Hybrid system consisting of solar collectors, phase change materials and borehole storages

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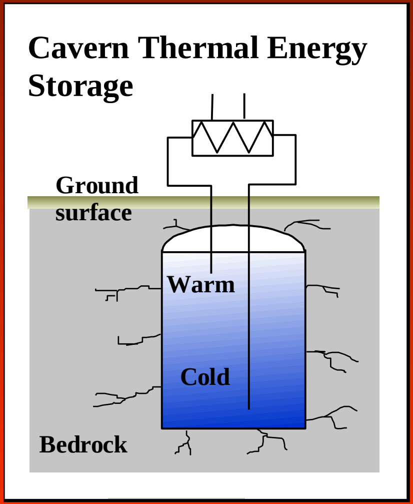
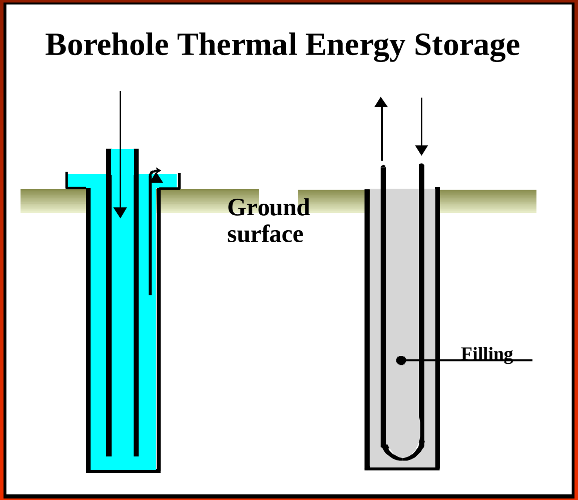
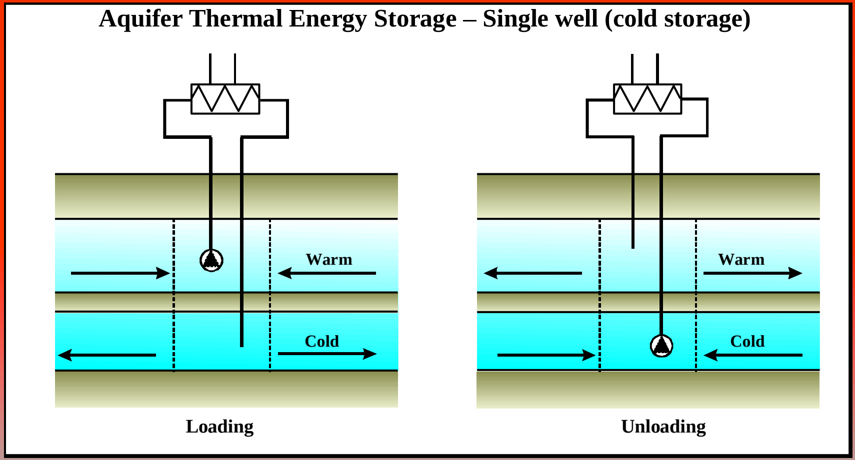
INTRODUCTION

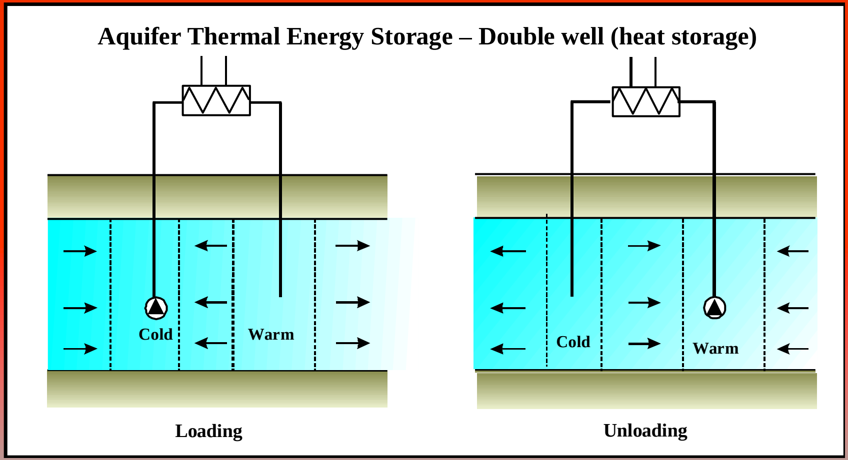
- There are some opportunities to store the gained thermal energy – it could be done in the form of sensible or latent heat.
- Underground thermal energy storage (UTES) is a favourable technology from both the technical and the economical point of view.
- The latent heat storage has high density at similar temperature range.
- A combination of seasonal and diurnal storages in building heating and cooling systems with a heat-pump is presented.

