
[Beyond]
the Yangtze River

Prime Horizontal, the Netherlands, discusses the successful installation of three parallel gas pipelines under the longest river in Asia.

In January 2013 China's Pipeline Bureau Planning, Shanghai Gas (Group) Company Ltd, commissioned CPP Crossing Company to manage a complex pipeline installation under the world famous Yangtze River in Chiangjiang City, near Shanghai, People's Republic of China. Three parallel gas pipelines were planned under the Yangtze River and a strict, six month deadline was given to complete all three crossings.

In order to solve the multitude of problems encountered, CPP Crossing Company and Prime Horizontal conducted a feasibility study. The intersect method was selected as the best method as it offered the safest solutions to overcome the extreme conditions of the crossings. With Prime Horizontal's track record

Figure 1. One of the American Augers drilling rigs.

Figure 2. Natural gas storage and processing plants with Yangtze River in the foreground.

of successful intersect drilling projects, the company was also selected as the guidance contractor.

Complex horizontal projects are often beyond the scope of conventional technology, either because the technology is not cost-effective or because the field problem itself is too complex due to drilling problems, extremes of local geology or long traverses.

These crossings were characterised by a high tidal flow, wide 3000 m crossings, heavy shipping traffic and alluvial sediments of soft sands and clays. The constraints meant that conventional crossing methods were severely limited, if not impossible. The soft sediments and long traverses would create high risks of becoming stuck in the hole with a conventional crossing. Intersect drilling from entry and exit effectively halved the length of the traverses and reduced the entry and exit angles, thus reducing the risk of becoming stuck. Shipping traffic would not be a problem since there would be no surface cables or obstructions.

Installed crossing equipment for the intersection

The ParaTrack-2 (P2) system was used with two different magnetic sources:

- A conventional wire coil, installed with conventional methods, was used for the first part of the crossing.
- A Rotating Magnet (RM) sub was installed behind the drilling motor when the intersect approached closure of the two drill pipes.

The RM sub was required to provide sufficient measurement precision for the actual closure of the entry bit and the exit bit. A conventional wire coil was used with the ParaTrack-2 system, allowing the coil to generate AC magnetic fields, rather than DC fields used by conventional tracking systems. The coil was implemented as two parallel single wires rather than one closed loop with two sides.

Installation of the two source cables was completed on 6 December 2012. The two 2900 m cables were parallel and separated by 100 m distance and 58 m at closest approach. The cables were installed between 1 - 1.5 m above the river bottom. Co-ordinate accuracy for cable positioning was 1 m within the error control of the Xi'an co-ordinate system of 1980.

The cables that formed the closed loop were shaped like an 'S' at their south ends, due to damage from the anchor vessels while the anchors were being deployed in the river. Before drilling, a simulation of the projected accuracy of the steering was conducted in the cable, power was supplied to the cable in the river and the maximum current reached was 5.2 A.

Rigs and the downhole assembly

Two self-contained DD-990 and DD-1100RS drilling rigs from American Augers were used. This was a result of their field-proven reputation on some of the toughest trenchless projects around the world.

The mud units were sourced and manufactured locally, as were the other tools in the Downhole Assembly (DHA).

The guidance system was Prime Horizontal's second generation ParaTrack-2 system.

The original ParaTrack System is an underground magnetic tracking system developed for use in the HDD market by Vector Magnetics and Prime Horizontal. ParaTrack-2 (P2) is an evolution adding greater capabilities. Rather than using a conventional surface guidewire or coil, the surface deployment of ParaTrack-2 will often use a guidewire along the centreline with a return cable placed offline so its magnetic signal is negligible. In specific circumstances, like those in this project, the centreline cable may be grounded on

each side of the crossing, negating the need for a return path with its significant deployment time.

ParaTrack-2 is the only tracking system able to use many different AC magnetic sources. Not only are guidewires on the surface and underground used, but the Rotating Magnet sub (RM), the Axial Magnet Sub (AM) and the AC Beacon, which all require no guidewires, are commonly used. These choices are a strong fit to the exacting requirements of most horizontal drilling projects, thus giving the necessary high accuracy needed for projects involving intersects. Primarily developed as an underground parallel drilling location system, ParaTrack's use has been enhanced by the addition of the wireless magnetic sources to Prime Horizontal's inventory of magnetic sources, the RM and the AM.

The Downhole Assembly (DHA) was built around a 9.875 in. drill bit with a 6.75 in. mud motor and an adjustable bent housing (ABH) of 1.76°, angled with a fixed bent sub, made in China, and two 6.75 in. non-magnetic drill collars. The drill string comprised of a combination of seventy 5.5 in. joints, a further 200 drill pipe joints of 6.625 in. and remaining joints of 7.625 in.

Inclusion of the pressure while drilling (PWD) sub in the drill string measured the pilot hole annulus pressure and the internal pipe pressure at the steering tool. By measuring the pilot hole annulus pressure, the driller also has much improved control of downhole pressures to limit the occurrence of formation fractures potentially causing severe environmental damage, a key concern of Shanghai Gas Group.

Figure 3. American Augers drilling rig.

Figure 4. Control room of American Augers drilling rig.

The intersect process entails pass-bys of the entry bit to the exit bit and downhole ranging of the RM to the ParaTrack-2 steering tool. The PWD is better able to alert the drilling engineer of increases in annular pressure, which would indicate an unclean hole. This allows for the possibility of quicker reactions as compared to monitoring returns on the surface, thereby lowering the risk of formation fractures.

Product pipes

The three gas lines used 3.3 km pilot holes. They were drilled using a 6.75 in. mud motor equipped with 9.875 in. drill bit as discussed above. The product pipes were welded in 12 m sections and were sourced locally. Usually a mud motor is not necessary for drilling in soft sands and clays, however the mud flow to clean the hole and the lengths of the pilot holes made the mud motor an essential part of the equipment.

Product pipe sizes for the three parallel parts of the project were 16 in. and two 28 in. pipes, sourced locally, for the first, second and third installations respectively. The ParaTrack-2 tracking system was ideal for the project, ensuring that the pilot holes stayed parallel and that the magnetic responses of existing pipes could be monitored.

During project planning, a contingency was discussed and used: After the intersect was completed one side had to trip all the way to the other side and during the exit curve the formation could be softer and the pilot hole possibly lost. In fact, while tripping the exit pilot post-intersect on the first pilot hole, the pilot hole string started to drill a new hole. The team worked quickly and effectively and washed over the two bits with 180 m of casing. Completion was achieved by pushing 3300 m of pilot hole drill string from North to South side.

The smaller 16 in. pilot hole was started on the 3 January 2013, intersected completed where the pilot bit punched out of the ground on the 28 January, this included a few days to run the casing.

The second pilot hole the 28 in. started on the 30 March 2013, intersected and the pilot hole was completed on the 12 April, this included three days to set the casing.

Having learned from the first two pilot holes that casing was set, for the third crossing, before the engineers arrived on site, the third pipe's pilot hole was started on the 23 June 2013, and intersected on the 29 June. The pilot hole was completed on the 1 July.

Initial difficulties meant the first intersect took 30 days, but with experience and refinement of techniques the second and third took only 12 days. The method of deploying ParaTrack-2 was considered a success, saving time and expense for the contractor.

This project was performed on time and within budget. The success of this project was due to the high collaborative efforts of all involved.