

## Table of Contents

|  |             |
|--|-------------|
| <b>Foreword</b> . . . . .  | <b>xv</b>   |
| Richard DARTON   |             |
| <b>Foreword</b> . . . . .  | <b>xvii</b> |
| Jean PELIN   |             |
| <b>Introduction</b> . . . . .  | <b>xix</b>  |
| Jean-Pierre DAL PONT   |             |
| <b>Acknowledgments</b> . . . . .   | <b>xxv</b>  |
| <b>PART 1: THE COMPANY AS OF TODAY</b> . . . . .   | <b>1</b>    |
| <b>Chapter 1. The Industrial Company: its Purpose, History,<br/>Context, and its Tomorrow?</b> . . . . . | <b>3</b>    |
| Jean-Pierre DAL PONT   |             |
| 1.1. Purpose, structure, typology . . . . .  | 4           |
| 1.1.1. The four pillars of the company . . . . .   | 5           |
| 1.1.2. Typology of enterprises . . . . .   | 7           |
| 1.2. A centennial history . . . . .  | 8           |
| 1.2.1. The Europeanization of the planet . . . . .   | 8           |
| 1.2.2. Evolution of the company over time . . . . .  | 10          |
| 1.2.3. The Industrial Revolution in England . . . . .  | 10          |
| 1.2.4. Taylorism, Fordism, Fayolism . . . . .  | 17          |
| 1.2.5. The advent of research . . . . .  | 19          |
| 1.2.6. The individual in the company . . . . .   | 20          |
| 1.3. New challenges imposed by globalization<br>and sustainable development . . . . .                    | 24          |
| 1.3.1. Globalization . . . . .   | 24          |
| 1.3.2. Sustainable development . . . . .   | 28          |

|   |            |
|---|------------|
| 1.4. Our planet . . . . .   | 32         |
| 1.4.1. Balances and biogeochemical cycles . . . . .   | 32         |
| 1.4.2. Global warming – greenhouse effect . . . . .   | 32         |
| 1.4.3. Ecology and ecosystems . . . . .   | 33         |
| 1.4.4. Oceans . . . . .   | 35         |
| 1.4.5. Demography . . . . .   | 37         |
| 1.4.6. Energy . . . . .   | 41         |
| 1.4.7. Water . . . . .  | 44         |
| 1.4.8. What will be the future for French agriculture? . . . . .  | 44         |
| 1.5. The company of tomorrow. Some thoughts . . . . .   | 45         |
| 1.5.1. Emerging countries . . . . .   | 46         |
| 1.5.2. What are the values for tomorrow? . . . . .  | 47         |
| 1.5.3. A new company for a new society . . . . .  | 48         |
| 1.6. Bibliography . . . . .   | 49         |
| <b>Chapter 2. The Two Modes of Operation of the Company – Operational and Entrepreneurial . . . . .</b> | <b>51</b>  |
| Jean-Pierre DAL PONT  |            |
| 2.1. Operational mode . . . . .   | 53         |
| 2.1.1. Management – company structure organization – organization chart . . . . .                       | 53         |
| 2.1.2. Corporate governance . . . . .   | 68         |
| 2.2. Entrepreneurial mode, project management – the operational/entrepreneurial conflict . . . . .      | 96         |
| 2.3. Bibliography . . . . .   | 99         |
| <b>Chapter 3. The Strategic Management of the Company: Industrial Aspects . . . . .</b>                 | <b>101</b> |
| Jean-Pierre DAL PONT  |            |
| 3.1. Systemic view of the industrial company . . . . .  | 102        |
| 3.2. Strategy and strategic analysis of the company . . . . .   | 103        |
| 3.2.1. Strategic analysis tools . . . . .   | 105        |
| 3.3. Development of the strategic plan: its deliverables . . . . .                                      | 107        |
| 3.4. Technological choices and vocations . . . . .  | 108        |
| 3.5. Bibliography . . . . .   | 111        |
| <b>PART 2: PROCESS DEVELOPMENT AND INDUSTRIALIZATION . . . . .</b>                                      | <b>113</b> |
| <b>Chapter 4. Chemical Engineering and Process Engineering . . . . .</b>                                | <b>115</b> |
| Jean-Pierre DAL PONT  |            |
| 4.1. History of chemical engineering and process engineering . . . . .                                  | 115        |
| 4.1.1. Chemical engineering . . . . .   | 116        |

