Talk Overview

1. Introduction/review of the U.S. Strategic Petroleum Reserve
2. General storage cavern operations
3. Recognition of integrity issues from pressure signature
4. Multi-arm Caliper data analysis
5. Case study – BH-105B
6. Why is this happening?
7. What is our best path forward?
8. Summary
The U.S. Strategic Petroleum Reserve

- SPR is spread across 4 Gulf Coast site locations
- Current oil inventory of about 700 million barrels
- Composed of 62 solution mined caverns
- About 120 cavern access wells – differing completions
- Mixture of pre-existing and purpose-built caverns
- Length of cased well sections range from ~1400 to ~2500 feet
- SPR – owned by DOE
  - Managed/operated by FFPO
  - SNL geotechnical advisors
The U.S. Strategic Petroleum Reserve

Overlying Strata

Salt Dome - plastic

Caprock - rigid

Gulf of Mexico
The Four SPR Sites

- Bryan Mound
- Big Hill
- Bayou Choctaw
- West Hackberry
SPR Cavern Operations – How Oil is Moved In and Out
Recognition of Well Integrity Issues at Big Hill

• 2009 - Recognition of loss of pressure integrity for BH-105B and BH-109B
• Wells subsequently remediated via liner installation
• Multi-Arm Caliper (MAC) Surveys of SPR wells started in 2010
Use raw radial arm measurement data to compute a summary parameter that describes radial casing deformation as a function of depth.

Investigations show that the coefficient of variation – \( Cv \) – of the diameter values provides a robust indicator of casing deformation suitable for differing well configurations.

**Nearly Circular Cross Section**

Diameter values nearly equal
Low \( Cv \) values

\[ Cv = \frac{\sigma}{\mu} \]

**Deformed Cross Section**

Diameter values vary significantly
Higher \( Cv \) values
SPR Well Grading System

- Well grading framework developed for SPR
- Considers geology, simulation results, cavern geometry, well history, etc.
- Main driving components are MAC survey data and pressure history

Grading Data Tabulation

Summary Plots
Cv Values Allows for Well-to-Well Comparisons

Three vertical plots showing the coefficient of variation (Cv) for BH-110A/BH-114A, BH-112A/BH-114A, and BH-112B/BH-114A. Each plot compares the depth in feet (ft) against Cv values.
Cv Values Provide Basis for Time-Dependent Analysis

BH-103B
Cv Values through time

2012 MAC on original casing

2014 MAC on new liner

2018 MAC on new liner

2014 Liner Cv Curve

2018 Liner Cv Curve
BH-105B Case Study

- BH-105B completed in Dec. 1984
- 2010 MAC shows significant casing deformation
- 2011 new well liner cemented in place
- 2020 evidence of deformation of the brine string
- MAC survey of the brine string indicated it deformed
- 2020 removal of the brine string and MAC survey of the liner showed severe deformation
- Geologic forces had deformed:
  - 20” outer casing
  - 13.375” original inner casing
  - 10.75” liner
  - 8.625” hanging string

27 years
9 years
Why is this Happening?

• Severe, rapid casing deformation at the salt-caprock interface is limited to the Big Hill SPR site.

• What is different about the Big Hill site?
  • Cavern operations are similar, caverns have desirable shape
  • Wells have well designed completions
  • Each dome has unique geology
  • Site nominal caprock thicknesses
    • Bayou Choctaw 200 – 300 feet
    • Bryan Mound 200 – 400 feet
    • West Hackberry 350 - 400 feet
    • Big Hill 850 – 1300 feet
Why is this Happening? Is there a spatial pattern?

- Deformation is always at the salt-caprock interface
- Deformation occurs over a narrow vertical interval
- Greatest level of deformation typical on western side of site
- No clear correlation to surface subsidence
- Some correlation to results from geomechanical modeling
- Maybe associated with different salt spines?
What is the best path forward?

- Current wells and remediations use cemented steel casings
- Are there other completion techniques and/or materials better suited to this dynamic environment
  - Packer and tubing completion
  - Deformable annular materials
- How do we know which completion and materials are best
- Mechanical/Geomechanical simulations of different options
  - Challenges in parameterizing simulations
  - Pull information from previous MAC surveys
- Going forward, MAC surveys will have absolute orientations to allow for better understanding of forces and comparisons with simulations
Summary, Conclusions, and Further Questions...

- The DOE SPR is a strategic resource currently storing 637 million barrels of crude oil.
- The Big Hill site currently holds 144 million barrels stored in 14 caverns.
- Certain cavern access wells at Big Hill are experiencing severe deformation at the salt-caprock interface due to geologic forces.
- These geologic forces are on-going and can not be stopped.
- Remediation of the deformed casings is necessary to assure cavern integrity.
- Historic liner installation remediations have demonstrated that liners may succumb to geologic forces within 10-11 years requiring further remediation.

**What are the specifics of the geologic mechanism causing this deformation?**

- **Are classic cemented-liner type remediations still the best option?**
- **Are there well completions and remediation options that will increase well longevity?**
  - Packer and tubing type completions
  - Deformable or more plastic annular materials
  - Larger diameter wells
  - Thicker casing material
  - Combination of the above?

- **Is there anyway to predict when this type of phenomena will arise?**
- **These questions need to be answered in order to move forward in an informed manner.**
Thank you

Questions?

Albuquerque Balloon Fiesta