Best Practices in Unconventional (Shale) Well Cementing

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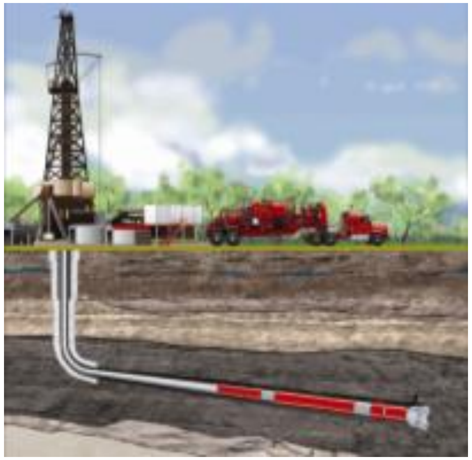
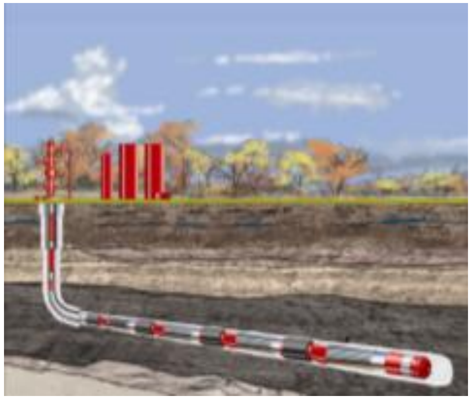
Agenda

- The Well Construction Process
- The Well Cementing Process
- Quality Assurance
- Cementing Placement & Evaluation
- USA Shale Well Experience
- Basin Specific Shale Best Practices





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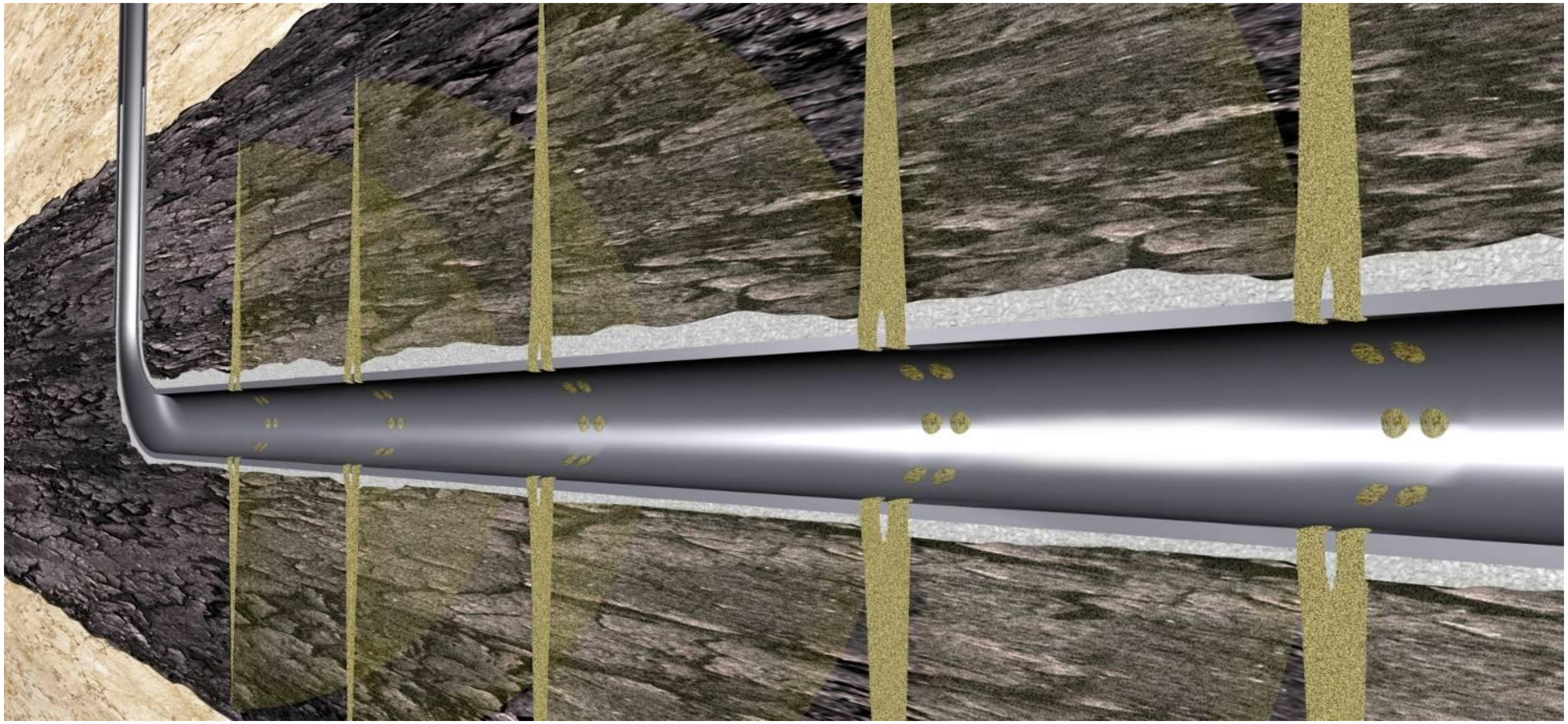
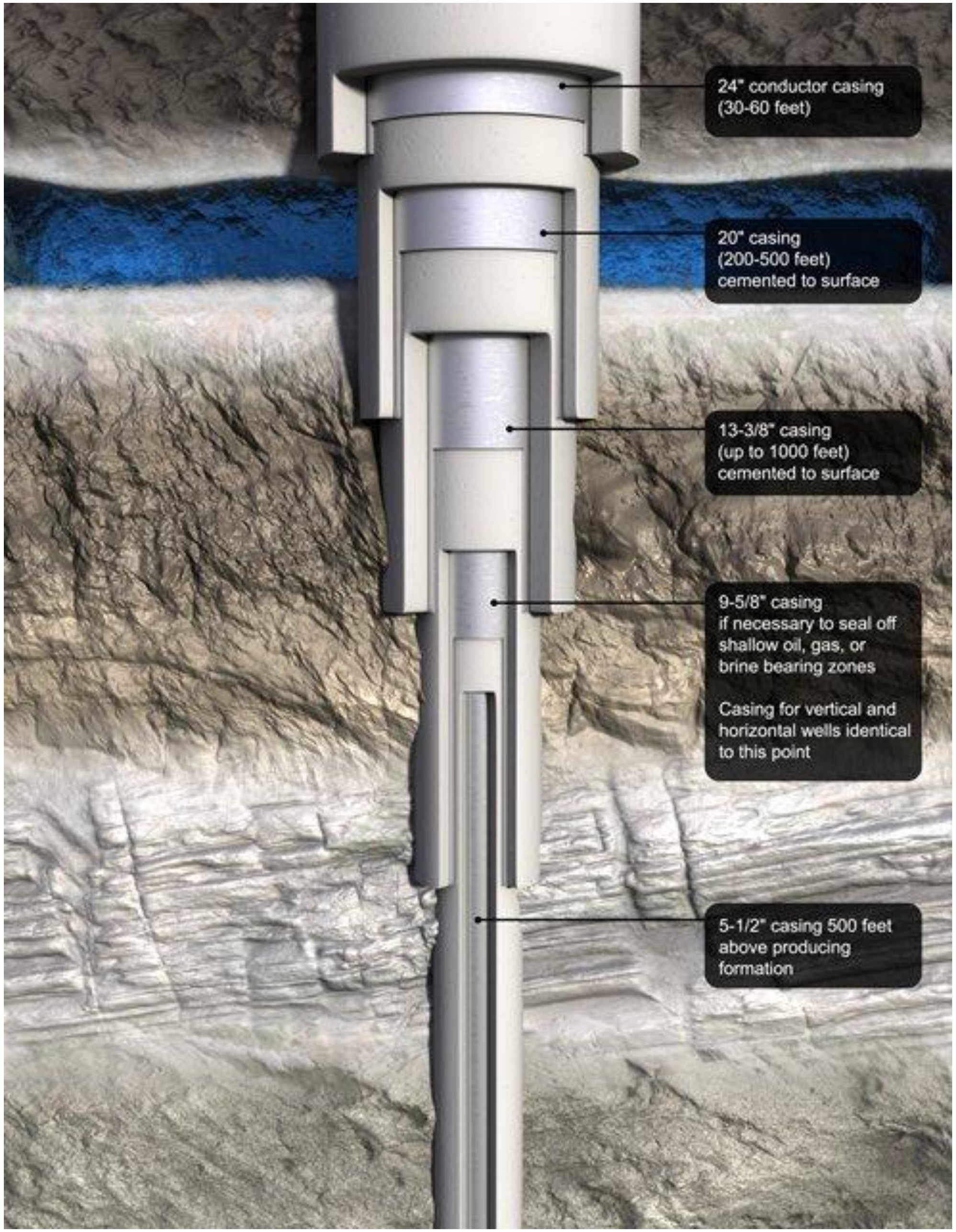
Well Construction

