Date :

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Course :

Well Completion – Production

Cased Hole Completion

To prepare a well to production, the oil string is set thru the pay zone, and the casing is perforated. Then, tubing is run into the well, and the packer is set to seal the space between the tubing and the casing. This is usually accomplished by placing some of the weight of the tubing on the packer. Friction devices, ~~Know~~ known as slips, prevent the packer from slipping down in the well.

Open Hole Completion

In cases where the producing formation is well consolidated, the oil-string casing is run and cemented at the top of the pay zone, and the hole is left open below that point

Liner Completion

There are other ways to bring the well into production. The casing may be set just above the pay zone. The producing formation is then drilled, and a small pipe (known as a liner) is run into the hole (Fig _) and cemented before the ~~formation~~ perforation process is started.

essure he y zone When a well is drilled, pressure in the pay zone is offset by the pressure of the drilling fluid in the hole. This fluid, of course, is left inside the casing after it is cemented so that the pressure of the ~~formation~~ fluid column will continue to hold back the formation pressure after the casing is perforated.

Set Tubing

The tubing is then run into the well. Displace the fluid in the tubing with water, and then set the packer — that is, seal the space between the tubing and the casing. This results in a column of water holding back the ~~pro~~ formation pressure.

Tubing

Because the casing and liner must remain in a well for a long time and their repair or replacement would be costly, another string of pipe is placed in the well thru which the oil is produced. This is called tubing and is used as the flow string.

During the later life of the well, the same tubing may be used to support a pump or for other means of artificial lift.

Tubing sizes range from 1 1/4 to 4 1/2 in. in diameter. The tubing is suspended from the well head (surface) and usually reaches to within a few feet of the bottom of the well.

[illegible] Tubing is used as the flow string because casing is usually too large to permit the well to flow efficiently, or (in some cases) to maintain continuous flow. Tubing is also ~~[illegible]~~ required in a pumping well to support the pump.

Packers

Tubing packers are sometimes used in the tubing string to seal off the space between the tubing and the oil string of casing. This is done particularly in wells where there are high reservoir pressure. By sealing off this space the casing is not exposed to high pressure, and the chances of a casing failure are reduced.

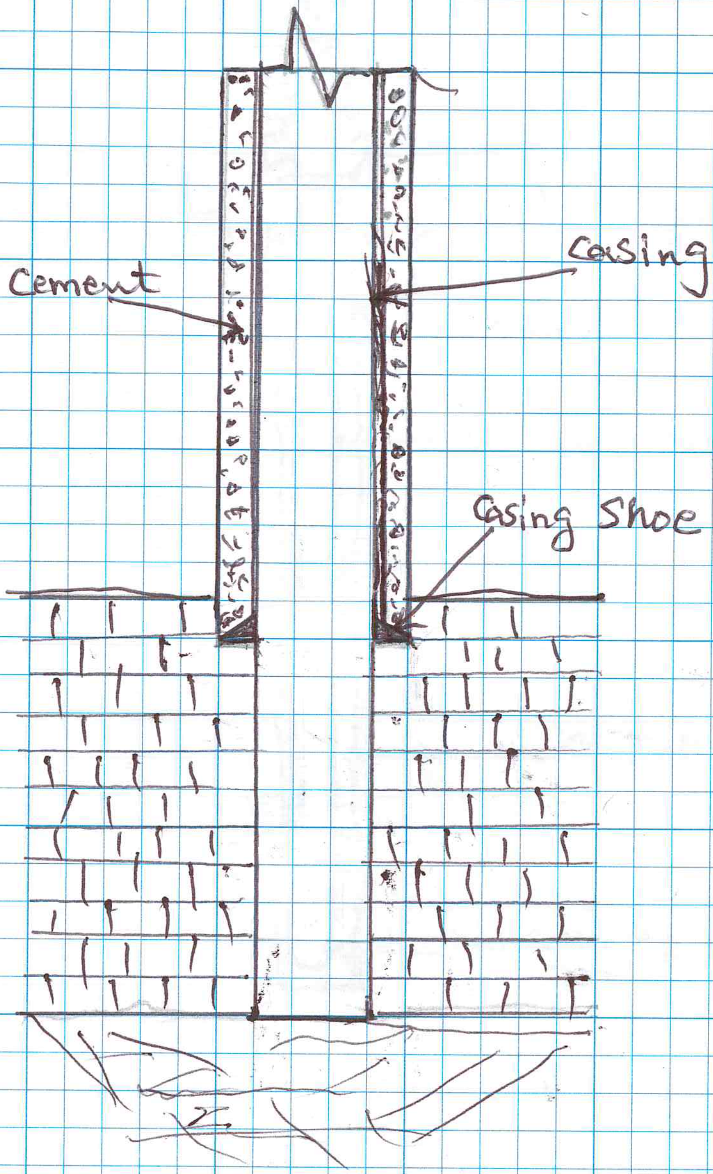
Tubing anchors and packers also support part of the weight of the tubing in the casing and prevent the tubing string from moving up and down.

