Performance comparison between a typical very shallow and an innovative configuration of ground heat exchangers

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ABSTRACT

Ground Heat Exchangers (GHEs), very shallow (baskets, spirals) as well as vertical (Borehole Heat Exchangers), transfer heat to the ground through the filling material. Research on filling materials has been developed to boost heat transfer and meanwhile protecting groundwater from pollution. Maximum result of filling material is a thermal conductivity similar to that of the ground (2.0-2.5 W/m·K). In very shallow applications, such as baskets and spirals, since high quality aquifers are not affected, filling material is the excavated soil itself, with very limited design possibilities to improve the heat exchange. Therefore, a possible way to maximize the heat exchange consists in modifying the configuration of the very shallow application. The scientific literature reports that water presence (phreatic aquifer or rainwater in superficial layers) enhances the GHE performance. Grouting and other filling materials, even with high thermal conductivity, lower the advection term due to the water movement and thus its contribution in the overall performance of the system. A solution to raise advection contribution, even in shallow systems, is to submerge geothermal pipes directly into the water. This can be achieved by the insertion of pipes into proper tanks/casings buried in the ground.

The present work illustrates an experimental campaign conducted to verify the performance of a geothermal Spiral (2 m deep) inside a water casing, by comparing it with the same Spiral, directly installed in the ground, at 4 m distance. A low power TRT machine was used for simultaneous comparison of two Spirals, by proper control of thermal power and water flow. This work illustrates the results of two 4 months' TRT campaign (summer and winter), showing how the innovative system improves, by a factor up to 200%, the thermal exchange between the geothermal pipes and the ground. Moreover, on medium-long term, the decrease of efficiency, due to thermal saturation of the medium, was slower in the innovative configuration than in the typical one. The study provides a preliminary quantification of the benefits and limitations of the proposed configuration. Coupling water tanks to GHE seems a promising innovation, with remarkable potential. Further studies will be carried out to verify the marketability of these systems, by exploring double usage (Combined water/energy savings), selecting best materials for all new parts of the system, deepening the tanks/casings and evaluating the feasibility in real applications for shallow and deeper systems.

1. INTRODUCTION

Ground source heat pumps (GSHP) have great potential to reduce the primary energy consumption compared with the conventional heating and cooling systems. GSHPs furnish thermal energy to the end user, by taking majority of it from the ambient (ground or aquifer), thus keeping the amount of electricity consumption lower than that of energy delivered (Wu 2009). Efficiency of the heat pump is directly related with design and performance of Ground Heat Exchangers (GHE). Optimally designed systems should contribute in decreasing required heating/cooling energy from conventional sources and therefore in lower associated costs. The main drawback for a wider implementation of GSHP systems at local level is the high initial cost of GHE installation (Self et al 2013). Currently, vertical borehole heat exchangers are the mainstream in this field with significant capital costs related to the borehole drilling, which can reach 100 m depth or more. Recent innovations and modifications, such as horizontal GHEs, very shallow GHEs and GHEs embedded in geostructures, have been developed with the idea of decreasing the initial costs of drilling. In these configurations, the depth of installation is 1.5 m to 6.0 m, thus heat exchange is affected by weather conditions. The system should be optimized in a way that heat exchange pipes are isolated from extreme winter conditions while in the same time depleted heat reservoir can be replenished during spring/summer season (Banks 2013). A significant advance of very shallow configurations is the flexibility of geometry and integrated design with other heating elements in hybrid configurations. Some prevailing versions that appeared on the market are Snail type, Slinky horizontal and vertical version, Helical (Spiral) vertical type. Helical configurations are also appealing because of minimal space requirement for their application and of their high value of heat transfer per unit length due to design geometry (Aydin et al 2015). Popular versions of Helical GHEs are Geothermal Baskets (GB) with recommended 6-9 units for a single-family house (BetaTherm commercial brochure, 2014). The typical length of the pipes in this configuration is 100 – 200 m and diameter is 2.4 m, while height depends on the product type. Spiral Heat Exchangers (SHE) are uniform systems usually installed in 3 to 5 m holes created with excavation or auger drill. On a place of installation, telescopic construction of SHEs can be extended from 1 m length (during the transport) to 3 m at the moment of installation. Like GB, several units of SHEs are recommended for supplying heat to a single-family house (Raugeo Sales Brochure, 2012). Recently, stand-alone SHEs are going out of the market due to the low power generated and wide installation area requirement; nevertheless, the configuration is increasingly adopted for integration in foundation piles. An additional important parameter in the design of very shallow geothermal field with Helical GHEs is spacing. Deghan et al (2016) investigated the influence of different spacing on the performance of the most common Helical GHE arrangements. The results show that minimal distance should be at least 7 m to keep the performance loss to less than 10%. The distance varies with the number of units and operational time and the middle unit is the most affected with performance loss. Moreover, performance of shallow GHEs depends on initial temperature at depth of installation and thermogeological parameters, with additional dependence on ambient. Shallow ground layers consist of unconsolidated material of different proportions. Excavated material is reused for backfilling the installations, so thermal conductivity at the site is hard to estimate. Recently Tinti et al. (2017) estimated the ground thermal diffusivity for a geothermal basket buried 2 m deep by an inverse analysis based on long-term ground and basket temperature monitoring. Afterwards, the variations of GHE efficiency were simulated, based on the monitored seasonal and daily temperature variations. Results were applied in a project of heat/cold recovery from the ground to satisfy the needs of a case study winery. Moisture content of the ground is also hard to estimate since it changes with seasonal drifts, conditioning the stability of thermophysical parameters, in particular volumetric heat capacity. Di Sipio et al. (2018) performed an extensive research on several compositions of filling material with different grain size and water content. Measurements confirmed that thermal conductivity increases gradually with the increase of water content for all filling material compositions although stabilized thermal conductivity in case of fine sand is 40% higher than in bentonite and clay. Gyu-Hyun et al. (2015), showed the importance of additional heat transfer due to advection, which is caused particularly by rainfall infiltration in very shallow ground layers, causing a wider gap between inlet and outlet temperature with thermal efficiency increase. Because of the proved efficiency variation due to the moisture content, recent attempts of inducing convection in GHEs have been realised. As an example, in Istria Region (Croatia), Helical GHEs were installed in concrete, water filled, tanks buried 2 m deep in two projects, one in Labin and one in Buzet (IPA-Adriatic, 2014; IPA-Adriatic, 2015). Preliminary results showed a general feasibility of this configuration, but further studies are needed for system optimization. Additionally, further applications involving water tanks have been presented in various patents, such as US 7,575,047 B2 and US 9,587,890.

