Professional Diamond Driller's Handbook

Practical guide

Atlas Copco

The information contained in this booklet provides the reader with suggestions and guidelines dealing with a number of hypothetical situations. Atlas copco accepts no responsibility for damages, consequential or otherwise, resulting from application of such guidelines and suggestions. The reader is strongly encouraged to contact an authorized Atlas Copco representative to obtain guidance in dealing with specific real situations.

Find us at www.atlascopcoexploration.com or email us at **info@atlascopcoexploration.com.**

COMMITMENT

Mining is the foundation of industry and exploration drilling is the foundation of mining. History owes a great debt to the men and women who have gone into remote places and worked under difficult conditions to "look into the earth" and find the minerals to sustain industries and build nations.

Atlas Copco salutes you, and makes a pledge to Professional Diamond Drillers the world over, to seek your advice and to hear your opinions. We will use our considerable resources to provide you with products and services that enhance your safety, ease your work load and increase your rewards.

Atlas Copco will be there to support your endeavors in both familiar and remote places. We will share in your challenges and celebrate your triumphs. We will be your supplier and partner.

Atlas Copco

CONTENTS

SAFETY

AN ACCIDENT IS AN UNPLANNED EVENT CAUSED BY AN UNSAFE ACT OR CONDITION.

Most accidents can be prevented through:

- Proper training.
- Proper supervision.
- Correct use of tools and equipment.
- Safe working practices.

Some safety rules:

- Wear well fitting protective clothing.
- Wear your hard hat, eye protection and safety boots.
- Use your safety belt and life line.
- Don't wear rings and jewelry at work.
- Use the right tool for the job and use it correctly.
- Don't try to repair moving machinery.
- Store your tools properly.
- Don't rush.
- Keep your work place neat and safe.
- Lift heavy objects properly.
- Know and respect fire hazards.
- Check wire rope and other equipment regularly.
- Replace worn equipment.
- Know your equipment. Study the operation manuals and follow the suppliers safety recommendations.

THE PROFESSIONAL DIAMOND DRILLER

INTRODUCTION

Successful exploration drilling results from a clear understanding and cooperation between two professionals, the Diamond Driller and the Geologist. Drilling operations are controlled by geologists but they lack the knowledge and experience to optimize the operation of the drill. The Professional Diamond Driller should not hesitate to share his knowledge to improve the operation.

ROCK FORMATIONS

The geological classifications of rock types are based on chemistry and structure. The hardness classification is a relative scale. So called soft rocks can prove more difficult to drill than hard rock and the same formations, in separate locations, can drill very differently. A specific rock type can change drastically, even in the same drill hole, requiring another choice of drill bit. Each rock type must be considered as a range with a number of variables affecting its drillability.

The factors most affecting the drillability of rock are: grain size, rock hardness, weathering and fracturing. Larger grain size and fracturing make the rock more abrasive, while fine grained, hard rock is less abrasive. Weathering reduces rock strength.

DRILL BITS

To accommodate these geological conditions, bit manufacturers have created a bewildering array of products and numbering systems that make it difficult to match bits to rock types.

The Atlas Copco system of numbering diamond bits has been developed to simplify the process. In this booklet common rock formations have been grouped into key rock groups based on the similarity of their drillability.

BIT SELECTION CHART

To simplify bit selection for the driller, rock formations have been categorized into three applications. Each application has a series of matrices designed specifically for that type of drilling condition which will provide optimum performance.

- Application 1 (Green) – Soft to medium hard, abrasive and fractured to competent formations.

- Application 2 (Blue) – Medium hard to hard, slightly abrasive, slightly fractured to competent formations

- Application 3 (Red) – Hard to extremely hard, competent formations.

IMPREGNATED BITS

Rock group	Rock characteristics	Rock type
1 - 4	Soft or medium soft Very abrasive to slightly abrasive Badly fractured to slightly broken	Conglomerate Shale Sandstone Limestone
5	Medium hard Abrasive Moderately fractured to slightly broken	Weathered granite Weathered gneiss Dolomite Tuff
6	Medium hard Moderately abrasive Moderately fractured to slightly broken	Unmetamorphosed or weakly metamorphosed diorite. Gabbro peridotite and gneiss. Basalt, andesite.
7	Medium hard - hard Moderately abrasive Slightly fractured to competent	Metabasalt, amphibolite. Metamorphosed diorite and gabbro. Diabase.
8	Hard Slightly abrasive Competent	Quartz rich skarn. Granite and pegmatite.
9	Very hard Slightly abrasive Very competent	Metamorphosed granitic rock and quartz rich gneiss.
10	Extremely hard Non-abrasive, fine grain Very competent	Chert and jasperite. Quartzite. Highly metamorphosed volcanic.

