

Problems and Hurdles in Designing a Nonglass Solar Vacuum Tube Collector

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ABSTRACT: This paper introduces some preliminary results in its design and fabrication of a non-glass solar vacuum tube collector where the thermosyphon (heat pipe) made of copper is used as a heat transfer device. A series of tests have been performed to assess the effects of the air remaining inside a vacuum tube. Different vacuum pressures inside non-glass evacuated tubes were tested along with their time variations to check any leakage or undesirable(unexpected) physical or chemical developments. Temperatures monitored during the process have revealed interesting but important facts concerning its performance to collect and deliver the sun's energy for water heating.

Keywords: non-glass solar vacuum tube, heat pipe, experimental, performance

1. INTRODUCTION

A costly duty of reducing greenhouse gases has been imposed on developed countries with the official effectuation of the Kyoto Protocol in 2005 and the Emission Trading which enables Annex I parties to acquire the emissions right from other Annex I parties and use them towards meeting their emissions targets set forth by the treaty. This global agreement also boosted the use of renewables for sustainable development, especially solar energy.

Solar energy systems are highly reliable and cost-effective when compared to other renewable energy systems. Of these, solar water heating (SWH) is the most simple, reliable, and prevalent method of harnessing the sun's energy to cater the energy needs of residential and industrial sectors of the society. Simply stated, SWH systems collect

the sun's to heat air or a fluid. Solar collectors are the key component of any SWH systems as they gather the sun's energy, transform its radiation into heat, then transfer that heat to water, working fluid, or air [1].

Flat-plate collectors are the most common solar collector for SWH systems before the arrival of evacuated tube collectors. Evacuated tube collectors can achieve extremely high temperatures (80°C to 200°C), suitable for cooling applications as well as commercial and industrial applications. There are currently two types of evacuated tube collectors: single glass tube and double glass tube. The former consists of a single glass tube which contains a flat or curved aluminium plate attached to a copper heat pipe or water flow pipe. The latter consists of rows of parallel transparent glass tubes, each of which contains an absorber tube (in place of the

absorber plate in a flat-plate collector) covered with a selective coating [2-3].

Evacuated tube collectors introduced above, however, pose some problems as they break rather easily under mechanical stresses. To cope with the inherent weakness of glass material, an experimental investigation has been carried in the present study to make an evacuated tube collector using non-glass materials. The paper introduces some details of the design and fabrication of a non-glass evacuated tube to harness the sun's energy.

2. DESIGN AND FABRICATION

2.1 Design

Development of a non-glass vacuum tube requires the integration of various technologies in mechanical engineering, chemical operations, physics, materials science and so on. It results in a new system technology apart from that of glass vacuum tubes.

Using non-glass materials to make a solar vacuum tube collector may require a special mechanism to prevent air infiltration through invisible pores of the tubular wall. Depending on the texture and wall thickness of the material used as well as the pressure difference between the interior and ambient, the rate of air infiltration changes which subsequently influences the heat exchange between the absorber surface and the ambient. In the present study, a tubular vacuum tube is designed and fabricated using acrylic plastics to investigate various thermal and physical characteristics as aforementioned.

To maintain the vacuum level inside the tube, two different methods are considered. First, a vacuum chamber is connected with vacuum tubes to discharge gas particles from a tube when its vacuum pressure overshoots the preset value. (cf. Fig.1). Second, a layer of gas barrier coating (cf. Fig.2) is considered to slow down the infiltration of air particles from the ambient.

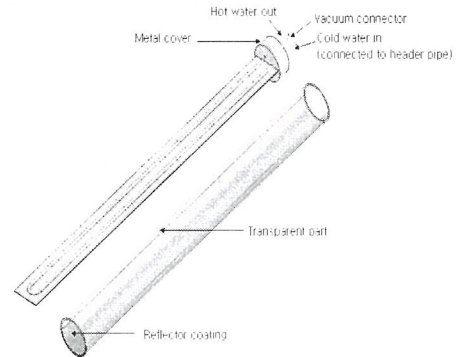


Figure 1: Design concept of a non-glass vacuum tube.

