



ISSN 1314-2550

Топлотехника

5

**НАЦИОНАЛНО НАУЧНО ТЕХНИЧЕСКО ДРУЖЕСТВО
(НАЦИОНАЛЕН КОМИТЕТ) ПО ТММ**

ТОПЛОТЕХНИКА

ГОДИНА 4, КНИГА 2, 2013

ИЗДАТЕЛСТВО НА ТЕХНИЧЕСКИ УНИВЕРСИТЕТ - ВАРНА

EXPERIMENTAL INSTALLATION FOR INVESTIGATION OF LATENT HEAT ACCUMULATOR AS A PART OF HYBRID SYSTEM FOR AIR-CONDITIONING

Anastas STOYANOV^a, Aleksandar GEORGIEV^a, Rumen POPOV^b

^aDepartment of Mechanics, Technical University of Sofia - Branch Plovdiv,
25 Tsanko Diustabanov St., 4000 Plovdiv, Bulgaria

^bDepartment of Optoelectronics and Laser Engineering, Technical University of Sofia - Branch Plovdiv,
25 Tsanko Diustabanov St., 4000 Plovdiv, Bulgaria

Abstract

An experimental installation consisting of latent thermal storage charged by solar energy was constructed and implemented. It is used to explore its applicability as an element of a hybrid air conditioning system. The system is built in the Laboratory of "Renewable Energy Sources" at the Technical University of Sofia, branch Plovdiv. The system consists of latent thermal storage, solar collectors, solar water heater and circulating pumps.

Key words

Phase Change Material system, experimental installation, latent heat.

Introduction

The solar thermal systems convert solar radiation into heat energy. The produced heat can be stored during the day and used during the night increasing system effectiveness [Cabeza et al. 2006]. The usage of latent accumulator is now one of the most attractive ways to store latent heat at a constant temperature. It is possible, thanks to the melting temperature of the Phase Change Materials (PCM) [Georgiev et al. 2011].

There is a statistics that systems with incorporated latent heat accumulators are 2.59 to 3.45 times more efficient than installations with heat sensitive accumulators [Esen, M., 2000].

Construction of the installation

An experimental system is created at the Technical University of Sofia, branch Plovdiv. It is used to study a latent heat accumulator charged by solar energy, which is a part of developed hybrid system for air conditioning. Various paraffins will be used in the latent heat accumulator as PCM. Eight species of paraffins were selected as the most appropriate (in price and technical parameters). They were purchased and tested. As a result of the experiments 3 types of paraffins (with the highest latent heat:) were selected - E46, E53 and ECP [Georgiev, 2011].

Some containers are situated in the storage. They contain the different types of paraffin (there

is an opportunity to change the paraffins and the containers).

The scheme of the designed and built system is shown in Fig.1. Here are the most important installation elements:

➤ **Solar collectors:** three pieces of the type "New Energy System" Ltd. are available. Here are the technical data - Model: "Select Classic", (collector area of 2,15 m²), with a transparent coating of prismatic tempered glass and a thickness of 4,2 mm (8 pieces heat-absorbing pipes). The absorber is covered with TINOX, the surface of each collector has an area of 1,94 m². The volume of the heat transfer medium in the collector is 1,6 l. Its maximum flow rate is 50 l/m².h. The maximum working pressure of the collector is 0,6 MPa. Stone wool with a thickness of $\delta=40$ mm is used on the back of the collector.

➤ **Solar Water Heater with two coils:** it is of the type "SB" on "New Energy System" Ltd., model V/S2 tank with a capacity of 200 l. The volume of the lower coil is 5,55 l and the heat exchange surface is 0,9 m². The upper coil has a volume of 3,7 l and has a heat exchange surface of 0,6 m². The working pressure in the tank is 10 bar and the pressure in the coil is 16 bar. The maximum temperatures of the fluid inside the tank and the coils is 95°C and 110°C correspondingly.

The tank is insulated by firm polyurethane (PUR)

with a thickness of $\delta=50$ mm.

