

THERMODYNAMIC AND HEAT TRANSFER STUDIES ON ALCOHOL-SALT MIXTURES FOR VAPOUR ABSORPTION REFRIGERATION SYSTEMS

A thesis submitted to the
Indian Institute of Technology, Delhi
for the award of the degree of

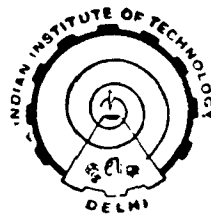
DOCTOR OF PHILOSOPHY

in

Mechanical Engineering

By

SALEM MOHAMMED BIN GADHI



Department of Mechanical Engineering
INDIAN INSTITUTE OF TECHNOLOGY, DELHI
NEW DELHI-110016 INDIA
November, 1986

DEDICATED TO MY PARENTS AND TEACHERS

CERTIFICATE

This is to certify that the thesis entitled, "THERMODYNAMIC AND HEAT TRANSFER STUDIES ON ALCOHAL-SALT MIXTURES FOR VAPOUR ABSORPT. REFRIGERATION SYSTEMS" being submitted by Mr. Salem Mohammed Bin Gadh to the Indian Institute of Technology, Delhi, for the award of Degree of 'Doctor of Philosophy' in the Mechanical Engineering, is a record of the candidate's own bonafide research work.

Mr. Salem Mohammed Bin Gadhi has worked under our guidance and supervision and has fulfilled the requirements for the submission of this thesis, which to our knowledge, has reached the requisite standard.

The results contained in this work have not been submitted in part or in full, to any other University or Institute for the award of any degree.

S.C. Kaushik

(Dr. S.C. Kaushik)

Assistant Professor,
Centre of Energy Studies
I.I.T. New Delhi-110016.

R. Agarwal

(Dr. R.S. Agarwal)

Professor
Mechanical Engg. Department
I.I.T. New Delhi-110016.

ACKNOWLEDGEMENTS

It is with great pleasure to express my heartfelt indebtedness and profound gratitude to my supervisors, Prof. R.S. Agarwal and Dr. S.C. Kaushik for their valuable guidance and moral support throughout the present work, without which this thesis would not have been completed today.

Grateful thanks to Heads, Mechanical Engineering and Centre of Energy Studies for their full cooperation and facilities at all stages.

The author is also extremely grateful to Dr. P.L. Dhar for his kind help and suggestions in the Thermal Design Chapter.

Special thanks are also to University of ADEN, People's Democratic Republic of Yemen to give me this opportunity to carry out this research work under Indo-PDR Yemen Cultural Exchange Programme.

Although, the inspirations received from my friends will be remembered for ever but I am thankful to Mr. Abdulla Bin Gouth and Mr. S. Dorairaj for their help and friendly discussions. Thanks are also due to Dr. Rajesh Kumar, Dr. J.V. Kandinya and Mr. Sanjay Kaul for their cooperation. Thanks are also conveyed to the staff of Refrigeration and Airconditioning Research Laboratories and Workshops in Mechanical Engineering and Centre of Energy Studies at I.I.T. Delhi.

Thanks are also due to Mr. V.P. Gulati and Mr. K.K. Choudhary for efficient typing and for the tracings with utmost care.

The author owes a sense of apology to his parents, brothers Omer and Hassan and other family members who patiently bore his neglect during this period.

Lastly, inexpressible thanks are also due to my wife and daughters for their patience, understanding and co-operation during their stay at Delhi for completion of this work.

SALEM MOHAMMED BIN GADHI

CONTENTS

		<u>page</u>
	CERTIFICATE	..
	ACKNOWLEDGEMENTS	..
	NOMENCLATURE	.. v
	LIST OF TABLES	.. x
	LIST OF FIGURES	.. xii
CHAPTER-1	INTRODUCTION	.. 1-4
CHAPTER-2	LITERATURE REVIEW AND CASE STUDY OF THE PRESENT THESIS	.. 5-17
CHAPTER-3	VAPOUR PRESSURE DATA MEASUREMENTS AND THERMODYNAMIC PROPERTY CORRELATIONS FOR METHANOL-SALT MIXTURES	.. 18-36
3.1	INTRODUCTION	.. 18
3.2	EXPERIMENTAL APPARATUS	.. 18
	3.2.1 Equilibrium Still	.. 19
	3.2.2 Thermostatically Controlled Temperature Bath	.. 19
	3.2.3 Pressure Measurement Device	.. 22
	3.2.4 Temperature Measurement Device	.. 22
3.3	SUBSTANCES USED FOR VAPOUR PRESSURE MEASUREMENT	.. 23
3.4	VAPOUR PRESSURE MEASUREMENT PROCEDURE	.. 25
3.5	THERMODYNAMIC PROPERTIES CORRELATION OF PURE METHANOL AND MIXTURES OF METHANOL- LiBr.ZnBr ₂	.. 29
	3.5.1 Pure Methanol Property Correlations	.. 29
	3.5.1.1 Pure methanol vapour pressure correlation	.. 29
	3.5.1.2 Correlation for saturated liquid enthalpy of methanol	.. 30