Underground Thermal Energy Systems - UTES









TRT stationary installation in Chile

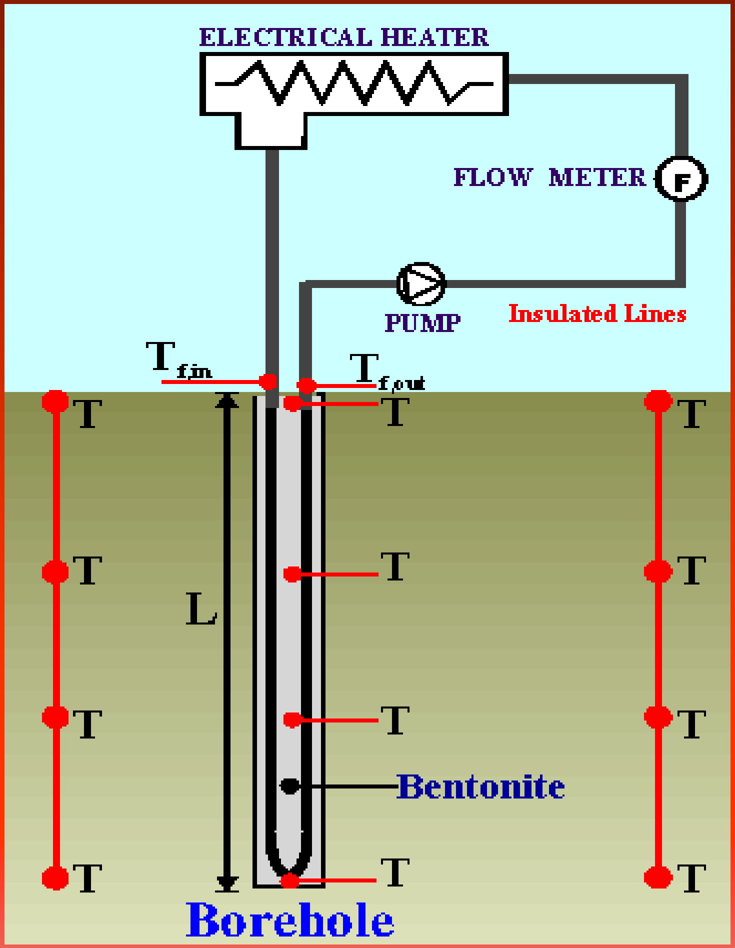
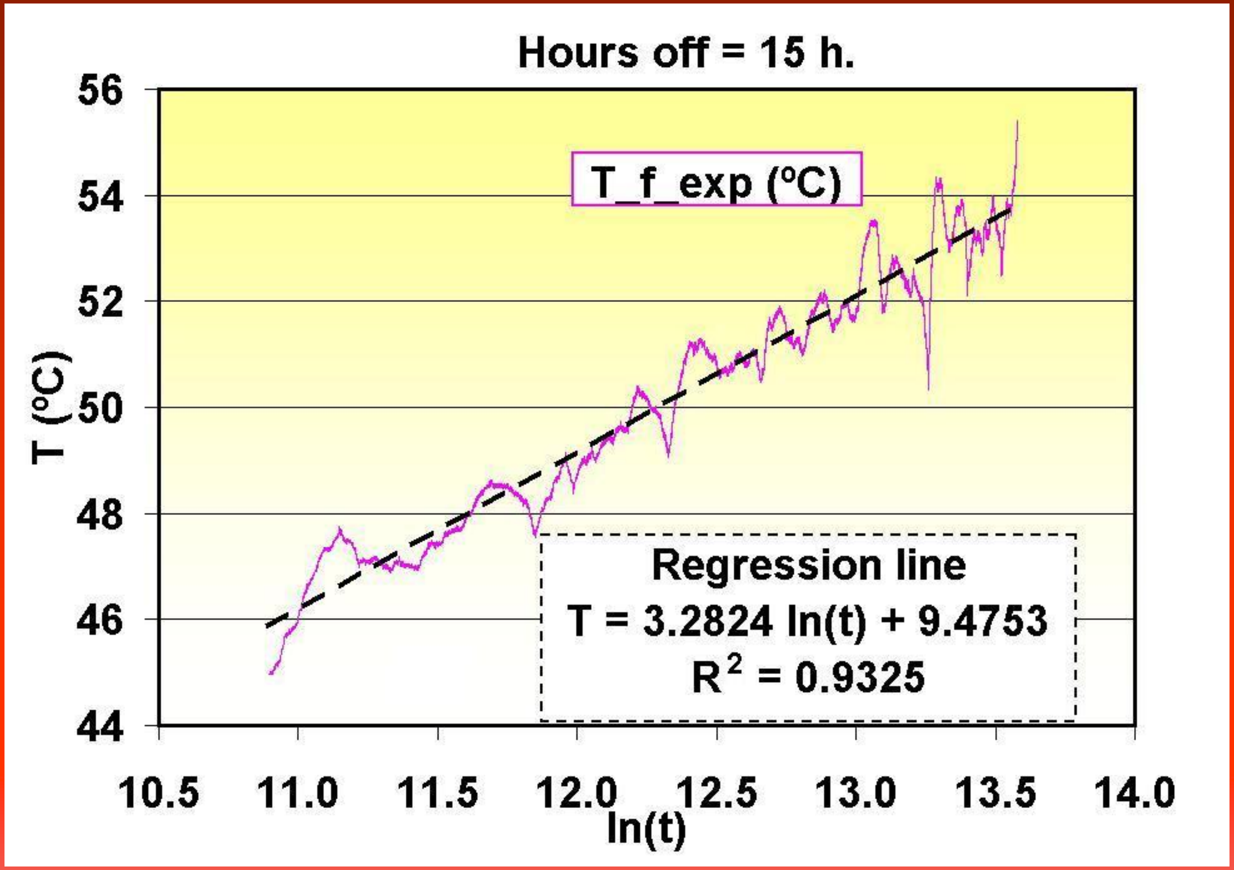


Fig. 1: Installation for testing of BTES.

