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**ULTRA DEEP DRILLING TECHNOLOGIES
FOR GEOTHERMAL ENERGY PRODUCTION**

Dipl. Ing. Ivan Kočíš, CSc., Dipl. Ing. Tomáš Krištofič
Geothermal Anywhere Bratislava, Slovak republic

ABSTRACT

At present, society and economics handle two main global ranges of problems in the long term, namely: 1. Energy - increase of energy carrier prices, impaired safety and self-sustainability, reduced imports, replacement by own resources. 2. Environment - environmental hazard due to climate changes, increasing level of emission gases, fight with CO₂ in production of energies. With serious approach of governments to the above problems, both factors evoke imperative demand of technologies for production of ecological energies, primarily of electric energy.

Substance of the presented research and development is the technology for realization of geothermal bores approximately 8 to 10km deep. In such depths, rock temperature reaches 200°C to 400°C practically all over the world. In this depth, thermal capacity of 1km³ is about 1017J (when cooled down by 100°C); this is comparable with annual demand for Slovakia. With real consumption of approximately 20 to 40MW the capacity of the same bore would be sufficient for several hundreds of years. Deep geothermal energy is available anywhere, there are no emissions (CO₂), represents serious candidate for base load 24/7 electricity production and is scalable according to the local needs. The main obstacle for utilization of the vast energy reserves is price rising exponentially per 1 km of bore depth in present-day boring technology. Costs of such bores cannot be considered as a basis of repeated projects in most territories of the world. Thus, intense research and development of new deep drilling technologies is necessary. There are approximately 25-30 researched drilling technologies, but none of them gave desired economic and technical parameters for 5-10km depth. The technology must be compatible with extreme conditions at such depth (pressure up to 1000 bar and temperature between 400°C and 600°C) and very hard rock like granite. Presented radically innovative concept of drilling and transport of energy and material is protected by patents and being a basis of a know-how based upon innovative utilization of proven technologies. The method is suitable primarily for extreme pressure and temperature conditions, and has all pre-requisites to meet the basic requirement – linear price growth with bore depth. The concept was presented during Conference of the 6th EU Framework Programme "Engine", aimed at ultra deep geothermal energy and related research within future 7th Framework Program projects. The concept aroused considerable attention and interest in participation in future projects.

INTRODUCTION

The latest MIT (USA) study "The Future of Geothermal Energy – Impact of Enhanced Geothermal Systems (EGS) on the United

States in the 21st Century" (2006) points out the essential importance of developing an economical deep geothermal boring technology. With current boring technologies, bore price rises exponentially with depth. Thus,

finding a boring technology with which the bore price rise would be approximately linear with increasing bore depth is an important challenge. In his presentation, Jefferson Tester, a co-author of this study, characterizes the requirements on new fast and ultra-deep boring technology as follows:

- the price of boring rises linearly with depth
 - bore axis with neutral floating
 - the possibility to make vertical or inclined bores up to 20 km deep
 - the possibility to make large diameter bores – even 5 times larger than on the ground compared to today drilling technologies
 - casing formed on site in the borehole
- There are above twenty innovative boring technologies of different maturity and degree of proving. Referring to state-of-the-art of the technique, only the most promising technologies will be described, as well as those which are now being proved. The technologies can also be evaluated with respect to properties such as specific energy required to extract one cubic centimeter, maximum output applicable at borehole bottom, or maximum achievable boring speed. The following examples of extrapolation solutions, which still do not have the properties of radical innovation necessary for deep geothermal systems, can be quoted:
1. Rotary drilling systems
 - Boring by help of rotary casing (TESCO CASING DRILLING).
 - The technology applying composite coil piping with electric line for drive (HALLIBURTON/STATOIL- ANACONDA).
 2. Spallation - considerable progress towards significant innovation is shown in US Pat 5771984 authored by Jefferson Tester et al.: "Continuous drilling of vertical boreholes by thermal processes: rock spallation and fusion", where energy for the boring equipment on the bottom is supplied by pressurized water for borehole flushing, and that for turbine drive and production of electric energy required for the boring proper is generated by help of thermal rock spallation or fusion. This invention is the basis for Potter Drilling LLC Company, where prototype tests are underway already. At Tel Aviv University, Jerby et al. described rock spallation by local microwave overheating in

Journal of Applied Physics 97 (2004). The technology is applicable to very small volumes so far.

3. Plasma – example of plasma jet rock cutting is described in US Pat 3788703 authored by Thorpe; however, removal of crushed rock is not covered.

