

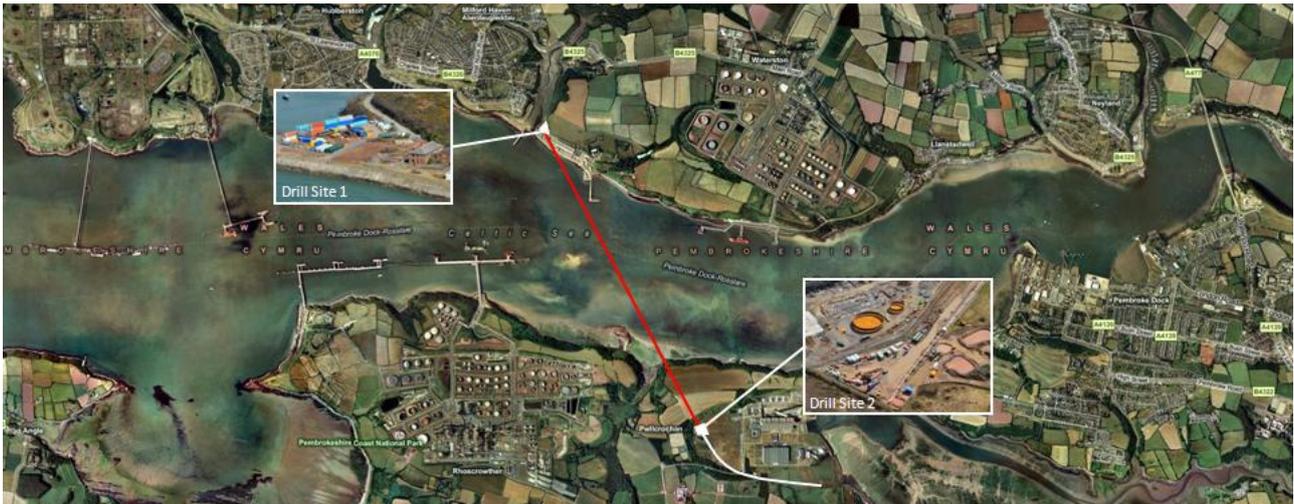
# LMR Drilling UK Ltd.

## Milford Haven?



## Pembroke Gas Pipeline: HDD Crossing of Milford Haven

**LMR Drilling UK Ltd.** has recently completed the installation of a 3,000 m long gas pipeline through rock by Horizontal Directional Drilling under Milford Haven, South Wales. This Project, the longest HDD to be completed in Europe and arguably the World's longest HDD in rock, was completed ahead of schedule with great satisfaction to all concerned.



Aerial View of Drilled Crossing showing Drill Alignment & Pipe Stringing Site

### Project Brief

RWE npower commissioned a new state-of-the-art 2,000 MW combined cycle gas turbine (CCGT) power station to be built at its existing Pembroke Power Station site. Land & Marine Project Engineering were awarded the Contract to install a 457 mm diameter steel pipe and AGI's to supply gas from the north side of Milford Haven to the Power Station on the south.

Conventional trenching of the foreshore either side of the Haven was not an acceptable option due to environmental concerns and the heavily trafficked shipping lane leading to numerous docks and the LNG terminal. Therefore, Trenchless techniques, such as Horizontal Directional Drilling, were considered as alternative methods for effecting a low impact installation. It soon became clear that HDD provided the most viable solution, despite the considerable distance across the Haven along the gas pipeline route.

