Crossing the river Amu Darya along 1,800 metres with a 56" high-pressure gas pipeline using the HDD method

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More and more frequently, gas transmission pipelines crossing rivers and natural obstacles are installed using the trenchless HDD technique (Horizontal Directional Drilling). Nowadays, the state-of-the-art HDD technique permits to install pipelines over distances longer than 1,800 m. However, this has not yet been implemented for pipelines with an outside diameter of more than 56''. The project of a river crossing near the Turkmen city of Karabekaul (trenchless laying of a 56'' gas pipeline towards China underneath the Amu Darya river) offered exactly such a challenge. Besides the drilling execution, the project planning and preparation were the special technical challenges. Prior to this extraordinary project, extensive examinations and plannings led to unusual measures for site facilities, execution and equipment to be applied. Among other things, special solutions regarding risk assessment during pipe insertion, drilling plant configuration and overbend construction were found and successfully implemented. In addition to the technical and local conditions, the tight schedule affected the planning and the choice of the equipment. The engineering, production and mobilization of the equipment preceded the technical implementation during a 2.5-month planning phase. The technical execution of the project (installing of the 56'' carrier pipe and the conduits running parallel) took 6 months and was finished successfully in February 2010. The successful HDD execution has a sustainable impact on the boundaries of the applied laying technique regarding feasible pipeline size and crossing section. More precisely, the experiences made during the project implementation enable a differentiated assessment of future large-scale projects regarding trenchless pipe laying.

Preamble

The Turkmenistan-China-Pipeline, commissioned in 2006 and begun in 2007, will on completion supply the Chinese city of Xinjiang and the West-East Gas Pipeline (WEGP) which begins there with some 40 billion cubic metres of gas a year from the gas fields of Turkmenistan. The pipeline running from Turkmenistan through Uzbekistan and Kazakhstan to the Chinese border will have a total length of some 7,000 km.

The Malay-Bagtiyarlyk passage with a length of 200 km, crosses the central Asian river Amu Darya. At this location the Amu Darya, which has its source in Afghanistan and flows into the Aral Sea, is bounded on its left bank by an approximately 10 to 20 kilometre wide agricultural belt, primarily used for growing cotton. The Karakum desert stretches down to its right bank. In the summer maximum temperatures regularly reach over 50° Celsius in the shade, accompanied by sand storms. In winter, temperatures can fall as low as -20° Celsius – conditions which impede construction of the pipeline.

The river crossing was originally planned to be a bridge structure. The very tight timetable for completion of the pipeline, allied to the increased safety demands on the pipeline, led the planners to conclude that trenchless installation using the HDD method would offer a fast, safe, inexpensive alternative. The location designated for the trenchless installation was the same as that previously planned for the bridge structure.

Once the client operating the pipeline, state-owned gas concern Turkmengaz, had decided to use HDD, the contractor – Russian pipeline construction company Stroytransgaz – quickly needed to find a partner to carry out

