- Preface p. xv
- Introduction: Standard Plastic Terminology p. xix
- 1 Plastic Program Analysis and Development p. 1
- Selecting the Design Team for Success p. 3
- Using Checklists to Develop Product Requirements p. 4
- Defining the Design Team p. 4
- Design and Development Scheduling p. 9
- Company Commitment to Plastics p. 11
- Product Conversion to Plastic p. 11
- Six-Sigma Process Control p. 14
- Reference p. 16
- 2 Checklists for Product Design, Development, and Manufacture p. 17
- Program Development Checklists p. 17
- Product Design, Development, and Scheduling Checklists p. 19
- Product Development p. 19
- Sales Contract p. 19
- Product Design p. 19
- Engineering Change p. 20
- Materials p. 20
- Purchasing p. 21
- Vendor Survey p. 21
- Customer Tooling and Tooling Design Requirements (Mold Design) p. 21
- Pricing--Determining Piece Part and Final Product Manufacturing Cost p. 21
- Program Scheduling for Manufacture p. 42
- Manufacturing p. 42
- Quality Control p. 43
- Assembly p. 45
- Decorating p. 46
- Packaging and Shipping p. 46
- Calculating Box Cost p. 48
- Warranty Problems p. 49
- Failure Analysis p. 50
- Analytical Tests p. 51
- Specifications and Certifications p. 54
- Product Specifications p. 54
- In-House Specifications p. 55
- Material Specifications p. 56
- Material Certification p. 57
- Purchased Parts p. 58
- Tooling Specifications p. 58
- Manufacturing and Process Specifications p. 59
- Assembly and Decorating p. 60
- Handling, Packaging, and Shipping Specifications p. 62
- References p. 62

- 3 Product Manufacturing Methods p. 63
- Selecting the Method of Manufacture p. 64
- Selecting the Product Manufacturer p. 66
- Interface with the Design Team when Quoting p. 66
- Tie-In Manufacturing with Control p. 66
- Injection Molding p. 68
- Injection-Molding Machine Basics p. 68
- Gas-Assisted Injection Molding p. 71
- Gas-Assisted Injection-Molding Precautions p. 71
- Types of Injection Molds p. 73
- Extrusion p. 73
- Blow Molding p. 77
- Conventional Blow Molding p. 79
- Extrusion Blow Molding--Multishaped p. 81
- Injection Blow Molding p. 81
- Rotational Molding p. 82
- Thermoforming p. 84
- Compression Molding p. 85
- Bulk Molding Compound Molding p. 86
- Sheet Molding Compound Molding p. 86
- References p. 87
- 4 Versatility of Design and Assembly with Plastics p. 88
- Product Design Analysis p. 89
- Metal Product Conversion to Plastic p. 90
- Processing to Maintain Physical Properties p. 91
- Plastic Material Modifiers p. 92
- Recycling p. 93
- Design, Development, and Assembly Considerations for Products p. 94
- Analysis of Resin Properties p. 95
- Thermal Analysis Techniques p. 96
- Manufacturing Considerations p. 100
- Manufacturing Methods p. 100
- Tolerance Considerations for Manufacturing p. 101
- Assembly Considerations p. 102
- Screws p. 103
- Product Surface Considerations for Decoration and Assembly p. 107
- Adhesives p. 108
- Thermal Bonding p. 109
- Flexible Hinges and Sections p. 110
- Decorating and Material Modifiers p. 113
- Pigmented and Colored Products p. 113
- References p. 117
- 5 Material Property Considerations p. 118
- Thermoplastics p. 118

- Thermosets p. 118
- Thermoelastomers p. 119
- End-Use Material Selection p. 120
- Sources for Material Selection Data p. 122
- Understanding Thermoplastics p. 127
- Amorphous Plastics p. 127
- Crystalline and Semicrystalline Materials p. 129
- Liquid Crystal Polymers p. 131
- Filled, Reinforced, and Modified Resins p. 132
- Fillers p. 132
- Reinforcements p. 132
- Modifiers and Additives p. 134
- Thermosets Resins p. 135
- Bulk Molding Compounds p. 135
- Sheet Molding Compounds p. 135
- Material Property Values p. 136
- Physical Properties Defined for Plastics p. 136
- Physical Property Data p. 137
- Material Selection p. 137
- Determining Product Material Requirements p. 137
- Product Life Considerations p. 138
- Product Part Function Consolidations p. 140
- Form, Fit, and Function p. 140
- Metal Replacement p. 141
- Design for Assembly and Service p. 143
- Material Identification and Specification p. 143
- References p. 145
- 6 Property Considerations When Designing Products in Plastic p. 146
- End-Use Effects on a Plastic's Physical Properties p. 146
- Product Finishing and Assembly Operations p. 148
- Product Preparation for Decorating p. 148
- Product Assembly Forces p. 148
- Thermal Expansion and Contraction Attachment Considerations p. 149
- Shipping Considerations p. 149
- Chemical Effects on Plastics p. 149
- Immersion p. 154
- Gas Bomb p. 154
- Mechanisms of Chemical Attack p. 154
- Environmental Effects on Plastics p. 155
- Weathering Effects p. 156
- Moisture Effects p. 156
- Moisture Consideration p. 157
- Humidity Effects p. 159
- Assembly Considerations p. 159

