

INJECTION MOLDING HANDBOOK

3rd Edition

Dominick V. Rosato
Donald V. Rosato
Marlene G. Rosato

Volume 2



Springer Science+Business Media, LLC

INJECTION

MOLDING

HANDBOOK

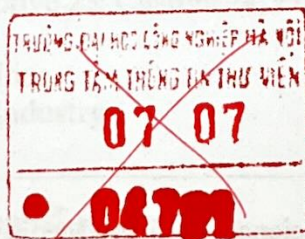
THIRD EDITION

EDITED BY

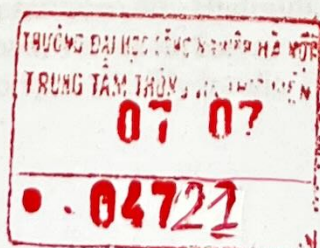
DOMINICK V. ROSATO, P. E.

DONALD V. ROSATO, PH.D.

MARLENE G. ROSATO, P. E.



Springer Science+Business Media, LLC



Contents

Preface		xxix
Chapter 1	The Complete Injection Molding Process	1
	Introduction	1
	Machine Characteristics	4
	Molding Plastics	4
	Molding Basics and Overview	4
	People and Productivity 6; Plastic Materials 6; Morphology and Performance 9; Melt Flow and Rheology 11; Plasticating 12; Screw Designs 14; Molds 15; Processing 16; Process Controls 18; Control Guides 20; Art of Processing 21; Fine Tuning 21	
	Molding Operations	22
	Automatic 22; Semiautomatic 22; Manual 22; Primary 23; Secondary 23	
	Purchasing and Handling Plastics	23
	Processors	23
	Captive 23; Custom 24; Proprietary 24	
	Training Programs	24
	Processor Certifications	24
	Plastics Machinery Industry	26
	Summary	26
Chapter 2	Injection Molding Machines	28
	Introduction	28
	Reciprocating (Single-Stage) Screw Machines	29
	Two-Stage Machines	32
	Injection Hydraulic Accumulator 32	
	Reciprocating vs. Two-Stage Machines	33
	Other Machine Types	37
	Machine Operating Systems	37
	Hydraulic Operations	37
	Reservoirs 40; Hydraulic Controls 42; Proportional Valves 42; Servovalves 43; Digital Hydraulic Control 43; Hydraulic Fluids and Influence of	

Heat 44; Pumps 44; Directional Valves 45; Servo and Proportional Valves 46	
Electrical Operation	46
Electric Motors 47; Adjustable-Speed Drive Motors 47; Servo Drives 47; Microtechnology Moldings 47; Injection Molding: A Technology in Transition to Electrical Power 48	
Hybrid Operations	58
Clamping Systems	59
Clamping Pressures 60; Hydraulic Clamps 61; Toggle Clamps 62; Hydromechanical Clamps 62; Hydroelectric Clamps 63; Comparison of Clamp Designs 64; Tie-bars 64; Tie-barless Systems 69; Platen Systems 71	
Barrels	72
Barrel Borescoping 72; Barrel and Feed Unit 72; Barrel Heaters 73; Barrel Cooling 74; Barrel Characteristics 75	
Screw Operations	75
Machine Sizes and Design Variations	75
Rebuilding and Repairs	79
Stripping, Polishing, and Plating 79; Machine Downsizing and Upsizing 79	
Safety	80
Machine Lockout 80; Machine Safety 81; Identification of Hazards 82; Safety Built into the Machines 82; Current and Former Installations 88; IMM Safety Checklist 88; Safety Rules for Molding Department 88; American National Standard 92; Safety Standards 92; Plasticator Safety 93; Barrel-Cover Safety 93; Plant Safety 93; Safety Information 93	
Designing Facilities	93
Upgrading 93; Clean Room 94; Clean Machines 94	
Noise Generation	97
Startup and Shutdown Operations	98
Molding Operation Training Program	98
First Stage: Running an IMM 99; The Sequence in a Cycle 102; Second Stage: Parameter Setting and Starting a Job 105	
Shear-Rate-Sensitive and -Insensitive Materials	109
Factors to Consider 113; Operating the Machine 127; Final Stage: Optimizing Molding Production 128; Specification Information, General 130; Specification Information, Details 131; Productivity and People 134; Training Information 136	
Molding Guide	136
Guide to IMM Selection	137
Terminology	139

