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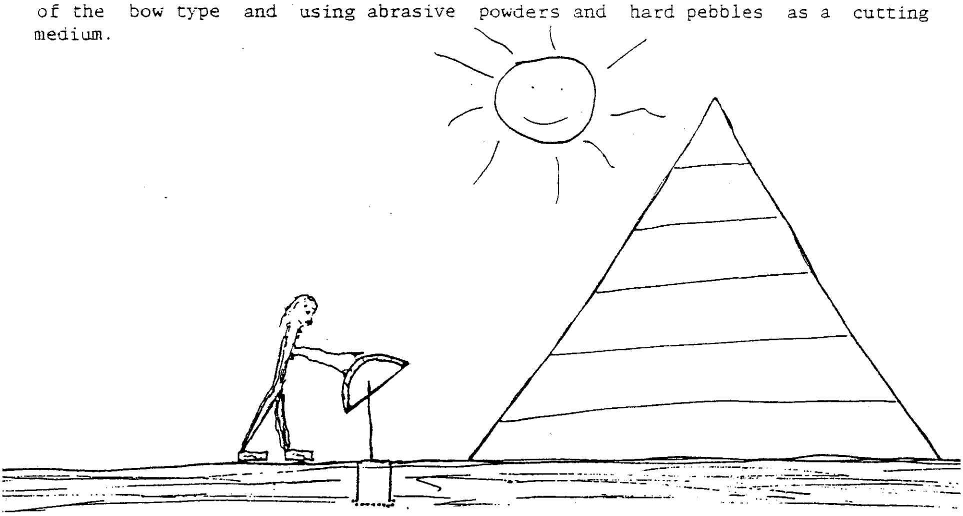
Developments in Diamond Drilling

Index:

EVOLUTION OF THE DIAMOND DRILL

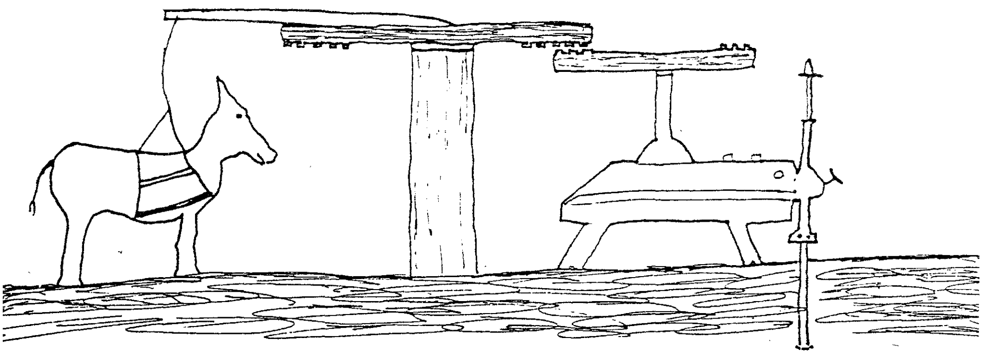
From the earliest times, mankind has treasured the ability to drill holes in rock. the early Egyptians to rock cores of short lengths during the construction of the pyramids. This was achieved using a twist drill, probably of the bow type and using abrasive powders and hard pebbles as a cutting medium.



In reviewing some of the historical books, it is written that one of the first steam driven, rotary rock drills was built in 1873. About 15 years later Isaac Signer (same individual that invented the Signer sewing machine in 1851) the steam turn drill. In 1858 the first modern air powered drill was produced in Germany. Many of these drills were complicated and unreliable. It is also written that in order to keep one drill operating, you required at least ten spare units to keep the project moving. (one must question the economics of this practise in todays drilling environment, where total cost per meter is closely monitored and down time kept to a minimum)

An early modern diamond drill was designed by the Swiss engineer who was engaged on the Cenis tunnel project in the European Alps. He called his invention the "Perforator" because it was designed to drill blast holes. The first drill bit was set with a ring of black diamonds and could bore 4.6 feet per hour through granite, producing a hole of 1 1/3 inches.

Over the decades the diamond drill has witnessed a steady evolution to the units available today. There has been man powered units, steam, air, and horse driven units, internal combustion engine powered and today there are electro and diesel hydraulic versions available and commonly found on drill sites.

