What is expected from the cement in cementing for the life of the well?

Simon James

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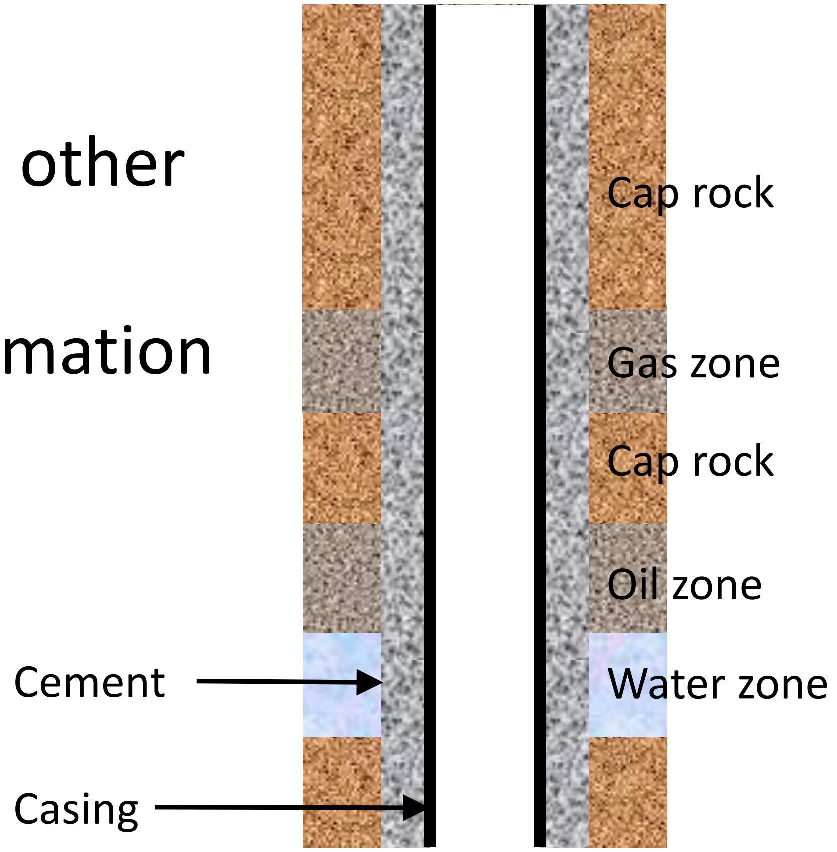
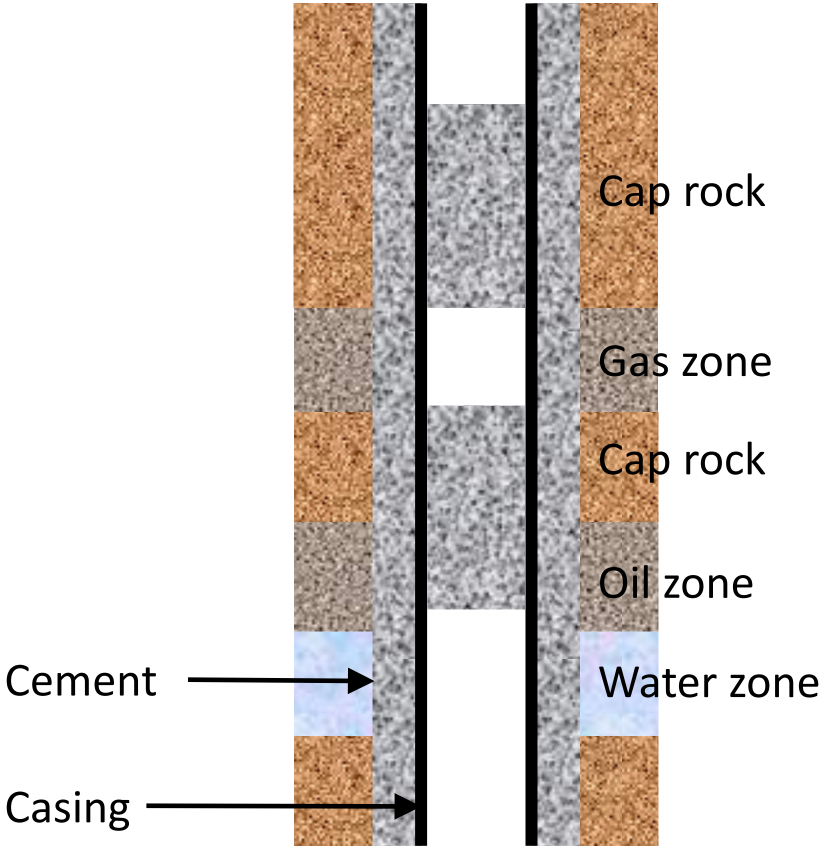
Why do we need a cement sheath around casing?

