

TABLE OF CONTENTS

CERTIFICATE	i
DECLARATION BY THE CANDIDATE	ii
COPYRIGHT TRANSFER CERTIFICATE.....	iii
ACKNOWLEDGEMENTS	iv
TABLE OF CONTENTS.....	vi
LIST OF TABLES	x
LIST OF FIGURES	xii
LIST OF SYMBOLS	xviii
ABSTRACT.....	xxi
Chapter 1: Introduction	1
1.1 Background and Motivation	1
1.2 Objectives and Novelty of the Thesis.....	5
1.3 Thesis Structure	6
Chapter 2: Literature Review.....	7
2.1 PTC Absorber: Heat Transfer and Heat Transfer Fluids	7
2.2 Nusselt Number Correlation: Pure and Nanofluids	11
2.3 PTC Absorber: Discrete Heating.....	14
2.4 Research Gaps	16
Chapter 3: A Generalized Nusselt Number Correlation for Nanofluids and Look-up Diagram to Select Heat Transfer Fluids.....	17

3.1	Selection Criteria for Heat Transfer Fluids	17
3.1.1	Dimensional and Non-dimensional Parameters.....	17
3.1.2	Pure Fluids	20
3.1.3	Nanofluids.....	23
3.2	Results and Discussion	35
3.2.1	Improved Nusselt Number Correlation for Nanofluids	35
3.2.2	Heat Transfer Fluid Selection: Dimensional Parameter	40
3.2.3	Heat Transfer Fluid Selection: Non-dimensional Figure of Merit.....	42
3.2.4	Heat Transfer Fluid Selection: Look-up Diagrams.....	44
3.2.5	Heat Transfer Fluid: Cost-benefit Analysis	48
3.3	Summary.....	49
	Chapter 4: A Generalized Nusselt Number Correlation for Binary Hybrid Nano-oils as Heat Transfer Fluid.....	51
4.1	Hybrid Nanofluids	51
4.1.1	Nusselt Number Correlations for Hybrid Nanofluids: A Comparative Assessment	52
4.1.2	Separation Approach: Generalized Nusselt Correlation for Hybrid Nanofluids	54
4.2	CFD Analysis: Turbulent Forced Convection	55
4.2.1	Problem Description	56
4.2.2	Mathematical Modeling.....	58
4.2.3	Boundary Conditions and Numerical Scheme.....	60

4.2.4	Grid Independence Test and Validation	61
4.3	Results and Discussion	65
4.3.1	Hydro-Termal Development of Turbulent Oil Flow	65
4.3.2	Separation-based Nu_{gen} : Need and Assessment	67
4.4	Summary.....	71
Chapter 5: New Insights in Turbulent Heat Transfer with Oil and Hybrid Nano-oils, Subject to Discrete Heating, for Parabolic Trough Absorbers		73
5.1	Computational Fluid Dynamics Framework	73
5.1.1	Problem Description	73
5.1.2	Mathematical Modeling.....	76
5.1.3	Grid Independence Test and Validation	80
5.2	Results and Discussion	82
5.2.1	Axial Velocity Contour.....	83
5.2.2	Radial Distribution of the Axial Velocity	86
5.2.3	Streamline	92
5.2.4	Temperature Contour	93
5.2.5	Radial Distribution of Statistical Temperature for TVP1	98
5.2.6	Surface-Area-Averaged Nusselt Number for Oil and Hybrid Nano-Oils..	102
5.3	Summary.....	106
Chapter 6: Experimental study with a Hybrid Nano-Oil for Assessing the Generalized Nusselt Number Correlation		109
6.1	Experimental Setup and Procedure.....	109

6.1.1	Hybrid Nano-Oil Preparation: Al ₂ O ₃ -CuO TVP1	113
6.1.2	Data Deduction	115
6.1.3	Uncertainty Analysis.....	116
6.1.4	Validation.....	117
6.2	Results and Discussion	118
6.2.1	Hybrid Nanofluid: Stability	118
6.2.2	Convective Heat Transfer Coefficient and Nusselt Number: Oil and Hybrid Nano-oil.....	119
6.2.3	Pressure drop and Friction Factor: Oil and Hybrid Nano-oil	120
6.2.4	Nusselt Number and Figure of Merit: Oil and Hybrid Nano-oil	120
6.3	Summary.....	121
	Chapter 7: Conclusions and Future Work.....	123
	REFERENCES	127
	LIST OF PUBLICATIONS AND CONFERENCES	145