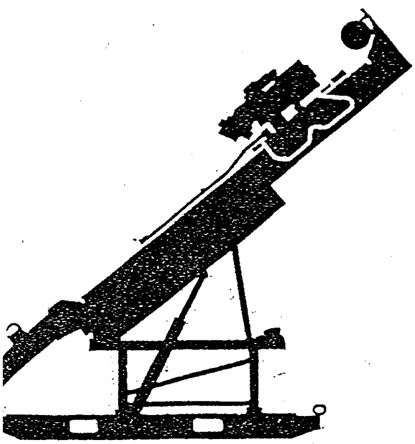


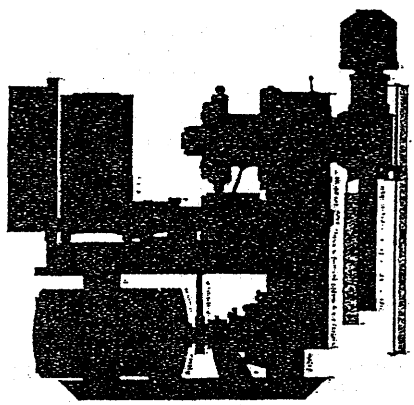
What the future holds for the diamond drill is yet to be determined and will be mentioned later. In some applications it has been found that drilling rigs invented in the 1950's are well suited to a particular application. There are many older drilling units to be found on mines and dams sites etc. that are still serviceable and cost effective for the operators. There has been a trend initiated by the industry towards drills having added safety features, while being more operator friendly, cost effective and less noisy. The drilling industry has put stringent demands on drill manufacturers to produce rigs suited to a given environment. For example a coal mine may dictate that flameproof hydraulic fluids and electric motors are used on electro hydraulic drilling machines, likewise a wet mine may require a nearly submersible electric motor for the same model of drill rig.

With the advent of hydraulic drilling rigs, many operators have found that their drillers are able to obtain increased meterage per shift and lower in-hole tooling costs, by being better able to monitor changing in-hole conditions. The advances made in hydraulic components has enabled drill manufacturers to cater to many of the end-users objectives. Many new features may be incorporated to a drill that not only make the drills safer but less tiresome for the drillers. Some of the latest features, include; Automated or semi-automated rod handling systems, rod-roller systems, positive break-out devices and features that make the drills less complicated and tiresome to install and set-up.

Finally, after several years, the misconception about all-hydraulic diamond core drills is being dispelled and we are beginning to see their usage in areas that for many years had their doubts (not totally unjustified). In the past hydraulic drills outperformed their mechanical counterparts while drilling, but because of the substantial down-time, they often produced less at a higher cost. This down time was the result of poor reliability coupled with the lack of understanding of hydraulics by field personnel. This situation was aggravated in countries where expert service was not readily available.

To help alleviate the problem, as an interim measure, some drill manufacturers introduced hybrid machines which combined the reliability of conventional spindle type machines with the convenience of hydraulics. These models allowed the driller to adjust hydraulic power to the drill string, on a smaller scale, without being overwhelmed by the complexities of a totally hydraulic drill.





Many mines have modernised their mining equipment and have had hydraulic jumbos and other complex hydraulic powered machinery commissioned, this, in turn, has been beneficial for the mines diamond drilling departments as the service of complex hydraulic systems is now becoming commonplace. During the past few years, the use of completely hydraulic, underground diamond drills has increased proportionally to improved machine reliability and knowledge of field personnel. Mounting management pressure to reduce cost and increase safety also played a part in the increased need to accept the use of hydraulic powered drills and have the personnel trained accordingly.

Following is a review of the advantages of hydraulic-powered underground drilling machines.

Electro-hydraulic diamond drills often have a greater depth capacity than air-powered drills. An electrically powered machine can be designed around an abundant electric supply, while an airpowered screwfeed machine is limited by often inefficient and inconsistent air supply. (some of the newer screwfeed machines have been designed with inconsistent air supply in mind and have fitted the appropriate air motors)

In underground drilling, safety is a prime consideration. All-hydraulic drills with mechanized rod handling offer greater safety in round-tripping operations, especially on up holes or in conditions with in-hole water pressure. Machines in which both the rod clamp and chuck are hydraulically interlocked (sequenced) with the movement of one lever are the safest. The sequenced rod handling controls may be considered an important feature when drilling dewatering holes.

Noise is also a serious health hazard. In some countries, provincial laws mandate a maximum allowable noise level in decibels that, in effect, no longer allow the use of screwfeed drills, even with hearing protection.

Modern electro-hydraulic machines are quiet. Typically, they come with a satellite control panel and a remote powerpack so that the major source of noise may be located at a distance from the driller. Electro-hydraulic drills with remote control panels having only low pressure pilot hoses running to the panel are the safest for the driller in case of a hydraulic hose burst there is less chance of injury than the units having high pressure control valves.

