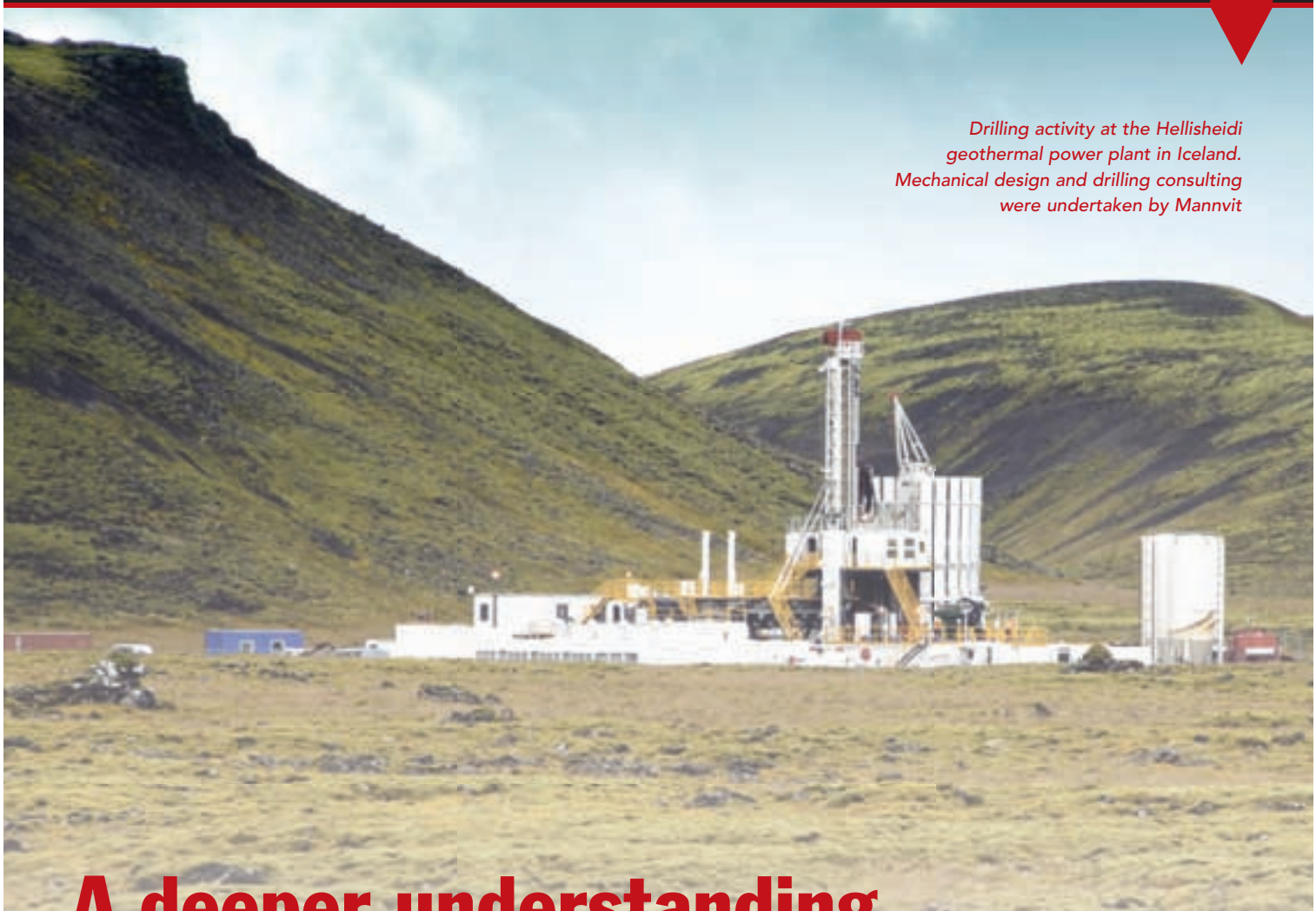

Drilling activity at the Hellisheidi geothermal power plant in Iceland. Mechanical design and drilling consulting were undertaken by Mannvit

A deeper understanding

GeoDrilling International talked to geothermal drill-rig manufacturers and industry experts about the main requirements of, and the latest trends in, deep geothermal drilling equipment and technology

When it comes to tapping into deep geothermal resources, the cost of drilling can make up around 60-70% of the total project costs, and can thus influence the overall success of a geothermal project. As a result, the industry has become more open to new technology, which might help reduce these costs.

