INNOVATIVE DIRECT 'PIPE METHOD' – CASE HISTORIES

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ABSTRACT

The Direct Pipe®-method combines the advantages of the established trenchless methods Microtunnelling and Horizontal Directional Drilling (HDD). With Direct Pipe® one single, continuous working operation is sufficient for the trenchless laying of a pre-fabricated pipeline and the simultaneous excavation of the necessary bore hole. The force required to feed the pipeline forward is exerted by a new type of auxiliary device known as the Herrenknecht Pipe Thruster, which is fixed horizontally and vertically. The Pipe Thruster embraces the pipeline with its clamping device and pushes the pipeline forward. Since the pipeline is coupled to a remote controlled Direct Pipe®-machine, the transport of the excavated material is carried out by a conventional slurry circuit back through the laid pipeline.

October 2007 saw the successful world premiere for the Herrenknecht Direct Pipe®-technology installing a 464 m (1,522 ft) long steel pipe underneath the Rhine River near Worms in Germany. The pipe was planned to serve as a conduit for a water pipeline and several ducts for power and telecommunication cables. Here, the Herrenknecht Pipe Thruster provided an average thrust force of 80 tons (175,000 lbs) to smoothly push the pipeline forward. The jobsite team realized maximum advance rates of 90 m (295 ft) in 24 hours. Breakthrough was achieved only 13 days after the beginning of the construction work.

For the second time, the Direct Pipe®-method was deployed in July 2009 near the city of Emden in Northern Germany. Here, subterranean storage caverns for natural gas are being built on the Ems River. This requires flushing out salt mines to produce large underground cavities. In order to discharge the concentrated saltwater (brine), a 42-kilometer (26 Miles) long pipeline must be laid to the Outer Ems – the last 283 meters (928ft) of the outflow pipe at the "Rysumer Nacken" artificial dune field were built as Sea Outfall using the Direct Pipe®-method. Compared with conventional methods, Direct Pipe® does not require the costly and time consuming installation of steel sheet piles alongside the offshore route. With top performances of up to 9m (29ft) / hour, Direct Pipe® met the high expectations of all parties involved as far as both efficiency and environmental protection were concerned.

After the first two successful Direct Pipe®-projects in Germany the first gas pipeline crossings (with a diameter of 48") were realised in spring 2010 with the Direct Pipe®-method in the Netherlands. The two crossings in sensitive areas, on which open trench was not possible, were part of the North-South-Trail of the Dutch gas supplier GASUNIE.

The geology on both crossings with a length of 371m and 435m was consisting of gravel, sand and also wood & stones. Maximum advance rates of 111 meters in a double shift (of 24 h) and 72 m in a single shift could be achieved. On both projects approximately 30% of the available 500 tons of the Pipe Thruster were utilized at the end. Maximum ground water depths of 5 - 10 m had to be dealt with.

Herrenknecht AG was nominated with Direct Pipe® for the internationally prestigious Hermes Award during the Hannover Fair 2008 and accepted the ISTT Product Award at the 2008 International No Dig Show in Moscow as well as the IPLOCA New Technologies Award in 2009.

KEYWORDS

Easy Pipe installation, possible in all geologies, space constraints

1 INTRODUCTION

Various methods have been used in the past for crossing works involving the laying of steel pressure pipelines. Pipe Jacking and segmental lining allow for the construction of protective tunnels with subsequent insertion of the pipe string. The HDD (Horizontal Directional Drilling) method, in contrast, includes the construction of a pilot bore prior to pipe pull-in. Recent developments such as the Easy Pipe method comprise jacking processes, where tight connection interim steel pipes are pushed towards the target shaft, coupled to a pipeline and then pulled back together. All these methods include a two- or multi-step pipe installation process. The multilevel nature of these methods and pertinent aspects such as costs and project duration led to the development of the Direct Pipe® method: Steel pipelines can now for the first time be jacked efficiently and fast in one single operation process.

