ABSTRACT

A water driven down-the-hole drilling equipment (Wassara) was developed some years ago at the Kiruna mine, Sweden, which is the largest underground mine in the world. This new drilling technology has been used in their mining production for a few years. It has several advantages to pneumatic drilling methods. This water driven hammer has now for the first time been tested in well drilling (110 mm) in hard rock. The first drilling was done in Örebro for the Swedish telephone company TELIA that is constructing a great number of borehole (direct cooling) systems for their telephone switching stations. The water hammer proved to be considerably more efficient; the drilling speed is about twice as high and the energy consumption is about 1/3, compared to that of the previously used air driven hammers. Another advantage is the possibility to drill several hundred meters in hard rock even in water rich and fractured rock. Experience of the first drilling is summarised.
1. INTRODUCTION

A large number of Borehole Thermal Energy Storage Systems (BTES) in bedrock, for heating, cooling or heating/cooling, have been drilled during the last 25 years. Most of the systems consist of one or a few boreholes but there are also systems of several hundreds of boreholes evenly spaced within a limited land area. The drilling equipment used is most often locally available well drilling equipment. Such equipment is usually air-driven and the pressure used in hard rock well drilling is about 2 MPa (20 bar, 300 psi), a pressure that corresponds to 200 m of water. Consequently, in fractured water rich rock the maximum drilling depth is limited by the air pressure and therefore the boreholes can usually not be drilled deeper than about 150 m. Lately air compressors that give 2.5 MPa are more often used, which means that the possible drilling depth has increased.

Within the framework of the IEA Energy Storage Implementing Agreement there is an ongoing international collaboration to Implement Underground Thermal Energy Storage (Annex 8). This group of experts have for many years seen the need for a drilling equipment more suited to UTES drilling. The annual drilling for BTES is about 100 million meters of borehole in rock. The cost of drilling varies strongly depending on the type of bedrock, but is about 30-50% of the investment of the BTES system.

A cut in the drilling cost and a considerable increase in drilling depth would mean that BTES systems become even more competitive. The newly developed water driven down-the-hole hammer (Wassara) could be the future BTES drilling equipment. The system was developed for production drilling at the Kiruna mine, Sweden, and now the first rig for BTES drilling is being tested in Sweden.

The Wassara Drilling System has been tested in Switzerland where a 600 m borehole has been drilled in crystalline rock. It is now being tested in Canada and there are also plans to carry out a test program for the Norwegian oil industry.

2. THE WASSARA DRILLING EQUIPMENT

The Wassara drilling equipment is a water driven, hydraulic, down-the-hole (DTH) percussive drilling system for hard rock. It was developed by G-Drill, a company owned by Sandvik Rock Tools and LKAB, a large Swedish mining company.

2.1 Operation

The main difference from pneumatic DTH equipment is that the power from above ground to the hammer is transferred by water. The Wassara drilling system runs on filtered water at pressures up to 18 MPa (180 bar, 2500 psi) from a conventional high-pressure plunger pump. Low velocity flushing water causes little wear to drill pipe and hammer case, allowing for tight stabilising and straight holes. After flushing the cuttings from the hole, water can be filtered and recycled to minimise loss. Although Wassara was developed for use in underground mining, it has features which can provide many economical and technical benefits in surface drilling. The main problem in UTES drilling is the filtering and recirculation of water.
2.2 Environment

When comparing drilling between Wassara and a conventional pneumatic DTH drilling system, the most obvious difference is a cleaner environment. Dust is virtually eliminated and because lubricating oil is not used in the hammer the atmosphere is oil free. Transmitting energy by means of water hydraulics is extremely energy efficient. By comparison, pneumatic equipment uses four to six times more energy for every meter drilled.

2.3 Drilling Accuracy

As a result of using water for flushing, erosion is greatly reduced on the outside of the hammer and drill string. This makes the use of close fitting stabilisers more practical. Consequently, the hole straightness can be improved even further over conventional DTH drilling.

2.4 Performance

Tests performed in LKAB’s Malmberget mine show that Wassara is giving two and a half times the penetration rate of a typical four inch air hammer operating at 2 MPa (20 bar, 300 psi). When compared to modern hydraulic top hammer drilling, the difference at the hole beginning is less pronounced, but at greater depths Wassara’s penetration rate is far superior.

| Table 1. Comparison Air Hammer DTH and Water Hammer DTH
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<td><strong>Power input</strong></td>
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<td><strong>Input volume - max.</strong></td>
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<td><strong>Power output at hammer</strong></td>
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<td><strong>Efficiency factor</strong></td>
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<td><strong>Penetration rate</strong></td>
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<td><strong>Depth capability</strong></td>
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* Varies with hole size, percussion pressure, bit button shape and rock hardness

3 FIELD TEST EXPERIENCE

3.1 Background

In June 1997 a drilling company (AB Norrfjärdens Brunnsbörningar) was contracted by the Swedish telephone company TELIA to drill a BTES cooling plant for an underground telephone switching station. TELIA is gradually replacing all their old cooling (CFC) machines by more environmentally friendly systems.