- About 10 years ago (June - July 2003) a Thermal Response Test was realized in Valparaiso, Chile - **the first one in South America**.
- Three perforations were done along a line to a depth of 22m, Ø 0.15 m.
- Central perforation is a U-loop BHE refilled with a 12% bentonite mixture.
- Other two perforations were - 0,4 m to the left of the BHE, - 0,8m to its right, replenished with the same soil.
- Sensors of thermocouples type K at depths of 20,5m, 13,67m, 6,84m and 0,25m were installed therein.
- Electric heater, 2 kW was mounted in the installation.

Thermal ResponseTest in Chile



Graphical representation (excluding the first 15 h) for the entire time span of the test and the slope of the associated regression line are shown.

Fig. 2: View of evaluation data interval.

Third stage (discharging)

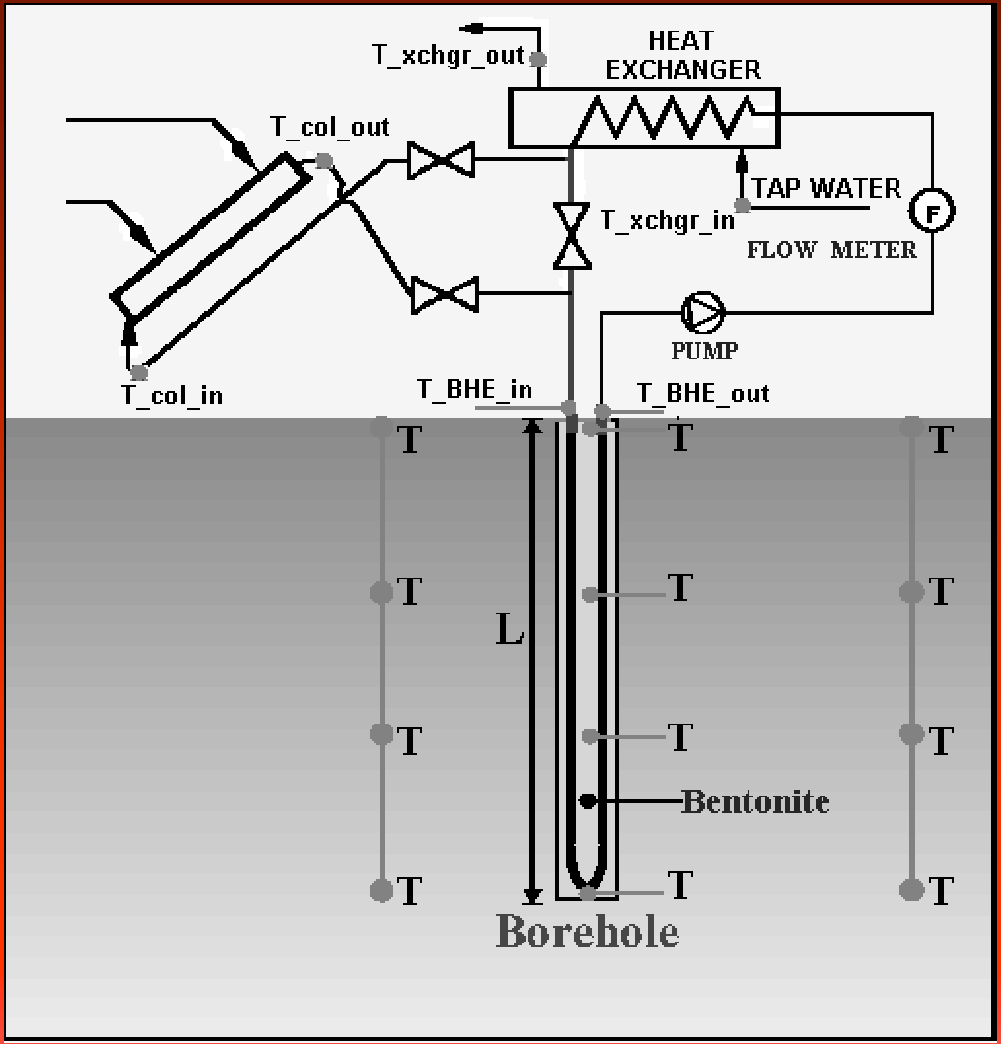


Fig. 3: Scheme of the test installation during charging and discharging.