Chapter 3	Plasticizing	151
	Introduction	151
	Plasticators	151
	Plastics Melt Flow 154; Barrel Temperature Override 157	
	Screw Sections	157
	Feed Section 157; Transition Section 161; Metering Section 162	
	Elements of the Plasticating Processes	163
	Screw Rotation 163; Soak Phenomena 164; Injection Stroke 165; Injection Pressure Required 166	
	Screw Plasticizing	168
	Screw Design Basics 170; Sequence of Operations 172; Advantages of Screw Plasticizing 173; Length-to-Diameter Ratios 173; Compression Ratios 174; Rotation Speeds 175	
	Processing Thermoplastics or Thermoset Plastics	175
	Screw Actions	176
	Mechanical Requirements 177; Torque 177; Torque vs. Speed 177	
	Injection Rates	177
	Back Pressures	178
	Melt Performance	179
	Melt Pumping	179
	Melt Temperature	179
	Temperature Sensitivity 179; Temperature Controls Required 179; Barrel Heating 180; Cooling 180	
	Melt Performance	181
	Residence Time	181
	Melt Cushions	181
	Melt Shear Rate	181
	Melt Displacement Rate	181
	Shot Size	181
	Recovery Rate 182	
	Screw-Barrel Bridging	182
	Vented Barrels	182
	Overview 182; Basic Operations 184; Barrel-Venting Safety 188	
	Screw Designs	188
	Design Basics 189; Design Performance 189; Mixing and Melting Devices 189; Screw Barriers 193; Specialized Screw Designs 196; Screw Tips 197; Influence of Screw Processing Plastics 201; Melt Quality 202; Materials of Construction 204	
	Screw Outputs	204
	Influence of Screw and Barrel Wear on Output	204
	Influence of the Material on Wear 205; Screw Wear 205; Production Variations 205; Screw Wear Inspections 207; Output Loss Due to Screw Wear	

	207; Screw Replacement 207; Screw Wear Protection 208	
Purging		208
Patents Influence Screw Designs		210
Terminology		210
Chapter 4 Molds to Products		221
Overview		221
	Interrelation of Plastic, Process, and Product 221; Molding Process Windows 221; Cycle Times 223; Molding Pressure Required 224; Products 224	
Processing Plastics		224
	Basics of Melt Flow 225; Mold Filling Hesitation 225; Melt Cushioning 225; Mold Filling Monitoring 225; Sink Marks 226	
Mold Descriptions		226
Mold Basics		230
Mold Optimization		234
	Computer Systems 235	
Mold Types		236
	Molds For Thermosets 238; Mold Classifications 241	
Plastic Melt Behaviors		241
	Cold-Slug Well 243; Melt Orientation 244;	
Cavity Melt Flow		249
	Fill Rates 250; Melt Temperature 250; Mold Temperature 250; Packing Pressure 251; Mold Geometry 251; Flash Guide 251	
Molding Variables vs. Performance		252
Shot-To-Shot Variation		253
Cavities		254
	Cavity Melt Flow Analyses 254; Cavity Melt Fountain Flow 254	
Cavity Evaluation		255
	Machine Size 258; Plasticizing Capacity 258; Economics 258; Cavity Draft 259; Cavity Packing 259; Cavity Surface 259	
Clamping Forces		260
	Contact Area at Parting Line 262	
Sprue-Runner-Gate Systems		262
	Sprues 263; Runner Systems 264; Gates 277; Gate Summary 287	
Correcting Mold Filling Imbalances in Geometrically Balanced Runner Systems		289
	Isolating Mold Variations in Multicavity Molds 291	
Mold Components		292
	Ejector Systems 293; Ejector Pin Strength 296; Sprue Pullers 300; Side Actions 300; Angle Pins 301; Cam Blocks 302; Stripper-Plate Ejection 302;	

