Parameters for the use of Drill Bits

1. Rock Drilling Characteristics

Strength and Fracture Toughness

The two main criteria of how easily a rock can be drilled are its strength and its fracture toughness. Described another way, this criteria reflects how easily a crack can be induced in a rock and how easily that crack may be induced to propagate.

From the description available of igneous, sedimentary and metamorphic rocks it can be seen that rock strength depends on the mineralogical make up of the rock, for example, sandstone with a high quartz content and cemented together with calcite has a low strength, because the calcite that bonds the grains together is weak, whereas granite which has far less quartz has a high strength because it does not have a continuous weak phase, as does sandstone.

Quartzite may have a higher strength than either sandstone or granite because it is all quartz. It does however have lower fracture toughness because there is a continuous medium, the silica cement, in which cracks can propagate.

Granite is made up of inter-grown crystals, with no continuous medium and any fracture, in consequence, has to keep crossing crystal boundaries.
Basalt has a much higher fracture toughness, because the inter-grown crystals are so much smaller and a propagating fracture meets crystal boundaries more often.

Abrasives

Rock abrasiveness is a rock property that is important in drilling with Diamond Bits. The abrasiveness can affect both penetration rate and the life of the Bit.

The abrasiveness of a rock is controlled by its mineralogical make up, so that a rock containing soft minerals will be less abrasive than a rock containing hard minerals.

Hardness of minerals is measured by the ability of one mineral to scratch another. This is measured as MOHs Hardness Scale.

In simple terms the harder the constituent of the rock the more abrasive it will be, regardless of its strength.

Of common rock forming minerals, quartz is rated as being hard, so that rocks containing large quantities of quartz will be abrasive. For example sandstone containing 60% quartz is far more abrasive than basalt, which is composed principally of feldspar even though basalt is harder than stronger than sandstone.

From knowledge of the mineralogy and the mode of rock origin of a rock, it is often possible to determine how well a Bit will drill but not how far it will drill.

2. Theoretical Cutting Action of a Diamond Bit

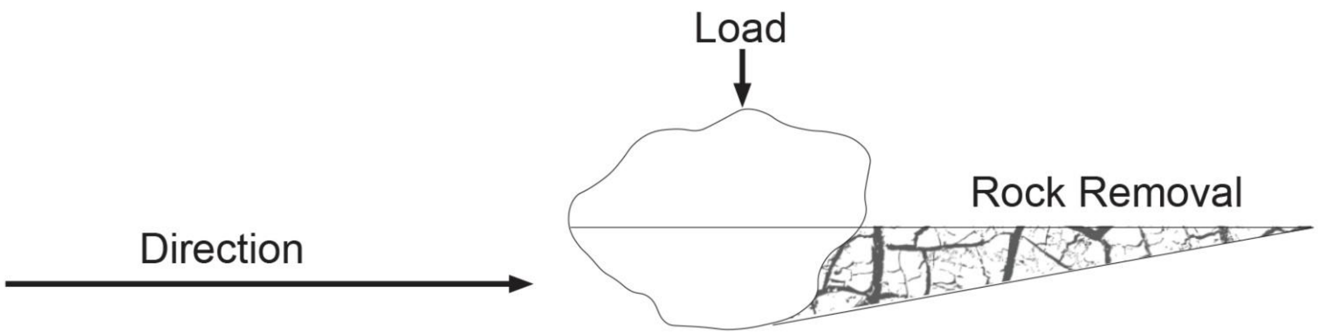
Much test work has been carried out to try and determine precisely what happens when Diamonds are cutting rocks in order to try and establish the main parameters that affect successful drilling.

The two most widely accepted theories generated by these studies can be summarised as follows:

2.1 Ploughing Theory

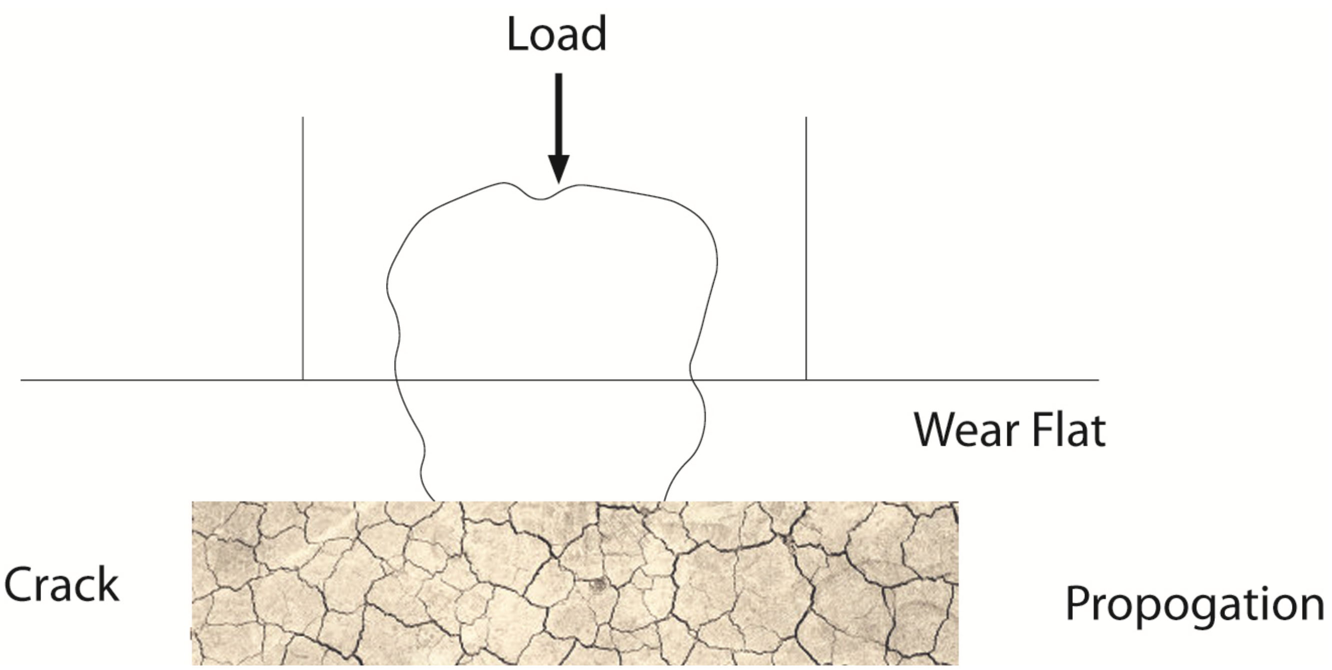
The Diamond makes an impression into the rock when moved.

