Contents

Preface xiii
Acknowledgments xv

1. Introduction to Fuel Blending 1

1.1. Overview 1
1.2. Fuel Blending for Solid Fuels 1
1.2.1. Blending System Considerations 1
1.2.2. Where Blending Can Occur 2
1.3. Objectives for Blending 5
1.3.1. Economic Considerations with Fuel Blending 7
1.3.2. Environmental Considerations with Fuel Blending 8
1.3.3. Historical and Technical Considerations for Fuel Blending 11
1.4. Blending for the Steel Industry—The Development of Petrology 13
1.4.1. Basics of Macerals 14
1.4.2. Petrography Applied to the Steel Industry 15
1.4.3. Conclusions on Blending for the Steel Industry 16
1.5. Typical Fuel Blends 16
1.5.1. Coal–Coal Blends 16
1.5.2. Coal–Biomass Blends 18
1.5.3. Coal–Opportunity Fuel Blends 21
1.6. Blends and Firing Systems 22
1.6.1. Types of Firing Systems 23
1.6.2. Types of Boilers 26
1.7. Conclusions 27
References 27

2. Principles of Solid Fuel Blending 31

2.1. Introduction: Blending for Dollars 31
2.2. Designing the Most Favorable Fuel 32
2.3. Influences on the Most Favorable Fuel Blend 34
2.3.1. Firing Method Considerations 34
2.3.2. Market Considerations 36
2.4. Developing a Fuel Blending Strategy 36
2.4.1. Blend Fuel Considerations 37
2.4.2. Combustion Characteristics of Binary and Ternary Blends 37
2.4.3. Reactivity, Ignition, and Flame Characteristics of Fuel Blends 42

2.5. Formation of Pollutants 48
2.6. Fuel Blending Characteristics Influencing Deposition 53
2.7. Fuel Blending and Corrosion 55
2.8. Blending's Impact on the Physical Characteristics of Solid Fuels 59
2.9. Management and Control of Fuel Blending 62
2.10. Conclusions 66
References 66

3. Blending Coal on Coal 71

3.1. Introduction and Basic Principles 71
3.2. Blending of Coal for Combustion and/or Gasification Purposes 75
3.3. Combustion and Gasification Processes 77
3.3.1. Combustion Processes and Fuel Blending 78
3.3.2. Coal Blending and the Combustion Process 80
3.3.3. Gasification Processes 84
3.4. Coals Used in Commercial Applications and Their Blending Potential 84
3.4.1. Characteristics of Various Commercially Significant Coals 84
3.4.2. Relationship of Chemical Composition to Petrography 93
3.4.3. Chemical Composition and Calorific Value 96
3.5. Kinetics and the Analysis of Coal Blend Reactivity 97
3.5.1. Devolatilization Kinetics 97
3.5.2. Reactivity and Ignition Temperature of Coal Blends 102
3.5.3. Char Oxidation Kinetics 102
3.6. The Behavior of Inorganic Constituents 103
3.6.1. Slagging and Blended Coals 104
3.6.2. Fouling and Blended Coals 109
3.6.3. Quantifying the Inorganic Interaction 111
3.7. Managing the Coal-on-Coal Blending Process 113
3.7.1. Where Blending Can Occur 113
3.7.2. Influence of Blending on Materials Handling Issues 115
3.7.3. How Coal Blends Can Be Managed 116
3.7.4. Other Considerations 118
3.8. Conclusions 119
References 120

4. Blending Coal with Biomass: Cofiring Biomass with Coal 125

4.1. Introduction 125
4.2. Biomass and Coal Blending 125
4.2.1. Properties of Biomass and Coal 126
4.3. Cofiring: Reducing a Plant's Carbon Footprint 134
4.3.1. The Carbon Cycle 135
4.3.2. The Role of Biomass for Coal-Fired Plants 135

4.4. Other Reasons for Cofiring 135
4.4.1. SO_2 Management 136
4.4.2. NO_x Management 137
4.5. Cofiring in the United States and Europe 137
4.6. Characteristics of Biomass 138
4.6.1. Types of Biomass 138
4.6.2. Standard Characteristics of Biofuels 142
4.6.3. Fuel Porosity and Its Implications 144
4.6.4. Proximate and Ultimate Analysis and Higher Heating Value 145
4.6.5. Ash Elemental Analysis 145
4.6.6. Trace Elements 146
4.7. Reactivity Measures for Biomass 146
4.7.1. Reactivity of Combustibles 146
4.7.2. Structure and Reactivity 148
4.7.3. Drop Tube Kinetics 149
4.8. Ratios from Other Measures 152
4.9. Comparisons of Biomass to Coal 156
4.9.1. Central Appalachian Bituminous Coal 156
4.9.2. Illinois Basin Coal 156
4.9.3. Powder River Basin Coal 156
4.9.4. Lignite 157
4.10. The Chemistry of Cofiring 157
4.10.1. Reactivity and Cofiring 157
4.10.2. Evolution of Specific Elements and Compounds 160
4.11. Burning Profiles of Biomass–Coal Blends 161
4.12. Implications for Biomass–Coal Cofiring Systems 169
4.12.1. Biomass–Coal Blend Issues 171
4.12.2. Biomass–Coal Blend Systems 173
4.12.3. Cofiring Methods and Equipment—Mechanical Systems 176
4.13. Case Studies in Cofiring 178
4.13.1. Cofiring Experiences 178
4.14. Conclusions 195
References 195