Strength Requirements for Molds	
Stress Level in Steel 364; Pillar Supports 365; Steel and Size of Mold Base 366	364
Deformation of Mold	
Mold Filling 367; Deflection of Mold Side Walls 368	367
Eyebolt Holes	
Quick Mold Change	371
Mold Protection	371
Automatic Systems 374; Heavy Molds 374	374
Preengineered Molds	
Standardized Mold Base Assemblies	378
Specialty Mold Components	380
Collapsible and Expandable Core Molds	381
Prototyping	386
Overview 387; Stereolithography 387; Rapid Tooling 388	387
Buying Molds	
Introduction 389; Industry Guide 389; Purchase Order 390; Mold Design 390; Production of Molds 392	389
Mold Storage	393
Computer-Aided Mold and Product Design	393
Production Control Systems	393
Computer Monitoring of Information	394
Productivity and People	394
Value Analyses	394
Zero Defects	395
Terminology	395
Chapter 5 Fundamentals of Designing Products	415
Overview	415
Molding Influences Product Performance	417
Design Optimization	421
Computer Analysis 422	
Material Optimization	423
Material Characteristics	423
Behavior of Plastics	431
Thermal Stresses 437; Viscoelastic Behavior 437	439
Molding Tolerances	
Tolerances and Designs 443; Tolerance Allowances 443; Tolerances and Shrinkages 444; Tolerances and Warpages 444; Thin-Wall Tolerances 444; Micron Tolerances 444; Tolerance Damage 444; Full Indicator Movements (FIMs) 444; Tolerance Selection 444; Tolerance Stack-Ups 445; Standard Tolerances 445	447
Tolerance Measurement and Quenching	448
Dimensional Properties	449
Dimensional Tolerances	
Product Specifications 449; Using Geometric Tolerancing 450	

Design Features That Influence Performance	451
Plastics Memory	451
Residence Time	453
Computerized Knowledge-Based Engineering	453
Orientation	453
Accidental Orientation 453; Orientation and Chemical Properties 453; Orientation and Mechanical Properties 454; Orientation and Optical Properties 454; Orientation Processing Characteristics 454; Orientation and Cost 454	
Molecular Orientation: Design of Integral Hinges	455
Interrelation of Material and Process with Design	455
Design Shapes	455
Shapes and Stiffness	456
Stress Relaxation	457
Predicting Performance	458
Choosing Materials and Design	458
Design Concept 458; Engineering Considerations 458	
Design Considerations	459
Design Parameters 460; Types of Plastics 460	
Long-Term Behavior of Plastics: Creep	461
Designing with Creep Data 463; Allowable Working Stress 465; Creep Behavior Guidelines 466	
Design Examples	466
Stapler 466; Snap-Fits 467; Springs 467	
Design Approach Example	467
Design Accuracy	467
Risks and the Products	472
Acceptable Risks 472; Acceptable Goals 473; Acceptable Packaging Risks 473; Risk Assessments 473; Fire Risks 473; Risk Management 473; Risk Retention 473	
Perfection	474
Cost Modeling	474
Innovative Designs	474
Protect Designs	474
Summary	475
Molders' Contributions 476	
Terminology	477
Chapter 6 Molding Materials	479
Overview	479
Definition of Plastics 484; Heat Profiles 488; Costs 489; Behavior of Plastics 490; Checking Materials Received 491	
Neat Plastics	491
Polymer Synthesis and Compositions	491
Polymerization 493	
Copolymers	493
Interpenetrating Networks	497
Graftings	498

