Global Geotech
Explorational Drilling & Sampling Equipment

CORE BIT OPERATING PARAMETERS

1. Calculation of rotational speed range

Diamonds cut best at certain speeds, and since they are mounted on a circular bit face, it is the peripheral speed, P, that determines how well a bit will cut. This is the linear speed measured at the outside diameter of the crown.

The Table below shows the ideal peripheral speed values for different types of bit

Bit Type	Ideal Peripheral Speed Values ("P") in metres/min	
	Minimum	Maximum
Impregnated Diamond	140	240
Surface Set Diamond	54	144
TSP Cube Set	54	108
PCD Set	36	90
Tungsten-Carbide Chip ("Carbotec" Type)	36	108
Tungsten-Carbide Insert ("Sawtooth" Type)	12	54

The recommended rotational speed, in revolutions per minute (RPM) is calculated from the core bit outside diameter, D, and the required peripheral speed, P, using the formula:

$RPM = (1000P) / (\pi D)$

The recommended maximum and minimum rotational speed for various sizes of core bit are shown in the table below (values are rounded to nearest 5 - 10 RPM)

Bit Size	Recommended Rotational Speed (RPM)							
	Impregnated Diamond		Surface-Set Diamond / TSP Cube		PCD and Tungsten Carbide Chip		Tungsten Carbide Insert	
	Max	Min	Max	Min	Max	Min	Max	Min
36mm	2100	1270	1290	490	-	-	-	-
46mm	1640	990	1010	380	760	250	-	-
56mm	1350	810	830	310	620	210	310	80
66mm	1150	690	700	270	530	180	260	60
76mm	1000	600	610	230	460	150	230	50
86mm	880	530	540	200	400	140	200	45
101mm	750	450	460	170	350	120	170	40
116mm	650	400	400	150	300	100	150	35
131mm	580	350	350	130	270	90	130	30
146mm	520	310	320	120	240	80	120	25
E	2030	1220	1240	470	-	-	-	-
A	1590	960	980	370	730	240	-	-
B	1270	770	780	290	590	200	290	70
N	1000	600	620	230	460	160	230	55
H	790	480	490	180	370	120	180	45
P	620	380	380	140	290	100	140	35
S	520	310	320	120	240	80	120	25

2. Weight on Bit

The weight on bit, WOB, is an important parameter in all drilling operations. Too little weight may mean that the bit fails to penetrate, too much weight and the bit may overheat, become damaged or suffer premature wear.

The method of calculating optimum weight on bit varies depending on the bit type.

Impregnated Diamond Bits: Optimal WOB depends on the bit face bearing area and the hardness of the matrix.

The minimum recommended WOB is 90 kg/cm^2
For Matrix types 1 – 4, the maximum recommended WOB is 150 kg/cm^2
For Matrix types 5 – 6, the maximum recommended WOB is 140 kg/cm^2
For Matrix types 7 – 12, the maximum recommended WOB is 130 kg/cm^2

The bearing area of the crown, A, can be calculated by the generalized formula:

$A = \pi(D^2 - d^2)/4 - NW(D - d)/2$

where
D is the outside diameter of the crown in cm
d is the inside diameter of the crown in cm
N is the number of waterways
W is the width of waterways in cm

Example: HWL Impregnated Bit, Matrix type 6, 10 waterways x 3mm wide, Bit OD 95.8mm, Bit ID 63.5mm

Bearing Area, $A = \pi(9.58^2 - 6.35^2)/4 - 10x0.3(9.58 - 6.35)/2 = 35.58$ cm^2

Minimum WOB = 90 x 35.58 = 3202 kg
Maximum WOB = 140 x 35.58 = 4981 kg

Surface Set Bits: Optimal WOB depends on the number of diamond stones set on the crown multiplied by a loading factor per diamond stone. The number of stones on a surface set bit is calculated from the total carat loading multiplied by stones per carat (SPC)

For AAA quality diamonds the maximum loading factor is 4 kg per stone

Example: HWG Surface Set Bit with 25 carats AAA diamond set at 30 SPC has a maximum WOB = 25 x 30 x 4 = 3000 kg.

TSP Cube Set Bits: Optimal WOB depends on the number of TSP cubes set on the crown multiplied by a loading factor per cube.

The maximum loading factor is 45 - 55 kg per cube

Example: HWG TSP Cube Bit set with 50 cubes has a maximum WOB = 2250 – 2750 kg

PCD Bits: Optimal WOB depends on the number of PCD cutters set on the crown multiplied by a loading factor per cutter.

