Webinars

Welcome!

The program will begin soon.

You will not hear audio until we begin.

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Cement is a barrier, only if…!

Ahmed Tawil

10 July 2023

SPE International

slb

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Agenda

- Cement as a Well Integrity barrier
- Basics and Types of cement jobs
- Cement job (Design – Execute – Evaluate)
- What can impact cement jobs (Mixing – Placement – Postplacement)
- Sustainability and CO2 reduction initiatives

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Cement as a Well Integrity barrier

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- Cement is an efficient and cost-effective element of Well Construction
- Set cement can have very low permeability
- Cement design and placement will affect the safety, the productivity and the lifetime of oil and gas wells
- Cement failures are a common cause of Well Integrity failures with possible severe consequences

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Cement ?

- Portland cement is the most common example of a hydraulic cement
- Sets through a chemical hydration process
  - does not need air to set
- Very complex chemistry
- Contains silica, alumina, iron oxide and other trace elements
- Grind the resulting product to a fine powder
- The final grade of cement is fit for 'oilwell' use under API Classification
  - Common oilfield grades are API Class G and API Class H

Source: https://commons.wikimedia.org/wiki/File:Factory_of_National_Cement_Share_Company.jpg

Consequences of the Cement Well Barrier Failure

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- **Poor Zonal Isolation**
  - Lost production, poor casing protection
  - Stimulation out of zone
  - Contamination of nearby formations
  - Over-pressured shallow formations
- **Environmental Damage**
  - Aquifers, Surface
- **Blow-out**
  - Danger to personnel
  - Damaged or lost equipment
- **Financial and Legal**
  - Costly remedial work
  - Complex regulatory requirements
  - Liability
  - Lost well

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Industry Standards and Local regulations

- Ensure knowing the governing requirements
  - Multiple industry standards cover cementing operations and Well Integrity requirements:
    - API, ISO, NORSOK, etc.
  - Local legal requirements and governing laws
  - Contractual terms and conditions, between operators and service companies
  - Past best practices and lessons learned
  - Cost effectiveness

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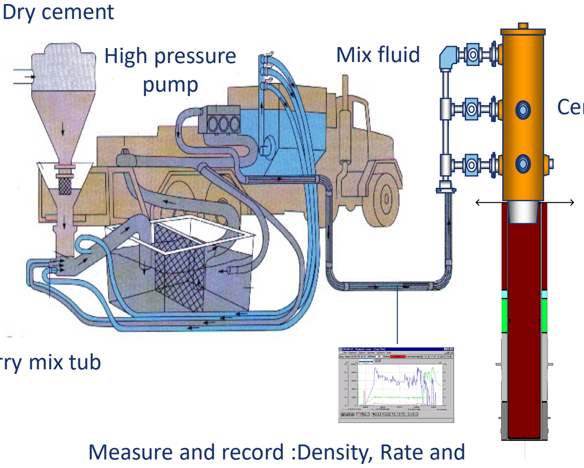
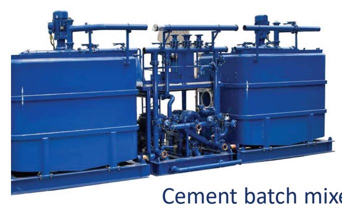
Basics and Types of Cement Jobs

- Mixing & pumping cement
- Primary cementing definition and process
- Primary cementing casings and placement techniques
- Primary cementing – casing hardware
- Remedial job – objectives, job types, and hardware

Basics of Mixing & Pumping Cement





Cement batch mixer

Control console

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Primary Cementing: Definition

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The introduction of a cementitious material or cement slurries into the annulus between casing and open hole or previous casing or both to:

- Provide zonal isolation
- Protect the casing string against corrosion
- Support axial load of casing strings and strings to be run later
- Support the borehole
- Meet government regulations

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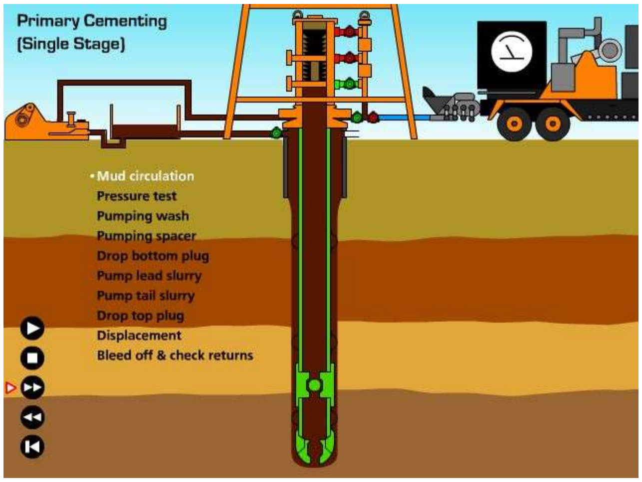
Primary Cement Job – Mud Circulation



