

Contents

Preface to the third edition — V

Preface to the second edition — VII

Preface — IX

1	Process Integration and Intensification: an introduction — 1
1.1	Process Intensification — 1
1.2	Process Systems Engineering and Process Integration — 3
1.3	Contributions to PIs and PI to energy and water saving — 4
1.4	What is Process Integration? — 5
1.5	A short history of the development of Process Integration — 6
1.6	The aim and scope of this textbook, acknowledgements — 11
	References — 13
2	Setting energy targets and Heat Integration — 18
2.1	Introduction — 18
2.1.1	Overall development of Heat Integration — 19
2.1.2	Pinch Technology and targeting Heat Recovery: the thermodynamic roots — 19
2.1.3	Supertargeting: full-fledged HEN targeting — 21
2.1.4	Modifying the Pinch Idea for HEN retrofit — 21
2.1.5	Benefits of Process Integration — 22
2.2	Pinch analysis for maximising energy efficiency — 23
2.2.1	Introduction to Heat Exchange and Heat Recovery — 23
2.2.2	Basic principles — 25
2.2.3	Basic Pinch Technology — 33
2.3	Summary — 68
	References — 71
3	Synthesis of Heat Exchanger Networks — 74
3.1	Introduction — 74
3.2	HEN synthesis — 75
3.2.1	The Pinch Design Method — 75
3.2.2	Methods using mathematical programming — 95
3.3	Grassroots and retrofits; the impact of economic criteria — 99
3.3.1	Network optimisation — 100
3.3.2	The Network Pinch — 100
3.4	Advanced Data Extraction — 102
3.4.1	Review of Data Extraction treatment in the literature — 103

- 3.4.2 Analysis of the Data Extraction workflow — **105**
- 3.4.3 Site- and process-level procedures — **106**
- 3.4.4 Illustrative example — **108**
- 3.5 Summary — **110**
- References — **111**

4 Total Site Integration — 114

- 4.1 Introduction — **114**
- 4.2 What is a Total Site, and what are the benefits? — **116**
 - 4.2.1 Total Site definition — **116**
 - 4.2.2 Total Site Analysis interfaces — **117**
- 4.3 HI extension for Total Sites: Data Extraction for Total Sites — **118**
 - 4.3.1 The algorithm — **118**
 - 4.3.2 Step-by-step guide — **119**
 - 4.3.3 Working session — **124**
- 4.4 Total Site Profiles and Total Site Composite Curves — **125**
- 4.5 Site Utility Grand Composite Curve (SUGCC) — **135**
- 4.6 Modelling of utility systems — **136**
 - 4.6.1 A flexible steam turbine model for cogeneration evaluation — **137**
 - 4.6.2 Utility network modelling: simulation and optimisation — **142**
 - 4.6.3 Utility system: an illustrative example — **143**
- 4.7 Targeting of Combined Heat and Power generation (CHP, cogeneration) during process design — **146**
 - 4.7.1 Targeting CHP using the SUGCC — **147**
 - 4.7.2 Choice of optimal steam pressure levels — **149**
- 4.8 Advanced Total Site developments — **151**
 - 4.8.1 Introduction of the process-specific minimum allowed temperature differences — **151**
 - 4.8.2 Retrofit of industrial energy systems at the site level — **152**
 - 4.8.3 Numerical tools for Total Site Heat Integration — **153**
 - 4.8.4 Power Integration — **159**
 - 4.8.5 Targeting for low CO₂ emissions with CO₂ emission Pinch Analysis — **172**
- 4.9 Summary — **179**
- References — **180**

5 An integrated Pinch Analysis framework for low CO₂ industrial site planning — 183

- 5.1 Introduction — **183**
- 5.2 Framework for low CO₂ emissions industrial site planning — **183**
- 5.3 Case study — **187**
 - 5.3.1 Stage 1: baseline study — **187**

