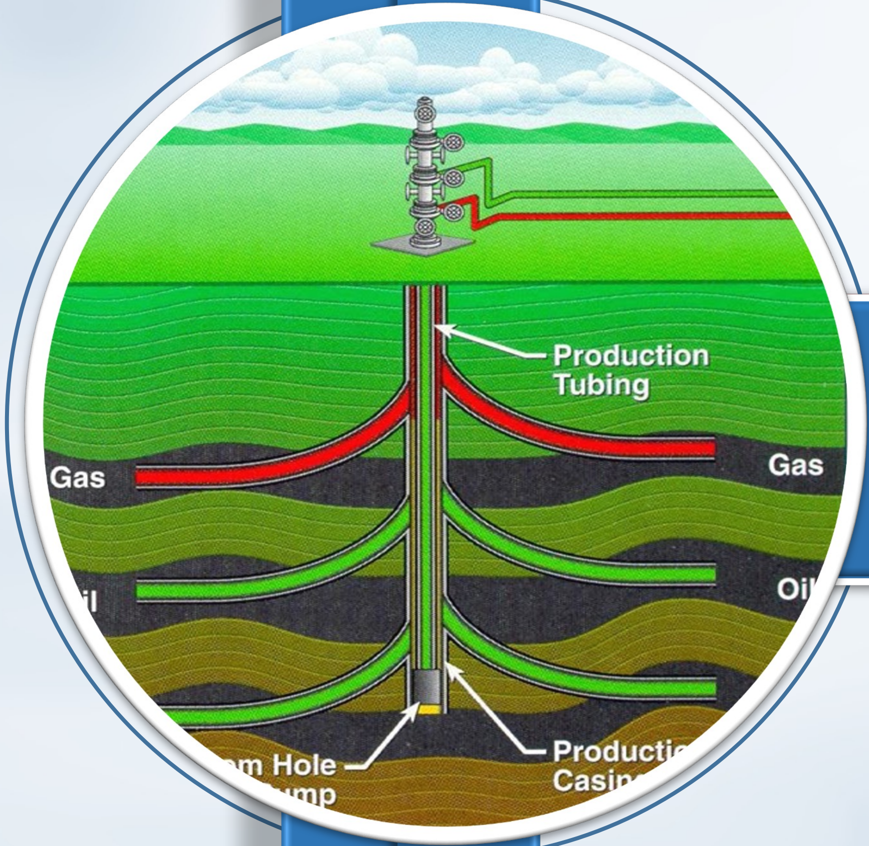


DRILLING ENGINEERING CONCEPTS

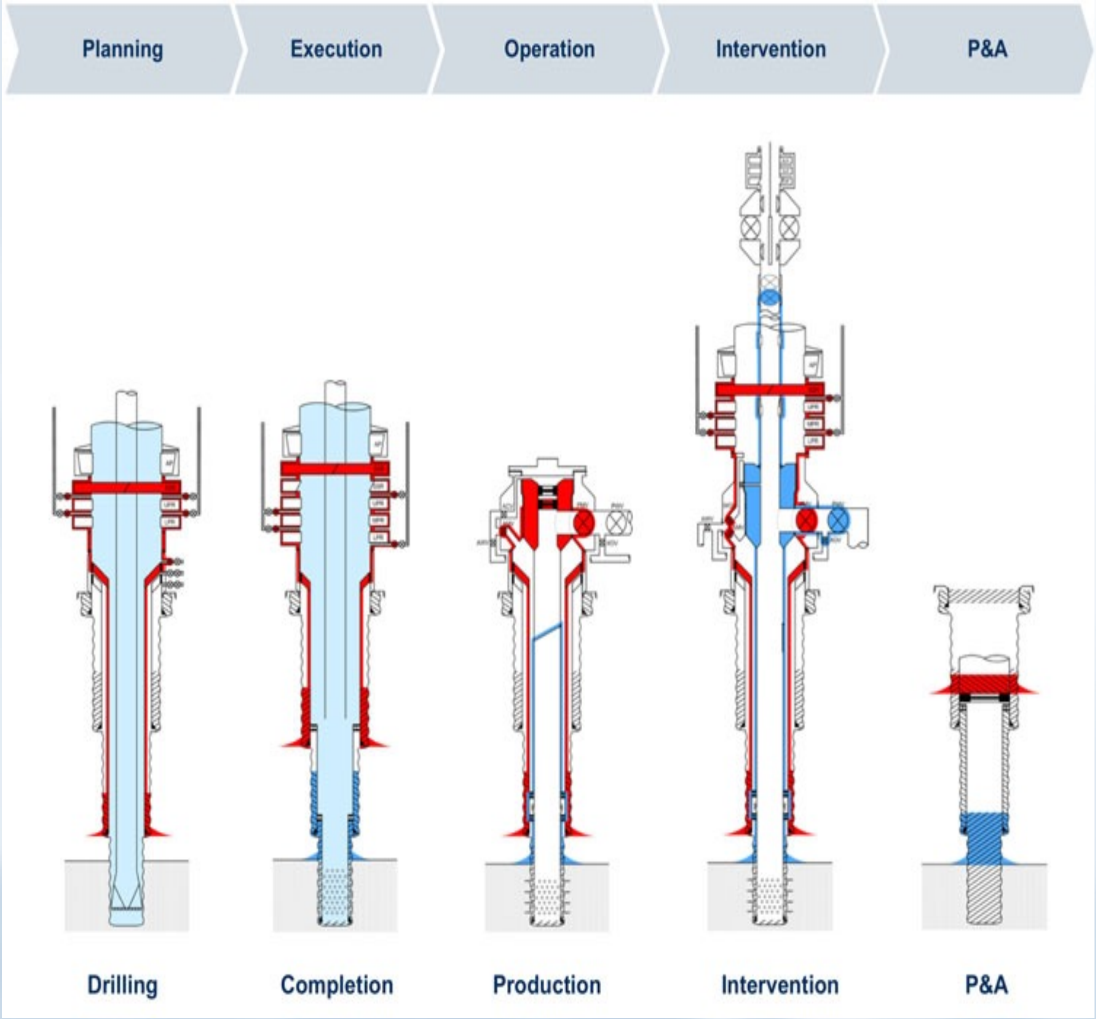
Drilling Engineering Concepts
Current Scope

A. Why Drill (not the only W ?)
B. Types of Rigs
C. Rig Systems
D. BHA
E. Casing

F. Cementing
G. Drilling Fluids
H. Basic Logging
I. Introduction to directional drilling

Cementing

Cementing – Well Barrier Element



Cement plays an important role in well's life cycle as primary well barrier element.

During drilling phase Cement not only helps in resolving hole problems, and secures the casing in place, but also help in isolating the production zones.

For abandonment cement plugs are an acceptable method by the Companies and regulators.

It is therefore very essential that the cement placement should be efficient and effective through the life of the well.

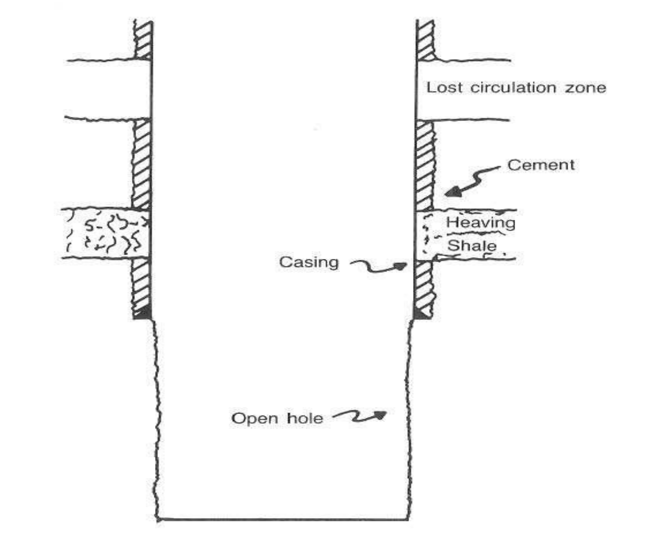
A common belief is a well designed and executed primary cement job can save lots of costs for the well. A properly planned cement program and well executed cement placement technique is essential for longevity of a successfully drilled well.

Cementing

Cement planning consists of several features, including the following:

- Assessment of hole conditions such as temperature, size, etc.
- Evaluation of mud properties
- Cement slurry design
- Cement Slurry placement techniques
- Equipment selection, such as centralizers, scratchers, and float equipment

Lack of any of the above will have direct impact on primary cementing of the well and will need other remedial work



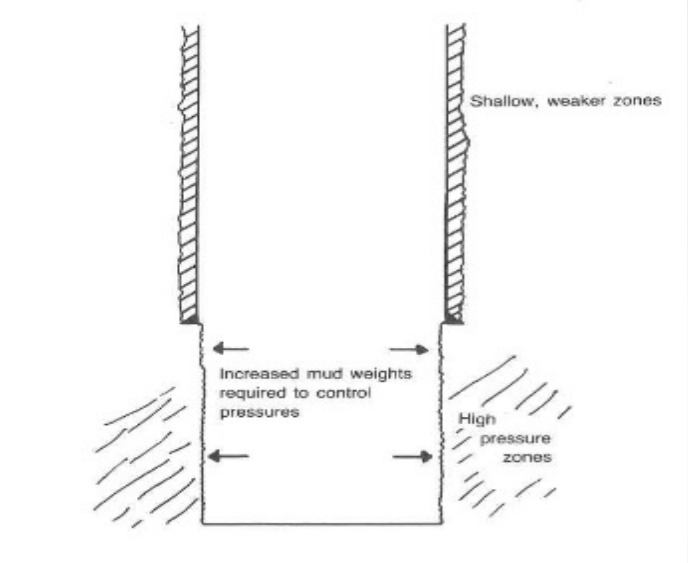
Cement placement in the well primarily falls into three categories:

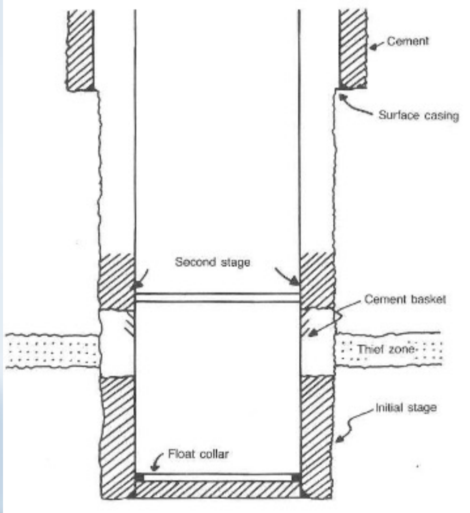
1. Primary cement job on a casing string
2. Squeeze / remedial Cementing
3. Cement Plugs (Abandonment purpose)

Various drilling conditions may warrant that several sections of the annulus be cemented without cementing the entire annulus.

A common cause is the presence of a lost circulation zone that negates the possibility of circulating cement up to the desired height.

Cementing





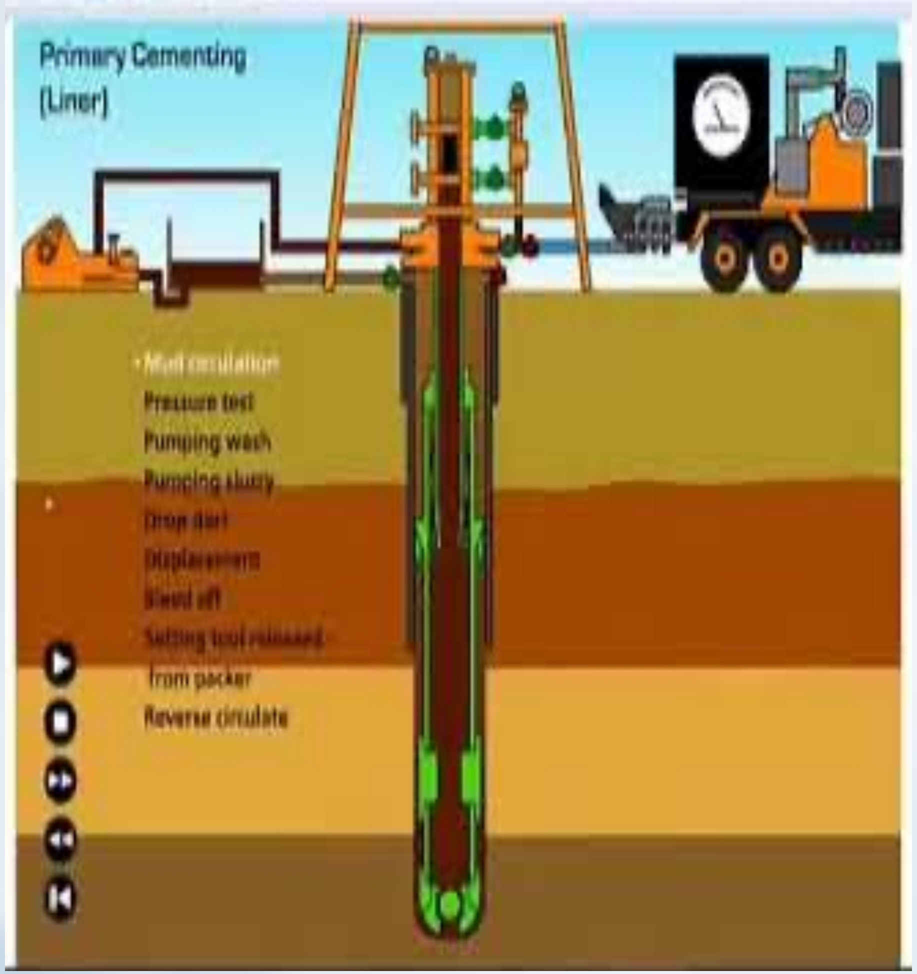
The cement is normally placed behind the casing in a single- or multi-stage technique. The single-stage technique pumps cement down the casing and up the annulus. The heavier cement in the annulus is prevented from U-tubing by back-pressure valves in the bottom of the casing string. (Floats)

Cement slurry is placed just before the high pressure zone by altering the casing depths and to protect the annular space between the casing and borehole. Normally casing setting depths are altered to be placed right above the high pressure zone. This ensures good shoe to drill ahead.

For a stage cement job the first / initial stage is planned as if it were a single-stage effort. Cement is pumped down the casing (or stabbed-in drillpipe) and up the annulus using a Stage tool / collar.
The next stage is pumped through a special port collar at the desired location up the annulus. The port is opened after the initial stage is cemented.

Stage tool is also placed strategically so that two zones will have good cement slurry for longer isolation during production life of the well.

Cementing



Liners are cemented in different fashion than casing strings. Cement slurry is pumped through the pipe prior to entering the liner.

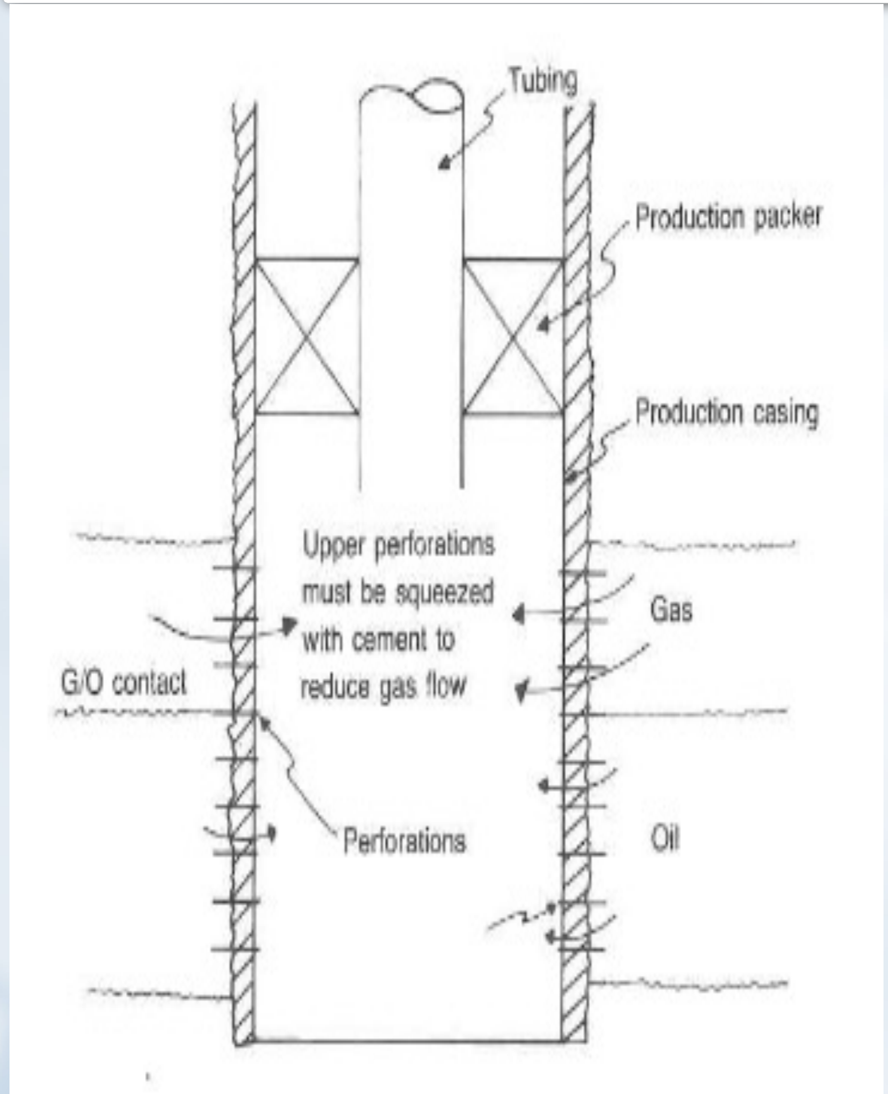
After the slurry for open hole is pumped, excess slurry volume is pumped from the well to cover the liner lap section. Circulating the excess volume after a liner job has caused problems in some wells.