An electro-hydraulic drill work station is free of air mist, which makes the work environment healthier, safer, pleasant and more efficient.

A contractor may find it advantageous to state the equipment he proposes to use on a particular job. A contractor with modern equipment could be more likely to be chosen over one with mechanical equipment, simply because the client may perceive the former as more efficient and reliable.

Hydraulic machines offer faster penetration due to greater horsepower and longer feed length. Hydraulic drills allow the driller to better monitor changing in-hole conditions on the gauges provided and in turn, increase the life of his diamond bits.

Rechucking times are dramatically reduced on hydraulic machines having a longer feed length and using a hydraulically activated chuck. Rod tripping times are reduced because of the longer head travel as opposed to the short stroke of rod pullers on air powered drills.

Taking these factors into account, including the physical dimensions of the drill and depth of the holes, it may pay (in higher production per shift and reduced labour cost) to consider a larger and more costly electro hydraulic drill when formulating a drilling program.

THE FUTURE

As hydraulic equipment continues to gain acceptability, several challenges lie ahead. Mechanisation will make drilling easier and more efficient for drillers who often work in conditions approaching the limits of human endurance. Increased mechanisation can be predicted in the areas of moves and setups, and more automation will occur in the drilling cycle. We have seen this with the introduction of rod rolling systems on short hole diamond drills. To implement automation, complex instrumentation to measure, interpret and control parameters may be developed. Drilling parameters may eventually be controlled with microprocessors. For certain, not all areas and drilling applications will require this new fangled' technology however these are innovations that are being considered by many manufacturers.

A third discipline, electronics, can be added to the existing two - mechanics and hydraulics - with serious repercussions in the area of field maintenance. We have seen these developments with electronically piloted control valves in other industries and some drill manufacturers have been using these electronic systems for several years in certain applications with extremely encouraging results.

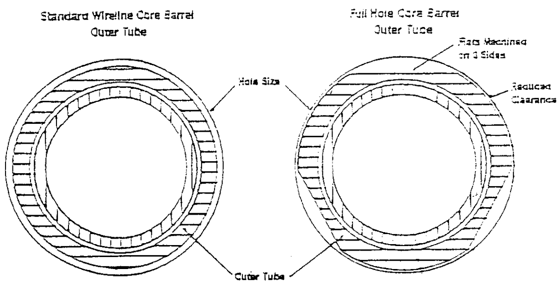
To effectively implement these technologies management will have to assess if their drilling personnel is capable of learning these new systems. Increased training will be needed at the operation and service levels to minimize down time. Drill operators will be required to drill with more finesse, aided by improved instrumentation. They will also be required to do basic troubleshooting and maintenance on more complex machinery, which will require the capacity to reason with abstract concepts. Service personnel will become proficient at troubleshooting and repairing complex hydraulic systems.

According to a senior manager at an underground diamond drilling contractor in Canada; "Equipment used on underground operations has recently gone through major changes. The air-powered screwfeed drills are being replaced by electro-hydraulic drills. The new style drills have production potential far exceeding the old style drills. In addition, these drills go far towards obtaining the objective of taking the muscle out of the drilling operations"

Performance data indicate that hydraulics are easier and more efficient to operate than ever before. Today productivity, reliability, convenience, safety and cost-effectiveness are the hallmarks of underground hydraulic diamond drilling worldwide. Manufacturers stand ready to work with customers to address their concerns and help them reach their goals in the future.

IN-HOLE TOOLING DEVELOPMENTS

In-hole tooling product developments are based on parameters and circumstances as required for a specific area or range of applications. Again these developments are dictated by the industries need to be more cost effective. There are many cases where mines have tried to introduce the "latest", only to find that what they had been using only required small modifications or had been completely satisfactory.



FULL - HOLE
Corebarrel
for
Drilling
Straighter
Holes

For manufacturers of in-hole tooling, many factors come in to play when developing new products; Market demands, Cost, wether their present manufacturing processes can be suited and effective for the new materials, delivery time from the supplier etc. etc. Manufacturing processes are being revised and new machining and quality control facilities are being introduced at most plants.

The quality of steel and availability of high tech. composite materials is improving, as manufactures find themselves in close liaison with the steel mills. The threads connections are improving with the availability of new technologies and materials, high tech glues, friction welding and modern thread profiles all can improve a tubular product.

