

## Table of Contents

- Preface p. xxiii
- Acknowledgments p. xxvii
- How to Use this Book p. xxix
- Abbreviations p. xxxi
- Distillation Troubleshooting Database of Published Case Histories
- 1 Troubleshooting Distillation Simulations p. 398
- 1.1 VLE p. 398
- 1.1.1 Close-Boiling Systems p. 398
- 1.1.2 Nonideal Systems p. 399
- 1.1.3 Nonideality Predicted in Ideal System p. 400
- 1.1.4 Nonideal VLE Extrapolated to Pure Products p. 400
- 1.1.5 Nonideal VLE Extrapolated to Different Pressures p. 401
- 1.1.6 Incorrect Accounting for Association Gives Wild Predictions p. 401
- 1.1.7 Poor Characterization of Petroleum Fractions p. 402
- 1.2 Chemistry, Process Sequence p. 402
- 1.3 Does Your Distillation Simulation Reflect the Real World? p. 404
- 1.3.1 General p. 404
- 1.3.2 With Second Liquid Phase p. 406
- 1.3.3 Refinery Vacuum Tower Wash Sections p. 406
- 1.3.7 Bug in Simulation p. 407
- 1.3.4 Modeling Tower Feed p. 406
- 1.3.5 Simulation/Plant Data Mismatch Can Be Due to an Unexpected Internal Leak p. 406
- 1.3.6 Simulation/Plant Data Mismatch Can Be Due to Liquid Entrainment in Vapor Draw p. 407
- 1.4 Graphical Techniques to Troubleshoot Simulations p. 407
- 1.4.1 McCabe-Thiele and Hengstebeck Diagrams p. 407
- 1.4.2 Multicomponent Composition Profiles p. 407
- 1.4.3 Residue Curve Maps p. 407
- 1.5 How Good Is Your Efficiency Estimate? p. 407
- 1.6 Simulator Hydraulic Predictions: To Trust or Not to Trust p. 409
- 1.6.1 Do Your Vapor and Liquid Loadings Correctly Reflect Subcool, Superheat, and Pumparounds? p. 409
- 1.6.2 How Good Are the Simulation Hydraulic Prediction Correlations? p. 409
- 2 Where Fractionation Goes Wrong p. 410
- 2.1 Insufficient Reflux or Stages; Pinches p. 410
- 2.2 No Stripping in Stripper p. 412
- 2.3 Unique Features of Multicomponent Distillation p. 412
- 2.4 Accumulation and Hiccups p. 413
- 2.4.1 Intermediate Component, No Hiccups p. 413
- 2.4.2 Intermediate Component, with Hiccups p. 414
- 2.4.3 Lights Accumulation p. 416
- 2.4.4 Accumulation between Feed and Top or Feed and Bottom p. 417
- 2.4.5 Accumulation by Recycling p. 418

- 2.4.6 Hydrates, Freeze-Ups p. 418
- 2.5 Two Liquid Phases p. 419
- 2.6 Azeotropic and Extractive Distillation p. 421
- 2.6.1 Problems Unique to Azeotroping p. 421
- 2.6.2 Problems Unique to Extractive Distillation p. 423
- 3 Energy Savings and Thermal Effects p. 424
- 3.1 Energy-Saving Designs and Operation p. 424
- 3.1.1 Excess Preheat and Precool p. 424
- 3.1.2 Side-Reboiler Problems p. 424
- 3.1.3 Bypassing a Feed around the Tower p. 424
- 3.1.4 Reducing Recycle p. 425
- 3.1.5 Heat Integration Imbalances p. 426
- 3.2 Subcooling: How It Impacts Towers p. 428
- 3.2.1 Additional Internal Condensation and Reflux p. 428
- 3.2.2 Less Loadings above Feed p. 429
- 3.2.3 Trapping Lights and Quenching p. 429
- 3.2.4 Others p. 430
- 3.3 Superheat: How It Impacts Towers p. 430
