SPE Distinguished Lecturer Program

The SPE Distinguished Lecturer Program is funded principally through a grant from the SPE Foundation.

The society gratefully acknowledges the companies that support this program by allowing their professionals to participate as lecturers.

Special thanks to the American Institute of Mining, Metallurgical, and Petroleum Engineers (AIME) for its contribution to the program.

Cement and Cementing: An Old Technique With a Future?

Bernard Piot
Schlumberger
Outline

• Cement
• Cementing: a necessary evil?
• Alternative isolation techniques
• Today’s well challenges
  – Cement versatility
• Well architecture tool for the future

Cement

Material and Regulations
Portland Cement

- Hydraulic binder
- Suspension (paste or slurry) for placement
- Controllable setting
- Solid
  - Strong
  - Impermeable
- Inexpensive
- Available everywhere

History of Oilfield Cement

- Before our era
  - Clay, lime
    \[ \text{Ca(OH)}_2 + \text{CO}_2 \rightarrow \text{CaCO}_3 \]
- Roman times
  - Pozzolanic cements
- 1824: Portland cement
  - Selected raw materials
- 1903: Portland cement in oil wells
- 1917: “Oilfield” cements
- API created 20 Mar 1919
- 1940: ASTM Types 1 to 5
- 1948: API Code 32 released
  - Became API RP10B in 52
- 1952: 6 classes of cement
- 1953: API Std 10A
- API Spec 10A in 72
- ISO 10426 since 2000
Cement Types

- Construction cements
  - Common cement
  - API classes A, B, C
- Retarded cements
  - Deeper wells
  - Classes D, E, F
  - Pressurized consistometer
  - Cementing companies
  - Abandoned early 80s
- Plain Portland cement
  - Classes G, H
  - Quality control, reproducibility
  - More universal
- Class J cement
  - Replaced by G/H + Silica
- Slag cement
  - ~80s Brine resistance
  - ~90s Mud compatibility
- Others

Use of Cement

- USA
  - ~ 80% class H and G
  - ~ 10% class A, ~ 10% Class C
- Rest of the world (international service companies)
  - >95% class G (often imported)
  - Class A or C; or local common cement: preferentially Type V (ASTM), or CEM-I 42.5 or 52.5 (EN 197-1)
    - Logistics allowing
    - If good and even quality
    - If adequate quality control
From API to ISO (since 1998)

- API Committee 10
- ISO TC 67 /SC 3/WG 2
- ISO 10426 – well cements
  - ISO 10426-1 (ANSI/API 10A) - specification
  - ISO 10426-2 (ANSI/API RP 10B-2) - testing
  - ISO 10426-3 (ANSI/API RP 10B-3) – deepwater wells
  - ISO 10426-4 (ANSI/API RP 10B-4) - foam cement
  - ISO 10426-5 (ANSI/API RP 10B-5) – shrinkage/expansion
  - ISO 10426-6 (ANSI/API RP 10B-6) – static gel strength
- Other work groups:
  - Evaluation (logs), High Temperature, Deepwater…

Cementing: A Necessary Evil?

Evolution of Equipment and Technology, and an Outline of Their Shortcomings
Technology Older Than a Century

- First well cementing ~ 1903
  - Perkins Oil Well Cementing Co., Calif.
  - Shovel/cement mixer
- First use of an eductor
  - Jet mixer invented 1921
  - “High pressure” mixing
  - In use till the 1970s
    - Still used by some
    - Gravity cement feed

Primary Cementing Objectives

- Casing anchor (axial support)
- Protection against corrosion and erosion
- Support of borehole walls
- **Zonal isolation**
Unsuccessful Zonal Isolation

Cementing Process at Surface
Handling Dry Cement

- From cutting sacks to pneumatic handling
  - Storage

Typical problems:
- Contamination
- Humidity (air)
- Deliverability
- Homogeneity

Fully automated blender

Control of Mixing

\[ \text{SG - 1.0} + \text{CEMENT SG - 3.2} = \text{SLURRY SG - 1.9} \]

Density Control
Cement Quality = Slurry Performance

- W/C ratio; extender; weighting agent
- Dispersant / viscosifier
- Anti-settling agent
- Fluid loss agent
- Retarder/accelerator

