

# **Physics and Technology of Solar Energy**

Volume 1

Solar Thermal Applications

# Physics and Technology of Solar Energy

Volume 1

Solar Thermal Applications

*Proceedings of the International Workshop on Physics of Solar Energy,  
New Delhi, India, November 24 - December 6, 1986*

Edited by

**H. P. Garg**

Centre of Energy Studies,  
Indian Institute of Technology, New Delhi, India

**M. Dayal**

Department of Non-Conventional Energy Sources,  
Ministry of Energy, New Delhi, India

**G. Furlan**

International Centre for Theoretical Physics, Trieste, Italy

and

**A. A. M. Sayigh**

Department of Engineering,  
The University of Reading, Reading, U.S.A.

Assistant Editor:

**V. K. Sharma**

Centre of Energy Studies,  
Indian Institute of Technology, New Delhi, India

**D. REIDEL PUBLISHING COMPANY**

A MEMBER OF THE KLUWER



ACADEMIC PUBLISHERS GROUP

DORDRECHT / BOSTON / LANCASTER / TOKYO

**Library of Congress Cataloging in Publication Data**

International Workshop on Physics of Solar Energy  
(1986: New Delhi, India)  
Physics and technology of solar energy.

**CIP**

Includes indexes.

Contents: v. 1. Solar thermal applications— v. 2. Photovoltaics and solar energy materials.

1. Solar energy—Congresses. I. Garg, H. P. II. Sharma, V. K.

III. Title.

TJ809.2.158 1986 621.47 87—13114

ISBN-13: 978-94-010-8247-1 e-ISBN-13: 978-94-009-3939-4

DOI: 10.1007/978-94-009-3939-4

---

Published by D. Reidel Publishing Company,  
P.O. Box 17, 3300 AA Dordrecht, Holland.

Sold and distributed in the U.S.A. and Canada  
by Kluwer Academic Publishers,  
101 Philip Drive, Assinippi Park, Norwell, MA 02061, U.S.A.

In all other countries, sold and distributed  
by Kluwer Academic Publishers Group,  
P.O. Box 322, 3300 AH Dordrecht, Holland.

All Rights Reserved

© 1987 by D. Reidel Publishing Company, Dordrecht, Holland  
Softcover reprint of the hardcover 1st edition 1987

No part of the material protected by this copyright notice may be reproduced or  
utilized in any form or by any means, electronic or mechanical  
including photocopying, recording or by any information storage and  
retrieval system, without written permission from the copyright owner

## CONTENTS

Preface	ix
Sponsors	xi

### SOLAR RADIATION MEASUREMENT AND MODELLING

1. Solar Radiation, its Measurement and Application in Solar Energy Utilization Programme A.Mani	1
2. A Program in Basic for Calculating Solar Radiation in Tropical Climates on Small Computers R.H.B.Exell	15

### SOLAR ENERGY COLLECTORS

3. Principles of solar thermal conversion R.H.B.Exell	27
4. Solar Concentrators S.S.Mathur	39
5. Stationary Asymmetric Concentrators K.D.Mannan	79
6. Thermal analysis of Compound Parabolic Concentrating Solar Energy Collectors B.Norton and D.E.Prapas	109
7. Physics of Solar Ponds C.L.Gupta	137
8. Operating Experience with solar ponds in Tropics C.L.Gupta	169
9. Testing of Liquid Collectors S.C.Mullick	187

## SOLAR PASSIVE HEATING AND COOLING

- |     |   |     |
|-----|---|-----|
| 10. | Passive heating and cooling concepts<br>R.L.Sawhney, M.S.Sodha and N.K.Bansal | 209 |
| 11. | Energy Conscious Building Design<br>F.M.Butera                                | 241 |
| 12. | Field Studies on Solar Passive Buildings in India<br>C.L.Gupta                | 319 |
| 13. | Monitoring and Modeling of Passive Solar Buildings<br>S.Mahajan               | 343 |

## SOLAR REFRIGERATION AND AIRCONDITIONING

- |     |  |     |
|-----|--|-----|
| 14. | Solar Energy Cooling in Buildings<br>A.A.M.Sayigh  | 369 |
| 15. | A Village size Solar Refrigerator<br>R.H.B.Exell   | 397 |
| 16. | Solar Cooling for Cold Storage Applications using Solid desiccants and Adsorbents<br>R.H.B.Exell, S.C.Bhattacharya and Y.R.Upadhyaya | 405 |

