Prevention and Remediation of Sustained Casing Pressure and other Isolation Breaches

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Kyle Combs

CSI Technologies

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National Energy Technology Laboratory

Mastering the Subsurface Through Technology, Innovation and Collaboration:
Carbon Storage and Oil and Natural Gas Technologies Review Meeting

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Presentation Outline

- Introduction/Project Description
- Project Overview
- Technical Status
  - Prevention of SCP
  - Remediation of SCP
- Accomplishments to Date
- Summary
  - Key Findings
  - Lessons Learned
  - Future Plans

Benefit to the Program

- The major program goal being addressed is well integrity in onshore unconventional wells

- This research project is developing techniques to mitigate risks to well integrity associated with shale gas development, to remediate failed annular seal to stop communication in an existing well, to improve techniques that enhance lifelong wellbore annular isolation during the wellbore construction process, and to prevent potential annular seal failure which can cause sustained casing pressure (SCP) later in the well life

Project Overview:
Goals and Objectives

- Develop techniques to mitigate risks to well integrity associated with shale gas development
- Remediate failed annular seal to stop communication in an existing well
- Improve techniques that enhance lifelong wellbore annular isolation during the wellbore construction process
- Prevent potential annular seal failure, which can cause sustained casing pressure (SCP) later in the well life

Project Overview

- RPSEA funded project to:
  - Devise a protocol to asses gas flow potential and apply appropriate methods to prevent SCP
  - Devise a method to detect, diagnose, and remediate unwanted gas flow the result in SCP
- Focused in Fayetteville Shale

Image from www.searcychamber.com

Sustained Casing Pressure (SCP)

- API STD 65-2 defines SCP as pressure in an annulus of casing strings that is:
  - Measurable at the wellhead of a casing annulus that rebuilds to at least the same pressure level when bled down
  - Not due solely to temperature fluctuations
  - Not a pressure that has been imposed by the operator
- SCP is not an indicator of well failure, but is an indicator of poor wellbore integrity

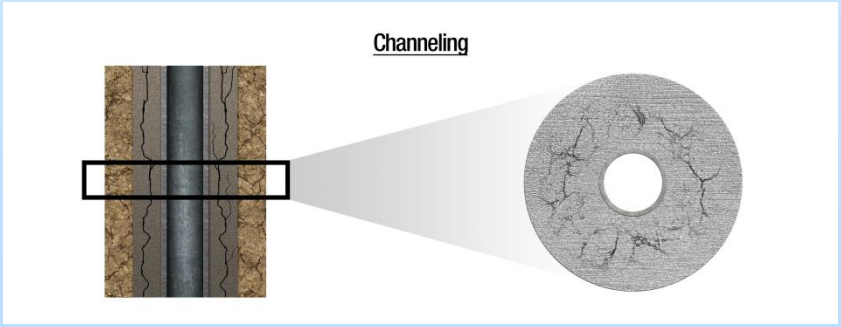
SCP Development Mechanisms

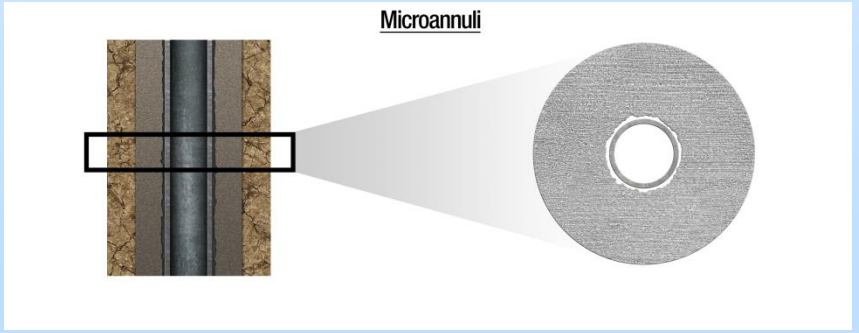
Short Term

- Occurs during cement setting reaction
  - Hydrostatic pressure reduction due to GST
  - Hydration Volume Reduction
- Channeling

Long Term

- Occurs after cement has set
  - Mechanical failure of cement
  - Poor mud removal
- Microannuli





