DRILLING METHODS

This continuing education unit reviews drilling methods common to drillers, with an emphasis on water well drilling methods. For completeness mention is made of methods or tools used in the oil & gas industry. Often methods or tools first employed in the oil or gas drilling industry eventually find their way into the water well drilling field. As well mention is made of drilling methods employed in the geotechnical or environmental drilling sector. However the coverage of the methods and tool of the geotechnical or environmental sector is not exhaustive.

Many drillers adopt their chosen method of both hole-making and hole clearing and become experts over time. Long and successful careers are had by working within the method of drilling/hole clearing chosen. These drillers identify themselves by their chosen methods: "cable tool driller" "mud rotary driller," "environmental/geotechnical driller." Large companies look for these specialists when seeking new employees.

Other drillers, by choice, or happenstance are exposed to several methods of making hole and hole clearing. These drillers become comfortable using different approaches depending upon hole size, engineering specifications, equipment availability and geology.

The material below reviews the range of hole making and hole clearing approaches in common use in the drilling industry.

Hole making methods

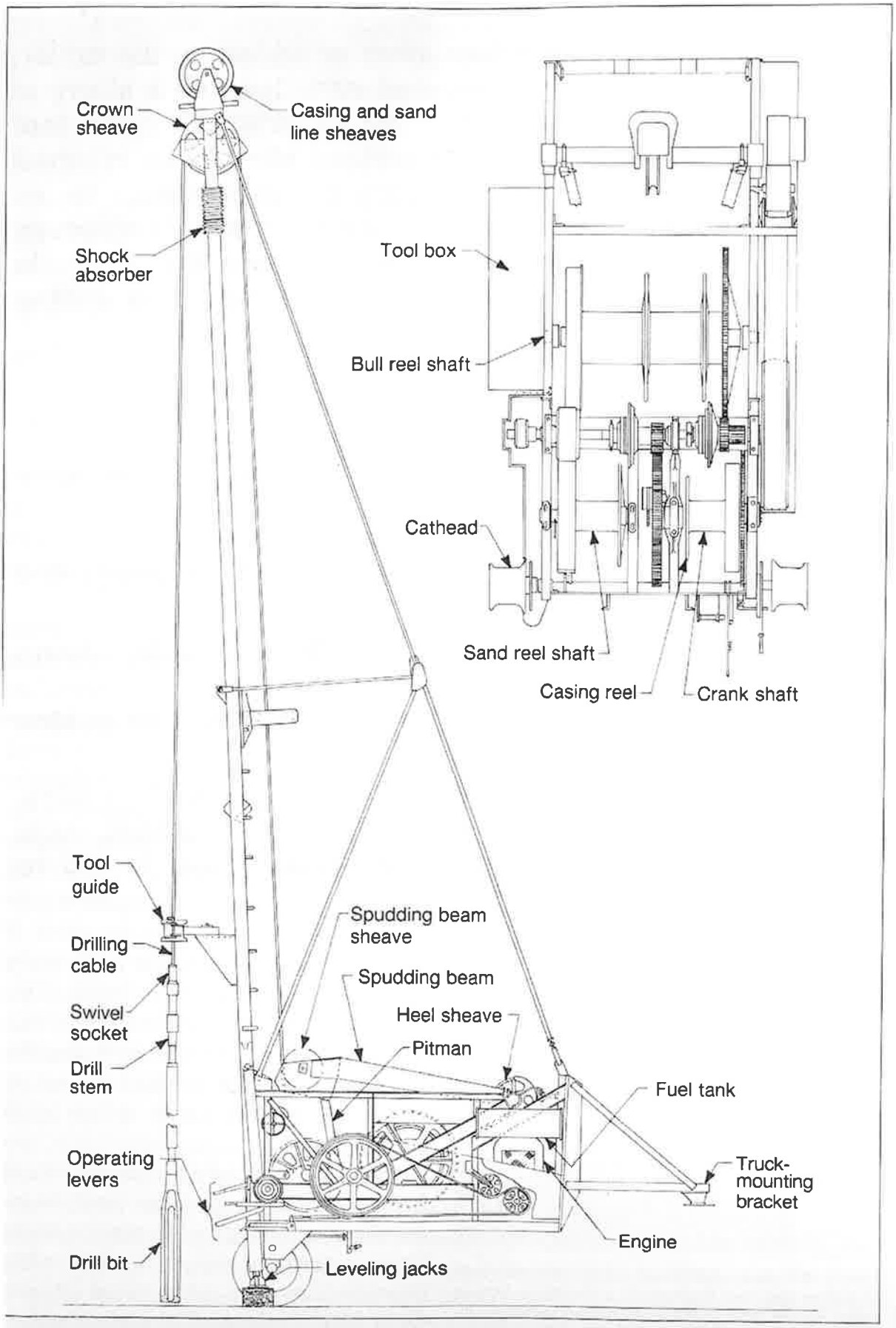
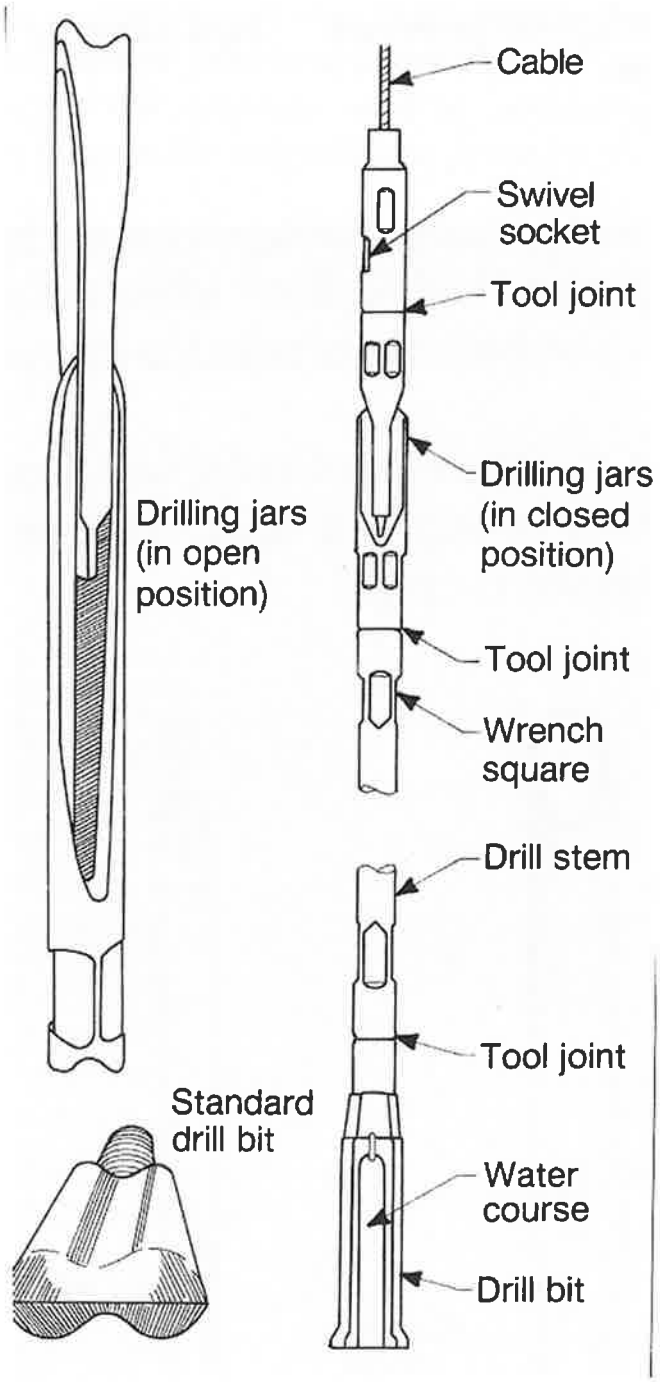