The development of Direct Pipe® was based on objectives such as the creation of a one-step pipe jacking method, provision of an economic alternative to existing methods, reduction of site-infrastructure areas and minimization of geological risks (e. g. drill-hole collapse). In addition it was necessary to eliminate the disadvantages of existing methods, whilst utilizing the particular advantages and including new technologies. The result was a combination of HDD, Microtunnelling and the Herrenknecht Pipe Thruster, which was presented for the first time at the Hannover Fair in 2006 and which has been proven in practice in various applications.

2 THE DIRECT PIPE®- METHOD

The Direct Pipe®-method includes the welding and testing of the pipeline, which is stored on rollers on the launch side. A Direct Pipe®-machine is mounted in front of the pipeline. This machine is very long in order to facilitate control of the machine and afterwards the whole pipeline. The Pipe Thruster operates as a thrust unit from the launch pit clamping the pipeline on the outside and pushing the machine as well as the pipeline into the ground.

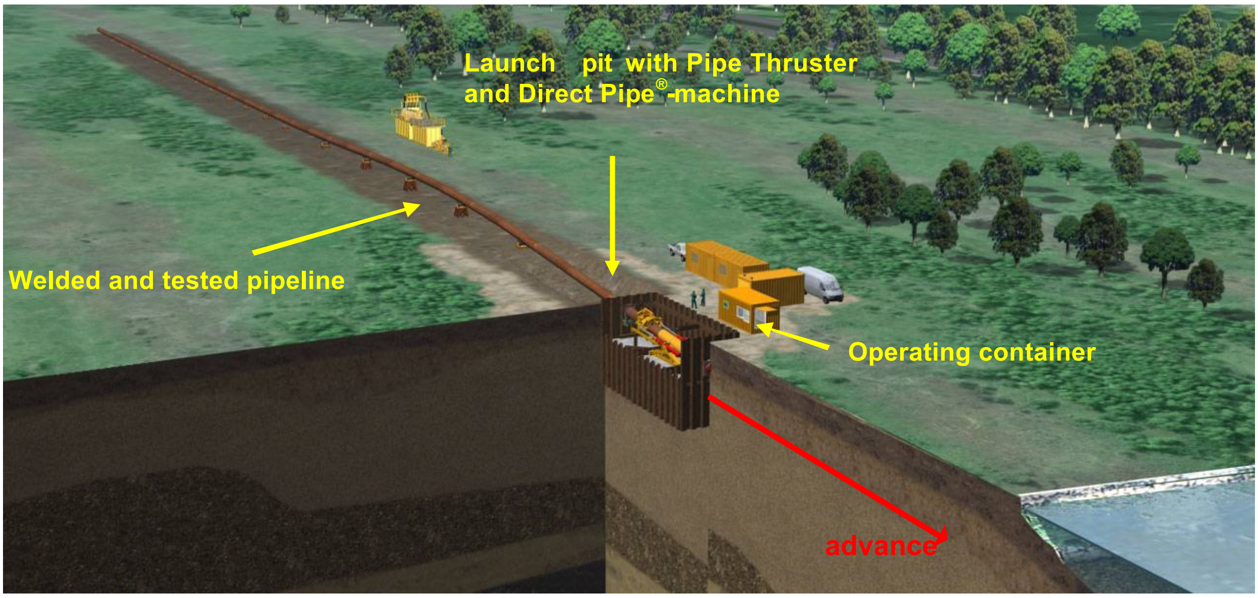

Figure 1: Cross section of a river Crossing using the Direct Pipe®-method (crossing from left to right)

In contrast to Pipe Jacking, with Direct Pipe® a Pipe Thruster is set up in the launch pit instead of a jacking frame. It is fixed horizontally and vertically with the aid of steel beams and anchors to transmit the thrust forces to the surrounding soil. Thereupon the Direct Pipe® machine is mounted on a special steel frame in front of the launch seal. Then the prefabricated and tested product pipeline is welded onto the end of the Direct Pipe®-

machine and the excavation process commences. The tunnel face is excavated by the Direct Pipe®-machine as with all slurry-machines, which have been established for several decades on pipe-jacking of reinforced concrete pipes. The tunnel face is slurry-supported using a bentonite suspension. The excavated material is removed via a slurry circuit to a separation plant in order to separate the soil from the slurry liquid before a feed pumps transport the liquid back to the tunnel face.

