TECHNICAL SCIENCES
Abbrev.: Techn. Sc., No 13, Y 2010

DOI 10.2478/v10022-010-0016-5

EXPERIMENTAL SOLAR INSTALLATION WITH A SELF-ACTING CIRCULATION PUMP, POWERED BY LOCAL HEAT

Jurij Dobriański, Michał Duda

Chair of Electrics and Power Enginering
University of Warmia and Mazury in Olsztyn

K e y w o r d s: solar energy, solar installation, circulation pump.

A b s t r a c t

The paper presents a diagram of an experimental solar installation with a self-acting circulation pump powered by local heat. The installation is a measuring stand which enables an assessment of this type of pumping device in terms of its practical operational efficiency. A self-acting circulation pump has been successfully tested in a laboratory.

EKSPERYMENTALNA INSTALACJA SŁONECZNA Z SAMOCZYNNĄ POMPĄ CYRKULACYJNĄ NAPĘDZANĄ CIEPŁEM LOKALNYM

Jurij Dobriański, Michał Duda

Katedra Elektrotechniki i Energetyki
Uniwersytet Warmińsko Mazurski w Olsztynie

S ł o w a k l u c z o w e: energia słoneczna, instalacja słoneczna, pompa cyrkulacyjna.

A b s t r a k t

W pracy przedstawiono schemat eksperymentalnej instalacji słonecznej z samoczynną pompą cyrkulacyjną napędzaną ciepłem lokalnym. Instalacja ta jest stanowiskiem badawczym pozwalającym na ocenę jakości tego typu urządzenia pompującego pod względem jego praktycznej efektywności eksploatacyjnej. Samoczynną pompę cyrkulacyjną pomyślnie sprawdzono w warunkach laboratoryjnych.

Introduction

Solar systems for water heating have been used in various configurations and can operate under several systems of control (CHOCHOWSKI, CZEKALSKI 1999). The simplest and the cheapest installation for heating water is a gravitational system, also known as thermosiphon. The flow of the heating agent in such installations takes place spontaneously owing to convection movements of hot mass (LEWANDOWSKI 2006). Such circulation is also self-controlled, i.e. the intensity of the agent movement depends on the temperature difference between the upper parts of the collectors and the lower part of the tank. The absence of a circulation pump and of automatic control are undoubtedly the advantage of this solution. However, to operate effectively, particular elements of the system have to be positioned appropriately. The tank should be situated above the upper edge of the collectors, which is impractical for roof collectors. Additional load on the roof is also a problem. It is an advantage of the solution that by placing the collectors on the roof, use is made of unshaded, unused space. The inclination angle of roofs frequently makes it possible to mount a collector directly on the roof. In such cases, installations are applied with active (i.e. forced) circulation of the agent in the system of solar collectors – accumulation tank. The agent circulation is usually started by a one-phase glandless pump, whose work is controlled by a differential temperature regulator.

In areas with no electricity supply, it is possible to power the pump by energy obtained in photo-voltaic cells. Such a system is self-controlled to a certain extent, but the cost of the cell purchase is an additional expense. This can be solved by applying a circulation pump powered by part of the heat, supplied to the system by the solar collector (DOBRIAŃSKI, WESOŁOWSKI 2003).

Materials and Methods

A self-acting circulation pump is known from a Ukrainian patent no. 15361A (DOBRIAŃSKI 1997). It is built as a closed loop, filled partly with a liquid working agent. The device operates in cycles. In the upper part of the downward circulation conduit, the liquid heat carrier is heated, which results in an increase in its saturated vapour pressure, which in turn pushes it downwards. The agent cools down in the lower part of the loop and flows to the upward conduit. This is a result of the pressure difference in the circulation conduits. After the specified pressure difference has been achieved, the passage in the upper part of the loop opens and the vapour from the upper part of the downward conduit passes to the upward conduit. At the same time, the excess of cooled-down liquid from the upward conduit pours down gravitationally through the intermediate conduit to the upper part of the cold conduit. There are several varieties of devices which transfer heat in this manner. In general, all the solutions have the form of a closed loop with an upward and downward conduit. The pump used in this system is based on patent PL 195 490 B1 (DOBRIAŃSKI, FIEDUCIK 2000). The device consists of two vessels (cold and hot), one placed above the other. The vessels are connected with an intermediate conduit, through which liquid pours down after a cycle of operation is finished, and a hydraulic valve which controls the entire process. The work in the circulation is performed by saturated pressure of the working agent.