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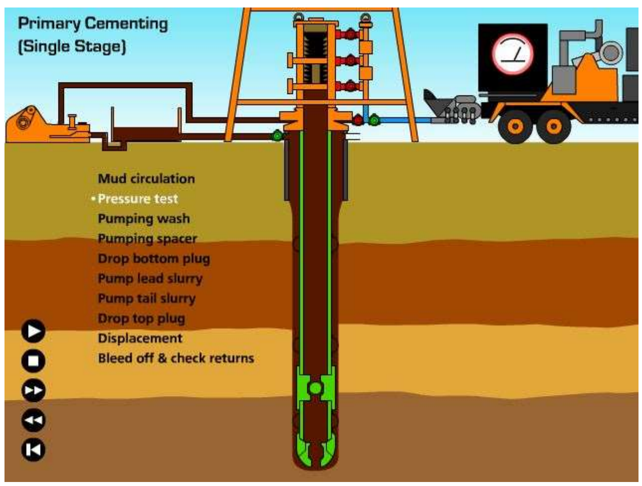
Primary Cement Job – Pressure Test



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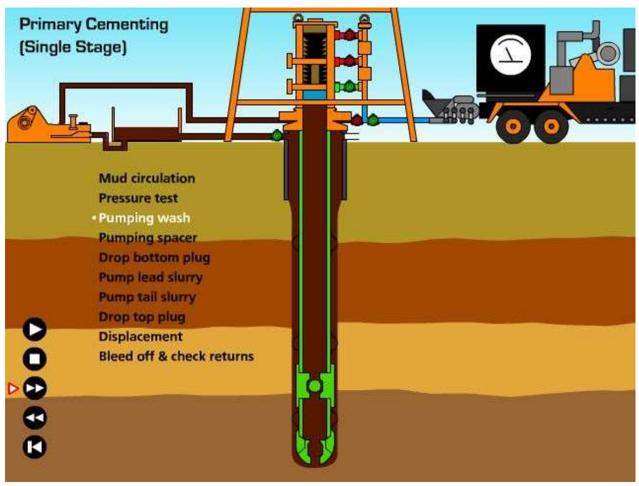
Primary Cement Job – Pump Wash



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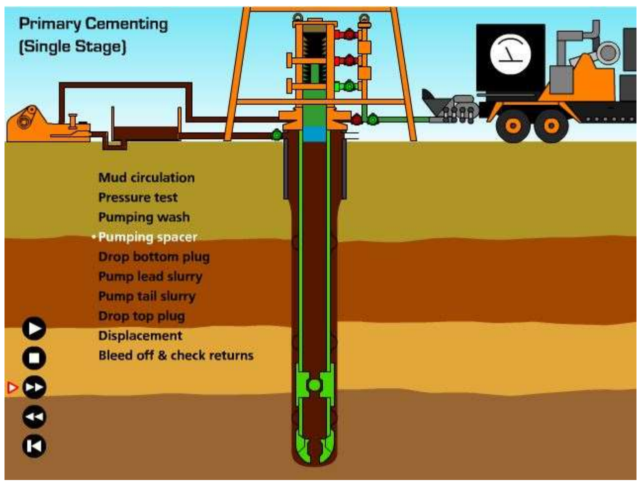
Primary Cement Job – Pump Spacer



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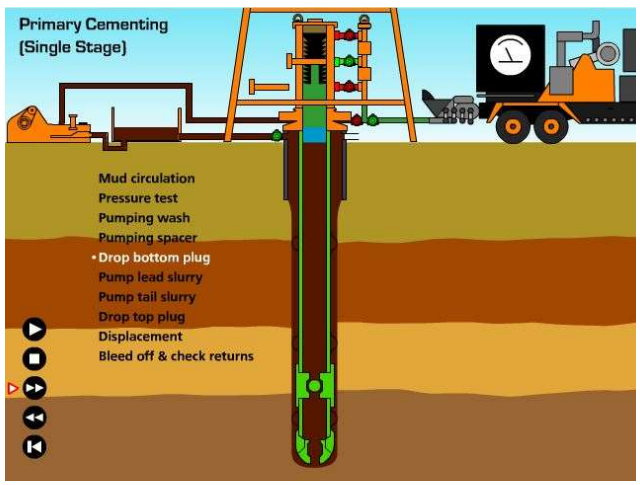
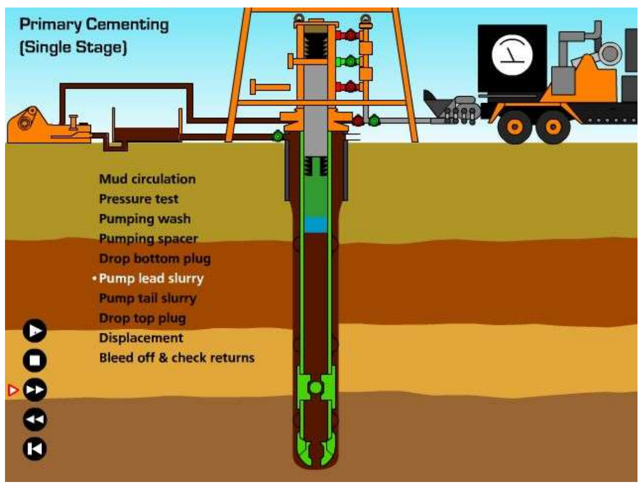
Primary Cement Job – Drop Bottom Plug



