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Field Training Report at DOSCO Petro Services

A study of casing and cementing in on-shore wells

By

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CHAPTER 1:

Introduction

Ever since its discovery, oil remains the most dominant primary energy source around the globe. It is used to produce electricity and fuel houses, facilities and automobiles… The earth has an enormous fortune of oil reserves, most of which have already been discovered and exploited by humans. Still a limited number of reserves remain unattainable till date.

Oil is a non-renewable energy source. Oil reserves are predicted to drain in about a hundred years from now, maybe even less. In order to get ahold of the oil, accurately designed wells must be drilled through the earth, from which the oil can be recovered and produced by various techniques.

<u>Figure 1:</u> Foraj Sonde drilling rig in Draganeasa, Romania

Drilling engineering is the field of planning and executing techniques to drill wells in order to extract oil and gas. Drilling engineers should ensure that the drilling process is accomplished as economically and safely as possible. They have a set of specialized technicians working under their supervision; and also work hand in hand with drilling and service contractors, geologists... Before any drilling job, the drilling engineer should finalize a series of tasks:

Step 1: Gathering enough geological and geophysical information about the proposed well after rigorous formation evaluation. Such information include the type and value of the reserves, well location, pressure profile, type of geological hazards…

Step 2: Designing the drilling plan: casing plans, cementing plans, directional drilling plans, drilling fluid programs, drilling equipment programs, well control equipment and procedures…

Step 3: Estimating the affiliated costs.

Step 4: Acquiring legal property and work licenses.

Step 5: Developing contracts with suppliers and starting the drilling process.

Casing and cementing are crucial procedures in any drilling operation. They maintain the wells and preserve their integrity. The following chapters are dedicated to specifically handle the casing and cementing parts of the drilling process.

CHAPTER 2:

Casing

2.1 Definition

During the drilling of oil wells, steel tubes are inserted all along the borehole to seal it. Such tubing is known as the “Casing”. The casing serves the following purposes:

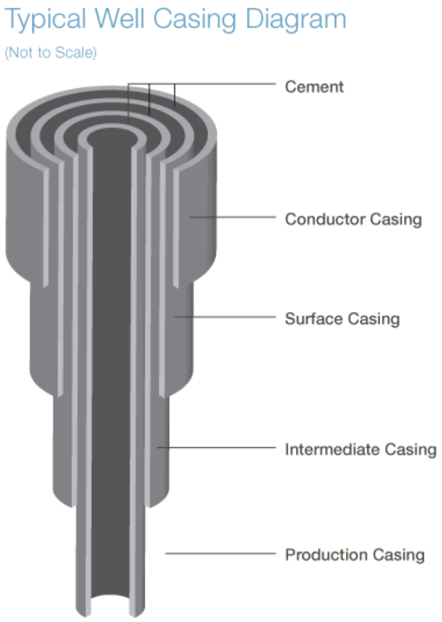
- Holding the well
- Offering support for the producing formations

The types and properties of the casings used by drilling engineers depend upon the nature and the location of the planned well.

Each casing is mounted with a section at which the tubing can be connected to another consequent casing. This connecting section is known as the “Coupling”. Couplings are usually in the form of threads.

2.2 Types of casing

Before installing the casings, a proper study must be done to determine the number of casings required, their types and their depths. Five types of casings are identified worldwide: conductor casing, surface casing, intermediate casing, production casing and liners.



<u>Figure 2:</u> Types of casing

2.2.1 Conductor Casing

The conductor casing is the first casing to be installed. It is usually shallow, having a maximum depth of about 20 m. It has many functions such as:

- Allowing a closed circulation system by transporting the drilling fluid back to the rig
- Protecting from and isolating unconsolidated surface formations, shallow gas and water
- Supporting the heavy weight of the wellhead and the blow-out preventer (BOP)

2.2.2 Surface Casing

The surface casing is introduced inside and is deeper than the conductor casing. They usually have a depth of 100 to 1000 m. Surface casings extend from the casing head and serve two major roles:

- Preventing the borehole from collapsing
- Allowing the firm attachment of the BOP onto the well
- Isolating water sands

- Allowing enough strength to drill at highly pressured areas

2.2.3 Intermediate Casing

After the surface casing, intermediate casings are inaugurated. They isolate unstable sections, low-circulation zones, low-pressure zones and production zones. Drilling engineers may decide to install one, two, three or even more intermediate casings, depending on the type of the well. Intermediate casings always start from the surface of the well, at the casing hanger (usually at ground level in onshore wells). The bottom tip of any intermediate casing is called the “Casing point”. Choosing the casing points, and thus the depth or length of this tubing, is essential. Casing points must be selected based on:

- Required mud weight
- Expected pore pressure
- Rock fracture gradient

2.2.4 Production Casing

The production casing is the last casing to be planted. It is very deep and must withstand extremely high pressures for long periods of time. It is the tubing through which the oil and hydrocarbons can be evacuated from the reservoir, safely and in a controllable manner. Production casings start at the casing head. In some cases, the production casing may contain another hole, which is not extended from the surface of the well. This is what one may call a “Liner”.

