General Discussion Items

• Stray Gas and Well Integrity Introduction
• Regulatory Considerations
• Holistic Well Evaluation Process
• Internal Well Integrity
  – Build-Up and Leak-Off Testing
  – Pressure Trend Analysis
• External Well Integrity
  – Vent Rate Testing and Analysis
  – Casing and Cementing
  – Temperature & Noise Logging
• Remedial Action Considerations
What is Stray Gas?
Why do Integrity testing?

- To assure objectives are achieved and to avoid unwanted or unauthorized releases/failures.
- Integrity testing serves to confirm that our physical and mechanical systems are functioning as designed.
- Integrity testing and analysis is used in multiple aspects of unconventional operations:
  - pressure testing before fracturing – injection well integrity – pipelines – casing and cementing for protection of groundwater – assessing possible behind pipe integrity (e.g., methane intrusion) – impoundments/tanks to avoid releases
More than Meets the Eye
Integrity testing is a daily procedure in the energy industry, including throughout the development of unconventional resources.

Integrity testing is utilized much more than might be imagined, especially by the public.

In 2011, well integrity is a major topic of discussion for a variety of reasons:

- Macondo Incident in the Gulf
- Various pipeline releases
- NGO/Public opposition (e.g., Gasland)
Well Integrity Considerations

• Internal Integrity
  – Tubing and Casing Integrity
  – Packers, Plugs, Perfs

• External Integrity
  – Cement, Mud, Annular fluids
  – Gas/Fluid Intrusion
    • Via Microannulus
    • Via Cement Channels
    • Through Cement Pores
    • Fracture Systems

Other Integrity Considerations

• Tanks and Trucks
• Pipelines
• Pumping Equipment
• Valves and Connections
• Well Pad, Pits, Impoundments
• Wellheads
• Geologic System and Confinement
• Other
Well Integrity & Gas Intrusion

- Assessing well integrity specific to stray gas intrusion varies from other well integrity concerns.
- Methods and tools ideal for evaluating the presence and significant movement of annular gas differ from assessing water/liquid migration.
- Bradenhead or annular pressure does not mean gas is the cause. Potential causes of annular pressure are plentiful.
- Assessing wells for stray gas intrusion and movement requires a holistic analysis. Well integrity analysis is one component of the analysis if alleged problems are being investigated. Understanding well integrity is critical.
Texas Statewide Rule 17 (SWR17)

- All wells shall be equipped with a Bradenhead. Whenever pressure develops between any two strings of casing, the district office shall be notified immediately. No cement may be pumped between any two strings of pipe at the top of the hole, except after permission has been granted by the District Office.

- (b) Any well showing pressure on the Bradenhead, or leaking gas, oil or geothermal resource between the surface and the production or oil string shall be tested in the following manner. The well shall be killed and pump pressure applied through the tubing head. Should the pressure gauge on the Bradenhead reflect the applied pressure, the casing shall be condemned and a new production or oil string shall be run and cemented. This method shall be used when the origin of the pressure cannot be determined otherwise.

RRC regulations require wells to be constructed in such a way as to be able to keep fluids in various strata separate and contain pressures (a condition described as wellbore mechanical integrity).
Annular Pressure Threshold*

• The APT is the amount of pressure that can be safely contained within an annulus and can vary based on a well’s construction.
• The APT is based on MAWOP as used in API RP 90 (see Appendix B and B1).
• APT-sc is calculated as the less of
  – 30% of the MIYP of the surface casing string
  – 0.5 psi/ft x surface casing setting depth
• APT-ic is calculated as the lesser of:
  – 50% of the MIYP of the intermediate string.
  – 80% of the MIYP of the next outer string.
  – 75% of the MCP (minimum collapse pressure) of the inner casing or the production string.

*NOT FINALIZED
<table>
<thead>
<tr>
<th>Pressure Observed</th>
<th>Report to RRC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>Is Pressure Caused by a Casing Leak</td>
</tr>
<tr>
<td>Repair to RRC</td>
<td>Satisfaction</td>
</tr>
<tr>
<td>No</td>
<td>Is Pressure &gt;APT-sc Or &gt;APT-ic</td>
</tr>
<tr>
<td></td>
<td>Diagnostics Determine Appropriate Response</td>
</tr>
<tr>
<td></td>
<td>Communicate with RRC with Recommendation</td>
</tr>
<tr>
<td></td>
<td>Implement Improved Response</td>
</tr>
<tr>
<td></td>
<td>Resume Monitoring</td>
</tr>
<tr>
<td>No</td>
<td>Communicate APT &amp; Statement of Casing Integrity to RRC</td>
</tr>
<tr>
<td>Optional Reporting Method</td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td></td>
</tr>
</tbody>
</table>
Pennsylvanian DEP