As a result, preplanning is important. If the volume of cement is to be circulated up the annulus, additional time will be required for removal of liner setting tool and recovery of the drill pipe.

Cement Thickening time must be reconfirmed using lab testing of the slurry to be pumped for liner cementation.

Many industry personnel believe the high frequency of squeeze jobs are required for liner overlaps can be avoided if proper planning is done

Cementing



Squeeze Cementing. A common method for repairing faulty primary casing jobs or performing remedial operations on the hole is squeeze cementing.

Major applications for squeeze cementing are as follows:

- supplement a faulty primary casing cement job
- reduce water-oil, water-gas, or gas-oil ratio
- Fracturing
- Repair casing leaks
- stop lost circulation in an open hole
- Isolate a zone before perforation for production (block squeezes) or before bring a well under control

Lost circulation problems can often, but not always, be solved by squeeze cementing. The type of lost circulation must respond to cement. For example, cementing a zone fractured from excessive pressures will not solve the problem unless the pressures are reduced.

Cementing

Placement techniques and slurry design are important considerations in squeeze operations.

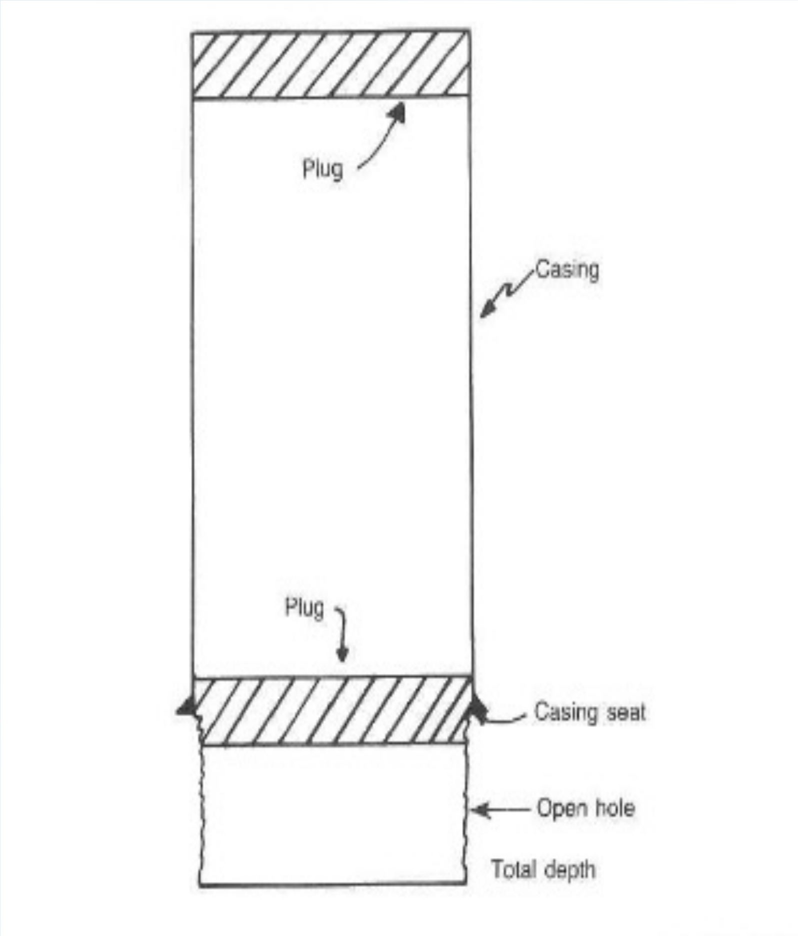
The initial cement job may have failed to hold pressure under integrity tests, or cement bond logs may have indicated poor or absent cement bonding.

Since the primary job is a major well control system, a bad job must be augmented with additional cement. Generally, this additional cement must be forced, or "squeezed," around the annulus by using high pump pressures. Squeeze techniques are discussed later in this chapter.

The reduction of producing fluid ratios by squeeze cementing is a common, necessary practice on many wells.

High gas volumes may deplete reservoir pressure prematurely, while high water volumes may create excessive separation costs at the surface production facilities or retard production. Specific sections of perforations may be closed by pumping cement. Gas volumes are reduced by cementing the upper perforations, while water is reduced by cementing the lower perforations.

Cementing



Setting plugs in the well commonly is used for the following reasons:

- plugback
- whipstock abandonment

A balanced plug technique is used usually for the placement technique. A plug-back operation may set a plug through or above the old pay zone when recompletion above a depleted producing zone is necessary. A plug may also be used in open-hole completions to shut off bottom-hole water.

A whipstock is often used when it becomes necessary to increase or de-crease the deviation of a hole or to change direction while drilling. The whipstock tool requires a solid cement plug to provide a seat or bridge. Whipstocks are also used to bypass junk or to reach a new objective.

Cementing

Good operating practices and the rules of regulatory bodies require abandoning wells in such a manner that fluid-bearing zones are properly sealed and protected.

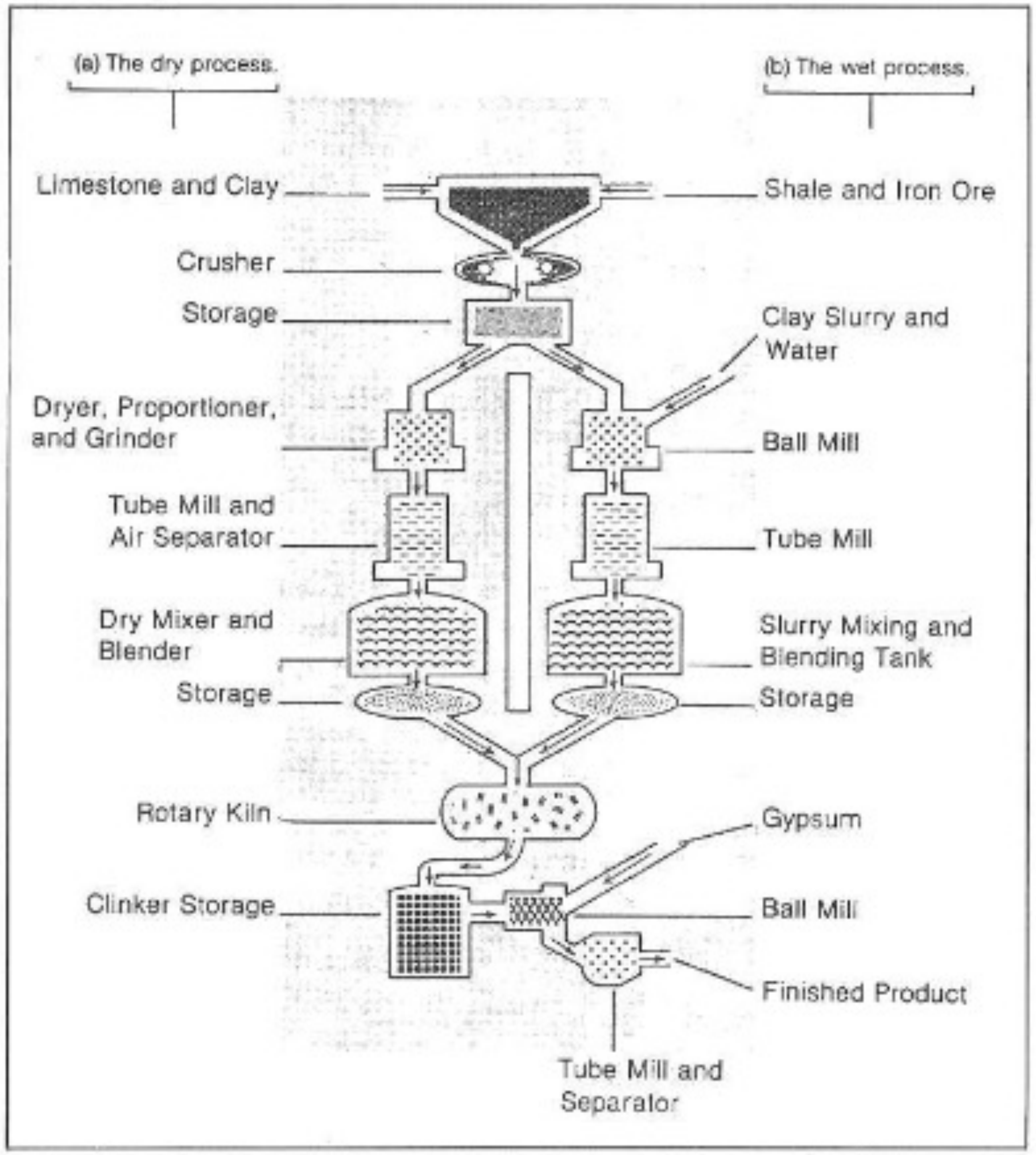
Cement plugs are commonly used to seal and protect these zones. As many as three plugs are set in deep wells.

A plug is usually set at the bottom of the surface casing or deeper casing string.

Uncased freshwater sands in abandoned wells are protected by plugs extending from below to above the sands.

Government regulations with jurisdiction over the wellsite should be consulted for specific abandonment procedures.

Cementing



API Cements are “Portland” cements. Also are called Hydraulic cements as they set up in water. Portland cement is manufactured by calcining lime- stone, clay, shale, and slag together at 2,OOO-2,600°F in a rotary kiln. The resulting material, clinker is cooled and grinded with addition of gypsum to form portland cement. In addition to the raw materials, other components such as sand, bauxite, and iron oxide may be added to adjust the chemical composition of the clinker for the different types of portland cement. The principal components of the finished portland cement are lime, silica, alumina, and iron. The components form complex compounds. Each compound affects the slurry in a different manner. When water is added to cement, setting and hardening reactions begin immediately. Most important of the property is Sulphate resistance (Zero, Medium, High). API uses this to specify cement for the wells.

Sulfate Rest.	API Class	ASTM Type	Percent MgO	Percent SO_3	Percent C_3A	Blain
O	A	I	6.0	3.0	N/A	1600
	C	III	6.0	4.5	15.0	2200
MSR	B	II	6.0	3.0	8.0	1600
	G	II	6.0	3.0	8.0	1800
	H	II	6.0	3.0	8.0	1600
HSR	B	N/A	6.0	3.0	3.0	1600
	C	N/A	6.0	3.0	3.0	2200
	G	N/A	6.0	3.0	3.0	1800
	H	N/A	6.0	3.0	3.0	1600

Cementing

API Class	Compounds, % C_3S	C_2S	C_3A	C_4AF	Fineness, sq cm/g	Water/cement ratio
A	53	24	8	8	1,500–1,900	0.46
B	47	32	3	12	1,500–1,900	0.46
C	70	10	3	13	2,000–2,400	0.56
D	26	54	2	12	1,100–1,500	0.38
G	52	32	8	12	1,400–1,600	0.44
H	52	32	8	12	1,200–1,400	0.38
J	53.8		38.8		1,240–2,480	0.44
	SiO_2		CaO			0.435

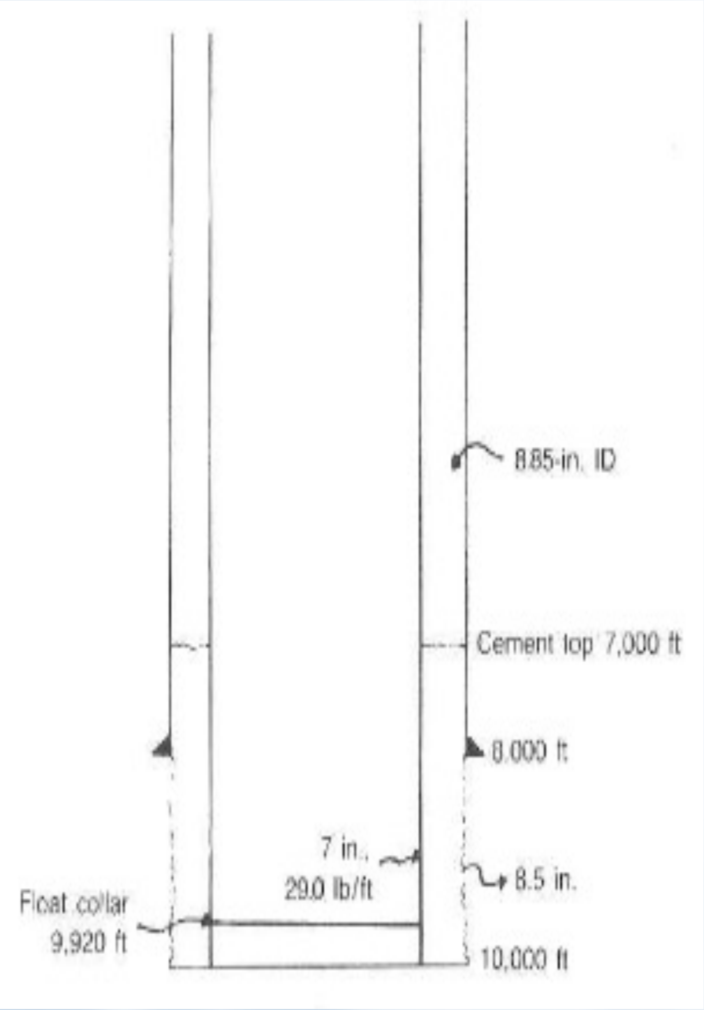
Compound	Characteristics
Tricalcium aluminate/C_3A ($3CaO \cdot Al_2O_3$)	Promotes rapid hydration Affects the initial setting and thickening time of the cement Makes the cement susceptible to sulfate attack
Tetracalcium aluminoferrite/C_4AF ($4CaO \cdot Al_2O_3 \cdot Fe_2O_3$)	Promotes low-heat hydration
Tricalcium silicate/C_3S ($3CaO \cdot SiO_2$)	Major component and produces most of the strength Responsible for early strength development
Dicalcium silicate/C_2S ($2CaO \cdot SiO_2$)	Hydrates slowly Promotes small, gradual gain in strength over an extended period of time

Cement Hydration reactions are very complex, and there are more than 35 chemical reactions happening simultaneously when water is added to the cement for preparing the cement slurry, and therefore the slurry should be designed to have specific properties desirable for effective placement in the well. Validating the properties in the lab as per design is a recommended practice, specifically for the production casing / liner cementation. API Spec 10 A requires only Class G / H cement to be used for oil wells. API Spec 10B / ISO 10426 standards are required to be followed for testing the cement slurry prior to placement. Typically slurry is prepared using water and additives for specified purpose such as better yield. Yield is defined as Volume / sack of cement used. Once the slurry is designed for a particular density, yield, mix water requirement is calculated. Slurry is made using samples of materials used from location and laboratory testing of properties at bottom hole temperature is performed prior to placement for effective placement:

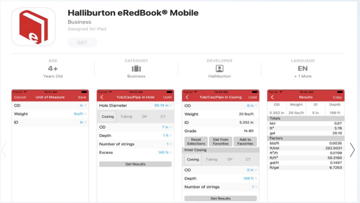
1. Slurry density, and Rheology
2. Thickening time
3. Fluid loss
4. Compressive strength