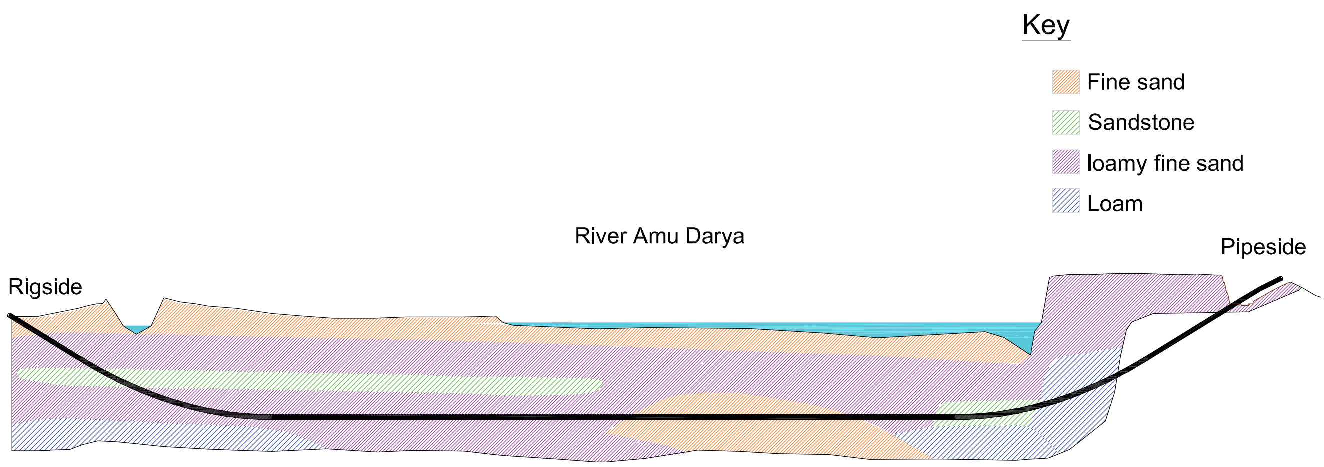

Fig. 1: Drilling profile of the HDD (segment exaggerated)

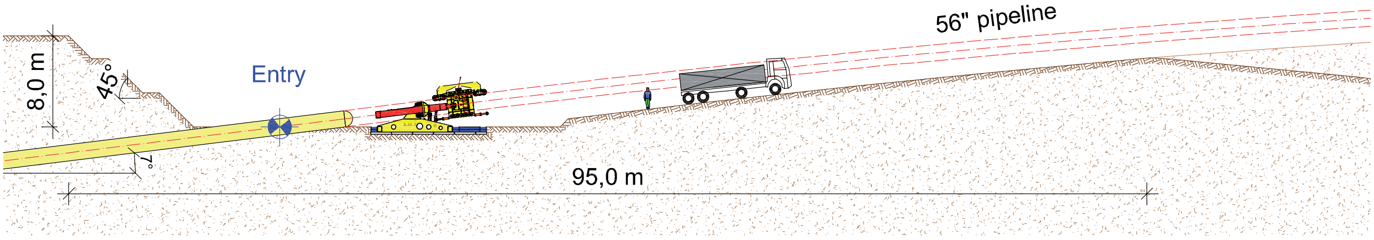

Fig. 2: Section through pit with pipe-thruster

the drilling work on the Amu Darya. In mid-2009 the Amu Darya crossing contract was awarded to Russian drilling company Energoperetok. The contract entailed laying a 56" gas pipeline together with a parallel 8" conduit. The equipment required for drilling was ordered by Energoperetok in July 2009 from Herrenknecht AG in Schwanau. The detail engineering was subcontracted to consulting engineers Dr.-Ing. Veenker Ingenieurgesellschaft mbH. In addition to planning of the site facilities, the assigned tasks also included detail engineering for the machine anchoring systems and the pipeline insertion.

The ground

The crossing stretch to be covered by the planned HDD works has a distance of approximately 1,800 metres. The difference in altitude between the two banks of the river is abaout 11 metres. The geological exploratory bores provided are in some cases incomplete and were produced originally for construction of the foundations for the bridge structure. The available geological data reveals many variations in ground formation, from extremely soft, water-saturated, sandy soil, abrasive sand, loams, soft and hard clay, through to compact sandstone. On the higher bank in particular (the pipe side) there was a 200 metre stretch for which no geological information at all was available. This related to the drilling area, which is higher and so – because of the hydrostatic conditions – is not supported by the bentonite (**Figure 1**). Another problem facing the mud engineers was the salty tempering water from the river for mixing with the bentonite.

Construction process planning

An initial major challenge was the decision as to the direction of the pilot bores. Owing to the low coverage of the pilot bore to the river bed in the pipe-side area and the bentonite pressures in the pilot bore, the risk of a blow-out in this area was much increased. Moreover, it was only possible to lay out the 56" pipeline on the pipe side. This was exacerbated by the geography at the location, whereby, over a distance of 200 metres, the terrain on the pipe side dropped into an approximately 9 metre deep valley. This feature posed a major challenge for the layout of the pipeline and the overbend construction. The appropriate solution for the choice of pilot bore direction and the pipeline layout was to excavate an 8 metre deep pit on the pipe side. This reduced the difference in altitude, and thus the risk of blow-out, and also it meant that the resultant spoil could be used to model the overbend and to even out the varying terrain. Another positive side-effect was that the area of unknown geology was partly bypassed (**Figure 2**).

