Escola Politécnica da Universidade de São Paulo

Departamento de Engenharia de Minas e de Petróleo

PMI-1841 ENGENHARIA DE PERFURAÇÃO

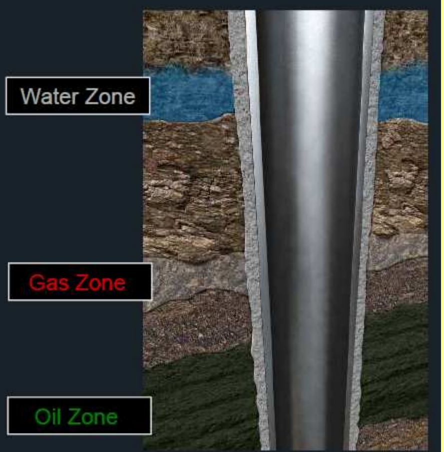
AULA 8 – CIMENTAÇÃO - Continuação

Wilson Siguemasa Iramina

Santos, setembro de 2016

Why do we cement wells

- Principle Functions of primary cementing
  - Restrict fluid movement between formations
  - Bond and support the casing
- Additional uses of cement
  - Protect the casing from corrosion
  - Prevent blowouts
  - Protect the casing from shock loads in drilling operations
  - Sealing off loss circulation or thief zones

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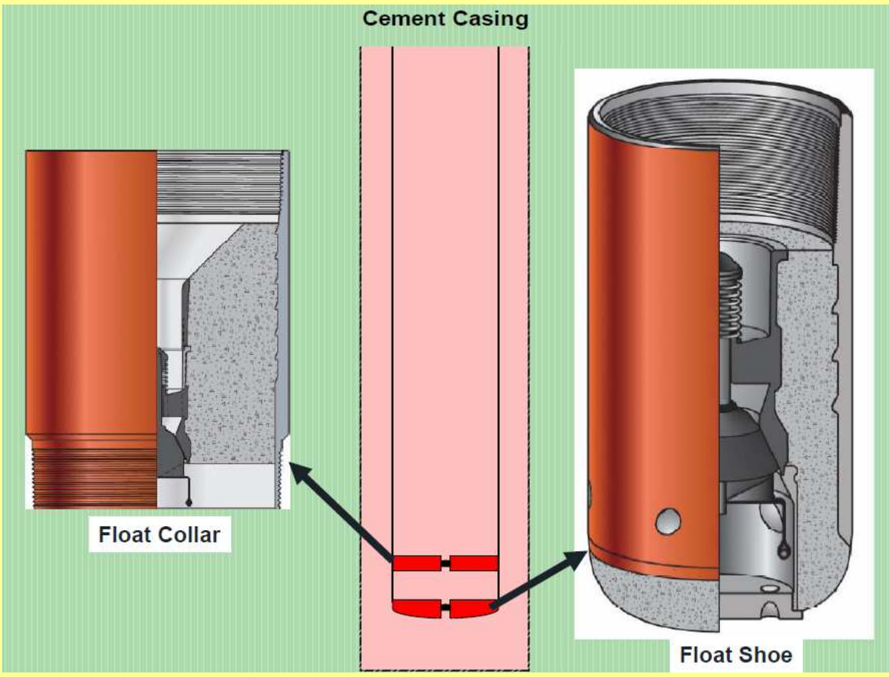
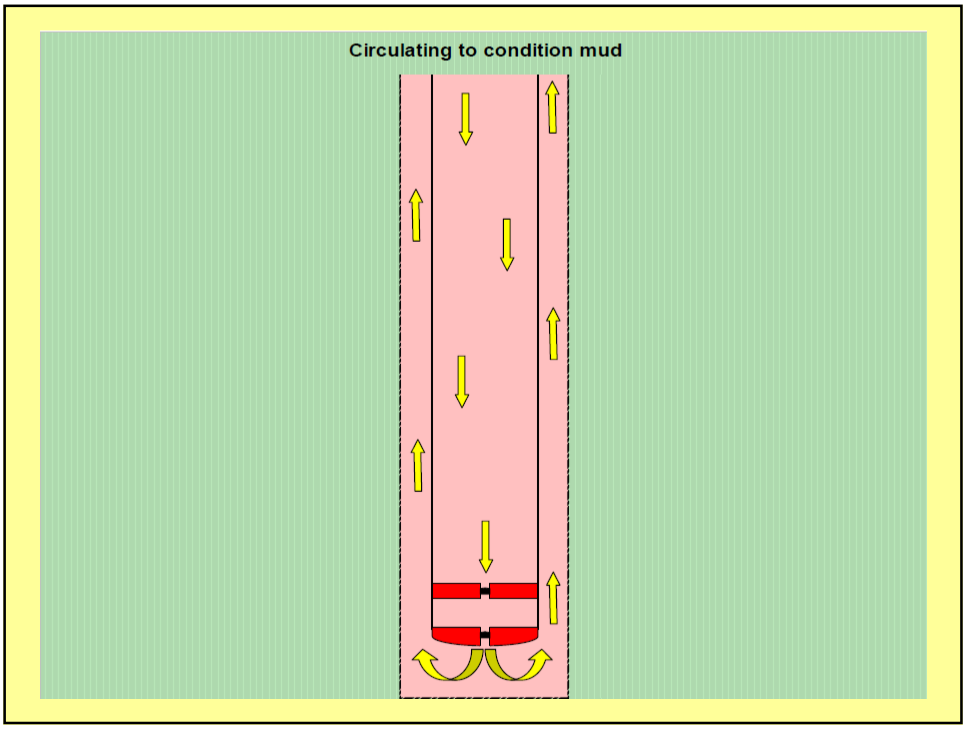
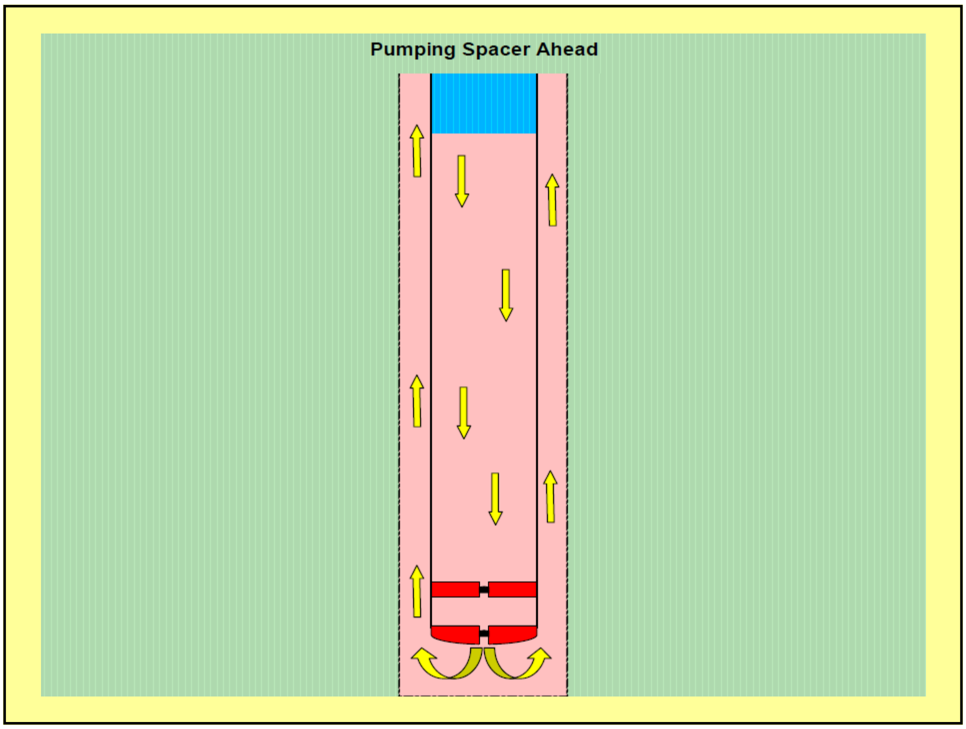
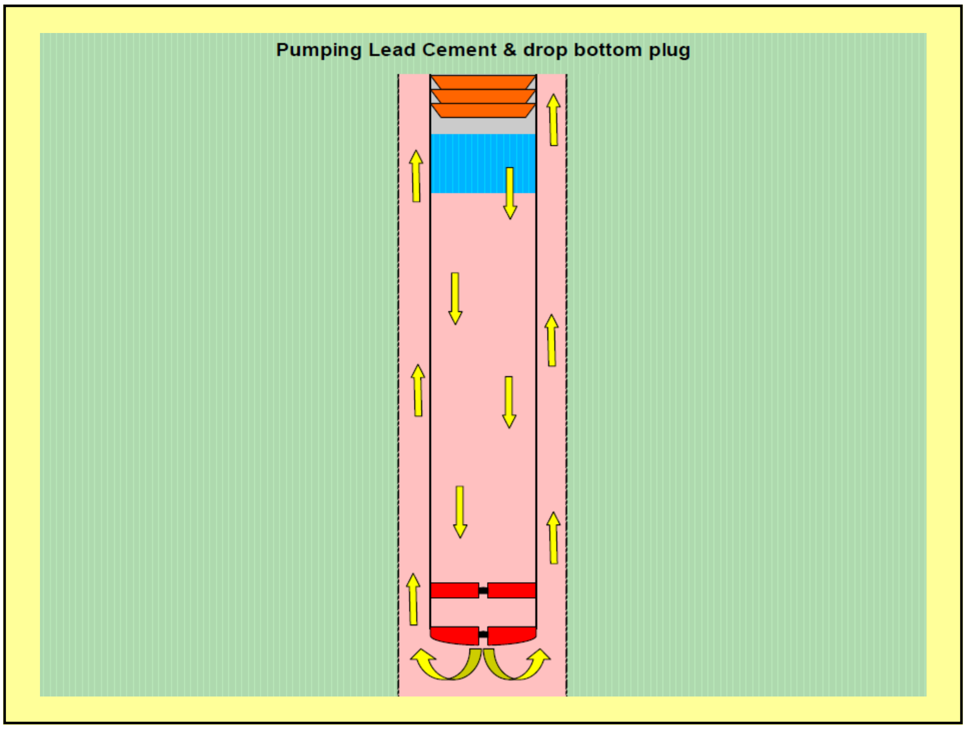
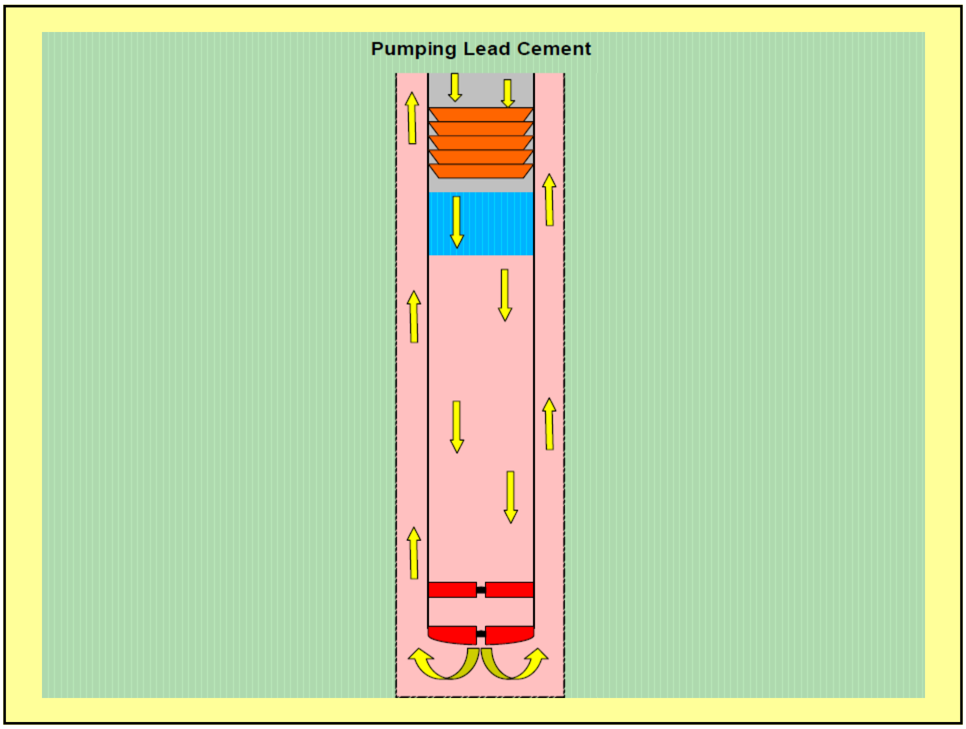
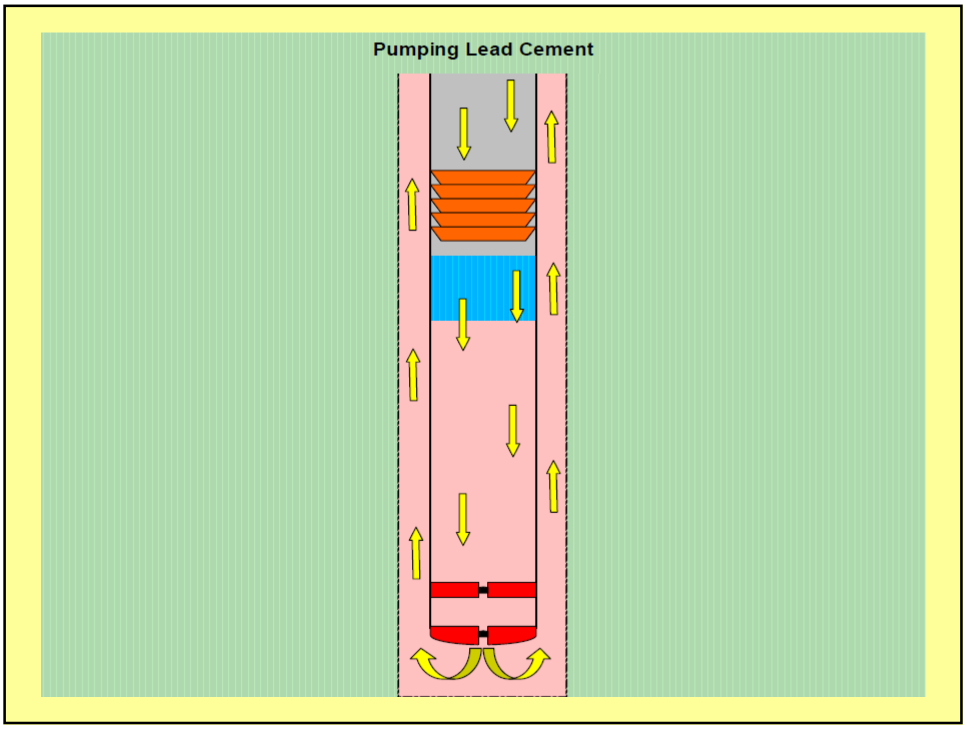

