CEMENTING

<u>The following topics well be discussed:</u>

- Functions of cement
- The manufacture of cement
- Classes and types of cement
- Basic components of cement
- Cement slurry
- Hydration of cement
- Soleplate resistance
- Strength retrogression of cement and the use of silica flour
- Properties of cement slurry
- Casing accessories
- Cement contamination
- Mechanics of cementing
- Liner cementing
- Practical calculations
- Squeeze cementing
- Plugging back operations

Functions of cement

- Restriction of fluid movement between permeable zones
- Provision of mechanical support of the casing string
- Protection of casing from corrosion
- Support of the well-bore walls to prevent collapse of formations

The manufacture and composition of cement

- Raw material from calcareous and argillaceous rocks (limestone, clay, shale and slag)
- Dry raw materials finely ground and mixed in correction proportions (kiln feed)
- Chemical compositions of dry mix determined and adjusted
- Kiln feed fed at a uniform rate in a sloping rotary kiln
- The mixture travels at the lower end
- Powdered coal, fuel oil or gas, fired into the kiln

- Temperature reached to 2600-2800 F (1427-1538 C), calcined
- Chemical reactions o raw materials took place and a new material formed (clinker)
- The clinker varies in size from dust to particles of several inches in diameter
- The clinkers sent to air cooler, quenched and put into storage (storage time)
- The clinker ground with a controlled amount of gypsum (Portland cement)
- Cement packed and transported for customers
- Gypsum between 1 to 3% to control setting and hardening of cement

Classes of cement

Nine API classes:

- Class A
  - Depth surface – 6000 ft (1830 m)
  - No special properties
  - Similar to ASTM C 150,Type I

- Class B
  - Depth surface – 6000 ft (1830 m)
  - Moderate to high sulphate resistance
  - Similar to ASTM C 150 Types II

- Class C
  - Depth surface – 6000 ft (1830 m)
  - High early strength
  - Moderate to high sulphate resistance
  - Similar to ASTM C 150 Types III

- Class D
  - Depth from 6000 ft – 10,000 ft (1830 m - 3050 m)
  - Moderate and high sulphate resistance
  - Moderately high pressure and temperature

- Class E

- Depth from 10,000 ft – 14,000 ft (3050 m - 4270 m)
- Moderate and high sulphate resistance
- High pressure and temperature

➢ Class F
- Depth from 10,000 ft – 16,000 ft (3050 m - 4270 m)
- Moderate to high sulphate resistance
- Extremely high pressure and temperature

➢ Class G
- Depth surface – 8000 ft (2440 m), as basic cement, fine
- Can be used with accelerators and retarders for other specifications
- Moderate to high sulphate resistance
- No addition other than calcium sulphate or water

➢ Class H
- Depth surface – 8000 ft (2440 m), as basic cement, course
- Can be used with accelerators and retarders for other specifications
- Moderate to high sulphate resistance
- No addition other than calcium sulphate or water

➢ Class J
- Depth 12,000 – 16,000 ft (3660 m - 4880 m)
- Extremely high pressure and temperature
- Can be used with accelerators and retarders for other specifications
- Moderate to high sulphate resistance
- No addition other than calcium sulphate or water

Class	Water,%	Depth, ft	Temp. F	Properties
A	46	0 – 6000	80-170	Ordinary class, normal properties, T.T. (90 min)
B	46	0 – 6000	80-170	HSR or MSR, T.T (90 min)
C	56	0 – 6000	80-170	MSR, HES, fine (90

				min)
D(retarded)	38	6000-10000	170-290	HSR or MSR, coarse (120)
E(retarded)	38	10000-14000	170-290	HSR or MSR, (154)
F(retarded)	38	10000-16000	230-320	Only in HSR, (180)
G	38	ALL depths		HSR, or MSR, fine
H	38	ALL depths		OSR or MSR, coarse
J	38	12000-16000		For temp. > 230 F, HSR

M: Medium H: High O: Ordinary S: Sulfate R: Resistance E: earlyT.T. Thickening Time

Portland Cement

Basic components of cement

Component	Formula	Trade name	Amount %	Function
Tricalcium silicate	3CaO.SiO2	C3S	50%	Fastest hydration Overall and early strength Protect sulphate attack
Dicalcium Silicate	2CaO.SiO2	C2S	25%	Slow reacting Responsible for gradual increase in strength
Tricalcium Aluminate	3CaO.Al2O3	C3A	10%	Initial set and early strength
Tetracalcium Aluminum				Initial set and early strength

Ferrite	4CaO.Al2O3.Fe2O3	C4AF	10%	Low heat of hydration
Other oxides such as gypsium, sulphate magnesia, free lime			5%	

- The effect they have on properties of the cement have made it possible to develop cements for special applications by varying the raw material used in manufacture:
- By increasing C3S content a high early strength can be obtained.
- At low heat of hydration cement is made by decreasing both C3S and C3A.
- High amounts of C3A , due to its high reaction speed and exothermic reaction, decreases the setting time of the slurry.
- Hydration of cement gives off considerable heat about 80 calories per gram of cement (80 BTU/lb).
- Maximum release of heat is obtained about 4 to 6 hours after hydration.
- The selection of cement and additives broadly resolves into choosing an economical material that may be satisfactory placed to achieve the required specifications after placement.
- The difference between construction cement and oil well cement are:
- No aggregate is added to oil well cement
- Large volumes of water are used in oilwell cements to make the slurry pumpable.

