

SHORT COMMUNICATION

**THE PERFORMANCE OF A FLAT PLATE SOLAR COLLECTOR
WITH SPIRAL THERMOPLASTIC NATURAL RUBBER TUBING**

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RINGKASAN : Prestasi sebuah pengumpul suria dengan tiub berlingkar Thermoplastic Natural Rubber (TPNR) sebagai penyerap dibentangkan. DVNR 9011 sejenis campuran komersial TPNR digunakan sebagai tiub berlingkar. Suhu keluar sehingga 75°C dicatitkan dengan kadar aliran jisim 2.2 g s⁻¹ untuk hari yang biasa pada 550 W m⁻² dan purata kecekapan plate pada 80%.

ABSTRACT: The performance of a solar collector with spiral Thermoplastic Natural Rubber (TPNR) tubing as the absorber plate is presented. A commercial blend of TPNR (DVNR 9011) was used as the spiral tubing. A temperature output upto 75°C was obtained with a mass flow rate of 2.2 g s⁻¹ for a typical day of 550 W m⁻², with an average plate efficiency of 80%.

KEYWORDS: Flat plate solar collector, thermoplastic natural rubber, spiral tubing, performance.

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INTRODUCTION

In recent years the use of plastic materials as absorber plates as well as tubes has increased (Lenel and Mudd, 1984). Plastic was not used initially because it has a tendency to degrade when exposed to sunlight, due to its low thermal conductivity and high coefficient of expansion. Recent advances in polymer technology have resulted in the development of a suitable plastic material which can withstand long exposure to sunlight. One such material is the Ethylene Propylene Diene Monomer (EPDM), a petroleum based product.

This paper studies the performance of a flat plate solar collector with a spiral TPNR, a natural rubber-based product, as the absorber plate.

THEORETICAL BACKGROUND

The useful energy (q_u) delivered to the working fluid of a solar collector is (Duffie and Beckman, 1980):

$$q_u = \dot{m} C_p (T_{fo} - T_{fi}) \quad (1)$$

where;

T_{fo}	=	fluid outlet temperature
T_{fi}	=	fluid inlet temperature
C_p	=	specific heat of water
\dot{m}	=	mass flow rate of water

Hence, the efficiency of the collector (η) is given by :

$$\eta = \frac{\dot{m} C_p (T_{fo} - T_{fi})}{A I_T} \quad (2)$$

where;

A	=	collector area
I_T	=	solar radiation that falls on the collector

Figure 1 shows a typical output of the experimental results.

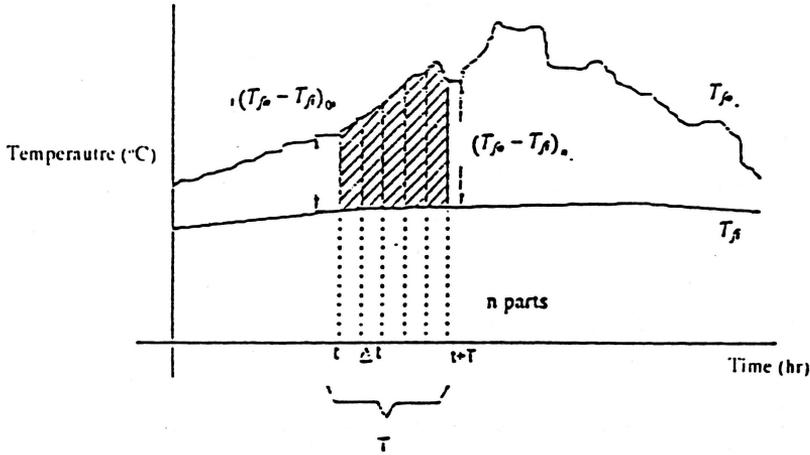


Figure 1. A typical result on a chart recorder

The fluid flow is relatively slow and the TPNR tube is long, therefore, for a specific time period, the intermittent nature of the solar radiation will result in inconsistencies in calculating the plate efficiency using equation (2)

In order to determine the true efficiency of the collector, It was assumed that the mass flow rate (\dot{m}) is constant for that period, hence,

$$\Delta E_g = (T_{fo} - T_{fi}) \dot{m} C_p \Delta t \tag{3}$$

$$E_g = \int_t^{t+T} \dot{m} C_p (T_{fo} - T_{fi}) dt \tag{4}$$

where;

