CHAPTER-8
COMPLETION, PRODUCTION and RESERVOIR ENGINEERING

8.1 Casing

Once the pipe is out, the casing crew moves, in to do its work. Since this is surface hole, the first string of casing they run is called *surface casing*. Surface casing is large in diameter and, like all casing is nothing more than steel pipe. Running casing into the hole is very similar to running drill pipe, except that the casing diameter is much larger and thus requires special elevators, tongs and slips to fit it. Also devices called *centralisers* and *scratchers* are often installed on the outside of the casing before it is lowered into the hole. Centralisers are attached to the casing and since, they have a bowed-spring arrangement, keep the casing centered in the hole after it is lowered. Centralized casing can make for a better cement job later. Scratchers also come into play when the casing is cemented. The idea is that if the casing is moved up and down or rotated, the scratchers will remove the wall cake formed by the drilling mud and the cement will thus be able to bond better to the hole. Other casing accessories include a *guide shoe*, a heavy steel and concrete piece attached to the bottom most joint of casing that helps guide the casing past small ledges or debris in the hole; and a *float collar,* a device with a valve installed in the casing string two or three joints from bottom. A float collar is designed to serve as receptacle for cement plugs and to keep drilling mud in the hole from entering the casing.

Drilling environments often require several casing strings in order to reach the total desired depth. Some of the casing strings are as follows: drive or structural, conductor, surface, intermediate, liners, production and tubing.

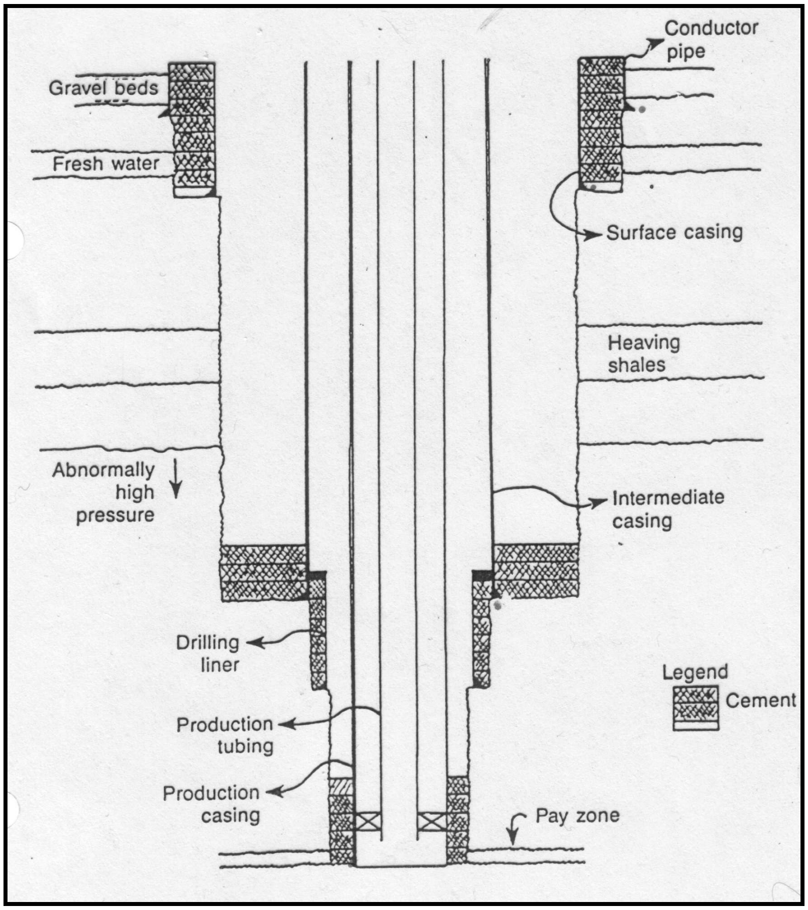

Figure 8-1 Typical Casing String Relationships

8.1.1 Drive Pipe or Conductor Casing:

The first string run or placed in the well is usually the drive pipe or conductor casing. The normal depth range is from **100-300 ft**. In soft-rock areas the pipe is hammered into the ground with large diesel hammer. Hard-rock areas require that a large diameter shallow hole be drilled before running and cementing the well. A primary purpose of this string of pipe is to provide a fluid conduit from the bit to the surface. An additional function of this string of pipe is to minimise hole-caving problems.

8.1.2 Structural Casing:

Drilling conditions will require that an additional string of casing be run between the drive pipe and surface casing. Typical depth range from **600-1000 ft**. Purpose of this pipe includes solving additional lost circulation or hole caving problems and minimising kick problems from shallow gas zones.