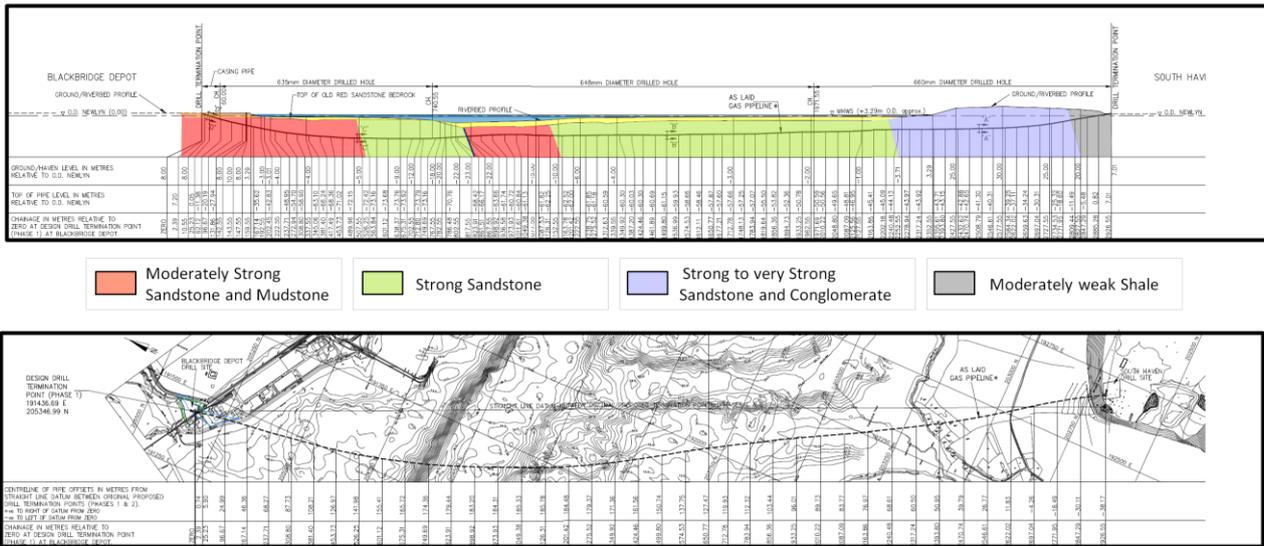
With the reputation for successfully tackling large diameter and long HDD crossings through extreme rock formations already well established, LMR Drilling were approached by Land & Marine as they prepared their bid for the gas pipeline.

Following early discussions with the Client and Land & Marine, LMR Drilling were awarded a Sub-Contract to execute a 1,980 m test drill from the north side of the Haven at Blackbridge in order to determine the feasibility of the 3,000 m pipeline installation through the rock formations under the Haven. The test drill was completed during the period April to July 2007 and indicated that the formations were suitable to enable a stable bore to be opened and maintained until the installation of the gas pipeline.

LMR Drilling prepared a detailed Post-Test Drill Report and, following discussions with RWE npower, instructions were given to proceed with the 3,000 m HDD crossing and pipeline installation. Construction of the HDD crossing commenced in October 2009 and was completed by May 2010.

### Geology

The formation under the Haven primarily comprised the steeply dipping Devonian Old Red Sandstone Formation. This typically consisted of



Long Section and Plan View As-Built showing geology along the Drill Path

5 mm to 5,000 mm thick beds of red, brown and grey, fine to very fine grained sandstone with some siltstone, red/brown mudstone, and conglomerate beds. The drill line also passed through the Ritic Fault, a major regional fault plane (see above). Depending on the formation, the compressive strength of the rock ranged from 20 to 140 MPa. The formations as drilled during the test drill proved to be moderately to very abrasive.

The strength and abrasivity of the rock over such a long crossing length presented a considerable challenge for the HDD. The downhole tooling and drilling fluid regime had to be chosen carefully to mitigate risk wherever possible.

### Drilling Equipment

Due to the length of the bore, drill rigs were required on both sides of the crossing to drill pilot holes, intersect these pilot holes to form a single bore and complete the hole-opening operations. LMR's 250 tonne and 350 tonne drill rigs were chosen, capable of producing 3,000 kN and 3,500 kN push/pull force and 120 kNm and 180 kNm of torque respectively.



Blackbridge Drill Site

### Pilot Hole

Due to the strength of the formations and length of the crossing, it was necessary to complete the 16" pilot drills in two sections, each drilled from opposite ends of the 3,000 m crossing. Drill sites were set up at Blackbridge on the north side of the Haven (350 tonne drill spread) and at the site of the new Power Station on the south side of the Haven (250 tonne drill spread).

The pilot hole drilled from the Blackbridge site followed the 1,980 m of existing bore drilled during the test drill phase. A new pilot hole was drilled from the Power Station site to a distance of 1,074 m.

In order to have a complete bore under the Haven, the 2 no. drilled holes had to be joined several tens of metres below the riverbed.