Solar installation – location and structure

A solar installation for operation with a self-acting circulation pump has been constructed at the Faculty of Technical Sciences of the University of Warmia and Mazury in Olsztyn. It is an active system with a liquid collector, area F = 2.0 m^2, fixed to the roof of the university building (Fig. 1). The collector is connected with a 300 L water heater, installed in the building basement. Two manners of forcing the solar liquid flow have been provided for. In the first one, the circulation is forced by an electric pump. It is a traditional

Fig. 1. Experimental solar installation on the roof of building

solution which requires the use of controlling systems. The system has been adapted for connection of another circulation forcing device – a self-acting circulation pump. The diagram of connecting such a pump is shown in Fig. 2.

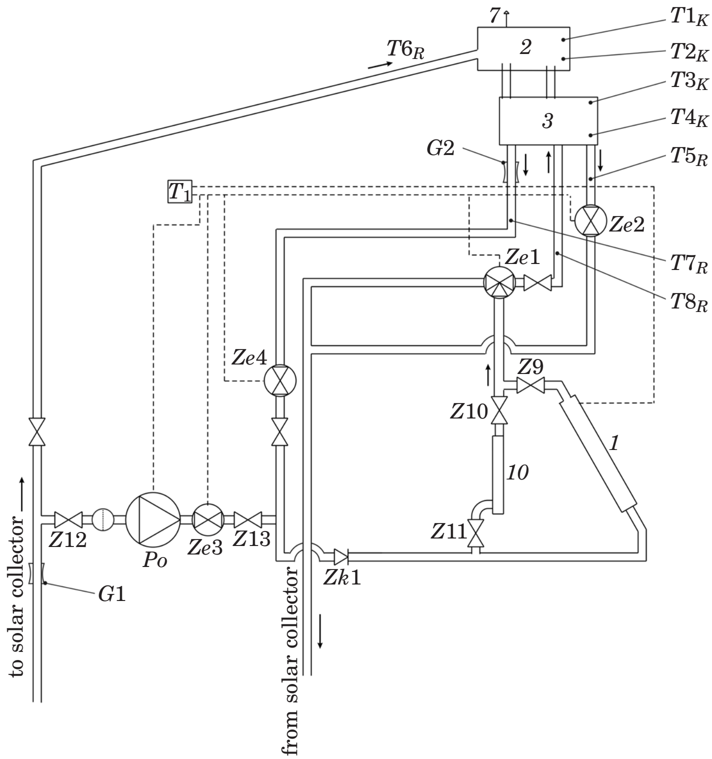

Fig. 2. Diagram of connection of self-acting circulation pump with solar installation: *1* – collector, *2,3* – vessels of the self-acting circulation pump; *T* – temperature sensors, *G* – flow sensor, *Z* – valve, *Po* – electrical circulating pump

Control and measurement system

Parameter of the system with a self-acting circulation pump can be checked owing to its cooperation with a control and measurement system. Empirical data can be obtained thanks to detailed measurements of the system under study. The measuring devices perform real-time measurements of the following parameters:

– temperature of the solar liquid at various points of the system;
– stream of the liquid flow;

– pressure in the self-acting circulation pump circuit.