Initial Fayetteville Shale Well Architecture

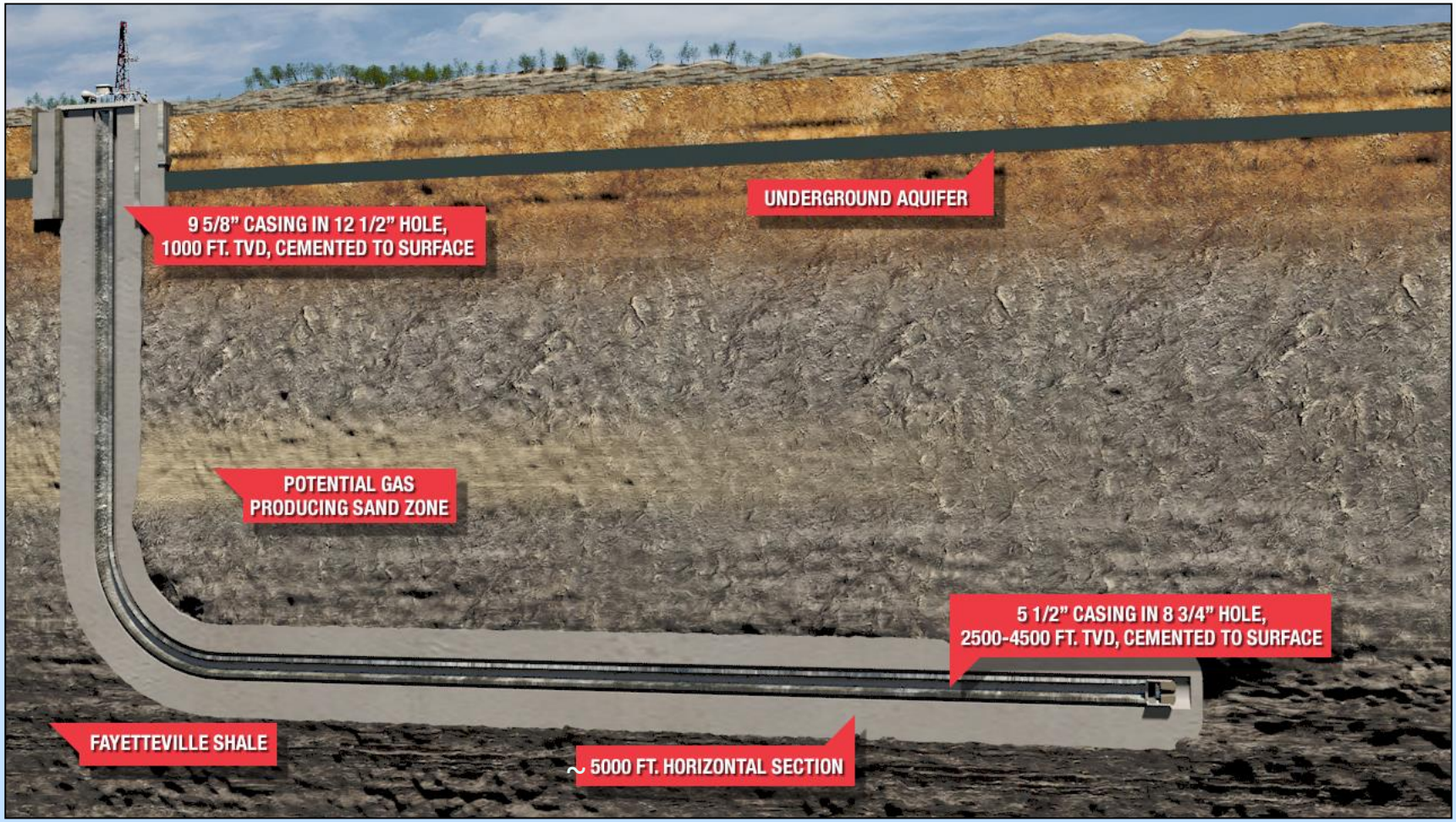
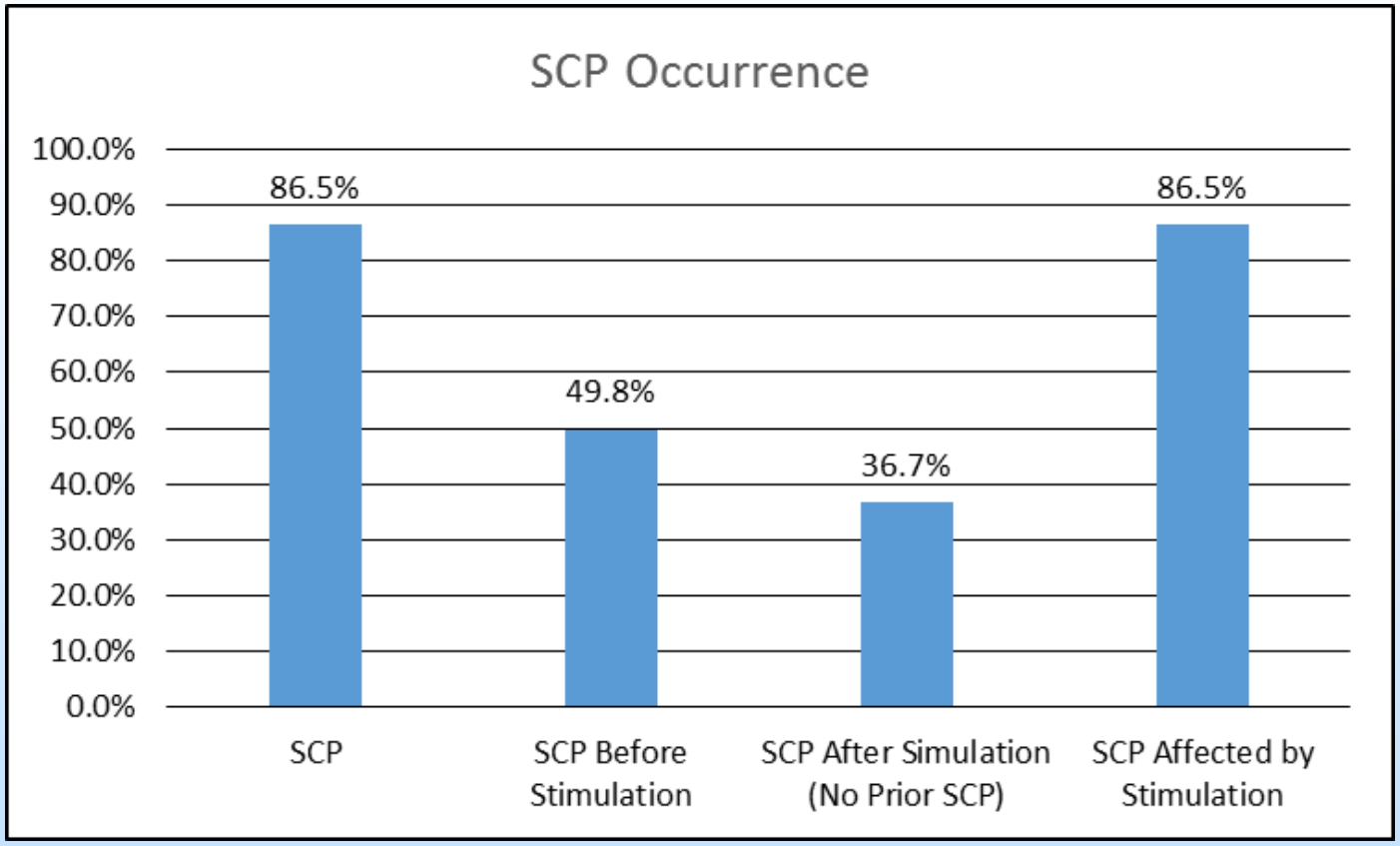