E_g = energy delivered from the collector by the working fluid at a time period T .

$$E_g = \sum \dot{m} C_p (T_{fo} - T_{fi}) \Delta t = \dot{m} C_p (n \Delta t) \sum (T_{fo} - T_{fi}), n \Delta t = T$$

$$= \dot{m} C_p \frac{T}{2} \left[(T_{fo} - T_{fi})_1 + 2 \left[(T_{fo} - T_{fi})_2 + (T_{fo} - T_{fi})_3 + \dots + (T_{fo} - T_{fi})_{n-1} \right] \right.$$

$$\left. + (T_{fo} - T_{fi})_n \right)$$

$$= \dot{m} C_p \frac{T}{2} \left(\text{Summation of Series } (T_{fo} - T_{fi}) \right) \tag{5}$$

Using the same approach, E_i solar radiation incident on the collector can be obtained from:

$$\begin{aligned} \Delta E_i &= A I_T \Delta t \\ E_i &= \int_{t_i}^{t_f} A I_T dt \\ &= A n \frac{\Delta t}{2} \left(\text{Summation of Series } (I_T) \right) \\ &= \frac{T A}{2} \left(\text{Summation of Series } (I_T) \right) \end{aligned} \tag{6}$$

Hence, the efficiency is calculated from:

$$n = \frac{E_g}{E_i} = \frac{\dot{m} C_p (\text{Summation of Series } (T_{fo} - T_{fi}))}{A (\text{Summation of Series } (I_T))} \tag{7}$$

EXPERIMENTAL

An experimental rig was fabricated as shown in Figure 2. The collector plate has an area of 1m² with a single glass glazed and tilted 8°. It has a spiral TPNR tubing as the absorber plate (Figure 3). Conventional polystyrene sheets were used to insulate the collector plate. A 40-litre polyethylene drum was used as the storage tank and insulated with a 5-cm thick ceramic fibre wool. The tank was filled with water and its flow rates varied. The collector input and output, ambient temperatures, and solar radiation were recorded. The flow rates were determined by the time taken to fill a measuring cylinder.