- 4 Tower Sizing and Material Selection Affect Performance p. 431
- 4.1 Undersizing Trays and Downcomers p. 431
- 4.2 Oversizing Trays p. 431
- 4.3 Tray Details Can Bottleneck Towers p. 433
- 4.4 Low Liquid Loads Can Be Troublesome p. 434
- 4.4.1 Loss of Downcomer Seal p. 434
- 4.4.2 Tray Dryout p. 435
- 4.5 Special Bubble-Cap Tray Problems p. 436
- 4.6 Misting p. 437
- 4.7 Undersizing Packings p. 437
- 4.8 Systems Where Packings Perform Different from Expectations p. 437
- 4.9 Packed Bed Too Long p. 438
- 4.10 Packing Supports Can Bottleneck Towers p. 439
- 4.11 Packing Hold-downs Are Sometimes Troublesome p. 440
- 4.12 Internals Unique to Packed Towers p. 440
- 4.13 Empty (Spray) Sections p. 440
- 5 Feed Entry Pitfalls in Tray Towers p. 441
- 5.1 Does the Feed Enter the Correct Tray? p. 441
- 5.2 Feed Pipes Obstructing Downcomer Entrance p. 441
- 5.3 Feed Flash Can Choke Downcomers p. 441
- 5.4 Subcooled Feeds, Refluxes Are Not Always Trouble Free p. 442
- 5.5 Liquid and Unsuitable Distributors Do Not Work with Flashing Feeds p. 442
- 5.6 Flashing Feeds Require More Space p. 443
- 5.7 Uneven or Restrictive Liquid Split to Multipass Trays at Feeds and Pass Transitions p. 443
- 5.8 Oversized Feed Pipes p. 444
- 5.9 Plugged Distributor Holes p. 444
- 5.10 Low  $[\Delta]P$  Trays Require Decent Distribution p. 445

- 6 Packed-Tower Liquid Distributors: Number 6 on the Top 10 Malfunctions p. 446
- 6.1 Better Quality Distributors Improve Performance p. 446
- 6.1.1 Original Distributor Orifice or Unspecified p. 446
- 6.1.2 Original Distributor Weir Type p. 447
- 6.1.3 Original Distributor Spray Type p. 447
- 6.2 Plugged Distributors Do Not Distribute Well p. 448
- 6.2.1 Pan/Trough Orifice Distributors p. 448
- 6.2.2 Pipe Orifice Distributors p. 449
- 6.2.3 Spray Distributors p. 450
- 6.3 Overflow in Gravity Distributors: Death to Distribution p. 451
- 6.4 Feed Pipe Entry and Predistributor Problems p. 454
- 6.5 Poor Flashing Feed Entry Bottleneck Towers p. 455
- 6.7.2 Others p. 457
- 6.6 Oversized Weep Holes Generate Undesirable Distribution p. 456
- 6.7 Damaged Distributors Do Not Distribute Well p. 457
- 6.7.1 Broken Flanges or Missing Spray Nozzles p. 457
- 6.8 Hole Pattern and Liquid Heads Determine Irrigation Quality p. 458
- 6.9 Gravity Distributors Are Meant to Be Level p. 459
- 6.10 Hold-Down Can Interfere with Distribution p. 460
- 6.11 Liquid Mixing Is Needed in Large-Diameter Distributors p. 460
- 6.12 Notched Distributors Have Unique Problems p. 461
- 6.13 Others p. 461
- 7 Vapor Maldistribution in Trays and Packings p. 462
- 7.1 Vapor Feed/Reboiler Return Maldistributes Vapor to Packing Above p. 462
- 7.1.1 Chemical/Gas Plant Packed Towers p. 462
- 7.1.2 Packed Refinery Main Fractionators p. 463
- 7.2 Experiences with Vapor Inlet Distribution Baffles p. 465
- 7.3 Packing Vapor Maldistribution at Intermediate Feeds and Chimney Trays p. 465