- Decoration Considerations p. 161
- Bacteria and Soil Fungi p. 161
- Food Products p. 161
- Sterilizable Plastics p. 162
- Types of Sterilization p. 162
- Transparent Plastics p. 164
- Product Design Considerations p. 167
- Agency and Code Regulations p. 167
- References p. 170
- 7 Temperature and Electrical Property Effects on Plastics p. 172
- Temperature and Thermal Effects on Plastics p. 172
- Heat Deflection Temperature p. 173
- Thermal Aging and Oxidation Effects p. 174
- Heat Resistance p. 174
- End-Use Temperatures p. 175
- Temperature Index p. 176
- Coefficient of Linear Thermal Expansion p. 176
- Thermal Stresses p. 177
- Controlling Differential Thermal Expansion p. 178
- Electrical Property Analysis p. 180
- Volume Resistivity p. 181
- Surface Resistivity p. 182
- Dielectric Strength p. 182
- Dielectric Constant (Permittivity) p. 183
- Dissipation Factor p. 184
- Arc Resistance p. 184
- Electrical Properties of Plastics p. 185
- Flammability and Smoke Generation of Plastics p. 186
- UL94 HB: Horizontal Burn p. 186
- UL94 V0, V1, V2, and V5: Vertical Burn p. 186
- References p. 188
- 8 Design Analysis of Material Properties p. 189
- Plastic Property Terminology p. 191
- Homogeneity p. 191
- Heterogeneity p. 191
- Isotropy p. 192
- Anisotropy p. 192
- Density p. 194
- Specific Gravity p. 194
- Elasticity p. 194
- Plasticity p. 194
- Coining p. 195
- Stress Whitening p. 195
- Ductility p. 197

- Toughness p. 197
- Gardner "Drop Weight" Impact p. 198
- Izod and Charpy Impact p. 199
- Tensile Impact p. 199
- Brittleness p. 201
- Notch Sensitivity p. 202
- Lubricity p. 202
- Abrasion, Wear, and Friction p. 202
- Shrinkages p. 205
- References p. 214
- 9 Product Design Considerations p. 215
- Effects of Elasticity, Homogeneity, and Isotropy p. 215
- Structural Product Analysis p. 216
- Product Geometry p. 216
- Stress-Strain Analysis of the Forces on a Product p. 217
- Viscoelastic Behavior p. 220
- Hygroscopic Material Effects p. 220
- Design Equations p. 221
- Analysis of Stress p. 221
- Selecting the Material Design Stress p. 222
- Modes of Product Failure p. 222
- Elastic Deformation p. 223
- Inelastic Deformation p. 224
- Fracture p. 224
- Stress-Strain Curves p. 224
- Selecting the Design Stress p. 228
- Material Creep/Elongation p. 229
- Apparent or Creep Modulus p. 230
- Hoop Stress p. 232
- Stress Relaxation p. 234
- Modulus of Elasticity Estimation for High-Strain Applications p. 235
- Drop-Weight Testing p. 235
- Impact Forces p. 236
- Stress Concentration Factor p. 236
- Safety Factors p. 237
- Failure Analysis p. 238
- Shear Stress p. 240
- Poisson's Ratio p. 241
- Relationship between Material Constants p. 242
- Measures of Strength and Modulus p. 243
- Bending Strength and Flexural Modulus p. 245
- Vibration and Fatigue Resistance p. 245
- References p. 248
- 10 Structural Product Analysis p. 250

