Pressure Pulse Code Testing

1. Synopsis

Pulse Code Pressure Pulsation Test (PCT) is a data acquisition and interpretation service based on the correlation between variations in production rates in the generating well during the test and the corresponding responses in bottomhole pressure in offset wells.

The connectivity assessed through PCT plays a vital role in various aspects of reservoir studies. It helps determine whether the wells are draining from the same reservoir, if they are situated within the same compartment, and if there are any signs of unintended cross-reservoir communication in generating or offset wells (due to borehole cross-flow or behind-casing channelling).

Additionally, PCT checks the extension, conductivity, and proximity of faults, as well as the lateral direction and extension of hydraulic fractures. It provides numerical values for cross-well connectivity, which are essential for calibrating full-field geological and dynamic models. In some reservoirs, PCT can also assess sweep efficiency in the cross-well interval.

PCT is an advanced modification of the conventional pressure interference test, offering two major advantages:

- It does not require shutting down the offset wells to capture pressure pulsations created by the generating well.
- The test data analysis is complemented by highly automated full-history production analysis using the **PolyPRIME** software facility.

The PCT procedure involves field operations to suspend downhole pressure gauges in the generating well and several offset responding wells.

Because the pressure responses in receivers are small, and the test duration is relatively long (typically ranging from one to a few months), it is best practice to use quartz-oscillator pressure gauges with a resolution of < 10 Pa. These gauges also provide excellent time/temperature stability during the survey.

Data processing and interpretation typically take less than a month for a typical PCT cell consisting of one generating well and five offset responding wells.

PCT relies heavily on computer-aided automation, making data processing and interpretation reasonable in terms of turnaround time. Machine learning approaches are used to perform production analysis to generate the final deliverables.

Using a cross-well pressure decomposition technique, PCT estimates potential drainage volumes, boundary types, their proximity, reservoir transmissibility, and cross-well connectivity, significantly enhancing conventional single-well PTA/RTA.

The PCT interpretation workflow includes the procedure for reconstructing the formation pressure and productivity index of the generating well during the test, providing valuable constraints for future reservoir modeling.

Furthermore, PCT aids in the selection of underperforming wells for remediation and/or additional surveillance activities.

Pressure Pulse Code Testing

2. Engineering Domain

- Reservoir study
  - Subsurface cross-well connectivity
  - Well-by-well production history analysis
  - Pressure/Rate Transient Analysis
  - Formation characterization

3. Target Consumers

- Reservoir Engineers
- Simulation Engineers
- Geologists/Petrophysicists
- Production Technologists
- Well Test Analysts

4. Key Product Deliverables

- Cross-well connectivity analysis (quantitative)
- Short-term Production Forecasts
- Thief water production suspects (quantitative appraisal)
- Thief water injection suspects (quantitative appraisal)

5. Key Advantages

- Analyzing cross-well connectivity with minimal to no production deferment
- Fast & highly automated heavy data processing
- Highly automated production history analysis utilizing machine learning

6. Data Outputs

Generating Well:

- Reconstruction of Formation Pressure dynamics during the test
- Reconstruction of Productivity Index dynamics during the test
- Production rate and Formation Pressure short-term forecasts based on the user-defined future BHP scenario
- BHP and Formation Pressure short-term forecasts based on the user-defined future Production Rate scenario
- Potential drainage volumes (with account of interference)
- Boundary type
- Boundary proximity
- Reservoir transmissibility
- Well-Reservoir Contact (skint-factor, fracture half-length, horizontal length, number of active frac zones)
- Well-bore storage
- Quantitative estimation of thief water injection/production production (if any)

Offset wells:

- Cross-well connectivity (absolute values and unit-rate values)
- Cross-well connectivity maps (absolute values and unit-rate values)
- Quantitative estimation of thief water injection in offset wells (if any)

7. Data Inputs

General:

- PVT model (FVF, compressibility, viscosity for oil/gas/water)
- Pore compressibility
- The following data is additional and only used for comparative study of PCT results against expectations from rock properties:
  - Relative Permeability Model
  - Reservoir Thickness Map

Generating Well:

- Production rate tests (both historical records and during the PCT tests)
- Reallocated monthly production (oil/gas/water) rate history (if available it may improve the rates reconstruction due to cumulative constraints)
- Long-term Permanent Downhole Pressure Gauge (PDG) history records (normally > 6 months but may depend on the data sampling and accuracy)
- Well Intervention History
- Reservoir thickness, porosity, permeability (only required for comparative analysis of PCT results vs expectation)

Offset wells:

- Production rate tests (both historical records and during the PCT tests)
- Reallocated monthly (oil/gas/water) production rate history (if available it may improve the rates reconstruction due to cumulative constraints)
- Well Intervention History
- Reservoir thickness, porosity, permeability (only required for comparative analysis of PCT results vs expectation)

8. Service facilities and procedures

- Office work:
  - High performance multi-core workstation
  - Polygon software facility
- Field opeations:
  - Suspend high-resolution downhole quartz-oscillator pressure gauges in generating and offset wells

9. Service duration

- Normally one month for one PCT cell with 1 generating well and 5 offset wells
- Field operation normally takes from one month for high permeability rocks (> 100 md) and up to 6 months for low permeability rocks (few md)

10. List of technologies used

- Pulse Code Decomposition (based on PolyGon PCD 2.0 module)
- Automated Production History Analysis (based on PolyGon PRIME module)