Image by Scott Holt, Wild Well Control Inc.

SCP Prevention In Fayetteville Shale

- Root cause analysis comprising of:
  - Comprehensive data mining campaign
  - Field personnel sent to location to observe cementing and stimulation operations
  - Current cement design testing

Data Mining Results



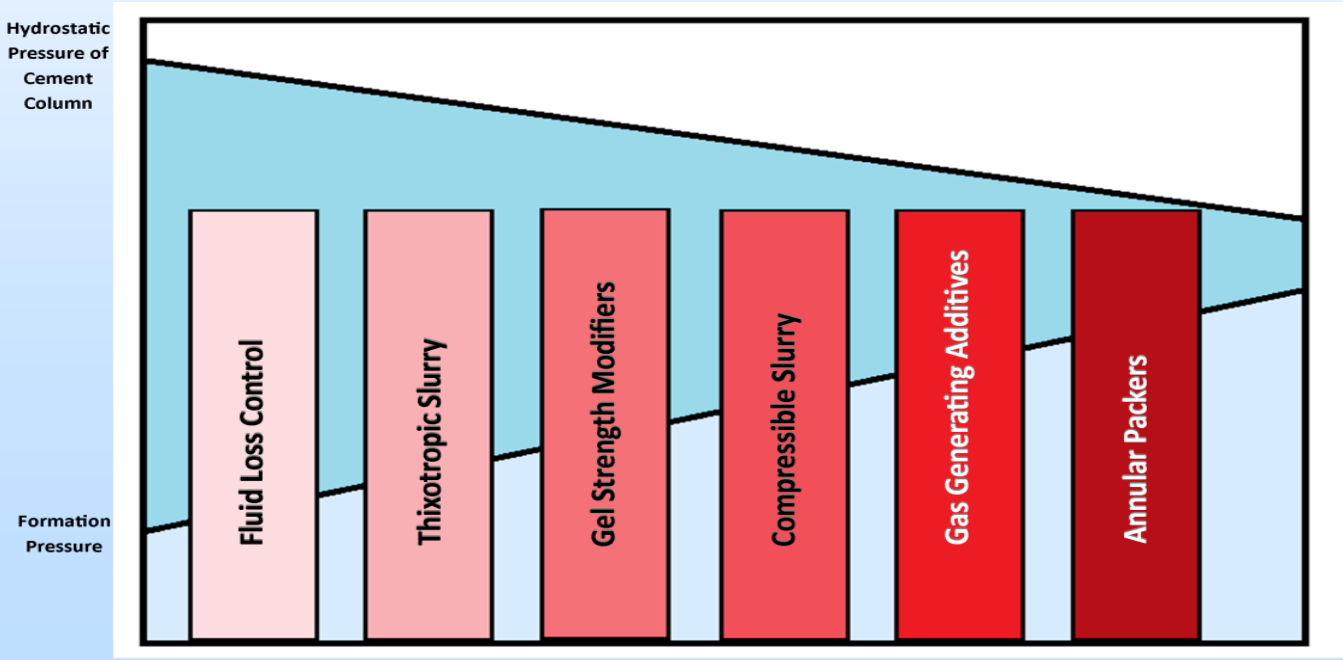
- **Both short and long term mechanisms present**

Cement System Testing Results

- Lead systems
  - Slow to develop compressive strength
  - Low ultimate compressive strength
  - High deformation
  - All results inadequate at surface casing shoe conditions
- Tail system
  - Adequate…but could be better

SCP Prevention Solution

- Optimize the lead system through density increase and additive manipulation
- Leave TOC below the surface