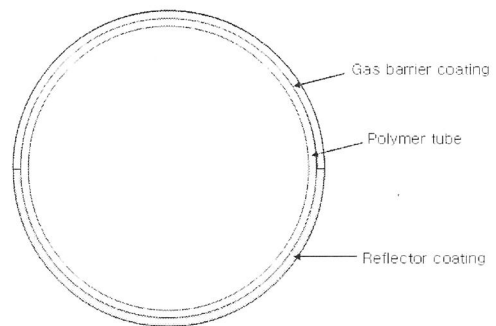


Figure 2 : A cross sectional view of the non-glass vacuum tube with a gas barrier coating.

2.1 Fabrication of a non-glass vacuum tube

The dimensions of a non-glass vacuum tube are determined according to those of a glass vacuum tube in order to perform a comparative investigation regarding its performance. An acrylic plastic pipe(5mm) was used for its fabrication as it was readily available and easy to handle. Both ends of the pipe were completely sealed by using acrylic caps and an adhesive made of chloroform. Fig. 3 shows the major components of a non-glass vacuum tube before they are assembled. In Fig. 4, a

prototype non-glass vacuum tube is given where the absorber plate is treated to have a selective surface.

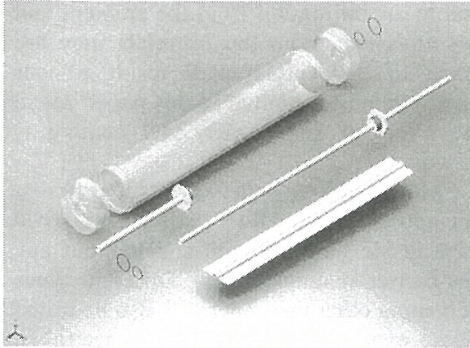


Figure 3: Major components of a non-glass vacuum tube.

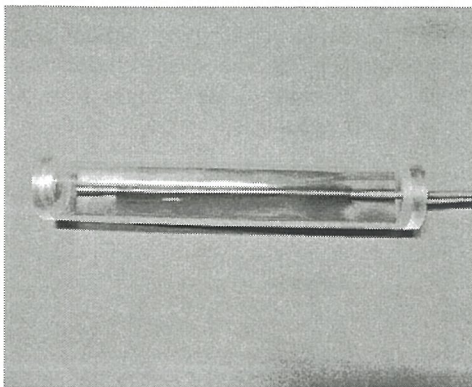


Figure 4: A prototype fabrication of a non-glass vacuum tube.

2.2 Heat pipe

Making a quality heat pipe is one of the most important processes in utilizing solar energy [4-6]. In the present study, a 6mm(OD) hollow copper tube is used with ethyl alcohol as working fluid. Fig. 5 shows the experimental apparatus used to create vacuum for the fabrication of heat pipes and non-glass evacuated tubes. Technical specifications of the apparatus is given in Table I.

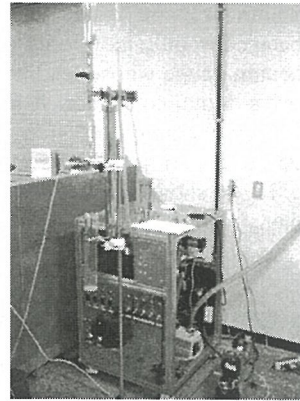


Figure 5: Experimental apparatus used for evacuation.

Table I: Specifications of the apparatus in Fig. 5.

Components	specifications	
Rotary Pump	Model	TRP-12
	Pumping Speed	200l /min
	Ultimate Pressure	5×10^{-4} Torr
	Motor	0.4kW
	Oil Filling	1.1 liter
Dry Bane Pump	Model	YFPV-200S-1
	Volt	200/200
	Hz	50/60
	Phase	1
	Ploes	4
	Output	0.15/2.0kW
	AMPS	1.4/1.6
Compressor	Model	NCP 031-T5
	RPM	1760
	Volt	220
	Hz	60
	AMPS	Max 1.8A
	Working Temp.	40°C
	Thermally Protected Max Pressure	7bars

The vacuum pressure inside the acrylic tube has been constantly monitored with the aid of a vacuum gauge whose readings were displayed by a digital controller. A program has been written by using LabVIEW to save and analyze the experimental data in a real-time mode. Fig. 6 shows a view of the front panel display.

