Internal and External Mechanical Integrity as Part of Unconventional Gas Development

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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

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Integrity Testing

- 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)

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More than Meets the Eye
Mechanical Integrity and Unconventionals

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

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Barriers of Protection

General Casing Design for a Marcellus Shale Well

Christmas Tree

Pipeline to Flow Process and Storage

Surface Casing

Intermediate Casing

Production Casing

Cement

Cement

Cement

Tubing

Well Fluids

Oil or Gas Zone

Perforations

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**HF Example**

- Integrity testing of well and pumping system components is a standard part of the hydraulic fracturing process.

- First, as part of the quality assurance process at the mill, pipe is hydrostatically tested (typically to 90% of the rated burst pressure).

- **General pre-HF integrity test process**
  - Using fresh water, pressure the well and pumping system to the max working pressure (commonly 10,000 psig).
  - Hold for 5 minutes and observe any pressure changes.

- In this example, pressure reached 1,000 psig and significant flow was observed on the annulus valve.

- Pipe was removed and a small hole was found.

- The pipe was replaced and successfully re-tested prior to the initiation of fracturing operations.

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Shut-In Surface Casing Pressure

- **Pressure (psig)**
- **Time (hours)**

Graph showing the pressure over time with two distinct phases:
- **Initial**
- **Post Remediation**

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Backside Volumetric Analysis

- Typically used for instances of methane 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 facilitates management of safety and environmental concerns

  - 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]
Cement Bond Long Interpretation

Good Cement
• Low Amplitude
• Strong VDL

No Cement
• High Amplitude
• VDL Straight
• Collars “Ringing”

Partial Cement
• Varied Amplitude
• Varied VDL

Microannulus
• Varied Amplitude
• Varied VDL
• Pressured/No Pressure

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Source: www.bridge7.com
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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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!

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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 (e.g., Standard Annulus Pressure Test).
- 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.
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Presentation Synopsis

Internal and external well integrity have been cornerstones of the U.S. Environmental Protection Agency’s Underground Injection Control (UIC) Program since it’s inception. Well integrity has also be a key aspect of oil & gas production for more than a century. Today, with the growth of unconventional resource development (especially shales) and the use of high volume hydraulic fracturing, well integrity is perhaps more critical than at any time in the history of the fossil energy business. This presentation explores well integrity issues as relates to unconventional gas and also oil development.