JANSEN hipress: New technologies for deep geothermal probes (for heating and cooling purposes)

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ABSTRACT

With deep geothermal probes, the energy requirements of large construction projects can be covered efficiently even with limited space. Developments in this direction have been taking place in many European markets for years. For example, in Switzerland many boreholes for geothermal energy use for heating and cooling purposes with depths of 350 m, 400 m or even deeper are drilled every year. However, the drilling depth also rises the demands on men, material and machinery. Previous technologies for geothermal probes are reaching their limits. Developers are looking for more reliable products that offer easy installation and forecastable results. How can geothermal probes for heat pumps with drilling depths > 300 m be planned and realized both safely and economically? The company Jansen from Oberriet is an expert in the development and production of geothermal systems. The new JANSEN hipress deep geothermal probe is the answer to these challenges and opens up new application possibilities.

1. INTRODUCTION

1.1 The underground as an energy source

The earth is an enormous energy storage. As the earth's temperature rises as you get deeper, the energy demand of high-rise construction projects and densely populated areas can be efficiently covered with deep vertical borehole heat exchangers even in situations with limited space availabilities, where not an unlimited number of boreholes can be deepened.

Up to a depth of around 20 meters below surface the temperature fluctuates depending of the time of the year. Below this point, the temperature rises by around 1 K (Kelvin) every 30 meters, depending on the local geothermal gradient. At a depth of 400 meters, this effect leads to a ground temperature of approximately 24°C (Fig. 1)

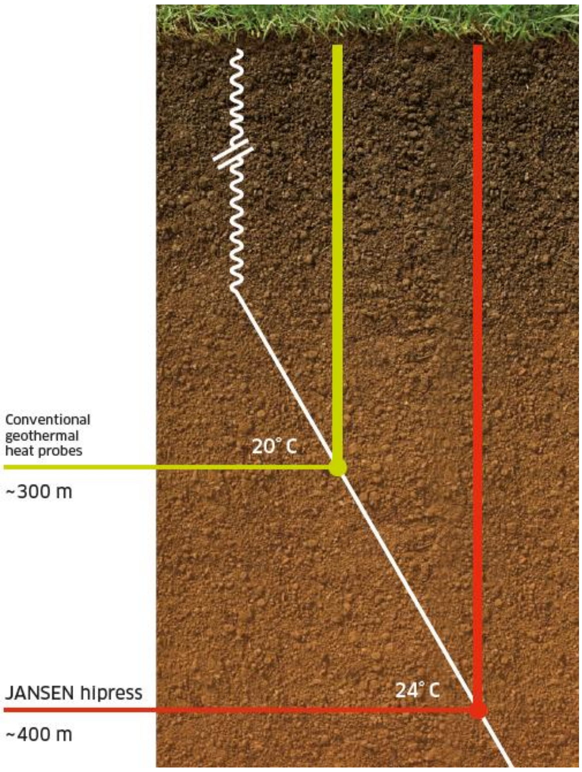

Figure 1: Higher temperatures in higher depths.

High temperatures at greater depths mean a greater energy reservoir and, at the same time, improve the efficiency of the heat pump. Thanks to the deeper borehole, the geothermal loop offers a larger heat exchanger surface, which can absorb more energy. Besides of the focus on geothermal heat pump systems for heating, cooling, and providing hot water, higher temperatures offer a variety of new application possibilities.

The Lindal diagram (Baldur Lindal, 1918-1997) shows the required temperature level of thermal processes (Fig. 2). These temperature levels can be achieved by using intermediate heat pumps, however, with deeper boreholes and therefore higher return temperatures of the heat carrier fluid, the direct use of the available heat gets a bigger meaning. The advantages are clear: higher overall system efficiency, lower system complexity, lower investment costs, higher profitability. New accessible direct applications include: air preheating, defrosting and cold protection of warehouses, factories, and similar facilities, de-icing of traffic areas and airports, process heat for industry processes, fermentation, and aquaculture, balneotherapy pools & spas, as well as direct underfloor heating.

