The trend towards medium-deep geothermal systems

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ABSTRACT

The medium-deep geothermal systems are becoming increasingly important for heating application considering the limited available space in urban areas and the trend to increased efficiency of the system with an annual performance factor of >5. Medium-deep geothermal system means increased demands on the quality of products as well as the installation of these systems.

Several medium-deep geothermal systems have already been successfully implemented in Zurich, Winterthur and Lausanne in different designs and put into operation. This confirms also the benefits of medium-deep geothermal systems in practice.

1. INTRODUCTION

Geothermal systems for heating and cooling of building are an important factor in order to save energy. The geothermal energy is available any time (any season, day and night) and everywhere. Therefore, no transportation is required because it can be used on side. However, the limited space situation in urban areas, require longer geothermal probes for the generation of the required power. Another important factor is the higher temperature in greater depths which results in higher efficient heating systems. This is the background to develop medium-deep geothermal systems with high performance and efficiency.

2. SITUATION IN EUROPEAN COUNTRIES

For European countries the average installed lengths of geothermal probes varies (Fig. 1). In Germany the average length is below 100m whereas in Switzerland more than 170m is achieved. Factors for the limitations are the drilling technology and experience including the material and installation process as well as applied regulations.

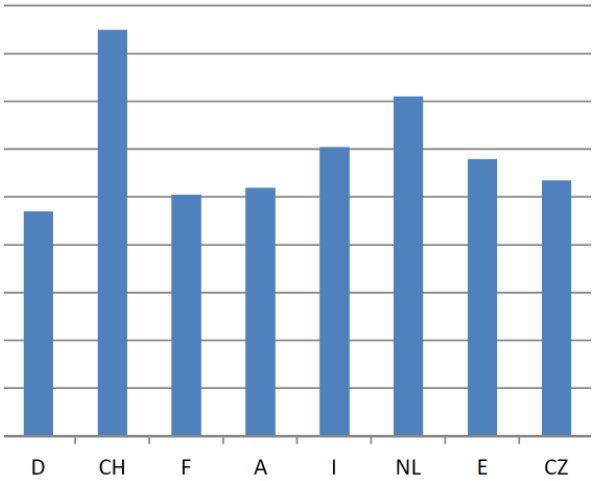


Figure 1: Average length of geothermal probes

3. TECHNICAL PARAMETERS

The design of a geothermal system using double-U probes depends on many parameters. One important parameter is the thermal performance of borehole. Another factor is the selection of the optimum double-U probe. In order to extract the power of the ground, a circulation of a fluid (normally mixture of water and glycol) is required. Longer geothermal probes provide a higher power which demands higher quantity of fluid. In order to achieve reasonable hydraulic pressure drops the design of the geothermal must be adequate. Assuming an average fluid rate (m/s) the pipe diameter of the double-U probe is 32mm up to 150m, 40mm up to 300m und 50mm up to 500m.

Taking into account a temperature difference of 4°K for flow and return and a reasonable fluid velocity a double-U probe with pipe diameter of 50mm is required for medium-deep geothermal systems (Fig. 2).

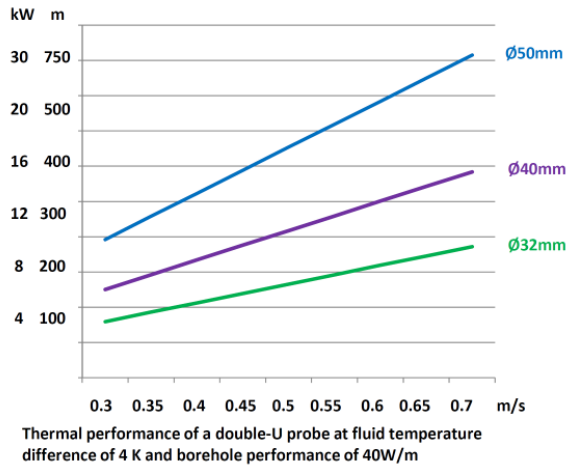


Figure 2: Application range of double-U probes

Important for the efficiency of the system is also the absolute temperature or the difference between temperature input and output of a heat pump. As higher the required temperature lifting is, as worse the COP (Coefficient of Performance). Increasing the absolute temperature only of +5°C provides a better efficiency of +15% (Fig. 3). Therefore, bring up higher temperature from the ground results in more efficient systems.