2.2.5 Liner

Liners are casings that are not suspended from the surface. They rather hang from the inside of the previous casing and are held in place by a special hanging device. They are usually used instead of either intermediate or production casings. Many factors can cause drilling engineers to choose working with liners, including the following:

- A liner costs considerably less than a full string casing
- The inside diameter of a liner is less than that of a full string casing
- Liners are accompanied by less tension on the rig

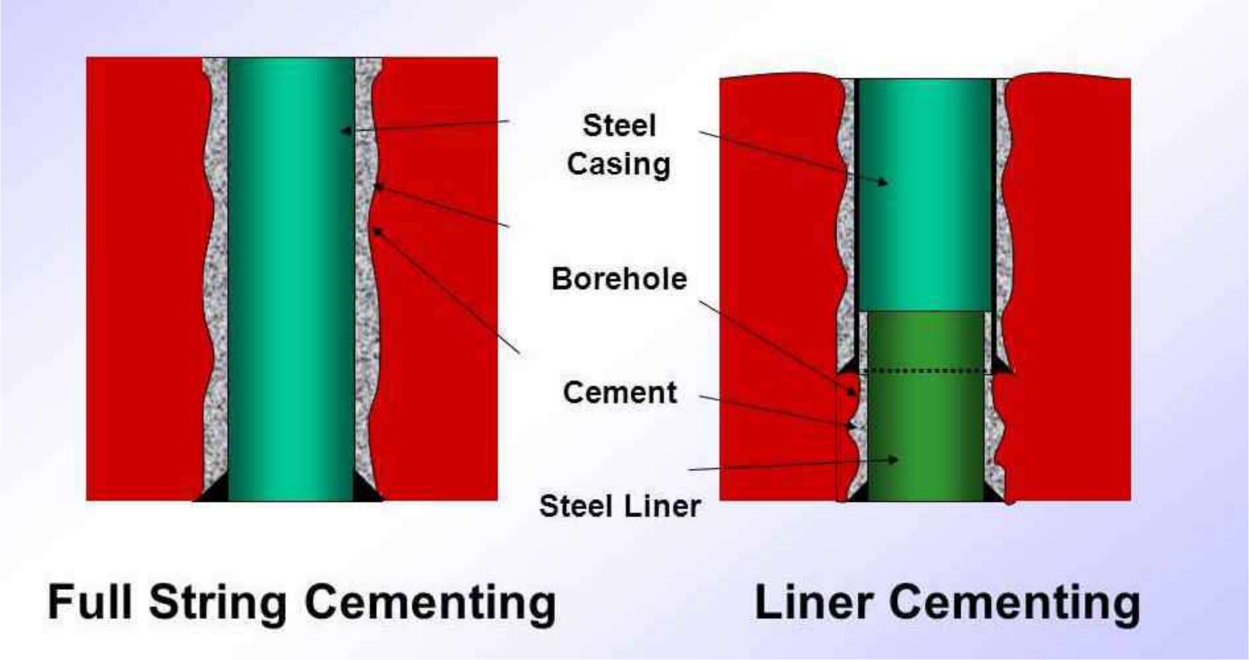


Figure 3: **Full string vs liner casings**

Nevertheless, such casings come with considerable drawbacks, like:

- Higher risk of accident, since the equipment used to run a liner are more complicated than those used to run full string casings
- Less amount of cement is required to hold this type of casing, causing major risks even with low levels of cement contamination

2.3 Casing properties

All types of casings can be characterized by a series of properties. There are three major groups of properties: geometrical, physical and mechanical properties.

2.3.1 Geometrical properties

Lengths and diameters are the main geometrical properties designated for the body of the casing. These properties have to obey a series of standards set by the American Petroleum Institute (or API).

- **Length:** It is divided into three ranges. The first range, called R-1, covers lengths from 16 to 25 ft. The second range, R-2, is for casings having lengths from 25 to 34 ft. The third range, R-3, is for casings with lengths above 34 ft.
- **Internal diameter:** It is the diameter of the internal section of the tubing.
- **Outer diameter:** It is the diameter of the casing from the outside.
- **Drift diameter:** The internal casing diameter is usually non-uniform throughout the tubing. For this reason, a diameter smaller than the internal diameter was defined.
- **Connection diameter:** It is the diameter of the coupling.

Couplings have geometrical properties too. According to the API standards, they can be:

- Couplings with round threads, which can be either long or short. “Long thread connections” or LTC have four pitches per inch and “Short thread connections” or STC have two pitches per inch.
- Couplings with asymmetrical trapezoidal thread buttress, known as “Buttress thread connection” or BTC.

