How to drill by cable percussion: D.V. Allen, C.Eng. MICE

FORAGER-55
CABLE PERCUSSION (Shell & Auger) DRILL RIGS
The techniques and tools available to users of a Consallen Forager-55 Cable Percussion (Shell & Auger) drilling machine.

(Best read in conjunction with our video showing setting up & use of the Forager-55, which may be found at: *http://www.consallen.com/forager/cable-tool/F-55_web_snippet-2.wmv*)

INTRODUCTION

In light cable percussion drilling the most basic tool is the clay cutter. It will cut and retain a solid plug of material, and haul it to the surface for easy removal. This is a rapid process, which results in a full size hole immediately. A cross-bit or chisel can be used to break rock, mix it with water to form mud, which can be removed using a bailer. Other tools combine the attributes of both crushing and clay cutting. Additional weight can be added by screwing sinker bars to the tools, and a sliding hammer can be used to drive tools by repeated short blows. Clay cutters can be fitted with retaining devices if the material will not remain in the tool due to suction or weakness.

The Forager-55/1250 has a free-fall winch, with which the tools are lifted, then allowed to fall freely for maximum impact. Both 'long drop' and 'short stroke' techniques may be employed. Both methods suit the directly controlled winch, allowing use of a wide range of tools and methods. The winch capacity is 1250 Kg single line bare drum.

The hole may, or may not, require support during drilling operations. Many materials will support themselves, but techniques are available if this is not the case. Keeping a head of water in the hole is a very successful method of preventing collapse when ground such as saturated sand and silt will not stand unsupported; Bentonite may be also added to the water to form a light drilling.

Steel casing can be used to prevent collapse – either temporary casing that is withdrawn afterwards, or permanent casing that is left in the hole. Excavation takes place in advance of the casing as it is lowered down. This method is used where the ground will stand unsupported for part of the hole. The casing may be quite loose and not require heavy driving, but performs the task of reaming and maintaining the hole size and straightness for the free fall of the tools. An oversized shoe is often used with this technique, ensuring some clearance between the outside of the casing and the hole. This clearance allows the casing to be lifted and dropped as a means of drilling and reaming, after the hole has been opened by the drilling tools. The 'loose casing' method is frequently used in conjunction with clay cutters and stubbers, which are also called 'dry' drilling tools – mostly this technique is used with flush jointed temporary casing, often referred to as "shell & auger" drilling. Loose casing may sink under it's own weight when bailing below the shoe in saturated sands and silts. If the stage is reached where heavy driving of the steel casing makes no further advance, a smaller casing can be telescoped inside the first, and progress is continued with smaller tools.

Temporary steel casing is usually flush butt thread jointed, and is removed for re-use whenever possible. Driving and recovery of steel casings are 'heavy weight' methods and can be used with light drilling machines like the Forager-55, where the weight of casing being handled does not exceed about 80% of the safe working load of the winch. In good conditions this may be the equivalent of 30 metres of 6-inch or 45 metres of 4-inch flush jointed steel casing on a direct pull. Additional weights of casing can be handled using snatch blocks to provide two, or more, falls of wire in a multi-part tackle. Some very thick-walled plastic tube can be forced down as the hole is drilled ahead of the leading edge,

protected by a steel shoe and with a suitable steel cap, but this is not the same as the heavy driving which can be sustained by a steel casing.
Although widely used in the UK for drilling to chalk aquifers, the use of steel for permanent casing in the majority of tropical countries is deprecated since they corrode in the mostly acidic groundwater, giving a bad taste to the water as well as having a relatively short useful life. Techniques most suited to drilling in tropical African conditions, use plastic permanent well casing, which can not be driven by traditional percussion methods. Plastic is light in weight, cheap enough to be regarded as disposable, is available almost everywhere for local purchase, and will not corrode nor impart taste & impurities to potable water. However, successful forcing requires the use of a steel shoe, and a cap designed to distribute the stresses employed in pulling down against ground anchors. The pull-down provided by the Forager-55 is equal to the winch hoist, and this can be increased using snatch blocks in multi-part tackles. Plastic casing employed in this way is generally regarded as permanent, or sacrificial. In water well drilling this is usually not a problem, but may not be an acceptable practice for site investigation work and prospecting, where temporary steel casing is normally used. Shoes for plastic casing may need to be stainless in aggressive groundwater. Double thickness "stove-pipe" plastic casing is very strong, is flush jointed, and requires no glue or adhesive. This material is made in such a way that considerable force is needed to push the two elements together. The result is a casing, which can be used in a manner similar to the loose casing technique described above. The shoe is larger than the casing pipe, giving some small additional space for the plastic tube, thus minimising friction. This type of casing has no strength in tension, and thus cannot be used where any 'hold-back' is necessary.

