

TABLE OF CONTENTS

STATUS OF THESIS.....	i
APPROVAL PAGE.....	ii
TITLE PAGE.....	iii
DECLARATION PAGE.....	iv
ACKNOWLEDGEMENT	v
ABSTRACT	vi
ABSTRAK	vii
COPYRIGHT PAGE	viii
TABLE OF CONTENTS.....	ix
LIST OF TABLES.....	xiii
LIST OF FIGURES	xiv
LIST OF ABBREVIATIONS.....	xviii
NOMENCLATURES	xix
CHAPTER 1: INTRODUCTION OF STUDY.....	1
1.1 Introduction.....	1
1.2 Project Background.....	1
1.3 Problem Statement.....	3
1.4 Aims and Objectives	4
1.5 Research Approach.....	4
1.6 Project Scope	5
1.7 Thesis Structure	6
CHAPTER 2: VOID FRACTION IN CO-CURRENT BUBBLE COLUMN.....	7
2.1 Introduction	7
2.2 Bubble Columns	7
2.2.1 Co-Current Bubble Column Pilot Plant.....	9

2.3	Void Fraction in Co-Current Bubble Columns	11
2.3.1	Definition	11
2.3.2	Hydrodynamic Parameter	12
2.4	Measurement Methods for Void Fraction Calculation	14
2.4.1	Experimental Measurements	14
2.4.2	Measurement by Empirical Correlation.....	15
2.4.3	Measurement by Using Pixels.....	17
2.4.4	Estimation by Using Photographs	18
2.5	Application of Void Fraction in Co-Current Bubble Column	19
2.6	Overview of Two-Phase Flow	20
2.7	Flow Pattern Classification in Co-Current Bubble Column	21
2.7.1	Flow Regimes in Co-Current Bubble Column.....	22
2.7.2	Flow Regime Map of Co-Current Bubble Column.....	23
2.8	Methods for Flow Regime Detection	25
2.8.1	Visual Observation	26
2.8.2	Advanced Measurement Technique	26
2.9	Basic Flow Measurement Parameters	27
2.9.1	Phase Volume Fraction.....	28
2.9.2	Superficial Velocity.....	28
2.9.3	Volumetric Flowrate, Holdup and Void Fraction	30
2.9.4	Slip and Non-Slip Conditions	31
2.9.5	Reynolds Number.....	31
2.10	Summary.....	32

CHAPTER 3: PRINCIPLES OF ELECTRICAL CAPACITANCE

TOMOGRAPHY AND DIFFERENTIAL PRESSURE

FOR VOID FRACTION MEASUREMENTS 33

3.1	Introduction.....	33
3.2	ECT Measurement System	35
3.2.1	Capacitance Measurement Principle	37
3.2.2	Factors Affecting Capacitance Measurement	39
3.2.3	ECT Sensor Characteristics	40
3.2.4	ECT Models	47

3.3	Differential Pressure Measurements	56
3.3.1	Theoretical Background	56
3.3.2	Mathematical Description	58
3.4	Summary	60
CHAPTER 4: EXPERIMENTAL SETUP AND PROCEDURE.....		61
4.1	Introduction	61
4.2	Two-Phase Flow Test Setup.....	61
4.3	Test Fluid.....	62
4.4	Fluid Supply Facilities	63
4.5	Metering Section.....	64
4.6	Test Section	65
4.7	Bubbles Generation.....	67
4.8	Instrumentation.....	68
4.9	Data Acquisition System.....	70
4.10	Operating Conditions	76
4.11	Experimental Procedure.....	76
4.12	Summary	84
CHAPTER 5: RESULTS AND ANALYSIS		85
5.1	Introduction	85
5.2	Analysis of Bubble Flow Regime.....	85
5.2.1	Visual Observations	86
5.2.2	Bubble Flow Regime Map for Air-Water Column.....	88
5.2.3	Bubble Characteristics	90
5.3	ECT Measurement	93
5.3.1	Calibration of an ECT Sensor.....	93
5.3.2	Online Measurement for Two-Phase Flow	95
5.3.3	Normalisation of Measurements.....	99
5.4	Modelling of ECT Sensor	101
5.4.1	Without Radial Guards.....	101
5.4.2	Effect of Radial Guards.....	103
5.5	Application of Distribution Models.....	105

5.5.1	Series Model	105
5.5.2	Parallel Model	106
5.5.3	Maxwell Model	107
5.5.4	Combined Model	108
5.5.5	Normalised Capacitance for Different Electrode Combinations	110
5.5.6	Estimation of Measured Capacitance	112
5.6	Void Fraction Calculation Using Normalised Capacitance	114
5.7	Void Fraction Calculation Using Normalised Pixels	115
5.8	Void Fraction Characterization	116
5.8.1	Estimation of Void Fraction Using Delta-P	117
5.8.2	Estimation of Volume Void Fraction Using Photograph	120
5.8.3	Application of Drift-Flux Model	121
5.8.4	Comparison between Measured and Calculated Void Fraction	124
5.8.5	Effect of Liquid Properties on Void Fraction	125
5.9	Comparison between ECT, ΔP and Photographic Void Fraction Measurements	126
5.10	Comparison between Experimental and Simulated Data	131
5.11	Summary	133
CHAPTER 6: CONCLUSION AND RECOMMENDATIONS		135
6.1	Conclusion	135
6.2	Recommendations for Future Work	138
REFERENCES		139
LIST OF PUBLICATIONS		148
APPENDIX A		149
APPENDIX B		153
APPENDIX C		154
APPENDIX D		156
APPENDIX E		158
APPENDIX F		159
APPENDIX G		160