8.1.3 Surface Casing:

Many purposes exist for running surface casing, including:

-cover fresh water sands
-maintain hole integrity by preventing caving
-minimise lost circulation into shallow- permeable zones
-cover weak zones
-provide a means for attaching the blow-out preventers
-support the weight of all casing strings (except liners) run below the surface pipe.

8.1.4 Intermediate Casing:

The primary applications of intermediate casing involve abnormally high formation pressures. Since higher mud weights are required to control these pressures, the shallower weak formations must be protected to prevent lost circulation or stuck pipe. It is used to isolate salt zones or zones those cause hole problems, such as heaving and sloughing shales.

8.1.5 Liners:

Drilling liners are used for the same purpose of intermediate casing. Instead of running the pipe to the surface, an abbreviated string is used from the bottom of the hole to a shallower depth inside the intermediate pipe. Usually the overlap between the two strings is **300-500 ft**. Drilling liners are used frequently as a cost-effective method to attain pressure or fracture gradient control without the expense of running a string to the surface. When a liner is used, the upper exposed casing, usually intermediate pipe, must be evaluated with respect to **burst** and **collapse** pressures for drilling the open hole below the liner.

8.1.6 Production Casing:

The production casing is often called the oil string. The pipe may be set at a depth slightly above, or below the pay zone. The pipe has the following purposes:

-isolate the producing zone from the other formations.

-provide a work shaft of a known diameter to the pay zone.

-protect the producing tubing equipment.

8.2 Cementing

After the casing string is run, the next task is cementing the casing in place. An oil well cementing service company is usually called in for this job although, as when casing is run, the rig crew is available to lend assistance. Cementing service companies stock various types of cement and have special transport equipment's to handle these material. Bulk cement storage and handling equipment is moved out to the rig, making it possible to mix large quantities of cement at the site. The cementing crew mixes the dry cement with water, using a device called jet-mixing hopper. The dry cement is gradually added to the hopper and a jet of water thoroughly mixes with the cement to make a slurry (very thin, water cement). Special pumps pick up the cement slurry and send it to a valve called a *cementing head* mounted on the top most joint of casing that is hanging in the mast or derrick a little above the rig floor. Just before the cement slurry arrives, a *rubber plug* (called the *bottom plug*) is released from the cementing head and precedes the slurry down the inside of the casing. The bottom plug stops or "seats" in the float collar, but continued pressure from the cement pumps opens a passageway through the bottom plug. Thus, the cement slurry passes through the bottom plug and continues on down the casing. The slurry then flows out through the opening in the guide shoe and starts up the annular space between the outside of the casing and wall of the hole. Pumping continues and the cement slurry fills the annular space. A *top plug*, which is similar to the bottom plug except that is solid, is released as the last of the cement slurry enters the casing. The top plug follows the remaining slurry down the casing as displacement fluid (usually salt water or drilling mud) is pumped in behind the top plug. Meanwhile, most of the cement slurry flows out of the casing and into the annular space. By the time the top plug seats on or "bumps" the bottom plug in the float collar, which signals the cementing pump operator to shut down the pumps, the cement is only in the casing below the float collar and in the annular space. Most of the casing is full of displacement fluid. After the cement is run, a waiting time is allotted to allow the slurry to harden. This period of time is referred to as *waiting on cement* or simply *WOC*. After the cement hardens, tests may be run to ensure a good cement job, for cement is very important. Cement supports the casing so the cement should be completely surrounded the casing. Also cement seals off formations to prevent fluids from one formation migrating up or down the hole and polluting the fluids in another formation. After the cement hardens and tests indicate that the job is good, the rig crew attaches the blow out preventer stack to the top of the casing. The BOP stack is pressure-tested, and the drilling is resumed.

8.3 Examining Cuttings

To help the operator make his/her decision, several techniques have been developed. One thing that helps indicate whether hydrocarbons have been tapped is a through examination of the cuttings brought up by the bit. The mud logger catches cuttings at the shale shaker and by using microscope or ultraviolet light can see whether oil is in the cutting. Or he may use a gas-detection instrument.