5. Waste Fuel–Coal Blending 201

5.1. Introduction 201
5.2. Tire-Derived Fuel 201
5.2.1. Overview 201
5.2.2. Typical Composition 202
5.2.3. Physical Characteristics 204
5.2.4. Types of Tire-Derived Fuel 205
5.2.5. Preparation and Handling Issues 205
5.2.6. Combustion Considerations 210
5.2.7. Case Studies 210
5.2.8. Conclusions Regarding Tire-Derived Fuel as a Blend Fuel 215

5.3. Petroleum Coke 216
5.3.1. Fuel Characteristics of Petroleum Coke 218
5.3.2. Petroleum Coke Issues 219
5.3.3. Petroleum Coke Utilization in Boilers 221
5.3.4. Petroleum Coke Utilization in Other Systems 230
5.4. Waste Plastics and Paper 232
5.4.1. Waste Plastic Composition 233
5.4.2. Waste Plastic and Paper Preparation 235
5.4.3. Waste Plastic Utilization 237
5.5. Hazardous Wastes 238
5.5.1. Fuel Characteristics of Hazardous Wastes 238
5.5.2. Combustion of Hazardous Wastes in Rotary Kilns 239
5.5.3. Waste Oil Utilization 241
5.6. Conclusions 243
References 244

6. Environmental Aspects of Fuel Blending 249

6.1. Introduction 249
6.2. Regulatory Climate as It Influences Blending and Cofiring 249
6.3. Blending for Environmental and Economic Reasons 250
6.4. Areas of Concern 250
6.4.1. Particulates 250
6.4.2. Sulfur Dioxide 251
6.4.3. Nitrogen Oxides 251
6.4.4. Mercury 251
6.4.5. Fossil CO_2 252
6.5. Ash Management for Power Plants 252
6.5.1. Bottom Ash 252
6.5.2. Flyash 252
6.6. Blending for Emission Benefits 253
6.6.1. Blending PRB Coal with Other Solid Fuels 253
6.6.2. Emission Aspects 254
6.6.3. Selected Case Studies 258
6.7. Cofiring Biomass with Coal 260
6.7.1. Emission Aspects 260
6.7.2. Cofiring in Europe 262
6.7.3. Selected Case Studies 262
6.7.4. Cofiring with Waste 264
6.7.5. Emission Aspects 264
6.7.6. Selected Case Studies 266
6.8. Conclusions 267
References 268

7. Modeling and Fuel Blending 271

7.1. Introduction 271
7.2. The Purposes of Modeling 272

7.3. Specific Applications of Modeling 272
7.3.1. Modeling to Reduce the Use of Physical Tests and Costs 273
7.3.2. Methods of Modeling 274
7.4. Principles of Physical Modeling 280
7.4.1. Some Applications of Physical Modeling 282
7.4.2. Computational Fluid Dynamics Modeling 283
7.5. The Basic Approach of Computational Fluid Dynamics Modeling 284
7.5.1. Computational Fluid Dynamics Modeling of Combustion Processes 285
7.5.2. Products of Combustion Modeling 288
7.5.3. Other Applications of Computational Fluid Dynamics Modeling 290
7.6. Modeling for Blending Purposes 290
7.6.1. The Traditional Approach to Blending Analysis 290
7.6.2. The Detailed Analytical Approach to Blending 291
7.7. Limitations of Modeling 291
7.8. Conclusions 291
References 292

8. Institutional Issues Associated with Coal Blending 295

8.1. Introduction 295
8.2. Institutional Issues Associated with Fuel Blending 297
8.3. Economic Considerations Associated with Blending 300
8.3.1. Fuels Availability 300
8.3.2. Fuel Procurement 304
8.3.3. Fuel Transportation 305
8.4. Process Modifications 309
8.4.1. Coal Handling and Storage 309
8.4.2. Coal Blending 310
8.4.3. Pulverizer Performance 310
8.4.4. Furnace Effects 311
8.4.5. Convective Pass 312
8.4.6. Emissions 312
8.5. Future U.S. and World Coal Production 313
8.6. Conclusions 320
References 320

Index 323