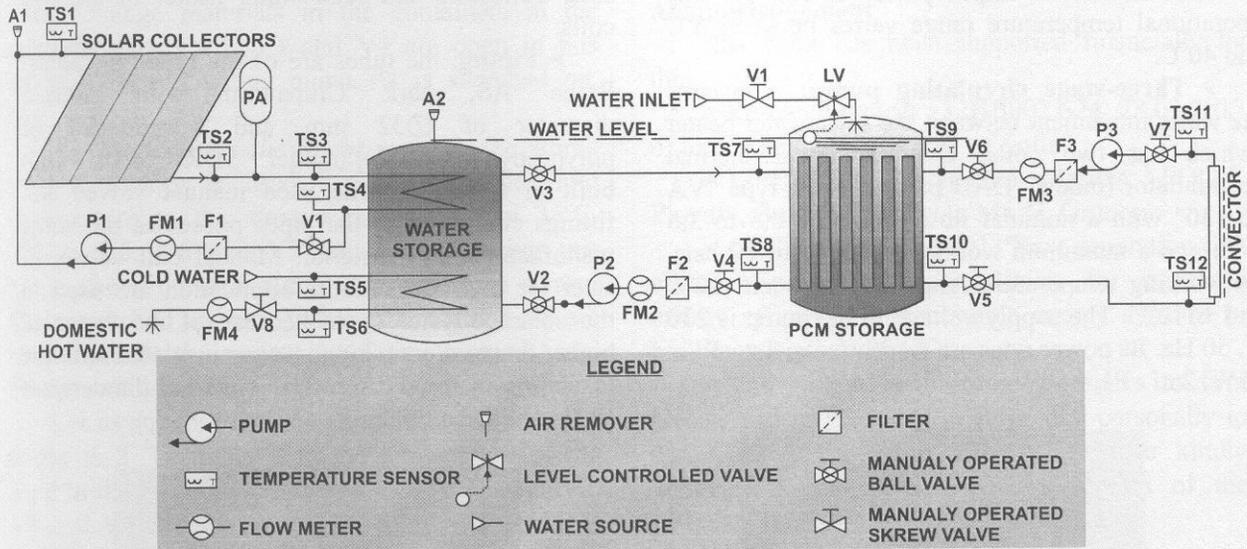


Fig. 1 Set-up of the test installation, which contains storage with phase change materials.

➤ **Latent heat storage:** it was developed by the team of the Technical University of Sofia, branch Plovdiv. Some design features are shown in the Figures 2 to 4. The tank and the containers of the storage are made of stainless steel grade AISI 304 L. The number of the containers is 39. They have a rectangular cross section with the following dimensions: 80 x 50 x 1,5 mm. They are coaxially disposed in the storage. There are two concentric circles - one external with 26 pieces and another internal with 13 pieces containers (it is shown in Fig.2). Brackets are placed in the tank for relief insertion and removal of the containers - both in the upper and lower part. The brackets provide reliable fixing of the containers in the storage, as shown in Fig.3. The brackets are fixed to the threaded perforations of the concentric situated bearing rings on the inner and outer circle of the containers. The bracelets on the lower row are welded to the tank bottom; at the same time the bracelets on the upper row are fixed to the storage by means of 3 studs (the difference between every two studs is 120°).

The thermal storage has 3 outputs (they are centrally located on the bottom of the tank). Additionally are available 3 inputs which are located in 120° angle on its periphery. The storage is insulated with mineral wool having a thickness of $\delta=50$ mm.

Fig.4 shows a photograph of the steady connected latent heat accumulator as a part of the experimental installation and a part of the existing global hybrid system.

➤ **Three-stage circulation pump:** it ensures the circulation of the medium in the intermediate cycle of the solar collector. Some technical data - model "Salmson"; type "NYL 53-15 P" with a rated

working pressure of 6 bar and a maximum pressure of 10 bar; nominal flow rate of 5,5 m³/h; operational temperature range of -10° to 160°C; supply voltage to the pump is 230 V, 50 Hz; different power rates respectively - 1st - P1 = 43 W, 2nd - P1 = 61 W, 3rd - P1 = 84 W.

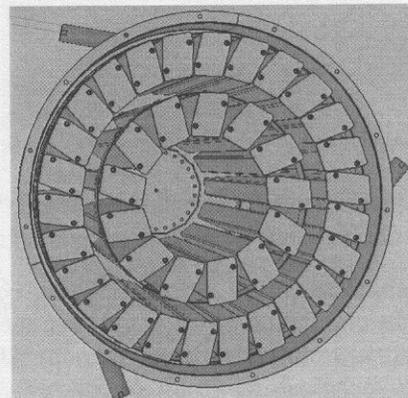


Fig. 2 Overlook of the latent thermal storage.

The pump is a part of the solar unit. It consists of solar collectors of the type "New Energy System" Ltd., Brand "Sunsystem", model "S002". The collector is insulated with thermal insulation of the type Foam Polyethylene (PPE). A manometer scale from 0 to 6 bar and temperature scale of the thermometer 0 to 160°C is available, too. A flow meter with a flow rate from 2 to 12 l/min and an expansion tank with a volume of 8 l is connected to the pump unit as well.