- To mechanically support the casing
- To hydraulically isolate zones from each other and from the surface
- To protect the casing from corrosive formation fluids
- During the life of the well



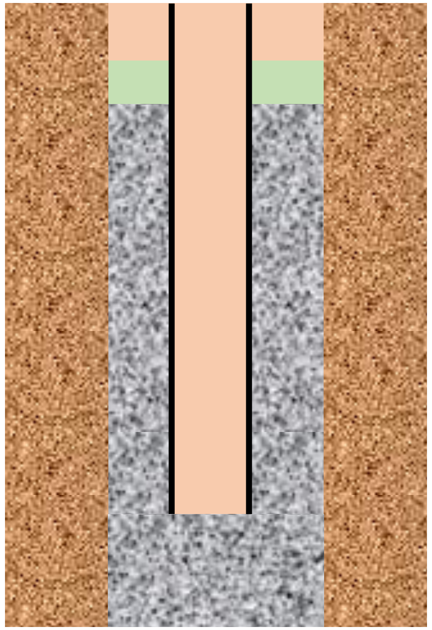
Why do we need a cement sheath around casing?

- After the end of production
- Plugging before abandonment



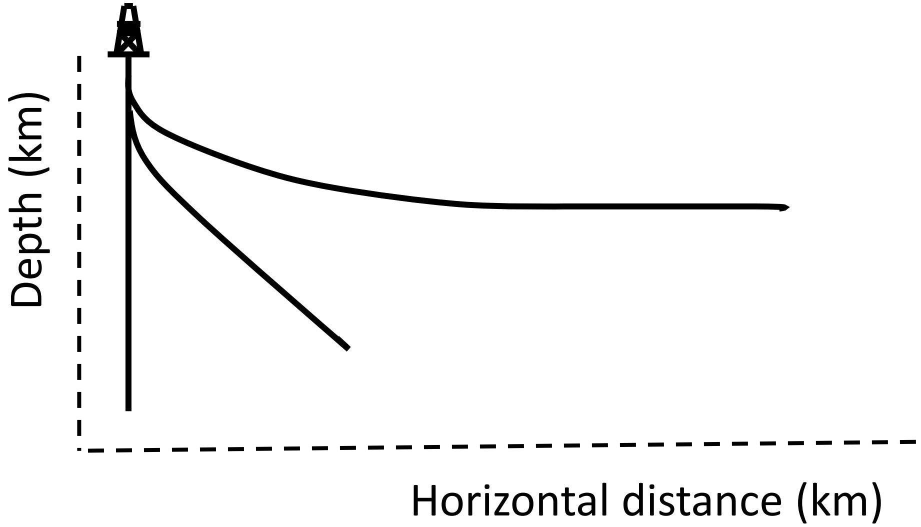
Process

- Mix the cement slurry on surface
- Pump it down hole displacing the drilling fluid
- Allow to set: transition from liquid to solid
- Set cement resists the downhole environment



Geometry

- 7 inch (177.8 mm) diameter casing
- 8.5 inch (215.9 mm) diameter hole
  - 19 mm annular thickness
- Length: 100's m
- Position: km's from surface
- Casings from vertical to horizontal
- Temperatures up to 200°C



- Deepest: 9500 m onshore
- Deepest: 10600 m offshore
- Longest: 14900 m (~2km deep)

