Encyclopaedia of Tunnelling, Mining and Drilling Equipment

Barbara Stack

Muden Publishing Company
Hobart, Australia

Pigott Shaft Drilling Limited

Titan Reverse Circulation Shaft Drilling Rig

In 1977 Pigott Shaft Drilling Limited, located in Lancashire, England, designed and built in their own workshops a reverse circulation shaft drilling rig. The machine was powered by a V16 GM diesel engine, driving four Sunstrand hydraulic pumps through a 'mechanical splitter box'.

The rig was fitted with an ex-oilfield 8 fall travelling block and was rated at 150 tonnes lifting capacity. The main winch was a purpose built hydraulic unit with twin drums, selected by dog clutch. A commercially available crane slew ring was used as a rotary table. The rotary table (driven by three Staffa motors through large spur gears) was 2.46 m (97 inches) in diameter, which permitted the passage of 2.43 m (8 ft) diameter tools. Three 2.43 m (8 ft) diameter holes were drilled with this rig.

Another three 2.43 m holes were drilled after extensive upgrading had been carried out. According to the Pigott company, this work (which included the fitting of a new removable crown block, travelling block and winch using 40 mm rope on 12 falls) 'rated the rig at 362,880 kgs (800,000 lbs) 'SAFE' working load after using U.K. factors of safety for lifting devices'.

Development of Special Mud Additives

On the first of the new holes, difficulties were experienced with 'bit balling'. This was resolved by two important developments - the first of these being the use of special mud additives which proved so effective that the company now sell this product to civil engineers and shaft drilling contractors.

In-shaft submersible pump

The second development concerned a revolutionary new reverse circulation method, namely the use of an 'in-shaft submersible pump' which greatly increased circulation rates.