One of the key risk-minimizing measures on the project was the deployment of the HK750 PT pipe-thruster. The object of this equipment was to assist the pullback of the 56" pipeline by the HK400M drilling rig. The pipe-thruster is able to push the pipeline into the bore hole with a force of up to 750 tonnes and also, as required, extract it again with the same force. The main task was to transmit the occurring pressure and tension forces, with suitable anchoring, into the ground without displacing the pipe-thruster from its anchoring point.

These measures reduced the total length of the bore to 1,705 metres. The decision to drill both pilot bores out of the pit on the pipe side to the actual rig side meant that the point of entry of the pipeline could be precisely defined during pullback. This was a help in that the foundation for the pipe-thruster could be planned and constructed as early as the reaming phase. This did, however require the position of the HK250T drilling rig in the pit to be changed after executing the pilot bore for the 56" pipeline. The machine was moved approximately 80 metres back towards the rim of the pit so as to make room to erect the pipe-thruster and its anchoring.

The very tight timetable, the difficult local infrastructure and the on-site conditions, such as with regard to climate and accommodation for the drilling personnel, pose additional technical challenges entailing a risk factor not to be underestimated in terms of the success of the undertaking.

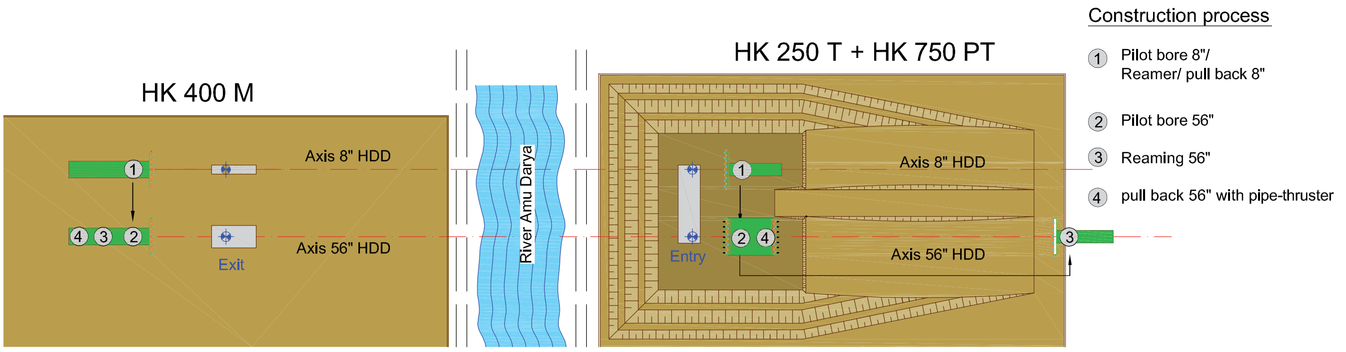

Fig. 3: Schematic view of the construction process

Fig. 4: Reaming a 72" borehole with two drilling rigs (pit with HK 250T and HK 750PT in foreground)

The construction process

The tight timetable imposed made it necessary to allocate two drilling rigs to the site (**Figure 3**). The first batch of equipment was flown by two Antonov cargo planes from Lahr airport in southern Germany to Turkmenistan just six weeks after the initial contact with the drilling contractor Energoperetok. This initial consignment included a HK250T drilling rig, which was used to lay the first 8" conduit, running in parallel with the 56" gas pipeline at a distance of 15 metres from it.