Cement hydration

- Dry cement mixed with water
- Slurry subjected to differential pressure and temperature
- Water is lost to formation by dehydration or evaporation
- Chemical reaction occurs (exothermal reaction)
- Hydrous compounds form an interlocking crystalline structure
- Structure bonds to casing and rock surfaces

Properties affecting selection of cement type

Slurry density

- Should be the same as mud to minimize the risk or blowouts or lost circulation
- Measured using mud balance
- Low density are prepared with bentonite, pozzolan, gilsonite, perlite, Diatomacous earth
- Bentonite is used in concentration up to 35%, the rduction is due to water added.
- Each 1% of bentonite needs 4% of water.
- One sack cement equals 94 lbs (50 kg) and measure 1 cu. ft
- Density increases by adding barite, iron ores or galena
- Each 1% of needs 0.2% increase in mixing water.

Thickening Time

- Determine the length of time the slurry can be pumped
- It is the time necessary for the slurry consistenecy to reach 100 poises under stimulated bottom hole pressure and temperature
- Measured using cement consistometer
- Thickening time is affected by:
- Pumping rate: eddies and currents resulting from turbulent flow increases thickening time.
- Fineness to which the clinker is ground
- Additives: accelerators to decrease thickening time, retarders to increase it.
- Accelerators are calcium chloride.
- Retarders are calcium lignosulphonate, pozzolan and CMHECand
- Accelarators are used to cement shallow wells and surface casings.
- Retarders are used for cementing deep and hot wells.
- In practice the thickening time should be at least 25% higher than the time necessary to accomplish the

Cement Strength

- Cement in oil wells is subjected to static and dynamic stresses

- Static stress due to dead weight of pipe; compressive stresses due to the action of fluid and formations
- Dynamic stresses resulting from drilling operation, especially the vibration of drill string
- To withstand these stresses a compressive strength of 500 psi after 24 hours period is needed
- High early strength possesses strength higher than ordinary strength in the first 30 hours.
- Density reduction materials always decreases cement strength
- Retarders reduce both early and late strength
- Fine sand increases final cement strength
- Strength retrograte between 80 to 120 C
- Silica flour is added to prevent temperature effect

Filtration

- Water loss of neat cement is very high
- Laboratory tests show that up to 50% of mixing water is lost by filtration through rock or filter papers
- Presence of small thickness mud cake reduces filtration
- High density slurry results in higher filtration loss
- Additives to reduce filtration are bentonite, organic colloids (CMHEC)

Permeability

- Naturally, permeability of set cement should be the lowest possible.
- Bentonite cements are known to be very permeable (values up to 10 md are reported, while special cements (latex cement) have permeabilities as low as one micodarcy.
- The following factors influence the permeability of the set cement:

    - Water/cemet ratios: High W/C ratio increases the permeability
    - Downhole conditions: high pressure and confinement due to their compacting effects decrease the permeability of set cement

Perforating Qualities

- Ordinary cements, when they are completely hardened, fracture excessively when perforated.
- Low strength cements are usually less brittle and have less tendency to shatter upon perforating.
- Shattering of cement is not a desired quality when near an O.W.C. or O.G.C.
- Additives such as bentonite, pozzolan and latex increase the ductility of set cement.

Corrosion Resistance

- Set cement could be penetrated by corrosive liquids especially those containing CO3 os SO4 irons.
- Cement corrosion decreases the final compressive strength render the cement more permeable.
- Reduction of the hardening time improves the cement resistance to corrosion by corrosive fluids.

Bond Requirements

- For clean surfaces (rock or metal) the bond increases with time and moderate temperatures.
- Mud cake and dirty casing surfaces reduce markedly the bond between casing or rock and cement.
- Additives such as salt and fine sand increases the bond between casing and the set cement.

Other Cement Types

- Pozzolanic Cements (pozzolan + Portland CMT or lime pozzolan cement)
- Pozzolan (siliceous rocks of volcanic origin) is added to portland cements or used with lime (lime-pozzolan cement).
- Pozzolan cements have higher permeability times than most conventional.
- Pozzolanic cements are light ducle and they are proved to be satisfactory deep well cements.