Different than Pipe Jacking or Microtunnelling, the Direct Pipe®-method allows installation of the slurry circuit at the onset of the project, therefore avoiding delayed installation and allowing successive extension of the circuit to the slurry and pump system is operated parallel to Pipe Jacking along the entire drive length. For the installation and fixing of the utility lines inside the pipeline – like slurry lines, electricity and data cables, air and bentonite lubrication lines – special steel frames with hooks and rollers are used, spaced about 3 m apart (see Fig. 2). After completion of the excavation, i. e. when the Direct Pipe®-machine has reached the target pit, the utility lines can be pulled out of the pipeline with the aid of the rolling steel frames – in one or two steps.

A newly developed electric-powered personnel transporter is used for comfortable surveys of the machine and the alignment. To guarantee the security of the personal, a permanent adequate supply of air and light has to be provided during the surveys.

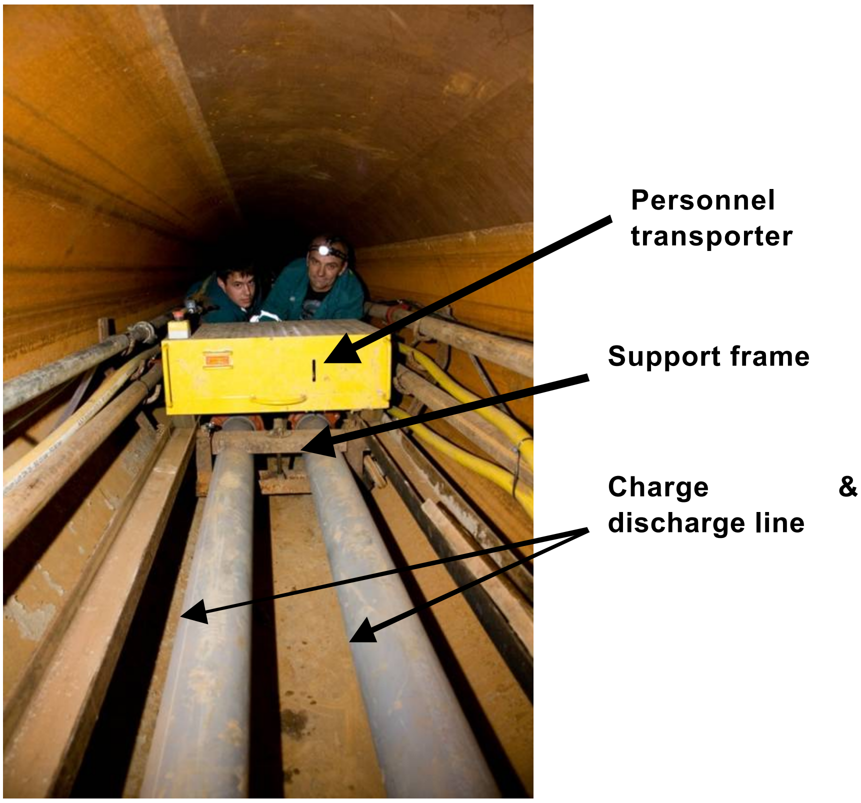

Figure 2: Attachment of cables and slurry lines on the support frame and comfortable access with an electric-powered personnel transporter.

The cutting wheel of the Direct Pipe®-machine can be equipped with cutting tools adapted to the specific geological conditions. In contrast to HDD technology, larger boulders, very hard rock as well as soft, unstable soils like gravel can be crossed because the borehole is directly filled with the pipeline and is not only stabilised with bentonite.

The machine is controlled from the operating container, which is located beside the launch pit (see figure 1). The high-precision navigation system of the Direct Pipe®-machine is used to survey its position in the ground. The vertical orientation is given with the aid of a hydrostatic water levelling system (maximum height differences are only about ± 3 to 15 mm). The horizontal orientation is given by means of a continuous measuring gyro compass: (maximum horizontal deviations are only about ± 5 cm). Therefore the launch point can be found very exactly – in contrast to HDD, where normally larger deviations occur.

The rear of the Direct Pipe®-machine (see Fig. 3) is designed conically. This increases the annular gap between the pipeline and the surrounding ground. Out from the lubrication ring, which is integrated in the conical rear of the machine, lubrication bentonite is injected into the annular gap to reduce the friction whilst pushing the pipeline through the ground.