- Perhaps the most visible stray gas controversy has occurred in Dimock, PA.
- Stray gas concerns have prompted changes/refinements to the regulatory framework.
- Draft guidance includes a critical pressure standard.
- Critical Pressure at Protected Casing Seat
  - Sec 78.73(c) requires pressure at the surface casing seat be no more than 80% of hydrostatic pressure at that depth. (0.8 x .433 x Depth)
**WELL INTEGRITY ASSESSMENT OBJECTIVE:** Develop and employ best practices to proactively maintain freshwater quality of the Commonwealth of Pennsylvania by mitigating potential threats to freshwater supplies associated with existing well inventory while protecting public safety.

**Pathway/Procedure TBD—consider statistical test to determine if increases in pressure and/or flow rate are statistically significant; reference API RP 90 benchmark of 10 psi (???)**

**Perform Post Drill Well Integrity Inspection on all Wells in existing Inventory Within Allotted Time Frame (TBD)**

**Criterion #1:** Surface Annular Pressure, psi (minimum 72-hr continuously monitored shut-in pressure build-up test)
1) Non-Freshwater Protection Casing Annulus: Threshold = 800 x 0.433 x shoe depth of shallowest shoe in tested annulus for wells within test, or build up signature reveals the formation gradient is overcome/exceeded or that threshold pressure will most likely be exceeded based on extrapolation using regression analysis.
2) Freshwater Protection Casing Annulus: Threshold = No bubbles and/or 0 psi.

**Criterion #2:** Stabilized Surface Vent Flow Rate (SVFR), scf/d
1) Non-Freshwater Protection Casing Annulus: Threshold = 5000 scf/d if TDC is not inside previous casing string. Threshold = 2000 scf/d if TDC is inside previous casing string.
2) Freshwater Protection Casing Annulus: Threshold = No bubbles and/or 0 scf/d.
3) Total allowable cumulative SVRF per well (all annuli combined): Threshold = 2000 scf/d if TOC is inside previous casing string. Threshold = 5000 scf/d if TOC is not inside previous casing string.

**Criterion #3:** Discharge of High TDS Fluids at Wellhead (TBD)
1) Non-Freshwater Protection Casing Annulus: Threshold = 500mg/l TDS within test, or build up signature reveals the formation.
2) Freshwater Protection Casing Annulus: Threshold = No TDS limit provided fluids are contained.

**Criterion #4:** Liquid Hydrocarbons
Presence of any liquid hydrocarbons at surface from any annulus.

**Criterion #5:** H2S Concentration Near Wellhead
H2S concentration taken 360 degrees around edge of cellar at 3 above ground level: Threshold > 20 ppm.

**Criterion #6:** Methane Concentration Near Wellhead (NLEL)
Methane concentration taken 360 degrees around the edge of cellar at 3 feet above ground level: Threshold >= 10% of LEL (or >= 0.5% concentration of methane in air).

**TIER 1 Well**
- No further non-routine evaluations required unless conditions at well change.

**TIER 2 Well**
- Exceed Any Single Threshold? YES or NO
- Provide results of initial screening process to DEP within 1 month of well inventory assessment completion. Update list annually.
- Exceed Any Single Threshold? Yes or NO
- 1) Develop evaluation plan for TIER 2 Wells based on environmental sensitivity.
- 2) Submit Plan to DEP within 1 MONTH of initial screening evaluation event, i.e., evaluation of wells against 6 Initial Screening Criteria).
- 3) Total elapsed time since FIRST quarterly monitoring event: 1 MONTH. Total time elapsed since commencement of initial screening process (????)

**TIER 3 Well**
- Exceedance of thresholds in #4, #5 and/or #6 requires immediate DEP notification and remediation/corrective action to reduce wellhead environment below thresholds. If no other threshold exceedances, becomes TIER 1 Well upon successful remediation; otherwise requires further evaluation.
- Exceed Any Single Criterion? Yes or NO
- 1) Develop evaluation plan following DEP approval.
- 2) Compile, submit, and present initial findings to DEP within 2 MONTHS of evaluation plan approval and provide progress reports at frequency specified in plan.