- <u>Perlite Cement</u> (Perlite + ordinary portland + bentonite)
- Perlite cements are prepared by adding perlite to ordinary portland.
- Perlite is a light volcanic ore, when heated to fusion it gives rise to a very low-density product (13 lb/ft^3).
- Bentonite is usually added to perlite cement slurries to disperse perlite more uniformly through the mixture. Perlite cements are very expensive.

- <u>Diesel Oil Cements</u> (DOC) [Latex + CMT + water]
- A portland cement to which; a surface active agent is added, it is designed for, mixing with diesel oil.
- Will not set and hardens unless it comes in contact with water.
- Used for shutting off; water production from completion interval of a well.

- <u>Latex cement</u> [Latex + CMT + Water)
- Composed of latex, cement and water.
- Used for plug back jobs for water exclusion.
- Especially resistant to oil and mud contamination.
- Gives a high strength bond with casing and rocks.

<u>Water Supply</u>

- Fresh water is suitable for cement, provided that is found sufficient quantities. Some water contains humic acid that acts as a retarder to hardening.
- Some rig water is found to contain phosphates, tannates (thinners used for mud), and those chemicals can seriously retard the setting of cement.
- The usual water cement ratio is 45% (5.2 gal/sack) of dry cement; 500 gal per cementing unit should be provided for priming, testing, and cleaning up.
- An additional 5130 gal should be provided as a minimum safety margin.
- Rate of water supply should be based on the rate of mixing cement: usually this is 5-6 bbl/min. for each pumping unit on the job.

- Hot mixing water may result in shorter allowable pumping time. Cold water may provide viscous slurry during mixing.

Cementing Equipment and Accessories

- In order to achieve the desired objective in cementing, special equipment has been designed

Cementing Plugs

- It consists of an aluminum body encased in a molded rubber cast in the desired shape.
- Bottom plug is used ahead of the cement t prevent contamination with the mud ahead of the slurry and it wipes off the film of the mud that adhears to the inside of the casing.
- When it reaches the float collar, the diaphragm in the plug ruptures to permit the cement slurry to proceed down the casing and up the annulus.
- Top plug serves to signal the proper placement of the slurry and prevents mixing of cement and displacing fluid.
- Strong undiluted cement is specially desirable near the casing shoe.

Wall Scratchers

- They are used to improve the bonding properties of cement to the formation by removing the mud cake from the wall of the hole.
- They are reciprocating or rotating.
- Reciprocating scratchers are normally spaced at 15-20 ft intervals through out the section to be cemented, but rotating are usually placed opposite the pay zone only.
- Casing that is equipped with reciprocating scratchers will be worked up and down for a distance depending on the spacing of the devices on the casing

Centralizers

These devices are designed to:

- Ensure a reasonable uniform distribution around the casing

- Obtain a competent seal between the casing and the formation
- Centralizers must have sufficient strength to center the casing reasonably in the hole and must leave enough space for the flow of circulating fluid.

Floating Equipment

- It normally consists of a guide shoe attached to the bottom end of the lower length of the casing and a float collar attached to the top of the last joint of the casing.

Casing Guide Shoes

- A guide shoe is basically a short section of steel pipe with the lower end rounded to facilitate passage of the casing through irregular places in the borehole.
- The lower portion of the guide shoe contains cement shock absorbing characteristics of the shoe. It also usually contains a backpressure valve arranged to permit circulation form the inside of the casing to the outside only.
- The primary purpose o this valve assembly is to prevent the cement slurry from reentering the inside of the casing after it had been placed.
- Also it allows the casing to be floated down the hole. That is, the inside of the casing of the casing is lift empty, or only partly filed to reduce the load on the derrick.

First Collar

- If the lowest joint of the casing is left filled with cement, the hazards of a pore cement job at the bottom of the casing are reduced.
- If the top of the cement is slightly contaminated with the displacing fluid, the contaminated portion will probably be lift in this last joint of casing.
- The collar joint has a back pressure valve similar to that of the guide shoe.
- The internal diameter of the float collar is reduced by cement or other drillable materials to provide a positive seat for the cementing plugs.

Casing Cementing Heads

- It is used to provide continuous cementing operations.
- A cementing head is fixed to the topmost joint and designed to receive the cement plug(s).
- Modern heads provide a quick change cap that can be removed to insert the cement plug.
- he bottom plug is inserted through the plug container into the casing before mixing starts.
- The top plug is loaded into the cementing head through the cap, resting on a special support bar that can be released by turning a specially designed releasing handle. Bottom plus is released a head of cement, top plug behind the cement.

Cone Jet Mixer

- Jet mixers making use of venturi effect are very popular. Mixer of this type is simple in design reliable and rugged in operation. Control mixing rate is dependent upon:
- Regulation of the volume of water forced through the jet, and
- Keeping the hopper full of dry cement.
- A by-pass line can supply extra water for lowering slurry weight by increase of water cement ratio.