The Well Cementing Process

"Oil well cementing is the process of mixing a slurry of cement and water and pumping it down through steel casing to critical points in the annulus around the casing or in the open hole below the casing string."

Source: Society of Petroleum Engineers, Cementing Monograph Volume 4, 1990





Reasons to Use the Cementing Process

- Restrict fluid movement between formations
  - Manage formation pressures
  - Seal off zones (i.e. water, thief, producing)
- Bond and support the casing
  - Protect from corrosion
  - Protect from shock loads

Source: Society of Petroleum Engineers, Cementing Monograph Volume 4, 1990

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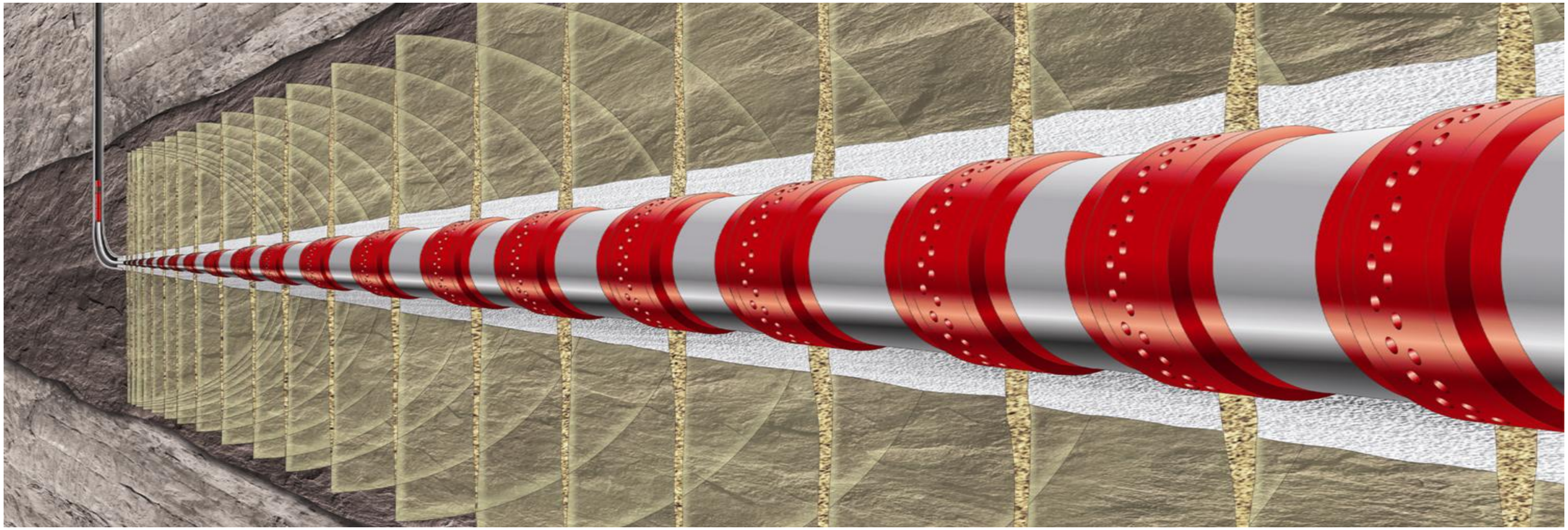
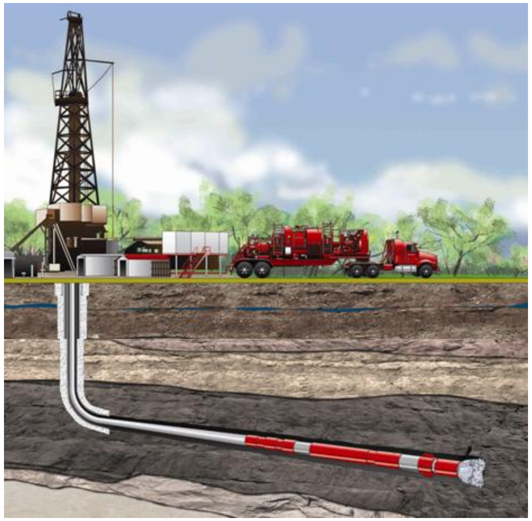
Purpose of Conventional Cementing

