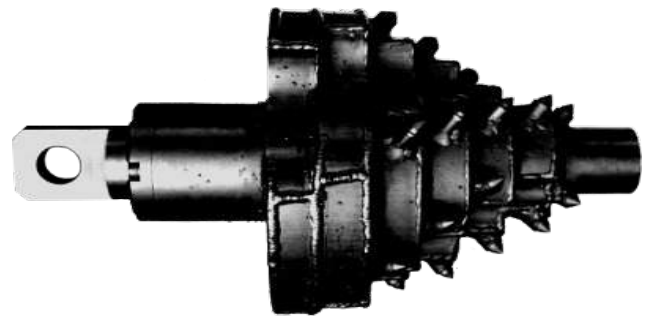
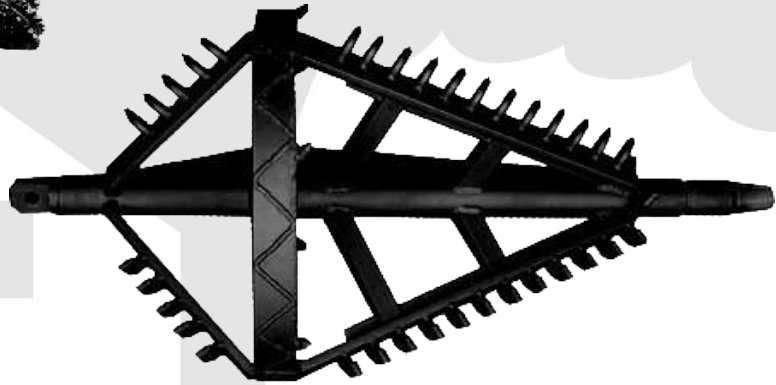


NO DIG *Equipment*

The Horizontal Boring Specialists



HDD

Reamer

Selection Guide

REAMER SELECTION GUIDE FOR SMALL & MEDIUM HDD DRILLS

This information is specifically aimed at selecting the right reamer for small to medium sized HDD rigs, which are probably the most common directional drills used in the industry, to provide drillers and rig owners with cost effective and long term solutions to their back reamer requirements.

Today's HDD rig operators are always trying to improve on their drilling time, reduce down time and maximise tooling costs. The purpose of this document is to provide guidance in selecting the correct Reaming Tool for the prevailing ground conditions, giving drillers the best chance for a successful drilling outcome.

As a basic guideline the size of the reamer should be approximately 1.5 times the diameter of the product pipe to be installed. This allows an annular void for the return of drilling fluids and cuttings, reducing frictional pull-back forces and allowing for adequate bend radius of the product pipe.

Selecting the right reamer for your directional drill shot can have a significant outcome on the success of your job. Reamers must be selected in accordance with the ground conditions present to ensure that the installation of the product is successful.

Four Basic Types of Ground Conditions

There are four basic types of ground conditions which a driller will encounter, these are: sand , clay, rock, and mixed ground, which may be a combination of all these soil types. Mixed ground is generally the most difficult of all the conditions from a drilling perspective, especially if the ground is laden with hard rock in soft sand or normal soil conditions.

Four Basic Types of Reamers

You might think that there is a reamer solution for each of the ground conditions mentioned above, unfortunately is not usually that easy. These reamer types generally provide some overlapping between designs in order to provide a tool which is capable of drilling a wider range of ground conditions. In order to define the choice of reamer to be used in any one type of ground condition we will go through basic designs one by one.

COMPACTION REAMER

These reamers are ideally suited to sandy and water charged ground conditions, where it is likely the hole which is reamed will not self support once the reamer passes through. Compaction reamers rely on the promotion of a bentonite filter cake, which is designed to force the drilling fluid (usually a Bentonite Clay slurry) into the surrounding soil matrix in order to provide support to the hole and prevent hole collapse.