Cement Casing
Float Collar
Float Shoe

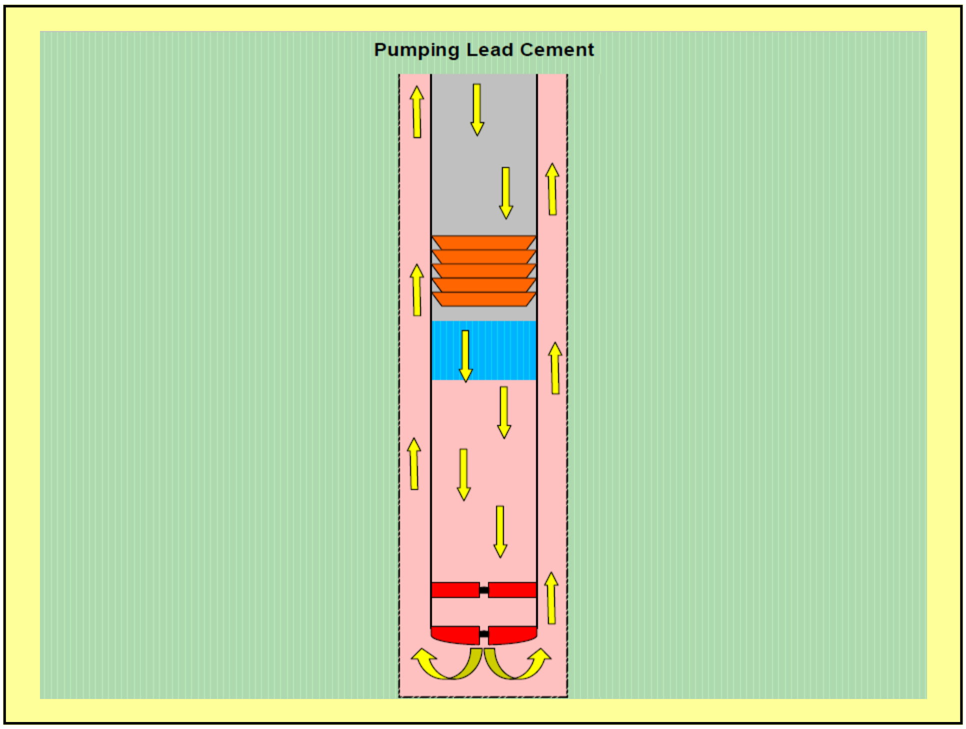

Circulating to condition mud

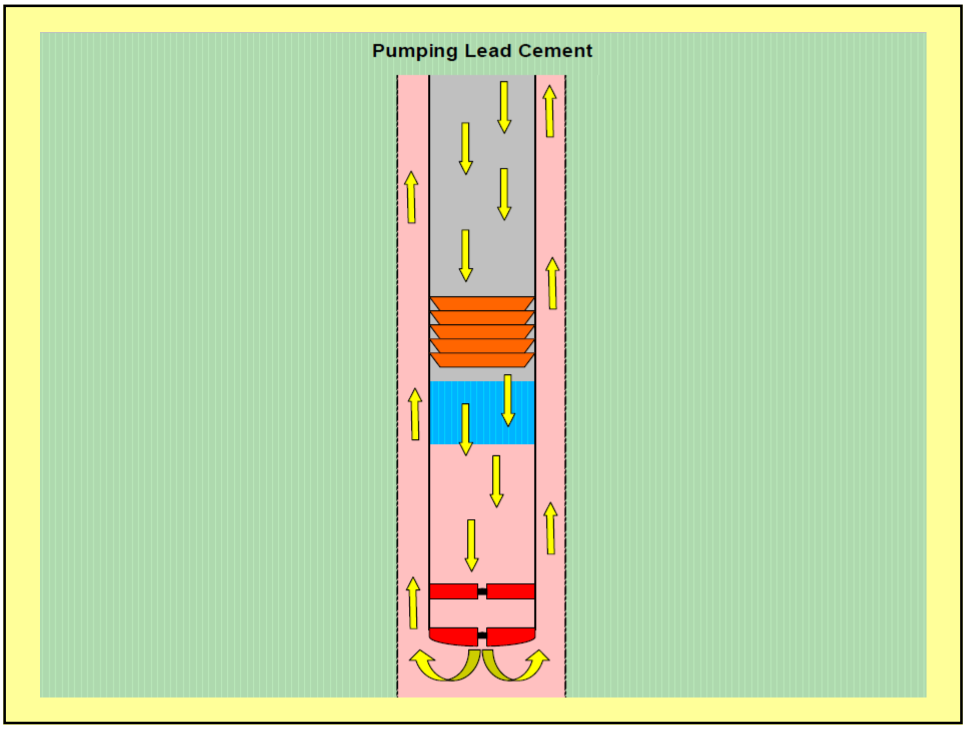

Pumping Spacer Ahead

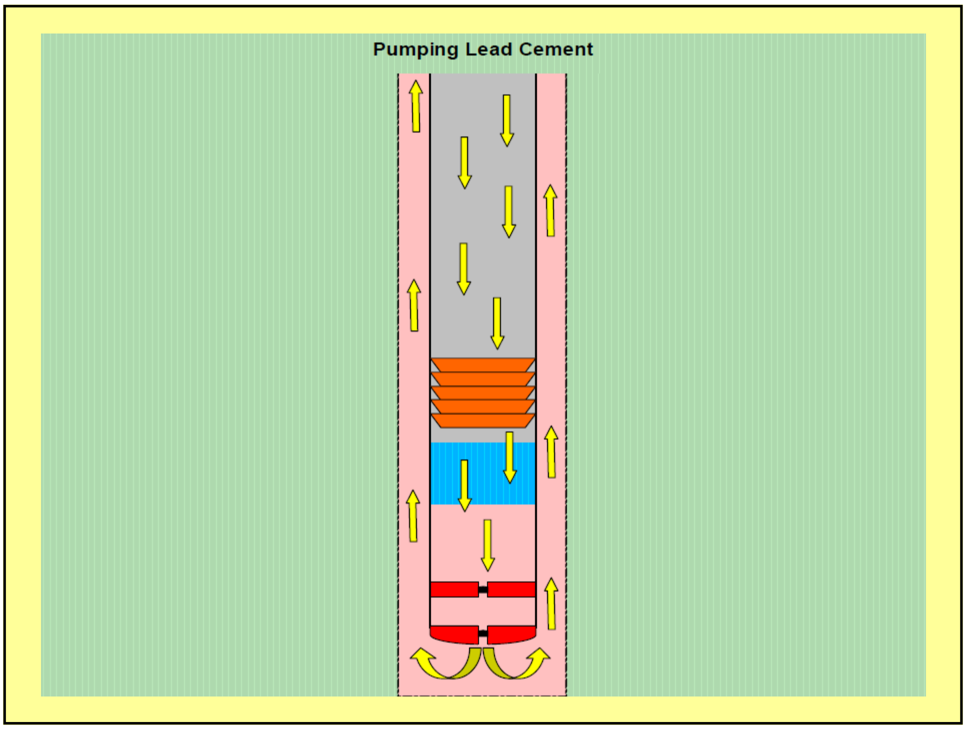

Pumping Lead Cement & drop bottom plug

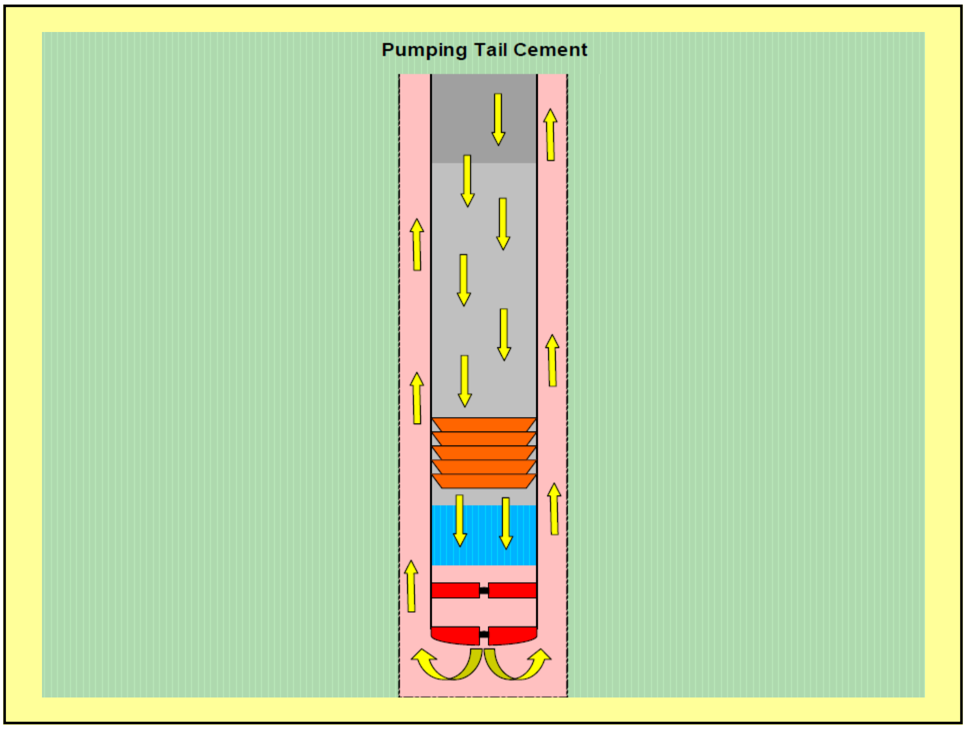

Pumping Lead Cement

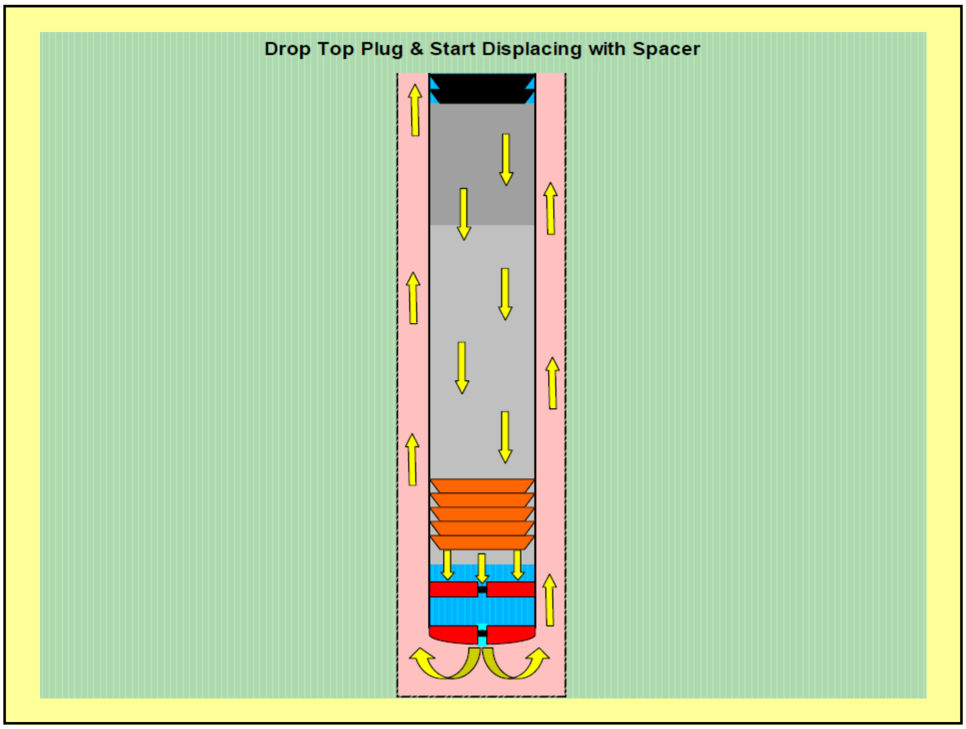

Pumping Lead Cement

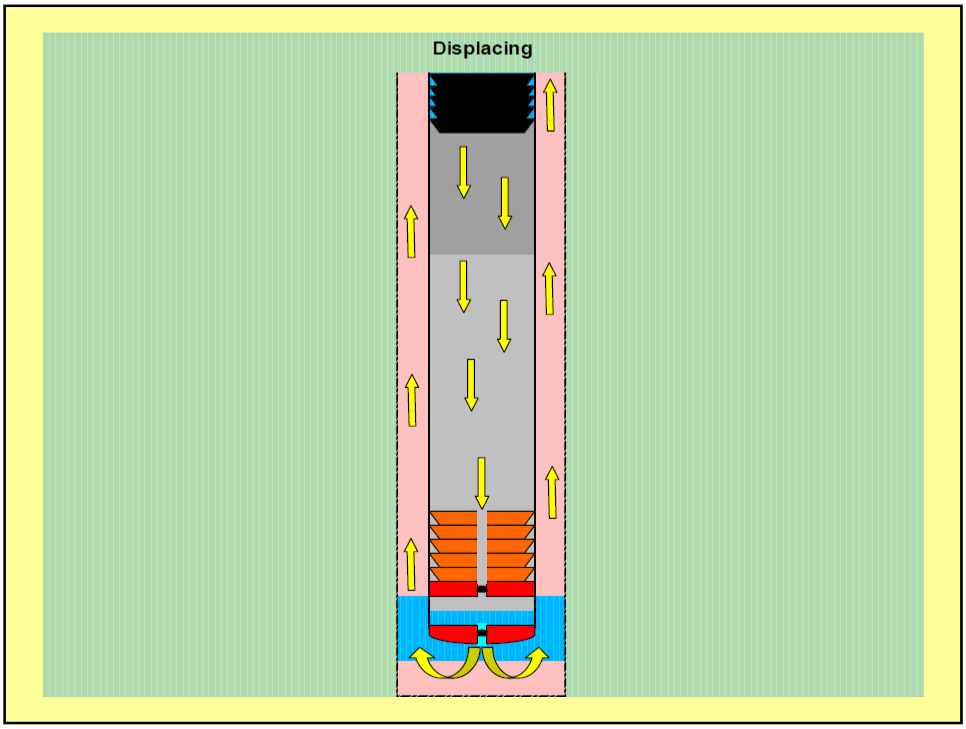

Pumping Lead Cement

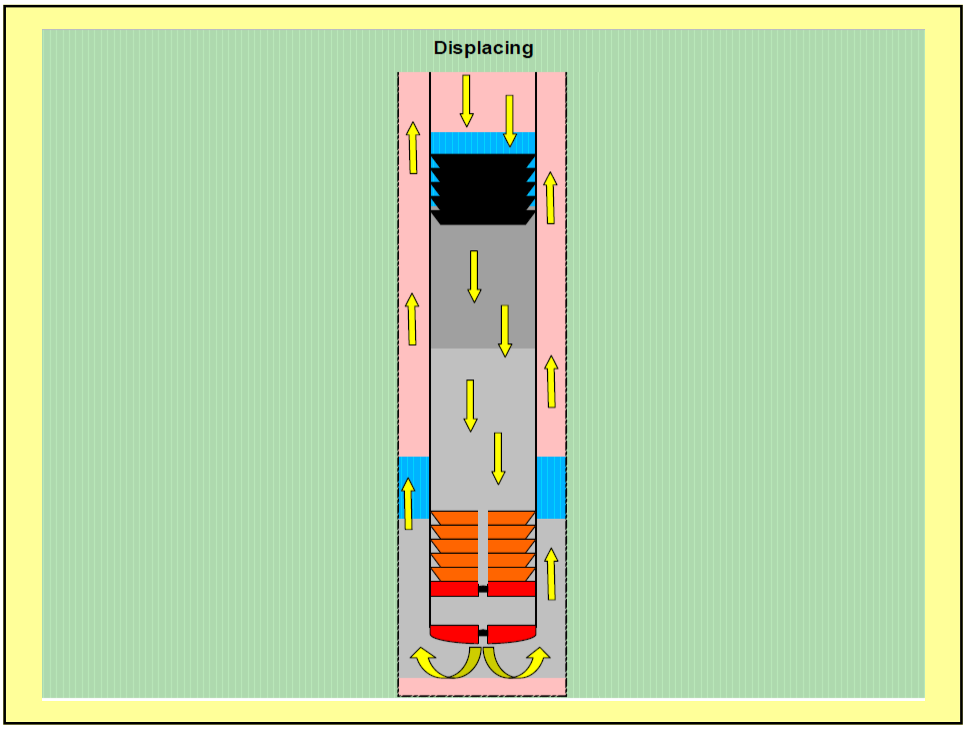

Pumping Lead Cement

