

PERP Report

Urea

06/07S3

October 2007



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

Copyright© by Nexant, Inc. 2007

This report was prepared by Nexant Inc ("Nexant"), for the use of Process Evaluation/Research Planning (PERP) Program (CLIENT) in support of their own consideration of whether and how to proceed with the subject of this report. Except where specifically stated otherwise in the report, the information contained herein was prepared on the basis of information that is publicly available or was provided by the Client and has not been independently verified or otherwise examined to determine its accuracy, completeness or financial feasibility.

Neither NEXANT, CLIENT 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. This report speaks only as of the date herein and NEXANT has no responsibility to update this report. This report is integral and must be read in its entirety.

The report is submitted on the understanding that the CLIENT will maintain the contents confidential except for the CLIENT's internal use. The report should not be reproduced, distributed or used without first obtaining prior written consent by NEXANT. This report may not be relied upon by others.

This notice must accompany every copy of this report.

Contents

Section	Page
1 Executive Summary	1
1.1 OVERVIEW	1
1.2 UREA PROPERTIES	2
1.3 PROCESS CHEMISTRY	3
1.4 UREA TECHNOLOGY LICENSORS.....	6
1.5 COMPARATIVE ECONOMICS	9
1.6 MARKET APPLICATIONS	11
1.6.1 Fertilizer.....	11
1.6.2 Chemical Uses	11
1.6.3 Other	14
1.7 STORAGE, HANDLING, AND TRANSPORTATION.....	14
1.8 MARKET ANALYSIS	15
1.8.1 Overview	15
1.8.2 North America	15
1.8.3 Western Europe.....	17
1.8.4 Japan	19
2 Chemistry and Technology	21
2.1 OVERVIEW	21
2.2 UREA PROPERTIES	22
2.3 PROCESS CHEMISTRY	23
2.4 MATERIALS OF CONSTRUCTION.....	26
2.5 UREA TECHNOLOGY LICENSORS.....	26
2.5.1 Overview	26
2.5.2 Snamprogetti	27
2.5.3 Stamicarbon	28
2.5.4 Toyo Engineering Corporation	28
3 Current Commercial Urea Technologies	30
3.1 INTRODUCTION	30
3.2 UREA SYNTHESIS, DECOMPOSITION, AND RECOVERY	31

3.2.1	Stripping Processes	31
3.2.2	Partial Recycle Process	46
3.2.3	Once Through Process	49
3.3	CONCENTRATION AND FINISHING	52
3.3.1	Introduction.....	52
3.3.2	Prilling.....	55
3.3.3	Granulation	57
3.3.4	Crystallization with Remelting	73
3.4	WASTEWATER TREATMENT	75
4	Revamp of Urea Plants	76
4.1	INTRODUCTION	76
4.2	SNAMPROGETTI.....	76
4.3	STAMICARBON	78
4.3.1	More-in, More-out Concept.....	78
4.3.2	The In-line Medium – Pressure Recirculation Concept.....	78
4.3.3	The Medium-Pressure Recirculation Add-On Concept.....	79
4.3.4	The Double Stripper Concept	82
4.3.5	The Pool Condenser Concept.....	82
4.3.6	The Combi-Reactor Concept	85
4.4	TOYO ENGINEERING CORPORATION.....	87
4.4.1	Revamp Sections.....	89
4.5	UHDE FERTILIZER TECHNOLOGY (UFT)	91
5	Technology Developments	92
5.1	INTRODUCTION	92
5.2	SELECTED RECENT PATENTS	92
6	Economic Analysis	99
6.1	BASIS	99
6.1.1	Pricing Basis	99
6.1.2	Investment Basis	99
6.1.3	Cost of Production Basis.....	100
6.2	PRODUCTION COST ESTIMATES.....	101

6.2.1	United States Basis	101
6.2.2	Middle East Basis	104
6.3	COMPARATIVE ECONOMICS	107
6.4	SENSITIVITY ANALYSIS	108
6.4.1	Effects of Ammonia Value	108
7	Commercial Analysis	112
7.1	MARKET APPLICATIONS	112
7.1.1	Fertilizer	112
7.1.2	Chemical Uses	113
7.1.3	Other	116
7.2	STORAGE, HANDLING, AND TRANSPORTATION.....	116
7.3	MARKET ANALYSIS	117
7.3.1	Overview	117
7.3.2	North America	117
7.3.3	Western Europe.....	119
7.3.4	Japan	121
8	References	123
Appendix		Page
A	Nexant's ChemSystems Capital Cost Estimates	A-1
B	PERP Program Title Index	B-1