After the charging cycle a new modification was introduced to the hydraulic system. One loop of a cross-flow water-water heat exchanger was connected to the BHE circuit instead of the collectors with the other loop fed with tap water.

Installation view

Fig.4: Upper part of the borehole with the mobile installation.

- The mobile installation for the TRT was constructed in 2007 at the Technical University of Sofia, branch Plovdiv;
- The laboratory has two parts (Fig. 4) combining two functions: an investigation installation and lodging;
- The first part (the bigger one) consists of a gas stove for heating, a gas cooker, refrigerator, sink, table and 2 beds (it is foreseen that the investigators will live and work during the TRTs).

Measuring device

Fig. 5: Photo of the measuring device.

The second one contains the working installation - the mechanical, measuring and control parts of the system (Fig. 5)

Installation set-up

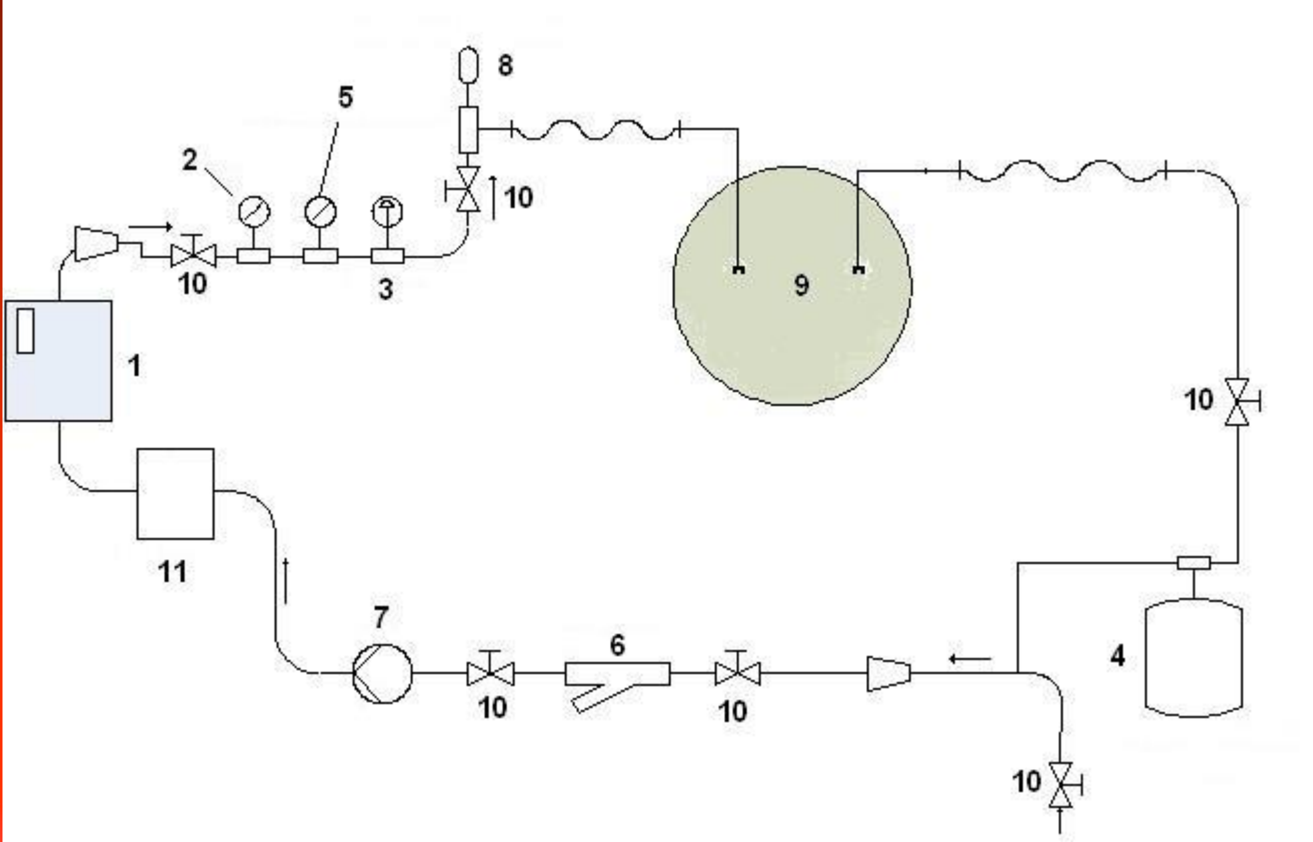


Fig. 6: Installation set-up

The following parts are presented:

-electrical boiler 1;

- calorimeter 2;

- pressure watch 3;

- expansion tank 4;

-thermo–manometer 5;

- filter 6;

- circulation pump 7;

- de-aeration pipe 8;

- quick couplings 9;

- valves 10;

- electrical unit 11.