- 7.4 Vapor Maldistribution Is Detrimental in Tray Towers p. 466
- 7.4.1 Vapor Cross-Flow Channeling p. 466
- 7.4.2 Multipass Trays p. 467
- 7.4.3 Others p. 467
- 8 Tower Base Level and Reboiler Return: Number 2 on the Top 10 Malfunctions p. 468
- 8.1 Causes of High Base Level p. 468
- 8.1.1 Faulty Level Measurement or Level Control p. 468
- 8.1.2 Operation p. 469
- 8.1.3 Excess Reboiler Pressure Drop p. 470
- 8.1.4 Undersized Bottom Draw Nozzle or Bottom Line p. 470
- 8.1.5 Others p. 470
- 8.2 High Base Level Causes Premature Tower Flood (No Tray/Packing Damage) p. 470
- 8.3 High Base Liquid Level Causes Tray/Packing Damage p. 471
- 8.4 Impingement by the Reboiler Return Inlet p. 472
- 8.4.1 On Liquid Level p. 472
- 8.4.2 On Instruments p. 473
- 8.4.3 On Tower Wall p. 473
- 8.4.4 Opposing Reboiler Return Lines p. 474

- 8.4.5 On Trays p. 474
- 8.4.6 On Seal Pan Overflow p. 474
- 8.5 Undersized Bottom Feed Line p. 475
- 8.6 Low Base Liquid Level p. 475
- 8.7 Issues with Tower Base Baffles p. 476
- 8.8 Vortexing p. 476
- 9 Chimney Tray Malfunctions: Part of Number 7 on the Top 10 Malfunctions p. 477
- 9.1 Leakage p. 477
- 9.2 Problem with Liquid Removal, Downcomers, or Overflows p. 478
- 9.3 Thermal Expansion Causing Warping, Out-of-Levelness p. 479
- 9.4 Chimneys Impeding Liquid Flow to Outlet p. 480
- 9.5 Vapor from Chimneys Interfering with Incoming Liquid p. 480
- 9.6 Level Measurement Problems p. 481
- 9.7 Coking, Fouling, Freezing p. 482
- 9.8 Other Chimney Tray Issues p. 482
- 10 Drawoff Malfunctions (Non-Chimney Tray): Part of Number 7 on the Top 10 Malfunctions p. 484
- 10.1 Vapor Chokes Liquid Draw Lines p. 484
- 10.1.1 Insufficient Degassing p. 484
- 10.1.2 Excess Line Pressure Drop p. 485
- 10.1.3 Vortexing p. 486
- 10.2 Leak at Draw Tray Starves Draw p. 486
- 10.3 Draw Pans and Draw Lines Plug Up p. 488
- 10.4 Draw Tray Damage Affects Draw Rates p. 488
- 10.5 Undersized Side-Stripper Overhead Lines Restrict Draw Rates p. 488
- 10.6 Degassed Draw Pan Liquid Initiates Downcomer Backup Flood p. 489
- 10.7 Other Problems with Tower Liquid Draws p. 489
- 10.8 Liquid Entrainment in Vapor Side Draws p. 490
- 10.9 Reflux Drum Malfunctions p. 490
- 10.9.1 Reflux Drum Level Problems p. 490
- 10.9.2 Undersized or Plugged Product Lines p. 490
- 10.9.3 Two Liquid Phases p. 490
- 11 Tower Assembly Mishaps: Number 5 on the Top 10 Malfunctions p. 491
- 11.1 Incorrect Tray Assembly p. 491
- 11.2 Downcomer Clearance and Inlet Weir Malinstallation p. 491
- 11.3 Flow Passage Obstruction and Internals Misorientation at Tray Tower Feeds and Draws p. 492
- 11.4 Leaking Trays and Accumulator Trays p. 493
- 11.5 Bolts, Nuts, Clamps p. 493
- 11.6 Manways/Hatchways Left Unbolted p. 493
- 11.7 Materials of Construction Inferior to Those Specified p. 494
- 11.8 Debris Left in Tower or Piping p. 494
- 11.9 Packing Assembly Mishaps p. 495
- 11.9.1 Random p. 495
- 11.9.2 Structured p. 496