Figure	Page
1.1 Urea Yield as a Function of NH ₃ /CO ₂ Ratio	4
1.2 Conversion of Carbon Dioxide to Urea at Different Temperatures.....	5
1.3 Comparison of Urea Costs	10
1.4 North America Urea Capacity Share	16
1.5 Western Europe Urea Capacity Share.....	18
2.1 Urea Yield as a Function of NH ₃ /CO ₂ Ratio	24
2.2 Conversion of Carbon Dioxide to Urea at Different Temperatures.....	25
3.1 Snamprogetti Ammonia Stripping Process for Urea	32
3.2 Stamicarbon Urea 2000plus™ Process	36
3.3 Stamicarbon 2000plus™ Mega Plant Concept for Urea	39
3.4 Toyo ACES Urea Process	42
3.5 Toyo ACES 21® Urea Process.....	44
3.6 Stamicarbon Partial Recycle UAN Process-Synthesis and Dissociation Sections ...	47
3.7 Stamicarbon Partial Recycle UAN Process-Neutralization Section	50
3.8 Stamicarbon Once-Through Urea Process.....	51
3.9 Prill Tower Scheme.....	56
3.10 Granulation Plant Scheme.....	58
3.11 Stamicarbon Process Flow Sheet Granulation Section	60
3.12 UFT Fluid Bed Granulation Process.....	65
3.13 TEC Spout-Fluid Bed Urea Granulation Process	68
3.14 Snamprogetti Granulation Process.....	71
3.15 Snamprogetti Fattening Process.....	74
4.1 Snamprogetti Revamped Conventional Total Recycle Plant.....	77
4.2 Stamicarbon Medium – Pressure Recirculation Concept	80
4.3 Stamicarbon Medium-Pressure Recirculation Add-on Concept.....	81
4.4 Stamicarbon Pool Condenser.....	83
4.5 Stamicarbon Pool Condenser Concept Process	84
4.6 Stamicarbon Combi-Reactor.....	85
4.7 Stamicarbon Combi-Reactor Concept Process	86

4.8	TEC Total Recycle C-Improved Process.....	88
4.9	TEC Revamped Synthesis Section.....	90
5.1	Vertical Condensation Synthesis Column and Stripper.....	96
5.2	Block Flow Diagram for the Production of Urea.....	97
6.1	Comparison of Urea Costs.....	108
6.2	Ammonia Value Effects on Middle East Urea Plants.....	111
7.1	Melamine End-Use Applications.....	113
7.2	North America Urea Capacity Share	118
7.3	Western Europe Urea Capacity Share.....	120

Table	Page
1.1 Typical Properties of Urea.....	3
1.2 Summary of Urea Processes	7
1.3 Urea Licensor Market Share	7
1.4 Summary of Urea Process Economics.....	9
1.5 North American Top Ten Urea Producers, 2006.....	16
1.6 North American Urea Supply/Demand and Trade.....	17
1.7 Western Europe Top Ten Urea Producers, 2006	18
1.8 Western Europe Urea Supply/Demand and Trade.....	19
1.9 Japan Urea Plant Capacities, 2006.....	20
1.10 Japan Urea Supply/Demand and Trade.....	20
2.1 Typical Properties of Urea.....	23
2.2 Summary of Urea Processes	27
2.3 Urea Licensor Market Share	27
3.1 Snamprogetti Urea Performance Data	35
3.2 Typical Consumption Figures for a Stamicarbon Mega Plant.....	41
3.3 Typical Stamicarbon UAN Consumption Figures.....	49
3.4 Urea Physical Property Comparison.....	53
3.5 Typical Consumption Factors for Urea Processes.....	54
3.6 Typical Urea Quality Specifications.....	54
3.7 Typical Product Quality: Stamicarbon Granulation Technology	59
3.8 Typical Stamicarbon Urea Plant Performance.....	62
3.9 Urea Product Characteristics.....	63
3.10 Typical Utility Consumptions for UFT Fluid Bed Granulation Plant	66
3.11 Typical UFT Product Characteristics.....	66
3.12 UFT Fluid Bed Granulation Plant Emission.....	67
3.13 Toyo Urea Granule Quality	69
3.14 Typical Utility Consumptions for TEC Spout-Fluid Granulation Plant.....	69
3.15 TEC Spout-Fluid Granulation Plant Emission.....	70
3.16 Snamprogetti Drum Granulation Emissions	72
3.17 Snamprogetti Urea Fattening Characteristics	73

4.1	Stamicarbon Revamping Concepts	78
4.2	TEC Revamping Technology Options.....	87
5.1	Additive Effect on Urea Performance.....	93
6.1	Price and Utilities Basis	99
6.2	Urea Capital Cost Estimates	100
6.3	Cost of Production Estimate for: Ammonia (USGC Basis; Conventional Reforming Process).....	102
6.4	Cost of Production Estimate for: Urea (USGC Basis; Conventional Ammonia Stripping Process)	103
6.5	Cost of Production Estimate for: Ammonia (Middle East Basis; Conventional Reforming Process).....	105
6.6	Cost of Production Estimate for: Urea (Middle East Basis; Conventional Ammonia Stripping Process)	106
6.7	Summary of Urea Process Economics.....	107
6.8	Cost of Production Estimate for: Urea (Middle East Basis, Conventional Ammonia Stripping Process)	109
6.9	Cost of Production Estimate for: Urea (Middle East Basis; Conventional Ammonia Stripping Process)	110
7.1	North American Top Ten Urea Producers, 2006	118
7.2	North American Urea Supply/Demand and Trade.....	119
7.3	Western Europe Top Ten Urea Producers, 2006	120
7.4	Western Europe Urea, Supply/Demand and Trade.....	121
7.5	Japan Urea Plant Capacities, 2006.....	122
7.6	Japan Urea Supply/Demand and Trade.....	122