After initial failure of the rock, Diamond penetration takes place causing the Diamond to "plough" the rock and the rock is broken by a shearing action.



2.2 Cutting by Crack Propagation

To drill a particular rock the stress level beneath the Diamond must exceed the strength of the rock, which forms cracks when this is achieved. The crack field becomes larger as the load is increased.



The performance of the Diamond is directly related to the wear flat area generated on the Diamond face.

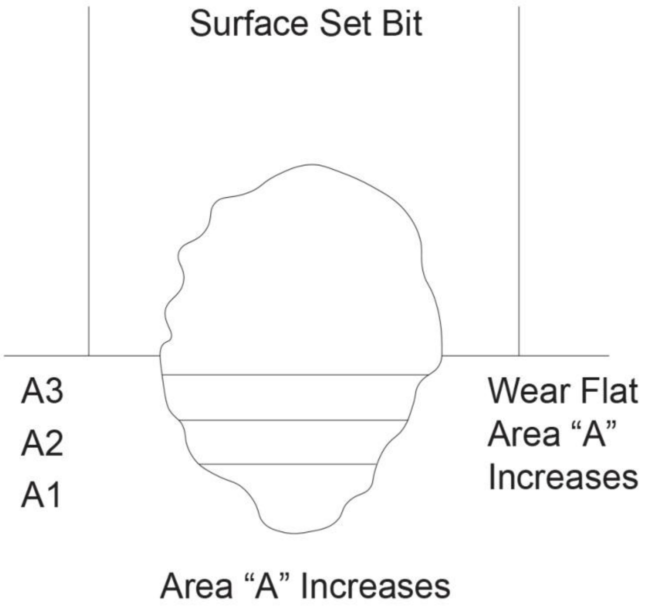
With new sharp Diamonds, the area in contact with the rock is small so that the load required is small.
As the Diamonds wear the contact area increases so the load has to increase.

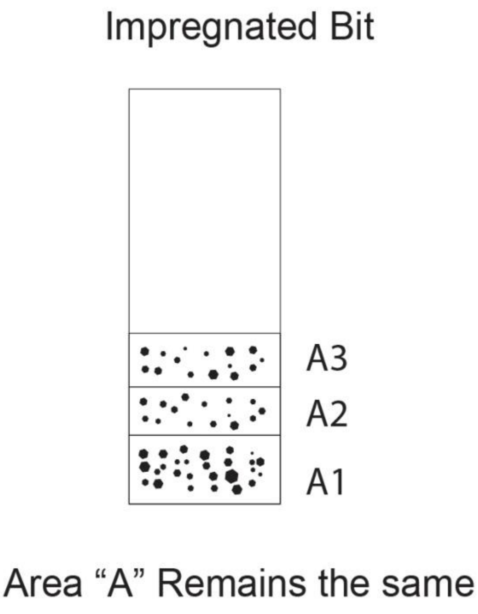
This relationship between the contact area (wear flat area) and the Bit load finally reaches a point where the load is not sufficient to permit drilling to continue, as the Diamonds are worn flush with the matrix.

With Surface Set Bits, it can be seen that the contact area increases as drilling progresses and the Diamonds wear.

With Impregnated Bits, as the matrix strips away and exposes new Diamonds, the total wear flat area remains reasonably constant and does not increase as it does with Surface Set Bits.

The following diagram illustrates this point:





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3. Surface Set Bits

Surface Set Bits are characterized by a single layer of Diamonds set on the working face of the Bit in a specific pattern.

