A PROACTIVE APPROACH TO ADDRESSING ANNULAR PRESSURE ISSUES AND STRAY GAS MIGRATION IN THE UNCONVENTIONAL SHALE PLAYS

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Introduction

Stray gas migration associated with the unconventional shale play development in the U.S. continues to be an area of concern.

Source: DMRM, 2010
Technical Challenges

• Stray gas zones and high reservoir pressures can create complex well control and primary cementing issues.

• These issues can lead to inadequate cement jobs and poor isolation of gas-producing formations.

Source: DOGRM, 2013
Annular Overpressurization

• The lack of isolation can cause sustained positive annular pressure behind multiple casing strings.

• Sustained annular pressures can lead to annular overpressurization and non-compliance of regulatory requirements.

Source: Harrison, 1985
Annular Pressure Regulatory Requirements

• A number of states have amended well integrity standards, particularly in those states where unconventional shale development has occurred.
• States such as Ohio and Pennsylvania have developed detailed regulatory requirements addressing annular pressure issues.
• These requirements include critical pressure limitations to casing shoes and pressure monitoring during stimulation operations.
Well Integrity Remediation

Source: ALL Consulting, 2015
Remediation Methods

• A multitude of remedial options are available, each having distinct advantages as well as challenges and concerns.

• All options should be fully evaluated when selecting the appropriate remedial method.

• Perforating and squeezing is a common remedial method.
  – Detailed squeeze procedures should be developed.
  – Procedures should be designed for the conditions at each well.
  – A variety of sealing materials with varying physical properties can be utilized for squeeze operations.

Source: ALL Consulting, 2015
Alternatives to Remedial Action

- Perforating and squeezing may not be necessary if wellbore methane gas intrusion can be controlled at the surface.
- Alternatives to perforating and squeezing include:
  - Continuous and long term pressure monitoring.
  - Plumbing casing strings to sales lines of the production operation.
  - Connecting the casing strings with annular pressure issues to a high pressure separator with a pressure relief valve for controlled venting and blow down.
  - Internal well integrity concerns (e.g. casing leaks) can often be controlled through the use of packers to isolate the leak and fluid filled tubing annulus to prevent migration of gas through the leak.
Well Integrity Assessment for Gas Migration Investigations

Source: ALL Consulting, 2015
Well Integrity

• A critical component of any gas migration investigation is the evaluation and assessment of well integrity at adjacent oil and gas wells.

• What is Well Integrity?
  – Well integrity can be simply defined as a lack of significant leakage within the well and wellbore.
  – Both internal and external integrity must be considered and evaluated:
    • Internal Integrity: Well casing, tubing packers, etc.
    • External Integrity: Cement, mud, annular fluids, etc.
Holistic Well Evaluation

- The presented well evaluation process was designed to facilitate the determination of well integrity and potential relationship with alleged gas migration incidents.
- The evaluation process is based on a holistic approach that does not rely on any single assessment tool but evaluates the overall well integrity by assessing the well through a litany of tests.
- No single finding alone is sufficient; rather, when evaluation methods are used in concert, a proper assessment of well integrity can be made.
Advanced Well Integrity Methodology

ALL Consulting has developed a comprehensive annular pressure methodology that includes site investigation, monitoring, analysis, and management of annular pressures.

Source: ALL Consulting, 2015
The Process

1. Identification of wells with potential positive annular pressure issues.
2. Wellhead field inspection and evaluation using standard well integrity practices.
3. Review of well construction, cementing, geology, and completion details.
4. Perform pressure and volumetric analysis.
Shut-in Pressure Build-Up Tests

• Shut-in pressure tests are used to quantify and characterize pressure build-up rates in casing or annular spaces.
• A shut-in pressure test consists of closing the valve on the casing annulus being tested and allowing the annular pressure to build over the duration of the test.
• Continuous collection of pressure data using transducers with data loggers is critical to fully understand annular pressure.
• The data recorded during the test allows for construction of a curve which provides a graphical representation of the pressure over time.
• The results can then be interpreted to assess the nature of the pressure within the annulus and may provide insight into the source of pressure.
Shut-in Pressure Test Equipment Setup

Pressure transducer and Data Logger
Test Assembly
Surface casing riser

Source: ALL Consulting, 2014
Quality Control for Pressure Testing

• Pressure testing of annular spaces requires quality control to achieve a good test.
• Leak testing should be done during or before pressure is bled off.
• If piping is exposed, freeze precautions may be required.
• It is critical that test procedures are developed and implemented for field personnel to utilize.

