Contents to Volume 1

Preface XXXVII
List of Contributors to the Second Edition XXXIX

1 Introduction 1
1.1 Paper and Board Today 1
  Herbert Holik
1.2 Paper and Board Manufacturing – an Overview 3
1.3 Economic Aspects 9
  Thomas Moldenhauer and Gert-Heinz Rentrop*
1.4 Historical Background and General Aspects 13
  Peter F. Tschudin
   1.4.1 Introduction 13
   1.4.2 Precursors of Paper 14
     1.4.2.1 Tapa (Bark cloth) 14
     1.4.2.2 Felt 14
   1.4.3 Paper 16
     1.4.3.1 Invention of Paper 16
     1.4.3.2 Chinese Paper 16
     1.4.3.3 The Eastern Spread of Papermaking 17
     1.4.3.4 The Spread of Papermaking into Central and Southern Asia 17
     1.4.3.5 Arab Paper 18
     1.4.3.6 Medieval European Paper 18
     1.4.3.7 Mechanization and Industrialization 19
     1.4.3.8 Paper Machines 21
     1.4.3.9 Pulping and Sizing 21
     1.4.3.10 From Industrialization to Automation and Globalization: Technical and Economic Trends of the Nineteenth and Twentieth Centuries 23
     1.4.4 Historical Watermarking and Security 24

† Deceased.
* Contributed to the First Edition.
1.5 A Philosophy of Papermaking: Life Lessons on the Formation of Paper and People 26

Wilhelm Kufferath von Kendenich

1.5.1 Fibers as Individuals 26
1.5.2 Paper as a Social Construct 27
1.5.3 Fiber Preformation and Human Training 27
1.5.4 Into the World of Turbulence 27
1.5.5 Flocs and Vicissitudes 28
1.5.6 Fibers Ready for the World, Part 1 28
1.5.7 Sheet Formation as the Basis of the Fiber’s Society 29
1.5.8 Fibers Ready for the World, Part 2 29
1.5.9 In Summary – Toward the End 30

References 30

Further Reading for Section 1.3 31
Further Reading for Section 1.5 31

2 Fibrous Materials for Paper and Board Manufacture 33

2.1 Overview 33

Jürgen Blechschmidt and Sabine Heinemann

2.2 Chemical Pulp 34

Sabine Heinemann and Jürgen Blechschmidt

2.2.1 Introduction 34
2.2.2 Wood Preparation for Pulping Processes 36
2.2.3 Sulfate Process 38
2.2.3.1 Cooking 39
2.2.3.2 Regeneration of Spent Cooking Liquor 41
2.2.4 Sulfite Pulp 42
2.2.5 Bleaching of Chemical Pulp 44
2.2.6 Semimechanical Pulp 44
2.2.7 Properties of Chemical Pulps 45
2.2.8 Properties of SemiMechanical Pulps 46

2.3 Mechanical Pulp 47

2.3.1 Introduction 47
2.3.2 The Grinding Process 48
2.3.3 The Refiner Process 50
2.3.3.1 Refining Principles 50
2.3.3.2 Mechanical, Thermal, and Chemical Impacts in the Refiner Process 51
2.3.3.3 Machines and Aggregates for the Refiner Process 53
2.3.4 Mechanical Pulp Processing 53
2.3.5 Mechanical Pulp Bleaching 54
2.3.6 Properties of Mechanical Pulp 56

2.4 Recovered Paper, Recycled Fibers 59

Hans-Joachim Putz

2.4.1 Role of Recovered Paper in the Paper and Board Industry 59
2.4.2 Main Definitions for Statistics 61
2.4.3 Utilization Rates for Different Paper Grades 63
2.4.4 Resources of Recovered Paper 65
2.4.5 Lists for Recovered Paper Grades 66
2.4.6 Use of Recovered Paper Grades 68
2.4.7 Requirements of Paper Products with Respect to Recyclability 69
2.4.7.1 Deinkability 72
2.4.7.2 Removability of Adhesives Applications from Graphic Paper Products 76
2.4.7.3 Removability of Adhesives Applications from Packaging Products 80
2.4.8 Multiple Paper Recycling 81
2.5 Wood Pulp Fiber Suspensions 85

Geoffrey G. Duffy
2.5.1 Introduction 85
2.5.2 Flocculation 86
2.5.3 The Flow of Wood Pulp Fiber Suspensions 87
2.5.4 The Mechanisms of Flow 88
2.5.4.1 Sub-Regime Zero–A 90
2.5.4.2 Sub-Regime A–B 90
2.5.4.3 Sub-Regime B–C 91
2.5.4.4 Sub-Regime D–F 92
2.5.4.5 Sub-Regime F–G 92
2.5.4.6 Sub-Regime H–I 93
2.5.4.7 Sub-Regime I–J and out to K 93
2.5.4.8 Some Differences with Mechanical Pulps 94
2.5.4.9 Flow of Fiber Suspensions in Small Diameter Pipes, Holes, Slots, and Gaps 94
2.5.4.10 The Effect of Increasing Liquid Viscosity on Fiber Suspension Flow 96
2.5.4.11 Nonsteady State Fiber Suspension Flow (Viscoelastic Suspension Behavior) 96
2.5.5 The Significance of Fiber Reflocculation after Dispersion 98
2.5.6 Medium Consistency MC Flow 98
2.5.7 Pulp Flow in Open Channels 100
2.5.8 Practical Design Methods for Determining the Pipe Friction Loss of Industrial Piping Systems 100
2.5.8.1 The Stepwise Approximation Method 101
2.5.8.2 Dimensional Analysis Single-Curve Method 103
2.5.9 Mechanistic-Based Models 103

References 104

3 Mineral Fillers in Papermaking 109

Maximilian Laufmann
3.1 History of the Use of Mineral Fillers in Papermaking 109
3.2 Global Mineral Consumption in the Paper and Board Industry 110
3.3 Why Use Mineral Fillers in Paper and Board? 111
3.4 Filler Loading Increase via Surface Application 115
3.5 Choice of Fillers 116

3.6 Characterization of Fillers 117

3.6.1 Brightness 117

3.6.2 Refractive Index 118

3.6.3 Particle Morphology 120

3.6.4 Particle Size and Particle Size Distribution 120

3.6.5 Specific Surface Area 122

3.6.6 Particle Charge 123

3.6.7 Abrasiveness 123

3.7 Main Mineral Fillers 124

3.7.1 Kaolin (Hydrous) 124

3.7.2 Natural Ground Calcium Carbonate (GCC) 127

3.7.3 Precipitated Calcium Carbonate (PCC) 130

3.7.4 Talc 133

3.7.5 Gypsum (Calcium Sulfate) 135

3.8 Specialty Filler Pigments 136

3.8.1 Calcined Clay 136

3.8.2 Titanium Dioxide 137

3.8.3 Amorphous Silicates and Silica 138

3.8.4 Aluminum Trihydrate ATH (Hydrated Alumina) 138

3.8.5 Modified Natural Ground Calcium Carbonate MCC 138

3.8.6 Amorphous Precipitated Calcium Carbonate 139

3.8.7 Other Fillers or Specialty Pigments 139

3.9 Preservation of Pigment slurries 140

Silvia Hubschmid

3.10 Outlook 141

Maximilian Laufmann

Acknowledgment 142

References 142

4 Functional Chemicals 145

4.1 Overview 145

Roland Pelzer

4.2 Starches in Papermaking 146

Johan Schrijver

4.2.1 General Remarks 146

4.2.2 Sources of Starch 148

4.2.3 Structural Unit and Starch Processing 149

4.2.4 Chemical Composition of Starches 153

4.2.5 Chemistry, Modification, and Conversion Technology 153

4.2.6 Applications 155

4.2.6.1 Wet End 155

4.2.7 Spraying Starch 157

4.2.8 Surface Sizing 157

4.2.9 Coating 159
4.3 Colorants 160

Klaus-Peter Kreutzer

4.3.1 General 160
4.3.2 Origin of Color 161
4.3.3 Colorant Classes 162
4.3.4 Dyeing Mechanism 162
4.3.4.1 Substantivity and Affinity 164
4.3.5 Direct Dyes 164
4.3.5.1 Anionic Direct Dyes 165
4.3.5.2 Cationic Direct Dyes 168
4.3.6 Basic Dyes 168
4.3.7 Sulfur Dyes 169
4.3.8 Acid Dyes 171
4.3.9 Pigments 171
4.3.9.1 Inorganic Pigments 171
4.3.9.2 Organic Pigments 172
4.3.10 Dosing of Dyes and Pigments 173
4.3.10.1 Stock Dyeing 174
4.3.10.2 Surface Coloration 176
4.3.10.3 Coating Coloration 176
4.3.11 Technical Properties of Coloration 176
4.3.11.1 Colorimetry 176
4.3.11.2 Light Fastness 177
4.3.11.3 Bleed Fastness 177
4.3.11.4 Other Properties 178
4.3.12 Ecology/Toxicology 178