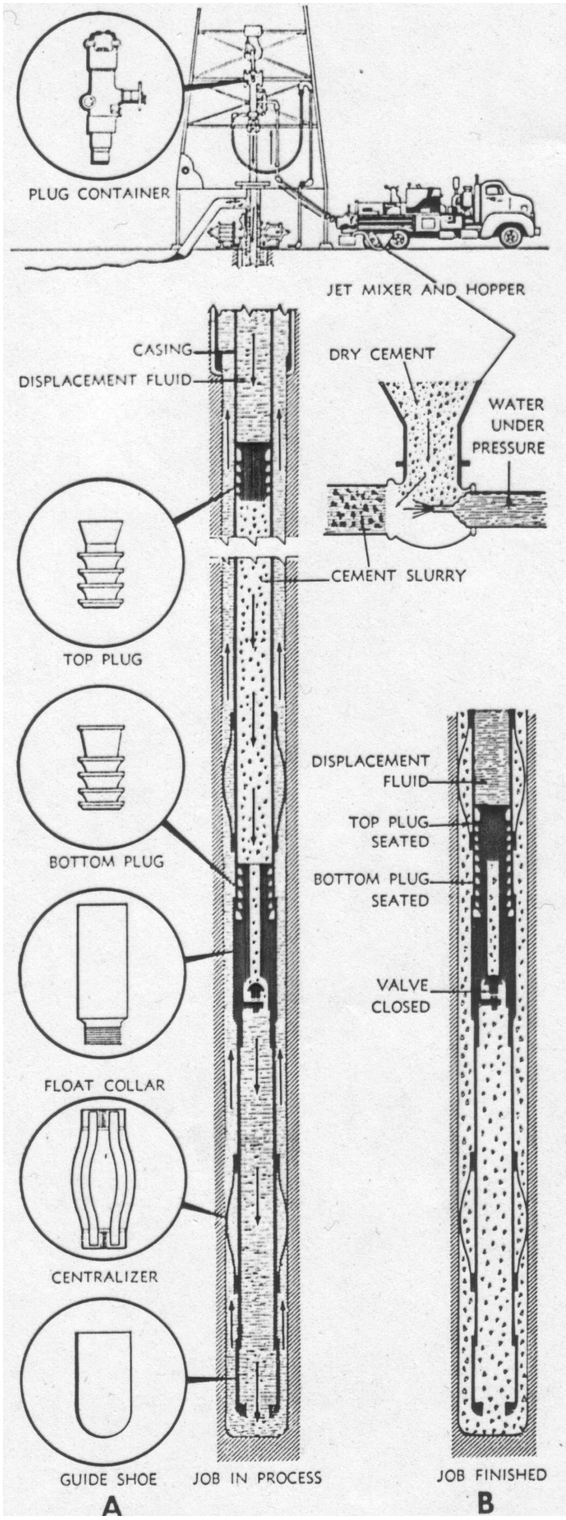

Figure 8-2 Cementing the Casing: **A-**The Job in Progress; **B-** the finished job.

8.4 Well Logging

Another valuable technique is well logging. A logging company is called to the well while the crew trips out all the drill string. Using a portable laboratory, truck mounted for land rigs and permanently mounted on offshore rigs, the well loggers lower devices called logging tools into the well on wire-line. The tools are lowered all the way to bottom and then reeled slowly back up. As the tools come back up the hole, they are able to measure the properties of the formation they pass. Electric logs measure and record natural and induced electricity in formations. Some logs pins formations with sound and measure and record sound reactions. Radioactivity logs measure and record the effects of natural and induced radiation in the formations. Since all logging tools make a record, which resembles a graph or an electrocardiogram the records or logs can be studies and interpreted by the experiences geologist or engineer to indicate not only the existence of oil or gas, but also how much may be there. Computers have made the interpretation of logs much easier.

8.5 Drill Stem Testing

Still another helpful technique is the drill stem test (DST) tool. This tool is made up on the drill string (the drill stem) and set down, on the bottom of the hole. A packer, an expandable hard-rubber sealing element, seals off the hole below it by expanding when weight is set down on it. A valve is opened, and any foramtion pressure and fluids present enter the tool. A recorder in the tool makes a graph of the formation pressure. Then the packer is released and the tool retrieved back to the surface. By looking at the record of the downhole pressures, a good indication of the characteristics of the reservoir can be obtained.