Figure 3: The Direct Pipe machine AVN1000XC for laying a 48"-pipeline.

When the site configuration of the construction site allows the laying out of the whole pipeline with Direct Pipe® it can be installed in one single step. If however there is not enough space the pipeline can be laid out and thrusted in sections. The pre-welded and tested pipeline sections are positioned on rollers and moved onto the piling ramp once the previous pipeline section has been thrusted into the ground (see Fig. 4).

Figure 4: Pipeline sections thrusted by the Pipe Thruster.

During the excavation of the soil the Pipe Thruster clamps the pipeline on the outside and pushes it stroke wise forward from the start to the target point with its two hydraulic thrust cylinders. The Pipe Thruster provides the necessary pressure for the drilling process on the cutter head of the machine. At the moment three models of the HERRENKNECHT Pipe Thruster are provided. By simply changing the clamping inserts one model can be used for different pipe diameters (see figure 5). The smallest model is the Pipe Thruster HK300PT with 300 tons push- and pull force. It can be used for pipes ranging from 20” to 36” (500 up to 914 mm). A larger unit HK500PT for pipe diameters ranging from 20″ to 48″ (500 up to 1200 mm) can apply push- and pull forces of 500 tons. The strongest and largest unit HK750PT is adapted to pipe diameters ranging from 40″ to 60″ (1000 up to 1500 mm) and has a push- and pull force of 750 t.

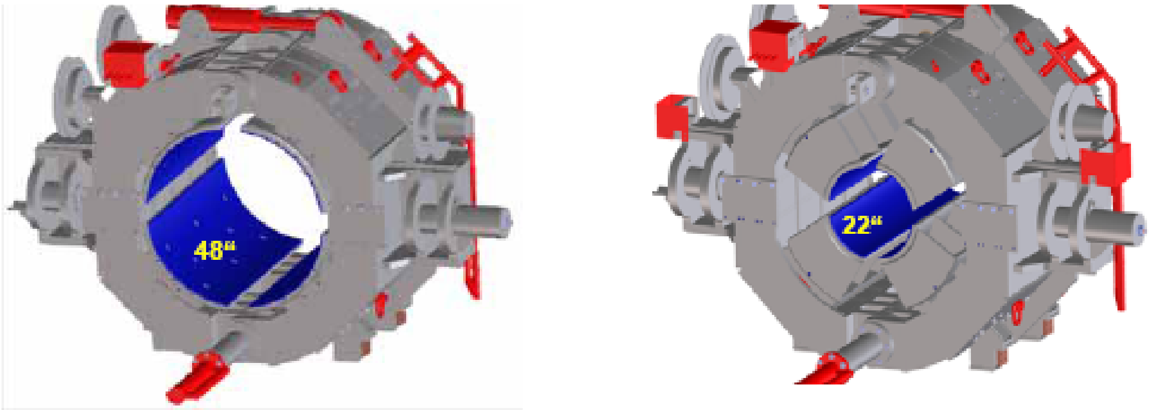

Figure 5: Clamping unit of the HK500PT (adaptable for a 48” pipe on the left and a 22” pipe on the right).

The clamping unit can be deployed on steel pipes with any kind of factory-made pipeline coating (except field coatings). The Pipe Thruster does not damage or weaken the coating. This has been demonstrated in extensive experiments and field tests and is guaranteed by Herrenknecht. The area of the clamping unit in contact with the coated pipe is large enough to spread the load on the coating. The clamping inserts of the clamping unit are coated with an approximately 10 mm thick hot vulcanized contact rubber which compensates for unevenness of the clamped steel pipe and its coating (see Fig. 6). The contact rubber is in a position to dissipate water or dirt which is located on the piping by means of grooves in the rubber. The integrity of the coating can also be checked before entering into the borehole (Cathodic corrosion test).