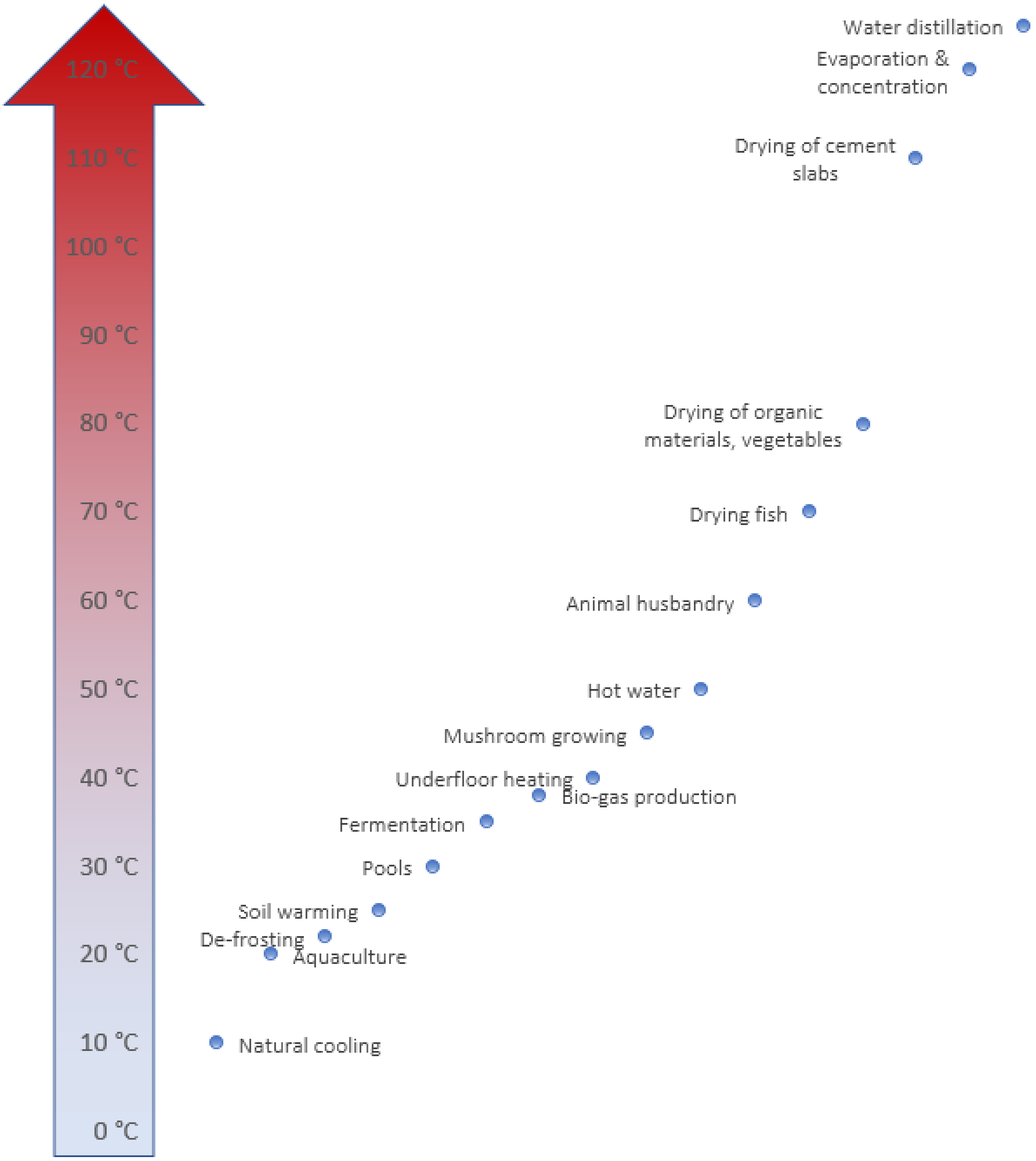

Figure 2: Lindal diagram, Data Source: BVG, Graphic: Pernter

1.2 Introduction into the paper topic

JANSEN hipress claims to be the strongest geothermal probe on the market. It withstands pressure demands up to PN35. It comes with a patented plastic/metal multilayer structure and a reinforced probe foot. Newly developed fabrication and welding technologies, especially for this application, lead to absolute safety, and long-lasting products.

At the same time, deep geothermal probes need to show at least the same economic feasibility as standard geothermal probes. Therefore, it was a key goal in the development of this new geothermal probe technology, that the installation into the borehole needs to be safe and easy, and the production costs of the probe material need to stay low. Furthermore, the thermal and hydraulic characteristics of the whole ground loop system need to be considered.

The main questions that are going to be answered in this paper are:

- How can deep geothermal probes be planned and realized successfully, safely and economically, even under difficult geological conditions? What is best practice?
- What were the main questions in the development of the JANSEN hipress and how can they be answered by the final product?
- Does the practical application show the desired ease of installation and the aimed success?