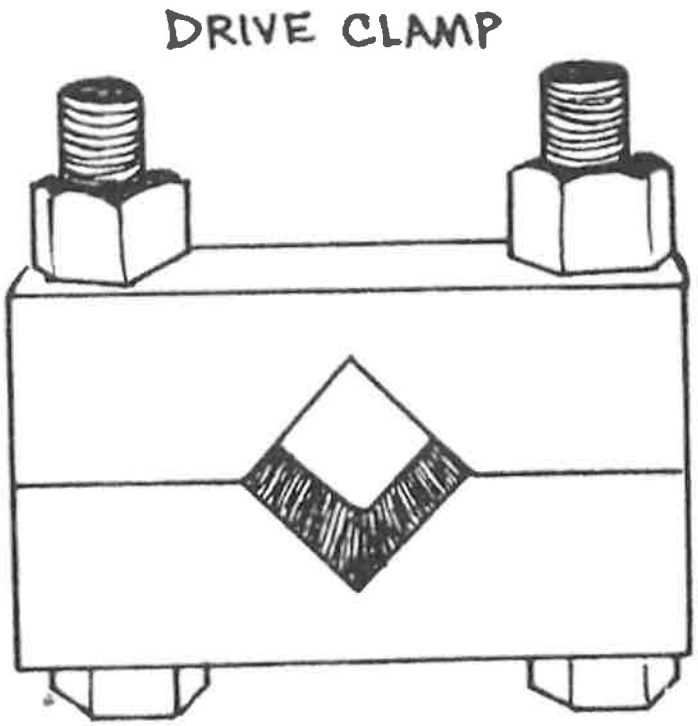
Figure 10.3. Engineering drawing of a Bucyrus-Erie Model 22-W shows how the drill line is reeved in a typical cable tool rig. The spudding action is



Tool joints connect the drill string components. Depending on formation the driller may add drilling jars to the drill string. The hammering action provided by

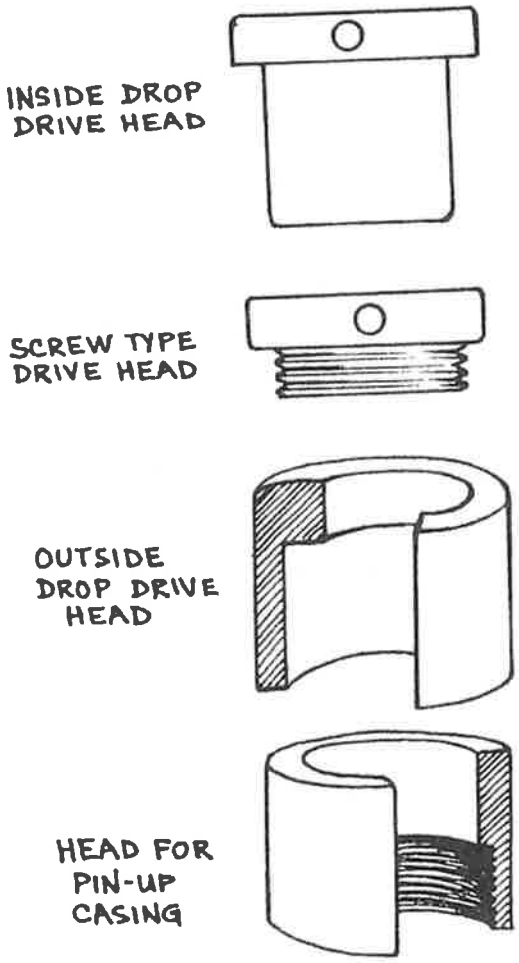
A bailer is run on a separate bailing line and is inserted after the drill string is removed from the hole. The bailer is used to remove slurry from the hole so that efficient penetration can continue.

Cable Tool Casing Driving Equipment

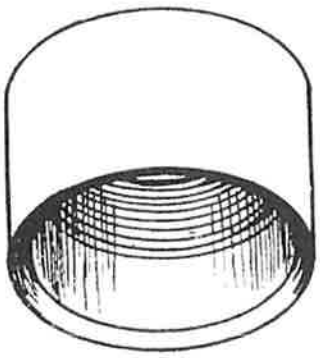


The driving of casing is an integral part of cable tool drilling. The driving force is provided by a drive clamp attached to the drill string. A wrench square is forged in the drill stem to allow for the attachment of the drive clamp.

A drive head is fitted or screwed to the top of the casing, to protect the casing from damage when being driven.



Casing which is to be driven is fitted with a **drive shoe.**



DRIVE SHOE

with the driving of casing the insertion of the drill bit, the operation of the bit until a slurry is formed and the bailing of the slurry until the casing reaches a desired depth.

