

PERP Report

Polyvinyl Chloride (PVC)

07/08-7

September 2008



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

Copyright© by Nexant, Inc. 2008

This Report was prepared by Nexant, Inc. ("Nexant") and is part of ChemSystems Process Evaluation/Research Planning (PERP) Program. 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. The aforesaid information has not been independently verified or otherwise examined to determine its accuracy, completeness, or 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 shall not be reproduced, distributed, or used outside Subscriber's organization without first obtaining prior written consent by Nexant. Each Subscriber agrees to use reasonable effort to protect the confidential nature of the Report.

Contents

Section	Page
1 Summary	1
1.1 INTRODUCTION	1
1.2 CHEMISTRY	2
1.3 PVC RESIN MANUFACTURING PROCESSES	4
1.4 END USES.....	5
1.5 PRODUCTION COSTS	6
1.6 MARKET ANALYSIS	7
1.6.1 United States	7
1.6.2 Western Europe.....	9
1.6.3 Asia Pasific	11
2 Introduction	14
3 Chemistry and Technology	19
3.1 CHEMISTRY	19
3.2 RESOURCES AND RAW MATERIALS.....	21
3.3 PVC RESIN MANUFACTURING PROCESSES	23
3.3.1 Suspension Polymerization.....	24
3.3.2 Emulsion Polymerization.....	36
3.3.3 Bulk or Mass Polymerization.....	43
3.3.4 Solution Polymerization.....	46
3.3.5 Microsuspension Polymerization.....	48
3.3.6 Gas Phase Polymerization.....	48
4 Commercially Licensed SPVC Technologies	49
4.1 INTRODUCTION	49
4.2 CHISSO	49
4.2.1 Background.....	49
4.2.2 Technology Features.....	49
4.2.3 Process Description.....	50
4.2.4 Licensees.....	53
4.3 INEOS VINYLs	54

4.3.1	Background.....	54
4.3.2	Technology Features.....	54
4.3.3	Process Description.....	56
4.3.4	Licensees.....	58
4.4	VINNOLIT	59
4.4.1	Background.....	59
4.4.2	Technology Features.....	59
4.4.3	Process Description.....	61
4.4.4	Waste and Emissions	66
4.4.5	Licensees.....	66
5	Technology Developments.....	68
5.1	INTRODUCTION	68
5.2	SELECTED RECENT PATENTS	68
5.2.1	Improvements in Process Design.....	68
5.2.2	New Performance Additives	70
5.2.3	New Technologies	71
6	Products and End Use	73
6.1	RESINS AND COMPOUNDS	73
6.1.1	Resin Properties	73
6.1.2	Storage and Transportation.....	77
6.1.3	Additives.....	77
6.1.4	Compounds	85
6.2	FABRICATION METHODS	88
6.2.1	Extrusion.....	88
6.2.2	Injection Molding.....	88
6.2.3	Blow Molding	88
6.2.4	Thermoforming.....	89
6.2.5	Calendering.....	89
6.2.6	Casting or Blowing Film.....	89
6.2.7	Slush Molding.....	89
6.2.8	Rotational Molding.....	89

6.2.9	Coating.....	90
6.3	PVC MAJOR MARKETS	90
6.3.1	Building and Construction	93
6.3.2	Electronic and Electrical	94
6.3.3	Transportation	94
6.3.4	Packaging	94
6.3.5	Consumer and Institutional	94
6.3.6	Furniture and Furnishings	94
6.4	END USES.....	95
6.4.1	Pipe	95
6.4.2	Siding	96
6.4.3	Rigid Profiles	96
6.4.4	Electrical	97
6.4.5	Blow Molding	97
6.4.6	Film and Sheet	97
6.4.7	Flooring.....	98
6.4.8	Flexible Tubes.....	98
6.4.9	PVC compounds	98
6.4.10	Emerging End-Uses	99
7	Health, Safety and Environmental Issues.....	101
7.1	SAFETY ASPECTS OF PVC PRODUCTION.....	101
7.1.1	Fire and Explosion	101
7.2	ENVIRONMENTAL ASPECTS OF PVC PRODUCTION	101
7.2.1	Vinyl Chloride Monomer (VCM).....	101
7.2.2	Chlorine (Cl ₂), Hydrogen Chloride (HCl), Dioxin.....	102
7.2.3	Polyvinyl Chloride (PVC).....	103
7.3	ENVIRONMENTAL ASPECTS OF PVC USE	105
7.3.1	Environmental Pressures by Region	105
7.3.2	Plasticizers	114
7.3.3	Stabilizers.....	117
7.3.4	Dyes and Pigments.....	119

