

Contents

Nomenclature	xv
1. Introduction to Industrial Sprays	1
1.1 Why Use a Spray?	1
1.2 Scope of this Book	3
1.2.1 Brief Glossary of Terms	3
1.2.2 When is a Spray an “Industrial Spray”?	3
1.2.3 Layout of this Book	3
1.2.4 The Approach to Information Provision on Each Process	4
1.3 Scope and Scale of Industrial Spraying	5
2. Background on Sprays and Their Production	7
2.1 Fundamentals of Sprays	7
2.1.1 Patterning	7
2.1.2 Drop Size Distributions and Mean Diameters	8
2.1.3 Atomization	12
2.1.4 Droplets and Their Dynamics	14
2.1.5 Deposition and Impact of Drops	15
2.1.6 Non-Newtonian Multi-Component Liquids and Slurries	16
2.2 Basic Atomizer Designs	17
2.2.1 Overview	17
2.2.2 Pressure Jet	17
2.2.3 Two-Fluid Atomizers	23
2.2.4 Other Designs	25
2.3 Measurement Techniques	28
2.3.1 Light Scattering: Laser Diffraction and PDA	28
2.3.2 Flow Visualization and Sheet Lighting	30
2.4 Computer Modelling (CFD)	31
References	32
3. Sprays in Industrial Production Processes	35
3.1 Food Processing	35
3.1.1 Introduction	35
3.1.2 Manufacturing Process Description	36
3.1.3 Atomizer Types, Design and Operating Parameters	44
3.1.4 Measurement Techniques and Performance Analysis	58
3.1.5 Problems and Future Challenges	64

3.2	Pharmaceutical Manufacturing.....	67
3.2.1	Introduction	67
3.2.2	Pharmaceutical Manufacturing Processes	68
3.2.3	Nozzle Types, Design and Operating Parameters.....	75
3.2.4	Measurement Techniques and Performance Analysis	82
3.2.5	Problems and Future Challenges	83
3.3	Sprays in Pulp and Paper Manufacturing	85
3.3.1	Introduction	85
3.3.2	Process Description	85
3.3.3	Spray Properties.....	106
3.3.3.1	Atomizer types, Design and Operating Parameters	106
3.3.3.2	Measurement Techniques and Performance Analysis	108
3.3.4	Problems and Future Challenges	111
3.4	Miscellaneous Applications	112
3.4.1	Introduction	112
3.4.2	Bonding	112
3.4.3	Polymers.....	112
3.4.4	Aerosol Cans	113
3.4.5	Future Developments.....	115
	References	116
4.	Processes Involving Vaporization, Cooling or Cleaning of Gases.....	119
4.1	Fire Suppression.....	119
4.1.1	Introduction	119
4.1.2	Process Description	121
4.1.2.1	Conventional Fire Fighting with Low-Pressure Nozzles	123
4.1.2.2	Fire Suppression with High-Pressure Water Fog.....	126
4.1.3	Spray Properties.....	131
4.1.3.1	Atomizer Types and Designs.....	131
4.1.3.2	Measurement Techniques and Data Analysis.....	135
4.1.4	Problems and Future Challenges	137
4.2	Air Humidification	138
4.2.1	Introduction	138
4.2.2	Process Description	139
4.2.2.1	Direct Air Humidification with Spray Nozzles	144
4.2.2.2	Air Scrubbers and Humidifiers.....	147
4.2.3	Spray Properties.....	153
4.2.3.1	Atomizer Types and Designs.....	153
4.2.3.2	Measurement Techniques and Data Analysis.....	156
4.2.4	Problems and Future Challenges	159
4.3	Gas Cleaning and Conditioning Processes	159
4.3.1	Introduction	159
4.3.2	Process Description	160
4.3.2.1	Gas Cooling.....	161
4.3.2.2	De-dusting of Gases.....	162
4.3.2.3	De-noxification of Exhaust Gases	163
4.3.2.4	Flue Gas De-sulphurization	165