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Borehole Heat Exchanger (BHE)

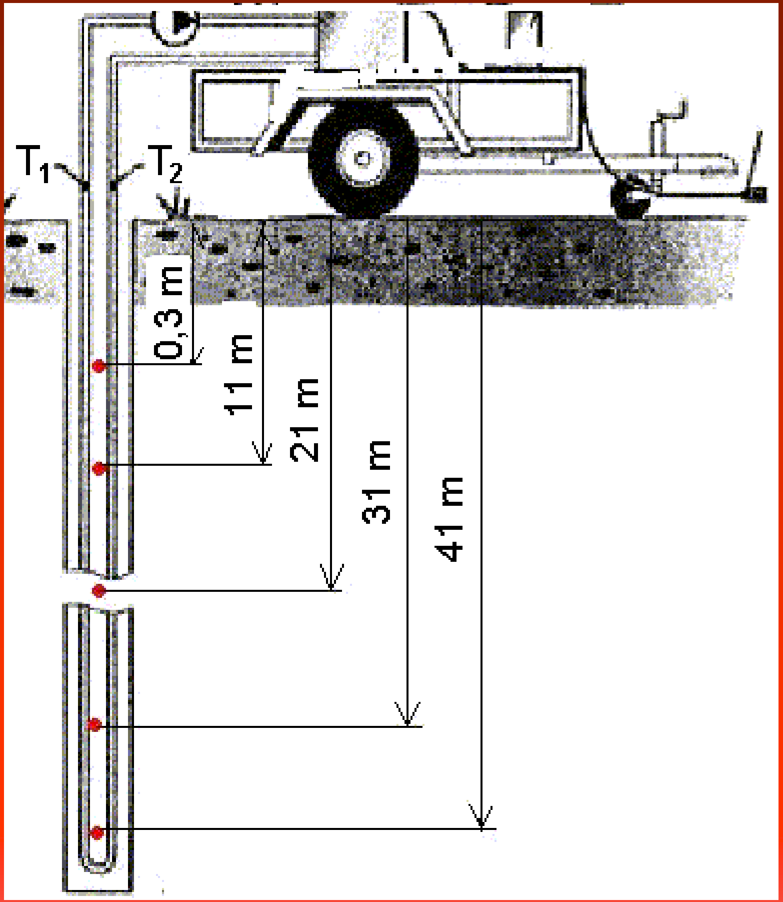

Fig. 7: Situation of the temperature sensors in the borehole.

A U-pipe of high density polyethylene (HDPE) with an external diameter of 25 mm was installed in the perforation;

A mixture consisting of 11% bentonite and 2% cement was used to grout the borehole;

Five temperature elements of the type PT100 were mounted at depths of 41, 31, 21, 11 and 0.30 m in the BHE body.

In order to reduce the further ambient influence on the system, a surface area of about 4 m² on top of the store was insulated with a layer of 0.1 m of high density polystyrene covered with aluminum folio.

The first Thermal Response Test in Bulgaria was implemented in January 2009 (at the Technical University - Sofia, branch Plovdiv).

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Lithological variety

Fig. 8: Ground sorts – 3m to 42m under the surface.

One perforation with a diameter of 180 mm was done to a depth of 42 m in November 2008;

The soil at the site consists of some different layers (mainly sand and clay), which are shown on Fig. 8 (the soil content for every 1 meter layer thickness is presented from the 3rd to the 42nd m under the surface).

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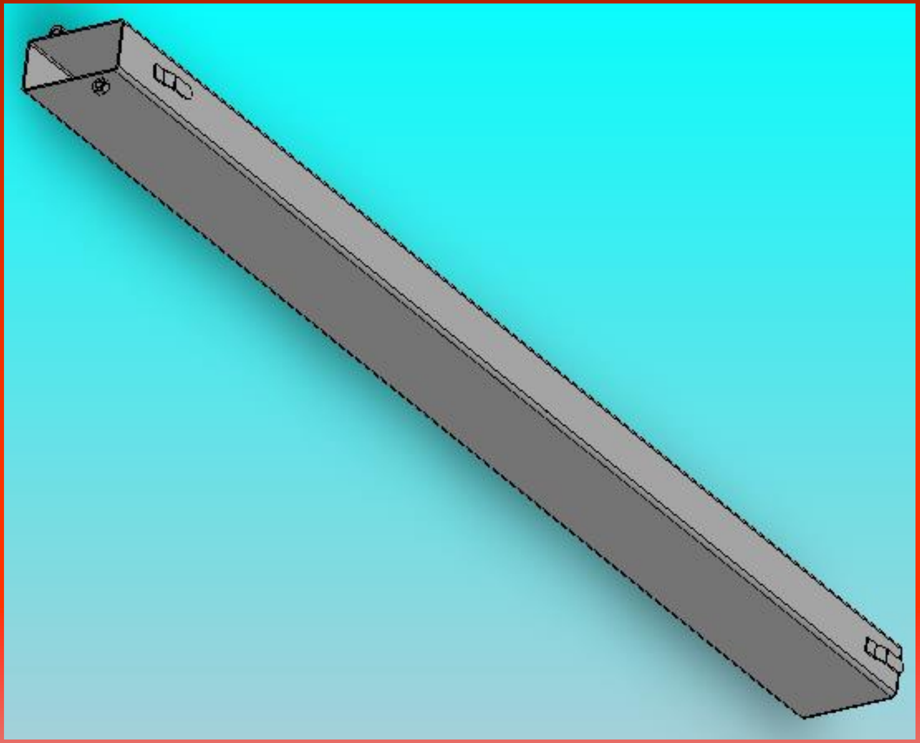
Borehole Heat Exchanger (BHE)