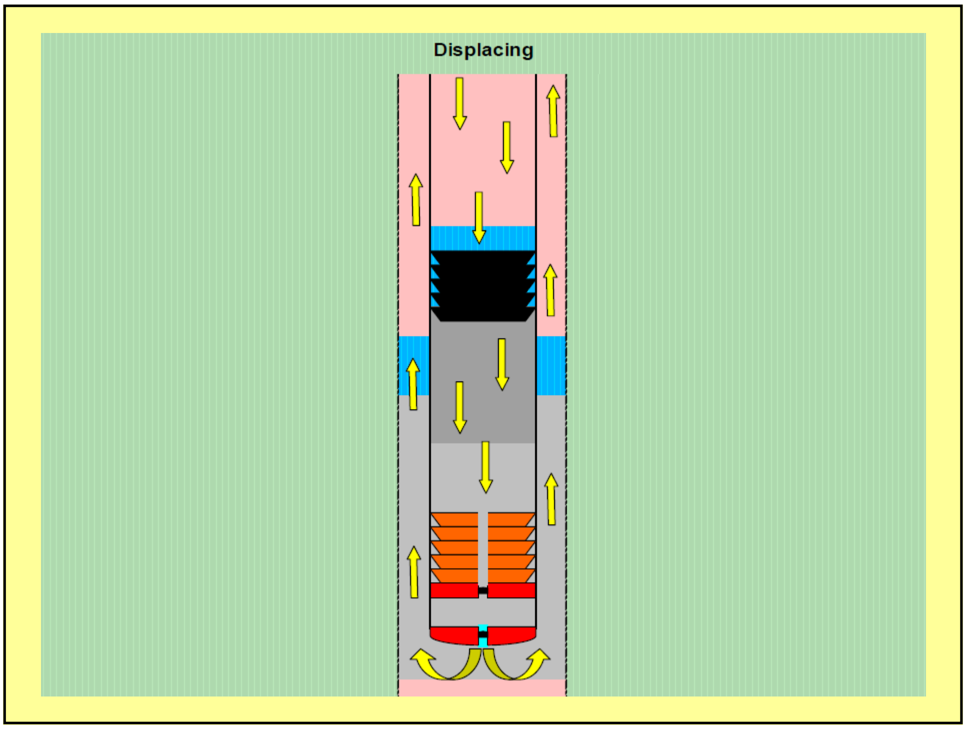

Pumping Lead Cement

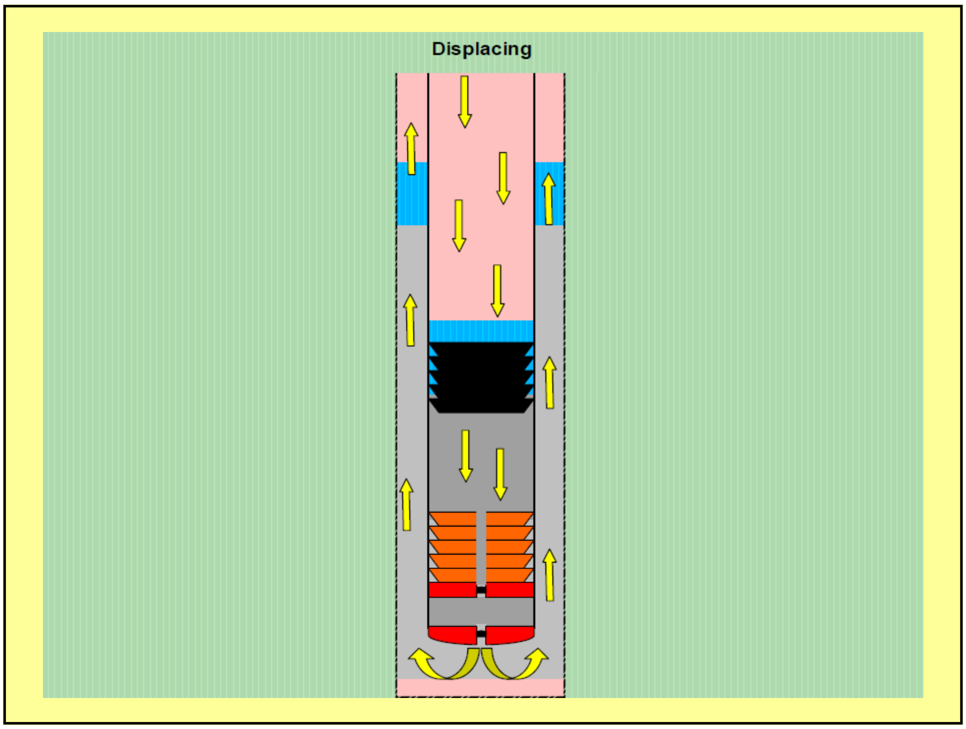

Pumping Tail Cement

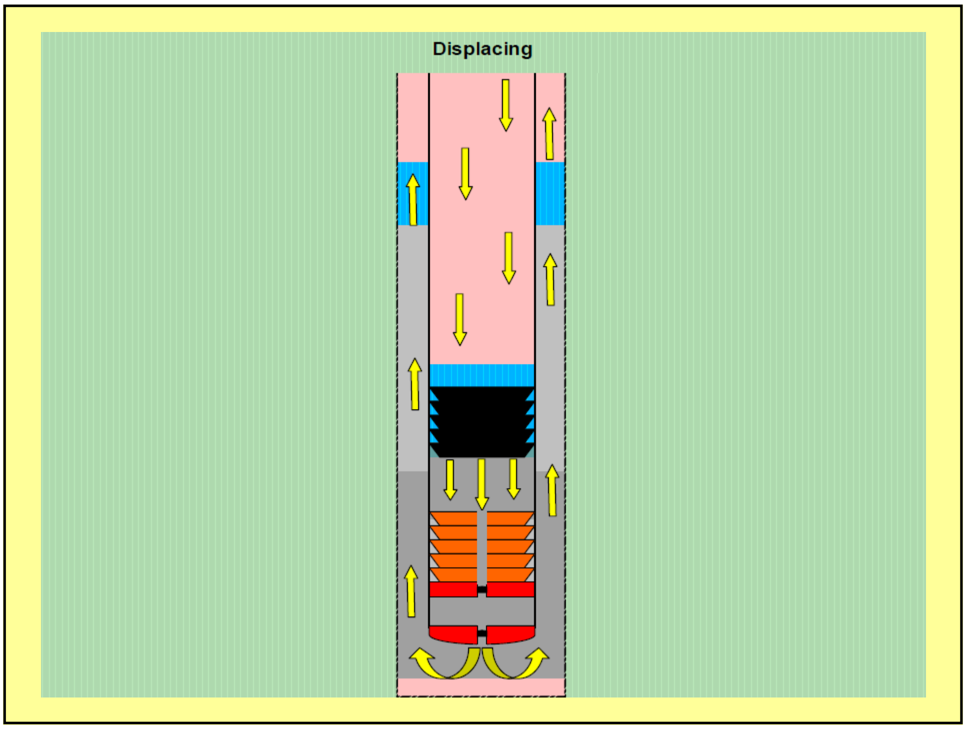

Drop Top Plug & Start Displacing with Spacer

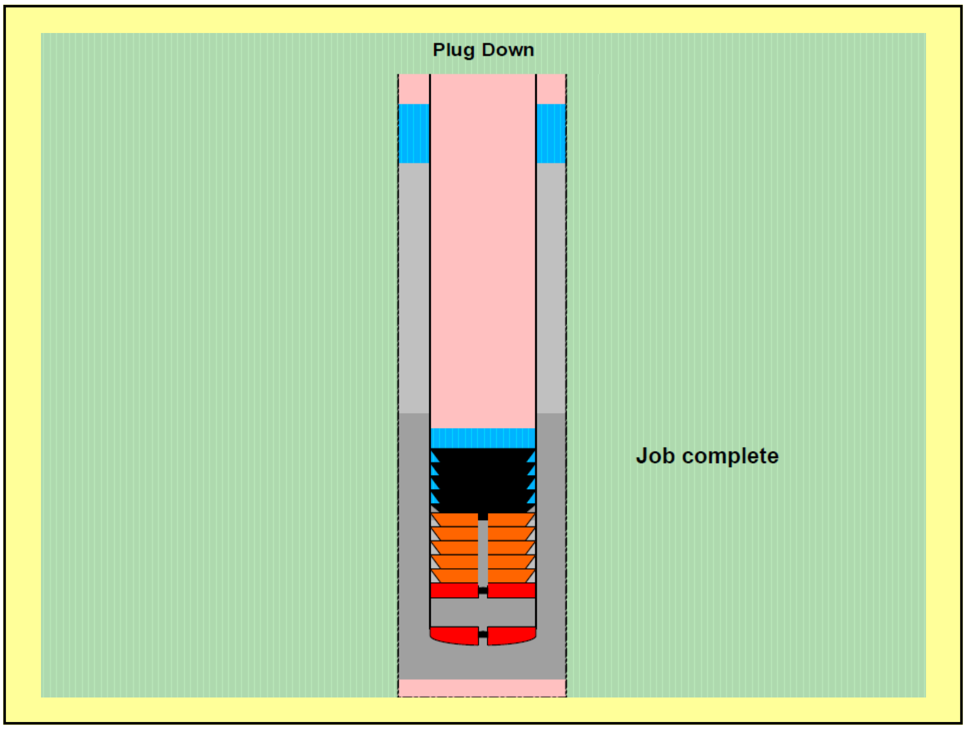

Displacing


Displacing

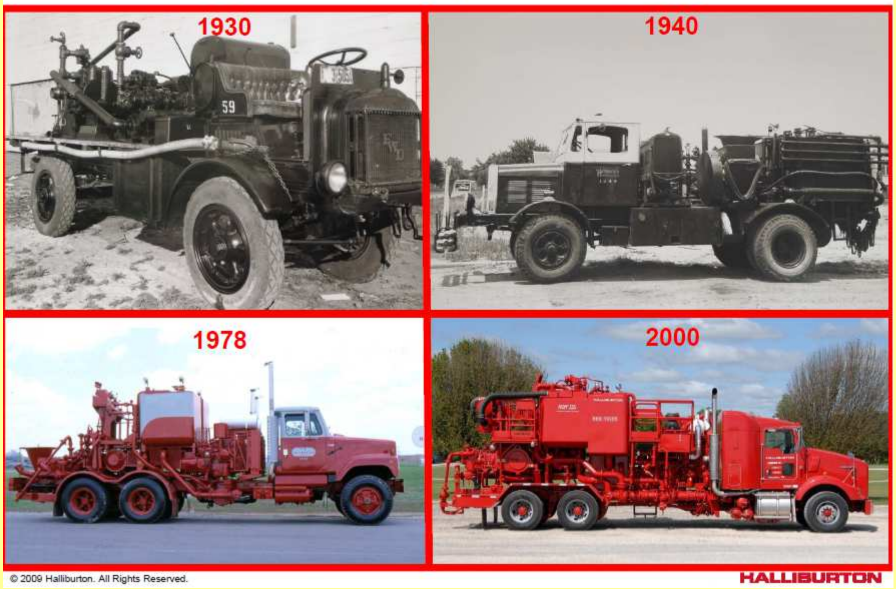

Displacing


Displacing


Displacing


Plug Down
Job complete

Cementing Equipment Evolution



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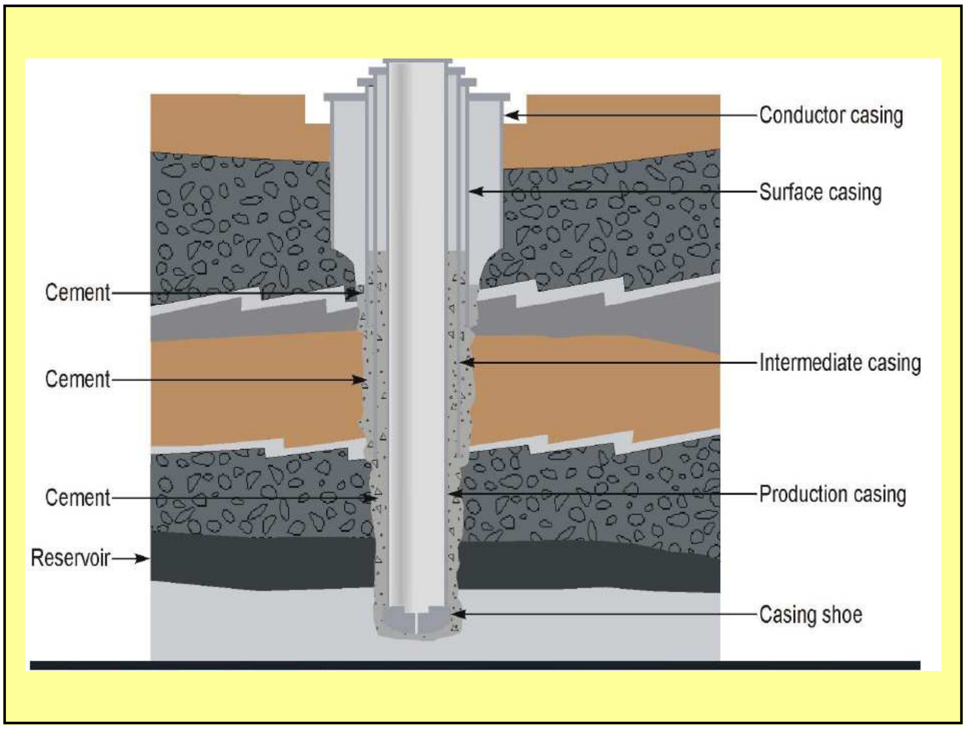