The design of these compaction reamers usually is in a cone shape which gradually increases in size progressively opening up the hole. This tapered design is optimised to force drilling fluids into the soil matrix which then helps with stabilising the bore hole to prevent it from collapsing.

Usually, the fluted reamer has canals cut or cast into the body. These channels allow for fluid and cuttings transportation. It is recommended to have large channels or flutes to allow the the spoil to pass and encourage good circulation and flow-back of cuttings. If the flutes are too small, mud pressure can build up in the bore hole and cause frack-outs and loss of mud circulation.

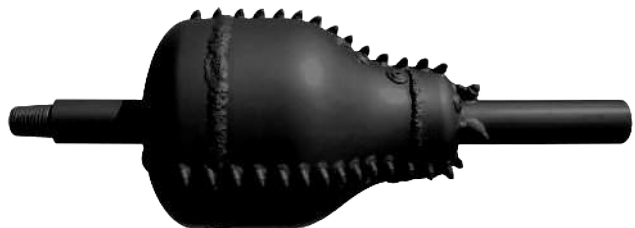
Care needs to be taken when using a fluted reamer as not all are created equal. A fluted reamer that is created out of solid material will withstand and outlast other types of fluted reamer which may be cast or fabricated. The additional weight might be a bit of an inconvenience, however the benefits of being able to easily repair and refurbish solid reamers greatly outweighs the convenience of hollow cast type fluted reamers.

Carbide cutting teeth on the cone can provide aggressive cutting and help break up roots or soft rock formation. This feature gives the fluted compaction reamer versatility and allows it to operate in a variety of soil, sand and even mixed ground conditions.

Built in swivels are preferable with these types of reamers, as they will generally shorten the package lengths. This also helps prevent the pipe getting stuck in case of the hole collapsing behind the reamer. The other advantage of a built in swivel is that it allows you to push back the package, in emergency situations, without jack-knifing your swivel and running over your package. This may be required when the reamer blocks and you need to clear the cuttings.



Fluted Compaction Reamer (with built in swivel)



Compaction / Barrel Reamer (no swivel)



Solid Compaction Reamer (with built in swivel)



Paddle Mixer type Compaction Reamer (no swivel)

MIXING REAMERS

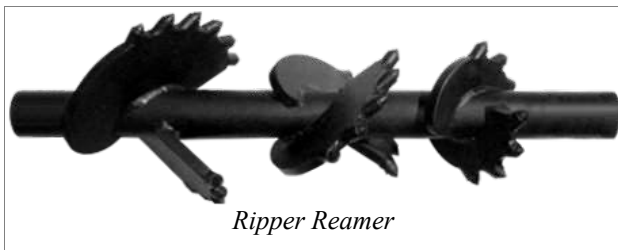
Mixing type reamers include the Beaver Tail, Fly Cutter and Ripper Reamer. These reamers are suited to clay and harder ground conditions where the soil is self supporting.

They are designed to break up the soil particles and provide a good mixing action with the drilling fluids. The mixing action helps break down the clay particles and combine cuttings with the drilling fluid in order to flow the cuttings out of the hole.

Clay particles when mixed with water can have a tendency to become sticky and ball up into clumps.

This can cause the bore to clog and it can make it very difficult to remove the cuttings. For this reason special types of cutting fluids must be used to break down the clay particles and provide good lubrication and flow properties in order to properly remove cuttings.

Fluid Pumping Action

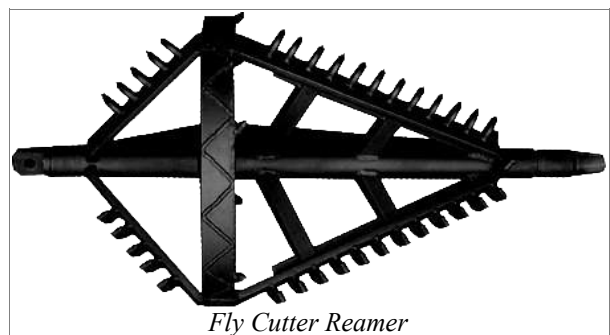


Ripper Reamer

It's beneficial to have a design which promotes good pumping action in order to clear the cuttings out of the bore hole. This can be achieved in two basic ways, the first is by using backward angled mud jets, and the second and preferable method is by designing the cutting blades to act like a boat propeller and literally pump the cuttings backwards through its mixing action.

