CONTENTS

ACKNOWLEDGEMENTS (ii)

ABSTRACT (iii)

CONTENTS (vi)

LIST OF FIGURES AND PLATES (ix)

LIST OF TABLES (xvii)

NOMENCLATURE (xvii)

1. **INTRODUCTION AND LITERATURE REVIEW**

1.1 Introduction **1**

1.1.1 Natural convective heat transfer 1

1.1.2 Natural Convection in rectangular enclosures 2

1.1.3 Natural Convection in cylindrical enclosures 3

1.1.4 Natural Convection in closed loop systems 4

1.2 Literature Review 6

1.2.1 Experimental 6

1.2.2 Numerical 10

1.2.3 Experimental and Numerical 24

1.3 Problem description 26

2. **EXPERIMENTAL SYSTEM** **29**

2.1 Experimental Set-up 29

2.1.1 Test Section 29

2.1.2 Separator 31

2.1.3 Condenser 32

2.1.4 Down flow pipe 32

2.1.5 Preheater 34

2.2 Calibration of the measuring devices 34

2.2.1 Calibration of thermocouples 34

2.2.2 Calibration of pressure transmitters 35

2.2.3 Calibration of flow measuring devices 35

2.2.4 Calibration of Power measuring devices 35

2.2.5 Data acquisition system 36

2.3 Instrumentation and Measurements 37
2.3.1 Power Measurements 37
2.3.2 Temperature measurements 37
2.3.3 Liquid flow rate measurements 42
2.3.4 Differential and gauge pressure measurements 43
2.4 Experimental Procedure 43
2.4.1 Testing and stabilization of the set-up 43
2.4.2 Data Collection 44
3. **COMPUTATIONAL METHODOLOGY** **45**
3.1 Problem Formulation 45
3.1.1 Statement of the problem 45
3.1.2 Governing equations 47
3.1.2.1 Bossinesq Approximation 48
3.1.2.2 Boundary conditions 50
3.1.3 Non-Dimensionalization 52
3.2 Numerical Scheme and Discretization 55
3.2.1 Basic approach of the modified SMAC scheme 56
3.2.2 Grid structure 58
3.2.3 Discretization 60
3.2.3.1 Spatial discretization 60
3.2.3.2 Discretization of pressure Poisson equation 62
3.2.4 Temporal integration 65
3.2.5 Consistency and stability 66
3.2.6 Solution of system of different equations 66
3.2.7 Domain decomposition and parallelization 73
3.3 Grid sensitivity test 74
3.4 Validation 76
4. EXPERIMENTAL RESULTS AND DISCUSSION **79**
4.1 Data Analysis 79
4.2 Uncertainty Analysis 82
4.2.1 Principles of uncertainty analysis 82
4.2.2 Uncertainty analysis in the present work 84
4.2.3 Uncertainties of measured parameters 86

4.3 Variation of measured test section wall and liquid temperatures 89
4.4 Variation of experimental heat transfer coefficient and Nusselt number 101
4.5 Variation of measured pressures in the test section 103
4.6 Variation of measured liquid mass flow (Circulation) rates 107

5. NUMERICAL RESULTS AND DISCUSSION 112

5.1 Spatio-temporal variation of flow properties 112
5.1.1 Temperature variation 112
5.1.2 Variation of the velocities 129
5.1.2.1 Variation of radial velocity 129
5.1.2.2 Variation of axial velocity 147
5.1.3 Variation of pressure 159
5.2 Design parameters 163
5.2.1 Variation of Nusselt Number 163
5.2.2 Variation in mass flow rate 165
5.3 Comparison with the experimental results 168

6. CONCLUSIONS 179

REFERENCES 183

APPENDIX A Experimental data for 10 kW/m^2 **193**

APPENDIX B Sample calculation **200**