EFFECT OF INTERNAL HEATING ON THERMAL PERFORMANCE OF HYBRID PHOTOVOLTAIC & THERMAL (PV/T) COLLECTOR

Erkata Yandri[1], Naoto Hagino[1], Haruhiko Imada[1], Kazutaka Itako[1], Hiro Yoshida[1]

[1] Dept. Vehicle system Engineering, Kanagawa Institute of Technology, Atsugi (Japan)

1. Introduction

The idea of combining PV cells with thermal collector, which is the PV/T collector, has been around since the early 1960s. Until now, principal aspects of PV/T have been discussed in various scientific papers. Most of them concern experiments conducted outdoor. In order to succeed in implementation, however, there is still some work to be done for PV/T collectors. That is the basic mechanism of interaction between the PV cell and the thermal collector in the PV/T system does not seem to be well understood. In our previous outdoor tests [Yandri et al, 2010], thermal efficiency of PV/T system differed depending on the operation mode, i.e., PV/T-mode and T-mode. The thermal efficiency η_{th} as defined by Chow, et al [2007]: $\eta_{th} = \alpha - U \frac{(T_{out} - T_a)}{I_t}$, where α , U , T_{out} , T_a , and I_t are the loss coefficients, the water temperature at the collector exit, ambient temperature, and the total irradiation onto the PV/T system in a period monitored, respectively. According to the definition of η_{th} , α and $U(T_{out} - T_a)$ terms are considered to be affected by the internal heating of PV cell. When there is a heating in the PV module, the apparent incident energy increases. This means that α becomes larger. In addition, $U(T_{out} - T_a)$ terms is prone to be larger due to apparent increase in T_{out} .

Within the authors knowledge, no studies have specifically addressed on the topic above mentioned. Some previous studies give us clues. Sandness and Rekstad [2002] studied a PV/T collector using black plastic heat absorber and wall to wall channel filled with ceramic granulates. The heat carrier fluid was water and it was circulated at a single flow rate. Within the range of reduced temperatures from 0.0 to 0.016 m^2C/W, the thermal efficiency of PV/T-mode was 10% lower than that of T-mode. Ito et al [2005] studied the performance of air collectors of three types; collector type I consisted of two PV modules connected in series under a glass cover, collector type II consisted of 10 amorphous silicon PV modules. The modules were connected in series in the space between a glass cover and a bottom plate at 1^o tilted angle. The collector type III was a flat plate without PV modules. For the collector Type I, within the range of reduced temperatures from 0 to 0.02 m^2K/W, the thermal efficiency of PV/T-mode was slightly higher than that of T-mode. Chow T. et al [2007] developed a prototype PV/T collector thermosyphon system made of aluminum alloy flat box. They compared performances of the closed-circuit (PV/T-mode) and the open circuit (T-mode) at 20^o and 38^o tilted angle. For the reduced temperatures from -0.5 to 2 m^2K/W, their results showed that the thermal efficiency for the closed-circuit is lower than that of the open circuit at incident angle considered. For the same operation mode, the case of 38^o inclination, gave higher thermal efficiency than the case of 20^o inclination.

Table 1. Summary of previous studies

Items	Sandnes and Rekstad [2002]	Ito et al [2005]	Chow et al [2007]
Absorber material	Plastic thermal absorber	Steel thermal absorber	Plastic thermal absorber
Solar cell type	Single crystal	Amorphous	Single crystal
System	Active	Active	Thermosyphon
Working fluid	Water	Air	Water
Flow rate	Single	Single	Natural
Inlet temperature	Single	Single	Natural
Thermal efficiency	PV/T-mode < T-mode in the range of reduced temperature (m^2C/W): $0<(T_i-T_a)/I<0.016$ (cross trend each other)	PV/T-mode > T-mode in the range of reduced temperature (m^2K/W): $0<(T_i-T_a)/I<0.016$ (parallel trend each other)	PV/T-mode < T-mode in the range of reduced temperature (m^2K/W): $-0.5<(T_i-T_a)/I<2.0$ (cross trend each other)

Summary of the previous study is given in Table 1. We can see that the thermal efficiencies of PV/T-mode and T-mode vary depending on the system configurations. An effort to elucidate behaviors of both modes still seems to be necessary. The purpose of the present study is to understand in more detail the behavior of the PV/T collector. For this purpose, a new testing facility was constructed for the laboratory experiment.