	Mechanical Properties and Molding Variables 601; Izod impact 602; Molding for Electroplating 605; Property Variation with Position Mold Geometry 605; Summary 606	
Polycarbonates	Drying 606; Recycle and Virgin Proportions 607; Processing 608; Hydrolysis 609; Rheology 609; Heat Transfer 609; Residual Stress 610; Annealing 611	606
Injection Molding Thermosets	Process 613; Hot- and Cold-Runner Molding 614; Material Stuffer 615	611
Energy Considerations		616
Summary		617
Terminology		617
Chapter 7 Process Control		623
Process Control Basics	Developing Melt and Flow Control 630; Inspection 630; Computer Process Data Acquisition 630; Control Flow Diagrams 632; Fishbone Diagram 632	623
Overview	Technology 636; Fast Response Controls 638; Control Approaches 639; Process Control Methods 640; Production Monitoring 640; On-Machine Monitoring 641	634
Temperature Control of Barrel and Melt		644
Electronic Controls		646
Fuzzy Logic Control		647
Process Control Techniques		648
Process Control Approaches	What Are the Variables? 652; Why Have Process Control? 654; Control of Which Parameters Can Best Eliminate Variability? 654; What Enables Parameter Controllability? 657; Where Does the Process Controller Go? 661; Basic Features a Process Controller Should Have 662; Applications 664; Summary 666	652
Process Control Problems		667
Cavity Melt Flow Analyses	Problem 669; Melt Viscosities versus Fill and Pack 669; Test Methodology 670; Analyzing Results 673; Example Test 673; Using Empirical Test Data to Optimize Fill Rates 674; Melt Vibrations during Filling 675; Stabilizing via Screw Return Time 675	668
Relating Process Control to Product Performances	Sensor Requirements 676; Molding Parameters 676; Display of Monitored Molding Parameters	676

Processing Rules	710
Processing and Patience	710
Processing Improvements	710
Control Advantages	711
Plantwide Control and Management	711
Automatic Detections	712
Terminology	713
Chapter 8 Design Features That Influence Product Performance	716
Overview	716
Audits 717; Computer Approaches 717; Design Feature That Influence Performance 718	
Plastic Product Failures	718
Design Failure Theory	719
Basic Detractors and Constraints	719
Tolerance and Shrinkage 721; Residual Stress 725; Stress Concentration 726; Sink Mark 727	
Design Concept	727
Terminology	730
Sharp Corners	730
Uniform Wall Thickness	732
Wall Thickness Tolerance	732
Flow Pattern	733
Parting Lines	733
Gate Size and Location	733
Taper or Draft Angle	735
Weld Lines	738
Meld Lines 740	
Vent, Trapped Air, and Ejector	740
Undercuts	740
Blind Holes	740
Bosses	747
Coring	750
Press Fits	751
Internal Plastic Threads	752
External Plastic Threads	752
Molded-In Inserts	753
Screws for Mechanical Assembly	754
Gears	759
Ribs	760
Geometric Structural Reinforcement	763
Snap Joints	764
Integral Hinges	765
Mold Action	766
Chapter 9 Computer Operations	770
Overview	770
Communication Benefits 773; Computerized Databases of Plastics 775; CAD/CAM/CAE Methods 775; Computer-Integrated Manufacturing 775	

	Injection Moldings and Molds 856; Materials 857; Shrinkage 858; Materials and Designs 859; Design Products 860; Engineering 861; Graphics 861; Management 862; General Information 862; Training 862	
	Plastics, Toys, and Computer Limitations	863
	Computers Not Designed for Home	863
	Summary	863
	Terminology	864
Chapter 10	Auxiliary Equipment and Secondary Operations	868
	Introduction	868
	Energy Conservation 870; Planning Ahead, Support Systems 871	
	Overview	871
	Hoppers 871; Material Handling, Feeding, and Blending 872; Material Handling Methods 872; Sensors 874	
	Materials Handling	875
	Bulk Density 875; Basic Principles of Pneumatic Conveying 876; Air Movers 883; Pneumatic Venturi Conveying 886; Powder Pumps 886; Piping 888; Hoppers 889; Filters 889; Bulk Storage 891; Blenders 891; Unloading Railcars and Tank Trucks 894	
	Drying Plastics	895
	Nonhygroscopic Plastics 895; Hygroscopic Plastics 895; Drying Overview 895; Dryers 896	
	Water Chilling and Recovery	904
	Overview 904; Heat-Transfer Calculations 905; Requirements Vary with Materials 905; Water Recovery 907; General Considerations 908; Calculation of the Cooling Load 911; Determining Water Loads 913	
	Energy-Saving Heat Pump Chillers	915
	Granulators	916
	Safety 916; Basics 917; Hoppers 917; Cutting Chambers 918; Cutting Chamber Assembly 921; Hard Face Welding 921; Screen Chambers 922; Auger Granulators 922; Granulating and Performance 924	
	Mold Dehumidification	929
	Dewpoints 929; Mold Surface Temperatures 929; Effect of Change in Air Properties 930; Air Conditioning and Desiccant Dehumidification 931; Dehumidification System 932	
	Parts-Handling Equipment	933
	Controlled Motions 933; People and PHE 935; Different Types 935; Value in Use 937; Detriments 938; Robots Performance 938; Safety Measures 938	