Cementing – Volume calculation

Example Cement Volume



The Oil Company is planning to set a 7.0-in. production string inside an 8.5" Open hole. The float collar is two joints above the guide shoe, i.e., at 9,920 ft. Company wants to use a sufficient volume of 15.8-lb/gal Class G cement Slurry such that the cement top is at least a 1,000 ft inside the intermediate casing, or at 7,000 ft in this case. Compute the following: (Assume 30% volumetric washout)

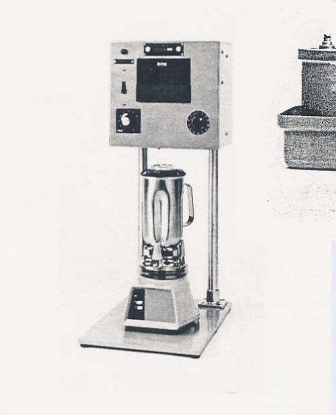


1. total fluid volume
2. cement requirements
3. water requirements

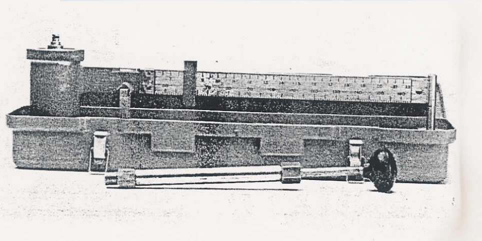
- Volume of Floats 80 ft of 29.0-lb/ft, 7-in. pipe : 0.2085 cuft/ft x 80 ft = 16.7 cuft
- Volume in Open Hole : 2,000 ft of 7-in. x 8.5-in. OHAnn 0.1268 cuft/ft x 2,000 ft = 253.60 cuft ; For 30% Wash out add 30% / 130% x 253.60 cu ft = 329.7 cu ft
- Volume in Cased Hole 1,000 ft of 7-in. x 8.835-in. pipe annulus 0.1858cuft/ft x 1,000ft = 158.5 cu ft
- Total volume = 504.9 cu ft or 90 Bbls
- As cement slurry yield is 1.17 cu ft/sack, shall need 504.9 cuft/1.17 = 431.5 sk
- Water requirement for 5. 19 gal/ sack: There fore water required : 5.19 gal/sack x 431.5 sx = 2,239.5 gal = 53.3 bbl

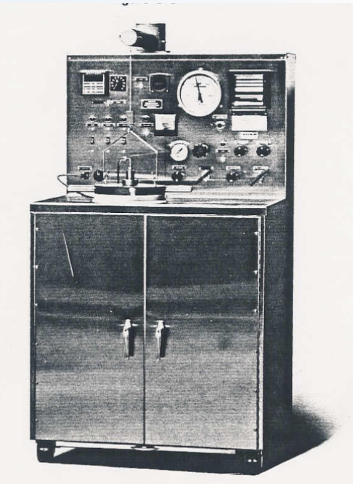
Total Slurry Volume shall be : 505 cu ft / 5.6146 cu ft / sack. Or say 90 Bbls

Cementing – Examples of Lab Equipment



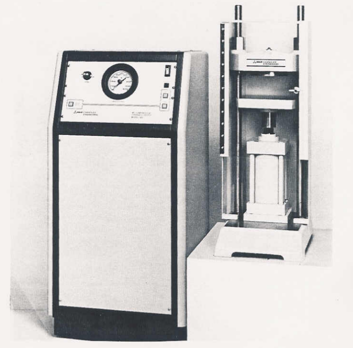
Chandler Automated Blender





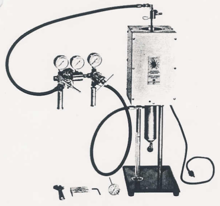
Chandler Pressurized Consistometer

2" Compressive Strength Molds



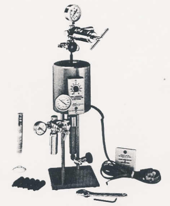
Chandler Hydraulic Press

FIGURE 3-4



Baroid 500 mL HPHT Filter Press

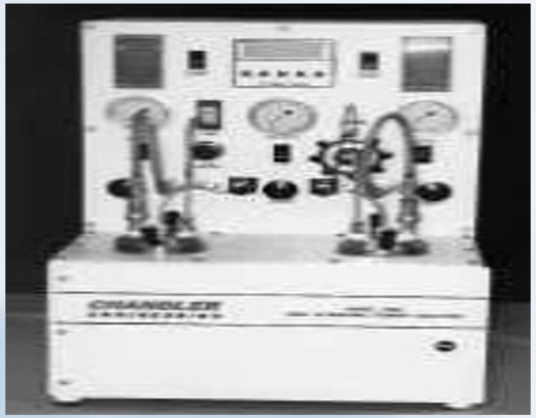
FIGURE 3-5



Baroid 260 mL HPHT Fluid Press

FIGURE 3-6

Baroid Double Ended Fluid Loss Cell

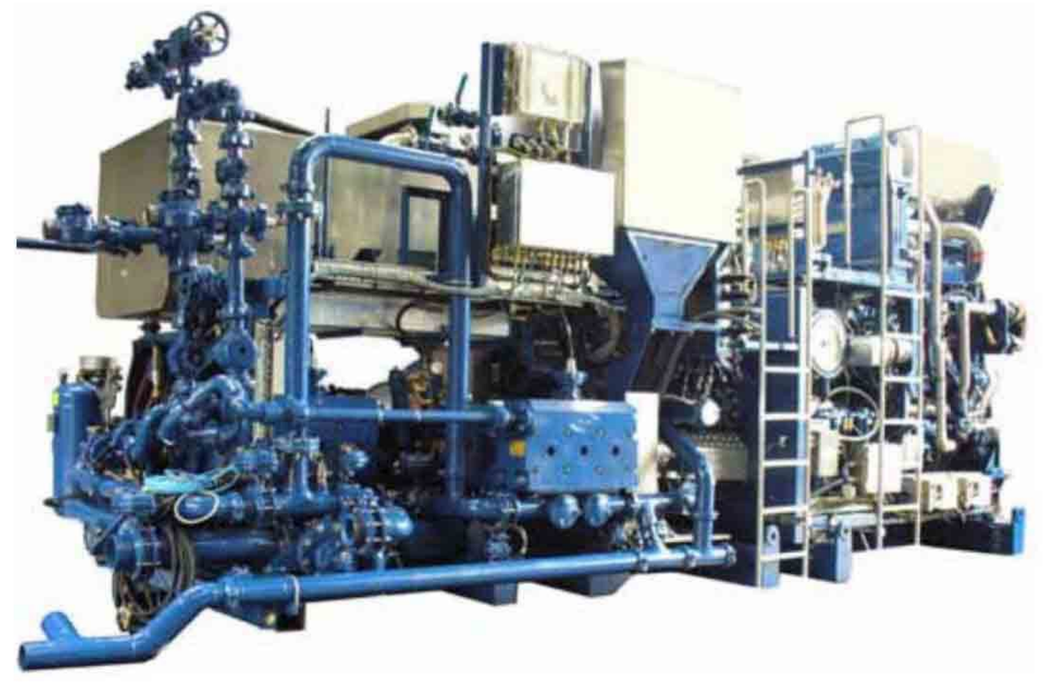


Cement slurry refers to mixture of water (44%) and Cement. Special chemicals are designed to be added to achieve some desired purpose(s). Additives fall into the following categories:

- Accelerators
- Retarders
- Density adjusters
- Dispersants
- Fluid loss additives / Gas Block Addtives

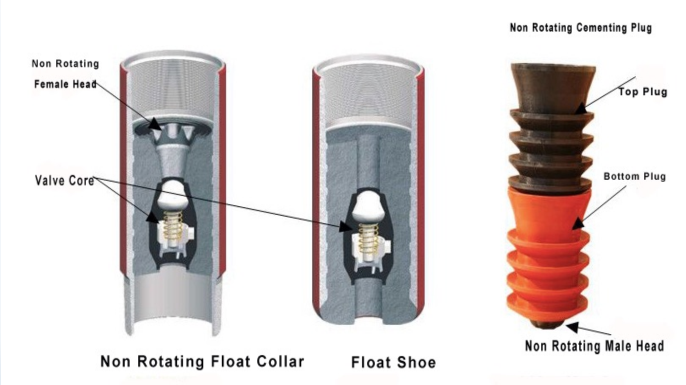
Cement slurry design is done by experienced engineers and once the slurry is designed samples, which represent the bulk at field location are brought in and the cement slurry is tested for required properties like thickening time, compressive strength, fluid loss / rheology using the lab equipment shown.

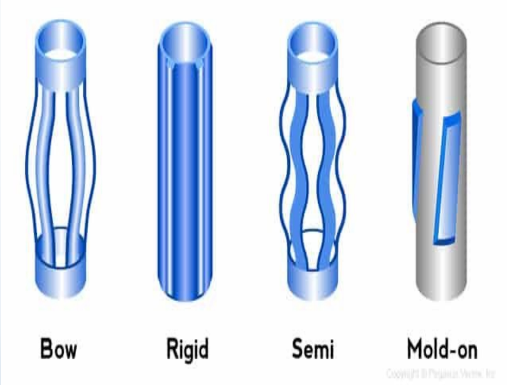
Cementing Equipment

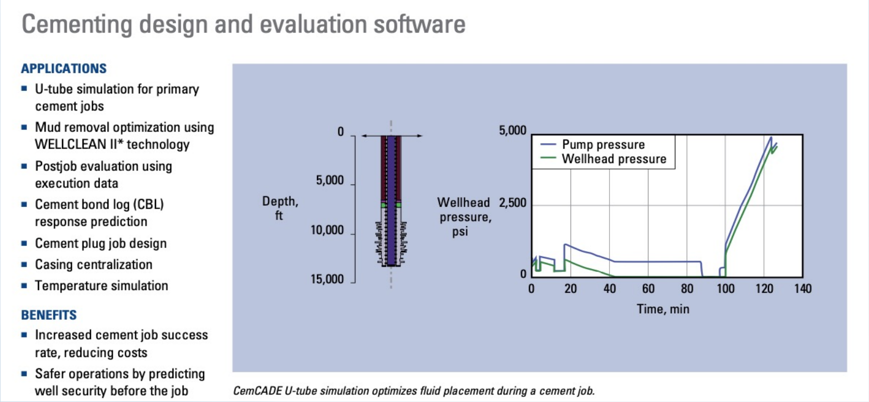


Cementing Equipment are required to place cement slurry in the the desired space.
A High pressure cement Pump is used to prepare the designed slurry at the location. It is pumped through cement head and reaches bottom hole prior to turning the corner.

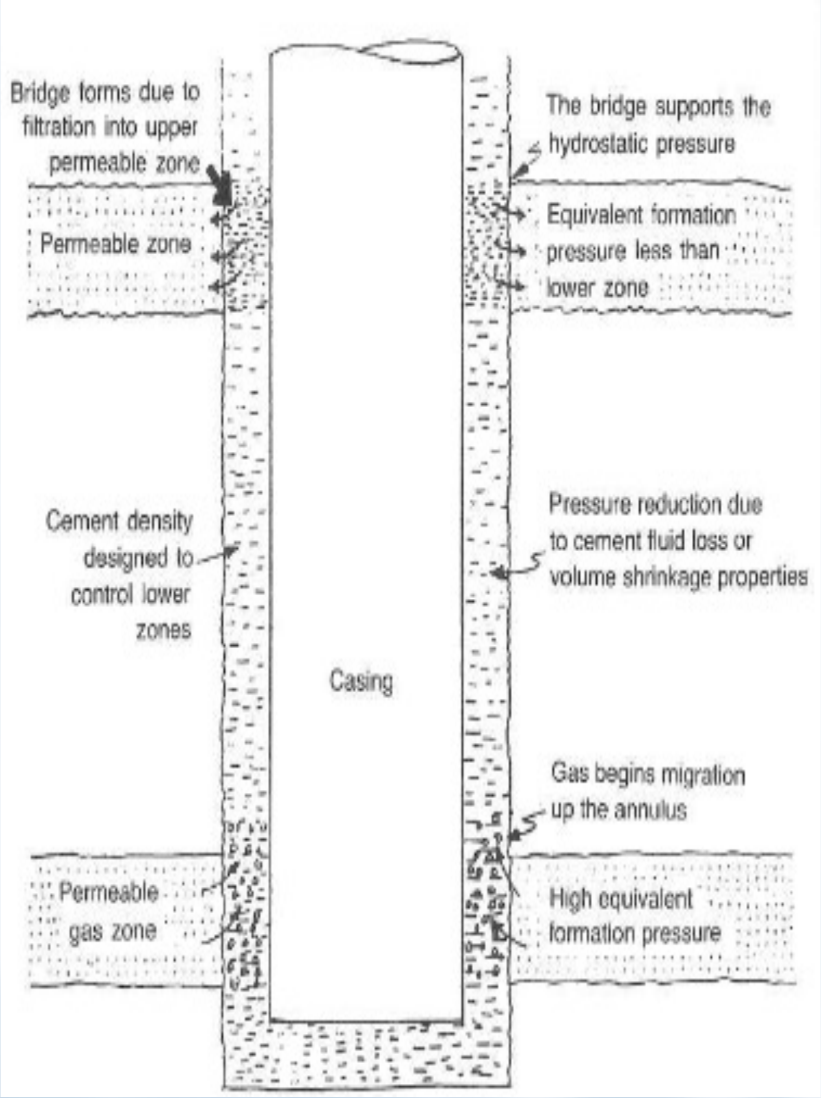
Details of the Float equipment and the casing accessories for guiding the flow of cement slurry and making the casing centralized in the open hole are shown below.







Cementing Challenges

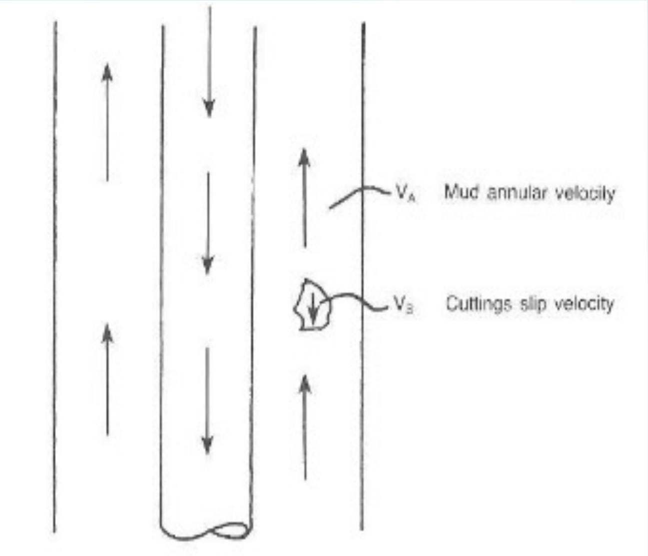


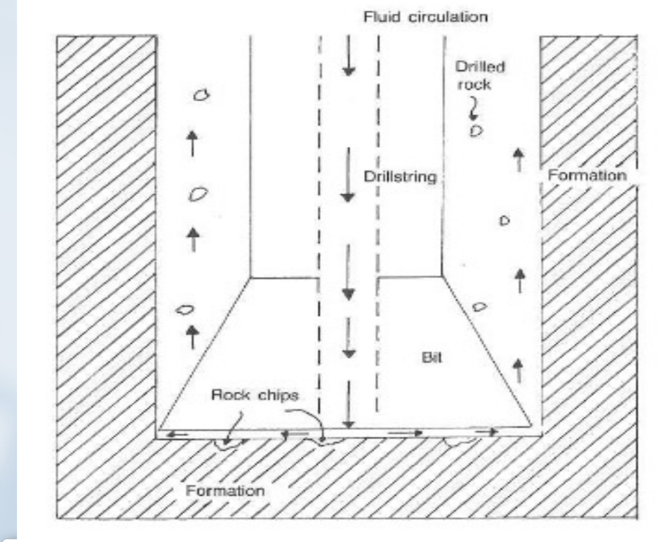
Salt Sections : Formations containing significant salt sections will wash out if conventional water-based mud and cement slurries are used. Drilling muds are usually modified so that the water phase is salt saturated or an oil mud is used. Likewise, the cement slurry must be designed so the water phase is salt saturated if effective bonding is to be achieved and washouts prevented.