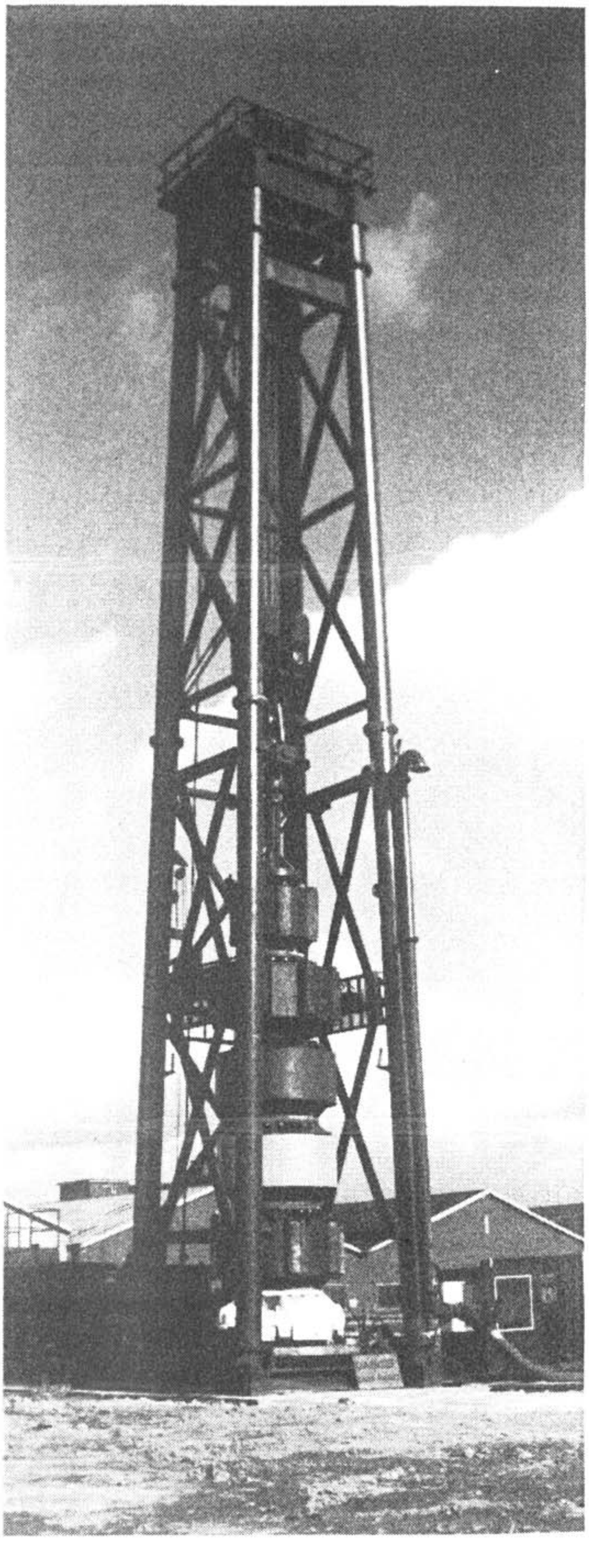


Figure 336.
Pigott 'Titan' airlift drilling rig fitted with Hughes flat bit.
(Courtesy Piggot Shaft Drilling Limited)