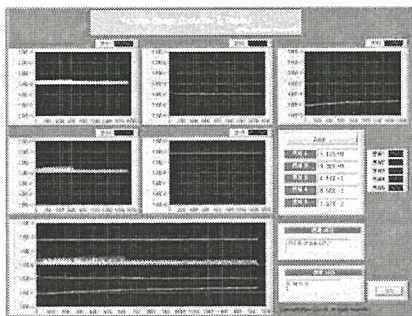


Figure 6: A view of the front panel display (LabVIEW).

2.3 ZnO Coating with a plasmatron

The acrylic tube used to make a solar vacuum tube collector requires a special mechanism to prevent air infiltration through invisible pores of the tubular wall. To delay or suppress the infiltration of air particles from the ambient, a gas barrier coating (ZnO) is tested by using a plasmatron. Plasmatron is a device intended for converting electric power, through an arc discharge, to thermal power of a gas jet. Fig. 7 shows the process of ZnO coating by using a plasmatron.

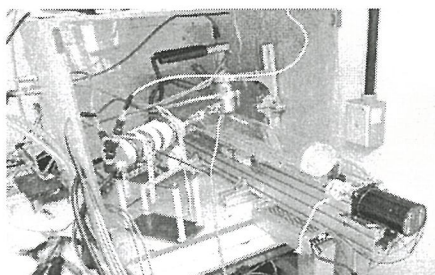


Figure 7: The process of ZnO coating by using a plasmatron.

3. RESULTS AND DISCUSSIONS

The level of vacuum inside acrylic tubes was monitored as it may change with time due to air infiltration from the ambient and gas emissions from the materials they are made of. A preliminary result of our investigation is reported in this paper where the effect of gas barrier ZnO coating is tested.

More work is underway with different vacuum pressures of 10^{-2} , 10^{-1} , 1 and 100 torrs inside the tube with and without any gas barrier coatings(layers). Different types of coating other than ZnO will also be tested. These experiments are especially useful in checking(or detecting) any leakage or undesirable(unexpected) physical or chemical developments inside the vacuum tube.

Fig. 8 shows the time variation of vacuum inside an acrylic tube without any measures to suppress the air infiltration. As shown, the pressure inside changes from 4 torr to 18 torr in 5 days.

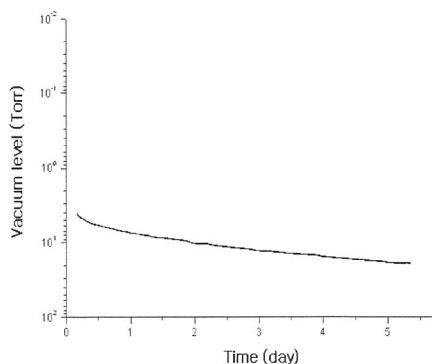


Figure 8: Pressure change inside a vacuum tube (without any gas barrier coating)

When its surface is treated with a gas barrier coating, it is rather difficult for air particles to penetrate through as shown in Fig. 9. The pressure barely changes from 4 torr to 4.2 torr. This is quite contrast to the above case. The effect of a gas barrier coating is undoubtedly clear.

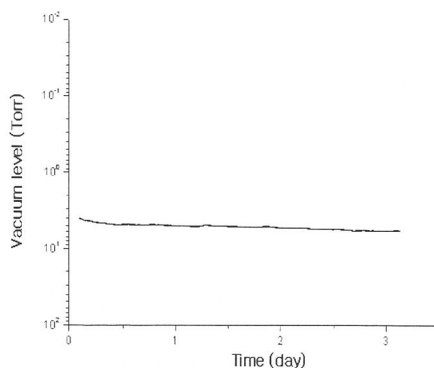


Figure 9: Pressure change inside a vacuum tube (with ZnO gas barrier coating).

Temperature variations monitored for different sets of vacuum tube collector systems have revealed the effect of vacuum as expected. It became more prominent when the system operated in high temperatures.

4. CONCLUSIONS

This paper reports some preliminary results when the solar absorber and heat transfer element(heat pipe) are contained in an evacuated tube made of a non-glass material. Unlike glass evacuated tubes, non-glass solar vacuum tubes generally require some measures to prevent air infiltration through invisible pores of the tubular wall. , The gas barrier coating(ZnO) prepared by using a plasmatron has shown a drastic improvement in suppressing(blocking) air infiltration. More study in underway to assess the effects of different types of gas barriers applicable on the surface of non-glass materials

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