- Wellbore stability
- Zonal isolation
  - E.g., Seals annular space to provide hydraulic isolation (especially between fracture stages)



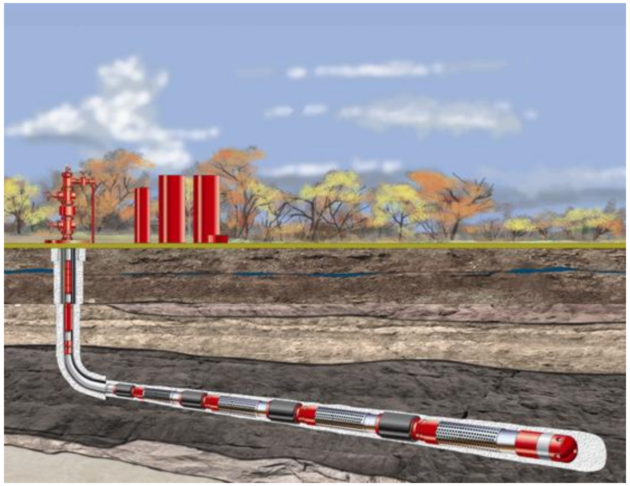
Cementing Process Goal:
Deliver Seal for the Life of the Well



Drilling

Completion

Production



BENEFITS OF LIFE-OF-THE-WELL CEMENTING
Long-Term Zonal Isolation
Help Increase Production and minimize the occurrence of sustained casing pressure
Help Minimize Remedial Costs
Help Reduce Environmental Impact

Key Elements of the Well Cementing Process

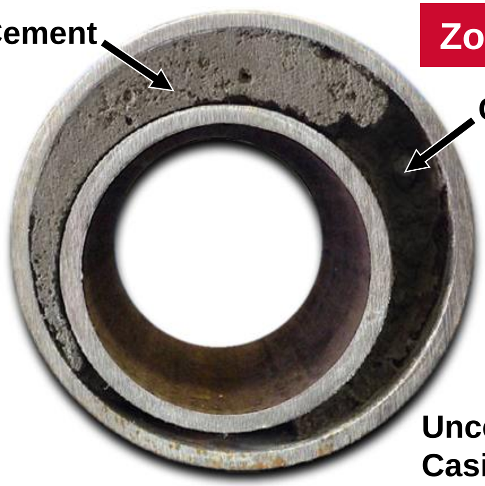
- **Materials**
  - Portland Cement (powder)
  - Cementing Additives
  - Water
- **Equipment**
  - Cement Mixing
  - Well Service Pumps
  - Cement Transport
- **Process Components**
  - Clean drilling fluid from the hole (displacement)
  - Avoid contamination of the cement
  - Cement slurry placement down hole – retain fluid characteristic
  - Quickly form a seal / harden once pumping has stopped – mechanical property development
  - Retain a seal for the life of the well

Cement Placement Planning Considerations

Cement

Zonal Isolation at Risk

Channel

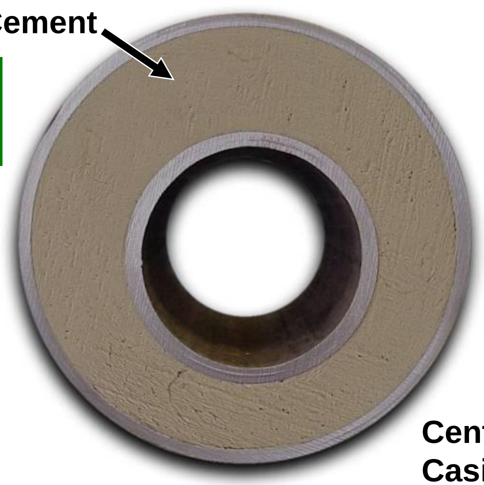


Uncentralized Casing

- Condition the Drilling Fluid
- Centralize the Casing
- Utilize Spacers & Flushes
- Move the Pipe
- Maximize Displacement Rate
- Design Slurry for Well Temperature
- Design Cementing System
- Test the Cementing Composition

Cement

Desired Zonal Isolation



Centralized Casing

(OGJ July 2001)

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Cementing Quality Assurance Standards

Cement slurries are designed using standards and procedures located in:

- ISO Standards
  - ISO10426-2 Testing of well cements
  - ISO 10426-3 Testing of deepwater well cement formulations
  - ISO 10426-4 Preparation and testing of foam cement slurries at atmospheric pressure
  - ISO 10426-5 Determination of shrinkage and expansion of well cement formulations at atmospheric pressure
  - ISO 10426-6 Methods for determining the static gel strength of cement formulations