- 11.9.3 Grid p. 496

- 11.10 Fabrication and Installation Mishaps in Packing Distributors p. 496
- 11.13 Auxiliary Piping Assembly Mishaps p. 498
- 11.11 Parts Not Fitting through Manholes p. 498
- 11.12 Auxiliary Heat Exchanger Fabrication and Assembly Mishaps p. 498
- 12 Difficulties during Start-Up, Shutdown, Commissioning, and Abnormal Operation: Number 4 on the Top 10 Malfunctions p. 499
- 12.1 Blinding/Unblinding Lines p. 499
- 12.2 Backflow p. 500
- 12.3 Dead-Pocket Accumulation and Release of Trapped Materials p. 501
- 12.4 Purging p. 501
- 12.5 Pressuring and Depressuring p. 502
- 12.6 Washing p. 502
- 12.7 On-Line Washes p. 504
- 12.8 Steam and Water Operations p. 506
- 12.9 Overheating p. 506
- 12.10 Cooling p. 507
- 12.11 Overchilling p. 507
- 12.12 Water Removal p. 508
- 12.12.1 Draining at Low Points p. 508
- 12.12.2 Oil Circulation p. 508
- 12.12.3 Condensation of Steam Purges p. 508
- 12.12.4 Dehydration by Other Procedures p. 508
- 12.13 Start-Up and Initial Operation p. 509
- 12.13.1 Total-Reflux Operation p. 509
- 12.13.2 Adding Components That Smooth Start-Up p. 509
- 12.13.3 Siphoning p. 509
- 12.13.4 Pressure Control at Start-Up p. 510
- 12.14 Confined Space and Manhole Hazards p. 510
- 13 Water-Induced Pressure Surges: Part of Number 3 on the Top 10 Malfunctions p. 512
- 13.1 Water in Feed and Slop p. 512
- 13.2 Accumulated Water in Transfer Line to Tower and in Heater Passes p. 513
- 13.3 Water Accumulation in Dead Pockets p. 513
- 13.4 Water Pockets in Pump or Spare Pump Lines p. 514
- 13.5 Undrained Stripping Steam Lines p. 515
- 13.6 Condensed Steam or Refluxed Water Reaching Hot Section p. 516
- 13.7 Oil Entering Water-Filled Region p. 517
- 14 Explosions, Fires, and Chemical Releases: Number 10 on the Top 10 Malfunctions p. 518
- 14.1 Explosions Due to Decomposition Reactions p. 518
- 14.1.1 Ethylene Oxide Towers p. 518
- 14.1.2 Peroxide Towers p. 519
- 14.1.3 Nitro Compound Towers p. 520
- 14.1.4 Other Unstable-Chemical Towers p. 521
- 14.2 Explosions Due to Violent Reactions p. 523
- 14.3 Explosions and Fires Due to Line Fracture p. 524

- 14.3.1 C<sub>3</sub>-C<sub>4</sub> Hydrocarbons p. 524
- 14.3.2 Overchilling p. 525
- 14.3.3 Water Freeze p. 526
- 14.3.4 Other p. 527
- 14.4 Explosions Due to Trapped Hydrocarbon or Chemical Release p. 527
- 14.5 Explosions Induced by Commissioning Operations p. 528
- 14.6 Packing Fires p. 529
  - 14.6.1 Initiated by Hot Work Above Steel Packing p. 529
  - 14.6.2 Pyrophoric Deposits Played a Major Role, Steel Packing p. 530
  - 14.6.3 Tower Manholes Opened While Packing Hot, Steel Packing p. 532
  - 14.6.4 Others, Steel Packing Fires p. 532
  - 14.6.5 Titanium, Zirconium Packing Fires p. 533
- 14.7 Fires Due to Opening Tower before Cooling or Combustible Removal p. 533
- 14.8 Fires Caused by Backflow p. 534
- 14.9 Fires by Other Causes p. 535
- 14.10 Chemical Releases by Backflow p. 536
