Giant Caspian Pipelines Completed With HDD Technology

By Ian Clarke

HDD Connects Pipelines from Azerbaijan to Georgia

In summer 2005, the taps were turned on in the BTC oil pipeline running from the Caspian Sea at Baku, Azerbaijan, through Tbilisi, Georgia, to the Mediterranean Sea at Ceyhan, Turkey.

Meanwhile, the SCP gas pipeline linking Baku to the Georgian coast of the Black Sea is progressing well. This $4 billion BTC-SCP pipeline project, capable of transporting one million barrels of oil and 22 million m³ of gas per day, is being built by a consortium of international oil companies led by BP, the operating company for the project. In an interview with BBC News on May 25, 2005, David Woodward, the head of BP's operations in Azerbaijan, said: "This pipeline represented Azerbaijan's rebirth as an important country for the oil industry, just as it was more than a century ago."

One of the final links in the pipelines was the crossing of the Kura East River in Georgia near the City of Rustavi, about one hour drive from the capital City of Tbilisi.

The final success of this challenging enterprise was made possible thanks to the excellent collaboration between the various teams from: the owner BP; main contractor Amec Spie-Petrofac International JV; the engineer, CB&I John Brown and its consultants Geoengineers; HDD contractor, Horizontal Drilling International, a French HDD company with both the experience and the drilling rigs capable of installing the largest of crossings, and the guidance system contractor Prime Horizontal Ltd., a U.K. company experienced in the use of the ParaTrack-II subsurface steering system.

The Herrenknecht HK250 drill rig completing an operation on one of the reaming passes.

Kura East River Crossing Project

The project called for the installation of three parallel crossings comprising the 1,168-mm diameter BTC oil pipeline, the 1,066-mm diameter SCP gas pipeline and a 150-mm diameter product pipe designed to carry a fiber-optic bundle. The crossing of the river was not possible with open-cut methods because the river is quite deep with strong currents. In addition to using HDD, the main contractor also investigated the use of microtunneling. HDD technology was finally selected as the preferred crossing technique to save money, and, more importantly, time. The microtunneling method was kept in reserve should the HDD method fail.

It is believed that the successful completion of the crossing would make it one of the largest diameter pipes ever installed in solid rock using HDD technology, if not the largest.

Project specifications called for a minimum of 10 m of separation between the BTC oil line and the SCP gas line. At the crossing point, the Kura River's span is 360 m, giving an actual drilling distance from the entry point on one side of the river to the exit on the other of 780 m, to keep above the minimum allowable bending radius of the product pipes and to clear a rail track running parallel to the riverbank. While the design called for a minimum radius of curvature of 1,400 m for the BTC and 1,200 m for the SCP over an arc length of three joints (about 29 m), the actual in-field design was 1,600 m, giving a wider margin of safety. This requirement on both entry and exit ends resulted in a 10-degree entry angle and a 6-degree exit angle.

The downhole motor used, therefore, had to be set to build a maximum bend at a rate of 0.34 degrees/9.5 m (the nominal length of one drill pipe) around an entry curve from 80 degrees to 90 degrees and an exit curve from 90 degrees to 96 degrees. The maximum allowable was 0.4 degrees, or 1.2 degrees over 29 m.

Geology

Fifteen investigation boreholes were drilled prior to the start of the HDD projects. Bore holes were vertically drilled to the planned depth of the crossings on both sides of the river. Results provided unconfined compressive strength and abrasivity values for the various rock formations encountered and a supplementary geophysical survey disclosed a 20-m wide relic river channel in the river bed, filled with packed cobbles and boulders, a feature that was drilled beneath during the HDD operations.

Ground conditions comprised vertical rock layers, alternating hard sandstone, softer claystone and siltstone, overlain by a 6-m thick surface layer of river gravel and cobbles on the exit side. Furthermore, the alignment of the vertical rock layers was almost parallel with the crossings axis, with an average offset of only 12 degrees. Even using a downhole motor with a rock bit, this geology proved extremely difficult to drill, since a prerequisite for the success of these two parallel crossings was to drill straight holes and achieve large radii of curvature due to the extreme stiffness of the large diameter and high steel grade of the two pipelines.

The continually changing formation dip and strike relative to the bore holes made it difficult to establish a single trend of tool face commands. For example, hydrated sandstone would quickly drop angle, whereas hard sandstone required hours of work to shave down the angle. So drilling proceeded slowly in order to remain in specification on the designed track. Also the lag time between the position of the bit and the location of the probe, housed in the non-magnetic drill collar behind the bit, proved difficult to compensate for when the rate of build would occasionally go above the acceptable 0.4 degrees per pipe joint.