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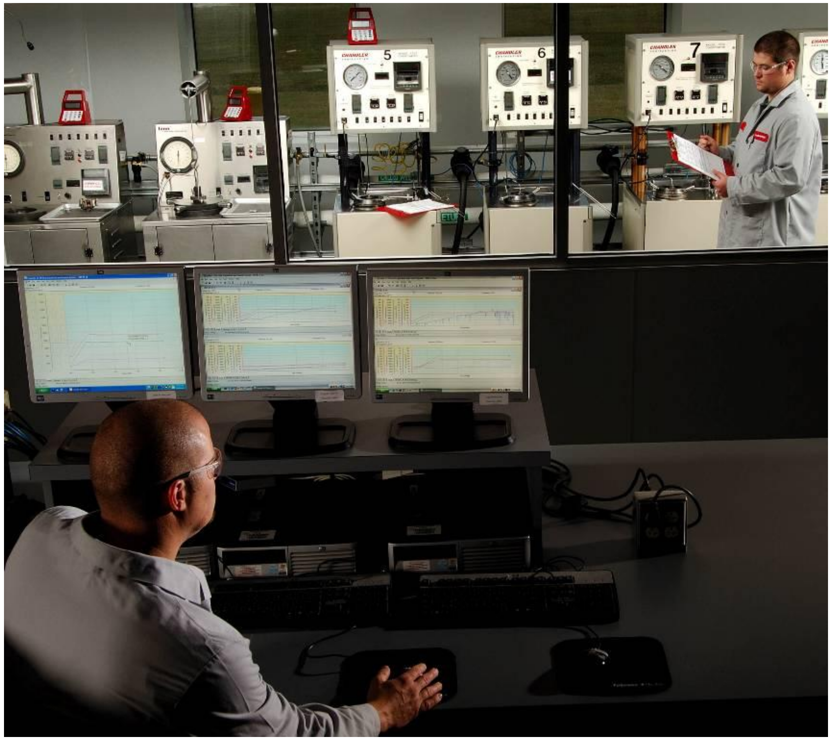
Cementing Quality Assurance Testing

Laboratory Testing
Thickening Time
Compressive Strength
Foam Compressive Strength
Free Water
Fluid Loss
Rheology
FYSA Rheology
Transition Time
Stability
Mud Balance Density
Slurry Mixability
Spacer – Mud Compatibility
Spacer wettability – conductivity
Spacer wettability – glass rod



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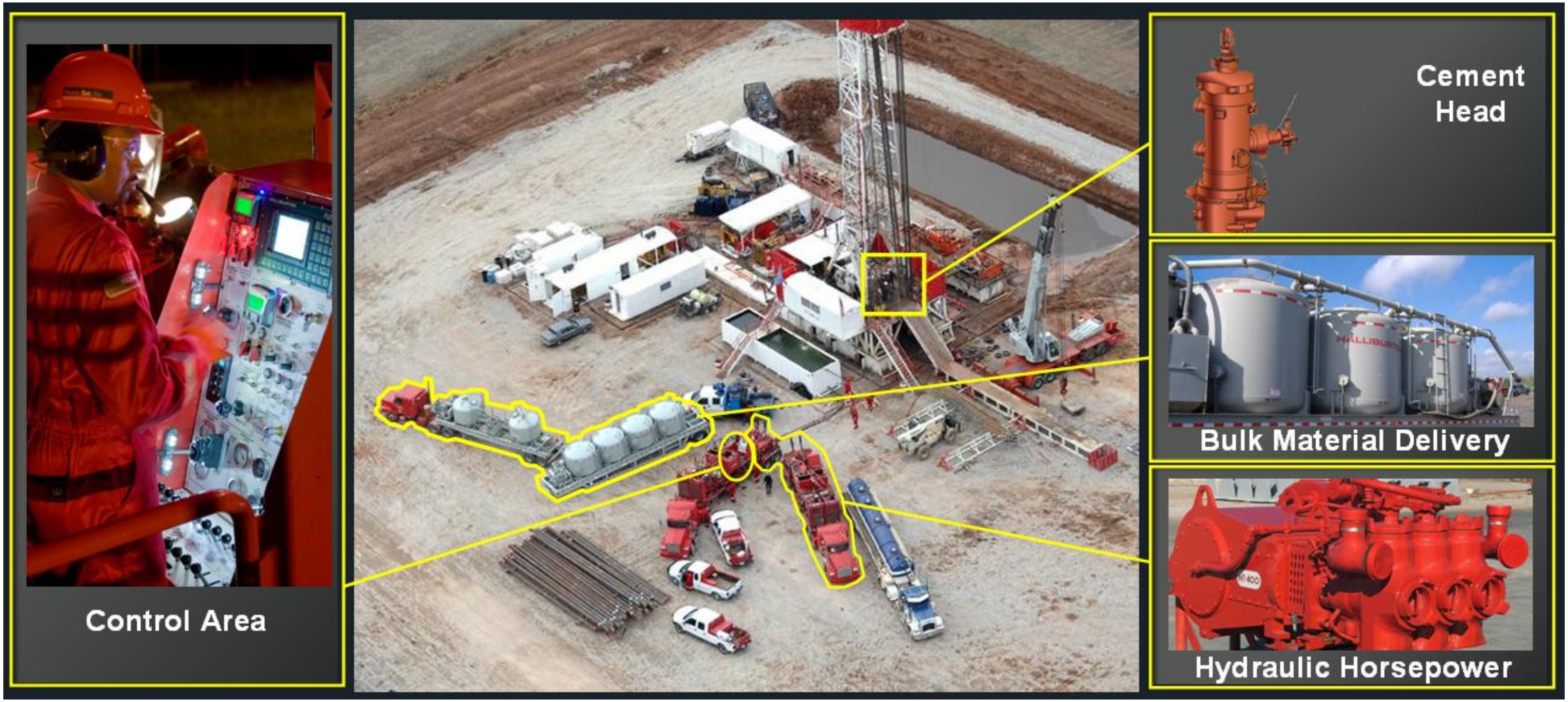
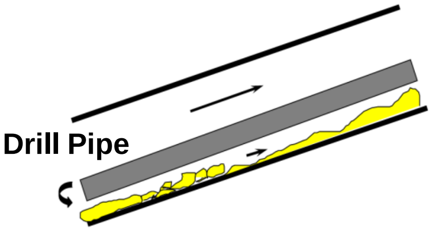
Cement Placement: Operations / Equipment



