

HIGHER TECHNICAL INSTITUTE

MECHANICAL ENGINEERING DEPARTMENT

DIPLOMA PROJECT

EVALUATION OF THE PERFORMANCE
OF THERMOSYPHON
SOLAR WATER HEATER

M/724

THRASYVOULOU THRASOS

JUNE 1995

EVALUATION OF THE PERFORMANCE OF THERMOSYPHON SOLAR WATER HEATER

by

THRASOS THRASYVOYLOY

Project Report

Submitted to

the Department of Mechanical Engineering
of the Higher Technical Institute

Nicosia - Cyprus

in partial fulfilment of the requirements

for the diploma of
TECHNICIAN ENGINEER

in

MECHANICAL ENGINEERING

June 1995

HIGHER TECHNICAL INSTITUTE	PROJECT NO 2482
----------------------------------	--------------------

CONTENTS

Pages

Summary

Introduction	1
--------------------	---

CHAPTER 1 : GENERIC TYPES OF SOLAR DOMESTIC HOT WATER SYSTEM

1.1	Recirculation system	4
1.2	Drain back system	5
1.3	Drain down system	6
1.4	Nonfreeze systems	7
1.5	Thermosyphon system	8
1.5.1	Thermosyphon description	8
1.5.2	Thermosyphon operation	9

CHAPTER 2 : PERFORMANCE OF A THERMOSYPHON SOLAR WATER HEATER

2.1	Flat plate collector	10
2.2	Collector composition	11
2.3	Heat transfer liquid	15
2.3	Mass flow rate	16
2.4	Collector efficiency	16
2.6	Collector efficiency factors	19
2.7	Hot water storage tank	20
2.7.1	Auxiliary heater	22

CHAPTER 3 : PARAMETERS WHICH INFLUENCE THE PERFORMANCE OF A THERMOSYPHON SOLAR WATER HEATING SYSTEM

3.1	System design	23
3.1.1	Materials related problems.....	23
3.1.2	Other collector design problems.....	26
3.1.3	Reverse flow	27

3.1.4	Collector tilt	28
3.1.5	Collector area to storage	30
3.1.6	Storage design	30
3.1.7	Stratification	30
3.1.8	Position of storage tank with respect to absorber plate.....	32
3.1.9	Overall heat loss coefficient.....	33
3.2	Climatic conditions	
3.4	Hot water heating load requirements	35

CHARTER 4 : SHORT TERM SYSTEM TEST METHOD

4.1	System description	36
4.2	Overall system performance test	37
4.2.1	General	37
4.3	Test installation for short term system test	38
4.3.1	Pipework.....	38
4.3.2	Flow control devices and flow meters	38
4.3.3	Temperature regulation of cold water supply	39
4.3.4	Draw-off bleed pipe	39
4.4	Preconditioning of the system	39
4.5	Test procedure	40
4.6	Analysis and presentation of results	41
4.6.1	Tables for short test results	43
4.6.2	Draw off temperature profiles	49
4.6.3	Mixing in storage vessel during draw-off	52
4.7	Overnight heat loss test of the storage vessel	53
4.7.1	Introduction	53
4.7.2	Test method	53
4.7.3	Calculation of heat loss coefficient of storage tank	54

CHARTER 5 : LONG TERM PREDICTION METHOD USING THE RESULTS OF THE
SHORT TERM SYSTEM TEST

5.1	Introduction	56
5.2	Climatic data and hot water load assumed in prediction	

in prediction	58
5.3 Monthly solar energy output	59
5.4 Monthly solar contribution	60
5.5 Conclusions	62

References

Appendix

LIST OF FIGURES

Pages

Figure i	An open loop system.....	4
Figure ii	Closed loop system.....	4
Figure 1.1	Recirculation system.....	5
Figure 1.2	Typical drainback system.....	6
Figure 1.3	Drain down system.....	7
Figure 1.4	Nonfreeze system.....	8
Figure 1.5.2	Thermosymhon system.....	10
Figure 2	Schematic diagram of a typical plate solar collector.....	11
Figure 2.1	Components of a flat plate collector.....	14
Figure 2.5.1	Collector efficiency curve.....	18
Figure 2.5.2	Heat loss coefficient against absorber temperature.....	19
Figure 3.1.1	Four methods of joining riser tubes to headers.....	25
Figure 3.1.2	Two suitable methods of aligning collectors in thermosymhon system.....	27
Figure 3.1.4	Typical collector performance at different incident angles.....	29
Figure 3.1.8	Positioning of storage tank with respect to absorber showing effect on efficiency....	32
Figure 3.1.9	Heat loss paths from collector plate.....	34
Figure 4.1	Schematic diagram of thermosyphon sytem....	37
Figure 4.5	Test loop for short term system testing....	45
Figure 4.6.3	Draw-off temperature profies	
Figure 5.4a	Comparison between horizontal and vertical storage tank.....	61
Figure 5.4b	Schematic diagram of thermosyphon solar water with horizontal storage cylinder....	61

