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The Effect of Adding Carbon (soot) to the Paint of an Absorbing Surface in Homemade Solar Systems

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ABSTRACT

Absorbing materials are key components of any solar water heater device. Silicon solar cells are very efficient but are highly expensive. An alternative is to use absorbing materials that are cheaper than silicon to produce. The use of carbon (soot) in the preparation of the coating layer of a homemade solar water heater has been investigated. When added in different proportions to oil-based white paint, marked increases in water temperatures were obtained. The increase in water temperature was directly proportional with the increase in the percentage of carbon in the coating layer. The maximum achieved outlet water temperature was 90° C in July and 70° C in November.

Due to its non-toxic nature and very low cost, carbon in the form of smoke suspension or soot, can provide a good and reliable alternative in the fabrication of domestic solar water heaters.

Keywords: carbon, coating, solar heater.

تأثير إضافة الكربون على الطلاء للسطح الماص في المجمعات الشمسية الحرارية

الملخص

تعد المواد الماصة جزءا مهما لأي نظام سخان حراري شمسي. تكون خلايا السليكا الشمسية ذات كفاءة عالية جدا لكنها مرتفعة الكلفة أيضا. إن البديل هو استخدام مواد ماصة أرخص كلفة من السليكا عند الإنتاج. إن استخدام الكربون في تحضير طبقة الطلاء لسخان ماء شمسي قد تم اختباره. فعندما يضاف الكربون بنسب مختلفة إلى طلاء زيتي أبيض، نحصل على درجة حرارة ماء مرتفعة. يتناسب ازدياد درجة حرارة الماء طرديا مع زيادة نسبة الكربون المضاف إلى طبقة الطلاء. كانت أعلى درجة حرارة للماء 90° سليزية في تموز و70° سليزية في تشرين الثاني.

وبالنظر إلى طبيعة الكربون غير السامة ورخص كلفته، فإنه يوفر بديلا جيدا يمكن اعتماده في عمل سخانات الماء الحرارية المحلية الصنع.

INTRODUCTION

Solar energy is a natural renewable source which originates in the sun. The use of solar energy has a promising potential. Solar energy is converted into thermal energy by using solar collectors. Batch-type homemade solar water heaters are among the most cost-effective solar devices.

Fig. 1: A homemade solar water heater device.

Many workers have investigated different ways for exploiting solar energy. A domestic solar water heater uses the sun to heat water for household uses. A rough black surface absorbs all wave lengths in the visible spectrum. Conversely, the transparent glass cover allows nearly all radiation to pass through it without little reflection or absorption, and without deflecting it from its parallel travel lines.

Different types of absorbing materials are in use. Solar energy is easily obtained by a black surface coated with a thin layer of black paint. An effective utilization of solar energy involves maximum absorption of the incident solar radiation and minimum emission of heat (Katzen *et al.*, 2005). A solar absorbing surface is a key component of the solar water heater and its properties and quality control both heat gains and losses.

Silicon solar cells are very efficient components. However, the widespread use of these cells is largely limited to the developed areas because of the expensive production cost. Researchers have therefore been investigating ways to develop solar cells based on organic materials which are more flexible and cheaper to produce than silica solar panels (NPG Asia materials, 2009).

Mitrea *et al.* (2008) used oxides coatings in their solar collectors. They remarked that coatings on solar collectors must have high absorption coefficient but low emission coefficient. Also, the coating must be able to absorb over 90% of the solar energy. Two kinds of absorption materials were tested: oxide coatings and alumina cement.

Another technique described by Katzen *et al.* (2005) involves the use of new film structures based on porous silica and nanosized carbon for selective absorbers. This absorbing material showed high rates of absorbance of solar energy and very limited emission of heat.

An unusual procedure to grow layers of conductive Bi_2S_3 films on fluorine-doped tin oxide glass substrate at room temperature was investigated by Zhou *et al.* (2006). Electrical characterization of Bi_2S_3 films was conducted using photocurrent spectroscopy. Results of measurements showed that efficiency of heat absorption increased with increasing thickness of Bi_2S_3 films.

In his thesis research, Ali (1979) tested an absorbing layer. The layer was fabricated from smoke suspension (soot) in oils. This layer enhanced the absorption of solar radiation and diminished heat emission. Efficiency of collector increased by 20% for 0.5 mm layer with smoke suspension.

Generally, absorber materials are governed by their durability and the expected service life (Carisson, 2004). Durability, in this case, is the ability of a material to resist deterioration caused by external factors in the environment (e.g. temperature, humidity and atmospheric corrosion), which may influence the performance of the material under service condition (Carisson, 2004).

This study describes the preparation and testing of an absorbing material for a homemade solar water heater. Mixtures of several proportions of carbon (soot) and oil paint were applied to the absorber's surface. The performance of the solar water heater was observed using four different coatings.