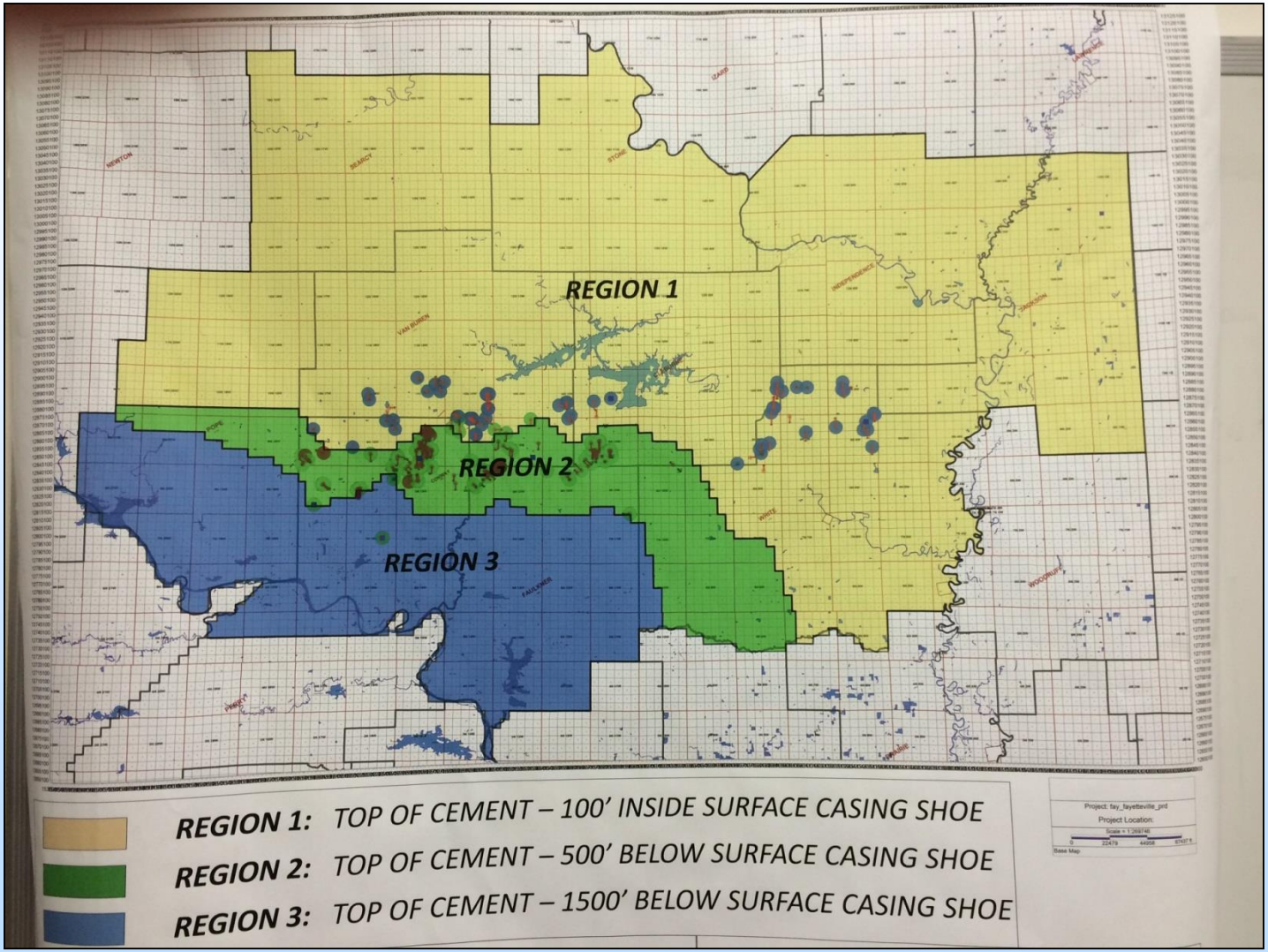
Cement to Surface

- 89.1% of wells with low TOC did not have SCP before stimulation
- Lowered TOC would allow:
  - Aid in the prevention of both short and long term mechanisms
    - Use of a higher density better quality cement
    - Shorter cement column, lower GFP
  - Provide numerous options should remediation be necessary

Regulation Change

- Proposed to change the regulation to allow for cement to be left below surface
- Change official as of May 22, 2015
  - Allows cement to be left below surface on production casing
  - Regulation change was driven directly from the results of the work done for this project

New Regulation



Results after Regulation Change

- Single cement system being used on all wells
  - 14.2 ppg
  - Increased FL Control, FF Control, Lowered GST
- Initial results indicate under 15% of new wells develop SCP – **70% reduction**
  - Limited sample size due to current economic status

Remediation of SCP

- “Perf and Squeeze” only option
- Much less than 50% success rate
  - Proper location difficult to determine
    - Educated guess based upon drilling logs
  - Proper sealant
    - Standard cement cannot penetrate annular flow pathways
  - Proper placement technique
    - Breaking down formation instead of squeezing into flow path

