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Blind boring system

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The paper will deal with an easier and safer way to develop connection holes between different levels in mines. The purpose of these holes could be ore passes, walk ways, ventilation holes or others. Basically there are two different situations:

- The 'upper level' is developed
- The 'upper level' is not developed.

In the first case there is the option to use normal raise drilling equipment, drill a pilot hole and ream the hole bottom up in the final diameter. This method is well established and used since long time. It needs a proper pavement for stabilization of the rig. It is still the common method for longer and/or bigger holes.

An other method is the drop raising principle. The blast hole will be drilled from top down for the wholeblast. The charging is done from bottom up in steps to allow the material to drop down to the lower level without 'freezing' the hole. The method is limited in the applicable length.

If the upper level is not developed, the only way is to develop the hole from bottom up. There are different ways available to solve this problem:

- Conventional method with drill and blast – still in use in South Africa
- The ALIMAK Method – this method is more frequently used over the world
- Long hole drilling from bottom up and blast the hole in one go with the risk to lose the hole (not a real option)
- Drill the hole bottom up with a modified raise bore rig. There are some limitations regarding the diameter and the length.
- The Sandvik Box Hole Borer MD320, which is a blind boring method with short mobilization and demobilisation times. The current available diameter is 1.6 m and the length of the hole is currently limited to 100 m.

The paper will deal in detail with the MD320 equipment and the experience we have gained in a two-year field application in a platinum mine in South Africa.

Introduction

During the development of a remote-controlled hard rock mining machine for low seam heights we have been confronted with the problems of development of the ore passes. Traditionally, conventional method (drill and blast) were used that are by nature very dangerous and slow. A high percentage of the fatalities are happening at these dangerous work places. The other problem is the relatively low advance speed of about 1.2 m/day (single blast per day and hand-held drilling). In addition, this results in the blocking of the haulage way during the duration of the hole development.

During the initial discussions with our customer we have agreed to the general requirements for a machine which had to comply with the given boundary conditions.The main focus was on the following areas:

- Increase of safety (zero fatalities)
- Reduction of development time by increasing the development speed
- Continuous operation and avoiding cyclical down times as a matter of fact with the blasting method ('better utilization of the face')
- Short mobilization and demobilization times to shorten the blockage of the main haulage road
- Easy relocation across the mine and from level to level
- Easy to operate and to maintain.

Requirements from the customer

In various discussions with the customer we agreed to the following specifications. This may be a bit specific for their application but an investigation on the market has proven these figures for a wide range of applications.

- Bore a blind hole of 1.6 m diameter
- Advance at a rate of 1.5 m per hour
- Length of the hole in the range of 15 m
- Inclination in the magnitude of 70°
- Powered by electro-hydraulics
- Reliable machine design
- High mobility for relocation–transportable via mine rail (specific for South Africa)
- Short mobilization and demobilization time
- Remove workers from a hazardous/arduous workplace

Design

Based on this specification we started with the layout of the machine. Considering the short relocation time there was the need to minimize the preparation work needed for the start-up of the machine such as special concrete floor laying and preparation of the roof.