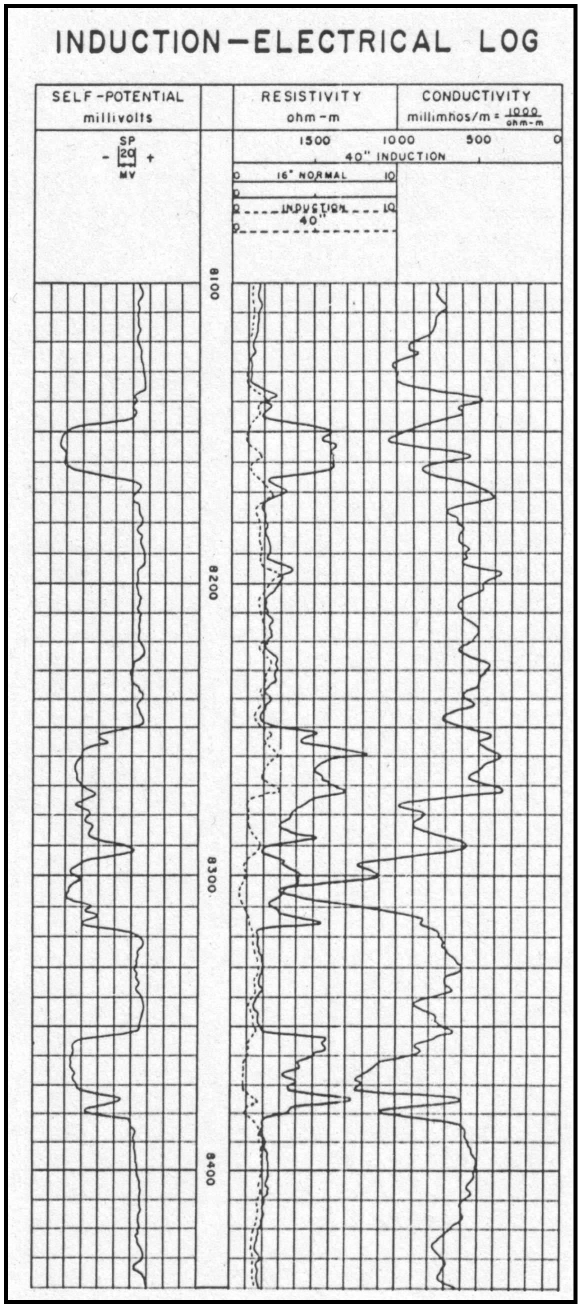

Figure 8-3 An Electrical Log

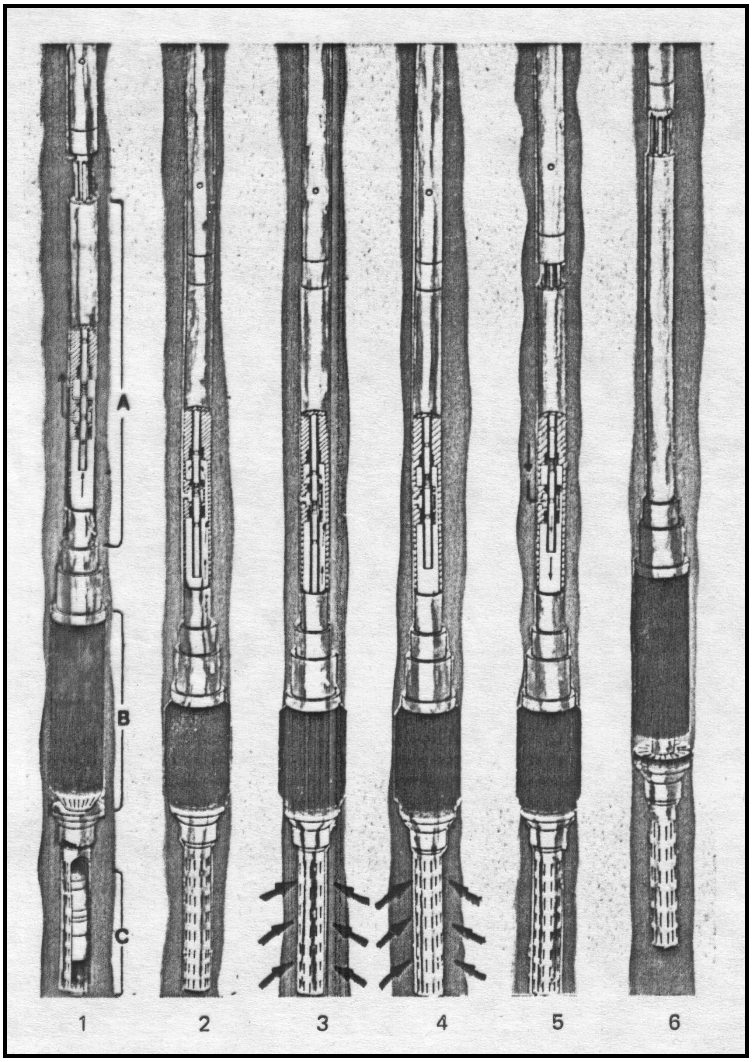

Figure 8-4 Principles of Drill Stem Testing

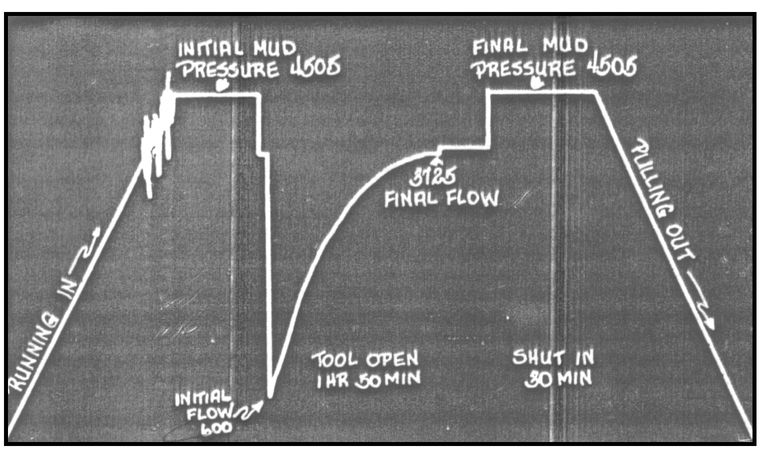

Figure 8-5 Bottomhole Pressure Record of a Drill Stem Test

8.6 Coring

In addition to tests mentioned above, froamtion core samples are sometimes taken. Two methods of obtaining cores are frequently used. In one, an assembly called a core barrel is made up on the drill string and run to the bottom of the hole. As the core barrel is rotated, it cuts a cylindrical core a few inches in diameter that is received in a tube above the core-cutting bit. A complete round trip is required for each core taken. The secons is a sidewall sampler in which a small explosive charge is fired to ram a small cylinder into the wall of the hole. When the tool is pulled out of the hole, the small core samples come out with the tool. Up to thirty of the small samples can be taken at any desired depth. Either type of core can be examined in a laboratory and may reveal much about the nature of the reservoir.

8.7 Completing the Well

After the operating company carefully considers all the data obtained from the various tests, it has been ordered to be run on the formation of formation of interest, a decision is made on whether to set production casing and complete the well or to plug and abandon it. If the decision is to abandon it, the hole is considered to be *dry*, that is, not capable of producing oil or gas in commercial quantities. In other words, some oil or gas may be present but not in amounts greater enough to justify the expense of completing the well. Therefore, several cement plugs will be set in the well to seal it off more or less permanently.

If the operating company decides to set casing, casing will be brought to the well and for one final time, the casing and cementing crew run and cement a string of casing. Usually, the production casing is set and cemented through the pay zone, that is, the hole is drilled to a depth beyond the production formation, and the casing is set to point near the bottom of the hole. As a result, the casing and cement actually seal of the producing zone- but only temporarily.

8.8 Perforating

Since the pay zone is sealed off by the production string and cement, perforations must be made in order for the oil or gas or to flow into the well-bore. Perforations are simply holes that are made through the casing and cement and extend some distance into the formation. The most common method of perforating incorporates shaped-charged explosives. Shaped charges accomplish penetration by creating a jet of high pressure, high velocity gas. The charges are arranged in a tool called a gun that is lowered into the well opposite the producing zone. Usually the gun is lowered in on a wire line. When the gun is in position, the charges are fired by electronic means from the surface. After the perforations are made, the tool is retrieved. A service company that specialized in this technique usually performs perforating.

