ATOM BITS DRILLING PARAMETER GUIDELINES

The performance of the bit is affected by the geological formation and the structural elements mainly within the formation. However, drilling factors such as hole diameter, depth, weight on bit (**WOB**), water flow (**WF**), rate of penetration (**ROP**), and revolution per minute (**RPM**) have direct impact on performance of the bits. To achieve the highest drilling rate while prolonging bit life, we recommend the following RPM rates as shown in Figure 1.

Table 1. Recommended RPM Rates for ATOM Bits

Bit Diameter	Revolution Per Minute (RPM)	Optimum RPM
A	1150 - 1920	1500
B	890 - 1510	1300
N	750 - 1200	1000
H	550 - 950	780
P	500 - 750	650

Unless drilling extremely broken and hard ground, speed can be increased to get higher penetration rates. However, if the head stalls the speed needs to be reduced to produce more effective torque and maintain constant rotation. In broken ground conditions, especially where there is loose rock, matrix and diamonds could be worn quickly, therefore rotation speed should be reduced to half RPM.

1. Sharpening the Bit

When there is a reduction in torque and penetration rate, the bit might be polished. If that is the case, controlling the water flow and WOB could be used to sharpen the bit. If not done properly, matrix will be worn out and the bit life will be shortened significantly. As a rule, increase the WOB 10-30% while reducing the water flow gradually. When the bit starts to sharpen, the system pressure will increase, and the rotation speed will reduce. Then reduce the WOB and increase the water flow right away to normal values. ***The circulation fluid rate should only be lowered if a bit will not sharpen on its own and must be restored to its original setting immediately after the bit has sharpened itself.***

Sharpening is necessary when a new bit is started, if too low a bit has been selected for the rock type or if an impregnated bit has been allowed to slow down and polish. Active sharpening should be done as little as necessary because it reduces bit life.

If frequent sharpening is needed, a higher series bit matrix should be selected.

2. Weight on Bit (WOB)

Weight on bit (WOB) is the main method of controlling bit life and penetration rate. The lowest possible bit load or WOB that will provide an acceptable rate of penetration should be applied when drilling with diamond impregnated core bits. In particularly deep holes, it is often necessary to “hold back” on the drill string in order to achieve the desired WOB while drilling.

Determining the appropriate bit load is a function of both the matrix type as well as the bit face contact area with the formation being drilled. The bit face contact area is largely influenced by the waterway configuration that has been selected for use. ***Always make sure that the selected bit load does not exceed the load bearing capacity of the drill string in use.***
For example, for N size drill string, 3,000-9,000 lbf is recommended, and for H size, 4,500-12,000 lbf is recommended. If higher loads are required, select a higher series bit. Increasing the bit series normally results in lower bit weights required for the same penetration rate. However, if the WOB is too low, then both the penetration and torque drops, resulting in low life and productivity. This condition is referred to as polishing where diamonds wear faster than the matrix until the face is flat, leaving no diamonds protruding from the face. If weight on bit is too high, characterized by very little or no increase in penetration rate for additional weight, the result is constant sharpening and rapid wear. As rods are added, force to maintain constant WOB will change, so WOB must be monitored to ensure consistent bit performance at all depths.
Higher bit loads (WOB) should only be applied if:

- circulating fluid rates towards the recommended Max are in use, or
- a suitable bit lubricant has been added to the circulation fluid solution.