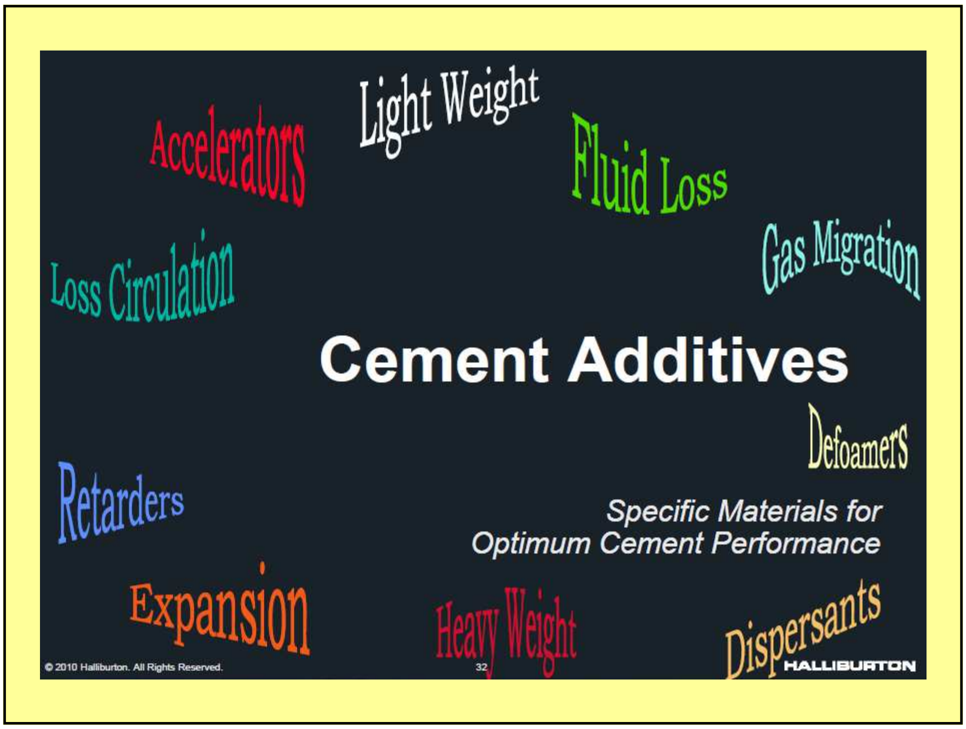

Conductor casing
Surface casing
Cement
Cement
Intermediate casing
Cement
Production casing
Reservoir
Casing shoe


Light Weight
Accelerators
Fluid Loss
Loss Circulation
Gas Migration
Cement Additives
Defoamers
Retarders
Specific Materials for
Optimum Cement Performance
Expansion
Heavy Weight
Dispersants
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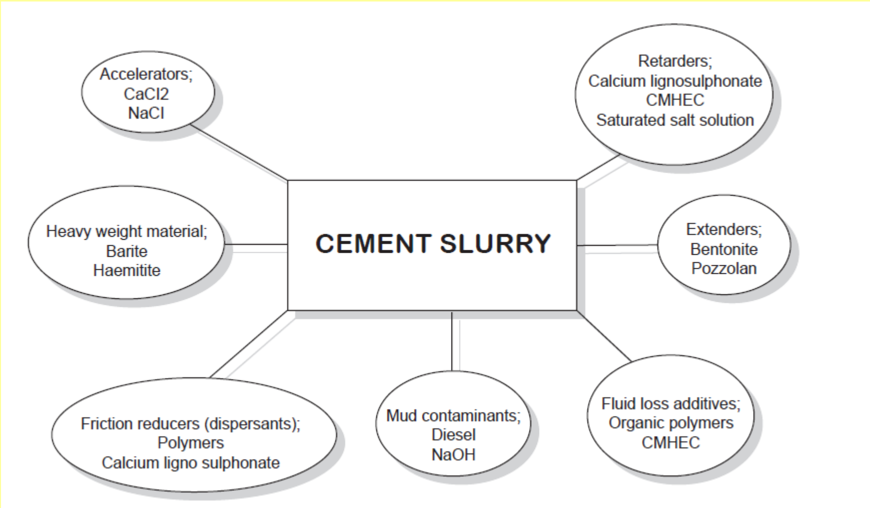

Lab Testing

- Compressive Strength, Fluid Loss, Thickening Time, Gel Strength