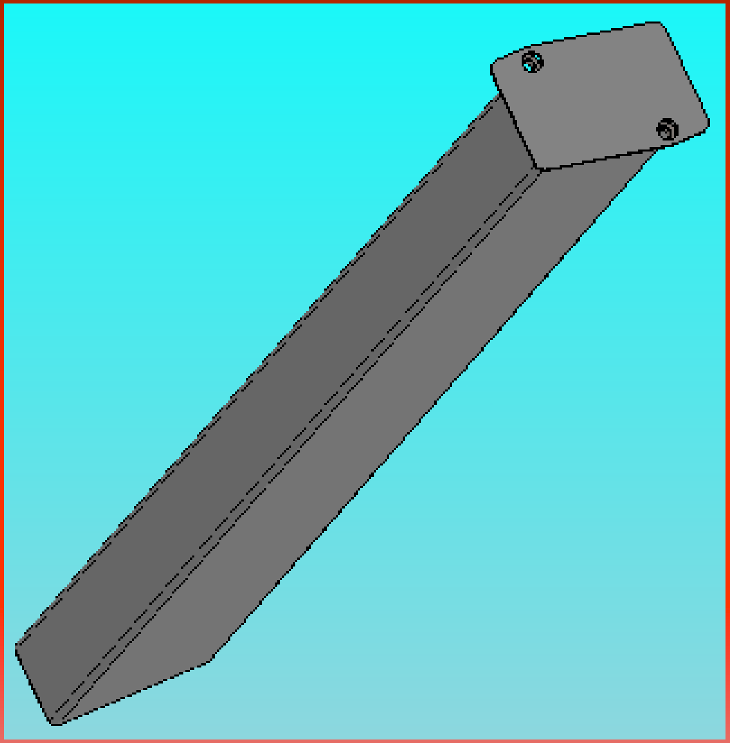
Fig. 9: The U-shape pipe.

A U-pipe of high density polyethylene (HDPE) with an external diameter of 25 mm was installed in the perforation.

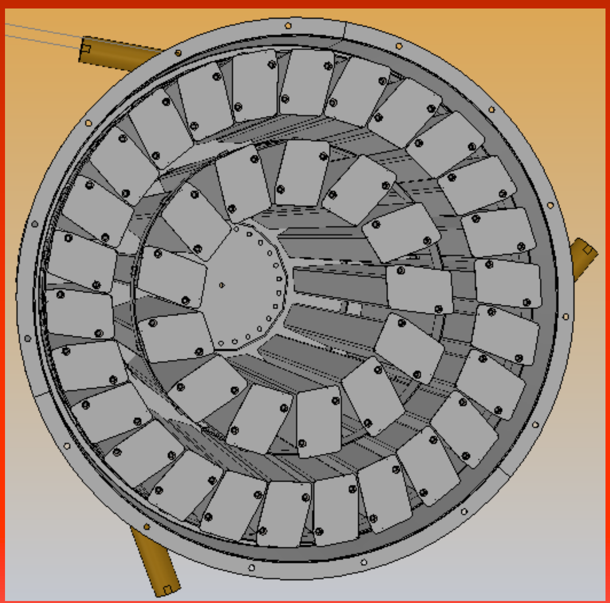
Test of the Paraffin's Thermal Properties

