Design, execution and analysis of pressure transient tests in slim-hole coalbed methane exploration wells

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ABSTRACT

The use of slim-holes for coalbed methane exploration is becoming increasingly popular in the international arena. The advantages a slim-hole provides over conventional hole sizes include lower cost and the ability to obtain continuous core over large vertical intervals. The main disadvantage is that a slim-hole cannot be produced. Therefore, the singular most important objective for an exploration slim-hole is the acquisition of sufficient high quality reservoir data such that realistic well performance forecasts can be generated and, hence, an evaluation of the commercial potential of an exploration prospect can be made. One reservoir parameter critical to well performance forecasting, permeability, is best determined through pressure transient testing.

Normally production forecasting requires that an estimate of absolute (single-phase) permeability be known. Since it is commonly accepted that coal reservoirs are initially 100% water saturated, and if coal penetrations are maintained in an overbalanced condition to avoid gas desorption, tests such as the slug test or an injection/falloff test should yield an estimate of single-phase permeability. Production tests, similar to conventional drill-stem tests are essentially the same as a slug test (in reverse) when the coal is underpressured, but have the disadvantage of measuring two-phase permeabilities.

Specialized procedures have been developed in the past for each of these test types in coal reservoirs, however, these require modification for application in slim-holes. Due to the significantly reduced annular area between the hole wall and the drill string with slim-holes, effective circulating densities while drilling can be much higher than with conventional holes. This exacerbates the degree of drilling damage caused to the coal, primarily due to underpressured conditions and low coal porosities. Furthermore, for a given volume of drilling fluid lost to the coal, the depth of invasion is greater when originating from a smaller diameter wellbore. Pressure transient tests must, therefore, be capable of measuring the formation permeability some distance from the wellbore beyond the influence of drilling damage. Slug tests, which by nature have a limited radius of investigation are, therefore, not recommended. Production tests, if followed by a shut-in period, can be useful in qualitatively distinguishing permeability (high, low) under high skin conditions despite the two-phase flow complications. Injection/falloff tests are the technique of choice. Design procedures are presented to determine injection time and rate necessary to measure virgin formation permeability beyond the influence of the damaged region, and to maintain low net stresses such that these effects on measured permeabilities are minimized.

Practical considerations when testing open-hole slim-holes are also carefully examined. Due to hole stability concerns (particularly in unknown frontier areas) and the likelihood of testing multiple coal horizons, require that each test take place in an expedient manner. The use of multiple-set packers systems and tests that require the least amount of time are recommended. Slug tests, which require that each zone be isolated and be allowed to equilibrate prior to testing, are not justified. Injection/falloff and production/build up tests are more applicable. The combined use of downhole shut-in assemblies and surface readout gauges can substantially reduce test durations and allow for the termination of each test at the earliest possible moment. Control and monitoring of injected fluid properties is achieved through the displacement of drilling mud with clean injection fluid across the test interval prior to testing, and by monitoring downhole fluid tempera-

ture such that temperature related viscosity adjustments can be made if necessary. A complete description of an advanced, field-proven slim-hole testing system capable of provided all of the above features is included.

In order to obtain an accurate estimate of permeability it is recommended that multiple analysis techniques be utilized and the results from each compared for repeatability. Slug tests can only be interpreted using one technique, type curve analysis, the curves of which show little character or uniqueness. Therefore, slug tests provide order-of-magnitude estimates of near-well permeability only. For comparative and quality assurance purposes, tests results should be reported in a consistent format and include values for permeability, skin, initial reservoir pressure, minimum and maximum radii of investigation and the average net pressure difference for the data analysed. Details of each analysis procedure should be presented as well as all assumptions made for the interpretation. An example is provided to demonstrate the recommended analysis and reporting procedures.