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Assessment of the influence of shortening the duration of TRT (thermal response test) on the precision of measured values

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ABSTRACT

In this paper the results of testing thermal parameters of the rock environment and measurement of borehole temperature profiles of the newly constructed experimental underground heat storage (BTES (Borehole Thermal Energy Storage)) in Paskov (Czech Republic) obtained with the TRT (thermal response method) and temperature measurement on boreholes at selected depth levels are summarised. The TRT measurement series on eight boreholes has shown the possibility to compare the differences among individual measurements in a practically identical rock environment. The temperature profiling of boreholes enabled studying the dynamics of temperature changes occurring in the rock environment as a reaction to the heat supply during the TRT.

The measurement series was performed with the aim to assess the possibility of shortening the TRT duration while maintaining the acceptable precision of the measured results. For this reason the software simulation of shortening the TRT duration to 24 h was performed, and the influence of such shortening to the precision of determination of values λ and R_B was studied. The simulation has shown that shortening the test to 24 h in our case would have brought an acceptable amount of inaccuracy with regard to the dispersion of measured values obtained from the real test.

1. Introduction

One of the ways to store surplus or unused heat, e.g. from solar panels, cogeneration units or waste heat from industrial technologies, is to accumulate the heat in underground heat storages. Where it is allowed by geology, the storage (known as BTES – Borehole Thermal Energy Storage, or UTES – Underground Thermal Energy Storage) can be constructed. The heat storage is performed through boreholes up to several tens of metres deep. The operating principle of this heat storage is simple. In regular distances, the system of boreholes is drilled into the earth. The boreholes are with the same well-completion as the boreholes for heat pumps. Warm water, e.g. from solar panels, is pumped into the boreholes and this water transfers (stores) heat to the surrounding rock environment. In case of the requirement for heat consumption, the process is reversed. The cooler water in boreholes is warmed by the heated rock and thus the heat of the boreholes is taken from the rock and it is used e.g. for heating buildings. The advantage of this type of heat storage is a lower cost of acquisition [16] when compared to heat storages where energy storage into subterranean water basins (natural or artificial) occurs.

The conditions of heat storage to the surrounding rock environment depend on the geological environment where the heat storage is operated. To verify the behaviour of this type of heat storage under those geological conditions during various predefined operating states, an experimental BTES consisting of 16 energy boreholes, each to the depth of 60 m, was constructed in Paskov.

In the heat storage construction phase, when the borehole field was developed and individual energy boreholes were still not connected through horizontal piping with the aboveground part of the heat storage technology, a series of thermal conductivity and thermal resistance measurements of boreholes and the rock environment using the thermal response method, and a series of borehole temperature profile measurements, was planned.

There are many factors such as the type of rocks in the site, extent of tectonic disintegration of rocks, thickness and type of quaternary covering, presence of flowing groundwater, etc., that

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influence the mechanism of heat storage in a BTES. These individual factors create a unique combination in each locality whilst the thermal properties of the rock environment, including boreholes as a whole, can be best assessed using a TRT (Thermal Response Test) that checks the ability of the borehole to accept the heat in the whole length under original natural conditions. In contrast to the laboratory research of the thermal conductivity of the rock samples from borehole cores, TRT determines the real thermal conductivity of the whole borehole including the influence of all factors present in the site. In this work, the results of the TRT measurement series in 8 out of the 16 charged boreholes forming the experimental heat storage in Paskov are summarised.

The result of this measurement series was the experimental determination of the dispersion of the measured values of thermal conductivity and thermal resistance in the boreholes, which are located in a square network with a side of 2.5 m, and in the same rock environment.

Simultaneously with the measurement of the thermal response of rocks, temperature profiling was performed on the boreholes of the polygon with the aim to assess the influence of TRT on temperature and its development, both in the tested borehole itself and also in the boreholes in the vicinity of the tested borehole. Based on these measurements, temperature profiles were constructed in the boreholes.

In addition to the measurement of thermal parameters characterising the rock environment where the heat storage is constructed, and which will be subsequently used for its experimental operation and assessment of individual operating modes and states, the measurement was performed with the aim to use the measured data for assessment and evaluation of the possibility of shortening the duration of TRT. The common duration of one test is currently 72 h. In cases when lengths or numbers of boreholes are changed, or the whole borehole field is modified based on the test results, the possibility of shortening the TRT duration while maintaining the acceptable precision may shorten the duration of drilling operations in the site with a positive influence on the price of these works. In the case of our measured results, as we have seen, TRT can be evaluated already after 24 h provided that certain conditions are met, whilst the amount of inaccuracy caused by shortening the test is acceptable when compared to the dispersion of measured values of both thermal conductivity and thermal resistance.