Cementing Additives Key Milestones

- Lignosulphonates and cellulosics
- Sugars and superplasticizing agents (~ 1960s)
- Polyamine/imine (~ 1970s)
- SB Latex (~ 1980s)
- Co/ter-polymers AMPS (~ 1980s)
  - Temperature stability
- Biopolymers (~ 1990s)
  - Not based on Xanthan gum
- Environmentally friendly additives (end 1990s)
  - OSPAR (OSlo-PARis) convention 1998
Cementing Process Downhole

- Failures identified 30-40s
- Field practices
  - Turbulent displacement
    - High Reynolds ~50s
    - 10 min contact ~60s
  - SloFlo / Plug Flow ~70s
    - Fluid with yield stress

Mud Removal Modeling

- More complex wells
  - Deviated, horizontal & extended reach
- More critical wells
  - Deepwater, high-pressure, high-temperature
- Importance for Zonal Isolation
  - Very difficult modeling
  - Computational Fluid Dynamics (CFD) tools not applicable
- Eccentricity effects
  - Modeling ~ end 80s
  - Turbulent/Effective Laminar Flow
  - Rheology/Density contrast
- Erodability / PDGM concept
  - Polymer muds
- Lubrication analytical model (2003)
Cement Evaluation Logs

• Sonic logs
  – CBL ~60s
  – Compensated CBL ~80s
  – Segmented Compensated

• Ultrasonic logs
  – 8 sensors ~80s
  – 1 rotating sensor ~90s

• Limitation of cement logs
  – Strength or Impedance ~80s
  – Microannulus/Isolation???
  – Microdebonding ~mid-90s
  – Casing interface exclusively

• Flexural Attenuation (2006)
  – 1 + 3 sensors
  – Full cemented annulus width
  – 3rd interface
  – Differentiate lightweight cements from liquids
  – Confirm hydraulic isolation
  – Visualize casing in borehole

Alternative Isolation Techniques

Other Fluids and Mechanical Means
Organic Resins

• Very limited applications
  – Cost
  – Shelf-life
  – Sensitivity
  – Health, safety, and environment
  – Compatibility (water, mud…)
  – Placement
  – …

Mechanical Systems

• Complementary to cement
  – Casing drilling, expandable casing (EC)
  – Swellable elastomer layer

• Exclusive of cement
  – EC/Casing with (oil or water) swellable packer
  – Another form of completion
    • May still require cement for most other casings
Today’s Well Challenges and Versatility of Cement

New Reservoir Isolation Challenges

• Aging and depleting fields
  – Completions at lower pressures
  – Steam injection, stimulation
  – Workovers and repairs
  – Plugging and abandonment

• Exploration and new developments
  – Isolation under higher pressure and temperature
  – Very narrow pore/frac pressures margin
  – In deeper water and at colder temperatures
Need for Ultra-Low Density

• Conventional Cement
  - Directly linked to W/C ratio
  - Slurry: Very low rheology, stability
  - Set cement: Very low strength, high permeability, very long setting times

• High performance/high solid cements
  - Adapted from the concrete industry
  - Same water/solid ratio at all densities
  - From 900 to 2800 kg/m³
  - Similar rheology
  - High strength, low permeability

Slurry Quality Control?

Solid Fraction Monitoring

What if density 1.0?
Well Architecture and Logistics

- Lighter isolation-quality cements
  - Depleted reservoirs
  - Single-stage cementing
  - Production liner instead of casing
- Light cements that set faster at low temperatures
  - Deepwater conductors, surface casings...

Is Isolation Durable?

Cement is strong, but fragile

- Understanding failures
  - P or T increases
  - Drilling, milling, repairs
  - P or T decreases
- Modeling capability
  - Parameter sensitivity
Isolation Made Durable

- Controlled flexibility and expansion
  - Isolation maintained during P, T changes
  - From construction to abandonment

A Tool in Well Architecture
Summary
Cement in the Past

- A necessary evil?
- Commodity?

Cementing Today

- Solutions portfolio
  - Not only slurry performance
  - Set material properties
  - Short/long-term well requirements
- Modeling tools
  - Fit-for-purpose, cost-effective system
Cementing Tomorrow: A Technology for the Future

- Evolving cement industry
  - Still considerable academic research
  - CO2 emissions
  - Important engineering development
    - Physically active, chemically reactive or inert materials
- Oilfield cementing industry
  - More tools in the toolbox
    - Materials, simulators
  - An interesting future
    - Process design and simulation
    - A true well engineering technology

Thank you for your attention