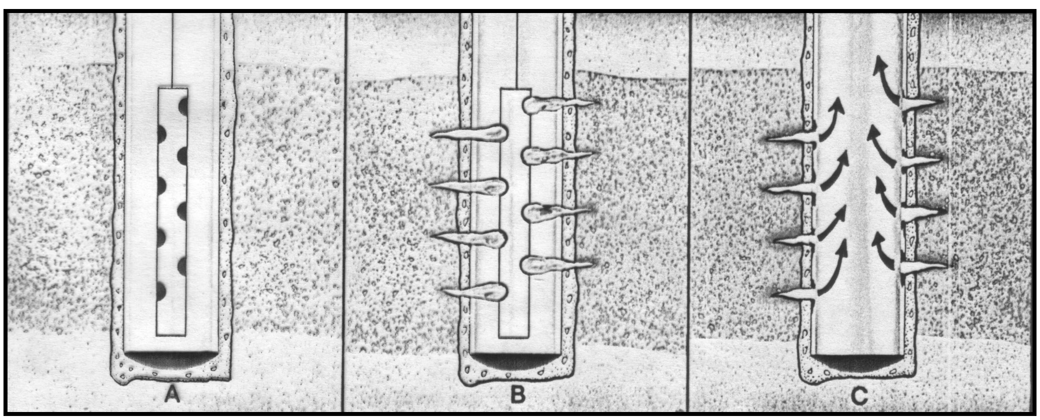

Figure 8-6 The Perforating Gun

8.9 Installing the Christmas Tree

Even though the oil or gas can flow into the casing after it is perforated usually, the well is not produced through the casing. Instead, small diameter pipe called *tubing* is placed in the well to serve as a way for the oil or gas to flow to the surface. The tubing is run into the well with a packer. The packer goes on the outside of the tubing and is placed at a depth just above the producing zone. When the packer is expanded it grips the wall of the production casing and forms a seal in the annular space between the outside of tubing and the inside of the casing. Thus, as the produced fluids flow out of the formation through the perforations, they are forced to enter the tubing to get to the surface. When casing is set, cemented and perforated and when the tubing string is run then a collection of valves, called *Christmas tree*, is installed on the surface at the top of the casing. Usually, once the Christmas tree is installed, the well can truly be said to be complete.

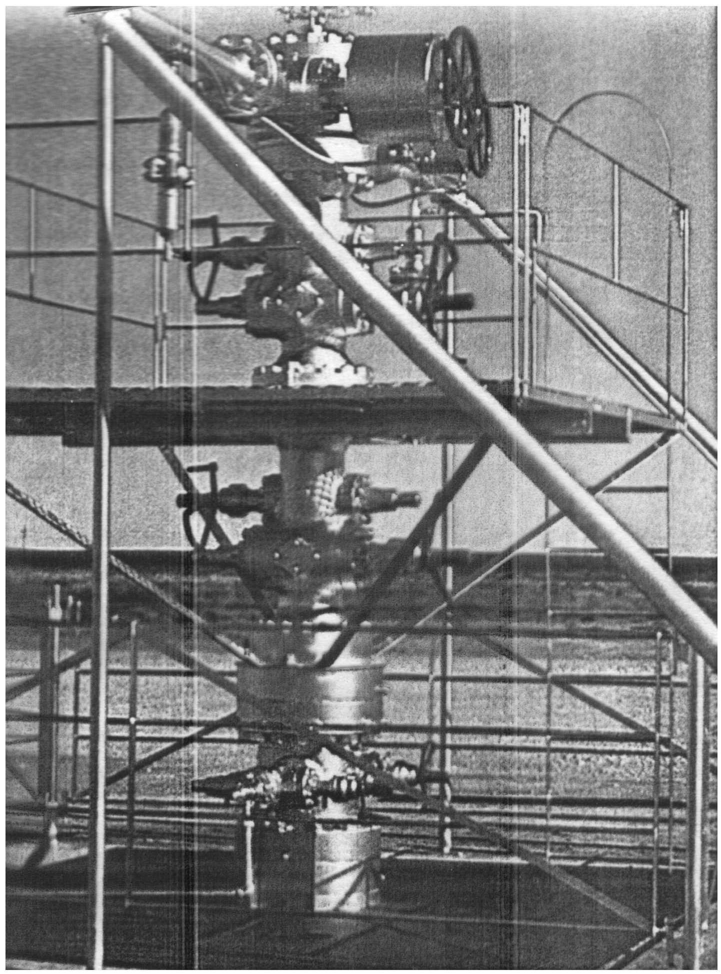

Figure 8-7 Christmas Tree of Control Valves is Positioned on the Completed Well

8.10 Drawdown and Productivity Index

Producing pressure at the bottom of the well is generally known as the bottom hole flowing pressure, P_{wf}. The difference between the reservoir pressure (P_R) and the flowing bottom hole pressure is called **drawdown**. The rate og the producing rate of a well,q, to its drawdown at that particular rate is called **Productivit Index (J)**.

$$\mathbf{J = q / (P_R - P_{wf})\ ;\ (bbl/day)\ /psi}$$

Higher the productivity index, higher the production rate; therefore production engineering involves in stimulating operations as acidizing and fracturing.