2.3.2 Physical properties

Casings can be described by some API approved physical properties as well, which are the wall thickness and the weight. The weight is divided into three subgroups:

- **Nominal weight:** It is the theoretical weight of the tubing with the couplings, for a twenty feet length per foot.
- **Plain end weight:** It is the weight of the casing without the couplings and threads.
- **Threaded and coupled weight:** It is the weight of the casing with the couplings.

2.3.3 Mechanical properties

The most basic mechanical properties for casings are the yield and tensile strengths, where:

Tensile strength: It is the ability of the casing to resist breaking when put under tension.

Yield strength: It is the tensile stress required to produce an elongation of 0.5% per unit length of the casing.

Based on these two properties, the API has graded casings as follows:

Table 1: API grading of casings

API Grade	Yield Strength (in min.psi)	Tensile Strength (in min.psi)
H-40	40,000	60,000
J-55	55,000	75,000
K-55	55,000	95,000
C-75	75,000	95,000
L-80	80,000	100,000
N-80	80,000	100,000
C-90	90,000	105,000
C-95	95,000	105,000

P-110	110,000	125,000

The first letter in each class is an abbreviation of the type of steel alloy used. Each type of steel is used for a specific type of formation. One might also mention the collapse strength and burst strength:

Collapse pressure: It is the maximum force required to cause the casing to collapse.

Burst pressure: It is the maximum internal pressure required to cause the casing to yield.

2.4 Casing Equipment

The following are the most common pieces of accessory added to the casing while it is being introduced in the well:

Guide shoe: It is connected to the bottom of the casing. Its sole purpose is to guide the tubing inside the well more easily.

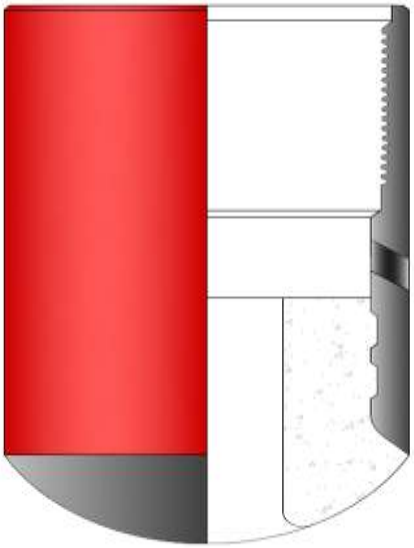


Figure 4: Casing guide shoe

Float shoe: It is similar to the guide shoe but the only difference is that it contains a valve that only allows fluids to flow down.

Float collar: It is an apparatus placed between casings. Its role is to hold the bottom plug used in cementing and to stop any fluids from flowing inside the casing.

