Technical Applications of Resins for Cost-Effective Deep-Water Well Abandonments

Mike Cowan
Overview of Content:

- Challenges for achieving a lasting seal
  - Barrier basics
  - Material property requirements
- Resin definition
- Technical advantages of resins versus cement
  - Resin types applicable for long-term barriers
  - New type of primary barrier
  - Reduce most common causes of barrier failure
- Basics of barrier design and installation procedures
  - Resin HSE issues
  - Equipment considerations, techniques and operational strategies
Barrier Basics: Challenges for Achieving a Lasting Seal

- Barrier Objective: Prevention of pressure and fluid transmission within a well system (mechanical and geo-mechanical) for geologic time.

- Success is ~80% Placement + 20% Material Characteristics
  - Smaller volumes of material require more attention to detail in job design and execution!

- Primary causes of failure:
  - Poor Placement
  - Contamination of Sealant

- There is only one chance to ‘get it right’ for each barrier
  - *It is nearly impossible to remediate a leaking barrier*

- Pressure test is only method to determine barrier effectiveness
  - Negative and Positive Test (in that order) across plug
  - Longer test times required to find smaller leaks
Resins: Working Definition

- Thermosetting natural or synthetic materials which become insoluble and infusible upon heating.
  - With or without catalyst or hardeners
  - Include water soluble and insoluble type
  - Include monomeric and polymeric materials
- Higher temperature = faster set time, less catalyst/initiator/hardener required
- Lower temperature = longer set time, more catalyst/initiator/hardener required
- Some resins/formulations may not set at low(er) temperatures
Resins for Oil and Gas Well Applications

• Resins have been used for more than 50 yrs. in well construction, repair, completion, production operations and abandonment.

• Types of resins applicable for long-term barriers have been identified
  – Epoxies, furans, phenolics, melamine types
  – Good to excellent chemical resistance, bonding, thermal stability, durability

• Sufficient information from oilfield and other industries to support long-term application between up to 250 F (120 C)
  – Higher temperature limits are possible for specific resins, formulations and conditions

• Proper formulation is CRITICAL for long-term performance
  – Industry expertise is limited and competency levels vary
Cement Barrier: Primary Barrier in Annulus

Primary Barrier in annulus
Cement placement critical
Minimum of 99% of fluid in the annulus must be displaced by cement over barrier length
Contamination of cement during placement may reduce barrier effectiveness
Cement formulation is critical to maintain long-term hydraulic seal
Filter-cake on formation increases potential for leak
Radial differential stress forcing pipe-cement-formation together is primary sealing force long-term. Changes in this stress may affect barrier performance.
Geo-Synthetic Composite: Primary Barrier in Formation

Geo-synthetic barrier created in formation surrounding well bore

Primary Barrier in geo- system

Cement, if used, is secondary barrier and structural support for casing

Alters near-wellbore material properties

Alters system stress/strain behavior

If resin is used instead of cement, geo-synthetic barrier may be created by filtration of resin into formation after resin placement.

Material properties and adhesion of resin often better than cement for long-term zonal isolation performance

Near-Wellbore Material Property Changes:
- Reduction/elimination of permeability
- Change (increase) in compressive and/or tensile strength
- Elastic Modulus, Poisson Ratio Changes
- Increase in near-wellbore fracture initiation pressure
**Rock-to-Rock Barrier Type: Cements versus Resins**

- **Casing is section-milled**
- **Interval is cleaned out to formation face**
- **Resin plug is set in section-milled interval**
- **Filtrate creates geo-synthetic barrier in formation**
- **Leak potential at interface eliminated even when solids-laden fluids are used in the milling operation and deposit filter-cake on formation face.**

- **Cement plug is set in section-milled interval**
- **Cement-formation face remains potential leak path**
- **Leak potential at interface increases if solids-laden fluids are used in the milling operation and deposit filter-cake on formation face.**
Penetration of Liquid Resin: Multiple Annuli/Eccentered Casing

Before Resin Injection

- No Plug Inside Casing
- Wellbore Perforation
- Casing(s)
- Resin-Filled Annulus
- Un-cemented Annuli

After Resin Injection

- Resin Plug Inside Casing
- Resin Penetration into Formation
Resin Contaminated Fluids Can Become Sealants

- Resin contamination of annular fluids can convert to solids – may be effective sealants.
- Resin and fluids must be chemically compatible. Resin should be soluble in the fluid.
- Beneficial for re-cementing and cementing un-cemented annuli (filtrate can create geosynthetic barrier in exposed formation(s)).
HSE and Mixing Equipment

• Resins are not ‘green’ in liquid form: (Resin, catalyst or both materials)
  – Hazards may be reduced/eliminated after hardening.
• Mixing and handling of unset liquid waste must be addressed in application design
  – Closed systems, mix-on-fly equipment recommended
  – Automated mix-on-fly systems prototyped in 1990’s – used with rig pumps
  – No current equipment available
• Down-hole mixing (concentric coil/spaghetti strings) enables more flexibility in material application, job design and reduced waiting time after placement
  – Single-most valuable advancement in placement for resins and cements in abandonment
Placement Techniques

• Hesitation squeeze technique is (generally) effective placement method
  – Spot-and-squeeze – patience is required - multiple cycles over several hours
  – Volumes and accuracy required work well with coiled tubing
  – Resin injected below fracture pressure (preferred)
  – Squeeze pressure may not be achieved – volume injected is key variable for design
  – Effective technique for multiple annuli that can be reliably accessed for injection
    • Larger volumes of resins may be required for multiple annuli for single-job success

• New design rules, techniques and procedures must be used for resins
  – Job design is critical for success
  – Squeeze training advised
Summary

- Resins can deliver a step-change in barrier technology
  - Enable new types of barriers
  - Enable options for well preparation and placement methods
  - Potential reduction for barrier failure related to placement and contamination

- Industry knows very little about them compared to cements
  - Limited expertise and significant competency gaps in formulation
  - Limited expertise in application design

- More product types need to be commercialized
- Laboratory testing and development of guidelines needed
- BSEE solicited projects related to resin application, regulation and industry standard development (1/2016: E16PS00024)