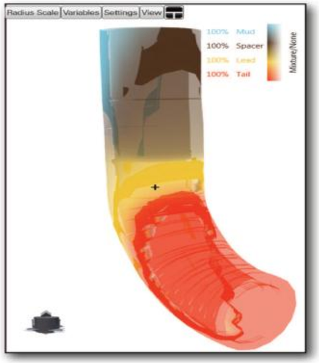
Cementing Placement

Implement Operational Plan



Maximize Pump Rate

- Mud Displacement Efficiency
- Dependent on drilling fluid (SPE 14198)



Hole Cleaning & Mud Properties

- Remove cuttings, Use Sweeps
- Optimize Mud Properties

Spacer Selection

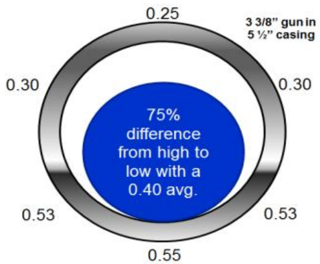
- Density, Viscosity, Volume
- Compatibility/Wettability
- Tuned Spacer IV & V

Mechanical Aids

- Rotation, Reciprocation
- Multiple bottom plugs

Temperature Determination

- WELLCAT™ Software, iCem® service, W. Logs
- DTS Fiber Optics



Industry Charge

Centralization

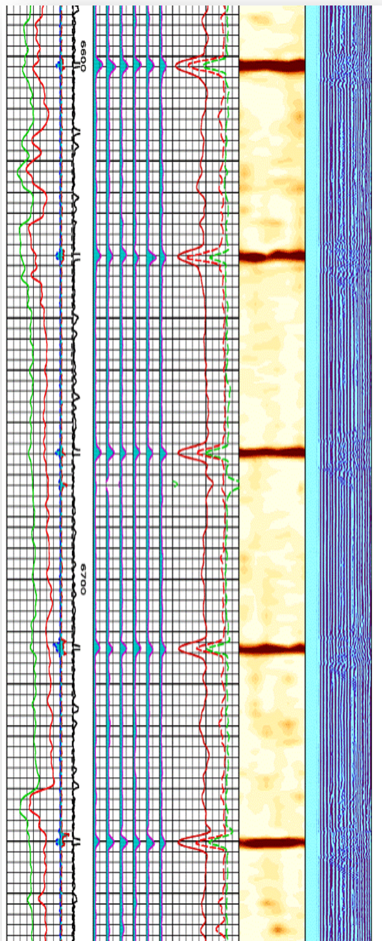
- Isolation between stages, Perf initiation
- Getting casing to bottom