Kicks Following Cementing : Kicks and blowouts have been experienced on wells immediately following apparently successful cementing operations. Although surface blowouts in this situation are dramatic, underground blowouts resulting from gas-through-cement kicks can also cause problems, such as pressure charging other zones that will affect offset drilling and the loss of hydro- carbon reserves.

Strength Retrogression : Long time exposure to higher temperatures over 230F, can cause degradation of set cement strength. Addition of silica in cement slurry during design and execution helps in alleviating this retrogression.

Drilling Fluids





The use of drilling fluids to remove cuttings from the borehole was first conceived by Fauvelle, a French engineer, in 1845. "Drilling fluids" describes a broad range of fluids, both liquids and gases, used in drilling operations to achieve specific purposes Drilling fluids are often referred to as drilling mud / simply ”mud”.

A complete and comprehensive mud plan is a must during planning the drilling. History has proven that an incomplete mud plan will cost the operator many hours of rig time and may mean the difference between a productive or a non-productive well.

Mud may be air, natural gas, water, oil, or a combination of liquids used with special chemicals and additives. Muds are designed to solve or minimize many drilling problems and, as such, an understanding of these purposes will help the drilling supervisor successfully prepare a mud program, use proper additives, and diagnose trouble areas.

Drilling Fluids

Mud serve many purposes during drilling.
The major functions include the following:

- Cool and lubricate the bit and drill string
- Clean the hole bottom and carry cuttings
- Control formation pressures
- Minimize formation damage maintain hole integrity
- Facilitate in well logging operations
- Minimize corrosion of the tubulars
- Minimize contamination problems
- Minimize torque, drag, and pipe sticking
- Improve drilling rate

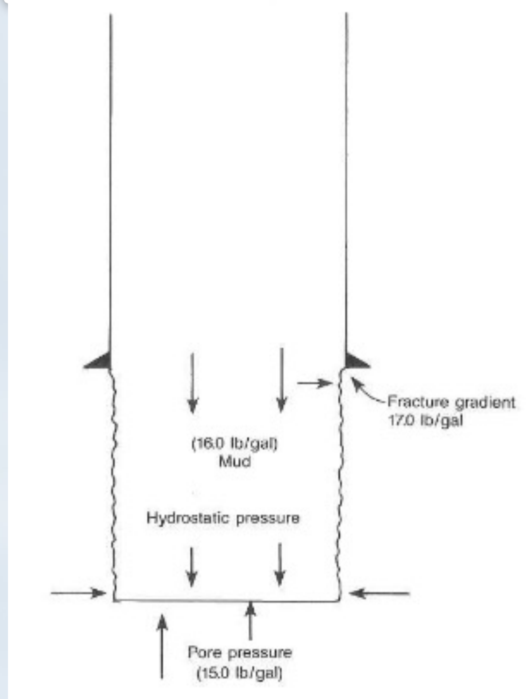
Due to various drilling conditions encountered, all functions will not be addressed on each well.
The mud program must be designed to satisfy the highest-priority requirements for drilling the prospect well.

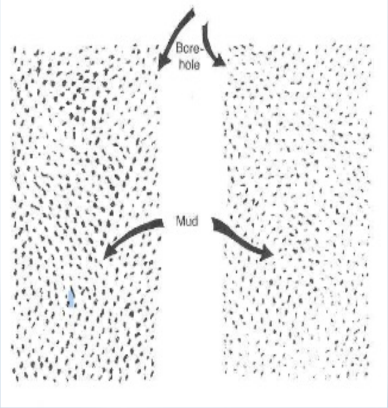
Unfortunately, drilling requirements may often be conflicting and/or may place demanding constraints on the system.
For example, a low-solids system may be desirable for improved drilling rates and minimum formation damage.
However, if high pressure, high-activity shales are drilled in an extreme temperature range, oil muds or dispersed lignosulfonate systems may be easier to control.
The engineer must attempt to select a system that will achieve the following goals:

- Satisfy the crucial items such as pressure control
- Satisfy all lower-priority requirements
- Avoid using systems that are completely unsatisfactory

An example of an unsatisfactory system might be using oil muds in formations that have historically proven non-productive due to emulsion blockage when oil muds are used.

Drilling Fluids



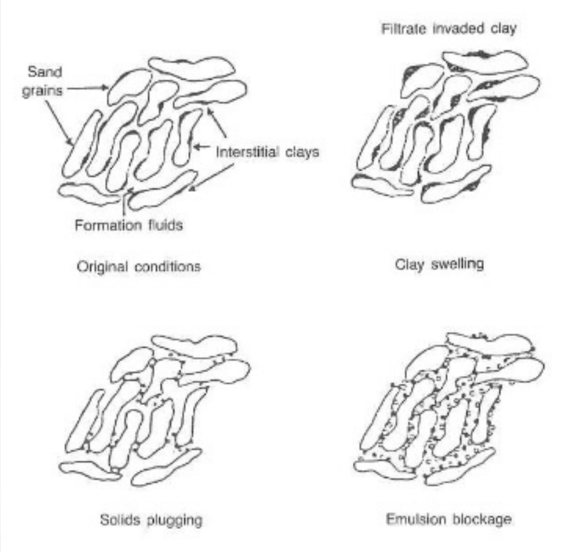


Planning a mud program is an essential step in the development of a workable overall well plan. Key steps, listed below, are followed on each well.

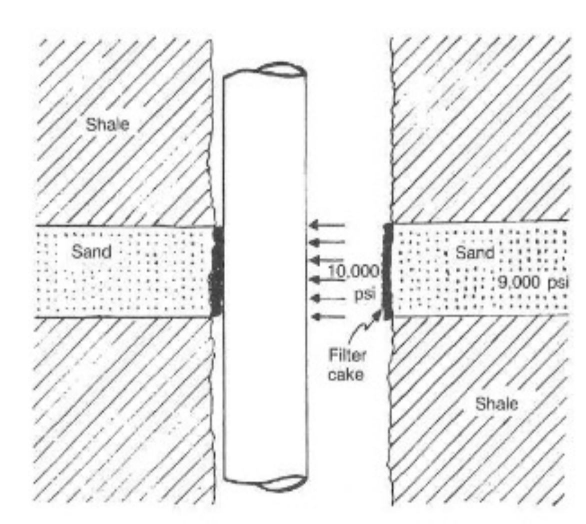
- Obtain pore pressures and casing program
- Look for geological hazards beginning with the deepest hole section .Set mud weights
- After checking geometry, ECDs, and hydraulics, set optimum viscosities
- Establish maximum fluid loss by interval
- Select mud types by interval, trying to match one interval to the next
- Set other critical properties (allowable sand content, pH, etc.)
- Check mud program against other phases of well plan for possible conflict
- Determine material requirements
- Write breakover instructions
- Develop contingency plans for kicks, hole trouble, etc.
- Line up supply of water, chemicals, etc.

Mud engineers can often provide insight into expected problems in an area.

Drilling Fluids

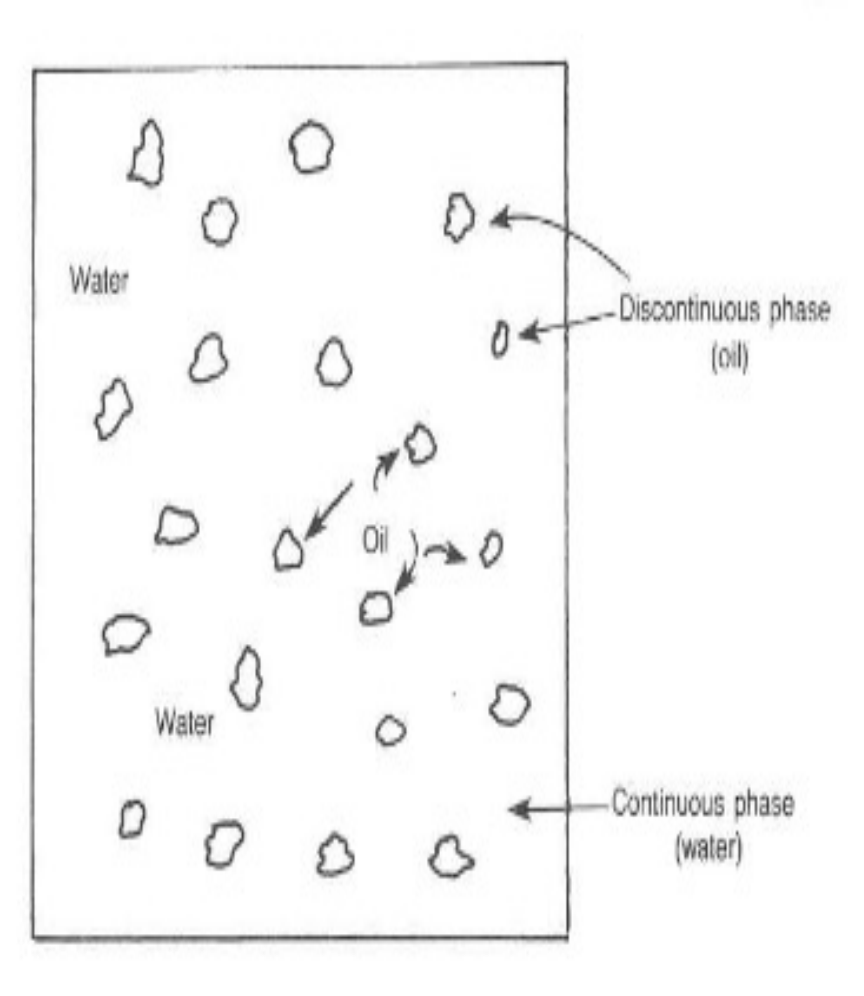


Minimizing Formation damage is one of the priority requirement of the mud. During drilling the mud is expected to form a cake against the porous media and only the filtrate can travel through the rock matrix. The filtrate, which is typically base fluid must be compatible with the reservoir fluids, in order to minimize the formation damage. Mud compatibility tests along with the formation fluids are also done on drilling location and Mud Chemist can alter the formulation / add specific additives such as surfactants to ensure the compatibility. At times when the mud is lost to the formation, chances of formation damage increase. Remedial treatments using the acid / surfactant solutions can be planned during completion.



Another priority task for the mud is to avoid differential sticking, and improve drilling rate. Alteration to liquid to solids ratio can cause premature sticking of the drill string. Low fluid loss mud can help reduce such events. Mud engineer on the rig will ensure that the required properties are maintained for the mud, and should they be altered during the drilling process due to mixing them with cutting / recycled mud contaminating the fresh mud used in the well. Mud engineer is expected to perform the laboratory tests for maintaining the QAQC for the fluids being pumped in the well during drilling. Mud engineer is in-charge of preparing and maintaining the mud requirements.

Drilling Fluids



Water-Based Mud (WBM) : The mud system used most frequently throughout the industry is the WBM. Water is the continuous phase, but it may contain oil (i.e., emulsion muds) or air (i.e., aerated mud) as the discontinuous phase. The oil must remain as segregated droplets.

Fresh water is often the base fluid when adding many chemicals such as clays, polymers, weight materials, and additives to control various properties.
The clays include sodium and calcium montmorillonite, attapulgite, and subgroups of montmorillonite.
Polymers cover a broad range of products such as CMC (carboxymethylcellulose) and HEC (hydroxyethylcellulose).

Weight materials include barite, galena, iron oxides, and hematite.
Special additives may be used for controlling mud properties such as fluid loss, viscosity, gel strength, and pH.

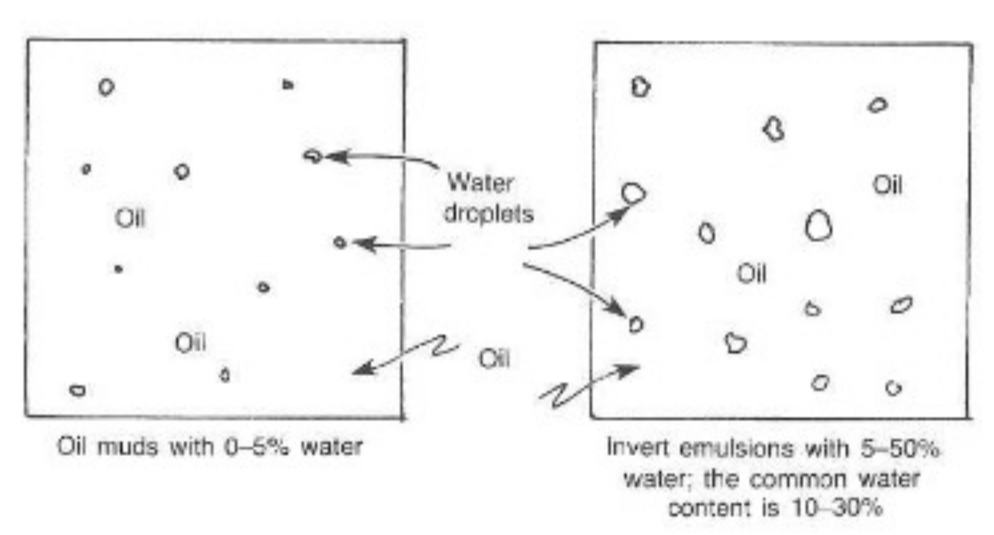
Drilling Fluids

Inhibited Water-Based Mud : An inhibited water-based mud is often used to minimize hole sloughing problems. "Inhibition" refers to retarding the rate at which formation clays hydrate. Hydration reduces the structural stability of the borehole, allowing it to fall, or slough, into the wellbore.
Common inhibited muds such as lime muds use calcium to retard hydration, while others use high concentrations of various salts. Four common mud systems that can be classified as inhibited muds are gyp muds, lime muds, seawater muds, and saturated saltwater muds. Lime muds have been widely used for many years as inhibited fluids. The hydrated lime, which is calcium hydroxide, reduces the amount of water attached to the clay structure.

Low-lime muds have been used successfully during recent years in high- temperature wells. High lime concentrations tend to cause clay flocculation in the upper temperature ranges. This mud system must be monitored closely to maintain undissolved lime in the system.

Gypsum (calcium sulfate) muds are used commonly in gyp and anhydrite formations. Gyp muds are similar to lime muds since they derive their inhibitive properties from soluble calcium and require a chemical thinner for viscosity control. These muds function at lower alkalinity ranges than lime muds and contain more soluble calcium.

Drilling Fluids



An "Oil-based mud" (OBM) usually refers to a mud that has 1-5% by volume water, and has base oil as its continuous phase.

"Invert muds," or invert emulsions, refers to a water-in-oil emulsion and has 5-50% by volume water with water droplets dispersed in the continuous phase of oil.

Emulsifiers are required to form an oil film completely around the water droplets. Emulsion will become unstable if proper dose of the emulsifiers are not used. Small amounts of additional water / its droplet size may cause severe problems, such as segregation of the oil and water phases.

Large droplets exhibit a greater tendency to combine. In order to obtain small, uniform water droplets, some type of shear force must be applied to the mud system.

This shearing can be accomplished with mud guns, centrifugal pumps, and circulating through the bit.

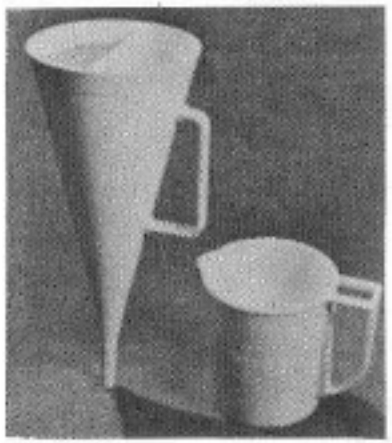
Water in an invert system helps support barite, acts as a fluid loss agent, allows many of the chemicals to dissolve, and contributes to viscosity and gel strengths.

Drilling Fluids

Oil added to an invert system usually increases the stability of the emulsion. Water added to an invert system decreases the stability and increases the yield point and the gel strengths. Calcium chloride is added to an invert emulsion to help dehydrate water sensitive formations. Formations hydrate or dehydrate when exposed to a drilling mud if a salinity difference exists between the formation and the drilling fluid. This osmotic force may be adsorption or desorption, depending on the salinity of the drilling fluid and the water in the formation. Contamination can another challenge during QAQC of the mud.