The task was to use boreholes in crystalline rock for continuos cooling (200 kW) of the telephone switching station in Örebro. The maximum water temperature allowed from the boreholes was limited to 19.5°C (the mean temperature at a depth of 200 m was 8.9 °C).
Performed pre-design of the BTES system showed that 72 boreholes (160 m) would be sufficient. Because of limited space for the drilling it was suggested to drill deeper holes and the after re-designing the plant it was found that 60 boreholes at 200 m would also fulfil the cooling requirements.

Previous drilling in the area showed that the rock was water rich and fractured, which means that it would be difficult if not impossible to perform the drilling with pneumatic DTH equipment. So, the drill rig was re-constructed for water driven DTH drilling.

3.2 Experience of Water Driven DTH Drilling

In mid November 1997 the drilling company (AB Norrfjärdens Brunssborningar) summarised the experience from 7500 m of drilling. A brief summary up to that date would be that the specified technical data have been correct while the expected life-time of the hammer is not at all fulfilled. The advantages and disadvantages (compared to the pneumatic DTH) are:

Advantages:
• High penetration rate, 0.5 to 1.0 m/min. The average penetration rate after 57 boreholes was 0.6 m/min.
• The penetration rate changes very little by increasing depth. It would be possible to drill to much greater depths.
• Only clean water is injected into the boreholes (no oils or other additives).
• The diesel oil consumption was reduced to 1/3 of conventional pneumatic DTH drilling.
• Very good working environment. No dust, no oil mist, no spill.
• Drill bit wearing comparable with pneumatic DTH drilling.
• Almost no wearing (blasting) on hammer and drill pipes.
• Rapid breaking of drill string because of immediate pressure drop when the hydraulic pump is switched off.
• The water driven drilling system is insensitive to water rich rock.

Disadvantages:
• Minimum water is high 200 l/min (when the hammer is new) and 300 l/min (when old).
• High requirements on the purity of water. Maximum grain size of 50 micron, desirable grain size 10 micron. Maximum 50 mg/l of water.
• High investment cost for re-circulation of water.
• Big stress wave rebound from the hammer resulting on heavy loads on the rotation unit, feed cylinders and drill pipes.
• Frequent and long standstills because of necessary maintenance and reparation of the drilling equipment due to the big stress wave rebound from the hammer.
• High hammer cost. The hammer is expensive in spite of its simple construction. In addition the life time is short and the spare parts are expensive. The total hammer cost is about 40 SEK/m of drilling (40 SEK = US$5) to be compared with the air hammer cost of about 6 SEK/m. The total drilling cost is approximately US$15.

The drilling company’s conclusion is that if the drill cost is reduced to a more reasonable level and the re-circulation of water would be achieved at a lower investment cost the Wassara hammer will become very competitive for drilling of single wells for both water and
energy extraction. When it comes to larger projects with many wells on a limited area it will be outstanding.

4. SUMMARY AND CONCLUSIONS

According to the manufacturer (G-Drill) of the water driven hammer some of the problems experienced by the drilling company were due to the inappropriate drill rig used in this first test drilling. G-Drill claims that a more suitable rig would reduce most of the problems. The drilling company is now considering a new rig for future water hammer drilling. Though Wassara was developed for underground mining, it has economical and technical benefits in surface drilling.

The main advantages compared to conventional well drilling equipment:
- No limitations in drilling depth.
- Cleaner environment. No dust, no oil mist, no spill.
- Energy consumption is reduced to 1/3.
- Hole straightness can be improved.
- Penetration rate is more than twice as high.

Follow-ups of performed UTES plants show that the drilling cost is about 30-50% of the total investment cost (Schunnesson, 1983). The split-up drilling cost shows the following percentages: energy (10%), labour (25%), hammer and drill bit cost (35%), capital cost (15%) and maintenance (15%). So, the reduced energy cost is important and so is the labour cost which is reduced due to the increased drilling speed.

The water driven drill system is of great interest for the BTES systems because of:
1. No limitations in drilling depth.
2. Cleaner environment while drilling.
3. The improved drilling accuracy.

In spite of the promising experience of this first drilling we should consider that experience of this technology is very limited so far. Today the main problem is not the investment cost of the filtering and recycling system but the lack of such systems.

REFERENCES