BIT SELECTION

Professional Diamond Drillers have chosen and depended on both Hobic and Craelius bits for many years and are familiar with the numbering systems used. Atlas Copco will continue to use those numbering systems by including them in the new groups, as seen on the following pages.

WHEN CHOOSING A BIT, THE FOLLOWING CROWN DESIGN FEATURES ARE CONSIDERED

Step 1 - Determine application and rock group (matrix)

Step 2 - Select appropriate crown profile

Step 3 - Select crown height

MATRIX - The matrix is a mixture of synthetic diamonds and various metals. Each of the matrices has a different resistance to abrasion and consequently a different rate of wear. A balanced rate of wear between the matrix material and the diamonds ensures a high rate of penetration and optimum bit life.

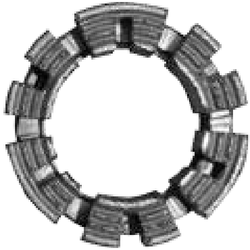
GAUGE - This refers to the outer and inner diameters of the bit that are in direct contact with the rock. These can be reinforced if required.

WATERWAYS - There are different waterway configurations available depending on the drilling conditions.

BIT SELECTION

Extended channel flushing (ECF)

- Standard profile - general purpose design
- Suitable for mixed formations containing broken and competent zones.
- Suitable for a broad range of formations.



Jet/V

- High performance «free cutting» bit
- High productivity
- Suitable for hard/competent formations

Face discharge (FD)

- Designed to minimize washing of core sample
- Suitable for broken/granular formations.

Sand

- Suitable for extremely broken or clay, clay/sand mixed formations.

BIT SELECTION

CF/CFF

- Standard profile for small/thin wall diameters in conventional systems TT/LTK
- Waterway depth can be adjusted using metal file for better flushing control.
- Suitable for broad range of formations.

Taper

- Profile used in hole wedging (directional drilling operations to ream wedged hole after pilot bit.

CROWN HEIGHT - Bits are manufactured with standard crown heights of 10, 13 and 16mm. The height of crown chosen is a cost decision based on hole depth and wear rate.

BIT SELECTION

Group 1 - 4

Badly Fractured Very Abrasive Rock

Rock Formation Examples		Recommended Bits
Conglomerate Shale Sandstone Limestone		2 - 4 4 - 6

Group 5

Moderately Fractured And/Or Abrasive Rock

Rock Formation Examples		Recommended Bits
Weathered Granite & Gneiss Dolomite Tuff Schist		4 - 6 5 - 7 AZURE

Group 6

Moderately Abrasive Rock

Rock Formation Examples

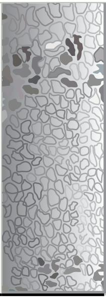
Basalt

Gabbro

Peridotite

Diorite

Gneiss



Recommended Bits

5 - 7

7AC

6 - 8

AZURE

Group 7

Competent, Moderately Abrasive Rock

Rock Formation Examples

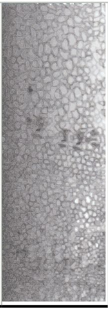
Metabasalt

Amphibolite

Diorite

Granite

Diabase



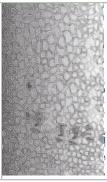
Recommended Bits

6 - 8

7AC “F”

AZURE

BIT SELECTION

Group 8		
Hard, Competent, Slightly Abrasive Rock		
Rock Formation Examples Granite Pegmatite		Recommended Bits AZURE KS (S++) 8AC - 9AC

Group 9		
Very Hard & Competent, Slightly Abrasive		
Rock Formation Examples Metamorphozed granite Quartz Rich gneiss		Recommended Bits 9 11AC

Group 10		
Very Competent Extremely Hard Rock		
Rock Formation Examples Chert Jasperite Quartzite Methamorfozed volcanics		Recommended Bits 9 10

Having chosen the right bit for the rock type and conditions, based on the information at hand, the correct drill settings must be used to get the best performance.

On some bits, the bit label has recommendations printed on it and these are a useful guide to begin drilling. However, it is likely that some adjustments to these values will be required to get optimum performance from the bit.

Reading The Bit Label	
Bit O.D.	N
Matrix Rock Group	Excore 8-9
Application 2/3	Hard-Very Hard, Competent
RPM	900-1200
Penetration Rate	12-25 cm/min (5-10 in/min)
Water Flow	Minimum 38 l/min (10 gpm) Sharpens at 29 l/min

INITIAL DRILL SETTINGS

Revolutions Per Minute (RPM) - The RPM is given as a fairly broad range. A number in the middle of the range should be used when starting and adjusted as required.