NOMENCLATURE

Symbol	Meaning	Units
Aa	Collector aperture area	m ²
Ag	Collector area	m ²
G	Solar irradiance at collector aperture	W/m ²
Gd	Diffuse solar radiation	W/m ²
Hd	Daily diffuse solar radiation	MJ/m ²
Qout	Useful energy output	MJ
Ta	Ambient air temperature	°C
Tc	Cold water temperature	°C
Td	draw off water temperature	°C
Tf	Final water temperature of the storage tank	°C
Ti	Initial water temperature of the storage tank	°C
U	Wind speed	m/s
Us	Heat loss coefficient of storage vessel	W/m ² k
Vs	Storage tank volume	Liter
n	Collector thermal efficiency	-
Dt	Duration	s
Htilt	Monthly average daily irradiation on the collector	MJ/m ²
Ta,av	Monthly average daily (24 h) ambient temperature	°C
Tref	Water temperature which is draw off	°C
FrU1	Slope of the collector efficiency curve	-
Fr(ta)n	Intercept of the collector efficiency curve	-
Gtest	Collector flow rate per unit area of collector at test conditions	kg/m ² h
Nr	Number of parallel collector risers	-
Paux	Auxiliary energy input to tank	Kw
β	Collector tilt angle	°

ACKNOWLEDGEMENTS

I would like to express my sincere appreciation and gratitude to my project supervisor Dr. I. Michaelides for his valuable assistance and guidance in the preparation and completion of this project.

I would also like to thank every one that helped me in anyway in producing this project.

SUMMARY

The objective of this project was to use the cyprus standard CYS:209:91 for performance characterisation and yearly performance of atypical Cypriot thermosyphon water heater.

The upcoming steps were followed for the completion of this project:

[1] First of all, a review study was done about different types of solar domestic hot water system employed in Cyprus.

[2] Then, a general review was carried out of the performance of a thermosyphon solar water heater such as collector, and collector efficiency , storage tank e.t.c.

[3] Furthermore, the parameters affecting the performance of a thermosyphon were analysed.

[4] Next, the term short system test method with results and draw off profiles were conducted. The results obtained from the short term test (4 days with daily solar irradiation in the range 15-25 MJ/m² and 2 days with daily solar irradiation in range 0-15 MJ/m) ie the performance characteristics of the system were independent of the location of the test.

[5] The final results of the test procedure and long term performance prediction were presented so that they can be easily understood by consumers and manufactures, in terms of anual energy savings (KWh/year). A procedure was therefore developed which used the results of the short term test to predict the long term performance of thermosyphon water heater.

The procedure described by the Cys:209 for experimentally

predicting the performance of SDH produces results which are not site specific and therefore are valid everywhere provided the local climatic conditions are known. AS the method is the same used in Greece and other European countries local SDH manufactures will be in position to take advantage of opportunities which arise in the European market.

- It gives consumers a criterion on which to base their selection of SWHS.
- It provides an indication to manufacturers and prospective buyers on how efficiently the system work. So far there were available test results on collectors and storage tanks but the behaviour of the system could not be characterised by the component test results. The test results can be used to assess the impact of design, insulation and other changes to the system as such.
- The procedure however required test, thus demanding to a long time and manpower.

INTRODUCTION

Cyprus enjoys excellent weather conditions for the development and utilization of solar energy in all sectors. It was these weather conditions that the cyriot manufactures took advantage of, when in 1960, they began manufacturing in cyprus the first solar heaters. After that, a period of exceptional widespread development of solar energy systems for the domestic sector began as a result of which, today, cyprus with its 227,000 systems installed, is probably the first country in Europe and the mediterranean regarding the number of solar heaters per head. Today 90% of individual houses are equipped with solar heaters ,in contrast to multi-apartment blocks where the percentage is 20%. Multipanel solar systems for the supply of large quantities of hot water were introduced in 1980, as a result of which, today 50% of hotels are equipped with solar systems. Further development of solar energy utilization, in individual houses built before 1965 proved to be rather expensive, because the necessary prerequisites for the installation were not taken into account when they were buit. Furthermore, the lack of methods for freezing protection of solar collectors is still a prohibitive factor for the widespread use for solar systems in the mountainous areas.

The nice weather conditions, the high cost of electricity and the financial benefits that result from the use of solar heaters were the principal reasons that contributed to the decision for the utilization of solar energy, as a result of which, cyprus became one of the first countries in the world with respect to the percentage of energy saved from the use of solar heaters (4%): The government also contributed in many ways towards this effort. One such contribution was the funding of the installation of 11,000 solar heaters installed on refugee housing built in the free part of Cyprus. Furthermore loans were offered to

individuals and hotel owners for the installation of such systems. Technical assistance is also provided to the manufacturers including the experimental determination of collector efficiency and the training of manufacturers in design and manufacturing of improved type of the collectors.

The most popular type of solar collector manufactured in Cyprus is the flat plate solar collector.

The fact that Cyprus has perhaps the higher percentage per capital of energy saved from the usage of solar systems in the world should not be a preventive factor for further development. For this to be achieved, the installation of solar heaters, by taking into account provisions, during the construction of multi-apartment blocks, for future installation of solar heaters and by divising ways of utilizing the common area on the roofs.

The state of solar technology in Cyprus today, makes it possible to install solar systems with a high degree of efficiency for preheating water for industrial purposes.