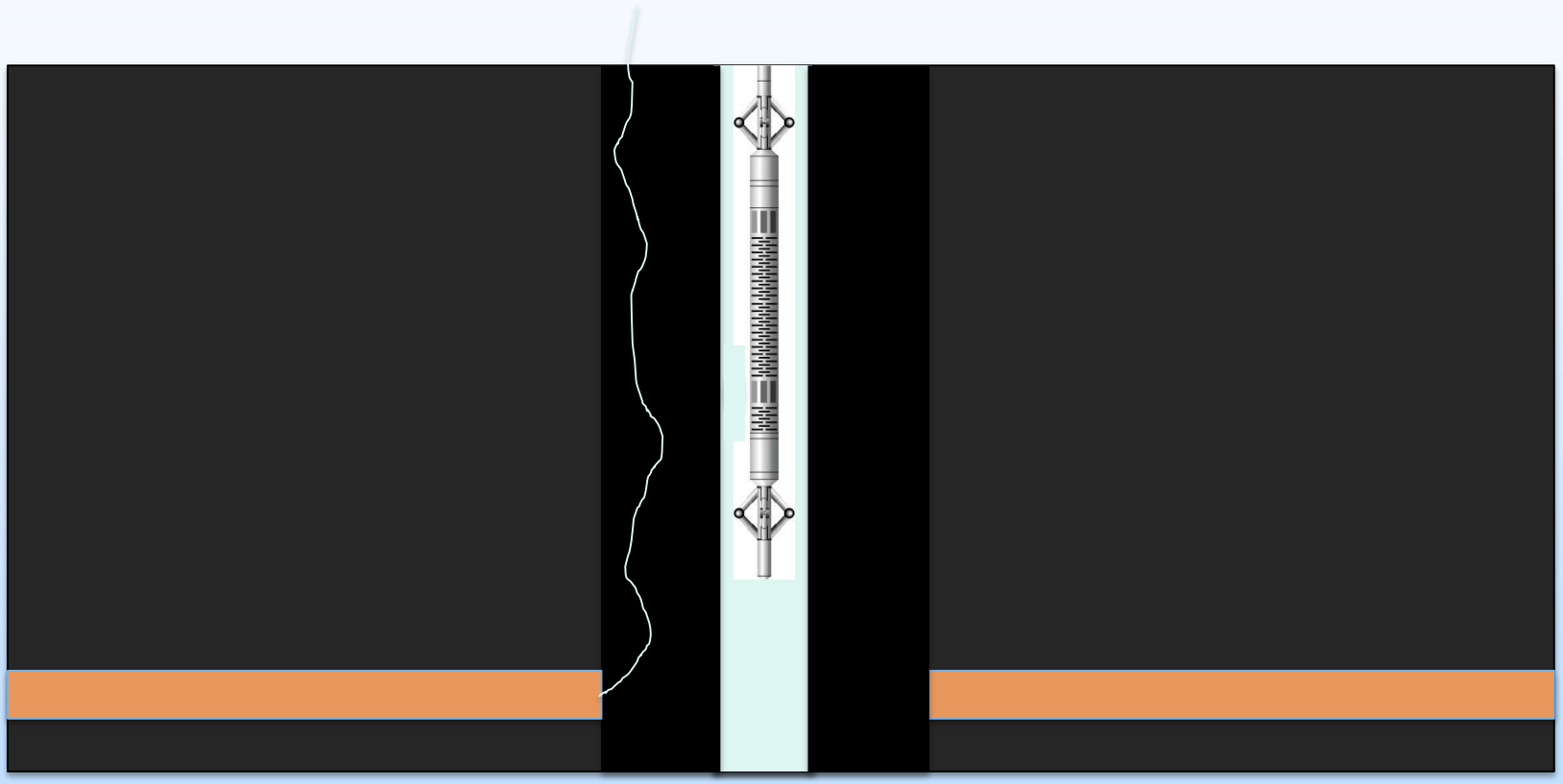
Proposed Remediation

- New method in development based on 4 important “needs”:
  - Location of flow pathways
    - Depth
    - Wellbore Orientation
  - Assurance of communication
  - Proper sealant selection
  - Proper sealant placement