2. PROBLEM STATEMENT

2.1 Status quo

For geothermal probes deeper than 200 m, the pressure rating and the hydraulics are of increasing importance.

The built-in probe product has a certain pressure resistance, which theoretically limits the overall installation depth. The limiting factor is the long-term pressure resistance to the internal water column. For example, a typical nominal pressure rating of PN16 leads to a nominal length of up to 160 m, however, geothermal probes in context with the borehole and its backfill represent an overall structural entity. For this reason, PN16 pipes have been successfully installed in greater depths for years. In addition to the stabilizing factor of the backfill, the nominal pressure rating also includes a safety factor. Nevertheless, there are higher risks if the nominal length is exceeded, in case if the continuity and compactness of the backfill cannot be guaranteed over a longer period of time. According to many relevant standards and guidelines, for example the SIA 384/6 (2010), geothermal systems are to be designed for an operating period of at least 50 years. This means that geothermal probes with PN16 can certainly be used at greater depths than 160 m, but at some point, they are no longer recommended. For a drilling depth of 300 and more meters, for example, they definitely not correspond to the current state of the art any more.

2.2 Previous solutions

The previous solution for ensuring higher pressure levels was to equip the geothermal probe tubes, made of plastic, with a higher wall thickness (Fig. 3). There comes the second challenge: Thicker walls lead to a smaller hydraulic cross section. At the same time, deeper geothermal probes are operated with higher absorption capacities and thus higher volume flows. This increases the hydraulic resistance (head loss) and at some point, depending on some boundary conditions, causes the needed circulation pump capacity and power consumption to increase disproportionately and unreasonably high.

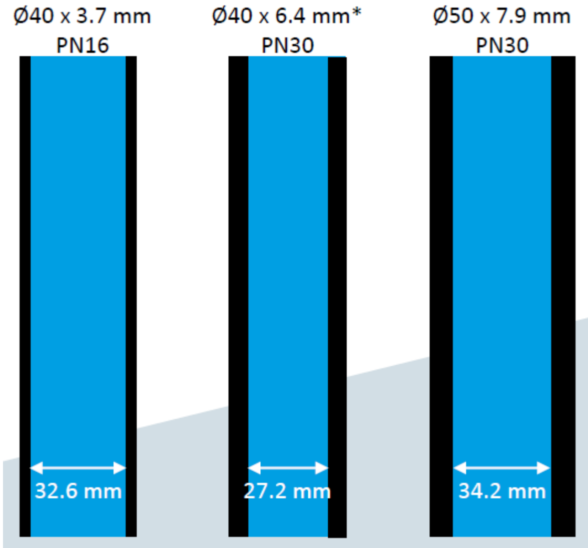

Figure 3: Typical probe pipe dimensions and wall thicknesses for probe lengths >200 m. *6.4mm is a theoretical wall thickness value for 40 mm pipes with PN30 and not commonly available.

A common solution for this problem was to increase the probe pipe dimensions. Instead of using 32 mm or 40 mm pipes, 50 mm pipes came into use. A practical example for this approach is the geothermal field for the city center of Uster, Switzerland. A corresponding project report was published by Jansen (2017) (Pict. 1). Such a solution is practicable and working, however, there are some disadvantages. On the one hand, the thick-walled pipe material is relatively expensive to manufacture. Accordingly, the product price is high. On the other hand, the larger pipes require a larger borehole diameter. And finally, more expensive installation tool is needed, for example, large or multiple bobbins. There are also disadvantages on the thermal side. The thicker the pipe wall is, the higher the thermal resistance, and thus the lower the achievable absorption capacity.

Picture 1: JANSEN vertex 50 mm double-u loop installation into borehole field in Uster, CH.

Another approach is the manufacture of conical pipe walls instead of cylindrical pipes. This means that for the upper part of the probe, pipes have a pressure rating of PN16, and gradually get thicker up to a pressure rating that corresponds to the final installation depth (Fig. 4). The idea is good so far, as it saves raw material in the upper area of the probe, has a larger hydraulic passage than in the lower area and yet the lower area has the necessary wall thickness for the high internal pressure. Still, there is a thick-walled area with high hydraulic resistance, reduced thermal conductivity and high material costs.

Figure 4: Conical pipe designs still have the disadvantage of a thick-walled area with high hydraulic resistance, reduced thermal conductivity and high material costs.

Large coaxial probes are another approach, but many engineers discard this because of the extremely high cost, difficulty of installation, and the existing thermal shortcut between internal and external fluid.

