Steering under the El

A combination of the ParaTrack II steering system and magnetic river-bottom benchmarks be a unique 2.6 km river crossing by HDD involving the precise intersection of bores from

THE construction of a 55 km-long ethylene pipeline connecting two chemical plants on opposite banks of the River Elbe required the river be crossed without excavation or dredging. Friedrich Vorwerk made the pipe for Sasol Germany GmbH.

The presence of supporting dykes on both sides of the river for flood control as well as rules prohibiting surface cables from crossing the river due to continual and heavy shipping traffic meant horizontal directional drilling (HDD) methods were needed to drill beneath the river. The borehole spanned both the dykes and the river over an underground track of 2.63 km. The crossing was completed in August.

John Teer, president of Prime Horizontal Ltd, the HDD magnetic guidance service company used by LMR Drilling GmbH, said: "This crossing has set three world records: one – this crossing is the longest successful river crossing in the world, to my knowledge. Two – it is certainly the longest underground intersect ever attempted and completed successfully. Three – it is the first time that magnetic benchmarks have been placed on a river bottom to guide the drilling of the boreholes beneath."

ELBE'S UNDERGROUND INTERSECT

From the start, this long river crossing was expected to pose unusual challenges for current HDD guidance technology. Conventionally, a magnetic steering tool would be placed behind the bit and the borehole would be steered according to its relationship to the Earth's magnetic field. However, this approach to steering is similar to dead reckoning and actual cumulative errors of position could grow quite large over a planned 2.63 km track.

The crossing's actual length in alluvial soils created doubt about the ability to push the pipe this distance. The next level of complexity that could have been taken was to drill a conventional intersect from each side. Due to the large water section of over 1,600 m, a long pullback was deemed necessary to correct the so-called 'dead-reckoning guidance' issues in tying together the two approaching bores. Sidetracks 2 km away from the drill rig would be difficult at best and were to be avoided at all costs.

LMR Drilling GmbH agreed to Prime Horizontal's proposal to drill an underground intersect, subject to the condition that no sidetracks be needed. The decision was based on Prime's demonstration that drilling such intersects, involving two pilot holes, one from each side of the river, and intersecting underground, can be performed consistently to great accuracy and a with high probability of success without sidetracks and pullbacks.

It was also realised that, even with this planned method of intersect drilling, the crossing's length was still a huge obstacle in order to assure that no sidetracks were necessary. A method was needed to calibrate the position of the drill bit periodically throughout the borehole's entire track, and, for this calibration, Prime developed the RM Magnetic Benchmark System, used to finish the Elbe intersect.

MAGNETIC BENCHMARKS

Intersect drilling, one of the most challenging HDD projects, requires accurate, first-time placement of the two approaching boreholes. These benchmarks, installed along the proposed borepath, allow positive confirmation of present location and continuous azimuth to eliminate pullbacks and sidetracks that could occur without this calibration.

The re-usable Benchmark is retrieved after project completion for preparation for the next job. It is configured with an acoustic transponder for activating when ready for use and for powering off when not in use. The benchmark has a 160 h operating time with a 30-day Reserve to First Actuation; it is rated to a water depth of 100 m. It is turned on for 15-minute intervals when needed, which is enough time to perform each calibration.

Before rig mobilisation for the Elbe project, LMR Drilling allotted Prime significant time for surface calibration of the benchmarks before deployment offshore. Three RM Benchmarks were then installed on the river bottom at pre-selected distances of 290 m, 1,545 m and 1,745 m, as measured from the entry point on the river's north bank. The locations were surveyed using GPS as the benchmarks were lowered into position from a barge.

"A long pullback was deemed necessary to correct the so-called 'dead-reckoning guidance' issues in tying together the two approaching bores"

As the borehole passed below each benchmark, the bit's actual position was calibrated, therefore eliminating most of the dead-reckoning error of the bit location accumulating between the calibration points. As the borehole approached the final benchmark, the two boreholes were found to be 60 cm in elevation and 30 cm in left/right from each other. The two boreholes therefore easily intersected within a few more drilled joints beyond the location of the third benchmark.

DRILLING OPERATIONS

About 1.9 km of the total 2.63 km-long crossing was drilled from the north river bank with an LMR drilling rig of 3,500 kN pull force and a torque of 180 kNm. A 2,500 kN LMR rig with torque of 120 kNm was used to drill 725 m from the south bank to intersect with the north side's pilot hole. High-torque 2 7/8 in drill-pipe was used to pilot-drill the 3½ in North pilot hole because of the extreme drilling distance. Both entry points were spaced at some distance back from the river banks to maintain appropriate safe cover under the dykes and other rights of way on both sides of the river.