Table 2. Maximum Recommended Bit Load for Atom Bits Blade Series

Atom Bits Series	Maximum Recommended Bit Load per Bit Face Contact Area	
Blade 2, Blade 3	175 kg/cm^2	2,500 lbs/in^2
Blade 5, Blade 7	160kg/cm^2	2,275 lbs/in^2
Blade 9	150 kg/cm^2	2,150 lbs/in^2
Blade 11, Blade 13	140 kg/cm^2	2,000 lbs/in^2
Blade 15	130 kg/cm^2	1,850 lbs/in^2

Table 3. Maximum Recommended Atom Bit Load for each Size

Wireline Size	Max Bit Load (kg)	Max Bit Load (lbs)
AWLTK	1,900	4,200
BTW	2,100	4,600
BWLTK	2,200	4,850
BWL	2,500	5,500
NTW	3,000	6,600
NWL2	3,500	7,700
NWL	4,100	9,000
NWL3 (NWLTT)	4,500	9.900
HTW	5,000	11,000
HWL	6,000	13,250
HWL3 (HWLTT)	6,500	14,300
PWL	9,000	19,800
PWL3 (PWLTT)	9,500	20,900

It is recommended to consider the bit's waterway configuration when determining the optimum bit load to apply. Multiply the bit load values listed in Tables 2 and 3 (above) by the values given in Table 4 (below) to determine the appropriate bit load value based on waterway configuration.
On the other hand, insufficient bit load will cause diamonds on the bit surface to blunt as they will be unable to sharpen and expose new cutting edges. As a result, the bit will not perform as

effectively for rate of penetration. **The minimum recommended bit load per bit face contact area for Atom Bits is 90kg/cm^2 (1,280lbs/inch^2).**

Table 4. Waterway Configurations

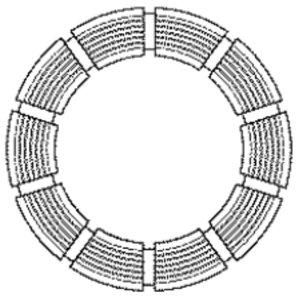
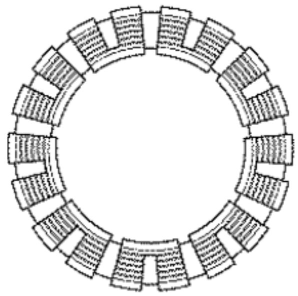
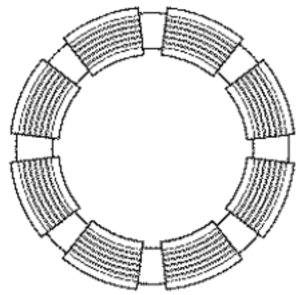
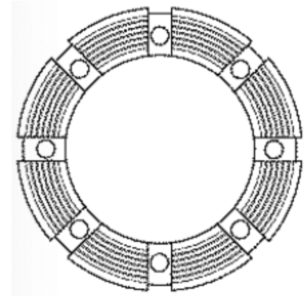
Regular (W)	Turbo (TT)	Extra Wide (EW)	Face Discharge (FD)
			
1.00	0.78	0.90	0.87

Table 5. Minimum Recommended Atom Bit Load for each Size

Wireline Size	Min Bit Load (kg)	Min Bit Load (lbs)
AWLTK	950	2,100
BTW	1,275	2,800
BWLTK	1,350	3,000
BWL	1,600	3,550
NTW	1,800	4,000
NWL2	2,200	4,850
NWL	2,400	5,300
NWL3 (NWLTT)	2,600	5,750
HTW	2,900	6,400
HWL	3,600	7,950
HWL3 (HWLTT)	3,850	8,500
PWL	5,450	12,020
PWL3 (PWLTT)	5,650	12,500

3. Torque

As the diamonds cut the rock formation, the bit generates torque as a function of sharpness of the bit and WOB. Decrease in torque and penetration rate is a sign of bit polishing. Maximum bit torque is generated during bit sharpening. It is a problem if the torque increases when restricting water or in lost circulation. Fluctuation in torque, particularly during sharpening, is caused by unstable rock fragmentation and/or insufficient rock penetration. WOB needs to be maintained to establish secondary fracturing and stable cutting. If the head stalls under normal operation, reduce speed to produce more torque and maintain steady rotation.

