10	Cost of Production Estimate for: Nylon 6,6 Process: Continuous Process, 60 KTA Capacity	106
7.11	Cost of Production Estimate for: Nylon 6,6 Process: Continuous Process, 100 KTA Capacity	107
7.12	Cost and Scale Comparisons of Nylon 6 and Nylon 6,6 Continuous Polymerization Processes	108
8.1	North America Nylon 6 ETP Demand Forecast	110
8.2	North America Nylon 6,6 ETP Demand Forecast	111
8.3	Nylon 6 and Nylon 6,6 ETP Capacity in North America, 2008	114
8.4	Europe Nylon 6 ETP Demand by End-Use, 2007	115
8.5	Europe Nylon 6,6 ETP Demand by End-Use, 2007	116
8.6	Nylon 6 and Nylon 6,6 ETP Capacity in Europe, 2008.....	118
8.7	Japan Nylon 6 ETP Demand by End-Use, 2007.....	119
8.8	Japan Nylon 6,6 ETP Demand by End-Use, 2007.....	121
8.9	Nylon 6 and Nylon 6,6 ETP Capacity in Japan, 2008	122
8.10	China Nylon 6 ETP Demand by End-Use, 2007	123
8.11	China Nylon 6,6 ETP Demand by End-Use, 2007	125
8.12	Nylon 6 and Nylon 6,6 ETP Capacity in China, 2008.....	127