Rate of Penetration (ROP) - Again, this is given as a range and will have to be adjusted as the WOB and RPM are varied.

Gallons Per Minute/Litres Per Minute (GPM/LPM) - The water flow is given as a minimum and the actual pump setting should be well above this.

Weight On Bit (WOB) - The weight on bit given is the maximum advisable. The initial drill setting should be below this.

BIT PERFORMANCE

Sharp diamonds cut rock, as they become dull they do so less effectively. The bit matrix should wear at a rate that continually exposes sharp diamonds and releases the worn ones.

Flushing fluid should be pumped across the bit at a rate that removes each tiny rock chip as it is loosened by the diamonds. Failure to do this results in the chip being re-ground, and the ROP and bit life are adversely affected.

The WOB is required to make the diamonds bite into the rock.

The RPM determines the rate at which the chips are being gouged from the rock.

Through his knowledge and experience the Professional Diamond Driller balances all these parameters to achieve the best, economic performance from the drill and drilling tools.

While the manufacturer does his best to make drill setting recommendations, he cannot know what rock type or conditions the bit will eventually be used in. Other factors affecting drill settings are:

- The size and power of the diamond drill.
- The type and size of the core barrel used.
- The flushing media.

Atlas Copco has world wide experience and specially trained representatives to assist you.

ROP

The rate of penetration is the key parameter when drilling with impregnated bits. Finding the optimum ROP for a given Rock Type, rock condition, bit and model of diamond drill is the goal of the Professional Diamond Driller. Once found, this ideal ROP is maintained by adjusting the WOB and RPM. A high water flow across the bit face should always be maintained at high rates of penetration.

Optimum ROP ensures:

- The best overall economy of the operation.
- The least work and highest rewards for the drill crew.
- That the bit remains sharp and does not polish.
- The best bit life.

Use the recommended ROP on the bit label as a starting point and then vary the WOB and RPM in small increments until the optimum ROP is found.

ALERT!

An excessive ROP will result in a high rate of matrix wear and diamonds will be expelled while they are still sharp. In this case any gain in ROP may be offset by more frequent bit changes, more work for the drill crew and an overall reduction in the economy of the operation.

The weight placed on the bit depends on the Rock Type and condition, bit type, RPM, ROP and water flow.

The WOB is a very important indicator of the actual drilling conditions.

Excessive WOB can result in:

- Abnormal bit wear.
- Hole deviation.
- Core barrel and rod damage.

Too little WOB will also result in a loss of productivity as the bit will lose its ability to self-sharpen and could become polished (see Section 4- Bit Sharpening).

Try to maintain a constant penetration rate by increasing the WOB if the ROP falls.

Max WOB shown in the table below should never be exceeded to avoid bit or core barrel damage.

Max WOB kN (lb)					
Bit Size	A	B	N	H	P
Max WOB	22 (5000)	30 (6400)	40 (9000)	50 (11000)	60 (13500)

ALERT!
The maximum permitted WOB shown in the Max WOB table is based on the structural integrity of the bit and may result in damage to the rod and core barrel if exceeded. Excessive WOB can also lead to hole deviation.

RPM

Rotation of the drill bit causes the diamonds to tear chips from the rock. Therefore, generally speaking, the more rotations per minute the higher the ROP. The rotation speed also serves to work the matrix to achieve a constant rate of exposure of new sharp diamonds and release of the worn ones.

RPM Chart

Bit Size	A	B	N	H	P
RPM min	1500	1200	900	750	600
RPM max	1700	1450	1200	950	750

ALERT!
Excessive RPM without matching penetration rate can result in polishing the bit and negatively affect the overall drilling economy.

Drilling performance is directly related to the fluid flow over the bit. Fluid flushing fills the following functions.

- Removal of cuttings.
- Cooling the bit.
- Lubricating the bit and rod.

Annular fluid velocity must be sufficient to keep the cuttings suspended. Recommended fluid flow for each hole size can be found in the table below.

Flow Chart l/min (US gal/min)					
Bit Size	A	B	N	H	P
Flow min	15 (4)	30 (8)	38 (10)	50 (13)	75 (20)
Flow max	20 (5)	36 (10)	45 (12)	60 (16)	84 (22)

RPI / RPC

Revolutions per inch (or centimeter) of advance has been used in the past as an index to maintain the correct relationship between RPM and ROP, eg for a rotation speed of 1200 RPM and a penetration rate of 6 in (15 cm) per minute:

RPI = 1200/6 = 200

RPC = 1200/15 = 80

The common recommendation of 200 - 250 RPI (80 - 100 RPC) can only be considered as a starting point: in modern drilling practices much higher penetration rates are often expected for a given rotation speed, resulting in a lower RPI value. Atlas Copco bits have been developed to accommodate these conditions.