Primary Cement Job – Pump Lead Slurry



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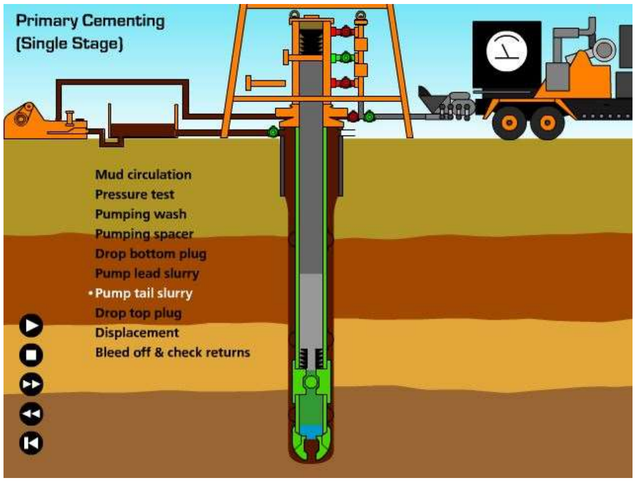
Primary Cement Job – Pump Tail Slurry



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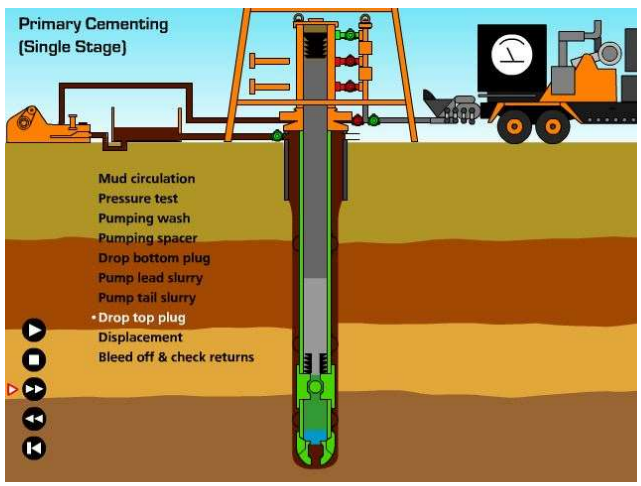
Primary Cement Job – Drop Top Plug



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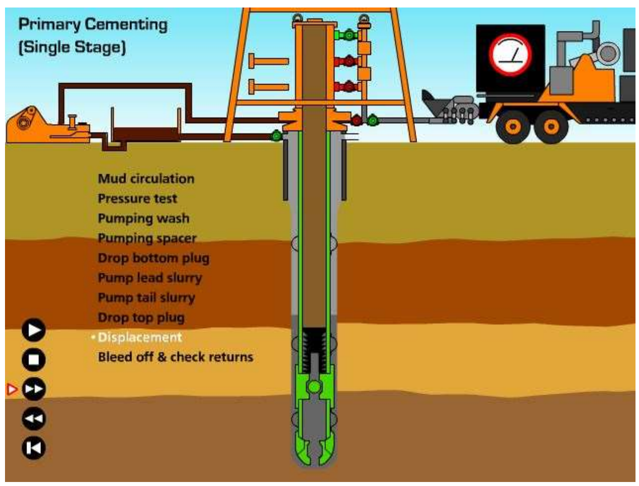
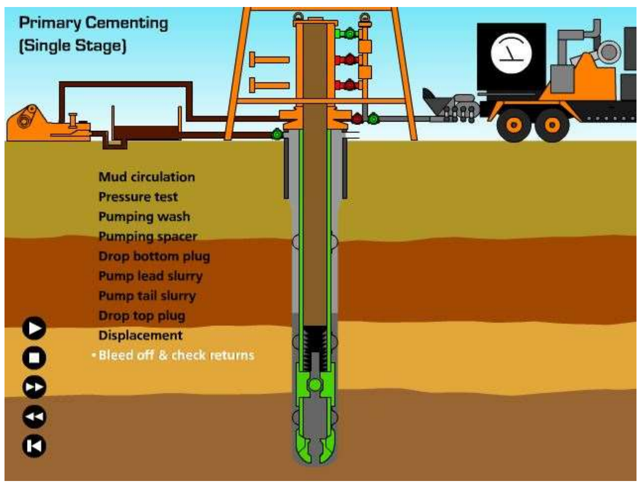
Primary Cement Job - Displacement