ISO/API Standards & Applicable Management Systems

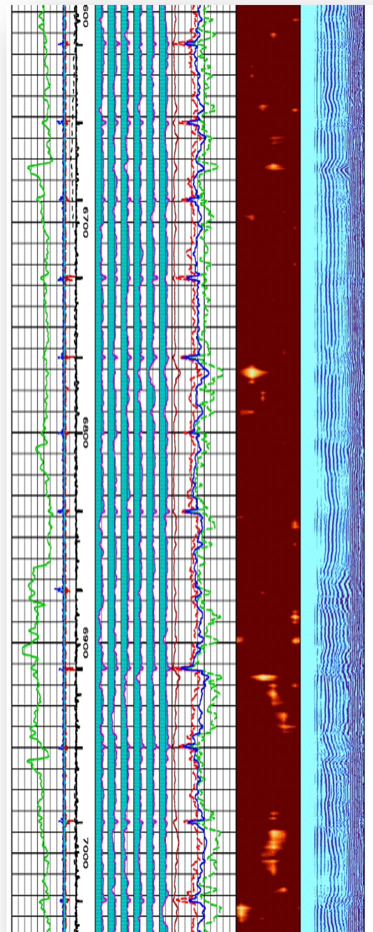
Results Evaluation

Poor Cement Placement

Poor Cement Bond Log



Excellent Cement Bond Log



Excellent Cement Placement

Poor cement placement can require remedial cementing operations

US Shale Play Characteristics – High Level Overview

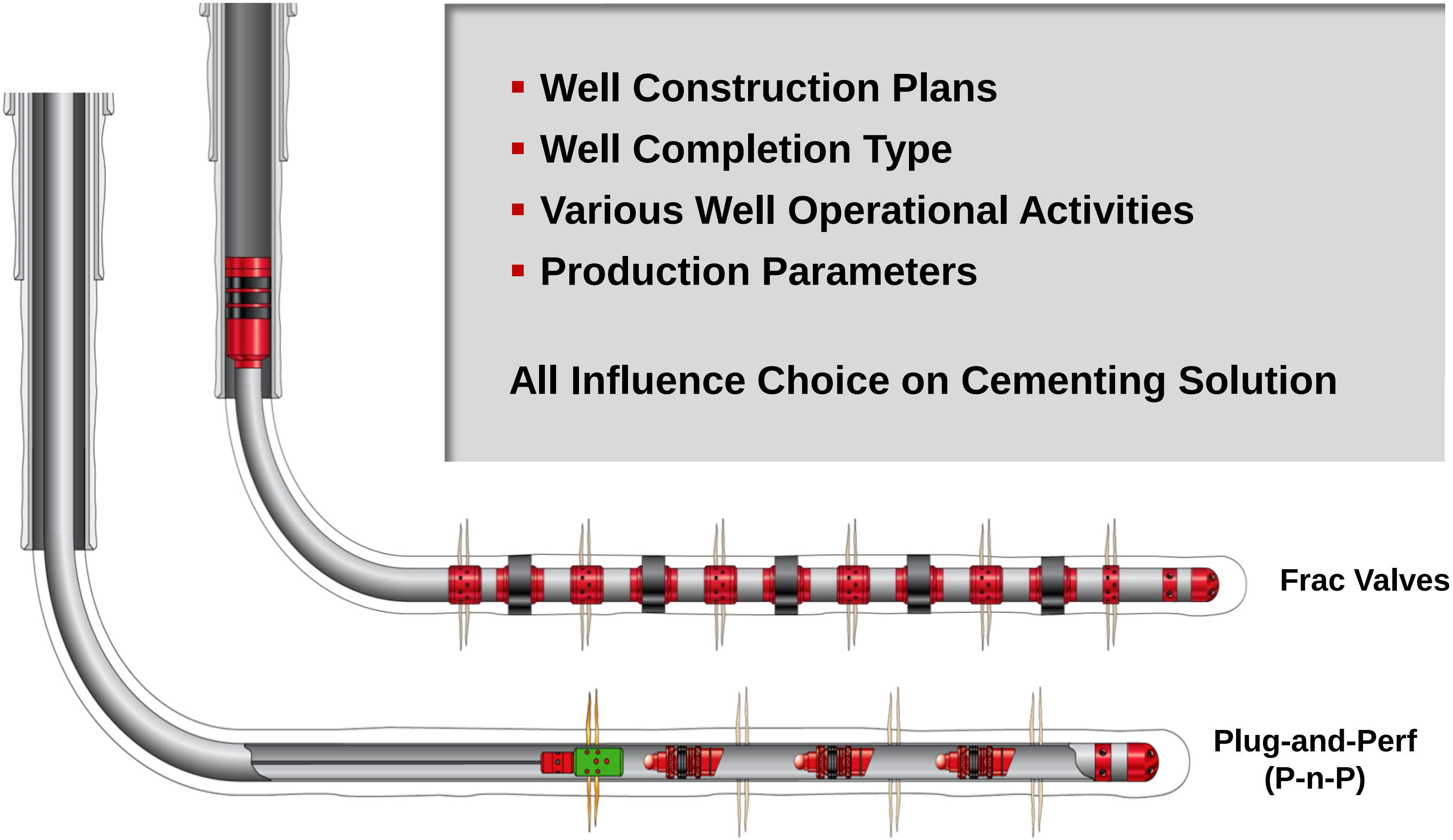
	Eagle Ford	Woodford	Haynesville	Bakken	Marcellus	Leonard
Hydrocarbon Type	Oil - Gas	Oil-Gas	Gas	Oil	Gas	Oil
TVD (ft)	4,000-14,000	6,000-9,000	10,000-13,500	9500-11000	4,000-8,000	5,000-10,000
Thickness (ft)	50-200	100-220	60-300	10-60	50 - 250	750 – 1,000
Horizontal section	5000-6000	1500-4000	4000-5000	4000 - 10000	2500-5000	2500-6000
Wellbore Orientation	NW - SE	N - S	N - S	EEN-WWS	NW - SE	N - S
Well Trajectory	3D	3D	3D	3D	3D	3D
Production hole	8 ½” - 8 3/4"	8 3/4"	6 1/2" - 6 3/4"	6"	8 3/4"	6 1/8” - 7 7/8"
DLS deg/100ft	12 - 16	10 - 15	13-18	10 -15	8 - 12	10 - 18
Mud Type	OBM	OBM	OBM	OBM	KCl	KCL / FW

All Shale Plays are Different – Influences Cementing Solution

Shale Resource – Well Construction Plans

- Well Construction Plans
- Well Completion Type
- Various Well Operational Activities
- Production Parameters

All Influence Choice on Cementing Solution



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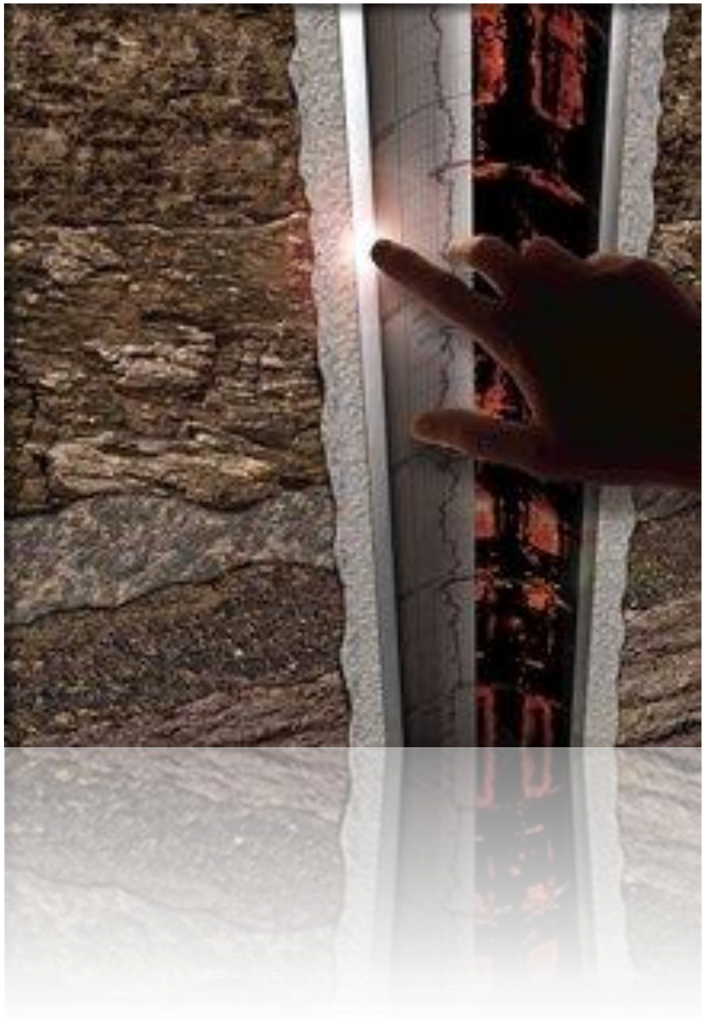
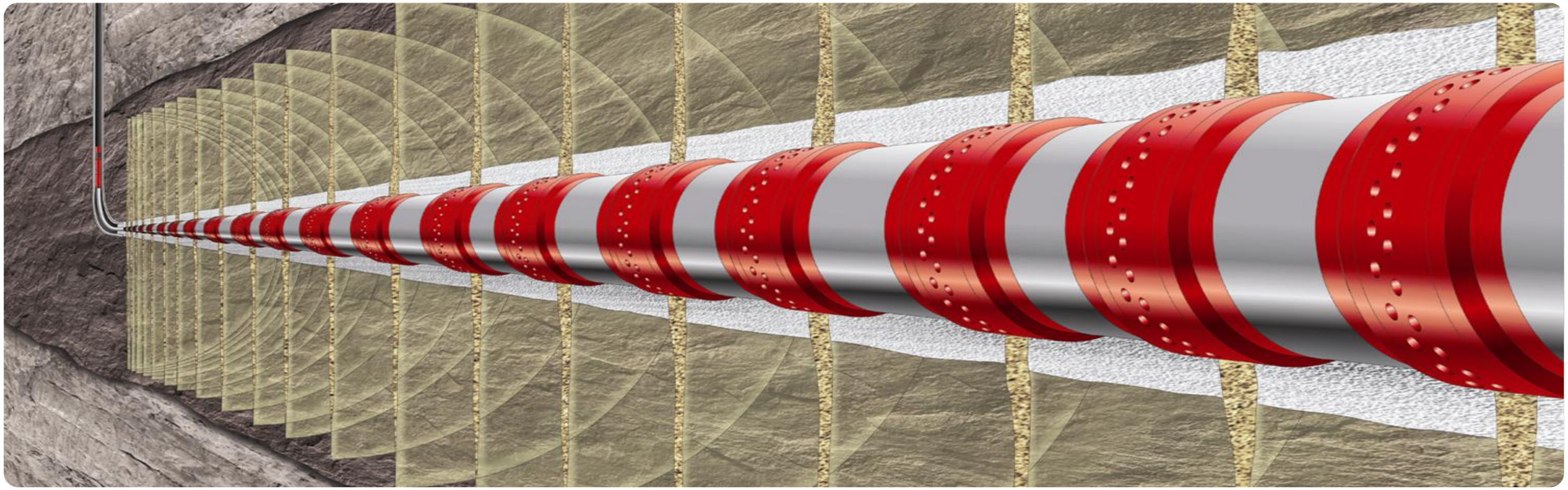
Cementing Solutions – Shale Cementing