These two features on any mixing type reamer along with the selection of the correct cutting fluid greatly increase the likely hood of a successful bore in sticky ground conditions.

Fly Cutter reamers are used primarily in soils that are hard and more compacted than most. Sandstone, Siltstone and other soft rock formations would fall into this category. Fly Cutters are designed to have a very open structure to allow large rocks or cobbles to easily pass through the reamer. Their design usually incorporates a welded ring around the outside of the blades, to provide support to the cutting arms and centralise the reamer in the bore hole to provide a smooth cutting action.



Fly Cutter Reamer

Jet nozzles are installed along the cutting arms to enable the driller to control the volume and pressure of the drilling fluid. Ideally some of the jets should be angled backwards to provide jetting of cuttings out of the hole. Angled stabilisers can also be incorporated to promote pumping and slurrification of the drilling fluids, to help pump cuttings out of the bore hole.

Cutter Options

Cutting teeth on these types of reamers are generally closely spaced and can be configured according to the formation that is to be cut.

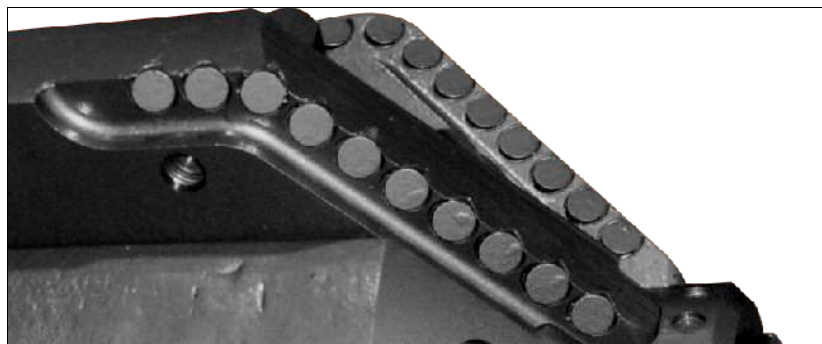
For instance tungsten carbide picks are best suited to softer clays or mudstone with inclusions of cobbles or harder rocks, as they are very tough and stand up well to mixed conditions and shock loads. These can be of welded type or replaceable picks, which are more easily serviced on site.



Example of weld-on and replaceable tungsten carbide bits



However in the case of homogeneous or consistent Sandstone or Limestone, PCD (diamond bits) will provide the best production and cost per drill meter on the bore. PCD's will however not stand up to shock loads as might be found in mixed ground conditions which could cause the PCD to crack and shatter, this would stop the reaming process and will probably cause the reamer to fail prematurely.



Poly Crystalline Diamond inserts (PCD)

The use for mixing reamers is for drilling in self supporting ground conditions, such as firm clay, loam and soft rock. They should not be used in sandy or wet running conditions where the soil is not self supporting, as the risk of the hole collapsing and getting your package stuck is very high.