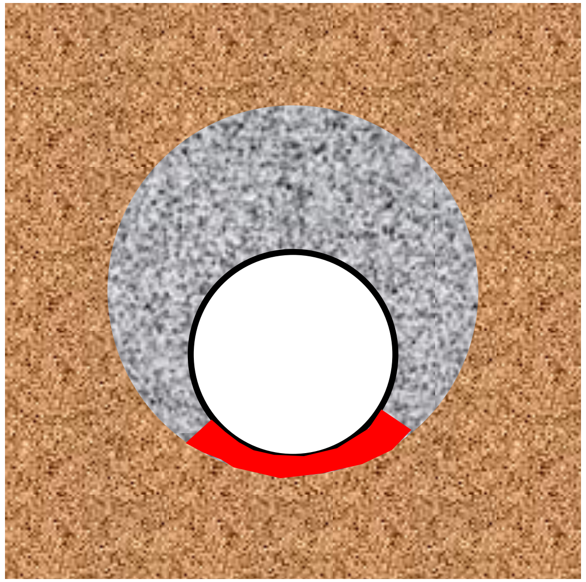
Placement

- Cement placement – drilling fluid displacement
  - Rheological properties and densities of all fluids
  - Compatibility of the fluids
  - Centralisation of the casing
  - Hole diameter uniformity
- Cement slurry properties
  - Thickening time
  - Fluid loss control

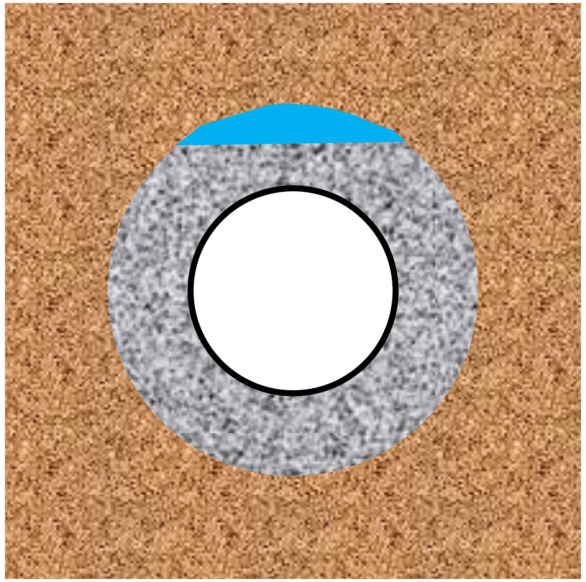
Failure modes - placement

- Highly deviated and horizontal wells are the most difficult
- Poor centralisation or control of rheological properties
- Poor slurry stability: free fluid, sedimentation