2. Experimental Set up

In the present system, PV module faces downwards to the halogen lamps placed in the bottom. The module is backed by the cooling copper pipe. Such structure enables us to monitor the temperature field in the back surface of the PV module.

Figure 1 shows the whole system and the main components. In Fig.1(a) is shown the layered structured of PV/T collector. A thermal absorber copper plate of 0.3 mm thick is backed by the mono-crystalline type of PV cell shown in Fig.1(b). The copper pipe of 4mm inner diameter is attached on the copper plate. Here we used two types of T absorber. Type I is constructed by attaching the Φi 4mm copper pipe onto δ0.3mm thick copper absorber plate (Fig.1(c)). Type II is constructed by combining the polyvinyl chloride (PVC) absorber plate of 8 mm thick onto δ0.3mm thick copper absorber plate. On the PVC plate aan open channel with 5 mm width and 5 mm depth is machined. A long the channel sealing rubber strings were installed. The PVC plate and the copper was glued to combined (Fig.1(d)). The outer dimension of PV/T collector is 380 x 350 x 35 mm and the effective area for collecting irradiation is 0.091 m^2 and 0.115 m^2 for PV and T, respectively. Whole view of the solar simulator is shown in Fig.1(e). The simulator has 16 Halogen bulbs with 50 W each as the light source [Ilie et al, 1996]. It can give radiation more than 1.000 W/m^2. Frame size of the simulator is 1,000(h) x 430(w) x 395(d) mm^3. The main advantage using this equipment is the high reproducibility.