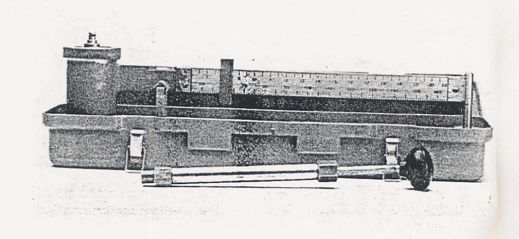
Contaminant	*Possible Corrective Actions**
Sodium chloride	
Bed salt	Add organic thinners, caustic soda; convert to saturated salt mud
Saltwater flow	Increase mud weight to stop the flow; add organic thinner, caustic soda; water dilution
Saline makeup water	Add organic thinners, caustic soda
Gypsum, anhydrite	Add soda ash, organic thinners; convert to gyp mud
Hard water (Ca and/or Mg)	Raise pH to 10.5+; add soda ash
Cement or lime	Add SAPP, sodium bicarbonate
Hydrogen sulfide	Raise pH to 10.5+; add scavengers, lime, thinners
Carbon dioxide	Raise pH to 10.5+; add thinners
Carbonate and bicarbonate	Add organic thinners, lime
Drill solids	Add water, caustic soda, organic thinners; solids control equipment
Oil	Add water, chemical emulsifier

Drilling Fluids



Test	Mud Type: Water-Based	Mud Type: Oil-Based
Mud weight	Mud balance	Mud balance
Viscosity	Marsh funnel and graduated cup	Marsh funnel and graduated cup
Sand content	Sand content kit	N/A*
Rheology (PV, YP, gels)	Viscometer	Viscometer
Shear strengths (Nonpressurized)	Shearometer	Shearometer
Low pressure filtration (100 psi)	API filter press	Usually not applicable except with a relaxed filtration mud
High pressure filtration	HPHT press	HPHT press
Static high-temperature shear strengths	High-temperature pressurized aging cells	High-temperature pressurized aging cells
Hydrogen ion determination	Modified colorimetric method (pHydrion dispenser) or electrometric method (pH meter)	N/A*
Oil, water, solids determination	Retort kit	Retort kit for determination of O/W ratio
Bentonite content	Methylene blue kit	N/A*
Chloride content	Potassium chromate, silver nitrate	N/A*
Water phase salinity and total soluble salts	N/A*	Measurement of calcium chloride and sodium chloride content percent by volume of water
Alkalinity	N-50 sulfuric acid, phenolphthalien, or methyl orange	N/A*
Calcium and magnesium	Versenate hardness test	N/A*
Electrical stability	N/A	Voltage breakdown meter

*Not applicable in most cases or is not customarily evaluated in field practices.



Drilling Fluid – Additives

To meet drilling requirements the mud uses several additives. Considering the requirement of carrying capacity viscosity must be managed and monitored. A viscometer is used to measure the shear rate at different RPMs. The device measures the plastic viscosity (PV) and the yield point (YP). The PV and YP units are in centipoises and Lb/100 Ft^2, respectively. PV is indicative of the size, shape, and number of particles in the mud. Yp is a measure of the interparticle attractive forces.

Viscosifiers :

The viscosity of a fluid is dependent upon interparticle force; size, shape, and number of particles; and viscosity of the base fluid. Following materials are used as viscosifiers.

- *Clays.* The bentonites, attapulgite clays, and sub-bentonites (all colloids) increase viscosity, yield point, and gel strengths. Additional colloids increase the number of particles and the interparticle force.
- *Polymers.* Some of the better-known polymers such as H*ydroxyethylcellulose* (HEC), nonionic polymeric viscosifier, *Carboxymethylcellulose* (CMC), anionic polymeric viscosifier used primarily in fresh water
- *Polysaccharide (high molecular weight),* suspends bridging agents and weight materials in fresh water and brines
- *Hydrocarbon copolymer,* increases viscosity in invert and oil muds
- *polyacrylamide polyacrylate (combination),* certain combinations of these two polymers will increase viscosity
- *polyacrylate,* used with bentonite will increase the yield of the bentonite without increasing the solids content

Drilling Fluids - Additives

Viscosity Reducers. A high viscosity caused by excessive colloids, undesirable drill solids, or contaminants can cause several drilling problems. Associated with high viscosities are excessive yield points and gel strengths, which cause an increase in the equivalent circulating density and may require high pump pressures to break circulation. These conditions can result in lost circulation and other wellbore problems.

Thinners and Dispersants. Chemicals that cause mud thinning disperse the clay platelets by reducing the interparticle attraction forces and, in some cases, by creating repulsion forces. Most thinners can be classified as organic materials or as inorganic complex phosphates.

The organic thinners include lignosulfonates, lignins, and tannins. Lignosulfonates with several metal compounds have been used successfully in a wide range of applications. Organic thinners can be used in higher-temperature wells and exhibit good filtration control properties.

Inorganic thinners Include sodium acid pyrophosphate (SAPP), tetrasodium pyrophosphate, sodium tetraphosphate, and sodium hexametaphosphate. Inorganic thinners are effective in very small amounts but are restricted to freshwater clay muds, low temperatures, low chlorides, low calcium/magnesium, and low pH values.

Addition of water or oil will decrease the viscosity. While drilling, water must be added continuously to compensate for extra solids added to the mud system / thinning.

Drilling Fluid – Additives

Chemical Breakers. Viscosity generated by polymers can be treated with special chemicals to cause fluid thinning. These mild acids, such as Clorox@, have been used successfully in the chemical breakdown of polymers. Due to the cost of polymer fluids, pilot testing should be done in a laboratory before adding chemical breakers to the system. Also, it is advisable in some cases to wait 12-18 hr after chemical breakers have been added before continuing operations.

Fluid Loss Agents. All muds lose fluid to the formations. Fluid reduction agents are developed to form thin, tough, semipermeable wall cakes. The hole becomes more stable, and productive zones are protected to some degree if invasion of drilling fluid filtrate is controlled. The deposition of solids too large to pass through the membrane pores minimizes the continuation of fluid loss. Permeability of a filter cake is dependent upon size and distribution of particles on the wall cake

pH Adjusters. The pH is a measurement of hydrogen ion concentrations. Due to the chemical composition of mud and the nature in which they react, it is necessary to maintain the pH of the mud in the alkaline range. Adding chemicals such as organic and inorganic thinners and water with high calcium/magnesium content and influx of certain contaminants will mandate additional pH control. Approximate pH ranges for optimum operations are determined by the type of drilling fluid and chemical additives.

Proper pH in water-based muds is usually achieved by adding sodium hydroxide ($NaOH$) or potassium hydroxide (KOH). Both chemicals provide an alkaline base to compensate for acidic chemicals and contaminated water. Oil- based muds do not rely on a pH value as measured in water-based muds. The lime and excess lime calculations in an oil-based mud reflect the alkalinity values.

Drilling Fluid – Additives

Density Control Materials : To drill a well successfully, the formation pressure must be controlled by the hydrostatic pressure (HH) of the mud. HH is increased by adding following materials from the table below.

Item	Chemical Name	Average Specific Gravity, ±	Maximum Mud Weight, ±, lb/gal
Barite	Barium sulfate	4.25	20–22
Galena	Lead sulfide	6.6	28–32
Calcium carbonate	Calcium carbonate	2.7	12
Bar-Gain	Ilmenite	4.5	21–23
Densimix	Hematite (itabrite ore)	5.1	24–26

*Exclusive of salts, drilled solids, and various less-common materials.

HH Computation is simple and can be done using following :

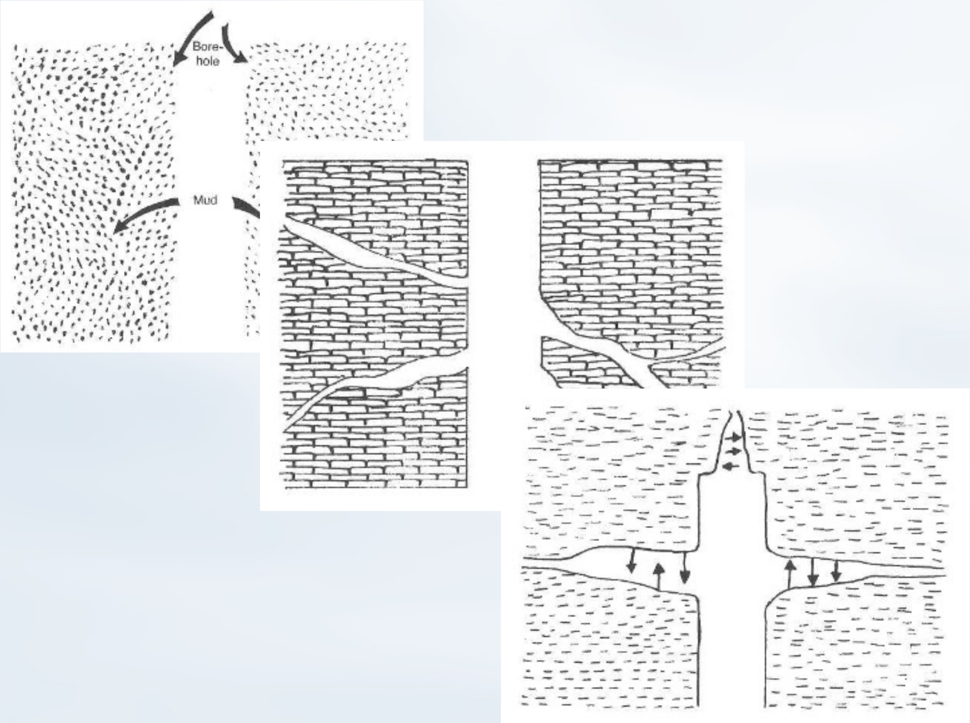
HH (psi) = 0.052 x Mud weight (ppg) X Vertical Depth (ft)
So for 10000ft as vertical depth and the mud weight of 12 ppg.

The Hydrostatic (psi) : 0.052 x 12 X 10000 = 6240 psi

Proper well planning requires that a sufficient quantity of barite be maintained on the drilling location to kill a kick. To calculate this volume of barite properly, many operators have established a 1.0 Lb/Gal safety measure, which means barite volumes will be maintained at a level sufficient to increase the present mud density by l ppg.
Formula for calculating the Barite requirement for increasing the mud weight by 1 ppg =
Barite (Lbs/ Bbl) = 1490 (Desired Mud Weight – Initial Mud weight). / 35.4 – Desired Mud weight)
For example : Say the Mud volume in pit is : 1200 bbls. And the desired mud weight is 13 ppg and Initial mud weight is 12 ppg then Barite in Lb/ Bbl = 1490 / (35.4 – 12) = 63.67 Lb / Bbl for 1200 Bbls you shall need 76410 Lbs or 764 Sacks (considering 100 Lb/Sk)

Drilling Fluid – Additives

Lost Circulation Materials. Lost circulation is perhaps the most costly drilling problem encountered in oil and gas exploration, with the exception of blowouts. Losses can occur if the hydrostatic is too high and there is no control on fluid loss / Natural fractures.

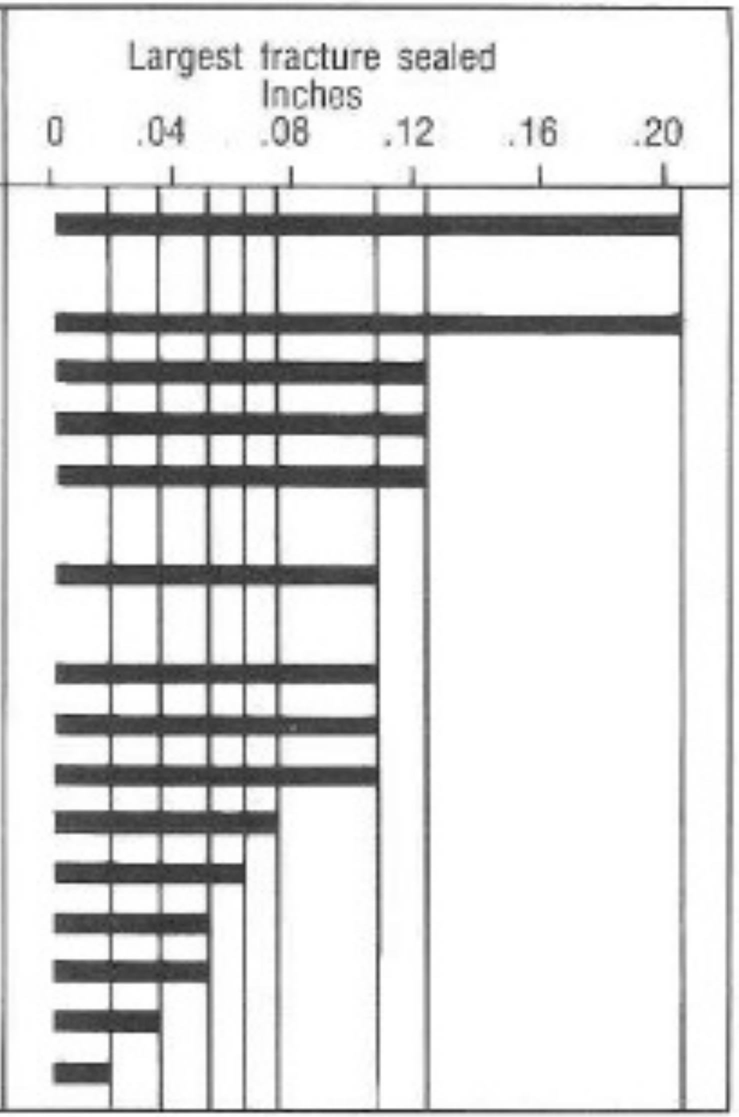


In a broad sense, the clay and other solids that are normal constituents of certain drilling muds are effective lost circulation materials and are adequate for sealing porous formations. Gravel beds and shell reefs / Fractures can take whole mud, even when it contains gel and barite. These formations are usually encountered at shallow depths. This type of loss can cause additional hole problems such as caving or heaving because the rate at which the zones can take mud may allow the hydrostatic pressure to be sufficiently reduced to allow a kick to occur. LCM products that have successfully been applied are items such as ground walnut hulls, cottonseed hulls, sawdust, cellophane flakes, and fibrous materials such as ground leather and cane fibre.

Lost circulation materials are not recommended in concentrations greater than 10-20 lb/bbl in the overall mud system.

Drilling Fluids - Examples of LCM

Material	Type	Description	Concen-tration lbs/bbl
Nut shell	Granular	50% - 3/16 + 10 Mesh 50% - 10 + 100 Mesh	20
Plastic	"	"	20
Limestone	"	"	40
Sulphur	"	"	120
Nut shell	"	50% - 10 + 16 Mesh 50% - 30 + 100 Mesh	20
Expanded Perlite	"	50% - 3/16 + 10 Mesh 50% - 10 + 100 Mesh	60
Cellophane	Lamellated	¾ in. Flakes	8
Sawdust	Fibrous	¼ in. Particles	10
Prairie Hay	"	½ in. Fibers	10
Bark	"	⅜ in. Fibers	10
Cotton seed hulls	Granular	Fine	10
Prairie Hay	Fibrous	⅜ in. Particles	12
Cellophane	Lamellated	½ in. Flakes	8
Shredded wood	Fibrous	¼ in. Fibers	8
Sawdust	"	1/16 in. Particles	20

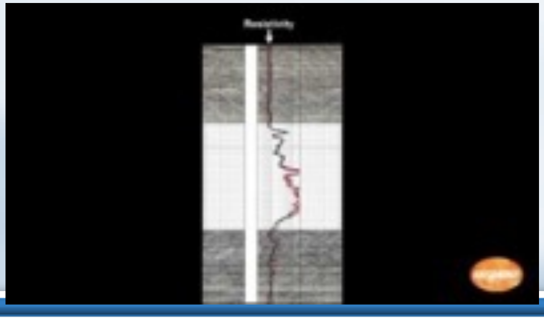


Basic Logging

Well logging is an important operation in oil and gas operations. Logs provide information about the well, which often needs to be interpreted. Logging can be either Open Hole logging / Cased hole logging.
Logging while drilling can be an effective technique for progress evaluation. A typical log analyst is a specialist who can evaluate well logs for porosity, fluid content, saturation levels, and permeability estimates. Although these types of calculations are essential to the operation of the well, other important parameters may be needed by the drilling engineer to successfully drill the well.

Special drilling logs might be defined as tools used primarily to evaluate the mechanics of the drilling operations. Their importance is obvious if they help the engineer drill the well to the target depth.