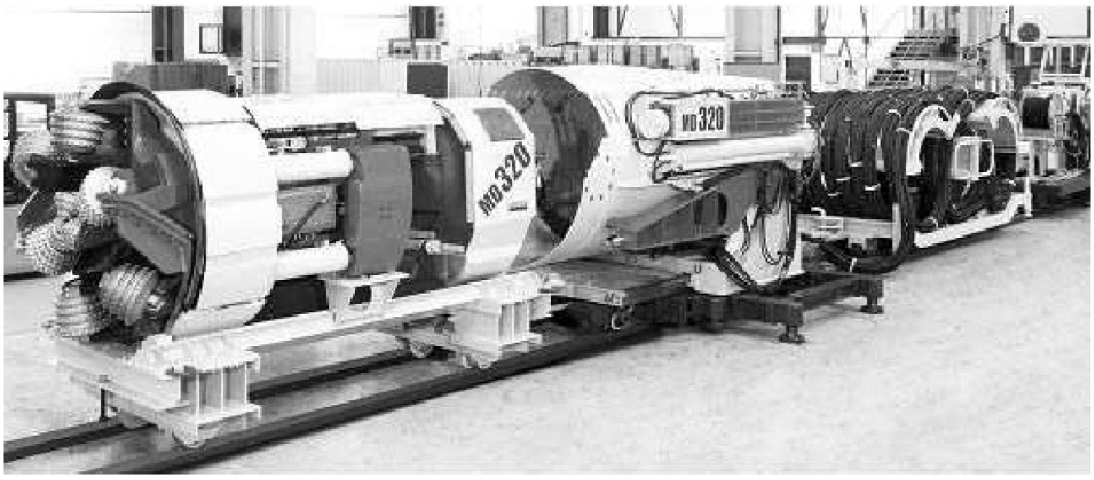


Figure 1.

Figure 2. Muck chute behind the machine

The concept of the machine is very similar to a small TBM. When the machine is in the hole, it should climb up without any further support to the floor—just based on the gripper system.

We have found a solution to start the machine from a launching tube which is jacked with hydraulic cylinders against the floor and the roof. This arrangement negates the need for special preparation like concrete pavements because the support forces will run down to the floor only during the time of collaring. This process operates with reduced forces and takes a relatively short time.

After the machine has fully entered the cut hole, about 3 m, the main grippers can be engaged against the side at operating conditional loads and the machine can start the normal advance process. The single steps of the various components are controlled via PLC and therefore the whole process runs on a high degree of automation.

The range of inclination that the machine can anticipate ranges from 0 to 90 degrees. However we have separated two areas:

- Gravity mucking above ± 40°
- Assisted mucking below ± 40°.

Gravity mucking

When the machine is climbing up the hole, it pulls a number of plastic pipes (muck chutes—as used in civil construction for refurbishing buildings) behind itself up the hole. The cuttings slide through the machine into these muck chutes and are guided down to the bottom area. This avoids damage to the hydraulic hoses running up the hole and contains and directs airborne dust.

Assisted mucking

If the machine has to develop a hole with an inclination less than about 40° (or material specific—if the cuttings do not slide down the muck chute) alternative measures are required to move the cuttings.

Typically this could be achieved with the use of a 'vacuum cleaner' and run the suction hose up the hole into the machine. This gives the advantage to discharge the material direct via the separators into the muck cars.

It is envisaged that if the machine is used in a mine or any other places where water-assisted material transport is a standard this could be incorperated. The onward transport from the 'catch box' can be done by pumps or also by using water jets.

Cutting head

The cutter head is similar to a raise borer head. The cutter dressing consists of 6 raise borer cutters and one 15-inch pilot bit for the centre in a 'flat head' configuration. At the circumference there are two muck shovels and two scraper plates to move the cuttings towards the opening to slide down the hole. The saddles are bolted to the rigid body of the cutter head and can be replaced in case of damage or wear. The shovels are covered with wear-resistant material to serve for a long lifetime.

The big advantage of this system is the direct connection of the cutter head to the main bearing and the cutter gear. This serves for smooth running of the head. The variation of the speed of the head from 0 to a maximum of 18 rpm allows for sensitive adjustment for the collaring process as well as for anticipating different geologies. The typical 'winding up' of the drill string that occurs at raise boring does therefore not occur on this system.

Optional head configuration for special applications would also be available, typically with an almost flat face

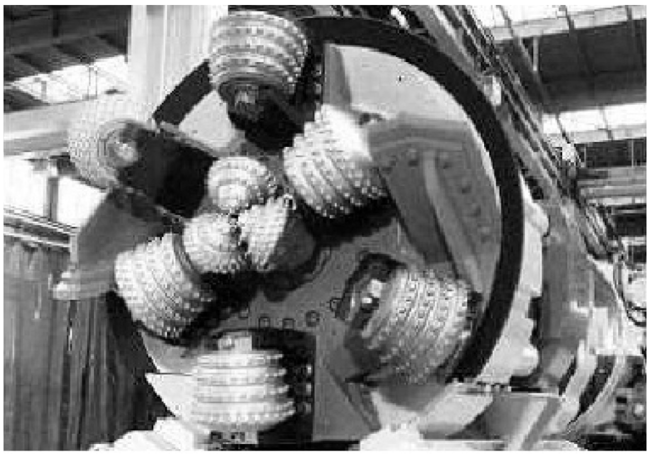


Figure 3. Cutter head

and recessed cutters to avoid stalling of the head in fractured and blocky ground.