8.11 Acidizing

Sometimes, however, petroleum exists in a formation but it is unable to flow readily into the well, because the formation has very low permeability. If the formation is composed of rocks that dissolve upon being contacted by acid, such as limestone or dolomite, then a technique known as *acidizing* may be required. Acidizing is usually performed by an acidizing service company and may be done after the rig is moved off the well; or it can also be done after the rig is moved away. In any case, the acidizing operation basically consist of pumping anywhere from fifty to thousand of gallons of acid down the well. The acid travels down the tubing, enters the perforations and contacts the formation. Continued pumping forces the acid into the formation where it etches channels-channels that provide a way for the formation's oil or gas to enter the well through the perforations.

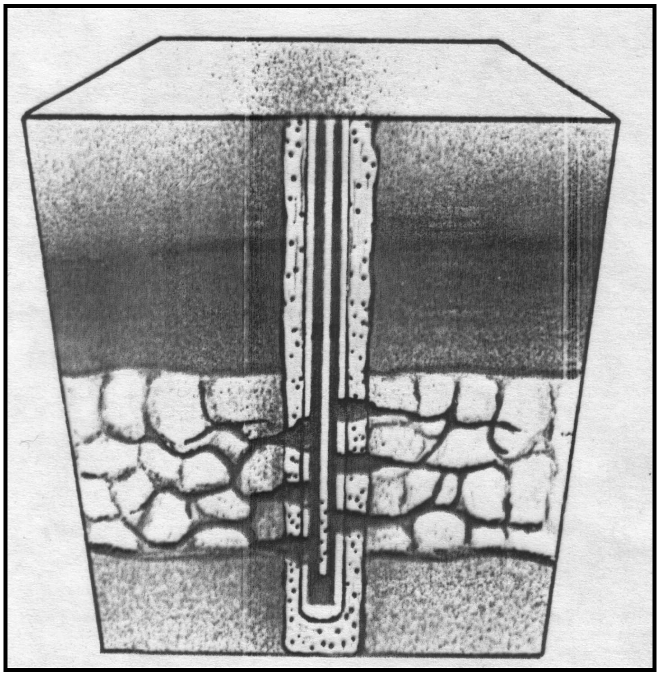

Figure 8-8 Acidizing; Several Pump Trucks Send Acid Down the Well.

<u>8.12 Fracturing</u>

When sandstone rock contain oil or gas in commercial quantities but the permeability is too low to permit good recovery, a process called *fracturing* may be used to increase permeability to a practical level. Basically to fracture a formation, a fracturing service company pumps a specially blended fluid down the well and into the formation under great pressure. Pumping continues until the formation literally cracks open. Meanwhile, sand, walnut hulls, or aluminum pellets are mixed into the fracturing fluid. These materials are called *proppants*. The proppant enters the fractures in the formation, and when pumping is stopped and the pressure allowed dissipating, the proppant remains in the fractures. When the pressure allowed dissipating, the proppant holds the fracture open and forms a permeable channel for formation fluids to flow into the well bore.

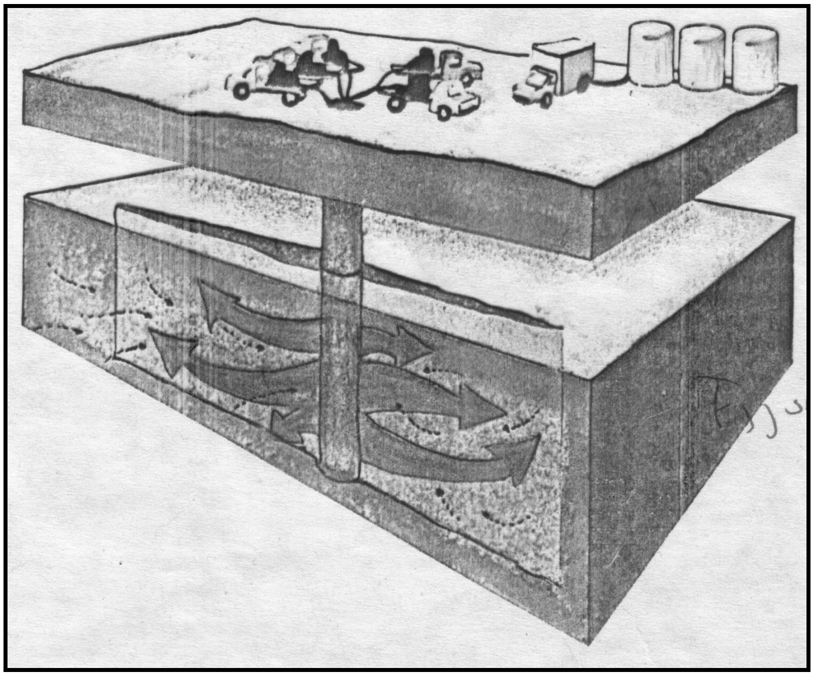

Figure 8-9 Fracturing; Several Pump Trucks Force Fluid Containing a Proppant down the Well and into the Perforations in the Casing.