- 14.11 Trapped Chemicals Released p. 536
- 14.12 Relief, Venting, Draining, Blowdown to Atmosphere p. 537
- 15 Undesired Reactions in Towers p. 539
  - 15.1 Excessive Bottom Temperature/Pressure p. 539
  - 15.2 Hot Spots p. 539
  - 15.3 Concentration or Entry of Reactive Chemical p. 539
  - 15.4 Chemicals from Commissioning p. 540
  - 15.5 Catalyst Fines, Rust, Tower Materials Promote Reaction p. 540
  - 15.6 Long Residence Times p. 541
  - 15.7 Inhibitor Problems p. 541
  - 15.8 Air Leaks Promote Tower Reactions p. 542
  - 15.9 Impurity in Product Causes Reaction Downstream p. 542
- 16 Foaming p. 543
  - 16.1 What Causes or Promotes Foaming? p. 543
    - 16.1.1 Solids, Corrosion Products p. 543
    - 16.1.2 Corrosion and Fouling Inhibitors, Additives, and Impurities p. 544
    - 16.1.3 Hydrocarbon Condensation into Aqueous Solutions p. 545
    - 16.1.4 Wrong Filter Elements p. 546
    - 16.1.5 Rapid Pressure Reduction p. 546
    - 16.1.6 Proximity to Solution Plait Point p. 546
  - 16.2 What Are Foams Sensitive To? p. 546
    - 16.2.1 Feedstock p. 546
    - 16.2.2 Temperature p. 547
    - 16.2.3 Pressure p. 547
  - 16.3 Laboratory Tests p. 547
    - 16.3.1 Sample Shake, Air Bubbling p. 547
    - 16.3.2 Oldershaw Column p. 547
    - 16.3.3 Foam Test Apparatus p. 548
  - 16.4.2 Some Antifoams Are More Effective Than Others p. 549
  - 16.3.4 At Plant Conditions p. 548

- 16.4 Antifoam Injection p. 548
- 16.4.1 Effective Only at the Correct Quantity/Concentration p. 548
- 16.4.3 Batch Injection Often Works, But Continuous Can Be Better p. 549
- 16.4.4 Correct Dispersal Is Important, Too p. 550
- 16.4.5 Antifoam Is Sometimes Adsorbed on Carbon Beds p. 550
- 16.4.6 Other Successful Antifoam Experiences p. 550
- 16.4.7 Sometimes Antifoam Is Less Effective p. 551
- 16.5 System Cleanup Mitigates Foaming p. 551
- 16.5.1 Improving Filtration p. 551
- 16.5.2 Carbon Beds Mitigate Foaming But Can Adsorb Antifoam p. 553
- 16.5.3 Removing Hydrocarbons from Aqueous Solvents p. 553
- 16.5.4 Changing Absorber Solvent p. 553
- 16.5.5 Other Contaminant Removal Techniques p. 554
- 16.6 Hardware Changes Can Debottleneck Foaming Towers p. 555
- 16.6.1 Larger Downcomers p. 555
- 16.6.2 Smaller Downcomer Backup (Lower Pressure Drop, Larger Clearances) p. 556
- 16.6.3 More Tray Spacing p. 556
- 16.6.4 Removing Top Two Trays Does Not Help p. 556
- 16.6.5 Trays Versus Packings p. 556
- 16.6.6 Larger Packings, High-Open-Area Distributors Help p. 557
- 16.6.7 Increased Agitation p. 557
- 16.6.8 Larger Tower p. 557
- 16.6.9 Reducing Base Level p. 557
- 17 The Tower as a Filter: Part A. Causes of Plugging-Number 1 on the Top 10 Malfunctions p. 558
- 17.1 Piping Scale/Corrosion Products p. 558
- 17.2 Salting Out/Precipitation p. 559
- 17.3 Polymer/Reaction Products p. 560
- 17.4 Solids/Entrainment in the Feed p. 561
- 17.5 Oil Leak p. 561
