

Formaldehyde

00/01-8

April 2001

TABLE OF CONTENTS

	Page
I EXECUTIVE SUMMARY	1
A. BACKGROUND	1
B. SILVER CATALYST PROCESS	1
1. Incomplete Conversion	2
2. Complete Conversion	3
C. METAL OXIDE CATALYST PROCESS	4
D. ECONOMICS AND PROCESS COMPARISON	5
E. PATENT ANALYSIS	7
F. DOWNSTREAM DERIVATIVES	7
G. ENVIRONMENTAL AND HEALTH ISSUES	8
H. COMMERCIAL ANALYSIS	9
II CURRENT TECHNOLOGY	11
A. BACKGROUND	11
B. SILVER CATALYST PROCESS	12
1. Process Chemistry	12
2. Process Description	14
(a) Incomplete Conversion with Methanol Recycle	14
(b) Complete Conversion without Methanol Recycle	17
3. Licensors	19
4. Product Properties	19
C. METAL OXIDE CATALYST PROCESS	21
1. Chemistry	21
2. Process Description	21
3. Licensors	24
D. ECONOMICS AND COMPARISON OF PROCESSES	25
1. Production Cost	25
2. Other Factors	32
III PATENT SURVEY	35
A. METHANE OXIDATION	35
B. DEHYDROGENATION	40
C. OTHER PATENTS OF INTEREST	41

**TABLE OF CONTENTS
(Continued)**

	Page
IV DOWNSTREAM DERIVATIVES	43
A. INTRODUCTION	43
B. PHENOL-FORMALDEHYDE RESINS	44
1. Background	44
(a) Novolaks	45
(b) Resols	45
2. Process Description	45
3. Production Cost	46
C. UREA FORMALDEHYDE RESINS	48
1. Background	48
2. Process Description	48
3. Production Cost	49
D. MELAMINE FORMALDEHYDE RESINS	51
1. Background	51
2. Process Description	51
3. Production Cost	51
E. POLYACETAL RESINS	53
1. Background	53
2. Process Chemistry	54
3. Process Description	56
4. Production Cost	58
F. 1,4-BUTANEDIOL	60
1. Background	60
2. Production Cost	60
G. NEOPENTYL GLYCOL	62
1. Background	62
2. Production Cost	62
H. POLYHYDRIC ALCOHOLS	64
1. Pentaerythritol	64
(a) Background	64
(b) Process Chemistry	64
(c) Process Description	65
(d) Production Cost	66

TABLE OF CONTENTS (Continued)

	Page
2. Trimethylolpropane	68
(a) Background	68
(b) Process Chemistry	68
(c) Process Description	68
(d) Production Cost	69
V ENVIRONMENTAL ISSUES	71
A. SOURCES OF FORMALDEHYDE	71
B. ENVIRONMENTAL AND HEALTH EFFECTS	73
C. PRODUCT-RELATED CONTROLS	74
D. FORMALDEHYDE PRODUCTION	78
VI COMMERCIAL ANALYSIS	79
A. COMMERCIAL APPLICATIONS	79
1. Chemical Uses	79
2. Urea-Formaldehyde Resins	79
(a) Background	79
(b) Adhesive Resins	79
(c) Other Uses	80
3. Phenol-Formaldehyde Resins	81
(a) Background	81
(b) Woodworking Adhesives	81
(c) Laminates	82
(d) Insulation	82
(e) Molding Compounds	83
(f) Foundry Resins	83
(g) Other Applications	84
4. Melamine-Formaldehyde Resins	84
(a) Background	84
(b) Laminates	84
(c) Molding Compounds	85
(d) Adhesives	85
(e) Other Applications	85

**TABLE OF CONTENTS
(Continued)**

	Page
5. Polyacetal Resins	86
(a) Background	86
(b) Applications	86
6. 1,4-Butanediol	87
7. Polyhydric Alcohols	88
8. Hexamine	89
9. Other Uses	89
B. FORMALDEHYDE SUPPLY/DEMAND	90
1. North America	90
(a) Supply	90
(b) Demand	91
2. Western Europe	94
(a) Supply	94
(b) Demand	94
3. Japan and the Far East	98
 REFERENCES	 101
 APPENDIX	 102