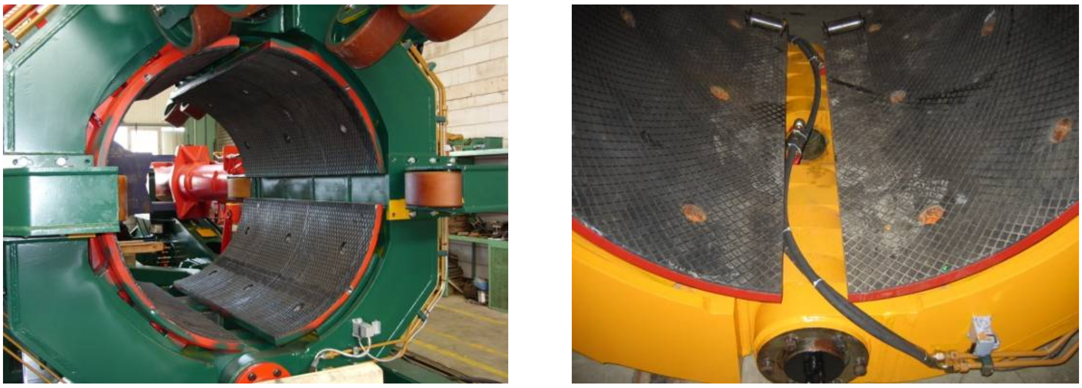

Figure 6: Clamping unit of the Pipe Thruster with clamping inserts with vulcanized contact rubber.

The two thrust cylinders of the Pipe Thruster are designed for a stroke of five meters and a maximum advance rate of 3 m/min. The Pipe Thruster is pivotable, which means that the clamping unit with its two thrust cylinder can be pushed forward at angles between 0° and 15°.

3 PILOT PROJECT “RHINE CROSSING NEAR WORMS (GERMANY)”

During the Rhine crossing near Worms in September 2007, the Direct Pipe® method made its debut. Contracted by Worms-based EWR Netz GmbH, Herrenknecht installed a culvert with a total length of 464 m parallel to the Nibelungen Bridge from the Hessian side of the Rhine River towards downtown Worms located on the other side of the river in the Federal State of Rhineland-Palatinate.

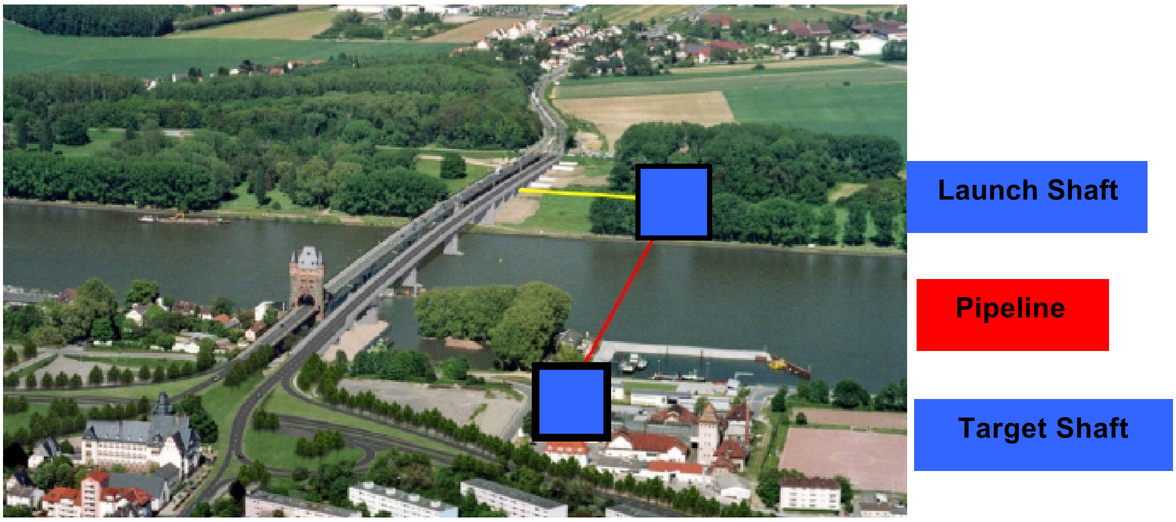

Figure 7: Bird’s eye view of the crossing of the river Rhine in Worms.