|   |            |
|---|------------|
| 4.2. Process engineering . . . . .  | 119        |
| 4.2.1. Objectives of process engineering . . . . .  | 119        |
| 4.2.2. The scientific bases and basic tools of process engineering . . . . .                                    | 119        |
| 4.3. The chemical reactor . . . . .   | 121        |
| 4.3.1. Classification of reactors based on the method of feeding . . . . .                                      | 121        |
| 4.3.2. Classification according to the phases present . . . . .   | 123        |
| 4.4. Bioreactors . . . . .  | 126        |
| 4.4.1. The enzymatic bioreactions . . . . .   | 126        |
| 4.4.2. Bioreactions using microorganisms . . . . .  | 127        |
| 4.5. Transportation and transfers . . . . .   | 129        |
| 4.5.1. Transportation and handling of fluids . . . . .  | 129        |
| 4.5.2. Heat transfer; power, cooling, and heat generation . . . . .   | 129        |
| 4.5.3. Transfer between two immiscible liquids . . . . .  | 131        |
| 4.6. Unit operations . . . . .  | 131        |
| 4.6.1. Crystallization in solution . . . . .  | 132        |
| 4.6.2. Drying and gas/solid contact . . . . .   | 133        |
| 4.6.3. Distillation . . . . .   | 134        |
| 4.6.4. Other operations . . . . .   | 136        |
| 4.6.5. An example of development: membrane technologies . . . . .   | 136        |
| 4.7. Separation processes: process engineering and the new challenges for life sciences . . . . .               | 141        |
| 4.8. Acknowledgments . . . . .  | 144        |
| 4.9. Bibliography . . . . .   | 145        |
| <b>Chapter 5. Foundations of Process Industrialization . . . . .</b>  | <b>147</b> |
| Jean-François JOLY  |            |
| 5.1. Introduction . . . . .   | 147        |
| 5.2. The various stages of process development: from research to the foundations of industrialization . . . . . | 148        |
| 5.3. The pre-study (or pre-development process) . . . . .   | 149        |
| 5.3.1. Experimental tools for acquiring kinetic data . . . . .  | 153        |
| 5.4. Development stage of the process . . . . .   | 157        |
| 5.4.1. Introduction . . . . .   | 157        |
| 5.4.2. Data acquisition process . . . . .   | 158        |
| 5.4.3. Process schemes, simulation, and optimization of the process as a whole . . . . .                        | 181        |
| 5.4.4. End of the development process, the foundations of industrialization . . . . .                           | 183        |
| 5.5. General conclusion . . . . .   | 184        |
| 5.6. Bibliography . . . . .   | 186        |
| 5.7. List of acronyms . . . . .   | 188        |

