The right direction

Permeability testing and impression packers were recently needed for two directionally cored boreholes as part of a site investigation in Hong Kong

"A total of 35 water-inflow tests were successfully executed in the two boreholes besides numerous classical step-rate injection tests"

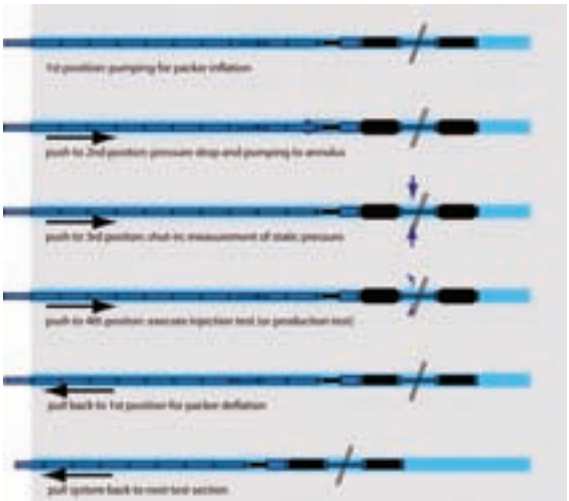
Well-testing consultant Polymetra's client in Hong Kong was recently contracted to drill two directional and cored NQ holes for the site investigation of a future railway tunnel. Both boreholes underwent permeability testing and orientation analysis of existing fractures, which involved the use of impression packers.

An STX60 and 57mm straddle packer system from Inflatable Packers International (IPI) was used on the permeability tests. The system was assembled with 30m and 35m straddle length made up of drill rods and installed in the borehole at the end of the drill string (tubing conveyed). This configuration was especially chosen to execute so-called 'water-inflow tests', where the natural water flow to the borehole was measured. A downhole shut-in tool was required to properly execute and analyse these tests.

Additionally, since this system does not require packer inflation/deflation lines, nor a data line, multiple tests could be carried out in one trip. The STX60's circulation function also proved helpful, although in long horizontal holes it needed some operator flair to steer the valve into the correct position. The circulation position was also beneficial as it defines a clear break between packer inflation and shut-in position noticeable with a pressure drop.

Assembling the STX60 with the straddle packer on the inclined drill rig

Trajectory of one of the two directionally cored boreholes



Testing procedure using a double-packer system with a STX4 setting tool. Multiple borehole sections can be tested with one installation as the packer system is moved from one test section to the next

TESTING STRATEGY

Using STX60 with a straddle packer enables the borehole to be drilled to 'total depth' before testing, reducing the rig's standby time. It then allowed two tests in one 10-hour working day.

The testing strategy included recording static pressure in the test section after packer inflation. The valve was then opened and free outflow was recorded with an electronic flowmeter and a data-acquisition system. After a one-hour flow period, the test section was shut in and pressure recovery was monitored. Both test phases (flow period and pressure recovery) were later analysed.

In borehole sections where the hydrostatic pressure was low, slug production tests were conducted. This involved emptying the drill string, easily achieved by moving the valve to circulation position directly after packer inflating and applying pressure with an air compressor connected to the well head. With the drill string still under pressure, the valve was closed and the air pressure released. After about one hour for monitoring the static pressure, the valve was opened and the water from the formation was allowed to rise in the test string. In case of very limited slug recovery in a low permeable borehole section, the test was analysed as a constant-rate production test.

In all, 35 water-inflow tests were successfully held in the two boreholes besides numerous classical step-rate injection tests.

IMPRESSION PACKERS

For impression-packer testing, an IPI NQ SWiPS (standard wireline packer system) was used, equipped with a pump seal, a 2m-long impression packer and

an orientation tool to record the roll angle. The SWiPS with impression-packer string was pumped through the standard NQ drill string until it landed. The pressure was allowed to increase, allowing the SWiPS integral inflation valve assembly (IVA) to inflate the packer and to engage the IVA. It was maintained at about 40bar so as to get impressions of joints in the rock mass. The IVA then opened upon pressure release, enabling packer deflation. The overshot tool was then pumped in to retrieve the packer system.