4. Revolution Per Minute (RPM)

Impregnated diamond bits require higher rotational speeds to achieve penetration rates comparable with those of surface set bits. This is simply because the diamond exposure (protrusion of the diamond) is less with an impregnated bit and consequently penetration per revolution is less. With impregnated bits, we recommend quite a different approach in which penetration rates are controlled with a fairly narrow range for a given RPM and the bit weight is of secondary importance. Peripherical speed 2-5m/s is recommended for impregnated bits. For surface set diamond bits, a peripherical speed of 1-3m/s is recommended. A higher peripherical speed will often yield a higher ROP. However, higher peripherical speeds often reduce the rate of wear on the bit's matrix layer – not allowing new layers of synthetic diamond to become exposed thus causing the original layers of diamond to become flat and polished. Conversely, a lower than recommended peripherical speed will cause the bit's matrix layer to abrade more readily, particularly under higher bit loads. This may result in the premature failure of the bit crown. A peripheral speed of 2.7 to 4.7 metres/second (9 to 15.5 feet/second) measured on the outside diameter of the bit crown will often provide an acceptable ROP.

For B size impregnated diamond bits use 1500-2300 RPM; for N size impregnated bits, 1300-2000 RPM; for H size diamond bits, 900-1700 RPM; and for P size diamond bits, 750-1300 RPM is recommended under normal conditions. For surface set diamond bits, 200-500 RPM less is recommended.

5. Rate of Penetration (ROP)

The value of ROP needs to be kept constant and as high as possible. However, as the formations become harder, the penetration rates should be reduced to achieve good bit life.

6. Water/Mud Flow

Bit performance is strongly dependent on water flushing for impregnated bits. The flushing has 3 purposes: cooling the bit, lubricating the bit and drill, and to lift up the cuttings. High penetration and rotation rates need additional flow to keep cuttings off the bit face. There is no maximum water flow rate, however at very high-flow rates, the bit can be lifted off the rock face, causing it to polish, especially when the WOB is too low.

While bit hydraulics are controlled to some extent by regulating the drill's circulating pump and circulating fluid viscosity, the actual amount of circulating fluid to apply is largely determined by the bit face waterway configuration as well as the annular gap between the outside diameter of the drill string and the drill hole wall. *Annular velocity is defined as the rate at which the circulating fluid and cuttings from the bit are returned to the surface through the annular gap between the drill hole wall and the drill string.* Excessive annular velocity may cause hydraulic erosion of the drill hole wall in soft formations while insufficient annular velocity will cause cuttings to remain suspended in the circulating fluid. This condition will result in stuck drill rods, equipment wear, low penetration rates and hole cave-ins. As an alternative to running with higher annular velocities, the drill operator may increase the viscosity of the circulating fluid for effective hole cleaning.

The Normal recommended annular velocity is:

Max: 90m/min (290 ft/min)
Min: 60m/min (200 ft/min)

Table 6. Recommended Circulation Pump Rates (Q) by Hole Size

Hole Gauge Size (Diameter)	Litres / Minute		Imperial Gallons / Minute		US Gallons / Minute	
	Min	**Max**	**Min**	**Max**	**Min**	**Max**
A (∅ 1.890 inch)	16	23	3.5	5.0	4.2	6.0
B (∅ 2.360 inch)	24	36	5.3	7.7	6.4	9.3
N (∅ 2.980 inch)	40	60	9.0	13.0	10.7	15.6
H (∅ 3.782 inch)	62	94	14.0	20.3	16.7	24.3
P (∅ 4.827 inch)	93	139	20.7	30.1	24.9	36.1