The TOOLS

Bailers

A bailer is an elongated bucket with a bottom valve allowing water and cuttings to enter, and then not escape. Bailers are used for to remove water, mud and cuttings arising from the drilling activity. Heavy weight bailers can be fitted with a cutter bar, and used as a drilling tool in suitable ground. Bailers are made in a variety of sizes to suit the casing in which they will work. The size used to describe a bailer is the casing size in which it operates, but in fact it is at least one size smaller. So a 4-inch bailer is 3½" (90mm) diameter for free movement – allowing water to escape round the sides – in a casing having a nominal bore of 4 inches (100mm). The nomenclature is the same whether casing is steel or plastic. Bailers are fitted with several types of shoes and valves, depending on the use and materials being drilled. Better quality (more expensive) bailers have replaceable screw-on shoes, allowing the use of different valve types in the same shell. Extension shells increase the volume of water bailed per stroke.

Drilling Bits A wide variety of bits may be employed to suit the material being excavated. Hard material like rock requires a bit which will crush, and less hard materials need chopping bits to cut and crush.

CLAY CUTTERS

Any material having some cohesion (containing clay) can be excavated using either a clay cutter or a stubber bit. These operate in both wet and dry conditions, cutting extruded cores of clay or clayey sand – they also work with some sand/silt mixtures with suitable moisture content. The impact of these tools causes material to be extruded into the body for easy removal at ground level. Rapid progress is possible if the correct tools are applied to suitable materials. Both clay cutters and stubbers work well in some materials using a sliding hammer to drive the tool by repeated small blows. Multiple drops of about ½m will drive the tool into the material and allow a longer core to be withdrawn than a single long fall. The use of the sliding hammer in this way also allows catching devices to be used in clay cutters to retain sands and gravel, which would normally drop out of the tool. Plastic basket catchers and Valvate discs work well in granular materials, in both high and low window clay cutters. The picture shows soft sandy clay being drilled. Retaining devices are placed with appropriate support rings above the shoes of clay cutters. In some sands, the rings themselves will be sufficient to cause material to form a bridge and be retained in the tool.

Reamers

These are employed to ensure that drilling tools have space to operate without becoming trapped by suction, or having the speed of fall impeded by trapped air or water. They are cutters, which shave or enlarge a hole made by other tools, to at least one size greater than the tool nominal diameter. Generally they excavate material in the manner of a stubber, but can allow cuttings to fall into the space previously made by other bits and cutters. Reamers have air/water ways to prevent suction or resistance, and clearance angles to avoid entrapment. Some stubbers can also be employed as reamers.

A spade reamer enlarges the hole made by other tools.

Sinkers

In order to drive drill bits a certain amount of weight is required, provided by sinker bars. These have threaded connections, and can be coupled together to provide any weight required for the materials encountered. Sinkers are supplied in sizes and weights to suit the drilling machine capability, in units that are easy to handle. The normal tool weight for the Forager-55 is 250 Kg. As an example of a sinker bar, a 4" (100mm diameter) bar weighs 62 Kg per metre, and the Forager-55 rig allows a drill string of 4.5 metres. This maximum can be made up of bits and sinkers, but allowance must be made for the height of any casing protruding from the ground, which the drill string must clear for removal from the hole. We supply sinkers having a weight of up to about 100 Kg each, and from 70 to 140mm diameter.

Drilling Jar (Sliding hammer)

A sliding hammer can be used to cause a snatch to the drill string if it should be temporarily stuck. When used as a sliding hammer, repeated blows can be delivered to a tool without pulling it out between blows or falls. They are often used with stubbers, clay cutters or drive tubes to obtain a bigger sample than can normally be obtained by the long drop technique. They also allow dry drilling in granular materials if a suitable retainer device is used in the drilling tool – see under Clay Cutters above.