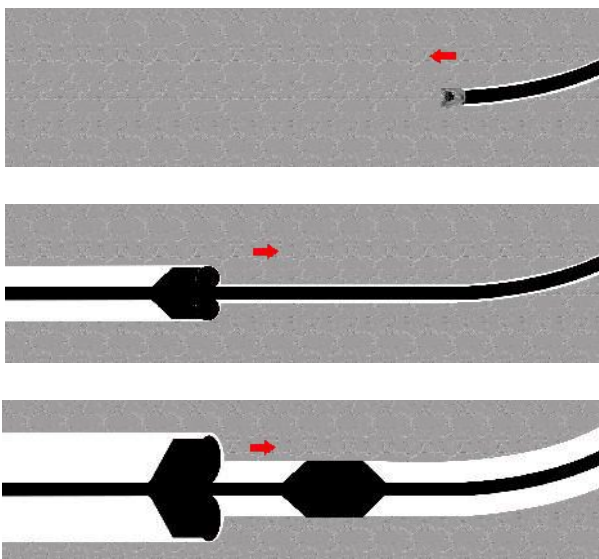
ROCK ROLLER / HOLE OPENERS

As the name suggests, these types of reamers are used in rocky ground conditions.

When formations cannot be penetrated with reamers, or if stalling or over-torquing of the reamer occurs, rock rollers or hole openers should be used. Hole openers that use rolling cutters are used primarily for reaming in rock formations and come in many sizes and configurations.

Most hole openers provide excellent flow characteristics, cutting capability and low torque due to the rolling cutters. The rollers are designed using a series of mill tooth or tungsten carbide inserts on a set of rollers which are designed to fracture the rock as they roll over the surface of the formation.

Reaming with hole openers usually requires opening up the hole in a series of small steps, progressively enlarging the drill hole on each pass. In order to accomplish this in a safe manner and prevent damage to the reamer it is necessary to centralise or stabilise each consecutive size reamer to the previous cut hole.



This can be done in various ways, a stabiliser reamer or barrel reamer can be run in front of the hole opener to centralise it to the previous cut hole. Alternatively a built in stabiliser can be incorporated to the hole opener either in the front or the back of the rock roller to centralise the reamer. The preferred option is to use a centralising barrel reamer at the front, but if the package length is restricted due to pit constraints, the next best option is to use a hole opener with a built in stabiliser on the front side to ensure proper alignment to the previous bored hole.

There is a wide range of cutters available for all the different types of rock hardness you are likely to encounter.

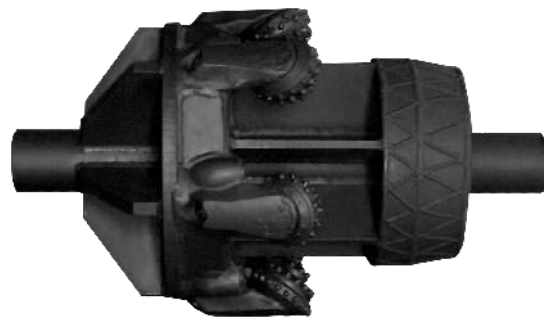
Drilling in rock should be centralised / stabilised

The correct cutter type must be selected to give the best and most cost effective performance in the prevailing ground conditions. To provide an indication of the type of cutters available and ground conditions ideally suited to the specific formation see Appendix 1 for examples.

Here is an example of two Rock Reamers with built-in stabiliser.



Back-stabilised Rock Reamer

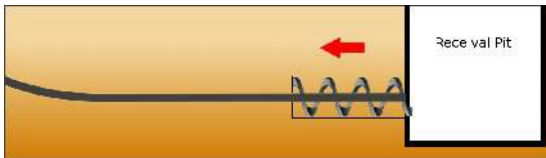


Front-stabilised Rock Reamer

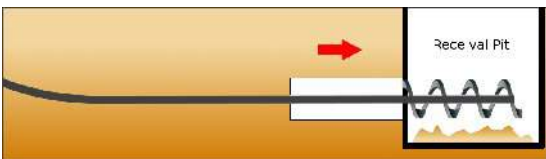
THE AUGER

This type of reaming style is a bit different from the normal. The system does not use a normal mud rotary technique, as is the case with all other reamers.

The design principal behind this system is that an auger cuts its way through the soil in relatively short section, like 2m-3m at a time, and then the reamer is physically pushed back out to the receival pit, pushing the excavated spoil in front of it. This process is repeated until the hole to be bored is completed.