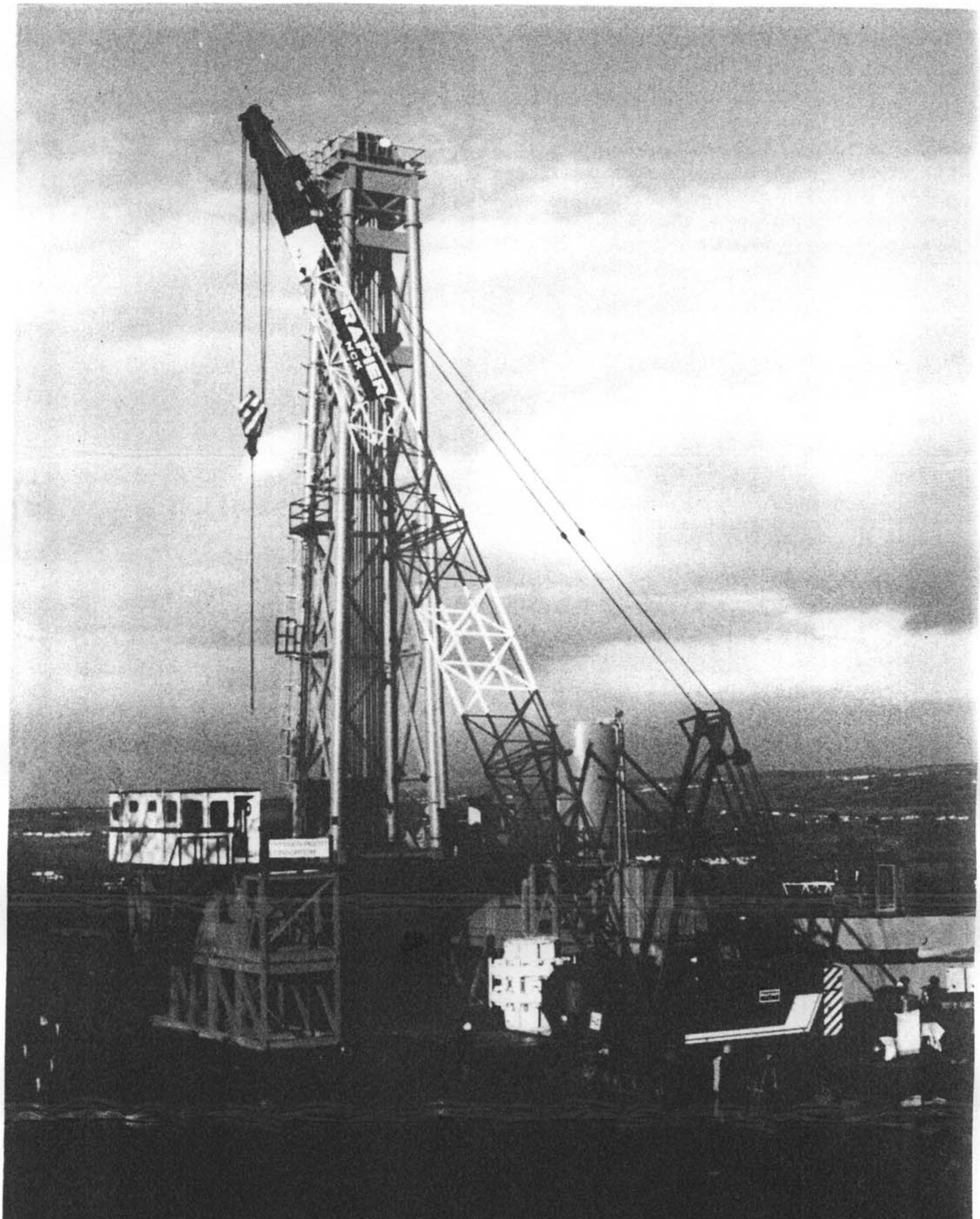


Figure 337.
Pigott 'Titan' on sub-structure fitted with Pigott conical bit dressed with Wirth disc cutters.
(Courtesy Pigott Shaft Drilling Limited)

The submersible pump system comprised a large solids handling dredging pump set inside a chamber that formed part of the upper drill string. Electrical power for the pump was transmitted through a heavy duty slip ring arrangement, set under the mud swivel. A cable joined the slip ring to the pump.

The advantage of this system was that a circulation rate of approximately 15,000 l.p.m. (4,000 g.p.m.) could be achieved as soon as the shaft was deep enough to accept the drilling tools and the pump — about 20 m. By contrast, rates remained relatively low when using conventional airlift methods, until a deep depth of submergence for the air injection point was reached.

An added advantage for the submersible system was that the pump only required 112 kW (150 hp), which was considered to be very low and economical compared to power consumption by conventional airlift systems.

Changes to the Drill Bit

After the completion of these project shafts, additional minor modifications were effected and the TITAN rig was then put to work drilling another four shafts in chalk. During this phase further significant changes were made to the equipment.

Pigott installed a new conical bit, designed and built by the company, which was dressed with Wirth disc cutters. Up to that stage, all bits used on the TITAN rig had been of the flat-bottomed type which were fitted with Hughes Tool Company milled tooth cutters.

This change increased drilling rates for two reasons. Firstly, the new shape encouraged the cuttings to fall towards the centre of the hole where the circulation pickup was located. Secondly, the disc cutters produced larger chips which were easily handled by the new improved reverse circulation pumping system.

A non-rotating stabiliser was used to limit damage to the shaft wall. It consisted of two rows of Caterpillar D8 bottom track rollers, mounted in the vertical plane and fitted with pressure compensators for the seals and bearings. This system proved to be very successful.

Larger diameter holes for Titan rig

The final modifications made to the Titan rig were, in the words of Colin Pigott, 'the most major' and were designed to allow 6 m (20 ft) diameter tools to be used.

These modifications included:

- Mounting the rig onto a sub-structure to permit the handling and support of 6 m diameter tools
- Replacing the V16 diesel engine with two electro-hydraulic units

The sub-structure consisted of four space frame boxes (built to the dimensions of standard 'ISO', 12 m (40 ft) freight containers) with two 12 m (40 ft) heavy duty cross beams and smaller stabilizing beams. The sub-structure was designed to carry the entire weight of the rig, which included the hook and dynamic loadings generated during drilling operations.

The modified rig, fitted with conical bit and dressed with tungsten carbide disc cutters, drilled a 3.75 m (12.3 ft) diameter shaft to a depth of 220 m (720 ft).

The amount of equipment for this project was considerable, involving 1000 tonnes of plant which was delivered in 40 trucks. This prompted Pigott Shaft Drilling Limited to consider whether a more economic method of blind shaft drilling could be devised and led to the announcement in June 1989 of a design for a Steerable Shaft Drill, designated the 'SSD'.

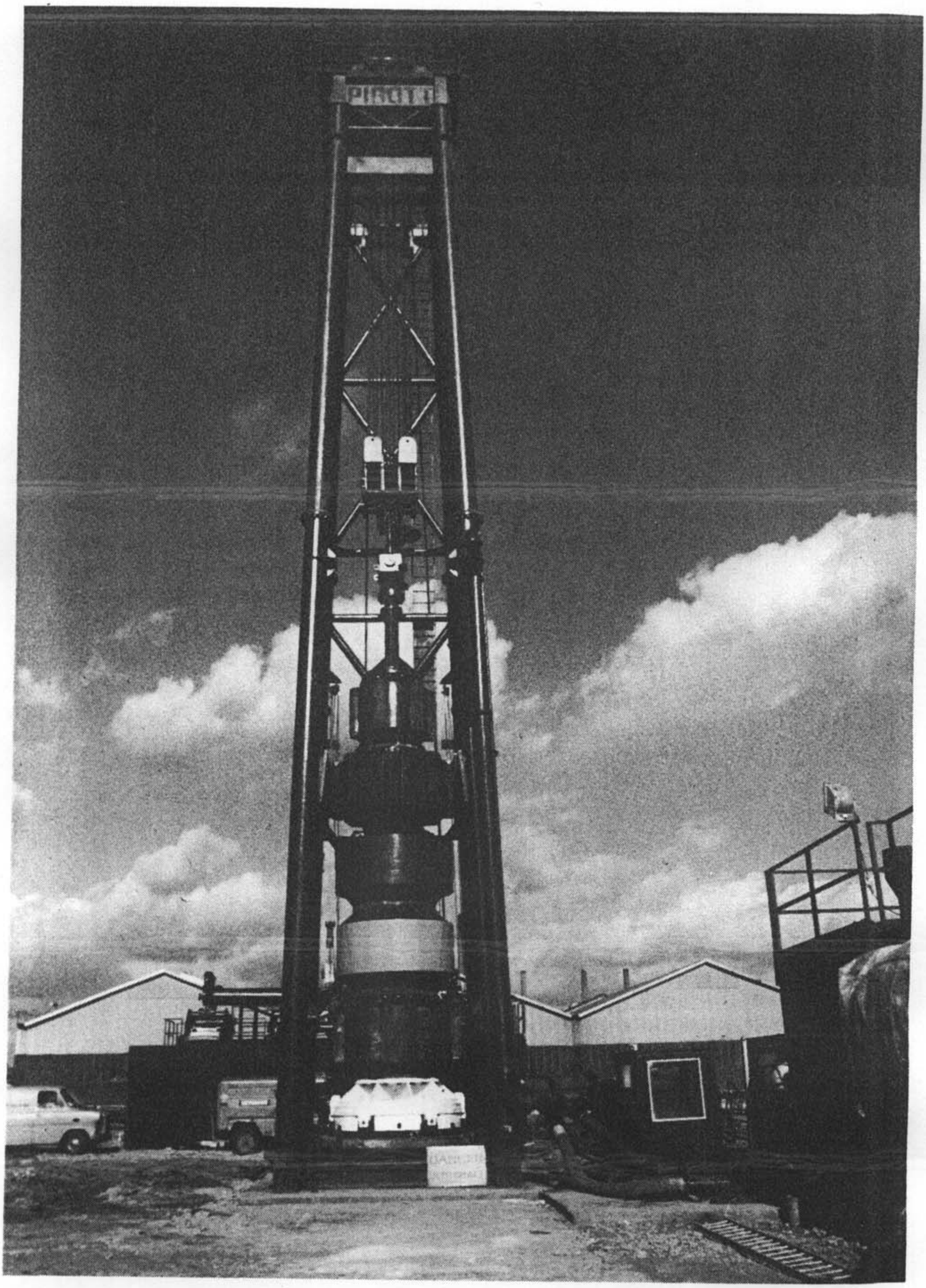


Figure 338.
Pigott Titan shaft drilling rig working at I.C.I. Wilton with 126 tonnes of bottom hole drill assembly hung in the mast.
(Courtesy Pigott Shaft Drilling Limited)

Steerable Shaft Drills

The further development of large diameter shaft drills was, until fairly recently, restricted due to the need to keep the drill string vertical to produce a straight hole.

Two methods have been used.

Conventionally the drill rig was used to 'hold back' a considerable proportion of the weight of the drilling assembly and bit. In the words of Colin Pigott, 'provided the assembly hangs in tension, this force acts to correct hole deviation by returning the bit and assembly to the vertical, somewhat like a pendulum'.[187]

The second method for keeping the hole straight involved the installation of a bottom hole drilling assembly consisting of a bit (coupled close to a stabilizer of about the same diameter as the bit), drill weights, plus one or more additional stabilizers, all coupled together to form a rigid heavy drill assembly which fitted firmly into the drill hole.

Either rotating stabilizers which turned with the drill string were used, or non-rotating spring-loaded stabilizers were installed. In the latter case the spring-loaded stabilizers pressed against the hole wall, while the inner core was rotated with the bit and drill pipe.

Apart from the 'rate of drilling' the shape of the bit also influenced the straightness of the hole.

As methods for cuttings removal improved, due to the use of larger drill pipes combined with better reverse circulation and mud flushing systems, the application of disc cutters, instead of milled tooth or tungsten carbide insert cutters became more practical.

Disc cutters were originally developed for use on tunnel boring machines and raise drills[188]. To function efficiently, however, disc cutters required higher loadings than milled-tooth cutters. In order to achieve this, it was necessary to increase the weight of the bit in the hole.

Increased bit loading, in turn, required the use of a more robust drilling rig capable of handling the extra weight. However, as pointed out by Colin Pigott, large proportions of the drill string weight needed to be held back in tension in order to provide a 'pendulum effect corrective force' to assist in the drilling of straight holes.

Pigott stated further that the actual effect on the bit of the pendulum righting force, became less, as the hole got deeper, or if the shaft was almost vertical. He commented that if the shaft was off vertical by 1 part in 100, then the righting force would be 1/100th of the hold back force. Or, if the shaft was off line by one part in 1,000, then the righting force would be only 1/1000th of the hold back force.

He added that it was very difficult to justify the provision of large amounts of extra drilling weights, a heavier rig and heavier drill pipes to handle this type of equipment, not to mention the problem of delivering them to and from the site, for the purpose of making available a force as small as only 1 kg per extra tonne of weight, in order to provide the required 'pendulum effect'.

For this reason the further development of large diameter shaft drills, using heavy weights, has been greatly inhibited.

To overcome this problem firms such as the Zeni Drilling Company in the United States and Wirth Maschinen-Und Bohrgerate-Fabrik GmbH, of West Germany, began development of down-the-hole steerable shaft drills.

As may be seen from the foregoing text, the Zeni Drilling Company in conjunction with the Hughes Tool Company built a 'steerable' *core drill* as early as 1953. This was followed shortly afterwards by the Zeni-McKinney-Williams mine shaft drilling machine.

Pigott Shaft Drilling Limited

Pigott SSD Machine

The design for the Pigott SSD (Steerable Shaft Drill) was announced in 1989, two years after the company had used a hydraulically activated off-centre stabilizer to help straighten a 3.75 m diameter drill shaft.

The Pigott design made use of expanding pads to grip the shaft wall and thrust rams were employed to provide downward force on the bit, thus obviating the need for drill weights or drill collars.

Bit rotation was provided by down-hole hydraulic motors and torque was reacted via the expanding gripper pads. The airlift circulation system was used to carry cuttings and fluid to the surface through a simple drill pipe.

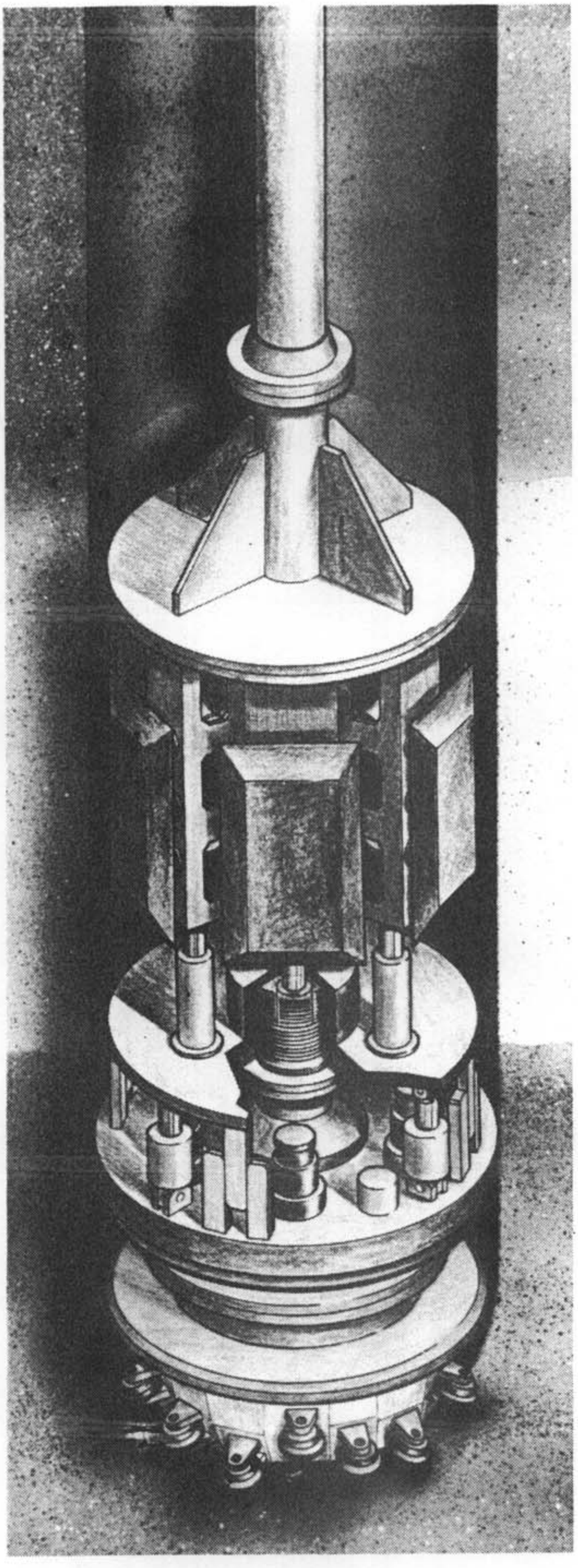
The drill pipe was also used to support the machine during the re-setting of the gripper pads and for the conveyance of the drilling mud. Pigott suggested that because it was non-rotating, the drill string could be supported by a crane on the surface instead of a drilling rig.

The Pigott SSD machine was still at the design stage at the time of writing (1990), and at that time it was envisaged that it would be used to drill 2.5 m diameter holes, either as a finished hole, or as a pilot hole which could later be reamed to a larger size, using the same machine fitted with a larger diameter bit and larger gripper pads.

Two illustrations were provided by Piggot for the design of his down-the-hole steerable drill. The first, which was the original drawing, depicted only one set of grippers. The more recent revised drawing depicted two sets of grippers. Pigott commented that two sets of grippers would permit the operation of the machine in softer materials that were not able to resist high gripping forces.

Specifications for proposed Pigott SSD (Steerable Shaft Drill)

Drilling diameter	2.5 to 5.0 metres
Gripping force	500 tonnes per pad
Down thrust	600 tonnes
Up thrust	200 tonnes
Rotary torque	69,000 kgm (500,000 lb.ft.)
Hydraulic pressure	275 bars (4,000 psi)
Rotary speed	10 r.p.m.
Steering	5 degrees, any direction
Drill pipe	400 mm bore
Circulation	reverse, air-lift or submerged pump
Height, excluding bit	4 metres
Weight, excluding bit	40 tonnes



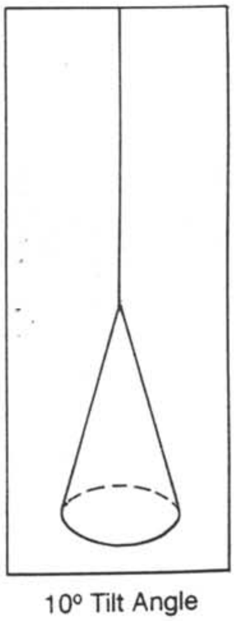


Figure 339.
Drawing of proposed Pigott SSD (Steerable Shaft Drill).
(Courtesy Pigott Shaft Drilling Ltd

Alternatively the double set could be used in very hard ground where increased gripping forces would be required to provide higher down-thrust It was suggested that a hemispherical bit dressed with disc cutters be used which, combined with a high fluid circulation, would assist steering and allow for rapid rates of advance.