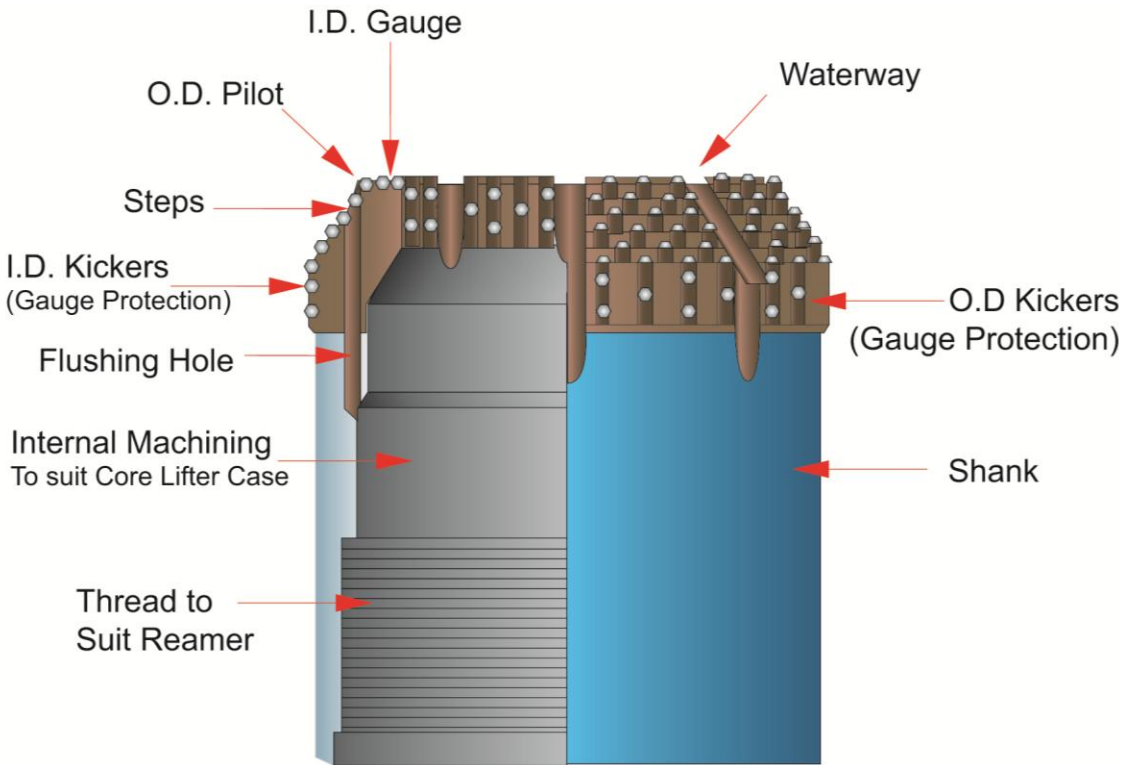
A wide range of standard Bits are manufactured by Asahi.

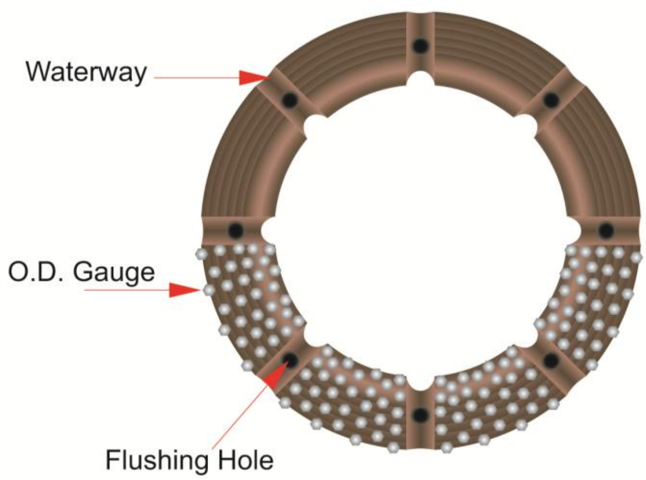
These include a variety of Bit profiles, Diamond grades and Diamond sizes designed to provide the most efficient cutting for the formation being drilled.

Surface Set Bits can be used to drill the entire range of rock formations, although advances in impregnated Bit technology means they are much more effective in harder formations.

Surface Set Core Bits

(Internal and Face Discharge)