An uninterruptible power supply battery voltage converter of the type DC12V-AC220V, 50 Hz, type "IN-100K" with a supply voltage 230V±10% and 50 Hz provides electricity for the pump unit.

Battery voltage is $12V \pm 2V$ and has a capacity of 7,5 Ah. The maximum output power is 100 W. The operational temperature range varies between 5°C and 40°C .

➤ **Three-stage circulating pump:** it ensures the water movement between the solar water heater (which has two coils) and the latent thermal accumulator (model "DAB pumps" SpA, type "VA 35/130" with a nominal flow rate from 0,5 to 3,6 m^3/h and a maximum working pressure to 10 bar). Its working temperature range lies between -10°C and $+110^{\circ}\text{C}$. The supply voltage to the pump is 230 V, 50 Hz. Its power rates are respectively: 1st - $P_1 = 35\text{W}$, 2nd - $P_1 = 50\text{W}$, 3rd - $P_1 = 56\text{W}$.

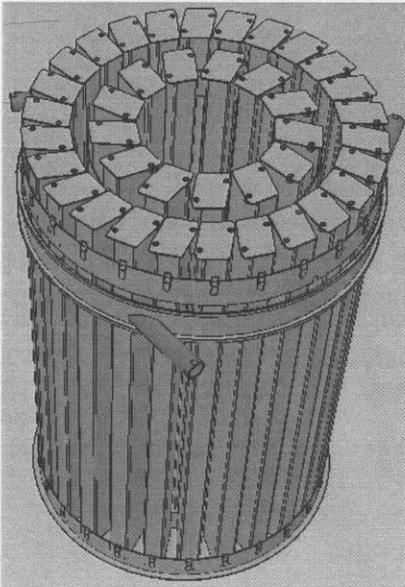


Fig. 3 Inner construction of the latent thermal storage.

➤ **Circulation pump with electronic control:** it ensures the circulation of water between the latent thermal storage and the consumer of thermal energy. Its technical data are as follows: model "DAB pumps" SpA, type "EVOPLUS 110/180XM", with nominal flow rate: 2 to 12 m^3/h and a maximum operating pressure of 16 bar. Its working temperature range is from -10° to 110°C . The supply voltage to the pump is 220/240 V, 50/60 Hz and has a maximum power of 170W.

➤ **Hot water flow meter:** it possesses of dry roller counter and pulse output with a maximum temperature of 90°C . Its type is "Belasitza" AD model "VITV-5" with a nominal flow rate $Q = 2,5 \text{ m}^3/\text{h}$ and a nominal working pressure of 10 bar. The supply voltage is $V_s = 2,4 \pm 5 \text{ V}$. The precision class of the unit is "B" for horizontal installation and "A" for vertical mounting.

➤ **Air purge valve for pressure:** they are up to 10 bar and temperatures up to 110°C , type

"WALMAT", included respectively in the range of solar collectors and solar water heater to the two coils.

➤ **Piping:** the tubes are of the type "Instaplast Praha" AS, mark "Climaterm" with external diameter of $\varnothing 32 \text{ mm}$ and a material of polypropylene (PPR), model "SDR 7,4/11" with built in fiberglass. The used manual valves and fittings connected to the pipes possesses the same manufacturer and material. Manual ball valves of steel for high temperature application are used in the solar collector cycle because of the expected higher temperatures. Pipelines are insulated with the insulating material "Aeroflex" (internal diameter of $\varnothing 35 \text{ mm}$ and a thickness of 9 mm).

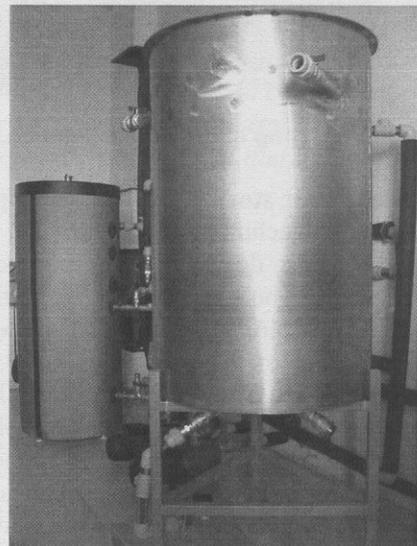


Fig. 4 Picture of the latent thermal storage with a part of the test installation.

➤ **Control system:** microprocessor control system is used to rule the created experimental installation – it is based on a PC. Two types of sensors (thermocouples and resistance temperature detectors, RTD) are used to monitor the temperature. The applicable control software is developed by the team from the TU Sofia, branch Plovdiv.