2. Foreign knowledge

In foreign countries attention is paid to the construction of BTES both in the field of theoretical research and also practical implementations in specific sites. The study of the influence of high-temperature energy storage in the rock environment was performed by a research group of the IEA (International Energy Agency), called ECES (Energy Conservation through Energy Storage), under the supervision of Prof. Burkhard Sanner, particularly under research project No. 12 – Annex 12, HT UTES (High-Temperature Underground Thermal Energy Storage). The results and the final reports and general recommendations for the construction of high-temperature heat storages can be found on the websites of ECES [10]. The TRT utilization for design of UTES is studied in ECES – Annex 21 (Thermal Response Test for Underground Thermal Energy Storages) [11]. The advantages and problems of the use of BTES are summarised in Ref. [15].

Several underground heat storages (BTES type), where the rock environment itself is used for the heat storage, have been constructed throughout the world. Nevertheless, there is not much experience with the storage of thermal energy with a higher temperature of the circulating fluid (70–90 °C). The reason is that in most cases the thermal energy is supplied rather for the purposes of thermal regeneration of boreholes for heat pumps. There are not many finished projects where the heat is stored for a long time and subsequently directly used for heating without heat pumps. 7 such projects are known to the authors. They are located at the following sites – Okotoks (Canada); Golm, Neckarsulm, Crailsheim, (Germany), Anneberg, Emmaboda (Sweden), Braedstrup (Denmark). Other purely experimental heat storages have been built beside these sites, such as at the university in Swedish Lund.

3. Research polygons in the Czech Republic

The technology of heat storage in the rock environment through the system of boreholes is not thus far verified in practice in the Czech Republic. Whereas there was a large increase in the number of installations where geothermal heat from boreholes is used for heating, there are currently no real BTES installations in the Czech Republic. Monitoring of temperature changes in the rock massive around operating boreholes with installed heat pumps is now performed in several research polygons.

The first experiments with heat storage in the rock environment through boreholes including assessment of its accumulation capability to ensure heat supply were performed by so-called Large and SRP (Small Research Polygons) at the Institute of Mining and Geology (VŠB – Technical University of Ostrava) within the school boundaries in Ostrava – Poruba [3,12].

3.1. A new high-temperature research polygon of Green Gas DPB, a.s

Cooperation between the Institute of Mining and Geology (VŠB – Technical University Ostrava) and the company DHI, a.s. has overseen the first high-temperature experimental BTES in the Czech Republic operating since 2011 (16 energy boreholes, each of a length of 60 m with a max. medium temperature of 95 °C) at the site of the company Green Gas DPB, a.s. This storage, constructed with the support of the TACR (Technological Agency of the Czech Republic), stores excessive waste heat from the CHP (Combined Heat and Power) unit. The aim of the experiment is to assess the behaviour of the rock environment and the storage system as a whole, and to verify its reactions to various operating states simulated in the heat storage, both in heat storage charging and in heat consumption from the storage.

The schematic geological profile in the site of the constructed BTES is visible in Fig. 3. The underground storage system itself is located in a partially closed covered object, which partly eliminates external climatic effects.

3.1.1. Design of the BTES

The heat storage consists of 16 energy boreholes performed to the depth of 60 m (see Fig. 2). In these boreholes, warm water from the CHP unit circulates and delivers the heat to the surrounding rock environment. The energy boreholes are completed with five monitoring boreholes where the temperature in the specified depth levels of the rock massive is measured. Four out of five monitoring boreholes with the depth of 15 m are located at the edges of the heat storage and are used for monitoring temperature development in the water-bearing rock environment. The central monitoring borehole is 80 m deep and its data enable studying the temperature development in the central part of the heat storage.

The boreholes are always two in a series; therefore there are eight loops, each with two boreholes. The arrangement diagram can be seen in Fig. 2, and the technical parameters are given in Table 1.

The construction of the small experimental BTES in the Czech Republic represents a unique opportunity to experience a new thermal energy storage technology in a rock environment, and thus open other options for the use of excessive or waste heat.