By-passed Drilling Fluid

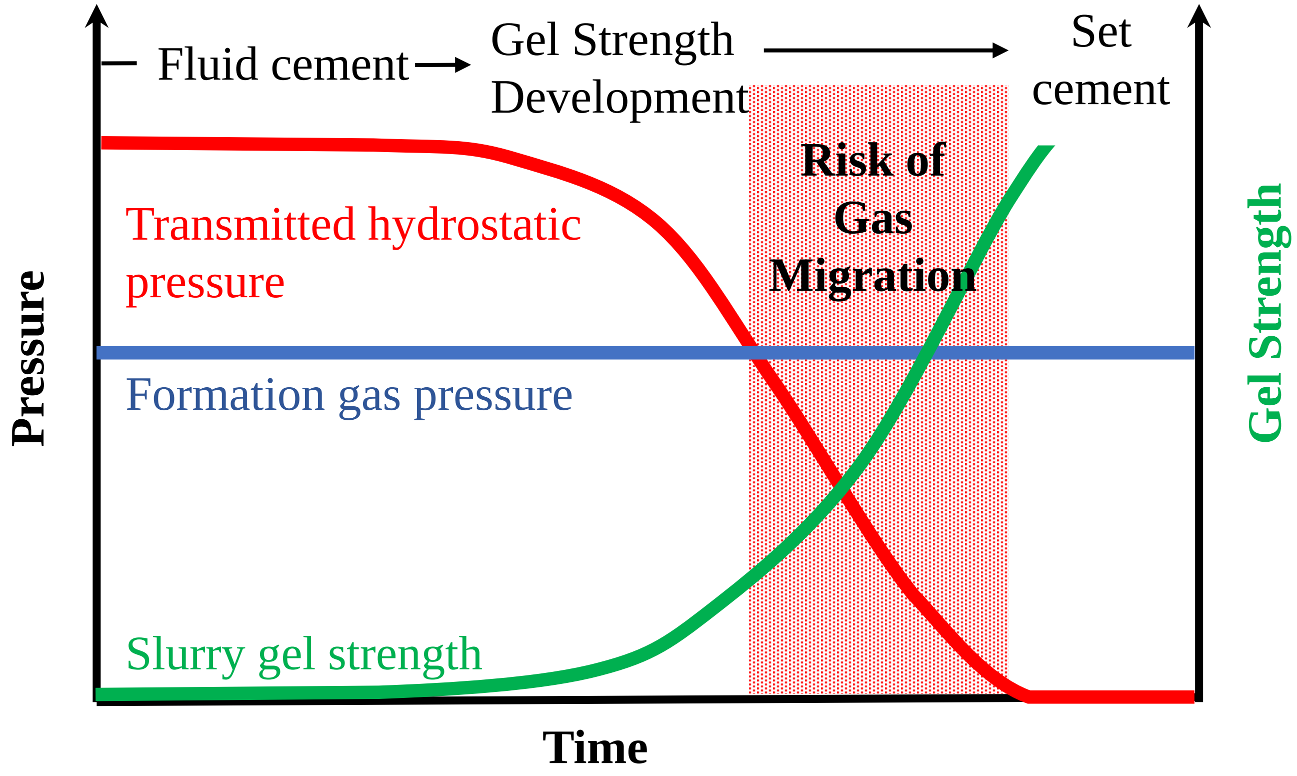


Slurry free fluid



Transition slurry to solid

- Development of gel strength
  - Reduction of hydrostatic pressure
- Loss of fluid to the formation
- Hydration
  - Decrease in volume
- Risk of gas influx:
  - High permeability path in cement
- Slurry optimisation
- Gas migration control additives



Transition slurry to solid

- Cement properties are continually changing
- Temperature and pressure changes
  - Hydration
  - Equilibration with the formation
- Formation and casing movement
- Cement sets in a stressed state

Set cement properties

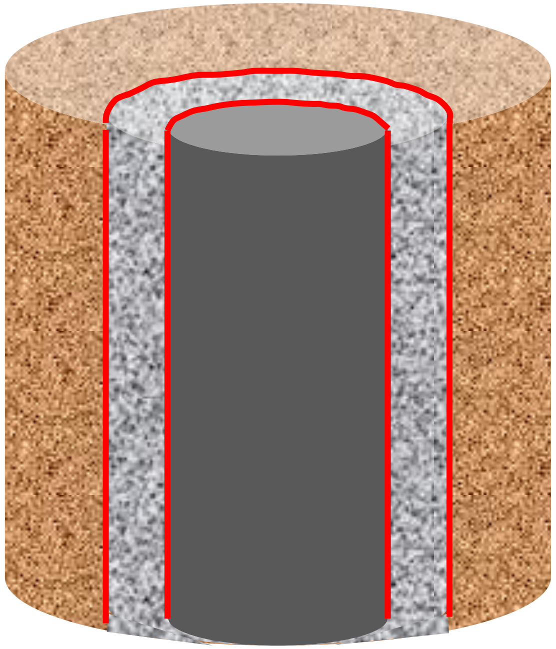
- Thermal stability
- Chemical stability
  - Sulphate resistant cements, CO_2 resistant cements
- Permeability of cement matrix
  - < 0.1 mDarcy
- Mechanical properties
  - UCS, Young's modulus, Poisson's ratio, tensile strength …
- Thermal properties
  - Thermal expansion, thermal conductivity

