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Raise Boring Rigs for shafts  
up to 2000 m depth

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## Introduction

With growing demand for raw materials, mines are applying increasing effort and expense to open up deep and difficult to access resources. With this in mind, the new Herrenknecht product portfolio of Raise Boring Rigs allows the optimal drilling of shafts with larger diameters at depths of up to 2000 meters. In the new and further development of Raise Boring Rigs, Herrenknecht draws on proven technologies and components as well as on extensive know-how in the area of mechanized tunnelling technology.

The Raise Boring Rigs from Herrenknecht have proven themselves worldwide in a variety of projects since the first use of a prototype in 2010 for the Vianden hydropower plant in Luxembourg [1]. They have demonstrated their efficiency both in drilling of production and ventilation shafts in mines (copper, coal, tin) as well as in infrastructure projects (pressure shafts for hydropower plants, ventilation shafts for road tunnels) (Table 1: all projects completed to date). Today Herrenknecht offers a product portfolio of four RBR types.

Depending on the project requirements, at the customer's request the Herrenknecht engineers develop individually customized Raise Boring Rigs. The automatic wrench unit and a forklift attachment for the crawler unit in Nant de Drance, modular reaming heads for the Huanuni Mine and a remote monitoring system for the River View Coal Mine are examples of this.

MINE SITE/PLACE	COUNTRY	DIAMETER [m]	SHAFT DEPTH [m]	MARKET
Vianden	Luxemburg	5,46	280	Hydropower
Bolzano	Italy	4,76	280	Civil
Venda Nova	Portugal	5,46	350	Hydropower
Nant de Drance, 1	Switzerland	2,4	420	Hydropower
Chuciquamata	Chile	3,5	350	Mining
Bergamo	Italy	3,68	200	Mining
River View Coal Mina	USA	4,3	90	Mining
Huanuni Mine	Bolivia	3,06	400	Mining
Nant de Drance, 2	Switzerland	2,4	420	Hydropower

Table 1: Herrenknecht Raise Boring Rigs project overview

### 1. Raise Boring Rig (RBR)

The Raise Boring Rig (RBR) developed by Herrenknecht is designed for the construction of shafts in hard rock down to depths of 2,000 meters. Reaming shafts with RBRs is safer, less labor intensive and more cost effective than conventional shaft sinking, which was previously the only possible method beyond 1200 meters.

With its compact design, the RBR offers high flexibility even in confined spaces and is therefore suitable for a variety of applications in the mining industry. It creates shafts for the transport of muck or ore, haulage shafts, pressure shafts for hydropower plants and supply shafts for energy, water and air. It has proven itself in use generally with its modular design and its powerful and highly efficient center-free drive.

#### Method of operation

Initially the rig is installed above the collaring point with the crawler unit or a crane. It drills the pilot hole downwards vertically or at an angle of up to 45 degrees with the drill bit. Depending on the drilling depth, further drill rods are installed progressively, until the target in an already existing tunnel or cavern is reached. The pilot hole drill bit is then removed in the cavern and the reaming head (or reamer) is connected to the drill string. After completion of the assembly work, the rig pulls the reaming head equipped with cutters upwards against the face.

