Raise boring is an important method of shaft excavation in the mining industry. It involves driving a vertical or near-vertical hole without explosives between an underground mine and the surface, or between two levels of a mine.

It has a number of advantages over other methods, such as shaft sinking, although raise boring is not suitable for all mines. It requires access to two levels – an upper level to mobilise the machine, and a lower level to mount the reaming head and to bog out the cuttings when reaming. Typically, the pilot hole is drilled from the top down and the final diameter is reamed from the bottom up.

Accuracy can be very high in raise boring if the machine is set up properly and operated carefully. In-hole directional devices are available to optimise drilling accuracy and correct the drilling if it starts to go off course. For example, the Micon rotary vertical drilling system has achieved accuracies of 100mm over 1,000m.

Koos Jordaan, technical director at Master Drilling, says: “Through trials conducted by Master Drilling, it is now possible to absolute-steer the directionality of a raise-bored shaft to within 150mm radius from the theoretical vertical centre of the shaft, irrespective of the depth.

“An example of this is a recently completed shaft where the hoisting displacement at 1,070m was 80mm from the theoretical shaft centre line.”

**HIGH ADVANCE RATES**

Advance rates differ according to rock types and strengths, but raise boring is generally quicker than other methods, especially if the design permits a split-level shaft construction.

Fast penetration and the long service life of cutters, together with gravity taking care of the cutting removal, makes raise boring faster than conventional shaft sinking. Advance rates can be in the order of 2-3m per hour in suitable rock.

Raise boring is also very safe, as it is mechanised and there is no requirement to have people working directly in the raise – as a result, all the staff are working in controlled/protected environments.

Raise boring leaves a shaft with smooth walls, requiring less rock support than traditional drilling and blasting, which makes it a cost-effective method of shaft excavation.

Mike Kelly, operations at Redpath, comments: “For a given raise diameter, the cost of raise boring is generally at least half that of shaft sinking. However, depending on the desired diameter, raise boring can be as little as a third of the cost of sinking.”

Most raise boring machines require a suitable power supply, water and air availability, and a competent rock base to be bolted down to. When choosing a raise-boring machine, it is important to be aware of the rock characteristics, strengths and elasticity/toughness before considering the diameter and depth of the raise to be excavated. A raise-boring machine is set up properly and operated carefully.

“Accuracy can be very high in raise boring if the machine is set up properly and operated carefully”
Above: a Sandvik RSS30 4.5m extendable raise-boring head being assembled

Above right: a 6m reamer being assembled in the RUC Cementation workshop

Recent launches and current projects

Master Drilling has released a new user interface for its machines, enabling some autonomous functions. The company is currently in a phased programme to grow this feature to full remote control of operations.

Master Drilling is also currently manufacturing a large raise-boring machine, which it states will challenge the capacity that has been available up to now for the excavation of large-diameter and deep shafts.

The company has been involved in the successful drilling of the first pilot hole for two ventilation shafts that will be constructed in South Africa using raise boring.

Jordaan says: “The contract will see the construction of two of the largest raise-bored shafts based on excavated volumes, and two of the largest-diameter shafts ever completed above a 1,070m depth.”

Murray & Roberts is currently doing remote shotcreting so that employees do not have to go into the shaft; not only is this a huge cost saving, but it reduces the risk exposure.

The company is also busy putting in shafts, combining overburden removal, shaft pre-cementation and raise boring with concrete rings being stacked to establish the shafts.

Redpath says that it is doing exciting work in Australia with the Redbore 100. Its latest large capacity machine, the Redbore 90, has been doing very well in Canada, another machine needs to have the operating torque and lift to be able to rotate the required reaming head at the required cutter loading to break the rock effectively.

Redpath 90 is on its way to Zambia and yet another on its way to Australia.

Redpath’s Redbore 50 and 30 models (upream machines) continue to see growing demand, with four additional units going into service in South America and Australia, the company reports.

Redpath has seven machines being manufactured now, to be delivered by the end of the year. Redpath is also completing the detailed design of a new member of the Redbore fleet, the Redbore 80, for delivery in the June quarter of 2014.

RUC Cementation has developed a multipurpose mid-range drill rig that is intended for inter-level slot and ventilation raises.