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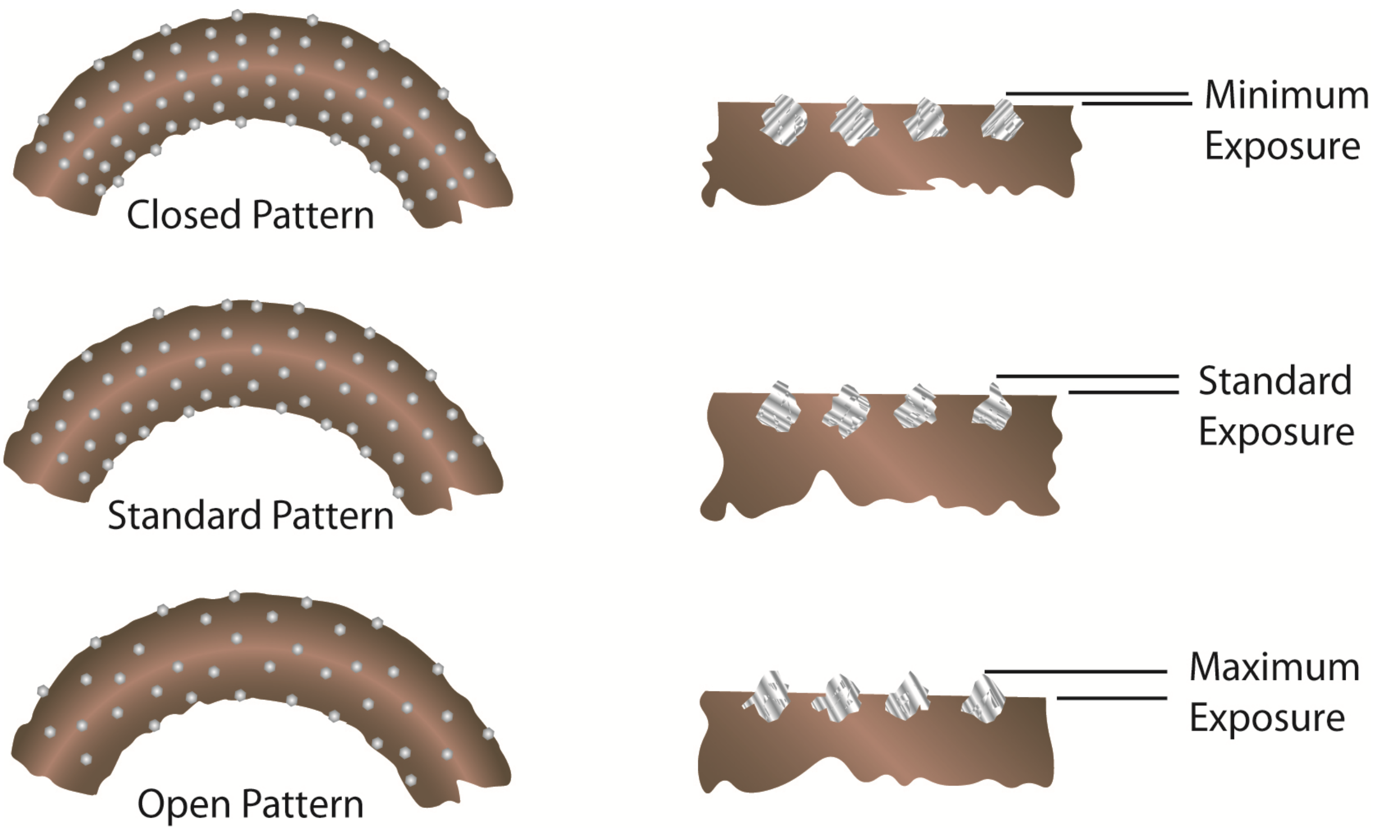
Drilling with Surface Set Bits generally continues until a substantial increase in required Bit weight indicates that the Diamonds have become "blunt" or broken, requiring the Bit to be pulled and either discarded or returned to the manufacturer for salvage.

There are a number of variables that are generally considered when determining a particular Surface Set Bit design. These are:

- Diamond size
- Diamond quality
- Diamond distribution
- Diamond shape
- Diamond quantity
- Diamond protrusion
- Face design

All are important but Diamond quality will be a significant factor in the initial price of the Bit, the life of the Bit and therefore the cost per meter drilling.



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Surface Set Bit Selection Chart

Rock Type	Rock Condition	Diamond Size Face Stones	Diamond Size Step Stones
Ultra Hard	All Types	Not Recommended – Use Impreg	
Very Hard	Competent	70/90 spc	55/70 spc
	Broken	55/70 spc	45/55 spc
Hard	Competent	55/70 spc	45/55 spc
	Broken	45/55 spc	35/45 spc
Medium Hard	Competent	45/55 spc	35/45 spc
	Broken	35/45 spc	25/35 spc
Soft	Competent	25/35 spc	15/25 spc
	Broken	15/25 spc	10/15 spc
Very Soft	All Types	10/15 spc	6/10 spc

3.1 The Crown Shape

The crown shape is largely dictated by the specific requirements of the job being done.

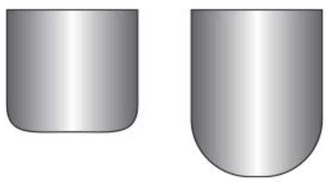
The most common profiles are flat, semi-round, single step or multi-step.

The semi-round crown is the most commonly used in conventional drilling, whilst the various step face profiles are predominately used in wire line drilling.

Surface Set Bit Profiles

Flat round profile

- Standard Profile
- Good all-round performance



Semi-round profile

- Strong Profile
- For use in fractured formations

Stepped profile

- Higher penetration rate
- Fragile and fractured formations

3.2 Flushing and Cooling

The drilling fluid serves two main purposes – it cools the cutting surfaces of the Bit flushing the cuttings from the face of the Bit, and transports them out of the hole.
In some cases, additives are used to lubricate the Bit, enhance Bit life and increase and carrying capacity of the fluid used.

Tests have shown that the cutting points on a Bit can very quickly reach temperatures of over 1,000 degrees Fahrenheit if they are not cooled. It is therefore essential to have fluid circulation across the face of the Bit at all times when drilling.

A suitable drilling fluid will not only cool the Bit, remove cuttings from the face and transport them from the hole, but will also readily drop the cuttings in the settling pits and help stabilize the hole and the rod string.

The amount of fluid pumped down the drill hole should be calculated to achieve an up-hole velocity in the annular space between rod and hole of 60 to 100 feet per minute (18 to 30 meters per minute).

The up-hole velocity is a function of the amount of fluid being pumped and the annular space between the rod and the hole.

The required flow rates can be calculated by using the formula:

F = C Multiplied by S

Where:

F = the flow rate in litres per minute
S = The annular section between rod and hole in square centimeters
(Dia Hole2 – Dia Rod2)

And:

C = 2.4 for the average, generally recommended value
C = 1.8 for the minimum recommended value
C = 3.0 for the maximum recommended value

Typical Flow Rates are:

Hole Size	Rod Size	Litres/min	Gallons/min
AMLC	AW/J	5 - 8	1 – 2
BMLC	BW/J	10 – 17	2 – 4
NMLC	NW	21 – 35	5 – 8
HMLC	HW	40 - 46	9 - 15

In practice these are guidelines only which should be varied as circumstances dictate.

