PE8604 - Drilling fluid and Cementing Techniques.

Unit - V

1. How are cements classified? Explain cement chemistry in brief.

Cement classification ref. Unit ③ q.no. ③

Cement chemistry:

* Cements are a mixture of anhydrous oxides of calcium, silica Aluminium and Iron.

* The oxides composition of cement is approximately (for class G/H cement)

⇒ Calcium oxide (CaO) - 65%
⇒ Silicon oxide (SiO_2) - 22%
⇒ Iron oxide (Fe_2O_3) - 4%
⇒ Aluminium oxide (Al_2O_3) - 5%
⇒ Magnesium oxides (MgO) - 1%
⇒ Sulphur Trioxides (SO_3) - 1.7%
⇒ ~~potassium~~ oxides (K_2O) - 0.1%
⇒ Loss on Ignition - 0.5% etc)

* On mixing with water these initially form a suspension which is called 'cement slurry'.

* During the setting process, the above oxides hydrate with water and form four major crystalline phases.

* They are,

1. Tricalcium Silicate - C_3S : Hexagonal or Angular crystals, highly coloured with blues and greens.

2. Dicalcium Silicate - C_2S : Spherical or rounded crystals, often with rough surfaces - not highly coloured.

3. Tricalcium Aluminate – C_3A : Grey flacks or -Streaks.
4. Tetra Calcium Aluminoferrite (C_4AF) : white matrix.

* By varying the mix composition of the above four Crystalline phases and the fineness of the cement powder, the properties of the cement can be varied.

* The API classified oil well cement A to H have the following composition

API class	compound (%) C_3S	C_2S	C_3A	C_4AF	Fineness (Cm^2/gm)
A	53	24	8+	8	1500–1900
B	47	24	5-	12	1500–1900
C	58	16	8	8	2000–2800
D&E	26	54	2	12	1200–1600
G&H	50	30	5	12	1400–1700

* The above classes are used in well of different Conditions. By controlling the composition of the crystalline phases we can achieve different properties as per the requirement.

1. By ↑ing C_3S & grainding finer – High early strength be achieved.
2. By controlling C_3S & C_3A content & grainding coarser – Better retardation is achieved.

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3. By limiting C_3S & C_3A content – Low heat of hydration while setting.
4. By limiting C_3A content – Resistance to sulphate water attack can be built up.

③ Q. Describe the procedure for single stage and multistage cementing with neat diagram.

Single Stage cementing (primary)

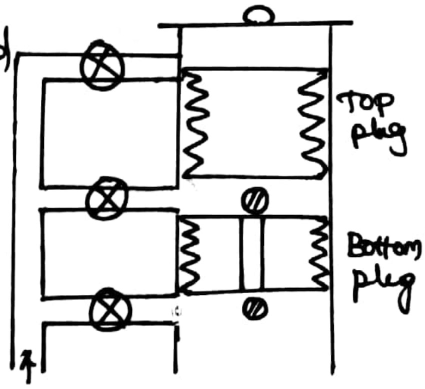
– Prior to running the casing string, it is necessary to circulate the drilling mud for 2 or 3 cycles to ensure that all the drill cuttings and any formation pieces that might have fallen are completely removed.

– The casing string is run into the well with a guide shoe. One to four joints above the guide shoe/float shoe float collar is placed. The float collar acts as a back flow valve that keeps the heavier cement slurry from flowing back into the casing string after it has been placed in the annulus.

– Typically casings are run with float shoe and a float collar both to provide a redundant check valve capability.

– centralizers are placed in varying numbers from 2 per casing to every 4 joints. The number of centralizers to be attached depends on the well profile, hole size and fluid rheology. There are softwares to determine the centralizer placement in a well based on the above considerations.

