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Exponential vs. Hyperbolic Decline in Tight Gas Sands — Understanding the Origin and Implications for Reserve Estimates Using Arps' Decline Curves

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Abstract

When tight gas sand reserves are assessed using the Arps rate-time equations, the decline behavior is typically defined in terms of the Arps decline exponent, *b*. The original Arps paper indicated that the *b*-exponent should lie between 0 and 1.0 on a semilog plot. However, in practice we often observe values much greater than 1.0, especially prior to the onset of true boundary-dominated flow. Unfortunately, the correct *b*-exponent is difficult (if not impossible) to identify during the early decline period — and (obviously) the selection of the wrong *b*-exponent will have a tremendous impact on reserve estimates, particularly when the *b*-exponent estimate is too high.

As an exercise to evaluate the *b*-exponent as a continuous function of time, we have used synthetic and field production profiles. We then compare the computed *b*-exponent trend graphically to assess the "hyperbolic" nature of each case (recall that the *b*-exponent should be constant for a given hyperbolic rate decline). The field data cases used in this study were selected from a tight gas reservoir that has been previously evaluated on a per well basis using the production model based on the elliptical flow concept. These cases indicate that only portions of the production history are matched by the hyperbolic rate decline relation — suggesting that using the hyperbolic relation by itself may not be appropriate for reserves extrapolations in tight gas reservoirs, or at least that great care must be used in creating production forecasts based on the hyperbolic rate decline relation.

In addition to the hyperbolic rate decline relation we have also developed and employed a new "power law loss-ratio" rate relation that has more generality than the hyperbolic rate decline relation. This new model tends to match production rate functions much better than the hyperbolic rate decline relation for tight gas and shale gas applications, but we must stress that at this time, the "power law exponential decline" rate relation is empirically derived from only tight gas/shale gas performance cases. We have applied the new model as well as the hyperbolic rate model to two synthetic (simulated) and field (tight gas well) cases for production forecast.

Furthermore, the results of our synthetic performance cases do suggest that layered reservoir behavior *can* be accurately represented by the hyperbolic rate decline relation. Unfortunately, as other studies have shown, multilayer reservoir performance can be extremely difficult to generalize — particularly when layers in transient and boundary-dominated flow are in communication. Hyperbolic rate decline relation might be considered as an acceptable mechanism for estimating reserves in tight gas/shale gas systems, however we urge extreme caution as the hyperbolic relation must be constrained to a relative small duration production forecast.

The major impact of this work is that it enables the analyst to have a diagnostic understanding of the hyperbolic rate decline relation (in terms of the *D* and *b*-parameters). Further, we also provide an alternative to the hyperbolic rate decline relation that appears to be substantially more robust, and the new "power law loss-ratio" rate relation can be validated and calibrated directly using rate functions.