Machining	939
Overview 939; Plastic Characteristics 939; Cutting Guidelines 940	
Joining and Assembling	941
Adhesives 941; Solvents 946; Welding Techniques 948; Welding Process Economic Guide 953	
Cleaning Tools	953
Abrasives 953; Carbon Dioxide 953; Cryogenic Deflashing 954; Brass 954; Hot Salts 954; Solvents 954; Ultrasonics 954; Vacuum Pyrolysis 954; Coatings 955	
Finishing and Decorating	955
Potential Preparation Problems 955; Pretreatments 959; Removing Mold Release Residues 959	
Terminology	963
Robot Terms 966	
Chapter 11 Troubleshooting and Maintenance	969
Troubleshooting Introduction	969
Plastic Material and Equipment Variables 970	
Definitions	971
Defects 972	
Remote Controls	972
Troubleshooting Approaches	972
Finding the Fault 976	
Shrinkages and Warpages	978
Weld Lines	978
Counterflow 979	
Troubleshooting Guides	979
Flashes	980
Injection Structural Foams	994
Hot-Runners	994
Hot-Stamp Decorating	994
Paint-Lines	994
Granulator Rotors	1001
Auxiliary Equipment	1001
Screw Wear Guide	1001
Inspection Rollers 1010; Diameters 1010; Depths 1011; Concentricity and Straightness 1011; Hardness 1011; Finish and Coating Thickness 1012; Screw Manufacturing Tolerances 1012	
Barrel Inspection Guide	1012
Inside Diameters 1012; Straightness and Concentricity 1012; Barrel Hardness 1012; Barrel Specifications 1012	
Preventive Maintenance	1013
Cleaning the Plasticator Screw 1014; Oil Changes and Oil Leaks 1015; Checking Band Heaters, Thermocouples, and Instruments 1015; Alignment, Level, and Parallelism 1015; Hydraulic,	

	Pneumatic, and Cooling-Water Systems 1015; Hydraulic Hose 1016	
	Keep the Shop Clean	1016
	Keep Spare Parts in Stock	1016
	Return on Investment	1016
	Maintenance	1018
	Hydraulic Fluid Maintenance Procedures 1020; Problems and Solutions 1020; Downtime Maintenance 1021; Preventative Maintenance 1021; Services 1022	
	Safety	1023
	Maintenance Software	1023
	Summary	1023
	Terminology	1023
Chapter 12	Testing, Inspection, and Quality Control	1028
	Testing	1028
	Design and Quality	1031
	Basic versus Complex Tests	1031
	Sampling	1032
	Acceptable Quality Level 1032; Sampling Plan 1032; Sampling Size 1033	
	Characterizing Properties and Tests	1033
	Orientation and Weld Lines 1033; Density and Specific Gravity 1035; Morphology: Amorphous and Crystalline Plastics 1036; Molecular Structures 1037	
	Mechanical Properties	1041
	Mechanical Test Equipment 1042; Tensile Test 1042; Deflection Temperature under Load 1045; Creep Data 1045	
	Electrical Tests	1046
	Thermal Properties	1046
	Chemical Properties	1046
	Chromatographic and Thermal Tests	1049
	Liquid Chromatography 1049; Gel Permeation Chromatography 1049; Gas Chromatography 1050; Ion Chromatography 1050; Thermoanalytical Method 1051; Thermogravimetric Analysis 1051; Differential Scanning Calorimetry 1052; Thermomechanical Analysis 1053; Dynamic Mechanical Analysis 1054; Infrared Spectroscopy 1054; X-Ray Spectroscopy 1055; Nuclear Magnetic Resonance Spectroscopy 1055; Atomic Absorption Spectroscopy 1055; Raman Spectroscopy 1055; Transmission Electron Microscopy 1056; Optical Emission Spectroscopy 1056; Summary of Characterizing Properties 1056	
	Types of Tests	1060
	Selected ASTM Tests 1062; Viscoelastic Properties 1079; Rheology, Viscosity, and Flow 1080;	