	<u>Page</u>
3.5.1.3	Correlations for saturated and superheated vapour enthalpy of methanol .. 31
3.5.2	Property Correlations for Methanol-LiBr.ZnBr ₂ (2/1 mole) Mixture .. 32
3.5.2.1	Pressure-concentration-temperature (p-x-t) correlation for methanol-LiBr.ZnBr ₂ (2/1) mixture .. 32
3.5.2.2	Enthalpy-concentration-temperature (h-x-t) correlation for Methanol-LiBr.ZnBr ₂ (2/1 mole) mixture .. 35
CHAPTER-4	THERMODYNAMIC MODELLING STUDIES OF SINGLE/DOUBLE EFFECT GENERATION ABSORPTION CYCLES USING METHANOL-LiBr.ZnBr ₂ MIXTURE .. 37-63
4.1	INTRODUCTION .. 37
4.2	BASIC PRINCIPLE OF SINGLE/DOUBLE EFFECT GENERATION ABSORPTION CYCLES .. 38
4.3	THERMODYNAMIC ANALYSIS .. 42
4.4	MODELLING RESULTS FOR SINGLE STAGE CYCLE .. 45
4.5	MODELLING RESULTS FOR DOUBLE EFFECT CYCLE .. 52
CHAPTER-5	COMPUTER SIMULATION STUDIES ON DOUBLE EFFECT ABSORPTION CYCLE USING METHANOL-LiBr.ZnBr ₂ MIXTURE .. 64-79
5.1	INTRODUCTION .. 64
5.2	COMPUTER SIMULATION MODEL .. 67
5.3	DISCUSSION OF RESULTS .. 69
CHAPTER-6	NUCLEATE POOL BOILING HEAT TRANSFER TO METHANOL-SALT (LiBr.ZnBr ₂) SOLUTIONS .. 80-102
6.1	INTRODUCTION .. 80
6.2	EXPERIMENTAL SET-UP .. 80

	<u>Page</u>
6.2.1 Test Vessel	.. 84
6.2.2 Test Section	.. 84
6.2.3 Condenser	.. 85
6.2.4 Water Chilling Unit	.. 85
6.2.5 Instrumentation	.. 86
6.3 EXPERIMENTAL PROCEDURE	.. 86
6.3.1 Charging Process	.. 87
6.3.2 Data Recording Procedure	.. 88
6.3.3 Reproducibility and Consistency of Experimental Data	.. 89
6.4 RESULTS AND DISCUSSION	.. 91
6.4.1 Effect of Heat Flux on Boiling Heat Transfer Coefficient	.. 91
6.4.2 Heat Transfer for Methanol Salt Mixtures	.. 100
6.4.2.1 The effect of salts and their concentration on boiling heat transfer coefficient	.. 100
6.5 EMPIRICAL CORRELATIONS	.. 101
CHAPTER-7 THERMAL DESIGN OF AN ABSORPTION UNIT USING METHANOL-LiBr,ZnBr ₂ MIXTURE	.. 103-140
7.1 INTRODUCTION	.. 103
7.2 COMPONENT HEAT EXCHANGER DESIGNS	.. 105
7.2.1 Generator Design	.. 107
7.2.2 Condenser Design	.. 111
7.2.3 Evaporator Design	.. 116
7.2.4 Absorber Design	.. 120
7.2.5 Liquid-Liquid Heat Exchanger Design	.. 134

	<u>Page</u>
7.3 SOLUTION PUMP ..	137
7.4 EXPANSION VALVES ..	137
7.5 PIPING ..	138
7.6 DISCUSSION AND CONCLUSIONS ..	138
CHAPTER-8 CLOSURE : CONCLUSIONS AND RECOMMENDATIONS ..	141-14
REFERENCES ..	145-14
APPENDIX-A ..	153-14
APPENDIX-B ..	157-14
ABOUT THE AUTHOR ..	171