Excessive drill rod vibrations result in:

- Impact loads on the bit resulting in early failure.
- Loss of core.
- Stress fatigue and premature failure of drill rod and core barrel.
- Higher fuel costs.
- Premature machine failure.

Excessive vibration can be the result of:

- Misaligned in-the-hole equipment.
- Undersize, worn, bent or oval rod.
- Vibration induced from the chuck or drill head.
- Incorrect pressure and volume of fluid.
- Loose rod not properly torqued.
- Drilling over core.
- Incorrect bit.
- Improper use of rod grease.
- Worn or improper reaming shell causing insufficient core barrel stabilization.

Some vibration is inevitable in rotating equipment. It can become excessive and destructive when a number of factors such as RPM, WOB, rock type, bit type, etc., are combined in proportions that set up large vibrations, After eliminating any cause related to the above list, the professional diamond driller can usually find a combination of WOB and RPM that eliminates the excess vibration and gives a good ROP.

DRILLING TIPS

ALWAYS

- Treat diamond bits with care and store properly.
- Start fluid circulation before running the bit to bottom.
- Start a new bit several centimeters above bottom and spin into the formation. Do not go to full ROP until you have drilled 10-20 centimeters (4-8 inches).
- Check all rod joints for leaks.
- Check the rod and core barrel for alignment.
- Keep the inside of rod and core barrel free from scale and dirt.
- Make sure the reaming shell is within gauge and out lasts the bit.

NEVER

- Drop the bit onto the hole bottom.
- Start the bit turning with weight on it.
- Collar a hole with a new bit.
- Contact the bit matrix with a pipe wrench.
- Grind the core.
- Allow vibration to occur.
- Force the bit, if it will not drill with normal pressure.

SHARPENING A BIT

Impregnated bits are self sharpening. As the matrix wears away new sharp diamonds are exposed at a constant rate. However, sometimes the diamonds on the face of the bit can become worn without the matrix abrading away. The bit will stop cutting. Generally this occurs when:

- The drill settings do not suit the conditions.
- The bit does not suit the rock.

This often results from rapid formation change.

The bit can be sharpened in the hole and drilling continued but this is a tricky operation and may consume a lot of matrix.

To sharpen the bit, momentarily increase the WOB by 15 to 20 percent, while at the same time reducing the water flow to near the minimum indicated on the bit label.

When the bit begins to cut, immediately lower the WOB and increase the water flow. Try different drill settings than used previously to prevent reoccurrence of the problem.

THE RIGHT CHOICE

OPTIMUM BIT WEAR	ANALYSIS
	• Bit feels sharp to the touch • Good comet tails (diamonds on bit face well supported at the back side by metal alloy) • The wear is even • OD and ID within gauge

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WHY? POSSIBLE REASONS

Rock related: This bit was well suited to the rock formation and conditions.

Drilling related: Drill setting sand flushing provided optimum drilling.

Bit related: The diamond and matrix wear are balanced to provide optimum performance.

WHAT TO DO? POSSIBLE SOLUTIONS

Drilling related: Continue to use the same drill settings unless the conditions change.

Bit related: Continue to drill with this bit type unless the rock formation and conditions change.

ALERT! Continue to watch for changes in the rock conditions and the performance of the drill.

WHAT WENT WRONG?

MATRIX EROSION	ANALYSIS
	• Very rough to the touch • Rapid crown wear • Diamonds overexposed • Gauges eroded

WHY? POSSIBLE REASONS

Rock related: Formation may have changed and is too coarse grained, fractured or abrasive for the bit used.

Drilling related: The solids content in drilling fluid may be too high. Excessive ROP is causing a high rate of matrix wear and premature diamond release.

Bit related: Matrix too fast wearing (soft), or waterway design unsuitable.

WHAT TO DO? POSSIBLE SOLUTIONS

Drilling related: Improve drilling fluid control.

Bit related: Change bit to harder matrix or different waterway design. Reduce ROP if optimum bit life is to be achieved.

ALERT! Advance carefully when re-entering the hole if there has been a lot of gauge wear.

WHAT WENT WRONG?

POLISHED CROWN	FAILURE ANALYSIS
	• Smooth to the touch • Matrix smeared, glazed appearance • No comet tails • Waterways restricted

WHY? POSSIBLE REASONS

Rock related: Formation has changed to harder, fine grained and less abrasive conditions.

Drilling related: ROP may be too low for the RPM used or flushing inadequate.