- 17.6 Poor Shutdown Wash/Flush p. 562
- 17.7 Entrainment or Drying at Low Liquid Rates p. 562
- 17.8 Others p. 562
- 18 The Tower as a Filter: Part B. Locations of Plugging-Number 1 on the Top 10 Malfunctions p. 563
- 18.1 Trays p. 563
- 18.2 Downcomers p. 564
- 18.3 Packings p. 565
- 18.4 How Packings and Trays Compare on Plugging Resistance p. 565
- 18.4.1 Trays versus Trays p. 565
- 18.4.2 Trays versus Packings p. 566
- 18.4.3 Packings versus Packings p. 567
- 18.5 Limited Zone Only p. 567
- 18.6 Draw, Exchanger, and Vent Lines p. 569
- 18.7 Feed and Inlet Lines p. 570
- 18.8 Instrument Lines p. 570

- 19 Coking: Part of Number 1 on Tower Top 10 Malfunctions p. 571
- 19.1 Insufficient Wash Flow Rate, Refinery Vacuum Towers p. 571
- 19.2 Other Causes, Refinery Vacuum Towers p. 572
- 19.3 Slurry Section, FCC Fractionators p. 573
- 19.4 Other Refinery Fractionators p. 574
- 19.5 Nonrefinery Fractionators p. 574
- 20 Leaks p. 575
- 20.1 Pump, Compressor p. 575
- 20.2.3 Auxiliary Heat Exchanger (Preheater, Pumparound) p. 576
- 20.2 Heat Exchanger p. 575
- 20.2.1 Reboiler Tube p. 575
- 20.2.2 Condenser Tube p. 576
- 20.3 Chemicals to/from Other Equipment p. 577
- 20.3.1 Leaking from Tower p. 577
- 20.3.2 Leaking into Tower p. 577
- 20.3.3 Product to Product p. 578
- 20.4 Atmospheric p. 578
- 20.4.1 Chemicals to Atmosphere p. 578
- 20.4.2 Air into Tower p. 579
- 21 Relief and Failure p. 580
- 21.1 Relief Requirements p. 580
- 21.2 Controls That Affect Relief Requirements and Frequency p. 580
- 21.3 Relief Causes Tower Damage, Shifts Deposits p. 581
- 21.4 Overpressure Due to Component Entry p. 581
- 21.5 Relief Protection Absent or Inadequate p. 582
- 21.6 Line Ruptures p. 583
- 21.7 All Indication Lost When Instrument Tap Plugged p. 584
- 21.8 Trips Not Activating or Incorrectly Set p. 584
- 21.9 Pump Failure p. 585
- 21.10 Loss of Vacuum p. 585
- 21.11 Power Loss p. 585
- 22 Tray, Packing, and Tower Damage: Part of Number 3 on the Top 10 Malfunctions p. 586
- 22.1 Vacuum p. 586
- 22.2 Insufficient Uplift Resistance p. 587
- 22.3 Uplift Due to Poor Tightening during Assembly p. 587
- 22.4 Uplift Due to Rapid Upward Gas Surge p. 589
- 22.5 Valves Popping Out p. 590
- 22.6 Downward Force on Trays p. 590
- 22.10 Flow-Induced Vibrations p. 593
- 22.7 Trays below Feed Bent Up, above Bent Down and Vice Versa p. 591
- 22.8 Downcomers Compressed, Bowed, Fallen p. 592
- 22.9 Uplift of Cartridge Trays p. 593
- 22.11 Compressor Surge p. 594
- 22.12 Packing Carryover p. 595
- 22.13 Melting, Breakage of Plastic Packing p. 595



- 22.14 Damage to Ceramic Packing p. 595
- 22.15 Damage to Other Packings p. 595
- 23 Reboilers That Did Not Work: Number 9 on the Top 10 Malfunctions p. 596
- 23.1 Circulating Thermosiphon Reboilers p. 596
  - 23.1.1 Excess Circulation p. 596
  - 23.1.2 Insufficient Circulation p. 596
  - 23.1.3 Insufficient  $[\Delta]T$ , Pinching p. 596