The common requirement is to drill blind up hole slots of 1-1.5m diameter and then provide a separate machine capable of drilling standard inter-level ventilation raises of 3-4m diameter; RUC Cementation has developed a drill rig capable of undertaking both requirements in relatively small chambers of 4.5-5m.

RUC Cementation has just completed the extension of an existing shaft from 700m vertical depth to 1,100m by raise drilling at 6.4m in diameter. Newnham says: “This project required perfect accuracy of the pilot hole and an underground raise-boring machine capable of reaming to the full diameter.”

Sandvik is currently in a very strong R&D phase to improve its raise-boring tools to cope with the market demand. Göran Strand, product line manager – raise boring at Sandvik Mining and Construction, comments: “We are still in a testing phase and hope to be able to launch some improved cutter features later this year.”

The Rhino 100HM highly mobile raise boring machine was a significant new product launch introduced in late 2012; Sandvik says that this is a completely new concept in raise boring.

Sandvik has been involved in a number of raise-boring projects recently, ranging from down-boring in a nuclear waste deposit site to extremely long conventional raise-boring projects. One of its most significant recent jobs is a box-hole boring project at Outokumpu’s Kemi chromium mine in Finland, using a Rhino 100HM machine and a tailor-made CRH 2 reaming head with a diameter of 660mm.

Jarko Salo, managing director at TRB-Raise Borers, tells MM: “This project is a good example of a perfectly functioning co-operation between Kemi mine, the machine supplier TRB-Raise Borers and the tool supplier Sandvik’s raise-boring team.

“The results have well exceeded all expectations – the penetration speeds have been higher than projected, raise-boring tool life has been longer and the mobilising/de-mobilising time has been shorter.”

“...raising and sinking...”
connections capable of withstanding the full tension while continuously rotating under high torque.”

**EVOLUTION OF RAISE BORING**

While the basic concept behind raise boring has stayed the same, there have been significant refinements to raise-boring equipment in the last decade, and modern machines are more powerful and efficient than their predecessors.

In-hold tooling has evolved with improved thread forms, rod-grease compositions, cutting-consumable quality and drill-rod metallurgical changes. The limitations of the equipment have been better defined, with the drill string usually being the limiting factor.

New drilling machines have been developed with improved, variable-speed electrical drives; as a result, machine control has improved greatly even compared with 10 years ago. However, Newnham cautions: “These units are as yet still unproven and will require far more specialised maintenance than the remote operating sites can offer.”

There has been a recent trend towards larger and longer raises, and to larger machines and bigger-diameter drill rods to allow for this. Recent technology has extended to improvements in vertical drilling tolerances and a better understanding of the forces being applied when drilling large-diameter raises. There has also been development towards higher productivity with less manpower required.

“Larger-diameter raise-boring and vertical hoisting systems have been at the forefront of the raise-boring agenda,” explains Newnham. “Large-diameter raise drilling has been around for 30 years, but it seems it has only lately become sought after.”

Automation research is continuing, and some companies believe it will gain greater acceptance in the industry. Marius Oosthuizen, project executive – mining services at Murray & Roberts Cementation, says: “The new-generation machine lends itself to automation.”

Raise-boring machines were partially automated some 30 years ago; however, it has taken many years for semi-auto systems to gain favour in raise boring and there is still a long way to go to reach full automation. Many of the early designs did not gain acceptance, and even today companies are not always receptive to the cost of a machine with a high level of automation.

Automation requires different skill sets and may be practical on a single long-term operation, but it can be impractical on remote projects that require manual attendance for the loading, maintenance and checking of drill rods and rigs.

Automation can also be difficult due to varying rock conditions and other technical aspects.

Up to this point, occupational safety concerns have driven automation and its development. The idea has been to remove operators from repetitive and/or hazardous tasks.

Anton Jurasovic, engineering manager and managing director at Terratec Australia, notes: “At the moment, Terratec machines have an ‘unattended’ feature, which allows a drill rod to be reamed to end of stroke, and then a controlled shutdown occurs.

“Also, the machine in this mode will shut down automatically if bed ground is encountered, or any loads on the machine spike or drop off. Very little automation other than this is used on most machines, so there is potential for a lot more automation to be installed on raise boring.”
**SELECTION GUIDELINES**

When choosing a raise-boring machine for a mining operation, companies should ensure that the physical size and weight of the machine can operate in the size of drifts that the mine has, and that it is a powerful enough machine for the specific raise-boring requirements – primarily raise diameter, length and rock conditions. Before any large shafts are raise bored, it is also critical to do a geotechnical risk assessment to determine upfront the risk on shaft stability.