Bit related: Matrix may be too hard or waterway design unsuitable.

WHAT TO DO? POSSIBLE SOLUTIONS

Drilling related: Increase ROP or decrease the RPM.

Bit related: Strip or dress the bit before starting to drill. Try a bit with a softer matrix or different waterway design if the problem persists.

ALERT! Watch the pump pressure and ROP carefully when starting to drill.

CONCAVE FACE WEAR	FAILURE ANALYSIS
	• Bit wear uneven • Face wear angled to ID • Diamonds poorly supported • ID gauge loss

WHY? POSSIBLE REASONS

Rock related: Formation may have changed to a coarser grained, abrasive or fractured rock type.

Drilling related: The solids content of the drilling fluid may be too high. May be core grinding. RPM too low or ROP too high.

Bit related: Matrix too soft or unsuitable waterway design.

WHAT TO DO? POSSIBLE SOLUTIONS

Drilling related: Lower solids in the drill fluid. Check the pump and drills string for leaks, increase pump output. Check and adjust length of the inner tube. Increase RPM or reduce ROP.

Bit related: Try harder matrix bit or one with a different waterway configuration.

ALERT! Continued drilling with concave face wear will cause the bit ID to ring-out.

WHAT WENT WRONG?

CONVEX FACE WEAR	FAILURE ANALYSIS
	• Outer edge of the face rounded • OD gauge wear

WHY? POSSIBLE REASONS

Rock related: Fractured formation.

5

Drilling related: Poor core barrel stabilization or rod vibration, insufficient fluid flow. Reaming down undersize hole.

Bit related: probably not bit related. Reaming shell may be worn and undersize.

WHAT TO DO? POSSIBLE SOLUTIONS

Drilling related: Check for vibration, stabilize rod and core barrel, try a different RPM. Check the stability of the drill. Check the pump and drill string for leaks, increase pump output.

Bit related: Change the reaming shell.

ALERT! Continued drilling with concave face wear will cause the bit OD to ring-out.

BURNT BIT	FAILURE ANALYSIS
	• Blackened areas • Smeared or broken out matrix • Closed waterways

WHY? POSSIBLE REASONS

Rock related: Formation may have changed to very fractured rock.

Drilling related: Poor bit cooling, pump failure, low flushing water, leaking drill string, plugged bit or lost circulation.

Bit related: Problem not likely bit related.

WHAT TO DO? POSSIBLE SOLUTIONS

Drilling related: Check the pump and drill string for leaks. Check the inner tube adjustment, the fluid circulation, cement the hole, and use fluid retention kit in your core barrel.

Bit related: No change required if the bit is suited to the formation.

ALERT! Be very careful when restarting to drill. Watch for pump pressure cut-off, loss of ROP, loss of circulation.

NOMINAL HOLE & CORE SIZES

Hole volume 168 L/100M

OD: max 46.12mm/1.816″
min 45.87mm/1.806″

ID: max 35.41mm/1.394″
min 35.15mm/1.384″

Reaming Shell
OD: max 46.42mm/1.828″
min 46.17mm/1.818″

Hole volume 181 L/100M

OD: max 47.75mm/1.880″
min 47.50mm/1.870″

ID: max 27.10mm/1.067″
min 26.85mm/1.057″

Reaming Shell
OD: max 48.13mm/1.895″
min 47.88mm/1.885″

Hole volume 181 L/100M

OD: max 47.75mm/1.880″
min 47.50mm/1.870″

ID: max 30.20mm/1.189″
min 30.00mm/1.181″

Reaming Shell
OD: max 48.13mm/1.895″
min 47.88mm/1.885″

NOMINAL HOLE & CORE SIZES

Hole volume 181 L/100M

OD: max 47.75mm/1.880″
min 47.5mm/1.870″

ID: max 30.43mm/1.198″
min 30.18mm/1.188″

Reaming Shell
OD: max 48.13mm/1.895″
min 47.88mm/1.885″

Hole volume 181 L/100M

OD: max 47.75mm/1.880″
min 47.50mm/1.870″

ID: max 35.41mm/1.394″
min 35.15mm/1.384″

Reaming Shell
OD: max 48.13mm/1.895″
min 47.88mm/1.885″

Hole volume 282 L/100M

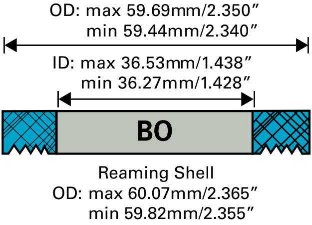
OD: max 59.69mm/2.350″
min 59.44mm/2.340″