4.3.3	Spray Properties.....	168
4.3.3.1	Atomizer Types and Designs.....	169
4.3.3.2	Measurement Techniques and Data Analysis.....	174
4.3.4	Problems and Future Challenges	179
	References	180
5.	Processes Involving Spray Surface Impact	185
5.1	Agricultural Sprays	185
5.1.1	Introduction	185
5.1.2	Process Description	185
5.1.2.1	Principles of Agricultural Spraying	185
5.1.2.2	Spray Drift and Biological Efficiency	191
5.1.2.3	Spraying from Aircraft	192
5.1.2.4	Electrostatic Spraying of Pesticides.....	195
5.1.3	Spray Properties.....	197
5.1.3.1	Atomizer Types and Designs.....	197
5.1.3.2	Measurement Techniques and Data Analysis.....	204
5.1.4	Problems and Future Challenges	208
5.2	Surface Cleaning and Treatment	209
5.2.1	Introduction	209
5.2.2	Process Description	211
5.2.2.1	Tank Washing.....	212
5.2.2.2	Surface Treatment	216
5.2.2.3	High -pressure Cleaning	220
5.2.3	Spray Properties.....	224
5.2.3.1	Atomizer Types and Designs.....	226
5.2.3.2	Measurement Techniques and Data Analysis.....	233
5.2.4	Problems and Future Challenges	235
5.3	Spray Painting and Coating.....	236
5.3.1	Introduction	236
5.3.2	Spray Painting and Coating in the Automotive Manufacturing Industry	237
5.3.3	Spray Painting and Coating Atomizer Systems.....	242
5.3.4	Measurement Techniques and Performance Analysis	255
5.3.5	Problems and Future Challenges	257
5.4	Printing Processes	261
5.4.1	Introduction	261
5.4.2	Inkjet Print Head Designs and Operating Parameters.....	263
5.4.3	Measurement Techniques and Performance Analysis	275
5.4.4	Problems and Future Challenges	282
	References	289
6.	Fuel Sprays for Fixed Plant.....	293
6.1	Burners, Boilers and Furnaces.....	293
6.1.1	Introduction	293
6.1.2	Description of Processes.....	295
6.1.2.1	Power Generation	295
6.1.2.2	Process Heat Generation.....	297

6.1.2.3	Hot Water or Steam Generation	300
6.1.3	Atomizer Types and Operating Conditions	303
6.1.3.1	Introduction	303
6.1.3.2	Operation of Different Atomizers.....	305
6.1.4	Measurement Techniques and Performance Analysis	315
6.1.4.1	Measurement Techniques	315
6.1.4.2	Performance Analysis.....	316
6.1.5	Problems and Future Challenges	322
6.2	Industrial Gas Turbines	324
6.2.1	Introduction	324
6.2.1.1	Basic Applications.....	324
6.2.1.2	Manufacturing Gas Turbine Atomizers	324
6.2.2	Process Description	326
6.2.3	Atomizer Types	326
6.2.4	Measurement Techniques and Performance Analysis	338
6.2.4.1	Verification and Validation of Fuel Injectors.....	338
6.2.5	Problems and Future Challenges	349
6.3	Industrial Diesel Engines.....	350
6.3.1	Introduction	350
6.3.2	Engines	350
6.3.2.1	General Description.....	350
6.3.2.2	Combustion Process and Engine Valve and Fuel Injection Timing	351
6.3.3	Injection Systems.....	356
6.3.4	Measurement Techniques and Performance Analysis	367
6.3.5	Problems and Future Challenges	376
	References	377
7.	Spraying Hot Surfaces for Making Steel and Other Metals.....	379
7.1	Continuous Casting	379
7.1.1	Introduction	379
7.1.2	Process Description	380
7.1.3	Spray Properties.....	385
7.1.3.1	Atomizer Types and Designs.....	385
7.1.3.2	Measurement Techniques and Data Analysis.....	390
7.1.4	Problems and Future Challenges	397
7.2	Hot and Cold Rolling Mills.....	398
7.2.1	Introduction	398
7.2.2	Process Description	398
7.2.3	Nozzle Types and Operating Parameters.....	403
7.2.4	Measurement Techniques and Performance Analysis	410
7.2.5	Problems and Future Challenges	414
7.3	Descaling	419
7.3.1	Introduction	419
7.3.2	Process Description	419
7.3.3	Spray Properties.....	427
7.3.3.1	Atomizer Types and Designs.....	428
7.3.3.2	Measurement Techniques and Performance Analysis .	430

7.3.4 Problems and Future Challenges	437
References	438
8. Spraying Molten Metals.....	441
8.1 Spray forming.....	441
8.1.1 Introduction	441
8.1.2 Process Description	441
8.1.2.1 Historical Background of Spray Forming Process.....	441
8.1.2.2 The Fundamental Process of Spray Forming.....	444
8.1.2.3 Various Spray Forming Plants.....	446
8.1.3 Atomizers and Spray Properties	452
8.1.3.1 Definition of Atomizer, Nozzle and Orifice in Spray Forming	452
8.1.3.2 Nozzle Types, Design and Operating Parameters.....	452
8.1.3.3 Measurement Techniques and Performance Analysis .	467
8.1.4 Problems and Future Challenges	481
8.2 Metal Powder Manufacture	482
8.2.1 Introduction	482
8.2.2 Atomizer Types	484
8.2.2.1 Introduction	484
8.2.2.2 Gas (Two-Fluid) Atomization	485
8.2.2.3 Water Atomization	486
8.2.2.4 Other Techniques.....	486
8.2.3 Measurement Techniques and Performance	489
8.2.3.1 Measurement Techniques	489
8.2.3.2 Atomizer Performance.....	491
8.2.4 Problems and Future Challenges	494
References	496
Index.....	499