DESIGN, PLACEMENT, AND EVALUATION OF CEMENT SLURRIES IN TODAY'S U.S. REGULATORY CLIMATE

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Agenda

- State or Federal regulations in effect since 2010
  - API RP 65-2 becomes Standard 65-2 in October 2010
  - Some US land regulations have same requirements concerning cement
  - 30CFR250 incorporates 65-2
  - Texas RRC Chapter 3, Rule 13

- Cementing from Standard 65-2
  - Cement design
  - Cement lab testing for confirmation
  - Pre-job cement simulation
  - Post job

- Confirmation and evaluation of the cement job once pumped

- Summary

Disclaimer: My job description is not "regulatory specialist", but…

- Knowledge of local regulations essential for the drilling team
- Team work is key to success
  - Regulatory group
  - Cementing engineer from service company
  - Reservoir management team (PE, CE, G&G)
  - Drilling Engineer
  - Mud Engineer
  - Drilling Superintendent
  - Company Man
- Plan the job early
  - Cement design - potential flow zone, critical zone or injection zone
  - Compressive strength time to 50 psi, 500psi
    - UCA or destructive tests
  - Pilot tests, field blend tests incorporating well site materials: mud, water
  - Simulation in planning phase as well as with actual well conditions as close as possible to time of the cement job

The New Regulatory Landscape – U.S. Land

- **December 2010**
  API RP 65-2 becomes API Standard 65-2 incorporated by reference in 30 CFR 250
  30 CFR 250 incorporated by reference into TRRC Ch. 3 Rule 13

- Texas RRC – Railroad Commission January 1, 2014

- BLM – 2012 revision of Cement Ordinance 2 (43 CFR 3160)
  - Federal onshore O&G for 12 states including approval of Bureau of Indian Affairs leases
  - Alaska, Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Wyoming, Utah, Eastern States
- Other states are following
  - New Mexico Oil and Gas Association (no federal lands)
  - Ca. State Lands Commission
  - Ca. Department of Conservation – DOGGR (Division of Oil, Gas,& Geothermal Resources)
  - COGCC (Colorado Oil and Gas Conservation Commission)
  - Louisiana Department of Natural Resources

The New Regulatory Landscape – U.S. Land

New cementing regulations apply to all cementing operations whether drilling, re-drilling, deepening, repairing, or plugging and abandoning of wells

The results of the cementing operation determine whether we are allowed to **hydraulically fracture** the well based on meeting state/federal cement requirements, or do we have to remediate a poor cement job. If so, when? At what cost?

So, how do I ensure that the cement job went as planned?

- Confirmation - volume, density, pressure, cement evaluation tools
- Verification - casing pressure test, inflow test,

What is API Standard 65-2, Normative References

Shall denotes a minimum requirement (82 shalls within Standard 65-2)

Should denotes a recommendation that is not required to conform to the Standard yet is a reference to a best practice guideline (240 shoulds within Standard 65-2)

4.6.3 WOC Guidelines Prior to Removing a Temporary Barrier Element

If no potential flow zone(s) exist or if alternate physical barrier elements are in place, subsequent operations may commence without WOC, if regulations allow.

If design and operational parameters indicate isolation of potential flow zones, cement **shall** be considered a physical barrier element only when it has attained a minimum of 50 psi compressive or sonic strength. The 50 psi compressive or sonic strength threshold exceeds the minimum static gel strength value needed to prevent fluid influx. Local regulations **shall** be adhered to with regards to WOC. However, caution should be exercised when the specified WOC time is less than the time required for the cement to reach a strength of 50 psi.

5.3.1 Drilling Fluid Selection

Drilling fluid (mud) selection and maintenance play a key role in cementing success. Drilling fluid performance affects hole condition (enlargements, etc.), drilling fluid filter cake thickness and gel strength (measured as described in API RP 13B-1/ISO 10414-1 or API RP 13B-2/ISO 10414-2), drilling fluid mobility, fluid and formation compatibility, and bonding of cement to formation.

Drilling fluid performance is controlled by many factors. Drilling with fluids that provide a thin, low permeability filter cake and low non-progressive gel strengths sufficient for transport of drill cuttings and barite support can be more effectively displaced when cementing. Achieving good cementing success through effective drilling fluid displacement requires proper planning. Computer modeling of cement placement or drilling fluid displacement requires careful evaluation of fluid properties and placement processes.