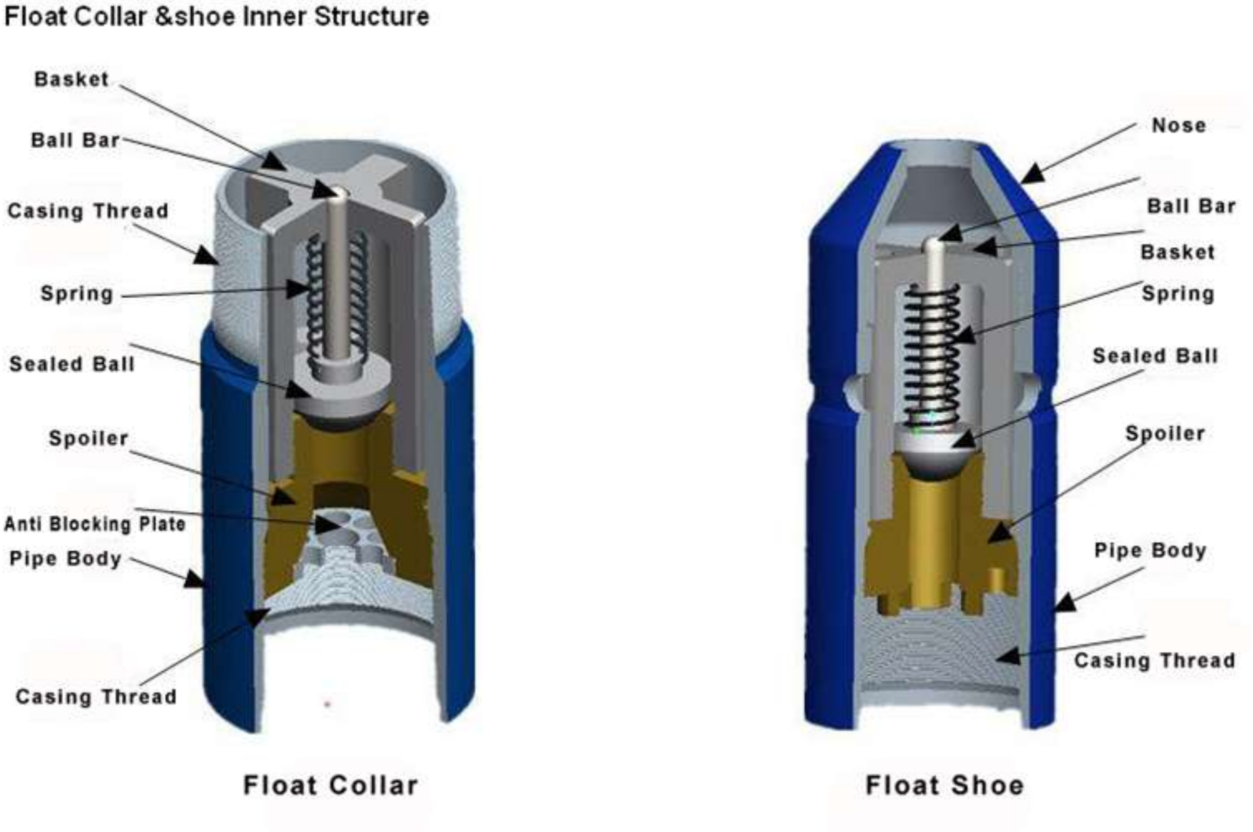
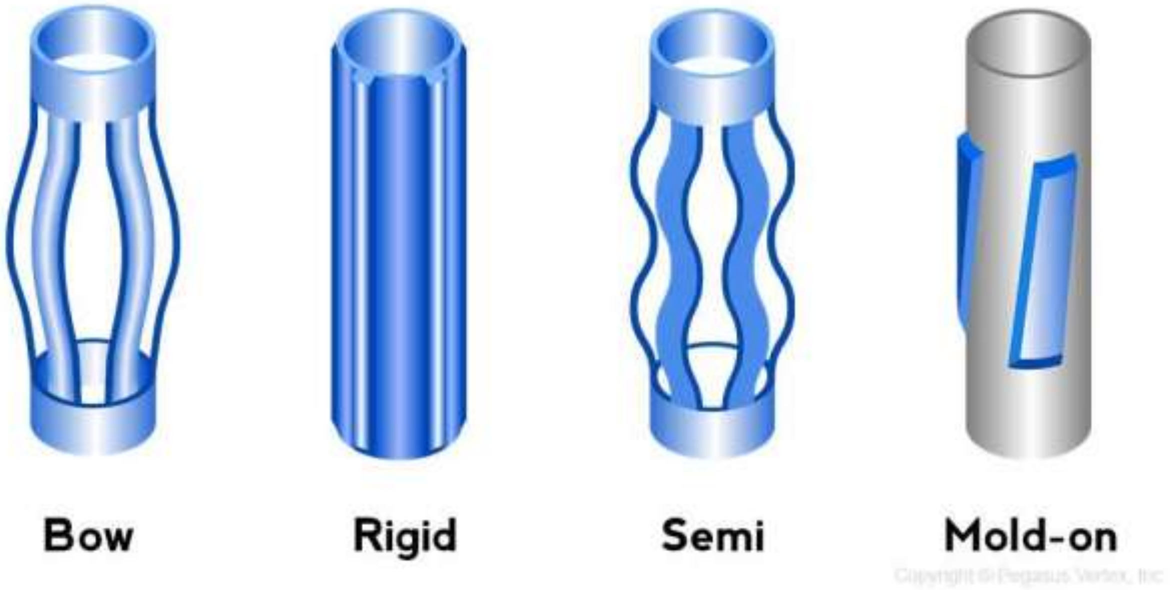


Figure 5: Float collar and float shoe

Centralizers: They are used to make sure that the casing stays in the middle of the borehole. This is essential for a successful cementing job to follow. Centralizers exist in different forms: bow, rigid, semi and mold-on.



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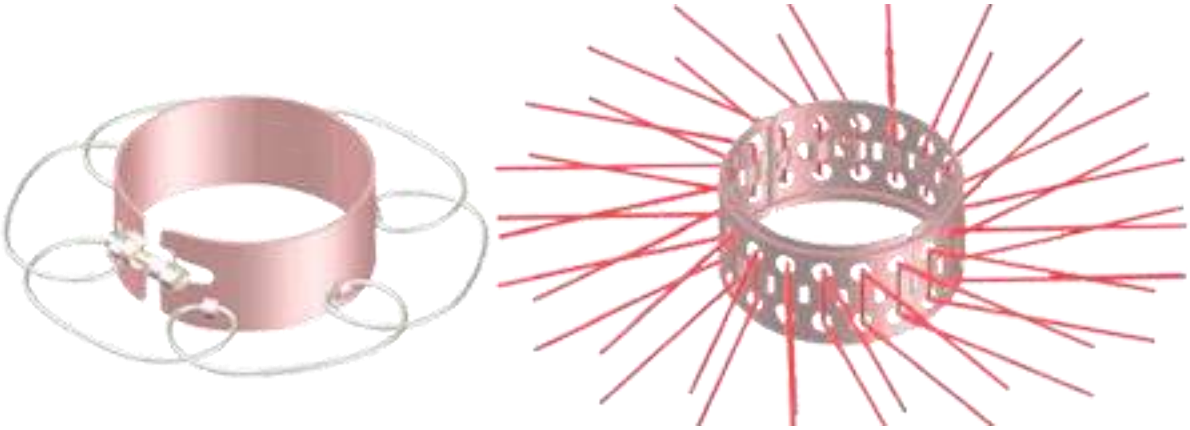
<u>Figure 6:</u> Centralizers

<u>Scratchers:</u> These tools are designed to scratch away any mud cake built up on the porous and permeable formations. There are two types of scratchers: bristle and wire loop scratchers.