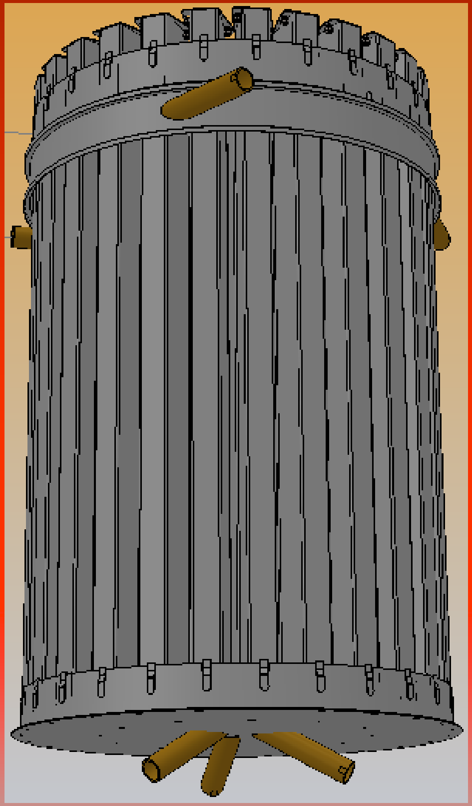
Elements of the PCM storage

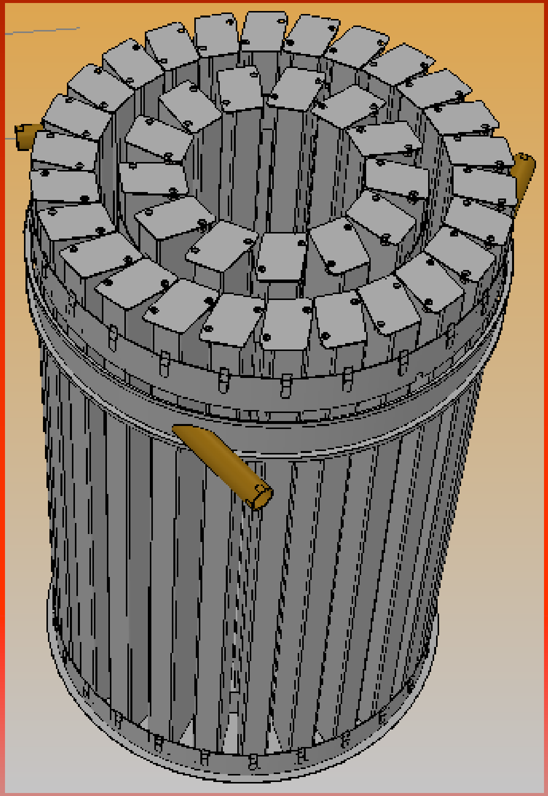




Elements of the PCM storage







Elements of the PCM storage

HYBRID TEST INSTALLATION

In 2013 year a hybrid test installation was developed at the Technical University of Sofia, branch Plovdiv.

It contains the following main parts:

- solar collectors;
- phase change material (PCM) storage;
- borehole storage;
- heat pump.

Hybrid installation (GSHP with PCM)

