

CONTENTS

OF VOLUME 1, PART I

INTRODUCTION TO THE SERIES	v
PREFACE TO VOLUME 1	ix
CONTRIBUTORS TO VOLUME 1, PARTS I AND II	xi
CONTENTS OF VOLUME 1, PART II	xxi

1. HISTORY AND STATUS OF PHOSPHORIC ACID 1

C. C. Legal and O. D. Myrick, Jr.

I. Introduction	2
II. History	5
A. Wet Process	6
B. Furnace Process	11
III. Chemistry	14
A. Wet-Process Acid	14
B. Electric Furnace Acid	16
IV. Raw Materials	16
A. Phosphate Rock	16
B. Sulfur	24
V. Production by Wet Methods	29
A. Dihydrate Process	29
B. Hemihydrate Processes	37
C. Hemihydrate-Dihydrate Processes	39
D. Anhydrite Processes	41
E. Use of Hydrochloric Acid	43
F. Nitric Acid	44
G. Concentration	46
H. Purification	48
I. Other Processes	50
VI. Production by Furnace Method	51
A. Electric Furnace Process	51
B. Other Furnace Methods	54

VII.	Superphosphoric Acid	55
VIII.	Status of Production	57
IX.	Production Economics	69
	A. Wet-Process Phosphoric Acid	69
	B. Electric Furnace Phosphoric Acid	75
	C. Phosphoric Acid Prices	79
X.	Waste Disposal	80
	A. Sludge	80
	B. Gypsum	80
	C. Fluorine	81
XI.	Uses of Phosphoric Acid	82
	A. Fertilizers	82
	B. Industrial Phosphates	87
	References	89

2. CHEMISTRY OF WET-PROCESS PHOSPHORIC ACID MANUFACTURE

91

Sven-Eric Dahlgren

I.	Crystal Forms of Calcium Sulfate	92
II.	Equilibria in the System $\text{CaSO}_4\text{-P}_2\text{O}_5\text{-H}_2\text{O}$	93
III.	Crystal Formation	96
	A. Fundamentals	96
	B. Crystal Formation in Phosphoric Acid Processes	99
	C. Crystal Habit Modification	103
IV.	Phosphate Substitution and Related Aspects	105
V.	Solubility of Calcium Sulfate in Phosphoric Acid Solutions	110
VI.	Interference by Impurities in Phosphoric Acid	113
	A. General Aspects	113
	B. Structural Considerations	114
	C. Effect on Viscosity	115
	D. Effect on Density	119
	E. Effect on Electrical Conductivity	121
VII.	Use of Physical Properties in Process Control	122
VIII.	Extraction of Phosphate Rock	123
	A. Structure of Phosphate Rock	123
	B. Reactivity of Phosphate Rock	125
	C. Blocking of the Reaction	128

D. Main Chemical Reactions	129
E. Thermochemistry	130
IX. Chemistry of the Various Processes for Production of Wet-Process Phosphoric Acid	133
A. Existence Regions of the Processes	133
B. Reactivity of Hemihydrate	135
C. Classification of Processes	137
X. Physical Properties of Phosphoric Acid	138
References	154

3. DIHYDRATE PROCESSES 157

I. Principles of Design and Operation	159
<i>W. A. Lutz and C. J. Pratt</i>	
A. Introduction	159
B. Raw Materials	161
C. General Design Principles for Phosphoric Acid Plants	169
D. Capital and Operating Costs	208
References	210
II. Commercial Processes	213
A. Dorr-Oliver	213
<i>R. L. Kulp and D. W. Leyshon</i>	
References	239
B. Fisons	241
<i>S. M. Janikowski</i>	
C. Prayon	253
<i>A. V. Slack</i>	
References	258
D. PSG-UCB	259
<i>Jean Roubinet</i>	
E. Singmaster and Breyer	273
<i>Robert L. Somerville and Roman Chelminski</i>	
F. Taki	279
<i>Keiji Kaji</i>	
References	284

4. HEMIHYDRATE AND ANHYDRITE PROCESSES	285
I. Hemihydrate-Dihydrate Processes in Japan	287
A. General Description	287
<i>Keiichi Murakami and Shoichiro Hori</i>	
References	297
B. Mitsubishi Process	299
<i>Hiroshi Takeuchi and Ikutaro Tayama</i>	
References	306
C. Nissan Process	307
<i>Taiji Yasuda and Mitsuya Miyamoto</i>	
References	320
D. NKK (Nippon Kokan Kabushiki Kaisha) Process	321
<i>Kazuo Shindo and Yoshibumi Harada</i>	
II. Hemihydrate and Anhydrite Processes in Europe	331
<i>P. M. R. Versteegh and J. T. Boontje</i>	
A. History	332
B. Physical Considerations	342
C. Plant Practice	347
D. Recent Developments	353
References	360
III. Singmaster and Breyer Hemihydrate-Dihydrate Process	363
<i>Roman Chelminski and Robert L. Somerville</i>	
References	368
IV. Hemihydrate by the Foam Process	369
<i>J. G. Getsinger</i>	
A. Introduction	369
B. Description of the Foam Process	370
C. Summary	382
Reference	382
V. Use of Surface-Active Agents in the Hemihydrate Process	383
<i>Keiji Kaji</i>	
Reference	386

VI. Use of Strong Sulfuric Acid in the Anhydrite Process	387
A. Davison Clinker Process	387
<i>G. L. Bridger</i>	
References	393
B. Fuming Sulfuric Acid Process	395
<i>J. M. Potts</i>	
References	404
 5. SEPARATION OF CALCIUM SULFATE	 405
I. Principles of Filter Design and Operation	407
<i>P. Moraillon, J. F. Gielly, and B. Bigot</i>	
A. History of Calcium Sulfate Separation	408
B. Theoretical Considerations in Filtration	410
C. Experimental Studies	413
D. Horizontal Vacuum Filters	425
E. Ancillary Equipment	433
F. Operating Conditions	435
G. Conclusions	441
References	441
II. Commercial Filters	443
A. Bird-Prayon	443
<i>J. T. Roos</i>	
B. Giorgini	461
<i>John G. Kronseder and Richard L. Kulp</i>	
C. Landskrona	473
<i>Rolf Nordengren</i>	
References	480
D. Lurgi	481
<i>Walter Blumrich</i>	
References	490
E. UCEGO	491
<i>Jean Roubinet</i>	
Reference	501