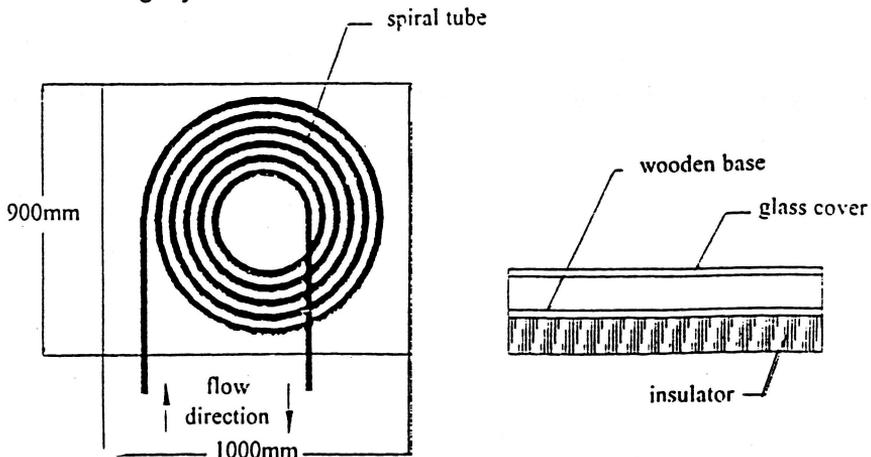


Figure 2. The spiral tube solar collector

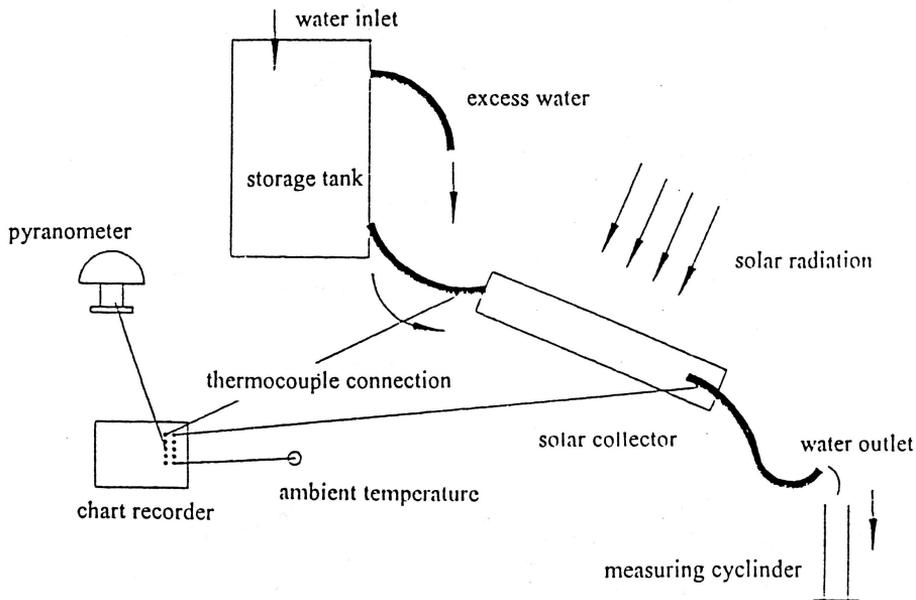


Figure 3. Experimental set-up

RESULTS AND DISCUSSION

The results presented here were performed on two typical days. One was bright and hot while the other cloudy and rainy. Figures 4 and 5 show the collector outlet, inlet and ambient temperatures, efficiency and solar radiation for the two days. It is observed that the efficiency is dependent on solar radiation. The efficiency reached an average of 80% on the hot and clear day while an average of 50% on the cloudy and rainy day. For the bright and hot day a temperature difference of 45°C was obtained with the inlet and outlet temperatures at 30°C and 75°C respectively. The flow rate was maintained at 2.2 g s⁻¹ while the solar radiation was at 510 W m⁻². On the cloudy and rainy day the outlet temperature of the collector reached 40°C at a flow rate of less than 2.0 g s⁻¹ and a solar radiation of less than 200 W m⁻².

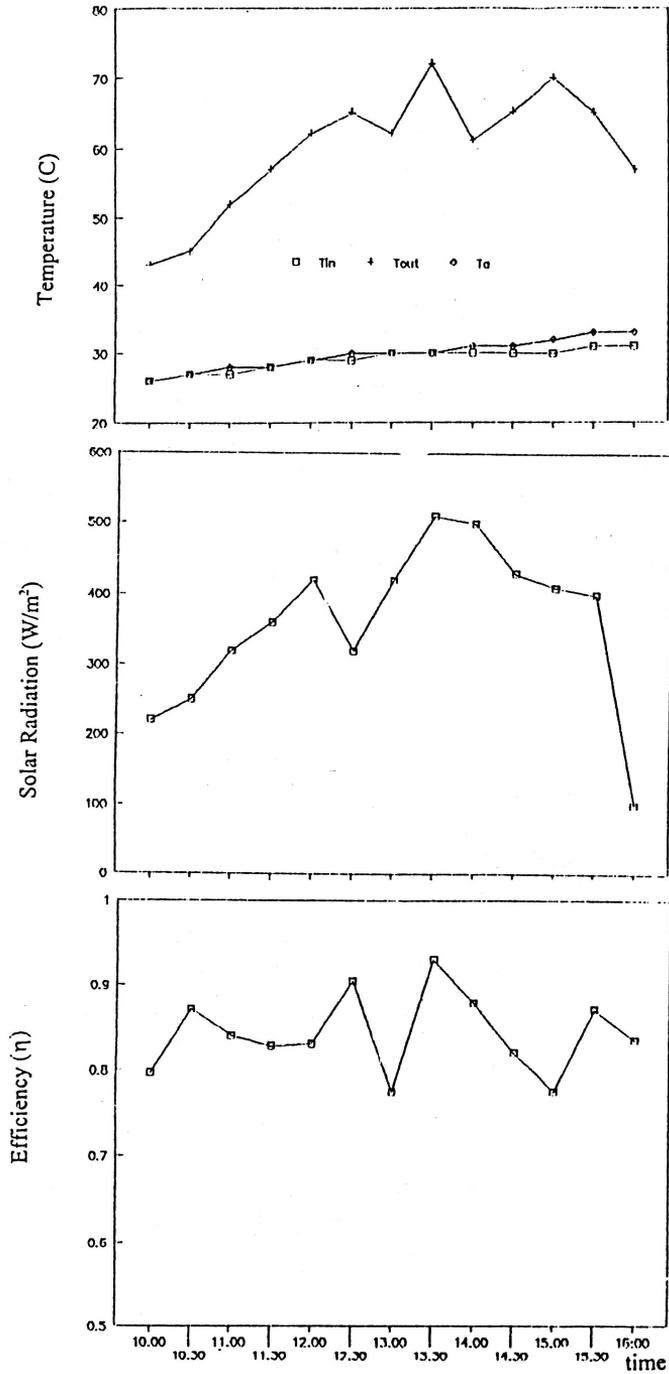


Figure 4. The collector outlet, inlet and ambient temperatures (T_{out} , T_{in} and T_a) respectively solar radiation and efficiency on a clear day.