The Post-Test Drill Report identified a suitable section of the test drill bore into which the new pilot hole could be drilled and the pilot hole from the Power Station was drilled into the pilot from the Blackbridge site, thus completing an intercept underground and forming a single, 3,000 m long x 16" diameter hole between the drill sites.

With the pilot hole joined together, the Power Station pilot assembly was withdrawn from the hole and the Blackbridge assembly was pushed through the bore and out onto the Power Station rig site.

The pilot holes were drilled with 16" tungsten-carbide insert (TCI) HDX® tri-cone bits, supplied by Inrock, with diamond enhanced inserts in the heel row and shirt tail so as to protect the gauge and maximise the bit life. The torque required to turn the bit was provided by a 9½" mud motor.

Although this was an unconventionally large size for the pilot drill, the use of such large tools mitigated risk during the pilot drill and, more significantly, reduced the risk during subsequent hole-opening operations in that all hole-openers could be constructed with large bodies and strong cutters. LMR had used this technique with great success on previous rock outfalls drills. In order to apply the requisite push forces to the drill bit, hevi-wate drill pipe was used to form the drill string.

Steering services were supplied by Prime Horizontal using the Paratrack® magnetic survey system. A surface coil was only placed overland to the low water mark in the Haven. Survey information gathered while drilling inside the coil was used to maintain accuracy while drilling outside this coil.

Paratrack® was used to bring the new pilot hole to within a few metres of the Blackbridge pilot hole. At that point, a rotating magnet in the Power Station pilot assembly was utilised to accurately steer the new pilot hole into the Blackbridge pilot hole.

### Hole-Opening

In order to accept the 457 mm diameter gas pipe, the 16" pilot bore was opened up to 26" during hole-opening.

Due to the hard abrasive nature of the rocks, bespoke, robust, well armoured hole-openers fitted with TCI cones had to be used during the hole-opening operations. These hole-openers were supplied by Inrock and originate from tri-cone HDX® rock bits and, as such, could be chosen with the same specification as the pilot hole bit. These were mounted onto hole-opener bodies so as to ream the appropriate diameter of hole.



26" Hole-Opener after 160 hrs

The hole-opener was attached to the drill string at the Power Station drill site and pulled through the hole from the Blackbridge drill site.

Due to the abrasive nature of the formation, it was necessary to complete the 3,000 m of hole-opening with three custom made hole-openers.

Upon completion of the hole-opening, two cleaning runs were completed to ensure that all of the formation cut during the pilot hole and hole-opening operations was completely removed from the bore.

Drilling-fluid engineering was performed by Clear Solutions, with their engineers constantly monitored the rheology of the drilling fluid pumped through the drilling assemblies to ensure that formation cuttings were carried the long distance through the bore from the cutting face to the surface.

### Pullback

During the construction of the 3,000 m long 26" bore, Land & Marine strung, welded, coated and tested the 457 mm gas pipeline along a 1,300 m stringing site at the Power Station. The pipe string could not be fabricated into one continuous length, so was strung out in three sections of varying lengths.

Upon completion of the final cleaning run, the 250 tonne drill rig at the Power Station site was rigged down and removed from site. A pulling head on the lead end of the first pipe string was connected to the drill string by the pulling assembly: a swivel, knuckle joint and barrel reamer.



Pipe String entering the Bore at the Power Station Drill Site

The pipe was then pulled into the hole by the 350 tonne drill rig at the Blackbridge site. The pullback was stopped twice so that tie-in welds to the second and third pipe string could be made. The pullback was completed over a 48 hour

period, with pull loads not exceeding 60 tonnes. The low pull load was testament to the detailed engineering of the crossing and the successful application of the HDD methodology during the construction phase.

## **Summary**

With the coastline around the Haven left untouched, shipping lanes left open and with minimal disturbance to local residents. LMR Drilling UK applied an innovative drilling solution to a unique situation to reduce cost and minimise environmental impact within the locale.

Despite the extreme length and challenging rock formations, the drilling works were completed within budget, within programme and without mishap, a satisfactory result for all concerned. LMR Drilling UK have again proven that, with careful planning, the right team ethos and the experience and knowledge gained from drilling in such formations, even the most challenging drilling projects can be tackled with confidence.

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