- The casing string is lowered into the well filled with the drilling mud using the drawworks and elevators. The displaced drilling mud flows to the mud tank and is stored then for later use.
- once the entire string is in place in the bore hole the casing string is kept hanging the casing string to be moved up and down and possibly rotated and its help in better mud removal and uniform cement sheath around the casing pipe.
- while the casing is still hanging in the elevators, a cementing head is madeup to the upper end of the casing string.
- The cementing head is then connected to the flow lines that come from the pump. The cementing head has two retainer values, that hold two rubber plugs (bottom plug and top plug) and two separate plug release pins.



- The blender in the cementing unit mixes the dry cement and aditives with water. The high pressure low volume triplex cement pump on the cementing unit pumps the cement slurry to the cementing head.
- Usually a spacer or preflush is initially pumped a head of the cement slurry. The spacer (usually about 20 bbl or $3.2 m^3$) is used to assist in removing the mud in the annulus.
- when the spacer and the cement slurry are to be pumped inside the casing through the cementing head the bottom plug release pin is removed. This releases the bottom wiper plug ahead of the

flowing spacer fluid. This bottom plug keeps the drilling mud from contaminating the spacer fluid and the cement slurry.

- when all the cement slurry has passed through the cementing head, the top plug release pin is removed releasing the top plug into the flow inside the casing. At this point the cementing unit starts pumping drilling mud through the cementing head.

- When the bottom plug reaches the float collar there will be no more free flow of liquids and this increases the pump pressure. When this increases by 400 psi the diaphragm in the bottom plug ruptures and the spacer followed by cement slurry flows into the annulus through the float/guide shoe. The spacer attains turbulent flow easily and helps remove the mud efficiently.

- when the top plug reaches the float collar, the pump pressure rises sharply as there can be no further flow into the well, indicating that the cement slurry has been completely displaced into the annulus. At this point the cementing pump is shut down and disconnected.

- The back flow valve in the float collar and float shoe stops the heavier cement slurry from flowing back into the casing. The pressure in the casing is released and the valve opened.

- Latest research has shown that a higher viscous cement slurry leads to a better displacement than the low viscosity cement slurry. It has also been found that spacer & cement slurry with a higher gel strengths (10 to 15 lbs/100 sq.ft) and a higher weight (2 to 4 ppg) lead to very good mud displacement in the annulus.

Multistage casing cementing:

It is used to cement long casing strings for the following reasons.

i) Reduce the pumping pressure to the handled by the pumping equipment.

ii) Reduce the hydrostatic pressure on weak formations and prevent fracture & consequent loss of circulation

iii) Selected formations can be cemented.

iv) Entire length of a long casing string can be cemented

v) Casing shoe of the previous casing string may be effectively cemented to the new casing string

vi) Reduce cement contamination.

Multistage casing cementation is carried out by the following methods.

a) Regular two stage cementing.

b) Continuous two stage casing.

c) Regular three stage cementing.

a) Regular two stage cementing: requires the use of a stage cementing collar and plugs in addition to the conventional cementing equipment.

- The stage cementing collar is placed in the casing string. Near the midpoint or at a position where the upper cementing of the casing is to take place.
- The fig. shows a schematic of the regular two stage cementing.
- The cementing collar is a special collar with pores to the annulus that can be opened and

closed by pressure.

- The first stage of cementing (the lower section of the annulus is carried out similar to a conventional single stage cementing. The exception is that the bottom wiper plug is not run in the casing prior to the spacer and the cement slurry.

- During the pumping of the spacer and the cement slurry for the lower section of the annulus, the pores on the stage cementing collar are closed.

b) continuous two stage cementing:

- This is an operation in which the cement slurry is displaced into the lower and upper sections of the annulus in sequence without stopping for dropping of the opening bomb to ~~the~~ continuous two stage cementing collar.

- In this operation the first stage cement slurry is pumped into the casing and the first stage topplug released after the cement. Once the cement slurry gets displaced into the annulus, the top plug goes and sits on the float collar.

