Introduction to Raise Boring

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This article provides some general information about raise boring techniques and also explains which applications the various styles of raise boring may be most suitable for. It is aimed at improving general knowledge about this method of shaft production for those not so familiar with the technology.

Terratec TR3000 Raise Borer - Set-up for Conventional Raise Boring

Raise Boring Technique

Raise Boring was first developed in the 1960s and some Raise Boring machines from that era are still operating around the world – after many refurbishments. The general concept of conventional Raise Boring has not changed much in that time, but the diameter and length of holes, machine reliability and production rates have all been increased markedly by applying new materials and updated power and control technologies.

The general method by which Raise Boring cuts rock is the "pressure flaking" method and it works in a very similar fashion to a hard rock Tunnel Boring Machine. The "cutters" are actually heavy duty rollers, with Tungsten Carbide Buttons positioned around their periphery. The cutters are arranged on a "reamer head" in such a way that when the reamer is rotated and forced into the rock face, the cutters roll around the rock face in a circular pattern and are spaced so that they cover the whole area being cut – like a Tunnel Borer Cutterhead. As the reamer is rotated and thrust is applied by the Raise Boring machine, the Tungsten Carbide buttons locally crush the rock as they pass by and the area of rock in between adjacent crushed zones "pops" out in tensile failure. Spacing between button rows is carefully arranged to match the optimum cutting characteristics of the particular rock being excavated. This style of cutting results in a relatively small amount of rock failing in the energy intensive crushing mode. Most rock is removed in the efficient tensile fracturing mode, resulting in most of the muck comprising of tensile failure "chips" rather than crushed rock dust.

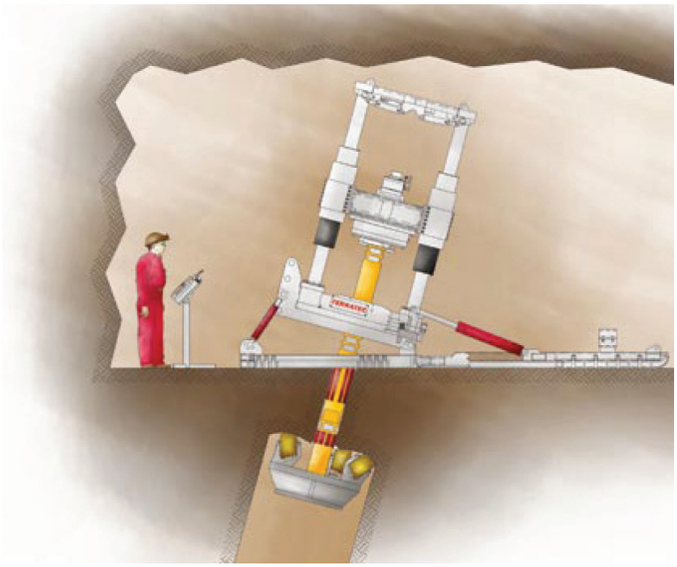
The production of shafts via Raise Boring technology is common in deep, hard rock mines and is also used in the coal sector to a small extent. The technique is used to create Ventilation Shafts, Access Shafts, Escape Ways, Ore Passes, Fill Passes etc. It is not so often used in civil projects, however it is relatively common for Hydro Electric head race or other shafts to be produced by Raise Boring.

Shaft production by Raise Boring has some major advantages over other methods. It is capable of efficiently excavating hard rock with a nominal UCS range of between 50–350MPa. It is a very safe method of producing deep shafts, as no personnel need to access the shaft during the boring process. With the right technology implemented, it is able to produce accurately positioned shafts, with minimal deviation along their length; shafts of varying dip angles can be easily produced-even horizontal shafts can be bored with carefully modified equipment. There is a relatively low labour content compared to other methods of shaft production. It is normally financially competitive on a cost per metre basis. There is very minimal disturbance to adjacent rock, unlike the case of a shaft produced by blasting. The finished shaft is a consistent diameter over the full length and has a very smooth finish – meaning there is a reduced need for lining, and there will be minimal extra friction if used for air or water flow.

Conventional Raise Boring

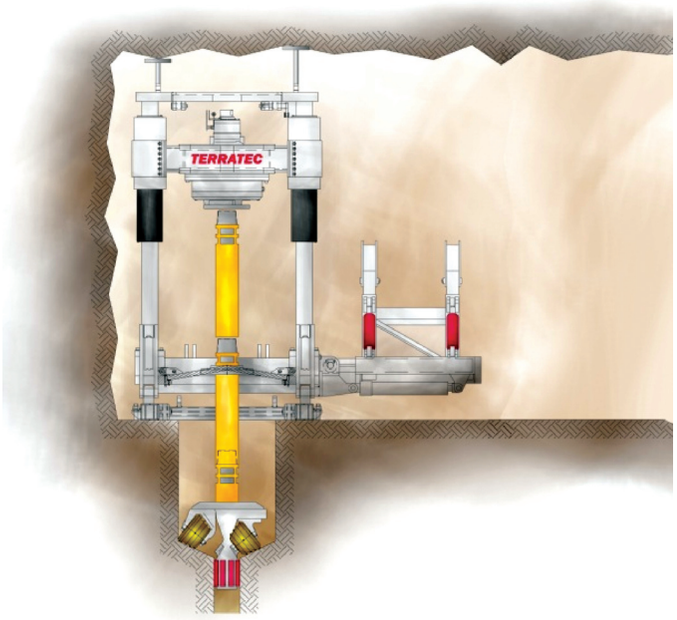
In conventional Raise Boring, personnel access is required at both ends of the shaft (such as when drilling between two levels in a mine – or connecting two tunnels in a Hydro Electric scheme etc.).The Raise Boring machine is set up at the upper level and a pilot hole is bored to intersect the lower level. Pieces of drill pipe are added via screwed connections as the pilot-hole progresses. Rock cuttings due to pilot hole drilling are removed by pumping air and/or water through the centre of the drill pipes, which then carries the rock chips back up the pilot hole in the annular area around the outside of the drill pipe, and then out of the hole.

Once the pilot hole has broken through into the lower level, the drill bit is removed and a reamer is attached. The reamer is



Terratec UB1000 Universal Borer in Conventional Raise Boring mode

then "pulled" while rotating, towards the Raise Boring Machine. Rock cuttings produced while reaming back towards the Raise Borer fall to the lower level and can be mucked out using conventional underground loaders. The reamer is either stopped just short of the Raise Boring Machine and the last small section of shaft blasted once the Raise Borer has been removed, or the Raise Borer can be mounted on beams which will support its weight and span the shaft diameter, so that the reamer can be pulled right through to the Raise Boring Machine.



Terratec UB1000 Universal Borer - In Down Ream Mode

Conventional Raise Boring is able to produce shafts from 600mm to over 6 metres in diameter, and up to 800 metres deep (sometimes even deeper in favourable conditions).

Down Reaming

When using a Raise Borer for Down Reaming, access is only required at the upper level, where the machine is operating, but an open lower level is required for the pilot hole to break through into. This technique is often used by mines to put shafts down into unstable chambers where personnel access is not permitted. Often these shafts are then used to insert "paste fill" to shore up the chamber, so adjacent ore can be safely mined.

Terratec TR2000 Down/Raise Borer with 1.8m Reamer being inserted. This machine is specifically designed for Down Reaming and Conventional Raise Boring

When Down Reaming, a pilot hole is drilled, in the same manner as for conventional reaming, but once it breaks through at the lower level, then the drill pipes are retrieved from the pilot hole and a reamer is pushed down from the upper level. The reamer has a "pilot nose" which follows the pilot hole, and its geometry is arranged so that with water flushing, the rock cuttings produced while reaming down are washed down into the pilot hole, and end up falling to the lower chamber.

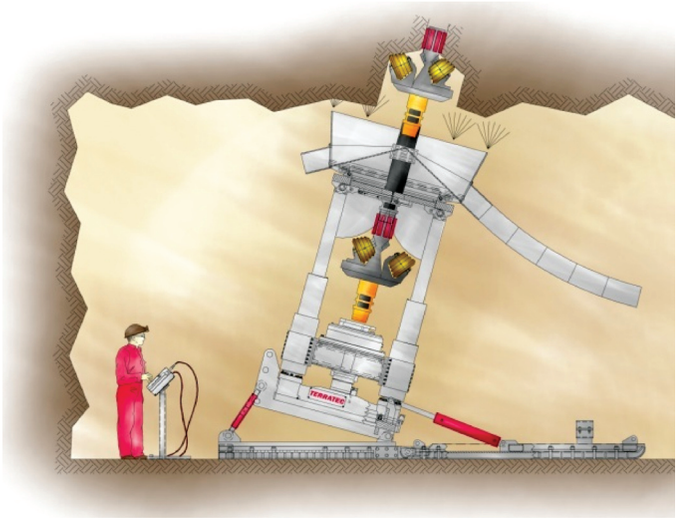
Specialist machines for Down Reaming have been produced, which have pipe-loader arms capable of loading the down reamer into the Raise Boring Machine, to reduce manual handling and

improve safety and speed of operation. These specialist down reaming machines also have work-table doors which open to allow the reamer past, then close behind it, to ensure that personnel are not exposed to the hole being down-reamed.

Down reaming "Through the Worktable" can be done from 600mm diameter up to 2 metre diameter. Larger down reamed holes can be achieved by excavating a pit below the Raise Borer to install the reamer and supporting the machine on beams while pilot hole drilling and down reaming. In order to prevent the drill pipes from buckling under the compressive loads induced when pushing down on the reamer, full shaft diameter stabilizers are added every 10 – 15 metres to keep the drill pipe in the centre of the shaft, while still allowing the drill pipes to rotate.

Blind Box-Hole Boring

Box-Hole boring is the process of boring a hole upwards from the Raise Boring Machine, usually a blind hole, with a pilot bit ahead of the reamer (no separate pilot-hole first). The reamer with pilot bit attached are sometimes installed above the machine, but the best option is to have a pipe-loader capable of loading the reamer into the Raise Borer, and then pass it through upper work-table doors, which then close behind the reamer for safety.



Terratec UB1000 Universal Borer, in Box-Hole mode

The reamer is then pushed upwards into the rock and cuttings fall back down the hole towards the machine. It is critical to have a large Muck Collection Chute which can be pushed close up against the upper rock face, to catch all the rock cuttings and water etc., and direct these away from the machine and also to prevent any falling large rocks etc., from escaping and potentially injuring operators. As with down reaming, the drill pipes are in compression during rock boring, so stabilizers need to be installed at regular intervals to prevent the drill pipes from buckling.

Terratec UB1000 Universal Borer, able to do Boxhole, Down Ream and Conventional Raise Boring

Terratec UB1000 Showing 1m diameter Boxhole Reamer passing through upper Worktable and Muck Chute

Box-Holing is mostly used for slot rises in mines with narrow vein ore bodies, to reduce the over break into waste rock when blasting to remove the ore. It is much safer and when the muck removal system is properly set up, it is also faster and cheaper than the traditional "Ladder Raising" method of creating up-holes, which involves manually drilling and blasting.

Raise Boring Machines for Various Applications

Terratec manufacture a number of different sized machines, with varying capabilities, so that a machine to suit almost any size shaft, or type of boring technique can be supplied.

The TR series are classic low profile Raise Boring Machines, specifically designed for efficient conventional raise-boring of shafts up to nominally 6 metres in diameter. The low profile design is advantageous in underground situations.

The TDR series machines are also low profile designs and are able to operate as Conventional Raise Borers, but also have work table doors which are able to be opened to allow a down reamer to pass. They are supplied as standard with a powerful pipe loader, capable of picking up from near ground level and installing into the machine the down reamer, of a size up to the maximum nominal down ream diameter that each machine is rated for.

The UB series machines are "Universal Borers" able to operate in conventional Raise Borer mode, Down Reaming mode and Blind Box-Hole mode. The gearbox and chuck of these machines is able to be easily reversed to point either up or down, to suit all three styles of boring. All of these machines can be supplied either on transport sleds, or mounted on a caterpillar crawler for easy movement from site to site.

Given below is a chart of the standard Terratec Raise Boring machines which are available and details of their capabilities. Custom designed machines to suit the client's particular requirements are also able to be supplied.

Terratec's Standard Raise Boring Machines

FEATURE			UB SERIES	TDR SERIES			TR SERIES			
			UB-1000	TDR-600	TDR-1000	TDR-2000	TR-2000	TR-3000	TR-4000	TR-6000
Nominal Hole Diameter	Raise-Boring	[mm]	1,800	1,500	1,500	2,000	2,000	3,000	4,000	6,000
	Down-Reaming		1,060	660	1,060	1,800	-	-	-	-
	Box-Holing		1,060	-	-	-	-	-	-	-
Nominal Hole Depth (at Nominal Diameter)	Raise-Boring	[m]	200	200	200	400	400	400	500	600
	Down-Reaming		200	200	200	200	-	-	-	-
	Box-Holing		100	-	-	-	-	-	-	-
Pilot Hole	Bit Diameter	[mm]	279	279	279	279	279	311	349	406
	Rod Diameter		254	254	254	254	254	286	327	378
	Rod Length		1,219	1,524	1,524	1,524	1,524	1,524	1,524	1,524
Installed Power		[kW]	140	97.5	121	242	242	352	450	704
Torque	Pilot Drilling	[Nm]	16,000	8,600	8,600	31,000	78,000	78,000	78,000	135,000
	Reaming Nominal		75,000	43,400	43,400	175,000	175,000	237,000	373,000	675,000
	Reaming Maximum		81,000	52,500	52,500	203,000	203,000	266,000	475,000	810,000
Rotation Speed	Pilot Drilling	[rpm]	0 ~ 100	0 ~ 120	0 ~ 120	0 ~ 60	0 ~ 60	0 ~ 57	0 ~ 42	0 ~ 42
	Reaming		0 ~ 21	0 ~ 23	0 ~ 23	0 ~ 14	0 ~ 14	0 ~ 13.5	0 ~ 10	0 ~ 8
Thrust	Down Ream	[kN]	1,780	550	750	1,647	530	1,600	1,600	1,600
	Up Ream		1,780	1,400	1,400	3,100	3,100	4,500	6,700	13,300
Derrick Dip Angle	From the Vertical	[deg]	0° ~ 45°	0° ~ 30°	0° ~ 30°	0° ~ 30°	0° ~ 30°	0° ~ 30°	0° ~ 30°	0°
Max Dimensions (Derrick Operating)	Height*	[mm]	4,200	4,250 (3,505)	4,195 (2,980)	4,650 (3,950)	4,500 (3,820)	4,500 (3,960)	5,400 (5,070)	5,800 (5,500)
	Width		2,500	2,150	2,550	3,180	2,250	2,300	2,700	2,850
	Length		2,450	5,040	5,970	6,670	1,950	2,300	2,600	2,800
Weight (Derrick only)		[kg]	17,500	9,300	12,100	19,350	18,500	22,500	31,000	44,000

* The dimensions shown between brackets correspond to the ones of the Low Profile "L" Version