The pipeline was planned to serve as a casing pipe (with a diameter of 1200 mm or 48-inch) for a 600 mm diameter water pipeline and additionally several ducts for power and telecommunication cables. The casing-pipe voids are cement-filled after product pipe pull-in to hold the ducts within the casing pipe in place and protect them for the duration of their service life. The new Direct Pipe® method, engineered and tendered by the Hamburg-based engineering firm de la Motte & Partner, bid by the construction company Sonntag Baugesellschaft mbH & Co. KG from Dörth in cooperation with Herrenknecht AG, was preferred over trenchless construction and HDD technology during the award process. The method was awarded due to its economic benefits and project-specific advantages such as the minimum space requirements on the target side in Worms only requiring a minimum pit size for the recovery of the micro machine; it was also chosen due to the tight schedule, which required a timely realization of the project because of a flooding danger, expected late September, that threatened the region of Worms and the entire site infrastructure. Ironically flooding of the Rhine River, caused by heavy rains in Switzerland, occurred during site set-up in mid-August, i. e. much earlier than expected, leading to a complete evacuation of the jobsite and a delay of approximately one month. The coverage of the culvert alignment underneath the Rhine River was approximately 10 m at a water depth of 5 m and 3 in the bank area. The alignment comprised a 100 m long straight drive with a 9.5% gradient and a circle section with a radius of 1450 m towards the target shaft. The maximum water pressure in the middle of the alignment under the riverbed of the Rhine was 1.5 bar. Since site infrastructure was spatially limited due to nearby woods, the pipeline could not be jacked in one step. Instead, pipe sections of 5 x 90 m and a first section of approximately 30 m length were prepared. The pipeline was extended by welding the pre-installed pipe sections together. Pipeline extension, welding of the pipe sections and coupling of the supply and discharge lines of the machine took between 12 and 15 hours (see Fig. 8).

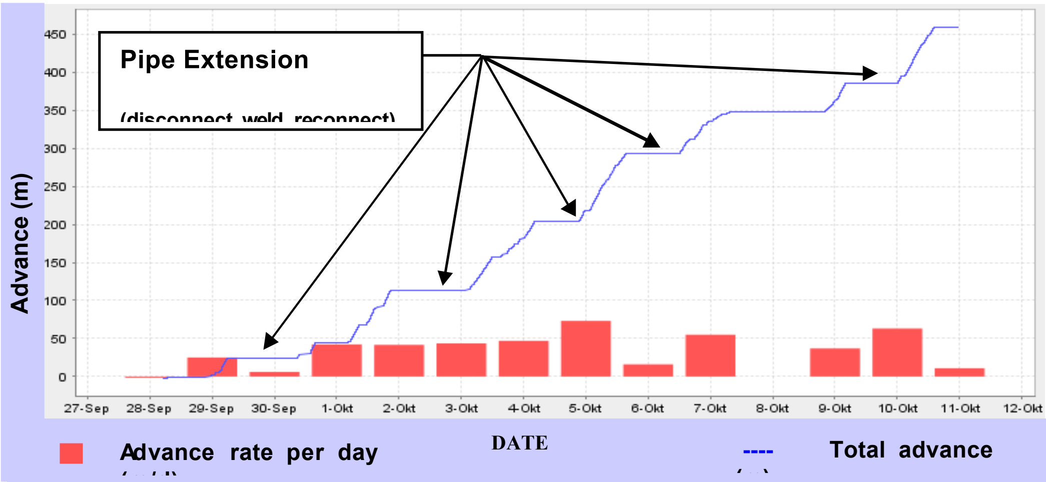

Figure 8: Progress of the Rhine River Crossing – 13 days for 464 meters.

After starting the excavation process, the new method exceeded even the most optimistic expectations. Average performance rates of 15 cm/min (maximum 25 cm/min) allowed for a fast installation of the pipe sections. On average, a 90 m long pipe section was jacked per day; with average thrust forces of only 70 to 80 t. The pipe string was lubricated through a lubrication ring from the machine and from an opening behind the launch seal in the launch shaft; pipe lubrication was not carried out automatically through openings in the pipe string. The over cut of 53 mm allowed the pipeline to “float” in the drill hole and helped to considerably reduce friction forces. Upon arrival in the target shaft (see Fig. 9), it became evident that the largest part of the thrust force had to be applied due to face pressure (which was no longer generated after the target shaft had been reached). The alignment soils were comprised of approximately 80% gravely sandy soils and up to 20% of silty clayey soils, which positively influenced performance rates.

