Proc. Estonian Acad. Sci. Engng., 1999, **5**, 1, 87–89
https://doi.org/10.3176/eng.1999.1.07

COMPARISON OF SINGLE-PASS AND MULTI-PASS SOLAR HOT WATER SYSTEMS

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Received 19 August 1998

Abstract. Single-pass and multi-pass versions of a solar domestic hot water system are compared for some conventional flat-plate collectors. It is shown that the single-pass version has higher productivity and is to be preferred.

Key words: solar hot water system, specific yield, single- and multi-pass systems.

A solar domestic hot water system [1] (Fig. 1) can be designed as a single- or multi-pass one. The flow rate for a single-pass system is assured by control of the circulation pump or by free thermosiphon circulation in the system with high hydraulic head in such a way that the heat carrier (water) is heated to the final temperature 60 °C immediately. In the multi-pass system the flow rate is higher and the water is heated for some degrees only, for instance for 10 K. In order to reach the required final temperature of 60 °C, water has to circulate the system several (in our example five) times. A benefit of the first modification is the possibility to produce water with required temperature, but in small quantities. Another benefit of the first modification, that has not been highlighted in the literature, is higher specific yield from the same solar collector area.

The simulation has been made for an Estonian statistical summer day with solar irradiation $I(h)$ and ambient temperature model $T_a(h)$, described in [2]. The collector output temperature $T_o(h) = 60\,°C$ has been considered to be constant and the storage tank to be stratified, approximated by a plug-flow model. It means that hot water fills the storage tank from above, and, separated by a temperature step, cold water leaves the tank from below.

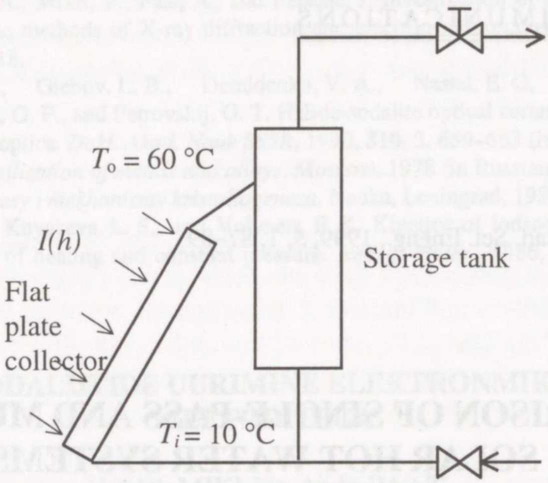

Fig. 1. Simplified layout of a solar domestic hot water system.

How $T_o(h) = 60\,°C = \text{const}$ is provided in the conditions of changing $I(h)$, is outside the scope of the present work. One possibility is automatic control of the circulation pump; also the thermosiphon system can keep nearly constant output temperature. The analysis below is made considering the heat transfer coefficient from the collector plate to the heat carrier to be constant.

Numerical simulation is carried out for three hypothetical flat plate collectors (FPC), each with a realistic combination of its parameters, with the EXCEL-5 worksheet. It is assumed that FPC1 is an "inexpensive" collector with moderate thermal insulation; FPC2 is an "expensive" unit with advanced thermal insulation, while FPC0 is a "conventional" collector. In the simulation model the collectors are tilted for 45° and oriented to south. The performance of a collector is described by the initial value of its efficiency η_0 and the coefficient of overall thermal losses U_L:

1) FPC1: $\eta_0 = 0.85$, $U_L = 0.01$ kWm^{-2}K^{-1}
2) FPC0: $\eta_0 = 0.75$, $U_L = 0.007$ kWm^{-2}K^{-1}
3) FPC2: $\eta_0 = 0.65$, $U_L = 0.004$ kWm^{-2}K^{-1}

The operation period of the system is from 08.00 till 16.00 (when the angle between the beam radiation and the normal of the collector surface remains below 60°), and the time is divided into intervals of five minutes. In simulation, the water mass heated during each interval for $\Delta T \in \{50,10\text{ K}\}$ is calculated. In the single-pass system the input water temperature is constant $T_i(h) = 10$ºC, but in the multi-pass system it is increased with a step of 10 K for each following pass, $T_i(h) \in \{10, 20, 30, 40, 50\text{ºC}\}$. The input temperature changes each time when 1/5 of the whole daily water mass has been warmed up by 10 K. Thus, the simulation model for the multi-pass system is iterative.

Table 1. Calculated daily energy, kWh/m^2

Collector	FPC1	FPC0	FPC2
Multi-pass (m-p) $\Delta T = 10$ K	1.36	1.66	1.91
Single-pass (s-p) $\Delta T = 50$ K	1.94	1.97	2.01
Ratio m-p vs s-p	0.70	0.84	0.95

Results of the simulation are presented in Table 1, from where follows:

1) for all FPCs, the single-pass performance provides higher yield;

2) the difference in the productivity decreases when insulation of the FPC is improved;

3) multi-pass system is more sensitive to the FPC quality.

It may be recommended to design home-made solar collectors single-pass as it is difficult to predict their quality. Up to now it is not clear if an artificial resistance (valve) in the hydraulic loop will warrant equal to serpentine piping limitation of the flow rate.

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ÜHE- JA MITMELÄBIVOOLSE HELIO-SOOJAVEESÜSTEEMI VÕRDLUS

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On võrreldud ühe- ja mitmeläbivoolse heliosüsteemi tootlikkust tavalise plaatkollektori puhul ja näidatud, et süsteemi üheläbivoolne režiim on tootlikum.