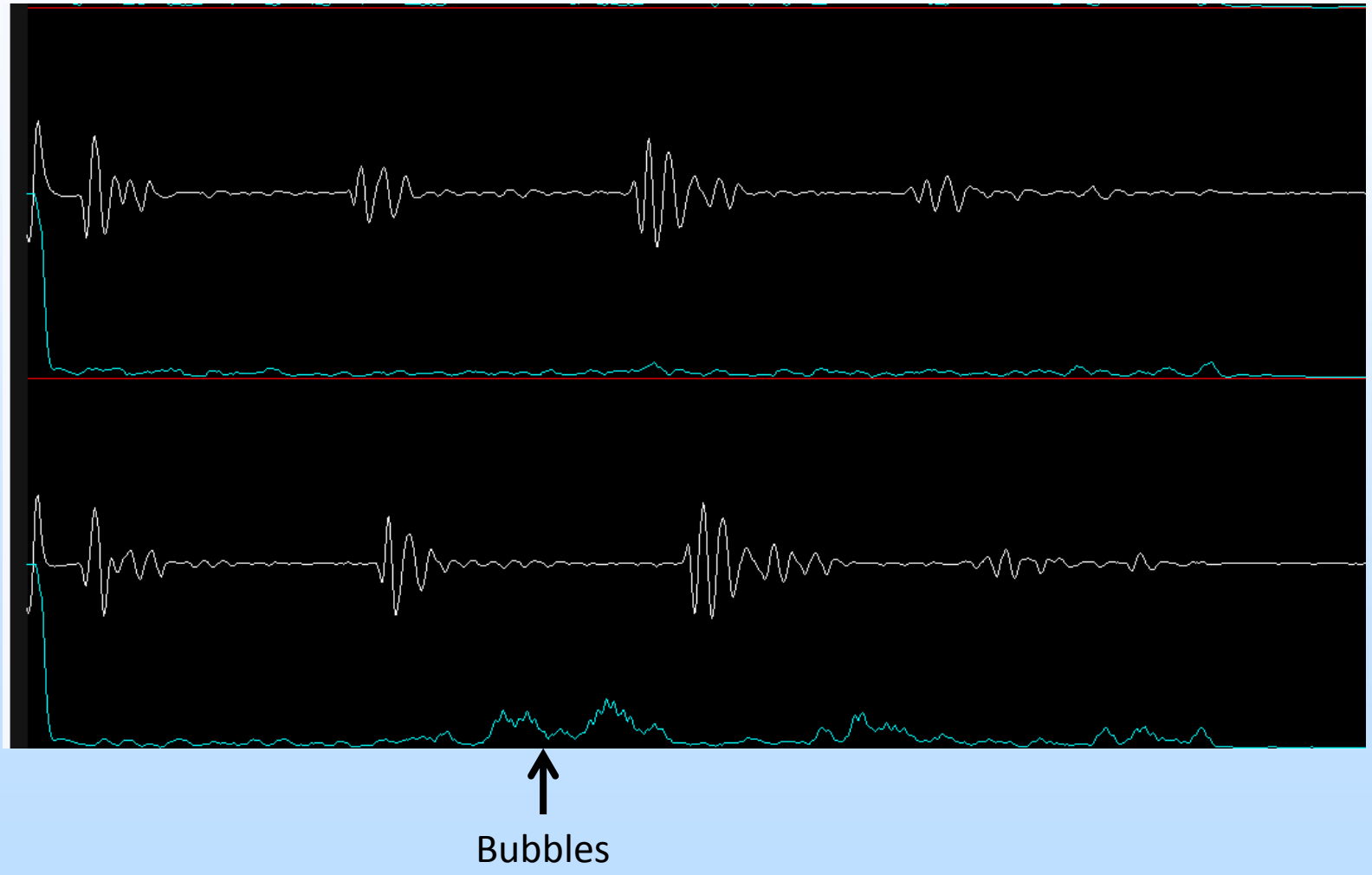
Developmental Flow Detection Methods

- Two methods in development to satisfy the first “need” of new remediation method
  - Active Method
    - Development of an Acoustic Tool
    - Based on “bubble detection"
      - Orientation and depth
  - Passive Method
    - Standard Low Frequency Noise Log Tool (NLT)
    - Developed signal analysis software
      - Depth and potentially type and magnitude of flow
- Used independently or jointly to locate flow

Active Method - Bubble Detection



Bubble Detection – Lab Testing



Active Flow Detection

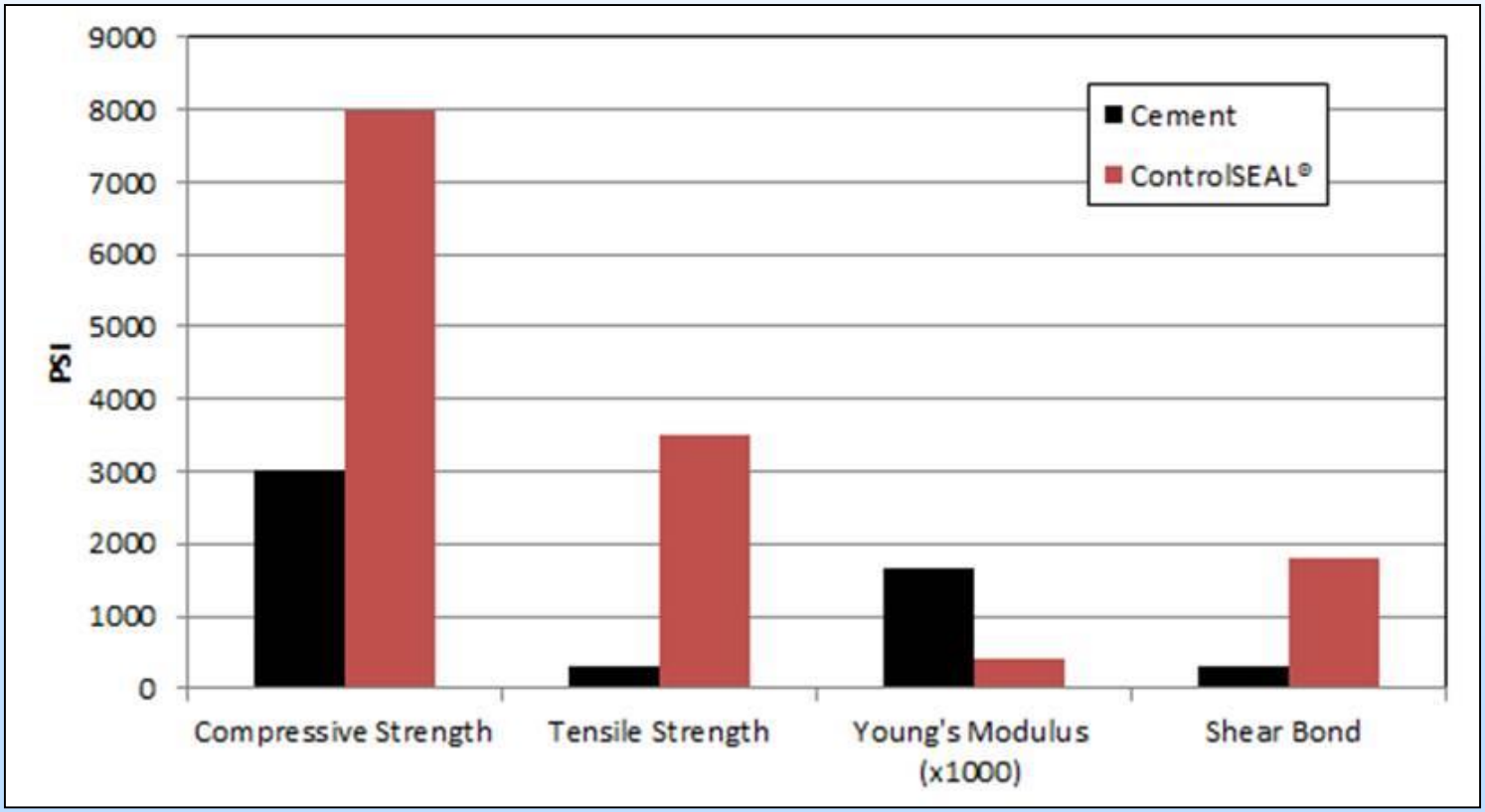
- Prototype built and successfully tested in lab
- Stipulation – 2 phases must exist in the annular flow path
- Awaiting field trial
  - Planned trial August 22, 2016