5.3.2	Stage 2: targeting for Total Site heat recovery with cogeneration using TSHI (Tool 1) —	190
5.3.3	Stage 3: targeting for hybrid power system, integrating RE resources with PoPA (Tool 2) —	193
5.3.4	Stage 4: targeting for low CO ₂ emission with CEPA (Tool 3) —	197
5.3.5	Summarised network diagram —	200
5.4	Conclusion —	200
	References —	202
6	Introduction to Water Pinch Analysis —	203
6.1	Water management and minimisation —	203
6.2	History and definition of Water Pinch Analysis —	204
6.3	Applications of Water Pinch Analysis —	205
6.4	Water Pinch Analysis steps —	206
6.5	Analysis of water networks and data extraction —	207
6.5.1	Analysis of water networks —	207
6.5.2	Data extraction —	209
6.5.3	Example —	210
6.6	Summary —	214
	References —	214
7	Setting the Maximum Water Recovery targets —	217
7.1	Introduction —	217
7.2	Maximum Water Recovery target for single pure freshwater —	220
7.2.1	Water Cascade Analysis technique —	220
7.2.2	Source/Sink Composite Curves (SSCC) —	223
7.2.3	Significance of the Pinch region —	224
7.3	Maximum Water Recovery target for a single impure freshwater source —	225
7.3.1	Pinched problems —	225
7.3.2	Threshold problems —	232
7.4	Maximum Water Recovery targets for multiple freshwater sources —	234
7.5	Working session —	236
7.6	Solution —	237
	References —	240
8	Water network design/retrofit —	242
8.1	Introduction —	242
8.2	Source/Sink Mapping Diagram (SSMD) —	242
8.3	Source and Sink Allocation Curves (SSAC) —	244

8.3.1	Example of network design using SSCC for utility purity superior to all other streams —	248
8.3.2	Example 8.1: Freshwater purity not superior to all other streams —	252
8.3.3	Simplification of a water network or constructing other network possibilities —	256
8.4	Working session —	258
8.5	Solution —	258
8.6	Optimal Water [®] software —	260
	References —	262
9	Design of Cost-Effective Minimum Water Network (CEMWN) —	263
9.1	Introduction —	263
9.2	Water Management Hierarchy —	263
9.3	Cost-Effective Minimum Water Network (CEMWN) —	265
9.4	Industrial case study: a semiconductor plant —	275
9.4.1	Using CEMWN targets as reference benchmarks —	289
10	Extension of Water Integration to Water Mains, Total Site targeting and multiple quality problems —	295
10.1	Introduction —	295
10.2	Water Mains/headers —	295
10.2.1	Working session 1: Water Mains/headers targeting with Pinch Analysis —	298
10.2.2	Working session 2 —	300
10.2.3	Solution —	301
10.3	Total Site Water Integration —	303
10.3.1	Targeting minimum fresh resources in a Total Site —	309
10.4	Targeting fresh resources for multiple qualities —	317
10.4.1	Conflicting sources —	320
10.4.2	Non-conflicting sources —	321
10.4.3	Sources with n -contaminants ($n > 2$) —	322
10.4.4	Working session: design and target for multi-contaminants water allocation networks with Pinch-based heuristics —	324
10.5	Conclusion —	329
	References —	329
11	Resources or Solid Waste Pinch Analysis —	331
11.1	Introduction and the concept —	331
11.2	Solid waste management targeting: time as quality indicator —	332
11.2.1	Step-by-step guidance —	332
11.2.2	Working session —	333
11.2.3	Solution —	335

11.3	Solid waste management targeting: moisture content as quality indicator — 338
11.3.1	Step-by-step guidance — 338
11.3.2	Working session — 339
11.3.3	Solution — 339
	References — 346
12	Conclusions and sources of further information — 347
12.1	HEN targeting, synthesis, and retrofit — 347
12.2	Total Site Integration — 348
12.3	Total Site Methodology addressing variable energy supply and demand — 350
12.4	Utility system optimisation accounting for cogeneration — 351
12.5	Maximum water recovery targeting and design — 352
12.5.1	Recommended books for further reading — 352
12.5.2	State of-the-art review — 354
12.6	Analysing the designs of isolated energy systems — 355
12.7	PI contribution to supply chain development — 356
12.8	Hydrogen networks design and management — 356
12.9	Oxygen Pinch Analysis — 357
12.10	Pressure drop considerations and heat transfer enhancement in Process Integration — 358
12.11	Power (electricity) and Hybrid Pinch — 360
12.12	Computational and modelling tools suitable for applying PI — 361
12.12.1	Heat and power PI applications — 361
12.12.2	Water Pinch software — 362
12.13	Challenges and recent developments in Pinch-based PI — 363
12.14	PRES Conferences on Process Integration, Modelling, and Optimisation for Energy Saving and Pollution Reduction — 364
	References — 366
Index	— 373