The maximum loading factor is 225 - 275 kg per cutter

Example: A T6-116 PCD Core Bit set with 8 PCD cutters has a maximum WOB = 1800 - 2200 kg.

Tungsten Carbide Chip ("Carbotec") Bits: Optimal WOB is a function of the bit face bearing area multiplied by a bit loading factor.

The maximum loading factor is 35 kg/cm^2 of bit face bearing area

Bit face bearing area, A, is given as before by the formula:

$A = \pi(D^2 - d^2)/4 - NW(D - d)/2$

Example: HWL Carbotec bit with 10 x 3mm wide waterways has a bit face bearing area of 35.58 cm^2. Therefore maximum WOB is 35 x 35.58 = 1245 kg

Tungsten Carbide Insert Bits: On a typical TC insert bit, each of the tungsten carbide cutters possesses a single cutting edge. The maximum bit load is determined by finding the sum of the linear lengths of cutting edges on all of the cutters on the bit face and multiplying this by a loading factor.

The maximum loading factor is 45 kg/cm of cutting edge.

Example: HWG TC Insert Bit has 8 cutters each of length 8mm (0.8cm). Therefore Maximum WOB = 8 x 0.8 x 45 = 288 kg

Summary table of formulae for calculating weight on bit

Bit Type	Weight on Bit Formula	
	Min (kg)	Max (kg)
Impregnated S 1-4	$90[\pi(D^2-d^2)/4 - NW(D-d)/2]$	$150[\pi(D^2-d^2)/4 - NW(D-d)/2]$
Impregnated S 5-6	$90[\pi(D^2-d^2)/4 - NW(D-d)/2]$	$140[\pi(D^2-d^2)/4 - NW(D-d)/2]$
Impregnated S 7-12	$90[\pi(D^2-d^2)/4 - NW(D-d)/2]$	$130[\pi(D^2-d^2)/4 - NW(D-d)/2]$
Surface Set		4 x carat loading x SPC
TSP Cube Set		55 x no. of cubes
PCD		275 x no. of PCD cutters
T.C. Chip		$35[\pi(D^2-d^2)/4 - NW(D-d)/2]$
T.C. Insert		45 x no. of inserts x (D-d)/2

D is outside diameter of crown in cm, d is inside diameter of crown in cm, N is number of waterways, W is width of waterways in cm, SPC is stones per carat.

3. Flush Volumes

Flushing serves two main purposes: 1) to cool the bit, and 2) to remove cuttings from the hole.

If flushing requirements are not adequately met, there can be serious damage to the bit due to overheating, and if cuttings are not removed from the borehole efficiently, the core barrel and rods may become stuck due to the build up of waste material.

To ensure that drill cuttings are removed from the borehole, and up-hole flush velocity must be achieved that exceeds the particle settling velocity.

1. Water Flush

When flushing with water, the up-hole velocity, V_w, should be:

Minimum 30 cm/s
Optimum 40 cm/s
Maximum 80 cm/s

The pump rate P_w in litres/min is given by the formula:

$$P_w = 0.047V_w (H^2 - S^2)$$

where H is the borehole diameter and S is the rod string diameter measured in centimetres.

The pump rates for common combinations of core barrel and drill rod are given in the table on the next page. Notice that when the drill rod is small in diameter compared to the core barrel, the annulus around the drill string is large, requiring a greater pump rate in order to maintain the required up-hole velocity to remove the cuttings. Therefore, for good hole-cleaning and hydraulics, it is recommended using a drill rod that is of a similar diameter to the core barrel. In any case, the drill rod should never be smaller in diameter than the size suggested by the connection in the core barrel head.

The table is for guidance purposes only. Circumstances may require some adjustment of pump rates. For instance, in soft formations where the core can be easily washed away by the flushing medium, a pump rate should be chosen towards the lower end of the recommended range. Conversely, when cuttings are very large (e.g. if using a PCD core bit), flow rates may need to be increased toward the maximum of the recommendations.

It is essential that the pumping arrangement has a flow meter so that the driller has continuous visual access to the flow rate.

As an alternative to running with higher pump rates, the drill operator may increase the viscosity of the drilling fluid by the use of additives. Then the cuttings can be removed from the borehole at much reduced velocity, requiring a lower volume of water.