A typical view of the pipe pull-in operation showing the buoyancy system within the large diameter product pipe.

Field Operations

Mobilization was completed over two months during 2004. Site preparation involved building access roads on both sides of the river, excavating the river gravel at pipe side and excavating the side of a hill at the entry side to prepare the drilling platform. Upon project completion, demobilization again took two months.

A first attempt to install the BTC crossing in 2004 was unsuccessful, after the hole partially collapsed in areas of fractured rock and cobble near the Baku-Tbilisi railway lines bordering the river. The railway tracks were quickly secured with grouting works before subsidence was observed.

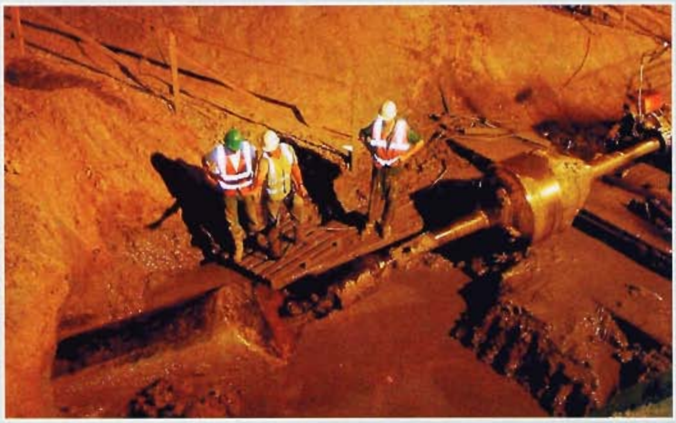
The HDD project resumed at the beginning of February 2005 and ended in August 2005. Almost seven months were necessary to complete the three crossings and tie-ins although originally planned for completion in six months. Timing for the individual operation stages were: fiber pipe pilot hole, 10 days; fiber pipe pullback, one day; BTC pilot hole, 18 days; BTC reaming to 1,625 mm diameter, 30 days; BTC pipe pullback, one day; SCP pilot hole, 15 days; SCP reaming to 1,372 mm diameter, 25 days; SCP pipe pullback, one day. All reaming, swabbing and pulling works were double shifted, with crew changes onsite.

Equipment

The HDD rig and backup equipment used for all of the crossing bores and reams included: a new Herrenknecht AG HK 250 drill rig, with 250-tonne nominal pulling force (its maximum being 330 t) and 100 kNm nominal torque; three high-pressure pumping skids (1 x Ellis Williams 446 and 2 x Shäffer & Urbach) with capacity of 2,000 l/min. each; two mud recycling units at the rig side including an SS150 and an SS240 manufactured by PSD, which were able to process 2,500 and 4,000 l/min., respectively and supported by a primary shaker at the pipe side.

The guidance system was a ParaTrack-II surface system provided by Prime Horizontal, using Vector probes owned by HDI.

The 172-mm diameter mud motors were supplied by INROCK, while the split bit hole-openers used, from 965 to 1,625 mm in diameter, were manufactured by Prime Horizontal and Sharewell. Rock reamers from 508 to 762 mm in diameter were manufactured by HTI. All hole-openers were fitted with TCI cutters. Barrel reamers utilized during reaming, from 864 to 1,422 mm in diameter were manufactured by SMFI. The drill pipes utilized were 127- and 168-mm diameter grade S135.


Completing a pipe pull-in.

Due to the remoteness, all the critical equipment components were redundant (one spare power pack for the rig, 3 HP pumps so that always two would work at all times, two mud cleaning units, two steering kits, etc.)

Pilot Holes

As the HDD project was crossing the Georgian national railway, the product pipes were installed within solid bedrock at a minimum depth of 17 m below the railway tracks. The railway traffic speed was reduced during completion of the HDD crossings in order to reduce the vibrations above the reamed holes. No settlement was observed during the final installation works.

Considering the large diameter of both main product pipes, the pilot holes for the BTC oil line and the SCP gas line had to be carefully completed to the planned large radius of curvature and with 10 m of separation distance. In order to remain on track with the necessary precision while drilling, three different configurations of AC guidewire reference sources were utilized for the magnetic steering tool in the three pilot holes so that continuous guidance data were always available when drilling under the river.

Each pilot hole utilized a different guidewire configuration to provide optimum guidance information. Steering for the first pilot hole to contain the 150-mm duct for the fiber-optic bundle utilized an entry coil extending to the near river's edge and an exit coil from the far river's edge to the exit point. Steering for the second pilot hole for the BTC oil line, utilized a guidewire pulled through the fiber-optic duct, as well as entry side and exit side AC coils. An entry side coil and exit side coil, as well as a metal guidance cable attached to two metal poles and stretched across and above the river was used to steer the third and final pilot hole for the SCP gas line while under the river.