Tubingless Completion

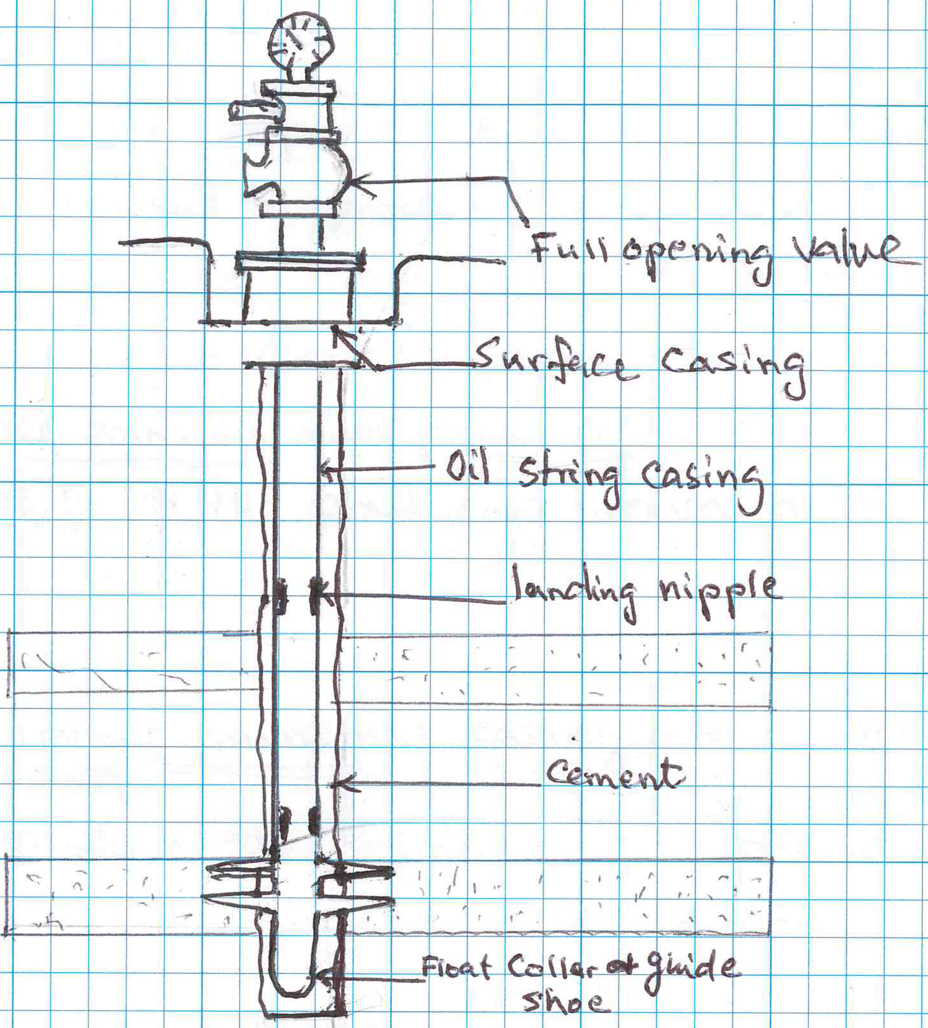
Sometimes it is both practical and economical to drill a small diameter hole and use conventional tubing as casing in completing a well. This is called a tubingless completion since no retrievable inner string of tubing is used to conduct fluids to the surface. The casing is ~~perforated~~ cemented from bottom to the top and perforated opposite the pay zone.

The equipment used is the same as in a conventional well, including a float collar, guide shoe with back pressure ~~valve~~ valve, and landing nipple. (see figure below).

Tubingless completions with pipe as small as $2\frac{7}{8}$ in. in outside diameter provide for well control, well stimulation, sand control, workover and artificial lift system.



Open-hole Completion



A schematic drawing of a tubingless completion

Perforating

Perforating is the process of piercing the casing wall and the cement to provide holes thru which formation fluids may enter. Perforation should

1. provide a clean, undamaged access between the annulus and producing formation.
2. Perforate the producing interval as far as possible
3. Shoot a smooth and round entrance hole in the casing
4. Produce minimal casing and cement damage, and
5. Produce the maximum flow rate with the minimum number of perforations.

Perforating Methods

There are two basic methods:

1. Bullet perforating, and
2. Jet perforating.

A bullet perforator offers greater performance in formations of low to moderate compressive strength.

Jet perforation is better in rocks having high compressive strength.

When determining which method to use, many factors – such as casing size, formation fluids, the formation, cementing procedure, hydrostatic pressure, and well temperature – must all be considered.

Artificial Lift

After the ~~well~~ tubing has been run, the pack set, and the well perforated, the well may not produce by natural flow. In such cases, artificial-lift equipment is usually installed to supplement the formation pressure, the mos common methods of providing artificial lift call for using gas lift or some sort of surface or subsurface pump.

Gas lift – Fig. 2-10
Sucker-Rod Pumps – Fig. 2-11
Hydraulic Pumps – Fig. 2-12
Submersible electric Pumps – Fig. 2-13

CHAPTER 2

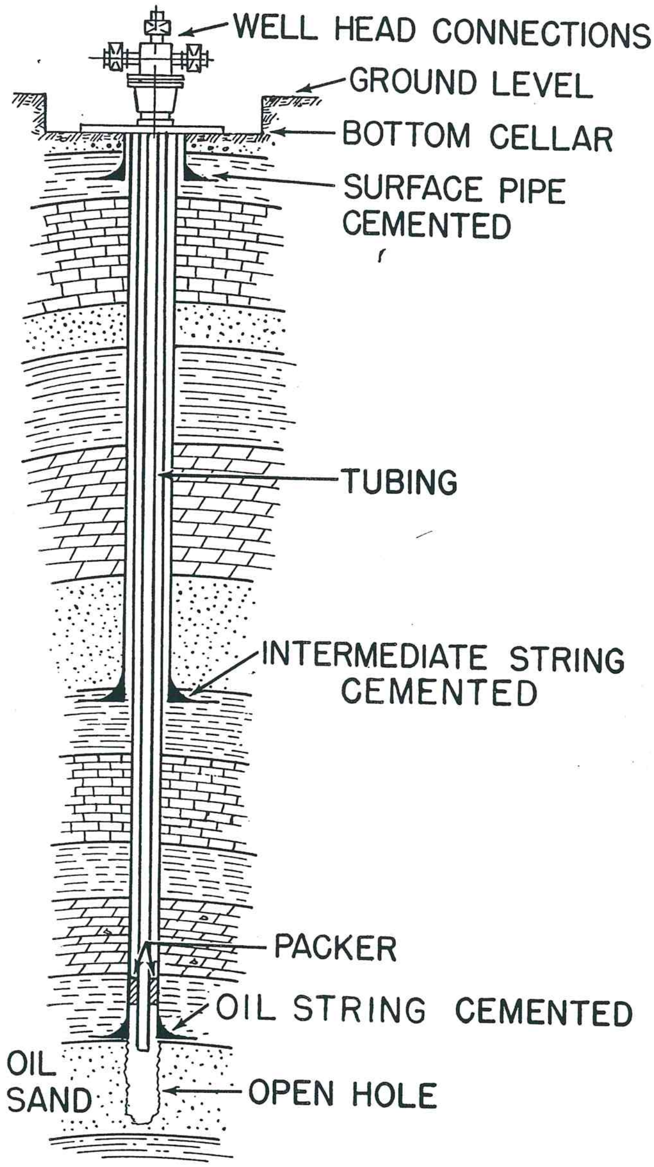
THE WELL

An oil well may best be described as a pipe line reaching from the top of the ground to the oil-producing formation. It is through this pipe line that oil is brought to the surface. This pipe line is a series of joints of a special kind of pipe (casing) screwed together to form a continuous tube or string for the oil and gas to flow through. A sketch of a well is shown in Fig. 1.