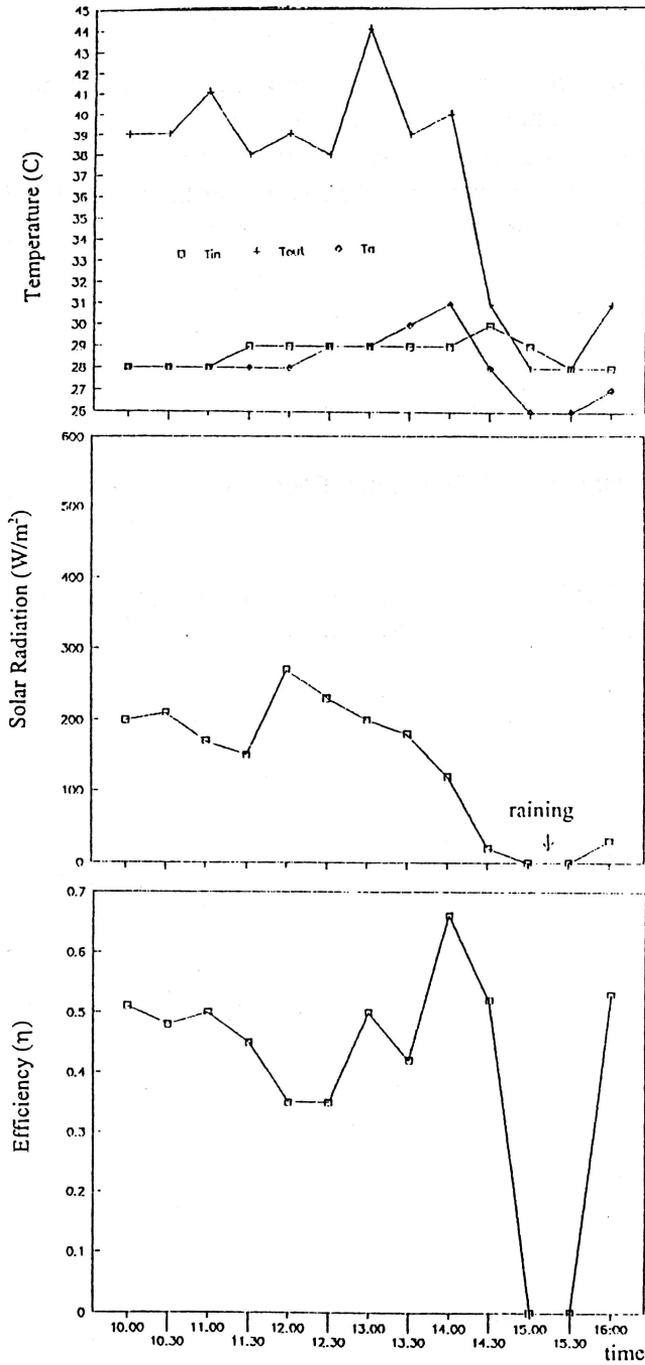


Figure 5. The collector outlet, inlet and ambient temperatures, solar radiation and efficiency on a cloudy day.

CONCLUSIONS

Promising results were obtained with the use of a spiral thermoplastic natural rubber (TPNR) tubing as the absorber plate in a solar collector. Furthermore, the use of plastic solar collector components have several advantages which include its lightness, easiness to fabricate, low cost and corrosion resistance. It can be concluded that, the spiral thermoplastic natural rubber tubing can replace other materials as solar collector absorber plates.

REFERENCE

Duffie, J.A. and Beckman, W.A. (1980). *Solar Engineering of Thermal Processes*, Wiley Interscience, New York.

Lenel, U.R. and Mudd, P.R. (1984). A review of materials for solar heating system for domestic hot water, *Solar Energy*, Vol. 32, 109-120.

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