The concept of applying induced natural convection has the potential to be adapted to deeper GHE, even involving the conventional borehole heat exchangers (BHE). Gustafsson and Westerlund (2009) presented a research about the effects of thermally induced convective heat flow on groundwater filled BHEs. Even in cases where groundwater flow is limited or absent, convection terms occur and leads to an increase of the heat transfer with respect to grouted BHE. As a result, borehole thermal resistance is lower and the system proves to be more efficient. In 2013, Focaccia and Tinti presented for the first time a research on a laboratory prototype of an innovative configuration of GHE inserted in a protective casing filled with water. The research has shown, both by analysing thermocouple and visual records, that natural convection movements are triggered in the water inside the tank. An additional claimed advantage of novel configuration is the environmental protection in case of leakage and possibility of checking and fixing the pipe system without the need for expensive excavation.

Researches about the quantification of the effect of ground thermophysical parameters and induced natural convection to the performance of very shallow GHE are resulting in novel configurations with improved efficiency. These novel configurations generally present an increased thermal conductivity and a lower borehole thermal resistance. This paper presents a further step of the ongoing research on the induced convection phenomena to improve the efficiency of GHE. A field test and a monitoring campaign have been performed on two Helical heat exchangers, one buried in the ground and the second one installed inside a protective casing filled with water, placed at 4 m distance. A preliminary quantification of the heat exchange, heat recovery and efficiency of the Spiral GHE submersed in water has been calculated, in comparison with the conventional installation of the same dimension in the ground. Results are based on a long-term Thermal Response Test (TRT) conducted for a total of four months during summer and winter.

2. MATERIALS AND METHODS

2.1 Description of the idea

The innovative idea consists in the installation of a protective casing around a GHE, filled with a thermoconductive fluid. In this way, probes are no longer inserted directly into the ground (and grouted when needed), but are first enclosed within the protective casing, which is subsequently lowered into the hole/excavation. The casing in the final configuration is in contact with the ground, thus assuring heat exchange, mechanical strength, elasticity and temperature resistance characteristics. The bottom of the casing is closed, to avoid the infiltration of groundwater or other external elements. In the annulus between the outer wall of the GHE and the inner wall of the casing, a fluid is inserted. The fluid never gets into direct contact with groundwater since it is enclosed within the bottom–closed casing.

The thermal model of the entire system was developed and the establishment of natural convection motions in the fluid was confirmed in a laboratory experiment performed in 2013 (Focaccia and Tinti, 2013). Authors compared the performance of traditional vertical BHE (PE 100 PN 16 DN 32) with the same BHE installed in a Plexiglas tube (diameter 150 mm, length 1 m) filled with water at constant temperature of 20°C. Additionally, the experimental results showed a decrease of the borehole thermal resistance of maximum 4% (for T = 15°C) and an increase of fluid interaction thermal resistance of around 77%. The decrease of borehole thermal resistance and the increase of fluid interaction thermal resistance, as well as the presence of natural convection motions, provide an enhancement of the heat exchange in the new configuration. Therefore, its resulting ability to extract energy from the ground is higher than the conventional system. All configurations of geothermal probes, inserted in the protective casing filled with a thermoconductive fluid, should then benefit of an improved efficiency. For ease of installation, the GHEs that should better fit in such innovative configuration are the SHEs and GBs, with limited depth of excavation/drilling, but considerable length of the pipes (around 50-100 m each). To take the research a step further, the SHE has been selected for testing the protective casing in a real environment. The real site prototype of the novel configuration was installed in April 2018 beside the Laboratory of Geoengineering and Natural Resources “LAGIRN” of the School of Engineering and Architecture of University of Bologna.