4. Erosion - most patents refer to water jet rock cutting. Different modification variants are described, e.g. utilization of cavitation, turbulent processes, combination with mechanical processes, etc. For example, US Pat 5291957 describes the water jet process combined with turbulent and mechanical processes.

5. Laser - during the recent decade intense research has been made into utilization of high energy laser beams for rock disintegration. Primarily conversion of military equipment is concerned. Laser energy is used for the process of thermal spallation, melting, or evaporation of rock. The patent by Japanese authors – Kobayashi et al.: US Pat 6870128 Laser Boring Method and System describes laser boring with the light beam carried from the ground to the borehole bottom via optical cable. The system evaporates rock, and thus high energy demand results. In the paper Laser Spallation of Rocks for Oil Well Drilling, published in Proceedings of the 23rd International Congress on Applications of Lasers and Electro-Optics 2004, Zhiyue Xu et al. describe thermal spallation method which is more advantageous as to energy, but crushed rock is being removed by help of classical flushing.

6. Electric discharge - The methods utilizing electric discharge are based on long-term experience gained in other application areas. The method described in US Pat 5425570 by G. Wilkinson is based on combination of electric discharge and subsequent explosion of a small dose of explosive or induced aluthermic process. In the paper "Pulsed Electric Breakdown and Destruction of Granite" published in Jpn. J. Appl. Phys. Vol.38 (1999), 6502-6505, Hiro-toshi et al. describe successful use of electric discharge on granite, a typical geothermal rock. There are under way more than 20 several research efforts solving innovative drilling technology such as: laser, spallation, plasma, electron beam, pallets, enhanced rotary, electric

spark and discharge, electric arc, water jet erosion, ultrasonic, chemical, induction, nuclear, forced flame explosive, turbine, high frequency, microwave, heating/cooling stress, electric current and several other. No one from these until now proved to be effective in severe conditions and no one is solving the problem in complex including the energy and material transport from 5 to 10 km technically and economically. We selected two possible drilling approaches, influencing the type of source of power according to the technologies for crushing the rock in extreme physical conditions of high temperatures (300°C - 400°C) and high pressures (to 1000Bar). After extensive analysis of over 20 technologies, emphasizing their compatibility with physical surrounding conditions resulted in narrowing the technologies substantially to water jet technologies and electrical discharge technology which have together with mechanical crushing the best energy efficiency per crushed cm³.

WHAT IS DIFFERENT FROM CURRENT „DRILLING-ONLY“ TECHNOLOGIES?

Process of rock disintegration is the most important when drilling ultra deep borehole, but not the only one contributing to the exponential price. Therefore completely new approach should be considered. That is also substantial difference between Geothermal Anywhere drilling concept and mentioned drilling technologies. In its research stage, the Ultra deep drilling technology handles the issues of innovative boring technology for 5-10km depth.

Unlike standard boring, the chosen patented concept does not use boring piping which has high energy demand in depths above 5km.

Exchange of boring heads is rather expensive and time consuming. Similarly, transport of extracted rock is rather energy demanding. Above 4km the bore price grows exponentially, not linearly.

Due to economic and the above-mentioned reasons, present technologies are not feasible for extraction of thermal energy from great depths. The presented system is a set of research activities, development of critical aggregates, proving correctness of the concept,

and preparation for the industrial development stage which should serve the application aspect.

The purpose of the project is to research all critical parts up to the level of functional laboratory samples. Sufficient background data for further industrial development should be provided. On the basis of the results obtained in technological parts of the solution, the project is assumed to give technological proof of the whole concept.

WHAT ARE THE INNOVATIONS OF THE CONCEPT?

Ultra deep drilling technology reflects innovative approach to several parts of the system: **The first innovation** of the presented system is the technology based upon the principle of transporting energy downwards to the rock cutting aggregate and extracting rock upwards to the ground applying the principle of uplift vessel – transport container which can move in both directions. **The second innovation** is in the drilling technology itself composed of proved water jet cutting technology modified for physical conditions of the bore driven with high pressure applying the principle of repeated detonation, similarly as in combustion engines; with the difference that water itself acts as the piston. For special purpose use of electric discharge rock cutting method will be used. Technology is compatible with aquatic environment in the bore. **The third innovation** is casing building and formation directly in the drilled hole parallel with the drilling process ensured by special concrete mixture for such extreme conditions. **The fourth innovation** is autonomous robotic platform with the control system working at high temperatures (300°C - 600°C) and high pressures (up to 1000 bar) down hole.