Companies should ask what size rods the drill will be using, and enquire about the remaining life and what the capacity of those rods is based on the manufacturer’s torque tension charts. Balanced systems are key, meaning that the trio of the machine, rods and reamer are designed to work in concert to capacity.

The physical dimensions of the machine and its mobility are also important, as the machine should be easily transported underground. It is essential to check the operating height of the machine.

Kelly says: “For example, our upream and downream machines are designed for the reamer to be installed within the machine – not above the machine in a nest, or below the machine in a pit, alleviating slashing of the site.

“If you’re advised by Redpath that a drill fits in a 3m back height, Redbore drills do. Some other designs require additional space for reamer installation outside the machine dimensions. Some machines for upreaming also require very large-diameter speciality pipe, which can

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**Terratec’s universal box-hole machine**

Terratec’s UB1000 universal box-hole boring machine, which was launched in July, can operate as a raise borer, box-hole machine or down-reaming machine. It was developed as a result of a request from a client in Western Australia for a safe, reliable box-hole boring machine with versatile features to allow a contractor to make use of the machine for other functions as well.

Terratec’s client was very keen to try to adapt the type of integrated systems that are used in tunnel boring to streamline and reduce manual handling during the boring and muck-removal process when box-holing.

The fully integrated system that Terratec supplied is designed to provide a cycle time of 4 x 12-hour shifts per 30m-long box hole (providing the holes are within a few hundred metres of each other). It includes a derrick/pile-loader, a rod rack, a crane-conveyor and stackable powerpack sleds.

The criteria that the client required included the ability to box-hole a 1.06m diameter to a maximum of 100m long, to conventionally back-ream at 2.4m diameter to 200m deep and to operate within a 4.5m x 4.5m drift.

The decision was made to design a machine around readily available, standard raise-boring drill rods and reamer. The drill rods used are 10in (25.4cm) diameter x 48in (121.9cm) long, with standard double-wrench flats. This technology allowed the client to make use of components that it already owned.

One of the major stumbling blocks with mechanised box boring has been machine reliability. The situation of having rock cuttings, and in many instances, hyper-saline water and ‘grinding paste’ falling onto the rig, can make keeping the machine running a big problem.

Terratec has designed this machine so that there are no electrics on the derrick, pipe loader, rod racks or crane conveyor. These are the areas that hyper-saline water and rock cuttings may fall onto, and long-term reliability of electrical systems in these circumstances has been proven to be poor. The parts of the system with no electrics are powered by hydraulic means only.

Thorough workshop testing of the unit was performed in July and August, and the machine will begin service in Western Australia soon.

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**Terratec’s UB1000-R16 universal box-hole borer derrick and pipe loader**

A Terratec UB1000-R16 universal box-hole borer derrick and pipe loader

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**“The physical dimensions of the machine and its mobility are also important”**
be 61cm or 91cm in diameter and up to 1m high – that can be a serious space/storage/movement issue in confined sites.

**TRAINING AND PROCEDURES**

Along with selecting equipment, there are other issues such as training, procedures and experience that mining companies should consider. Jordaan explains: “It is important to understand the critical nature of these excavations for the rest of a company’s operations and the risk it may pose to operations if these infrastructures are not delivered on time, as well as the commercial viability of purchasing a rig only. Selecting an experienced contractor can be much safer and more cost-effective.”

Good operator training is vital to a successful raise-boring project due to the potential risk of operators making mistakes such as dropping a reamer head or getting a drill rod stuck during the drilling process, which can be very costly. These risks can be mitigated and managed through proper training, allowing operators to learn to operate the machine safely in various rock conditions to avoid or reduce the risk of any damage.

Newnham says: “A good operator needs to have the experience and training to undertake the task at hand, but also needs the insight and feeling to understand what is happening at the cutter face and how to improve or protect the situation.

“There are numerous drillers that will select a setting and wait for a result, yet the good ones will work at achieving the best result by constantly monitoring and changing settings as circumstances dictate.”

Redpath has formalised a ‘raise boring school’ that covers areas from technical assistance to formal training and on-the-job training.

The curriculum comprises general training, as well as machine-specific training, which includes classroom and on-site instruction.