2.2 Description of the field test

The test site consists of two Helical heat exchangers (Spirals) with the following characteristics:

- Material: PE-Xa;
- External diameter: 25.0 mm;
- Thickness: 2.3 mm;
- Internal diameter: 20.4 mm;
- Length: 40.0 m;
- Vertical length of the cylinder: 2.0 m;
- Diameter of the cylinder: 500.0 mm;
- Number of coils: 26
- Spacing between coils: 80.0 mm;
- Weight: 7.5 kg;
- Fluid volume: 13.07 l.

The first one (hereinafter Spiral 1) is installed in the protective casing, while the second one (hereinafter Spiral 2) is buried in the ground.

The protective casing has the following characteristics:

- Material: PVC;
- Material of the bottom: PE;
- Material of the closure cap: PE;
- External diameter: 630.0 mm;
- Thickness: 16.0 mm;
- Internal diameter: 614.0 mm.

The casing is equipped with three temperature strings to measure fluid temperature in different points. A simplified scheme of the configuration is presented in Figure 1 while photo is presented in Figure 2

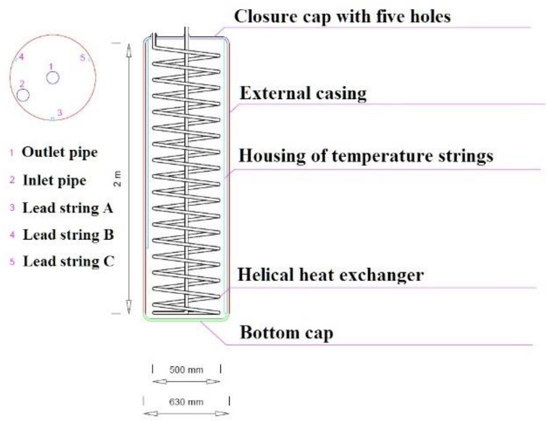


Figure 1: Scheme of the geothermal Spiral installed inside the protective casing.

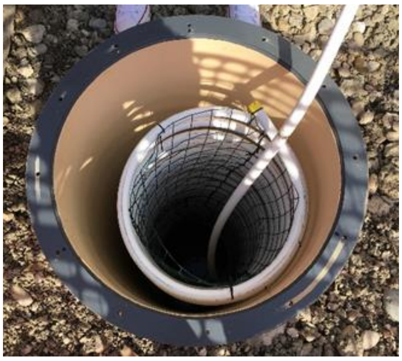


Figure 2: Helical heat exchanger (Spiral) in the casing.

The two Spirals are 4 m distant (Figure 3 and Figure 4). Two PVC pipes have been placed in the ground for further insertion of temperature strings: the first pipe is positioned at the mid between the two Spirals (D), while the second pipe is positioned in the centre of the Spiral buried in the ground (E).

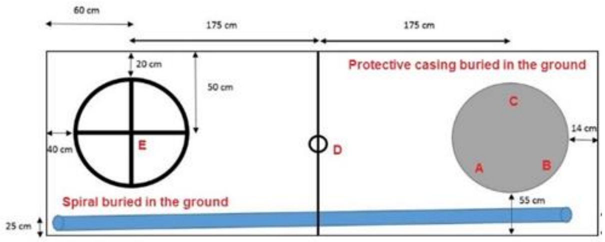


Figure 3: Scheme of the test site, with indication of temperature measuring points (A, B, C, D and E).

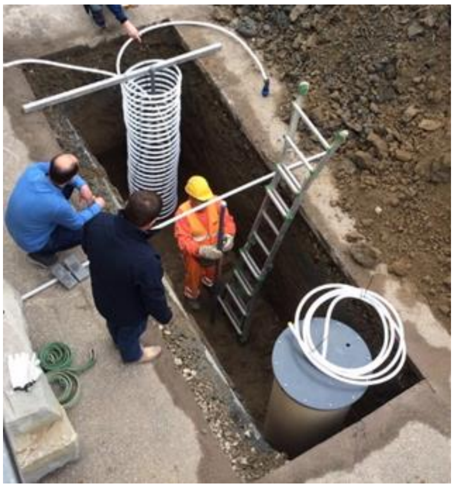


Figure 4: Installation of the two Spirals in the test site.

Stratigraphy of the ground in the excavated zone is reported in Table 1.

Table 1. Stratigraphy of the test site

Depth (cm)	Thickness (cm)	Lithology
10	10	Asphalt
50	40	Gravel
87	37	Clay
200	113	Silty sand

Excavated soil has been repositioned, trying to recreate the original condition, with the exception of shallow asphalt, which has been substituted by a layer of gravel (8-15 mm) and sand. Shallowest 5 cm have not been refilled.

Figure 5: Refilling of the test site with a sandy layer at the top.

Samples from the excavated soil have been taken and grain size analysed in the lab, with laser instruments. Water content of silty sand has been measured around 15% of the total weight. Measured grain size of clay was less than 15 microns, identifying a low permeability of the shallow layer at 87 cm depth, inhibiting the penetration of rainwater to the deeper sandy layers.