Primary Cement Job – Bleed Off



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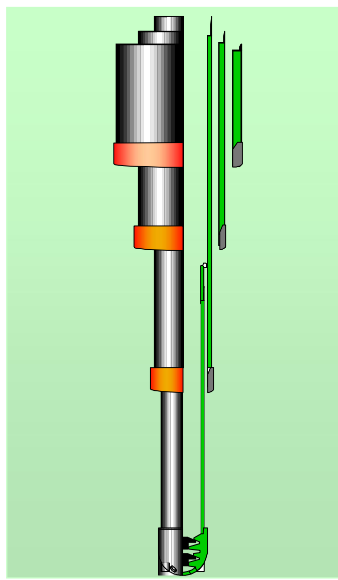
Types of Casings

- Conductor
- Surface
- Intermediate
- Production



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Conductor

- Can be driven in the ground or cemented
- Remarks:
  - Plugs not used
  - Careful pumping practices / Losses
  - Large excess required
  - Thru-drill pipe cementing common
  - BOP usually not connected
  - Common Cement
    – Accelerated Neat unless for shallow flow

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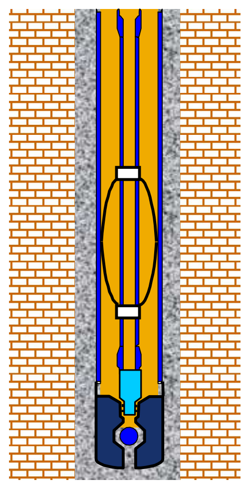
Thru-Drill Pipe Cementing

Key Points:

- Reduce:
  - Cement contamination
  - Channelling
- Small displacement volume
- Ability to pump until cement reaches surface



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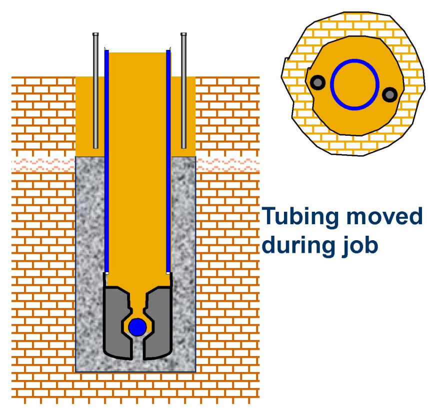
Outside Cementing (Top Job)

- Purpose
  - Place a cement cap close to surface
- Macaroni tubing used
- Shallow depths
- High friction pressures
- Uncontrolled placement
- Cement free falling post placement



Surface Cementing

- Excess of 100% plus is common
- Recommend thru-drill pipe method to save
  - Cement
  - Rig time
- Common cements:
  - Lead light weight slurries with high yields
  - Neat tail slurries with good compressive strength
  - Reduce WOC to a minimum with accelerators
  - More complicated designs as required

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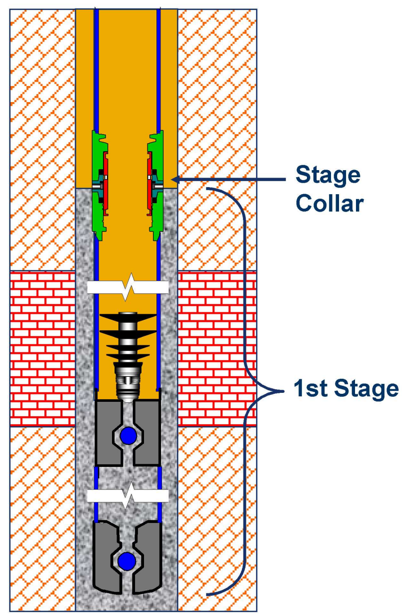
Intermediate Casings

- Cemented to surface or to previous casing shoe
- Two stage jobs
- Plugs, casing equipment, casing accessories (typical)
- Good cementing practices are required
- Large cement volumes
- Common Cements:
  - Typically filler slurries followed by high compressive tail (depending on job requirements)
  - Specialised (light, heavy, salt - saturated, etc)

Two Stage Cementing

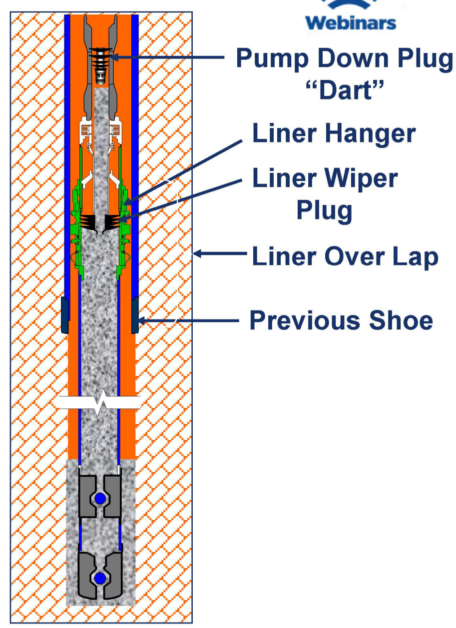
Key Points:

- Separation and isolation of zones
- Reduces hydrostatic
- Can leave zone in the annulus uncemented (cement at TD and surface)



Production

- Isolates the pay zone from other formations and the fluids in them (Critical cement design).
- Cement placement verification is usually done.
- Cement design done to meet the placement and post placement conditions
- Liners are often used



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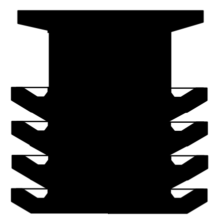
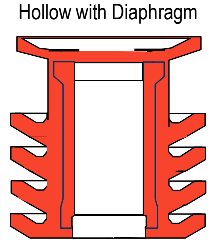
Casing Hardware

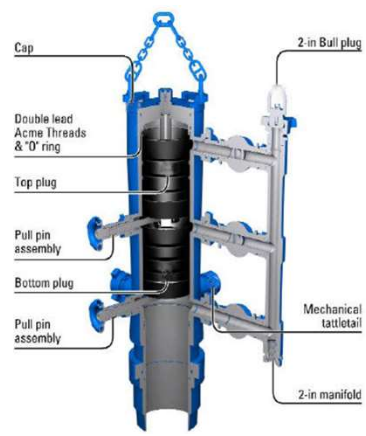
Top Plug
Solid



- Cement Head
  - Container to launch wiper plugs
  - Connection to pump fluids down casing during cement job
- Wiper plugs
  - Physical barrier between fluids inside pipe to prevent contamination
  - Wipe inner surface of pipe
  - Give surface indication (pressure) of downhole event

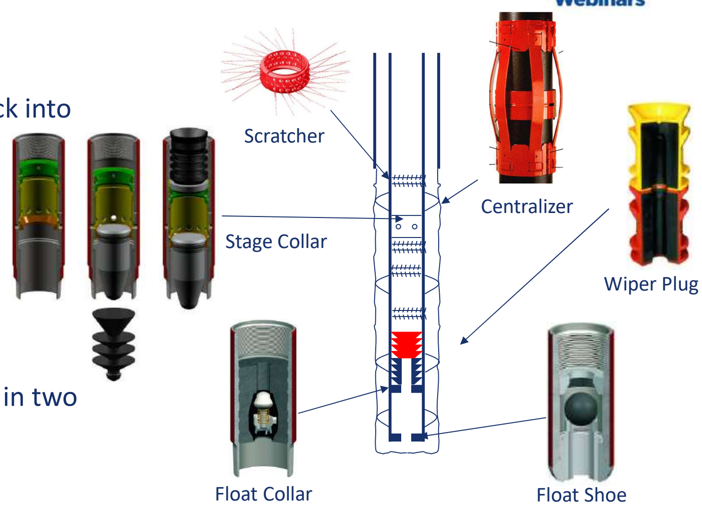
Bottom Plug
Hollow with Diaphragm





Casing Hardware

- Float shoe and collar
  - Check valve, prevent flow back into casing
  - Landing device for plugs
- Centralizers
  - Center casing to aid in mud removal (Rigid / Bow)
- Scratchers
  - Remove filter cake
- Stage collar
  - Allow cement job to be done in two stages
  - Reduce hydrostatics on weak formations



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Remedial Cementing

- Plug Cementing
- Squeeze Cementing

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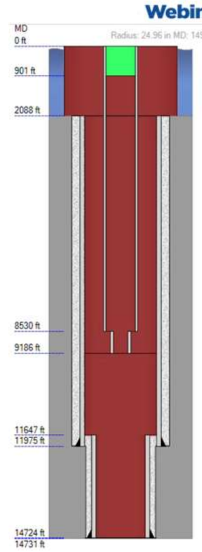
Plug Cementing

- Side track above a fish or to initiate directional drilling
- Plug back a zone
- Well abandonment
- Solve a lost-circulation problem during the drilling phase
- Protect / isolate a low-pressure zone during a work over treatment

Cement Plug Placement

- Balanced Plug
- Pump & Pull Method using Drill Pipe or Coiled Tubing
- Dump Bailer
- Sacrificial tubing for very long plugs



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Placement Tools

- Mechanical Fluid Separators
  - Foam Balls
  - Use of darts
- Competent Bases
  - Mechanical
    - Bridge Plug
    - Inflatable Packer
    - Cement Support Tool
    - Existing Cement Plug
  - Fluid
    - Viscous Pills
    - Reactive Pill (not recommended in horizontal sections)

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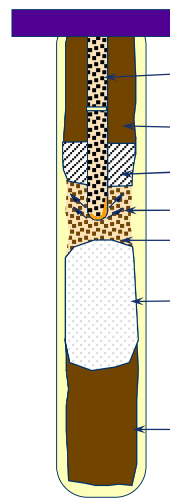
Competent Base – Viscous Pill