This leads to the question: What alternative solution is there to plan and implement deep geothermal probes successfully, safely and economically?

3. PRESENTATION OF THE JANSEN HIPRESS GEOTHERMAL PROBE SOLUTION

3.1 Development

With more than 60 years of experience in the development and manufacture of innovative plastic pipe systems since 1955, Jansen, as a Swiss industrial business, stands for both the highest precision and pioneering high-tech solutions. Thanks to intensive research, Jansen could find a solution for the above mentioned problems.

For the development it was necessary to combine several disciplines: plastic pipe extrusion, multilayer metal reinforcement, welding technologies and 3D metal printing. The outcome is the world’s first series-produced deep geothermal high-pressure loop: JANSEN hipress (Pict. 2).

Picture 2: JANSEN hipress double-u deep geothermal probe PN35.

The pipe with a pressure resistance of 35 bar is built up in 3 layers: PE100RC, aluminium in the middle, and another PE100RC layer. Overall, it has a diameter of 42 mm and a wall thickness of only 3.5 mm.

The probe foot comes with a metal case as a reinforcement. The probe foot and the high-pressure pipe are welded together in factory. For this purpose, a special double-socket welding technology was developed. Both the inner and the outer plastic layer are welded together with the moulded probe foot.

The upper part of the probe consists of regular 40 x 3.7 mm PE pipes. This allows the double-U probe to be connected horizontally, for example with regular electrofusion fittings. The transition between the high-pressure pipe and the regular PE pipe is also realized by means of the above mentioned double-socket welding.

3.2 Advantage: Pressure requirements up to PN35

With its metal multi-layer design and the high-pressure probe foot with a metal jacket, JANSEN hipress withstands the highest pressure loads and raw construction site conditions. The double-socket welding process, developed in-house, stands for absolute safety.

3.3 Advantage: Minimal hydraulic resistance

The cylindrical pipe structure offers minimal head loss. The inner diameter of the high-pressure pipe is consistently 35 mm, from the connection on the top to the probe foot on the bottom. This represents the lowest hydraulic resistance available in relation to the required installation diameter – the absolute front-runner on the market.

3.4 Advantage: Small installation diameter

With a pipe outer diameter of 42 mm, JANSEN hipress has almost the same installation diameter as a conventional 40-mm-double-U probe: 128 mm (Fig. 5). With the JANSEN adapter for displaced probe foot fixation, the effectively required installation diameter can be made even smaller: 123 mm (Fig. 6).

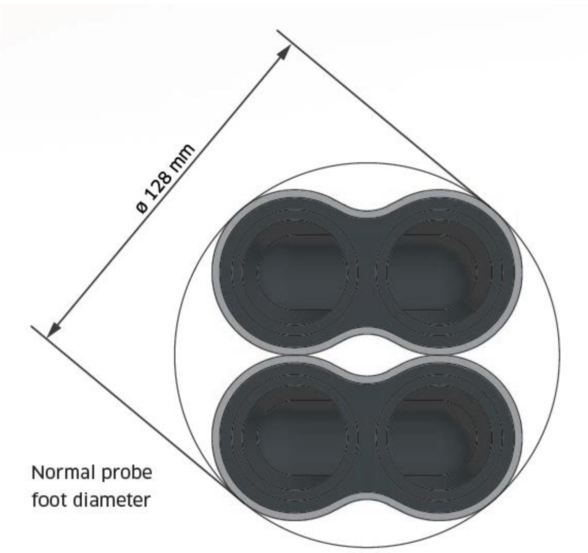

Figure 5: Small installation diameter.

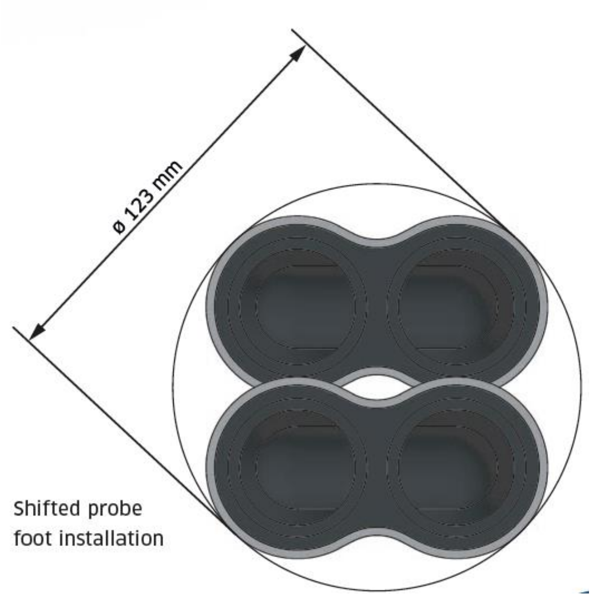

Figure 6: Even smaller installation diameter with the displace probe foot fixation.