- After the required volume of cement slurry is pumped into the casing, the top plug of the first stage is released. This plug is so designed that it passes through the stage collar without actuating it and goes and lands on the float collar, then his a pressure increase and this indicates that the cement has been displaced into the lower part of the annulus.

- After the first stage cementing operation is over, the opening bomb is dropped into the casing and allowed to fall by gravity to the lower seal of the stage cementing collar. Once the opening bomb is seated on the stage collar the pump pressure is applied that allows the hydraulic force to be applied on the lower seal of the stage collar. This force shear the retaining pins of the lower sleeve and the sleeve is pushed down exposing the ports to the annulus.

- Once the ports are opened, the drilling fluid is circulated, conditioned and then the second stage cement slurry is pumped into the casing without a bottom plug. The slurry flows through the ports of the the stage collar into the upper portion of the annulus.

- The top plug of the second stage is now released after completing the cement slurry and this plug goes and sits on the upper sleeve of the stage collar. A pressure of about 1,500 psi causes the retaining pins of the upper sleeve to shear and this forces the sleeves down to close the ports in the stage collar.

- Thus cementing of the annulus is achieved in two stages. The second stage can be done after allowing the lower cement column an initial set. However it must be ensured that the cement has not risen upto the stage collar ports.

- At this point there will be some pressure rise, but the flow will not stop will flow through a bypass insert past the plug, float collar after the plug has landed.
- At this point the 2nd stage opening plug is pumped inside the casing followed by cement and the spacer. The opening plug opens the ports in the stage collar by sitting on the lower sleeve and pushing it down.
- The cement slurry flows into the upper portion of the annulus and once the cement slurry is pumped completely the 2nd stage top plug (or closing plug) is pumped into the casing. This plug goes and sits on the upper sleeve of the stage collar and with hydraulic pressure, closing the ports in the stage collar.
- Thus both the stages of cementing are achieved seamlessly without any break and hence this is the continuously two stage cementing job.

C) <u>Regular three stage cementing</u>:

- Three stage cementing is carried out using the same procedure as the regular two stage cementing except that there will be an additional stages collar placed at appropriate depths as per requirements.

*Each stage of cementing is carried out in sequence the lower annulus section cemented first the middle annulus section next and the top annulus section last.

*Each stage of cement can be allowed to go into initial set before starting the next stage, but care must be taken not to allow the annular cement to rise upto the next higher stage collar.

4. Explain the chemistry behind the well cementing techniques in detail.

*Oil well cementing is the process of mixing a slurry of cement and water and pumping it down through the casing pipes in to the annular space between the casing pipes and bore hole.

*The principle function of oil well cementing is to isolate oil gas and water producing formations and prevent flow of these fluids to other formations. Cementing also secures and supports the casing and enables further drilling of the oil well.

* It also protects the casing from corrosion, prevents blow outs by quickly forming a seal and protects the casing from shock loads in drilling deeper.

* Before pumping the slurry into the casing pipe and into the annulus, the drilling mud in circulation must be conditioned - the viscosity should be reduced to the lowest possible value (just enough to keep the suspension). The yield point and gel values must be low as possible.

* Once the casing has been lowered to the arrived depth, the mud should be again conditioned so as to remove any gelation in any portion of the mud coloumn. Normally circulating about two to three hole volumes is considered sufficient conditioning.

* One of the important preparations for a successful cementation job is to estimate the volume of cement slurry required. This is calculated from the hole diameter and the outer diameter of the casing. If the bore hole has caved during drilling, the average hole diameter has to be computed from caliper logs.

* From the fracture gradient of the formation to be cemented, the maximum allowable slurry density is arrived. This helps in calculating the amount of cement and mix water required for the job.

* Based on the pump capacity, well depth time required for pumping the slurry into its place is calculated and by using, proper additives either retarders or accelerators, the cement setting time tailored to suit the required cement job time.

* The rheology of the cement slurry is so adjust that the cement when it moves up the annulus it flows in a turbulent flow to ensure proper mud displacement.