API Standard 65-2 Normative References

Normative References in API Standard 65-2

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

API Recommended Practice 10B-2/ISO 10426-2, *Recommended Practice for Testing Well Cements*

API Recommended Practice 10B-3/ISO 10426-3, *Recommended Practice on Testing of Deepwater Well Cement Formulations*

API Recommended Practice 10B-4/ISO 10426-4, *Recommended Practice on Preparation and Testing of Foamed Cement Slurries at Atmospheric Pressure*

API Recommended Practice 10B-5/ISO 10426-5, *Recommended Practice on Determination of Shrinkage and Expansion of Well Cement Formulations at Atmospheric Pressure*

API Recommended Practice 10B-6/ISO 10426-6, *Recommended Practice on Determining the Static Gel Strength of Cement Formulations*

API Specification 10D/ISO 10427-1, *Specification for Bow-Spring Casing Centralizers*

API Standard 65-2 Normative References

API Specification 10D-2/ISO 10427-2, *Recommended Practice for Centralizer Placement and Stop Collar Testing*

API Recommended Practice 10F/ISO 10427-3, *Recommended Practice for Performance Testing of Cementing Float Equipment*

API Technical Report 10TR1, *Cement Sheath Evaluation*

API Technical Report 10TR3, *Temperatures for API Cement Operating Thickening Time Tests*

API Technical Report 10TR4, *Technical Report on Considerations Regarding Selection of Centralizers for Primary Cementing Operations*

API Technical Report 10TR5, *Technical Report on Methods for Testing of Solid and Rigid Centralizers*

API Recommended Practice 13B-1/ISO 10414-1, *Recommended Practice for Field Testing Water-Based Drilling Fluids*

API Recommended Practice 13B-2/ISO 10414-2, *Recommended Practice for Field Testing Oil-based Drilling Fluids*

API Recommended Practice 53, *Blowout Prevention Equipment Systems for Drilling Operations*

API Recommended Practice 65, *Cementing Shallow Water Flow Zones in Deep Water Wells*

API Recommended Practice 90, *Annular Casing Pressure Management for Offshore Wells*

API Standard 65-2: Scope

ISOLATION OF POTENTIAL FLOW ZONES IN THE WELL

Cement discussion in API Standard 65-2

- Definitions of physical barriers
  - Hydrostatic, mechanical, set cement in annulus, shoe track or a PA plug
  - <u>At 50 psi CS cement is considered a physical barrier</u>

- Practices affecting cementing success
  - **Drilled hole quality**
  - **Drilling fluid**
  - Casing hardware
    - Float equipment, centralizers, plugs, plug containers (heads)
  - Cement design considerations for close-tolerances or flow restrictions
    - Stage collars, ECPs, liner top packers, PBRs, internal ID of liner hangers, expandable tubulars

- Mechanical barriers
  - Liner top packers, expandable casings

Cement discussion in API Standard 65-2

<u>General</u>

- Determination of zonal coverage
- Understanding and use of a pressure profile to model the cement job
- Temperature
- **Drilling fluid removal**
  - **Annular velocity, rheology, density, drilling fluid compressibility**
  - **Cement spacer considerations (pre-flush, chemical washes)**
  - **Pipe movement**
  - **Centralization**
- Engineering Software
  - Swab and surge calculations
  - ECDs to predict if cement job will remain in pore pressure/frac gradient window to include annular restrictions and casing hardware restrictions
  - Centralization/standoff calculations
  - **Mud displacement effectiveness**
- Foamed Cement Modeling (N2, quality of foam, T, P)

Cement discussion in API Standard 65-2

Prior to the cement job

- Slurry design and testing considerations (cement lab testing parameters)
  - Rheological properties, hydrostatic pressure control, fluid loss control, free fluid, sedimentation control, static gel strength development, resistance to invasion of gas or formation fluid, time to 50 psi, compressive strength (sonic, mechanical), shrinkage, expansion, density, thickening time, fluid(s) compatibility
- Modeling of mechanical properties to predict cement sheath longevity (annular leaks, SCP, environmental release)
  - Ability to withstand future pressure temperature cycles during drilling, testing, fracturing and production, reservoir pressure decline
- Cement slurry design technique for controlling annular flow
  - Service company area of expertise: compressible, expansive, latex, micro-silicas, surfactants
- Computer modeled predictive failure analysis
  - Compressive strength, Young's modulus, Poisson's ratio, Cohesive strength, internal angle of friction
- Wellbore preparation prior to cementing
- **Lost circulation – assessment of lost circulation effect on the primary cement job**
- **Drilling fluid – proper conditioning and effect on ECDs, pressures to remove**
- **Effect of a long rat hole – contamination of cement increased risk**

