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Challenges and Takeaways from Field Pressure Signal Testing in a Low-Temperature Geothermal Reservoir in Northern China

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MOTIVATION: DATA QUALITY IN OPERATING LOW-TEMPERATURE GEOTHERMAL WELLS

- Pressure signal testing supports reservoir diagnosis and model calibration, but reliable interpretation depends on high-quality data.
- Field tests are often conducted in operating wells, where direct reservoir or bottomhole pressure is difficult to measure, and pressure is commonly recorded at the wellhead instead.
- Data acquisition and processing can be more challenging than expected, and pressure losses between measured wellhead and actual bottomhole pressure are sometimes overlooked.

⇒ **Aim:** To use simple, cost-effective but accurate devices to collect large, continuous datasets with short time intervals, and to apply straightforward data-processing methods to evaluate wellbore pressure loss and emphasize the importance of data quality control.

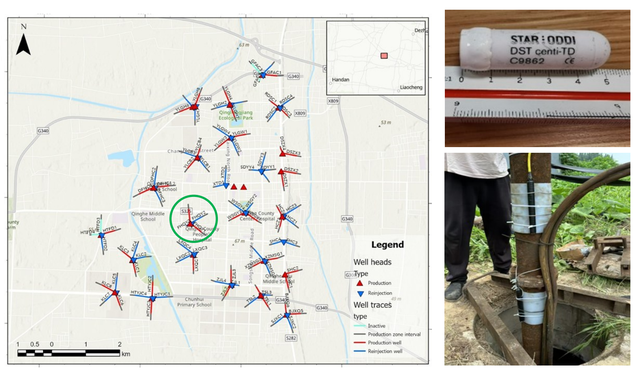


Figure 1. Geothermal well distribution in the study area. The green circle marks the four test wells (FHQY#1 & #4 producers; FHQY#2 & #3 injectors). Photos: offline pressure sensor and installation on pumping pipeline.

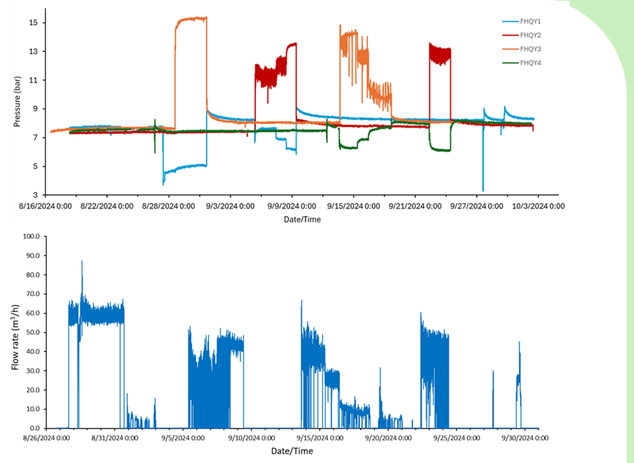


Figure 2. Raw time-series data from the four active wells: upper panel shows pressure recorded by the offline sensor; lower panel shows raw flowrate variations.

DATA ACQUISITION, PROCESSING & CALCULATION

- Data collected every 1 minute for ~30 days
- Offline sensors installed at ~150 m depth (Figure 1 and 3), with measurement resolution ~50 cm water level
- Flowrate changes performed in one production–reinjection quadruplet (Figure 2)
- Pressure and temperature responses continuously monitored (Figure 2)
- ◊ Data preprocessing by noise filtering, outlier detection and removal, missing data handling, data smoothing and time resampling

⇒ Downhole pressure estimated using a simplified wellbore equation below and concept is shown in Figure 3

$$p_w = p_o + \Delta p_{f,ru} + p_{ro}$$

Darcy-Weisbach Equation:

$$\Delta p_{f,ru} = \Delta h_{ru} \cdot f_d \cdot \frac{\rho}{2} \frac{\langle v \rangle^2}{D}$$

p_w - pressure at the bottom of the well,
p_o - measured pressure,
$\Delta p_{f,ru}$ - estimated frictional pressure loss in the wellbore,
p_{ro} - hydrostatic pressure of the water column,
Δh_{ru} - flow path length,
f_d - Darcy friction factor,
ρ - fluid density,
v - flow velocity through the cross-sectional area
D - internal diameter of the pipe.