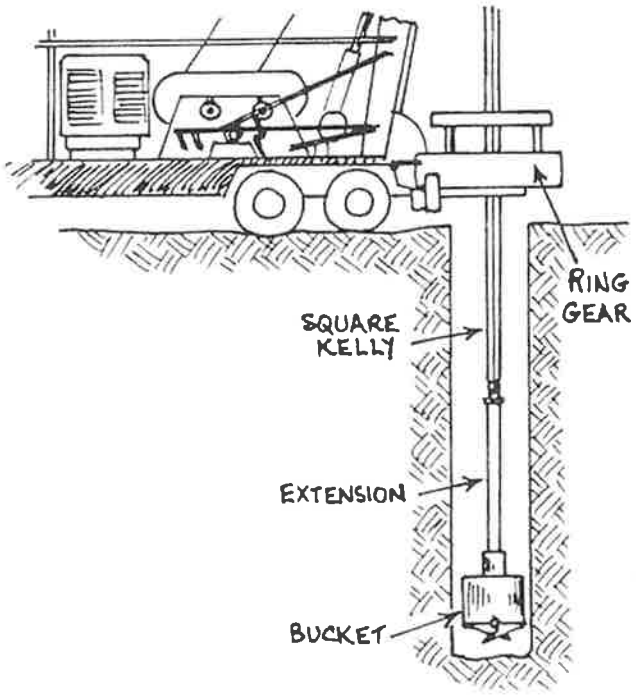
While drilling, a depth may be reached where casing cannot be driven further without risking damage to it. If this point is reached and sufficient water has not yet been found, the casing diameter will then be reduced and drilling will continue inside the smaller casing. Drillers anticipating the need to telescope casing downward will begin drilling a borehole of a larger size to accommodate telescoping down during the drilling process.

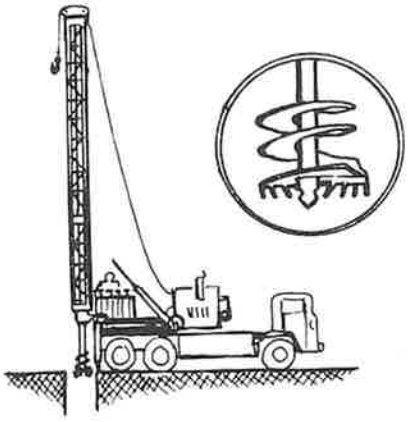
Advantages of the cable tool:

1. Highly suitable for remote settings. The cable tool's low fuel consumption, small needs for water and other materials and reliability make it an excellent choice for remote site locations.
2. Low capital investment and cheap maintenance. Capital costs of new cable tool rigs are generally significantly less than the costs of new rotary drilling machines of similar capacity. As well, cable tool maintenance is less expensive than parts for the less mechanical, more hydraulically equipped rotary systems.
3. Particularly suited to water poor areas. Cable tool drilling more easily identifies each water bearing formation penetrated, even those of small yields.
4. Efficient use of personnel. Cable tool rigs are often operated by a single person.

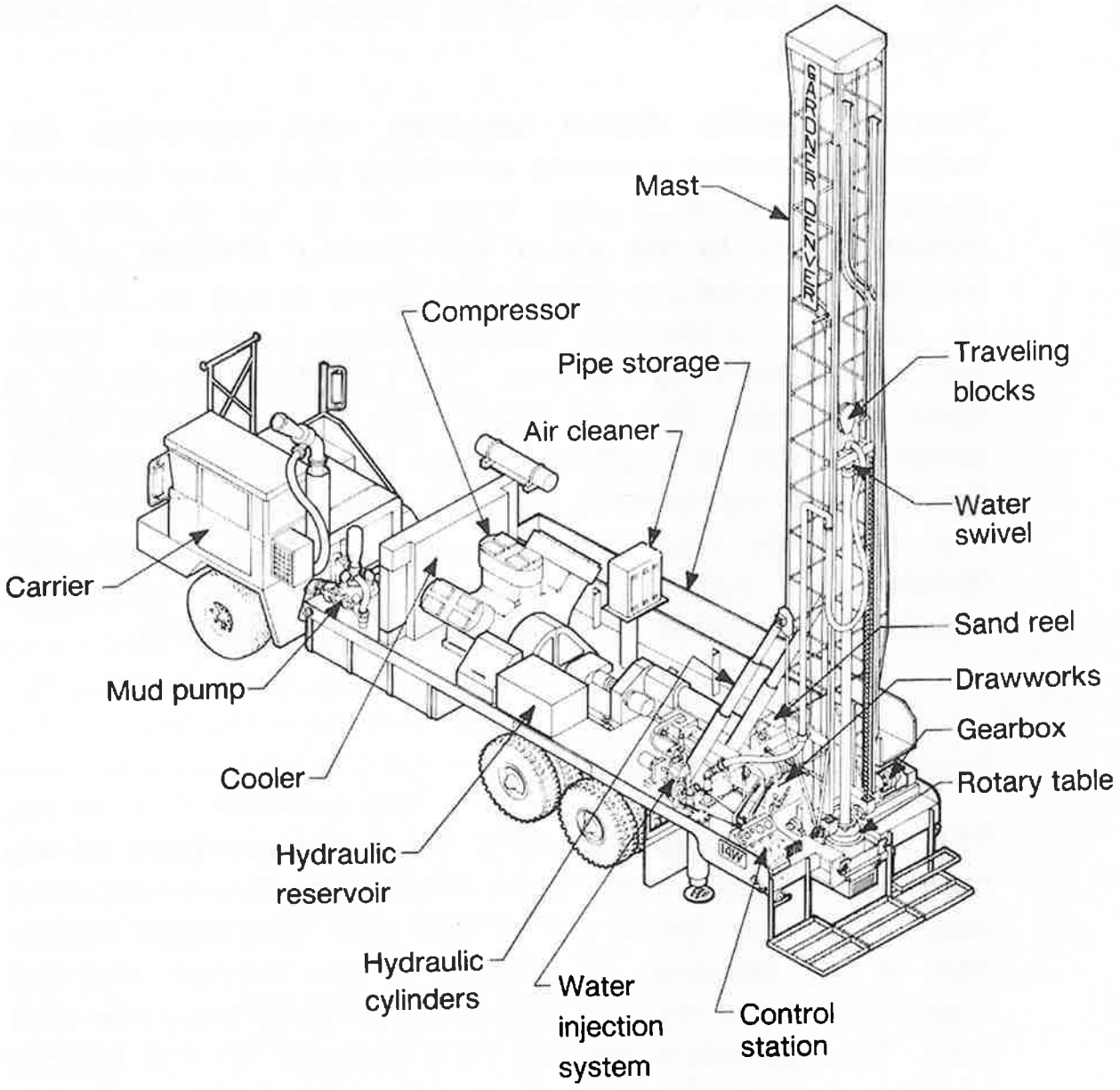
Disadvantages of Cable tool drilling:

Bucket augers: The cuttings are picked up in the bucket, hoisted to the surface and dumped through the hinged bottom of the bucket. Extensions are added as the hole gets deeper.