It is necessary to protect the hole from underground water and from loose earth falling from the surface. Also, the fresh water zones must be protected from the drilling and produced fluids. To provide this protection, usually two or more strings of casing are cemented in the hole. The first and larger of the casings is called the surface string. This casing will extend from the surface to a depth great enough to keep surface waters and loose earth from entering the well. The length of the surface string will vary from 200 ft. to 1,500 ft. depending upon the local conditions encountered.

A second protective string may be used. This casing is called the intermediate string or "salt string" because it generally is run to a depth sufficient to case off salt and anhydrite formations. Such a string may be set at a depth of 5,000 ft. or more.

The final string of casing, called the oil string, will usually extend from the surface through the surface and intermediate pipe, to the top of and sometimes through the producing zone at total depths of 20,000 ft. or more. Because both strings of casing are subjected to large pressures and forces, it is necessary that the casing string be carefully designed and properly run into the well.



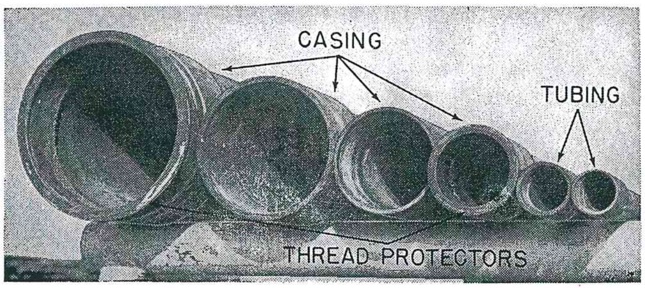


Fig. 1 — (upper right) The oil well is a vertical pipe line reaching from the surface of the ground to the oil pay, shown here by sketch.

Fig. 2 — (lower right) Casing is made in several sizes so that one string will fit inside the other and give a clearance of one-half inch or more. Individual joints of casing range in lengths of about 20, 30, and 40 ft.

Casing Strings

The American Petroleum Institute has very carefully set up specifications as to size, grade, weight per foot, type of screwed connection, and length of each section or joint of casing. Fig. 2 shows some of the various sizes of casing.

Completion Methods

The methods of preparing an oil well to produce are many and are governed by the kind of oil reservoir. If the well is bottomed in hard formations, the oil-producing zone may be left entirely open, with no perforated casing or liner used to

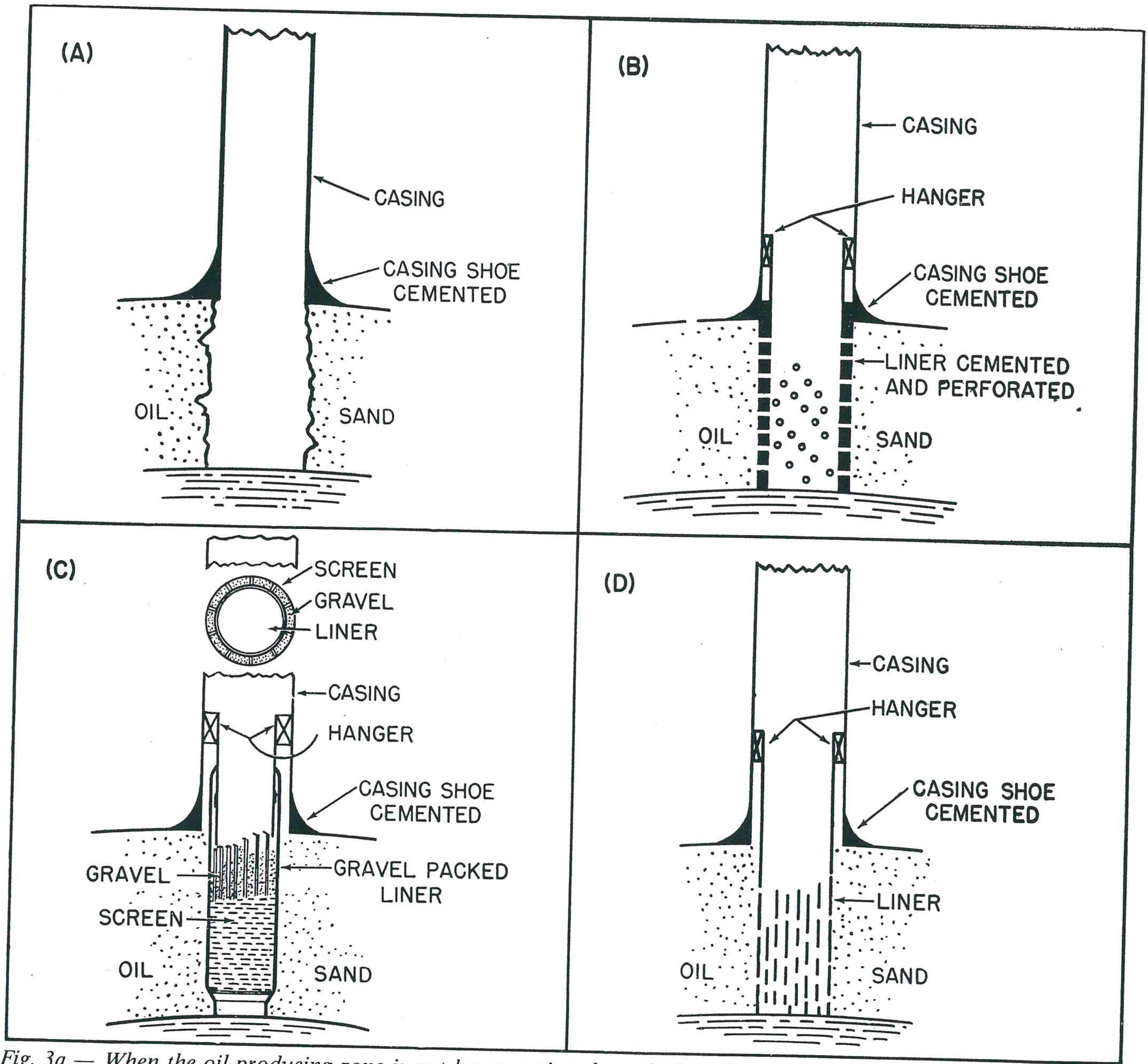


Fig. 3a — When the oil-producing zone is not loose, casing through the oil zone is sometimes not necessary. In this case the hole is left open, sometimes called "bare-foot."
Fig. 3b — A gun-perforated liner is made by actually shooting bullets or shaped charges (jets) through a section of cemented casing at the level of the oil zone that is to be produced. A similar and very common type of completion consists of setting the oil string through the oil sand, cementing it in place, and perforating it.
Fig. 3c — A gravel-packed liner is used in a well in which the producing sands are fine-grained and loose. The gravel in the space around the liner acts as a filter and keeps the sand out of the well.
Fig. 3d — When the producing sand is loose, but is made up of fine to coarse sand grains, a section of casing in which narrow vertical slots have been cut can be used as a liner. The grains of sand form a bridge across the slot, through which the oil can enter the well.