- Properties-
  - Optimum Density- close to the cement or at least Mud Weight + 1 ppg
  - Thixotropic properties
  - Highest possible Ty (~ 100lbf/100ft2)
- Placement
  - Minimum pill length of 300ft, preferable = cement plug length
  - Place with balance plug method
  - Use a placement software for optimum placement volume and contamination



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Remedial Cementing

- Plug Cementing
- Squeeze Cementing

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Squeeze Cementing

- Repair deficient primary cement job
- Shut off unwanted water production
- Abandon nonproductive or depleted zones
- Reduce high gas-oil ratio (GOR)
- Repair casing leaks
- Repair liner-top leaks
- Seal off lost-circulation zones
- Repair micro-annulus

Placement Design

- **Squeeze job classifications:**
  - Low Pressure Squeeze
  - High Pressure Squeeze
- **Within these two classes, there are three basic placement techniques:**
  - Bradenhead squeeze without the squeeze tool
  - Squeeze by utilizing the squeeze tool (a cement retainer or a packer)
  - Squeeze by utilizing coil tubing equipment.
- **And there are three pumping methods:**
  - Running squeeze
  - Hesitation squeeze
  - Circulation squeeze

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Cement job (Design – Execute – Evaluate)

- Design
  - Materials used
  - Cement slurry properties
  - Required data
  - Open hole effects
  - Simulate and assess placement and post placement conditions
  - Mud removal
  - Lab testing
- Execute
  - Recording of parameters
  - Sampling
  - Quality control (QC)
  - Special cases
- Evaluate
  - Hydraulic
  - Lift pressure
  - Cement logging

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Families of Cementing Additives

DEFINITION

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- Accelerators
- Retarders
- Extenders
- Weighting agents
- Dispersants
- Fluid-loss control additives

- Specialty additives
  - Antifoam/defoamer
  - Anti-settling agents
  - Strength retrogression
  - Gas migration control
  - Loss circulation (Thixo – fibers – LCM)
  - Set cement flexibility
  - Expanding agents
  - Resisting CO_2
  - Self-healing (hydrocarbon / CO_2)

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Slurry Density

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Lighter

More Water

or

- Absorbent
- Light Material

Lower Density

Changing of slurry density

Neat Cement
15.6 ppg Class A
15.8 ppg Class G
16.4 ppg Class H

Heavier

Less Water

or

- Heavy Material
- Dispersant

Higher Density

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Cement Slurry properties

- Thickening time
  - Controlled using Accelerators or Retarders
- Free fluid
  - Use of extenders
- Mud removal
  - Optimized rheology
  - Density
- Stability
  - Solid volume fraction
  - Rheology
  - Fluid loss

Free Fluid and Sedimentation

- Compatibility with well fluids
  - Salinity match
  - Use of spacers
- Lost circulation
  - Rheology
  - Thixotropy
  - Fibers addition

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Cement Slurry properties

- Gas migration
  - Free Fluid / Fluid loss
  - Block the entrance of gases
  - Reduce the Critical Gel Strength Period (API Standard 65-2)

$$\boxed{\mathrm{CSGS} = \frac{OBP * Deff * 300}{L}}$$

Where:

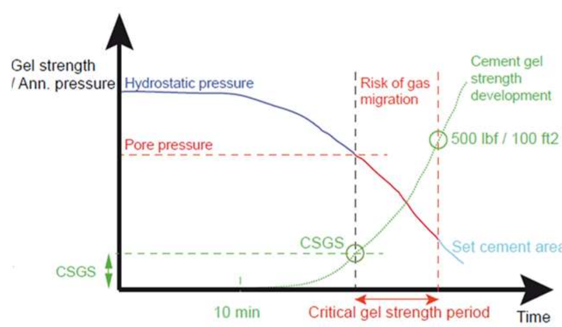
D_{OH}: Open Hole diameter (in)

D_{CSG}: Casing OD (in)

D_{eff}: Effective diameter (D_{OH}-D_{OD}) (in)

L: cement column length (ft)

OBP: Overbalance Pressure ($P_{Hyd} - P_{Pore}$) (psi)



Set Cement properties

- Compressive strength
  - Cement content
  - Solid volume fraction
  - Accelerators and retarders
- Strength retrogression
  - Addition of Silica
- Debonding / Shrinkage
  - Use of expansion agents
- Flexibility
  - Addition of flexible materials
  - Withstand downhole stresses
- Permeability
  - Solid volume fraction
  - Fluid loss
- Self healing
  - React with hydrocarbon / CO_2 to seal small cracks

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Design – Required Data

- Cement job objectives
- Offset wells' data
- Casing (size, type, depth, hardware, previous casing)
- Lithology, depths, mechanical properties, problem zones (losses, washouts, water flow, high pressure gas, etc.),
- Open hole geometry (caliper, excess, depths, etc.)
- Survey (KOP, bearing, azimuth)
- Pore and fracture pressures
- Temperature
- Mud properties (density, type, etc.)
- Centralizers to be used and possible pipe rotation or reciprocation