The rigs used to drill geothermal wells are the same as those used in the oil and gas (O&G) industry. The most common types are conventional mechanical rotary rigs and newer hydraulic/electrical rigs. The kind of rig ultimately used varies based on: the requirements of the planned drilling programme; region; official regulations; price; and the availability of rigs.

"To reach the higher depths of deep geothermal reservoirs, normally bigger rigs with 1,500-2,000hp are used. The rigs are mechanical, DC- or AC-driven, but the geothermal industry also tends to use hydraulic rigs because they are considered to produce less noise emissions, based on the hydraulic cylinder instead of a drawwork," explains Maximilian Trombitas, sales director for America at Bauer Deep Drilling.

Stefano Angeli, worldwide commercial director of Drillmec, part of the Trevi Group, adds: "Considering the larger diameter of boreholes compared to conventional wells, some precautions are usually taken in respect of the equipment choice, i.e. the mud pump should have a higher volumetric capacity. Equally, the mud programme is driven by different parameters."

Drilling techniques in the geothermal field include overbalanced, hammer and underbalanced drilling, among others.

"The most common method is rotary drilling by direct circulation of water-based drilling mud or water in the production part. Other frequently used methods are the aerated drilling ones. Reasons for introducing air into the drilling fluid might be highly permeable formations causing loss of circulation or to minimise formation damage to enhance possible productivity of the wells," explain Kristinn Ingason and Thoroddur Sigurdsson from the geothermal drilling department of Mannvit, an Iceland-based engineering consulting firm.

"The top sections (for surface ►

"The rock in geothermal drilling is commonly hard, fractured and heterogeneous, making drilling operations challenging"

A Drillmec HH-202 extreme drilling geothermal wells in Chile more than 4,600m above sea level

Comparison: Geothermal v O&G

Mannvit explains the differences between O&G and high-enthalpy geothermal drilling related to the following topics:

Explosive atmosphere: Because of the possibility of flammable gases, the O&G industry must have its drilling equipment ATEX-certified, and employs degassers and flare pits to handle gas that reaches the surface while drilling. Geothermal drilling generally does not have to account for flammable gases unless the wells are being drilled in O&G areas.

High temperature: Mud chillers (usually air-cooled) are generally not required in O&G drilling but are necessary in geothermal drilling. Temperature limitations of downhole equipment can be a limiting factor in high-enthalpy geothermal wells, especially for directional tools (MWD) and wireline-logging equipment.

High pressures: The downhole pressures encountered in O&G drilling are generally much higher than in geothermal wells. Therefore the blow-out preventers (BOPs) are usually rated higher (5,000-10,000psi/345-690 bar) in O&G compared to geothermal (2,000-3,000psi/138-207 bar). Formation pressures in geothermal drilling are usually less than hydrostatic.

Directional accuracy: The drilling targets in geothermal wells are generally much bigger than in O&G drilling. Therefore, the level of directional accuracy is much more important in the O&G industry, which uses state-of-the-art RSS, while the geothermal industry uses the cheaper alternative of positive displacement motors (PDMs).

Well completions: The well completions are quite different in the geothermal field compared to O&G. There is no production tubing in geothermal, therefore the produced fluid comes in direct contact with the production casing. Larger production casings and production hole sections are required to accommodate the high flow-rates required to produce geothermal wells economically. The geothermal production sections have uncemented perforated liners or just an open-hole completion ('barefoot'). Multilateral and/or horizontal wells are rare in the geothermal industry.

