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BROOKHAVEN NATIONAL LABORATORY DESIGNED COLLECTOR: PERFORMANCE IN INDIA

V. Mubayi

August 1985

Prepared for presentation at the U.S.-India Binational Symposium Workshop on Solar Energy Research and Applications; National Science Foundation and the Department of Non-Conventional Energy Sources, Government of India; Roorkee, India; August 1985.

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DEPARTMENT OF APPLIED SCIENCE

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ABSTRACT

Results are presented on the thermal performance of an advanced concept flat plate solar collector developed at Brookhaven National Laboratory (BNL), Upton, New York. The instantaneous collector efficiency tests were performed in India as part of a collaborative research program in solar thermal technology between the Solar Thermal Energy Center, Department of Non-Conventional Energy Sources, Government of India (STEC), and BNL. Test data was taken over a two month period using a first generation design. The results indicate high thermal performance replicative of the results obtained in the United States.

INTRODUCTION

The collaborative research and development program in solar thermal technology between STEC and BNL was initiated in 1983. This program had, at its inception, two purposes: first, to introduce some of the innovative concepts in solar technology being explored in the U.S. to Indian researchers, and second, to contribute to a program of institutional support and joint collaboration with STEC. This included the transfer of selected instrumentation and training in its use for measuring solar device performance to STEC.

The project provided three prototype BNL collectors and a "smart" data logging instrumentation package to the STEC facility at Dundahara, Haryana. Assistance was also given in familiarizing the STEC staff with current solar testing methods and procedures. Measurement of collector performance was based on instantaneous operating performance in which a number of data points were recorded and used to establish the performance curves with linear regression techniques. Results obtained on the testing of the BNL solar flat plate collector will be reported on in this paper.

SIGNIFICANCE OF THE NEW COLLECTOR DESIGN

The solar flat plate collector that was tested at STEC is based on a new design philosophy guided by cost reduction motives. The object was to create significant cost reduction opportunities without sacrificing performance or durability. The design is based on a unique construction method and a liberal use of high performance polymer materials.

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The polymer materials include thin films used in the glazing and weather sealing of the collector. A rigid monolithic polymer foam core is used for insulation and structural support. A very strong and rigid panel is achieved with a monocoque construction that allows the polymer films to perform the function of structural tension members in combination with the insulating core in compression (Figure 1). A light, thin aluminum bent metal frame acts as a transition section to elevate the stressed glazing film above the absorber plate.

The BNL collector tested at STEC used a conventional tube and fin absorber plate instead of the thin material unpressurized design currently under development at BNL. This allowed the BNL light weight design to be applied to conventional pressurized system operation such as in thermosyphoned water heating. The 2 m^2 panels delivered to STEC weighed about 14 kg or about 30% as much as conventional designs.

EXPERIMENTAL TESTING OF THE BNL COLLECTOR

The experiment was performed using continuous pumped flow operation. The collector inlet (Tin) and outlet (Tout) temperatures and the ambient (Ta) temperatures were monitored with precision ($T<\pm 0.1\alpha C$) temperature sensors (resistance temperature devices, [RTDs]) connected to the "smart" datalogger. The datalogger provided under the project is an Acurex Corporation Autodata 10/4 with multichannel capability and an internal programming capability for manipulating and reducing the raw sensor information thus permitting automated data reduction. This instrument is connected to a hard copy terminal for programming and recording of the output.

A constant flowrate of 2.56 l/min was maintained through the collector by means of a motor driven pump and a restricting flow valve system in the water circuit. The mass flowrate ($\dot{m}$) was monitored with a Brooks flow meter with the heat transfer rate (Q_T) estimated from:

$$Q_T = \dot{m}\ (Tout - Tin)$$

The solar insolation (I) was measured by a Licor pyranometer connected to the datalogger. This permits determination of the total input energy (I_T) relative to the collector gross area (A_c):

$$I_T = IA_c$$

Instantaneous efficiency was simply derived from:

$$c = \frac{Q_T}{I_T}$$

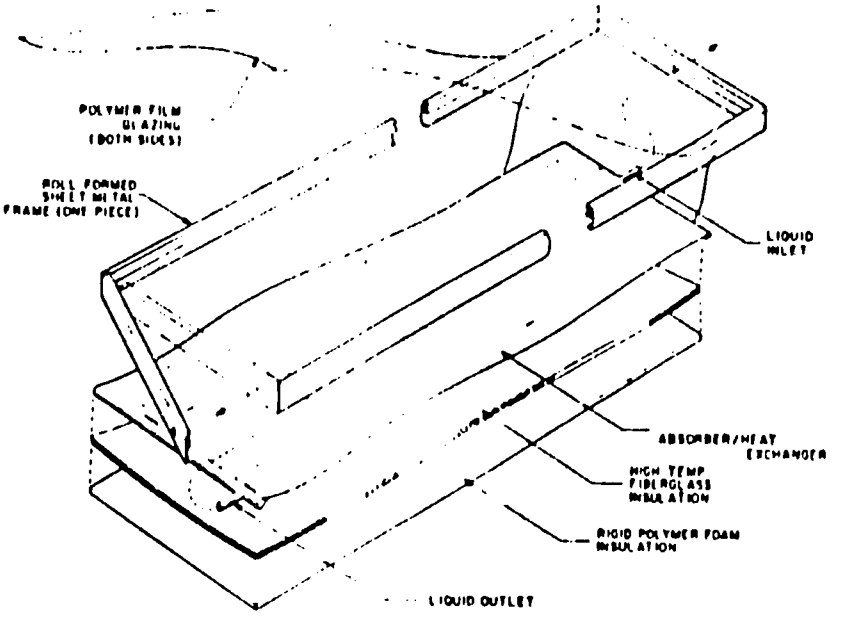

Fig. 1. BNL thin material solar flat plate collector.

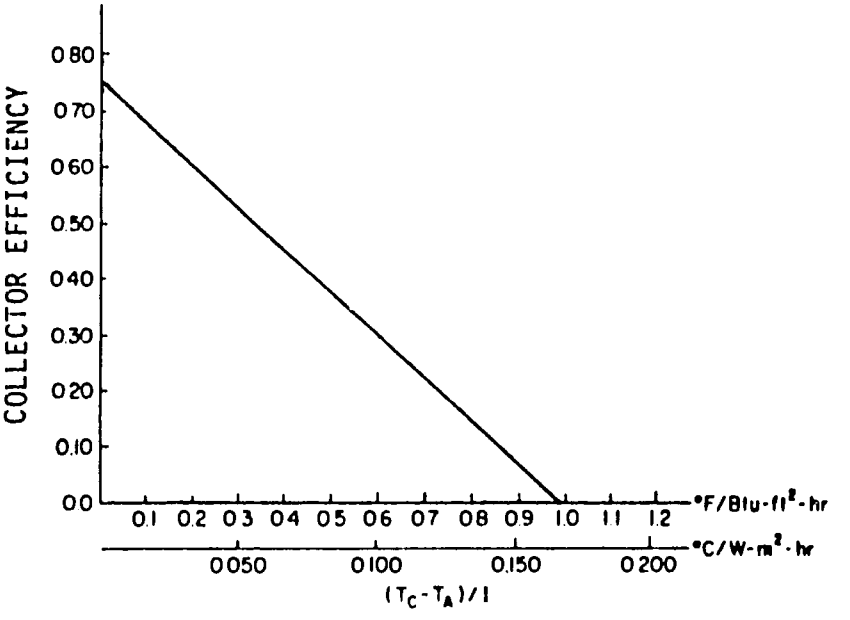

Fig. 2. Indian test results.

PERFORMANCE RESULTS

Test data were obtained over a period of two months from mid-November 1984 to mid-January 1985. A large number of data points were obtained at various operating points ($\Delta T/I$) to insure a good statistical data base for the performance curve, as well as to generate confidence in the overall test fixture including test stand and instrumentation.

The results are shown in Figure 2 which is a standard plot of the instantaneous collector efficiency, $_c$, versus $\Delta T/I$ where:

$\Delta T = T_{inlet} - T_{ambient}$ in ^oC

I = solar insolation in watts/m^2.

The curve was estimated by performing a linear regression on 119 test data points of the form

$Y = a + bx$

where Y is the efficiency and $x = \Delta T/I$.

The regression results were as follows:

Input data (119 points):

cmin = 0.09 $(\Delta T/I)_{min} = 0.0008$

cmax = 0.82 $(\Delta T/I)_{max} = 0.174$

Estimated value of a = 0.75 (t = 190.7)

Estimated value of b = -4.54 (t = -76.2)

$R^2 = 0.98$.

The high value of R^2 and the t-statistics show that the data fit the estimated form very well and that the estimates of the regression parameters are highly significant at the 0.01 level.

$(\Delta T/I)$ intercept ^{y} 0.165$^oC/W\text{-}m^2\text{-}hr$

CONCLUSIONS

The test data obtained indicate that the BNL ultralight collector design performed well in the fairly severe Indian environment. Conditions at the STEC test site tended to be desert-like with high, dry temperatures and frequent wind blown dust. These conditions where much harsher than test conditions experienced in the U.S. so the results where quite useful in confirming the potential durability of the design, especially when considering its high thermal performance. Surface dust accumulation occurred at a very high rate

requiring frequent washing or wiping of the collector (at least twice daily) in order to maintain test conditions. Since the BNL design uses a polymer film glazing, abrasion and degradation of the window surface were important factors under investigation. Encouragingly, no measurable degradation in performance was detected over the two month test period. Preliminary indications are that the BNL collector, because of its excellent high temperature efficiency and apparent durability would be a candidate for solar absorption air-conditioning in India.

ACKNOWLEDGEMENT

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