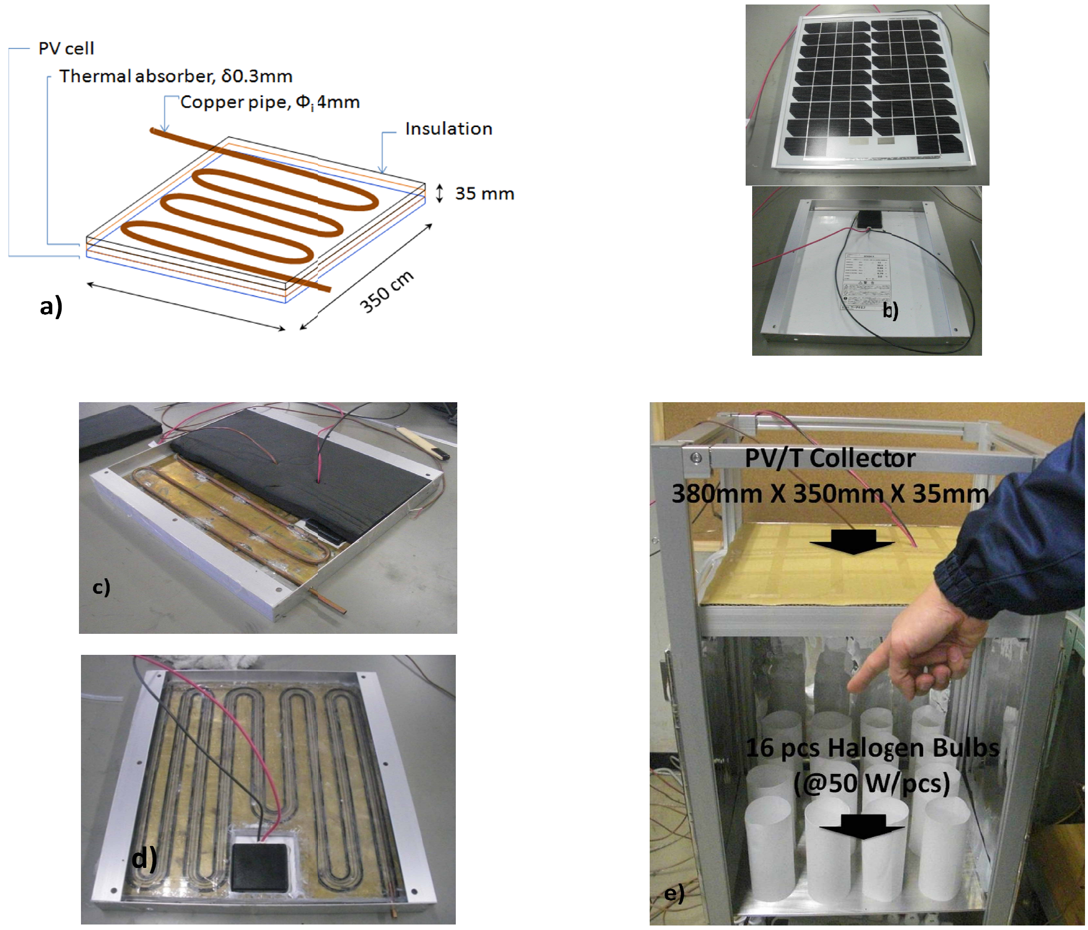

Fig.1. Equipments, a). PV/T collector structure, b). Front and back side of PV collector, c). Type I PV/T collector, d). Type II PV/T collector, e). Solar simulator with installed PV/T collector

For the thermal data, we put the thermocouple in the inlet position of water (T_{in}), outlet position of water (T_{out}), in the middle position of thermal (T) absorber (T_{pv}), then the indoor (T_{room}) and the outdoor temperatures (T_a). For electrical data, we apply a variable resistor in order to be able to measure both closed circuit voltage (V) and open circuit (V_{oc}), also current (A). The maximum power point is achieved for 30 Ω.

The analog output of PV was converted into digital using a analog to digital converter e-Front runners WE1C, both with the thermal outputs sent to GRAPHTEC midi LOGGER GL 220, which has 10 channels.

We apply 2 different mass flow rate of water, m, ie: 200 and 300 g/min and 3 different solar radiation, I , ie. 1000, 700, and 400 W/m^2.