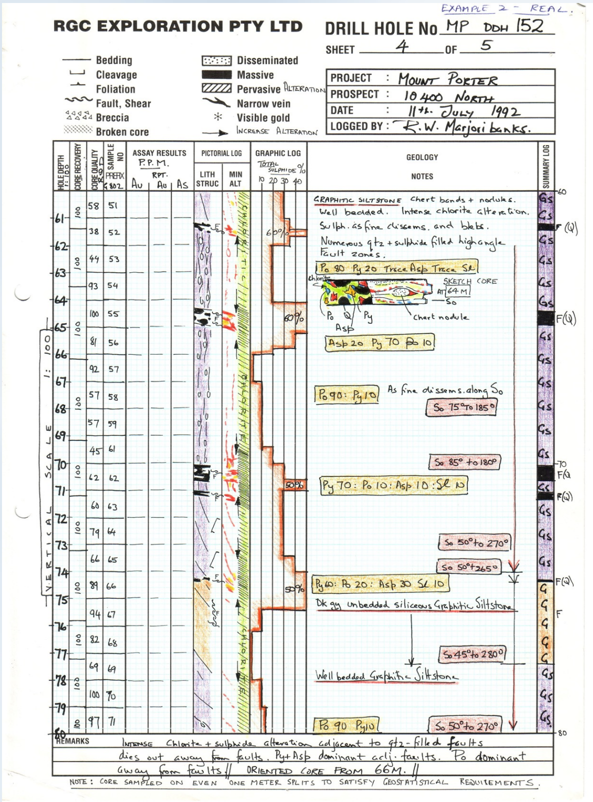
Generally, special drilling logs may not be used in formation evaluation with the exception of the sophisticated measurement-while-drilling (MWD) / Logging While Drilling (LWD) tools. Basic logs for the properties are described in the video.

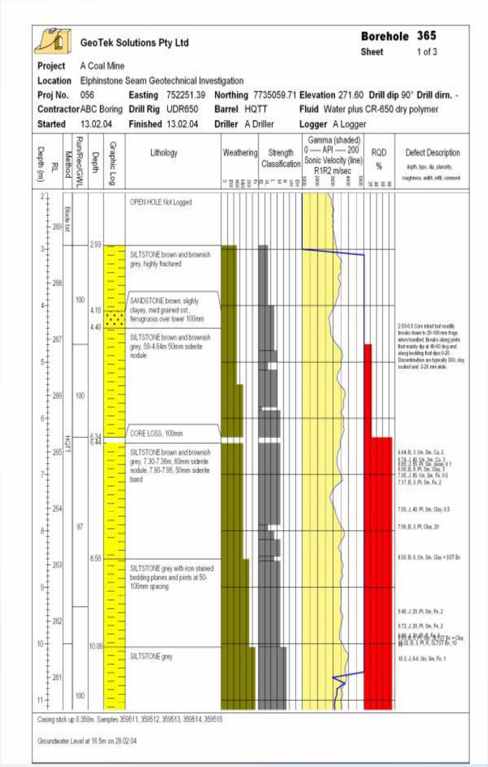


https://youtu.be/i0_BqY-ApEM?t=25

Basic Logging – Drilling Logs

Examples of Drilling Log





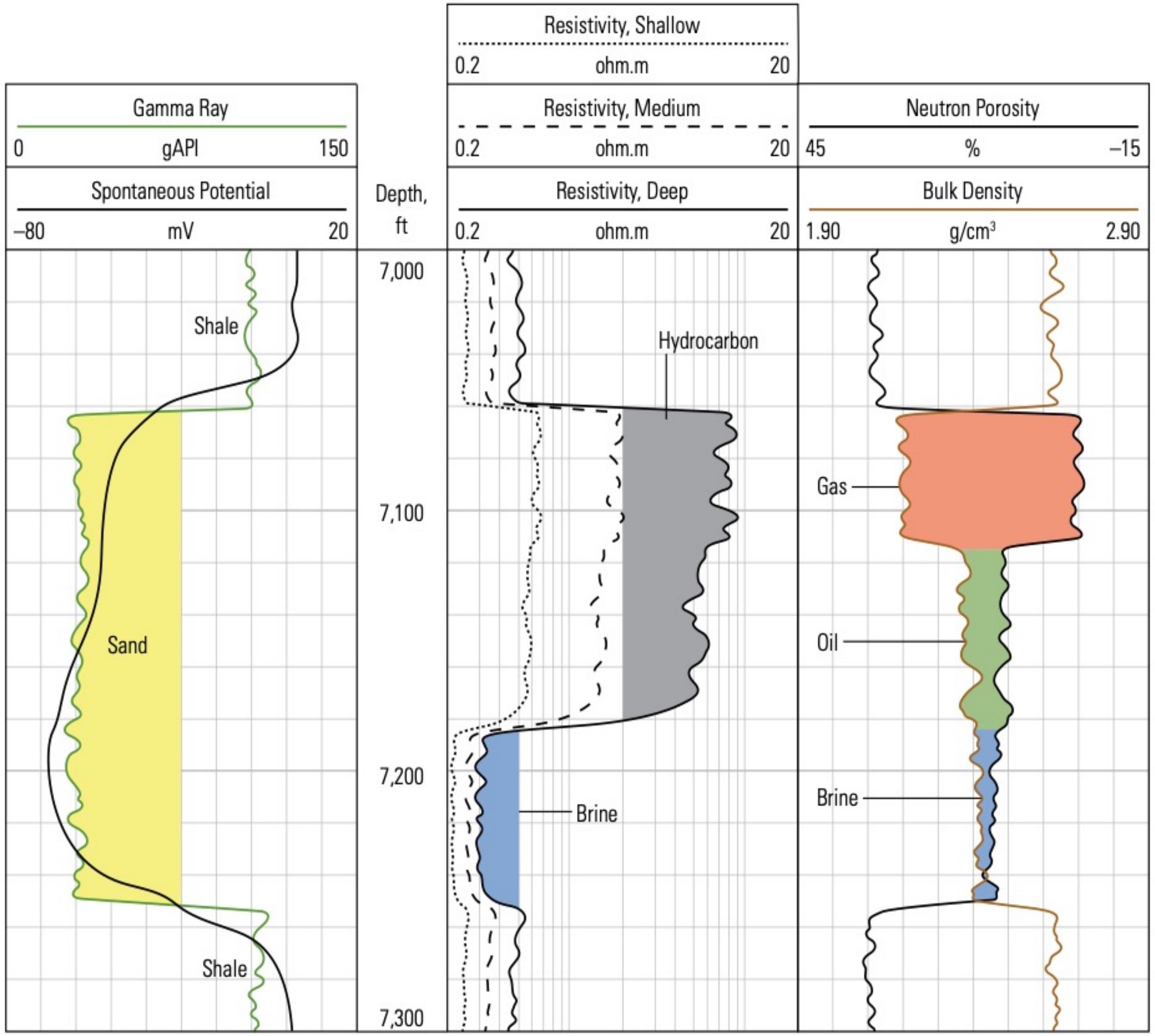
Logging during drilling can be done either using wireline and tools or using mud pulse technology. These logging operations are performed by Service Companies in Open hole environment, with exception of Cement Bond Log which is the only log done in cased hole environment during drilling phase.

Interpretation of drilling logs can be complicated for several reasons. Quite often, the logs are run under adverse conditions such as kicks, lost circulation, or stuck pipe where the downhole conditions are not known. In addition, each supplier's tools may function differently and, as such, the interpretation techniques will vary.

Well logging for pore pressure evaluation is of primary importance to the drilling engineer as the pore pressures affect the major aspects of the well prognosis, including mud, cement, and pipe design

The intention for this topic is to introduce services available for drilling engineers. Normally Geophysicist / geologists design and implement the logging function

Basic Logging - Offset Well



Few Basic logs which are referred to finalize the drilling location are the Spontaneous Potential, Gamma Ray, Resistivity, Neutron density and bulk porosity.

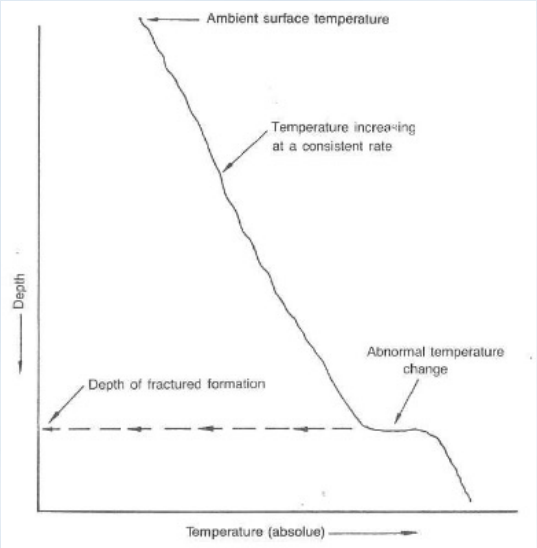
These logs help to identify the possible locations for drilling as this indicates lithology, pore volume and the type of fluid which can be produced for a given location.

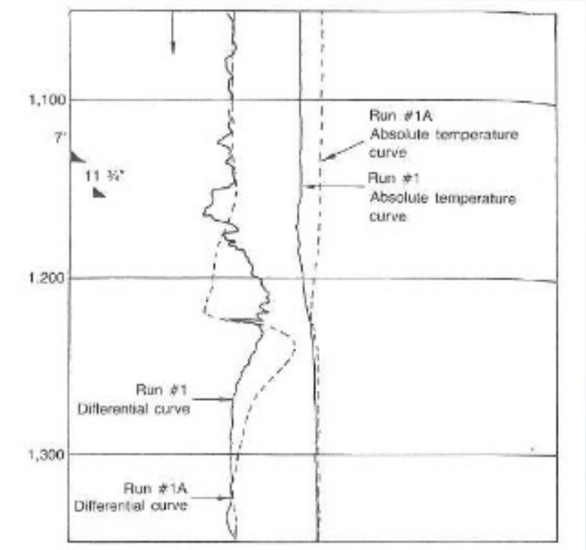
Basic Logging – Types of Logs

Log Type	Function*
Temperature	Detects lost circulation zone
Radioactive tracer	Detects lost circulation zone; identifies flow behind pipe; provides perforation evaluation
Noise	Evaluates fluid flow quantitatively and qualitatively
Free point	Identifies deepest free section of pipe
Pipe recovery	Identifies all sections of free pipe, even below a stuck section
Backoff**	Unscrews pipe at a tool joint
ULSEL	Measures distance from a relief well to a blowout well
Magrange II	Measures distance and direction from a relief well to a blowout well
Casing inspection	Evaluates casing wear or corrosion
Measurement while drilling (MWD)	Provides a real-time formation evaluation tool, from directional guidance to complete petrophysical evaluation
Mud	Provides formation evaluation from drilling and mud parameters

*Partial list of primary functions
**Tool, not a log

Basic Logging – Temperature Log





Temperature Log :

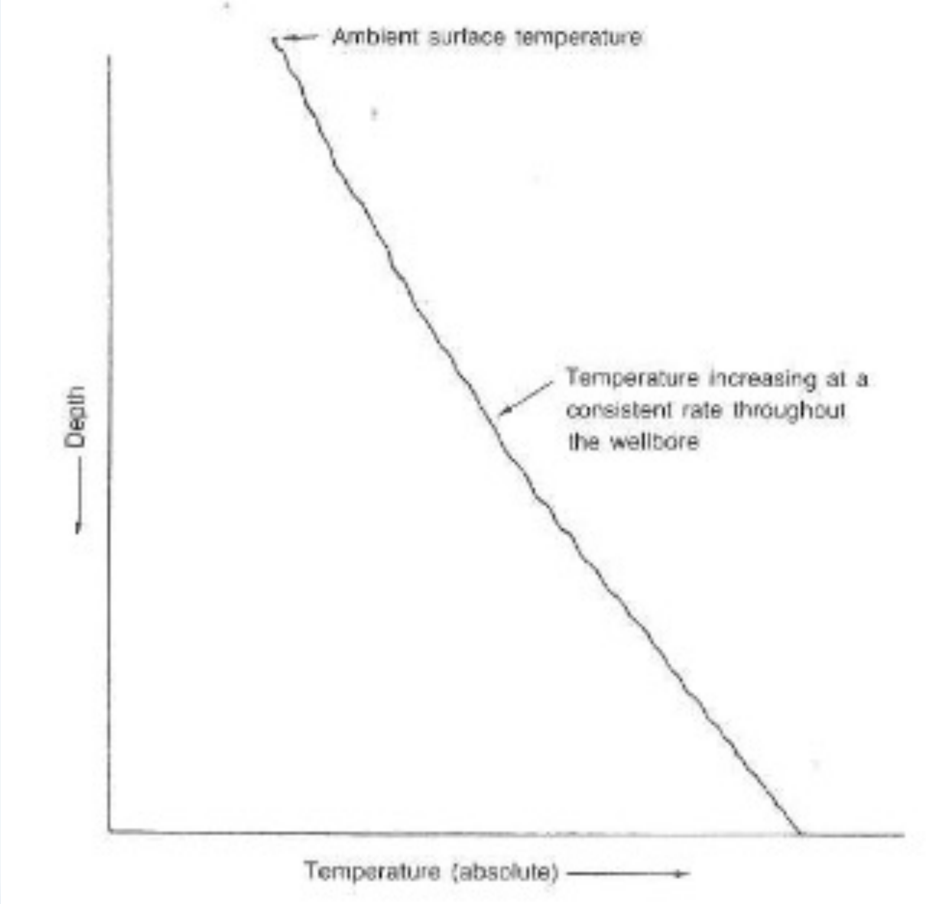
A common tool used to define lost circulation intervals is the temperature log. This log may be used to record absolute temperature or differential temperature.

As the logging tool is lowered down the drillpipe, it reads an abnormal change at the loss zone if the underground flow is continuous.
The tool senses the heat from the fluid that is greater than it should be for the depth at which it is encountered. In some cases, the temperature change is reported as a cooling effect, supposedly due to gas expansion. Nonetheless, a temperature change is the key.

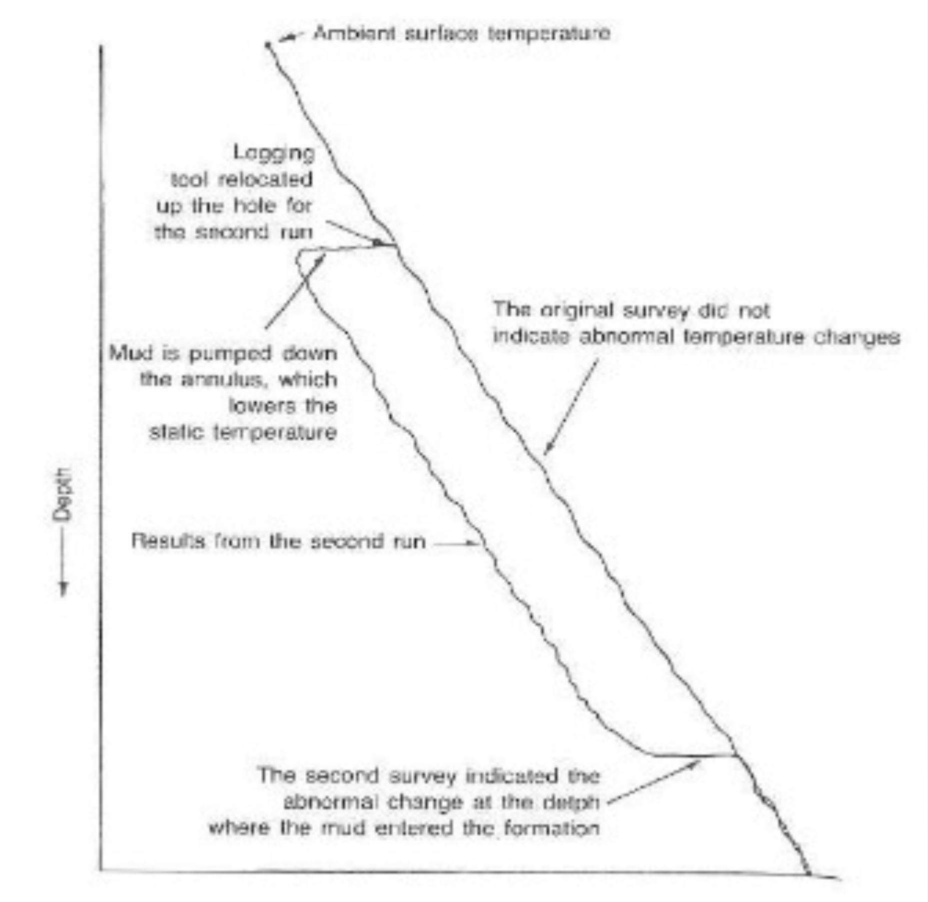
A section from an actual temperature log, indicating a fluid exit at approximately 1,225 ft.