4.4 Optical Brightening Agents (OBA), Fluorescent Whitening Agents (FWAs) 178

Bernhard Hunke and Günter Klug

4.4.1 Introduction 178
4.4.2 Basics about Whiteness 179
4.4.3 The CIE Whiteness 180
4.4.4 Fluorescent Whitening Agents 181
4.4.4.1 Structural Formula 182
4.4.4.2 Types of Fluorescent Whitening Agents 183
4.4.4.3 Hue of Fluorescence 184
4.4.5 Factors Influencing the Performance of FWAs 184
4.4.5.1 Mill Water 184
4.4.5.2 Fiber Materials 185
4.4.5.3 Fillers (White Pigments) 186
4.4.5.4 Acid and Alum 187
4.4.5.5 Sizing 187
4.4.5.6 Cationic Additives 187
4.4.5.7 Greening/Graying Limit 188
4.4.5.8 Light Fastness 190
4.4.6 Application of FWAs 190
4.4.6.1 Addition of FWAs to the Stock 190
4.4.6.2 Addition of FWAs via Size Press 191
4.4.6.3 Addition of FWAs to Pigment Coating Mixtures 191
4.4.7 New Developments 191

4.5 Sizing Agents 192

Jochen Hoffmann

4.5.1 Fundamental Aspects of Sizing of Paper 192
4.5.2 General Features of Sizing Agents 194
4.5.3 Rosin Sizes 195
4.5.3.1 Raw Materials and Chemical Modifications 195
4.5.3.2 Delivery and Application Forms 196
4.5.3.3 Rosin Sizing and Aluminum 196
4.5.3.4 Features of Rosin Sizing 197
4.5.3.5 Application of Rosin Sizes 197
4.5.4 Alkyl Ketene Dimer (AKD) 198
4.5.4.1 AKD Wax 198
4.5.4.2 AKD Dispersions 198
4.5.4.3 AKD Reactions/Features of AKD Sizing 199
4.5.4.4 Application of AKD Sizes 200
4.5.5 Alkenyl Succinic Anhydride (ASA) 201
4.5.5.1 Preparation and Chemical Properties of ASA 201
4.5.5.2 Preparation of ASA Size Emulsions 203
4.5.5.3 Features of ASA Sizing 203
4.5.5.4 Application of ASA Sizes 204
4.5.6 Comparison of Internal Sizing Systems – Rosin, AKD, and ASA 204
4.5.7 Polymeric Sizing Agents 204
4.5.7.1 Styrene-Maleic Anhydride Copolymers (SMAs) 204
4.5.7.2 Styrene-Acrylic Ester Copolymers (SAEs) 206

4.6 Wet-Strength Resins (WSR) and Dry Strength Resins (DSR) 207

Gunnar Kramer and Dominik Stumm

4.6.1 Introduction 207
4.6.2 Theory of Paper Strength 208
4.6.2.1 Models to Explain Strength Increase 208
4.6.2.2 How Dry Strength Additives Can Improve Paper Strength 209
4.6.2.3 How Wet-Strength Additives Can Retain Paper Strength 210
4.6.3 Dry Strength Additives (DSAs) 211
4.6.3.1 Cellulose Derivatives 211
4.6.3.2 Synthetic Dry Strength Additives 212
4.6.3.3 Application 213
4.6.4 Wet-Strength Resins (WSA) 214
4.6.4.1 Overview 214
4.6.4.2 Melamine–Formaldehyde Resins 216
4.6.4.3 Urea–Formaldehyde Resins 217
4.6.5 Epoxidized Polyamide Resins 218
4.6.5.1 Glyoxalated Polyacrylamide Resins 223
4.6.6 Other Wet-Strength Resins 224
4.7 Properties of Specialty Papers and Related Chemical Additives 226
Roland Pelzer
4.7.1 Tissue 226
4.7.2 Parchment and Barrier Papers 227
4.7.3 NCR-Paper (Noncarbon Required) 229
4.7.4 Thermographic Paper 230
4.7.5 Flame-Retardant Paper 231
4.7.6 More Specialty Papers at a Glance 231
References 233
Further Reading for Section 4.2 233
Further Reading for Section 4.5 234
Further Reading for Section 4.6 234

5 Coating Colors – Components, Make Down, and Properties 235
Reinhard Sangl, Werner J. Auhorn*, Thoralf Gliese*, and Werner Kogler†

5.1 Overview 235
5.1.1 General Aspects 235
5.1.2 Market Situation and Future Trends 237
5.2 Coating Color Components 238
5.2.1 Coating Pigments 238
5.2.1.1 Pigment Characteristics: Aspect Ratio, Particle Size, and Particle Size Distribution 239
5.2.1.2 Main Coating Pigments 242
5.2.1.3 Special Pigments 245
5.2.2 Dispersants 247
5.2.3 Binders 250
5.2.3.1 Derivatives of Natural Polymer Binders 252
5.2.3.2 Synthetic Latex Binders 253
5.2.4 Additives Influencing the Properties and Processing of the Coating Color 254
5.2.4.1 Cobinders 255
5.2.4.2 Thickeners 258
5.2.4.3 Associative Thickeners 260
5.2.4.4 Lubricants 263
5.2.4.5 Defoamers/Deaerators 265
5.2.5 Additives Influencing the Quality and Printability of the Paper Surface 266
5.2.5.1 Cobinders and Thickeners 266
5.2.5.2 Insolubilizers 266
5.2.5.3 Tinting (Shading) 268
5.2.5.4 Optical Brightening Agents (OBA) 268
5.2.5.5 OBA Carrier 270
5.2.5.6 Influencing Opacity 270
5.2.5.7 Influencing Smoothness and Gloss 270
5.2.5.8 Influencing Porosity, Print Gloss, and Glueability 270
5.2.5.9 Influencing Printability 271
5.3 Properties of Coating Colors 272
5.3.1 Coating Color Formulations 272
5.3.2 Important Coating Color Properties 274
5.3.2.1 Viscosity 274
5.3.2.2 Viscoelasticity 275
5.3.2.3 Water Retention 276
5.3.2.4 Solids Content 277
5.3.2.5 pH 277
5.3.2.6 Screening Residue 277
5.3.2.7 Bacteria Level 277
5.4 Coating Color Preparation 278
5.4.1 General Aspects of Coating Kitchen Set Up 278
5.4.2 Dispersing of Pigments 279
5.4.3 Processing of Binders 281
5.4.3.1 Latexes 281
5.4.3.2 Starch 281
5.4.3.3 Other Binders 283
5.4.3.4 Additives 284
5.4.4 Tanks 284
5.4.5 Screens and Filters 285
5.4.6 Degassing of Coating Colors 285
5.4.6.1 Vacuum Degassing for Curtain Coating 287
5.4.7 Batch Preparation of Coating Colors 287
5.4.8 Continuous Coating Color Preparation 287
5.4.9 Coating Color Supply Systems for Coaters 288