EXPERIMENTAL PROCEDURE

A homemade passive solar water heater (1m x 1m) was positioned facing South at an angle of 45° for the purpose of this study. The surface was coated with a layer made up of a mixture of carbon (soot) and oil-based white paint. Four coatings with different carbon proportions were applied to the absorbing surface to monitor the performance of the system on four separate sunny days in July and November 2010 (Tables 1 and 2). Weight percentages of carbon in the coating layers were 20, 30, 40 and 50. Coating thicknesses increased as carbon percentage increased. At the 50% mark, the coating was almost 0.5 mm thick.

Water temperature was recorded during a 14 hour period starting at 06:00 a.m. for the month of July and for an 11 hour period for the month of November (Tables 1 and 2). For everyday during the experiment, the tank was first drained and then filled up with water provided from a nearby tank placed in the shade. Inlet as well as outlet water temperatures were recorded at one-hour interval.

RESULTS AND DISCUSSION

Performance of the absorbing surface is determined by measuring its solar absorption and heat emission. The use of absorber material is governed by its cost durability and expected service life (Carisson, 2004). High quality absorber materials, such as silicon, are very efficient but are also very expensive.

The use of carbon (soot) which is cheap and non-toxic provided a good alternative for an absorbing material in this study. Absorption of solar radiation increased with the increase of carbon percentage in the coating layer (Tables 1 and 2). The highest water temperatures achieved were 90°C for the month of July and 70° C for the month of November with 50% carbon in the paint. All peak water temperatures were recorded during the 12:00-13:00 period. It is obvious that during that period (12:00-13:00), the angle of incidence of solar radiation was at its maximum as a result of increasing of solar altitude. In addition, for all test days, outlet water temperatures remained above 45°C the next morning in July. Whereas, those of November were below 30°C.

It should be mentioned that in July 2010 recordings, the rise in outlet water temperatures during the period 8:00-9:00 was relatively low particularly for the 20 and 40% coating. This could possibly attributed to the angle of solar radiation at that period.

Table 1: Recordings of water temperatures for the four coatings (July, 2010).

% of carbon in paint	**20**		**30**		**40**		**50**	
Date T°C	09/07/2010 H: 43°C; L: 31°C		12/07/2010 H: 45°C; L: 29°C		17/07/2010 H: 42°C; L: 30°C		19/07/2010 H: 43°C; L: 28°C	
T°C / Time	**Inlet**	**Outlet**	**Inlet**	**Outlet**	**Inlet**	**Outlet**	**Inlet**	**Outlet**
06:00	28	28	30	30	28	28	29	29
07:00	30	42	32	44	29	43	30	44
08:00	30	50	34	60	30	62	31	65
09:00	31	51	35	62	32	65	31	71
10:00	31	60	35	70	31	72	31	77
11:00	32	67.5	36	79	32	80	32	85
12:00	33	72	36	84	33	87	33	89
13:00	33	73	36	81	34	81.5	33	90
14:00	33	71	37	76	34	78	33	85
15:00	34	69	36	72	33	74	33	80
16:00	34	66	36	69	32	72	34	76
17:00	34	64	36	66	32	70	34	72
18:00	34	61.5	36	63	32	67	34	70
19:00	34	59	36	60	32	64	34	67

Generally, water temperatures of the four coatings exhibit one distinct pattern. A rapid rise in water temperature followed by a slightly slower drop around noon (Figs. 2 and 3).

Thicknesses of coating layers increased with the increase of carbon proportion in the paint. Hence, solar absorption increased as the thickness of the layer increased. However, attempts to increase the amount of carbon in the paint beyond the 50% mark did not succeed as no homogeneous mixture could be obtained to provide a coating layer.