For example: If the penetration is very rapid, the flow rate may have to be adjusted to remove the greater volume of cutting or the larger size of the cuttings. In very soft or sticky ground the number of waterways should be increased to prevent the Bit from mudding up.

3.3 Peripheral Speeds

The peripheral speed depends on the rock being drilled, but should normally vary in the range 1 to 3.5 meters per second.

The peripheral speed is normally measured at the outer edge of the Bit, or OD; being the fastest moving part of the Bit.

The peripheral speed can be calculated using the formula:

$$PS = \frac{3.14 \times Dia}{1000} \times \frac{RPM}{60}$$

Where:

PS =	Peripheral speed in meters/min
Dia =	Diameter of the Bit in mm
RPM =	Spindle or head revolutions per minute

Recommended rotation speeds are:

A size	400 to 1,400 rpm
B size	320 to 1,120 rpm
N size	250 to 890 rpm
H size	200 to 700 rpm
P size	150 to 550 rpm

3.4 Weight on Bit

There are a number of factors that influence the recommended weight on an Asahi Surface Set Bit:

- Diamond quality
- Size, shape, number and distribution of Diamonds
- Profile of the crown
- The formation being drilled
- Deviation in the hole and other hole conditions
- Characteristics of the flushing fluid

While there is a relationship between Bit pressure, rotation speed and penetration rate, weight on the Bit should be adjusted to give the best performance per Diamond and per revolution.

A Diamond graded AAA will fracture under a static load of about 10.2kg, while poorer quality stones will fracture at static loads less than this.

Impact loads are thought to cause fractures at less than static loads, which explains the damage caused to Diamond Bits by vibration.

As rule of thumb, weight on the Bit should not exceed:

$$W\ max = C \times N \times 5kg$$

Where:

C = active carat weight, about 66% of the total set weight of the Bit
N = the average number of stones per carat

For example:

An NQ Bit set with 17 carats of 40 – 60 spc Diamonds would have a maximum allowable weight on Bit of

$$W\ Max = (17 \times 0.66) \times 50 \times 5 = 2{,}805kgs = 2.8\ tonnes$$

4. Impregnated Core Bits

The objective of an Impregnated Diamond Bit is to produce a Bit where the matrix erodes at a specific rate. As active Diamonds become blunt they are released to expose fresh, sharp Diamonds to continue cutting efficiently.

The matrix is a critical factor in impregnated Bit manufacture. It must have the capacity to retain the synthetic Diamonds for as long as they continue to cut, but also wear at a rate that will allow non-performing Diamonds to strip out exposing new sharp Diamonds.

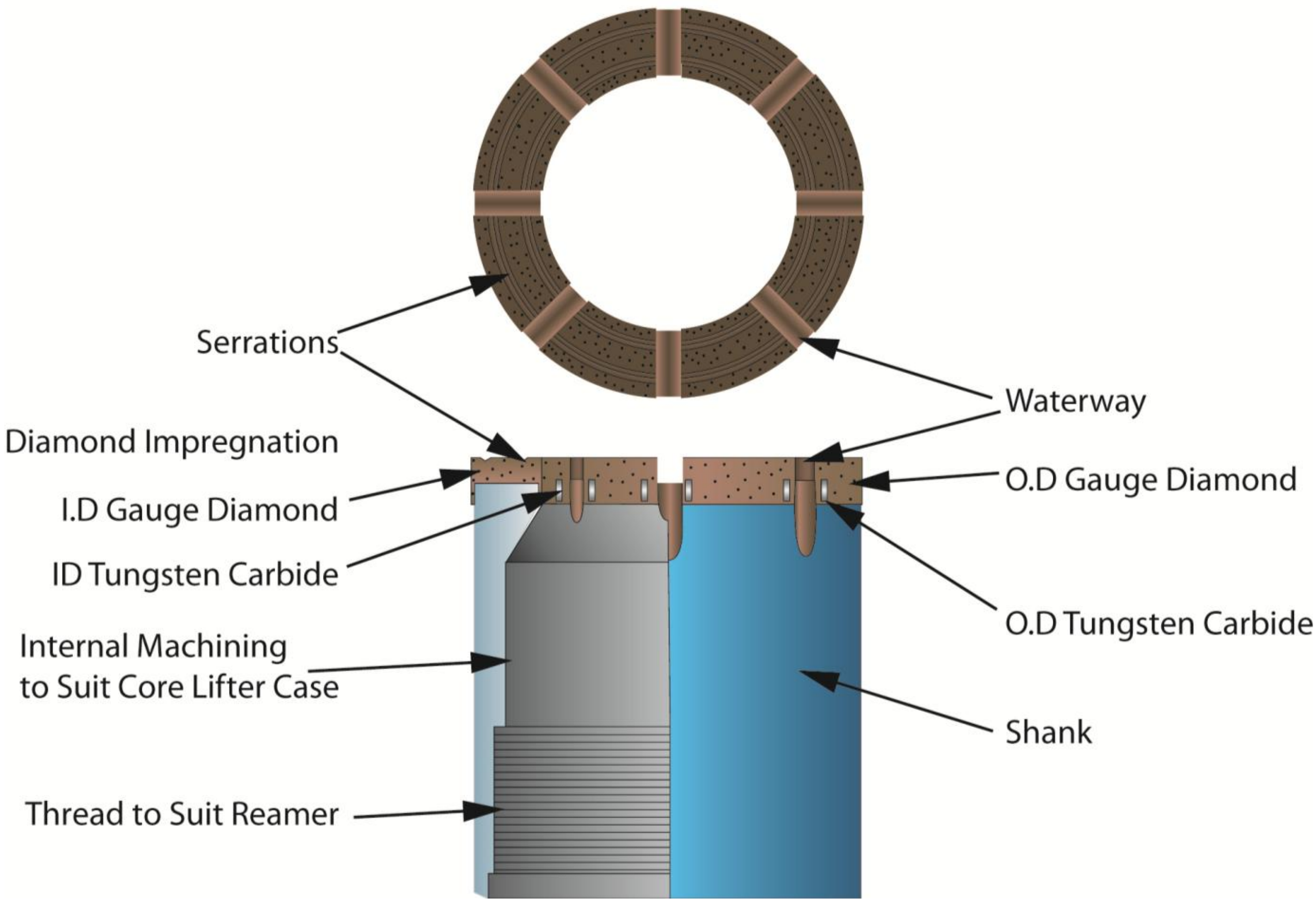
Diamond concentration is a further important consideration in an Impregnated Core Bit. An increase in concentration reduces the strip rate of the matrix and increases the load required for self-sharpening.