Further Reading 290

6 Process Chemicals 291
6.1 Overview 291
   Roland Pelzer
6.2 Aluminum Compounds 291
   Hubert Dörrer
6.3Retention Aids and Drainage Accelerators 295
   Jan-Luiken Hemmes
6.3.1 Functionality 295
6.3.2 Chemistry 296
6.3.3 Application 298
6.3.4 Trends 299
   Abbreviations 300
6.4 Fixatives and Charge Control 300
   Antonius Moormann-Schmitz
6.4.1 Overview 300
<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.4.2</td>
<td>Treatment Strategies for Interfering Substances</td>
<td>300</td>
</tr>
<tr>
<td>6.4.3</td>
<td>Chemistry of Fixing Agents</td>
<td>302</td>
</tr>
<tr>
<td>6.4.4</td>
<td>Fixation of Dissolved Substances</td>
<td>303</td>
</tr>
<tr>
<td>6.4.5</td>
<td>Treatment of Particular Substances</td>
<td>303</td>
</tr>
<tr>
<td>6.4.6.1</td>
<td>Tests with an Optical Laser Pitch Counter</td>
<td>305</td>
</tr>
<tr>
<td>6.4.6.2</td>
<td>Results</td>
<td>306</td>
</tr>
<tr>
<td>6.4.7</td>
<td>Charge Control with Cationic Polymers</td>
<td>307</td>
</tr>
<tr>
<td>6.5</td>
<td><strong>Deposit Control and Biocides</strong></td>
<td>309</td>
</tr>
<tr>
<td></td>
<td><em>Ute Höötmann</em></td>
<td></td>
</tr>
<tr>
<td>6.5.1</td>
<td>Introduction</td>
<td>309</td>
</tr>
<tr>
<td>6.5.2</td>
<td>Some Basics of Microbiology in PaperMaking</td>
<td>309</td>
</tr>
<tr>
<td>6.5.3</td>
<td>Impairments Caused by Microorganisms</td>
<td>310</td>
</tr>
<tr>
<td>6.5.4</td>
<td>Prevention: What Can Be Done in the Run-Up?</td>
<td>312</td>
</tr>
<tr>
<td>6.5.5</td>
<td>Dispersants, Biocides, Cleaners: The Deposit Control Concept</td>
<td>312</td>
</tr>
<tr>
<td>6.5.6</td>
<td>Survey of Deposit Control Applications</td>
<td>314</td>
</tr>
<tr>
<td>6.5.7</td>
<td>Regulatory Affairs</td>
<td>315</td>
</tr>
<tr>
<td>6.5.8</td>
<td>Coordinated Approach: A Deposit Control Project</td>
<td>315</td>
</tr>
<tr>
<td>6.6</td>
<td><strong>Defoamers and Deaerators</strong></td>
<td>316</td>
</tr>
<tr>
<td></td>
<td><em>Christoph Blickenstorfer</em></td>
<td></td>
</tr>
<tr>
<td>6.6.1</td>
<td>Appearance of Air along the Process and Sources of Surface-Active</td>
<td>316</td>
</tr>
<tr>
<td></td>
<td>Substances to Stabilize Foam</td>
<td></td>
</tr>
<tr>
<td>6.6.2</td>
<td>Disturbances Caused by High Foam and Air Content</td>
<td>319</td>
</tr>
<tr>
<td>6.6.3</td>
<td>Defoaming and Deaeration Chemicals</td>
<td>319</td>
</tr>
<tr>
<td>6.6.4</td>
<td>Application of Defoamer and Deaerator and Measurement of Air/Gas</td>
<td>321</td>
</tr>
<tr>
<td>6.7</td>
<td><strong>Chelating Agents</strong></td>
<td>322</td>
</tr>
<tr>
<td></td>
<td><em>Gunnar Kramer</em></td>
<td></td>
</tr>
<tr>
<td>6.8</td>
<td><strong>Additives for Repulping</strong></td>
<td>325</td>
</tr>
<tr>
<td>6.9</td>
<td><strong>Deinking Additives</strong></td>
<td>327</td>
</tr>
<tr>
<td>6.10</td>
<td><strong>Cleaning Agents and Fabric Conditioning</strong></td>
<td>330</td>
</tr>
<tr>
<td></td>
<td><em>Kathrin Otto and Christoph Blickenstorfer</em></td>
<td></td>
</tr>
<tr>
<td>6.10.1</td>
<td>Contaminations and Factors for a Successful Cleaning Result</td>
<td>330</td>
</tr>
<tr>
<td>6.10.2</td>
<td>Cleaning Agents</td>
<td>331</td>
</tr>
<tr>
<td>6.10.3</td>
<td>Conditioning Agents</td>
<td>333</td>
</tr>
<tr>
<td>6.10.4</td>
<td>Cleaning of Machinery and Water Circuit</td>
<td>334</td>
</tr>
<tr>
<td>6.10.5</td>
<td>Cleaning and Conditioning of Paper Machine Clothing</td>
<td>334</td>
</tr>
<tr>
<td>6.11</td>
<td><strong>Internal Water and Effluent Treatment</strong></td>
<td>336</td>
</tr>
<tr>
<td></td>
<td><em>Arne Hörsken, Andreas Opalka, and Stefan Nierhoff</em></td>
<td></td>
</tr>
<tr>
<td>6.11.1</td>
<td>Water Systems in Paper and Board Mills</td>
<td>336</td>
</tr>
<tr>
<td>6.11.2</td>
<td>Water: Chemical and Physical Parameters</td>
<td>337</td>
</tr>
<tr>
<td>6.11.3</td>
<td>Flocculation</td>
<td>338</td>
</tr>
<tr>
<td>6.11.4</td>
<td>Potential Problems by Use of Acidic Aluminum Salts in Water Systems</td>
<td>341</td>
</tr>
<tr>
<td>6.11.4.1</td>
<td>Use of Aluminum Sulfate</td>
<td>341</td>
</tr>
</tbody>
</table>
6.11.4.2 Use of Aluminum (Hydroxide) Chloride 341
6.11.4.3 Use of Aluminum Nitrate 342
6.11.5 Freshwater Treatment 342
6.11.6 Internal Water Treatment 343
6.11.7 Wastewater Treatment in Paper and Board Manufacturing 343
6.12 Interactions of Chemical Additives 344
Roland Pelzer
References 348
Further Reading for Section 6.5 349

7 Unit Operations 351
7.1 Overview 351
Herbert Holik and Harald Heß
7.1.1 Objectives and General Solutions 351
7.1.1.1 Systems 351
7.1.1.2 Unit Processes 352
7.1.2 Separation Processes 353
7.1.3 Unit Processes in Stock Preparation Systems 354
7.1.4 Definitions in Separation Processes 355
7.2 Fiber Materials Feeding 359
Harald Heß and Herbert Holik
7.2.1 Overview 359
7.2.2 Virgin Pulp 359
7.2.3 Recovered Paper 359
7.3 Disintegration 362
Harald Heß, Herbert Holik, and Wolfgang Müller
7.3.1 Overview and Theoretical Aspects 362
7.3.1.1 Objectives and General Solutions 362
7.3.1.2 Some Basics 362
7.3.1.3 Steps in Disintegration 363
7.3.2 Machines for Primary Disintegration 364
7.3.2.1 Pulpers 364
7.3.3 Machines for Secondary Disintegration 371
7.3.3.1 Deflaker 372
7.3.3.2 Disk Screen 372
7.3.4 Operational Principles and Technological Results 373
7.3.4.1 Continuous and Discontinuous Disintegration 373
7.3.4.2 Flake Content in Primary Disintegration 374
7.3.4.3 Flake Reduction in Primary and Secondary Disintegration 376
7.3.4.4 Disintegration of a Stock Containing Plastic Foils 376
7.4 Screening 377
Harald Heß and Herbert Holik
7.4.1 Overview and Principle Aspects 377
7.4.1.1 Objective 377
7.4.1.2 Principle Solution 378
7.4.1.3 Application 379
7.4.2 Screening Theory – Some Remarks 379
7.4.2.1 Probability of Separation 379
7.4.2.2 Flow Approaching the Screen Openings 380
7.4.2.3 Flow through the Screen Openings 382
7.4.2.4 Flow in the Accept Area 382
7.4.3 Screening Equipment and Systems 384
7.4.3.1 Machine and Operational Parameters Influencing Screening Effect 384
7.4.3.2 Coarse Screening 385
7.4.3.3 Fine Screening 388
7.4.4 Operational Aspects and Technological Results 392
7.4.4.1 Deflaking Effect 392
7.4.4.2 Screening Gap 392
7.4.4.3 Thickening Factor 394
7.4.4.4 Screening Efficiency 394
7.5 Centrifugal Cleaning 397
7.5.1 Overview 397
7.5.1.1 Objectives 397
7.5.1.2 Principle Solution 398
7.5.1.3 Applications 398
7.5.2 Theoretical Aspects 399
7.5.2.1 Basics of Hydrocyclones 399
7.5.3 Cleaner Types and Systems 401
7.5.3.1 General Remarks 401
7.5.3.2 High Consistency (HC) Cleaners and Systems 403
7.5.3.3 Low Consistency (LC) Cleaners and Systems 403
7.5.3.4 Cleaner with Rotating Housing 407
7.5.4 Operational and Technological Results 408
7.5.4.1 Overview on Design and Operational Conditions 408
7.5.4.2 Typical Technological Results 408
7.6 Selective Flotation 411
7.6.1 Overview and Theoretical Aspects 411
7.6.1.1 Objectives 411
7.6.1.2 Principle Solutions 412
7.6.1.3 Main Prerequisites for Good Flotation Results 412
7.6.1.4 Two-Phase Flow in Flotation 412
7.6.2 Chemistry in Flotation 414
7.6.2.1 Fatty Acid Soap 414
7.6.2.2 Synthetic Surfactants 416
7.6.2.3 Silicone Derivatives 416
7.6.3 Equipment and Systems 417
7.6.3.1 Flotation Cells 417
7.6.3.2 Flotation Systems and Flotation Selectivity 420
7.6.3.3 Foam Handling 421
7.6.4 Operating Conditions and Technological Results 422
7.6.4.1 Operating Conditions 422
7.6.4.2 General Technological Results 423