Remediation Sealant

- Identified and tested sealants capable of penetrating small annular flow pathways
  - Developed a resin system and determined it as the best candidate for sealant in SCP remediation operations
- Resin Placement Advantages
  - Newtonian flow behavior
  - Increased depth of treatment as this allows flow into micro-geometries unachievable by even micro-cements

Remediation Sealant

- Resin vs. Cement Mechanical Advantages:
  - Increased strength / flexibility / durability



Accomplishments to Date

- Prevention
  - Root cause analysis of SCP occurrence in Fayetteville Shale
  - Changing of cementing regulations in region to allow for cement to be left below surface
  - Improvement of cement system currently being used

Accomplishments to Date

- Remediation
  - Behind casing flow detection tool prototype developed (to be tested August 22nd, 2016)
  - Resin sealant developed and tested that will provide superior mechanical properties and penetration than standard or specialty cements

Synergy Opportunities

- Collaboration among projects could provide the following benefits to this project:
  - Additional sealant technologies for annular barrier remediation
- From this project:
  - Resin being used as a sealant in annular sealing operations
  - Behind casing flow detection

Key Findings

- Using an in depth, detailed root cause analysis to identify and categorize the development mechanisms of an issue is key in determining how to resolve that issue
- SCP can be controlled and prevented through engineering and cement design optimization
- Ultrasonic tools are capable of detecting bubbles behind casing using the dual pulse method

Upcoming Operations

- Prototype tool field trial – 8-22-16
- Remediation method and resin sealant field trials
  - August 10, 2016
  - August 17, 2016
- Final report for project will be finished and submitted by September 30, 2016