* In addition to cementing plugs, some times spacers (liquids of different density & viscosity) is used between the mud and the cement and between the cement and displacing mud. These are called

'preflush' and 'postflush'. Generally water mixed with some thinners is used for this purpose.

* when the top plug hits the bottom plug and cement slurry displacement is complete, the casing is kept under pressure to balance the additional hydrostatic head of the cement coloumn acting on the outside of the casing pipe. when the cement is about to set, this pressure is released, so that the casing bond well with the cement without leaving any micro channel.

* Generally 48-72 hrs are sufficients for the cement to gain enough to allow drilling further and carry out other operations.

5. What are the requirements of regular two stage and three stage cementing? Explain in detail.

ref. q. no (2).

6. Write a short note on: i) Secondary cementing; ii) linear cementing; iii) plug cementing.

i) Secondary cementing.

* Secondary cementing is remedial cementing. This refers to cementing operations that are intended to use cement as a means of maintaing or improving the wells operational performance.

* There are two general secondary cementing operations namely a) plug cementing b) squeeze cementing

a) plug cementing:

plug cementing is placing a cement plug at the required depth and allowing it to set. Cement plug are placed for a number of reasons.

i) Abandonement: State regulations require that an oil well when abandoned will have to be sealed off by placing two 100m long cement plugs, one at the top of the open hole and another below the surface casing.

ii) Kick-off plug: Whenever the well is to be side tracked after a failed fishing job, a kick off plug is placed above the leftover string (fish) and the profile is changed by kicking off in a new direction.

iii) Seal off loss circulation Zones: Cement slurry is dumped against a loss circulation zone and the cement seals off loss causing fractures or voids in the formation.

iv) Open hole completions: In open hole completions it becomes necessary to shut off water bearing formations or shut off a weaker formations while testing a higher pressured upper formation. Sometimes the plug will be required to anchor the testing tools.

There are two methods of placing a cement plug.

i) Balance plug method: This is the most commonly used method. Cement slurry is placed at the desired depth through drill pipe or tubing. A spacer is placed below and above the cement slurry to prevent contamination by drilling mud. The slurry is allowed to rise in the annular space to the same height as that of the cement in the pipe. The drill pipe or tubing is slowly pulled out without disturbing the plug.

ii) Dump bailing method: This method utilises a bailing device that contains a measured volume of cement slurry. The bailer is run to the appropriate depth on a wireline and releases its load when its bottom pumps on a permanent bridge plug set at the desired depth or even the bottom of the bore hole.

* Cement plugs sometimes fail for the following reasons

a) Lack of hardness

b) Contaminated cement slurry

c) placed at wrong depth

d) plug migrating from the intended depth location due to lack of balancing control.

b) Squeeze cementing:

* Squeeze cementing operation utilizes the mechanical power of the cement pumps to force a cement slurry into the annular space or into the formation for the following reasons/purposes.

- Repair a faulty primary cementing job
- Stop loss of circulation in the open hole during drilling operations.

- **Reduce** water-oil; water-gas and gas-oil ratios by selectively sealing certain fluid producing form actions.
- Seal abandoned or depleted formations.
- Repair casing leaks such as joint leaks, split casing, parted casing or corroded casing.
- Isolate a production zone by sealing off an adjacent nonproductive zone.

*In squeeze cementing, cement slurry is forced into rock formation and the slurry losses part of its mix water. This forms a filter cake of cement particles at the interface and the channels / fractures are sealed and the pressure increases indicating that the squeeze has been done.

*Important considerations regarding cement slurry design for a squeeze cementing job.

1. Fluid Loss control: For low permeability formations fluid loss to be 100-200 ml/30 min and for high permeable formations it should be 50-100ml/30min

2. Slurry Volume: High pressure squeeze operations of high permeability formations that have relatively low fracture strength will require large volumes of slurry low pressure squeeze operation through perforation will require low volumes.