Total Quality Management	1117
Training and People	1117
Training and Quality	1117
Emerging Trends in Training	1117
Training versus Education	1118
Economic Significance of Quality	1118
Cost of Quality	1119
Terminology	1119
Chapter 13 Statistical Process Control and Quality Control	1127
Overview	1127
Combining Online SPC and Offline SQC	1127;
Improve Quality and Increase Profits	1128;
Statistical Material Selections: Reliabilities	1128;
Statistical Material Selections: Uncertainties That Are Nonstatistical	1129;
Statistical Probabilities and Quality Control	1129;
Statistics and Commitments	1129;
Statistics and Injection Molding	1129
Computers and Statistics	1131;
Statistical Tools	1134
Online Monitoring of Process Variables	1134
Gathering and Analyzing Data	1135
Process Control and Process Capability	1138
Control Charts	1138
Defect Prevention	1139
Understanding Modern Methods of Control	1140
Standard Deviations	1142;
Frequency Distribution	1143;
Control Chart	1145
Standard Deviation versus Range	1147
Basic Statistical Concepts	1148
Mean Value, Range, and Standard Deviation	1148;
Distribution	1149;
Process Control Chart	1150;
Machine Capability	1150;
Process Capability	1150
Importance of Control Charts	1151
Practical Example	1152
Machine Capability	1153;
Process Capability	1153;
Control Limits for the Process Control Chart	1154
A Successful SPC System	1154
Production Controls	1155;
SPC Step One: Raw Material	1156;
SPC Step Two: Materials Handling	1156;
SPC Step Three: Injection Molding	1156;
SPC Implementation: Summary of Experience	1156
How to Succeed with SPC	1159
Outlook	1160
Terminology	1160

Chapter 14	Costing, Economics, and Management	1163
Overview		1163
	Machine Sales 1163; Formulas for Business Failures 1164; Managing 1164	
Costing		1165
	Estimating Part Cost 1167; Automation of Data Gathering 1169; Machinery Financing 1169; Energy Savings 1170	
Technical Cost Modeling		1171
Cost Analysis Methods		1171
	Material Times Two 1171; Material Cost plus Shop Time 1172; Material Cost plus Loaded Shop Time 1172; Quotes 1172	
Technical Cost Analysis		1173
	Variable Cost Elements 1173; Fixed Costs 1174; Summary of Fixed and Variable Costs 1177; Process Parameters 1178; Technical Cost Modeling 1178; Summary of Technical Cost Analysis 1179	
Financial Plant Management		1180
Cost Management		1180
	Information Necessary for Product Costing and Cost Control 1182; Reporting from the Production Floor and Management Control Reports 1183	
Profit Planning and Budgeting		1185
	Gathering the Data for Profit Planning and Budgeting 1186; Establishing Profit, Goals, and Sales Forecasts 1186; Developing the Detailed Plans and Budgets 1187; Flexible Budgeting 1187	
Materials Management		1188
	Order Processing 1188; Inventory Control 1189; Production Scheduling and Control 1189; Scheduling Approaches 1190; Purchasing 1191	
Terminology		1192
Chapter 15	Specialized Injection Molding Processes	1197
Introduction		1197
Blow Moldings		1197
	Injection Blow Moldings 1201; Stretched Blow Moldings 1204; Stretched Blow Moldings with Handle 1206; Stretched Blow Molding Operation Specialties 1207; Blow Molding Shrinkages 1209; Troubleshooting 1211; Blow Molding versus Injection Molding 1215	
Coinjection Molding		1216
Injection Molding Sandwich Structures		1218
Gas-Assist Injection Molding		1219
	Advantages and Disadvantages 1220; Basic Processes and Procedures 1220; Molding Aspects 1223; Shrinkage 1224; Summary 1224	