ID: max 42.14mm/1.659″
min 41.88mm/1.649″

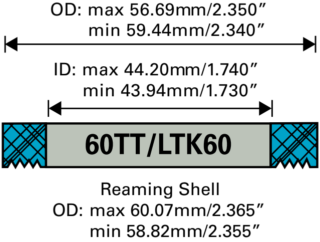
Reaming Shell
OD: max 60.07mm/2.365″
min 59.82mm/2.355″

NOMINAL HOLE & CORE SIZES

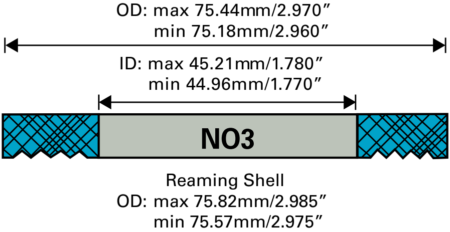
Hole volume 282 L/100M



Hole volume 282 L/100M



Hole volume 451 L/100M



NOMINAL HOLE & CORE SIZES

Hole volume 451 L/100M

OD: max 75.44mm/2.970″
min 75.18mm/2.960″

ID: max 47.75mm/1.880″
min 47.50mm/1.870″

Reaming Shell
OD: max 75.82mm/2.985″
min 75.57mm/2.975″

Hole volume 451 L/100M

OD: max 75.44mm/2.970″
min 75.18mm/2.960″

ID: max 50.80mm/2.000″
min 50.65mm/1.990″

Reaming Shell
OD: max 75.82mm/2.985″
min 75.57mm/2.975″

Hole volume 451 L/100M

OD: max 75.44mm/2.970″
min 75.18mm/2.960″

ID: max 56.24mm/2.214″
min 55.98mm/2.204″

Reaming Shell
OD: max 75.82mm/2.985″
min 75.57mm/2.975″

NOMINAL HOLE & CORE SIZES

Hole volume 724 L/100M

OD: max 95.76mm/3.770″
min 95.38mm/3.755″

ID: max 61.24mm/2.411″
min 60.99mm/2.401″

Reaming Shell
OD: max 96.27mm/3.790″
min 95.89mm/3.775″

Hole volume 724 L/100M

OD: max 95.76mm/3.770″
min 95.38mm/3.755″

ID: max 63.63mm/2.505″
min 63.38mm/2.495″

Reaming Shell
OD: max 96.27mm/3.790″
min 95.89mm/3.775″

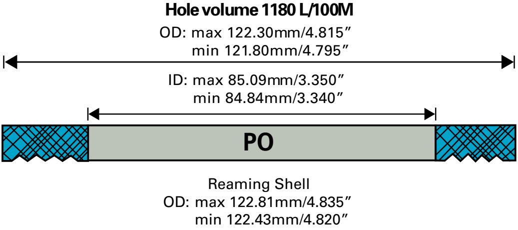
Hole volume 1180 L/100M

OD: max 122.30mm/4.815″
min 121.80mm/4.795″

ID: max 83.19mm/3.275″
min 82.93mm/3.265″

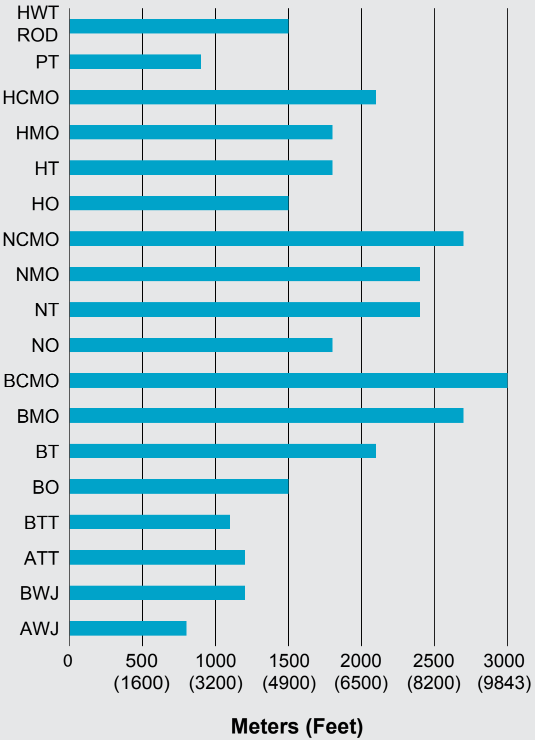
Reaming Shell
OD: max 122.81mm/4.835″
min 122.43mm/4.820″

NOMINAL HOLE & CORE SIZES



DRILL ROD

Drill Rod Depth Capacity



Recommended maximum depth (m). A factor of safety applies to depth capacities. These are based on straight vertical down holes and fluid filled holes.