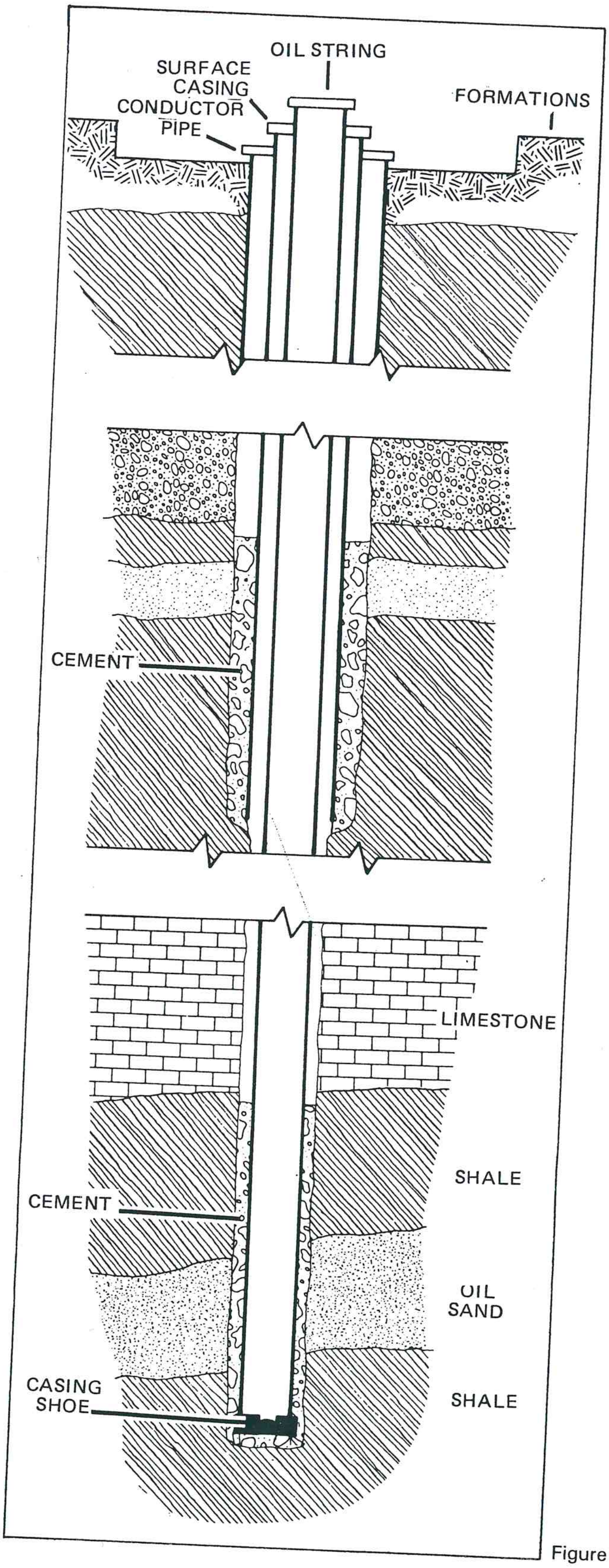


Figure 1.11. Oil-string casing

joints are put together, not cross-threaded (misaligned), and completely tightened to the manufacturer's specifications to insure that the joints will hold rated pressures. When the pipe is pulled out of the hole, the connecting joints must be carefully broken out so that the threads are not damaged. Tubing or casing that is laid down should be fitted with protectors to prevent thread damage.

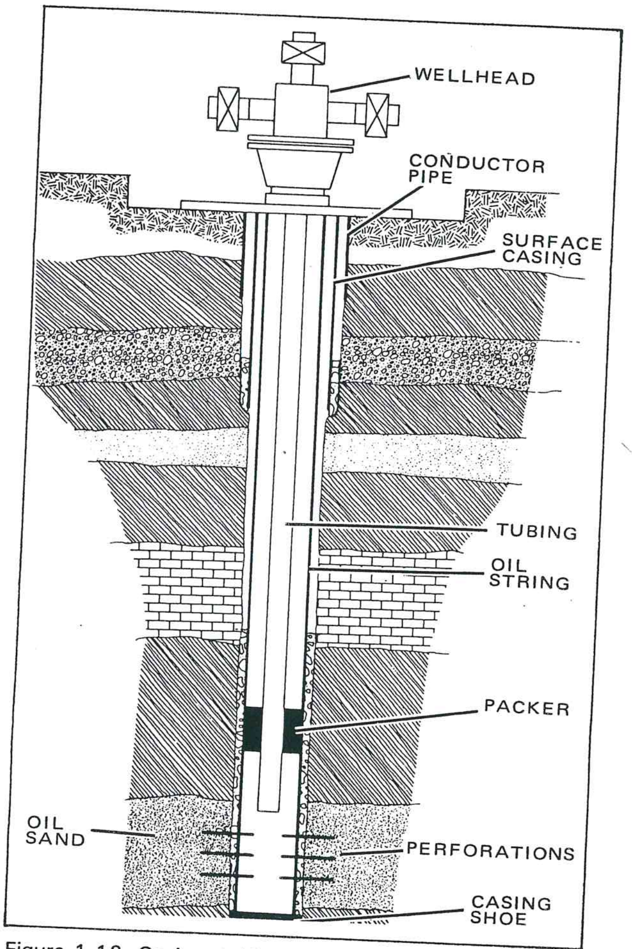


Figure 1.12. Casing, tubing, and packer arrangement in a flowing well

charges into the hole on a wireline. Sometimes a mechanical collar locator, which has been installed at the top of the gun, is used by the perforating crew to help determine the exact position of the gun in relation to the formation outside the casing. Knowing the location of the collars makes it possible for the gun to be placed in the well at the desired point. A sonic device and a magnetic locator, which is activated by the extra thickness of metal at each casing coupling, are also used to

