Understanding Mechanical Integrity Testing and Underground Gas Storage: The Key to Success

Prepared by:
J. Daniel Arthur, P.E., SPEC (ALL Consulting)
Tom Tomastik, C.P.G. (ALL Consulting)
Jeff Kennedy (ALL Consulting)

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Discussion Items

- Introduction
- Major Issues and Concerns
- Objectives of Integrity Testing
- Testing Methods & Technologies
  - Well casing & cementing review
  - Well integrity testing
  - Well logging
- Conclusions

Source: ALL Consulting, 2016
Introduction

• Mechanical integrity testing of underground gas and hydrocarbon storage wells is a critical aspect of long-term success for any gas storage project.
• Gas storage wells vary widely in age and construction and can include storage wells that are over 70 years in age, converted oil and gas production wells, and wells completed into bedded or domal salt deposits and aquifers.
• Testing and evaluation methods for assessing mechanical integrity can vary considerably do to the variation in well age and construction.
• Regulatory scrutiny of well integrity and its assessment has increased due to recent incidents such as Aliso Canyon.
• A holistic, risk-based approach to mechanical integrity testing with specific testing methods that are appropriate for gas storage wells, should be used to facilitate the determination of well integrity.
Major Issues and Concerns

• The loss of well integrity is one of the greatest threats to gas or hydrocarbon storage.

• A large percentage of existing gas storage fields in the U.S. were converted from depleted oil and gas reservoirs with many wells not drilled and completed to today’s standards.

• Therefore, well integrity is an ongoing issue in many storage reservoir fields that must be addressed using the proper well integrity testing methodologies and remediating any well integrity deficiencies.

Source: Southern California Gas Company, 2017
OBJECTIVES OF INTEGRITY TESTING
What is Mechanical Integrity?

- **General Definition**: The design, installation, operation and maintenance of all well equipment to a standard that ensures the safe containment of well fluids and injectate for the life of the well.

- **Types of Integrity**: Internal and external integrity must be considered and evaluated.

**Internal Integrity Considerations**
- Wellhead Integrity (e.g. hanger leak, configuration)
- Casing and Tubing Integrity (e.g. casing and collar leaks)
- Casing corrosion and damage
- Annular Fluids
- Packer and Plug Integrity

**External Integrity Considerations**
- Cement Bond (casing and formation)
- Casing Seat/Formation Integrity
- Annular Fluids
- Cement Slurry
- Casing corrosion and damage
- External Packers
- External Fluid/Gas Migration
- Cavern Integrity

Source: ALL Consulting, States First Gas Storage Workshop, 2017
Integrity Testing Objectives

- Well integrity testing can help ensure the following objectives are met:
  1) Protection of USDWs or other protected groundwater
  2) Proper well configuration for the demands of underground gas and hydrocarbon storage
  3) Safety and risk prevention
  4) Meeting regulatory goals and operational demands.

- Test objectives and methodology should be tailored for gas storage wells.

- Industry standard testing methodologies were often developed for production and injection wells and may not be appropriate for the assessment of gas storage wells.

Source: ALL Consulting, 2013
Holistic Well Integrity Evaluation

- A complete assessment of mechanical integrity requires a holistic, risk-based approach.
- This approach does not rely on any single tool, but evaluates overall well integrity using a variety of industry standard tests and logs that have been refined to achieve specific testing objectives.
- No single test or log can provide a proper determination of mechanical integrity.
- The holistic well integrity assessment process should include a series of analytical reviews and tests which includes but is not limited to:

  - Well Casing & Cementing Review
  - Well Integrity Testing
  - Well Logging
  - Routine Monitoring
Assessing Casing and Cement

- Casing and cement evaluation is a critical step in the assessment of well integrity.
- Understanding cementing methods is critical. Insights regarding hole preparation, procedures, cement types, additives, etc. is important.
- Cement evaluation logs provides insight into level of cement bond to the casing and formation as well as cement integrity conditions including:
  - Micro-annulus
  - Channeling
  - Compromised cement
- A wide variety of cement evaluation logs are available each with distinct advantages.
- It is vital to understand wellbore conditions to prevent erroneous interpretations.