Main frame and gripper arrangement

One of the challenges in developing this machine was the limited space available for, transport, erection, deployment in the hole. The usual dimension of the starting area is a cubicle of about 4 × 4 m. To allow the manoeuvring of the machine, the body has to be as short as possible but giving a reasonable length of one stroke to minimize the re-gripping time. This has led to a machine length of 3.2 m with a length of the advance stroke of 500 mm.

Front gripper—dust shield

As in a normal TBM the machine is guided at the front end via an expandable front gripper. This gripper slides along the wall and supports the radial reaction forces from the cutter head. The bottom part is rigid for reference and steering and the top part can be extended via hydraulic cylinders. In retracted position, the front gripper has a clearance to the bore diameter of 100 mm.

Inside the front gripper there is the main gear including the main bearing and the drive motor. The front support points of the advance cylinders are attached to the main gear.

Main frame

The main frame runs in the upper area from the main gear to the rear end and is connected with the safety grippers (back fall gripper). The main grippers are guided on this main frame. This guiding serves for the torque support and the general guiding of the machine.

Main gripper

The main grippers are essential for the advance of the machine. They are expanded by a big hydraulic cylinder against the wall of the hole. The gripper pads are designed of massive steel parts to transfer the needed gripper force into the rock even if the ground is not ideal. To avoid slipping of the grippers, they are equipped with 9 TC spikes. The gripper pads are attached to the gripper cylinder by spherical bearings to allow adjustments of the gripper pads if the sidewall is not totally even.

The horizontal steering is also done by the main grippers in side-shifting the gripper pads—without influence to the gripper pressure. It can be done continuously during the advance of the machine.

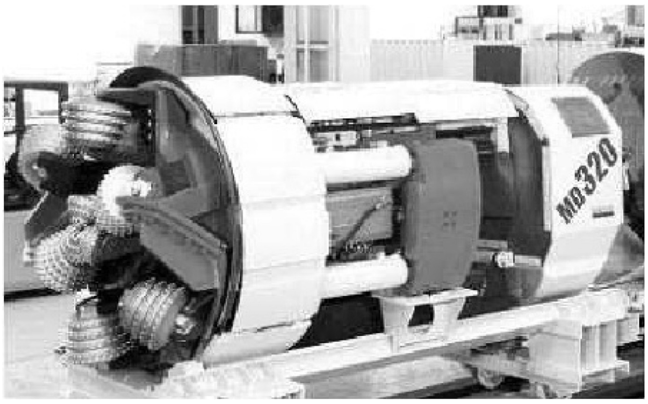


Figure 4. Main frame and gripper arrangement

The four advance cylinders are attached direct to the main gripper pads to get the forces on the shortest possible way into the rock.

To protect the machine against damage, all movements are observed by sensors. If components are moving out of their limits, there will be a warning to the operator or an automatic shut down of the movement.

Safety gripper—back fall device

The machine is moving usually in inclinations, where it would slip down if the gripper force would be released. To avoid safely this situation under any circumstance like break-down of energy, hydraulic failure, hose burst and so on, a pair of safety grippers is installed. This safety gripper is spring-loaded and hydraulically released. If anything unforeseen happens, this grippers will engage immediately and keep the machine in a safe position. Also these grippers are equipped with TC spikes.

In normal operating mode, both grippers are interlocked and one gripper can be released only if the other one is on a safe pressure level. For the re-grip, the safety gripper has to be engaged before the main gripper can be released and repositioned and vice versa.

The vertical steering is done via the safety gripper. It can be adjusted vertically by means of a hydraulic cylinder. The vertical steering can only be done during the re-grip.

Launching tube

A major requirement was mobility. The start-up procedure is an important part of the process and has to be planned carefully. To minimize the efforts to take support forces and to get the alignment of the machine we have designed a launching tube. This tube is mounted on an undercarriage and is serving for relocation as well as for the start-up process.

The example shows a solution for track bound mines—as usual in South African Gold and Platinum mines. The undercarriage consists of a cross-moving table to allow the adjustment of the centre line of the machine according to the surveyor's advice. For legs with turn buckles are used to support the cross-moving table. On this cross-moving table the carrier for the launching tube is mounted at a pivot point able to rotate 360°. The rotation as well as the elevation of the tube is done by hydraulic cylinders.

The stabilization of the launching tube during the collaring is done by four hydraulic cylinders, two of them against the ceiling and two of them against the cross floor.

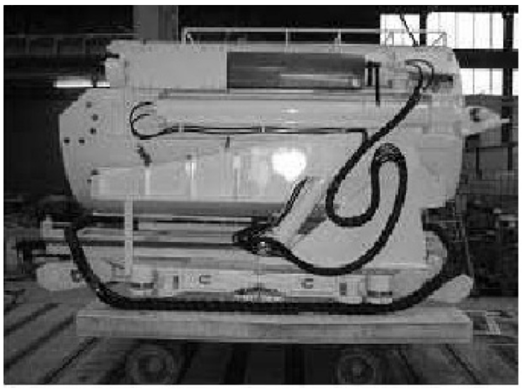


Figure 5. Launching tube

To keep the side forces, in case the inclination is different from 90°, turn buckles are supporting the bottom cylinders against the side wall.

The launching tube has inside a kind of a 'staircase' to allow the machine to climb out without applying big gripper forces. After finishing the collaring process and the machine is in the sound rock, no forces are transferred to the launching tube.

Power pack and operators control station

The machine is powered by electro hydraulic. The hydraulic power pack is located on a platform wagon and keeps on one end the operator's place. All functions of the machine are displayed on big screens. The machine is operated by push button controls and the integrated PLC. As an optional extra an operator's cabins with an air conditioner is also available.

The machine is connected with the power pack via a hose bundle and a control cable for the solenoids up in the boring unit. For shorter holes—up to 30 m length—the hoses can be reeled on a hose reel. If the machine has to do longer holes up to 100 m, the hose bundle is stored on a hose car (in an eight loop).

The cooling of the power pack is done by an oil-water heat exchanger. Cooling water should run up to the power pack and will be returned with a separate line or can be dumped in a ditch, if available.

Operation of the machine

The whole train moves to the place of the new hole. The cars have to be shunted in the correct sequence for the operation. After aligning of the launching tube—as mentioned before—the machine starts with the collaring process. As the surface after blasting is very uneven, the collaring process is a very sensitive process to create a smooth face. This will be done with a reduced speed as well with reduced advance forces. After the machine has drilled a hole of about 300 mm, it will be moved back into the launching tube and the whole launching tube shifts into this predrilled hole. This serves for better stability of the tube for the further collaring process.

The second critical phase is the stepping over with the grippers from the launching tube into the rock. As the rock is usually blast damaged at the surface, the gripper forces have to be reduced to a minimum until the machine has done a full grip into the rock.

After about 3 m of advance the machine can change into the normal operating mode and can be used to its set performances.

The machine is equipped with sensors giving information about the advance—a predefined hole length can be kept within close tolerance.

If the machine has to drill longer holes, it will be equipped with a laser target. The laser beam, mounted in the launching tube will hit a laser target. The picture is displayed on a monitor at the operator's desk and allows the

Figure 6. Operator's place trackbound

Figure 7. Operator's cabin trackless

Figure 8.

operator to do the necessary steering action. The machine can anticipate curve radii of about 25 m. Usual deviation on a 15 m hole without steering is about 5 cm.

Moving the machine back after finishing the hole will be done in the reverse mode than drilling. After walking the machine down the hole into the launching tube, the tube will be retracted and lowered. Depending on the available loco, the machine can stay in the launching tube for relocation or will move out onto a service/relocation car to be moved to the next site.

Experience with the prototype

After a period of about one year, the machine was designed and built and ready to be tested in the workshop in Austria. As the machine had implemented a lot of safety functions and interlockings, we decided to perform a full function test in an 'artificial mine'. For this reason we cast a concrete block in the yard and have prepared a starting cavity as close as possible to the reality.

The test should show the function of the safety and emergency precautions and was not meant to be a cutting test (concrete is not a challenge to the machine).

All the integrated functions have proven and the machine was ready to be delivered after the shop commissioning by the customer.

On the mine site in South Africa at Lonmin's Newman Shaft, the machine had a start-up without problems. During the development of the holes some improvements have been done especially in the area of mucking (optimization of the separators and the placement and transport in the main road).

One major problem was encountered very soon. In the specification we have received an envelope dimension, where the machine has to fit through. We have built the machine about 200 mm smaller than the given dimension but the reality was 400 mm smaller (and that has caused some limitations in relocation of the machine in the mine).

A newly designed relocation car for the launching tube and the machine as well as some modifications on the power pack have solved this problem and the whole equipment is now able to relocate below a height of 1 850 mm.

Performance of the machine

The machine has achieved the set KPI's (net cutting rate of 1.5 m/h and quick relocation) basically from the beginning. The average time to produce a hole in the length of about 12 m takes inclusive mobilization and demobilization between 40 and 45 hours. Best advance rate achieved was 2.4 m/h in the South African host rock like Pegmatite, Norite and similar, with a UCS up to 250 MPa.

Figure 9. Artificial mine

Figure 10. Collaring process

Figure 11. Box front with reduced clearance

The average time distribution for one hole is shown as an example in Figure 14.

The cutter consumption has turned out to be low. The predicted life on the cutters is about 400 m per set. After total 255 m drilled, the originally mounted cutters are still in good shape and ready to go for another 250 m.

Reliability of the machine

The machine is now in operation for two years. Beside some small electronic parts and one cutter saddle, which was changed because of damage caused by operator's mistake, the machine did not show any weak points. The concept could be used for the production of further machine without changes.

Changed had the shape of the transport cars and the storage of the hose bundle because of changed conditions in different mines.

For short holes (up to 30 m), a hose reel is mounted on the power pack which is coiling up the hoses in a convenient way. For longer holes, the hose bundle is stored on a special hose car, because the hose reel serving for 100 m hose length, would not fit in any roadways.

Safety aspects

During the two years of operation we did not have one accident caused by the machine or machine-related equipment. The system has proven easy and safe operation and provides convenient working conditions to the crew.

Crew size

The actual crew size deployed per shift for the cutting operation was two multi-skilled "cutting" technicians and one assistant. It should be noted that an artisan is only required for maintenance and in the event of an engineering breakdown therefore we opted for artisans (1× electrical and 1× fitter) with operational ability to run the machine during the test phase.

Dust control

As with any cutting machine, careful consideration has to be taken with respect to dust and setting up the systems to

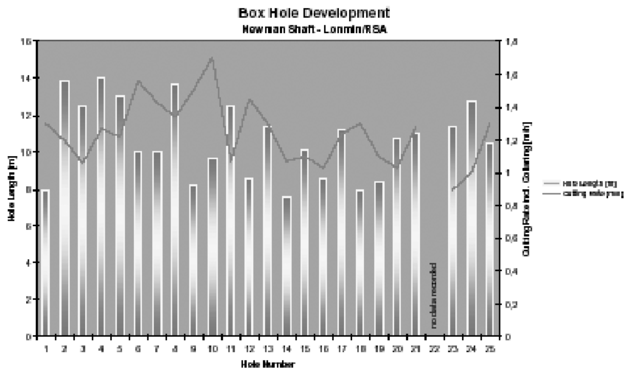


Figure 12. Net cutting time per hole

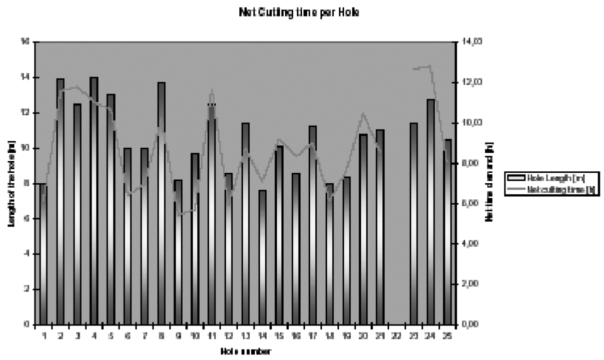


Figure 13. Achieved performance

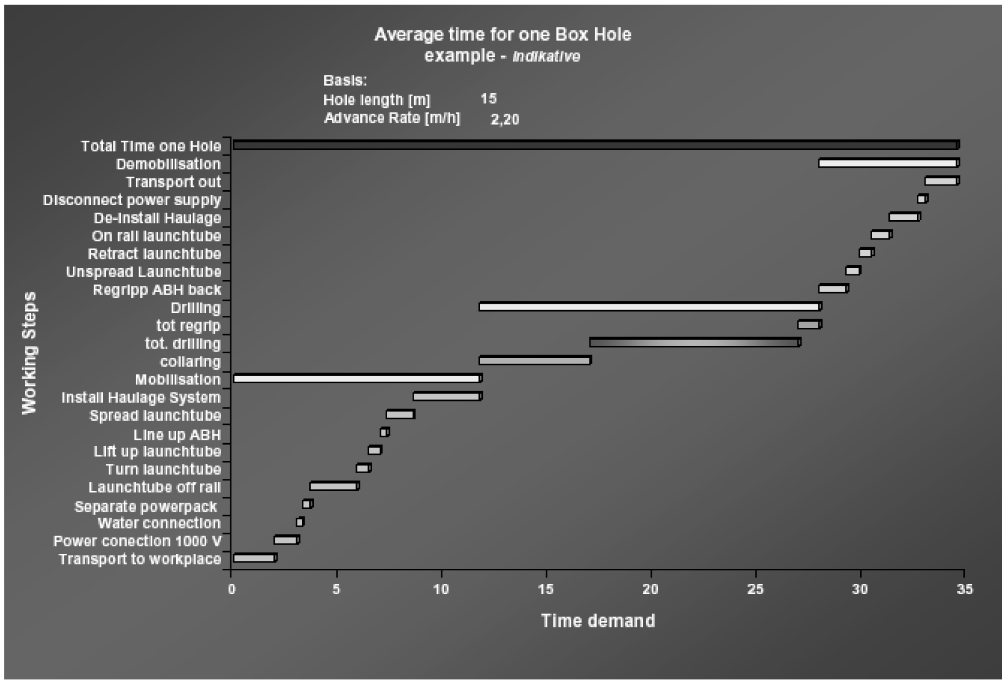


Figure 14. Average time distribution

Figure 15. Gage cutter

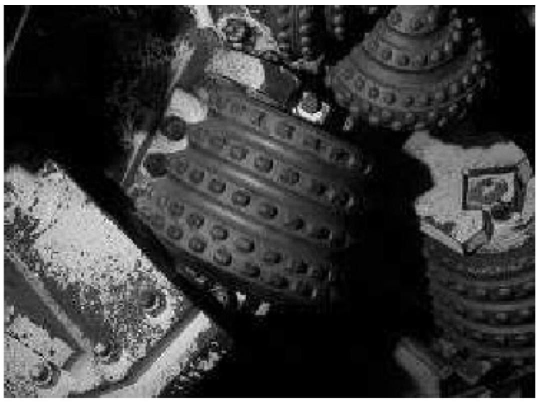


Figure 16. Inner position

work in conjunction with the mine's ventilation systems. There were two major areas of airborne dust generation:

- At the bottom of the launch tube where the cut material hit the ground and for the purposes of the trial a 750 mm suction tube attached to a Colliery Dust Control (CDC) system wet bed scrubber was deployed.
- At the hopper where and when the vacuum system discharges the cuttings, a mist curtain was provided around the 'collectors' to contain the dust.

It is recommended that good quality PPE dust protection device is utilized in any case.

Cuttings

During the testing in homogeneous ground conditions found in the typically 'Bushveld Complex' the chipping size was about 25 mm, however this was in relatively unstressed geological conditions.

Improvements and modifications still required

While the average length of hole during the testing was only 10.5 metres it is believed that this does not justify the set-up and deployment; ideally the length should be greater than 15 m.

The ideal application would require a number of sites being made ready for launching to limit the need to move the machine in and out.

The 'train' of equipment was too long for the continued operation at Newman Shaft and this needs to be reduced to be more effective (further investigation on this aspect is ongoing, e.g. dumping directly into hoppers from the hole.

