

Contents

Foreword	ix
Philippe MARTY	
Chapter 1. Sensible Heat Storage: Overview	1
Régis OLIVÈS	
1.1. Introduction.	1
1.2. General principles	2
1.3. Storage configurations	2
1.4. Modeling of thermocline storage	4
1.5. References	11
Chapter 2. Low-Temperature Sensible Heat Storage	13
Pierre ODRU	
2.1. Sensible heat storage associated with buildings	13
2.1.1. Short duration storage	14
2.1.2. Long duration (seasonal) solar heat storage	16
2.1.3. The stratification problem	16
2.2. Underground thermal energy storage.	17
2.2.1. Principle of the aquifer thermal energy storage	19
2.2.2. Borehole thermal energy storage	21
2.2.3. Other types of underground storage	23
2.3. References	23

Chapter 3. High-Temperature Heat Storage for Electricity	25
Lionel NADAU, Philippe MUGUERRA and Pierre ODRU	
3.1. Heat storage associated with compressed air electricity storage	28
3.1.1. Adiabatic CAES.	29
3.1.2. Thermal energy storage	31
3.1.3. Search project	31
3.1.4. SACRE project	35
3.2. Electricity storage by Carnot batteries	37
3.2.1. Modified Brayton cycle: operating principle	37
3.2.2. Modified Brayton cycle: energy balance	39
3.2.3. Feasibility	41
3.2.4. Potential characteristics of a thermal pumping system	43
3.2.5. Brayton cycle variant.	44
3.2.6. Phase change cycle	45
3.3. References	46
Chapter 4. Latent Heat Storage: Fundamentals and Most Widely Used Phase Change Materials	49
Ana LAZARO and Erwin FRANQUET	
4.1. Fundamentals of latent heat storage	49
4.2. Phase change materials classification and criteria for selection	52
4.3. Commonly used PCMs	58
4.4. Tecno-economic evaluation	61
4.5. Emerging alternative materials	63
4.6. References	65
Chapter 5. Engineering Phase Change Materials to Improve Their Properties and Broaden Applications	69
Stefania DOPPIU and Elena PALOMO DEL BARRIO	
5.1. Introduction.	69
5.2. Micro-/nanoencapsulated PCMs	73
5.2.1. Shell materials and encapsulation methods.	74
5.2.2. Micro-/nanoencapsulated PCMs	77
5.2.3. Innovative designs for versatile applications	80
5.3. Shape-stabilized PCMs	83
5.3.1. Overview of porous supports and preparation methods.	85
5.3.2. Porous carbon-based SS-PCMs.	88
5.3.3. Porous oxide-based SS-PCMs	94

5.3.4. Summary of porous supports and perspectives.	99
5.4. Conclusion	102
5.5. References	103

Chapter 6. Latent Heat Storage Systems: Concepts and Applications 109

Marie DUQUESNE and Wahbi JOMAA

6.1. Introduction.	109
6.2. Types of systems and main components	111
6.2.1. LH-TESS classification	111
6.2.2. Materials	112
6.3. Cold storage	115
6.3.1. “Ice-on-tube” cold storage systems	120
6.3.2. Cold storage systems with encapsulated PCM	120
6.3.3. Cold storage systems with ice slurry.	121
6.3.4. Cold storage systems with ice recovery	121
6.4. Applications in the building sector	122
6.4.1. Passive systems	122
6.4.2. Active use of PCM in buildings	125
6.5. Applications in industry	127
6.6. Concentrated solar power plants	129
6.7. Other domains	134
6.8. Conclusion	135
6.9. References	139

Chapter 7. Use of Hydrates for Cold Storage and Distribution in Refrigeration and Air-Conditioning Applications 151

Anthony DELAHAYE and Laurence FOURNAISON

7.1. Introduction.	151
7.2. Hydrate definition and properties	153
7.2.1. Definition of gas hydrates	153
7.2.2. Clathrate hydrate structures	154
7.2.3. Semiclathrate structures	156
7.2.4. Hydration number.	156
7.2.5. Phase diagram of water-CO ₂ mixtures including CO ₂ hydrates	157
7.3. Hydrate systems for cold storage and distribution	158
7.3.1. Refrigerant gas hydrate applied to cold storage	159
7.3.2. CO ₂ hydrates applied to cold storage and distribution	159
7.3.3. Quaternary salt hydrates for cold storage and distribution	160

7.3.4. Other hydrates applied to cold storage and distribution.	161
7.3.5. Mixed gas-salt/THF hydrates for cold storage and distribution . .	162
7.4. Criteria for use of hydrates in refrigeration	163
7.4.1. Thermodynamic criterion	163
7.4.2. Flow criterion	167
7.4.3. Thermal criterion	171
7.4.4. Kinetic criterion	173
7.4.5. Energy and environment criterion	175
7.5. Hydrate applications in refrigeration and air-conditioning	176
7.5.1. Slurry generation methods.	176
7.5.2. Examples of hydrate-based refrigeration systems	177
7.6. Conclusion	181
7.7. References	182
Chapter 8. Concentrated Solar Power Plants and Storage.	201
Régis OLIVÈS	
8.1. Introduction.	201
8.2. Concentrated solar power plants and storage	202
8.2.1. General principles.	202
8.2.2. Objectives and strategy	205
8.2.3. Global performances and efficiency	206
8.3. Storage types	211
8.3.1. Sensible heat storage	212
8.3.2. Latent heat storage	215
8.3.3. Thermochemical storage.	219
8.3.4. Materials and fluids.	223
8.3.5. Other components.	234
8.4. Analysis of systems	236
8.4.1. Active systems.	237
8.4.2. Passive systems	247
8.4.3. Technical-economic analysis	261
8.4.4. Life cycle analysis, efficiency, concentration and eco-design . . .	263
8.5. References	266
List of Authors	271
Index	273
Summary of Volume 2	279