Source: DOGRM, 2013
Cement Evaluation Log Examples

- Acoustic Cement Bond Log (CBL)
- Digital Magnelog (DMAG): Electromagnetic multi-frequency, multi-spacing casing inspection log.
- Radial Analysis Bond Log (RAL): Improved cement evaluation capabilities
- Segmented Bond Log (SBT): Quantitatively measures cement bond integrity in six angular segments.

Source: Baker Hughes, 2013
TESTING METHODS & TECHNOLOGIES
Mechanical Integrity Tests

Internal Integrity Tests
• Standard Annular Pressure Test (SAPT)
• Infrared Imaging
• Downhole Video Log
• Nitrogen-Brine Interface Test (Cavern Wells)
• Freshwater-Brine Interface Test (Cavern wells)

External Integrity Tests
• Pressure Build-up Testing
• Annular Venting Flow Rate Test
Mechanical Integrity Testing Challenges

- Test methods and objectives must be specifically tailored for gas storage wells!
- To meet testing objectives, detailed implementation procedures and explicit requirements for test results should be established.
- Proper quality control procedures must be implemented to ensure accuracy of test results.
- Tests which require the removal of tubing, change of downhole conditions, or an insertion of new tools downhole introduce some risk to well operation.
- Risks associated with performing tests should be considered when determining testing schedules.

Source: ALL Consulting, 2016
Source: ALL Consulting, 2012
WELL LOGGING
Well Integrity Logging

• A multitude of logging methods and technologies are available for the assessment of mechanical integrity.

• Examples of logging methods include:
  – **Geophysical Logs**: Temperature Log, Audio Log, Ultrasonic Noise Log, etc.
  – **Corrosion Logs**: Multi-Finger Caliper Log, Electromagnetic Casing Inspection Log, Magnetic Flux Leakage Tool, Ultrasonic Casing Imager
  – **Cement Evaluation Logs**: CBL, RCBL, Cement Evaluation Tool, Segmented Bond Tool, USIT, etc. (discussed in previous slide)

• As with integrity testing, the logging method and procedures must be specifically tailored for gas storage wells.

• Not all logging methods are appropriate for the assessment of gas storage wells.
Geophysical Logging Examples

• **Temperature Logs**
  – One of the most basic logging tools used for downhole evaluations.
  – Wellbore temperatures that deviate from an expected gradient can help identify fluid flow in the wellbore.

• **Audio Logs**
  – A series of audible sound measurements recorded at prescribed intervals throughout a wellbore.
  – Audio frequency and amplitude provide insight into the type of flow (e.g. single vs two phase flow) and relative magnitude of flow.

• **Ultrasonic Noise Log**
  – A relatively new sound log that focuses on monitoring sound characteristics of gas leaks through casing.
  – Unlike audio logs, ultrasonic logging measure energy in the 40 KHz range where energy from a small casing breach is likely to occur.
Corrosion Log Examples

- Corrosion is almost impossible to prevent.
- Controlling and monitoring of corrosion is often the preferred approach to managing corrosion.
- It is a concern throughout the life of the well and therefore must be monitored throughout the life of the well.
- There are several corrosion logs available including:
  - Multi-Finger Caliper Log
  - Electromagnetic Casing Inspection Log
  - Magnetic Flux Leakage Tool
  - Ultrasonic Casing Imager
Conclusions

- A complete assessment of mechanical integrity requires a holistic, risk based approach.
- This holistic approach should assess mechanical integrity and draw results based on an overall well evaluation analysis.
- No single test or log can provide a proper determination of mechanical integrity.
- Testing and logging methods must be specifically tailored for gas storage wells.
- Routine monitoring, testing, and record keeping for the life of a well can ensure mechanical integrity objectives are met.
CONTACT INFORMATION

J. Daniel Arthur, P.E., SPEC
Project Manager
darthur@all-llc.com
ALL Consulting
Tulsa, OK
www.all-llc.com

Citation Information: