CONTENTS

Preface xi
Acknowledgements xiii
List of Examples xv
List of Tables xvii

1 Steam: A Heat Transfer Fluid 1
   What is Steam? 1
   Steam Is Safe and Flexible 2
   Steam Is Easy to Control 2
   Steam System Types 3
   The Process Steam System 6

2 Steam Formation, Accumulation, and Condensation 9
   The Formation of Steam; Boiling 9
      Pressure and Boiling 11
      The Ideal Gas Law 11
   The Boiling Process 13
      Steaming 14
      Latent and Sensible Heat versus Pressure 16
   The Formation of Flash Steam 16
   Steam Accumulation and Storage 18
   Condensation of Steam 20
### Contents

#### 3 Understanding Heat Transfer
- Radiation Type Heat Transfer 23
- Conduction Type Heat Transfer 26
- Convection-Type Heat Transfer 29
  - *The Heat Transfer Equations* 31
  - *The Overall Heat Transfer Coefficient (U)* 31
  - *Mean Temperature Difference (ΔT_m)* 33
  - ΔT_m for a Steam Boiler 34
  - ΔT_m for a Steam to Process Fluid Heat Exchanger 35
  - Surface Area (m) 35
- Heat Flux 37

#### 4 Steam Quality: It Matters
- Why Steam Quality is Important 40
- Poor Steam Quality Cause and Cures 40
- Steam Classifications 43
- Measuring Steam Quality 45
- Superheated Steam 46

#### 5 Boiler Room Considerations
- Steam Generator Selection 49
  - *Codes and Standards* 49
- Steam System Performance Considerations 53
- Environmental Considerations 55
- Boiler Room Utilities 60

#### 6 The Steam Generator
- The Ideal Steam Generator 68
  - *Steam Generator Types* 70
- Fossil Fuel-Fired Boilers 70
- Solid Fuel-Fired Boilers 76
- Electric Boilers 78
- Unfired Steam Generators 81

#### 7 Boiler Trim, Fuel Delivery, and Combustion Control System
- The Packaged Boiler Concept 83
- Fuel Delivery and Combustion Systems 91
- Low Emissions 98

#### 8 The Steam Delivery System
- Steam Flow 103
- Steam Distribution Piping 104
- Control Valves 115
CONTENTS

Steam Accumulators 121
Steam Filtration 124
Sensing Equipment 126
Stop and Safety Valves 127

9 The Condensate Recovery System 131
Condensate Line Sizing 133
Steam Trap Applications 136
   Thermostatic Group 136
   Mechanical Group 136
   Thermodynamic Group 136
   Thermostatic Steam Trap Group 136
   Mechanical Group 138
   Thermodynamic Group 141
Flash Steam Utilization 144
   How to Size Flash Tanks and Vent Lines 145
Condensate Collection 147
   Electric Condensate Return System 148
   Pressure Motive Condensate Pump 150
   Pressure Motive Pump Installation Requirements 150
   Pumped Condensate Return Line Installation 153
Surge Tank Application 153

10 The Feed Water System 155
Feed Water Deaeration 155
   The Elimination of Dissolved Gases 156
Feed Water Tanks 158
   Feed Water Tank Sizing 160
Feed Water Pumps 162
   Feed Water Pump Sizing 166
Feed Water Piping 167

11 Steam System Chemistry Control 171
Basic Water Chemistry 171
Scale Control 172
Fouling Control 176
Corrosion Control 177
Boiler Blowdown (BD) 180
   Best Operating Practices for Boiler BD 181
   Automatic versus Manual BD Controls 181
   Determining BD Rate 181
Chemical Feed Systems 183
Chemistry Limits 186
12 **Steam System Applications**  
- High-Pressure Steam with High Condensate Returns 189  
- Low-Pressure Steam with High Condensate Returns 190  
- High- or Low-Pressure Steam with Little or No Returns 192  
- High-Pressure or Superheated Steam with Condensate Returns 195  
- Multiple Boiler Installations 195  
- Specialized Steam Equipment 197  
  - **Back Pressure Turbine or BPT** 197  
  - **Steam Hydro Heater** 198  
  - **Steam Superheaters** 200  
  - **Steam Discharge Mufflers** 202

13 **Steam System Efficiency**  
- The System Heat Balance  
  - **Boiler Heat Balance** 207  
- Boiler Efficiency 207  
- Steam System Efficiency 213  
  - **Boiler Internal Cleanliness** 216  
  - **Steam Delivery System Efficiency** 217  
  - **Condensate and Feed Water System Efficiency** 217  
  - **Biomass Fuel Water Content Reduction** 219

14 **Shutdown, Startup, Inspection, and Maintenance**  
- Shutdown and Startup Practices 223  
- Boiler Safety Checks 225  
- Maintenance and Inspection Practices 227  
  - **Inspections** 228  
- Boil Out and Layup Practices 231

15 **Troubleshooting and Commissioning Basics**  
- Startup versus Commissioning 235  
- Approach to Troubleshooting 236  
- Don’t Play the Blame Game 236  
- Precommissioning 237

16 **Commissioning and Troubleshooting the Steam Generator**  
- Determining Boiler Input, Output, and Efficiency 239  
- Boiler Performance Test 241  
- Commissioning the Boiler/Burner Controls 243  
- Commissioning the Boiler Pressure Control System 243  
- Commissioning the Boiler Level Control System 244  
- Commissioning the Boiler Blowdown Controls 244  
- Steam Boiler Troubleshooting 244
17 Commissioning and Troubleshooting the Steam Delivery System 253
   Steam Distribution Piping 253
   Control Valves 254
   Steam Piping Venting 255
   Condensate Trapping/Draining 255
   Troubleshooting the Steam Delivery System 255

18 Commissioning and Troubleshooting the Condensate
   and Feed Water System 257
   Condensate Collection 257
   Feed Water System 258
   Troubleshooting the Condensate and Feed Water Systems 259

19 Commissioning and Troubleshooting the Water Treatment
   Equipment 263
   Setting Up the Water Treatment Systems 263
   Troubleshooting Water Treatment System Problems 264

Appendix A References and Reference Information 267
Appendix B Operations, Maintenance, and Inspection Guidance 283
Appendix C Steam System Design and Commissioning Guidance 293
Index 301