Research on the test site has been performed by using Micro – Thermal response Test machine (M-TRT machine). This lightweight and low-cost machine was specially designed and built for conducting the long and unsupervised TRT on very shallow GHEs thanks to wireless real-time monitoring (Verdecchia, et al, 2016). The machine can provide up to 1500 W of heat with three individual heaters of 500 W each. It is strictly necessary to have sufficient level of power to correctly test the working mode of geothermal closed loop system (ISO, 2015). In the specific case, producers estimate that larger configurations of Spiral GHE, with pipe length of 100 m, can achieve average 400 W per unit or 700 W per unit in optimal condition. Therefore, 1500 W of M-TRT machine is enough for testing together both installed Spirals, each with pipe length 40 m per unit. M-TRT machine consists of hydraulic and electronic part, the latter responsible for managing the whole machine. All physical data about the status of the machine are recorded and real–time measurements are obtained from signal conditioning circuit. The analogic data recorded are then converted into digital data with Analog to Digital Converter (ADC). Details of the elaboration procedure of the machine data can be found in Verdecchia et al., 2016. The monitoring system provides information about:

- Inlet and outlet flow temperature from the machine;
- Inlet and outlet flow temperature from both Spirals;
- Flow rate of working fluid;
- Electric power consumptions of the circulation pump;
- Electric power consumption of the heater.

Temperature measurements along the circuit are realised using PT100 sensors and an appropriate circuit with accuracy of 0,01°C and precision of +/- 0,03°C. Connecting pipes have been insulated with two PVC and one reflective layer.

Regular monitoring of the ground and water temperature on pilot site consists of five temperature strings, each with 5 temperature sensors embedded, every 0.4 m up to 2.0 m depth. The registration and record of the measurements taken with the sensors is performed using Long Range Radio Technology. Accuracy and precision of the temperature sensors are the same of the ones inserted in the TRT machine (0.01°C and +/- 0.03°C). The details about the technology is found in Brunelli et al, 2016. A, B and C temperature strings are installed inside the protective casing to measure the temperature of the water around Spiral 1. D is installed between the two heat exchangers, inside a plastic pipe buried in the ground, while string E is installed inside a second plastic pipe, in the centre of Spiral 2. In further representation of results, index *t1* is the deepest level of monitoring (2.0 m) and *t5* is the shallowest (0.4 m) below the surface level. The system is set to monitor the temperature approximately every three minutes.

2.3 Description of the thermal response tests performed in the testing campaign

Thermal Response Test (TRT) is a standard production test for shallow geothermal systems evaluation. By interpreting and analysing its measured data, it is possible to determine thermogeological parameters of the test site, effective thermal conductivity and borehole thermal resistance. There are different recommendations about the duration and procedure of the test. TRT is performed by providing a constant heat injection to the circulating working fluid while monitoring the inlet and outlet temperature. In general, TRT should be performed in 24 h cycles to get an insight about daily discrepancies and oscillations of electric power. ASHRAE Handbook recommends duration of 36 – 48 hours (ASHRAE, 2007), but there are many advantages of conducting longer TRT, such as the increased accuracy of the determined parameters (Bujok et al, 2014). In test campaign, TRT was performed by using the technique of multiple power steps of same duration (Witte and Van Gelder, 2006). The shallow installation depth of the Spirals, coupled with the fact that the innovative configuration is inside a protective casing, allows us to distinguish between the additional heat transfer, due to the presence of water in the ground (rain in this case), and the natural advection phenomena happening in the water filled protective casing. A first period of extended TRT was conducted during the summer season from 28th of May to 18th of June 2018, simultaneously on both Spirals. After the installation of both configurations and before running the TRT, two weeks of monitoring of the temperature at final depth of installation were conducted. After connecting the TRT machine to GHEs, two hours of circulation of the working fluid without heating were run to reach stabilisation of temperature. Three different power steps were then applied in the following order:

- 1300 W;
- 930 W;
- 470 W.

Duration of each period was approximately 7 days. A period of additional eleven days (till 29th of June) was used for circulating the water in the heat exchangers without the heating. The goal was to observe the heat recovery of the system and ground. A second period of extended TRT was conducted during the winter season, from 27th of January – 17th of February 2019, simultaneously on both Spirals under same conditions. Each power step was applied for approximately 7 days. After that, only circulation was conducted, without the heating, to observe the heat recovery. Gathered data was used to calculate difference in the power of the heat exchanger and in the theoretical efficiency between conventional and innovative configuration. The interpretation of results was done with respect to the ambient temperature and the water content in periods of heavy rain.

2.4 Subsoil temperature modelling

Data gathered from the water temperature monitoring strings, installed inside the casing (A, B, C), between the Spirals (D) and at the centre of the conventional Spiral (E) were used to calibrate the yearly model of temperature behaviour of water and ground of the test site. Data from three months of monitoring (10th of October 2018 – 9th of January 2019) were used for the calibration. Two correlations have been tested with respect to climate conditions of the location (Table 2) for describing the temperature distribution, Baggs (1983) and Hillel (1982). Results are presented in Figure 6.