7.3.5	Mercury Catalysts	120
8	Economic Analysis	121
8.1	BASIS	121
8.1.1	Pricing Basis	121
8.1.2	Investment Basis	121
8.1.3	Cost of Production Basis.....	122
8.2	ECONOMICS	123
8.2.1	Investment.....	123
8.2.2	Production Costs	123
8.3	RAW MATERIAL SENSITIVITY: EFFECT OF BACK INTEGRATION	130
8.4	SENSITIVITY TO SCALE	132
9	Market Analysis	136
9.1	UNITED STATES	136
9.1.1	Overview.....	136
9.1.2	Demand.....	136
9.1.3	Supply	138
9.1.4	Supply, Demand and Trade.....	139
9.2	WESTERN EUROPE	140
9.2.1	Overview.....	140
9.2.2	Demand.....	140
9.2.3	Supply	142
9.2.4	Supply, Demand and Trade.....	144
9.3	ASIA PASIFIC	145
9.3.1	Overview.....	145
9.3.2	Demand.....	145
9.3.3	Supply	148
9.3.4	Supply, Demand and Trade.....	152
10	Reference	155

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

Figure	Page
1.1 Estimated Global Demand of PVC by End Use, 2007	5
1.2 PVC Production Cost	7
1.3 United States PVC Consumption, 2007	9
1.4 Western Europe PVC Consumption, 2007	11
1.5 Asia Pacific PVC Consumption, 2007	13
3.1 VCM Production via Ethylene-Based Process	21
3.2 VCM Production via Acetylene-Based Process	22
3.3 Schematic View of PVC Granule Formation.....	26
3.4 Suspension Polymerization Process: Reaction and Slurry Stripping.....	29
3.5 Suspension Polymerization: Solids Drying and Handling.....	30
3.6 Suspension Polymerization Process: Monomer Recovery	31
3.7 Pressure and Conversion Profiles for PVC Suspension Process	34
3.8 Schematic Diagram of Emulsion Polymerization.....	37
3.9 Batch Emulsion.....	39
3.10 Batch Emulsion Process: Drying and Handling.....	40
3.11 PVC Mass Polymerization.....	44
4.1 Flow Scheme of the Chisso PVC Process.....	52
4.2 Schematic Overview of the Vinnolit S-PVC Production Steps.....	62
4.3 Comparison of Conventional Reactor Versus Vinnolit's HP reactor	63
4.4 Comparison of Different Reactor Systems	64
4.5 Vinnolit Cyclone Dryer.....	65
6.1 Types of PVC Plasticizers	83
6.2 PVC Demand by Market Sector	91
6.3 Estimated Global Demand of PVC by End Use, 2007	95
7.1 Dioxin Emissions Versus Vinyl Chloride Monomer Production	103
7.2 Key Milestones of the Voluntary Commitment o the PVC Industry.....	111
8.1 PVC Production Cost.....	124
8.2 Suspension PVC - Sensitivity to VCM Price.....	131
8.3 Emulsion PVC – Sensitivity to VCM Price	131

8.4	PVC Production Cost.....	132
9.1	United States PVC Consumption, 2007.....	137
9.2	United States PVC Supply/Demand and Operating rate.....	139
9.3	Western Europe PVC Consumption, 2007	141
9.4	Western Europe PVC Supply/Demand and Operating Rate.....	145
9.5	Asia Pacific PVC Consumption, 2007	147
9.6	Asia Pacific PVC Supply/Demand and Operating Rate	154