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Recommended Pump Rates using water as the flushing medium for various Core Barrel / Drill Rod combinations

Core Barrel	Drill Rod	Hole Diameter (cm) H	Rod Diameter (cm) S	Pump Rate (litres/min)		
				Min	Opt	Max
BWL	BWL	5.99	5.56	7.1	9.4	18.9
NWL	NWL	7.57	6.99	11.9	15.9	31.8
HWL	HWL	9.63	8.89	19.3	25.8	51.5
PWL	PHD/HWT	12.28	11.43	28.4	37.9	75.8
GBS	GBS	14.60	13.97	25.4	33.8	67.7
BWG	BW/BWY	5.99	5.40	9.5	12.6	25.3
NWG	BW/BWY	7.57	5.40	39.7	52.9	105.8
	NW/NWY		6.67	18.1	24.1	48.2
HWG/HWF	BW/BWY	9.92	5.40	97.6	130.2	260.4
	NW/NWY		6.67	76	101.4	202.7
	HW/HWY		8.89	27.3	36.4	72.8
PWF	NW/NWY	12.06	6.67	142.3	189.8	379.6
	HW/HWY		8.89	93.6	124.9	249.7
SWF	NW/NWY	14.60	6.67	237.8	317.1	634.2
	HW/HWY		8.89	189.1	252.2	504.3
TT46	42mm	4.63	4.20	5.4	7.1	14.3
TT56/T2-56	50mm	5.63	5.00	9.4	12.6	25.2
T2-66	50mm	6.63	5.00	26.7	35.6	71.3
T2-76/T6-76	50mm	7.63	5.00	46.8	62.4	124.9
T2-86/T6-86	50mm	8.63	5.00	69.8	93	186
T2-101/T6-101	NW/NWY	10.13	6.67	82	109.3	218.6
	PR76		7.60	63.2	84.3	168.7
T6-116	NW	11.63	6.67	128	170.6	341.3
	PR76		7.60	109.3	145.7	291.4
	HW/HWY/PR89		8.89	79.3	105.7	211.4
T6-131	NW	13.13	6.67	180.4	240.5	480.9
	PR76		7.60	161.6	215.5	431
	HW/HWY/PR89		8.89	131.6	175.5	351.1
T6-146	NW	14.63	6.67	239.1	318.8	637.5
	PR76		7.60	220.4	293.8	587.6
	HW/HWY/PR89		8.89	190.4	253.8	507.6

To convert from Litres/min to Imperial Gallons/min divide by 4.546
To convert from Litres/min to U.S. Gallons/min divide by 3.785

2. Air Flush

When air is used as the flushing medium, the desired up-hole velocity, V_a, is 20 m/s

The pump rate P_a in cubic metres per min is given by the formula:

$P_a = 0.0047V_a (H^2–S^2)$

For $V_a = 20$ this reduces to:

$P_a = 0.094 (H^2–S^2)$

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Recommended Pump Rates using air as the flushing medium for various Core Barrel / Drill Rod combinations

Core Barrel	Drill Rod	Hole Diameter (cm) H	Rod Diameter (cm) S	Air Flow Rate (cubic metres/min)
412F	NW/NWY	10.72	6.67	6.6
	PR76		7.60	5.4
T6-101*	NW/NWY	10.43	6.67	6.0
	PR76		7.60	4.8
T6-116*	NW/NWY	12.03	6.67	9.4
	PR76		7.60	8.2
	HW/HWY/PR89		8.89	6.2
T6-131*	NW/NWY	13.43	6.67	12.8
	PR76		7.60	11.5
	HW/HWY/PR89		8.89	9.5
T6-146*	NW/NWY	14.93	6.67	16.8
	PR76		7.60	15.5
	HW/HWY/PR89		8.89	13.5

* When using air flush with T6 series core barrels it is recommended that the outside diameter of the core bit and core barrel coupling be over-set by 3mm

To convert from cubic metres/min to cubic feet/min multiply by 35.3

Air can be used effectively in some rocks to improve core recovery. However, not all drilling equipment is designed for use with air flush and the driller should ensure that all bits, core barrels, rods, swivels and hoses are suitable.

The table above is given for guidance purposes only. In practice it is wise to have a compressor with rather more capacity than required, but if too much air is used it can cause disturbance of fractured rocks and erode the core bits and core barrels.

If the compressor is not capable of producing the desired flow rate, the annular area should be reduced by using drill rods of a larger diameter, or by using a foaming additive. The use of foam can substantially reduce the flow of air needed because it is more efficient in lifting the cuttings and it is usually possible to use a much smaller compressor.