

Contents

AUTHORS' PREFACE	vii
FOREWORD BY SIR HARRY MELVILLE, F.R.S.	xi
LIST OF PLATES	xix
CHAPTER 1. INTRODUCTION	
1.1 Introduction.	1
1.2 Historical Background.	2
1.3 Types of Solid Polyurethane Elastomers. <i>Linear Polyurethanes – Castable Polyurethanes – Millable Polyurethanes – Thermoplastic Polyurethanes – Cellular Polyurethanes – Sprayable Polyurethanes – Poromeric Polyurethanes – Spandex Fibres.</i>	5
1.4 Solid Polyurethane Elastomer Market.	9
References.	12
CHAPTER 2. CHEMISTRY OF SOLID POLYURETHANE ELASTOMERS	
2.1 Introduction.	13
2.2 Reactions of Isocyanates. <i>Compounds Containing OH Groups – Compounds Containing NH Group – Isocyanate Dimers and Trimers – Carbodiimide Formation – Miscellaneous Reactions.</i>	13
2.3 Polymer Formation <i>Hydroxyl-diisocyanate Systems – Hydroxyl-diisocyanate-diamine Systems – One-shot Systems – Bischloroformate Process.</i>	21
2.4 Reaction Rates. <i>Effect of Isocyanate Structure – Effect of Polyol Structure – Effect of Temperature – Effect of Catalysts.</i>	25
2.5 Effect of Structure on Properties. <i>Molecular Weight and Crosslinking – Chemical Group Structure.</i>	38
2.6 Practical Polyurethane Systems.	57
References.	61

CHAPTER 3.	MANUFACTURE OF RAW MATERIALS	
3.1	Polyesters.	64
3.2	Polyethers.	66
3.3	Diisocyanates.	68
3.4	Glycols.	71
3.5	Diamines.	72
	References.	72
CHAPTER 4.	PHYSIOLOGICAL EFFECTS	
4.1	Isocyanates.	73
	<i>Tolylene Diisocyanate – 1,5-Naphthalene Diisocyanate – 4,4'-Diphenylmethane Diisocyanate – 1,6-Hexamethylene Diisocyanate – General – Animal Toxicity Studies.</i>	
4.2	Polyesters and Glycols.	79
4.3	Diamines.	79
4.4	Precautions necessary in the Handling of Raw Materials.	79
	<i>Isocyanates – Spillages on Floors – Skin and Eye Contamination – Polyesters and Polyethers – Glycols – Diamines – Disposal of Waste – General.</i>	
	References.	82
CHAPTER 5.	ANALYTICAL PROCEDURES	
5.1	General Analytic Methods.	84
	<i>Diisocyanates – Determination of Diisocyanates in the Atmosphere – Polyesters and Polyethers.</i>	
5.2	Analysis of Polyurethane Polymers.	92
	<i>Rapid Chemical Analysis – Infra-Red Spectroscopy – Nuclear Magnetic Resonance – Chromatography.</i>	
5.3	General.	101
	References.	102
CHAPTER 6.	CAST POLYURETHANES	
6.1	Introduction.	103
6.2	Methods of Manufacture.	104
	<i>Unstable Prepolymer Systems (Vulkollan) – Stable Prepolymer Systems – One-Shot Systems.</i>	

CONTENTS

xv

6.3	Vulkollan. <i>Raw Materials – Manufacture of Vulkollan – Additives – Water Cross-linked Vulkollan – Cellular Vulkollan – Sprayable System.</i>	106
6.4	Adiprene. <i>Raw Materials – Processing of Adiprene – Processing Variables – Cellular Adiprene.</i>	122
6.5	Other Prepolymer Systems. <i>Castomer A4 and A7 – Conathane – Cyanaprene – Formrez – Multrathane – Solithane – Vibrathane – General.</i>	136
6.6	One-shot Polyurethane Systems. <i>Wyandotte Chemical Corporation – The Upjohn Company.</i>	146
	References.	150

CHAPTER 7. MILLABLE POLYURETHANES

7.1	General Considerations.	153
7.2	Diisocyanate Cured Systems. <i>Urepan 600 – Processing – Properties.</i>	154
7.3	Peroxide-Cured Systems. <i>General – Curing Conditions – Effect of Fillers – Combined Peroxide and Diisocyanate Cures.</i>	162
7.4	Sulphur-Cured Systems.	170
	References.	178

CHAPTER 8. THERMOPLASTIC POLYURETHANES

8.1	General. <i>Linear Polyurethanes – Partially Cross-linked Thermoplastics.</i>	179
8.2	Processing Techniques <i>Injection Moulding – Extrusion – Calendering – Solution Applications – Miscellaneous Processing Techniques.</i>	187
8.3	Properties.	197
	References.	197

CHAPTER 9. ADDITIONAL MANUFACTURING DETAILS

9.1	Tooling Design. <i>Cast Polyurethanes – Millable and Thermoplastic Polyurethanes – Shrinkage.</i>	199
9.2	Mould Lubrication and Cleaning.	202

9.3	Machining.	203
9.4	Rejects and Quality of Control. <i>Reject Levels and Material Utilization.</i>	204
9.5	Re-Use of Scrap Material.	205

CHAPTER 10. PROPERTIES

10.1	General Stress-Strain Properties. <i>Introduction – Elastic Moduli of Polyurethanes.</i>	207
10.2	General Mechanical Properties. <i>Resilience, Hysteresis and Damping – Tear Strength and Abrasion Resistance – Coefficient of Friction.</i>	215
10.3	Environmental Properties. <i>High Temperature – Low Temperature – Hydrolytic Stability – Chemical Resistance – Resistance to Radiation.</i>	225
10.4	Electrical Properties	243
	References.	246

CHAPTER 11. APPLICATIONS

11.1	Introduction.	247
11.2	Solid Tyres and Rollers. <i>Industrial Truck Tyres – Overhead Cranes – Rotary Screen Plant – Pulleys – Rollers.</i>	249
11.3	Automotive Industry. <i>Flexible Gaiters – Gear Change Levers – Miscellaneous Uses.</i>	257
11.4	Sealing Applications. <i>Pneumatic and Hydraulic Seals – Miscellaneous Sealing Applications.</i>	260
11.5	Metal Forming. <i>Press-Brake Forming – Bulging and Drawing – Piercing and Blanking.</i>	264
11.6	Mining and Quarrying.	268
11.7	General Engineering Applications. <i>Aircraft Industry – Textile Machinery – Shoes and Shoe Machinery – Paper-making and Printing.</i>	269
11.8	Miscellaneous Industries.	272
11.9	Blocks and Sheets.	273
11.10	Cellular Polyurethanes.	274
11.11	Sprayable Polyurethanes.	276
	References.	277

CONTENTS

xvii

CHAPTER 12. ECONOMICS

12.1	Economics of Manufacture.	278
12.2	Economics of Selling.	284
12.3	Future Cost Trends.	285

CHAPTER 13. FUTURE DEVELOPMENTS

13.1	New Starting Materials. <i>Polyols – Diisocyanates.</i>	286
13.2	General Purpose Polyurethanes. <i>Elastomeric Materials – Structural Materials.</i>	295
	References.	300

APPENDIX 1.	Trade names of polyurethane elastomers and intermediates.	301
-------------	---	-----

APPENDIX 2.	Hardness scale for elastomers.	305
-------------	--------------------------------	-----

AUTHOR INDEX		309
--------------	--	-----

SUBJECT INDEX		313
---------------	--	-----