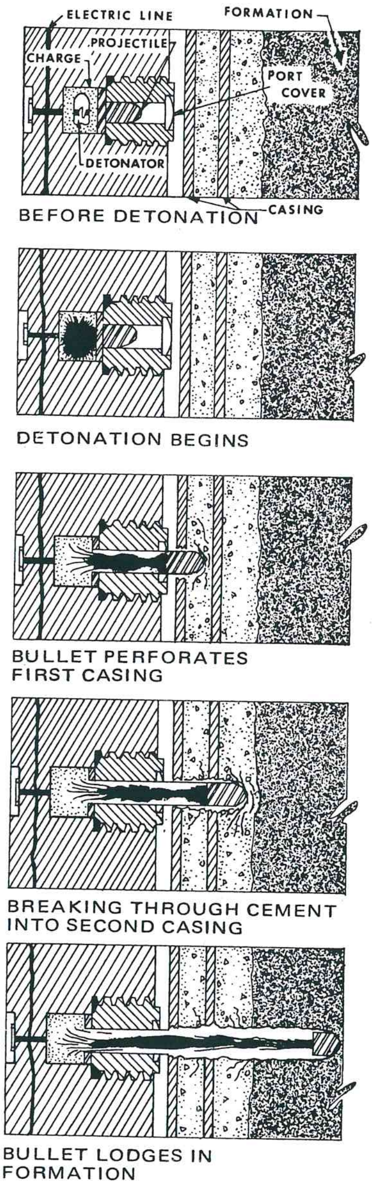


Figure 2.5. Bullet perforating

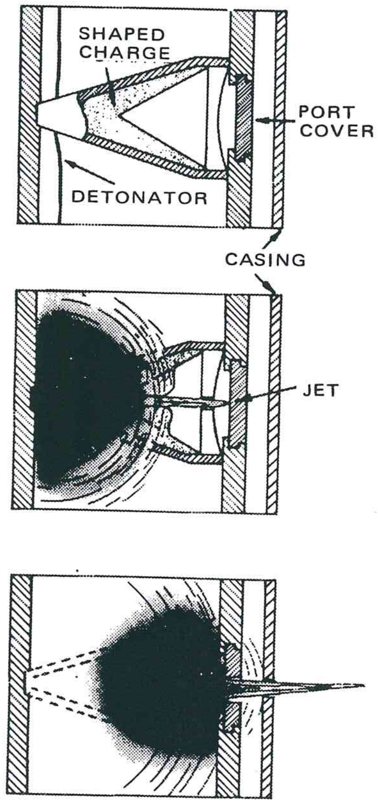


Figure 2.6. Jet perforating

determine the location of the gun, as is the odometer that measures the amount of line fed into the hole to lower the equipment.

Bullet Perforators. Bullet perforating (fig. 2.5) was developed in 1932 and has been widely used since then. The bullet perforator is a multibarrel gun that is lowered into the hole on a wireline, and it is fired electrically from surface controls. Bullet guns leave no debris in the well to plug chokes and cause other production problems. Bullets cause little casing damage and less damage to the cement sheath between the pipe and the wall of the hole than jet charges.

Jet Perforators. Jet perforating, which was developed in 1946, is similar to bullet perforating except that shaped-charge explosives are employed instead of bullets (fig. 2.6). Hollow carrier guns can be used in small pipes, and capsule charges can be used for 1.9-inch pipe. Shaped