The 2 7/8 in drill-pipes were washed over with 6 6/8 in wash pipes to maintain good hole condition, avoid mud losses to the formation and control torque and push forces. A similar arrangement was used to drill the shorter south pilot hole. The location of the intersect point, about 40 m sub-bottom depth and 725 m from the southern entry point was carefully chosen during pre-project planning to enable the use of a conventional guidewire for most of the drilling of the south pilot hole. As the south pilot hole was on final approach to the underground intersection point, the magnetic source was switched from the guidewire to Prime's Axial Magnet,

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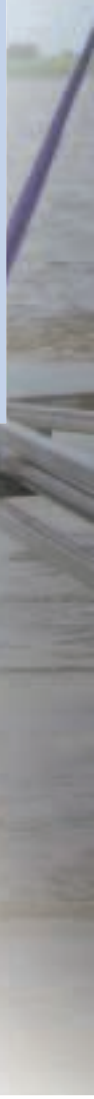
THE PARATRACK II SYSTEM

The ParaTrack II Magnetic Guidance System, co-developed by Prime and manufacturer, Vector Magnetics Inc, consists of two subsystems: a selectable magnetic source used as a positional reference and the steering tool with its three-axis magnetometer to receive magnetic data from the steering tool and derives the 3-D location of the steering tool with respect to the magnetic source.

The ParaTrack II system's steering tool consists of a three-axis magnetometer placed inside a non-magnetic housing and deployed inside a non-magnetic drill collar just behind the drill bit. It detects and measures the three magnetic components, B_x, B_y and B_z, of the total vector magnetic field that exists at the location of the magnetometer. The attitude and direction of the drilling assembly is computed by the ParaTrack II system's software after the measurements are transmitted back up the drill-pipe on a wire to a receiving unit. Knowing the actual track of the drill, the driller may take whatever action is necessary to maintain the borehole on the pre-planned path. ParaTrack II has available an entire suite of magnetic sources to be used when the Earth's field is too weak or is influenced by nearby magnetic interference. The steering tool and its associated software can guide with any of the available magnetic sources.

In particular, for underground intersects requiring the most precision, the Axial Magnet Source of the ParaTrack II system is used as the final approach target as it is accurate to within several centimetres.



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have helped what may either side of the river

"Benchmarks allow positive confirmation of present location and continuous azimuth to eliminate pullbacks and sidetracks that could occur without this calibration"

The benchmark being lowered to the Elbe river bottom. Inset, top right: preparing to deploy three benchmarks on the Elbe river bottom at pre-selected locations surveyed with GPS

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The Axial Magnets used for final approach to the underground intersection point

Preparing the entry point for the north pilot hole

installed as a Bit Sub in the north pilot hole. The Axial Magnet was then used as the target for the steering tool in the south pilot hole, giving centimetre accuracy of its relative position to the target bore until the relative position went to zero and intercept was achieved.

According to Günter Kruse, project manager of the HDD crossing project, "the cobble layers on both sides of the river were cased with 20 in casing pipes over about 250 m each, installed with a wash-over technique by the HDD rigs. After the intercept was completed, the pilot hole was reamed to a diameter of 18½ in. Both rigs pumped drilling fluid to the reamer, thereby avoiding fluid transfer across the river.

"The pullback of the sleeve and product pipe string, which was constructed in one piece on the south bank, took 18 hours. A customised pullback assembly was used to avoid jamming of stones in front of the pullhead. It included a swivel with reaming capability. The pulling forces were as pre-calculated.

"The net drilling time was six weeks. To meet this time frame, the project was carried out in a two-shift operation working seven days a week."

THE INTERSECT

A series of short pullbacks (1-2 m each) were made to calibrate the relative position of the steering tool in the south pipe with respect to the bottom hole position of the Axial Magnet Sub. After it was determined that the required precision in location of the relative position of the steering tool to the Axial Magnet sub had been achieved, the north probe was pulled back one joint, exposing the north hole to the intercept. The south side wash pipe and steering tool was then pulled back three joints and drilling began slowly until intercept occurred.

SUCCESS

In post-project analyses, it was agreed that the Elbe River crossing was a textbook project whose success was attributed in no small measure to the intensive, pre-project planning by everyone involved and by the excellent and continuing co-operation of project management and field crews.

Without the approval and willingness of Sasol to try out a technology new to them, there would have been no underground intersect project. The use of the ParaTrack II Magnetic Guidance System by Prime Horizontal, coupled with the RM benchmarks on the river bottom for calibration of drill-bit position on the world-record crossing of the Elbe river demonstrates once again that river crossings with underground intersects are not only possible but also are cost-effective and highly feasible.

Acknowledgements

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