

Contents

Acknowledgements	iii
Abstract	v
Version Abrégée	vii
List of Figures	xiv
List of Tables	xxii
Nomenclature	xxv
1 Introduction	1
2 Fundamental definitions and flow parameters	5
2.1 Two-phase flow	5
2.2 Vapor quality	5
2.3 Mass flux	6
2.4 Velocities	6
2.4.1 True average velocities	7
2.4.2 Superficial velocities	7
2.4.3 Drift velocities	7
2.5 Void fraction	8
2.6 Definition of non-dimensional numbers	9
2.6.1 Reynolds number	9
2.6.2 Weber number	10
2.6.3 Boiling number	11

2.6.4 Martinelli parameter	11
2.7 Conclusions	12
3 State of the Art Review	13
3.1 Critical heat flux	13
3.1.1 The Gambill and Lienhard study	13
3.1.2 The Katto and Ohno study	14
3.1.3 The Qu and Mudawar study	15
3.1.4 The Pribyl et al. study	17
3.1.5 Conclusions	17
3.2 Flow pattern maps	18
3.2.1 Flow patterns in conventional channels	18
3.2.2 Flow pattern maps in conventional channels	20
3.2.3 Flow patterns and flow pattern maps in microchannels	23
3.2.4 Conclusions	31
3.3 Void fraction	32
3.3.1 Homogeneous model	32
3.3.2 The general drift flux model of Zuber and Findlay	32
3.3.3 The Tripplet et al. study	35
3.3.4 The Serizawa et al. study	36
3.3.5 The Chung and Kawaji study	36
3.3.6 The Kawahara et al. study	39
3.3.7 Conclusions	40
3.4 Two-phase pressure drop	42
3.4.1 Homogeneous model	42
3.4.2 The separated flow model of Lockhart and Martinelli	43
3.4.3 The Friedel correlation	44
3.4.4 The Chisholm's method	45
3.4.5 The Mishima and Hibiki study	46
3.4.6 The Lee and Lee study	48
3.4.7 The Kawahara et al. study	48

3.4.8	The Lee and Mudawar study	50
3.4.9	The Zhang and Webb study	53
3.4.10	The Tran et al. study	54
3.4.11	The Cavallini et al. study	55
3.4.12	The Müller-Steinhagen and Heck study	55
3.4.13	Conclusions	57
4	Description of experiments	59
4.1	General description	59
4.2	Test section	59
4.3	Optical measurement technique	61
4.4	Measurements and accuracy	68
4.4.1	Diameter	69
4.4.2	Surface roughness	69
4.4.3	Microevaporator length	70
4.4.4	Distance between the lasers	70
4.4.5	Temperature	70
4.4.6	Fluid properties	71
4.4.7	Mass Flow	72
4.4.8	Mass flux	72
4.4.9	Pressure	73
4.4.10	Energy balance	73
4.4.11	Heat flux	75
4.4.12	Vapor quality	77
4.4.13	Vapor bubble velocity	78
4.4.14	Pressure drop	79
4.4.15	Inlet subcooling	83
4.4.16	Superficial velocities	84
4.4.17	Repeatability of the experiments	84
4.5	Conclusions on the test facility and measurement technique	84
5	Critical heat flux	87

5.1	Experimental procedure	87
5.2	Experimental results	87
5.3	Correlations for saturated CHF	91
5.4	Flow patterns and critical quality	93
5.5	Conclusions from the CHF study	94
6	Flow patterns	97
6.1	Experimental procedure	97
6.2	Experimental flow patterns	97
6.3	Experimental flow pattern maps	105
6.3.1	Comparison with the Kattan et al. macroscale map	109
6.3.2	Comparison with the Tripplet et al. adiabatic microscale map	109
6.3.3	Comparison with the Garimella et al. [22] transition line	110
6.3.4	Effect of the inlet subcooling	110
6.3.5	Effect of the saturation temperature	110
6.3.6	Effect of the microevaporator length	112
6.3.7	Effect of the tube diameter	112
6.3.8	Effect of the fluid	114
6.4	New flow pattern map for evaporating flows in microchannels	115
6.4.1	The isolated bubble regime to coalescing bubble regime transition	115
6.4.2	The coalescing bubble regime to annular regime transition	118
6.5	Conclusions from the flow pattern study in microchannels	120
7	Velocity and void fraction	121
7.1	Experimental velocity	121
7.1.1	Effect of the inlet subcooling	122
7.1.2	Effect of the saturation temperature	122
7.1.3	Effect of the microevaporator length	122
7.1.4	Effect of the diameter	122
7.1.5	Effect of the fluid	124
7.1.6	Velocities below homogeneous model predictions	125
7.2	Drift flux model applied to the vapor velocity	126

7.2.1	R-134a results	126
7.2.2	R-245fa results	128
7.3	Experimental time averaged void fractions	128
7.4	Drift flux model applied to the cross sectional void fraction	129
7.5	Conclusions on the velocity and void fraction results	131
8	Adiabatic two-phase pressure drop	133
8.1	Experimental two-phase frictional pressure drop	133
8.1.1	Effect of the inlet subcooling	134
8.1.2	Effect of the saturation temperature	134
8.1.3	Effect of the microevaporator length	137
8.1.4	Effect of the microevaporator diameter	137
8.1.5	Effect of the fluid	138
8.1.6	The two-phase friction factor	138
8.2	Comparisons with existing prediction methods	139
8.3	New prediction method	145
8.3.1	Homogeneous model with a new two-phase friction factor	145
8.3.2	Lockhart-Martinelli model with a new C parameter	146
8.4	Conclusions on the adiabatic two-phase pressure drop	150
9	Conclusions	151
A	Fluid physical properties	155
	Bibliography	156
	Curriculum vitae	163
	Publications	165