Figure 9: Successful arrival in the target pit in the harbour of Worms.

4 SECOND DIRECT PIPE®-PROJECT IN EMDEN, NORTHERN GERMANY.

On the shore of the Rysumer Nacken artificial dune field near the city of Emden, the Hamburg based construction company Meyer & John GmbH & Co. KG Tief- und Rohrleitungsbau is using Herrenknecht's innovative Direct Pipe®-method to lay the final 283 meters beneath the River Ems. A Direct Pipe®-machine worked its way from the launch pit on the shore towards the target pit in the Ems, with a maximum Pipe Thruster power of 750 tones. For this single-step pipe laying method, the Herrenknecht TBM, with a drilling diameter of 1,325 millimeters, proceeds with a 48-inch, PE-coated pipeline in tow. When the TBM reaches the target pit, it is detached from the installed pipeline and recovered. At this stage, the sea outfall is complete, and the pipeline is ready for operation.

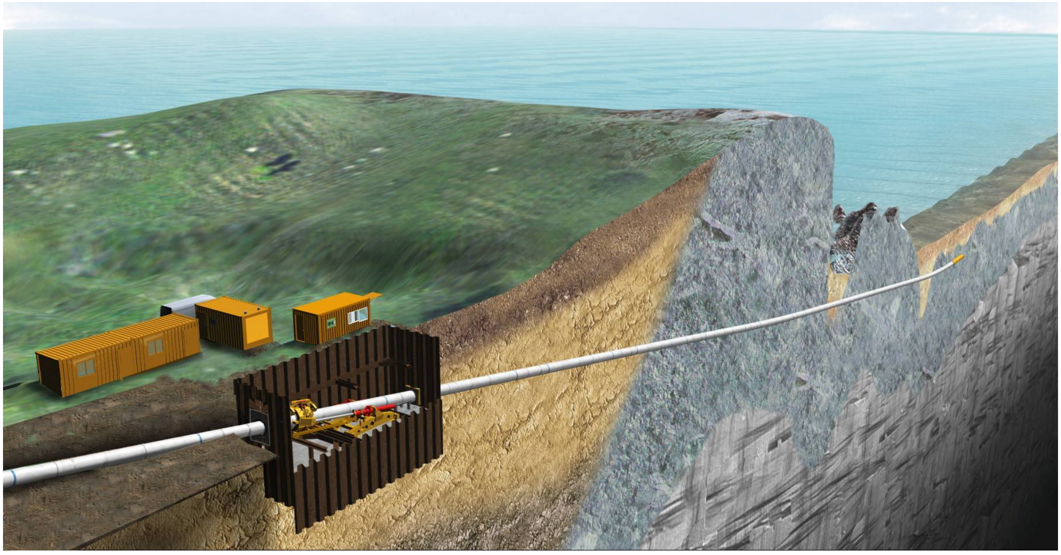

Figure 10: Direct Pipe®-application in submarine outfalls-

Tunneling in Emden began on July 7, 2009 and just 7 tunneling days later ling days later, 246 meters of pipeline had been laid. Because of the tight space constraints at the construction site, the pipeline could not be laid in one length. For this reason, individual, 36-meter pipe lengths were prepared and joined onto the pipe string. An accident occurred at the target pit during crane operations, which were not within the responsibility of the client, and this led to the discontinuation of all construction work on July 21. The target pit is necessary so that the TBM can be recovered at a later date. The drill hole created while the pipeline was being laid using the Direct Pipe®-method was secured during this interruption of work and was not in jeopardy. Tunneling activity was able to be restarted on August 6, 2009. The TBM reached its target with supreme precision; its deviation from the ideal line was a minimal 3 centimeters. With a maximum gas storage volume of 300 million cubic meters, the first caverns of the Jemgum gas storage facility will be ready for operation in 2013. Following final completion of the construction work in 2016, the storage facility will have a working gas volume of 1.2 billion m^3 and a withdrawal capacity of 1.2 million m^3/h.