The Geothermal Anywhere's radical innovative patented concept solves:

- Transport of energy to the drilling process
- Transport of disintegrated rock towards the surface by positive buoyancy
- No physical connection between ground and underground base station
- Solution suitable for any depth of drill hole
- Building of casing in hole parallel with drilling
- Energy-saving cutting and transport of

mined rock

□ Speed of overall process

HOW IS THAT POSSIBLE?

The innovation concept is able to integrate the proven technologies compatible with high temperatures and pressures using the combination of chemical energy source for both – producing the needed form energy and for enabling the buoyancy effect for transport. The rock crushing technologies will be used in synergy of mechanical, electrical discharge and water jet in appropriate alternatives which will be the subject of technology feasibility study and proof of the concept research and experimental work. This radical innovative method that avoids the inherent limitations of conventional rotary drilling and material transport Complexity of the problem, harsh environment in which the targeted technology shall work and the radical innovation concept, requires gradual approach to the research, development and realization of the whole system.

THE STRUCTURE OF THE INNOVATIVE DRILLING SYSTEM

The system is comprising from the - Underground drilling module - Surface base - Borehole filled with water - Transport containers

THE PROCESS OF DRILLING THE BOREHOLE.

- The container is filled inside surface base with the required load for the down hole boring process and the resulting total specific weight is greater than 1, which causes that container is “falling” down in the surrounding water until it is connected to the drilling module on the borehole bottom.
- The process of drilling continues with new charge of fuel.
- Combustion and/or detonation process delivers the appropriate form of energy as high pressure water and mechanical impact erosion. The high pressure water then is through a set of specialized nozzles delivered to the rock

surface.

- In the second alternative solution the combustion process through special but standard turbine produces electrical energy for electro impulse discharge erosion of the rock.
- The sequences are controlled by control unit which is able to work in high temperatures and pressure.
- The combustion gases are after some additional functions connected with cleaning and conditioning the working place collected in the container. In the container there is simultaneously loaded the crushed rock by hydraulic means inside drilling module and container.
- Inside container the hot gasses and with additional explosive dose will bring the total container specific weight to less than 1.
- The container after disconnection from drilling module will be lifted by buoyancy forces to the surface. In the process of rising to the surface the surplus pressure of gases will be used for additional drive and lowering the overall friction.
- The process is repeated and continuously the energy is brought down and crushed material up.

ULTRA DEEP DRILLING TECHNOLOGY - GEOTHERMAL ENERGY REVOLUTION ENABLER.

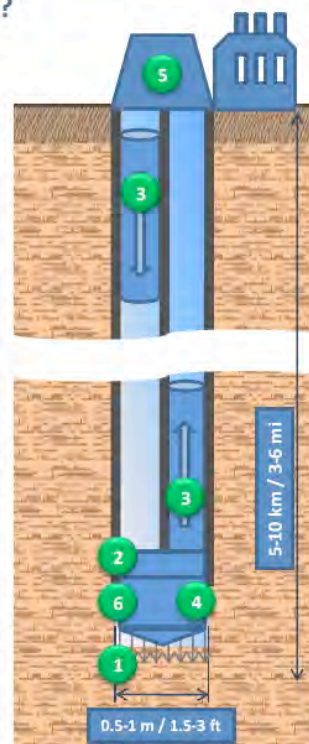
Realization of the Ultra deep drilling technology will open the way to thermal energy resources to be used for production of electric energy without greenhouse gas emission and with zero operation costs of fuel. The current status of electric energy production is based upon fossil fuel, is not compatible with reduction of emissions, and, moreover, is not resistant against increase of prices of crude oil and gas in the world, and of those of nuclear fuel, which are derived from them.

Deep geothermal systems open the way to replacing coal and gas capacities by geothermal capacities within the future 20 years.

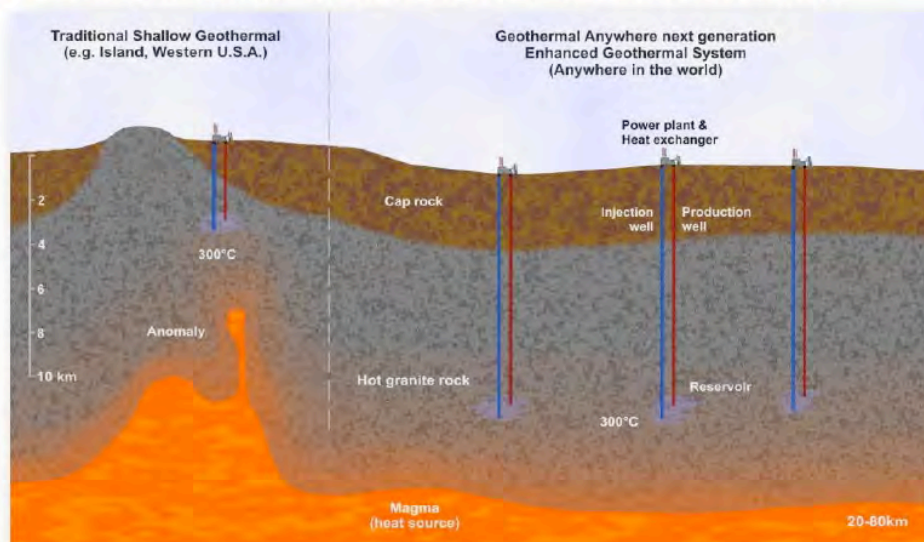
HOW DO WE DRILL USING GATec DRILLING TECHNOLOGY ?

- GATec is a revolutionary innovative cost-effective technology for drilling, and transport of energy and material.
- It consists of following main cornerstones:

1	GADigger	▪ Non-contact drilling process based on innovative approach modified for extreme thermal, physical and pressure conditions.
2	GABuilder	▪ Continual casing production system working parallel to the drilling process ensuring bore hole structure and robustness.
3	GATransport	▪ Casing mixture and fuel transport for underground GA robotic platform, container transportation with loaded drilled rock toward Earth's surface.
4	GALoading	▪ Drilled rock removal from the bottom and loading crumbled rock fragments into the container.
5	GAExchange	▪ Container injection and ejection into and from the drilling system.
6	GASupervisor GAPower	▪ Autonomous control system working at high temperatures and high pressure. ▪ Source of energy for GA robotic platform subsystems.



HOW IS EGS DIFFERENT FROM TRADITIONAL GEOTHERMAL ENERGY?



- GA Enhanced Geothermal Systems (EGS)** can effectively produce energy from previously unusable sites. Unlike traditional geothermal, which relies on locating anomalies and heated water, this technology uses hot dry rock to heat water in artificially created reservoirs anywhere. Traditional geothermal energy systems can be potentially used only on less than 10 percent of Earth's surface. **Potential of EGS is massively larger than traditional geothermal.**

Such resource of energy will adequately satisfy the demand of energy which has the following properties: - It is local, stable, scalable upon need, with no losses caused by long distance transfer. - It does not produce any emissions, and is safe. - No supply of energy carriers is needed, "fuel" costs are zero and unaffected by world prices variation, crisis developments and geopolitical situations. -

Creates numerous secondary applications, primarily for small and medium enterprises; moreover, creation of job opportunities is enhanced.

Calculations show that economic and technological parameters would allow extension into all regions of the EU, allowing replacement of substantial part of coal and gas power plants by 2020, and perspective replacement of all CO₂ generating energy resources by 2050. In case of completion of

Ultra deep drilling technology, important geothermal aspects could become a reality:

- Fast payoff of geothermal power plant installation within several years.
- Almost zero fuel costs in production of thermal and electric energy by help of industrial deep geothermal systems.
- Coverage of current heat demand and pronounced coverage of installed electric capacity in the EU within several years (fuel savings during these years equals to investment costs of power plants based on industrial deep geothermal systems).
- Energy safety and higher independence on other energy carriers.

ADDITIONAL POSITIVE FACTORS

- Distributed production at consumption locations, minimum distribution losses, as one

of the aims of the EU

- Operation safety and resistance against offence and terrorist attacks.
- Failures and related repairs will require shutting down a small portion of total capacity only, with minimum spare parts and aggregates required.
- The possibility to maintain or even drop energy prices without dependence upon the development of energy carrier prices in the world.
- Energy production with practically no emissions, the possibility of trading with green energy and certificates.
- The possibility to extend the number of long-distance heating customers in small towns and villages due to distributed production and lower prices.
- Development of local business – spas, greenhouses, biotechnologies, fish breeding, etc.

CONCLUSION

The radical innovative technology of the deep borehole drilling and transport of the energy downward and transport of crushed material (rock) upwards, leads to new implementation possibilities. It is a radical abandonment of the classic drilling technologies with connected tubes in long strings with inefficient energy transport to the drilling site on the bottom of the borehole and complicated, inefficient pumping of the crushed material to the surface. The patented technology concept is the result of long year's effort to solve the problem of the exponentially growing price in relation to the depth drilling and thus enabling real exploitation of geothermal energy for electrical power generation.