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Open Hole effects

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- Enough annular gap
- Mud circulated with known properties
- No losses and no flow
- Mud filter cake sealing permeable zones (not too thick)
- OH size is known (Effects of washouts)
- Minimum dog leg severity
- Presence of any problematic formations
  - Reactive shales
  - Fractured formation

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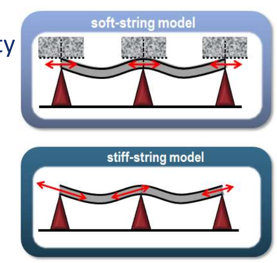
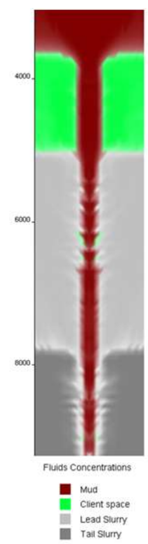
Run job Simulations

- First run
  - Assess well security
    - Consider fluids' compressibility (effects on volume and ECDs)
  - Obtain Bottom Hole Circulation Temperature (BHCT)
    - Confirm mud circulation and temperature
    - Note the effect of longer or shorter circulation on BHCT
  - Evaluate the mud removal requirements in terms of volumes and rheologies
  - For potential flow zones, check the Critical Static Gel Strength (CSGS)
- Second run
  - Use the actual tested spacer and slurry properties
  - Reassess all simulations
  - Simulate post placement conditions (pressure tests, change of fluids, production temperature)

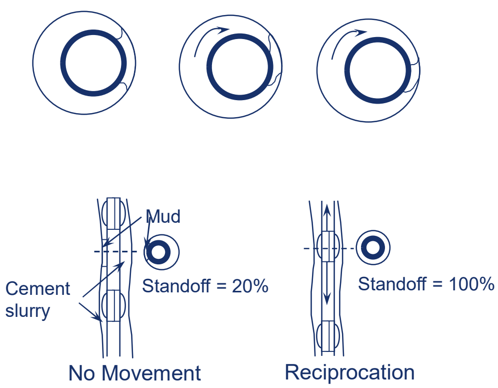
Mud removal

- Wellbore geometry
  - Annulus with low dog leg severity, free of washouts and adequate width
- Centralization
  - Use of Soft String module vs. Stiff String module
  - Placement of fluids
- Mud conditioning
  - Remove gas and cuttings, and break the mud's gel strength and lower viscosity
- Use of Spacers
  - Pumped as a buffer and to address possible incompatibility
- Cement plugs
- Wettability change (Non-Aqueous Fluids NAF)
- Pipe movement





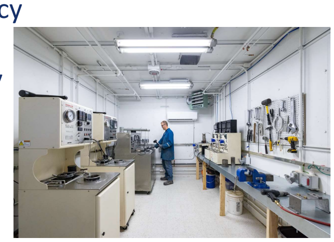
Pipe Movement



- Rotation
  - Circular motion
  - Breaks gelled mud
  - Requires a rotating cement head
- Reciprocation
  - Up and down movement
  - Changes casing standoff
  - Drags out gelled mud
  - Does not involve specialized equipment
- Attention
  - Consider pipe movement when running mud removal simulations
  - Can play a major role in horizontal sections
  - Stop rotation when PooH from a cement plug

Lab Testing

- API
  - API RP 10B-2 - Recommended Practice for Testing Well Cements
  - API RP 10B-3 - Testing of Well Cements Used in Deepwater Well Construction
  - API RP 10B-4 - Preparation and Testing of Foamed Cement Formulations at Atmospheric Pressure
  - API RP 10B-5 - Recommended Practice on Determination of Shrinkage and Expansion of Well Cement Formulations at Atmospheric Pressure
  - API RP 10B-6 - Recommended Practice on Determining the Static Gel Strength of Cement Formulations
- ISO
  - ISO 10426-2:2003 Petroleum and natural gas industries — Cements and materials for well cementing
- Some tests are based on local practices:
  - Lost circulation slot test
  - Continuous cement addition
  - Foaming tendency
  - Slurry mixability
  - Blend flowability
- Samples



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Execution

- Job program to be followed with no deviation
- Monitoring and recording of job parameters (Pressure, Rate and Density)
- Take samples of cement and all fluids
- Ensure that all used chemicals Lot numbers match the lab report
- Perform QC for spacer and mix fluid rheology (if applicable)
- Use a Solid Fraction Monitor for very light slurries
- Report any unusual observations
- Wash all equipment and lines

Execution

- Offline cementing
  - Removes the cementing process, vendors, and equipment from the critical path of the Drilling Rig
  - Extra care in control of the mixed densities
  - Only qualified supervisors to operate the HP manifold valves
- Managed pressure cementing
  - Making cement jobs possible in a narrow pore/frac window
  - Back pressure monitoring and to ensure it is as per plan
  - Incase of an emergency stop, activate the contingency plan to avoid potential formation flow.
  - Be prepared in case cement reaches the MPD equipment

