

Contents

Abstract.....	II
Acknowledgments.....	V
Nomenclature.....	IX
List of Figures.....	XII
List of Tables.....	XIV
1 Introduction	1
2 Phase change material(PCM)	6
2.1 Types of heat storage	6
2.1.1 Sensible heat storage.....	6
2.1.2 Latent heat storage	7
2.1.3 Thermochemical heat storage	7
2.2 What is PCM.....	7
2.3 Advantages and disadvantages of PCM.....	7
2.4 Types of PCM and their properties	8
2.4.1 Inorganic pcms.....	8
2.4.2 Organic pcms.....	9
2.5 Uses of pcms.....	11
2.6 PCM problem.....	12
2.6.1 History of Stefan problem.....	12
2.6.2 Description PCM problem.....	13
2.6.3 The numerical solution of PCM problem	17
2.6.3.1 Mathematical formulation.....	17
2.6.3.1.1. Overview of the Phenomena Involved a PCM.....	17
2.6.3.1.2.The assumptions of the mathematical formulation.....	19
2.6.3.1.3.The enthalpy formulation.....	20
2.6.3.2 Melting and solidification formulation	25
2.6.3.2.1 The melting process.....	25
2.6.3.2.2.The solidification process.....	27

2.6.3.3.Melting and solidification of PCM with constant end wall temperature.....	28
2.6.3.4. Melting and solidification with convectional, constant end wall fluid temperature.....	29
2.6.3.5.Flowchart of melting or solidification of the PCM.....	32
2.6.3.6. Simulation of melting and solidification processes of rectangular container of PCM	33
 2.6.3.6.1. Constant temperature end walls of rectangular container of PCM.....	34
 2.6.3.6.2. Constant fluid temperature at end walls of rectangular container of PCM.....	36
3. The greenhouse.....	42
 3.1. The aim of using greenhouses.....	42
 3.2. <i>Static design procedure</i>.....	44
 3.2.1. Heating load requirements.....	44
 3.2.1.1. Transmission heat losses calculation conduction.....	45
 3.2.1.2. Infiltration heat loss calculation.....	46
 3.2.1.3. Solar radiation heat gain.....	48
 3.2.1.3.1. Solar radiation transmission	50
 3.3. Orientation of the greenhouse	53
 3.4. Mathematical modeling of the greenhouse.....	53
 3.4.1. Introduction.....	53
 3.4.2. The heat balance equation of the greenhouse without PCM..	54
 3.4.3. Simulation of greenhouse inside air temperature without PCM with various covers at 23th July at Al-Aroub.....	58
4 Simulating the greenhouse with pcm.....	63
 4.1. The heat balance equation of the greenhouse with PCM	63
 4.2. Results of the simulation of the greenhouse with pcm.....	66
 4.2.1. The greenhouse with PCM in 23th July in Al-Aroub.....	66
 4.2.2. The greenhouse with PCM in 21th January in Al-Aroub...76	76

4.2.3. The greenhouse with PCM in 23 th February in Al-Aroub.....	82
5 Conclusions and recommendations.....	86
Appendices.....	89
Appendix A.....	89
Appendix B.....	176
References	183