Two extremes of Diamond size and Diamond concentration within a matrix are possible.
At one extreme, the matrix is far too hard and worn Diamonds will not be released, at the other extreme the matrix releases Diamonds prematurely while they still have cutting life left.

In the former Bits become glazed and excessive loads are required to continue drilling, penetration can even stop altogether. In the latter the Bit wears far too rapidly and Bit costs increase significantly.

Impregnated Core Bit

(Internal Discharge)



The final consideration in the manufacture of Bits, whether surface set or impregnated, is the waterways.

With the matrix to rock clearance much smaller in impregnated Bits, the waterways assume an even greater degree of importance.

Where Bit clogging can occur, coolant flow has been found to be a controlling factor in achieving maximum penetration rates.

An adequate number and depth of waterways is therefore required to ensure adequate cleaning of drilled material and maximize penetration.

4.1 Operational Guidelines

As with Surface Set Bits there are no hard or fast rules, but there are certain basic requirements, and a driller who is used to drilling with Surface Set Bits has to learn different drilling techniques to obtain maximum benefit from impregnated Bits.

Asahi's Impregnated Bits, which are generally used at higher rotating speeds than Surface Set Bits, need to be operated within a working range of penetration rate and RPM.

These two parameters combine to provide the RPC index, or, revolutions per centimeter of penetration, which is a useful guide to successful drilling.

The third parameter used is load, or Bit weight on the Bit. It has been observed that too much weight on the Bit can actually reduce penetration and it has been found that the Asahi TA series Bits require less weight than other Bits to cut at an optimum speed. Too little weight will, however, tend to cause “glazing”.

4.1 A Rotation Speeds

The recommended speed range for Asahi's impregnated core Bits is 3 to 5 meters per second.

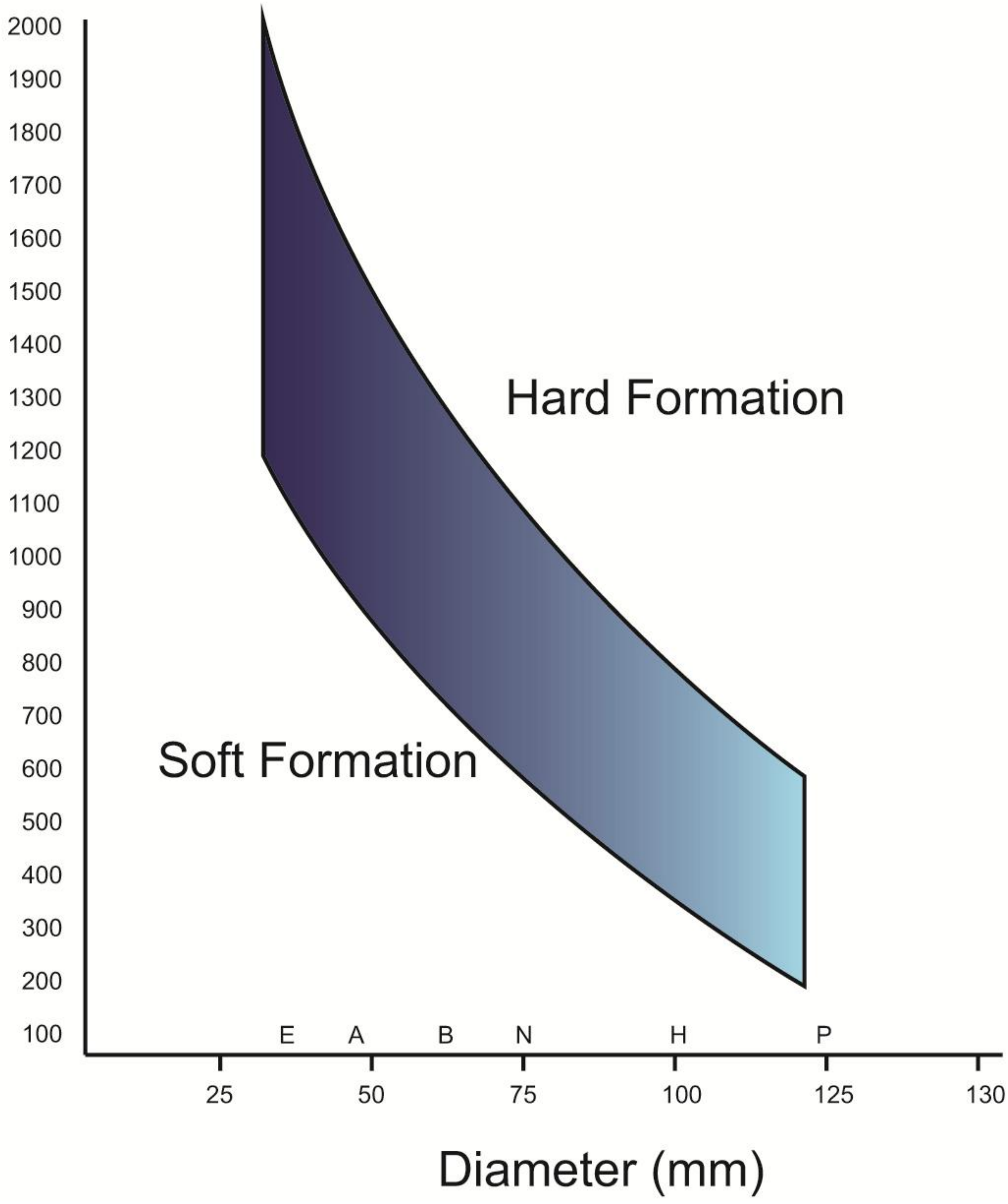
The formula for calculating the peripheral speeds is the same as with the surface set Bits and has been mentioned previously.

