Putting rotary drilling into perspective

Atlas Copco now offers a complete range of rotary as well as DTH and tophammer drill rigs for most types of open pit mining and quarrying applications. But how do these technologies complement each other and how do drillers know which method to choose, and when? As readers of M&C are well acquainted with DTH drilling, this article puts rotary drilling into perspective.

Fig 1. Drilling methods (1) Down-the-Hole (DTH); (2) Tophammer; (3) COPROD; (4) Rotary tricone.

With the acquisition of the Ingersoll-Rand's Drilling Solutions and Baker Hughes Mining Tools (BHMT) businesses, there is now another way to break rock within the Atlas Copco family of products. Much of the world's mining output begins through drilling of holes with rotary drills. Ingersoll-Rand built air-powered rotary drills for many years prior to the introduction of their first fully hydraulic unit, the T4, in 1968.

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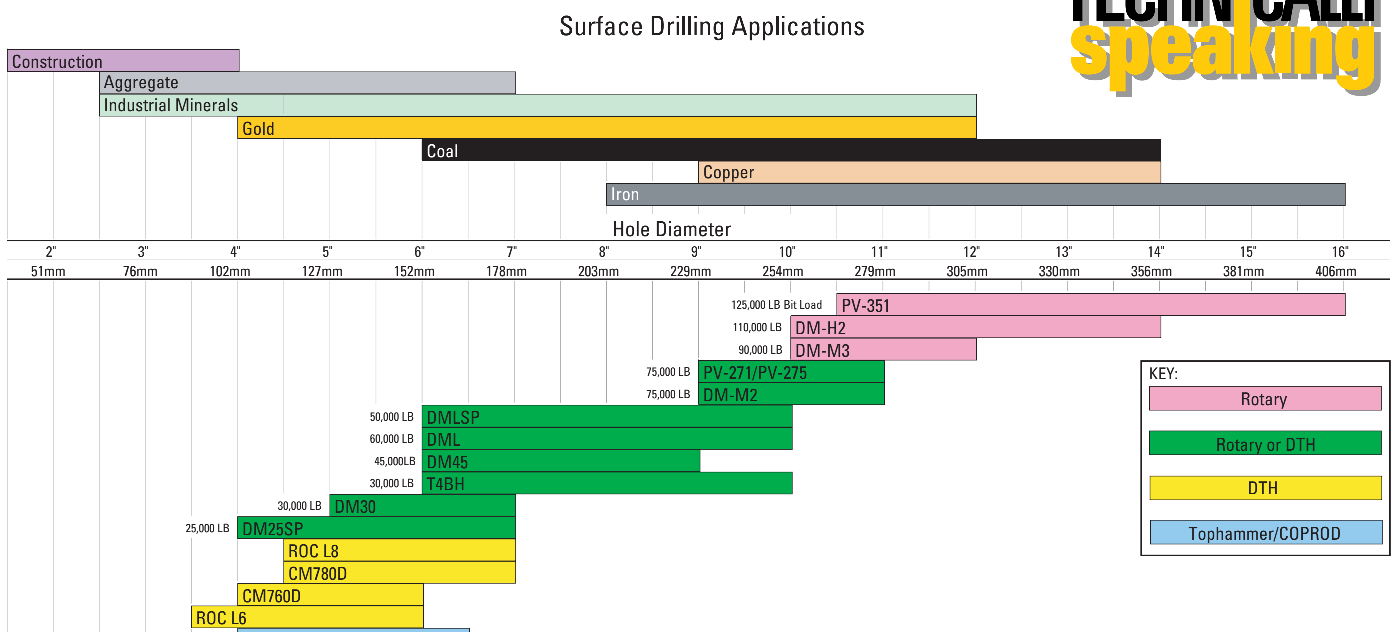
About rotary drills

It is important to note that rotary drills are capable of two methods of drilling. The majority of the units operate as pure rotary drills, driving tricone or fixed-type bits. The fixed-type bits, such as claw or drag bits, have no moving parts and cut through rock by shearing it. Thus, these bits are limited to the softest material. The other method utilized by rotary drill rigs is down-the-hole (DTH) drilling. High pressure air compressors are used to provide compressed air through the drill string to drive the DTH hammer.

The main blasthole drilling methods are shown in Fig 1. The primary difference between rotary drilling and other methods is the absence of percussion. In most rotary applications, the preferred bit is the tricone bit. Tricone bits rely on crushing and spalling the rock. This is accomplished through transferring downforce, known as pulldown, to the bit while rotating in order to drive the carbides into the rock as the three cones rotate around their respective axis. Rotation is provided by a hydraulic or electric motor-driven gearbox (called a rotary head) that moves up and down the tower via a feed system. Feed systems utilize cables, chains or rack-and-pinion mechanisms driven by hydraulic cylinders, hydraulic motors or electric motors. Pulldown is the force generated by the feed system. The actual weight on bit, or bit load, is the pulldown plus any dead



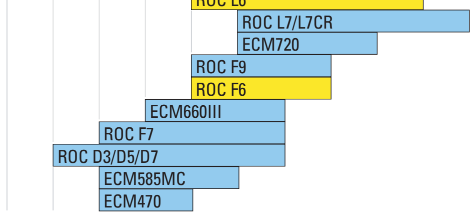


Fig 2: The Atlas Copco product range by application and method

weight such as the rotary head, drill rods and cables.