Thank You / Questions

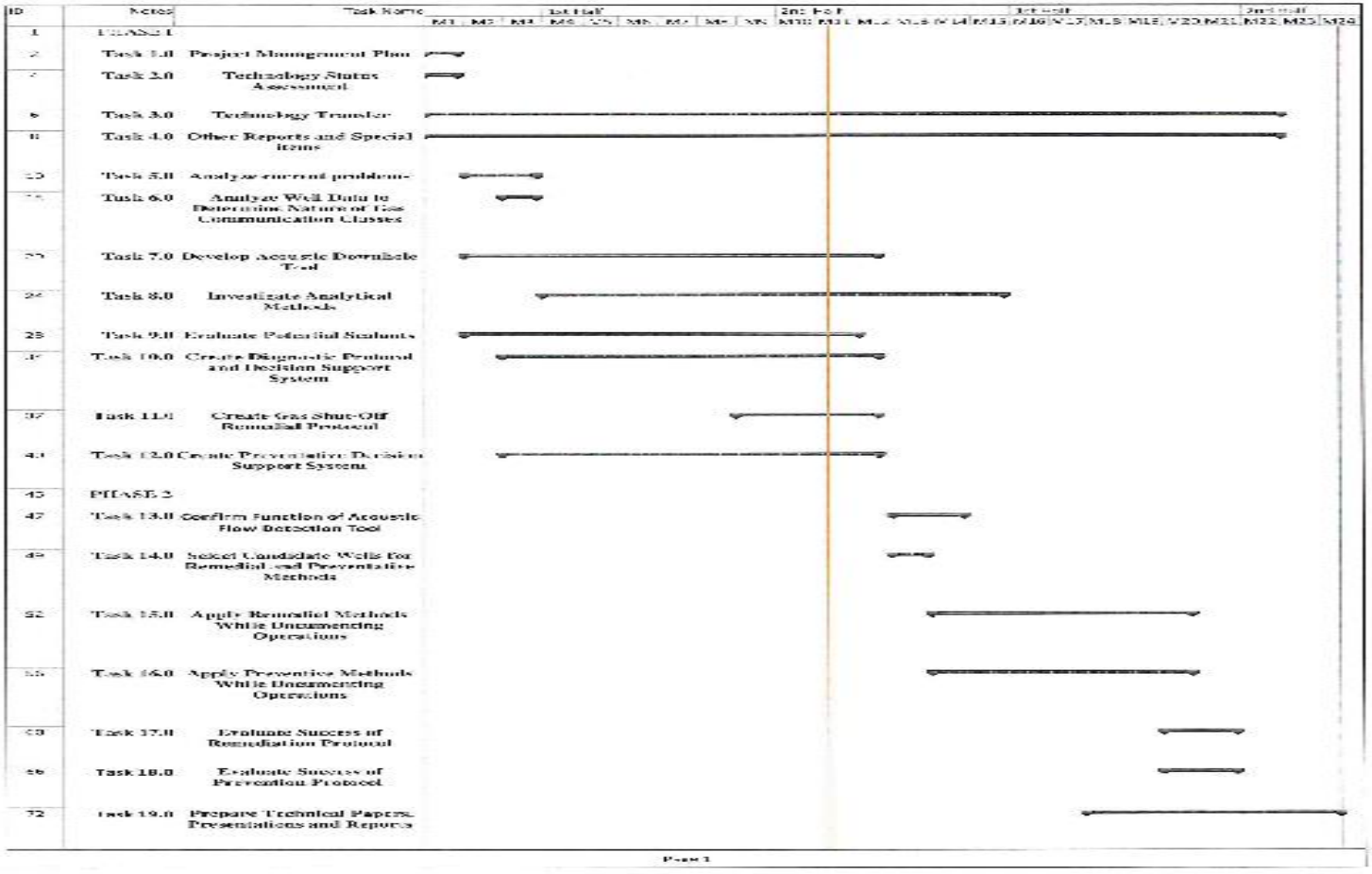
Funding for the project is provided through the “Ultra-Deepwater and Unconventional Natural Gas and Other Petroleum Resources Research and Development Program” authorized by the Energy Policy Act of 2005. This program—funded from lease bonuses and royalties paid by industry to produce oil and gas on federal lands—is designed to assess and mitigate risk enhancing the environmental sustainability of oil and gas exploration and production activities. RPSEA is under contract with the U.S. Department of Energy’s National Energy Technology Laboratory to administer three areas of research. RPSEA is a 501(c)(3) nonprofit consortium with more than 180 members, including 24 of the nation's premier research universities, five national laboratories, other major research institutions, large and small energy producers and energy consumers. The mission of RPSEA, headquartered in Sugar Land, Texas, is to provide a stewardship role in ensuring the focused research, development and deployment of safe and environmentally responsible technology that can effectively deliver hydrocarbons from domestic resources to the citizens of the United States. Additional information can be found at www.rpsea.org

Appendix Slides

Organization Chart

- Project team:
  - CSI Technologies (Primary)
    - Majority of research on prevention and remediation parts of the project
    - Project Manager
  - Southwestern Energy
    - Partnering Operator for this project
  - The Measurement Group (Subcontractor)
    - Prototype flow detection tool development
  - University of Houston (Subcontractor)
    - Aided in root cause analysis

Gantt Chart


ID
Task Name
Task 1.0 Project Management Plan
Task 2.0 Technology Status Assessment
Task 3.0 Technology Transfer
Task 4.0 Other Reports and Special Items
Task 5.0 Analyze current problems
Task 6.0 Analyze Well Data to Determine Nature of Gas Communication Classes
Task 7.0 Develop Acoustic Borehole Tool
Task 8.0 Investigate Analytical Methods
Task 9.0 Evaluate Potential Sealants
Task 10.0 Create Diagnostic Protocol and Decision Support System
Task 11.0 Create Gas Shut-Off Remedial Protocol
Task 12.0 Create Preventative Decision Support System
PHASE 2
Task 13.0 Confirm Function of Acoustic Flow Detection Tool
Task 14.0 Select Candidate Wells for Remedial and Preventative Methods
Task 15.0 Apply Remedial Methods While Documenting Operations
Task 16.0 Apply Preventive Methods While Documenting Operations
Task 17.0 Evaluate Success of Remediation Protocol
Task 18.0 Evaluate Success of Prevention Protocol
Task 19.0 Prepare Technical Papers, Presentations and Reports

Bibliography

- Kaufman, H., Shadravan, A., Song, G., and Sutton, J. 2013. Devil is in the Details. Oilfield Technology, September 2013.
- Combs, N. K., Watters, L. T., McDaniel, J., Maki, V., & Hall, C. R. D. (2014, August 28). The Development of a Tool and Methods to be used in Flow Path Detection behind Casing for use in the Fayetteville Shale. Society of Petroleum Engineers. doi:10.15530/urtec-2014-1922758