ESSENTIAL GUIDE TO DRILLING PARAMETERS

INTRODUCTION

Drilling parameters play a large role in helping drillers achieve superior drilling performance and long equipment life. They are basic recommendations that help guide a driller avoid burning core bits or damaging other drilling equipment, and help achieve a good rate of penetration and core recovery.

You should always keep in mind that there is a relationship between the drilling parameters and all others factors in drilling. These include:

- Size and diameter of the equipment being used
- Rock hardness or ground variability
- Size and power of the drill rig being used
- Whether drilling fluid additives are being used
- The depth and angle of the borehole

Understanding how to adjust drilling parameters and how one parameter can affect the other, can help drillers improve performance in difficult drilling situations.

1 CHOOSE THE RIGHT EQUIPMENT

To achieve optimal drilling performance, you must choose the right equipment for the drilling project. Drill bits are made with a different combination of metals and alloys; they have different levels of impregnation of diamonds, different heights and different configurations, so choosing the right bit can be complex.

Ground factors that you must consider include:

- Hardness of ground
- Variability of ground
- Abrasiveness of ground
- Competency of ground

Other factors to consider:

- Type of drill rig
- Expertise of driller
- Knowledge of area to be drilled
- Depth of drilling expected

You can learn more about choosing the right core bit in our guide: Mineral Exploration: Guide to Choosing the Right Core Bit

Once you have determined the best core bit to use, you must also consider the type of core bit configuration to use. In this case, you will choosing options such as:

- Crown height
- Discharge options
- Number of waterways
- Width of waterways
- Shape of waterways

You can learn more about choosing the right core bit configuration in our guide: Fundamental Guide to Core Bit Configurations

2 STARTING POINT

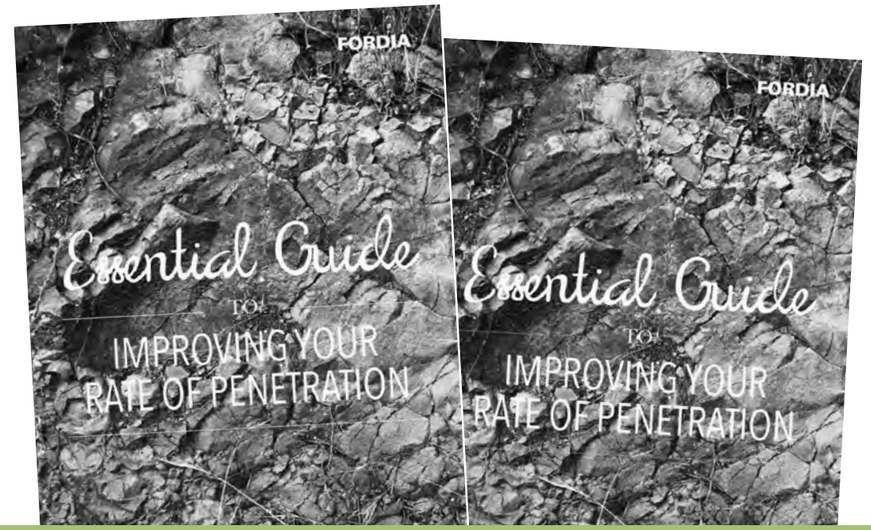
Most core bits come with reccomendations for the drilling parameters for that particular type of core bit. These can be found on a label, on the core bit itself or printed in a technical document or booklet. These recommendations can guide you with a starting point for your parameters. The recommendations will provide a range, from low to high, and it is recommended that you start somewhere in between. You can always make adjustments as you go in order to get your best drilling performance.

3 RATE OF PENETRATION (ROP)

In the drilling industry, the rate of penetration (ROP) is the speed at which a drill bit advances through the rock under it to deepen the borehole. Also known as penetration rate or drill rate, it is normally measured in inches per minute or meters per hour, but sometimes it is expressed in feet per minute.

The ROP is the key parameter in diamond drilling. Finding the optimum ROP for a given type of rock, ground condition, core bit and type of diamond drill rig will improve drilling performance. To find the optimum ROP, you should start by using the ROP suggested on the bit label. You can then fine tune the weight on bit (WOB) and rotation speed (RPM) in small increments.