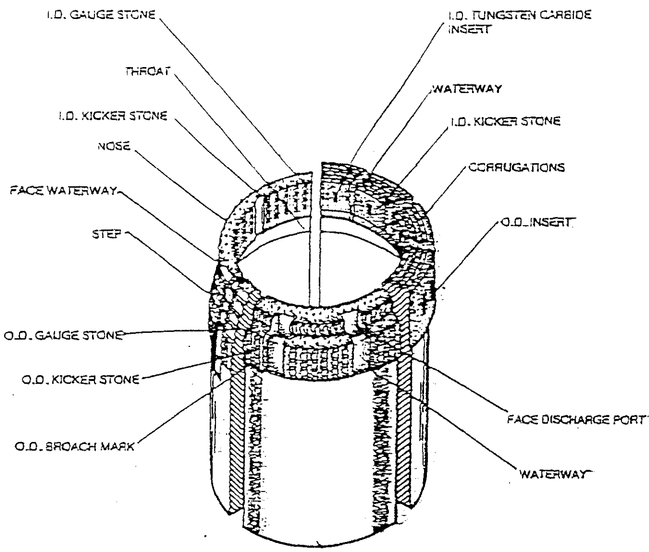
Other innovations, being, that manufacturers are trying (in order to be cost effective for the end-user) to adapt readily available material to a variety of products, by using new manufacturing methods. A large proportion of diamond drilling is done in A,B,N and H sizes, both wireline and conventional with their respective raw materials being used. Today there are moves towards using a wireline rod mid-body fitted with a conventional thread type; W or the new WJ taper profile. These developments are now possible using special glues and new connecting threads while maintaining interchangeability with older products still in use. A string of AW drill rods is soon to be delivered to the Zambian Copperbelt, in fact, these rods are AQ mid-bodies with AW threads fitted. By analysing these possibilities, manufacturers are able to provide cost effective, quality products in much shorter lead times.

With new materials and processes available, manufacturers are constantly on the look out' for improvements that can be made to their existing products. ie; Corebarrel bearings, improved rubbers for shut off valves, better steel, etc. Thread profiles are also being tested and it is expected that many mines will replace their conventional W rods with the new taper thread (WJ) This will make the drillers job of coupling rods less arduous while reducing the likelihood of thread damage.

DIAMOND BIT TECHNOLOGY

Diamond bit technology has seen many changes over the past decade. The larger manufacturers have invested in specially designed, atmospherically controlled furnaces for furnacing their bits. Even the smaller manufacturers have been able to benefit from the new raw materials now available. Metal powders, used in the bit matrix, play an important role in manufacturing processes, as do the synthetic diamond grit used in the popular Impregnated Diamond Bits (IDB) used in most hard rock mines today. Metal powders, synthetic diamonds and manufacturing processes have all improved to suit their respective diamond drilling usages.

For softer formations, Tungsten Carbide (TC) has been in use for several years, today we are seeing a greater call for PolyCrystalline Diamond (PCD) and Thermally Stable Diamond (TSD) bits, due to their greater life and faster penetration. There are even developments towards making impregnated core bits reinforced with TSD triangles incorporated in the IDB matrix.



Manufacturers of diamond bits have done a great deal of work, together with their clients, towards developing bits best suited to the clients equipment and suitable to the formations to be drilled. Most manufacturers are prepared to listen to a clients suggestions and implement his ideas as to how a bit can be modified to suit a particular formation/application. There is of course a cost to developing non-standard products, however some very good bits have been developed for non-standard applications, based on a driller's suggestions.

Operating parameters have a great deal of influence on the drilling results and the following should provide a fairly comprehensive outline.

OPERATING PARAMETERS

Each product has its specific operating parameters. The recommendations given with each product should be seen as a guide-line only and due to specific circumstances the optimum parameters may well be different from the figures given.

When extreme or abnormal wear patterns, low penetration rates or other drilling problems are encountered a comparison between the real and recommended parameters may give an indication to the cause of the problem.

– RPC Index (Revolutions per cm drilled).

In diamond drilling the penetration rate depends on the type of bit and on the peripheral speed of the bit, and is in direct proportion to the diameter and the RPM.

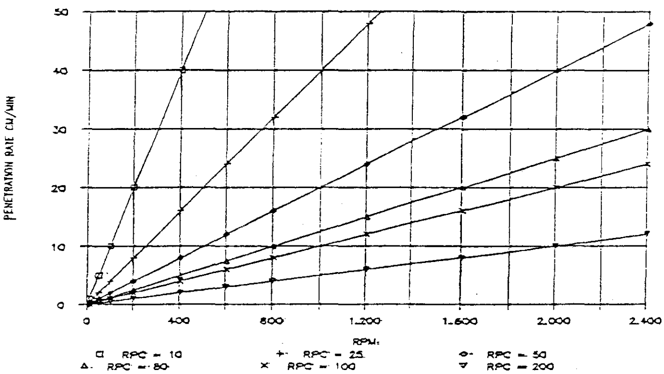
Some bittypes require relatively high RPMs to achieve an acceptable penetration rate while others advance quite well at low RPMs. The former would have a high RPC index and the latter a low. Typical examples of high RPC bits are impregnated bits in general, and Series 10 in particular. The RPC of surface set bits is lower, but still high compared with sawtooth and other TSD bits. PCD bits have a very low RPC index.