  - Up to 600 °F and 40,000 psi

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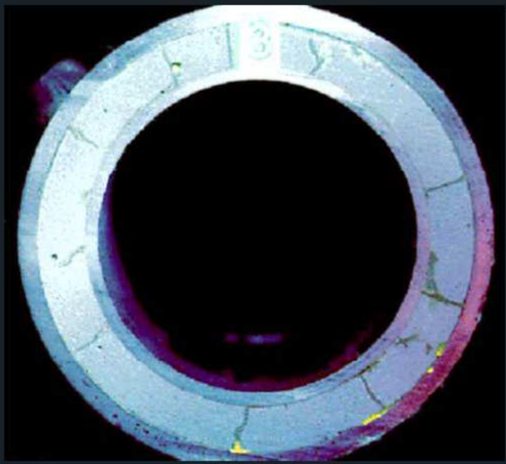
Conventional Cement

- Cement is brittle
- Radial cracks formed
- Longitudinal communication occurred
- Cement bond failed creating a microannulus



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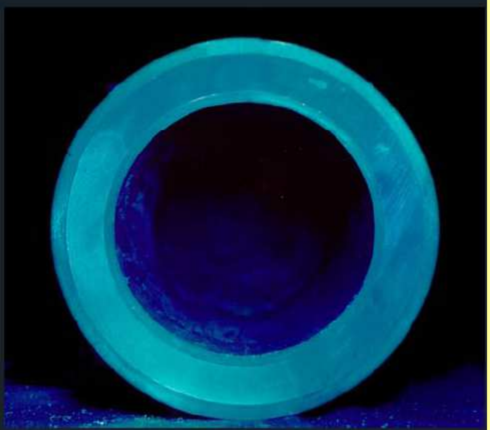
Foam Cement

- No radial cracks
- Only slight debonding
- Foamed cement deformed and absorbed the expansive energy without failure due to its elastic nature