7.7 Nonselective Flotation (Dissolved Air Flotation DAF) 426
7.7.1 Overview and Theoretical Aspects 426
7.7.1.1 Objectives 426
7.7.1.2 Principle Solution 426
7.7.1.3 Solubility of Air in Water 427
7.7.2 Equipment 427
7.7.3 Technological Aspects 429
7.7.3.1 Cleanliness 429
7.7.3.2 Sludge Handling 430

7.8 Fractionation 430
7.8.1 Objectives and Principle Solutions 430
7.8.2 Basics 430
7.8.3 Machinery 432
7.8.4 Operational and Technological Remarks 433

7.9 Dewatering 434
7.9.1 Overview and Theoretical Aspects 434
7.9.1.1 Objectives 434
7.9.1.2 Basics and Principle Solutions 435
7.9.2 Machinery 436
7.9.2.1 Drum Thickeners 436
7.9.2.2 Belt Filters, Twin-Wire Presses 437
7.9.2.3 Disk Thickener 437
7.9.2.4 Disk Filters 438
7.9.2.5 Screw Presses 441

7.10 Washing 442
7.10.1 Overview and Theoretical Background 442
7.10.2 Machinery 443
7.10.3 Technological Aspects 444

7.11 Mixing and Storing 446
7.11.1 Overview 446
7.11.2 Mixing 447
7.11.3 Storing 448
7.11.3.1 Storing at Low Consistencies 448
7.11.3.2 Storing at Medium and High Consistencies 449

7.12 Bleaching of Secondary Fibers 451
7.12.1 Objectives and Principles 451
7.12.2 Peroxide Bleaching 452
7.12.3 Reductive Bleaching 453

7.13 Refining

Herbert Holik and Oliver Lüdtke

7.13.1 Overview 454
7.13.1.1 Objectives 454
9.2.3 Boundaries and Ownership Alternatives 496
9.2.4 The Urban Mill Model 498
9.3 Subsystems for Water, Reject, and Sludge (WSR) 499
  9.3.1 Water Subsystems 500
  9.3.2 Sludge Subsystems 500
  9.3.3 Reject Subsystems 501
9.4 Water Circuits 501
  Lucas Menke and Andrea Stetter*
    9.4.1 Introduction 501
    9.4.2 Freshwater 502
    9.4.3 Process Water 502
    9.4.3.1 Detrimental Substances 502
    9.4.4 Typical Paper Mill Water loops 503
      9.4.4.1 White Water Circuit System 504
      9.4.4.2 Water Circuit Systems in Stock Preparation 505
      9.4.4.3 Examples of Millwide Water Circuit Systems 506
      9.4.4.4 Current Limits on Circuit Closure 508
      9.4.4.5 Zero-Effluent Systems 509
9.5 Reject Systems 510
  Lucas Menke
    9.5.1 Definitions 510
      9.5.1.1 Waste 511
      9.5.1.2 Residuals 511
      9.5.1.3 Trash 511
      9.5.1.4 Reject Systems 511
    9.5.2 Types of Rejects from Different Process Stages in Stock Preparation 512
      9.5.2.1 Coarse Rejects 513
      9.5.2.2 Fine Rejects 516
    9.5.3 Technology of Reject Handling Systems 518
      9.5.3.1 Coarse Reject Handling 520
      9.5.3.2 Fine Reject Handling and Combined Systems 523
    9.5.4 Reject Conveying and Storage Equipment 525
      9.5.4.1 Reject Shredding 525
      9.5.4.2 Reject Dewatering – Reject Pressing 525
      9.5.4.3 Metal Detection and Magnetic Separation 526
      9.5.4.4 Reject Conveying Systems 526
      9.5.4.5 Reject Storage Systems 528
9.6 Sludge Dewatering Systems 528
  9.6.1 Sludge from Different Process Stages and Their Characteristics 529
    9.6.1.1 Sludges from LC Cleaners and Slotted Screens 529
    9.6.1.2 Deinking Sludges 529
    9.6.1.3 Sludge from Microflotation or Circuit Cleaning 529
    9.6.1.4 Sludges from Washing Process Stages 529
10.2.2.2 Spreader Rolls 561
10.2.2.3 Center-Supported Guide Rolls 562
10.2.3 Rolls to Affect the Paper and Board Web 562
10.2.3.1 Perforated (Open) Rolls 562
10.2.3.2 Press Rolls 567
10.2.4 Deflection Control Rolls 572
10.2.4.1 Controlled Nip Line Load Distribution 572
10.2.4.2 One-Zone Rolls 573
10.2.4.3 Multizone Rolls 573

10.3 Roll Covers and Coatings 575
Yang Shieh, Johan Einarsson, Franz Grohmann, and Norbert Gamsjäger∗
10.3.1 Objectives and Basic Design Criteria 575
10.3.2 Application and Function 577
10.3.2.1 Corrosion and Wear Protection 577
10.3.2.2 Nip Design in the Press Section 577
10.3.2.3 Release Properties 578
10.3.2.4 Nip Design in Coating and Sizing 578
10.3.2.5 Nip Design in Calenders 579
10.3.2.6 Other Applications 579
10.3.2.7 Application Overview 579
10.3.3 Materials 582
10.3.3.1 Rubber Roll Covers 582
10.3.3.2 Polyurethane Roll Covers 583
10.3.3.3 Composite Roll Covers 585
10.3.3.4 Thermal Coatings 587
10.3.3.5 Chromium Coatings 588
10.3.3.6 Thermoplastic Covers, Sleeves, and Coatings 588
10.3.3.7 Granite Rolls and Calender Paper Shafts 589

Contents to Volume 2

List of Contributors to the Second Edition XXXVII

11 Fabrics for Paper and Board Production 591
Matthias W. Schmitt

11.1 Forming Fabrics 592
Matthias Höhsl and Arved Westerkamp∗
11.1.1 Requirements 592
11.1.2 Designs and History 592
11.1.3 Fabric Design Parameters 595
11.1.4 Manufacturing Technology 596

11.2 Press Felts 598
Matthias W. Schmitt
11.2.1 Requirements 598
11.2.2 Press Felt Design and History 600
11.2.3 Manufacturing 601
11.2.4 Transfer Belts 602

11.3 Dryer Fabrics 603
  Juergen Abraham and Antony Morton∗
  11.3.1 Requirements 603
  11.3.2 Fabric Design and History 604
  11.3.3 Dryer Fabric Manufacture 605