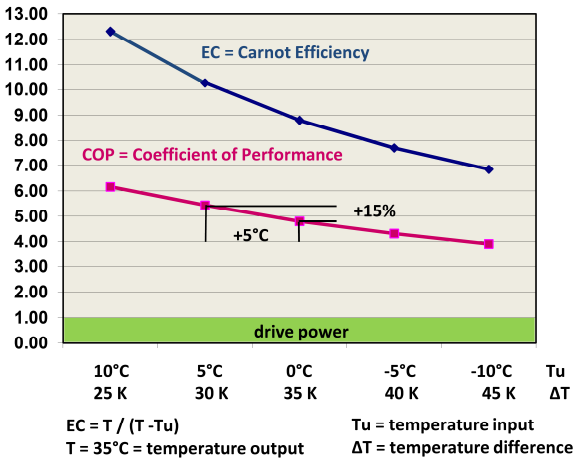


Figure 3: Efficiency of heat pumps

Evaluation of technical and economic considerations:

Technical requirements:
- small drilling diameter (geology, grouting)
- long probes (material / pressure rating)
- low hydraulic pressure drop (double-U, pipe diameter)
- long service life (quality)

Economic requirements:
- low cost grouting (thermal conductivity)
- short drilling (costs)
- tubes for geothermal probes with small diameter or single-U version
- good price / value for money
- easy transportation and installation

Taking into account all technical and economic aspects confirms that double-U probes PE 100-RC, design PN16 or PN 20 are optimal solutions.

4. GEOTHERMAL PROBES DOUBLE-U 50MM

Geothermal probes up to 500m are designed for a small borehole diameter of 156mm. The foot of the probe is small in order to achieve a diagonal diameter of 137mm. There is space for total 4 injection pipes of 32mm to be installed in different lengths. With this design the smallest possible drilling diameter is possible (Fig. 4)

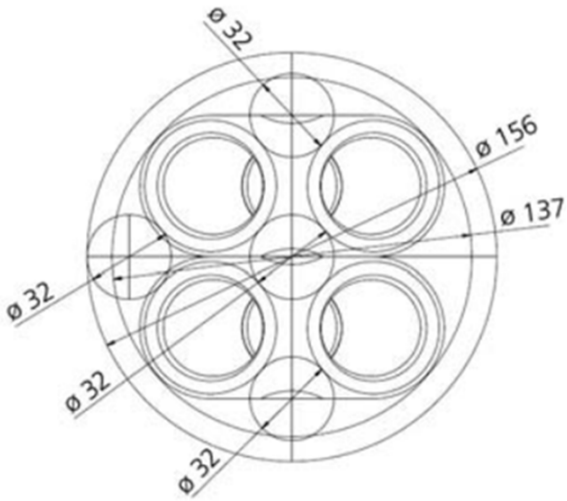


Figure 4: Cross section of double-U 50mm

The main features of this design are:
- geothermal probes length of 300m up to 500m
- production and delivery on reels
- transportation on reel in order to avoid damages
- installation in the borehole direct from reel
- Narrow borehole diameter of only 156mm for double-U probe and injection pipes

For an apartment building in Zürich the heating system has been refurbished with a heat pump. Based on the heat demand and due to the limit space for this project, three boreholes of 420m and double-U probes 50mm have been installed (Fig. 5, 6).

A complete quality assurance during production of the probe, a correct planning and careful execution the geothermal drilling including probe installation are a guarantee for a perfect functioning of geothermal overall system.



Figure 5: Geothermal probe on the reel



Figure 6: Foot 50mm

At CH-Lausanne the SIL «Services industriels de Lausanne» has decided to start a project with 8x500m geothermal probes. The background of this idea is to provide the heating power for the entire city from geothermal.

This project will give enough information regarding the geology, drilling situation and possible energy delivery.

The first three geothermal double-U probes of 505m Ø50mm have been successfully installed including fibre optic cables for temperature measurement. The temperature gradient was measured and found +26°C at 505m depth.

In addition the return of the probe is insulated on the top 120m (Fig. 7)

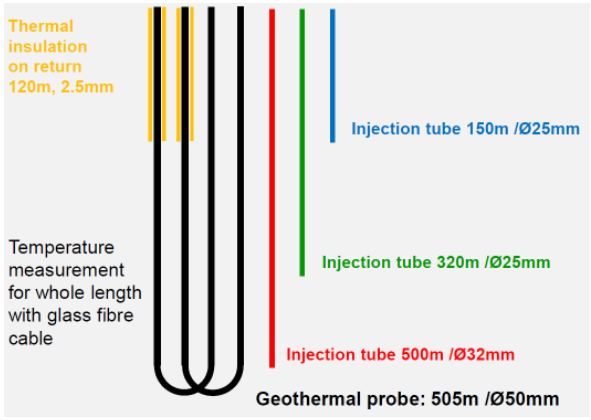


Figure 7: Installation scheme project SIL



Figure 8: Installation with probes on reels

5. GEOTHERMAL PROBES PN 20

Especially in difficult geological conditions the geothermal probes with pressure rating PN 20 are suitable and provide additional security for the planers and the builders.