Cement job discussed in API Standard 65-2

Loading out the job

- Cement bulk plant QA/QC
- Calibration of scales, system to identify cement and additive lot numbers for future traceability, sampling and retention of blend testing
- Cement lab pilot and field blend testing requirements
- Transportation of cement to rig
- Inspection of storage tanks

Mixing and pumping the job

- Density control, maintain modeled rates for ECDs (loss of well control), computer assisted density, batch mixers, low density consideration (glass spheres), data acquisition, lost circulation contingency planning

Cement job discussed in API Standard 65-2

<u>Post job operations</u>

- Holding pressure inside casing
- Maintaining a full hole/annulus
- WOC
- Top job
- Casing shoe integrity test (FIT), (LOT), (PIT)

<u>Post job Analysis</u>

- Material Inventory
- Job data – pressure match?
- Cement Evaluation

Texas RRC Chapter 3 Rule 3.13 Incorporates as a reference 65-2

Texas Administrative Code

TITLE 16	ECONOMIC REGULATION
PART 1	RAILROAD COMMISSION OF TEXAS
CHAPTER 3	OIL AND GAS DIVISION
RULE §3.13	**Casing, Cementing, Drilling, Well Control, and Completion Requirements**

(a) General. Operators shall comply with this section for any wells that will be spudded on or after January 1, 2014.

(1) Intent. The operator is responsible for compliance with this section during all operations at the well. It is the intent of all provisions of this section that casing be securely anchored in the hole in order to effectively control the well at all times, all usable-quality water zones be isolated and sealed off to effectively prevent contamination or harm, and all productive zones, potential flow zones, and zones with corrosive formation fluids be isolated and sealed off to prevent vertical migration of fluids, including gases, behind the casing. When the section does not detail specific methods to achieve these objectives, the responsible party shall make every effort to follow the intent of the section, using good engineering practices and the best currently available technology. In accordance with §3.17 of this title (relating to Pressure on Bradenhead), operators must notify the Commission of bradenhead pressure. The Commission will evaluate notices of bradenhead pressure on a case-by-case basis to determine further action and will provide guidance to assist operators in wellbore evaluation.

TRRC Rule 3.13 Jan 1, 2014 Amendment Goals

- Clearly state the intent of the law (House Bill 2694 [2011])
- Require isolation of potential flow zones and zones with corrosive formation fluids
- Update References to Cement Quality (Standard 65-2)
- Update the requirements for drilling, casing, cementing and fracture stimulation
- Consolidate the requirements for well control and blow-out preventers

TRRC Rule 13 Definitions

- Zone of Critical Cement (Surface) - bottom 20%, < 1000’ or 300’
- Zone of Critical Cement (Intermediate) – bottom 20% or 300’ above casing shoe or top of highest proposed productive zone, whichever is less
- Protection Depth – determined by Groundwater Advisory Unit (GAU) letter
- Stand under pressure – hydrostatic no added pressure allowed
- Productive Zone – zone with commercial quantities oil/gas
- Potential Flow Zone – zone requiring isolation to prevent sustained pressure on casing annuli and presents a threat to subsurface water or oil, gas or geothermal resources
- Usable Quality Water – not just fresh water, see GAU letter (containing 10,000 ppm dissolved solids)

TRRC Rule 13 3.13(a)(2) Definitions

(A) Potential Flow Zone

- A zone designated by the director or identified by the operator using available data that needs to be isolated to prevent sustained pressurization of the surface/intermediate casing or production casing annulus sufficient to cause damage to casing and/or cement in a well such that it presents a threat to subsurface water or oil, gas, or geothermal resources.

- The Commission will maintain a list of known zones by district and county that are considered potential flow zones and make this information available to all operators.

- The Commission will revise this list as necessary based on information provided, or otherwise made available, to the Commission by the lease operator.