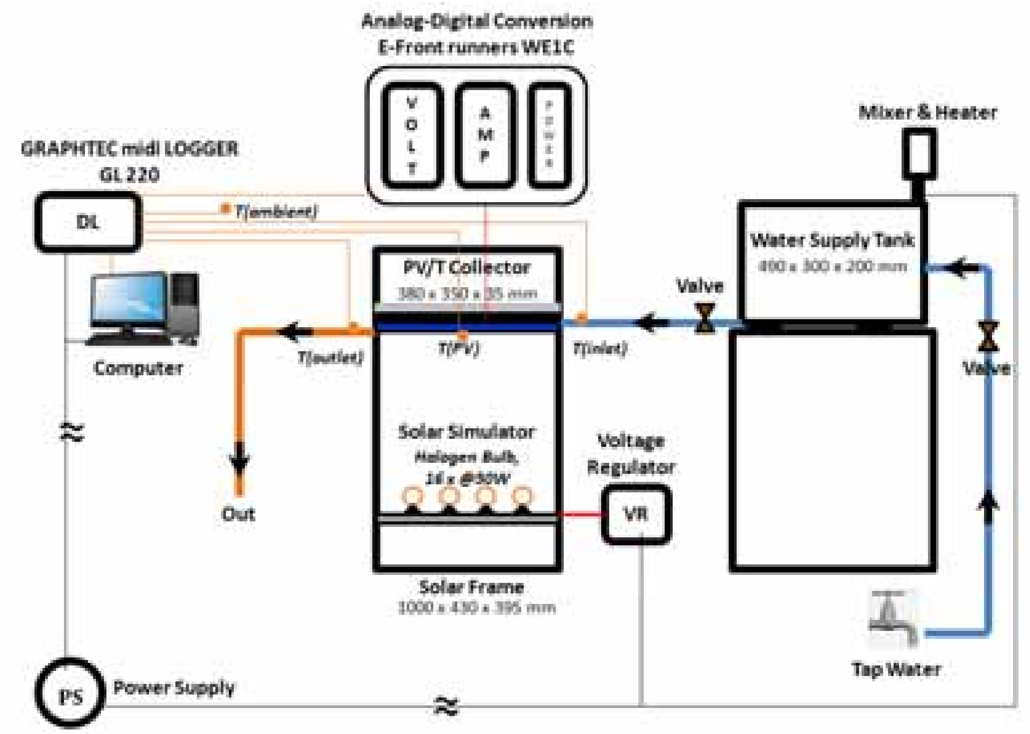

Fig.2. Experimental setup and measurement position

3. Result and Discussion

Fig.3 explains the differences of PV surface temperature, T_{pv} , for Type I and Type II collector. It should be noted that, for collectors Type II, the experiment conducted a view days with fairly extreme weather change, so that the room temperature becomes less equal. For the mass flow rate 200 g/min (Fig.3a), T_{pv} for Type I collector shows instability compared with the Type II collector. For mass flow rate 300 g/min (Fig.3b), T_{pv} is more stable for both type I and II collector. For the same flow rate, T_{pv} for the Type II collector is lower than Type I collector. However, T_{pv} for the mass flow rate of 200 g/min remained greater than 300 g/min for both types of collector. In this case, the T_{pv} for the T-mode is slightly higher than T_{pv} for PV/T-mode, however, the difference is greater for Type I collector, especially for solar radiation 1000 and 700W/m^2.

The effect of T_{pv} difference for two types collectors can be explained with temperature difference, ΔT , between the water outlet to the inlet water to and from the collector, as shown in Fig.4. For mass flow rate 200 g/min (Fig. 4.a) and 300 g/min (Fig.4b), ΔT for Type II collector is larger than the Type I collector. Especially for Type I collector, the only small different ΔT between PV/T-mode and T-mode happened for 1000 W/m^2 solar radiation. While, for the both mass flow rate and also for the 3 solar radiations, ΔT for Type II collector is relatively similar with small difference.

As seen in Fig.5, it looks no significant differences in the electrical power output between the two Type I and Type II collector. However, they still make little difference to electrical power output of between 200 g/min with 300 g/min, especially for 1000 W/m^2.