Table 2: Climate data for test site location (Bologna).

T_m	15.5 °C
$A_{o,s}$	13.0 °C
p	365 days
t_0	10 days

The respective equations of Baggs and Hillel are the following ones:

$$T_g(d,t) = T_m - A_{o,s} \cdot \mathrm{EXP}\left[-d \cdot \sqrt{\frac{\pi}{(p \cdot \alpha_{eff})}}\right] \cdot cos\left[\frac{2\pi}{365} \cdot \left(t - t_0 - \frac{d}{2} \cdot \sqrt{\frac{p}{\pi \cdot \alpha_{eff}}}\right)\right] \quad [1]$$

$$T_g(d,t) = T_m + A_{o,s} \cdot EXP(-\frac{d}{\Psi_p}) \cdot sin\left[2\pi \cdot \frac{t}{p} - \frac{d}{\Psi_p} - \frac{2\pi}{3}\right] \quad [2]$$

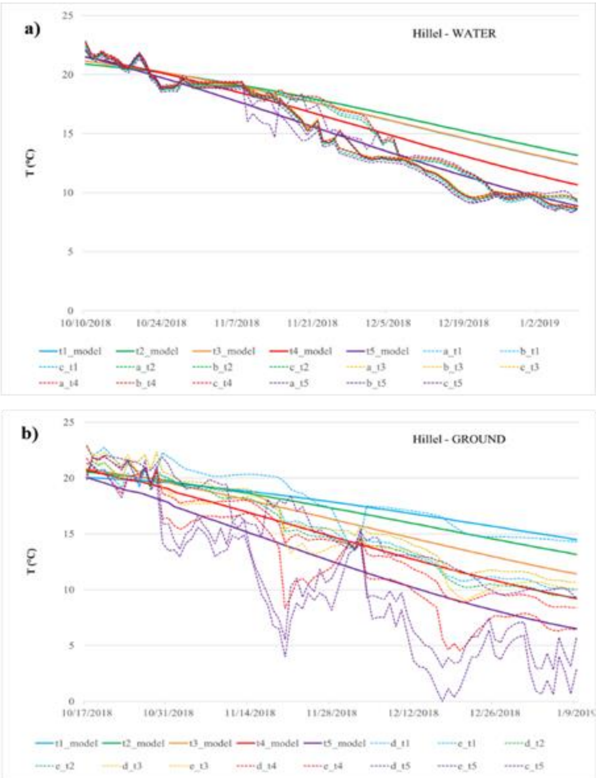
where:

- T_g – temperature of the ground, function of depth and time (°C);
- T_m – annual average external temperature (°C);
- $A_{o,s}$ – external temperature wave amplitude (°C);
- d – depth (m);
- p – period (days);
- t – time (days);
- t_0 – time of minimum external temperature (days);
- α_{eff} – effective ground thermal diffusivity (m^2/day);

Dumping depth $\Psi_p=\sqrt{(2\ \alpha_{eff}/\omega)}$ is the depth at which the annual temperature amplitude of the ground decreases to 1⁄e of surface air temperature amplitude and ω is period for sine function, ω=2π/p. The effective thermal diffusivity values were changed in order to fit the model with the real measured data. For the ground model, value of α_{eff} was chosen according to the soil composition on the test site, while for water model values of α_{eff} differ with layer depths depending on the differential contribution of PE top closure and of the advective heat transfer (Table 3).

Table 3: Preliminary results of calibration for values of αeff in the two models.

Depth (m)	α(m^2/day) A, B, C	α(m^2/day) D, E
0,4	0,01	0,035
0,8	0,02	0,035
1,2	0,025	0,035
1,6	0,035	0,035
2,0	0,070	0,035



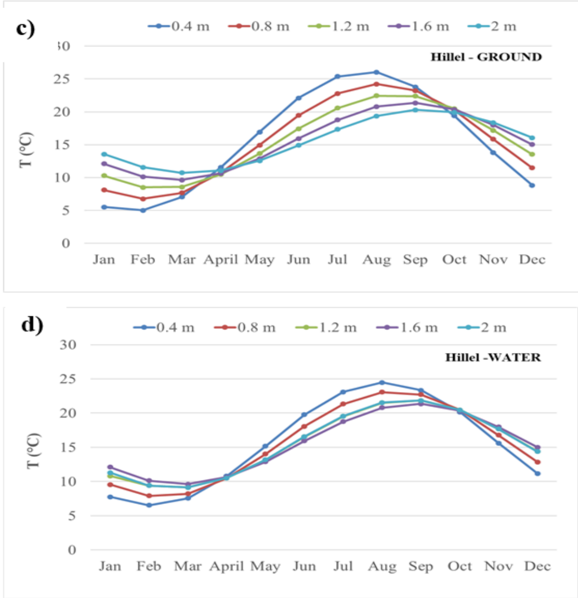


Figure 6: Models for describing annual temperature distribution on test site in surrounding environment of Spiral 1 and Spiral 2 (a) Comparison of Hillel's model for water environment and measured temp. values, b) Comparison of Hillel's model for ground environment and measured temp. values, c) and d) Hillel's yearly model of temperature distribution in ground/water).