Wireline Drill Rod - Standard				
Size	OD mm (inch)	ID mm (inch)	Weight kg/3m (lb / 10 feet)	Content l/100m (gal/328 feet)
AO	44.5 (1.8)	34.9 (1.4)	13.9 (30.6)	96.0 (25.4)
BO/BT/BMO	55.6 (2.2)	46.0 (1.8)	17.9 (39.5)	166.0 (43.9)
NO/NT/NMO	69.9 (2.8)	60.3 (2.4)	22.9 (50.5)	286.0 (75.6)
HO/HT/HMO	88.9 (3.5)	77.8 (3.1)	34.2 (75.4)	477.0 (126.0)
PT / HWT	114.3 (4.5)	101.6 (4.0)	56.0 (123.5)	1180.0 (311.7)

MAKE UP TORQUE

Once the stand off joint is closed, there is a need to apply additional torque to pre-load the joint sufficiently. The joint will NOT make itself up during normal drilling operation and must be pre-loaded manually with adequate wrench sizes or mechanically with equipment. This is to avoid joints from leaking but also premature fatigue and failure of the joint.

WIRELINE DRILL ROD

Wireline Drill Rod	Minimum Make Up Torque	
	Nm	ft-lbs
AOTW, ATT	340	250
BO, BT, BMO, BTT	400	300
NO, NT, MNO, NTW	600	450
HO,HT,HMO	1000	750
HWT Drill Rods	1000	750

Wireline Drill Rod - Thin Wall				
Size	OD mm (inch)	ID mm (inch)	Weight kg/3m (lb / 10 feet)	Content l/100m (gal/328 feet)
ATT/AOTW	44.5 (1.75)	36.8 (1.45)	11.8 (26.01)	106.0 (28.00)
BTT/BOTW	56.5 (2.22)	48.8 (1.92)	15.3 (33.73)	189.0 (49.93)

Conventional Drill Rod				
Size	OD mm (inch)	ID mm (inch)	Weight kg/3m (lb / 10 feet)	Content l/100m (gal/328 feet)
AWJ	44.5 (1.75)	34.9 (1.37)	14.3 (31.53)	75.0 (19.81)
BWJ	55.6 (2.19)	46.0 (1.81)	18.4 (40.57)	155.0 (40.95)
NWJ	66.7 (2.63)	60.3 (2.37)	24.4 (53.79)	256.0 (67.63)

Flush Joint Casing				
Size	OD mm (inch)	ID mm (inch)	Weight kg/3m (lb/10 feet)	Content l/100m (gal/328 feet)
AW	57.1 (2.25)	48.4 (1.91)	16.9 (37.26)	184.0 (48.61)
BW	73.0 (2.87)	60.3 (2.37)	31.2 (68.78)	285.0 (75.29)
NW	88.9 (3.50)	76.2 (3.00)	38.8 (85.54)	456.0 (120.46)
HW/HWT	114.3 (4.50)	101.6 (4.00)	50.8 (111.99)	811.0 (214.24)
PW	139.7 (5.50)	127.0 (5.00)	64.3 (141.76)	1267.0 (334.71)

ATLAS COPCO EXPLORATION PRODUCTS

Atlas Copco manufactures and supplies a full range of exploration drilling equipment from locations around the world.

DIAMOND DRILLS

Christensen surface drills are available in light duty (also fly-in), medium duty and deep hole models. Diamec underground drills are also available for four duty ranges. Christensen surface drills are available for three duty ranges.

DRILL RODS

Atlas Copco offers all popular sizes of drill rods including O, T and MO threads.

CORE BARRELS

Atlas Copco supplies a full range of both conventional and wireline core barrels including our revolutionary and patented Excore Safety Overshot and Core Barrel Head Assembly. Visit our website for more information: www.atlascopcoexploration.com

Atlas Copco produces a range of reaming shells in diamond impregnated and surface set styles. Reaming shells are essential for maintaining proper hole size and stabilizing the core barrel.

SURFACE SET AND IMPREGNATED REAMING SHELLS

Excore reaming shells are manufactured to withstand difficult drilling conditions and provide long life. Surface set reaming shells in all common DCDMA sizes are a stock item.

Impregnated reaming shells and reaming shells in full hole profile are also available. Reaming shells are available in industry standard lengths of 15 cm (6"), 25 cm (10") and 46 cm (18 3/8"). A combination of polycrystalline diamonds (PCD) and natural diamonds are utilized for most standard reaming shells and all heavy duty reaming shells.