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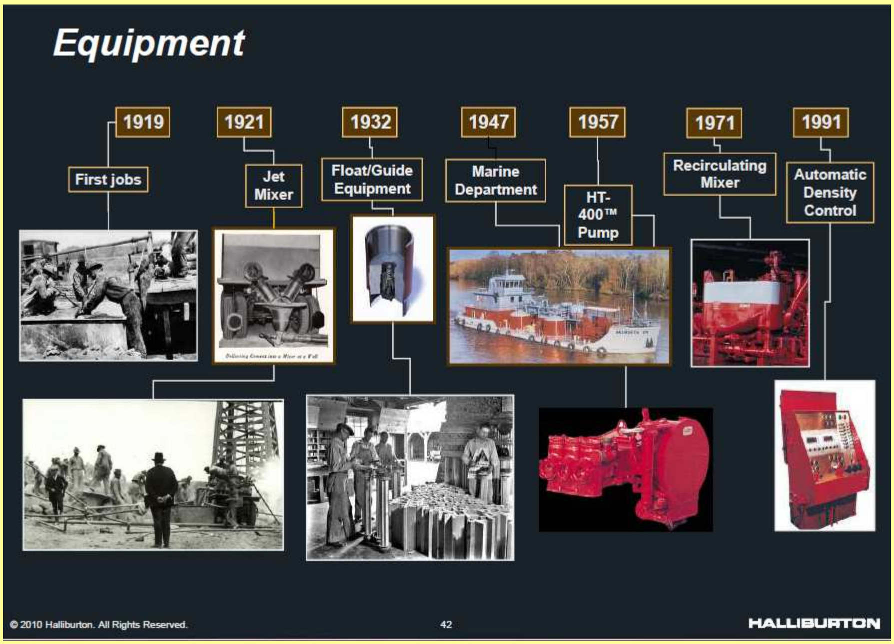
Equipment
1919
First jobs
1921
Jet Mixer
1932
Float/Guide Equipment
1947
Marine Department
1957
HT-400™ Pump
1971
Recirculating Mixer
1991
Automatic Density Control
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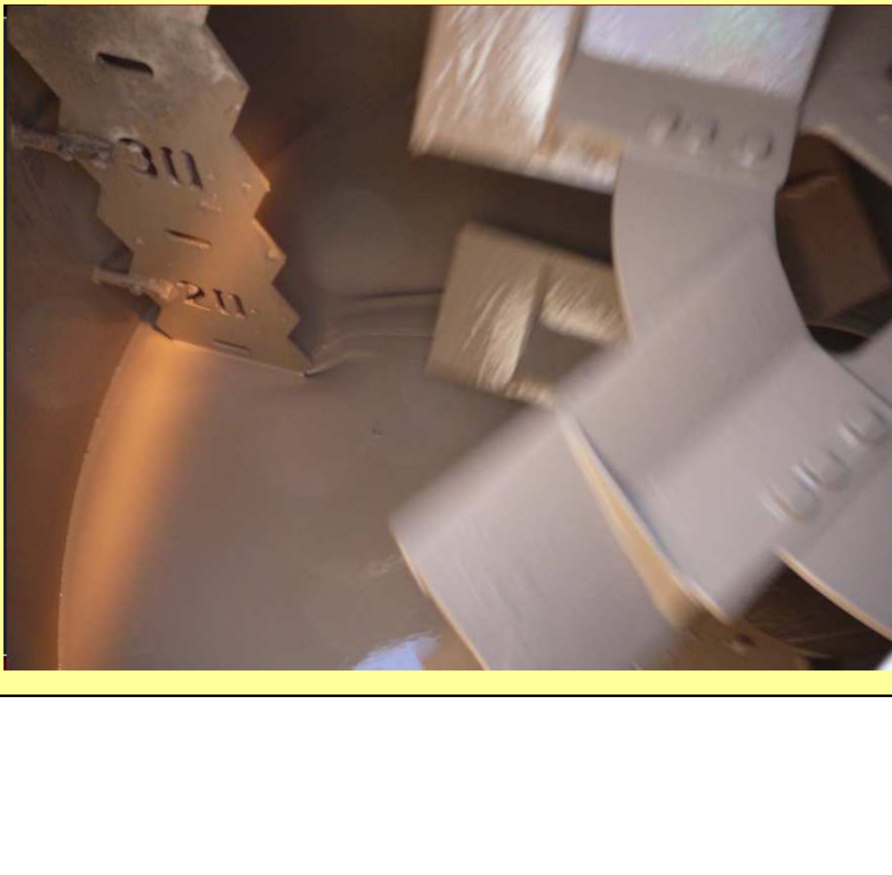
RTON


30
20

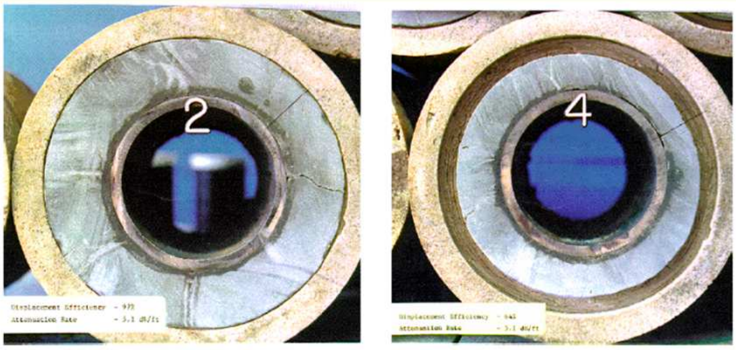
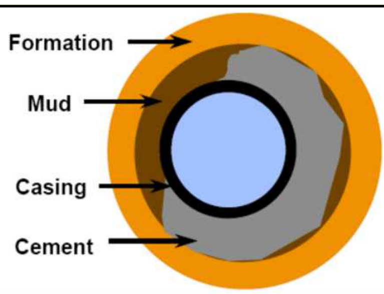


Figure 4.8 – Test samples showing cement displacement efficiencies: Sample 2 is 97% efficient and Sample 4 is only 64% efficient (notice the mud between the cement and the outer casing).



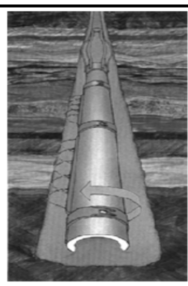


Figure 4.12 – Pipe movement.

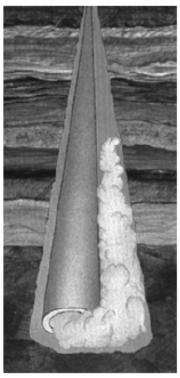


Figure 4.14 – Pipe centralization.

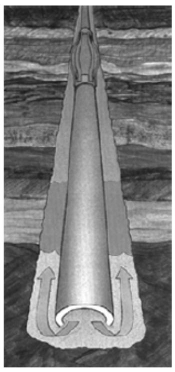


Figure 4.15 – Use of spacers.

Flow Properties

Mud removal in the annulus is a function of the flow patterns that are achieved. Three types of flow patterns are:

Plug Flow - mud removal is minimal due to low frictional or drag forces exerted on the mud layer. This flowrate can remove only about 60% of the mud from the pipe.

Laminar Flow - fluid velocity is higher creating more friction. This results in more force being exerted on the mud layer by frictional drag, resulting in improved mud removal. This flowrate can remove as much as 90% of the mud from the pipe.

Turbulent Flow - A maximum mud removal capability is reached due to high frictional or drag forces. Eddies and current in the fluid result in a mud removal percentage as high as 95%.

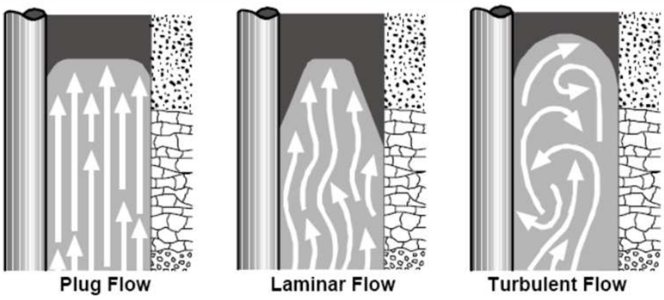
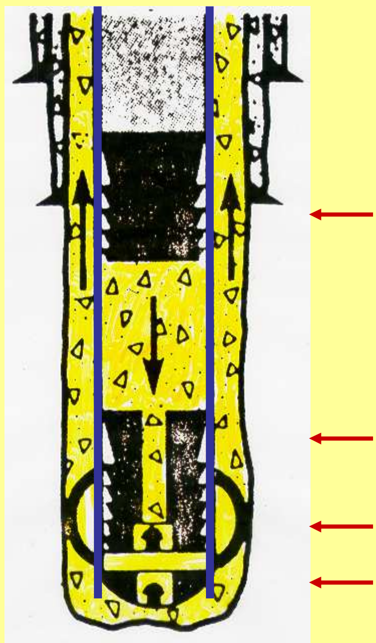


Figure 4.9 Plug flows

Large-Hole Cementing

Normal Displacement Method

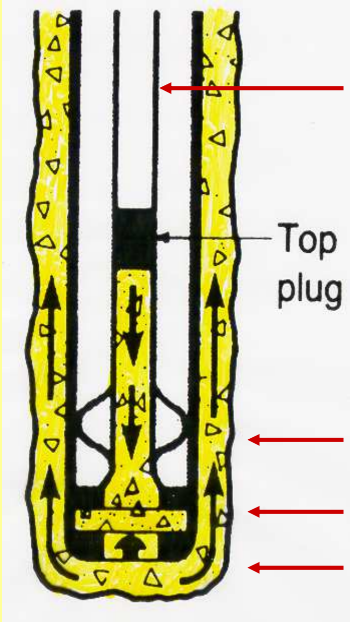
- Down the inside of the Csg.
- Use two wiper plugs
- Takes a long time . . .
- Large surface area exposed to the cmt.