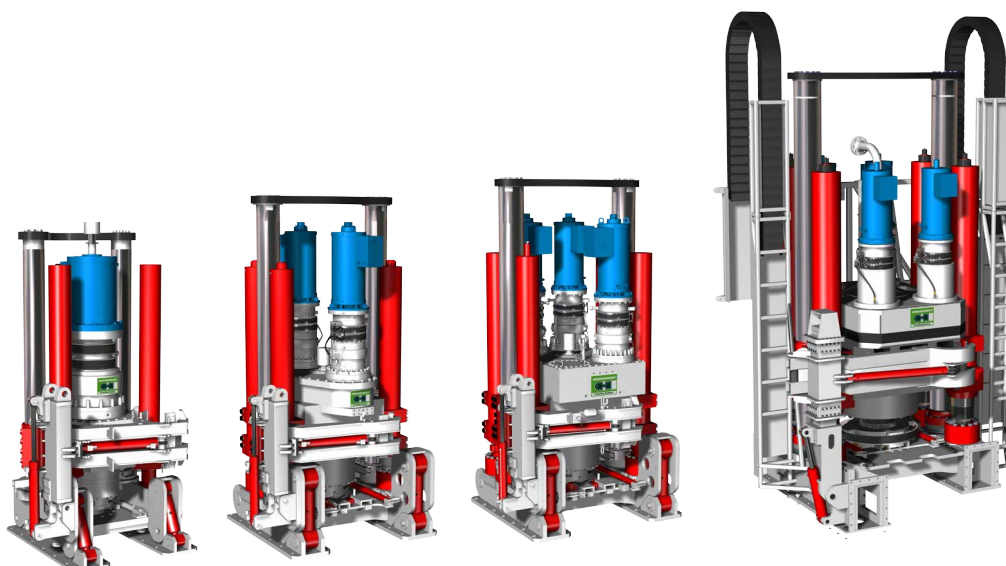


Fig. 1: Herrenknecht Raise Boring Rigs size overview

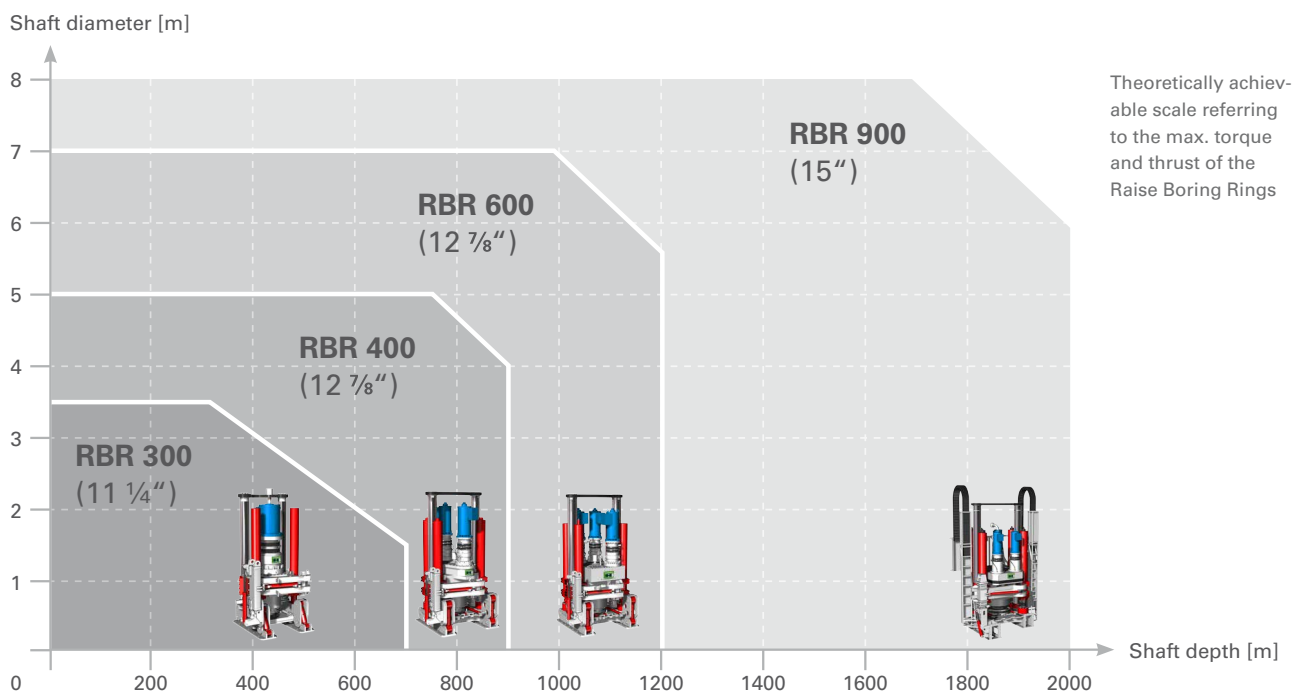


Fig. 2: Herrenknecht Raise Boring Rigs capabilities

The rotation of the rig is transferred via the drill string to the cutterhead, which in combination with the contact pressure of the cutters crushes the rock. The material falls down and can be easily removed. In this way, the entire shaft is reamed upwards to the required diameter.

## 2. Product portfolio of Herrenknecht Raise Boring Rigs

The product portfolio of Raise Boring Rigs from Herrenknecht includes the types RBR300VF, RBR400VF, RBR600VF and RBR900VF (Fig.1). With power ratings between 300kW and 800kW (402hp–1,072hp) and thrust forces between 458t (1,009,717 lbf) and 2,243t (4,944,969 lbf), they cover a wide range of applications (Fig. 2).