Basic Logging – Temperature Log

Temperature Logs

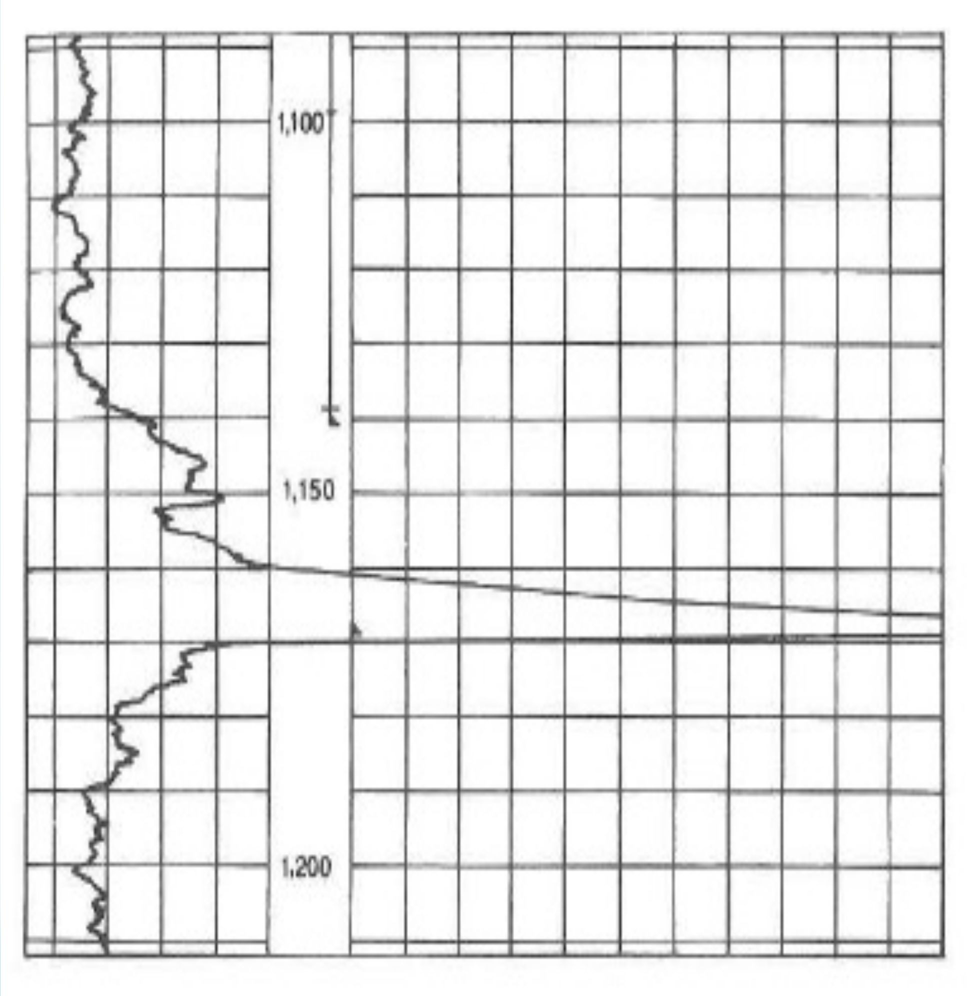


Temperature Log : When well is static



Temperature Log : When well is circulated with mud. Indicating lower temperature at bottom indicates lost circulation zone

Basic Logging – Radioactive Tracer



A radioactive tracer survey is used to follow the movement of fluids by introducing a radioactive isotope into the fluid. This isotope is tracked with a gamma ray counter.

The most common radioactive tracer material used in the Gulf Coast area is iodine 131. This material has a half-life of 8.1 days and is soluble in water. Iodine 131 is placed in the borehole with a special injector tool. Each injection puts a measured amount of solution in the borehole.

This slug of tracer material is followed by movement of a gamma ray detector. The slug can be followed from the tool to a zone of lost circulation or underground blowout. When the radioactive material enters a zone of lost circulation. it will concentrate and show an increase in radiation for that zone. Repeat runs with the gamma ray tool will define the location and thickness of the invaded zone.

Basic Logging – Noise Log

Noise Logging Applications

- Drilling wells
  - Lost circulation zones
  - Underground cross flow or blowouts
- Flow behind casing
  - Cross flow behind cemented casing before perforating
  - Cross flow from squeezed zones
  - Producing wells with channeling in producing zone
- Leaks in tubing or casing
  - Leaking tool joints, flow couplings, liner tops, etc.
  - Communication between multiple-string completion zones
- Flowmeter in producing wells
  - Producing zones
  - Relative production from each zone
- Flowmeter in injection wells
  - Zones taking fluid
  - Relative flow into each zone
- Limitations on the noise tool
  - Cannot distinguish oil from water
  - Only gives flow rates to the nearest order of magnitude
  - Determining the direction of flow depends on knowledge of downhole pressures
  - Distinguishes gas flow through fluids only at relatively low flow rates

Noise logging is a technique for measuring and analyzing acoustical noise generated downhole by turbulent flows of liquids or gases.

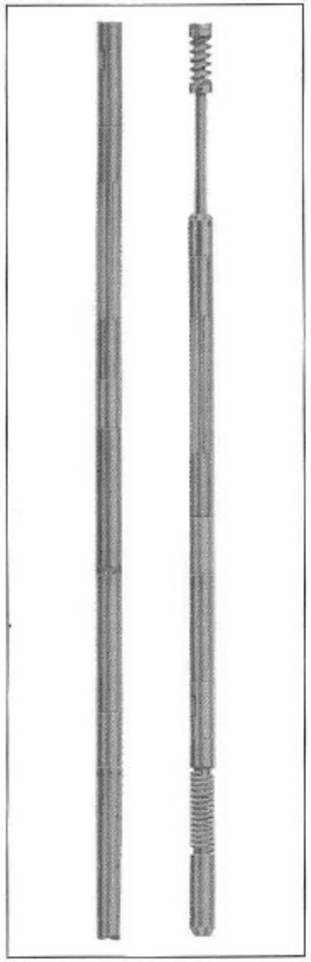
Noise amplitude and frequency data are recorded vs depth to produce a log from which a downhole flow can be located and traced from source to sink.

The log will also describe the flow as single- or two-phase and will provide information for estimating the flow rate.

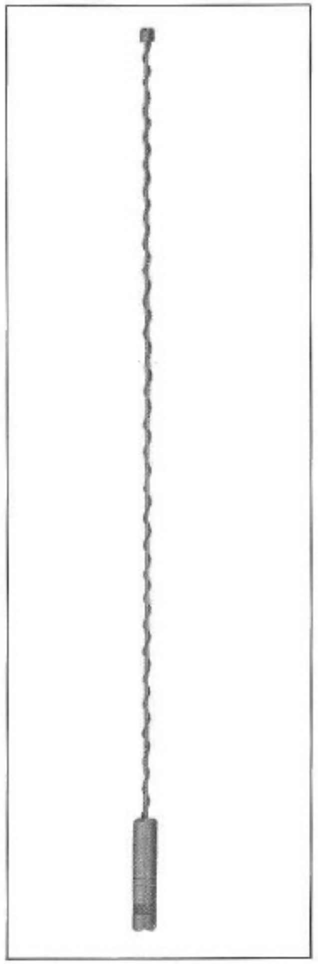
To date noise logging has been used successfully to locate cross-flow channelling behind casing, to locate channel flows feeding into perforated intervals, to investigate underground blowouts, and to locate tubing and casing leaks.

The technique has also been used as an open-hole flowmeter in gas wells to locate and evaluate producing zones and as a flowmeter in cased holes to measure the output of individual perforations.

Basic Logging – Stuck Pipe Log



Free point Indicator



Sting Shot Backoff

Free-Point Indicator. The free-point indicator measures the shallowest top of the stuck section. It is possible that free pipe exists below the upper stuck section.

The tool, shown in usually consists of two electromagnets connected with a telescopic joint. It is designed to measure stretch and torque movement in a string of stuck pipe. Upward pull, or tension, and rotary torque are applied to the pipe. Since the applied tension and torque are not transmitted through the stuck section, the free section of the pipe is identified by the measured stretch and torque. Thus, the shallowest stuck pipe point is located.

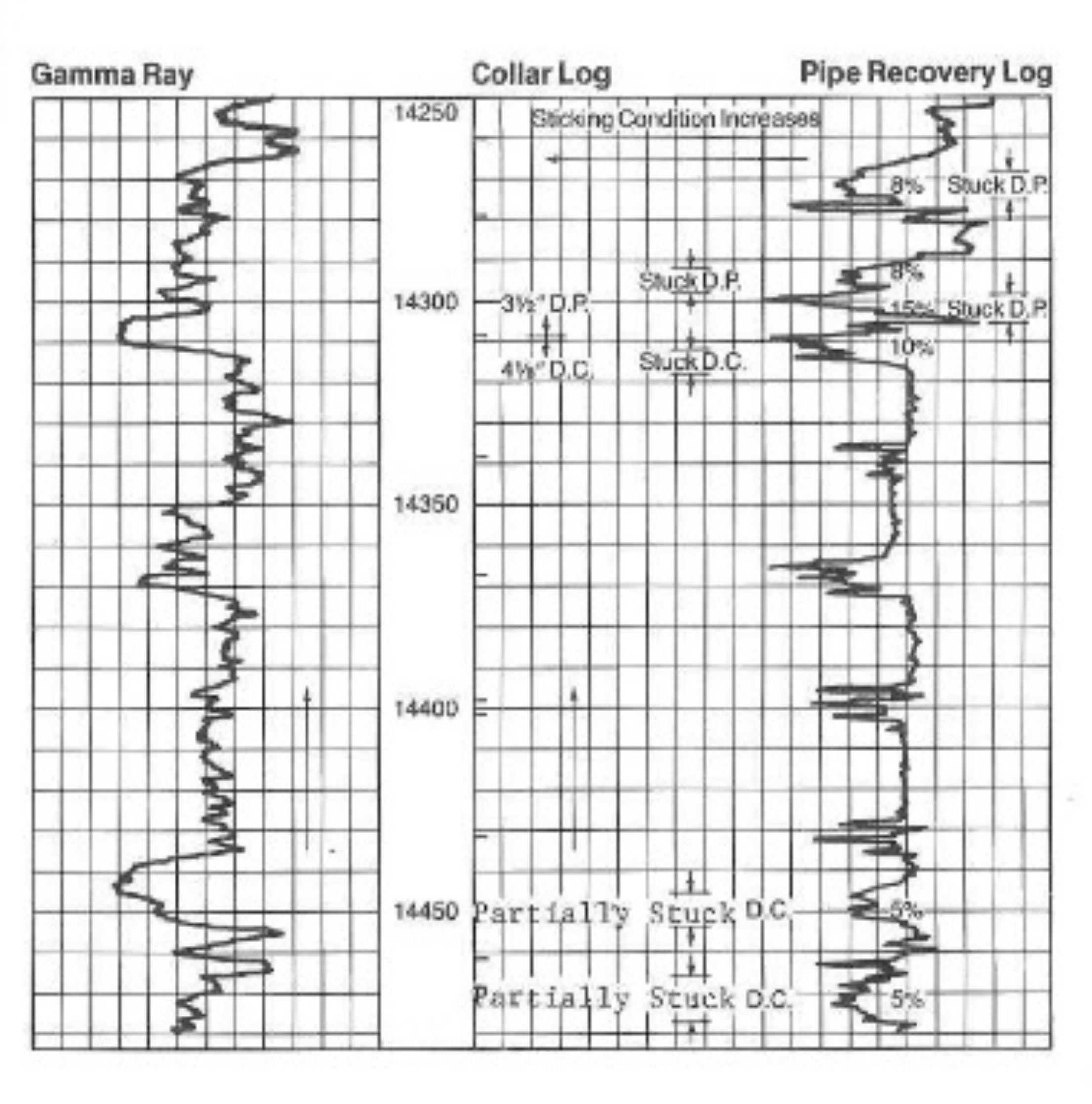
String Shot Backoff Tool : The string shot backoff tool uses a precisely calculated quantity of explosive detonating cord (Prima Cord) to produce a vibratory shock wave for loosening or unscrewing a predetermined joint of pipe.

It is detonated by an electrical blasting cap. The backoff is accomplished by applying left-hand torque in the string when the shot is exploded.

The torque is applied at the neutral weight, with the pipe in neither compression nor tension at the shot point.

The explosion produces the same effect as a hammer blow and is designed to cause the joint to unscrew at the proper point.

Basic Logging

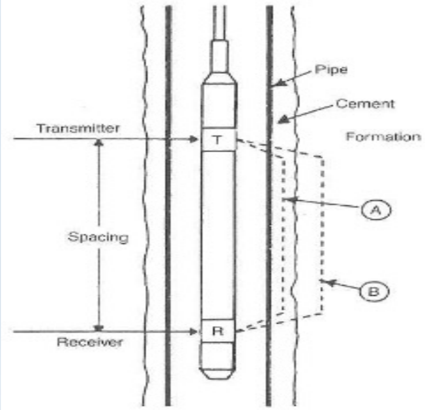


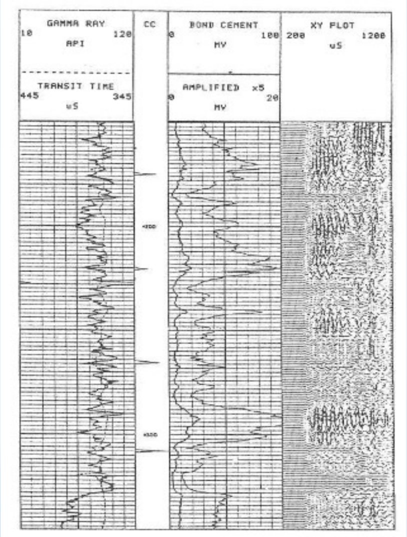
Pipe Recovery Log. The pipe recovery log gives a complete record of all stuck intervals and possible trouble areas in a string of stuck pipe. It indicates the length of each interval, the severity of stuck conditions at each interval, and the amount that each interval contributes to the total stuck condition.

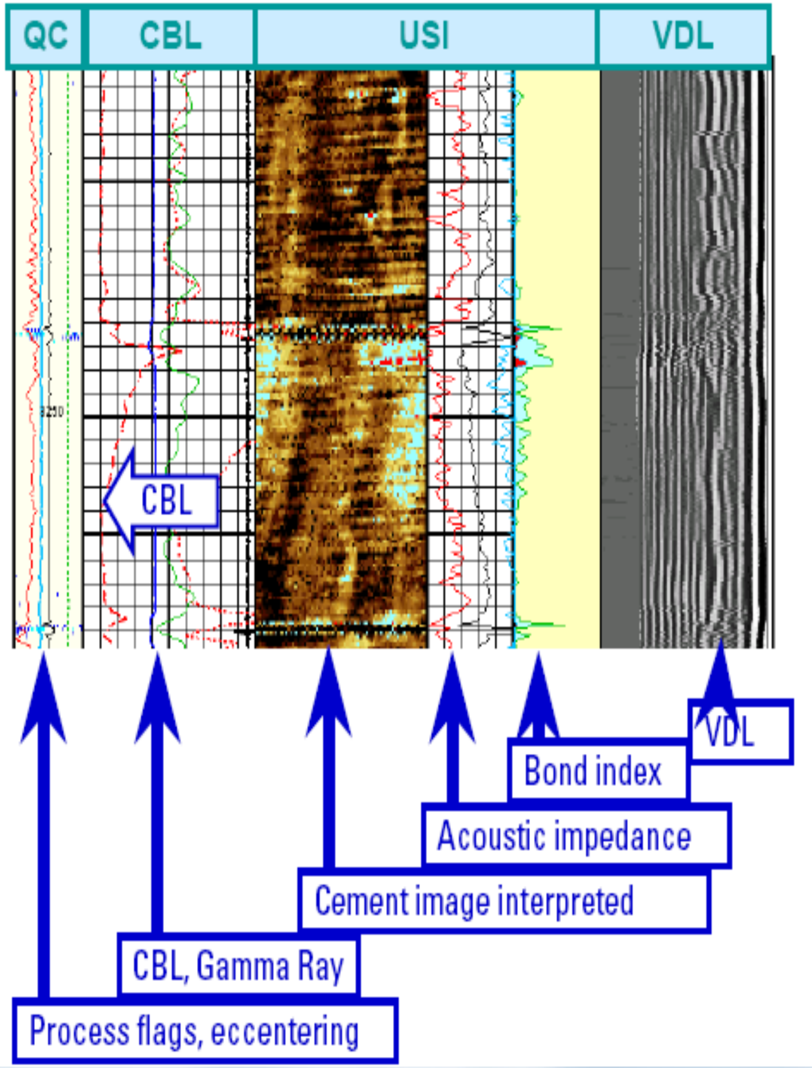
The tool is calibrated in known free pipe, normally near the bottom of the surface pipe or the last casing string. A signal attenuation scale is placed on the log. The scale, expressed in percentages, indicates the severity of the stuck condition at each interval.