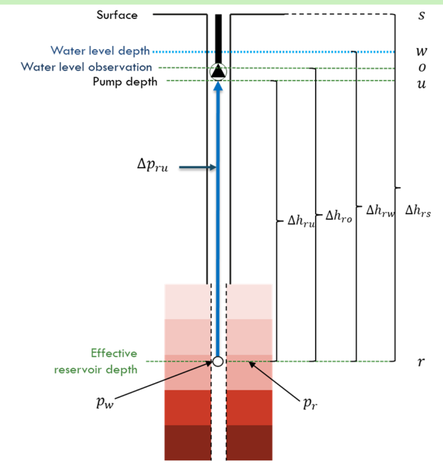


Figure 3. Conceptual sketch showing pressure loss between the downhole pressure and the pressure at borehole measurement depth.

WELLBORE & TEMPERATURE EFFECTS SIGNIFICANTLY DISTORT MEASURED PRESSURE SIGNALS

Results (Figure 4 and 5) show significant differences, 0.4 to 1 bar, between near-surface and bottomhole pressure variations.

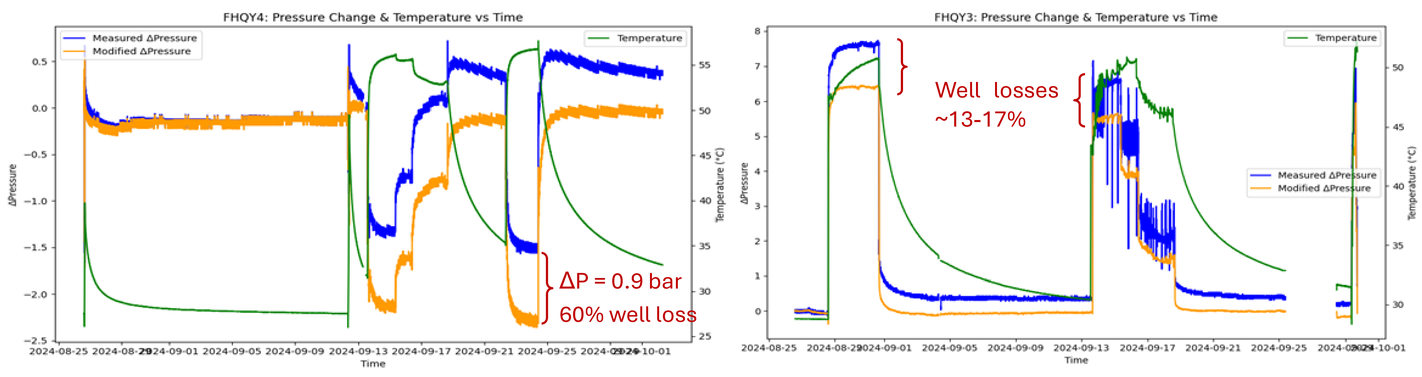


Figure 4. Comparison of measured pressure changes at shallow depth (blue), estimated bottomhole pressure (yellow), and measured shallow water temperature (green) for one production well FHQY4 and one reinjection well FHQY3.

