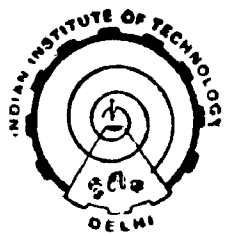
HEAT TRANSFER STUDIES ON SOLAR ENERGY COLLECTOR-CUM-STORAGE SYSTEMS

By

D. S. HRISHIKESAN

Thesis Submitted to the
Indian Institute of Technology, Delhi
for the award of the degree of
DOCTOR OF PHILOSOPHY



Centre for Energy Studies
INDIAN INSTITUTE OF TECHNOLOGY, DELHI
INDIA

April, 1987

CERTIFICATE

It is certified that the thesis entitled, 'Heat Transfer Studies on Solar Energy Collector-Cum-Storage Systems', being submitted by Mr. D.S. Hrishikesan is worthy of consideration for the award of the Degree of Doctor of Philosophy and is a record of bona fide research work carried out by him under my guidance and supervision. The results contained in this thesis have not been submitted in part or full to any other University or Institute for the award of any degree or diploma.

Prof. H.P. Garg
Centre for Energy Studies
Indian Institute of Technology
New Delhi 110 016, India

ACKNOWLEDGEMENTS

I wish to express my deep sense of gratitude to Prof. H.P. Garg for providing me with an opportunity to undertake this research work. I am greatly indebted for the interest he has shown in this work. But for his constant encouragements, suggestions and critical discussions, this work would not have reached the final stage. I am at a loss for words for the academic and vocational support that he has been giving me in abundance.

I am grateful to Dr, P.K. Bansal who initiated me into research and took care to see that I have a footing in this field. His friendly nature and creative approach to problems produced an atmosphere conducive to learning.

I had opportunity to work with Dr. N.K. Bansal and Dr. J. Prakash. Both of them lay me under a profound sense of indebtedness for the pains they have taken to see me through this ordeal. Dr. Prakash has given invaluable suggestions while this thesis was taking shape.

I am grateful to Prof. M.S. Sodha, Prof. S.S. Mathur and Prof. P.D. Grover, for the interest they have evinced in my work and for the facilities provided.

The faculty members, the technical staff and the office staff of the Centre for Energy Studies have always been cooperative and helpful to me during the course of

this work. My friends, specially in CES and in IIT at large made my stay in the campus a pleasant one.

I owe a word of thanks to Dr. V.K. Sharma, who has been standing by me through my thick and thin. He always rendered a helping hand whenever I felt that I touched the rock bottom. I am grateful to Mr.S.N. Garg, whom I always felt free to approach with my problems, irrespective of their nature. I have a word of appreciation for my colleagues, Dr. Gouri Datta, Dr. Sumana C. Datta, Dr. Madhuri Sachan, Mrs. Rashmi Rakshit, Mrs.Ranjana Jha, Miss Ratna Verma, Dr. B. Bandyopadhyay, Dr.A.R. Shukla, Dr. R.C. Agnihotri, Dr. Indrajit, Mr. Rai Ajai Pat Ray, Mr. Sanjay Sharma, Mr. Ram Kumar Agarwal, Mr. Sukhpal Singh Yadav and Mr. Teeka Ram, who helped me directly during my stay in the group.

Finally, I would like to put on record my gratitude to the Department of Non-Conventional Energy Sources, Government of India, and the Indian Institute of Technology, Delhi, for providing me with the financial support and research facilities.

It is my pleasure to acknowledge the care Mr. P.M. Padmanabhan Nambiar has taken to make this thesis elegant by neat typing.

D.S. Hrishikesan

D.S. HRISHIKESAN

SUMMARY

In this thesis an attempt is made to identify and optimize various parameters which influence the thermal performance of various solar collector-cum-storage systems - shallow solar ponds (SSP), plastic bag water heaters and built-in-storage type solar water heaters. Here, the aspects of these systems which have not so far been attempted, but which are important from their wide applications point of view, are investigated deeply.

The enhancement in solar radiation absorbed by a flat plate collector by a pair of booster mirrors is theoretically investigated. The model, very comprehensive in nature, is capable of predicting the enhancement in solar radiation absorbed by a collector, provided with two reflectors of most general orientations, for any location and for any day of the year. The thermal performance of a shallow solar pond augmented by a plane mirror is studied experimentally as well as theoretically.

By formulating a mathematical model, the effect of a heat exchanger in the form of a serpentine tube on the performance of SSP is studied by employing periodic analysis. The variation in the behaviour of the system

with flow rate of the fluid flowing through the heat exchanger and length of the heat exchanger is studied.

With the help of a transient model, the performance of a plastic bag water heater is studied theoretically and the findings are supported by experimental results. The reduction in efficiency of the system due to the ultra violet degradation of poly vinyl chloride and its economic viability are also investigated.

The performance of an array of plastic bag water heaters in series and parallel connections is analytically evaluated employing periodic analysis method. An empirical relation is formulated between the stagnation temperature of the fluid, the number of bags to be connected in series to reach the stagnation temperature and the flow rate of the fluid maintained in the system.

The improvement in the thermal behaviour of a built-in-storage type solar water heater, when it is subjected to different types of tracking, is theoretically studied for different duty cycles, viz. no-flow (with and without night insulation), continuous flow, intermittent withdrawal, instantaneous withdrawal, minimum temperature limit withdrawal and constant temperature withdrawal. Forward time step marching technique is used for solving the energy balance equations.

CONTENTS