TRRC Rule 13 3.13(a)(2) Definitions – use of shall

(D) <u>Zonal Isolation</u> – Casing <u>shall</u> be cemented across and above all productive zones, potential flow zones, and/or zones with corrosive formation fluids, as follows:

- (i) If the top of cement is determined through calculation, across and extending at least 600 ft (MD) above the zones;
- (ii) If the top of cement is determined through the performance of a temperature survey, across and extending 250 ft (MD) above the zones;
- (iii) If the top of cement is determined through the performance of a cement evaluation log, across and extending 100 ft (MD) above the zones;
- (iv) Across and extending at least 200 ft into the previous casing shoe (or to the surface if the shoe is less than 200 ft from the surface; or
- (v) As approved by the District Director

(E) **<u>Where necessary</u>, the cement slurry <u>shall</u> be designed to control annular gas migration consistent with, or equivalent to the standards in API Standard 65-2:Isolating Potential Flow Zones During Well Construction.**

Texas RRC Chapter 3 Rule 3.13

For cementing potential flow zones we clearly are being told to follow the cement design, pumping guidelines, and principles discussed in

API Standard 65-2

CONFIRMATION AND VERIFICATION METHODS OF CEMENT JOB EVALUATION

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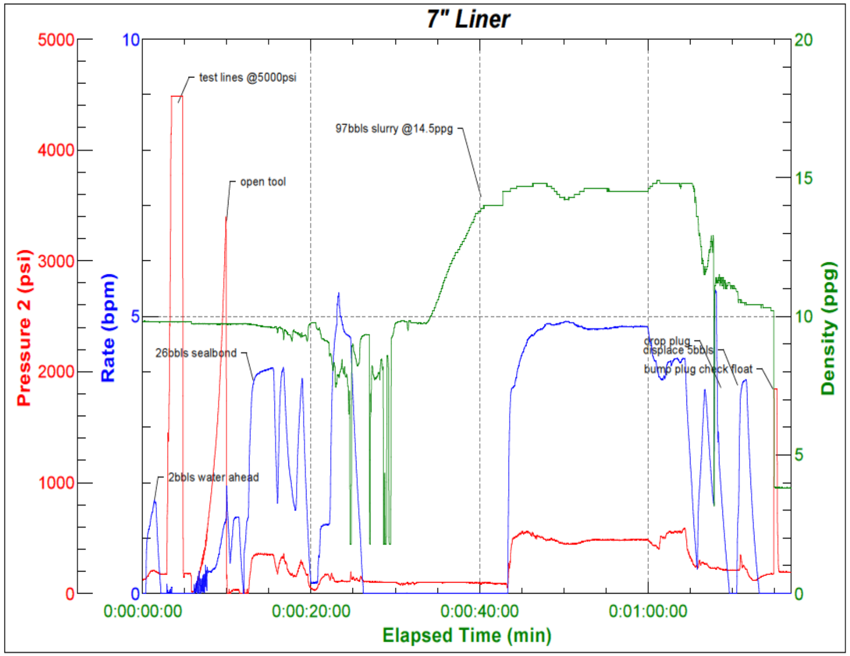
To Frac: Confirmed Barrier Acceptance Criteria

A barrier whose performance has been confirrmed through meeting the acceptance criteria of a post-installation evaluation (other than that of a tested barrier), or through evaluating data collected during installation.

ASK: How did the job go? Was the drilling portion problem free? Was cement pumped as designed?

- **Drilling problems / Hole quality**
- Job designed as per best practice and executed as designed
  - Properly centralized pipe
  - **Effective mud displacement**
  - Pre job simulation shows no losses & ECD's in line
  - No significant events occurred during the job
  - Unplanned shutdowns
- Post job analysis
  - Pressure Match
  - bbl in for bbl out – Can we even get here?
  - Cement evaluation logs

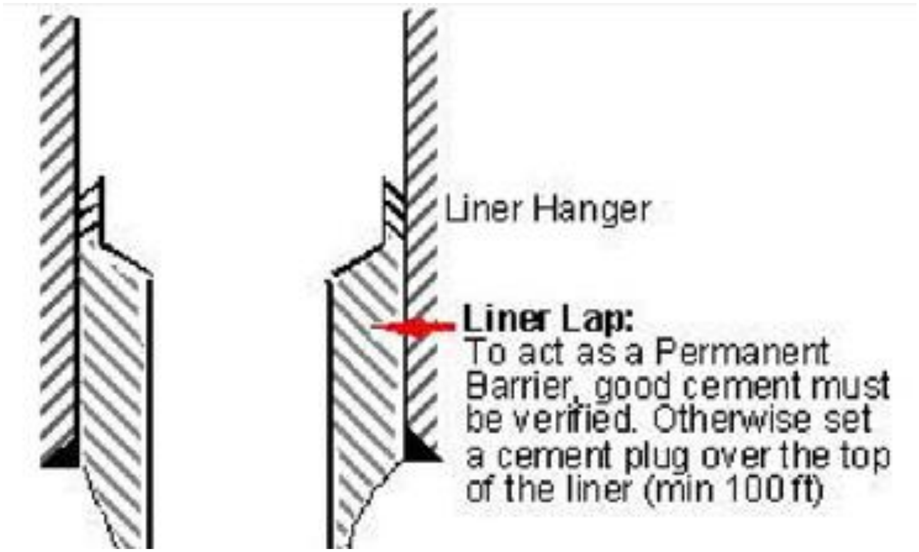


To Frac – Verified Tested Barrier Acceptance Criteria

Verified: a barrier whose performance has been verified through meeting the acceptance criteria of a pressure test.