CASING

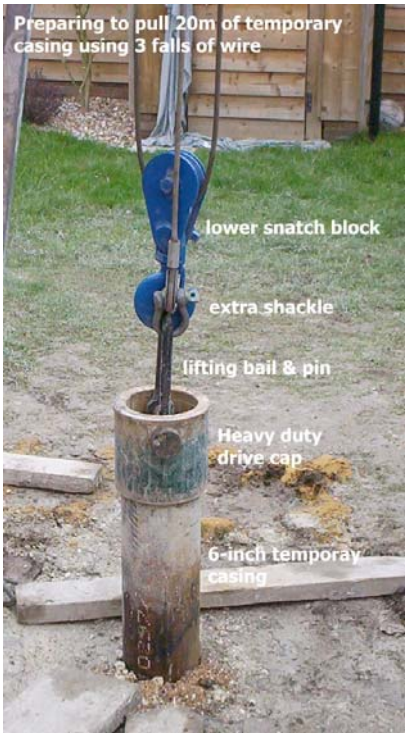
Flush jointed temporary steel water well casing to BS 879 (Flush butt)

This material is available in different lengths, but is most useful in 1.5m (5-foot) lengths for 'shell & auger' drilling by light cable percussion rigs. For the Forager-55, 6-inch nominal bore casing is a common starting size, but, depending on the anticipated ground conditions, 8-inch or 10-inch may be required. Tools sizes are based on the next pipe size down, so for 6-inch casing – 5-inch sized bailers, clay cutters stubbers etc. The casing is flush jointed inside and out. The threads butt to one another, allowing heavy driving if necessary. A leading shoe is used, which may be either the same size as the casing outer diameter, or oversized. A drive cap is used of a heavy section, allowing heavy driving without damage to either cap or casing threads. The drive cap is supplied with a cross-hole to take a bail and pin for lifting the casing string. A typical 1.5m length of this material weighs about 60 Kg. Casing shoes may be made oversize by adding hard-face welding – which can also be removed by grinding.

Temporary casing is used as a means of holding a hole open, or as a method of keeping a hole straight and reamed to size, while allowing drilling tools to work in a protected open space. It may also be

required in order to seal off unwanted water-yielding horizons. When possible, the 'loose casing' method of drilling is used, with heavy driving only if unavoidable. The 'loose casing method' operates by drilling ahead of the casing shoe. The self-weight of the casing is then allowed to ream the hole as lengths are added. Temporary casing also allows the installation of uncontaminated gravel packs of an even thickness around permanent screens & casing, before being pulled back.

A jacking system may be required for removal of temporary casing after the permanent casing, gravel pack etc. has been placed. This consists of hydraulic jacks and pump, arranged to give an upward force appropriate to the casing size. 20-ton and 40-ton sets for use with 6-inch casing are available. A hand-operated 20-ton version can be used to lift casing at about 2 metres per hour. The set applies an equalised force to the drive cap totalling 20,000 Kg. A power pack can be used in place of the hand pump; it requires a deliverable oil capacity of at least 5 litres and an operating pressure of 200 Bar. Having started the upward movement, casing can often be pulled by the rig using a multi-part tackle. The Forager-55 can employ a 7-part tackle to provide about 8 Tonnes of extraction force. The photo (right) shows a 3-part tackle being used. When using multi-part tackles, all the leg braces should be in place and the tripod feet prevented from spreading by an effective method.



3-part tackle being used with a Forager-55 to hoist out 20m of 6-inch temporary casing.

Plastic permanent casing

Usually threaded, flush, butt jointed and may be in uPVC or Polyethylene. This is the best for water well casing, but glued uPVC pipe can also be used. Glued pipe has O-Gee joints which are not flush, but formed by re-heating one end of a pipe and forming it into a socket with an inside about the same as the normal outside diameter of the pipe. The pipe's wall thickness is not critical for most shallow wells, and pipes made for drainage purposes can often be used. Pipes made for pressure purposes are better quality and strength, and should be used for heavier duty applications, deeper holes and in unstable ground.