Large-Hole Cementing

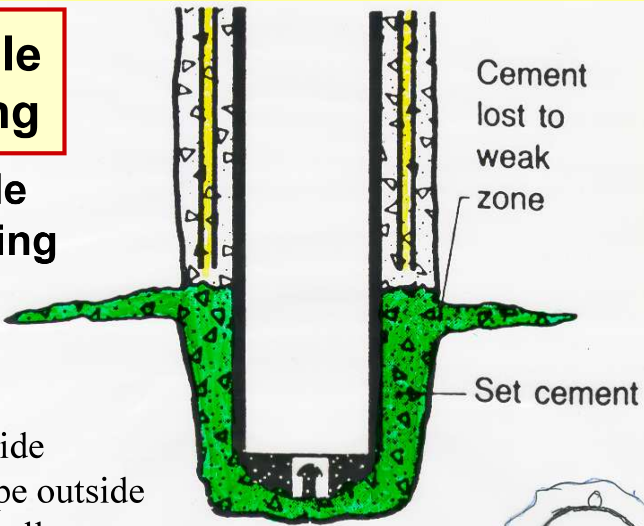
Inner String Cementing

- Down the inside of the DP
- Use top wiper plug
- Stab-in adapter
- Much shorter displ. time



Large-Hole Cementing

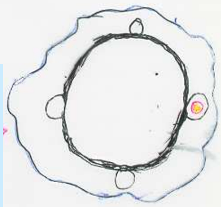
Outside Cementing



1. Down the inside
2. Small-dia. pipe outside

- Cmt and gradually remove the pipes

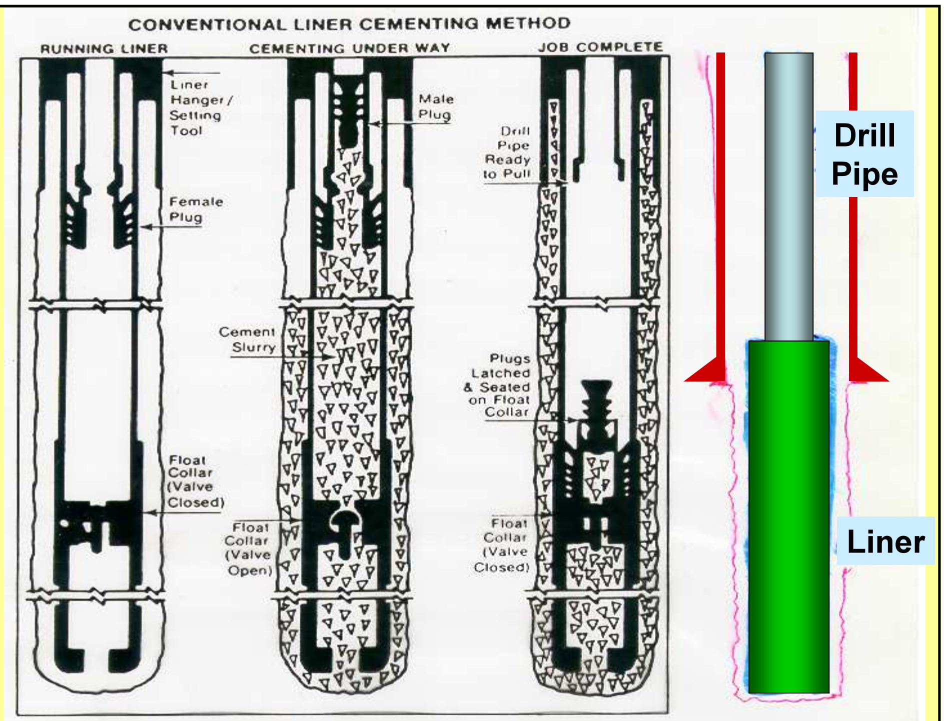
Alternative:
Pipes attached
(for large pipes)

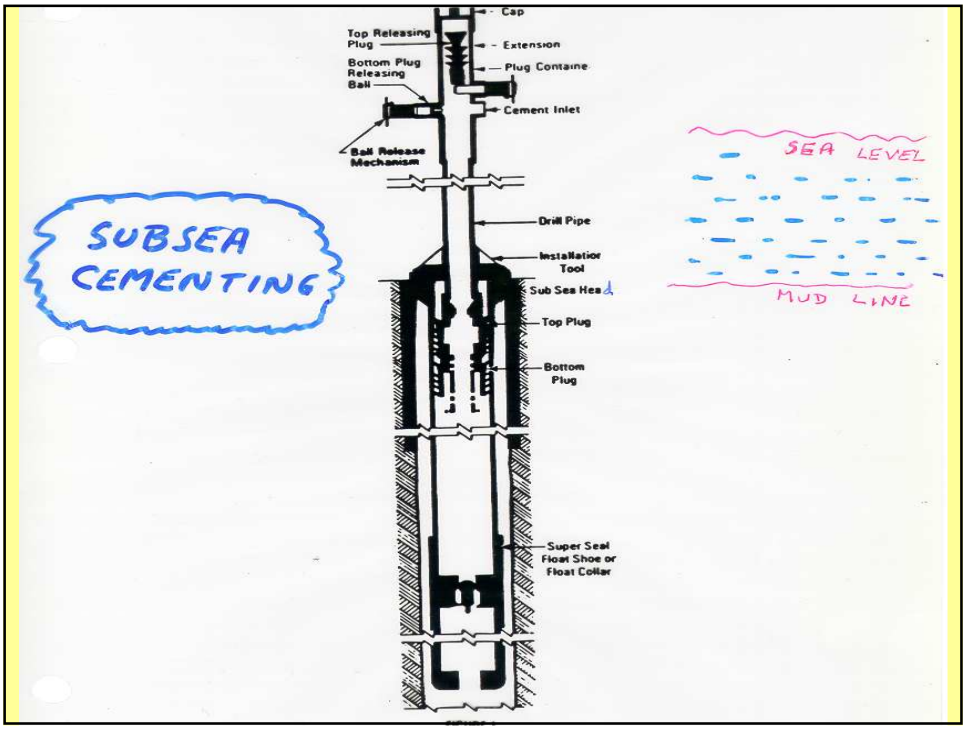


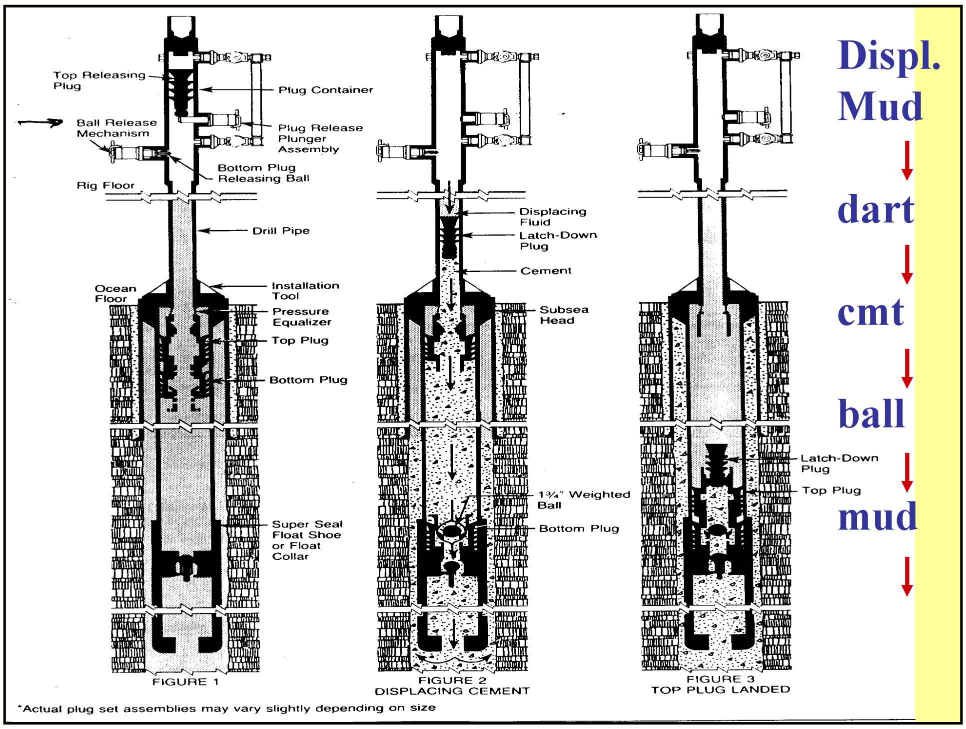
Drilling Liners

Liners are commonly used to seal the openhole below a long intermediate casing string to:

1. Case off the open hole to **enable deeper drilling.**
2. Control **water or gas** production
3. Hold back **unconsolidated or sloughing** formations.
4. Case off zones of **lost circulation** and/or zones of **high pressure** encountered during drilling operations.



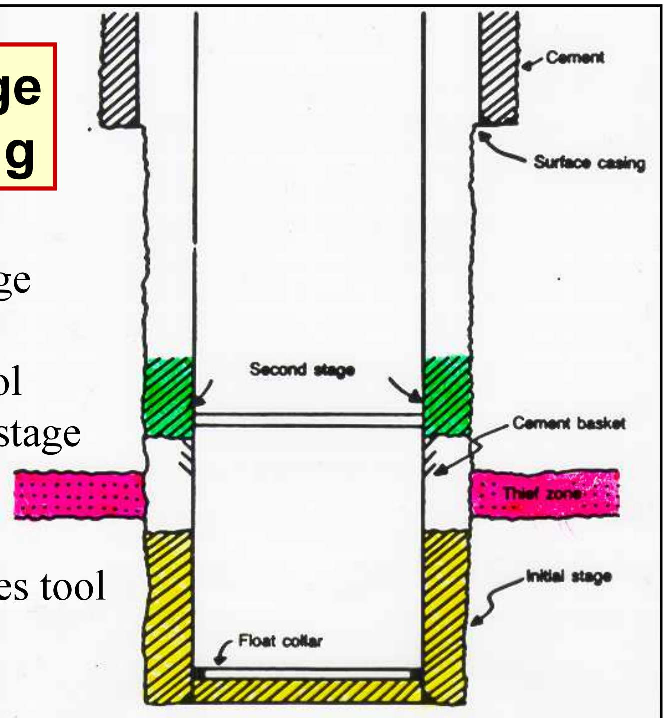

SUBSEA CEMENTING
SEA LEVEL
MUD LINE
Cap
Top Releasing Plug
Extension
Bottom Plug Releasing Ball
Plug Containe
Cement Inlet
Ball Release Mechanism
Drill Pipe
Installation Tool
Sub Sea Head
Top Plug
Bottom Plug
Super Seal Float Shoe or Float Collar