Figure 6 presents the deviation of theoretical (model) temperature values from the measured ones, as well as a complete yearly model by Hillel's correlation, which appeared to be more accurate than Baggs' one.

3. RESULTS

M-TRT machine enables conducting TRT on both Spirals simultaneously in a way that outlet flow from M-TRT machine is divided into two equal inlet flows for Spirals. The measured temperature development during summer and winter TRT for Spiral 1 and Spiral 2 are shown in Figure 7. It is possible to discern the high impact of seasonal ambient temperature on measured values and how changing the power level has different effects depending on the season, as the possibility for natural thermal recovery are varying. The first power step in winter TRT was affected by some snowy days, which caused the decrease of the temperature (from 2nd to 5th day).

Theoretical extractable heating power depends on the difference between inlet and outlet flow temperature, specific heat of heat carrier fluid and its density. It is possible to observe bigger difference between inlet and outlet flow temperature for Spiral 1 in comparison with conventional Spiral 2 (Figure 7).

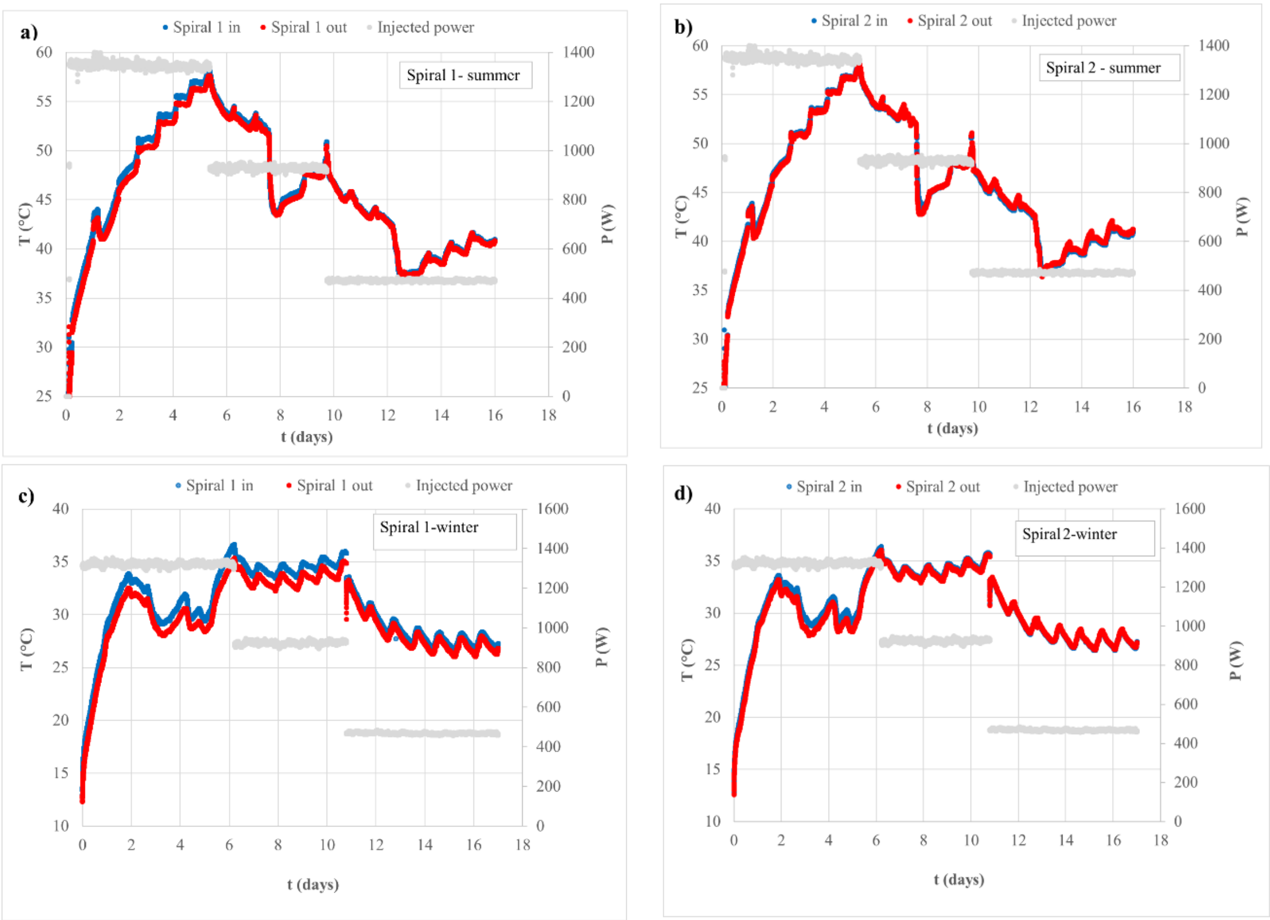


Figure 7: Monitoring data of two TRTs conducted on the test site (a: summer TRT, Spiral 1; b: summer TRT, Spiral 2; c: winter TRT, Spiral 1; d: winter TRT, Spiral 2).