11.4 Fabrics in Operation 606
  Matthias W. Schmitt
  11.4.1 Stretching and Guiding of Fabrics and Belts 606
  11.4.1.1 Functional Principle of the Guiding Unit 607
  11.4.1.2 Functional Principle of the Palm Unit 607
  11.4.2 Cleaning and Conditioning of Fabrics 609
  11.4.2.1 Cleaning of Forming Fabrics 611
  11.4.2.2 Cleaning of Press Felts and Transfer Belts 612
  11.4.2.3 Cleaning of Dryer Fabrics 614

11.5 Changing of Fabrics 615
  Herbert Holik and Johann Moser

References 617

Further Reading for Section 11.4 617

12 Approach Flow System 619
  Christian Bangert, Herbert Holik, and Andrea Stetter∗
  12.1 Definition and Tasks of the Approach Flow System 619
  12.2 Metering and Mixing of the Stock Components and Feed to the
     Headbox 620
  12.2.1 Metering and Mixing of the Stock Components 620
  12.2.1.1 Dosing 620
  12.2.1.2 Mixing of Stock Components 620
  12.2.2 Metering and Mixing of Thick Stock and White Water 621
  12.3 Final Cleaning and Screening 622
  12.3.1 Final Cleaning 622
  12.3.2 Final Screening 622

12.4 Air in the Papermaking Process and Its Removal 623
  12.4.1 General Overview 623
  12.4.2 Avoiding Air Intake 623
  12.4.3 Deaeration 624
  12.4.3.1 Deaeration by Gravity 625
  12.4.3.2 Deaeration by Vacuum 625
  12.4.3.3 Deaeration by Centrifugal Forces 626
  12.5 Further Aspects 628
  12.5.1 Energy Recovery from Backflows 628
  12.5.2 Engineering 629
  12.5.3 Automation 629
## Contents

12.6 **Approach Flow Design** 630

12.6.1 Approach Flow System for Graphic Paper Machines 630

12.6.2 Approach Flow System for Packaging Paper and Board Machines 631

12.6.3 Approach Flow System for Tissue Grade Machines 632

12.6.4 Approach Flow System for Specialty Paper Machines 632

**References** 634

13 **Headbox** 635

*Herbert Holik, Johann Moser, and Thomas Ruehl*

13.1 **Overview and Principle Aspects** 635

13.1.1 Objectives 635

13.1.2 Tasks and Principle Solutions 635

13.1.3 Some Basics 636

13.1.3.1 Uniform Distribution across Machine Width 636

13.1.3.2 Turbulence 636

13.1.3.3 Jet Velocity 637

13.1.3.4 Volumetric and Stock Mass Flow 638

13.1.3.5 Jet Direction 638

13.1.3.6 Pulsation Damping 638

13.2 **Historical Review** 639

13.2.1 Distribution 639

13.2.2 Suspension Acceleration, Deflocculation, and Delivery 640

13.2.3 Pulsation Elimination (for MD Basis Weight Control) 641

13.2.4 Cross Machine (CD) Control of Basis Weight and Fiber Orientation 642

13.3 **State-of-the-Art Headboxes** 642

13.3.1 Rectifier Roll Headboxes 643

13.3.1.1 General Design Features 643

13.3.1.2 Application 643

13.3.1.3 Distribution 644

13.3.1.4 Deflocculation 644

13.3.1.5 Suspension Flow, Acceleration, and Jet Formation 644

13.3.1.6 Pulsation Dampening 644

13.3.2 Hydraulic Headboxes 644

13.3.2.1 Hydraulic Headbox for Fourdrinier Wire Section 644

13.3.2.2 Hydraulic Headbox for Twin-Wire Gap Formers 647

13.3.2.3 Two-Layer Headbox 648

13.3.2.4 Secondary Headbox 649

13.3.3 Headbox with a Central Distributor Tank 650

13.4 **Influence of Operational and Design Parameters on Technological Results** 651

13.4.1 Changing Operational Parameters 651

13.4.1.1 Change of Consistency at Constant Basis Weight 651

13.4.1.2 Change of Basis Weight 651
13.4.1.3 Change of Jet Velocity and Jet Angle 651
13.4.2 Technological Dependencies 651
13.4.2.1 MD/CD Ratio of Paper Properties 651
13.4.2.2 Formation Quality 652
13.4.2.3 Nonsymmetry in z-Direction 654
13.4.2.4 CD Basis Weight Profile 654
13.4.2.5 CD Main Fiber Orientation Profile 656

References 657

14  Wire Section 659
   Herbert Holik, Johann Moser, and Thomas Ruehl
14.1 Overview and Theoretical Aspects 659
14.1.1 Objectives 659
14.1.2 Drainage and Retention 659
14.1.3 Jet Quality as a Precondition for Good Formation Results 662
14.1.4 Fiber Deposition and Orientation 662
14.1.5 Control of Flocculation Level and Dispersing in Web Formation 663
14.2 Historical Review 663
14.2.1 Fourdrinier Wire Section 663
14.2.2 Cylinder Formers 665
14.2.3 Twin-Wire Formers 665
14.2.4 Wires, Retention Aids, and Chemical Additives 666
14.3 State-of-the-Art Web Forming Designs 666
14.3.1 The Fourdrinier Wire Section 666
14.3.2 Inclined Wire 667
14.3.3 Hybrid Former 668
14.3.4 Gap Former 668
14.3.5 Cylinder Former 669
14.4 Machine Elements 670
14.5 Wires 672
14.6 Operational and Technological Aspects 672
14.6.1 General Remarks 672
14.6.2 Web-Forming and Dryness Increase Functions 673
14.6.3 Web Formation 675
14.6.4 Web Symmetry in Fines and Filler Distribution 676
14.6.5 Fiber Orientation Anisotropy in the Web 676

References 678

15  Press Section 679
   Herbert Holik, Daniel Gronych, and Joachim Henssler
15.1 Introduction 679
15.1.1 Overview 679
15.1.2 Operating Principles Governing the Press Section 679
15.2 Theoretical Aspects of Press Dewatering 681
15.2.1 Hydraulic Pressure and Fiber Structure Resistance 681
15.2.2 The Four Phases during Dewatering in the Nip 683
15.2.3 Influence of Furnish Type on Dewatering 685
15.2.4 Rewetting 686
15.2.5 Crushing 688
15.3 State-of-the-Art Press Sections 689
15.3.1 Press Designs with Roll Press Nips 689
15.3.2 Press Designs with Shoe Presses 690
15.3.2.1 The Shoe Press 690
15.3.2.2 Press Designs with Shoe Nips 691
15.3.2.3 Single-Nip Shoe Press 692
15.4 Historical Review 694
15.5 Further Approaches in Pressing 695
15.5.1 High-Intensity Pressing 696
15.5.2 Displacement Dewatering 696
15.5.2.1 Displacement Dewatering by Pressure 697
15.5.2.2 Displacement Dewatering by Vacuum 697
15.6 Operational and Technological Aspects 698
15.6.1 Dryness 698
15.6.2 CD Moisture Profiles 698
15.6.3 Felts 699
15.6.4 Web Transfer and Guiding 701
15.6.4.1 Web Transfer 701
15.6.4.2 Web Guiding 704
15.7 Impact of Wet Pressing on Paper Surface Properties 705
15.7.1 Surface Roughness 705
15.7.2 Surface Densification 707
15.7.2.1 Dewatering and Densification 707
15.7.2.2 Absorption 707
15.8 Acknowledgments 710
15.9 References 710

16 Dryer Section 713
16.1 Overview 713
16.2 Drying Principles and Basics 713
16.2.1 Drying Rate and Energy Balance 713
16.2.2 Contact Drying with Steam Heated Cylinders 715
16.2.3 Air Impingement Drying 720
16.2.4 Through Air Drying 721
16.2.5 Infrared Drying 722
16.2.6 Press Drying 723
16.2.7 Impulse Drying 723
16.2.8 Air–Water Mixture in the Mollier Diagram 723
16.3 Basics Related to Paper Drying 725
16.3.1 Drying Curve 725
16.3.2 Paper Shrinkage 727
16.3.3 Change in Wet Strength of a Paper Sheet during Drying 728
16.3.4 Paper Curl 729