Once at surface, the team noted the imprinted joints with a water-resistant marker. They then wrapped transparent plastic film around the impression packer, and copied the marks, together with the reference line, which corresponded to a key connector that held the orientation tool in a fixed position. The roll angle was read from the data logger of the orientation tool and noted on the plastic film. In the meantime, the drillers retrieved the drill string to the next test section.

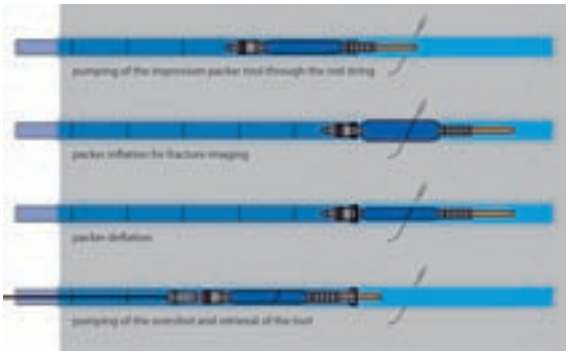
DATA ANALYSIS

These films were then sent to Polymetra's offices, where it scanned them for representation in the final report. The impression marks of the imaged joints were represented as sinusoidal curves on the plastic film.

Positions of the minima and maxima with respect to the reference line and amplitudes were measured.

The relevant data was entered together with borehole survey data and recorded roll angle in a special program developed for core orientation for interpreting geological structures to calculate the dip and strike of each joint. Finally, the output data were used in another program to represent the oriented joints in equal area plots and in rose diagrams.

A total of 48 impression tests were conducted in the two boreholes. This method has proved to be efficient and and relaible in boreholes where a borehole televiewer (BHTV) cannot be applied but structural data is still required.



Fracture imaging using a SWiPS system with a pump-down head and an impression packer. An orientation tool mounted in front of the packer records the roll angle of the system which is retrieved with the overshot tool after the test

Meanwhile in the US

Eric Swanson, with AquaLithos Consulting, is a Denver-based mining hydrogeologist and veteran SWiPS operator, who is now using IPI's STX60 permeability-testing system.

Before starting AquaLithos in 2009, he specialised in packer and hydraulic testing with SRK Consulting and Golder Associates. Currently, packer testing makes up over half of his business.

"When IPI introduced the SWiPS packer system, the rules of the game changed. It let us collect hydrogeological data under conditions that were just not previously possible on so many projects that it became a standard tool for mining hydrogeology," Swanson claims.

"Now with the introduction of the STX-60, the rules have changed yet again. The STX-60 is even faster to use, allows me to perform zero displacement shut-in tests, and even circulate mud while packer testing. I'll still use the SWiPS for single-packer operations, but for post-borehole completion testing using a straddle packer configuration, the STX is my 'go to' tool. Once it is in the borehole, I don't have to remove it until all the tests are completed – and that saves my clients time and money. The STX has even opened up testing opportunities in reverse-circulation drilling as you can thread it directly on to the drill rod."

Recently, Swanson used the STX-60 on two projects: packer testing for a new shaft design in Mexico, and assessing rock strength limits (hydrofracturing pressures) in a proposed in-situ leaching operation.

"The shaft design project was performed on an underground drilling rig. We had time limitations on how long we could be in place between blasting

One of five rigs (out of a total of 21) running SWiPS in the Sahara desert in Mauritania

operations, a low ceiling clearance and some strong upward hydraulic gradients. I chose the STX-60 because I wanted to run shut-in tests with the packer during the times when we had to leave the rig due to blasting. Although the STX-60 is a long tool and our overhead clearance was low, I was able to break down the tool, assemble it on the mast in pieces, and get the job done quickly because I didn't have to remove the packer between tests.

"The other project was totally different in scope, but the STX-60 was still my go-to tool, because I could configure it to withstand pressures of up to 3,000psi [207bar] and still work within an HQ borehole."

As the STX-60 is a long tool, it is bulky to transport, particularly if you need a lot of straddle extension pipe between the packers.

"But it's nothing like the logistical pain of transporting nitrogen bottles, and dealing with support cable or inflation lines. If you have to, the tool can be broken down into relatively small sections – in fact, I transported the tool in the back of a small Toyota pickup over some really rough roads on my last project with no issues."

Swanson has run the SWiPS and the STX in some very remote places, including the Canadian Arctic, the extreme heat of the Sahara desert and deep within the jungles of the Congo.