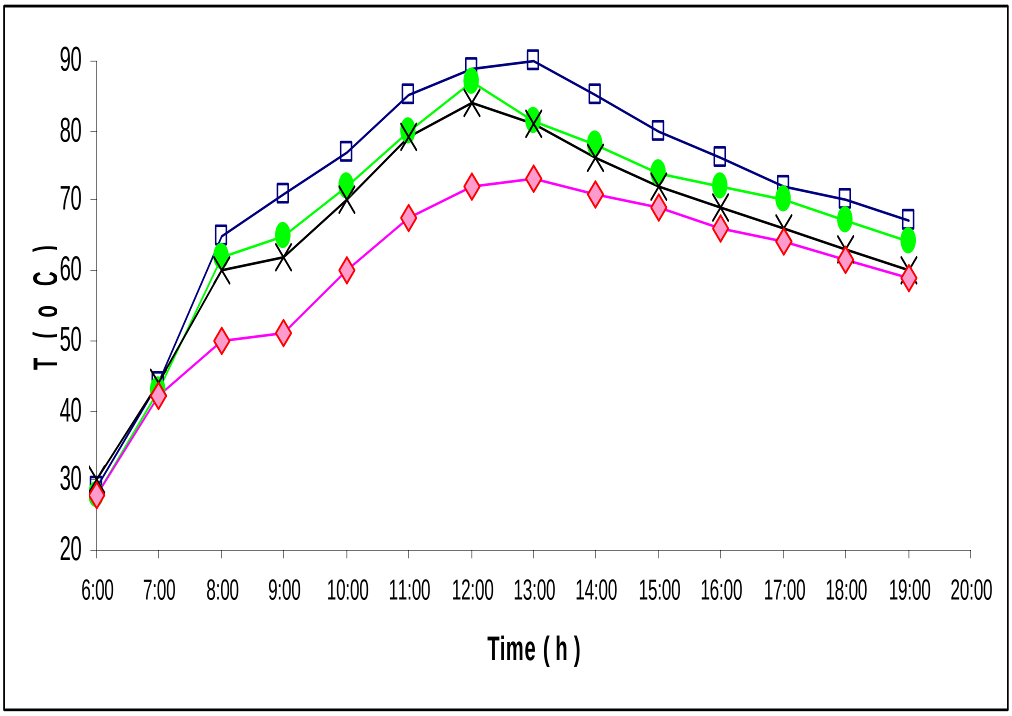

Fig. 2: Response of outlet water temperatures (July, 2010) to the percentage of carbon in the absorbing surface. 20% carbon (solid diamonds), 30% carbon (crosses), 40% carbon (solid circles) and 50% carbon (open squares).

Table 2: Recordings of water temperatures for the four coatings (November, 2010).

% of carbon in paint	20		30		40		50	
Date T°C	03/11/2010 H: 27°C; L: 8.5°C		06/11/2010 H: 27.5°C; L: 5°C		11/11/2010 H: 28°C; L: 9.4°C		14/11/2010 H: 28.5°C; L: 7.5°C	
T°C / Time	**Inlet**	**Outlet**	**Inlet**	**Outlet**	**Inlet**	**Outlet**	**Inlet**	**Outlet**
07:00	10	10	8	8	11	11	9	9
08:00	10	14	9	15	11	17	9	16
09:00	11	19	10	21	11	24	9	26
10:00	12	26	11	32	11	35	10	38
11:00	12	32	11	41	12	45	10	49
12:00	12	40	13	47	13	55	11	60
13:00	13	45	13	54	13	62	11	70
14:00	13	40	13	49	13	55	12	62
15:00	14	36	14	40	14	43	13	53
16:00	14	30	14	32	14	34	13	41
17:00	14	24	14	25	14	28	13	32

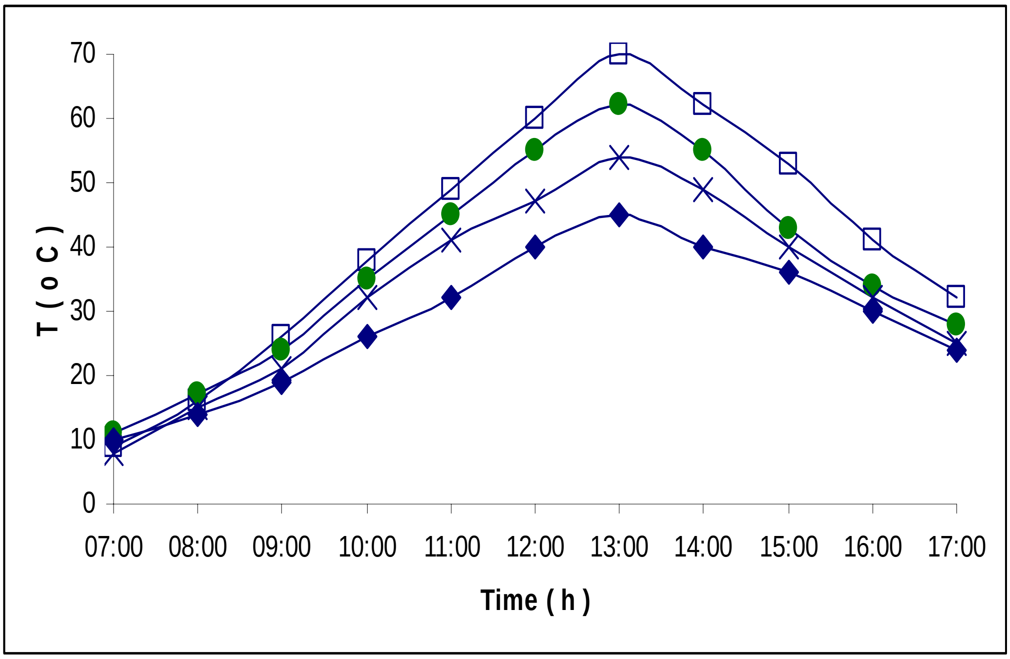

Fig. 3: Response of outlet water temperatures (November, 2010) to the percentage of carbon in the absorbing surface. 20% carbon (solid diamonds), 30% carbon (crosses), 40% carbon (solid circles) and 50% carbon (open squares).

CONCLUSIONS

Carbon in the form of smoke suspension (soot) added to oil-based white paint provided a low cost non-toxic material in the fabrication of a homemade solar water heater. Four different coating layers with carbon percentages 20, 30, 40 and 50 were tested for four days.

Outlet water temperatures showed marked increases with the increase of carbon proportion in the coating layer. The higher the carbon percentage, the thicker the coating layer and therefore the higher the solar absorption. The maximum water temperatures obtained were 90°C in July and 70°C in November when both coating layers had 50% carbon in the mixture. Next morning temperature was well above 45°C during the experiment, during the month of July.

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