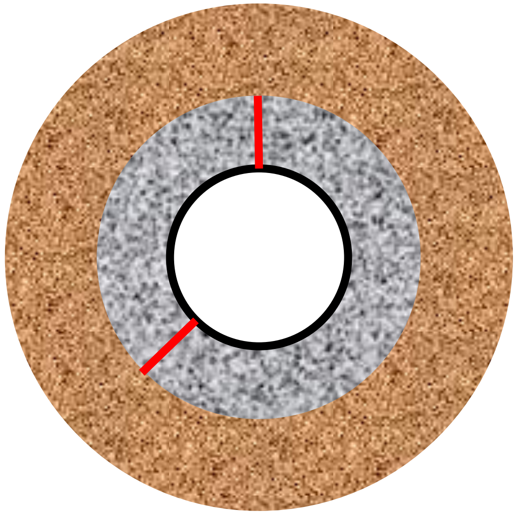
Failure of set cement

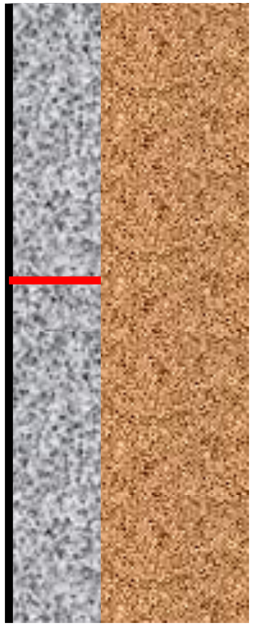
- Mechanical failure of the casing/cement/wellbore system
- Pressure changes:
  - Casing pressure tests
  - Fracture stimulation treatments
  - Production
- Temperature changes:
  - Steam injection wells
  - Production from higher temperature zones at greater depth