Rotary Drilling



1. Prime Movers

The prime movers in a rotary drilling rig are those pieces of equipment that provide the power to the entire rig. Steam engines provided the power to the early drill

drill pipe, drill bit, and drill collars (thicker drill pipe located just above the bit) may be in excess of thousands of pounds. The hoisting equipment is used to raise all of this equipment to the surface so that the drill bit may be replaced, at which point the entire chain of drill pipe is lowered back into the well.

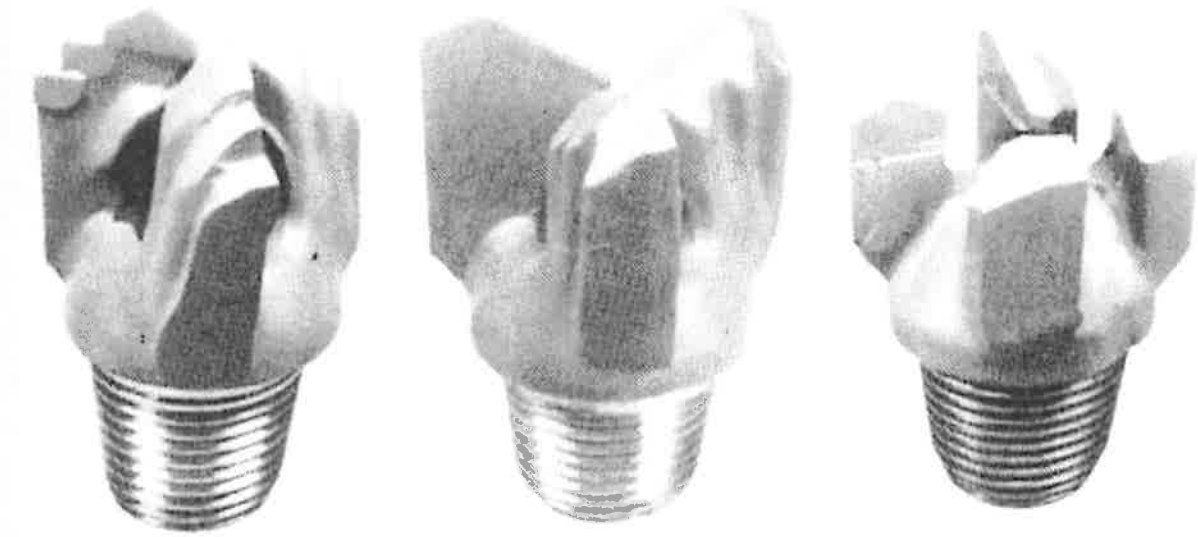
The height of a rigs derrick can often be a clue as to the depth of the well being dug. Drill pipe traditionally comes in 20ft sections, which are joined together as the well is dug deeper and deeper. This means that even if a well is 1200 feet deep, the drill string must still be taken out in 20 foot sections. However, if the derrick is tall enough, multiple joints of drill pipe may be removed at once, speeding up the process a great deal.

3. Rotating Equipment

The rotating equipment on a rotary drilling rig consists of the components that actually serve to rotate the drill bit, which in turn digs the hole deeper and deeper into the ground. The rotating equipment consists of a number of different parts, all of which contribute to transferring power from the prime mover to the drill bit itself. The prime mover supplies power to the rotary, which is the device that turns the drill pipe, which in turn is attached to the drill bit. A component called the swivel, which is attached to the hoisting equipment, carries the entire weight of the drill string, but allows it to rotate freely.

The drill pipe (which, when joined together, forms the drill string) consists of 20ft sections of heavy steel pipe. The pipes are threaded so that they can interlock together. Drill pipe is manufactured to meet specifications laid out by the American Petroleum

1. **Blade or Drag Bits forged steel with tungsten carbide cutting surfaces for drilling unconsolidated formations. Also called wing bits or fishtail bits were the first rotary bits. They are available in 3 way or 6 way designs.**
   Their cutting action is through a shearing action on the formation.



Drag bits with tungsten carbide inserts

2. **Steel Tooth Rotary Bits, tricone being the most common type. Rock or roller cone bits, as they are often known, were invented in the early 1900's and have evolved over the years. They are the most common drill bit type for all drilling industry sectors. Long tooth roller cone bits are used for soft formations with short toothed bits used for hard formations. The cutting action is through a crushing and chipping action. Tungsten carbide studs are used in place of**

4. Diamond Bits have industrial diamonds implanted in them, to drill through extremely hard rock formations. Diamond bits are forty to fifty times harder than traditional steel bits, and can thus be used to drill through extremely hard rock without dulling overly quickly.