3.6 Advantage: Highest heat transition

The highly stable pipe wall design with the metal core can manage with a thickness of just 3.5 mm. This minimises the heat resistance and, thanks to optimum heat transition, ensures an efficient use of the existing geothermal energy. Here, too, JANSEN hipress beats every conventional double-u borehole heat exchanger (Fig. 7).

	Ø42 mm PN 32 Kunststoff	Ø42 mm PN 35 JANSEN hipress
Innendurchmesser	28 mm	35 mm

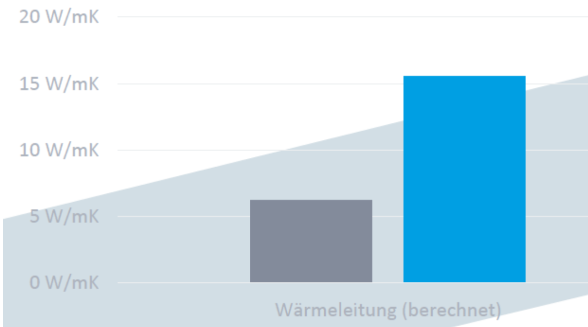

Figure 7: The JANSEN hipress pipe offers about 3 times the heat transfer compared to a conventional plastic pipe with the same nominal pressure resistance. (Note: Heat transfer coefficient k_2, in W/mK)

3.7 Advantage: Diffusion resistant

In the geological context, the diffusion-tightness of geothermal probes is discussed again and again. In this phenomenon, called diffusion or permeation, the entry of gases into the system through the pipe wall causes system problems. So far, there are hardly any practicable or economical solutions.

Gas deposits in the underground can mainly be natural gas / methane gas, carbon dioxide, air / oxygen, and others. Normal PE pipes, including PE-RT and PE-X pipes, are not diffusion-tight against the gases mentioned. This means, the gas inlet through the closed pipe wall is faster or slower depending on pressure, temperature and pipe wall thickness. Even other measures, such as additional EVOH barrier layers, offer no security against all occurring gases.

Only a metal layer like in the JANSEN hipress guarantees the desired diffusion resistance for geothermal systems. As a diffusion barrier, the metal interlayer of the JANSEN hipress probe prevents the intrusion of gases through the pipe walls and guarantees a permanently danger and trouble-free operation.

3.8 Advantage: Usual handling

The double-U loop is separable, suitable for all conventional installation methods, and can be decoiled from classic installation device. The universally linkable JANSEN probe weights are compatible.

3.9 Production technologies

The newest production facilities have been set up in order to manufacture the multilayer pipe. The probe foot is fabricated with the latest 3D printing methods. Thanks to state-of-the-art technologies and highly qualified employees assembling the probe, Jansen ensures a long-lasting product. The continuously high quality is ensured by the careful selection of materials used as well as continuous monitoring, which exceed the latest international standards.

The production process also allows for the new JANSEN shark pipe inner surface to be implemented. This technology imitates the riblets on the shark's scales in order to further reduce the hydraulic resistance of circulating fluids. More information about this technology is available at www.jansen.com/shark.

3. CONCLUSIONS

For geothermal probes deeper than 200 m, the pressure rating and the hydraulics are of increasing importance. The thermal performance as well as the ease of installation should also not be disregarded.

The JANSEN hipress geothermal probe is the ideal solution with a pressure resistance of 35 bar. It is particularly suitable for increased pressure requirements and difficult geological conditions. It impresses with low hydraulic resistance, high heat transfer, a minimum installation diameter of 123 mm, and full gas diffusion resistance. The multi-layer structure with metal reinforcement, selected materials, monitored production processes, as well as the patented JANSEN double-socket welding technology and the metal case at the probe foot stand for absolute safety and longevity. Installation can be carried out with classic drill rigs and standard probe decoilers. The JANSEN hipress probe is delivered ready for installation and enables the economic use of high temperatures in greater depths. The huge, clean, renewable energy storage is ready to be explored. JANSEN hipress: safe, economical, and the most powerful series-produced borehole heat exchanger in the world.

More information about JANSEN hipress is available online at www.jansen.com/hipress

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