Post Job Evaluation

- Hydraulic:
  - Pressure testing / Formation Integrity Test (FIT)
  - Inflow test / negative pressure test
- Mechanical:
  - Tagging (cement plugs or on drill-out)
- Volumetric, analytical:
  - Monitoring returns to surface
  - Pressure matching
- Logs:
  - Temperature log
  - Sonic & Ultrasonic Logs

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What can Impact Cement Jobs

- Mixing
- Placement
- Post-placement

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What can impact cement jobs (Mixing)

- Ambient temperature not as per the lab repot
- Fluids contamination
- Job delayed after mixing the mix fluid (Ageing)
- Job stopped while mixing cement (on the fly)
- Cement not mixed as per design
- The bulk delivery rate to match the desired slurry flow rate

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What can impact cement jobs (Placement)

- Well control (Losses or gains)
- Hole stability
- No back-up for the High Pressure (HP) pump
- Mud properties not as per design (Well Security / Mud removal)
- Over displacement leading to wet shoe
- Floats or plug malfunctioning (not to pump back)
- Flow rate not as per design
- Sensors not calibrated (Pressure – Rate – Density)
- Job interruptions during pumping (Cement is time sensitive)

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What can impact cement jobs (Postplacement)

- Cement losing its hydrostatic pressure
- Interaction with formation fluids
- Rat hole fluid’s interaction
- Displacing the casing with a light fluid
- Casing pressure testing
- Tectonic movements
- Salt creeping
- Produced / injected fluids temperature and pressure
- Frac operations

Sustainability and CO_2 reduction initiatives

- Cement manufacturing emits huge amounts of CO_2
- Some companies started to offer non-Portland cement materials
- Preference given to local products to reduce transportation
- Proper planning of products' requirements
- Efforts to come up with a standard way to estimate CO_2 equivalent emissions
- Remote operations
- Well Integrity standards being updated to cover the use of non cementing materials
  - NORSOK Standard D-010 (Well Barrier Element Acceptance Criteria)

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Cement is a Barrier, only if…

- Sufficient and accurate well data is available
  - Stable and uniform well bore
- Job design meets all requirements
  - Have clear job objectives and acceptance criteria
- Placement executed as per job program
  - Management of change to be activated as required
- Successful post job evaluation

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Thank you

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Q&A Session

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- API SPEC 10A - Cements and Materials for Well Cementing –
- API RP 10B-2 - Recommended Practice for Testing Well Cements –
- API RP 10B-3 - Testing of Well Cements Used in Deepwater Well Construction –
- API RP 10B-4 - Preparation and Testing of Foamed Cement Formulations at Atmospheric Pressure –
- API RP 10B-5 - Recommended Practice on Determination of Shrinkage and Expansion of Well Cement Formulations at Atmospheric Pressure –
- API RP 10B-6 - Recommended Practice on Determining the Static Gel Strength of Cement Formulations –
- API SPEC 10D - Casing Bow-spring Centralizers –
- API RP 10D-2 - Recommended Practice for Centralizer Placement and Stop-collar Testing –
- API SPEC 10F - Cementing Float Equipment Testing –
- API RP 10G - Product Evaluation, Application, and Testing of Stage Cementing Collars –
- API TR 10TR1 - Cement Sheath Evaluation –
- API TR 10TR2 - Shrinkage and Expansion in Oilwell Cements –
- API TR 10TR3 - Technical Report on Temperatures for API Cement Operating Thickening Time Tests; 1993 Report from the API Task Group on Cementing Temperature Schedules –
- API TR 10TR4 - Selection of Centralizers for Primary Cementing Operations –
- API TR 10TR5 - Methods for Testing of Solid and Rigid Centralizers –
- API TR 10TR6 - Evaluation and Testing of Mechanical Cement Wiper Plugs –
- API TR 10TR7 - Mechanical Behavior of Cement –
- API RP 45 - Recommended Practice for Analysis of Oilfield Waters –
- API RP 59 - Recommended Practice for Well Control Operations –
- API RP 65-1 - Cementing Shallow-water Flow Zones in Deepwater Wells –
- API STD 65-2 - Isolating Potential Flow Zones During Well Construction –
- API RP 65-3 - Wellbore Plugging and Abandonment –
- API RP 96 - Deepwater Well Design and Construction –
- API RP 90 - Annular Casing Pressure Management for Offshore Wells –
- API RP 90-2 - Annular Casing Pressure Management for Onshore Wells –
- API BULLETIN 92L - Drilling Ahead Safely with Lost Circulation in the Gulf of Mexico –
- API BULL 97 - Well Construction Interface Document Guidelines –
- API RP 100-1 - Hydraulic Fracturing-Well Integrity and Fracture Containment –
- API BULL E3 - Wellbore Plugging and Abandonment Practices -

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