<u>Figure 7:</u> Wire loop and bristle scratchers

CHAPTER 3:

Cementing

3.1 Definition

Right after the casing is introduced in the borehole, it has to be strongly attached to the formation so that it doesn’t fall down the well. This can only be done if cement slurry is pumped inside the casing and around it. The cement is initially in liquid form. Following its introduction in the tubing, it dries and turns to a hard solid fixing the casing in its place. Cementing provides the following functions:

- Structural support for the casing
- Protection of the casing from corrosion
- Isolation of hazardous and troublesome areas like high pressure zones or swelling clays
- Protection of usable water

3.2 Cement Components

The cement slurry is a mixture of cement (powder), water and several additives. The most famous cement powder used is the “Portland Cement”. It is made out of four major components, which are mixed under the effect of heat. These four components are the following:

- **Tricalcium Silicate** or $3CaO:SiO_2$ - C_3S
- **Dicalcium Silicate** or $CaO:SiO_2$ – C_2S
- **Tricalcium Aluminate** or $3CaO:Al_2O_3$ – C_3A
- **Tetracalcium Aluminoferrite** or $4CaO:Al_2O_3:Fe_2O_3$ – C_4AF

The water is added because it allows the smooth pumping of the cement, by turning it from a solid phase to a liquid phase. Additives, however, are chemicals that are added to modify and enhance the characteristics of the cement, including the application and type of wells for which such cements can be used. These additives can be:

- **Accelerators:** These are added to decrease the thickening time of the cement slurry, by accelerating the reaction between the cement and the water. They are mostly used for shallow and low temperature formations. The most common additives are: sodium chloride, seawater, sodium metasilicate, gypsum, anhydrous calcium chloride and potassium chloride.
- **Retarders:** Opposite to accelerators, retarders increase the thickening time of the cement slurry. This causes the pumping time to rise and affects the viscosity. Some of the most widely used retarders are: organic acids, borax, modified cellulose and lignosulphonates.
- **Extenders:** Adding extenders to the cement slurry, prevents the solids from separating, when more water is added. This is accompanied by a decrease in the hydrostatic pressure on weak formations and the cost of the cement slurry. Extenders also influence the thickening time, water loss and compressive strength. The extenders can be: bentonite, fly ash and diatomaceous earth.
- **Pozzolans:** Pozzzolans decrease the slurry’s density and viscosity, making the cement more resistive. The pozzolans are: fly ash and diatomaceous earth.
- **Weighting agents:** Weighting agents increase the density of the cement slurry. They usually have a large particle size, high specific gravities, low water absorption; and are not too expensive. Some weighting agents are the following: iron-titanium oxide (Ilmenite), iron oxide (Barite) and Haematite.

- **Lost circulation materials:** They are also known as “LCM”. LCM prevent the formation of induced fractures and, thus, low permeability bridges around the casing. In consequence, LCM inhibit any lost circulations. They exist in different forms: granular, fibrous or flakey.
- **Special additives:** Such additives can be thixotropic agents (to stop lost circulation), defoaming agents (to remove foam), strength retrogression prevention agents or gas channeling preventing agents.
- **Fluid loss additives**
- **Dispersants**

3.3 Cement Classes

The API has classified cements in nine major classes, according to their physical and chemical properties.

Table 2: Cement API classes

API Class	Application
A	Used at depths from 0 to 6000 ft and temperatures up to 170°F
B	Used at depths from 0 to 6000 ft and temperatures up to 170°F
C	Used at depths from 0 to 6000 ft and temperatures up to 170°F
D,E	Used at depths from 6000 to 10000 ft and temperatures from 170 to 260°F

F	Used at depths from 10000 to 16000 ft and temperatures from 230 to 320°F
G,H	Used at depths from 0 to 8000 ft and temperatures up to 200°F
J	Used at depths from 12000 to 16000 ft and temperatures from 170 to 320°F

Each cement class in this table requires the addition of a certain amount of water to make it pumpable. For example, the “G” class cement entails 4.96 gallons of water for each 94 pounds of dry cement. This “G” class cement has proved to be the most useful around the world. This is due to the fact that it is highly sulfate resistant (for sour formations) and has good moisture tolerance.