## SOLAR DRYING

- |     |   |     |
|-----|---|-----|
| 17. | Solar Crop drying<br>N.K.Bansal   | 413 |
| 18. | Passive Autarkic Solar Drying Techniques<br>B.Norton, P.D.Fleming and O.V.Ekechukwu | 447 |

## OTHER THERMAL APPLICATIONS

- |     |   |     |
|-----|---|-----|
| 19. | Solar Thermal Applications<br>G.D.Sootha  | 467 |
| 20. | Solar Cookers<br>H.P.Garg   | 475 |
| 21. | Solar Desalination Techniques<br>H.P.Garg   | 517 |
| 22. | Thermodynamic Analysis of a Direct Expansion Solar Assisted Heat Pump<br>S.K.Chaturvedi | 561 |

CONTENTS

vii

23. Instrumentation in Solar Energy Applications 583  
M.Ramakrishna Rao

AUTHOR INDEX 601

SUBJECT INDEX 607

## PREFACE

The 'fuel crises' in 1972-73 generated world wide effort for the search for an Alternative Energy source to fossil fuels. Solar energy was identified as one of the alternatives to fossil fuels. On one hand the developed countries are trying to maintain their standard of living while the developing countries are trying to solve their industrial, social and economical problems to increase their standard of living. After this period a lot of Research and Development in the field of solar energy was carried out both in developing and developed countries and solar energy is utilized in domestic, agricultural and industrial sectors and also in the space. During the period of "Oil Crises" industrialized countries expended their activities in solar energy and substantial progress was made. In few developing countries separate funding in the field of solar energy R&D was also provided through national and international, organizations. Time has now come when one should seriously look into the problems and screen, select, adapt, and manage emerging solar energy technology for its use in developing countries. Also the International Organizations will have to play a major role in this direction which may assist building up of a local solar energy R & D and manufacturing capabilities in developing countries which should be based on a long term but on necessary basis.

With this in view, an International Workshop on Physics of Solar Energy was organised with the support of many National and International Organisations with the idea to identify the priority areas in the field of solar energy materials, solar photovoltaic, and solar thermal applications. The main objective of this International Workshop was also to improve communications between individual scientists, academic institutions, industries and research institutions working in the field of solar energy and to discuss the latest developments in the field of solar energy and its potential uses. The purpose was also to provide training for scientists, engineers and academicians from developing countries of the world.

The Workshop is organised under the joint sponsorship of Indian Institute of Technology, New Delhi, India; International Centre for Theoretical Physics, Trieste, Italy; United Nations Educational Scientific and Cultural Organisation (UNESCO); COSTED; United Nations University (UNU); British Council; International Bureau, West Germany; Department of Science & Technology; Council of Scientific

and Industrial Research; Indian National Science Academy; India; and Tata Energy Research Institute. Keeping the objectives of the Workshop in view, topics for discussions were selected and eminent scientists were invited from all over the world to present lectures on these selected topics. In all 46 invited lectures were delivered during the Workshop period. The proceedings of the Workshop is being prepared in two volumes. Volume one deals with selected topics on Solar Thermal Applications containing 23 lectures while volume two contains 16 lectures dealing with Photovoltaics and Solar Energy Materials. Few lectures which are of general nature are not included in the final proceedings.

The International Advisory Board and National Organising Committee of the Workshop extend their thanks to Govt. of India and Prof. Abdus Salam, Director, ICTP, Trieste, Italy for all the support for holding this International Workshop at IIT Delhi, India. Prof. H.P.Garg who is the Organising Secretary of this International Workshop is particularly grateful to all the sponsors and co-sponsors of this Workshop and specially to Prof. Abdus Salam, Director, ICTP, Trieste, Italy for generous support and for supplying the necessary funds, personnel and advice.

H.P. Garg  
Maheshwar Dayal  
G. Furlan  
A.A.M. Sayigh  
V.K. Sharma



## SPONSORS

British Council

Committee on Science and Technology in Developing Countries (COSTED).

Council of Scientific and Industrial Research (CSIR), New Delhi, India.

Department of Non-Conventional Energy Source (DNES), New Delhi, India.

Department of Science and Technology (DST), New Delhi, India.

Indian Institute of Technology, New Delhi, India

Indian National Science Academy (INSA), New Delhi, India

International Bureau, Julich, West Germany.

International Centre for Theoretical Physics (ICTP), Trieste Italy.

Solar Energy Society of India (SESI), India.

Tata Energy Research Institute (TERI), New Delhi, India.

United Nations Educational Scientific and Cultural Organisation (UNESCO).

United Nations Industrial Development Organization (UNIDO).

United Nations University (UNU), Tokyo, Japan.

University Grants Commission (UGC), New Delhi, India.