# Propionic Acid 98/99S10

May 1999

### **TABLE OF CONTENTS**

					Page		
I	EXECUTIVE SUMMARY						
	A.	INTRODUCTION					
	B.						
	C.						
	D.	ECC	ECONOMIC SUMMARY				
	E.	APF	APPLICATIONS				
	F.	DEMAND					
II	TECHNOLOGY						
	A.	INTRODUCTION					
	B.	CO	COMMERCIAL ROUTES				
		1. Hydrocarboxylation of Ethylene with Carbon Mor		Irocarboxylation of Ethylene with Carbon Monoxide			
			an	d Water	11		
			(a)	Chemistry	12		
			(b)	Process Description	12		
			(c)	Economics	15		
		2.	Ethy	ylene Hydroformylation/Oxidation	15		
			(a)	Chemistry	17		
			(b)	Process Description	17		
			(c)	Economics	21		
		<ol><li>Direct Oxidation of Hydrocarbons</li></ol>		21			
			(a)	•	23		
			(b)	S .	24		
	_		` '	Economics	27 27		
	C.		SPECULATIVE ROUTES				
		1.		tic Acid Homologation	27		
			. ,	Chemistry	27		
			(b)	Process Design	28		
		0	(c)	Economics	31		
		2.		anol Carbonylation	31		
			(a)	Chemistry	31		
			(b)	Process Design	34		
			(c)	Economics	34		

## TABLE OF CONTENTS (Continued)

			Page				
		Developments in Hydrocarboxylation	36				
		(a) Halogen-Containing Catalyst Systems	36				
		(b) Halogen-Free Catalyst Systems	38				
	D.	ECONOMIC SUMMARY	42				
Ш	COMMERCIAL 44						
	A.	INTRODUCTION	44				
		1. Food 44					
		2. Herbicides	44				
		<ol><li>Intermediate for Specialty Chemicals</li></ol>	45				
		4. Rubber 45					
		5. Fragrances	45				
		6. Coatings 45					
	B. UNITED STATES		48				
		1. Demand 48					
		2. Supply	48				
		3. Supply and Demand	49				
	C.	EUROPE 50					
		1. Demand 50					
		2. Supply	51				
		3. Supply/Demand Balance	52				
	D. JAPAN 53						
		1. Demand 53					
		2. Supply	54				
		3. Supply/Demand Balance	54				
	REFERENCES						
		PENDIX: ELEMENTS OF CHEM SYSTEMS' CAPITAL COST					
	ES	STIMATES	56				
	PER	RP TITLE INDEX	61				

### **TABLES**

		Page
Table I.D.1	Summary of Propionic Acid Economics	6
Table I.F.1	U.S. Propionic Acid Supply/Demand Balance	9
Table I.F.2	European Propionic Acid Supply/Demand Balance	9
Table I.F.3	Japanese Propionic Acid Supply/Demand Balance	9
Table II.B.1	Cost Estimate of Propionic Acid Production via Ethylene Carbonylation	16
Table II.B.2	Cost Estimate of Propionic Acid Production via	. •
	Ethylene Hydroformylation/Oxidation	22
Table II.C.1	Cost Estimate of Propionic Acid Production via	
	Homologation of Acetic Acid (3:1 Syngas)	32
Table II.C.2	Cost Estimate of Syngas (H2:CO=3:1) Production via	
	Steam Methane Reforming	33
Table II.C.3	Cost Estimate of Propionic Acid Production via	
Table II O 4	Ethanol Carbonylation	35
Table II.C.4	Patent Example Test Results	39
Table II.C.5	Cost Estimate of Propionic Acid Production via Low Pressure Ethylene Hydrocarbonylation	41
Table II.D.1	Summary of Propionic Acid Economics	42
Table III.A.1	Propionate Characteristics	45
Table III.A.2	Typical Solvent Properties	46
Table III.B.1	U.S. Propionic Acid End-Use Breakdown	48
Table III.B.2	U.S. Propionic Acid Demand	48
Table III.B.3	U.S. Propionic Acid Capacity by Producer	49
Table III.B.4	U.S. Propionic Acid Exports, 1997	49
Table III.B.5	U.S. Propionic Acid Imports, 1997	50
Table III.B.6	U.S. Propionic Acid Supply/Demand Balance	50
Table III.C.1	European Propionic Acid End-Use Breakdown	51
Table III.C.2	European Propionic Acid Demand Forecast	51
Table III.C.3	European Propionic Acid Producers	52
Table III.C.4	European Propionic Acid Supply/Demand Balance	53
Table III.D.1	Japanese Propionic Acid End-Use Breakdown	53
Table III.D.2	Japanese Propionic Acid Demand	53
Table III.D.3	Japanese Propionic Acid Capacity by Producer	54
Table III.D.4	Japanese Propionic Acid Supply/Demand Balance	54

### **FIGURES**

		Page
Figure I.A.1	Propionic Acid Production Routes	2
Figure I.E.1	Propionic Acid End-Use Applications	7
Figure II.A.1	Propionic Acid Production Routes	11
Figure II.B.1	Mechanism for Propionic Acid Formation via	
	Ethylene Hydrocarboxylation	13
Figure II.B.2	Propionic Acid Production via Ethylene Hydrocarboxylation	14
Figure II.B.3	Propionaldehyde Production via Ethylene Hydroformylation	18
Figure II.B.4	Propionaldehyde Oxidation to Propionic Acid	19
Figure II.B.5	Acetic Acid via Butane Oxidation	26
Figure II.C.1	Propionic Acid Production via Acetic Acid Homologation	29
Figure III.A.1	Propionic Acid End-Use Applications	47