Legacy Oil & Gas Well Integrity in the Midwest U.S.- Regional Data Analysis and Field-Testing

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Introduction

- Areas in the Midwest U.S. have a long history of oil and gas development.
- Oil & gas well drilling technology has progressed from cable tool wells in 1800s to rotary wells in 1900s to unconventional horizontal wells in 2000s.

Shallow Cable Tool Wells → Conventional Wells → Unconventional Wells

Titusville, PA, 1865
Source: Drake Well Museum.

Morrow Co., OH, 1964

West Virginia, 2020
Introduction

- >1 million legacy oil and gas wells exist in the region including gas storage and unconventional wells.
- Potential for additional “unknown wells” in some areas of the region.

from Hennora Resources LLC, 2019
Introduction

- Wells may exhibit combined effect of many types of well defects, which may migrate to wellhead and be exhibited as sustained casing pressure or leaks.
- How to determine if a well has a defect, nature of defect, and magnitude of defects (with non-invasive methods)?

<table>
<thead>
<tr>
<th>Well Integrity Item</th>
<th>Evaluation Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement degradation</td>
<td>Cement type, cement age, additives, hydrogeologic conditions</td>
</tr>
<tr>
<td>Cracks and Microannuli</td>
<td>Cement age, plug intervals, cement type</td>
</tr>
<tr>
<td>Acid-Gas Zones</td>
<td>Geologic logs, drilling logs, hydrogeologic zones</td>
</tr>
<tr>
<td>Channeling</td>
<td>Cementing procedures, cement age, cement mix</td>
</tr>
<tr>
<td>Casing Corrosion</td>
<td>Casing inspection logs, case studies</td>
</tr>
</tbody>
</table>
It is difficult to field survey and/or test 100,000s of legacy oil & gas wells. Connect field testing with regional datasets for indicators of well integrity. Non-invasive testing methods can help classify and quantify well defects.

Tools for evaluating well integrity: GIS-spatial well integrity analysis tool, systematic cement bond log analysis tool, wellhead sustained casing pressure test kit.
Well Integrity Based on Regional Data Analysis

- Complete a systematic assessment of well integrity through collection and analysis of well records.
- Integrate results with analysis of existing gas storage and O&G fields where field testing of well conditions/defects is possible.
- Results provide predictive methods to survey, identify, characterize, and manage well integrity for subsurface applications.

GIS-Spatial Well Integrity Indicator Tool

- Wells have variable age, depth, geologic formations, and status that may be indicators of wellbore integrity.
- Statistical analysis completed to portray well integrity indicator index based on wells depth, age, status.

Ref: Approach for Assessing Wellbore Integrity to Prioritize Study Areas for Potential Siting of a Carbon Dioxide Repository, Bruce Buxton, Stephanie Weber, Mark Moody, Neeraj Gupta, Joel Sminchak. SPE Eastern Regional Meeting, September 13-15, 2015, Morgantown, WV, SPE-177315-MS
Example: site screening

Site A: Salina Formation N-Central

Site B: Salina Formation Southeast

Site C: Copper Ridge formation S-Central

Systematic Cement Bond Log Evaluation Tool

- Cement bond log systematic evaluation tool to evaluate cement condition around well casing for fields of oil & gas wells.
- Results can be analyzed with statistics to assess trends with cement bond versus geologic formation, depth, and age.

Ref; Utilizing Cement Bond Logs to Evaluate Wellbore Integrity on Local and Regional Scales. Autumn Haagsma, Andrew Burchwell, Mark Moody, Jackie Gerst, and Joel Sminchak, SPE Eastern Regional Meeting, 13-15 October 2015, Morgantown, West Virginia.
Sustained Casing Pressure Well Integrity Test Kit

- Sustained casing pressure can come from a leak in the casing and/or tubing, cement defects, or sources above the cement.
- SCP test kit and analysis method developed to determine nature and magnitude of well defects.

**Rate Profiles for SCP Bleed and Build Models for Same Cumulative Gas**

- **Instant Release Metric (IRM)**
  - Indicate potential volume of sudden gas release
  - Unit is MSCF
  - \( IRM = f(P_{\text{asym}}, V_g) \)

- **Sustained Leakage Metric (SLM)**
  - Maximum possible gas leakage rate
  - Unit is MSCFD
  - \( SLM = DF \)

- **Defect Factor (DF)**
  - Predict well integrity for containment
  - Unit is \( \mu m^2 \)

Ref: *Sustained Casing Pressure Diagnosis Using the Wellhead Model*, Bryan Dotson, Mark Moody, and Matthew Place, SPE/CSGM Gas Migration Challenges – Identification and Treatment Workshop, 13-14 May 2015, Banff, Alberta, Canada.
Sustained Casing Pressure Well Integrity Test Kit

- Sustained casing pressure testing at wellhead can show mechanical, permeable cement, or crack/orifice in cement & magnitude.
- Non-invasive, inexpensive option, may be suitable to demonstrate integrity rather than requiring expensive corrective action (like replugging, overdrilling, etc).
Field Testing

- Kits tested on >80 wells at gas storage and CO2-EOR fields.

Appalachian Basin Sites

Michigan Basin site

Williston Basin site

Ref: Case Study on Wellbore Integrity for Two Fields with Wells Exposed to CO2 in the Subsurface in the Midwest U.S. Jacob Markiewicz, J.R. Sminchak, and Mark Moody. SPE Eastern Section Regional Meeting, 4-6 October 2017, Lexington, Kentucky.
## Well Integrity Corrective Actions & Costs

- 6 study areas examined for CO$_2$ storage scenario to estimate corrective actions and costs for sites in Midwest U.S.

<table>
<thead>
<tr>
<th>Corrective Action</th>
<th>Cost Per Well</th>
<th>Michigan</th>
<th>Ohio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Total # of Wells</td>
<td>22</td>
<td>446</td>
<td>156</td>
</tr>
<tr>
<td>Zero Corrective Action</td>
<td>$0</td>
<td>$0</td>
<td>$0</td>
</tr>
<tr>
<td>Inspect Well Head</td>
<td>$400</td>
<td>$0</td>
<td>$49,200</td>
</tr>
<tr>
<td>Test Well</td>
<td>$25,000</td>
<td>$0</td>
<td>$0</td>
</tr>
<tr>
<td>Monitor Wellhead</td>
<td>$20,000</td>
<td>$0</td>
<td>$0</td>
</tr>
<tr>
<td>Add Plugs to Well</td>
<td>$75,000</td>
<td>$0</td>
<td>$750,000</td>
</tr>
<tr>
<td>Re-enter &amp; Plug</td>
<td>$145,000</td>
<td>$0</td>
<td>$0</td>
</tr>
<tr>
<td>Test Study Area Cost Estimate</td>
<td>$0</td>
<td>~$800,000</td>
<td>~$1,425,000</td>
</tr>
</tbody>
</table>
Conclusions

- A combination of regional geospatial analysis methods and field testing is effective for examining well integrity:
  - GIS-spatial well integrity analysis tool for historical well records,
  - Systematic cement bond log evaluation tool for rating cement in boreholes,
  - Sustained casing pressure field test kit and analysis methodology.

- Well records in Midwest U.S. suggest oil and gas wells are clustered along O&G fields, and many of the deep saline formations are penetrated by few wells.

- Systematic evaluation of 278 cement bond logs from Michigan and Ohio suggested that most wells had adequate cement above the isolation zone.

- Field testing of sustained casing pressure provided a defect factor that reflected combined well integrity items. Analysis indicated that intermediate zones appeared to present more of a risk for borehole migration of reservoir gases.