16.4 Dryer Sections 730
16.4.1 Multicylinder Dryer Section 730
16.4.1.1 Types of Multicylinder Dryer Section 730
16.4.1.2 Tail Threading and Web Handling 732
16.4.1.3 Steam and Condensate Systems 735
16.4.2 Ventilation Systems 736
16.4.2.1 Pocket Ventilation 736
16.4.2.2 Dryer Hood Ventilation 737
16.4.2.3 Machine Room Ventilation 738
16.4.2.4 Heat Recovery System 738
16.4.3 Tissue Dryer Section 739
16.4.3.1 Tissue Cylinder 739
16.4.3.2 Tissue Dryer Hood 740
16.4.3.3 Through Air Dryer 740
16.4.4 Drying of Coated and Surface-Sized Paper and Board 742

References 744

17 Surface Sizing and Coating 745
Reinhard Sangl, Werner Auhorn*, Werner Kogler†*, and Martin Tietz*

17.1 Surface Sizing 745
17.1.1 Objectives of Surface Sizing 745
17.1.2 The Sizing Principle 745
17.1.3 Application of the Sizing Solution 747

17.2 Coating 747
17.2.1 Overview 747
17.2.1.1 History of Paper Coating 749
17.2.1.2 Technological Developments 750
17.2.1.3 Why Paper Is Coated 752
17.2.1.4 Requirements for Coated Paper and Board from Consecutive Processes 755
17.2.1.5 Requirements for Coating Colors from Consecutive Processes 755
17.2.2 The Process of Coating 757
17.2.2.1 Penetration and Migration 757
17.2.2.2 Absorbency and Porosity Influence Quality and Runnability 757
17.2.2.3 Means to Adapt the Coating Base 759
17.2.2.4 Properties of Base Paper in Order to Meet the Requirements of the Coating Process 760
17.2.3 Components and Properties of Coating Colors 764
17.2.3.1 Pigments 765
17.2.3.2 Binders 765
17.2.3.3 Requirements Based on Coating Color Components 767
17.2.4 Coating Color Formulations 768
17.2.4.1 Model Composition of a Coating Color 769
17.2.5 Coating Machines 772
17.2.5.1 Overview 772
17.2.5.2 Applicators 773
17.2.5.3 Typical Applications 779
17.2.6 Drying 780
17.3 Coated Paper and Board Grades 783

References 784
Further Reading 784

18 Calendering 785
Rüdiger Feldmann

18.1 Objective and General Description of the Calendering Process 785
18.2 History of Calendering 786
18.3 The Different Calender Types 789
18.3.1 Machine Calenders 789
18.3.2 Supercalenders 789
18.3.3 Soft calenders 790
18.3.4 Modern Multinip Calenders 791
18.3.5 Extended Nip Calenders 792
Jörg Rheims and Rüdiger Feldmann
18.3.6 Embossing Calenders 793
Rüdiger Feldmann
18.3.7 Friction Calenders 794
18.4 The Main Calendering Methods for Various Paper and Board Grades 795
18.4.1 Wood-Containing Paper Grades 795
18.4.1.1 Newsprint 795
18.4.1.2 SC-B/Offset and Rotogravure 795
18.4.1.3 SC-A/Offset and Rotogravure 796
18.4.1.4 Blade-Coated LWC/Offset and Rotogravure 796
18.4.1.5 Film-Coated LWC Offset 797
18.4.2 Woodfree Paper Grades 797
18.4.2.1 Woodfree Uncoated Papers 797
18.4.2.2 Woodfree Coated Paper Grades 798
18.4.3 Specialty Papers 798
18.4.3.1 Silicone Base Paper 798
18.4.3.2 Laminated Base Paper 799
18.4.4 Board 799
Jörg Rheims and Rüdiger Feldmann
18.4.4.1 Uncoated Board 799
18.4.4.2 Coated Board 799

References 800
Further Reading 800
<table>
<thead>
<tr>
<th>19</th>
<th>Reeling</th>
<th>801</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Matthias Wohlfahrt</td>
<td></td>
</tr>
<tr>
<td>19.1</td>
<td>Objectives and Basics</td>
<td>801</td>
</tr>
<tr>
<td>19.2</td>
<td>History</td>
<td>802</td>
</tr>
<tr>
<td>19.3</td>
<td>New Generation Reels</td>
<td>804</td>
</tr>
<tr>
<td>19.3.1</td>
<td>Center Drive</td>
<td>804</td>
</tr>
<tr>
<td>19.3.2</td>
<td>Nip Load System</td>
<td>805</td>
</tr>
<tr>
<td>19.3.3</td>
<td>Oscillation</td>
<td>806</td>
</tr>
<tr>
<td>19.4</td>
<td>Reel Drum Design</td>
<td>806</td>
</tr>
<tr>
<td>19.5</td>
<td>Turnup Systems</td>
<td>808</td>
</tr>
<tr>
<td>19.5.1</td>
<td>General</td>
<td>808</td>
</tr>
<tr>
<td>19.5.2</td>
<td>Nordic Turnup</td>
<td>809</td>
</tr>
<tr>
<td>19.5.3</td>
<td>Web-Wide Cutting Knife</td>
<td>809</td>
</tr>
<tr>
<td>19.5.4</td>
<td>Air-Supported Turnup Systems (Gooseneck, Cobra)</td>
<td>809</td>
</tr>
<tr>
<td>19.5.5</td>
<td>Tape Turnup System</td>
<td>810</td>
</tr>
<tr>
<td>19.5.6</td>
<td>Turnup with High-Pressure Water Jet</td>
<td>810</td>
</tr>
<tr>
<td></td>
<td>References</td>
<td>811</td>
</tr>
</tbody>
</table>

| 20 | Paper, Packaging, and Carton Board Machines | 813 |
|    | Herbert Holik |       |
| 20.1 | Graphic Paper Machines | 813 |
| 20.1.1 | Johann Moser and Herbert Holik |       |
| 20.1.2 | Newsprint Paper Machines | 814 |
| 20.1.3 | SC Paper Machines | 815 |
| 20.1.4 | LWC Paper Machines | 817 |
| 20.1.5 | Machines for woodfree uncoated (WFU) Paper Production | 817 |
| 20.2 | Packaging Paper Machines | 820 |
| 20.3 | Carton Board Machines | 823 |
| 20.4 | Tissue Machines | 827 |
| 20.4.1 | Herbert Holik, Rogério Berardi, and Thomas Scherb |       |
| 20.4.2 | Overview | 827 |
| 20.4.2.1 | Web Forming | 827 |
| 20.4.2.2 | Dewatering | 829 |
| 20.4.2.3 | Drying | 829 |
| 20.4.2.4 | Creping | 829 |
| 20.4.3 | Conventional Tissue Machines | 830 |
| 20.4.3.1 | Wet Creped Tissue | 830 |
| 20.4.4 | TAD Tissue Machine | 830 |
| 20.4.5 | Wet Moulding Tissue Machines – ATMOS | 832 |
| 20.5 | Specialty Paper Machines | 833 |
|    | Peter Mirsberger |       |
XXVIII

Contents

21  Finishing  841
Rüdiger Feldmann
  21.1  Reel Slitting  841
   21.1.1  Objective and General Description of Reel Slitting  841
   21.1.2  The Different Winder Types and Their Suitability for the Various Paper Grades  844
      21.1.2.1  Classical Two-Drum Winders  844
      21.1.2.2  Modified Two-Drum Winders  845
      21.1.2.3  Two-Drum Winders with Air Relief  845
      21.1.2.4  Two-Drum Winders with Belt Support  846
      21.1.2.5  Two-Drum Winders with Soft Covered Drums  846
   21.1.3  Single-Drum Winders  847
   21.1.4  Automatic Functions  848
   21.1.5  Automation/Operation  849
  21.2  Roll Handling  849
   21.2.1  Objective and General Description of Roll Handling  849
   21.2.2  Roll Wrapping  849
      21.2.2.1  Wrapping Material  849
      21.2.2.2  The Different Types of Wrapping Machines  850
      21.2.2.3  Wrapping Machines Using Stretch Film as Packaging Material  853
   21.2.3  Roll Conveying  854
   21.2.4  Automation  856