In addition to safety in long-term behaviour geothermal probes in PN 20 provide more opportunities during erection. The greatly improved outside pressure behaviour also allows the introduction of heavier grouting material, which is increasingly used to enhance the thermal conductivity.

Comparison of the thermal performance PN 16 vs. PN 20 of the shallow geothermal systems has been performed by tewag, dated July 23rd, 2012 (Table 1).

For the calculations the following parameters have been used:
- length of probe: 195m
- spec. extraction rate: 43W/m
- brine flow rate: 2.5 m3/h
- heat transfer medium: 25% ethylene glycol - water

Table 1: Comparison of thermal performance

Criteria	PN 16	PN 20
Borehole thermal resistance with optimal positioning of the geothermal probe pipes	0.105 (mK/W)	0.110 (mK/W)
Temperature differences between the flow and return at an extraction rate of 43W / m	4.3 K	4.0 K
COP (coefficient of performance) of heat pump	4.6	4.5
Hydraulic pressure loss for a probe	473mbar	601mbar
The seasonal performance factor is slightly reduced, taking into account the slightly higher power consumption of the pump	4.50	4.46

Several medium-deep geothermal systems have been successfully implemented in Switzerland in various designs and put into operation Fig. 9). It also shows the advantages of the medium deep geothermal systems in practice (Table 2).

Table 2: Comparison of geothermal probes

Criteria	PN 16	PN 20
Inside pressure behaviour according to DIN 8074 (HR 3.26/A 278)	16 bar (foot 20 bar)	20 bar
Outside pressure behaviour at 20ºC and 24h	14,1 bar	27.2 bar
Flow cross-section	834mm2	754mm2
Foot dimension / diagonal dimension for double-U 40mm geothermal probes	112mm (Figure 3)	
Role dimensions / packing	identical	
Compatibility	Compatible with GEROtherm® system (Y-pipes, electric welding couplers, GEROtherm® -Push, etc.) (Figure 4)	
Product certificate / traceability according to EN 10204 2.2	yellow etiquette	light blue etiquette



Figure 3: Small double-U foot PN 20



Figure 4: Push and protection sleeve



Figure 9: Installation of geothermal probes at CH-Winterthur, 42 x 305m DE 40mm / PN 20

6. QUALITY REQUIREMENTS

The entire quality chain from planning to the execution must be considered. Installation criteria and quality assurance on site of medium-deep geothermal systems are the most important factor.

Most important points to be considered:
- medium deep geothermal probe requires high standards for the drilling, installation, and material.
- the probes are during installation and later during operating exposed to high loads.
- high quality of the geothermal probes is a condition.
- for geothermal probes it should be considered 100% control from raw material to the finished product
- continuous testing / certification of all the parts (Pipes, foot, welding, etc.)
- documentation for clients / authorities:
  - product certificate
  - installation certificate

After installation of geothermal probes it is essential to insure the quality of the workmanship with:
- pressure test with certification
- flow test with certification

7. CONCLUSION / OUTLOOK

The costs for primary energy will increase and therefore systems with high efficiency are required. Geothermal systems using heat pumps for heating and cooling provide the best efficiency and are therefore suitable for the future. The key is the system optimisation considering all parts (e.g. heat pumps, geothermal probes, etc.). A system certification regarding the overall efficiency (e.g. energy labels A, B, etc.) would help to support the application of geothermal energy.

Many successful geothermal systems confirm already today the economical operation. With medium-deep geothermal systems the economic will improve and the application in urban areas will increase.

Summary:
- the trend is towards medium-deep probes
- the combination heating and storage on a higher temperature results in more efficient installations
- systems achieve a better SPF (seasonal performance factor) and are therefore more economical
- especially in urban areas is due to the limited surface, depth required
- drilling equipment and geothermal probes are being developed for the required depths

Outlook:
Geothermal systems will continue to develop positively thanks to high reliability and economic aspects.