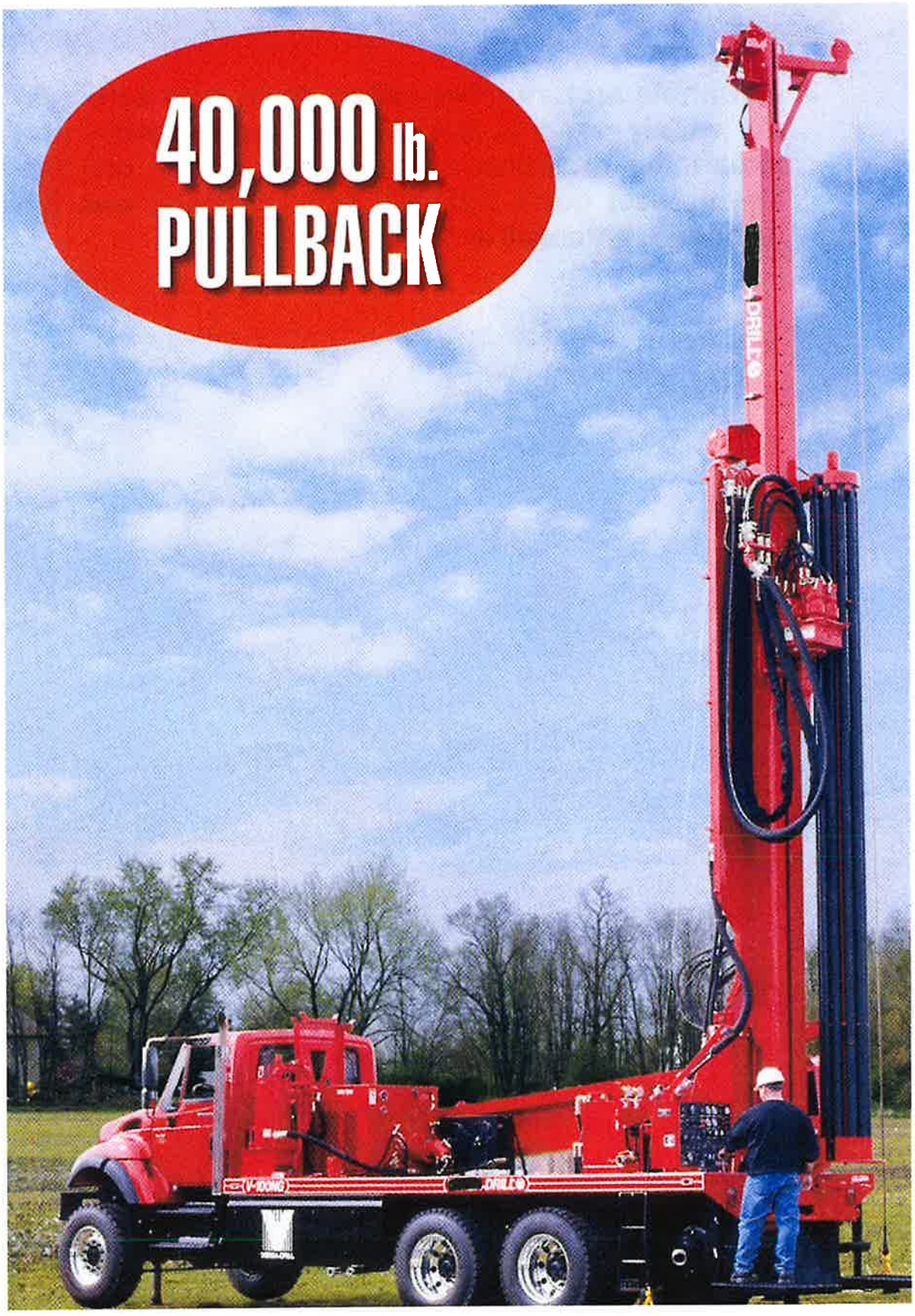
Bit types 1&2 are most commonly used in the water well drilling industry. Bit type 3, in addition to the oil and gas industry, also has applications in the directional drilling sector. Bit type 4 is used in geophysical drilling for coring applications

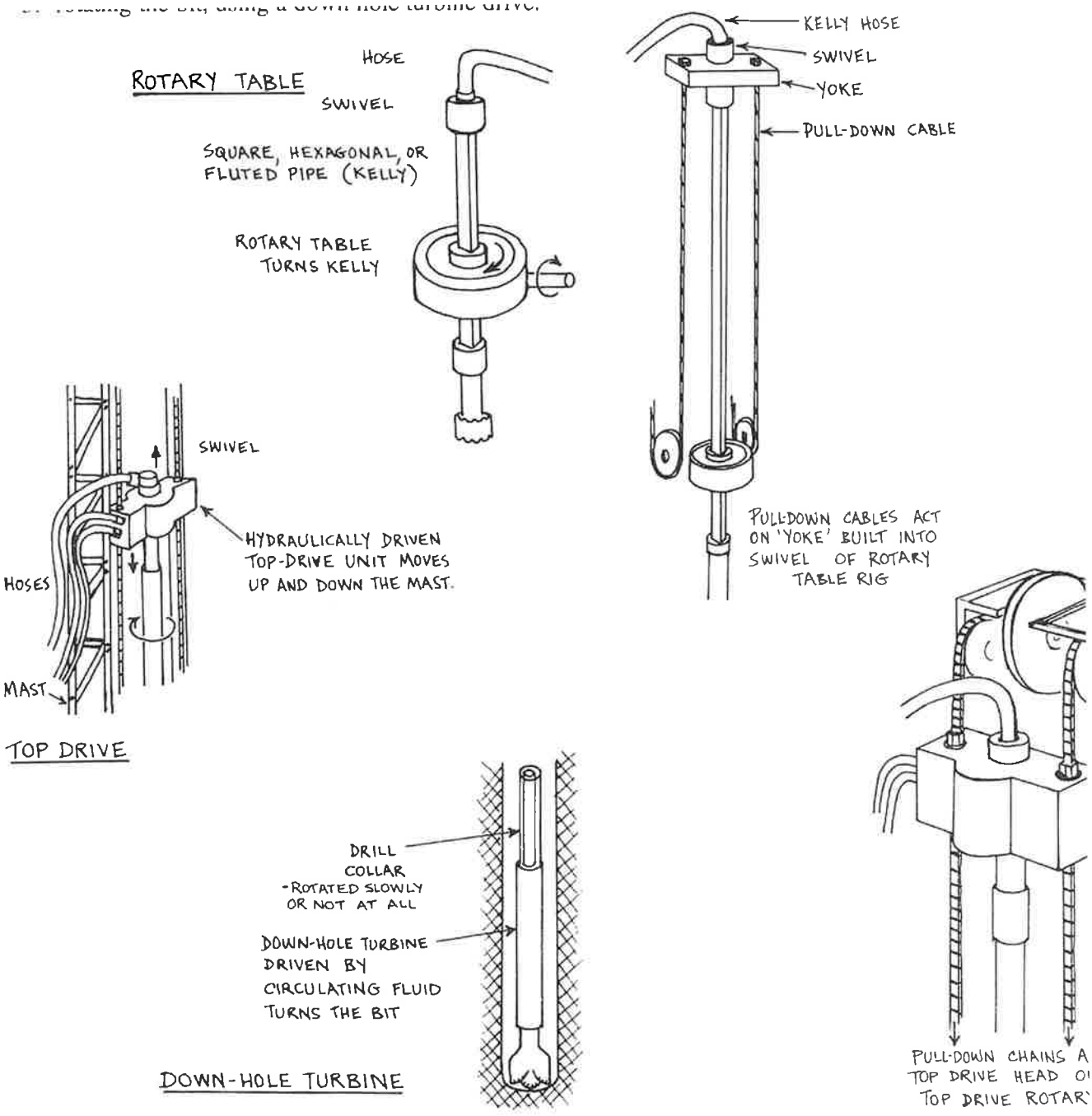
Regardless of the drill bit selected continuous cutting removal is essential to rotary drilling. It is an awareness of this fact that lead to the development of alternative means to achieve continuous cuttings removal in all geologic formations. Whatever circulation method chosen, the purpose of fluid circulation is to keep the hole clean and the bit turning freely against the bottom.