- Defining Structural Requirements p. 252
- Support Conditions p. 254
- Design Assumptions and Simplifications p. 255
- Stress Concentration Factors p. 256
- Structural Analysis p. 258
- Beams p. 258
- Shear Stress p. 271
- Pressure Vessels and Tubing p. 275
- Buckling of Columns, Rings, and Arches p. 275
- Flat Plates p. 281
- Ribbed Plate Design p. 281
- Unidirectional Ribbing p. 290
- Multiribbing Considerations p. 293
- Analysis of Plate Design for Support p. 294
- Cross-Ribbing p. 299
- Designing Plastic Springs p. 304
- Snap-Fit Design Modifications p. 312
- Snap-Fit Assembly Speed p. 315
- New Snap-Fit Stress Deflection Analysis p. 316
- Typical Snap-Fit Designs p. 323
- Designing for Round Snap Fits p. 323
- References p. 328
- 11 Design for Product Performance p. 329
- Design for Assembly and Service p. 329
- Computer-Aided Design and Manufacture p. 330
- Computer-Aided Design p. 330
- Selecting the CAD System p. 332
- CAD-Generated Models p. 333
- Prototype Modeling p. 333
- SLA/SLS Models p. 334
- Machined Models p. 336
- Prototype Molded Models p. 336
- Regrind Consideration p. 337
- Prototype and End-Use Product Testing p. 337
- Die-Cast Models p. 338
- Prototype Molded Product Characteristics p. 338
- CAD Systems p. 339
- Finite-Element Analysis p. 340
- Preprocessing Analysis p. 341
- FEA Elements p. 341
- Plate and Shell Elements p. 343
- Mesh Density Setup p. 344
- Symmetry p. 345
- Boundary and Constraint Conditions p. 345

- Processing Time and Node Density p. 345
- Processing the FEA Model p. 348
- PostProcessing p. 348
- Failure Analysis p. 350
- Mold Design Considerations p. 351
- Alternate Mold Process Analysis Methods p. 354
- Mold Filling Analysis (Simplified) p. 354
- Mold Filling and Cooling Analysis p. 356
- Simultaneous or Concurrent Engineering Concept p. 357
- Analysis Utilizing FEA for Molding Assistance p. 360
- Control of Product Tolerances p. 364
- Product Tolerances p. 364
- Tolerance Factors p. 368
- Process Control p. 370
- Plastic Resin Variability p. 370
- Product Released for Manufacturing p. 371
- Closed-Loop Process Control p. 371
- Determining Molding Process Capability p. 371
- Production Mold Qualification p. 372
- Verifying Manufacturing Control and Capability p. 372
- Determining Molding Machine Capability p. 375
- CpK Capability Analysis p. 383
- Design of Experiments p. 389
- References p. 392
- 12 Product and Tooling Design Guidelines p. 393
- Product Manufacturing Analysis p. 393
- Material Consultants p. 394
- Uniform Product Section p. 395
- Material Flow Analysis p. 397
- Amorphous Resins p. 397
- Crystalline Resins p. 398
- Uniform Product Thickness p. 401
- Product Mold Design Considerations p. 404
- Product Mold Type Consideration p. 405
- Mold Materials of Construction p. 405
- Mold Base and Components p. 407
- Cavity Tolerance Control p. 408
- Mold Cavity Considerations p. 411
- Electrodischarge Machining p. 413
- Mold Cavity and Core Alignment p. 414
- Cavity-to-Cavity Accuracy p. 415
- Cavity Temperature Control p. 418
- Runner and Product Gating Considerations p. 421
- Flow in the Product Cavity p. 422

- Cavity Pressure Sensors p. 424
- Controlling Molded-in Stresses in the Product p. 424
- Control of Weld Lines p. 425
- Venting the Mold Cavity p. 429
- Increasing Product Strength and Stiffness p. 430
- Ribs p. 430
- Radii p. 432
- Visual Measurement of Stresses p. 433
- Draft and Product Ejection in the Mold p. 436
- Textured Cavity Surfaces p. 439
- Mold Finish and Polishing p. 440
- Mold Ejector System p. 441
- References p. 442
- 13 Plastic Product Design and Development Program Analysis p. 443
- Successful Product Development Plan p. 445
- Appendix A Checklist Forms p. 447
- Checklist 1 Assembly Checklist p. 449
- Checklist 2 Product Design Checklist p. 451
- Checklist 3 Decorating Checklist p. 457
- Checklist 4 Materials Checklist p. 459
- Checklist 5 Manufacturing Checklist p. 461
- Checklist 6 Packaging Checklist p. 464
- Checklist 7 Product Development Checklist p. 466
- Checklist 8 Program Scheduling Checklist p. 475
- Checklist 9 Price Estimating Checklist p. 479
- Checklist 10 Purchasing Checklist p. 481
- Checklist 11 Quality Checklist p. 486
- Checklist 12 Sales Contract Checklist p. 489
- Checklist 13 Warranty Problem Checklist p. 494
- Checklist 14 Engineering Change Request Check Sheet p. 498
- Checklist 15 Supplier Quality Self-Survey Report p. 500
- Checklist 16 Supplier Survey Report p. 504
- Checklist 17 Mold Design Checklist p. 519
- Appendix B Glossary of Terms Used in Design and Development of Plastic Products p. 527
- Index p. 561