Failure modes

- Micro-annuli at interfaces
- Radial and horizontal cracks

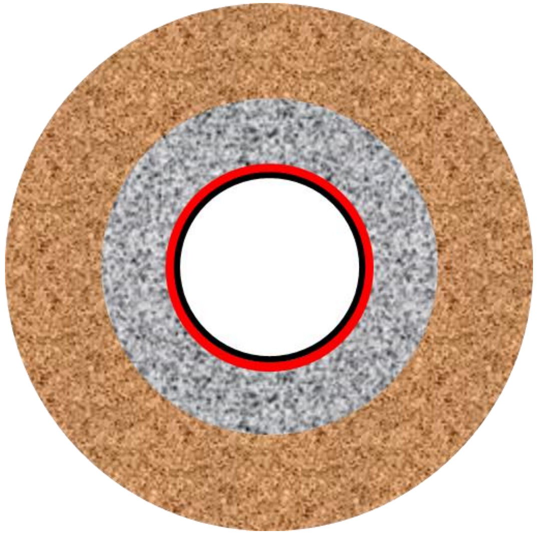




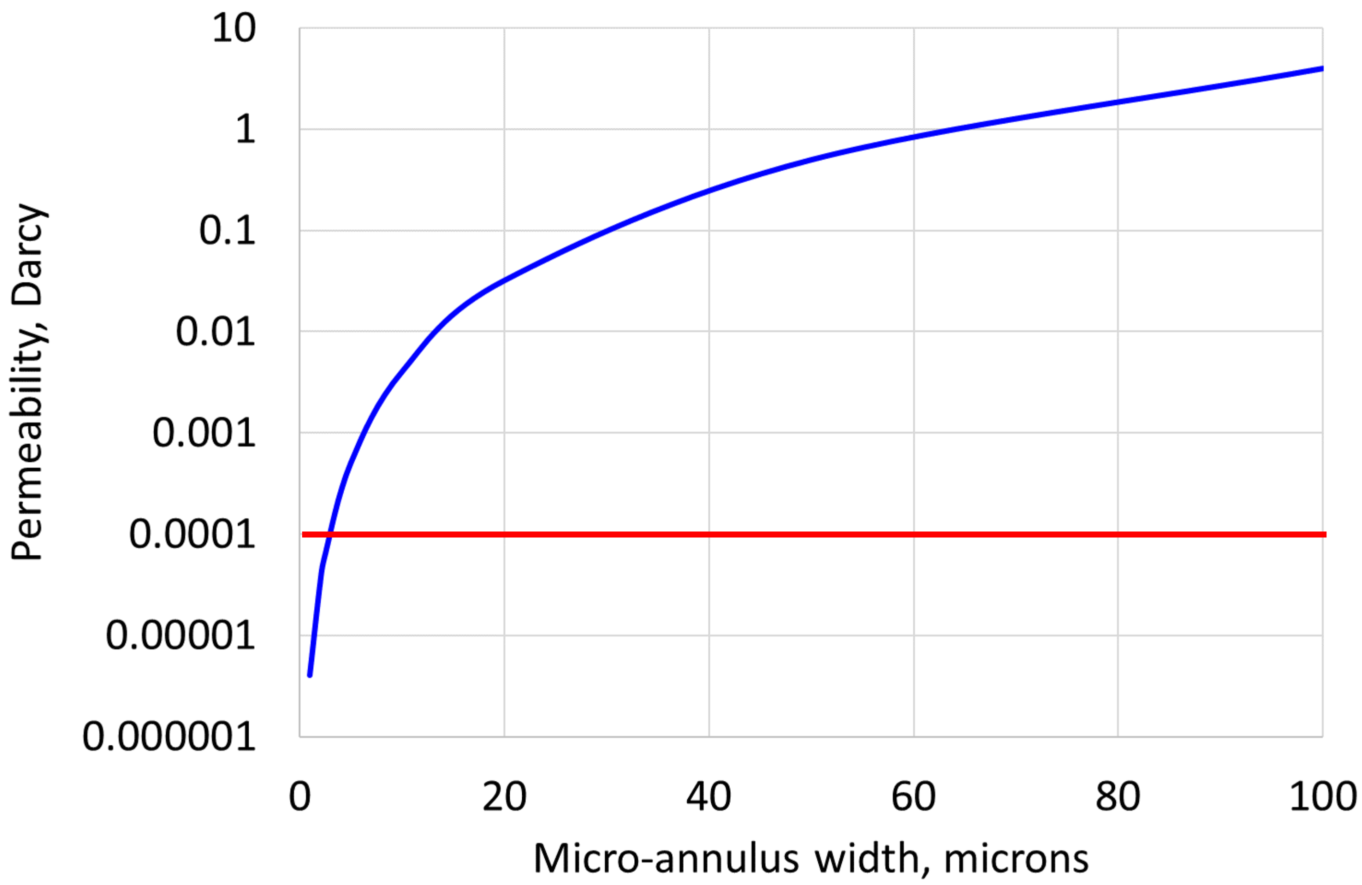


Micro-annuli and permeability

- What is the effective permeability of a micro-annulus and cement?
- Calculate flow through a uniform micro-annulus (slot flow)
- Assume flow is average over entire annulus area (equivalent cement permeability)
- 7 inch casing 8.5 inch hole



Effective permeability



- 0.1 mDarcy ~3µm
- ~Casing roughness

Minimising risk of mechanical failure

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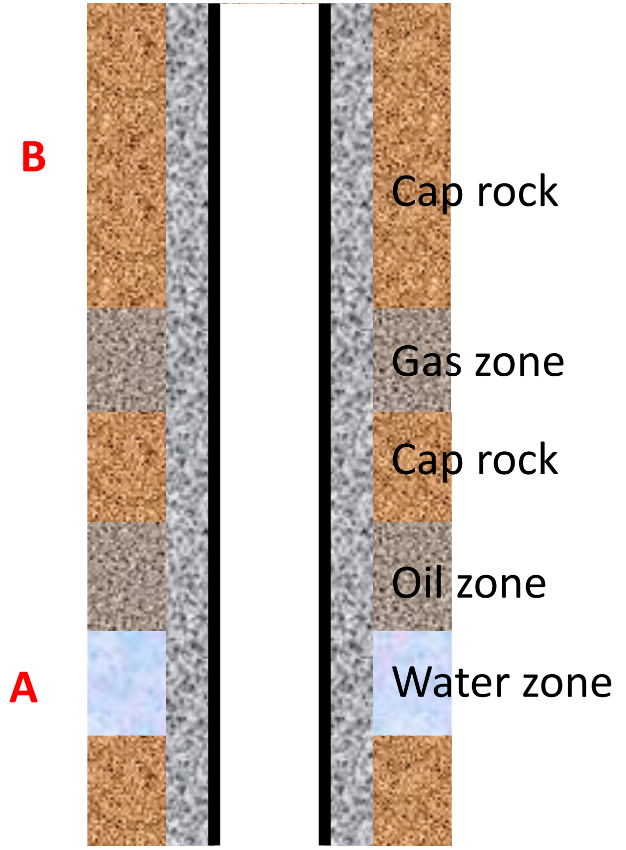
- Slurry design options
  - Water:cement ratio
  - Presence of fillers with different mechanical and/or thermal properties
  - Expanding agents
- All may affect the stress state in the cement
  - Quantification?

Chemical durability

- Local environment
  - Degree of confinement
  - Fluid contact
- Type of chemical reaction
  - Magnesium chloride brines – expansion, possible rapid failure
  - CO_2 diffusion limited – slow attack



Summary

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- Correctly placing cement in a well can be a complex process
- Requiring several steps to be correctly performed
  - Drilling a uniform hole
  - Displacing the drilling fluid
  - Designing cement systems with suitable slurry and set properties
- Technology available for most situations
- Need better understanding of the liquid to solid transition and the effect of slurry design