Calculating the Circulation Pump Rate (Q):

$$Q = V_a \left[\frac{0.785(d^2 - s^2)h}{c} \right]$$

Table 7. Circulation Pump Rate Calculation Variables

Variable	Variable Description	Units and Constants		
Q	Pump Rate	US Gallons/min	Imperial gal/min	Litres/min
V_a	Annular Velocity	Feet/min	Feet/min	Metres/min
h	Unit Weight of Annulus	12 inches/foot	12 inches/foot	1000 mm/metre
d	Drill Hole Diameter	Inches	Inches	Mm
s	Drill String Diameter	Inches	Inches	Mm
C	Volume Conversion	231 $inch^3$/US gallon	277$inch^3$/Imp gallon	$1x10^6$ mm^3/litre

Q values close to Max limits should be used in special cases such as those outlined below:

- The cuttings are relatively large.
- The hardness of the formation causes considerable friction on the bit surface resulting in high heat generation.
- The formation is relatively consolidated with little or no fluid return loss.

Q values close to Min limits should be used in special cases outlined below:

- The cuttings are relatively fine.
- The formation is susceptible to hydraulic erosion.

In very hard formations, it might be desirable to operate impregnated diamond bits close to minimum circulation pump rates. This will promote some controlled abrasion of the matrix in order to maintain a satisfactory rate of penetration.

Where the bit in use has a waterway configuration with a small number of narrow fluid passages, the use of a circulation rate that approaches the minimum recommendation will reduce the fluid pressure at the bit face and will in turn reduce the effect of hydraulic lift that tends to counteract the applied bit load.

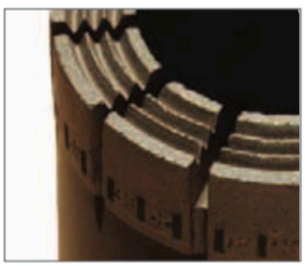
The flow of circulation fluid must **never** be completely shut-off to a bit rotating under load.

The waterway configuration on the bit face has a considerable effect on its performance. Regular (W), Turbo (TT), Extra Wide (EW) waterway configurations produce a higher fluid pressure at the bit face than the High-Flow (HF) or Face Discharge (FD) waterway configurations. Higher fluid pressures through the fluid passages through which the circulating fluid is introduced to the bit crown, may be desirable when trying to create a jetting action across the bit face to move fine cuttings. Lower fluid pressures through the input ports may be desirable where the formation being drilled is susceptible to hydraulic erosion, where the existence of a hydraulic lift condition is an issue or where fluid turbulence at the bit face hampers performance.

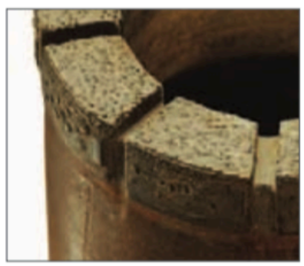
7. Reading the Signs of a Used Bit

Ideal wear of diamond bit happens when the matrix and diamond wears away at the same time. One of the first indicators that a bit is getting close to its end of life is a sudden increase in pump pressure due to the diminishing depth of waterways. Below are some photos of bit wear and their causes.

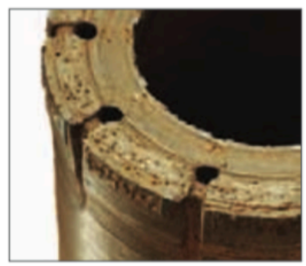
NORMAL WEAR PATTERNS



New Condition

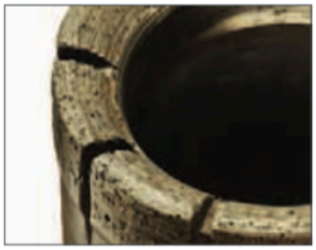


Ideal Wear Pattern
The face wear pattern of an impregnated bit should be relatively flat with slightly chamfered sides. Bit feels sharp, comet tails have formed to support diamonds. Diamonds release from matrix as they are worn. Gauge stays within tolerance.



Normal Retirement
Full depth of impregnation evenly consumed. Gauge stays within tolerance.