3.4 Cement Properties

Cement is characterized by:

- **Slurry density:** It is affected by the water to cement ratio and is expressed in ppg or Kg/L.
- **Slurry viscosity:** Slurries with low viscosities are mostly used, since cements with high viscosities will not flow easily.
- **Gel strength:** It is the time it takes for the cement slurry to turn into a gel form. Just like the viscosity, the gel strength should also be as low as possible.
- **Pumping time:** It is the amount of time during which the cement slurry can be pumped before drying and turning to solid.

- **Thickening time:** It is the time necessary for the slurry’s consistency to reach 100 Bearden units. The thickening time depends upon the well temperature, pressure and the pumping rate. It should be kept as small as reasonably possible.
- **Rheology:** Rheology is a form of evaluating the flow of non-Newtonian fluids. It affects the downhole pressure, mud displacement, mixability, pumpability... Many factors affect the rheology, like: size and shape of the cement powder, flow regime, temperature and pressure.
- **Compressive strength:** The oil present inside the wells undergoes static stress from the weight of the pipe, compressive stress from the formation and dynamic stress from the drilling operation itself. The compressive strength is the ability of the cement to overcome such stress.
- **Free water:** Free water is the amount of excess water that didn’t mix the cement. This property should be kept very low to prevent water channels from developing.
- **Fluid loss/Filtration:** It is the loss of water from the cement slurry, which forms a filter cake on the casing.
- **Cement permeability:** It should be as low as possible to avoid corrosion and the formation of a filter cake.
- **Perforating qualities:** After the cement dries, it should be perforated to retrieve the oil from the reservoir. The perforating quality measures the tendency of the cement to fracture when it is perforated. Fracturing the cement is surely undesirable.
- **Bond requirements:** This property measures the bond between the cement and the casing.

- **Corrosion resistance:** It is the ability of the cement to resist to corrosion by certain fluids coming from the formation.

3.5 Cementing Equipment

There are several tools involved in all cementing jobs:

Mud pits: Pits are large tanks where the drilling fluid (also called “mud”) is stored on a drilling rig. This drilling fluid is used, in cementing, in order to displace the cement down the borehole.

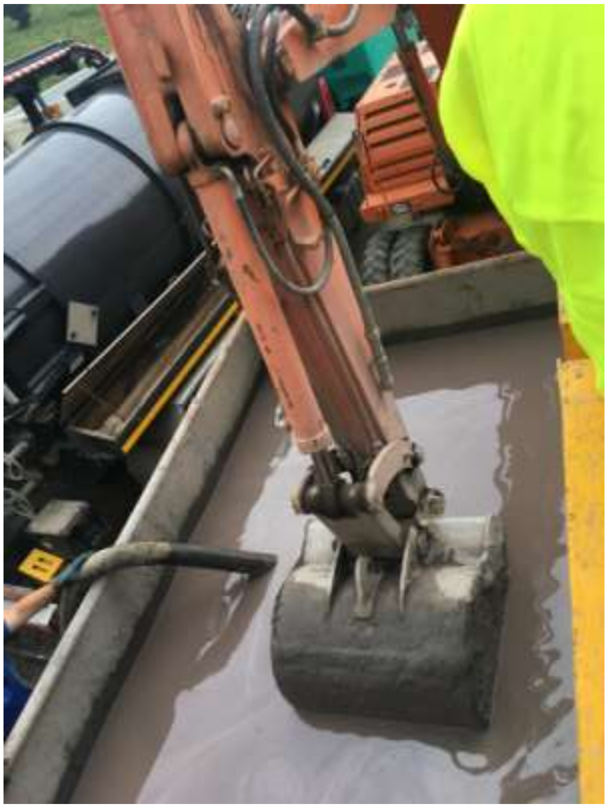


Figure 8: Mud pit in Foraj Sonde drilling rig in Draganeasa, Romania

Mud pumps: Such tools are used to pump the drilling fluid from the pit through the casing and back to the pits.

<u>Figure 9:</u> Mud pump in Foraj Sonde drilling rig in Draganeasa, Romania

<u>Cement units:</u> A cement unit is a system consisting of pumps, a power motor, mixwater tanks, a Re-Circulating Mixer (RCM), hoppers and pipes. The mixwater tanks are mostly two 10 barrel tanks. The cement, water and additives are mixed in such tanks and are, then, pumped to the RCM. In the RCM, they are blended with dry cement to form the cement slurry. Mixing hoppers feed the dry cement to the RCM. Finally, this slurry is pumped down the borehole. The same process goes on and on until no more cement slurry is required for the cementing job. The cement unit also comprises of an Automatic Density Controller (ADC), which monitors the density of the cement slurry at all times.

Figure 10: **Cement unit**

Surface equipment: These are pumps designated to drive spacers and chemical washes into the borehole before the casing can be cemented.

Cement head: This is the device through which the cement slurry will be fed into the casing. It uses plugs to sort out the cement slurry, spacer and displacement fluid.

Figure 11: **Cement head**

Float collar: This apparatus was previously described in Chapter 2.