CEMENTING PROCEDURE

Preparing the Hole

- Preparation of the hole for the cementing jobs starts long before the cementing operation itself.
- Before lowering the casing, usually drill pipes have been out of the hole a matter of 12 to 24 hours while surveys and other information were being obtained prior to the decision to set the casing, for example caliper survey of the hole size are run to know the exact dimension of the hole.
- Before pumping the slurry, mud circulation appears necessary to clean the hole and to remove cuttings and mud cake attached to the walls.

- At the same time the casing is worked up or down or rotated during mud circulation.
- Sometimes, immediately before putting cement, water added with 5% hexametaphosphate is pumped down the casing to disintegrate the mud cake.

Injection Of Slurry

- Most bore holes are filled with drilling fluid when the cementing operation begins and for this reason drilling mud is normally used as the displacing fluid.
- After the introduction of, the bottom plug, as the cement is pumped inside the casing the pumping pressure steadily decreases.
- When the bottom plug reaches the float collar (joint) pressure slightly increases then drop to indicate the rupture of the top plug.
- Then, the circulation pressure steadily increases indicating an increasing amount of slurry outside the casing. The arrival of the top plug on the bottom plug results in a sharp increase of the pump pressure.
- During the cementing operation, the return mud will flow back into the mud tanks.
- The returning mud should be watched carefully.
- If mud returns are not obtained at the surface while the cement is being pumped into the casing, then some fluid, either cement or mud is being lost in the formations.
- When this occurs, there is always some doubt about the proper placement of cement.

Considerations After Cementing

- After cement hardens, release the pressure on the casing permits it to contract so that the bond with the cement may be loosened. Release of pressure on the casing before the cement sets eliminates this problem. Bleed off the pressure is made if the the back pressure valve in the casing is holding satisfactorily.
- The usual waiting on cement (WOC) before drilling starts is about 12 hours for intermediate casing and 5 to 8 hours for

surface casing counted from the moment the top plug reaches the float collar seat.

- WOC is required in order that the cement: anchors the pipe and withstands the shocks of subsequent operations; seals the permeable zones for prevention of the fluid movements behind the casing.
- The WOC usually employed permits a compressive strength of 500 psi to develop.
- Roughly WOC is equal to three times the thickening time under hole conditions.
- Temperature surveys to determine the cement top behind the casing should be run 4 to 6 hours after mixing. In most areas casing is pressure tested after the casing head and blowout preventers have been installed.
- The general practice is to exert 1500 psi with the rig pumps and hold this pressure for 30 minutes a pressure drop of 50psi/min is considered satisfactory.

Multi-Stage Cementing

- This technique is used for cementing two or more separate sections behind the casing string: when
- a long cement column could not be used without because if breakdown of the formation behind the casing,
- it is necessary to reduce the pump pressure at the surface, especially in cementing deep wells, and
- slurries of different compositions are used for cementing distinct sections.
- Multi stage cementing devices are used for stage cementing operations which when properly placed in the casing string will allow cement to be placed at the desired locations.
- Cementing of the lower section of casing is done first in the usual manner using plugs that will pass through the multistage collar without opening the ports of the collar.
- Special plugs can open the multi stage collar hydraulically and slurry is then circulated through the tool to the annular space.
- A special cementing basket attached to the outside of the casing to prevent the slurry from flowing down by gravity and directs it towards the surface.

Squeeze Cementing

- Squeeze cementing is a secondary cementing method in which relatively large pressures are used to force cement into places such as sealing off zones of lost.

Laws of Cementing Calculations

Thickening Time

- Thickening Time T.T. = Mixing and Pumping Time + Displacement Time + Plug Release Time + Safety Factor

- Mixing and Pumping Time

- Mixing and Pumping Time = Volume of Cement Slurry / Mixing Rate

- Displacement Time = Displacement Volume / displacement rate

- Safety Factor = 30 – 60 min. normally used

- Notes
  - Sp. Gr. of cement = 3.14
  - Sp. Gr. of bentonite = 2.65
  - Sp. Gr. of brite = 4.25
  - Sp. Gr. of pozzolan = 2.5
  - Sp. Gr. of perlite = 2.2
  - Sp. Gr. of gilsonite = 1.07

- Surface Time is the time required for the cement slurry to be prepared at the surface and retained for testing. This time is namely small and can be included as part of the mixing time.
- Displacement Time: during mixing the cement slurry is pumped inside the casing until the entire dry volume of cement is mixed.

This time is dependent on casing capacity and the displacement rate

- Number of sacks = Slurry volume / Slurry Yield
- Weight of cement = Volume x density
- Number of sacks of bentonite = amount of bentonite / 94
- Volume of mix water = No. of Sacks x water required per sack