Drilling shafts up to 2,000 meters with large diameters of up to eight meters requires rigs with high torque and high thrust forces. This need is targeted particularly by the Raise Boring Rig RBR900VF with torque of 900 kNm (663,805 ft-lbf) and thrust of 2,243t (4,945,797 lbf), developed by Herrenknecht in cooperation with Australian mining contractor Macmahon. The RBR900VF is the most powerful Raise Boring Rig currently on the market (Fig. 3).



Fig. 3: RBR 900 VF at the factory acceptance in Schwanau

In addition to its high performance the RBR900VF is distinguished by the automated drill pipe feeder developed by Herrenknecht. Compared with manual handling, the remote controlled system ensures both efficient workflows as well as significantly greater work safety for the personnel during installation and removal of the drill string.

Herrenknecht Raise Boring Rigs are generally used over several years and in different projects. Besides their high performance and operational safety they are distinguished by their reliability and long service life. Their design allows quick installation of spare parts and flexible adjustments of their performance: all rig types have a powerful and highly efficient center-free drive. Multiple identical motor gear units are arranged around the center of the drive, so that even if one of the motors fails, work can continue with reduced power without interruption. This drive system also allows additional equipping with more motors. For example, a standard RBR600VF can subsequently have an additional 4th motor retrofitted. The total drive power and the available torque are consequently increased so that the rig can be used for larger shafts and drill rod diameters.



Effectiveness and precision reduce wear and thus additionally prolong service life. The tried and tested frequency converter controlled drive concept used in Herrenknecht tunnel boring machines means energy consumption is lower. The electric motors achieve significantly higher efficiency compared to hydraulically powered machines. Variable speed and torque control also allows the precise transmission of power to the drill string. This increases the efficiency of the drilling operation without risking overloading of the individual drill pipes. With heavy drill rods in particular, the innovative active float concept designed by Herrenknecht can also reduce the load on threaded connections when screwing and unscrewing. Lifting the floating box by means of a hydraulic cylinder reduces wear and extends the life of the drill rods.

All Herrenknecht rigs are characterized by a compact and modular design. Transport of the rigs can be by road with trucks without special transports and by ship in standard sea containers.

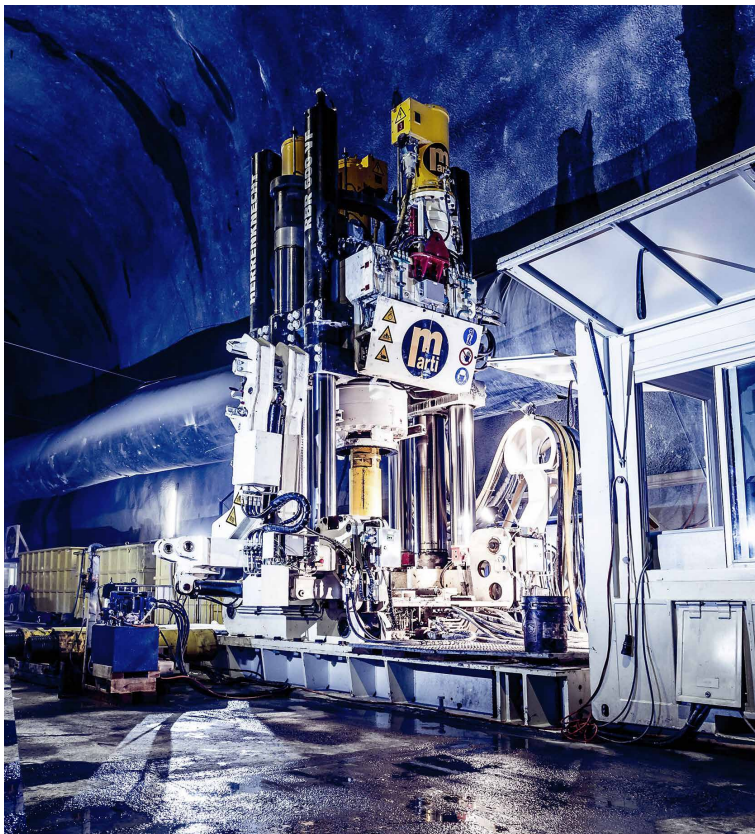


Fig. 4: RBR 600 VF in use in Nant de Drance



### 3. Project deployments of Herrenknecht RBRs

#### 3.1 Nant de Drance, Switzerland

Marti Contractors Ltd used two RBR600VF rigs to bore two vertical pressure shafts for the new Nant de Drance pumped storage power plant (Canton of Valais, Switzerland). Between August 2012 and November 2013 the two rigs drilled two shafts with a length of 420 meters and a diameter of 2.4 meters through rock with strengths of up to 150 MPa (Fig. 4).