Recommended rotation speeds are:

TT 46 / A size	1,000 to 1,800 rpm
TT 56 / B size	850 to 1,550 rpm
N size	620 to 1,200 rpm
H size	420 to 880 rpm
P size	300 to 580 rpm

Recommended Rotation Speed Range

Impregnated Drill Bits



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4.1 B Feed Pressure

The feed pressure on an Asahi Impregnated Core Bit can vary widely depending on the formation being drilled and the Bit being used.

The feed pressure can usually be increased as long as this results in an increase in penetration rate, but reference should constantly be made to the RPC index and the rotation speed being used.

In any event the total weight should never exceed 2,000lbs per square inch of kerf area (150kg per square centimeter).

- If the load is too light the Diamond particles will polish and glaze and the Bit will become blunt
- If the load is too high abnormally high Bit wear will occur
- The use of high drilling loads will also increase the risk of uneven profile wear, with the inside gauge wearing more rapidly than the outside gauge
- This leaves a large part of the Diamond impregnation unused and unusable

The recommended Bit weight is:

TT 46	450 – 1,350kg / 1,000 – 3,000lbs
TT 56	900 – 1,800kg / 2,000 – 4,000lbs
BQ	900 – 2,800kg / 2,000 – 6,000lbs
NQ	1,350 – 2,800kg / 3,000 – 6,000lbs
HQ	1,800 – 3,600kg / 4,000 – 8,000lbs
PQ	2,270 – 4500kg / 5,000 – 9,950lbs