Glued jointed uPVC casing, while being cheap, has the disadvantage that the joint protrudes from the general line of the pipe outer wall. UPVC plastic casing cannot be driven, so when glue jointed pipe is used as casing, it must be placed in a drilled hole which is big enough to avoid problems with inserting the stepped joints. This is not usually a problem if the hole is designed for a gravel pack and surface cementing for hygienic protection. Careful joint surface preparation, cleanliness and correct use of the glue (solvent cement) is essential if the joints are to hold while the casing string is installed

Flush jointed screwed casing in plastic, when fitted with a suitable (stainless) steel shoe, can be pushed and bumped – not driven – down a hole close in size to it's outside diameter. In some conditions it can be used in the same way as the loose steel casing discussed in the Introduction above, by drilling ahead of the shoe position and then pushing or pulling the casing down. Pulling a casing down requires the use of ground, or 'dead man', anchors.

The pull-down technique also works with 'stovepipe' casing. This is made by cutting cheap drainage pipe into short lengths, to form both inner and outer components of a composite tube. The inner component is slit lengthways and a suitable width strip removed. This allows it to be forced half way into a normal un-split similar length. If the lengths are uniformly about 2 feet each (600mm, say), the composites can be pushed as the hole progresses 2 feet at a time. Some glue can also be used with

both the makeup of the composite shells and when placing them as casing. Slitting can be done with normal hand metal (tinsmith's) shears, and cutting into lengths with a hack saw.

Flush butt threaded plastic casing has a limited allowable pullback force stated by the maker. None of the other plastic casing types have capacity for pulling back whatever. Neither glued joints, nor the push together stovepipe joints have any reliable resistance in tension, and the protrusions of the glued system of O-Gee joints makes pull-back virtually impossible unless the hole has been drilled very oversize in suitable material.

DRILLING

Cable percussion drilling

The Consallen Forager-55 is designed for drilling water wells and other holes for completion using 4-inch plastic casing. This means that a drilled hole is required which may be up to 6½ inches clear diameter for installation of casing and the placing of gravel pack and cementing. The basic purpose for which the machine was developed is the construction of low cost water wells as an alternative to hand digging in the Developing world - generally for use with hand pumps. The depth to which holes can be drilled in suitable conditions and using suitable tools is about the same as the length of wire supplied with the winch. The maximum is usually 60 metres, which also coincides with the capability of most hand pumps designed for community use. In some circumstances the hole can be as much as 100 metres, which is the limit for small (3") submersible pumps. These latter can be used in casing with a nominal 3-inch inside diameter – externally about 90mm. Such casing is a useful reduction from 4-inch casing used in upper layers.

Drilling Clays, and sand with some clay content (very common materials) and Laterite

Most material like clay, or sands exhibiting cohesive qualities can be rapidly drilled using clay cutters and stubbers. The falling tools cause cohesive materials to extrude into the tool, where it is retained. The material is then easily removed from the tool on being brought to the surface. Stubbers work well with softer clays, and the ease with which the tools can be cleared make this method a rapid drilling technique.

Using Stubbers

One of the clay cutting bits, which operates by extruding cohesive material through the cutter ring into the spaces between the three legs. Stubbers operate by either the long drop method, or by using a sliding hammer in harder clays, and are simply and easily emptied at ground level.

This version has a threaded connection at the top allowing it to be screwed to a heavy sinker bar, which drives it into the material being drilled. This tool is 140mm diameter and is being driven by a 100 Kg. sinker bar of 125mm diameter.

Stiffer clays may require a clay cutter, with one or more sinker bars to deliver suitable force, depending on the available fall, and number of sinkers employed. Several falls may be needed to fill the cutter, while at times the cutter may fill readily with a single fall of the tools. Another method of using a clay cutter is to empty it after each fall, using a swan-neck clearing tool. Clay cutters also obtain excellent results in conjunction with sliding hammers.

Stubbers and clay cutters operating in clay require adequate clearance to prevent them and sinkers acting like pistons in a cylinder. Unless reaming follows the tools quite closely, the effect of a falling tool string can be neutralised by air trapped in the hole forming a cushion. Also, with the cushioning effect, suction may prevent easy removal of the tool string. Suction increases with water in the hole, which can also cause clays to swell, further impeding both the fall of the tools and their recovery, making reaming an important activity.
Usually it will be necessary to ream a clay hole as soon as the hole advances more than a metre or so beyond the last reamed position. However, the driller will be aware of how the tools are performing and the need or otherwise to ream.

Stubbers may also work in some sands, which although having no cohesion, can behave as if they had, and will readily pack into the tool for removal at ground level.