SIZE	ESTIMATED PENETRATION RATES (ROP)	
	150 rev/in drilled 60 rev/cm drilled	250 rev/in drilled 100 rev/cm drilled
AO **AO THIN KERF**	5.3 to 13.2 in/min 13 to 34 cm/min	3.2 to 7.9 in/min 8.1 to 20 cm/min
BO **BO THIN KERF**	4.2 to 10.6 in/min 11 to 27 cm/min	2.5 to 6.4 in/min 6.4 to 16 cm/min
NO **NO THIN KERF**	3.4 to 8.4 in/min 8.6 to 21 cm/min	2.0 to 5.0 in/min 5.1 to 13 cm/min
HO	2.6 to 6.6 in/min 6.6 to 17 cm/min	1.6 to 4.0 in/min 4.1 to 10 cm/min
PO	2.1 to 5.2 in/min 5.3 to 13 cm/min	1.2 to 3.1 in/min 3.0 to 7.9 cm/min



Finding your optimum ROP ensures that you get the longest bit life and that your core bit stays sharp and does not polish. It will allow you and your drill team to perform the least amount of work for the best drilling performance and represents the greatest economy for the drilling project. A ROP that is too high can cause too much wear on the matrix and can result in the diamonds being expelled while they are still sharp.

Once you have found your ideal ROP, you can maintain it by adjusting the bit pressure or WOB, and your RPM. You will also have to monitor your water flow especially with high ROP, as cooling and flushing the core bit is very important.

The ROP is often used as a benchmark against which to measure any changes in drilling parameters or processes. For example, let's say you wanted to test a new core bit. To determine if this new core bit was better, you would look at the ROP with the old bit and compare it with the ROP you are achieving using the new bit. In the same way, if you were to change your rotation speed or bit pressure, you would want to see how it affects your ROP.

Read more about how to improve your ROP here.

4 ROTATION SPEED OR REVOLUTIONS PER MINUTE (RPM)

The rotation speed is also referred to as Revolutions per Minute (RPM) and is measured using a tachometer. The suggested rotation speed is often given as a range and you start somewhere in the middle.

The rotation of the core bit causes the diamonds impregnated in the matrix to cut into the rock and tear away rock cuttings. The rotation speed therefore determines the rate at which the rock is being cut and the cuttings torn away. Generally speaking, the higher the rotation speed, the higher the ROP. The rotation speed also helps wear down the matrix and aims to expose new diamonds at a constant rate. In this way, new sharp diamonds are being exposed and dull, worn out diamonds are being released.

Rotation speed should be chosen carefully based on the diameter of the system you are using. Other variables can affect the choice of your rotation speed. These include the diameter of the core bit, depth of the hole, the ROP and vibration.

A rotation speed that is too high can polish the core bit, but if it is too low it can cause the bit to wear out prematurely.

If you are penetrating the rock quickly, it is possible to rotate the rods faster which will enhance ROP. Or if you are having difficulty penetrating the rock, you can reduce RPM and help increase ROP.

SIZE	NORMAL RECOMMENDED RPM
AO AO THIN KERF	800 to 2,000 RPM
BO BO THIN KERF	650 to 1,600 RPM
NO NO THIN KERF	500 to 1,250 RPM
HO	400 to 1,000 RPM
PO	300 to 800 RPM

5 WATER FLOW

The water flow is often given in terms of Gallons per Minute/Litres per Minute (GPM/LPM) The suggested water flow should be considered as a minimum and the setting of your pump should be well above this. Your drilling performance is directly related to the water flow across the bit face.

Drilling fluids should be pumped across the core bit at a rate that flushes away the rock cuttings as they are cut by the diamonds. Improper flushing results in a negative impact on ROP and bit life because the rock cuttings will be reground. Correct water flow will ensure that flushing removes the rock cuttings, cools the bit face and lubricates the core bit and drill rod. The velocity of the drilling fluids must be high enough to keep the rock cuttings suspended.

Chart below gives the water flow suggested for different standard sizes of core bits.