Cement plugs: There are two kinds of plugs used in every cementing job: the top plug and the bottom plug. Plugs are prevention tools against cement contamination. They have fins on their outer surface to clean the inside of the casings from mud. The bottom plug is also known as the "Diaphragm plug". It is the first plug to be introduced in the casing. A bottom plug is hollow on the inside but contains a diaphragm. This diaphragm breaks when the bottom plug touches the float collar. This causes the cement to pass through the plug down the casing. The top plug, on the other hand, is filled with rubber on the inside and is mounted with a deep cup on its head. It is introduced after the cement is pumped in; and protects the cement from contamination by the displacement fluid.

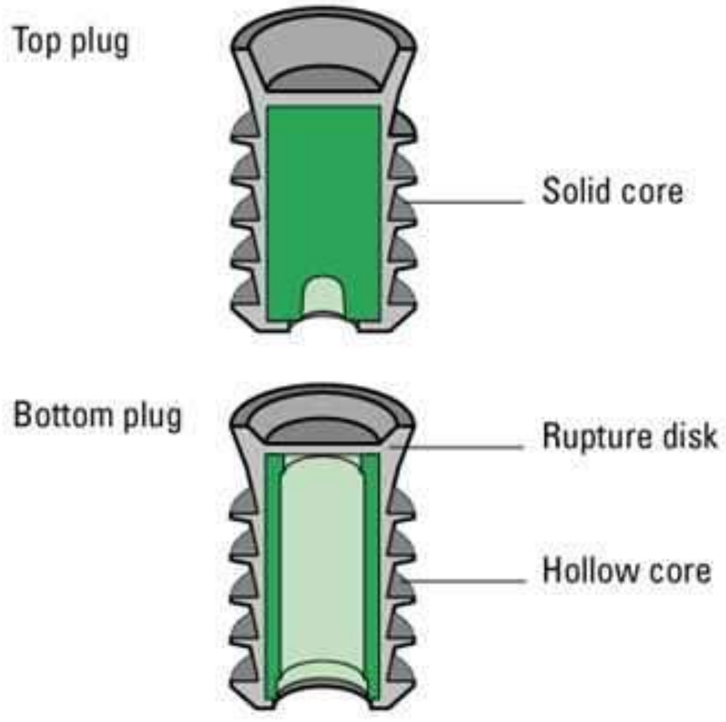


Figure 12: Cement top and bottom plugs

Cement stinger: This tool is used to spot plugs. It facilitates an even spreading of the cement slurry in the casing.

N.B: The drilling engineer must continuously evaluate the density, temperature, flow rate and pressure of the cement slurry, using special tools.

CHAPTER 4:

Casing and Cementing Procedure

The casing and cementing procedure can be divided into two major steps:

- Introducing the casing
- Injecting the cement

4.1 Introducing the casing

The process begins by placing the conductor casing first. It is pushed and forced through the ground by "Hammering". A basic hammer is depicted in Figure 13. After the first casing is set and before engineers can go any deeper in the ground, the formation must be assessed. Studies result in choosing the right type, length and number of casings required for the next step. The drilling rig is, then, installed and drilling the first section takes place. The surface casing is placed at this stage and the Blow-out Preventer (or BOP) can be affixed. After the surface casing, intermediate casings (or liners), and finally the production casing (or liner), must be mounted. In order to drill each section, a drilling fluid (mud) is introduced in the well, to clean all cuttings. Now, the first step is done. Each casing has to be

Figure 13: **Hammer produced by DOSCO Petroservices, Romania**

cemented right after it is introduced and before the next casing can be inaugurated. This constitutes the second step to come.

