Mining Oil and Gas Well Integrity Data in Colorado and New Mexico

Greg Lackey
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Wattenberg Field

4th largest oil field
9th largest gas field

Stray gas contamination:
Thermogenic CH$_4$
42 water wells
32 cases
11 “culprit” oil and gas wells
Wattenberg Field

4th largest oil field
9th largest gas field

Stray gas contamination:
Thermogenic CH₄
42 water wells
32 cases
11 “culprit” oil and gas wells

How did thermogenic stray gas migrate into the shallow subsurface through these culprit wells?
Well Leakage

1. Casing leak

2. Unknown intermediate

3. Faulty cement seal or improper cement coverage
Sustained Casing Pressure (SCP)
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Sustained annular pressure (SAP), Bradenhead pressure, surface casing vent flow (SCVF)
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Sustained annular pressure (SAP), bradenhead pressure, surface casing vent flow (SCVF)

Should be no SCP in a properly functioning well
Sustained Casing Pressure (SCP)

Sustained annular pressure (SAP), bradenhead pressure, surface casing vent flow (SCVF)

Should be no SCP in a properly functioning well

Sustained casing pressure is an easily measured gauge of well integrity, but is poorly documented
Not all wells that develop SCP induce stray gas migration
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As pressure builds annular liquid is displaced
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When SCP = formation fluid pressure at bottom of surface casing stray gas migration can be induced
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As pressure builds annular liquid is displaced

When SCP = formation fluid pressure at bottom of surface casing stray gas migration can be induced

**Critical sustained casing pressure is a well-specific physically meaningful indicator of stray gas migration**
# Bradenhead Testing

## BRADENHEAD TEST REPORT

1. **Operator Number:** [Enter]
2. **Name of Operator:** [Enter]
3. **BLM Lea...**
4. **API Number:** [Enter]
5. **Multiple completion?** [Yes/No]
6. **Well Name:** [Enter]
7. **Location (City, State, Sec., Twp., Rng., Merid., Lat…):** [Enter]
8. **County:** [Enter]
9. **Field Name:** [Enter]
10. **Minerals:** [Free, State, Federal, Indian]

### STEP 1: EXISTING PRESSURES

<table>
<thead>
<tr>
<th>Record as found</th>
<th>Surface Casing</th>
</tr>
</thead>
<tbody>
<tr>
<td>tubing</td>
<td>tubing</td>
</tr>
</tbody>
</table>

### STEP 2: BRADENHEAD TEST

- **Suture valve?** [Yes/No/Confirmed open?]
- **Recent Time (mm/dd):** [Enter]
- **Flow Rate:** [Enter]

### BRAKENHEAD SAMPLE TAKEN?

- **Yes/No**
- **Gas**
- **Liquid**

### CHARACTER OF BRADENHEAD BUILD?

- **Solid**
- **Lithic**
- **Mud**
- [Other (If any...)]

### STEP 4: INTERMEDIATE CASING TEST

- **Suture valve?** [Yes/No/Confirmed open?]
- **Recent Time (mm/dd):** [Enter]
- **Flow Rate:** [Enter]

---

Note: Instructions for the test are located above.
Bradenhead Testing

- Pressure measured as found on surface casing
• Pressure measured as found on surface casing
• Instantaneous pressure measured at the end of the test
Bradenhead Testing

- Pressure measured as found on surface casing
- Instantaneous pressure measured at the end of the test
- Filed as text-based PDFs that can be mined using Python
First Well Integrity Study

2010 bradenhead testing policy establishes Wattenberg Test Zone (WTZ)
First Well Integrity Study

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3,923 readable bradenhead tests (after QA/QC)
First Well Integrity Study

2010 bradenhead testing policy establishes Wattenberg Test Zone (WTZ)

3,923 readable bradenhead tests (after QA/QC)

Paired with QA/QC well construction data
How Many Wells Have SCP?

All Wells (13.8%), Vertical Wells (7.4%), Deviated Wells (21.9%), and Horizontal Wells (18%)
How Many Wells Have SCP?

Deviated and horizontal wells exhibit SCP ≥ 1034 more frequently than vertical wells.

All Wells (13.8%), Vertical Wells (7.4%), Deviated Wells (21.9%), and Horizontal Wells (18%)
Critical SCP typically increases with surface casing depth
Critical SCP typically increases with surface casing depth.
Critical SCP

Newer horizontal wells, built with deeper surface casings that exceed current regulations, pose a lower risk for inducing stray gas migration than older vertical wells.