**Submit annual report to DEP including results of quarterly MIT inspections under 78.88 (?????)**

**TIER 1 Well with no confirmed gas migration:**
1) Inspect Well on quarterly basis and continue to monitor the exceeded criteria.
2) If criteria does not fall below threshold within 1 year, becomes a TIER 3 well and must be remediated unless otherwise approved by DEP.

**TIER 2 Well with confirmed gas migration:**
1) If confirmed Gas Migration Case, i.e., post-drill methane in freshwater wells significantly greater than pre-drill methane levels or any other evidence that gas is escaping from the well and impacting

**TIER 3 Well with confirmed gas migration:**
1) Remediate/repair well until criteria is below threshold.
2) Compile, submit, and present results to DEP within 1 MONTH of successful remediation.
3) If unsuccessful, prepare, discuss, and implement secondary evaluation/remediation plan within 1 MONTH of determination that remediation/repair was not successful.

**Submit annual report to DEP including results of quarterly MIT inspections under 78.88 (?????)**
HOLISTIC WELL EVALUATION

Well Integrity Certainty

- Timeline Analysis
- Casing & Cementing
- Monitoring Data Analysis
- Pressure & Vent Rates

HOLISTIC WELL EVALUATION
Holistic Well Evaluation

- Well evaluation may compliment a regional or area analysis, but should consider issues of concern away from the well itself.
- Developing an understanding of regional geology & hydrogeology, drilling & completion practices, well integrity practices, historic area issues, etc. are combined in holistic analysis.
- Very detailed well information may be required depending on the issue(s) of concern.
- No single data result is likely to conclusively demonstrate an overall finding relative to MI. Rather, it’s a combination.

- Well Drilling & Completion
- Timeline Analysis
- SISCP & Vent Rate Testing
- Well IWI/EWI Analysis
- Remedial Action as Necessary (e.g., Venting)
PRESSURE BUILD-UP TESTING
Shut-In Surface Casing Pressure

Pressure (psig) vs. Time (hours)

- Initial
- Post Remediation

July 25, 2012
Copyright (c) 2012 ALL Consulting
Testing Methods (IWI)

• Visual Inspection
• Pressure Testing
  – Shut-In Surface Casing Pressure Testing
  – Production Casing Build-Up/Leak-Off Testing
  – Pressure Differential Testing
• Pressure testing can be done as a single testing event or can be done using multiple tests to assess trends.
• Continuous pressure recordings are key.
Pressure Testing

• Build-up and fall-off testing are used for various purposes:
  – Characterizing & evaluating integrity
  – Checking integrity of perforations
• For wells having more than one exterior annulus (e.g., 3-string well), all annular spaces should be tested.
• Transducers and data loggers should be utilized to ensure accurate and continuous monitoring and to allow for more detailed characterization and evaluation.
• Annular pressures are generally stopped if pressures exceed 300 psig as a safety precaution.
Shut-in Surface Casing Pressure Test

Pressure Transducer & Data Logger

Test Assembly

Surface Casing Riser
QC for Pressure Testing

- Pressure testing annular spaces requires quality control to achieve a good test.
- SISCP testing is a BU test opposed to a typical SAPT for SWDs. Leak testing (e.g., couplings) should be done during or before pressure is bled off.
- If piping is exposed, freeze precautions may be required.
- Equipment should be tested and managed to avoid mud-plugging.
- Continuous recordings are important to confirm quality of results.
- Gages used should be of appropriate scale compared to pressure recorded
  - Using a 10,000 psig gage to measure 20 psig pressure is inappropriate.
- Testing Procedures are recommended for field personnel to utilize.
In some cases, some sort of stray gas may be identified from an annular space without an assembly to facilitate pressuring monitoring. Retrofitted well caps can be used in these cases to facilitate testing/monitoring.
Pressure Trend Analysis

- Assessing pressures for well integrity requires continuous recording for purposes of assessing pressure signatures, anomalies, and trends.
- Casing annular pressures may be exposed to open borehole and various geologic units that may create varied signatures compared to a SAPT of a casing/tubing annulus.
- Weather and external conditions can also impact results, making continuous recording a necessity.
Pressure test signatures collected using continuous monitoring devices allow detailed evaluation of annular pressure and its significance.

Pressure curve analysis facilitates a more robust assessment of trends than would otherwise be possible.
An added benefit of the continuous data collection is that it also has proven to be a valuable tool in identifying testing errors.
Identifying Pressure Trends

![Graph showing pressure trends over time for different months from September 2011 to May 2012. The graph plots pressure on the y-axis and time on the x-axis. The months are represented by different colored lines: September-11 (white), December-11 (orange), February-12 (yellow), March-12 (light blue), and May-12 (light green).]
Pressure Decline Analysis

Pressure Range of Expected Decline

[Graph showing pressure decline from July 2011 to January 2013 with key points labeled from 132 to 62.]
Lack of Stabilized Pressure
Formation influences to Pressure

Graph showing the relationship between Pressure and Time.
Multiple Influences on Pressure
Leaks, Weather, or ??