Sands, gravel, cobbles and Silt
Sands gravel, cobbles (large gravel) and silts, which are dry, can appear very hard. They can be drilled using a clay cutter, to which has been fitted a bailer valve. The added weight of a sinker bar allows the cutting shoe to drive into the material, which is then retained by the valve. As an alternative to a bailer valve, a plastic core retainer can be fitted and used very effectively. In other types of sand, a simple extrusion ring can be relied on to retain a plug of sand in a clay cutter. The tool can be emptied using a suitable scoop at ground level in the case of valves and core retainers, but an extrusion ring requires only the use of a swan-neck expressing tool. The technique also works in wet sand, and removes only small amount, of water from the hole. Loose sands can also be drilled using a bailer and sufficient added water to allow entry through a clack valve. The surge of water round the tools as they are pulled up scours sands into suspension, allowing them to be captured by the tool as it falls. Some sands may drill better with a cutter shoe on the bailer, and a sand pump can be tried if there the hole is making water. The basket catcher will retain large cobbles up to about 120mm across, which would not pass through a clack valve.

Most sands and silts will not stand below water level and some provision for casing must be made when water is found. Either casing must be installed, and/or sufficient water, or light mud, must be maintained to stabilise the section. If this is not the main water-bearing horizon, a casing will usually be required to isolate it, perhaps also with a cementing process. Further drilling will be at a reduced size. Sand pumps, and sampling tubes with suction valves can be used in sands and silts below water level. Often, bailing inside a screen or casing will allow the tube to sink under it's own weight in water-bearing sands. Good progress can often be made using a bailer and very short strokes to surge sand, silt and gravel into the tool. Using a clay cutter in the same way and in the same material removes less water from the hole, while removing the material. Removing less water reduces the risk of the hole collapsing, while making space for advancing the casing.

Hard Ground
Indurated Laterite, Shale & Marls
Laterite is a material with a significant clay content, and may be drilled using stubbers and clay cutters. When it is dried out, the same material is more like marl or shale and needs drilling using a cross bit, chisel and some water to make slurry. Generally laterite will stand well and can be drilled easily. Marls and shale may slake, and absorb water. All three of these materials may swell on water absorption or relief of pressure, causing the hole to reduce in diameter; reaming is part of the solution.

Limestone, coral, dolomite & chalk
Use a chisel or a cross bit to fragment the rock and add sufficient water to mix into slurry, which can then be bailed out; no collapse problems in these materials. In some conditions, the bailer alone can be used both to break up the material, and bail it out of the hole. A stubber works well in softer chalk, as does a clay cutter – aided by a sliding hammer in some cases – a cross bit is also very reliable. In very hard limestones a button bit may be needed to crush the material, and a suitable weight of sinkers will

be required. A 6-inch tungsten carbide button bit may need 500 Kg (1100 lbs) of sinker bar to make progress.

Granite, Basalt & other igneous rocks
These brittle rocks can be crushed with a blunt chisel bit, and combined with water into slurry. A California regular bit may be used, or a bit with tungsten carbide button inserts – see above. A cross bit with hard faced edges may also work.

GENERAL

A successful driller needs to be resourceful & aware at all times of the way the tools are operating, and with an eye on rate of progress. Tools can get stuck, and he needs to know what resources are available to him to free them. The drilling cable has greater strength than the winch, the capacity of which can be multiplied by use of snatch blocks and a wire grip. A wire grip and levers can be used to quickly free tools, in addition to the effect of a sliding hammer. The tripod has a capacity exceeding that of the wire, but both can be hauled at more than the normal load if factors of safety are eroded. The breaking load of the 10mm wire we supply as standard is about 6500 Kg (6½ tons or 14,300 Lbs.).

KNOWN AFRICAN DRILLING PROBLEMS

The in-situ weathered overburden (Regolith) to Basement Complex rocks
[Regolith = The layer of loose heterogeneous material covering the bedrock made up of material originating through rock-weathering] Water should be found in the coarse material immediately above the un-weathered bedrock.

