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## **Analysis of Permanent Downhole Gauge Data by Cointerpretation of Simultaneous Pressure and Flow Rate Signals**

Sanghui Ahn, SPE, and Roland N. Horne, SPE, Stanford University

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### **Abstract**

Modern permanent downhole gauges have the capability to measure both pressure and flow rate, which provides data with the potential for a wider range of reservoir analysis applications than just pressure data alone. It is important to pair the data analysis of pressure and flow rate streams together. Reservoir physics imposes a relationship between the two data sets. Investigation into the interrelation of data pairs provides a better way of characterizing the true reservoir response.

Deconvolution is an important tool for understanding the interrelationship between variable pressure and flow rate. Using convex optimization approaches to achieve deconvolution in the time domain was found to be successful in extracting the constant rate pressure response.

We evaluated the noise model of pressure and flow rate data for each pair of measurement points. We were able to estimate pairs of noise-reduced pressure and flow rate data according to the interdependence of the original data streams, thus honoring the reservoir physics. Analysis of the interrelation allowed us also to update the estimate of the constant rate reservoir response.

Investigating pressure and flow rate pairs simultaneously may improve the match and accuracy of the reservoir model. The ability to incorporate and retain interrelations suggested by true pressure and flow rate pairs is useful to the interpretation of reservoir behavior. Cointerpreting the two data streams simultaneously provides better information about the reservoir. Following noise reduction by cointerpretation, the data can then be used in more complex reservoir engineering functions, such as closed loop optimization.

### **Introduction**

Advanced permanent downhole gauges developed since 1963 (Nestlerode, 1963) have enhanced reservoir description, analysis and diagnosis, and have been used for well testing studies in a variety of important ways (Chorneyko, 2006). A new variant of these tools provides the ability to measure pressure and flow rate at the same time, however interpretation methods for the simultaneous interpretation of pressure and flow rate have yet to appear in common practice (Horne, 2007). The convolution relationship between pressure and flow rate signals is essential in the diagnosis of the reservoir by inferring the reservoir response to constant rate production. The underlying constant rate response can be used to determine which data pairs are consistent with the overall behavior and which are aberrations.

Time series deconvolution studies have been enhanced using the nonlinear Total Least Squares approach (von Schroeter et al 2002, 2004; Levitan 2005). Here, we are interested in seeing how the convolution principle can be applied to extract noise attributes in pressure and flow rate data. The noise measured from permanent downhole gauges may be due to parasitic phenomena, such as electronic noise or external events such as variations in the wellbore environment. The more general formulation is to consider the varying noise attributes in both pressure and flow rate, thereby honoring reservoir physics while discerning the effect of measurement noise. Assuming measurement noise in pressure and flow rate to be univariate normally distributed neglects the different levels of noise over time. We can handle unknown noise by either assuming a multivariate normal distribution or by removing some of the obvious noisy time points above a certain threshold. When the noise is assumed to have a multivariate normal distribution over time, maximum likelihood estimation provides the appropriate weights for penalizing raw data with preconditioned noise information constructed by a sample covariance matrix. Modeling the noise heuristically as the discrepancy between the raw and estimated data for pressure and flow rate, we find that a more general yet simpler flow rate estimate can be obtained and then used to update the flow rate data.

The optimization procedure is fundamentally similar to the current time-series two step deconvolution procedure, except that we iterate alternately between optimizations over two different variables to tackle the biconvexity of the problem. In