3. Thickening Time: High pressure squeeze jobs that pump large volumes in a rather short time period usually require accelator additives. Low pressure slow pumping squeeze operations usually require retarder additives.

4. Dispersion: Thick slurries will not flow well in narrow channel. Hence all squeeze cement slurry should be thin (i.e, low viscosity) and have low yield points. Thinners must be added to the cement slurries in all Squeeze jobs.

There are two basic squeeze cementing techniques used (i) The high pressure squeeze operation: This is utilize where the hydraulic pressure is used to make new channels in the rock formations by fracturing the rock and forcing the cement slurry into these fractures.

(ii) Low pressure squeeze operation: These are utilised where the existing permeability is sufficient to allow the cement slurry to efficiently move into the formation without making new fractures.

In both high and low pressure squeeze operations "hesitation method" of applying pressure (i.e.) intermittant application of pressure) has been found to be more effective than continuous pressure application.

* Normal squeeze jobs are performed both within the casing (against perforations) and in the open hole, by lowering a tail pipe with a retrievable packer to be set above the zone of squeeze and placing the cement slurry against the squeeze zone and then lifting the tail pipe above the cement setting packer and applying pressure through the mud in the drill pipe and tail pipe.

ii) Liner cementing:

* A liner is a short string of casing that does not reach the surface. The liner is hung from the bottom of the previous casing string using a liner hanger that grips the bottom of the previous casing with a set of slips.

* The liner is run into the well using drill pipes and the cementing operation is carried out through the same drillpipe. The placing of liners and their cementing are some of the most difficult operations in the entire well drilling and completion operations.

A typical liner assembly consist of

i) A float shoe : This is placed at the bottom of the liner and is a combination of a guide shoe and a float collar.

ii) Landing collar: A short sub placed in the string to provide a seat for the plug.

iii) Liner: This is liner string of required length below the previous casing and generally it overlaps the previous casing by about 200-500 ft (60-150 mts).

iv) Liner hanger: This is a special tool installed on top of the liner string. This can be connected to the drill pipe on the top. The hanger can be set at the required depth either mechanically or hydraulically within the previous casing. This is the key element in the liner operation.