Gas Counterflow Molding	1225
Melt Counterflow Molding	1225
Structural Foam Molding	1225
Overview 1225; Performance 1226; Plastic Materials 1226; Characteristics of Foam 1226; Design Analysis 1227; Blowing Agents 1229; Methods of Processing SF with Chemical Blowing Agents 1230; Processing SF with Gas Blowing Agents 1232; Tooling 1234; Start-up for Molding 1234	
Injection-Compression Molding (Coining)	1235
Multiline Molding	1236
Counterflow Molding	1236
Oscillatory Molding of Optical Compact Disks	1237
Digital Video Disk Moldings 1238	
Continuous Injection Molding	1239
Velcro Strips 1239; Electrically Insulated Buttons for Coaxial Cables 1242; Railtrack Molding 1243	
Reaction Injection Molding	1244
The Mold 1248; Process Controls 1249	
Liquid Injection Molding	1250
Soluble Core Molding	1251
Insert Molding	1252
Inmolding	1252
Two-Color Molding 1253; Decoration 1253; Paint Coating 1254; Back Molding 1254; Two-Shot Molding 1254; Inmold Assemblies 1254; Double-Daylight Process 1255	
Overmolding Compatible Plastics with No Welding	1255
Closure Moldings	1256
Unscrewing Closures 1256; Conventional Unscrewing Molds 1256; Unscrewing System Moldings 1256; Collapsible and Expandable Core Molds 1257; Split-Cavity Molds 1258; Strippable Thread Molds 1258	
Vacuum Molding	1260
Tandem Injection Molding	1260
Molding Melt Flow Oscillations	1261
Ram Injection Molding	1262
Golf Ball Moldings	1262
Micro Injection Molding	1264
Aircraft Canopies	1265
Injection Molding Nonplastics	1266
Introduction 1266; Metal Injection Molding 1266; Ceramic Injection Molding 1268	
Terminology	1268
Chapter 16 Injection Molding Competition	1270
Introduction	1270
Plastic Fabricating Processes	1272
Rotational Molding	1274
Extrusions	1283

Extrusion Blow Moldings	1284
Formings	1288
Thermoforming	1289
Molds 1291	
Cold Forming	1291
Cold Draw Forming	1292
Dip Forming	1292
Pressure Forming	1292
Rubber Pad Forming	1292
Compression-Stretched Moldings	1293
Solid-Phase Scrapless Forming	1293
Solid-Phase Pressure Forming	1293
Slip Forming	1293
Castings	1293
Foam Molding	1294
Expandable Plastics	1294
Expandable Polystyrenes 1294	
Compression Molding	1295
Laminates 1297	
Transfer Molding	1298
Screw Plunger Transfer Molding 1298	
Reinforced Plastics	1298
Directional Properties 1301; Processes and Products 1301	
Stampable Reinforced Plastics	1303
Machining Plastics	1304
Processor Competition	1304
Legal Matters	1304
Accident Reports 1304; Acknowledgments 1304; Chapter 11 Act 1304; Conflicts of Interest 1304; Consumer Product Safety Act 1304; Copyright 1305; Defendant 1305; Employee Invention Assignment 1305; Expert Witness 1305; Insurance Risk Retention Act 1305; Invention 1305; Mold Contractual Obligation 1305; Patent 1305; Patentability 1306; Patent Information 1306; Patent Infringement 1306; Patent Pooling with Competitors 1306; Patent Search 1306; Patent Term Extension 1306; Patent Terminology 1306; Plaintiff 1306; Processor, Contract 1307; Product Liability Law 1307; Protection Strategies 1307; Quotations 1307; Right-To-Know 1307; Shop-Right 1307; Software and Patents 1307; Tariff 1307; Term 1307; Tort Liability 1308; Trademark 1308; Trade Name 1308; Warranty 1308	
Chapter 17 Summary	1309
The Most Important Forming Technique	1309
Processing Trends	1311
Productivity	1313
Machine Aging 1315; Response to Change 1316	