The system operation parameter values will be collected and sent to the central unit through a module with analogue and 4-20 mA current inputs. Operation of all the devices of the system can be visualised as a graphic mask, shown in Fig. 2. It displays changes of all the measured parameters. The mask contains descriptions of the sensors which comprise the installation's measuring system:

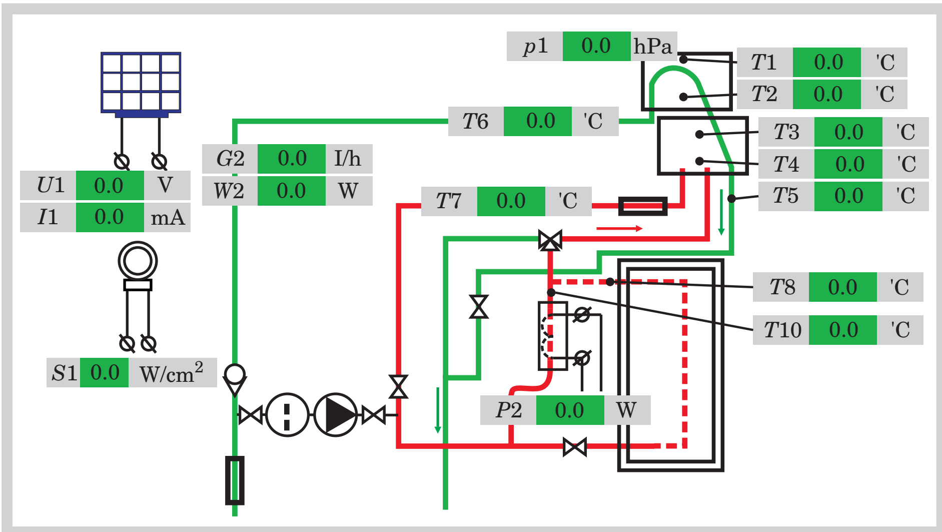

Fig. 3. Display of measured magnitudes of test solar installation with self-acting circulation pump

The method of laboratory tests of the self-acting pump

The self-acting pump was tested in a laboratory. The collector in the tested model was replaced with a 300 W electric heater with a thermoadjuster; water was used as the heat carrier. The pump forced the medium through a copper heat exchanger, placed in a 7 L insulated tank, filled with water. No heat exchange in the tank took place during the experiment. During the device operation, temperature measurements were performed in the downward and upward conduits as well as in the tank. The sensor deployment places are shown in Fig. 4.

Three calibrated resistance thermal sensors̀ Cu 100' with an accuracy of +/-0,5°C connected to visualization and data acquisition system were used to measure the temperature of water. The temperature measurements were made with the frequency of 0.1 Hz. The experiment was carried out successively for two different temperature values of source heat (35°C and 60°C) set with an accuracy of +/-5°C. An algorithm written in MS Excel for measurement noise reduction in periodical processes was used in empirical data processing (DOBRIAŃSKI, DUDA 2007).

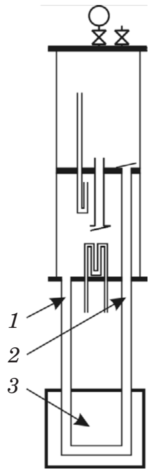

Fig. 4. Scheme of sensor layout: *1* – pump's supply conduit, *2* – pump's return tube, *3* – heat exchanger in tank-accumulator

Results

The experiment results are shown in Figs. 5 and 6. In the first case, the system was started when the liquid temperature was 17°C and the upper limit of the heat source temperature was established as 35°C. The system operation