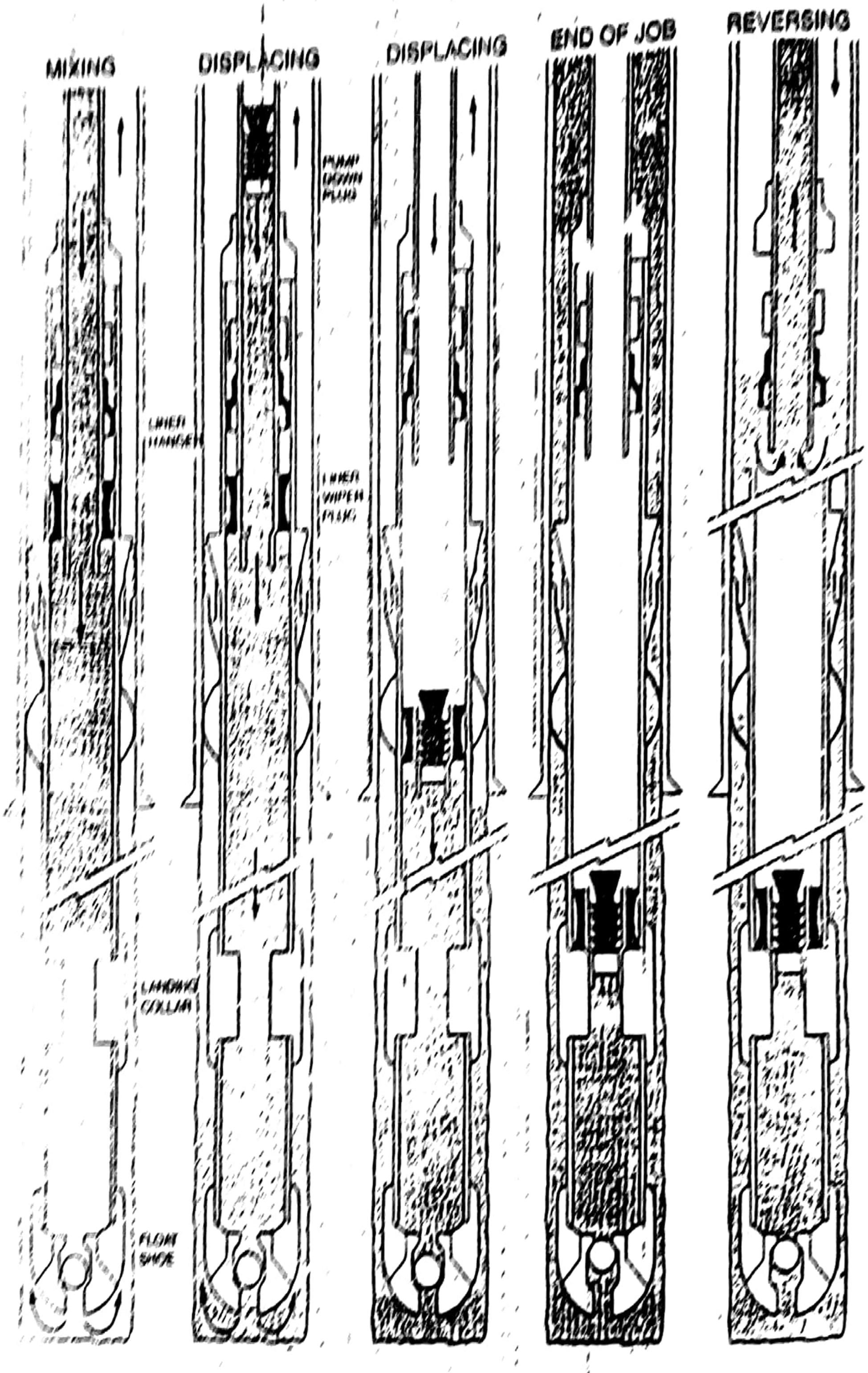


FIGURE 9.21 Liner cementing [2].