Source: ALL Consulting, 2014
Shut-In Pressure Build-Up Analysis

- Characteristic shut-in pressure build-up curves have been observed during the evaluation of thousands of tests.
- Identification of build-up curve signatures has allowed for a more robust analysis of annular pressure which may provide insight into the source.
- Testing errors and anomalies can also be identified based on build-up curves signatures.
Evaluation of Pressure Trends

- The evaluation of trends requires the repeated performance of tests over time.
- Shut-in pressure test results can be plotted using several methods, including chronological and elapsed time.
  - A chronological plot of end of test pressure data allows for extrapolation of expected future pressure test results.
  - Graphing repeated shut-in pressure build-up curves on a single chart (elapsed time) can demonstrate the depletion of pressure build-up rate over time and can demonstrate effectiveness of remedial measures if implemented.
Vent Rate Testing and Analysis

- Vent rate tests are performed to quantify the volume of gas that may be present in the casing or annulus.
- In conjunction with shut-in pressure build-up tests, they help to identify and characterize wellbore methane gas intrusion and are a key component in the assessment of well integrity.
- An orifice well tester or the critical flow prover can be used to provide a quantitative measurement of flow.
- If a flow rate is less than the reportable limit for the instrument being used, qualitative testing using either a balloon test or bubble test may be conducted.

Source: ALL Consulting, 2015
Bubbling Cellar Assessment

• Wells may exhibit “bubbling cellars” when rising gas reaches standing water in the cellar of the wellhead.
• Observation and measurement of the size and frequency of the bubbles may be used to estimate the volume of gas emanating from the well or cellar.
• Infrared video can be a valuable tool to evaluate well conditions.
• Infrared video can provide a visual representation of gas flow from the well or cellar.

Source: ALL Consulting, 2015
Infrared (IR) and Methane Gas

Passive infrared imaging of gas leaks visualizes radiation from the gas itself and the adsorption of background radiation by the gas. When a scene is viewed using an infrared camera, infrared radiation emanating from background materials is adsorbed by methane gas in the atmosphere. When methane gas is at a elevated concentration the background radiation is obscured and the methane appears as smoke or fog.

Source: ALL Consulting, 2015
IR Camera Videography

Source: ALL Consulting, 2015
IR Camera Bubbling Cellar

Hydrocarbon vapor is visible in infrared

Source: ALL Consulting, 2015
Additional IR Camera Analysis

Visible Light  
Gas Venting from a Surface Casing

Infrared  
Hydrocarbon Vapor

Source: ALL Consulting, 2015
Audio (Noise) Logging

• Simply, an audio log is a series of audible sound measurements recorded at intervals throughout a wellbore and filtered into frequency ranges.

• Interpretation of the audio log is based on the principle that when fluid or gas flows through a constriction or throttle, turbulence is created, which in turn generates noise.

• By utilizing audio logs during the well evaluation process, one can determine:
  – When and where flow is occurring, and
  – What type of flow is occurring.
    • Single-phase flow (gas or fluid flow)
    • Two-phase flow (gas through fluid flow)
Example 1
Gas entering the wellbore at depth, traveling upwards through the annular space, and venting at the surface.

Example 2
Gas entering the wellbore, traveling upwards and dissipating below the next outer casing string.
Temperature Logging

• Temperature logging is one of the oldest forms of production logging.
• Temperature logs are based on fact that temperature typically increases uniformly with depth in natural setting unaffected by human influence.
• Deviations from the normal gradient may result from the presence of a fluid derived from a different depth (and hence a fluid at a different temperature) or gas entering the wellbore.
• The intent of conducting temperature logs is to identify depths at which deviations from the geothermal gradient occur, as deviations may indicate gas or fluid movement within the wellbore.
Temperature Log Interpretation

Fluid Entrance from Formation

Fluid Entrance & Downward Fluid Movement

Gas Intrusion

Recorded Temperature

Temperature Gradient

Recorded Temperature

Temperature Gradient

Temperature Gradient

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Cement Evaluation Logs

• Cement evaluation is a vital step in the assessment of well integrity for gas migration investigations.

• The completion and analysis of 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.
Logging Options

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.

Note: These examples provided by Baker Hughes as an example of various logging options.
Cement Bond Long Interpretation

**Good Cement**
- Low Amplitude
- Strong VDL

**Partial Cement**
- Varied Amplitude
- Varied VDL

**No Cement**
- High Amplitude
- VDL Straight
- Collars “Ringing”

**Microannulus**
- Varied Amplitude
- Varied VDL
- Pressured/No Pressure Pass

Source: www.bridge7.com
Conclusions

• The assessment of well integrity for gas migration investigations requires a holistic approach and a detailed evaluation process.

• The presented well evaluation process has been developed and refined through the completion of more than a thousand wellbore integrity studies.

• A multitude of well integrity tests and evaluation methods are available, each with unique challenges.

• While any one test may indicate a potential concern, no single finding alone is sufficient; rather, when evaluation methods are used in concert, a proper assessment of well integrity can be made.
Recommendations

• Certain areas of the unconventional shale plays have stray gas issues or exhibit overpressurized situations.

• An operator within these plays must be prepared to address these issues.

• Evaluation of wellbore conditions during drilling operations and modification of primary cement jobs to address stray gas or overpressurized situations can avoid costly remedial operations.
Questions?

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