The top daily performances were 62 meters (pilot hole) and 50 meters (reaming). The reaming of the second shaft was successfully completed after nine days and an average drilling performance of 46 meters a day.

To improve work safety for the operating personnel, the second Nant de Drance rig Marti ordered was equipped with an automatic wrench unit from Herrenknecht. It replaces the conventional manual attachment method of screwing and unscrewing the drill rods that the personnel otherwise have to do directly on the rig. In addition, the automatic wrench unit speeds up installation and removal of the drill string. This optimization in the workflow has a positive effect especially when a complete drill string has to be removed and re-installed for servicing.

With the forklift equipment that can be attached to the crawler unit Herrenknecht implemented another innovation to meet customer requirements: the rig's crawler unit, which usually remains unused during the drilling process, was designed so that it can be used on site as a forklift (Fig. 5). Thus a high degree of autonomy is achieved for the operation of the rig, because components and equipment as well as power packs can be transported independently and rapidly on site.



Fig. 5: Forklift equipment installed at the crawler unit



After completion of the RBR drilling in Nant de Drance a Herrenknecht Shaft Drilling Jumbo was used to enlarge the shafts to a diameter of eight meters. In addition, Marti Tunnelbau AG used a Herrenknecht tunnel boring machine (Gripper TBM, Ø9,450 mm) in the Nant de Drance project to drive a 5.6 km long access tunnel to the machine cavern of the power plant.

### **3.2 Huanuni Mine, Bolivia**

For the construction of ventilation shafts for the Huanuni mine (Bolivia), in September 2013 Herrenknecht delivered a rig of the type RBR400VF (Fig. 6). In the largest tin mine in South America, approximately 250 kilometers south of the capital La Paz in Bolivia, up to 10,000 tonnes of tin are recovered annually. The Huanuni mining company has scheduled the Herrenknecht rig to create ventilation shafts with diameters of 1.6 m to 3 m and up to 700 meters deep. The local customer support in Bolivia is being handled by the Herrenknecht subsidiary in Santiago (Chile), together with the mining specialists at its headquarters in Germany.

At the extreme altitude of 4,800 m above sea level, the cooling of the rig via the closed internal water circuit has proved itself. Regardless of the altitude of the operating location, the performance of the water cooling remains constant, as opposed to air cooling, whose effect decreases with increasing altitude.

Tailored to the project requirement of being able to create different shaft diameters, Herrenknecht supplied modular designed reaming heads for the Huanuni mine. The center of the cutterhead can be combined with different sized segments so that different diameters can be realized.

For the first time, in addition to the rig, Herrenknecht supplied the entire suite of equipment needed for the excavation of the shafts in Bolivia. So that the customer can use perfectly matched components and equipment and if necessary only has a single service partner for all questions, Herrenknecht put together a complete package consisting of Raise Boring Rig, drill rods and reamer.

### **3.3 River View Coal Mine, U.S.A.**

The U.S. raise boring operator Frontier-Kemper ordered an RBR600VF rig from Herrenknecht, which was used to drill a ventilation shaft for the River View Coal Mine in Kentucky, U.S.A. In November 2013, within 16 days the shaft sinking specialists drilled the pilot hole and reamed it to a diameter of 4.3 meters and a depth of 90 meters (Fig. 7). Customer support for the rig is provided by Herrenknecht Tunnelling Systems USA in Sumner, near Seattle.

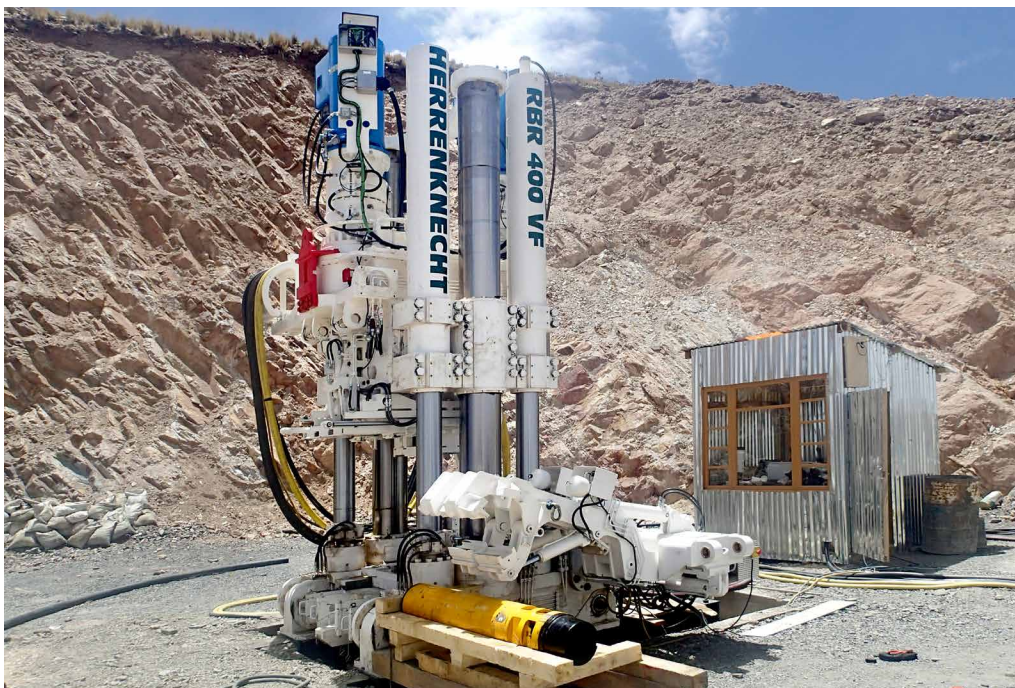


Fig. 6: RBR 400 VF in use in Bolivia

A world premiere is the system for remote maintenance of the rig with the „Digital Drilling Report“, used here for the first time. Over a network connection it offers Frontier-Kemper the possibility of monitoring the drilling performance of the rig, its availability as well as any difficulties encountered during operation, in real time, from the jobsite office or from company headquarters. The system replaces the usual manual drilling report, simplifies evaluation and allows more reliable drilling data analyses that can be used for the optimization of future projects.

The supplied integrated cooling unit ensures the operational readiness of the rig at outside temperatures up to 40°C. Dependence on an external and potentially costly cooling water supply is not necessary.

At the customer's request Herrenknecht equipped the RBR600VF rig with control components from an U.S. manufacturer (Allen-Bradley) and hydraulic components in accordance with SAE specifications. This adaptation makes maintenance and the procurement of spare parts in his home market easier for the customer.



Fig. 7: RBR 600 VF mounted on a support frame for use over a presink

#### 4. Summary and Outlook

The newly developed Raise Boring Rigs from Herrenknecht have proven themselves worldwide in numerous project deployments. Altogether, nine shafts with a total length of 2800 meters have been created with the Herrenknecht rigs in mining projects as well as in hydropower plant and road construction projects.

The Herrenknecht RBR product portfolio targets the growing need for deep shafts with large diameters and the development of project-specific, innovative technologies. On the basis of many years of experience as a market and technology leader in the area of mechanized tunneling, Herrenknecht actively supports clients and projects with its great innovation capacity and its global service network as well as with short reaction times.



### **Herrenknecht AG**

The product portfolio of the Herrenknecht Group also includes mechanized mining equipment, tailor-made tunnel boring machines for transport tunnels and supply and disposal tunnels as well as additional equipment and service packages. Herrenknecht also manufactures drilling rigs for vertical and inclined shafts as well as deep drilling rigs. In 2012 the Herrenknecht Group achieved total revenues of 1.135 billion euros and currently employs around 4,600 people. Headquartered in Schwanau (Southern Germany), Herrenknecht is represented by 78 subsidiaries and associated companies worldwide. Through its worldwide network of Group companies, for all products and projects around the globe Herrenknecht offers tailored service close to the customer and the project.

**[1] Künstle, B., Frey, A. (2011)** Vertical Shaft Construction at the Pump Storage Plant Vianden/Luxembourg. TUNNEL 4/2011, 56-59.