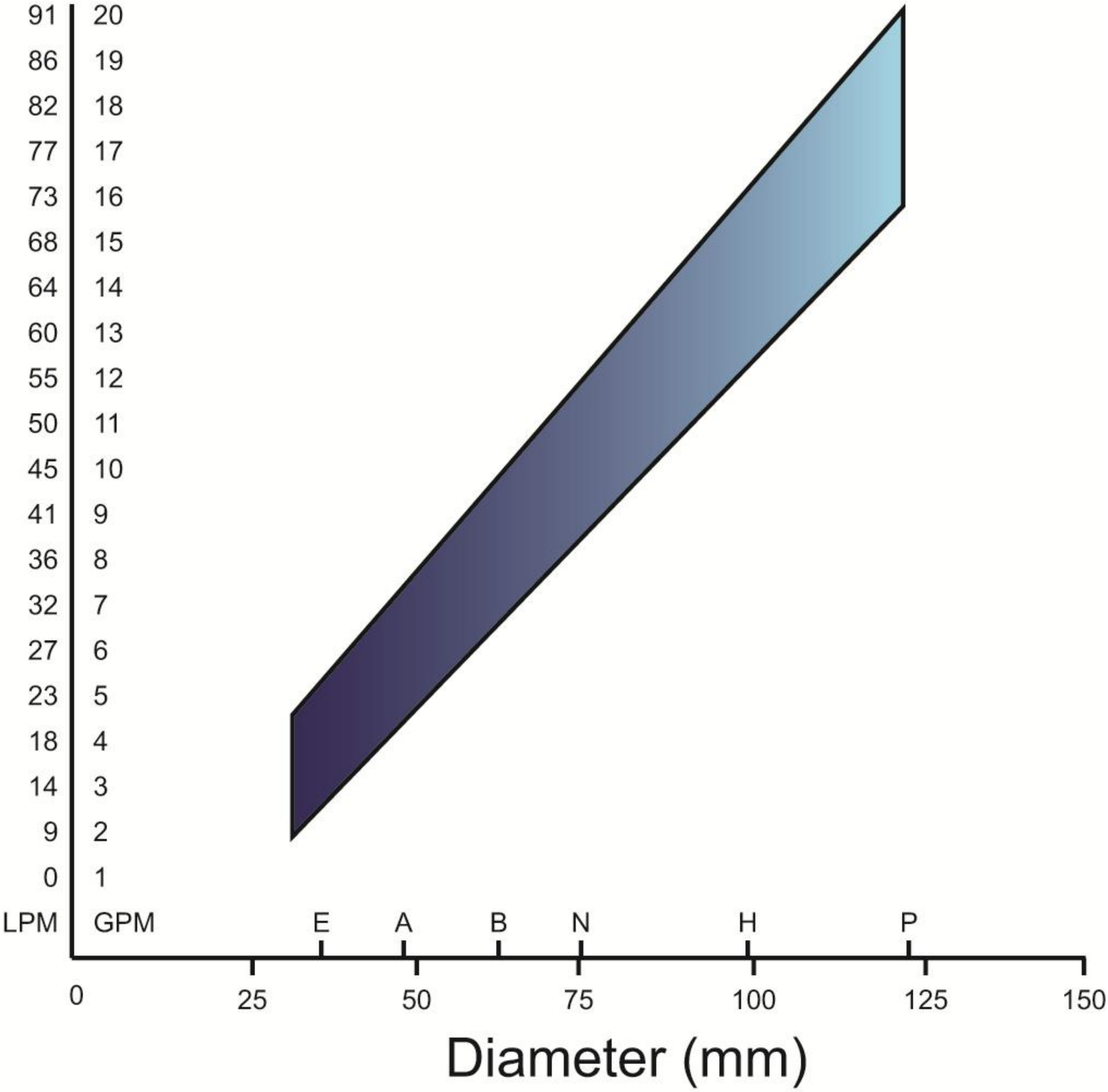
4.2 C Coolant

When drilling with Impregnated Core Bits a higher coolant flow rate is required than when drilling with Surface Set Bits. This is particularly the case with wire line drilling where flow rates are 20% - 30% greater using Impregnated Core Bits than Surface Set Bits to adequately cool the Bit and remove cuttings.

Typical recommended flow rates for impregnated Bits are:

Hole size	Rod size	Litres/min	Gallons/min
TT 46	46mm	11 – 16	2.5 – 3.5
TT 56	56mm	16 – 27	3.5 – 6.0
BQ	BQ	27 - 36	6.0 – 8.0
NQ	NQ	36 – 40	8.0 – 10.0
HQ	HQ	46 - 67	10.0 – 15.0
PQ	PQ	87 - 112	18.0 – 25.0

Recommended Fluid Flow Rates



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4.2 D RPC Index

The revolutions per cm of penetration, or RPC index, is probably the most important parameter in achieving maximum productivity and lowest Bit costs.

The RPC index can be quite simply calculated by dividing the spindle RPM by the penetration rate in cm per minute

Example:

800rpm divided by 10cm/minute penetration rate = 80 RPC

Ideally the RPC to aim for is between 100 and 75. If the RPC is well below 75 then excessive Bit weight will result.

Either RPM should be increased or penetration rate decreased by reducing the weight on the Bit.

If the RPM or Bit weight cannot be altered, the Bit should be changed for the next one down in the series.

If the RPC is much above the recommended maximum of 100 the Bit could polish.
Either reduce the RPM or increase the penetration rate by increasing the Bit weight.
If the RPM or Bit weight cannot be altered change the Bit for the next up in the series.

RPC index for the Asahi Australia TA Series

Formula	RPM/RPC = Pen Rate @ Revolutions per cm	
Spindle RPM	100 mm	75 mm
	Penetration Rate / Min	
350	35	47
400	40	53
450	45	60
500	50	67
600	60	80
700	70	93
800	80	107
900	90	120
1000	100	133
1100	110	147
1200	120	160
1300	130	173
1400	140	187

4.2 E Bit Observation

It is important when drilling to try and understand what is going on down the hole.

When the Bit is pulled the driller should examine it to try and correlate its condition with what he thought had been going on down the hole. This way he should achieve a greater understanding of the use of Impregnated Bits and achieve maximum benefit from their use.

The most common problems encountered when using Impregnated Core Bits tend to be improper selection of matrix for the ground being drilled, poorly maintained equipment such as pressure pumps, hydraulic systems, rod strings and unstable core barrels, plus a basic misunderstanding about what is going on down the hole.

For all drillers the main objective should be to obtain the ideal wear pattern of a flat face, with slight chamfered edges, and to obtain maximum productivity. If these results are achieved it can be assumed that that correct parameters have been used while drilling.

4.2F Advantages of Impregnated Core Bits

- In medium to hard formations, Impregnated Core Bits are capable of achieving higher Bit life and greater productivity than Surface Set Bits, in which will result in lower overall costs and higher profits.
- Impregnated Bits are robust and capable of withstanding rougher treatment.
- Impregnated Core Bits are not so easily damaged by broken and fractured formations so that they can provide a less costly alternative for drilling in these conditions.
- Impregnated Core Bits have been shown to provide better directional stability than Surface Set Bits.
- Impregnated Bits can provide a cost saving on inventory investment as each Impregnated Core Bit covers a wider range of rack types.
- Impregnated Core Bits are fully consumable and are not returnable for salvage. They do not generate accounting costs and the problems associated with a circulating population of Surface Set Bits.