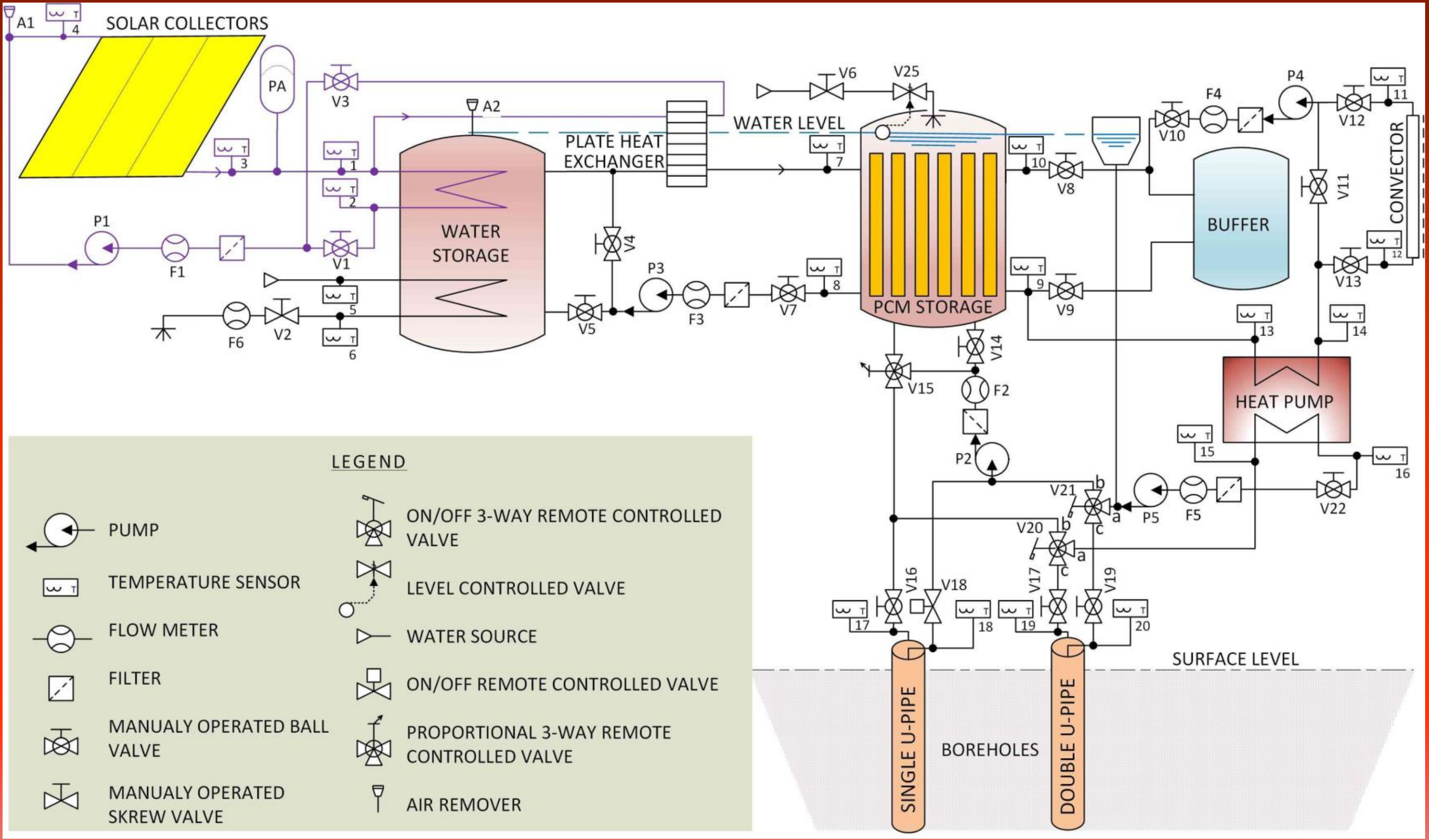
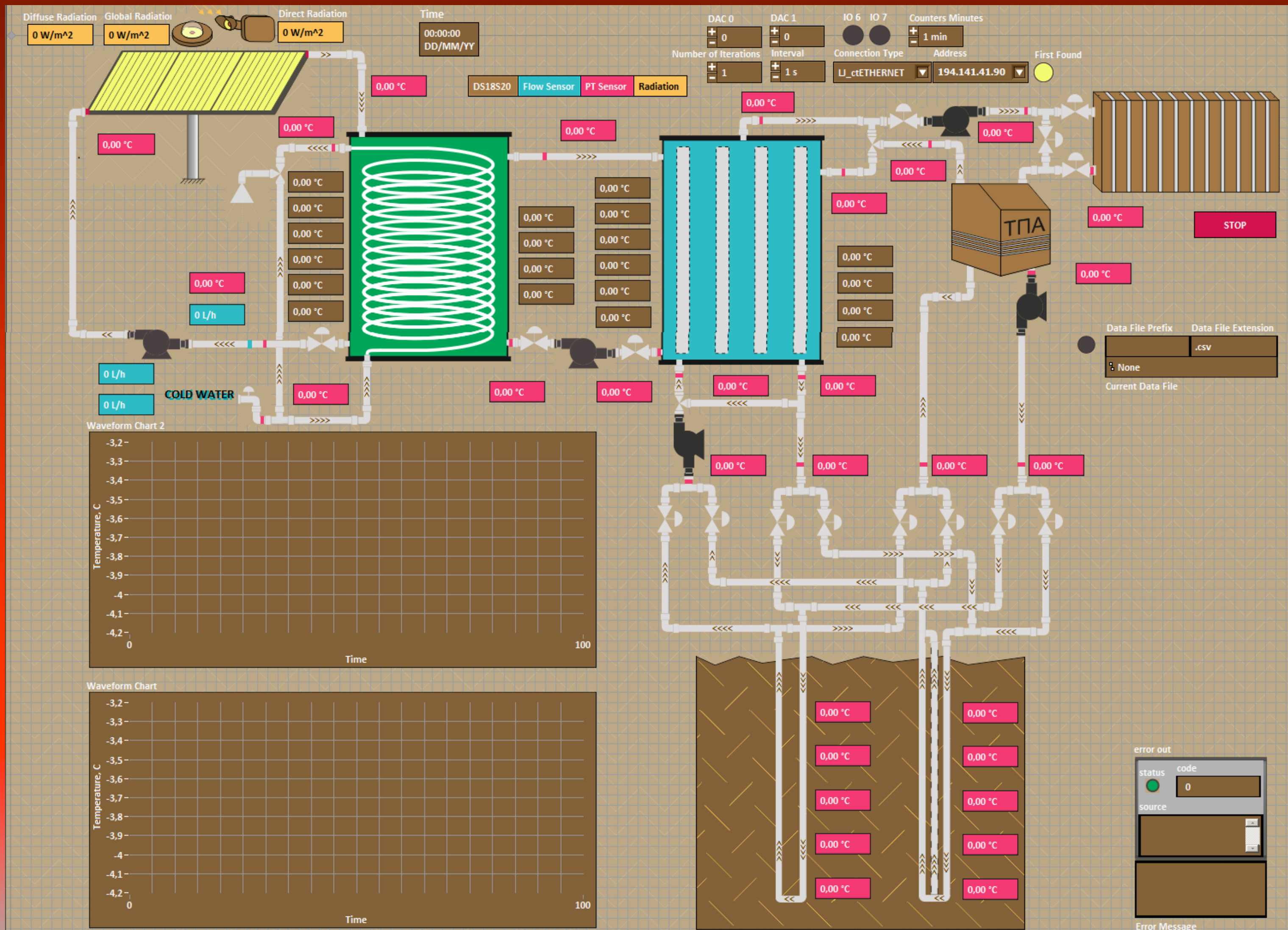


Fig. 10: Scheme of the hybrid installation (GSHP with PCM storage).

Different regimes for system operation

Mode 1 (solar energy diurnal storage).
Mode 2 (charging of the borehole storage).
Mode 3 (direct solar heating).
Mode 4 (indoor heating using supplied energy from diurnal storages).
Mode 5 (ground-source heat pump heating).
Mode 6 (heating with solar assisted heat pump).
Mode 7 (production of domestic hot water, DHW).

SCADA Control Screen – Hybrid System



Hybrid system - solar collectors, PCM, BTES