This drilling process is confined to good non sticky clay materials where the ground is self supporting and generally not too hard to drill. This is necessary in order to allow the auger to screw its way into the dirt like a cork screw. This then allows it to push a semi solid soil mass back out of the hole.



Very little drilling fluid is used with this system and generally only water is used as a lubricant and to help break up the clay particles.



The benefit of this is that the drill cuttings are in a near solid mass and can generally be dealt by an excavator and loaded straight into the back of a truck for solid waste disposal. This is always much cheaper than dealing with a liquid slurry that is produced by the normal mud rotary process. Liquid wastes usually requires the use of a Sucker Truck or slurry pumps, and this waste is always considerably more expensive to dispose of than solids.



The disadvantage of this system is that it is fairly slow when compared to conventional drilling. Because the auger can only push back 2-3m of spoil at a time it is very time consuming to continually shuttle the rods back and forth to complete the bore. Therefore this technique is really only practical with rigs that have automatic rod loading systems.

Another disadvantage is that the rod sting is under a fair bit of compressive load when the reamer is being pushed back out to the receival pit, particularly if there is a bit of dirt being pushed along as well. Because the rods are unsupported within the reamed hole the compressive loads can cause the rods to buckle and bend. Therefore one must be extremely careful when utilising the technique, otherwise you might end up with a very expensive rod replacement bill.

SWIVELS

Swivels are a major requirement with any directional bore. The swivel prevents the pipe or cable being installed from spinning in the bore whilst the reamer is pulling the package into the ground.

For general purposes the design capacity of the swivel should be at least the same as the pull-back power of the drill rig to ensure the swivel does not fail prematurely.

Pull-back swivels come in two standard forms, either built into the reamer or as a standalone unit. Both these have their respective advantages. In the case of a standalone swivel the advantage is in cost, as you are able to use the same swivel on different reamers, which means the overall cost of the reamer is generally cheaper.

Some of the disadvantages of standalone swivels are that they can jack-knife the reamer package in the hole, if the package needs to be backed up for any reason. They also increase the length of the package significantly which means longer receival pits may be required. In many instances standalone swivels are joined to the reamer and the pulling package using D-shackles, and even though these are generally rated they provide further points of weakness and potential failure in the boring process.



Jack knifing can occur if drill package needs to be pushed back for any reason. This can damage the reamer, the swivel and sometimes also the product.

Built in swivels on the other hand are generally not transferable over different reamers. However the advantages they provide are significant.

The reaming package is usually reduced significantly making it easier in tight places. Also the shorter distance between reamer and pipe can significantly decrease the chance of a hole collapse or rocks falling between the reamer and pipe package. Therefore reducing chances of jam ups.



Built-in Swivel

Therefore it is recommended that reamers with built in swivels are always selected where possible. The cost might be a little more on the initial purchase, but the benefits they provide in ensuring a bore works out well are considerable. Particularly if one strikes trouble part way during the bore, having a fixed swivel that is built into the reamer can dramatically increase the chance of completing the bore successfully, especially if a reamer blockage occurs and the package needs to be pushed out.



Screw-in Swivel - when the diameter of the reamer is too small for a built-in swivel

SAVER SUBS

The sub is a replaceable thread on the end of the reamer which connect your reamer to the drill rods or starter rod. This thread is generally a proprietary thread form like the Vermeer or Ditch Witch quick connect thread.

Some form of quick connect thread is typical on small and mid sized rigs, as they allow breaking out the sonde housing and changing over to the reamer at the receival pit without the requirements of using some sort of manual or hydraulic break-out tool.

These threads must be designed to be easily screwed together and apart and must be strong enough to transfer all of the pull-back load from the drill rig to the reamer.

With time these threads tend to wear, firstly because the high loads they are subjected to and also due to potential bentonite leakage which can act like a grinding paste on rod threads.

