

*High Temperature
Thermoplastic Nylons
01/02S3*

May 2002

Nexant, Inc./Chem Systems
44 South Broadway
White Plains, New York 10601-4425
Telephone (914) 609-0300 Facsimile (914) 609-0399
www.chemsystems.com

TABLE OF CONTENTS

	Page
I SUMMARY	1
A. INTRODUCTION	1
B. CHEMISTRY	3
1. Nylon 4,6	4
2. Polyphthalamide Chemistries	6
C. ECONOMICS	10
D. END-USES	12
E. DEMAND	14
F. SUPPLY	16
II INTRODUCTION	17
A. HIGH TEMPERATURE THERMOPLASTIC NYLONS	17
B. OVERVIEW OF THE ENGINEERING THERMOPLASTICS INDUSTRY	26
III TECHNOLOGY	36
A. CHEMISTRY	36
1. Nylon 4,6	36
2. Polyphthalamide Chemistries	40
3. Other High Temperature Nylon Chemistries	44
4. Nylon 6,6	45
B. PROCESS DESIGN	47
1. Nylon 4,6 Continuous Process	47
2. Nylon 6,T/6,I/6,6 Continuous Process	52
3. Nylon 6T/6I2 Batch Process	53
4. Nylon 6,6 Continuous Process	56
(a) Salt Preparation	56
(b) Polymerization	58
C. TRENDS IN HIGH TEMPERATURE NYLON TECHNOLOGY	60
IV PROCESS ECONOMICS	61
A. BASIS	61
B. INVESTMENT	63
C. ECONOMICS	64

TABLE OF CONTENTS (Continued)

	Page
D. RAW MATERIAL SENSITIVITY	70
E. SENSITIVITY TO SCALE	73
V COMMERCIAL ANALYSIS	79
A. END-USES	79
B. DEMAND	82
C. SUPPLY	85
REFERENCES	86
GLOSSARY	87
APPENDIX	89
PERP TITLE INDEX	94

TABLES

		Page
Table I.A.1	High Temperature Polyamide Resins	2
Table I.C.1	Cost Comparison of High Temperature Nylons	11
Table I.D.1	High Temperature Nylon End-Users in Other Applications	13
Table I.E.1	Global Demand Summary for High Temperature Nylons	14
Table I.F.1	Global High Temperature Nylon Compounding Capacity	16
Table II.A.1	High Temperature Polyamide Resins	18
Table II.A.2	Properties of Selected High Temperature Nylons Versus Nylon 6,6	19
Table II.B.1	Performance Factors (Neat Resin) of Interpolymer Competition	31
Table II.B.2	Properties of Selected Glass Filled Engineering Thermoplastics	32
Table IV.B.1	USGC Nylon 6 and 6,6 Production Capital Cost Estimates	63
Table IV.C.1	Cost Comparison of High Temperature Nylons	64
Table IV.C.2	Cost of Production Estimate for: Nylon 4,6 Process: DSM – Continuous; Integrated with 1,4-Diaminobutane Production	66
Table IV.C.3	Cost of Production Estimate for: Nylon 6T/6I/66 (AMODEL) Process: Amoco – Continuous	67
Table IV.C.4	Cost of Production Estimate for: Nylon 6T/6I2 Process: Batch	68
Table IV.C.5	Cost of Production Estimate for: Nylon 6/6 Process: Continuous	69
Table IV.E.1	Cost of Production Estimate for: Nylon 4/6 Process: DSM – Continuous; Integrated with 1,4-Diaminobutane Production	74
Table IV.E.2	Cost of Production Estimate for: Nylon 6T/6I/66 (AMODEL) Process: Amoco – Continuous	75
Table IV.E.3	Cost of Production Estimate for: Nylon 6T/6I2 Process: Batch	76
Table IV.E.4	Cost Comparison and Scale Sensitivity of High Temperature Nylons	77
Table V.A.1	High Temperature Nylon End-Use Applications in Electrical/ Electronics	80

TABLES (Continued)

	Page
Table V.A.2 High Temperature Nylon End-Use Applications in Automotive	81
Table V.A.3 High Temperature Nylon End-Use in Other Applications	82
Table V.B.1 Global Demand Summary for High Temperature Nylons	83
Table V.C.1 Global High Temperature Nylon Compounding Capacity	85

FIGURES

	Page
Figure I.C.1	Cost Comparison of High Temperature Nylons 11
Figure I.D.1	Global HTN Consumption by End-Use, 2001 13
Figure I.E.1	Global High Temperature Nylon Demand by Region, 2001 14
Figure I.E.2	Global HTN Consumption by Region 15
Figure II.A.1	High Heat Properties of Engineering Plastics 21
Figure II.A.2	Impact Resistance of 30% Glass Fiber Reinforced Engineering Plastics 22
Figure II.A.3	High Temperature Polymer Resistance Against IR Reflow Soldering 22
Figure II.A.4	Comparison of Coefficient of Thermal Expansion for Selected High Temperature Polymers 23
Figure II.A.5	Property Comparison of Selected Semi-Crystalline Polymers 24
Figure II.A.6	Comparison of Mold Shrinkage of High Temperature Polymers 25
Figure II.A.7	High Temperature Polymer Flow Characteristics 25
Figure II.B.1	Engineering Thermoplastics Price/Performance 27
Figure II.B.2	Competition Among the Engineering Thermoplastics 28
Figure II.B.3	Primary Engineering Thermoplastics End-Use Market Requirements 29
Figure II.B.4	Properties of Composite Materials 32
Figure III.A.1	Formation of PyrrolidinyI End Groups 40
Figure III.B.1	Succinonitrile Synthesis and Hydrogenation 48
Figure III.B.2	Nylon 4,6 Salt Preparation 49
Figure III.B.3	Nylon 4,6 Polymerization 50
Figure III.B.4	Continuous Process for Polyphthalamide 54
Figure III.B.5	Batch Nylon 6T/612 Process 55
Figure III.B.6	Continuous Nylon 6,6 AH Salt Preparation 57
Figure III.B.7	Nylon 6,6 Continuous Polymerization Pelletizing, and Drying 59
Figure IV.C.1	Cost Comparison of High Temperature Nylons 65
Figure IV.D.1	Effect of HMDA Cost on High Temperature Nylon Resin Economics 71

FIGURES (Continued)

	Page
Figure IV.D.2 Effect of Dodecanedioic Acid Cost on Nylon 6T/612 Resin Economics	72
Figure IV.E.1 Cost and Scale Comparisons of High Temperature Nylon Polymerization Processes	78
Figure V.A.1 Global HTN Consumption by End-Use, 2001	80
Figure V.B.1 Global High Temperature Nylon Demand by Region, 2001	83
Figure V.B.2 Global HTN Consumption by Region	84