TYPES	WATER FLOW GAL IMP/MIN (L/MIN)				
	AO	BO	NO	HO	PO
Very hard to extremely hard and competent	3-4 (14-18)	5-6 (23-27)	6-8 (27-36)	8-9 (36-41)	10-11 (45-50)
Hard to very hard and competent	4-5 (18-23)	6-8 (23-36)	8-9 (36-50)	10-12 (45-54)	12-13 (55-60)
Other	6-8 (27-36)	7-10 (32-45)	12-14 (56-64)	14-16 (64-73)	15-17 (68-77)

SIZE	NORMAL RECOMMENDED FLUID CIRCULATION RATES
AO AO THIN KERF	1.5 to 3.5 US Gal/min 5.7 to 13 Liter/min
BO BO THIN KERF	2 to 5.5 US Gal/min 7.6 to 21 Liter/min
NO NO THIN KERF	3.5 to 9 US Gal/min 13 to 34 Liter/min
HO	5 to 14 US Gal/min 19 to 53 Liter/min
PO	7.5 to 20 US Gal/min 28 to 76 Liter/min

DD-2000

The water flow should be as high as possible but must be related to the bit size and type of rock to be drilled. For example, in soft or fractured rock, the water flow must be high. However in a very hard and competent rock, where the speed of penetration is low, the water flow must be reduced to enable the cutting of the rock and to reduce the risk of polishing the diamonds.

You should always make sure there is proper and sufficient water flow to the bit. A quick inspection that your rods don't leak is always a good idea.

The use of drilling additives, such as DD-2000, can help with flushing cuttings so that coring is faster and wear on the drill bit is reduced. Torqueless is an excellent product that reduces torque, protects against wear and extends bit life.

6 WEIGHT ON BIT (WOB)

The weight on bit (WOB) is also known as the bit pressure. It is required to make the diamonds in the core bit cut into the rock and advance into the borehole. The amount of weight that is placed on the bit depends on several variables, including the type of rock, ground conditions, type of core bit type used, the water flow, the depth of the bore hole, length of the rod string, the RPM, and the ROP.

The recommended WOB is the maximum that should be used. When starting to drill, the initial WOB setting should be below the recommended setting. Bit pressure or WOB that is too high can result in premature wear of the mechanical components of the drill, the drill rods, the core bit and the core barrel.

There will also be a higher probability of borehole deviation if the WOB is too high. Read more about how to avoid hole deviation here.

WOB that is too low will lead to a reduction in productivity and the core bit can become polished. If this occurs, you may have to sharpen the bit to maintain your productivity.

As a rule, bit pressure, or the force applied on the bit, plus the weight of the rods that are being used must be as low as possible while maintaining a good penetration rate. You should put only as much pressure on the bit as you need to advance. To achieve a good penetration rate you must aim for the ideal combination of rotation speed and bit pressure. This relationship will change as you add each rod.

As you advance deeper into the hole, you will add rods and your rod weight will increase. It is likely that you will need to reduce your feed pressure. At some point if you are using many rods, your rod weight alone can become more than the pressure you have been exerting, meaning that you may need to hold back some of your rod weight using the hydraulic holdback pressure.

This needs to be managed carefully and many experienced drillers “feel” when the pressure needs to change or be held back. While drilling, the force applied by the drill and the weight of the rods must be as low as possible. It is important to keep sufficient speed of penetration in order to prevent the polishing of diamonds.

SIZE	NORMAL RECOMMENDED BIT LOAD RANGE (WOB)
AO	2,000 to 4,000 lb 8.9 to 18 kN
AO THIN KERF	2,000 to 3,500 lb 7.9 to 16 kN
BO	3,000 to 5,500 lb 13 to 24 kN
BO THIN KERF	2,500 to 5,000 lb 11 to 21 kN
NO	4,500 to 8,500 lb 20 to 38 kN
NO THIN KERF	4,000 to 8,000 lb 19 to 35 kN
HO	6,500 to 13,000 lb 29 to 58 kN
PO	10,000 to 19,000 lb 44 to 84 kN

CONCLUSION

Drilling parameters play an important role in helping drillers achieve a good drilling performance. With each parameter, recommendations are provided to help drillers avoid burning core bits or damaging other drilling equipment.

There is a clear relationship between the drilling parameters and all others factors in drilling, such as the diameter of the equipment you're using, rock hardness or ground variability. We have seen that when drilling conditions change, drillers will adjust their drilling parameters. Understanding how to adjust drilling parameters can help drillers improve performance in difficult drilling situations.

Our tech team is always ready to guide drillers when drilling parameters need to be reviewed, so don't hesitate to contact them.