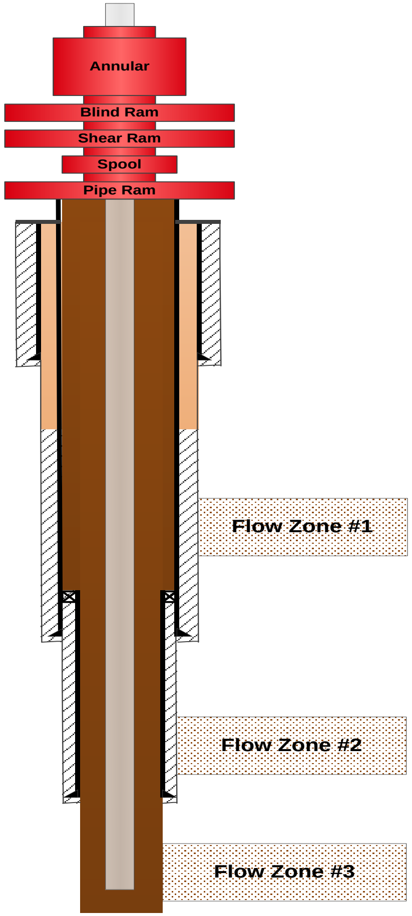
The test is in the direction of flow and to a pressure differential equal to or greater than the maximum differential pressure anticipated during the life of the barrier.

- Pressure communication test - Annulus
- FIT/LOT
- Pressure testing – positive/negative
- Liner top
- Cement PA Plugs
- Continuous monitoring of wells



Local regulations may specify alternative acceptance criteria or evaluation steps.

API 10 TR1



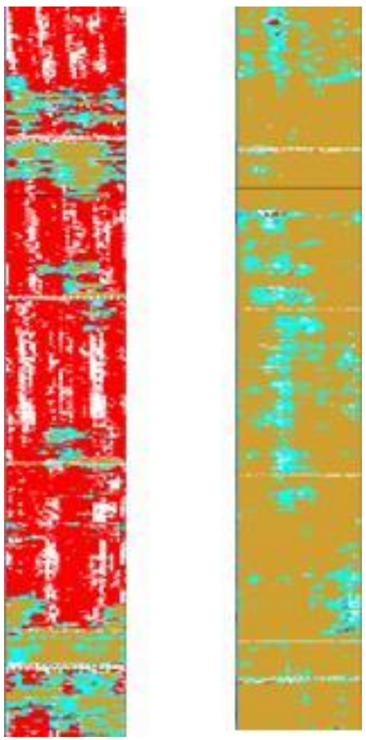
One must understand and never lose sight of the purpose of cement-sheath evaluation. It is ultimately to assess the cement's integrity and ability to achieve its objectives throughout the lifetime of the well. It is not to interpret whether the logs indicate a "good" or "bad" cement bond. Such misguided practice tends to be more prone to error. It can cause financial loss and has, in part, given cement evaluation a bad name. Tools employed in logging operations have various physical limitations that will be described later; for this reason, one must never interpret logs in isolation, without the well and cementing data. Without a clear perspective and strategy for cement-sheath evaluation, one cannot defend against the age-old and often sensible assault. API 10TR1

> *If all we obtain from the logs is comfort when they look good, or discomfort when they look bad, but no confident remedial option, why do we waste time and money running the logs?*

Therefore, performing a cementing job correctly in terms of design and execution is far more important. However, proper evaluation is indispensable, and the evaluation process is a powerful tool if used appropriately to improve future jobs.

In Summary

0 psi 1,000 psi



CBL

Is the confirmed versus verified methodology enough to guarantee long term zonal isolation?

Effective mud removal critical

Cement design for isolation of Potential Flow Zones is extremely important if not critical to success

New federal and local cementing regulations demand proper planning, pumping, and evaluation of all cement jobs with requirements for zonal isolation across intervals with potential for flow after cementing.