|  |            |
|--|------------|
| <b>Chapter 6. The Industrialization Process: Preliminary Projects . . . . .</b>                    | <b>189</b> |
| Jean-Pierre DAL PONT and Michel ROYER  |            |
| 6.1. Steps of industrialization . . . . .  | 192        |
| 6.2. Bases of industrialization or process development . . . . .                                   | 193        |
| 6.3. Feasibility study . . . . .   | 194        |
| 6.3.1. Design of the industrial process – preliminary engineering – preliminary projects . . . . . | 194        |
| 6.4. Cost and typical duration of industrialization studies . . . . .                              | 198        |
| 6.5. Content of an industrialization project – conceptual engineering . . . . .                    | 199        |
| 6.6. Typical organization of an industrialization project . . . . .                                | 201        |
| 6.7. Business/industrial interface . . . . .   | 202        |
| 6.7.1. The questions posed by the business to the industrial function . . . . .                    | 203        |
| 6.7.2. The questions posed by the industrial function to the business . . . . .                    | 203        |
| 6.8. Typology of industrialization projects . . . . .  | 204        |
| 6.8.1. Parallel projects . . . . .   | 204        |
| 6.8.2. Small scale projects . . . . .  | 205        |
| 6.9. The industrial preliminary projects . . . . .   | 205        |
| 6.9.1. Origin of industrial preliminary projects . . . . .   | 206        |
| 6.9.2. Perception of a preliminary project by the various players in the company . . . . .         | 207        |
| 6.10. Selection of production sites . . . . .  | 209        |
| 6.11. The consideration of sustainability in the preliminary projects . . . . .                    | 210        |
| 6.11.1. HHS indicator . . . . .  | 211        |
| 6.11.2. MIPS indicator . . . . .   | 212        |
| 6.11.3. SEP indicator . . . . .  | 212        |
| 6.11.4. SPI indicator . . . . .  | 213        |
| 6.11.5. SETAC indicator . . . . .  | 214        |
| 6.11.6. EPS indicator . . . . .  | 214        |
| 6.12. Tips for conducting preliminary projects . . . . .   | 215        |
| 6.12.1. Capacities of the installation . . . . .   | 215        |
| 6.12.2. Description of the process and essential characteristics . . . . .                         | 217        |
| 6.12.3. Risk analysis . . . . .  | 221        |
| 6.12.4. Regulatory risks . . . . .   | 221        |
| 6.13. Modification of the project scope . . . . .  | 222        |
| 6.14. Host site . . . . .  | 223        |
| 6.14.1. Essential characteristics of an industrial site . . . . .                                  | 223        |
| 6.14.2. Impact of a new process unit on an existing site . . . . .                                 | 226        |
| 6.15. Reporting . . . . .  | 228        |
| 6.15.1. Technical checklist . . . . .  | 229        |
| 6.15.2. Executive summary . . . . .  | 229        |
| 6.16. Bibliography . . . . .   | 232        |

|  |            |
|--|------------|
| <b>Chapter 7. Lifecycle Analysis and Eco-Design:<br/>Innovation Tools for Sustainable Industrial Chemistry . . . . .</b> | <b>233</b> |
| Sylvain CAILLOL  |            |
| 7.1. Contextual elements . . . . .   | 233        |
| 7.1.1. The lessons of Easter Island . . . . .  | 233        |
| 7.1.2. On the carrying capacity . . . . .  | 236        |
| 7.2. The chemical industry mobilized against upheavals . . . . .   | 237        |
| 7.2.1. Global turmoils . . . . .   | 237        |
| 7.2.2. New constraints of industrial chemistry . . . . .   | 240        |
| 7.3. The lifecycle analysis, an eco-design<br>tool – definitions and concepts . . . . .                                  | 243        |
| 7.3.1. Eco-design: a few definitions . . . . .   | 243        |
| 7.3.2. The lifecycle assessment: history . . . . .   | 244        |
| 7.3.3. Lifecycle assessment: concept and definitions . . . . .   | 246        |
| 7.3.4. Defining the objectives and scope<br>of the lifecycle assessment . . . . .  | 247        |
| 7.3.5. Lifecycle inventory analysis . . . . .  | 249        |
| 7.3.6. Assessing the impact of the lifecycle . . . . .   | 251        |
| 7.3.7. Interpretation of the lifecycle . . . . .   | 255        |
| 7.3.8. LCA software . . . . .  | 257        |
| 7.4. Innovation through eco-design . . . . .   | 258        |
| 7.4.1. Example: LCA of supermarket shopping bags. . . . .  | 258        |
| 7.4.2. Example of eco-design from<br>a manufacturer of office furniture . . . . .  | 264        |
| 7.4.3. Example of eco-design from<br>a manufacturer of detergents . . . . .  | 265        |
| 7.4.4. The integration process of eco-design in the company . . . . .  | 265        |
| 7.5. Limits of the tool . . . . .  | 267        |
| 7.5.1. On the importance of hypotheses . . . . .   | 267        |
| 7.5.2. On the relevance of inventory data . . . . .  | 269        |
| 7.5.3. On the influence of allocation rules . . . . .  | 269        |
| 7.5.4. On the choice of recycling . . . . .  | 270        |
| 7.6. Conclusion: the future of eco-design . . . . .  | 271        |
| 7.7. Bibliography . . . . .  | 273        |
| <b>Chapter 8. Methods for Design and Evaluation of Sustainable<br/>Processes and Industrial Systems . . . . .</b>        | <b>275</b> |
| Catherine AZZARO-PANTEL  |            |
| 8.1. Introduction . . . . .  | 275        |
| 8.1.1. Concept of sustainable development in process engineering . . . . .   | 275        |
| 8.1.2. Indicators, indices, and metrics of sustainable<br>development in process engineering . . . . .                   | 276        |

