

Contents

Kurzfassung	IX
Abstract	XI
List of figures	XIII
List of tables	XVII
Notation	XIX

1 Introduction	1
2 State-of-the-art and limitations of evaporators for adsorption chillers	5
2.1 Adsorption chillers	5
2.1.1 Adsorption: from working principle to cycle performance	6
2.1.2 Water-based adsorption chillers: advantages and limitations . .	12
2.1.3 Evaporators in adsorption chillers	14
2.2 Evaporation: heat transfer and phase change	18
2.2.1 Different regimes of pool boiling: Nukiyama curve	20
2.2.2 Wetting: interaction of fluids and solids	22
2.2.3 Capillary action applied in heat transfer: heat pipes	26
2.2.4 Challenge: sub-atmospheric evaporation of water	28
2.2.5 Capillary-assisted evaporators for adsorption chillers	31
2.2.6 Evaporation from an extended meniscus	34
2.3 Summary and contribution of this thesis	38
3 Experiments and measurement uncertainty	43
3.1 Adsorption experiments	43

V

3.1.1	Adsorption chiller	44
3.1.2	Experimental setup	47
3.1.3	Data reduction	53
3.2	Evaporation experiments	54
3.2.1	Condenser	59
3.2.2	Evaporator	60
3.2.3	Data reduction	65
3.3	Analysis of measurement uncertainty	67
3.3.1	Sensor calibration: correction of measured values and quantification of uncertainty	67
4	Validating setup and procedure for the evaporation experiments	75
4.1	Introduction	76
4.2	Materials and methods	77
4.2.1	Investigated finned copper tubes	77
4.2.2	Experimental setups	78
4.2.3	Data reduction	81
4.2.4	Uncertainty in measurement	82
4.2.5	Experimental procedure	82
4.2.6	Input parameters	83
4.3	Results and discussion	85
4.3.1	Impact of experimental setups	85
4.3.2	Impact of dynamic effects: constant vs. continuously decreasing filling level	93
4.4	Conclusions	95
5	Characterisation of capillary-assisted evaporation	99
5.1	Materials and methods	100
5.1.1	Experimental procedure	102
5.1.2	Data reduction	102
5.1.3	Experiments	103
5.2	Results and discussion	104
5.2.1	U -value as function of driving force	104
5.2.2	Maximum UA_{eff} -values as function of driving force for different evaporator inlet temperatures	107
5.2.3	Correlation between tubes' surface properties and maximum evaporation performance	110
5.3	Conclusions	113

6	Water-based adsorption cooling below 0 °C	117
6.1	Introduction	118
6.2	Working fluid mixture glycol–water	119
6.3	Experimental setup	122
6.4	Results	125
6.4.1	Glycol as anti-freezing agent	125
6.4.2	Performance for non-freezing operational conditions	127
6.5	Conclusions	130
7	Summary, conclusions and future perspectives	135
7.1	Summary and conclusions	135
7.2	Future perspectives	139

Appendices

A	Overview of evaporator patents	146
B	Details of the experimental setups	149
B.1	Adsorption chiller	150
B.1.1	Adsorber	150
B.1.2	Evaporator	152
B.1.3	Condenser	154
B.1.4	Experimental equipment	155
B.2	Evaporation experiments	159
B.2.1	Evaporator	160
B.2.2	Condenser	162
B.2.3	Experimental equipment	163
B.3	Equipment used in both experimental setups	167
C	Analysis of measurement uncertainty	169
D	Supplementary information to Chapter 4	173
D.1	Input conditions for experiments	174
D.2	Uncertainty in measurement	176
D.3	Discussion of other potential reasons for observed deviations between RWTH and ISE	183
D.4	Relative filling level detected in experimental setup at RWTH	186

D.5 Contact angle	187
E Supplementary information to Chapter 6	189
F Publications and student theses	195
Bibliography	201