

# **SOME STUDIES ON NORMAL AND REVERSE FLAT-PLATE COLLECTORS**

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TO MY PARENTS

CERTIFICATE

It is certified that the thesis entitled "Some Studies on Normal and Reverse Flat-Plate Collectors" being submitted by Vinod Kumar Goel is worthy of consideration for the award of the degree of Doctor of Philosophy and is a record of the original bonafide research work carried out by him under our guidance and supervision. The results contained in this thesis have not been submitted in part or full to any other University or Institute for award of any degree or diploma.

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(Vinod Kumar Goel)

## OBJECTIVES OF THE THESIS

The primary objective of this thesis is to investigate (theoretically and experimentally) a number of design variations of solar air heating system (based on nonporous absorbers) for increasing efficiency and economy. Interesting variations of normal flat-plate collectors (having single absorber) and reverse flat-plate collectors have been included in the scope of work; the collectors with different design variations have been fabricated and tested for experimental validation of the analytical models. The corresponding techno-economic analysis has also been made. It is concluded that a two pass reverse flat-plate collector having a single absorber is a highly desirable option.

## PREFACE

In this thesis the author has studied the dependance of the performance of solar air heaters with nonporous absorbers on various parameters. One of the important design parameter in double pass heaters is the depth of the flow channel because both the forced convective heat transfer coefficient and pumping power needed to blow the air into solar air heater depend on it. In published literature, it varies from 2 cm to 10 cm. The author has optimized the flow channel depth corresponding to minimum cost of delivered heat in a two pass solar air heater. The outlet air temperature was obtained using three correlations for the heat transfer coefficient in the duct.

In conventional solar air collectors, the air duct is formed between two metallic plates, the top plate which is the absorber, and a bottom plate, followed by adequate insulation. Another alternative is a system consisting of the absorber plate and a rigid synthetic foam covered by aluminium reflecting foil. A solar air heater of such a duct design may be called single absorber solar air heater. The absorber could be flat, corrugated or vee-corrugated. These types of single absorber solar air heaters have been analysed

in detail in this thesis. The effect of parameters like heat transfer coefficient,  $\tau$ , flow rate on the thermal performance of these collectors has been evaluated. These collectors are then fabricated and tested to obtain the dependence of thermal efficiency  $\eta$  on  $\Delta T/I$ . The analytical results are compared with the experimental results and the heat transfer coefficient correlation which give the best agreement with, has been identified. The values of  $F_R U_L$  and  $F_R (\tau \alpha)$  are also obtained and compared with experiment.

A number of designs of reverse flat-plate collectors have been proposed and analysed in this thesis. Their thermal performance is compared with that the originally proposed reverse flat-plate collector and also with the conventional flat-plate collectors. The performance of two absorber double pass reverse flat-plate collector is found to be better than the other designs considered here. This collector is then tested in order to validate the analytical model.

The techno-economics of two absorber double pass reverse flat-plate collector have been compared with that of conventional collectors and also with other energy sources (like wood, oil, gas and electricity) by taking a working example of paddy drying in a spouted bed dryer. It is concluded that drying of paddy at

100°C in a spouted bed dryer is economical.

The above mentioned work has partially appeared in the following research publications/communications:

1. Chandra, R., Goel, V.K., and Raychaudhuri, B.C., (1983), "Universal Curves for natural convection heat transfer coefficients in flat-plate solar energy collectors", Applied Energy, 13 p. 101.
2. Chandra, R., Goel, V.K. and Raychaudhuri, B.C., (1983), "Performance comparison of two-pass modified reverse flat-plate collector with conventional flat-plate collectors", Energy Convers. Mgmt., 23, p. 177.
3. Goel, V.K., Chandra, R. and Raychaudhuri, B.C., (1987), "A study on the performance of a two absorber reverse flat-plate collector", Energy Conver. Mgmt., 27, p. 335.
4. Goel, V.K., Chandra, R. and Raychaudhuri, B.C., (1987), "Experimental investigations on single absorber solar air heaters", Energy Convers. Mgmt., 27, No.4, p.343.
5. Chandra, R., Goel, V.K. and Raychaudhuri, B.C., (1982), "A double exposure two pass reverse flat-plate collector for irrigation pumping in rural

areas, presented in National Seminar on Rural Development with alternative Energy Resources held in Kamla Nehru Institute of Science and Technology", Sultanpur during Feb. 24-25.

6. Goel, V.K., Chandra, R. and Raychaudhuri, B.C., (1985), "Thermal performance of a two pass/double exposure reverse flat-plate collector", Proc. National Solar Energy Convention, Feb. 10-12, Bhopal.

In addition the author has also contributed the following research papers.

1. Chandra R., Goel, V.K., Krishnan, H.A. and Raychaudhuri, B.C., (1983), "Effect of Air Humidity on the performance of a solar air heater", Proc. National Solar Energy Convention held in New Delhi during Dec. 17-19, p. 4043.
2. Goel, V.K., Ram Chandra and B.C. Raychaudhuri, (1984), "Experimental study on performance comparison of two pass reverse flat-plate collector with normal flat-plate collector" Proc. National Symp. on Renewable Sources of Energy, B.I.T.S. Pilani.

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