- Conventional Cement
- Tuned® Light Cement
- Latex Based Cement
- Acid Soluble Cement
- ZoneSeal® Isolation Process
- WellLife® Cement
- WellLock™ Resin System



Eagle Ford Shale Cemented RapidSuite™ Completion Tools

Results:	**RapidStage™ System enabled 75% time savings and has resulted in higher initial production rates.**
Current Capability:	RapidStage: 2-7/8" thru 7", 26 Intervals
Current Capability:	RapidFrac: 4-1/2" & 5-1/2", 25 Intervals
Run History:	570+ RapidSuite™ Tools cemented; 215+ with ASC; 10+ Customers



For more info. on Cemented Sleeves reference "SPE-158490 "
Presenting at SPE ATCE; San Antonio, Oct. 2012

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Haynesville Shale and Latex Cement

- Deep, hot, extended reach horizontals
- Bridging issues across the region
  - Optimize fluid velocity through simulations

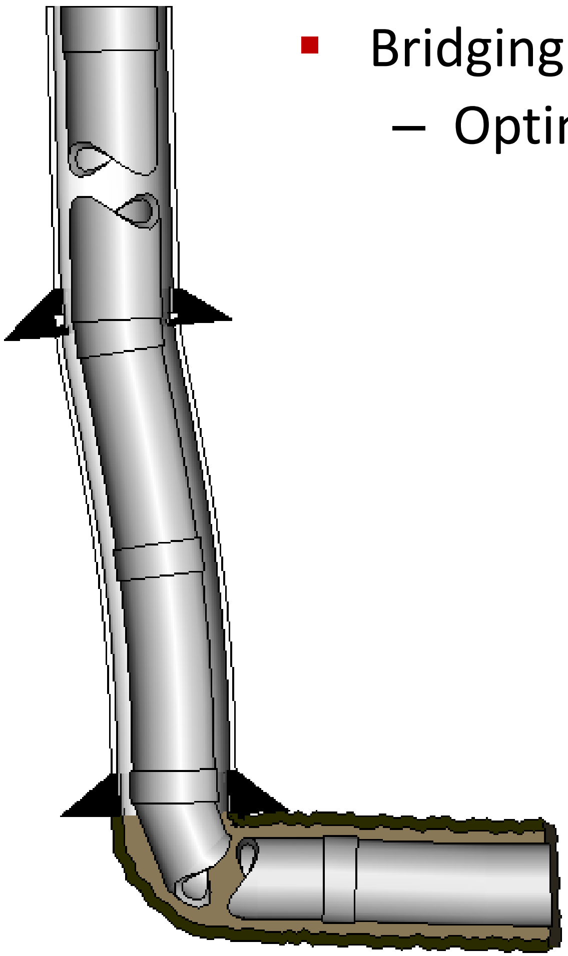


TABLE 5—WELLBORE PROPERTIES FROM JOB	
Measured depth (ft)	19,315
True vertical depth (ft)	13,400
Previous casing	7.625 in. 39 lb/ft at 12,344 ft
Open hole (in.)	6.25
Production casing	5 in. 23.2 lb/ft at 19,315 ft
BHCT (°F)	335
Mud type	Oil-based mud
Mud weight (lbm/gal)	15.4
Top of cement (ft)	5,800
Openhole excess (%)	15
Hole inclination at TD (°)	89
Pore pressure (lbm/gal)	15.4
Fracture gradient (psi/ft)	1.0

SPE 152730 “Latex-Based Cement Design: Meeting the Challenges of the Haynesville Shale,” presentation at Americas Unconventional Resources Conference, June 2012

Shale Well Construction Globally

Cementing Case History: Neuquén Basin Argentina

Major challenge

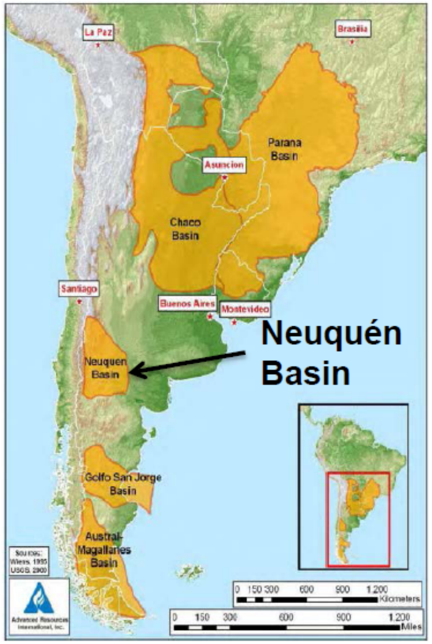
- Isolation of the layered production zone considering HPHT conditions & reduced pore-fracture pressure window.