Critical SCP typically increases with surface casing depth.
New Mexico

http://www.emnrd.state.nm.us/ocd/
# Bradenhead Test Report

**New Mexico**

## Bradenhead Test Report

<table>
<thead>
<tr>
<th>Date of Test</th>
<th>10-27-11</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Internal API 1008-45 - 23145</td>
</tr>
<tr>
<td>Property Name</td>
<td>N/A</td>
</tr>
<tr>
<td>Well No.</td>
<td>2417</td>
</tr>
<tr>
<td>Section</td>
<td>12E</td>
</tr>
<tr>
<td>Quarter</td>
<td>1/2</td>
</tr>
</tbody>
</table>
| Description of Production Unit | Interbedding 8 |}

<table>
<thead>
<tr>
<th>TIME</th>
<th>END</th>
<th>INTERNAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 min</td>
<td>143</td>
<td>143</td>
</tr>
<tr>
<td>10 min</td>
<td>143</td>
<td>143</td>
</tr>
<tr>
<td>15 min</td>
<td>143</td>
<td>143</td>
</tr>
<tr>
<td>20 min</td>
<td>143</td>
<td>143</td>
</tr>
<tr>
<td>25 min</td>
<td>143</td>
<td>143</td>
</tr>
<tr>
<td>30 min</td>
<td>143</td>
<td>143</td>
</tr>
</tbody>
</table>

### Flow Characteristics

<table>
<thead>
<tr>
<th>BRADENHEAD</th>
<th>INTERMEDIATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas</td>
<td></td>
</tr>
<tr>
<td>Water</td>
<td></td>
</tr>
<tr>
<td>Gas &amp; Water</td>
<td></td>
</tr>
</tbody>
</table>

---

**Parameters**

- **BP**: 4200 Lbf/in²
- **Pressure**: 1000 Lbf/in²
- **Remarks**: 

  - No water or gas present. No debris, etc. 200.0 psi. 1000 Lbf/in².

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**Signature**

- **Author**: [Signature]
- **Date**: 10/22/11
- **Department**: Dist. 3
New Mexico Challenges

2.25 million documents labeled only by API# and all are scanned images (~600,000 of interest)
New Mexico Challenges

How do you sort through hundreds of thousands of image based documents in a reasonable manner?

2.25 million documents labeled only by API# and all are scanned images (~600,000 of interest)
TensorFlow

Open source machine learning framework developed by Google
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Can be used for broad range of machine learning tasks but was developed for deep neural network modeling
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Can be used for broad range of machine learning tasks but was developed for deep neural network modeling

Commonly used for categorization tasks
Roughly How it Works

“MobileNet” convolutional neural network


Already trained using ImageNet (>14 million images)
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Already trained using ImageNet (>14 million images)

Retraining

(https://codelabs.developers.google.com/codelabs/tensorflow-for-poets/#)
Roughly How it Works

“MobileNet” convolutional neural network

Already trained using ImageNet (>14 million images)

~18,500 BHTs

45,000 Other Docs

~98% of Bradenhead documents accurately identified

Retraining
(https://codelabs.developers.google.com/codelabs/tensorflow-for-poets/#)
Document Sorting

~575,000 Mixed Documents
Document Sorting

~575,000 Mixed Documents

~45,000 BHTs

~530,000 Other Docs
New Mexico Challenges

How do you get data from thousands of images that change format and are often scanned poorly?

2.25 million documents labeled only by API# and all are scanned images (~600,000 of interest)
Web Application

Please log in to access this page.

Sign In

Username

Password

Remember Me

Sign In

scraper.airwatergas.org
Hi, greg!
You have scraped 221 documents.
A total of 6191 documents have been scraped thus far.
There are 39210 documents left to be scraped.

Begin Scraping

Score Board

valerie_c: 173
steven_y: 108
marcus_k: 44
benjamin_w: 60
devansh: 715
Web Application
Web Application

Website accessible from anywhere

Multiple scrapers can work at the same time

~15 seconds a document

190 hours of work
Preliminary Data
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Well construction records for 232,645 wells in Colorado (114,843) and New Mexico (117,802).
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Well integrity test records for 34,727 wells. 19,540 in Colorado and 15,187 in New Mexico.
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Well construction records for 232,645 wells in Colorado (114,843) and New Mexico (117,802).

Well integrity test records for 34,727 wells. 19,540 in Colorado and 15,187 in New Mexico.

After release of PA DEP well integrity data this will be the second largest dataset of well integrity information in the United States.
Conclusions

• Sustained casing pressure is an easily measure, but poorly documented, gauge of oil and gas well integrity.

• Bradenhead testing in Colorado and New Mexico provides insight into the development of SCP in oil and gas wells and can be used to identify wells that pose a high risk of inducing stray gas migration.

• Image based documents of interest can be identified and sorted from databases that contain seemingly unmanageable numbers of files using TensorFlow.

• Data from these documents can be easily obtained using a simple document scraping web application.
Acknowledgements

• National Science Foundation Sustainability Research Network Program (Grant CBET-1240584).

• Harihar Rajaram, Owen Sherwood, Joe Ryan, Troy Burke, Devansh Chauhan

• Summer scrapers: Natalie Guinan, Steven Wilder, Lewis Schiebel, Marcus Knipp, Valerie Constien, Benjamin Willows, Ludvig Zwilgmeyer
Extra Slides
Drilling in Colorado

Four major oil and gas basins: DJ, Piceance, San Juan, and Raton
Drilling in Colorado

> 300,000 Water wells
Drilling in Colorado

Total: 64,289; Vert: 42,279; Dev: 18,761; Horiz: 3,249
Well Configurations

Vertical

Deviated/Directional

Horizontal
Drilling in Colorado

Total: 64,289; Vert: 42,279; Dev: 18,761; Horiz: 3,249
Drilling in Colorado

Total: 64,289; Vert: 42,279; Dev: 18,761; Horiz: 3,249
COGCC Data

cogcc.state.co.us

Scrapy
Python web scraping application