Table		Page
1.1	Percentage Market Share of PVC Production Processes by Region.....	4
1.2	PVC Production Costs	6
1.3	United States PVC Consumption Forecast	8
1.4	Western Europe PVC Consumption Forecast.....	11
1.5	Asia Pacific PVC Consumption.....	13
2.1	Example of General Purpose Flexible and Rigid PVC Formulations.....	15
2.2	Typical Commercial Products for Unfilled PVC.....	16
2.3	Typical Commercial Products for Filled Flexible PVC.....	17
3.1	Commonly Used PVC Production Process Additives	23
3.2	Percentage Market Share of PVC Production Processes by Region.....	24
3.3	Representative Suspension Polymerization Cycle.....	28
3.4	Vinyl Chloride Monomer Specifications	32
3.5	Demineralized Water Specifications.....	32
3.6	Polymerization Recipe for Pipe Grade Suspension PVC	32
3.7	Typical Emulsion Polymerization Recipe	41
3.8	MPVC Production Cycle	46
4.1	Typical Raw Materials and Utilities Consumption for Chisso Process.....	50
4.2	Typical Properties of Chisso PVC Products	51
4.3	Chisso PVC Licensees	53
4.4	INEOS Vinyls PVC licensees.....	58
4.5	Typical Raw Materials and Utilities Consumption.....	60

4.6	Typical Properties of Vinnolit PVC Products for Rigid Applications.....	60
4.7	Typical Properties of Vinnolit PVC Products for Flexible Application.....	61
4.8	Performance Comparison of Conventional Reactor Versus Vinnolit's HP Reactor .	64
4.9	Emission Figures and Losses of VCM and PVC in the Vinnolit Process	66
4.10	Vinnolit PVC Licensees.....	67
6.1	Representative PVC Suspension Polymers.....	75
6.2	Representative Emulsion PVC Polymers	76
6.3	Commonly Used Thermal Stabilizers for PVC	79
6.4	Classes of Stabilizer for Major Applications in the United States and the World.....	80
6.5	Impact Modifiers Used for PVC Applications.....	81
6.6	Commonly Used PVC Plasticizers	82
6.7	Typical Rigid PVC Compound.....	86
6.8	Typical Rigid PVC Compound Applications	86
6.9	Typical Flexible PVC Compound Applications	87
6.10	PVC End Uses by Major Market	91
7.1	Summary of Environmental Issues in PVC and Vinyls Chain Production.....	104
7.2	Vinyl 2010 Commitments.....	109
7.3	Vinyl 2010 Keys Achievements	110
7.4	Initiatives and Future Plans by Major U.S. Companies on the Use of PVC.....	114
7.5	Risk Assessment Results for Five Phthalates	116
8.1	Price and Utilities Basis.....	121
8.2	USGC PVC Capital Cost Estimates.....	123
8.3	PVC Production Costs	124
8.4	Cost of Production Estimate for: PVC Process: Suspension Polymerization.....	126
8.5	Cost of Production Estimate for: PVC Process: Emulsion Polymerization	127
8.6	Cost of Production Estimate for: PVC Process: Mass Polymerization	128
8.7	Cost of Production Estimate for: PVC Process: Microsuspension Polymerization	129
8.8	Cost Comparison of Alternative VCM Prices on PVC Production Costs	130

8.9	Cost of Production Estimate for: PVC Process: Suspension Polymerization.....	133
8.10	Cost of Production Estimate for: PVC Process: Emulsion Polymerization	134
8.11	Scale Sensitivity of Suspension and Emulsion PVC	135
9.1	United States PVC Consumption Forecast	137
9.2	PVC Capacity in the United States, 2007	138
9.3	United States PVC Supply/Demand and Trade	139
9.4	Western Europe PVC Consumption Forecast.....	142
9.5	PVC Capacity in Western Europe, 2007.....	143
9.6	Western Europe PVC Supply/Demand and Trade.....	144
9.7	Asia Pacific PVC Consumption.....	147
9.8	PVC Capacity in Asia Pacific, 2007	149
9.9	Asia Pacific PVC Supply/Demand and Trade	153