Repairing Worn Threads

A worn thread on your reamer usually means that there is a high possibility of failure, especially under high loads which can result in the back reamer tearing off from the drill string. This usually happens when it is half way under the highway that is being drilled and can results in expensive repair work and sometimes requires abandonment of expensive tooling and product if the failure occurs under critical infrastructure like a highway or under a river where excavation is not possible.

For this reason it is always important to have a mechanism to change out this quick connect thread once it wears, to ensure a good connection is always available, especially on critical bores. With many reamers this is not an option as the thread is part of the total reamer and not usually removable.

In these cases limited options are available to repair the reamer. A common option is to weld up the old worn thread form (preferably with a Low Hydrogen welding rod) and try to re-cut a new thread which matches the original. Alternatively you try to weld or thread a new sub onto the existing worn thread, this can increase the length of the reamer package considerably and can provide another area where failure can easily occur.

Neither of these options are optimum. In the first instance the welding process can significantly change the properties of the steel leaving the new thread weakened and possible brittle, which may cause premature failure. Secondly, it is difficult to ensure that the new thread is exactly the right form to match the rest of your tooling. These parts are generally machined using CNC lathes to ensure high tolerances and repeatability. This accuracy is usually very difficult to achieve when you are trying to swing a 80kg reamer in a manual lathe and you are trying to achieve tolerance like that of a CNC controlled machine.

For this reason it is always best to select reamers which have the built in facility to change out these critical threads with saver subs. These saver subs can increase your reamer life considerably and keep the cost of the tooling repair down to a minimum.

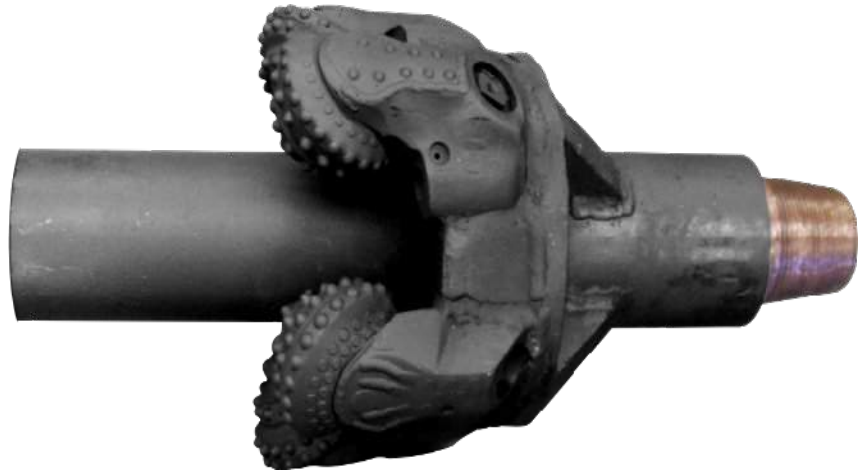
The other advantage with this system is that you can easily adapt reamers between different machines and systems. Well built reamers can be very expensive to purchase, so having the ability to swap reamers between different machines just by changing out an inexpensive saver-sub can provide a very cost effective solution.

EXAMPLE OF QUICK CONNECT SAVER SUBS

Large connection



Vermeer Spline Lock



Small connection



Quick Connect VERMEER D7x11



Quick Connect Ditch Witch



THE ROLE OF DRILLING FLUIDS

Directional drilling is basically a form of mud rotary drilling. The use of mud or drilling fluid is required to remove the cuttings and sometimes stabilise the hole.

The range of drilling fluids is very large and can range from: air, water, foam, Bentonite, oil based drilling fluids, polymers, detergents and quite a few more.

However the main ones used in HDD are - Bentonite, Polymer, Wetting Agents and just plain water.