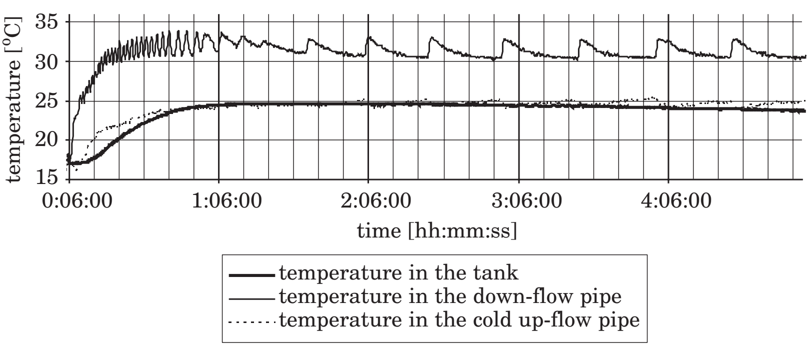

Fig. 5. Temperature diagram for different measurement points of laboratory model at heater temperature 35°C

started upon switching on the heater. The initial cycles of the medium pumping were intense, which resulted in a temperature increase at every measurement point. Subsequently, the temperature in the tank and in the upward conduit settled at 25°C, and in the downward conduit it fluctuated within the range from 31°C to 33°C. At the same time, a noticeable increase in the length of the pumping cycles was recorded. The other diagram shows the system operation at an established initial heater temperature of 60°C. As in the previous case, the temperature in each measurement point rose initially until it settled at about 47°C for the upward conduit and the tank and about 55°C for the downward conduit.

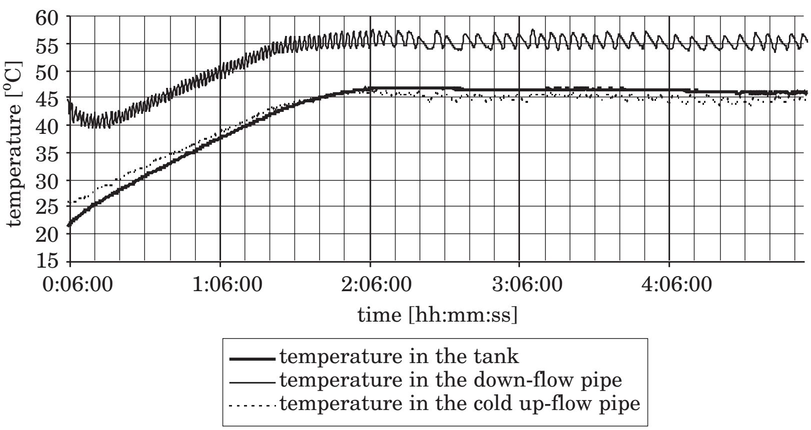

Fig. 6. Temperature diagram for different measurement points of laboratory model at heater temperature 60°C

Summary

The experiment results confirmed the periodical character of the device operation, which starts pumping the medium upon switching on the heat source. The pumping intensity depends on the source power and on the temperature difference between the source and the hot water tank. In this case, the system can be regarded as self-controlling. Thanks to successful tests of the laboratory model it was possible to build the solar installation discussed here. Subsequent tests will be related to the checking of the installation with the use of the self-acting circulation pump in the installation.

Accepted for print 19.02.2010

Reference

CHOCHOWSKI A., CZEKALSKI D. 1999. *Słoneczne instalacje grzewcze.* Wyd. COIB. Warszawa.

DOBRIAŃSKI J., DUDA M. 2007. *An algorithm for handling experimental data of periodical processes with Microsoft Excel.* Technical Siences, 10.

DOBRIANSKI YU. P. 1997. *Sposib teploperedachi i prystriy do yego zdiysnienia*. Patent of Ukraine. UA 15361 A; MPK F 28 D 25/00.

DOBRIAŃSKI J., WESOŁOWSKI M. 2003. *Ocena techniczno-ekonomiczna zastosowania samoczynnego obiegu cyrkulacyjnego w słonecznej instalacji grzewczej*. Problemy Inżynierii Rolniczej, 3: 71–78.

DOBRIAŃSKI J., FIEDUCIK J. 2000. *Urządzenie do przekazywania ciepła w kierunku przeciwnym do konwekcji naturalnej.* Patent PL 195490 B1.

LEWANDOWSKI W. 2006. *Proekologiczne odnawialne źródła energii*. WNT, Warszawa.