Moreover, power of heat exchange was calculated and compared for each power step together with the forecast of long-term power behaviour. It was possible to have a preliminary estimation of the complete ground thermal saturation, with no heat exchange (Table 4 and Figure 8).

Table 4: Comparison of power levels at different working time (T_s – Static temperature of working fluid before 1st power step).

	Summer T_s = 24.8°C		Winter T_s = 12.9°C	
Time (h)	Spiral 1 (kW)	Spiral 2 (kW)	Spiral 1 (kW)	Spiral 2 (kW)
12	0.622	0.294	0.752	0.373
24	0.537	0.187	0.673	0.277
36	0.526	0.175	0.826	0.272
48	0.503	0.164	0.684	0.492
60	0.532	0.187	0.690	0.436
72	0.492	0.141	0.588	0.594
84	0.430	0.147	0.639	0.430
96	0.402	0.113	0.752	0.311
108	0.385	0.147	0.543	0.537
120	0.447	0.057	0.566	0.498

Innovative configuration of Spiral 1 proves higher capacity for heat exchange in general for all conditions. On the other hand, certain weather phenomena, like rain and snow, were causing heat recovery of surrounding ground higher in Spiral 2 than in Spiral 1, resulting with additional potential for heat exchange. One possible explanation is the thermal insulation effect of the casing walls of Spiral 1 from the external weather phenomena.

Comparison between the Spirals can also be conducted regarding the theoretical efficiency of heat exchange. Theoretical efficiency of the shallow geothermal system can be estimated considering the aiming temperature for cooling/heating and average temperature value of inlet and outlet flow of working fluid. A set of possible temperatures for cooling mode was assigned to calculate associated trend of theoretical efficiency for both systems. The selected period of analysis is the period of stabilization of theoretical efficiency. Temperature ranges of measured TRT data in winter season are narrower than in summer season hence the range of input temperatures in calculation is decreased. Due to measured increased heat exchange, Spiral 1 proves to be more efficient for cooling mode than the conventional Spiral 2 in both seasons (Figure 9). In summer season, Spiral 1 has 1.5 % - 2.5 % higher theoretical efficiency for cooling than Spiral 2 while in winter season theoretical efficiency for cooling is 5% - 10% higher in Spiral 1 than in Spiral 2. Although in winter season cooling mode is not useful in regular domestic applications, it can find a use in specific case studies with unconventional needs of heating and cooling, specially dealing with agriculture sector.