IRREGULAR WEAR PATTERNS

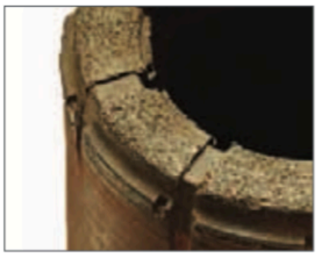


Concave Face Wear (Rounded to Inner Diameter)
Cause: Often caused by excessive penetration rate for the RPM used. This can also be caused by core grinding, overdrilling.

Solution: Reduce penetration rate or increase RPM

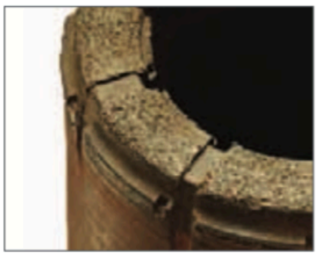
Concave Face Wear (Rounded to Outer Diameter)
Cause: Insufficient water flow

Solution: Check pump and rod string for leaks; increase pump output.



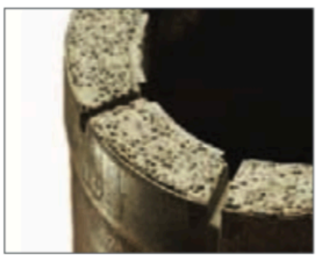
Gauge Loss ID
Cause: (A) Overfeeding (B) Broken formations (C) Drilling over lost core (D) Insufficient drilling fluid

Solution: (A) Reduce penetration rate (B) Cement or change to a lower series bit (C) Check core barrel/core lifter/core lifter case (D) Check inner tube length adjustment; check pump and rod string for leaks – increase pump output



Gauge Loss Outer Diameter
Cause: (A) Lack of circulation (B) Bit being reamed down under-size hole (C) Vibration

Solution: (A) Increase coolant flow rate (B) Check reamer shell gauge and replace if under-sized (C) Alter RPM



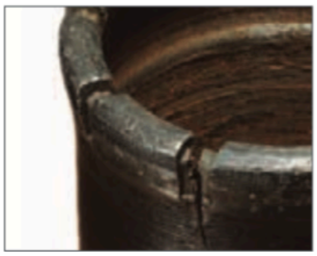
Excessive Diamond Exposure
Matrix abrades away before diamonds have worn sufficiently, resulting in high diamond exposure and low bit life.

Cause: Caused by overfeeding/over drilling

Solution: Increase RPM, change to a lower series bit, or reduce bit weight

Face Glazed (Diamond Polished and Metal Bound)
Bit does not feel sharp; diamonds flush w matrix; no significant “comet tails” behind each diamond.

Sand blast face or use other recommended methods to re-expose diamond. If the face glazes repeatedly, change to a higher bit.



Cracked Waterways (Diamonds Polished)
Cause: (A) Excessive bit load; dropped rods; free fall of (wireline) inner tube in dry hole; (B) bit crushed by rod holder, foot clamp or pipe wrench; (C) Pushed down an undersized hole (i.e., reaming shell worn out).

Solution: Review proper operating procedures.

Burnt
Cause: (A) Lack of fluid. (B) Too high of weight on bit being used

Solution: Check pump and rod string for leaks, check inner tube adjustment, maintain coolant flow rates

Revision History:

Revision	Date	Description of changes	Requested By
1.0	July 6, 2020	Initial Release	

The technical application data in this document is intended as a basic guideline for the selection of the appropriate parameters for your drilling job. As drilling conditions and the capabilities of drilling equipment vary considerably from site to site, it is impossible to define absolute parameters for the application of our drilling tools. Some experimentation on the part of the end user may be required as parameters outside of those recommended in Atom Bits' product literature may be applicable. Please contact us if you have different experiences with Atom Bits products, to improve this datasheet. Atom Bits cannot accept any liability due to errors or omissions in the data that we provide. Atom Bits is constantly working to improve our products and therefore reserve the right to make changes to materials, specifications, prices and technical data without prior notice.