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**THEORETICAL AND EXPERIMENTAL STUDY
OF HEAT PUMPS
USING PURE AND MIXTURE REFRIGERANTS**



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ABSTRACT

In this thesis, a theoretical and experimental study of the performance of two heat pump systems, one is water to water heat pump and the other is a direct expansion solar assisted heat pump, is presented. From the theoretical study the refrigerants R407C, R1270, R290, R170/R290, and R134A were selected and their performances were theoretically and experimentally compared with those of R22 when used in a propriety vapor compression refrigeration unit initially designed to operate with R22.

To carry out the experimental performances of the selected refrigerants, in the first part, the water to water heat pump has been designed and tested for the selected refrigerants. The experimental results showed that R1270 has a higher heating capacity up to 12% than that of R22 and the heating capacity of R290 is 5% to 10% lower than that of R22. R134a has remarkably lower heating capacity than R22, around 25% lower. Refrigerants mixture R407C and R290/170 showed better capacity compared to R22.

All the tested refrigerants showed a higher COP than that of R22 except for that of R407C which is overlapping with that of R22 and is about 3% better than R22 on average, for the tested conditions. R1270, R290 has an increase in COP from 10 to 20% than R22. Refrigerant charge required for hydrocarbons (R1270 and R290 and R290/170) systems is only 40% of that in R-22. Thus, we can substantially minimize the effects to global warming and environmental hazard.

In the second part of the experimental work, a solar-assisted heat-pump water heater has been designed and tested for the selected refrigerants. The performance of the system has been investigated under the meteorological conditions of Malaysia. Similar trend of performance results for the tested refrigerants were obtained with an increase in the heating capacity and the COP. This increase in the performance is due to the high

energy available from the solar radiation. The optimum solar collector area was found to be $A_c = 5.8 \text{ m}^2$ for this specific system, where it is possible to have a continuous supply of hot water at 60°C from a water supply of 30°C with a coefficient of performance up to 5.

In the modeling and simulation part, a steady state model for predicting the performance of vapor compression heat pumps over a wide range of operating conditions is presented. The model overcomes the idealizations of previous models, where the loss and efficiency-based is used to model the compressor and an elemental effectiveness-NTU methodology to model both brazed plate condenser and evaporator. The model requires only inputs that are readily available to the user (e.g. condenser and evaporator inlet water temperatures and mass flow rates). The outputs of the model include system performance variables such as the heating capacity, the coefficient of performance, the compressor electrical work input as well as states of the refrigerant throughout the heat pump cycle. The methodology employed within the model also allows the performance of heat pumps using mixtures to be modeled. The model is validated with experimental data where the agreement is found to be within $\pm 10\%$ for pure refrigerants and 15% for mixtures.

The results showed that the developed method for the theoretical performance calculation can be used to evaluate and compare the performance of the refrigerants in a heat pump system with moderate accuracy and to have first judgments before any system is designed and fabricated.

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TABLE OF CONTENTS

ABSTRACT	iii
ACKNOWLEDGEMENTS	v
LIST OF TABLES	ix
LIST OF FIGURES	x
NOMENCLATURE.....	xvii
 1. INTRODUCTION.....	 1
1.1 Overview	1
1.2 Heat pump	3
1.3 Refrigerants	4
1.4 Solar energy and solar water heating systems	6
1.4.1 Conventional solar water heating systems.....	7
1.4.2 Solar-assisted heat pump	9
1.5 Objectives	11
1.6 Scope and methodology	12
1.7 Outline of thesis.....	14
1.8 Motivation	16
 2. LITERATURE REVIEW	 18
2.1 Introduction	18
2.2 Previous work in R-22 replacement refrigerants.....	18
2.3 Review of previous works on DESAHP	22
2.4 Heat pump and chiller models.....	25
2.5 The reciprocating compressor modeling	30
2.6 The modeling of heat exchangers.....	34
2.7 Heat transfer correlations	36
2.7.1 Single phase heat transfer correlations	37
2.7.2 Heat transfer during a phase change.....	38
2.7.2.1 Evaporation heat transfer coefficient for pure refrigerants.....	38
2.7.2.2 Evaporation heat transfer coefficient for mixture refrigerants	46
2.7.2.3 Condensation heat transfer correlations	57
2.8 Pressure drop in the straight tubes.....	67
2.9 Pressure drop in tube bends.....	70