22  Control Systems for Paper Machines  859
Rudolf Münch
  22.1  Objective and General Terms of PM Control Systems  859
     22.1.1  Objective  859
     22.1.2  Explanation of Terms  859
  22.2  Quality Control System (QCS)  864
     22.2.1  Quality Measurements  864
        22.2.1.1  Scanning Measurement  864
        22.2.1.2  Fixed Point Measurement  865
        22.2.1.3  Basis Weight  865
        22.2.1.4  Moisture  866
        22.2.1.5  Fillers  866
        22.2.1.6  Caliper  867
        22.2.1.7  Coat Weight  868
        22.2.1.8  Color  868
        22.2.1.9  Gloss  868
        22.2.1.10  Others  868
     22.2.2  Quality Control  869
        22.2.2.1  Machine Direction Control  869
        22.2.2.2  Cross Direction Control  872
22.3 Information Systems 875
22.3.1 Importance of Information Systems 875
22.3.2 Process Analysis Using Information Systems 877

23 Uniformity of Paper Web Properties 879
Herbert Holik and Johann Moser

23.1 Overview 879
23.1.1 Defining Profile Deviations by Statistical Methods 879
23.1.2 Requirements and Some Interdependencies Regarding MD and CD Profiles 880
23.1.3 Symmetry in z-Direction 880

23.2 MD Profiles 881
23.2.1 MD Basis Weight Profile 881
23.2.1.1 Consistency 881
23.2.1.2 Retention 882
23.2.1.3 Headbox Flow Rate 882
23.2.1.4 Vacuum Variation 883
23.2.2 MD Caliper Profile 884
23.2.3 MD Coat Weight Profile 886
23.2.4 MD Irregularities in Tissue Making 887

23.3 CD Profiles 887
23.3.1 CD Basis Weight Profile 887
23.3.2 CD Main Fiber Orientation (MFO) Profile 890
23.3.3 CD Moisture Profile 892
23.3.4 CD Caliper Profile 897
23.3.5 CD Smoothness and Gloss Profiles 900

23.4 Some Aspects of MD and CD Basis Weight Profile Tests in the Laboratory 900
23.4.1 Test Samples Gained from a Limited Production Time 902
23.4.2 Synchronized and Unsynchronized CD Profiles 902

23.5 Symmetry in z-Direction 903
23.5.1 Surface Characteristics 903
23.5.1.1 Fines and Filler Distribution 903
23.5.1.2 Surface Smoothness 904
23.5.1.3 Surface Densification 904
23.5.2 Curl 904
23.5.2.1 Definition of Curl 904
23.5.2.2 Mechanism of Curl 905
23.5.2.3 Causes and Cure of Curl 905
23.5.3 Cockling 906

23.6 Formation 907

References 909
<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>24</td>
<td>Paper and Board Converting and Printing</td>
<td>911</td>
</tr>
<tr>
<td>24.1</td>
<td>Converting Processes for Paper and Board</td>
<td>911</td>
</tr>
<tr>
<td>24.1.1</td>
<td>Overview</td>
<td>911</td>
</tr>
<tr>
<td>24.1.2</td>
<td>Forming</td>
<td>913</td>
</tr>
<tr>
<td>24.1.2.1</td>
<td>Introduction</td>
<td>913</td>
</tr>
<tr>
<td>24.1.2.2</td>
<td>Folding</td>
<td>914</td>
</tr>
<tr>
<td>24.1.2.3</td>
<td>Embossing</td>
<td>916</td>
</tr>
<tr>
<td>24.1.2.4</td>
<td>Winding</td>
<td>916</td>
</tr>
<tr>
<td>24.1.2.5</td>
<td>Corrugating</td>
<td>917</td>
</tr>
<tr>
<td>24.1.3</td>
<td>Separating</td>
<td>918</td>
</tr>
<tr>
<td>24.1.3.1</td>
<td>Introduction</td>
<td>918</td>
</tr>
<tr>
<td>24.1.3.2</td>
<td>Separating by Splitting</td>
<td>918</td>
</tr>
<tr>
<td>24.1.3.3</td>
<td>Ablating</td>
<td>926</td>
</tr>
<tr>
<td>24.1.4</td>
<td>Joining</td>
<td>927</td>
</tr>
<tr>
<td>24.1.4.1</td>
<td>Introduction</td>
<td>927</td>
</tr>
<tr>
<td>24.1.4.2</td>
<td>Gluing</td>
<td>928</td>
</tr>
<tr>
<td>24.1.4.3</td>
<td>Sealing</td>
<td>930</td>
</tr>
<tr>
<td>24.1.4.4</td>
<td>Frictional Connection and Positive Locking</td>
<td>931</td>
</tr>
<tr>
<td>24.1.5</td>
<td>Combining Different Materials</td>
<td>931</td>
</tr>
<tr>
<td>24.1.5.1</td>
<td>Introduction</td>
<td>931</td>
</tr>
<tr>
<td>24.1.5.2</td>
<td>Impregnation</td>
<td>933</td>
</tr>
<tr>
<td>24.1.5.3</td>
<td>Coating</td>
<td>933</td>
</tr>
<tr>
<td>24.1.5.4</td>
<td>Laminating</td>
<td>933</td>
</tr>
<tr>
<td>24.1.6</td>
<td>Transport in Machines</td>
<td>934</td>
</tr>
<tr>
<td>24.1.6.1</td>
<td>Introduction</td>
<td>934</td>
</tr>
<tr>
<td>24.1.6.2</td>
<td>Transport Roll-to-Roll</td>
<td>934</td>
</tr>
<tr>
<td>24.1.6.3</td>
<td>Transport Sheet-to-Sheet</td>
<td>936</td>
</tr>
<tr>
<td>24.2</td>
<td>Testing of Converting Products</td>
<td>937</td>
</tr>
<tr>
<td>24.2.1</td>
<td>Testing in Paper Converting – General Remarks</td>
<td>937</td>
</tr>
<tr>
<td>24.2.2</td>
<td>Converting-Specific Material Tests</td>
<td>938</td>
</tr>
<tr>
<td>24.2.2.1</td>
<td>Overview of Test Methods for Paper, Paperboard, and Board</td>
<td>938</td>
</tr>
<tr>
<td>24.2.3</td>
<td>Testing of Converting Products</td>
<td>947</td>
</tr>
<tr>
<td>24.2.3.1</td>
<td>Corrugated Board</td>
<td>947</td>
</tr>
<tr>
<td>24.2.3.2</td>
<td>Packages</td>
<td>948</td>
</tr>
<tr>
<td>24.2.3.3</td>
<td>Cores</td>
<td>949</td>
</tr>
<tr>
<td>24.2.3.4</td>
<td>Labels</td>
<td>949</td>
</tr>
<tr>
<td>24.2.3.5</td>
<td>Tissue Paper and Tissue Products</td>
<td>949</td>
</tr>
<tr>
<td>24.2.3.6</td>
<td>Bookbinding Products (Adhesive Binding)</td>
<td>950</td>
</tr>
<tr>
<td>24.2.4</td>
<td>Transportation Tests</td>
<td>951</td>
</tr>
<tr>
<td>24.3</td>
<td>Printing Technologies</td>
<td>953</td>
</tr>
<tr>
<td>24.3.1</td>
<td>Introduction</td>
<td>953</td>
</tr>
<tr>
<td>24.3.2</td>
<td>Gravure Printing</td>
<td>954</td>
</tr>
</tbody>
</table>
24.3.2.1 General Description  954
24.3.2.2 Process  955
24.3.2.3 Inks and Process Properties  956
24.3.2.4 Gravure Presses  956
24.3.3 Flexographic Printing  956
24.3.3.1 General Description  956
24.3.3.2 Process  957
24.3.3.3 Inks and Process Properties  958
24.3.3.4 Flexographic Presses  958
24.3.4 Offset Printing  959
24.3.4.1 General Description  959
24.3.4.2 Process  960
24.3.4.3 Inks and Process Properties  961
24.3.4.4 Offset Presses  961
24.3.5 Inkjet Printing  962
24.3.5.1 General Description  962
24.3.5.2 Process  962
24.3.5.3 Inks and Process Parameters  964
24.3.5.4 Inkjet Printers  964
24.3.6 Electrophotography  965
24.3.7 Process and Quality Parameters  966
24.4 Requirements on Paper  966
   Rainer Klein and Martina Miletić
24.4.1 What Do the Requirements on Paper for Print Products Come from?  966
24.4.2 Standardization Aspects  969
24.4.2.1 The Paper Industry  969
24.4.2.2 The Printing Industry  969
24.4.3 Requirements on Gravure Paper  972
24.4.4 Requirements on Offset Paper  974
24.4.4.1 Cross-Procedural Issues  974
24.4.4.2 Paper for Coldset Printing  975
24.4.4.3 Paper for Heatset Printing  975
24.4.4.4 Paper for Sheet-Fed Offset Printing  976
24.4.5 Requirements on Paper for Flexographic Printing  976
24.4.6 Requirements on Paper for Digital Printing  977
24.4.6.1 Electrophotographic Printing (Laser Printing)  977
24.4.6.2 Inkjet Printing  978
24.4.6.3 Cross-Technological Requirements on Paper  979
References  979
Further Reading for Section 24.2  981
Further Reading for Section 24.3  981
Contents