As the drill pipe did not transmit torque, it needed to be only thin-walled and comparatively large in size, say 400 - 500 mm in diameter. This would permit very high fluid circulation rates, using the airlift method.

Pigott advised that further design work was under way to produce a continuous survey system that could operate down-hole and be used to control the steering of the SSD, so that the shaft was formed to the required angle or verticality.

Although most of the above section was written during the early 1990s, the author has been in recent contact with this firm and finds that they, too, have been affected by the widespread economic depression. With news of a large diameter shaft borer sitting unsold in the factory of one manufacturer, it is not surprising that Pigott has decided not to pursue this matter any further at this stage.

Wirth Maschinen-und Bohrgeräte-Fabrik GmbH

Down-the-hole Steerable Drills

Faced with the problem of sinking deep shafts in unstable formations and through solid rock, using air-lift technology, Wirth GmbH began developmental work to produce a bit which would change its drilling direction in the vertical plane in order to correct hole deviation.

The first unit produced with a steerable bit was tested drilling a 2.1 m well to a depth of over 200 m for the RWE Company. The unit was capable of being steered by means of clamping devices which acted to thrust the head to either side of the bore and thus

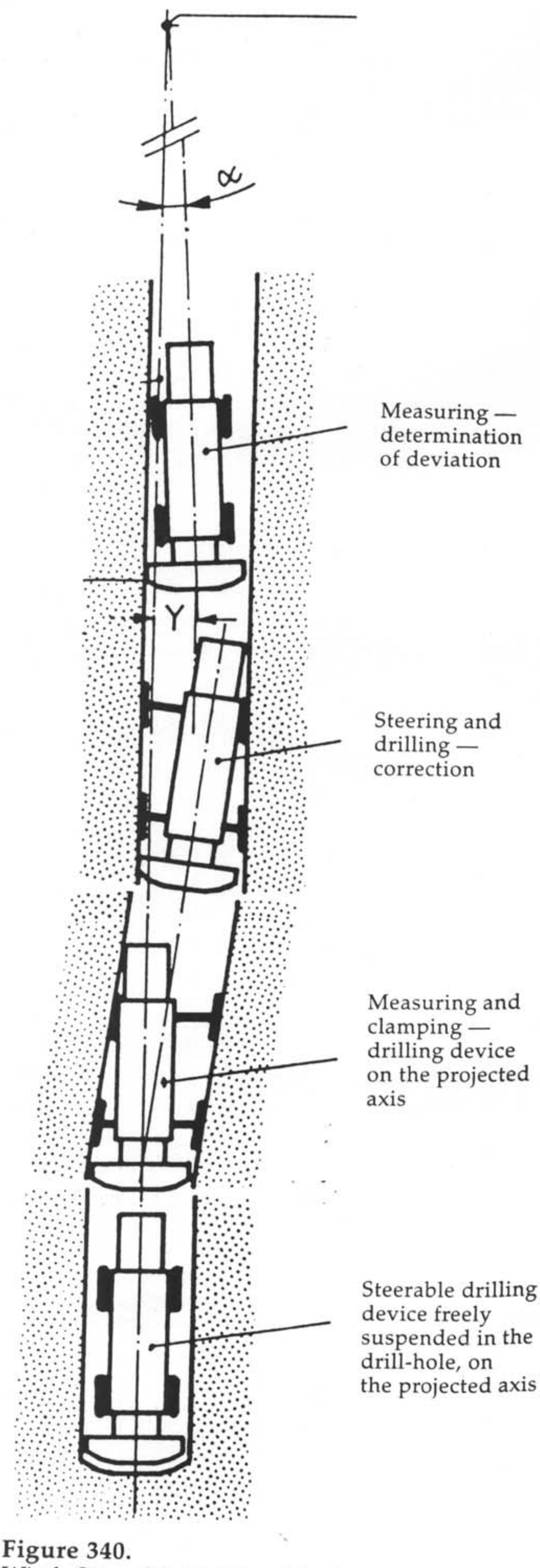


Figure 340.
Wirth Steerable Drilling Device.
(Courtesy Wirth GmbH, Erkelenz)