The drilling rig was erected in the pit on the pipe side, in order to drill the pilot bore from there using a 12½" diameter jetting assembly. The first pilot bore served as an exploratory bore and as the reference for the parallel-running pipeline. So as to be prepared for the more solid rock layers further down the bore, a high-powered drilling motor was also supplied, and was also deployed on some sections of the pilot bore. The disadvantage, however, is that in widely varying geology – and especially in soft formations – a high degree of drift occurs and as a result the laying radius is less than the planned 1,400 metres. To counter this risk, most of the bore was jetted. Once the pilot bore had successfully emerged on the rig side, the 8" conduit was inserted using the HK250T drilling rig (1). The pullforce applied in this process was a maximum of 25 tonnes. After repositioning the HK250T rig onto the parallel axis of the pilot bore for the 56" pipeline, the "Paratrack 2" surveying system was then used to execute the second pilot bore for the 56" pipeline. The HK250T drilling rig was able to carry out the first two reaming operations by itself. While this was being done the HK400M on the rig side was moved to the position of the 56" pipeline (2). Once the HK400M had been relocated, the drill string was connected to the HK250T on the rig side. Beginning with the 36" reaming, both rigs rotated the drill string under control. The main advantage of this method is the certainty that every joint in the drill string is tightened to the exact torque. It also prevents pressure forces from being generated on the drill string if the reamer becomes stuck. Factor not to be underestimated are that mud can be pumped to the reamer from both sides of the drill string and that the second drilling rig applies a defined low torque to the string. Overall, the bore was expanded in six reaming stages to a final diameter of 1.83 metres. In addition to the reaming stages, four cleaning passes were executed to ensure that the displaced cuttings are also transported out of the bore hole (3). Very good indicators of this are the sand content in the return, which was measured once per drill rod, and the torque of the drill string in the bore hole, which was likewise checked once per drill rod. On the large reaming passes in particular, as many as five tools were installed in combination, with a total length of up to 40 metres, in order to centre the drilling tool. The drilling tools used were fly-cutters (for cutting) and barrel-reamers (for centring and cleaning) specially developed and adapted to the prevailing geology. The hard-facing and cladding of tools posed a particular challenge, as much of the bore was routed through weathered sandstone. The tools on the circumference of the large reaming stages had to run for distances of some 1,000 kilometres in order to cut through the geology.

The to date unique installation and anchoring of the HK750PT pipe-thruster on a HDD project had to be executed while work to expand the bore hole was ongoing. So as not to lose much time on installing the pipe-thruster after completing the pilot bore, the HK250T drilling rig was moved behind the

Fig. 5: Installation of 56" pipeline

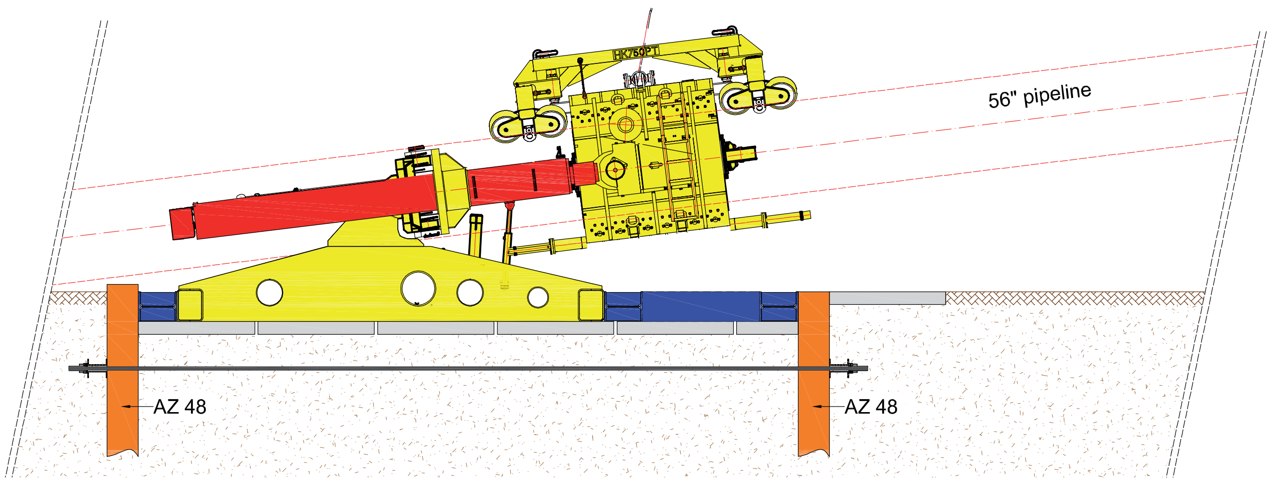

Fig. 6: Pipe-thruster anchoring

foundation of the pipe-thruster in order to continue working on the expansion of the bore hole. In this, the freely rotating drill rod was protected by a casing to safeguard execution of the installation and anchoring (**Figure 4**).