x Process Engineering and Industrial Management

|   |            |
|---|------------|
| 8.2. AIChE and IChemE metrics . . . . .   | 279        |
| 8.2.1. AIChE metrics . . . . .  | 279        |
| 8.2.2. IChemE metrics . . . . .   | 281        |
| 8.2.3. Using sustainable development metrics . . . . .  | 285        |
| 8.3. Potential environmental impact index<br>( <i>waste reduction algorithm</i> ) . . . . .             | 286        |
| 8.3.1. Theory of the potential environmental impact . . . . .   | 287        |
| 8.3.2. Categories of environmental impacts . . . . .  | 289        |
| 8.3.3. Application of the WAR algorithm . . . . .   | 292        |
| 8.4. SPI (Sustainable Process Index) . . . . .  | 292        |
| 8.5. Exergy as a thermodynamic base for a sustainable<br>development metrics . . . . .                  | 294        |
| 8.6. Indicators resulting from a lifecycle assessment . . . . .   | 294        |
| 8.6.1. Main methods of impact categories . . . . .  | 295        |
| 8.6.2. Choice of the method of impact categories . . . . .  | 295        |
| 8.6.3. Toward a sustainable lifecycle assessment . . . . .  | 297        |
| 8.7. Process design methods and sustainable systems . . . . .   | 297        |
| 8.8. Conclusion . . . . .   | 299        |
| 8.9. Bibliography . . . . .   | 301        |
| <b>Chapter 9. Project Management Techniques: Engineering . . . . .</b>                                  | <b>307</b> |
| Jean-Pierre DAL PONT  |            |
| 9.1. Engineer and engineering . . . . .   | 307        |
| 9.1.1. The engineer . . . . .   | 307        |
| 9.1.2. Engineering . . . . .  | 309        |
| 9.2. Project organization . . . . .   | 310        |
| 9.2.1. Project concept . . . . .  | 310        |
| 9.2.2. Organization of an engineering<br>project – client / project manager interface . . . . .         | 312        |
| 9.3. Management tools for industrial projects . . . . .   | 314        |
| 9.3.1. WBS (work breakdown structure) . . . . .   | 314        |
| 9.3.2. Value analysis (VA) [AFN 97, DAL 03, LED 91] . . . . .   | 317        |
| 9.3.3. Functional analysis (FA) . . . . .   | 322        |
| 9.3.4. The project scope (PS) . . . . .   | 328        |
| 9.3.5. Planning . . . . .   | 329        |
| 9.4. The engineering project: from <i>Process Engineering</i><br>to the start of the facility . . . . . | 331        |
| 9.4.1. Process Engineering . . . . .  | 331        |
| 9.4.2. Construction management – monitoring the progress<br>of the project – cost and time . . . . .    | 342        |
| 9.4.3. Management of change orders . . . . .  | 344        |
| 9.5. The amount of investment . . . . .   | 346        |
| 9.6. Profitability on investment [DOR 81, MIK 10] . . . . .   | 350        |