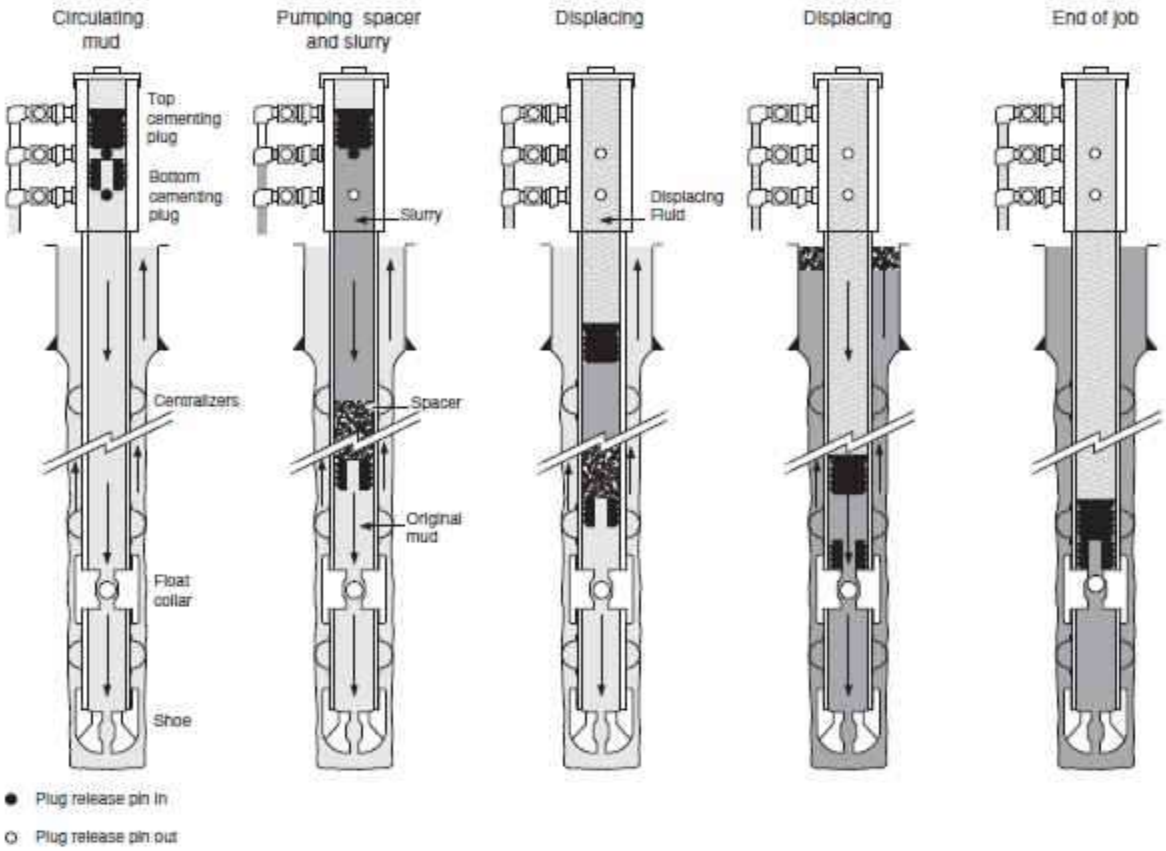


Figure 14: Cementing procedure

4.2 Injecting the cement

This process is summarized in Figure 14 above. At this stage, the borehole is filled with drilling fluid. This mud will be used, later on, as a displacement fluid. Before this fluid can be put to use, it is pumped back to the mud pits. Plus, the BOP must be removed for a little while, and replaced by the cement head to execute the cementing neatly. This leaves the well uncovered at the surface, which might be risky.

The spacer can now be injected in the casing. It is a fluid having a controlled viscosity, gel strength and density. It separates the cement from the drilling fluid to prevent cement contamination. Afterwards, the already mixed cement slurry is injected between the bottom and top plugs while they are still in the cement head. The displacement fluid is infused. This pushes both plugs, with the cement between them, down the casing. When the bottom plug reaches the float collar, it stops moving and the diaphragm inside it ruptures. The top plug keeps descending, shoving down the cement. Finally, the top plug rests on the bottom plug. At this point, the cement won’t be able to move up the casing, now filled with mud again. Hence, the cement starts to build up around the casing, filling that area. The cement must be waited out to dry completely, before the drilling process can be presumed.

N.B: All pressures must be carefully monitored throughout this process.

CHAPTER 5:

Conclusion

In conclusion, casing and cementing is a delicate procedure that requires undivided attention. It is a crucial step for any successful drilling job. It cannot be neglected nor avoided. The drilling engineer and technicians must work hand in hand to ensure that this step of the drilling operation is handled accurately and safely. Its completion marks the future of the well and whether or not this well can produce oil swiftly and without any problems. The drilling engineer must select the proper type, number and length of the casings required, depending on the type of the formation. The properties of any casing must be rigorously evaluated. Then, after the hole is drilled, the casing can be set using special equipment.

Before the drilling engineer can decide to dig deeper, the casing installed must be firmly bonded with the ground so that it doesn't collapse. This can only be achieved by cementing the casing to the borehole. For cementing, the cement slurry is prepared. It is made out of cement powder, water and some additives. The cement slurry also has some properties that must be defined before the cement can be used. Using the properties of the casing and the cement slurry, the drilling engineer will calculate the volume of slurry required to fix the casing.

Cementing jobs can encounter numerous accidents. Examples include: problems with the pumping of the cement slurry, sudden pressure drop, lost circulation... Troubleshooting and fixing such problems can be difficult and, sometimes, ineffective. Nonetheless, after the cementing job is finished, some methods may be applied to determine the degree of success of the cementing operation. Such methods are the following:

- **Cement Bond Log (CBL):** This method consists of sending sound waves through the well and collecting the response.
- **Variable Density Log (VDL):** It is an improved form of the CBL method that yields visual representations of the amplitude of sonic waves returned by the well.
- **Compensated Cement Bond Log:** This method is even more advanced than the VDL, as it is more flexible.
- **Cement Evaluation Tools (CET):** These tools assess the accuracy of the cementing job using thermometers or even radioactivity.

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