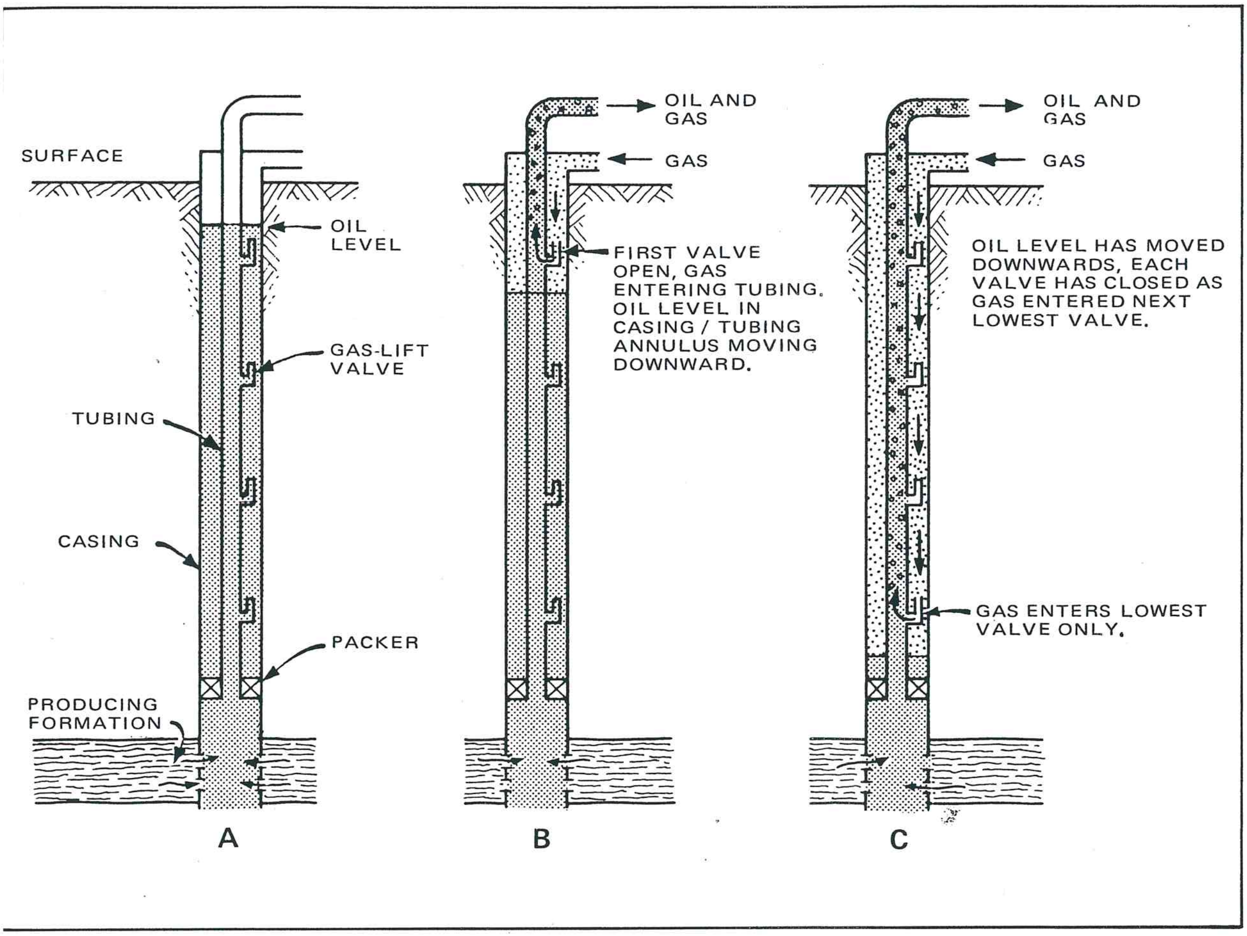


Figure 2.10. Principles of gas lift

plunger, pump submerged in the fluid of a well. Most rod-pumping units have the same general operating principles.

Hydraulic Pumps

Hydraulic pumps are so called because they are operated by a hydraulic motor in the unit at the bottom of the well. The fluid used to drive the motor is the oil from the well itself. The motor, in turn, drives a pump that pumps the oil to the surface.

Hydraulic Free Pumps. One type of hydraulic pump is the free pump. This pump is installed in the bottom of the tubing and is operated by oil taken from the tank at the surface and pumped downward through the tubing (fig. 2.12). The power oil is returned to the surface through the small tubing along with new oil taken from the formation. When this pump needs servicing, the flow is reversed at the surface, and the pressure going down the small line forces the pump up through the tubing to the surface where it can be recovered for inspection and/or repairs.

Hydraulic Conventional Pumps. Other types of hydraulic pumps are available, and all of them use the same basic fluid motor and pump in the bottom of the hole. The motor and pumping unit are lowered into the well on a string of tubing, and the pump and power-oil tubing can be run either inside the regular well tubing or inside the casing. The conventional pump receives power oil through the small tubing. It pumps produced oil to the surface through the annular space between the power-oil tubing and the regular tubing or casing.

Submersible Electric Pumps. In many fields, older wells produce a large volume of water in relation to the volume of oil, and, in order to be economically justifiable, tremendous volumes of

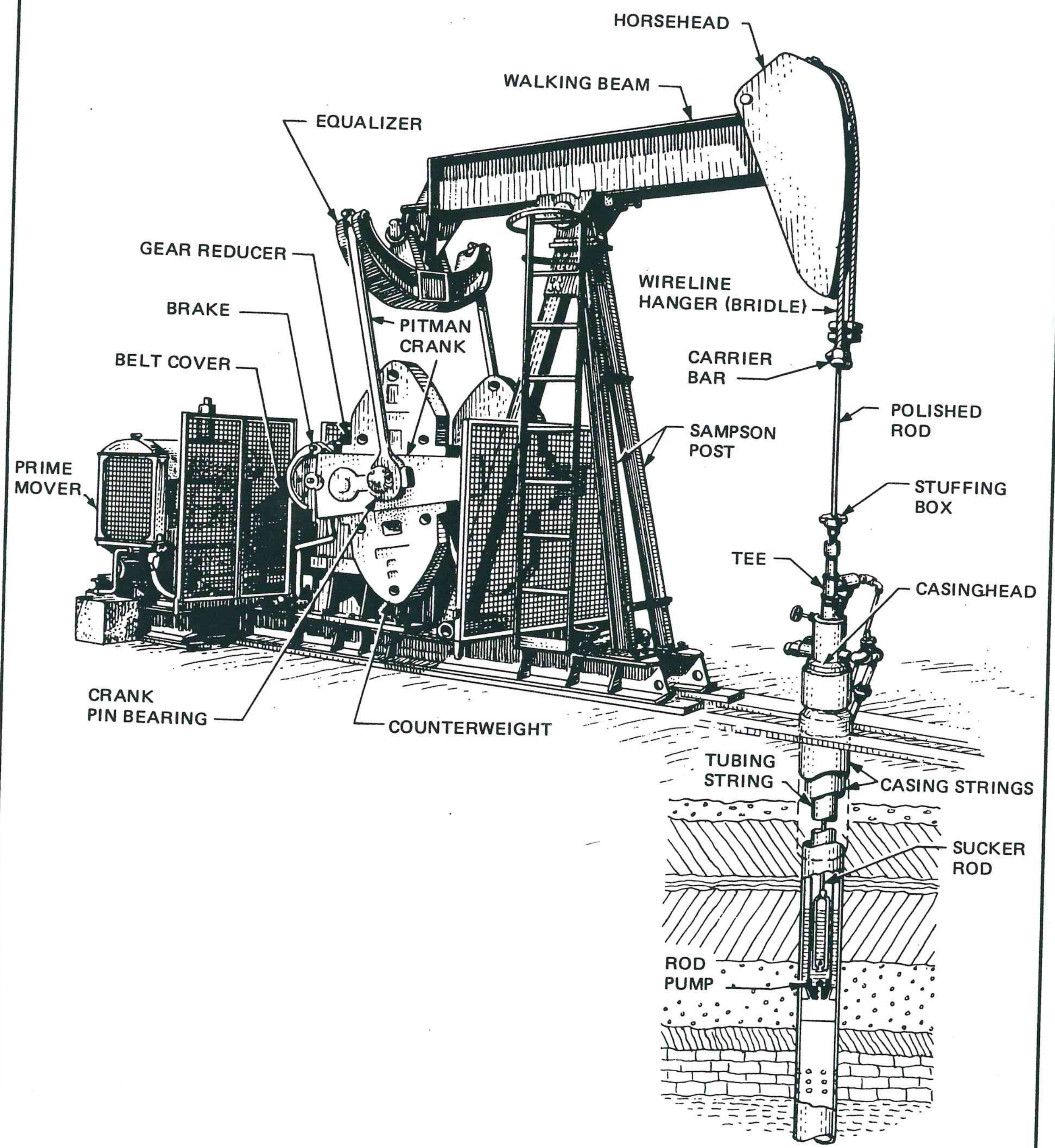


Figure 2.11. Sucker-rod-pump components

uid have to be lifted from the well. In these circumstances, an electric submersible pump (fig. .13) may be installed either in the tubing or in he casing. Since both the pump motor and the ump are submerged in the well fluid, the electric urrent is supplied through a special heavy-duty rmored cable.