- Hydraulic Loss Effect: Friction, Flowrate dependency, Wellbore diameter
- Thermal Effect: Density change, Temperature variation, Transient effects during flow changes

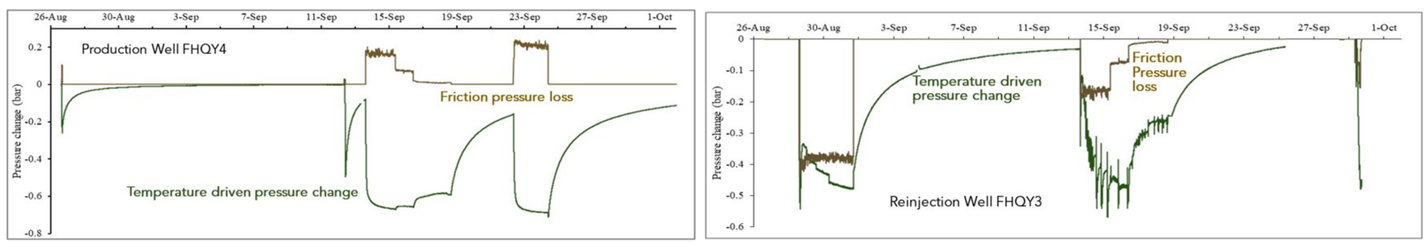


Figure 5. Estimated frictional pressure losses and pressure variations induced by temperature changes for one production well FHQY4 and one reinjection well FHQY3.

PARALLEL VALIDATION USING DIRECT DOWNHOLE PRESSURE MEASUREMENTS

A parallel validation test was conducted in reinjection well FHQY#3 to assess wellbore pressure-loss uncertainty.

Pressure was simultaneously measured at ~150 m and near the main aquifer (~1397 m) under varying flow rates.

Calculated downhole pressures (Figure 6) showed strong agreement with directly measured deep-sensor data, confirming that the simplified estimation method can reliably approximate true downhole pressure.

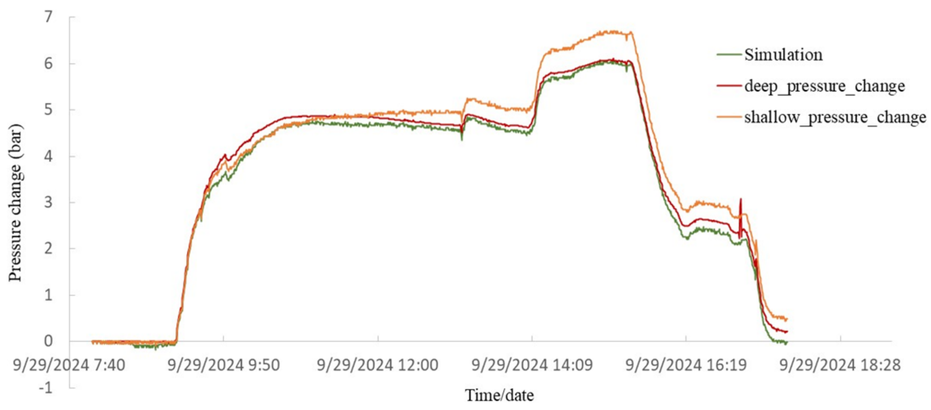


Figure 6. Comparison of pressure responses measured at shallow depth, near-bottom depth, and estimated downhole pressures under variable reinjection flow rates. The calculated results show good agreement with measured deep-pressure data.

CONCLUSIONS

- Wellhead pressure does not directly represent reservoir pressure under operating conditions.
- Wellbore losses can account for up to 60% of observed pressure variation during flow changes.
- Frictional losses are flowrate-dependent, while hydrostatic pressure is strongly affected by temperature-induced density changes.
- In low-temperature wells, temperature effects on pressure are greater than commonly expected.
- Without correcting for wellbore and thermal effects, reservoir properties may be significantly misinterpreted.

OUTLOOK & IMPLICATIONS

- Quantify wellbore losses before reservoir interpretation in low-temperature systems.
- Integrate temperature monitoring into pressure analysis for accurate hydrostatic correction.
- Reliable results are achievable with simple, cost-effective sensors when supported by rigorous preprocessing.
- Incorporate standardized wellbore correction workflows into routine geothermal pressure testing.

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