More weight with rotary

It only takes one look to see that the biggest DTH and tophammer drill rigs are very different to the biggest rotary blasthole rigs. In fact, the Pit Viper 351 rotary drill rig weighs in excess of nine times that of our largest DTH hammer drill rig, the ROC L8. Yet it is drilling a hole that is generally only twice the diameter. Take a typical medium formation tricone bit with a recommended maximum loading of 900 kg/cm of bit diameter (5000 lbs per inch of diameter). With a 200 mm (7-⁷/₈") bit, you could run about 18,000 kg (40,000 lbs) of weight on the bit. The laws of physics dictate that for every action, there is an equal and opposite reaction, meaning that if you push on the ground with 18,000 kg (40,000 lbs), the same force will push back on the unit. Therefore, the weight of the machine must be over 18,000 kg (40,000 lbs) at the location of the drill string to avoid the machine "lifting off" the jacks. To achieve a stable platform through proper placement of the tracks and levelling jacks, the distribution of weight results in an overall machine weight that approaches or exceeds twice the bit load rating. This weight does add cost to the machine, but the size of the components also translates to long life. Even smaller rotary blasthole drills are built to run 30,000 hours of operation.

The importance of air

A key parameter of rotary drilling is flushing the cuttings from the hole. In most rotary blasthole drills, cuttings are lifted between the wall of the hole and the drill rods by compressed air. Sufficient air volume is required to lift these cuttings.

Many types of tricone bits have been developed to meet various drilling needs. Softer formation bits are built with long carbides with wide spacing on the face of the bit. This design yields large cuttings which increase drill speed and reduce dust. It is important to have sufficient clearance between the wall of the hole and the drill rods in order for such large cuttings to pass. If this clearance, known as annular area, is not sufficient, the cuttings will be ground between the wall of the hole and the rods or by the bit itself (called regrinding) until they are small enough to exit the hole. This results in excess dust and accelerated wear on the bit and drill rod.

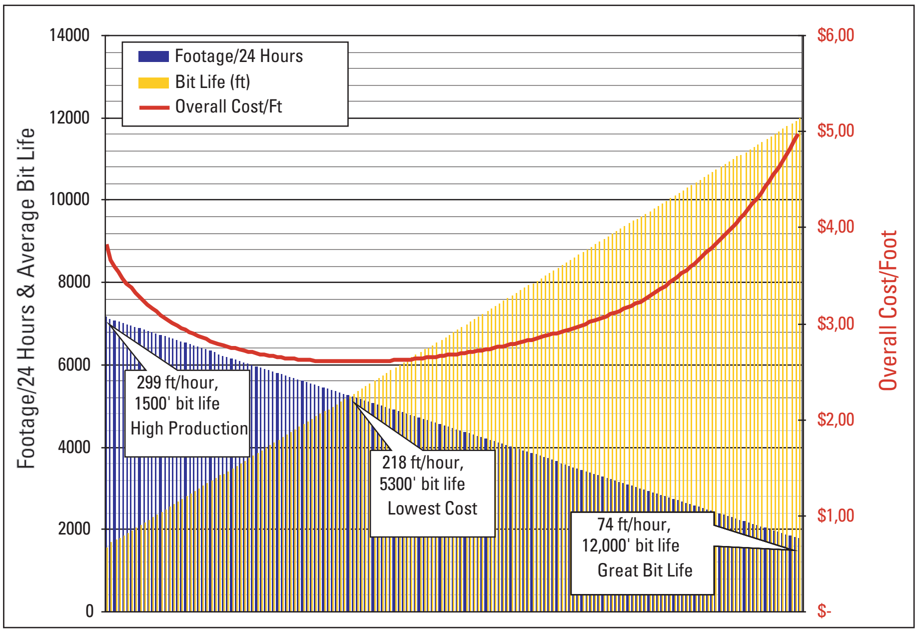
Bailing velocity

A traditional rule-of-thumb is a minimum of 1,525 m/min (5000 ft/min) of uphole velocity, the speed at which air exits the hole. The actual amount of air required will vary widely based on the density of the material and the size of the cuttings. Dense cuttings as found in iron ore mines will settle much quicker than lightweight overburden in coal mines and thus need more air coming up the hole to lift them; 1,525 m/min (5000 ft/min) may not be enough. However, harder material is generally drilled with hard formation bits that utilize shorter cutting structures, thus yielding smaller chips. Conversely, some soft material can be drilled effectively with only 915 m/min (3000 ft/min) uphole velocity. Unfortunately, many operations have tried to increase uphole velocity by increasing the diameter of the drill rod. This is obviously much easier than getting a larger air compressor by retrofitting or purchasing a new machine. In some conditions, this strategy works, but more often, the reduced annular area results in increased wear and dust, and the drill rate may even drop. Whatever the application, it is critical to have proper bailing air.