|   |            |
|---|------------|
| 9.6.1. Principle of calculation of cash flows . . . . .                             | 350        |
| 9.6.2. Depreciation and amortization . . . . .                                      | 351        |
| 9.6.3. Concept of discount [MAR 79] . . . . .                                       | 351        |
| 9.6.4. Concept of internal rate of return (IRR) . . . . .                           | 352        |
| 9.6.5. Rapid methods: the calculations of the grocer (examples) . . . . .           | 352        |
| 9.7. Conclusion . . . . .   | 353        |
| 9.8. Bibliography . . . . .   | 353        |
| <b>PART 3: THE NECESSARY ADAPTATION<br/>OF THE COMPANY FOR THE FUTURE . . . . .</b> | <b>355</b> |
| <b>Chapter 10. Japanese Methods . . . . .</b>                                       | <b>357</b> |
| Jean-Pierre DAL PONT  |            |
| 10.1. Japan from the Meiji era to now.  |            |
| The origin of the Japanese miracle . . . . .  | 357        |
| 10.1.1. A bit of geography . . . . .  | 357        |
| 10.1.2. A bit of history . . . . .  | 357        |
| 10.2. W.E. Deming and Japan . . . . .   | 359        |
| 10.2.1. A brief account of the Deming system . . . . .                              | 359        |
| 10.2.2. The Japanese system from SQC to TQM . . . . .                               | 360        |
| 10.3. The Toyoda family – Taiichi Ohno – The Toyota Empire . . . . .                | 362        |
| 10.3.1. Taiichi Ohno (1912–1990), the man<br>of JIT (just in time) . . . . .        | 363        |
| 10.4. Toyotism. . . . .   | 363        |
| 10.4.1. General philosophy – principles of management. . . . .                      | 364        |
| 10.4.2. Problem solving . . . . .   | 365        |
| 10.4.3. The KJ method or affinity diagram . . . . .                                 | 366        |
| 10.4.4. Statistical process control . . . . .                                       | 366        |
| 10.4.5. Improvements at the workplace . . . . .                                     | 366        |
| 10.4.6. Human aspects . . . . .   | 368        |
| 10.5. The American response . . . . .   | 368        |
| 10.6. Bibliography . . . . .  | 369        |
| <b>Chapter 11. Innovation in Chemical Engineering Industries . . . . .</b>          | <b>371</b> |
| Oliver POTIER and Mauricio CAMARGO  |            |
| 11.1. Definition of innovation . . . . .  | 372        |
| 11.2. Field of innovation in the chemical engineering industry . . . . .            | 376        |
| 11.3. The need for innovation . . . . .   | 377        |
| 11.4. Methods for innovation in chemical engineering industry . . . . .             | 380        |
| 11.4.1. Method of “Creativity Under Constraints” . . . . .                          | 381        |
| 11.4.2. Approach by the TRIZ method . . . . .                                       | 383        |
| 11.4.3. Management of the innovation process . . . . .                              | 385        |