Solution

- Use a Tail Acid Soluble Cement, for lower breakdown pressures during the hydraulic fracturing job.
- Use cement design with good technical properties (low fluid loss, good Compression Strength, stable at service temperature and able to prevent retrogression).
  - Also very low rheologies in order to decrease the ECD during pumping.

Results

- Decreased around 1000-1500 psi friction pressure during hydraulic fractures.
- Isolated the productive zones and obtained the required Top Of Cement according to the program.



Modified from EIA report; Stevens, Kuuskraa, etc.
Feb 2011

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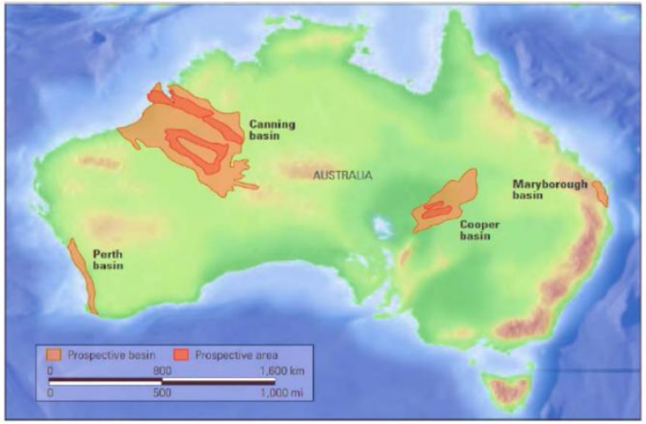
Shale Well Construction Globally

Cementing Case History: Cooper Basin Australia

Challenge

- HPHT wells - BHST 400°F
- Combination of cyclic heat loading and high fracture pressures



Modified from EIA report; Stevens, Kuuskraa, etc. Feb 2011

Solution

- Utilize cement job simulator (iCem® service) effectively
- Adhere to and push cementing best practices
- Use an elastic (WellLife) cement system above the reservoir zone to better prevent cement sheath failure
- Use Acid Soluble Cement (ASC) across the reservoir zone to reduce breakdown pressures

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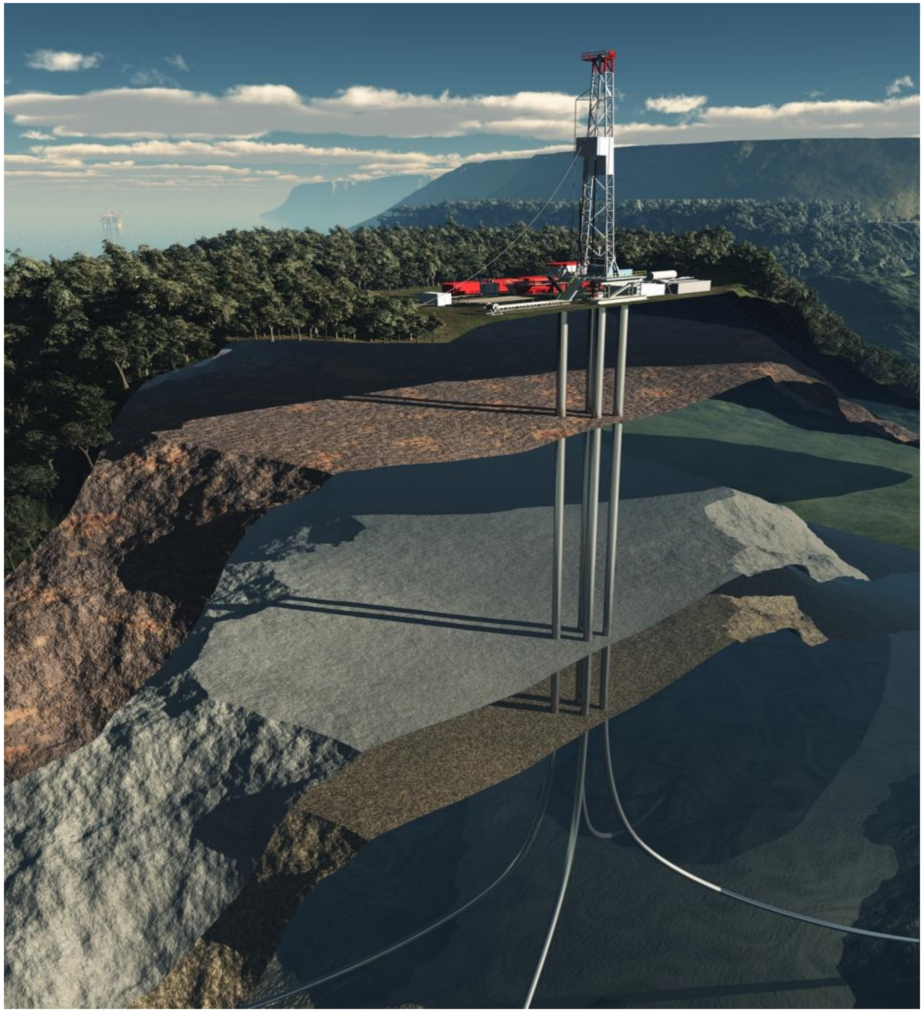
Best Practices in Shale Well Cementing



Well Construction/Cementing

Quality Assurance

Experience

Best Practices

THANK YOU