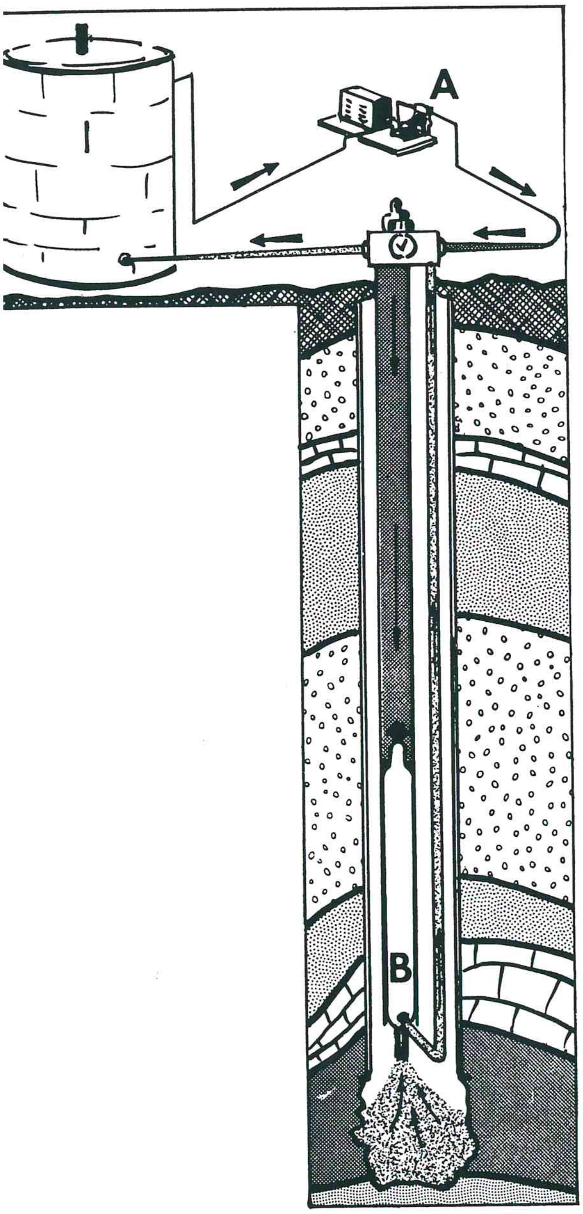


Figure 2.12. Hydraulic pump system in a well. This type of artificial lift utilizes crude oil under high pressure from a surface pump (*A*) through the tubing to a motor at the bottom of the well to operate a pump (*B*). This pump raises produced oil to the surface. Oil leaving the motor is exhausted into the stream of produced crude oil.

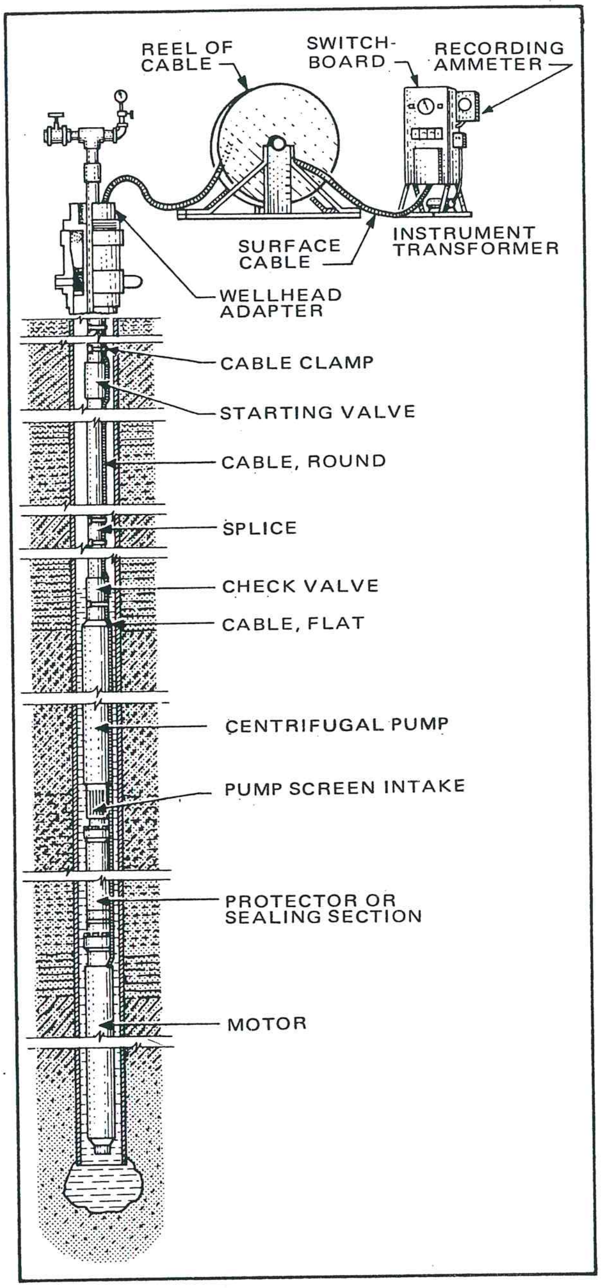


Figure 2.13. Equipment arrangement for a submersible electric pump

Logging

Well logging (fig. 1.13) is a method for evaluating a potentially productive formation. Common logs are drilling-time logs, mud logs, core analyses, electric logs, acoustic logs, and radioactivity logs. Mud logs, drill-stem-test (DST) reports, core analyses, and electric logs constitute the permanent records of a well that are useful throughout its life. Logs are invaluable when planning a workover, repair, or recompletion.

Improved electric-logging methods and better techniques of interpretation make it possible to evaluate formation porosity and fluid saturation with a high degree of accuracy (fig. 1.14). For open hole, logs now available include the conventional electric survey; guard-electrode log; Microlog; induction log; and acoustic, density, and radioactive surveys. There are also caliper logs, directional surveys, and dipmeter surveys.