When rotary is better

Every drilling application is different, so we cannot say that there are particular breakpoints where you should transition between drilling methods. Generally, drilling below 152 mm (6") is best accomplished with tophammer units. Above this diameter, it is typically done with a rotary rig, although tophammer units are doing some of this work effectively with the introduction of larger platforms and more powerful rock drills. For harder material, say above 100 MPa (15,000 psi), unconfined compressive strength (UCS), DTH is often faster than pure rotary drilling if provided there is enough air pressure on board. Simply looking at our product range (Fig 2) gives an indication of which methods are commonly used for the different diameters found in construction and mining.

Fig 4. The impact of bit life and productivity on overall cost/foot (1 ft = 0.305 metres).



There are certain limitations imposed on each method of drilling. With top-hammer percussive drills, the power of the rock drill itself limits the ability to transmit adequate force to larger diameter bits, especially at deeper depths when percussive energy is successively reduced with each new rod connection. Down-the-hole (DTH) tools solve this energy loss problem, but their maximum hole diameter is limited by the volume of air. To build the air pressure that translates directly to impact energy, a certain volume of air is required. Take for example a Secoroc QL80 203 mm (8") DTH hammer that is designed to operate at 25 bar (350 psi). Even with our largest high pressure compressor 686 litres per second (1,450 ft^3/min), the pressure will only build to 23 bar (325 psi), thus providing less impact energy. In real terms, each blow of the piston is about 45 kg (100 lbs) less than it is designed for. In some cases, this method will still outperform rotary drilling. For most large diameter blasthole drilling, there is simply not enough air on-board for a DTH to be as cost effective as rotary drilling with a tricone bit.

Rotary drilling is still the predominant method of drilling 230 mm (9") diameter or greater. This is driven primarily by the current limitations of tophammer units and rig air systems. Tricone bits also become more cost effective as the larger bits are equipped with larger bearings which in turn can handle higher loads. These higher loads translate to improved drill rates.

Another advantage of rotary rigs is the length of the drill rods that can be carried on board. Longer rods mean fewer connections. Further, some rotary rigs are large enough to handle a long tower that enables drilling of the entire bench height in a single-pass. At the largest open pit mines, rotary units are drilling 20 m (65 ft) deep holes in a single-pass to match the bench heights dictated by the large electric shovels which can dig a 17 m (55 ft) bench.

Productivity versus cost

Studies have shown that pure penetration rate will increase linearly with increased pulldown. The same has also been said of rotation speed. So why doesn't every operation use more of each? Unfortunately, higher pulldown and rpm usually results in increased vibration and lower bit life. The vibration causes increased wear-and-tear on the rig, but more importantly, it creates a very unpleasant environment for the operator. What invariably happens is that the operator reduces the weight or rpm until the vibration returns to a comfortable level. Some operations limit bit load and rpm even if there is no vibration in order to improve bit life. This is often the wrong strategy as the overall drilling cost per unit, also known as Total Drilling Cost (TDC), should be considered.

TDC is calculated using the bit cost per metre/foot and the total rig cost per hour. The unit cost per hour includes labour, maintenance and power, and possibly the capital cost. The drilling speed really doesn't impact this cost per hour figure. What it does impact though is the cost per unit produced (cost/metre/foot, cost/ton, etc…). You generally want to push the rig harder to reduce the cost/foot, but there will be a point where the rig overloads the bits (see fig 3).

Operator	Steady Eddie	Smart Sam	Wild Jack
Production Rate (Feet/Hour)	120	138	180
Bit Life (Feet)	10,000	8,000	4,000
Bit Cost	$4,000	$4,000	$4,000
Bit Cost/Foot	$0.40	$0.50	$1.00
Rig Cost/Hour	$175	$175	$175
Total Drilling Cost/Foot	$1.86	$1.77	$1.97

Fig 3. The table compares three operators on the same drill rig – Steady Eddie, Smart Sam and Wild Jack. The cost chart, using actual data collected at a major copper mine further illustrates the balance required.

Large versus small

There are some drawbacks to rotary rigs. Smaller crawler rigs are more flexible with many advantages such as articulating and extendable booms and guides that allow drilling at many different angles. Some models also offer significantly more technology with automated rod handling systems and automatic drilling. The components on rotary rigs are not enclosed. They are mounted onto the frame in an open layout which makes them extremely easy to service. Looks are not of primary concern for a rig that is subjected to the rigors of breaking rock for more than 60,000 hours.

The general trend for 165 mm (6-½") or less is towards the smaller, more flexible units. However, many large scale quarries and small mines still favour the durability, life and simplicity of the larger rotary rigs for these small diameters. For the large scale open pit operations that yield a high percentage of the total worldwide mineral production, it is anticipated that rotary drilling will remain the primary method for years to come. M&C 2-05