|  |            |
|--|------------|
| 11.4.4. The company organized to innovate . . . . .  | 391        |
| 11.4.5. Technical choices . . . . .  | 394        |
| 11.5. Conclusion . . . . .   | 395        |
| 11.6. Bibliography . . . . .   | 396        |
| <b>Chapter 12. The Place of Intensified Processes<br/>in the Plant of the Future . . . . .</b> | <b>401</b> |
| Laurent FALK   |            |
| 12.1. Process intensification in the context<br>of sustainable development . . . . .           | 401        |
| 12.2. Main principles of intensification . . . . .   | 404        |
| 12.2.1. Mass, heat and mixing limitations . . . . .  | 405        |
| 12.2.2. Thermodynamic limitations . . . . .  | 406        |
| 12.2.3. Limitation by energy input . . . . .   | 407        |
| 12.2.4. Kinetic limitations. . . . .   | 408        |
| 12.3. Connection between intensification and miniaturization . . . . .                         | 408        |
| 12.4. Applications. . . . .  | 414        |
| 12.4.1. Intensification for safer processes . . . . .  | 414        |
| 12.4.2. Intensified processes for energy . . . . .   | 415        |
| 12.5. New economic models implied<br>by process intensification . . . . .                      | 416        |
| 12.5.1. Assessment of operation cost reduction . . . . .                                       | 417        |
| 12.5.2. Assessment of investment costs<br>of intensified processes . . . . .                   | 420        |
| 12.5.3. Technico-economic advantages of the modular plant . . . . .                            | 424        |
| 12.6. Conclusion . . . . .   | 429        |
| 12.7. Bibliography . . . . .   | 430        |
| <b>Chapter 13. Change Management . . . . .</b>   | <b>437</b> |
| Jean-Pierre DAL PONT   |            |
| 13.1. The company: adapt or die . . . . .  | 438        |
| 13.2. The company: processes and know-how . . . . .  | 438        |
| 13.2.1. The company, a multitude of processes<br>(processes, methods, procedures) . . . . .    | 438        |
| 13.2.2. The expertise of the company – core competencies . . . . .                             | 440        |
| 13.3. Human aspects of change . . . . .  | 444        |
| 13.3.1. Creating a feeling of trust . . . . .  | 445        |
| 13.3.2. Visual management . . . . .  | 446        |
| 13.3.3. Brainstorming . . . . .  | 446        |
| 13.4. Basic tools for change management . . . . .  | 447        |
| 13.4.1. Systems analysis . . . . .   | 447        |
| 13.4.2. Continuous improvement,<br>the PDCA, the Deming wheel . . . . .                        | 450        |

|   |     |
|---|-----|
| 13.4.3. Pareto analysis . . . . .   | 452 |
| 13.4.4. External audits . . . . .   | 453 |
| 13.5. Changes and improvement of the industrial facility . . . . .                        | 454 |
| 13.5.1. Continuous improvement and process control . . . . .                              | 454 |
| 13.5.2. Looking for a breakthrough . . . . .  | 457 |
| 13.5.3. Corporate risk . . . . .  | 459 |
| 13.6. Re-engineering, the American way . . . . .  | 461 |
| 13.7. Conclusion . . . . .  | 462 |
| 13.8. Bibliography . . . . .  | 463 |
| <b>Chapter 14. The Plant of the Future.</b> . . . . .                                     | 465 |
| Jean-Pierre DAL PONT  |     |
| 14.1. Developed countries – companies – industrial firms . . . . .                        | 466 |
| 14.1.1. France – heat wave of 2003 . . . . .  | 466 |
| 14.1.2. The ISO 26 000 standard . . . . .   | 468 |
| 14.2. Typology of means of production . . . . .   | 469 |
| 14.2.1. Industrial facilities reviewed in the light of the supply chain – flows . . . . . | 471 |
| 14.3. Product and plant design . . . . .  | 473 |
| 14.3.1. Products . . . . .  | 473 |
| 14.3.2. Processes . . . . .   | 474 |
| 14.3.3. The plant of the future . . . . .   | 474 |
| 14.4. Management of production and operations (MPO) . . . . .                             | 477 |
| 14.4.1. Essential tasks . . . . .   | 477 |
| 14.4.2. Tools of the MPO . . . . .  | 477 |
| 14.5. The IT revolution – IT management . . . . .   | 479 |
| 14.6. And the individual? . . . . .   | 480 |
| 14.7. Conclusion . . . . .  | 481 |
| 14.8. Bibliography . . . . .  | 482 |
| <b>List of Authors</b> . . . . .  | 485 |
| <b>Index</b> . . . . .  | 487 |