
Contents

Preface to the First Edition.....	xi
Preface to the Second Edition.....	xiii
Authors	xv

Part I General Discussion: Conventional and Novel Drying Concepts 1

1 Need for Advanced Drying Technologies.....	3
1.1 Why New Drying Technologies?	3
1.2 Intensification of Drying Rates.....	4
1.3 Multistage Dryers	7
References	9
2 Classification and Selection Criteria: Conventional versus Novel Technologies	11
References	17
3 Innovation and Trends in Drying Technologies.....	19
3.1 Introduction.....	19
3.2 Innovation: Types and Common Features.....	19
3.3 Development of Improved Drying Technologies	23
3.4 Trends in Drying Research and Development.....	24
References	26

Part II Selected Advanced Drying Technologies 27

4 Drying on Inert Particles	29
4.1 Introduction.....	29
4.2 Drying Mechanism and Process Considerations	29
4.3 Modeling and Scale-Up	38
4.4 Selected Dryers with Inert Particles	42
References	51
5 Impinging Stream Drying.....	55
5.1 Basic Features	55

5.2	Hydrodynamics and Heat Transfer	62
5.2.1	Penetration Depth and Oscillation Time	63
5.2.2	Pressure Drop	65
5.2.3	Heat Transfer.....	66
5.3	Drying	67
5.4	Some Recent Studies on ISD	71
	References	73
6	Drying in Pulsed Fluid Beds.....	77
	References	87
7	Superheated Steam Drying	89
7.1	Introduction.....	89
7.2	Basic Principles of Superheated Steam Drying	91
7.3	Classification and Selection of Superheated Steam Dryers	93
7.4	Quality Considerations.....	94
7.5	Superheated Steam Drying of Selected Products	97
7.5.1	Drying of Sludges.....	97
7.5.2	Drying of Coal	98
7.5.3	Drying of Beet Pulp	101
7.5.4	Drying of Lumber	103
7.5.5	Drying of Pulp	106
7.5.6	Drying of Peat.....	108
7.5.7	Drying of Paper and Tissue	111
7.5.8	Drying of Wood Particles and Wood Wafers.....	112
7.5.9	Low-Pressure Drying with Superheated Steam	113
7.5.10	Miscellaneous Applications.....	113
7.6	Utilization of Exhaust Steam	114
7.7	Closing Remarks.....	117
	References	118
8	Airless Drying.....	123
	References	127
9	Drying in Mobilized Beds.....	129
	References	140
10	Drying with Shock Waves	143
	Appendix: Process Calculations and Equipment Design	153
	References	159
11	Vacu Jet Drying System.....	161
	References	167

12 Contact-Sorption Drying	169
12.1 General Characteristics	169
12.2 Mechanism of Contact-Sorption Drying	171
12.3 Characteristics of Sorbents/Carriers	179
12.4 Technology of Contact-Sorption Drying	184
12.4.1 Drying of Particulate Materials on Inert Sorbent	184
12.4.2 Drying in a Fluid Bed of Inert Sorbent	185
12.4.3 Sorption Drying Using Filler Materials	187
12.4.4 Contact-Sorption Freeze-Drying	194
References	197
13 Sonic Drying	199
13.1 Basic Characteristics of Sound	199
13.2 Sound Generation	203
13.3 Mechanism of Sonic Drying	205
13.4 Drying Kinetics	210
13.5 Sound-Assisted Dryers	215
References	221
14 Pulse Combustion Drying	225
14.1 Principle of Pulse Combustion	225
14.2 Pulse Combustors: Design and Operation	229
14.2.1 Basic Types of Pulse Combustors	229
14.2.1.1 Quarter-Wave (Schmidt) Pulse Combustor	229
14.2.1.2 Helmholtz Pulse Combustor	230
14.2.1.3 Rijke-Type Pulse Combustor	230
14.2.2 Valve and Valveless Pulse Combustors	230
14.2.2.1 Flapper and Reed-Type Valves	231
14.2.2.2 Rotary Valves	232
14.2.2.3 Aerodynamic Valves	234
14.3 Pulse Combustion in Drying	236
14.4 Numerical Simulation of Pulse Combustion Drying	250
References	258
15 Heat Pump Drying	263
15.1 Introduction	263
15.2 Principle of Heat Pump Operation	263
15.3 Low-Temperature Heat Pump Drying	272
15.4 Chemical Heat Pump Drying	278
15.5 New Developments and Trends in Heat Pump Drying	286
References	288

16 Fry-Drying	293
References	297

Part III Selected Techniques for Drying and Dewatering 299

17 Mechanical Thermal Expression.....	301
References	306
18 Displacement Drying.....	307
References	314
19 Vapor Drying.....	315
References	319
20 Slush Drying	321
References	325
21 Atmospheric Freeze-Drying.....	327
References	335
22 Spray-Freeze-Drying.....	337
References	341
23 Refractance Window	343
References	346
24 Carver-Greenfield Process.....	347
References	350

Part IV Hybrid Drying Technologies 351

25 Microwave-Convective Drying with Cogeneration	353
References	362
26 Microwave-Vacuum Drying	363
References	369
27 Filtermat Drying	371
References	373
28 Spray-Fluid Bed-Vibrated Fluid Bed Dryer.....	375
Reference	377

29 Combined Filtration and Drying	379
29.1 Introduction	379
29.2 Pressure Filtration and Drying	381
29.3 Centrifuge Dryer	384
29.4 Vapor Pressure Dewatering	385
29.5 Steam Pressure Filtration	390
29.6 Jet Stream Centrifugation	392
29.7 Microwave-Assisted Filter Drying	393
References	395
30 Radio-Frequency Drying with 50 Ω Technology	397
References	405
31 Radio Frequency-Assisted Heat Pump Drying	407
References	412
32 Radio Frequency-Vacuum Drying	413
References	417
33 Miscellaneous Hybrid Technologies	419
33.1 Combined Microwave and Superheated Steam Drying	419
33.2 Combined Infrared and Convection Drying	420
33.3 Infrared Heat Pump Drying	420
33.4 Heat Pump Superheated Steam Drying	421
33.5 Infrared-Microwave Freeze-Drying	422
References	423
 Part V Other Techniques	 425
34 Special Drying Technologies	427
34.1 Drying by Alternating High- and Low-Pressure Operations	427
34.2 Through-Air Rotary Dryer	429
34.3 Drying with Bed Mixing	434
34.4 Drying at Ambient Air Temperature	438
34.5 Vacuum-Superheated Steam Drying and Granulation	441
34.6 Drying in Rotating-Jet Spouted Bed	445
34.7 Drying with Sol-Gel Transformations	448
34.8 Supercritical Fluid Technology to Produce Dry Particles	452
References	453
Index	457