8.13 Flowing Well Performance

The processes involved in bringing oil or gas from the underground reservoir to the surface of the ground may be considered to comprise two systems. These are the *inflow* and *outflow* systems of the well. The inflow system represents the flow from the reservoir into the well bore under the influence of the driving forces. The outflow system represents the flowing or lifting of the production from the bottom of the well to the surface of the ground into the flow line.

8.14 Artificial Lift Methods

When pressures in the oil reservoir have fallen to the point where a well will not be produced by natural energy, some method of artificial lift must be used. For this purpose oil well pumps are used, which are divided into three general groups.

-pumps at the bottom of the hole run by a string of rods

-pumps at the bottom of the hole run by high pressure liquids

-bottom hole centrifugal pumps.

Another method of artificial lift uses high pressure gas to lift the oil from the reservoir.

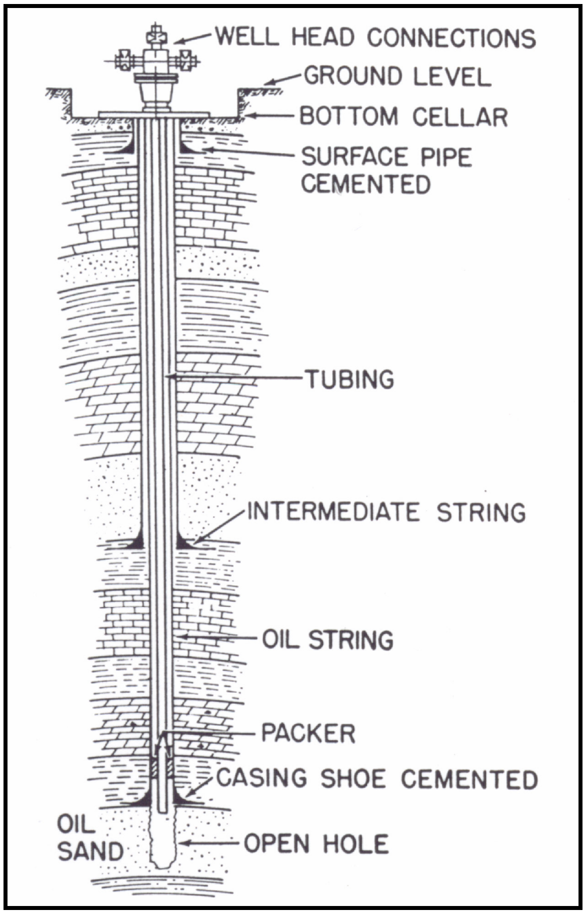

Figure 8-10 Sketch of Typical Completed Well

8.15 Reservoir Engineering

The job of reservoir engineering is to produce oil and gas reservoirs in such a way that the recovery is maximized and the rate at which the petroleum is produced is maximized. Reservoir engineer deals with:

-control of amount of gas and water produced with oil,

-proper placement of wells,

-use of proper distance between wells,

-injection of water or other fluids into the reservoir and many other means are used to help to maximize the oil.

8.16 Enhanced Oil Recovery (EOR)

After the primary recovery period of a reservoir is over, the area may not be abandoned as was done in the past, efforts, commence to obtain all the petroleum possible through the techniques of secondary and even tertiary recovery.

Secondary recovery processes generally use the injection of water or natural gas into the production reservoir to replace or assist the natural reservoir drive or primary production.

Tertiary recovery methods go ahead where secondary recovery methods leave-off. They are usually divided into three major categories; thermal, chemical and miscible displacement. Thermal processes are divided as steam stimulation, steam flooding and in-situ combustion. Steam stimulation process involves injecting steam into a producing well for two or three weeks. The well is shut in so the heat can dissipate and transfer the oil. Steam flooding process is similar to water flooding, input wells are located in a pattern for injection while the oil is produced from adjacent wells. In-situ combustion process involves burning the reservoir oil from one side of the reservoir.

Chemical process includes surfactant-polymer injection, polymer flooding and caustic flooding. Polymer reduces the volume of water required and increases sweep efficiency. Caustic flooding changes the pH of the water, making it more acidic. This helps open passages in the pores and increases production. Miscible displacement process include miscible hydrocarbon displacement, CO_2 injection and inert gas (nitrogen) injection.