In preparation for the subsequent pipeline pullback, the HK250T drilling rig complete with anchoring was dismantled and the 56" product pipe was advanced approximately 100 metres to the pipe-thruster using the HK400M drilling rig. The extensive clear-out work in the pit was completed after just 36 hours. The clamp of the pipe-thruster was positioned ready for use adjacent to the pipeline and would have been mounted within two hours if needed, in order to deliver an additional force of up to 750 tonnes for the pullback. It was not necessary to use the pipe-thruster, however, as during the 30-hour pullback phase no significant rise in pullforce was observed at any time. The pipeline slid into the bore hole with an average pullforce of 134 tonnes, which the HK400M drilling rig was able to handle without problem (4). These low pullforce indicate that the bore was executed with no substantial deviation from the target profile, the bore hole was well cleaned, and the ballasting of the product pipe worked (**Figure 5**).

The ballast was executed with a DN800 PE tube which served as an air-filled lift body in the water-filled 56" pipeline. In summary, drilling operations supervisor Carsten Brückner comments: "The method of executing a large-scale bore using the two drilling rigs and the pipe-thruster for safety entails reasonable risk and results in a controllable drilling process". The principle will doubtless be applied more often in future, particularly on construction projects of this scale.

The detail engineering

In the detail engineering the machine anchoring solutions were developed in conjunction with the pit and machine layout drawings. In addition to the HK250T and HK400M drilling rigs, the job also involved developing a suitable anchoring solution for the 750 tonne pipe-thruster. As well as calculating the anchoring structure measurements, this also included the production of detailed drawings for on-site execution.

The HK250T and HK400M drilling rigs were anchored on sheet piles. AZ 48 profiles, with foundations sunk to a depth of 8 metres, were selected for the calculations and for the construction. The main challenge on this project, however, was to absorb the forces of the 750 tonne pipe-thruster with a suitable sheet pile structure. In operation, the pipe-thruster develops horizontal pressure and tension of up to 750 tonnes and vertical pressure and tension of up to 280 tonnes. Initial calculations showed that a single sheet pile made of AZ-48 profiles would not be capable of absorbing those forces. The solution was to develop a double sheet pile structure (**Figure 6**).

In detail, the structure consists of two sheet piles spaced approximately 10 metres apart, with foundations sunk to a depth of 8 metres, along a length of 9 metres. The sheet piles are joined together by seven tie rods, which distribute the forces across both. The pipe-thruster was placed between the two sheet piles and anchored to them by a structural steel construction in order to route the horizontal and vertical forces into them. As the specified profile types were not always available on-site, variants of the structures with different profile types were created.

The overbend construction

The optimum overbend construction is a key factor in ensuring insertion of the pipeline under reduced load and without damage. A particular challenge was to define the overbend geometry for the 56" pipeline with a bend radius of 1,400 metres.

The overbend geometry for large pipelines (> 48" outer diameter) not only has to be determined dependent on the geometric conditions but also has to be adapted to the local terrain and the reaction forces on the guiding roller blocks. If the 56" pipeline was to be extracted, the increased loads resulting from the filling of the pipeline needed to be incorporated into the calculations. To this end, a FEM model with pressure-spring elements was produced, taking into account the reaction forces of the 56" pipeline and providing indications as to the deformation response of the pipeline. The most important criterion, however, was that the pitch of the pipeline at the pipe-thruster should be neither above nor below 7°, so as to be able to insert the 56" pipeline smoothly into the bore hole at the desired entry angle. With the results from the calculation, static strength testing of the pipeline was carried out and the arrangement of the roller blocks was defined. The result for the 56" pipeline was an overbend geometry of 450 metres length and 13.5 metres crown height.

Summary

This project posed particular challenges to the HDD crossing technique in terms of planning and technical requirements. As well as mastering the logistical, geological and process engineering difficulties, the project very efficiently handled the special features of the locality and the regional characteristics. This success is based on a high level of technical expertise as well as on very good planning in advance of the project. The potential project risks were identified right from the planning phase and were minimized by appropriate measures. Those measures included the deployment of a pipe-thruster, changing the direction of insertion and excavating a pit. Other key factors in the efficient drilling operation and the successful pipeline insertion were the selection of suitable tools and the decision to work with two drilling rigs on one drill string. Ballasting of the 56" pipeline and adaptation of the overbend geometry also enabled force-optimized insertion.

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