![Graph showing pressure over time]

- **Pressure** is on the y-axis.
- **Time** is on the x-axis.

The graph indicates fluctuations in pressure over time, suggesting possible correlations with leaks, weather, or other factors. The exact nature of these correlations would depend on additional data and analysis.
Peak followed by Stabilization
EXTERNAL WELL INTEGRITY

EPA National Mechanical Integrity Test Working Group, Eastern Kansas, 1987

Photo Source: J. Daniel Arthur, 1987
What are We Testing For?

- Well integrity specific to stray gas intrusion within the wellbore and/or specific to a nearby issue (such as a complaint).
- Potential presence of natural gas external to the production casing.
- Testing methods target assessment of significant gas or two-phase fluid movement external to the production casing.
Testing Limitations

- Testing methods focus on the vertical portion of the wellbore.
- Depending on the location of the suspected gas intrusion, well modification may be required to fully assess (e.g., pulling tubing or casing).
- Each test has limitations (e.g., determining flow direction)
- Failure to effectively plan and implement quality control measures will likely yield poor results.
Common Questions

• Can testing methods confirm whether flow from the production zone is occurring versus flow from shallower zones?
  – YES! Testing methods are available that can confirm where external flow is occurring and whether it may be coming from the production zone or a shallower zone.

• Can testing methods confirm a well is or is not impacting shallow groundwater?
  – Depends. Methods can be used to confirm whether or not the well has adequate integrity. Analysis can also confirm where gas flow is and often whether it is significant. However, other testing may be required depending on the situation. If a well has no integrity issues, it cannot be the cause of shallow groundwater problems...
Testing Methods (EWI)

- Visual Analysis and inspection
- Well drilling and completion analysis
  - Casing and cementing records review
- Vent Rate testing
- Geology Review
- Cement bond type logs
- Temperature Logs
- Noise Logs
- Perforation – Build-Up testing
Visual Inspection

• Visual Inspection is a necessity!
• Visual inspection is important to assess site safety.
• LEL monitoring/testing is a recommended BMP for gas well operations (see following slide)
• Visual inspection can facilitate:
  – identification of bubbling in the well cellar.
    • Bubbling is generally heard before it’s seen.
  – Whether pipe fittings or valves may be leaking?
  – Other issues that may be present?
LEL Monitoring Recommendations

• Monitor at the lip of the cellar at the well pad surface (i.e. at the ground surface level).

• If there is no wind:
  – Monitor at the edge of the cellar at a height of five (5) feet (ft) above the ground surface (ags).
  – Monitor 5 ft ags & 5 ft from edge of cellar. Repeat at 5 ft intervals until no readings detected.
  – Monitor in 4 directions/90 degree separation.

• Additional monitoring is required if there is a residence or private/public building within approximately 500 ft radial distance of the cellar:
  – Monitor at a distance of five (5) ft away from the edge of the cellar in a direction towards the building and at a height of five (5) ft ags. Continually make measurements at increasing distances (in 5 foot increments) away from the edge of the cellar in a direction towards the building until two consecutive non-detect readings are obtained.
Vent Rate Testing

- Vent Rate testing is done to compliment pressure build-up testing and to obtain an idea of the volume of gas may be present?
- Vent rate testing can be done using flow meter or manometer – depending on rate.
- Most annular venting, when present, are extremely low, making a manometer or balloon test most appropriate.
- Even if no venting is identified, balloon tests provide good visual documentation.
Annular Vent Rate Testing

- Used to measure gas venting volumes.
- Measured in inches of water using a U-tube manometer.
- Measurement converted to a flow rate recorded as thousand cubic feet per day (MCF/d).
- Balloon tests are completed when manometer readings are <0.1 inches of water.
- Photographic documentation of balloon after 10 minutes.
Volumetric Analysis

• Typically used for instances of stray gas intrusion
• Volumetric analysis can supplement other analyses in assessing well integrity and developing a plan for corrective action (if one is needed)
• If venting is used as a remedial measure, understanding volume and vent rate trends facilitates safe and effective action plans
  – NOTE: A Canadian study showed that surface casing vent flows (SCVFs) are considered non-serious when venting sweet gas at low rates (<10.6 MCF/D). [Komex International, May 2002]
• Understanding local and regional geology as well as historic activities is critical to assessing an alleged stray gas issue.
  – Many areas of the country have shallow-system naturally occurring gas from various sources (e.g., coals, shales, etc.).
  – Several areas have had significant historic oil and/or gas development with wells abandoned for more than 50 or even 100 years.