Bentonite Drilling Fluids

The drilling fluid to use is very much dependent on the ground conditions that are being drilled. The most common fluid is a Bentonite / water mix, where the Bentonite provides excellent spoil carrying capacity, hole stabilisation and lubrication. Bentonite based drilling fluids are a must in sandy soils as they provide hole support by forming a filter cake which prevents the bore hole from collapsing.

Polymer Drilling Fluids

These drilling fluids are generally used in clay type formation and provide the carrying capacity and lubrication which would otherwise be provided by the Bentonite.

In sticky clay situations polymers are generally mixed with detergents or wetting agents to break down the clay particles and stop them from clumping, this helps with flushing out the cuttings.

Water

Water is the main ingredient in all cutting fluids, however in certain ground conditions and generally smaller bores, plain water may be adequate for drilling. These conditions may include certain types of clay or loamy material as well as small rock bores. However incorporating some type of additive to your drilling fluid will invariably improve the drilling process.

The back reaming process which uses an auger system generally uses only plain water for its drilling process. However, as this type of reaming process is not a mud rotary process, it is limited to specific ground conditions.

Drill Fluid Selection Guide

To provide some guidance for the selection of the correct drilling fluid in varying ground conditions, I have included a one page reference guide. The guide is based on Baroid Drilling Products, but similar products are available from all major manufacturers of drilling fluids.

The guide includes a range of basic products, and common ground conditions, as well as a list of specialised additives to provide solutions for varied ground conditions and common problems encountered in drilling.

To see which drilling fluids are best suited to your conditions, See Appendix 2 for your Drilling Fluid Selection Guide.

CONCLUSION

Select a Reamer which Suits the Ground Conditions

The selection of the correct reamer and drilling fluid play a very important part in ensuring the successful outcome of your directional drilling job.

Selecting the right tool may initially cost a little more, but in the long run will save the contractor grief and money by assuring the bore gets done right the first time.

Use Saver Sub for your Machine Connection

Features like saver subs will reduce overall costs in the long term, as these provide a mechanism for easy repair in the future. This feature along with a good quality, well built reamer will provide a good tool for many years to come.

Select the Right Swivel, in Accordance with the Pulling Forces

Swivels play a very important roll in a successful bore, swivels should preferably be built into the reamer or at a minimum, be designed so that it CAN NOT jack-knife in the bore when the package gets pushed backwards.

Select the Right Drilling Fluid

Finally directional drilling in not an exact science and if the ground conditions are OK a successful bore is usually not so hard to achieve. However as most drillers know, easy and consistent ground conditions are not the norm and every bore can throw up a different set of challenges. Having the right combination of reamer, swivel and drilling fluid will greatly increase the chance of a successful outcome.

Hopefully this document gives some guidance to selecting the right tool for the job and making sure that the drilling process becomes much less “Guess-Work” and brings success on even the most challenging jobs.

No Dig Equipment is a supplier and manufacturer of Trenchless Technology equipment. For more information on the types of products we can supply please have a look on our website.

www.NoDigEquipment.com.au

Alternatively if you would like to discuss any Trenchless options with us please call me at +61 8 9493 0642 or email me at:

Craig@NoDigEquipment.com.au

Appendix 1

Mill Tooth Cutters

Soft Formation Tooth Bits

Used in shales, clays, red beds, salts, soft limestone and unconsolidated sands

PSI: 3000 - 5000 lbs of bit diameter

RPM: 120 - 90 reduce weight as RPM increases

J1 IADC 116



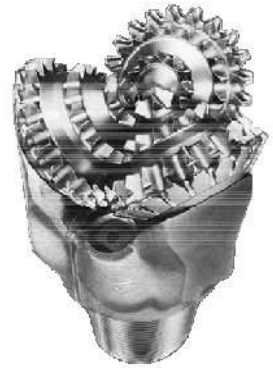
Hard Formation Tooth Bits

For use in hard sands, cherty limestone, dolomite, chert

PSI: 4500 - 8000 lbs. of bit diameter

RPM: 80 - 45 reduce weight as RPM increases

J7 IADC 316



TCI Tungsten Carbide Cutters

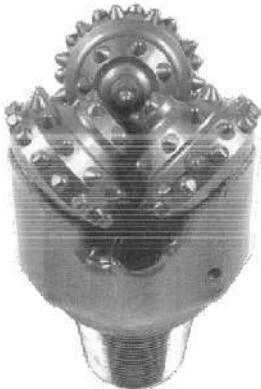
Soft Formation TCI Bits

Used in shale, clay, red bed, salt, sand, soft limestone and soft anhydrite

PSI: 2000 - 5000 lbs of bit diameter

RPM: 140 - 60 reduce weight as RPM increases

C27 IADC 527



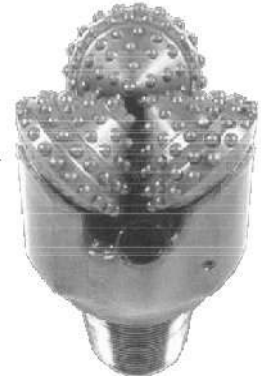
Very Hard Formation TCI Bits

Used in high strength abrasive formations: sand, chert, quartzite, pyrite, granite and quartzitic.

PSI: 5000 - 6500 of bit diameter

RPM: 60 - 35 reduce weight as RBM increase

C9 IADC 837



Appendix 2 Drilling Fluid Selection Guide

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Drilling Conditions	Fluid Make-Up	
Sand (Fine – Med)	Quik Gel	1-2 sx / 1000L
Sand (Coarse)	Quik Gel	2-3 sx / 1000L
	Quik-Trol LV	0.5–2.0 Kg / 1000L
Gravel – Cobble	Quik Gel	2-4 sx / 1000L
	N-Seal	5-25 Kg / 1000L
Sand, Silt & Clay (Loam)	Quik Gel	1-2 sx / 1000L
	Ez-Mud Gold	0.5–2.0 Kg / 1000L
	Penetrol	1-2 L / 1000L (if needed)
Clay-Sticky or Swelling	Poly Bore	0.4-0.5 kg / 1000L
	Penetrol	1-2L / 1000L
	Aqua-Clear PFD	0.25-0.5L / 1000L

Specialty Products		
Name	Function	Amount
EZ-Mud Gold	Easy to mix, low viscosity Clay/Shale stabiliser	0.5-2 kg / 1000L
Poly Bore	Clay / Shale stabiliser	0.4-0.5 kg / 1000L
Penetrol	Bit Balling, Sticky Clay	1-2 L / 1000L
N-Seal	Lost Circulation / Hole Sweep	5-25 kg / 1000L
Diamond Seal	Lost Circulation & Hole stabilisation in Cobble	As needed
No Sag	Increases carrying capacity	0.5-2.5 kg / 1000L
Quik-Trol LV	Decrease fluid loss with minimal viscosity increase	0.5-2.5 kg / 1000L
Dinomul	Torque / Friction reducer	2-20 L / 1000 L
Aqua Clear PFD	Mud / Slurry thinner	0.25-0.5 L / 1000L

Note: N-SEAL and/or DIAMOND SEAL can be used to control excessive fluid loss

MAKE-UP WATER	ACTION REQUIRED
ph 8.5 – 9.5	Raise pH using Soda Ash – 0.5-1.0 Kg / 1000L
Hardness < 100mg/L	Remove Hardness using Soda Ash 0.5-1.0 Kg / 1000L
Salt	Change water source
Chlorine	Change water source in tank or allow to circulate if no other source is available
Solids	Pre-filter into tank to remove sand

General Comments
Mix Quik Gel before adding any polymers
NO-SAG and QUIK-TROL both hydrate and build viscosity in salt water
Penetrol and Dinomul may foam when used in high concentrations
Additional Soda Ash (1kg/ 1000L) can help protect bentonite when drilling in brackish or saline water