The recovery log is best run in conjunction with a gamma ray log if no other lithology log on the well is available. The gamma ray log shows the type of formation causing the stuck pipe. This information is beneficial in identifying the type of problem and in helping select the most practical solution

Basic Logging – Cement Evaluation Log





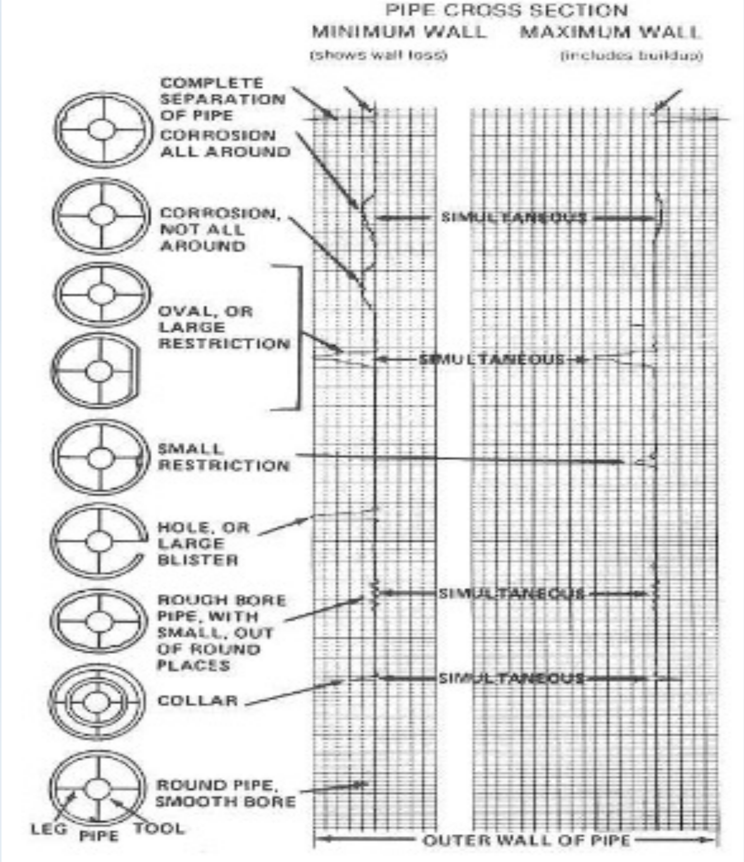


The Cement Bond Log (CBL) and Variable Density Log (VDL) are used to evaluate cement placement in the annulus after the operation. This cased hole log is one of the most useful logs available to the drilling engineer :

- Measures the effectiveness of bond between the casing and formation with the cement column (Bond Index)
- Gives positive location of cement tops and the column in old and new wells
- Aids in planning completion procedures remedial work
- Aids in evaluating effectiveness of squeeze cementing operations prior to perforating, / stimulation

However its quite challenging to interpret as it records the electronic voltage corelated with sound wave attenuation through different media available. This had been most mis understood log but if run with recent advances such as Ultrasonic Imager coupled with variable density can help to get better understanding.

Basic Logging – Casing Inspection



Multi finger

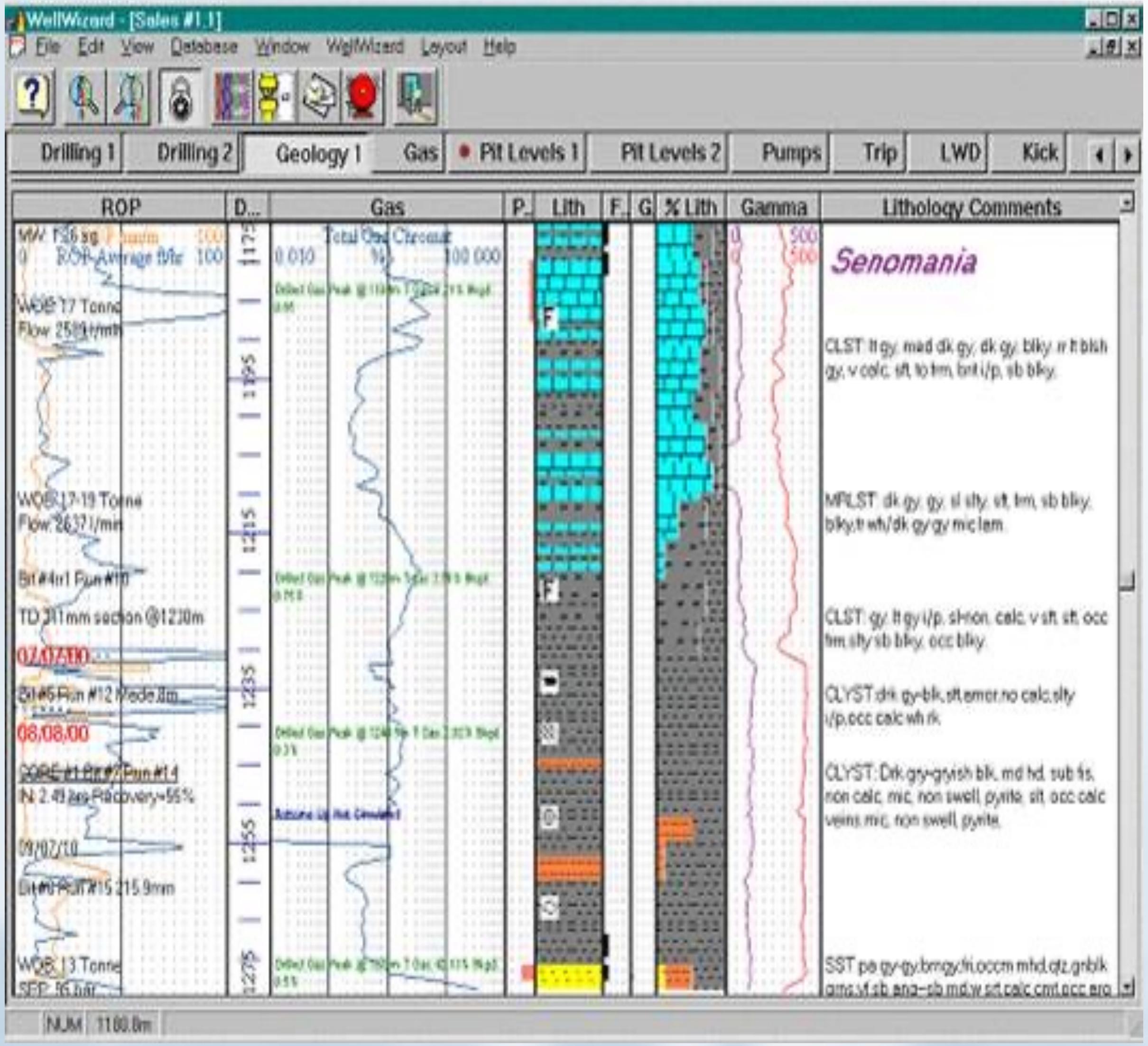
Casing inspection tools are designed to detect and record the extent of casing damage caused by corrosion or drillpipe wear. They locate pits, holes, vertical splits, cracks, and parted or broken collars, and they reveal the extent of damage caused by the wearing action of sucker rods, tubing, or drillpipe. The tool calipers the wall thickness of the pipe by measuring the total metal loss on the inside and outside of the pipe. A calibrated curve of average wall thickness is presented on the log

The two major classes of tools are electronic and mechanical.

The electronic inspection tools usually use a method of relating surface currents induced on the inner diameter of casing or tubing to the inner diameter of that casing or tubing. The tool consists of a non contacting coil system generating an electromagnetic field that sets up surface currents on the inner surface of the pipe. These currents are detected by the coil system.

Other type touches the ID of the casing with its fingers and the data is captured along 360 degrees to create internal profile of the Casing. Although this is direct measurement at times scale, paraffin / wax may give erroneous readings.

Basic Logging – Mud Logging



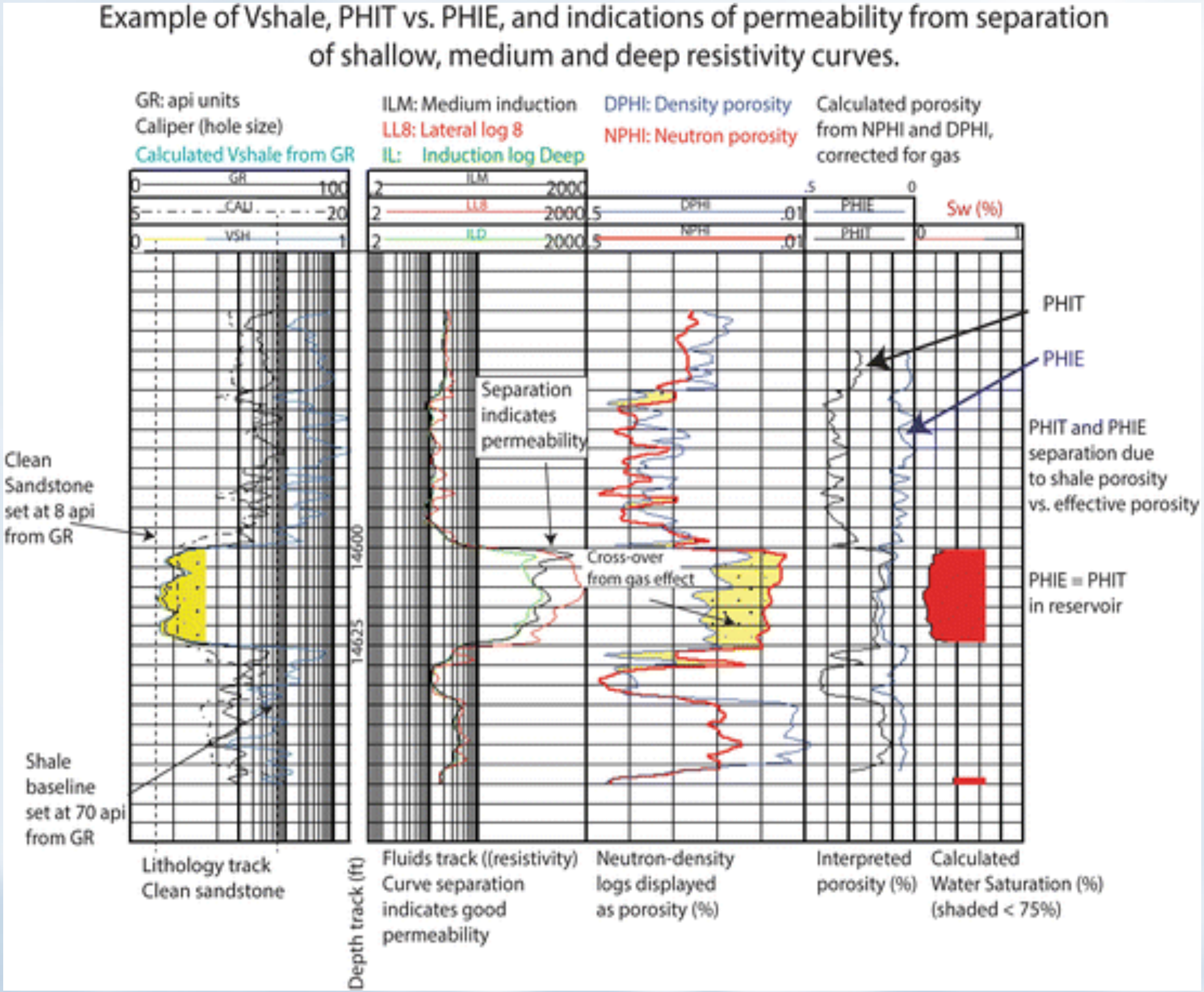
Mud logging is a commonly used service to obtain data from the mud system and drilling parameters that can infer valuable information about the formation.

It can be as simple as recording mud weight, rotary speed, and bit weight or as sophisticated as recording numerous variables and making several calculations relating to pore pressure evaluations. At times specific monitoring for H2S can also be done using the services.

The computerized units for mud logging provide details on many parameters on a real-time or instantaneous basis.

Most mud logging units are "manned," which means that mud logging personnel are on site to perform some of the required analysis. Unmanned systems that perform fewer functions but are less expensive have received significant use in recent years. Trailers or work quarters provided by the service company contain the monitoring equipment and serve as a work station for the mud logger.

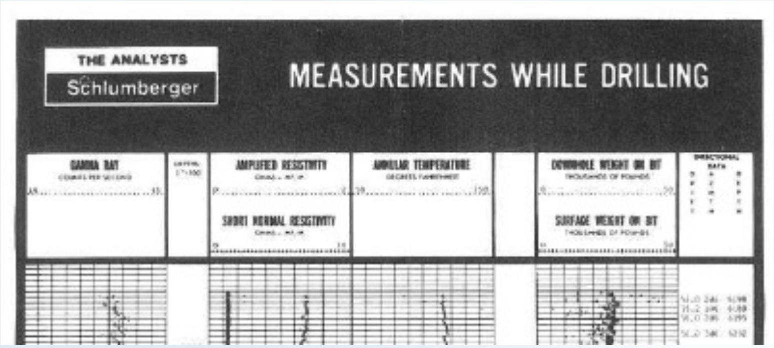
Basic Logging – Data Validation

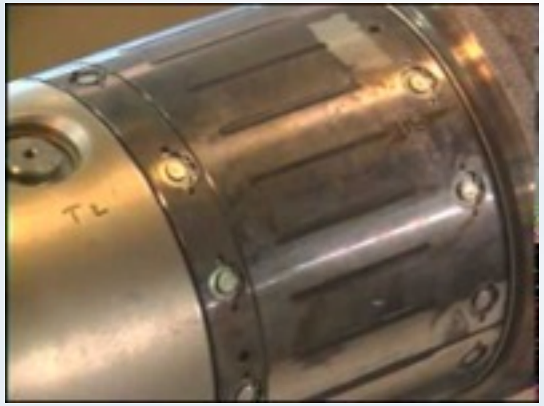


Volume of Shale is computed from Gamma Ray and porosity related information derived should be validated. Two main types of porosity are defined: total porosity (PHIT) and effective porosity (PHIE). PHIE is the percentage of the rock volumes which represents the connected porosity. It is made of all the pores that are connected and form the pore network. Only fluids in the pore network can be moved through production (unless some recovery techniques are used to connect some of the non-connected pores to the pore network). The total porosity is the fraction of the rock made of all the pores, both connected and non-connected. PHIT includes PHIE and mathematically PHIT is always greater or equal to PHIE.

Total water saturation (SWT) and effective water saturation (SWE) are associated respectively to PHIT and PHIE. The water saturation represents the percentage of the pore volume (total or effective) filed with water.

Basic Logging - MWD + LWD





https://youtu.be/-vCEIWxJ02s

The technical innovations in drilling logging available to the on-site engineer have been Measurement while drilling (MWD) logs. The MWD tool is designed to provide a real-time, or instantaneous, recording and transmission to the surface of down- hole data.

MWD tools are placed near bit to gather live data. Parameters are available virtually at the time of the recording and are not delayed by the time required to pump the mud from the bit to the surface. Quite often, operators use MWD and mud logging tools simultaneously because of their complementary services. Sample of earlier logs is available.

A variety of MWD services are available. The most common is the steering tool application, which provides a continuous reading of drift angle and azimuth for directional drilling.

MWD tools are mounted in a nonmagnetic drill collar that is placed in the drillstring as near to the bit as practical. Electrical power is generated by some type of turbine or is stored in a battery. Tools from different suppliers vary in length and size. LWD are more recent services which provide similar information for drilling applications.

Thank You

Thank You for your undivided attention !

We are now open to questions.

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