This material is generally easy to drill by cable percussion methods, and therein lies a possible trap for the unwary. The surface layers are often a firm to stiff lateritic clay, which stands well and is easy drilling. There may be 15 metres or more of this material, which may contain stones or rocks. Below is a softer clay material descending into silty clay, frequently showing signs of water. This is the dangerous material because progress is rapid and the presence of some water leads the driller to think that he is close to completing the well. The danger is that there may be a sudden collapse of the soft wet material, which exhibits properties like a 'running sand'. This material may rise up a borehole, completely smothering the tools, and making them impossible to withdraw. The mixture of clay, silt, sand and water under pressure may rise 6 or more metres up the hole.

One answer to the problem is to case the hole as far as possible upon first signs of water, and in the obvious presence of wet silt-rich clay materials. Maintain at least 3 metres of water in the hole while drilling on, and advancing the casing at the same time. The casing will protect the hole and the drilling tools only while there is a sufficient head of water to prevent the 'running sand' from collapse. Further drilling will take the hole into a cleaner sandier material that does not 'run', as it contains less clay and silt. At this point, the natural standing water level can be established in the hole, and bailing may determine the possible yield. If satisfactory, the screen and permanent casing can be installed, together with gravel pack & casing stabiliser. The hole should be continued if possible into the coarse screenable material, which is located immediately above bedrock. Most water is found in this area, and is usually of the best available quality. It should be noted that the danger of collapse does not disappear until a casing has been placed through the running sand area. On passing through to the coarser material, the water being used to hold back the running sand may be lost downwards into the main aquifer, allowing collapse. There are occasions where the lateritic layers are either thin or completely absent, and the problems start closer to ground level; the solutions are similar.

Another approach to the 'running sand' problem is to employ temporary **steel** casing – if it is available - to hold the hole open. This has the advantage that it can be driven through the layers liable to run. However, keeping enough water in the hole is still necessary in order to prevent running material shooting up and trapping the tools. Standard flush jointed steel casing can be used either with normal

shoes on the bottom, or with oversized shoes. The latter can be used with Bentonite clay, if available, to fill the additional space formed by the oversized shoe. The Bentonite forms a wet, slick, sleeve between the casing and the ground to be supported; it provides hydrostatic support to the hole and any material likely to run. The Bentonite slick assists in removing the temporary casing after the permanent well casing has been installed.

Keeping water in the hole while drilling can be done using the clay-cutter, tool with a bailer valve fitted. The excavated material can be removed from the clay-cutter window by hand, and the removal of water is minimised. Using a basket catcher in the clay-cutter has the same effect, and allows the use of the sliding hammer to advance the clay-cutter.

TEMPORARY CASING

The following are required for drilling using flush jointed steel casing: a quantity of casing in lengths of 1.5 metres, casing shoe, drive cap, lifting bail, swivel hook, set of 2 no. double sheave snatch blocks, casing clamps & chain wrench. These items comprise a set of equipment typically used for water well drilling in UK, where the soils are very variable. The basket catcher arrangement consists of a plastic basket, and two steel support rings. Widely used here, they are very useful in retaining granular materials and soft clay, which fails to stick in the clay-cutter. Temporary casing in 1.5 metre lengths for easy handling, and in the 6-inch size weighs about 90 Kg per piece. Bentonite is supplied in 25 Kg bags and is used in mixtures of 1 Kg into 10 litres of water.

ROCKS

The Regolith, may also contain randomly distributed large rocks, which have become detached from the main bedrock; they may be at almost any level. These rocks are often the reason for the failure of hand dug excavations for wells. They vary in size from that of a football to perhaps 10 metres or more. Whereas cable percussion drilling will – in time – penetrate these rocks, it is unprofitable to spend much time trying. If a rock is struck, which is clearly large, at a level, which indicates it is not 'bedrock' it is generally better to move the rig rather than to persist with drilling. Moving the rig perhaps 50 metres in any direction will usually be sufficient to find the limit of the rock, and avoid unprofitable pounding, and also wear and tear on the tools. It is quicker to find a place where there are no rocks by moving the rig than to spend time trying to drill through.

WIRE GRIP (Wire Puller)

The picture on the left shows a typical wire. The load is carried on the Load Point, which may be any distance below the grip, with the Hoist Point attached to the lower of a pair of snatch blocks. The upper snatch block would be attached to the rig frame near the apex at the strong-point provided.

The wire grip may also be used with a suitable lever as a quick means of giving an extra heave to stuck tools.

The Wire grip shown has a maximum safe working load of 2000 Kg, and can accommodate up to 5/8" (19mm) diameter wire.