• Geologic review may incorporate review of mud logs, seismic, geophysical logs, research geologic units, researching historic activities (e.g., former commercially productive zones, etc.)

• The Geology review can help to understand what potential sources may be present that could be a source for stray gas intrusion into the wellbore?
Casing & Cementing

- In addition to understanding details of drilling & completion activities, once a well is in operation, casing & cementing is key in assessing well integrity relative to possible stray gas intrusion and related EWI issues.
- Pressure testing casing shoes before drill-out and casings prior to fracturing has become commonplace.
- Cement evaluation is often a critical piece in the assessment of stray gas intrusion and EWI evaluation.
Assessing Casing & Cement

• Prior to considering logging, understanding cementing methods is critical. Insights regarding hole preparation, procedures, cement types, additives, etc. is important.
  – For instance, a lighter weight cement may show differently on a bond log than a heavier cement.

• Cementing Records
• Logging tools used for assessing cement bonding
• Physical testing
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

Source: www.bridge7.com
A Microannulus (MA) is typically defined as a small separation between casing and cement where gas can travel, but not liquid.

A misconception is that if a well has a MA, it is continuous over the entire wellbore.

Actual conditions and testing reveal that often times, a MA occurs over discrete intervals (see example).

Recognizing the presence of the MA is important when assessing EWI related to stray gas intrusion in a wellbore annular space.
Temperature & Noise Logging

- Temperature & noise logging, in association with cement evaluation type logging, is likely the most useful when attempting to assess gas movement behind pipe.
- Effective T/A logging requires planning and well preparation.
- T/A logging should be complimented by other information (e.g., vent rate, RCBL, etc.).
- T/A logs can be used to confirm EWI relative to gas movement behind pipe.
- T/A logging can confirm the general source (e.g., producing zone versus shallower interval).
Prior to logging the well, the well needs to be prepared for noise and temperature logging.
  – Production Tubing Removed.
  – Wellbore and annular spaces should be 100% fluid filled.
• The well should be allowed to stabilize (e.g., temperature, pressure, fluids).
• Temperature is logged from top to bottom and noise is typically logged on the upward pass.
• Logging should be conducted with the wellbore configured for the particular issue and often requires multiple configurations to fully assess
  – Example: Production Casing Closed/Surface Casing Venting
• The logging company will log temperature on the downward pass at a consistent speed of no more than 35 ft/min.
• Anomalies identified on the temperature log should be documented and evaluated closely during noise logging.
• After completion of the temperature log on the downward pass, fluid levels in all casings should be re-filled as required.
• All unnecessary equipment should be turned off to minimize noise prior to the commencement of the upward pass.
• Noise logging intervals commonly range from 25 to 250 feet. Data collection intervals can be made more dense in the event an issue is identified.
Temperature-Audio Logging Tool
(Photo taken by ALL Consulting with permission granted by CDK Perforating, 2012)

Logging Truck running a Temperature-Audio Log
(Photo taken by ALL Consulting with permission granted by CDK Perforating, 2012)
Temperature logging is one of the most basic logging tools used for downhole evaluations.

Temperature logs are routinely used in the UIC program for assessing EWI, confirming injected waste is arriving and staying in the permitted injection zone, assessing wells for remedial workovers, and more.

Temperature logging not limited for use by the oil & gas industry or for injection wells.
Noise Logging

- First described by Arco in ~1955 as a “quantitative“ tool, but utility was questionable.
- In 1973, Dr. McKinley (Exxon) started pointing out the utility of noise logging and ultimately worked with EPA and published a document on MI.
- For identification of gas movement behind pipe, noise logging can be crucial.
- Typically run with a temperature log and interpreted using other logs and data for the subject well.
- Unfortunately, interpretation is not commonly as straightforward as you might think!
Stray Gas and Noise Logging

- When evaluating gas movement behind pipe opposed to liquid, audio analysis is a fundamental tool.
- As McKinley documented in 1979, gas movement makes more noise than liquid movement past a detector.
- Although noise logging can be used to assess liquid movement behind pipe, it is ideal for assessing gas movement!
Noise Audio Logs