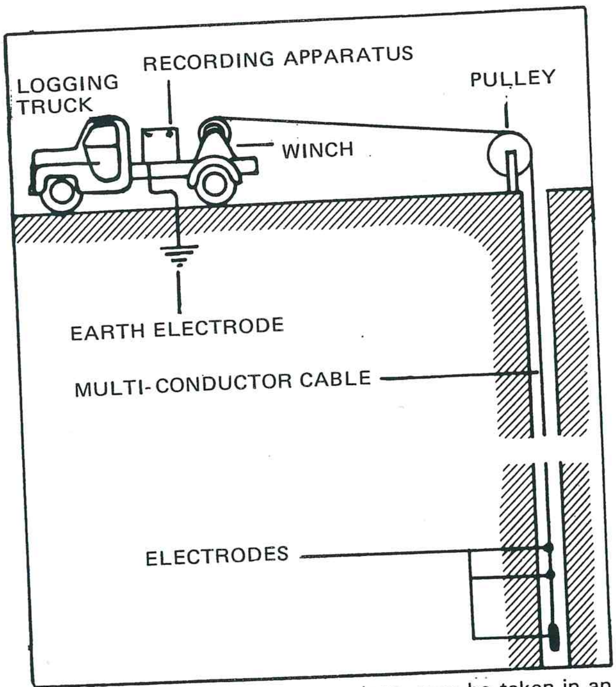


Figure 1.13. Electric surveys, or logs, may be taken in an open but not in a cased hole. Electrical impulses from the electrodes vary according to the adjacent formations as the cable is slowly pulled out of the well by the winch. The impulses are recorded simultaneously with the depth reading of the electrode in the well.

INDUCTION-ELECTRICAL LOG

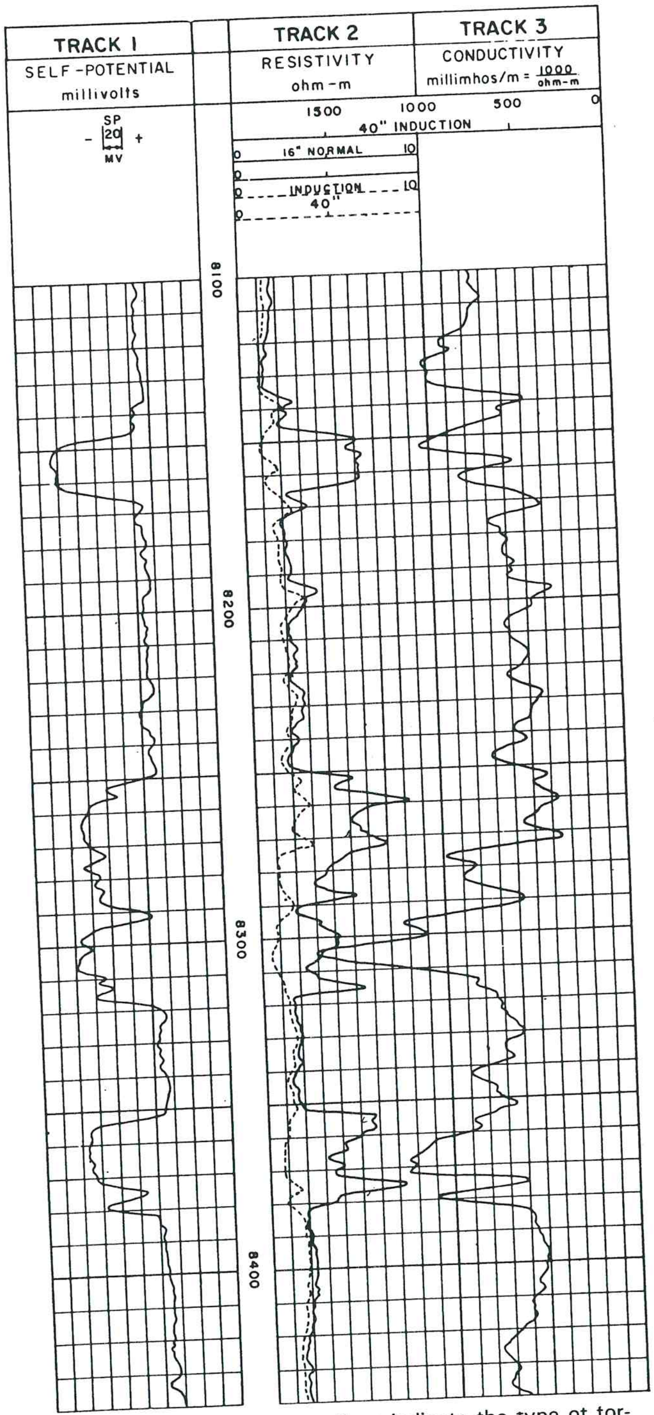


Figure 1.14. Electric-log readings indicate the type of formations and permit assessment of their fluid content.

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✓ Well Testing – ~~Production~~

In producing gas and oil, more importance is being placed upon most efficient performance of the producing wells.

i.e. Test must be made to determine the performance of an oil or gas well. The procedure followed is called testing. There are a large number of types of well tests, and each is conducted to obtain contain information about the well.

The Potential Test

Is a measurement of the largest amount of oil & gas a well will produce in a 24-hr. period under contain fixed conditions.

The produced oil is measured in an automatically controlled production and test unit, or by wireline measurement in the lease tank, and the produced gas is measured at the same time with equipment such as an orifice meter or an orifice tester.

A test of this type is normally made on each newly completed well and often during its production life.

The Bottom-Hole Pressure Test.

Is a measure of the reservoir pressure of the well taken at a specific depth, or at midpoint of the producing interval.

The purpose of this test is to measure the pressure in the zone in which the well is completed. In making this test, a special pressure gage is lowered into the well by means of a wire line — the pressure at a selected depth is recorded by the gage, and the gage is then pulled to the surface and taken from the well —

Several variations to this type of test such as
- flowing bottom-hole pressure test - is taken while the well is flowing, and a "shut-in bottom-hole pressure test, which is a measurement taken after the well has been shut in for a specified length of time.

Productivity Tests

Are made on both oil and gas wells, and include both the potential test and the bottom-hole pressure test.

The purpose of this test is to determine the effects of different flow tests on the pressure within the producing zone of the well —

* The procedure in conducting a productivity test is first to measure the "closed-in bottom-hole pressure" of the well, then open the well and produce it at several stabilized rates of flow. At each rate of flow ~~rate~~, the "flowing bottom-hole pressure" is measured. These data, when interpreted by the engineer, provide an estimate of maximum flow to be expected from the well.

The three tests described above are probably the most common of all the various tests that are made on oil and gas wells.

Two types of special test are also made:

1. Fluid-level determination — Performed on wells which will not flow — introduce pumping.
2. Bottom-hole temperature determination —