  - 23.1.4 Surging p. 596
  - 23.1.5 Velocities Too Low in Vertical Thermosiphons p. 597
  - 23.1.6 Problems Unique to Horizontal Thermosiphons p. 597
- 23.2 Once-Through Thermosiphon Reboilers p. 597
  - 23.2.1 Leaking Draw Tray or Draw Pan p. 597
  - 23.2.2 No Vaporization/Thermosiphon p. 598
  - 23.2.3 Slug Flow in Outlet Line p. 599
- 23.3 Forced-Circulation Reboilers p. 599
- 23.4 Kettle Reboilers p. 599
  - 23.4.1 Excess  $[\Delta]P$  in Circuit p. 599
  - 23.4.2 Poor Liquid Spread p. 601
  - 23.4.3 Liquid Level above Overflow Baffle p. 602
- 23.5 Internal Reboilers p. 602
- 23.6 Kettle and Thermosiphon Reboilers in Series p. 603
- 23.7 Side Reboilers p. 603
  - 23.7.1 Inability to Start p. 603
  - 23.7.2 Liquid Draw and Vapor Return Problems p. 603
  - 23.7.3 Hydrates p. 603
  - 23.7.4 Pinching p. 604
  - 23.7.5 Control Issues p. 604
- 23.8 All Reboilers, Boiling Side p. 604
  - 23.8.1 Debris/Deposits in Reboiler Lines p. 604
  - 23.8.2 Undersizing p. 604
  - 23.8.3 Film Boiling p. 604
- 23.9 All Reboilers, Condensing Side p. 605
  - 23.9.1 Non condensables in Heating Medium p. 605
  - 23.9.2 Loss of Condensate Seal p. 605
  - 23.9.3 Condensate Draining Problems p. 606
  - 23.9.4 Vapor/Steam Supply Bottleneck p. 606
- 24 Condensers That Did Not Work p. 607
  - 24.1 Inerts Blanketing p. 607
    - 24.1.1 Inadequate Venting p. 607
    - 24.1.2 Excess Lights in Feed p. 608
  - 24.2 Inadequate Condensate Removal p. 608
    - 24.2.1 Undersized Condensate Lines p. 608
    - 24.2.2 Exchanger Design p. 609
  - 24.3 Unexpected Condensation Heat Curve p. 609
  - 24.4 Problems with Condenser Hardware p. 610
  - 24.5 Maldistribution between Parallel Condensers p. 611

- 24.6 Flooding/Entrainment in Partial Condensers p. 611
- 24.7 Interaction with Vacuum and Recompression Equipment p. 612
- 24.8 Others p. 612
- 25 Misleading Measurements: Number 8 on the Top 10 Malfunctions p. 613
- 25.1 Incorrect Readings p. 613
- 25.2 Meter or Taps Fouled or Plugged p. 614
- 25.3 Missing Meter p. 615
- 25.4 Incorrect Meter Location p. 615
- 25.5 Problems with Meter and Meter Tubing Installation p. 616
- 25.5.1 Incorrect Meter Installation p. 616
- 25.5.2 Instrument Tubing Problems p. 616
- 25.6 Incorrect Meter Calibration, Meter Factor p. 617
- 25.7 Level Instrument Fooled p. 617
- 25.7.1 By Froth or Foam p. 617
- 25.7.2 By Oil Accumulation above Aqueous Level p. 618
- 25.7.3 By Lights p. 619
- 25.7.4 By Radioactivity (Nucleonic Meter) p. 619
- 25.7.5 Interface-Level Metering Problems p. 619
- 25.8 Meter Readings Ignored p. 619
- 25.9 Electric Storm Causes Signal Failure p. 619
- 26 Control System Assembly Difficulties p. 620
- 26.1 No Material Balance Control p. 620
- 26.2 Controlling Two Temperatures/Compositions Simultaneously Produces Interaction p. 621
- 26.3 Problems with the Common Control Schemes, No Side Draws p. 622
- 26.3.1 Boil-Up on TC/AC, Reflux on FC p. 622