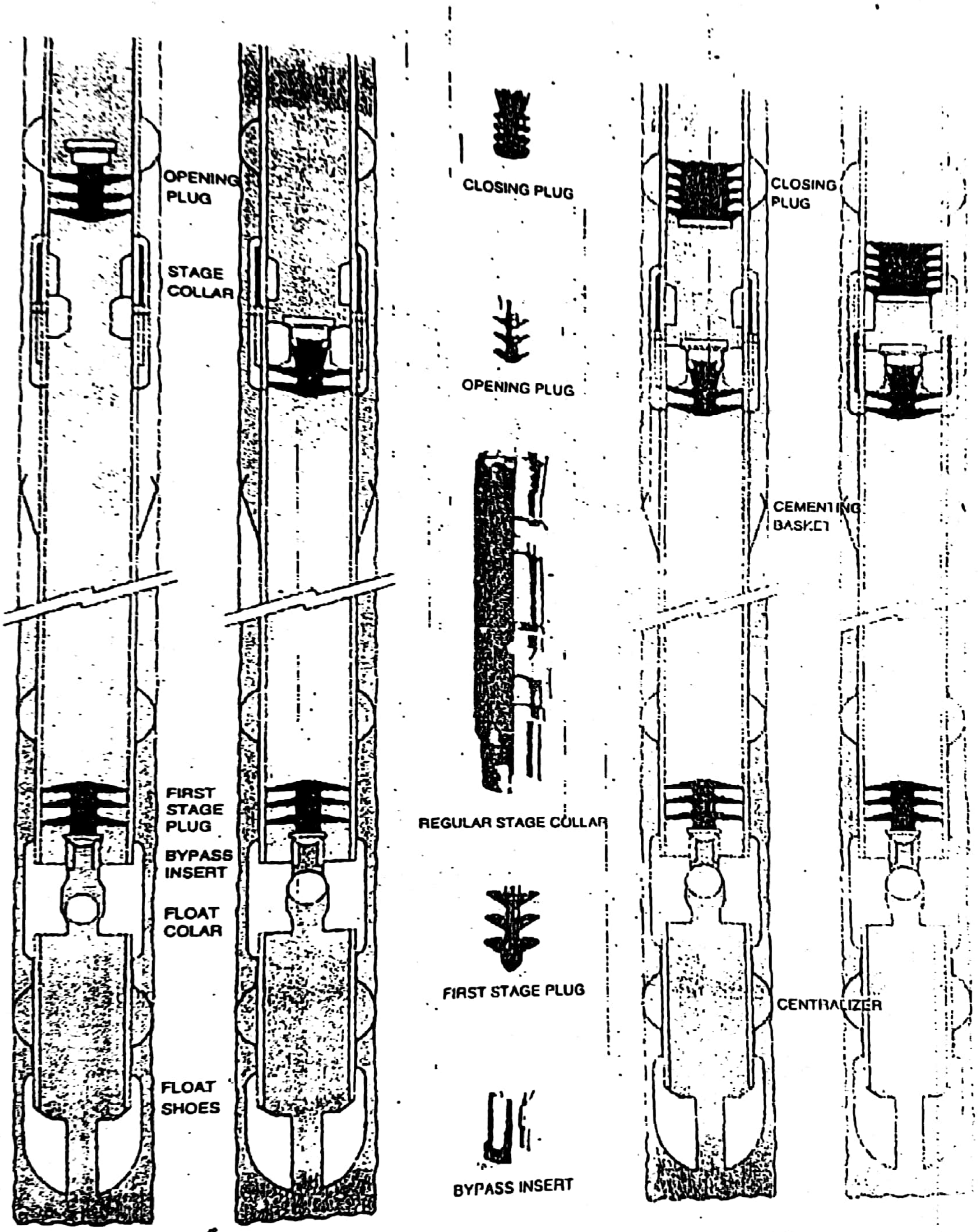


FIGURE 9.17 Continuous two-stage cementing [2].