Figure 11: Second Direct Pipe®-project in Emden, Northern Germany. Jobsite installation.

5 TWO 48” GAS PIPELINE PROJECTS IN THE NETHERLANDS.

After the first two successful Direct Pipe®-projects in Germany the first gas pipeline crossings were realised in spring 2010 in the Netherlands with the Direct Pipe®-method.

Since 2008 the so called North-South-Trail with a diameter of 48” is built to enlarge the gas transportation network of the Dutch gas supplier GASUNIE. The construction of such a large diameter pipeline in an area with a lot of infrastructure, highways, railways and a vast network of piping requires resourceful drilling and an installation system which is reasonable in areas with space constraints and above all with difficult ground conditions. The two successfully realized crossings of sensitive areas, on which open trench was not possible, were part of a trail from Angerlo to Beuningen and realized from the Dutch construction company A.Hak Drillcon.

Figure 12: Jobsite installation one the second Direct Pipe® gas pipeline project in Elst, Netherlands.

For the first 371m long crossing of an historical monument near Arnheim the benefit of Direct Pipe® was leveraged that the pipeline has not to be assembled in one piece as it is usual with HDD. On the second crossing the 470 m long pipeline was completely preassembled to benefit from the time saving of the otherwise needed coupling times.

The Polypropylen-coating (PP) of the 48”- gas pipeline was tested prior to the realization of the projects to be resistant against the clamping forces of the Pipe Thruster in the workshop of Herrenknecht AG.

Figure 13: Coating Test realized in the workshop in Germany.

The geology on both crossings was consisting of gravel, sand and also wood & stones. The minimum radius of the alignments was 1.400 meters. Maximum advance rates of 111 meters in a double shift (of 24 h) and 72 m in a single shift could be achieved. On both projects approximately 30% of the available 500 tons of the Pipe Thruster were utilized. Maximum ground water depths of 5 - 10 m had to be dealt with. The recovery of the Direct Pipe®-machine at the target side was realized without pit lining. It was thrusted into a ditch and disassembled afterwards in sections (see picture 13).

Figure 14: Arrival of the Direct Pipe-machine on the target side in Elst, Netherlands.

ADVANTAGES AND MAIN CHARACTERISTICS OF DIRECT PIPE®

- Large-diameter product pipes can be laid without casing pipes.
- One-step jacking method, i.e. the product pipeline is pushed into the ground in one step, in contrast to all common methods, which have so far been applied.

- Due to continuous pipe jacking the effective drilling time is low and a high laying performance can be expected. High performance rates are possible due to the deployment of the Pipe Thruster and the possibility to install the entire tested pipeline or large pipeline sections
- Permanent drill-hole support in order to prevent a drill-hole collapse, advantage over HDD. Thus the risk of failure due to subsoil conditions is minimized.
- Very large bending radii can be driven with a high accuracy due to the approved steering mechanism, thereby avoiding excessive bending stress (inadmissible low bending radii of the pipeline) and excessive laying forces.
- Cutting wheel and cutting tools of the Direct Pipe® machine can be adapted to any geological conditions, which is a useful improvement over HDD.
- Rocks can be crushed and removed through supply lines within the product pipe out of the borehole; therefore deposits in the bore hole are impossible.
- Minimum space required, only on the launch side: Advantage over other methods, which either require considerable storage space on the launch side (pipe jacking / segmental lining), which require considerable space in order to install the product pipeline on the target side (HDD) or which require space on both sides (Easy Pipe). Due to the small over cut a minimal bore hole diameter can be realized (thus the amount of excavated material is minimized) and a minimum slurry volume is required.

6 CONCLUSION

Direct Pipe® is an alternative method for pipeline installation having not only theoretical advantages over existing methods (in particular over HDD technology and especially regarding large diameters) but also achieving impressive practical results. Direct Pipe® accommodates project requirements and jacking performances which are not achievable using other methods. Future projects will show how far the limits can be pushed with regard to alignment length and performance rates. Already a large number of possible upcoming projects are being considered, promoted by the high and continuously growing worldwide demand for pipelines and under crossing structures required for the oil and gas industry, for freshwater and sewage transportation as well as or supply and communication lines.