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## **Scatter Search for Optimizing the Formation-Rate Analysis (FRA) Model**

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### **Abstract**

The Formation Rate Analysis (FRA) method applies the multivariate linear regression method to invert pressure test data to estimate formation parameters. This method is simple and works well if the measured pressure transient noise is small. However, if the noise is large, errors in the estimated formation parameters are unacceptably large.

To solve this problem, we present a multi-scale scatter search optimization method. The basic idea of this optimization method is to iteratively generate sampling points using Hammersley random sequences in regions of various sizes in the parameter space. A reference data set is generated from the candidate optimal solutions and then used to filter the generated sampling points. The uncertainty of the calibrated formation parameters is quantified based on the searched valid optimal solutions.

We test this algorithm with formation test data from low permeability, high permeability, and tight formations. Its accuracy, efficiency, and reliability are validated. We also compare it with the original FRA method. The test results show that:

- compared with the linear regression method, this algorithm more accurately estimates the formation parameters, particularly for the tight formation;
- compared with the direct Monte Carlo method, this new algorithm more efficiently provides calibrated formation parameters and quantifies more accurately the associated uncertainties;
- for high permeability formations, the estimated uncertainty of the calibrated formation pressure is very small;
- for tight formations, flow-line fluid compressibility can be effectively calibrated. However, the short length of the measured pressure transient results in a large uncertainty in the estimated formation pressure and mobility. Also, the mean value of the formation pressure is underestimated if the pressure transient is far from being stabilized.

### **Introduction**

Formation pressure and mobility are important formation parameters for reservoir engineers. These parameters can be obtained from formation pressure testing. Formation pressure and mobility can be analyzed with the conventional techniques of the pressure transient analysis (PTA), including log-log plots and typed-curve analysis. They can be more accurately determined with the modern PTA analysis technique (Houzé et al., 2007), such as deconvolution and pressure matching. Formation Rate Analysis (FRA™) provides a physical model (Samaha et al., 1996; Kasap et al., 1999) for performing pressure matching to calibrate the formation parameters with the optimization technique.

The FRA model was first introduced by Kasap et al. for formation test data analysis. Essentially, it is a mass conservation equation of the fluid in the flow line of a formation tester. It is based on modeling the storage effect of the fluid in flow line, instead of using the drawdown rate as the formation rate. Not only is it used to estimate the formation parameters, but it is also applied to the quality control of the LWD technique (Meister et al., 2003), and to optimize pressure tests while drilling (Lee et al., 2005).

The validation of the FRA model is based on the validation of its model assumptions, i.e. spherical flow near the probe, single phase flow of the fluid of constant compressibility, and homogeneous formation. However, formation tests may not be so ideal. Typically, there may be gauge measurement errors, non-Darcy flow effects, supercharging problems, mud filtrate invasion problems, probe sealing problems, mechanical vibration of the piston, etc. All these problems can introduce measured noise and errors into the pressure transient data.

The errors of the measured pressure transient will propagate to the estimated formation parameters. First, they will directly affect the fitting error, which is the error between the measured pressure and numerical solution of the FRA model. The fitting error is minimized by pressure history matching. Second, the finite difference of the measured pressure transient is used to