4. Circulating System

The final component of rotary drilling consists of the circulating system. There are a number of main objectives of this system, including cooling and lubricating the drill bit, removing debris and cuttings, and coating the walls of the well with a mud type-cake. The circulating system consists of drilling fluid, which is circulated down through the well hole throughout the drilling process. The components of the circulating system include drilling fluid pumps, compressors, related plumbing fixtures, and specialty injectors for the addition of additives to the fluid flow stream.

2. Rotating the drill string directly by a hydraulic unit attached directly to the top of the drill string.


40,000 lb.
PULLBACK



4. Dual rotary rigs which operate upper and lower top head drives impart rotary cutting motion to both the drill bit and casing.

found on more recently manufactured drill rigs, with screw, cable and chain pull down arrangements more commonly found on older rotary rigs.

The driller controls the pull-down pressure and thus the speed of penetration. It must be noted as said in the beginning of this text that part of the art of rotary drilling is the matching of pull-down pressure to the formation. Excessive pull-down pressure can damage drill bits, drill pipe and the trueness of the borehole. Thus applying more pull-down pressure is not always the best drilling practice.

Rotary Fluid Circulation

Rotary drilling requires one of several methods of fluid circulation to clear cuttings from the borehole. Several types of rotary drilling methods are best classified by the type of drilling fluid used, and/or the way in which the fluid is circulated through the borehole.

Direct circulation- Mud Rotary

The drilling fluid, much like the bit, is custom designed and chosen depending on what type of subsurface conditions are expected or experienced. The drilling fluid chosen must have a number of properties to allow it to accomplish its tasks.

It must be light and thin enough to circulate through the drill bit, cooling the bit as it drills as well as lubricating the moving parts. The fluid must be heavy enough to carry drill cuttings away from the bit and back to the surface. In addition, the drilling fluid must be thick enough to coat the borehole with a cake, which serves to temporarily seal the walls of the well until casing can be installed.

In direct circulation drilling the circulating system consists of a starting point, the mud pit, where the drilling fluid ingredients are stored. Mixing takes place at the mud pit or in a drum or mixer used for this purpose. After mixing or the addition of additives the fluid is forced through pumps up to the swivel and down all the way through the drill pipe, emerging through the drill bit itself. From there, the drilling fluid circulates through the bit, picking up debris and drill cuttings, to be circulated back up the well, traveling between the drill string and the walls of the well (also called the 'annular space').

At the surface the fluid is channeled into settling pits or tanks where most of the cuttings settle out. Clean fluid is picked up from the opposite end of the settling area. If portable mud pits are employed, a series of baffles is used to aid in the settling process. The drilling fluid is then re-circulated down the hole. The process is repeated until drilling is completed.

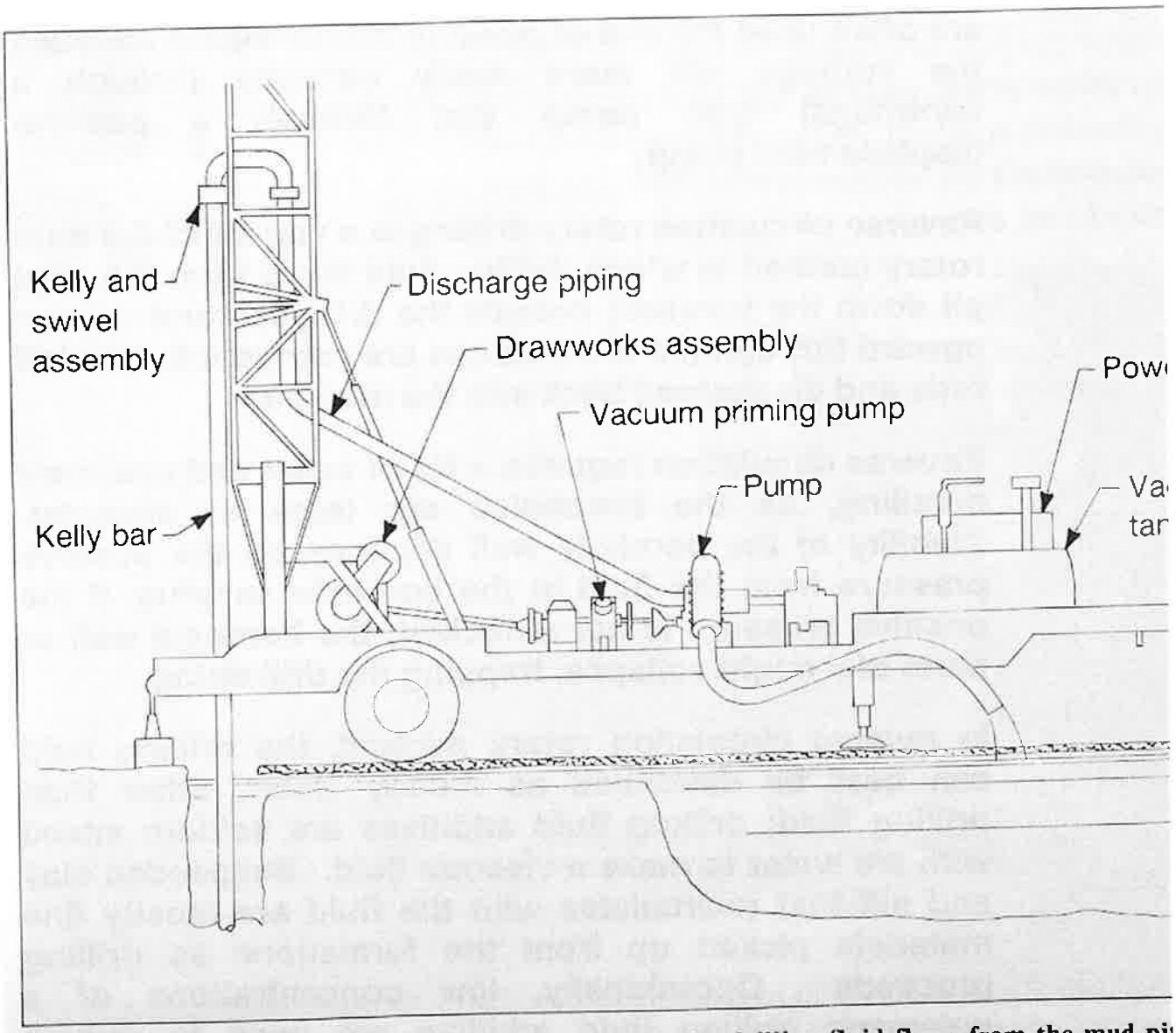


Figure 10.26. In a reverse rotary circulation system, the drilling fluid flows from the mud pi borehole outside the drill rods, then passes upward through the bit into the drill rods after the cuttings. After flowing through the swivel and mud pump, it passes into the mud pit where t

Reverse circulation drilling was developed to allow for larger borehole drilling without the limiting factors of drilling fluid pump capacities. Rotary rigs designed for reverse circulation have larger capacity mud pumps and air compressors to allow for increased pressures needed to insure the removal of cuttings from large boreholes. These drill rigs are far larger than those used for domestic purposes. Centrifugal mud pumps

downward moving water outside the drill pipe are what support the borehole wall. Erosion of the wall is usually not a problem because velocity in the annular space in low.

A considerable quantity of make up water is usually required and must be immediately available at all times when drilling in permeable sand and gravel. Under these conditions, water loss can increase suddenly, and if this causes the fluid level in the hole to drop significantly below the ground surface, caving usually results. Water loss can be addressed by the addition of clay additives, but this action is only taken as a last resort.

Often to aid the upward movement of water through the drill string, air is injected, lifting the contents to the surface. Another reason to use air is the fact that the suction pump lift is limited in its capacity to create enough vacuum to start up the water movement after a rod change. When air lifting is used to assist in reverse mud drilling this method becomes similar to the reverse air rotary drilling method discussed below.

Reverse mud is a cost effective method for drilling bore holes of 24" and greater. This method is most successful in unconsolidated formations.

Advantages of Reverse Circulation Mud Rotary

1. The near-well area of the borehole is relatively undisturbed and uncontaminated with drilling additives and the porosity and permeability of the formation remains close to its original hydrogeologic condition.

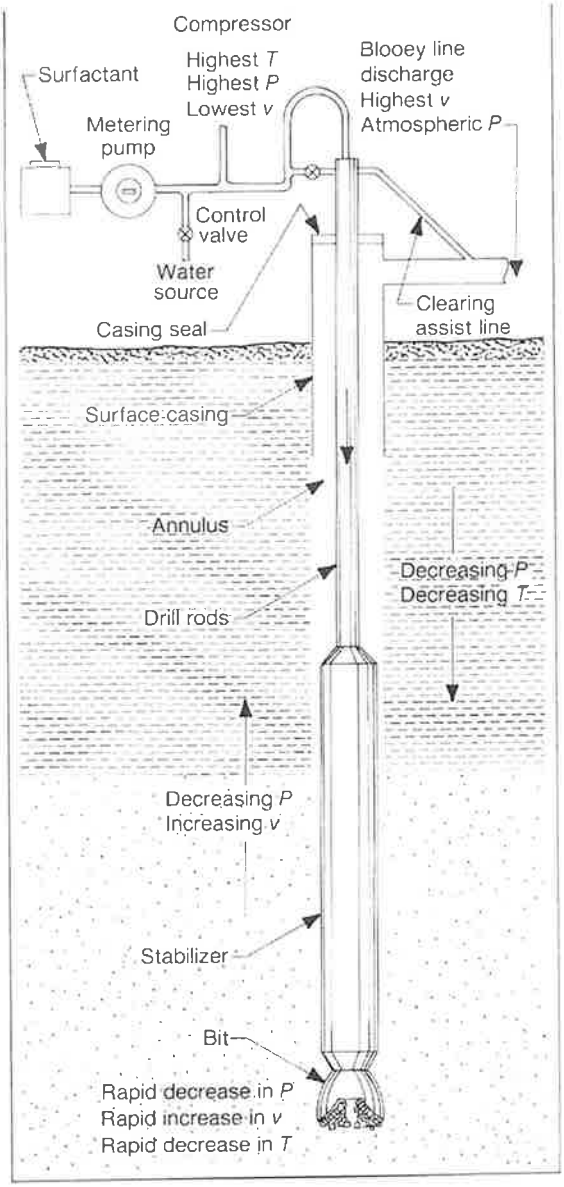


Figure 11.30. Basic components of an operating air rotary circulation system showing the pressure and volume conditions in the drilling fluid at various sites. Greatest pressure and volume changes generally occur at the bit, which is the most critical point in an air drilling-fluid system.

Air is low in density. It is also low in viscosity, having a viscosity approximately 2% that of water. Therefore the up-hole or bailing velocity must be at least 20 times as high as the velocity required when using water. Air drilling has many advantages:

Figure 11.34. The liquid-volume fraction determines how the foam looks as it leave the foam is relatively dry, it collects around the top of the borehole (left). If the LV tends to run away on the surface of the water brought up the borehole. *(Nelson Well Service Company)*

Roller-type rock bits, similar those designed for drilling with water-based fluid, can be used when drilling with air. Tricone rock bits are commonly used. Button bits are also used successfully. Field test have shown faster penetration rates and longer bit life when using air and compared with water-based drilling fluids.