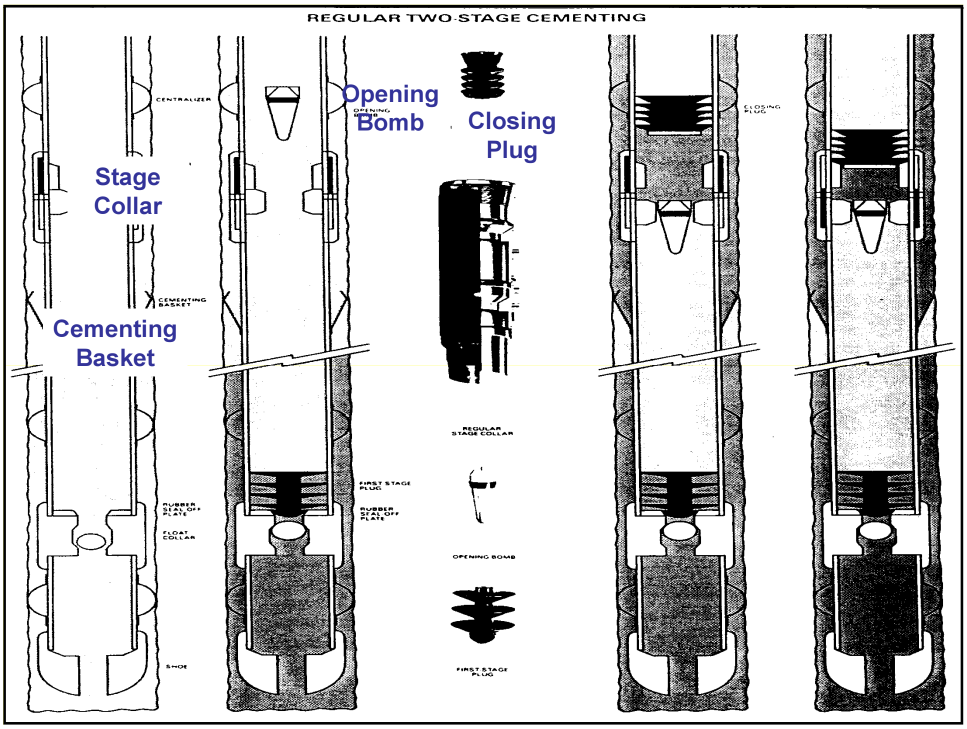

Top Releasing Plug
Plug Container
Ball Release Mechanism
Plug Release Plunger Assembly
Bottom Plug Releasing Ball
Rig Floor
Drill Pipe
Ocean Floor
Installation Tool
Pressure Equalizer
Top Plug
Bottom Plug
Super Seal Float Shoe or Float Collar
FIGURE 1
Displacing Fluid
Latch-Down Plug
Cement
Subsea Head
1¾" Weighted Ball
Bottom Plug
FIGURE 2
DISPLACING CEMENT
Latch-Down Plug
Top Plug
FIGURE 3
TOP PLUG LANDED
*Actual plug set assemblies may vary slightly depending on size
Displ. Mud
↓
dart
↓
cmt
↓
ball
↓
mud
↓

Multi-Stage Cementing

- Pump first stage
- Displace cmt.
- Open stage tool
- Pump second stage

- Displace cmt
- Last plug closes tool





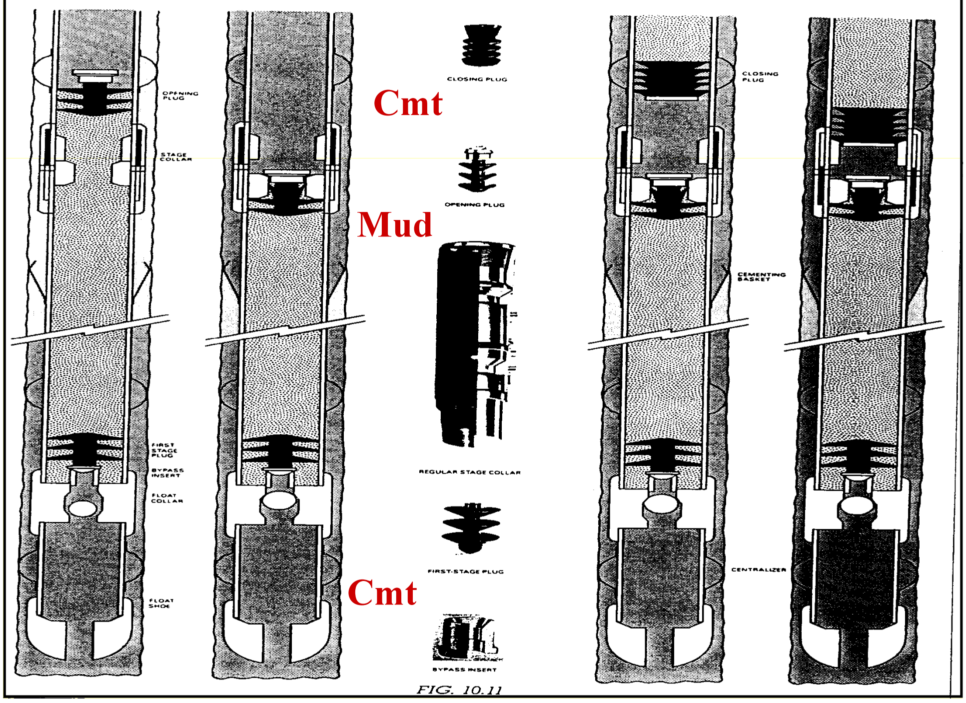
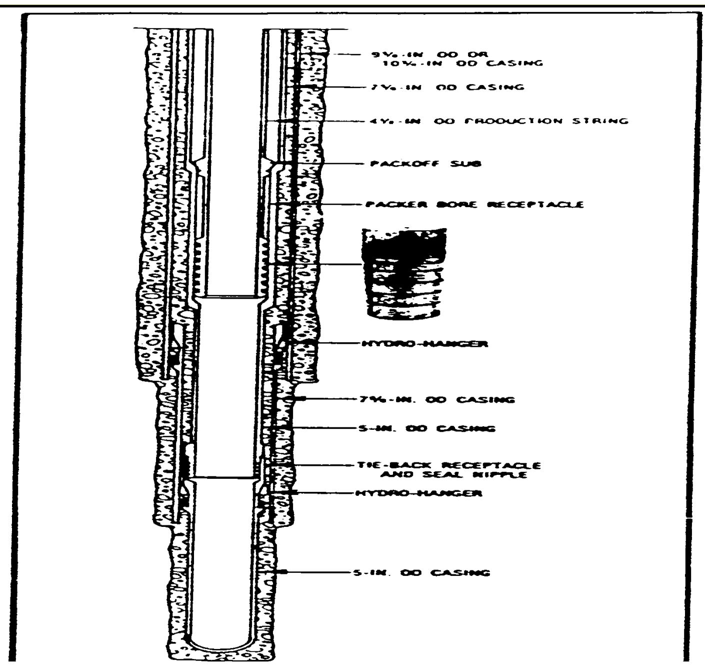


FIG. 10.11



Tieback liner showing sealing nipple

Valores e cálculos básicos

Gradiente geotérmico: é a taxa de variação da temperatura com a profundidade, expresso em ºC/km ou ºF/100 pés. Seu valor depende da litologia local, devido à variação da condutividade térmica para os diferentes tipos de formação.

Temperatura de circulação no fundo do poço (BHCT – Bottom Hole Circulation Temperature): valor menor do que a temperatura estática devido ao resfriamneto causado pela circulação do fluido de perfuração, sendo calculada em função do gradiente geotérmico e do tempo de circulação

$$T_c = H \times G_g + T_s$$

H = profundidade, km ou 100 pés

G_g = gradiente geotérmico ºC/km ou ºF/100 pés,

T_s = Temperatura de superfície (~27 ºC ou 80 ºF)

Valores e cálculos básicos

Volume de pasta: é calculado separadamente para cada pasta utilizada, pelo cálculo do volume estimado do trecho a ser coberto, pelo somatório dos produtos do comprimento de cada trecho de mesma geometria por sua capacidade volumétrica:

$V_p = \Sigma H_i.C_i$

Fator água / cimento: é a relação entre o peso da água e o peso do cimento empregados no preparo da pasta. (Dar exemplos da Petrobrás).

Água para hidratação dos aditivos: Embora alguns aditivos como a bentonita absorvam grandes quantidade de água, a água absorvida pela maioria deles é pouca, podendo ser desprezada para cálculos expeditos. O volume dos aditivos líquidos deve estar incluído no fator água/cimento pois os mesmos são em geral simples prediluição de aditivos em pó. Os fabricantes dos aditivos indicam a quantidade de água que estes devem absorver.

CEMENTING CALCULATIONS

The following calculations must be undertaken prior to a cementation operation:

- Slurry Requirements
- No. of sacks of Cement
- Volume of Mixwater
- Volume of Additives
- Displacement Volume Duration of Operation

Slurry density

To minimize the danger of fracturing the formations, lost circulation or kicks, the cement slurry density should be the same as the drilling fluid density at cementing operations. The following equation gives the slurry density ρ_{cs} in [ppg]:

$$\rho_{cs} = \frac{\text{[lb] Cement} + \text{[lb] Water} + \text{[lb] Additive}}{\text{[gal] Cement} + \text{[gal] Water} + \text{[gal] Additive}} \tag{12.1}$$

To compute the absolute volume of solid constituents, the equation 12.2 is applied:

$$\text{gal} = \frac{\text{lb of Material}}{(8.34 \text{ ppg})(\text{s.g. of Material})} \tag{12.2}$$

Yield

By definition, the yield is the volume of cement slurry obtained when mixing one sack of cement with a specified amount of water as well as other additives. Note that one sack cement (94 [lb] sack) contains 1 [ft^3] bulk volume and 0.48 [ft^3] absolute volume. To compute the yield in [ft^3], equation 12.3 is applied:

$$\text{Yield} = \frac{\text{[gal] Cement} + \text{[gal] Water} + \text{[gal] Additive}}{7.48\left[\frac{\text{gal}}{\text{ft}^3}\right]} \tag{12.3}$$

Thickening Time

The length of time the cement slurry is pumpable is also called "thickening time". To control the thickening time, adding of setting time retarders, a reduction of rapidly hydrating components and an adjustment of the cement fineness is performed. When the time it takes to properly place the cement slurry at the predetermined annulus interval (mixing and displacement time), including a safety factor, exceeds the thickening time, parts of the cement will remain in the tubular used to pump down the cement slurry. To determine the mixing and displacement times, equations 12.4 and 12.5 applied:

$$T_m = \frac{\text{Volume of Dry Cement}}{\text{Mixing Rate}} \tag{12.4}$$

$$T_d = \frac{\text{Amount of Fluid Required to Displace Top Plug}}{\text{Displacement Rate}} \tag{12.5}$$