The specified length of hole for Lonmin was 30 metres however the machine has now been modified for a maximum hole length of 100 m but not yet tested these are ongoing.

Further development

The original machine was developed for South African mine conditions. Most of the mines run track-bound

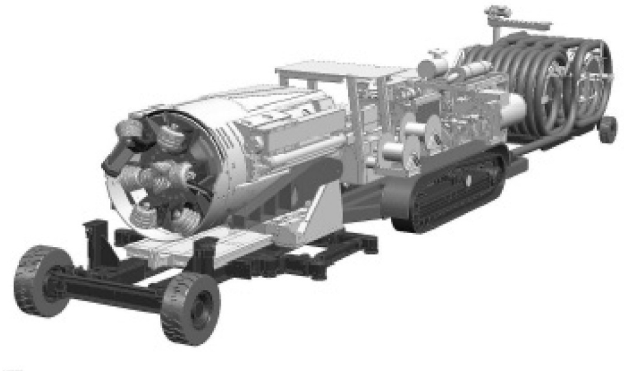


Figure 18.

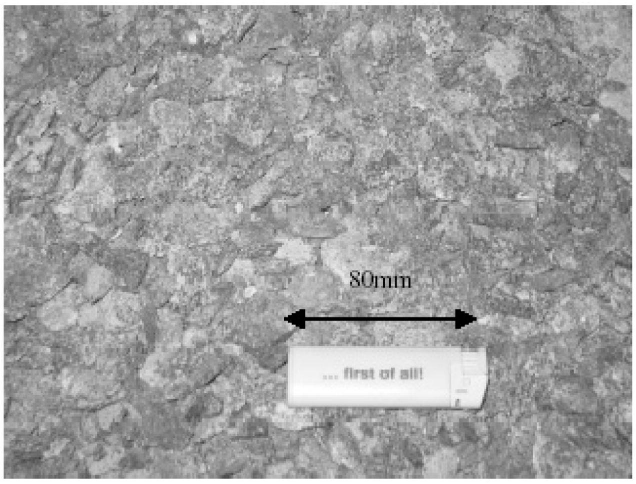


Figure 17.

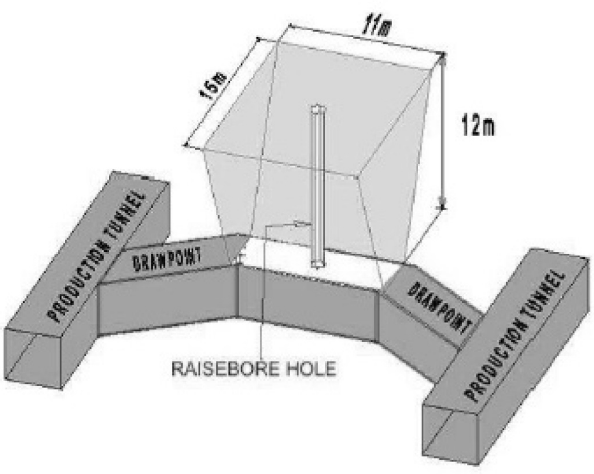


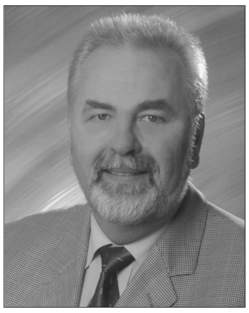
Figure 19.

haulage systems and therefore the machine had to be track-bound for relocation.

South Africa is still the country showing the biggest interest and the deployment of the machine into deep level mines has indicated totally different needs, and is still under investigation, but for example in highly stressed ground the cutting size has increased to the point of making the vacuum cleaner ineffective and a new discharge system is being tested.

Nevertheless, mines outside South Africa have similar demand for holes and could use this machine concept as well particularly for 'slot' drilling in open and sublevel stopping mining. As these mines are mostly trackless we have designed a machine for trackless relocation. The first machine of this type has been ordered from Portugal and has been delivered in March 2008.

Another application would be the centre hole at the draw points. As the equipment is very mobile, it could contribute to shorten the time needed for such burn holes.



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