- 26.3.2 Boil-Up on FC, Reflux on TC/AC p. 623
- 26.3.3 Boil-Up on FC, Reflux on LC p. 624
- 26.3.4 Boil-Up on LC, Bottoms on TC/AC p. 625
- 26.3.5 Reflux on Base LC, Bottoms on TC/AC p. 626
- 26.4 Problems with Side-Draw Controls p. 626
- 26.4.1 Small Reflux below Liquid Draw Should Not Be on Level or Difference Control p. 626
- 26.4.2 Incomplete Material Balance Control with Liquid Draw p. 628
- 26.4.3 Steam Spikes with Liquid Draw p. 628
- 27.1 Temperature Control p. 629
- 26.4.4 Internal Vapor Control makes or Breaks Vapor Draw Control p. 628
- 26.4.5 Others p. 628
- 27 Where Do Temperature and Composition Controls Go Wrong? p. 629
- 27.1.1 No Good Temperature Control Tray p. 629
- 27.1.2 Best Control Tray p. 630
- 27.1.3 Fooling by Nonkeys p. 630
- 27.1.4 Averaging (Including Double Differential) p. 631
- 27.1.5 Azeotropic Distillation p. 631
- 27.1.6 Extractive Distillation p. 631
- 27.1.7 Other p. 632

- 27.2 Pressure-Compensated Temperature Controls p. 632
- 27.2.1  $[\Delta]T$  Control p. 632
- 27.2.2 Other Pressure Compensation p. 633
- 27.3 Analyzer Control p. 633
- 27.3.1 Obtaining a Valid Analysis for Control p. 633
- 27.3.2 Long Lags and High Off-Line Times p. 633
- 27.3.3 Intermittent Analysis p. 634
- 27.3.4 Handling Feed Fluctuations p. 635
- 27.3.5 Analyzer-Temperature Control Cascade p. 635
- 27.3.6 Analyzer On Next Tower p. 635
- 28 Misbehaved Pressure, Condenser, Reboiler, and Preheater Controls p. 636
- 28.1 Pressure Controls by Vapor Flow Variations p. 636
- 28.2 Flooded Condenser Pressure Controls p. 637
- 28.2.1 Valve in the Condensate, Unflooded Drum p. 637
- 28.2.2 Flooded Drum p. 637
- 28.2.3 Hot-Vapor Bypass p. 637
- 28.2.4 Valve in the Vapor to the Condenser p. 639
- 28.3 Coolant Throttling Pressure Controls p. 640
- 28.3.1 Cooling-Water Throttling p. 640
- 28.3.2 Manipulating Airflow p. 640
- 28.3.3 Steam Generator Overhead Condenser p. 640
- 28.3.4 Controlling Cooling-Water Supply Temperature p. 640
- 28.4 Pressure Control Signal p. 641
- 28.4.1 From Tower or from Reflux Drum? p. 641
- 28.4.2 Controlling Pressure via Condensate Temperature p. 641
- 28.5 Throttling Steam/Vapor to Reboiler or Preheater p. 641
- 28.6 Throttling Condensate from Reboiler p. 642
- 28.7 Preheater Controls p. 643
- 29 Miscellaneous Control Problems p. 644
- 29.1 Interaction with the Process p. 644
- 29.2  $[\Delta]P$  Control p. 644
- 29.3 Flood Controls and Indicators p. 644
- 29.4 Batch Distillation Control p. 645
- 29.5 Problems in the Control Engineer's Domain p. 645
- 29.6 Advanced Controls Problems p. 646
- 29.6.1 Updating Multivariable Controls p. 646
- 29.6.2 Advanced Controls Fooled by Bad Measurements p. 646
- 29.6.3 Issues with Model Inaccuracies p. 647
- 29.6.4 Effect of Power Dips p. 647
- 29.6.5 Experiences with Composition Predictors in Multivariable Controls p. 647
- References p. 649
- Index p. 669
- About the Author p. 713