➤ **Operation modes:** the following operation modes can be realized with the described system:

I. Twenty-four hours accumulation of solar energy (with the following possible two sub modes):

1a. Thermal loading of the solar water heater with two serpentes: if the temperature of the intermediate heat transfer medium in the solar collectors is 10°C higher than that of the fluid in the boiler - then a heat transfer to the tank begins. Valve V1 is open in this mode, the three-stage circulation pump P1 is switched on, too.

1b. Thermal charge of the latent storage: the temperature of the fluid in the solar water heater is

10°C higher than the melting temperature of the phase change materials in the containers in the storage. Valves V2, V3 and V4 are open in this mode, three-circulating pump P2 is switched on, too.

II. Discharge of the latent storage: the stored thermal energy is used for heating. The fluid temperature in the storage is higher than 35°C. Valves V5, V6 and V7 are opened during this mode, the circulation pump with electronic control P3 is switched on, too. Valves V2, V3 and V4 are closed and the three cycle circulating pumps P1 and P2 are switched off.

Let us suppose that the temperature in the solar boiler is 2 °C higher than the temperature of the fluid in the latent accumulator. Then the valves V2, V3 and V4 have to be opened and the pump P2 is switched on, too. Thus a transfer of the stored thermal energy to the consumer is realized (both – from the latent accumulator and as well from the stored thermal energy in the solar heater).

III. Providing of domestic hot water: valve V8 opens at a fluid temperature in the solar boiler higher than 50°C. Heat is supplied from the solar collectors or from the latent accumulator in this mode.

Conclusions

The following main conclusions can be drawn:

- An installation containing latent heat storage was constructed in the Laboratory of “Renewable Energy Sources” at the Technical University of Sofia, branch Plovdiv.

- The number of the containers with PCM in the latent storage can be changed - this leads to different modifications of the storages with several operation modes;

- The described latent device can be considered as diurnal accumulator of a hybrid system with various types of storages.

Acknowledgement

This work has been supported financially by the:

➤ Research project 132ПД0023-24/ 28.03.2013 of the Technical University of Sofia;

➤ LIEBHERR Hausgeräte Maritza -EOD, Plovdiv, Bulgaria, thanks to Mr. G. Gruber;

➤ COST Action TU0802 “Next generation cost effective phase change materials for increased energy efficiency in renewable energy systems in buildings. NeCoE-PCM”.

➤ The authors would like to thanks to firm Geosis Ltd in Plovdiv, Bulgaria, and personally to Mr. O. Pekov and A. Angelov for their kindly cooperation and support in construction of the installation.

References

Georgiev A. Perspectives for development of phase change material thermal energy storages. TU Varna Edition, Thermo techniques, year 2, book 1: 2011, ISSN 1314-2550, pp. 76-79 (in Bulgarian).

Georgiev, A. Tabakova S., Popov R., Valkov I., Moev, S., Barzilova S., Lishev S., Takev M., Vasilev A., Boichev A. Constuction and modelling of heat energy storage with fhasе change materials, Journal of the TU-Sofia, branch Plovdiv, “Fundamental Sciences and Applications”: Vol. 16, 2011, pp. 45-51 (in Bulgarian).

Cabeza, L., Ibanez M., Sole C., Roca J., Nogues M. Experimentation with a water tank including a PCM module. Sol. Energy Mater Solar Cells: Vol. 90, 2006, pp. 1273–1282.

Esen, M. Thermal performance of a solar-aided latent heat store used for space heating by heat pump. Solar Energy: Vol. 69 (1), 2000, pp. 15–25.

ЕКСПЕРИМЕНТАЛНА УРЕДБА ЗА ИЗСЛЕДВАНЕ НА ЛАТЕНТЕН ТОПЛИНЕН АКУМУЛАТОР КАТО ЧАСТ ОТ ХИБРИДНА СИСТЕМА ЗА КЛИМАТИЗАЦИЯ

А. Стоянов, А. Георгиев, Р. Попов

Резюме

Разработена и реализирана е експериментална уредба за практическо изследване на латентен топлинен акумулатор, зареждан със слънчева енергия. Чрез нея се изследва приложимостта му като елемент от хибридна система за климатизация. Системата е изградена в лабораторията по „Възобновяеми източници на енергия“ при Технически университет София, филиал Пловдив. Системата се състои от топлинен енергиен акумулатор, слънчеви колектори, водоподгревател и циркуляционни помпи.