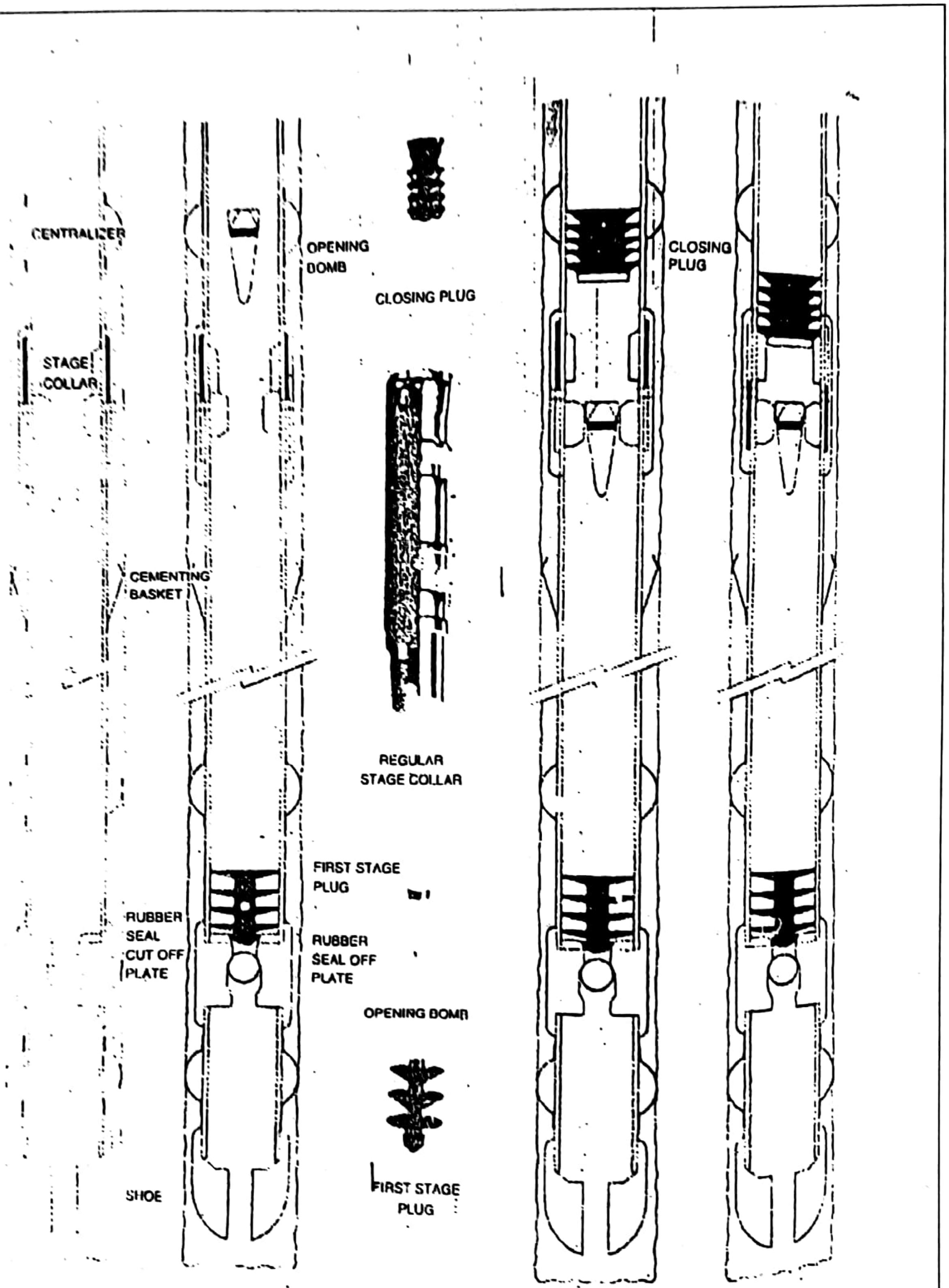


FIGURE 9.16 Regular two-stage cementing [2].

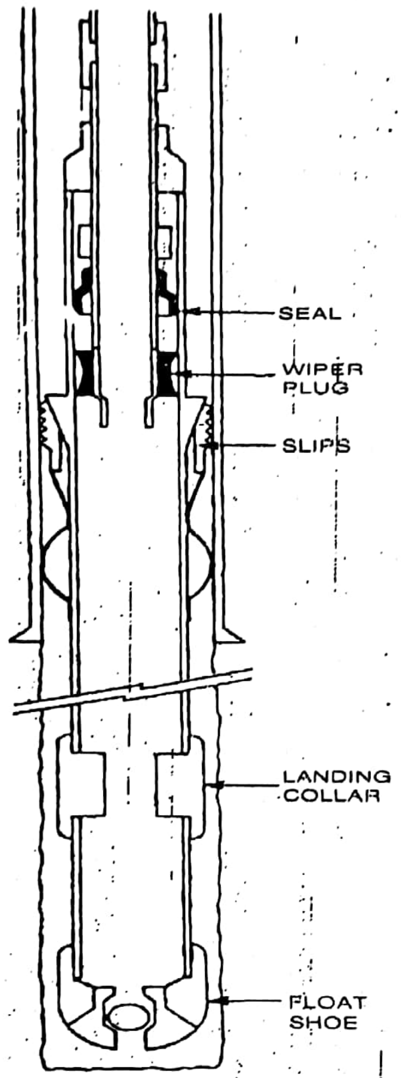


FIGURE 9.19 Liner assembly [2].