3. THEORETICAL STUDY, WORKING FLUIDS FOR HEAT PUMPS.	71
3.1 Overview	71
3.2 Thermodynamic analysis.....	72
3.2.1 Theoretical cycle analysis.....	73
3.3 A selection guide for “drop-in refrigerants”.....	88
3.3.1 A thermodynamic comparison of the selected refrigerants	90
3.4 Environmental aspects.....	96
3.5 Design issue and refrigerant charge of heat pump using hydrocarbon	98
3.5.1 General safety issues	99
3.6 Refrigerant mixtures.....	101
3.6.1 Consequences of the thermodynamics	103
3.6.2 Practical aspects of mixtures as working fluids.....	105
3.7 Properties of the refrigerants studied.....	107
3.8 Summary.....	108
 4. EXPERIMENTAL STUDY, RESULTS AND DISCUSSION	 110
4.1 Introduction	110
4.2 Water to water heat pump (WWHP) test rig.	110
4.3 The direct expansion solar assisted heat pump (DESAHP) test rig.	114
4.4 Measuring stations and commissioning.....	116
4.5 Experimental setup and procedure.	117
4.5.1 The uncertainties of the instrumentations and experimental results...121	
4.6 Results and discussion for the water to water heat pump tests.....	126
4.6.1 Compressor discharge temperatures	126
4.6.2 Compressor discharge pressure and system pressure ratio.....	129
4.6.3 Compressor volumetric efficiency.....	132
4.6.4 Refrigerant mass flow rate.....	134
4.6.5 Refrigerant pressure drop in the evaporator and the condenser	137
4.6.6 Compressor power input.....	142
4.6.7 System heating capacity	145
4.6.8 Coefficient of performance.....	153
4.7 The DESAHP results and discussions.....	162
4.7.1 Typical results of a DESAHP using refrigerant R22.....	162
4.7.2 Results of DESAHP for different collector areas for R22.....	171
4.7.3 Comparison of the DESAHP and WWHP results R22	177

4.7.4 Results of the DESAHP using different refrigerants.....	184
4.8 Concluding remarks.....	189
5. THERMODYNAMIC ANALYSIS AND SIMULATION RESULTS	191
5.1 Introduction	191
5.2 Compressor model.....	191
5.2.1 Parameters identification	198
5.2.2 Compressor model validation with experimental results	203
5.3 Heat exchangers modeling	208
5.4 Plate condenser model.....	212
5.4.1 Condenser heat transfer coefficient's correlations	215
5.4.2 Condenser pressure drop calculation	215
5.4.3 Condenser simulation results.....	218
5.5 Plate evaporator model	221
5.5.1 Evaporator heat transfer coefficient's correlations.....	222
5.5.2 Evaporator pressure drop calculation	223
5.5.3 Evaporator simulation results	224
5.6 Expansion valve model.....	227
5.7 System simulation methodology an results	229
5.8 DESAHP system simulation.....	232
5.8.1 Theoretical calculation for collector-evaporator performance	232
5.8.2 Simulation results for the DESAHP	240
5.9 Summary.....	245
6. CONCLUSIONS	246
6.1 Conclusions	246
6.2 Suggestions for further work	249
REFERENCES.....	250
APPENDICES	265
Appendix A: Photos of the WWHP and the DESAHP systems.	265
Appendix B: Some results of 3 collectors DESAHP for tested refrigerants.....	267
Appendix C: Some results of the DESAHP with different collectors areas.	269
Appendix D: Some comparison results of the DESAHP with WWHP.....	271
Appendix E: Some results of 1 solar collector DESAHP, for tested refrigerants.....	273
Publications:	275