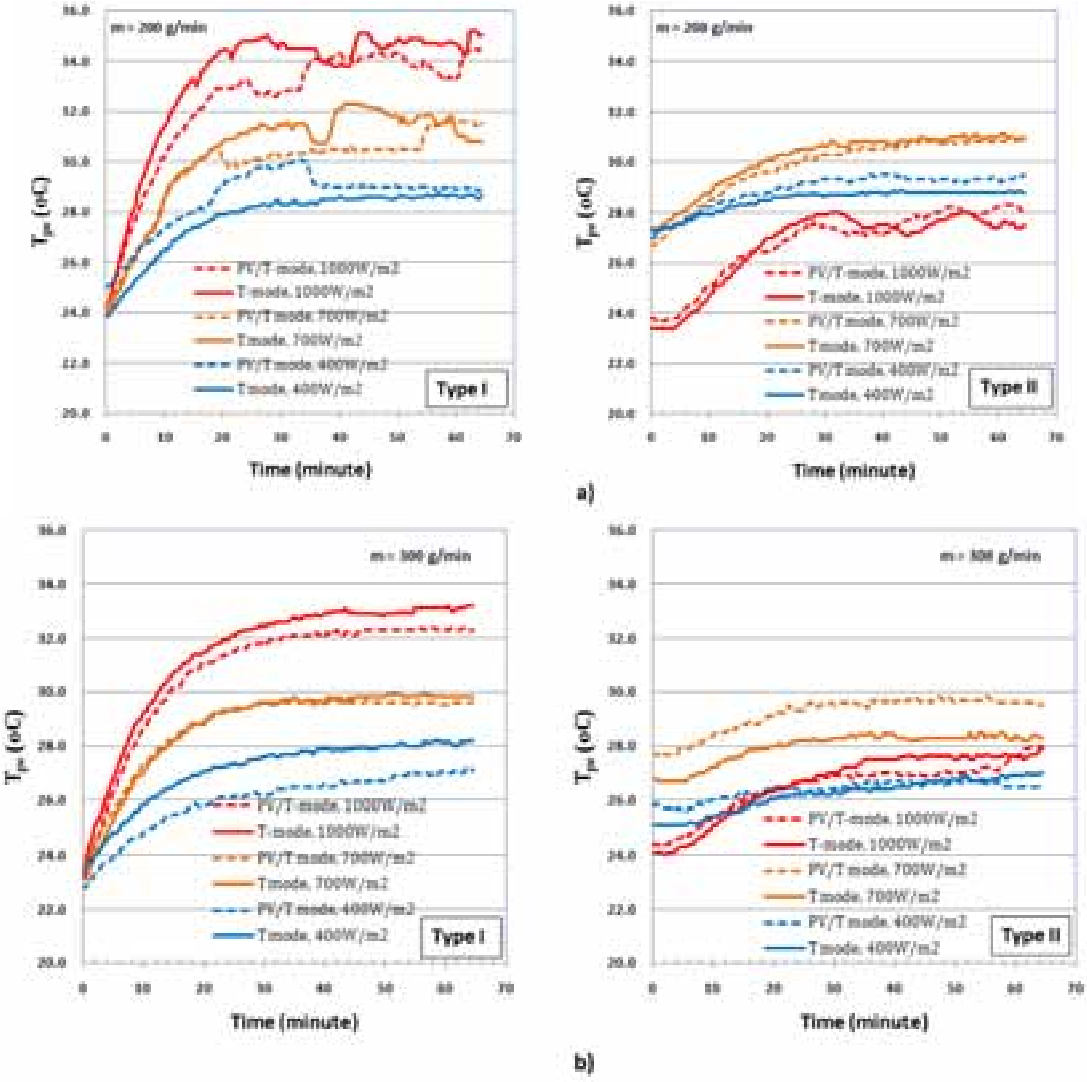

Fig. 3. Comparing PV surface temperature (T_{pv}), a). 200 g/min, b). 300 g/min

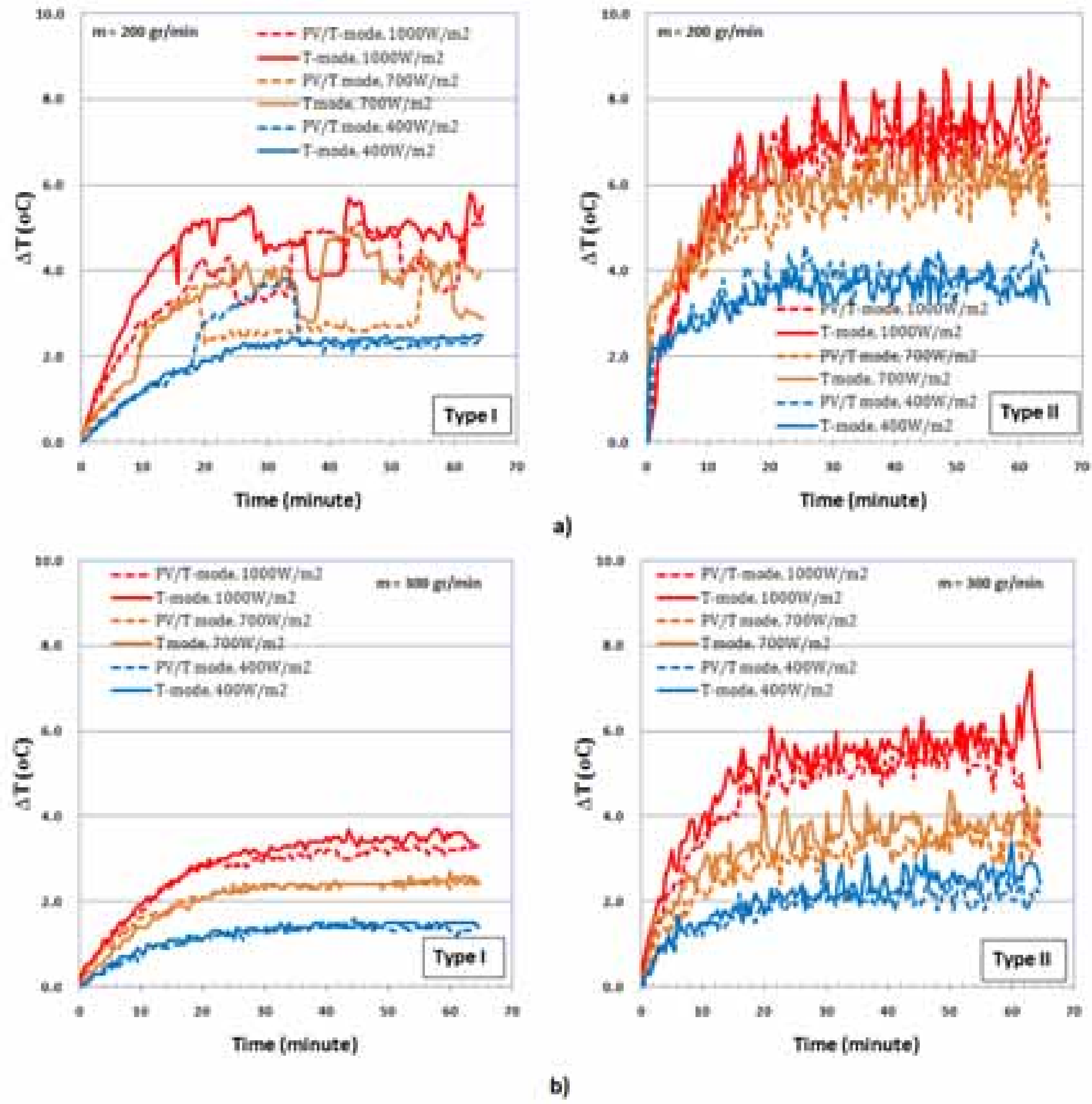

Fig. 4. Comparing inlet and outlet temperature different (ΔT), a). 200 g/min, b). 300 g/min

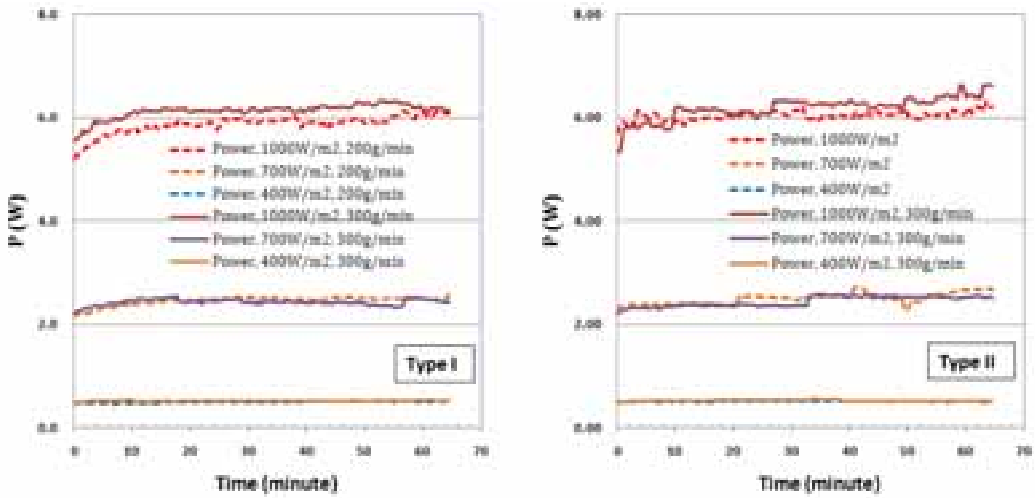

Fig. 5. Comparing the electrical output power

4. Conclusion

So far, the experiment with two type of collector, two different flow rate and also 3 different solar radiation, shows the difference behaviour between the PV/T and T-mode. Comparing both collector, the Type I collector is more sensitive to change in parameters than the Type II collector.

5. Acknowledgment

This study was supported by the “High-Tech Research Centre Project for Private Universities: Matching fund subsidy from MEXT, 2007-2011.

6. References

Yandri, E., Yoshida, H., Miura, N., Fujisawa, T., Yoshinaga, M., 2010. Performance of photovoltaic and thermal (PV/T) collector with single and double generation. Renewable Energy 2010, Yokohama, paper #P-Th-7

Chow T.T., Ji J., and He W., 2007. Photovoltaic-thermal collector system for domestic application, Journal of Solar Energy Engineering, Vol. 129 / 205

Sandnes B., and Rekstad J., 2002. A photovoltaic/thermal with a polymer absorber plate, experimental study and analytical model, *Solar Energy* **Vol. 72, No. 1**, pp. 63-73

Ito S., Sato K., and Miura N., 2005.Performance of photovoltaic and thermal hybrid air collectors, *Proceedings of ISES Solar Word Congress*, Orlando, USA, Paper No. 1349

Ilie, C., Olariu, N., Oros C., 1996. Indoor PV Devices Testing. IEEE 0-7803-3223-7/96