The most difficult pilot hole to navigate was the SCP pilot hole. In spite of the variable signal strength caused by flooding from snow melt, the real time position fixes, as validated with an independent survey performed by HDI after drilling was completed, verified that the SCP pilot hole separation from the BTC line was greater than the minimum 10 m required.

Reaming & Pipe Installation

Both product pipes were API 5L x 70 steel pipes coated with three layers of PE. The fiber pipe was a basic steel product pipe without coating.

Due to the large size of hole-openers used, high torques were expected on the drill string when cutting the rock. The weight of the larger hole-openers was in excess of 4.5 tonnes, thus generating large longitudinal torques along the downhole assembly.

A series of precautions was taken to reduce the risk of twist-offs and other problems downhole including: Premium larger diameter drill pipe was used for all hole opening passes of 762 mm in diameter and above; front centralizers made of heavy-duty barrel reamers were used for all phases of 965 mm in diameter and above; all threaded connections were specially engineered to obtain homogeneous bending strength ratio (BSR) averaging 2.25 along the downhole assemblies for all reaming phases; and torque was intentionally limited to 60 kNm, even though the HDI rig delivers a nominal torque of 100 kNm. Systematic swabbing passes with barrel reamers were also performed between the reaming phases in order to reduce the torque on the string. Finally, the tail string was screwed to the bottom hole assembly (BHA) without a swivel joint so that it could be used to retrieve the BHA from the pipe side if necessary with rotation being applied from the pipe side.

Upon the initial completion of the pilot hole for the BTC oil pipe, the rig began opening up the bore size with staged reamers in readiness to pull in the first large diameter pipe. Unfortunately at this stage, the hole could not be held open long enough to install the BTC product pipe due to the unconsolidated gravel and cobble beneath the railroad. So the rig was moved 18 m to the right of its original location and a new profile was designed for a drill path that went below this problem zone. The drilling pattern was aggressive to counter a right and then left drift caused by the dipping ground formations. Finally, this hole was stage reamed to 1,625 mm and the BTC pipe was successfully pulled into position.

Drilling Fluid

The mud formulation used was based on Premium High Gelling Bentonite from Egypt Bentonite & Derivatives Co., which was enhanced with Xantham Gum as a fluid loss reducer/stabilizer, and with a cellulosic polymer as a rheological additive, provided by Süd Chemie of Germany.

The mud was monitored by a mud engineer and two qualified mud technicians, to make sure that it was recycled adequately and that the viscosity was maintained between 60 and 75 seconds/qt, thus avoiding unnecessary torque generation on the string and tools.

Despite these precautions, a few twist-offs occurred during the last reaming phases. Because the hole was clear and clean, tooling was quickly recovered without any further complication. Three roller cones were lost during the final BTC opening, and two additional swabbing passes were necessary prior to the pipe pull to ensure the hole was clear of any object likely to damage the pipe coating.

For both large diameter product pipes, a buoyancy control system was utilized comprising three 450-mm diameter HDPE pipes previously installed inside the BTC pipe and then transferred to the SCP product pipe. The HDPE pipes were pressurized during the pullback operations and the annulus was progressively filled with water while the pulls progressed. This system made both pipes almost weightless once immersed in the drilling fluid. This, combined with carefully controlled drilling radii, enabled two smooth pull-in operations, with low pulling forces and very minimal damage to the PE coatings despite the abrasive sandstone side walls.

Conclusions

This project was both important to the world's energy economy and to the consortium of companies that own and operate the pipelines. Due to its importance, the design specifications and in-field quality control were stringent, especially in light of the vertical hard rock formations encountered.

The project demonstrated that the use of HDD technology is highly applicable to river crossings in hard rock for large diameter product pipes. Geological surveys prior to field operations are necessary in order to design both the drilling plan and the downhole drilling string. The ParaTrack-II magnetic guidance system is an optimum system for downhole steering. For this project, it was felt that the ParaTrack-II system was the only subsurface guidance system that would work. A magnetic guidance system based on DC electric current would not work because of the magnetic interference from nearby pipes and north seeking laser gyros are not currently available.

On completion of the works during his address giving special thanks to all those involved, Chris Walker, CB&I, who had overall responsibility for river crossings in both Azerbaijan and Georgia, said, "The crossing of the Kura East River in Georgia was one of the greatest technical challenges faced during the construction of the BTC and SCP pipelines. The successful outcome can be attributed to the dedication and hard work of those involved. Integration of both construction and engineering teams played a key part in achieving the final goal and forms a necessary part of constructing HDD crossings in adverse terrain and geological conditions."

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