TABLES

		Page
Table II.B.1	Typical Properties of Formaldehyde Solutions	20
Table II.D.1	Formaldehyde Production Cost Summary	26
Table II.D.2	Cost of Production Estimate for: Formalin (37 wt%) Process: Silver Catalyst w/o Recycle	27
Table II.D.3	Cost of Production Estimate for: Formalin (37 wt%) Process: Mo/Fe Oxide Catalyst	28
Table II.D.4	Cost of Production Estimate for: Formalin (37 wt%) Process: Silver Catalyst w/Recycle	29
Table II.D.5	Cost of Production Estimate for: Methanol Process: ICI w/Steam Reformer & Quench Converter	30
Table III.A.1	Product Distribution of Snamprogetti Methane to Formaldehyde Process	36
Table III.A.2	Cost of Production Estimate for: Formalin (37%) Process: POX of CH ₄	39
Table IV.B.1	Cost of Production Estimate for: Phenol-Formaldehyde Resin Process: Batch Polymerization	47
Table IV.C.1	Cost of Production Estimate for: Urea-Formaldehyde Resin Process: Batch Polymerization	50
Table IV.D.1	Cost of Production Estimate for: Melamine-Formaldehyde Resin Process: Batch Polymerization	52
Table IV.E.1	Cost of Production Estimate for: Polyacetal Homopolymer Process: Formaldehyde Polymerization	59
Table IV.F.1	Cost of Production Estimate for: 1,4-Butanediol Process: Reppe	61
Table IV.G.1	Cost of Production Estimate for: Neo-Pentyl Glycol Process: Condensation/Hydrogenation	63
Table IV.H.1	Cost of Production Estimate for: Pentaerythritol Process: Condensation	67
Table IV.H.2	Cost of Production Estimate for: Trimethylolpropane Process: Condensation	70

**TABLES
(Continued)**

		Page
Table V.A.1	Contribution to Atmospheric Formaldehyde	71
Table V.B.1	Irritation Level of Formaldehyde	73
Table V.C.1	Formaldehyde Concentration Limits	75
Table V.C.2	Formaldehyde Product Requirements	76
Table VI.B.1	North American Formaldehyde Capacity by Producer, 2000	90
Table VI.B.2	U.S. Formaldehyde Demand	93
Table VI.B.3	West European Formaldehyde Capacity by Producer, 1995	96-97
Table VI.B.4	West European Formaldehyde Demand	98
Table VI.B.5	Japanese Formaldehyde Capacity by Producer, 1995	100
Table VI.B.6	Estimated Japanese Formaldehyde Demand	100

FIGURES

		Page
Figure I.D.1	Formaldehyde Production Cost Comparison, 37 Percent Basis, U.S. Gulf Coast, 2nd Quarter 2000	5
Figure I.H.1	U.S. Formaldehyde Downstream Derivative Demand	9
Figure I.H.2	West European Formaldehyde Demand	10
Figure I.H.3	Japanese Formaldehyde Derivative Demand	10
Figure II.B.1	Methanol Conversion: Silver Process	13
Figure II.B.2	Formaldehyde Production Silver Catalyst: Incomplete Conversion	15
Figure II.B.3	Formaldehyde Production Silver Catalyst: Complete Conversion	18
Figure II.C.1	Formaldehyde Production via Metal Oxide Catalyst Process	22
Figure II.D.1	Formaldehyde Production Cost Comparison, 37 Percent Basis, U.S. Gulf Coast, 2nd Quarter 2000	25
Figure II.D.2	Feed Price Effect on Formalin (37%) Cost: Cash Cost via Various Routes	31
Figure II.D.3	Feed Price Effect on Formalin (37%) Cost: Cost + ROCE via Various Routes	33
Figure VI.B.1	U.S. Formaldehyde Downstream Derivative Demand: Total 2000 Demand = 4.2 Million Metric Tons	92
Figure VI.B.2	West European Formaldehyde Demand: Total 2000 Demand = 6.5 Million Metric Tons	95
Figure VI.B.3	Japanese Formaldehyde Derivative Demand: Total 2000 Demand = 1.5 Million Metric Tons	99