Pressure Monitoring, Field Observations and Interpretation Challenges

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Pressure Transient Analysis (PTA)

Source: ww.fekete.com
Challenges in Leakage Detection

- Area of coverage (e.g., T vs. P)
- Timing (Shallow vs. deep monitoring)
- Tool reliability (New technologies)
- Cost
- Detection threshold (slow leakage)
- $\text{CO}_2$ (Gas) vs. brine leak
Pressure-Based Monitoring

- **Target**
  - In-zone
  - Above-zone
- **Injection setting**
  - Brine storage
  - EOR
- **Approach**
  - Active
  - Passive
- **Goal**
  - Leakage feature identification: improperly completed/abandoned wells, leaky faults, semi-pervious cap-rock
  - Leakage fluid identification: single-phase (brine) or two-phase (brine+CO₂)
Pressure Based Monitoring Pros

- Area of coverage is large
- Can be deployed at most depths
- Pressure gauges are well developed
- Cheap compared to most other methods
- Very small changes in pressure detectable
- Can distinguish CO$_2$ leak from brine leak
- Can detect small leaks (over long time)
Pressure Based Monitoring Challenges

- Requires wells
- Noise
- Data resolution and frequency (operation vs. monitoring)
- Drift (both in time and pressure recordings)
- Interference (access to operations data)
- Power and instrument problems
- Storage memory shortage
Noise & High vs. Low Frequency/Resolution

Average pressure = 2192.8 ± 0.3 psi
Gauge resolution = 0.1 psi
Above-zone: Passive
Above-zone; Passive
Above-zone; Passive

Sun et al., 2012, AWR
Above-zone; Passive

Above-zone monitoring interval (AZMI)
Injection zone (IZ)
Confining layer

~3.2km
~120m
68m 44m
Above-zone; Passive

Kim et al 2013
Above-zone; Passive

31F-2

31F-3
Above-zone: Passive
Above-zone; Passive
Above-zone; Passive; Pressure Drop in AZMI with Start of Injection
Above-zone; Passive; Geo-mechanics?

Kry, 2001, JCPT
Active Monitoring

Signal Analysis

Data Assimilation
- Parameter update
- Storage formation state update

Inversion
- Parameter estimation
  - Leak detection
In-zone Active
Above-zone; Active

Map view of monitoring zone
Brine injection to 7803
Pressure observation in 7605

CO2 Injection Zone

INCREASED HETEROGENEITY
Test Setup

- Frac tank
- Pump
- Flow meter
- 7803
Above-zone; Active

Pressure Response for Pusle Test Number 1

Storativity \((S) = \phi h c_t\)
Transmissibility \((T) = k h / \mu\)
Diffusivity \((D) = T / S\)
Above-zone; Active

Superposition Principle - Well 7605

Matching Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>S ((\phi hct))</td>
<td>0.0000312</td>
</tr>
<tr>
<td>T (kh/(\mu))</td>
<td>222922</td>
</tr>
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- Pressure (psi) vs. Time (hrs) graph
- Data and Model comparison

The graph illustrates the pressure (psi) over time (hrs) for Well 7605, showing the superposition principle in action.
Above-zone; Active; Time-lapse

Data 06-27-13
Model 04-07-15
Conclusion

• 40 years of modeling development and hundreds of papers on pressure analysis
• Mature analytical models
• Pressure monitoring in characterizing the reservoir
• Pressure in development as a tool to evaluate containment.