See Atlas Copco catalogue for detailed information for ordering reaming shells, or contact our customer service desk for help in making the correct choice.

EXCORE CASING & ROD SHOES

Atlas Copco supplies impregnated casing shoes and rod shoes.

IMPREGNATED CASING SHOES

Excore casing and rod shoes are manufactured to handle a broad range of conditions, from unconsolidated overburden to broken, abrasive formations. Impregnated standard and heavy duty casing shoes are stock items.

See Atlas Copco catalogue for detailed information for ordering casing shoes or contact our customer service desk for help in making the correct choice.

Length		Times		Equals
in (inches)	x	25.4	=	mm
ft (feet)	x	0.305	=	m
yd (yard)	x	0.914	=	m
miles	x	1609	=	m
5ft (feet)	x	0.305	=	1.524m
10ft (feet)	x	0.305	=	3.048m
m (meter)	x	39.37	=	in
1.5m (meter)	x	39.37	=	59.055in
3m (meters)	x	39.37	=	118.11in

Area		Times		Equals
mm^2 (square mm)	x	0.000001	=	m^2
cm^2 (square cm)	x	0.0001	=	m^2
in^2 (square inches)	x	645	=	mm^2
ft^2 (square feet)	x	0.0929	=	m^2
yd^2 (square yards)	x	0.8361	=	m^2
Acres	x	4047	=	m^2
Square miles	x	2.590	=	km^2

CONVERSION TABLES

Volume		Times		Equals
l (liters)	x	0.001	=	m^3
ml (milliliters)	x	0.001	=	l
dm^3 (cubic decimeters)	x	1.0	=	l
cm^3 (cubic centimeters)	x	1.0	=	ml
mm^3 (cubic millimeters)	x	0.001	=	ml
in^3 (cubic inches)	x	16.39	=	ml
ft^3 (cubic feet)	x	28.316	=	l
Imperial gallon	x	4.546	=	l
U.S. gallon	x	3.785	=	l
Ounces (Imp. fluid oz)	x	28.41	=	ml
Ounces (U.S. fluid oz)	x	29.57	=	ml
Pints (U.S. liq)	x	0.4732	=	l
Quarts (U.S. liq)	x	0.9463	=	l
yd^3 (cubic yards)	x	0.7646	=	m^3

Mass (Weight)		Times		Equals
g (grams)	x	0.001	=	kg
t (tonnes, metric)	x	1000	=	kg
grains	x	0.0648	=	g
oz (ounce)	x	28.35	=	g
lb (pounds)	x	0.4536	=	kg
tons (long, U.S.)	x	1016	=	kg
tons (U.K.)	x	1016	=	kg
tons (short)	x	907	=	kg

Power		Times		Equals
kW (kilowatts)	x	1000	=	W
Horsepower, metric	x	735.5	=	W
Horsepower, U.K.	x	745.7	=	W
ft. lbf/sec	x	1.36	=	W
Btu/h	x	0.29	=	W

Speed		Times		Equals
km/h (kilometers/hour)	x	0.2777	=	m/s
m/s	x	3.6	=	km/h
mph (miles/hour)	x	0.45	=	m/s
mph	x	1.61	=	km/h
ft/s (foot/second)	x	0.3048	=	m/s
ft/s (foot/second)	x	18.29	=	ft/min
ft/min (foot/minute)	x	0.3048	=	m/min

Frequency		Times		Equals
r/min (rev./minute)	x	0.01667	=	r/s
degrees/second	x	0.1667	=	r/min
radians/second	x	0.1592	=	r/s

CONVERSION TABLES

Pressure		Times		Equals
bar	x	100	=	kPa
bar	x	100 000	=	Pa
kp/cm^2	x	0.98	=	bar
atm (atmospheres)	x	1.01	=	bar
psi (pounds/in^2)	x	6.895	=	kPa
psi	x	0.06895	=	bar

Force		Times		Equals
kN (kilonewton)	x	1000	=	N
kp (kilopond)	x	9.81	=	N
kgf (kilogram force)	x	9.81	=	N
lbf (pound force)	x	4.45	=	N

Torque		Times		Equals
kpm (kilopondmeters)	x	9.81	=	Nm
lbf In (pound force inch)	x	9.81	=	Nm
lbf ft (pound force foot)	x	1.36	=	Nm

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Atlas Copco

Sustainable Productivity

We stand by our responsibilities wards our customers, towards the environment and the people around us. We make performance stand the test of time. This is what we call - Sustainable Productivity.

Atlas Copco Secoroc AB
PO Box 521, 737 25 Fagersta, Sweden
Phone: +46 223 461 00
www.atlascopco.com/secoroc

Atlas Copco

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