25 Health and Safety 983
  25.1 Occupational Health and Safety 983
      Winfried Harren
      25.1.1 Introduction 983
      25.1.2 Health Protection 984
      25.1.2.1 General Remarks 984
      25.1.2.2 Hazardous Substances 985
      25.1.2.3 Noise 986
      25.1.2.4 Hazards Caused by Electricity 987
      25.1.2.5 Intoxication 987
      25.1.2.6 Hazards Caused by Radiation 988
      25.1.2.7 Personal Protection 989
      25.1.2.8 Safety and Health Protection Signs 989
      25.1.2.9 First Aid 990
      25.1.3 Occupational Safety 991
      25.1.3.1 Pressure Equipment 991
      25.1.3.2 Fire Protection 992
      25.1.3.3 Industrial Trucks 993
      25.1.3.4 Load-Lifting Equipment in Hoisting Operation 993
      25.1.3.5 Falling Hazards on Papermaking Plants 994
  25.2 Noise Abatement and Protection 995
      Herbert Holik
      25.2.1 Overview 995
      25.2.2 Some Basics on Acoustics 995
      25.2.3 Sound, Noise, and Men 996
      25.2.4 Noise, Noise Abatement, and Noise Protection in the Paper Industry 997
      25.2.4.1 Primary Measures 997
      25.2.4.2 Secondary Measures 998
      25.2.4.3 Noise Protection of the Neighborhood of Paper Mills 1002
      References 1002

26 Plant Engineering and Energy 1003
  26.1 Plant Engineering 1003
      Thomas Mack
      26.1.1 Scope and Task of Plant Engineering 1003
      26.1.2 Principle Methods of Plant Engineering 1004
      26.1.3 Basic Engineering 1005
      26.1.3.1 Balancing 1006
      26.1.3.2 Process and Instrumentation Diagrams 1007
      26.1.3.3 Layout and Load Plans 1007
      26.1.4 Detail Engineering 1009
      26.1.4.1 Foundation Plans 1010
      26.1.4.2 Outline or Manufacturing Drawings 1010
      26.1.4.3 Piping 1011
26.1.5 Procurement Engineering 1012

26.2 Energy 1013

Hermann-Josef Post

26.2.1 Significance of Energy 1013
26.2.2 Energy Efficiency Assessment 1014
26.2.3 Energy Optimization 1016
26.2.4 Investment in More Energy-Efficient Equipment 1017
26.2.5 Process Modifications to Bring Down the Energy Intake 1017
26.2.6 An Optimal Energy Layout for the Entire Paper Mill 1018

27 Environmentally Friendly Paper and Board Production 1021

Günter Müller and Ingrid Demel

27.1 Background 1021

27.2 Environmental Relevance along the Value Chain of Paper and Board Production 1021

27.3 Sustainability 1023
27.3.1 Worldwide and European Efforts 1023
27.3.2 Sustainability in Paper and Board Production 1023

27.4 Resource Utilization in Paper and Board Production 1023
27.4.1 Virgin Pulps 1024
27.4.2 Secondary Pulps 1025
27.4.3 Energy 1026
27.4.4 Water 1026

27.5 Evaluation and Communication of Environmental Impacts 1026
27.5.1 Demand for Products with High Environmental Performance 1026
27.5.2 Complexity of Available Tools 1027
27.5.3 Eco-Label – a Possibility for Communicating Product Eco-Friendliness to the Consumer 1029

27.6 Practical Implementation of Environmental Issues 1031

References 1032

28 Paper and Board Grades and Their Properties 1035

Heinz-Joachim Schaffrath and Otmar Tillmann*

28.1 The Material Paper: A Survey 1035
28.1.1 Introduction 1035
28.1.2 Material Properties 1036
28.1.3 Summary 1039

28.2 Types of Paper, Board, and Cardboard 1040
28.2.1 Graphic Papers 1041
28.2.1.1 Printing and Press Papers 1041
28.2.1.2 Office and Administration Papers 1046
28.2.2 Packaging Paper and Board Grades 1048
28.2.2.1 Overview 1048
28.2.2.2 Packaging Papers 1049
28.2.2.3 Board and Cardboard 1051
Contents

28.2.3 Hygienic Papers 1053
28.2.3.1 Cellulose Wadding 1053
28.2.3.2 Tissue 1053
28.2.3.3 Crepe Paper 1054
28.2.4 Paper and Board for Technical and Specialty Uses 1054

References 1058
Further Reading 1058

29 Testing of Fibers, Suspensions, and Paper and Board Grades 1059
Heinz-Joachim Schaffrath and Otmar Tillmann*

29.1 General Aspects 1059
29.2 Testing of Fibrous Material 1061
29.2.1 Composition 1061
29.2.2 Length and Length-Related Properties 1062
29.2.3 Fiber Fractionation 1063
29.3 Testing of Fiber Suspensions 1064
29.3.1 Sampling 1064
29.3.2 Consistency 1065
29.3.3 Shives and Flake Content 1066
29.3.4 Fiber Classification 1066
29.3.5 Beating Degree 1066
29.3.6 Water Retention 1067
29.3.7 Water Properties 1068
29.3.8 Stickies 1068
29.3.9 Dirt 1069
29.3.10 Brightness 1070
29.4 Testing of Paper and Board 1070
29.4.1 Basic Properties 1071
29.4.2 Composition and Chemical Paper Testing 1072
29.4.3 Strength Properties 1074
29.4.4 Load-Deformation Properties 1078
29.4.5 Surface Properties 1079
29.4.6 Optical Properties 1080
29.4.7 Printing Properties 1081
29.4.8 Behavior toward Liquids 1083
29.4.9 Exclusion of Gases and Vapors 1084
29.4.10 Additional Testing 1084
29.4.11 Measurements of Coated Surface 1085

References 1086
Further Reading 1086

30 Book and Paper Preservation 1087
Manfred Anders

30.1 Introduction 1087
30.2 Mechanisms of Paper Deterioration 1088
30.2.1 Paper Deterioration by Aging 1088
30.2.2 Oxidative Deterioration Processes 1090
30.2.3 Alterations due to Paper Aging 1091
30.2.3.1 Yellowing 1091
30.2.3.2 Embrittlement of Paper 1092
30.3 Development of Mass Deacidification Processes 1092
30.3.1 Overview 1092
30.3.2 History of Commercial Mass Deacidification 1094
30.3.2.1 BPA Process and DAE Process 1095
30.3.2.2 The DEZ Process 1096
30.3.2.3 The Wei T’o Process 1096
30.3.2.4 The British Library Process 1097
30.3.2.5 The FMC or Lithco Process 1098
30.4 Current Commercial Processes 1098
30.4.1 Papersave Process® 1098
30.4.1.1 ZFB:2 Procedure 1100
30.4.2 The Bookkeeper Process 1101
30.4.3 Magnesium Oxide Dust 1102
30.4.4 CSC Booksaver 1102
30.4.5 Aqueous Processes 1102
30.4.5.1 Bückeburger Process 1102
30.4.5.2 The Austrian National Library Process 1103
30.5 Strengthening Old and Brittle Paper 1103
30.5.1 Overview 1103
30.5.2 Preservation of Originals by (Mechanical) Paper Splitting (Leipzig Paper Splitting Technique) 1104
30.6 Commercial Prospects 1105
References 1106

31 Paper Associations 1109
Herbert Holik

Index 1113