The path for fluid circulation when drilling using direct rotary air is somewhat the same as for mud rotary drilling:

A tremie pipe is inserted inside the drill pipe with a check valve on the bottom of the tremie. Once the formation has produced water reverse air drilling can be begun. As drill rods are added, lengths of tremie pipe are also added until the tremie is submerged more than 20 ft. Air is introduced into the tremie which aerates the column of water within the drill rod. The now aerated column is less heavy then the fluid outside the drill pipe.

Extra work required to add and remove tremie line during tripping in and tripping out
slower pace of drilling
plugging of string
broken tremie or dislodged check valve

Down the hole air hammer

To drill effectively in hard formations, rotary bits require very high pull down pressures. These pressures may be beyond the design capabilities of small to medium drill rigs. And, as was stated earlier, excessive pull down pressures may damage the drill string and deflect the trueness of the hole. If the hard rock formation is near the surface, even larger rigs have trouble with penetration as the weight of the drill string is not relatively great when drilling is beginning.

The down hole hammer is an air activated percussive drilling bit which operates in the manner of the jack hammer commonly seen in surface construction. Constructed from alloy steel with heavy tungsten-carbide inserts that provide the cutting or chipping surfaces. These inserts are subject to wear and may be replaced or reground improve penetration rates. Corrosion (rust) is the DHH's greatest enemy. It must be kept well lubricated at all times. And it should be opened and inspected after every 100 hours of continuous operation.

Advantages of Down the Hole Hammer

- fastest hard formation penetration method
- aquifer not tampered with by muds
- extended bit life
- cold weather non factor
- easy yield estimates
- no mud pumps

Disadvantages of Down the Hole Hammer

- initial costs of air compressors
- maintenance and repair costs of compressor and DHH

Jet Drilling

Drilling in unconsolidated formation with high water availability allows jet drilling to be a viable drilling method. Often employed in drilling shallow irrigation wells, jet drilling is achieved by water circulation down through the rods washing cuttings from in front of the bit. The cutting flow up the annular space and in a settling pit so that the water can be recirculated.

Jetting in semi consolidated formations may be assisted by using a hammering technique to "chop" through hard bands. This technique is a combination of jetting and percussion. A fish-tail type rotary bit may be used and the pipe rotated to "cut the hole. All hydraulic (water based) drilling requires that the hole be kept full off water until it is cased.

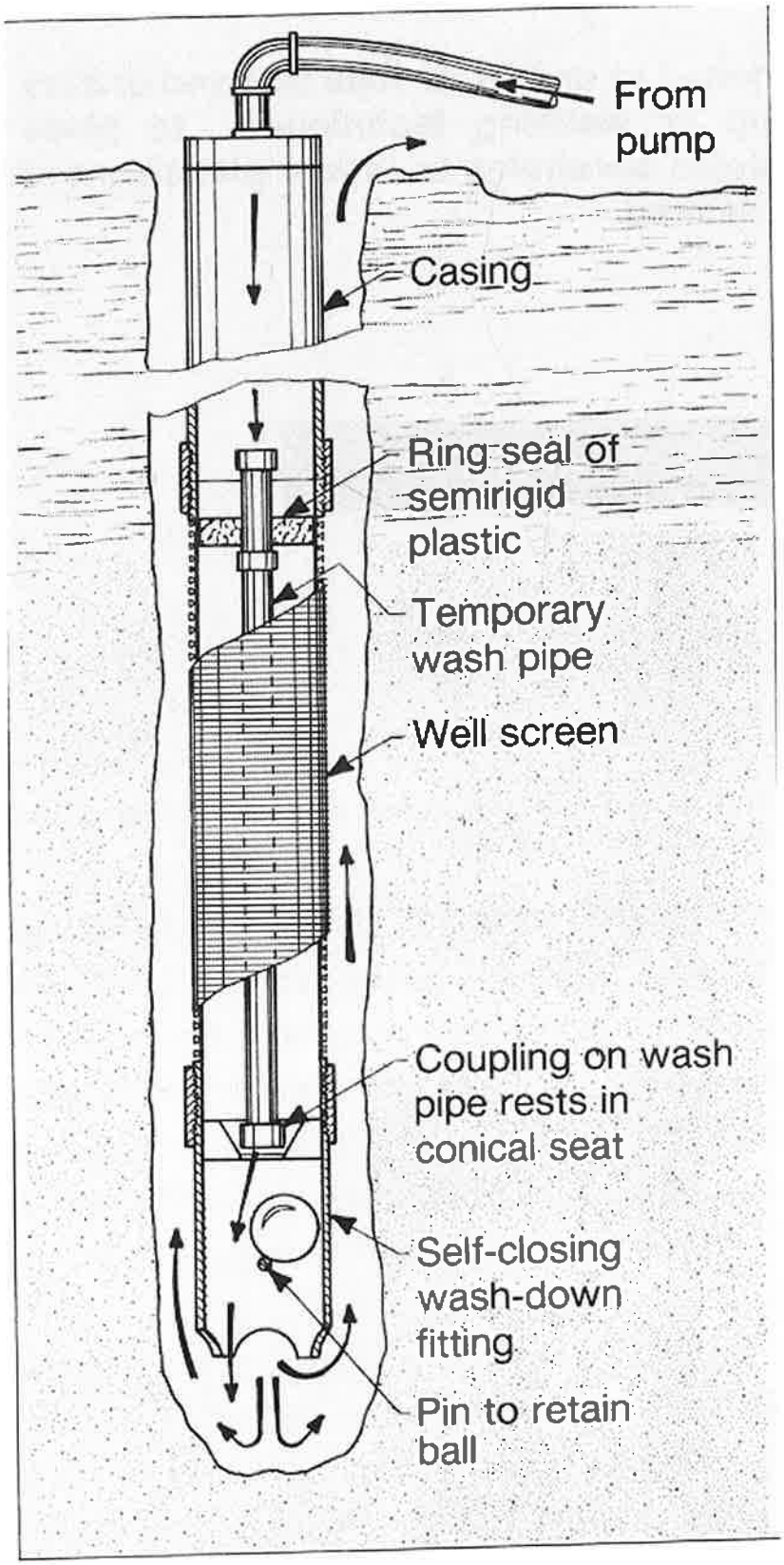


Figure 14.28. Small-diameter screens can be washed into place by jetting through a wash pipe and wash-down bottom with floating-ball valve.