Much work is presently being done to lower the RPC index of impregnated bits. The GTC bit (a TSD reinforced impregnated bit) has a considerably lower RPC index than a standard impregnated bit.

Due to the lower peripheral speed the RPC of small bits is proportionally lower.

To obtain the RPC index divide the RPM by the penetration rate ROP.
Examples:

RPM	ROP	RPC
50	2	25
100	2	50
100	15	7
200	12	17
400	8	50
600	12	50
800	15	53
1200	10	120
1500	10	150
1500	20	75
2200	20	110
RPM	CM/MIN	RPC



- Fluid volume:

The main purpose of the fluid is transport of cuttings. A fluid velocity of at least 0,5 meter per second is required to lift the cuttings. With wide kerf bits and high penetration rates fluid volume should be higher. In weak formations a maximum of 0,9 m/s is recommended to prevent the turbulence having a negative influence on the hole wall stability.
In most applications waterflush is the most appropriate. When drilling swelling clays or mudstones use of airflush, preferably with foam, may be more suitable. Use of polymers or other additives is is recommended for most applications.

CALCULATIONS

To calculate the up-hole velocity (v) in m/s for a given fluid volume:

Annular Area A (mm^2) : ((Hole OD)^2 - (Rod OD)^2) x PI/4

Fluid Volume Q (l/min)
Fluid Volume q (l/s) Q / 60

Velocity v (m/s) q / A x 1000

To calculate the required fluid volume to obtain the desired up hole velocity:

Fluid Volume q (l/s) v x A / 1000

Fluid Volume Q (l/min) q x 60

Required volume for up hole velocity of 0,5 m/s (MIN.) and 0,9 m/s

			0,5	0,9
HOLE	ROD	A	Q	Q
AQ	AQ	254	8	14
BQ	BQ	399	12	22
NQ	NQ	663	20	36
HQ	HQ	1.031	31	56
PQ	PQ	1.544	46	83
SQ	SQ	1.414	42	76
46,3	43	231	7	12
56,3	53	283	8	15
66,3	53	1.246	37	67
76,3	NW	1.078	32	58
86,3	NW	2.355	71	127
101,3	HW	1.852	56	100
116,3	HW	4.416	132	238
131,3	HW	7.333	220	396
146,3	HW	10.603	318	573
mm		mm^2	l/min	l/min

Weight (Thrust)

The required thrust can vary substantially and it is difficult to give hard and fast rules.
Obviously big wide kerf bits require more weight than small thin kerf bits. In hard formations more thrust is required than in soft formations. In very soft formations waterways may get blocked with too much thrust. With all other things being equal some bittypes require more thrust than others. In the parameters recommended for bittypes in this section this is given as low, medium or high. In the table below medium recommended thrusts are given. Low thrust could be less than half, while high weights could be twice the figure in the table.

BIT	KG
AQ	1000
BQ	1200
NQ	1500
HQ	2000
PQ	2200
SQ	2500
46 B, T, LTK	500
56 B, T, LTK	600
66 B, T	800
76 B, T, T6....	900
86 B, T, T6....	1100
101 B, T, T6....	1500
116 B, T6....	1700
131 B, T6....	1900
146 B, T6....	2200

For surface set bits a weight of 3 to 5 kg per diamond is a useful guideline.

CONCLUSION

It can be seen that there are many developments towards implementing new technologies in the diamond drilling industry. Suppliers and end-users view these developments with varying degrees of scepticism as not all developments may suit a particular job at hand. Time will bear testimony as to what developments are most needed and subsequently introduced to areas of the drilling industry. Without doubt the drilling suppliers, are today, more than ever, prepared to listen to what the industry is calling for, and work towards developing the most practical equipment needed.

The author of this paper has tried not to use names of suppliers in this presentation and would like to thank all those involved for their help and cooperation. We trust the accompanying slide presentation, literature and sample material may be of interest. Should any participants have any specific interests please feel free to make contact.

A special thanks to the Konkola mine and its employees for hosting this symposium.