<table>
<thead>
<tr>
<th>Frequency Cuts</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Below 200 Hz</td>
<td>- Noise in the range from 10 Hz to 100 Hz generally accounts for mechanical or surface noise including cable vibrations caused by the motors of logging trucks, by lubricator motion, and other surface disturbances</td>
</tr>
</tbody>
</table>
| 200 Hz – 600 Hz | - Eliminates most surface noise while still being low enough to detect the action of gas moving upward through liquid (McKinley, Bowler and Rumble, 1973).  
- Discrete bubbling – reflected by a spectrum peak in the 300 to 600 Hz range (McKinley, Bowler and Rumble, 1973)  
- Mild Slugging – spectrum peak above 200 Hz decreases with only a slight indication of bubble peak, (McKinley, Bowler and Rumble, 1973)  
- Severe Slugging - more energy is transferred into a band around 200 Hz. (McKinley, Bowler and Rumble, 1973)  
- Above 200 Hz, channel type leaks exhibit the same frequency structure as does free-stream, grid-generated turbulence (McKinley, Bowler and Rumble, 1973). |
| 1,000 Hz – 2,000 Hz | - Noise spectra show presence of free-stream turbulence which is characteristic of single-phase flow (McKinley, Bowler and Rumble, 1973).  
- Above 1,000 Hz two-phase leaks are indiscernible from single-phase leaks (McKinley, Bowler and Rumble, 1973). |
The amplitude distribution varies depending on single or dual-phase flow.
Single v. Dual Phase Flow

Noise Log characteristics of single phase leak

Noise Log characteristics of a gas-liquid, two phase leak
Restrictions and Two-Phase Flow

NOTE: the example above is from McKinley (1973) and although a great example, actual conditions can vary. The example to the right shows two-phase flow and a restriction as evident from the RCBL.
• Noise logging rarely yields ideal results.
• Even with good cement, audio amplitudes within the 30 mV range are common.
• However, sometimes a near perfect log is obtained. This example also is void of near surface disturbance, which is common with noise logging (i.e., increase noise activity in the upper 500’).
• Remember that noise logs, like most logs, have settings controlled by the logging engineer and so logs can vary based on factors other than EWI.
In this example, gas intrusion is observed above 2,000’ with apparent flow upward.

Flow appears to be single phase flow (gas only).

The noise log confirms the absence of deep gas in the annular space.
• Similar to the previous slide, gas intrusion in the well’s mid-section is identified.
• However, noise amplitudes are much higher than the prior example.
• This may indicate higher rates or flow through tighter restrictions.
• Review of the entire log also shows higher sensitivity on the lower portion of the log. This suggests that sensitivities may be artificially higher than actual.
• The noise log confirms the absence of deep gas in the annular space.
In this example, gas intrusion is observed at about 3,500’.

Flow appears to be single phase flow (gas only).

Audio peaks likely due to restrictions or second gas intrusion point present.

The noise log confirms the absence of deep gas in the annular space.
REMEDIAL ACTION

CONSIDERATIONS

Photo Courtesy Baker Hughes
• Keep in mind that the best option for remediation of stray gas intrusion into the wellbore may simply be “venting”.

• Physical remedial activities, such as perforating the production casing and squeezing with cement or other products is, challenging!

• Often, specialty products, such as micro-fine cement, resins (e.g., Maraseal), etc. may be required.

• Assuring perforations are sealed for purposes of production operations must also be considered.
Considerations...

• A combination of testing methods and analyses can be used effectively to assess well integrity.
• Regulatory Agencies tend to seek tests and analysis methods that provide a black & white answer, but tend to recognize the complexities.
• Most testing methods do not offer an absolute and definitive answer regarding well integrity.
• Sometimes, achieving an absolute finding is difficult or impossible. This is why EPA allows some leak-off on the SAPT – achieving a zero leak-off is generally impossible considering all the factors involved.
• Some issues are simply a nuisance and not a significant environmental or safety concern.
Special Thanks to:
Greg Casey, P.E.
Jeff Kennedy
Preston Wilson
Daniel Wheaton
Will Green
Tate Byers
Teresa Arthur

Citation Information:
Arthur, J.D. (ALL Consulting); Casey, Greg (ALL Consulting);
Kennedy, J. (ALL Consulting); Wilson, P. (ALL Consulting). “Understanding and Assessing Well Integrity Relative to Wellbore Stray Gas Intrusion Issues”.
Presented at the Ground Water Protection Council’s Stray Gas Forum, Cleveland, Ohio, July 24-26, 2012.