Drill bits: High-enthalpy geothermal wells are generally drilled in igneous rock formations usually with tungsten-carbide roller-cone bits. PDC bits, frequently used in O&G, have rarely been applied to high-enthalpy geothermal drilling but are more common in low-enthalpy geothermal wells (especially those drilled in sedimentary formations).

casings) of geothermal wells may also be drilled by percussion methods, such as the air-hammer method with air and foam, especially in hard-rock formations."

The requirements of the geothermal and O&G industries are practically the same. Both industries face the same challenges and have the same end goals: drilling a well into rock to a specific depth in order to reach a reservoir.

"The main difference we can see is that the geothermal industry is more focused on rigs which have less environmental impact, e.g. smaller footprints and low noise emission," says Trombitas.

"A lot of rigs used for geothermal drilling projects are equipped with skidding or walking units, to enable the operator to move the whole rig without taking it apart, which saves time and therefore a lot of money. Most of the geothermal projects require at least two wells on one well pad, therefore skidding and walking units are a big cost-saving option. Further, the geothermal industry tends to drill bigger diameters, as it requires higher volumes to be economical."

FACING FAILURES

Similar to other drilling operations, there are many potential problems and failures related

Latest addition

Bauer Deep Drilling's (BDD's) newest rig is the automated PR 440 M2. The 2,000hp AC-powered walking rig features a pipe-handling system, which supersedes the monkey-board with its derrickman, one of the most dangerous working places on a drill rig, and offers new possibilities to achieve fully integrated process automation. This rig is the first step by BDD to reach its goal of developing a 100% hands-free and fully automated drilling system by 2020.

The rig is operated by a driller and a pipe-handling system operator. The driller can fully concentrate on the drilling process, including making/breaking connections with the automated power tong. The pipe-handling system operator at the same time takes care of the pipe manipulation on the rig.

The target for the next rigs is a fully automated push-the-button solution, which offers the possibility to trip in/out of drill pipes to a certain depth in cased holes, without any interference of a human being.

The PR 440 M2 has a 880,000lb (400t) static hook load rating, but will be upgraded to 1,000,000lb (454t) on the next new-build. The rig is able to handle double range 2 drill pipes and drill collars up to 9.5in (241mm).

A PR 300/440 M1 drilling a geothermal test well

PR 440 M2: the newest rig in BDD's portfolio

to geothermal drilling.

The US Sandia National Laboratories' Douglas Blankenship explains: "Lost circulation is a common problem in geothermal drilling, and cementing due to lost circulation can be problematic as well. The rate of penetration (ROP) tends to be low compared to O&G, particularly when compared to the rates at which shale gas/oil wells are drilled.►

An HH rig currently operating on a geothermal project in Italy, working in an area with 1,400MW theoretical power potential

"The rock in geothermal drilling is commonly hard, fractured and heterogeneous, making drilling operations challenging. Temperature is an obvious issue, many of the downhole tools for drilling, logging and monitoring that are available to O&G are simply not available for geothermal because of temperature limitations."

Some issues are also related to geographical location. According to Mannvit, loss of circulation in the cased-off sections can be quite problematic in some parts of the world, like Africa.

However, generally, high operative temperatures and fractured rocks drive most of the problems and failures.

"From a rig designer's perspective, the rig is usually equipped with supplementary units to lower the circulating fluid temperature. Fractured rocks also generate loss of drilling fluids into the pores resulting in wellbore instability. Generally, losing drilling fluids is costly and impacting the overall control of the well, which is more prone to incident and loss of time," comments Angeli.

In addition, like in every industry, bad planning and project management can also be behind a lot of detrimental issues.

Research

The geothermal work at Sandia mainly involves research related to access, monitoring and development of geothermal thermal resources – both conventional and EGS. Through its sponsor, the US Department of Energy (DoE) Geothermal Technologies Office – which is the largest and most important funder of geothermal-related research in the country – it has current work efforts in all of these areas. A few examples of these efforts include:

1) The development of a high-temperature downhole motor that has a performance envelope similar to current PDMs, but eliminates the requisite elastomers and does not have the attendant lateral vibrations of PDMs.
2) Sandia is developing a high-temperature logging tool that will be able to measure concentrations of ionic tracers and pH of wellbore fluids as a function of depth rather than simply use an integrated measurement at the surface.
3) It is also developing an approach to reservoir stimulation using environmentally friendly energetic materials, where it can tailor both the borehole pressurisation rate and the peak pressures. It has also invested internal Sandia funding (referred to as laboratory directed research and development) into the area active suppression of drill string vibrations.

A major effort the DoE has initiated is known as the Frontier Observatory for Research in Geothermal Energy (FORGE). FORGE will be a field laboratory directed to performing vital research needed to push EGS into the mainstream. This is a major endeavour, and drilling technology research, development, and demonstration will be an important part of the FORGE effort.

EVOLUTION OF TECHNOLOGY

As geothermal drilling technology is based on O&G drilling, its progress naturally follows in the industry's footsteps. The equipment is also being designed to be more resilient in the face of higher temperatures down the well.

"In recent years, drilling fluid and aerated drilling have been developed in geothermal drilling as well as drill bits for increased ROP. Health, safety, environment and quality procedures related to drilling have evolved. And well design, suitable for higher temperature, is also under development. Innovative drilling technology, which will reduce the time and cost of drilling, is being developed but is not commercial as of yet," say Ingason and Sigurdsson.

Trombitas notes that when it comes to drill rigs, the main innovations or technology steps are made on hydraulic machines. They have been designed to be more efficient, easier to operate, easier to maintain and to have less environmental impact.

Drillmec's Angeli says the ►

company's Hydraulic Hoist (HH) series, since its entrance into the drilling market, emphasises reduced footprint compared with the traditional rig design (assuming an equal hook load capacity), which has improved public acceptance of drilling in areas close to urban settlements.

Trombitas comments: "A few companies, especially in Europe, brought out some hands-free drilling rig solutions. We can also see a lot of innovations in the downhole industry. The tools are getting more resistant and reliable against higher temperatures. Therefore, they can be used for higher depths with higher temperatures without failing."

What about the future of geothermal drilling technology? Angeli says: "If we compare soft rocks typical of oil drilling, geothermal formations are more difficult and hard to control. For this reason, we foresee that the next evolution will be the integration between the next generation of drilling automated rig (such as Drillmec's AHEAD – advanced hydraulic electrical automated driller) with continuous circulation systems (Drillmec's HoD – heart of drilling)."

Following in the footsteps of the O&G industry, geothermal drilling will start using rotary steerable systems (RSS) for directional drilling to allow for extended-reach drilling and/or deeper directional wells, add Mannvit's geothermal experts.

Geothermal drilling could also be on the cusp of adopting rock reduction methods other than roller bits. Blankenship confirms that, for example, polycrystalline diamond compact (PDC) bits have been shown to be capable of drilling geothermal formations, and industry adoption will have a substantial impact on the sector.

He continues: "I have personally not been a fan of 'microhole' drilling, but my feelings here have changed remarkably in the last couple of years. Microholes have been an unfulfilled promise, but with the advent of new rock reduction methods that require very low weight-on-bit, I have come to believe that there may be a path forward for microholes, and their associated anticipated cost savings, to have a role in geothermal exploration."

According to Mannvit, drilling into and exploiting supercritical reservoirs where the fluid temperature is above 400°C and the pressure above 220bar is next on the agenda.

Also drilling for and exploiting superheated steam, as the IDDP-1 well drilled in Krafla, Iceland, produced.

Finally, further development of enhanced geothermal system (ESG) drilling technology in order to be able to drill at lower costs deep into the hard formation associated with the solution.

Featured equipment: TEI Radio-Controlled HEM Hydraulic Excavator Drill attachment with TE560 Hydraulic Drifter is available with an EU Certified protective cover.