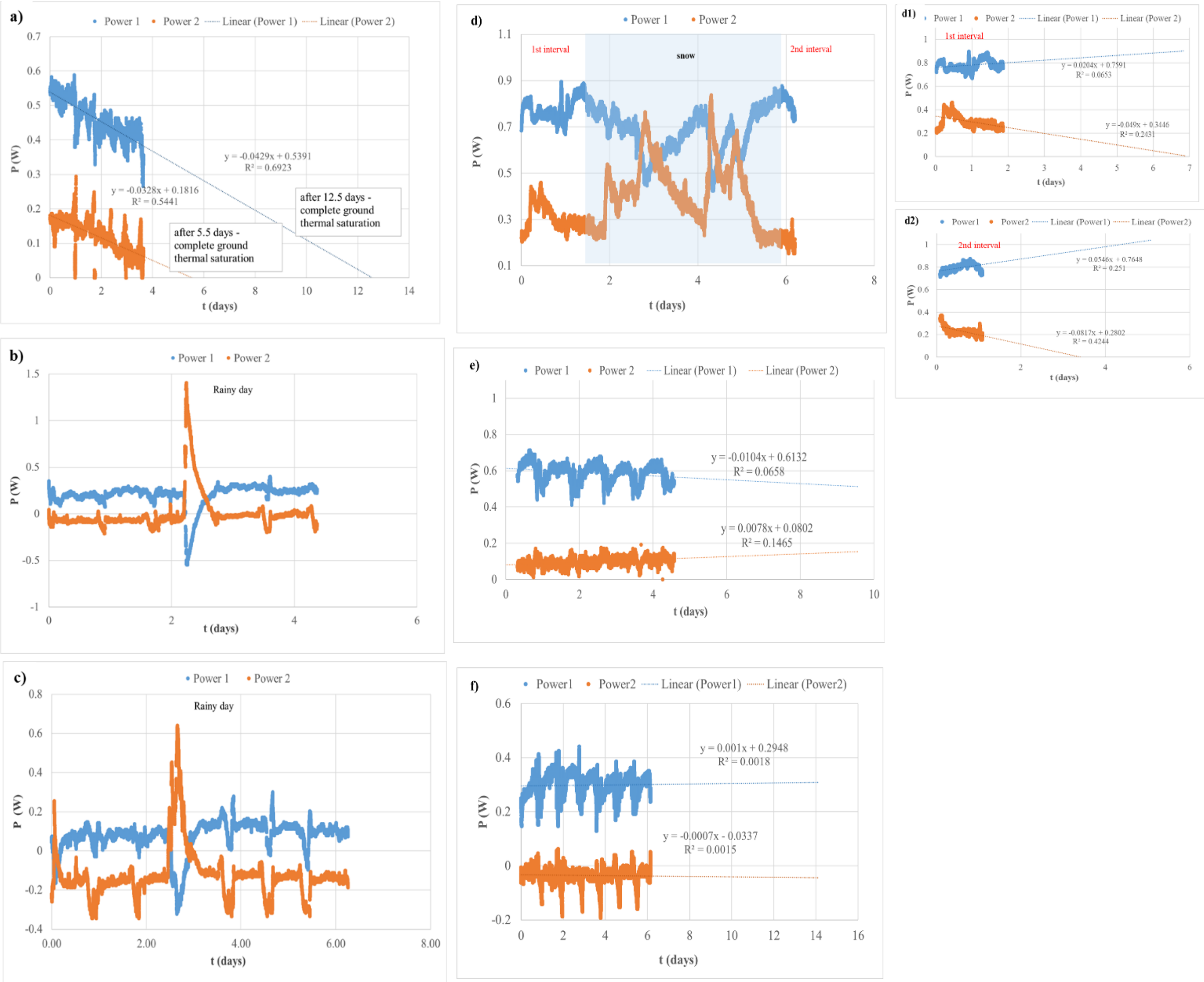


Figure 8: Analysis and forecast of heat exchange power for Spiral 1 and Spiral 2 during different power steps and seasons (a) 1st power step – summer; b) 2nd power step –summer; c) 3rd power step –summer; d) 1st power step – winter; d1) 1st interval of 1st step –winter; d2) 2nd interval of 1st step –winter; e) 2nd power step –winter; f) 3rd power step -winter).

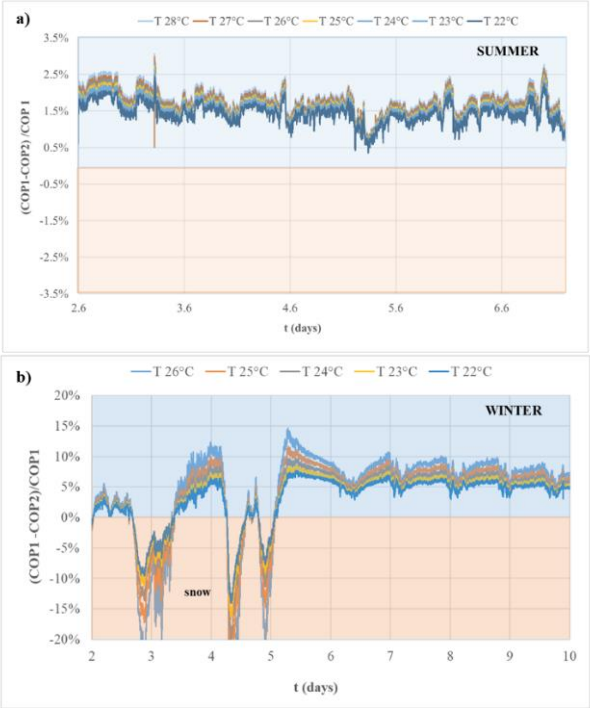


Figure 9: Theoretical efficiency analysis in a stabilized period of TRT (a: Summer TRT; b: Winter TRT).

4. CONCLUSIONS

The results of two thermal response test campaigns on a new configuration of geothermal Spiral and its comparison with the traditional one have been presented in the paper. The innovation of the new configuration resides in the installation of the Spiral inside a protective casing filled with a secondary fluid, buried in the ground. Because of the low depth of installation, the weather influence could not be ignored and the tests, in heating mode and lasting approximately four weeks, were conducted both in summer and in winter. A complete set of temperature sensors, in the ground, in the Spirals and in the fluid, was put in place in order to allow for the evaluation of the external factors influencing the behaviour of the two geothermal systems. Results showed how the innovative configuration achieved better heat exchange with the ground than the traditional one, with variable values but with peaks of improvement up to 200%. On the other hand, faster ground thermal depletion on the long term was neither observed nor forecasted. Possible explanations reside in the higher heat exchange area and the triggering of forced natural convection effects inside the casing. Weather phenomena, such as rain and snow, affected the results as well, with improved cool recovery. The experience done emphasised the value of convection phenomena in shallow geothermal systems and the importance of knowing and predicting the ambient effects. Experience revealed also how the installation procedures of the new configuration are similar to the traditional one, with the exception of the system size and its transport. On the other hand, the increase of weight allowed an easier stabilization of the geothermal exchanger in the ground. Further improvements are planned, in particular regarding the possibility of changing the secondary fluid filling the protective casing, for heat recovery purposes and to further increase the cooling efficiency of the system. Possible applications of this configuration are expected in the traditional residential and commercial sectors (especially in Southern Europe, with high cooling request), but also in the agricultural and breeding sector, where heating and cooling needs are substantial, not completely following seasonality, and usually correlated to high water usage and demand.

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