Multi-rate Well Testing

This article describes different types of multi-rate tests, as well as addressing which type of well test should be performed to meet a given objective. Different types of multi-rate tests are performed to meet the following objectives:

1. Evaluate the completion (skin, type of skin, DeltaP across completion)
2. Evaluate the reservoir (permeability, distance to limits, reservoir volume, P*)
3. Satisfy state or federal regulations (MMS initial or annual survey, state mandated deliverability tests, etc.)
4. Determine deliverability or AOF as required by pipeline operators

Rate-After-Rate Test

The most common type of multi-rate test is rate-after-rate test. To perform this type of test, pressures are recorded during a build-up and during successively increasing rate steps as the well is opened. Rates, as well as pressures, should be recorded during the flow periods. It is recommended for SPIIDR® gauge (surface) tests that this initial rate be 1.2 times the unloading velocity of the well bore. After the rate and pressure have stabilized, or after a given fixed time interval, the rate is then increased. This process is then repeated as desired (usually 4 rates for a 4-pt. test), and then the well is either shut-in again or simply allowed to produce. It is common practice to have the final rate be 2-3 times as long as the previous rates. Once the data has been gathered, the BHP's are plotted on an Absolute Open Flow (AOF) plot to determine the deliverability of the well and the Absolute Open Flow of the well. AOF is defined as the number of cubic feet of gas per 24 hours that would be produced by a well if the only pressure against the face of the producing reservoir in the well bore were atmospheric pressure. The flow of gas to the well bore can be described as \( Q = C (BHP_{si}^2 - BHP_{wf}^2)^n \) where \( Q \) is the rate, \( BHP_{si} \) is the shut in BHP and \( BHP_{wf} \) is the flowing BHP. \( C \) is a constant that describes the position of the stabilized deliverability line, and \( n \) is an exponent that accounts for non-ideal gas and non-steady state flow.

2-Rate Modified Drawdown Test

Another version of a multi-rate test is a 2-rate modified drawdown. In this case, a flowing well has its rate doubled to start a new transient. The drop in Flowing Bottom Hole Pressure's (FBHP's) enables reservoir and completion evaluation. Another type of 2-rate test is performed by reducing the rate and observing the pressure increase in the FBHP's. This type of test is performed on wells where there is concern for phase re-segregation during a build-up. Hypothetically, this partial build-up should provide everything that a normal build-up would provide. In practice, this type of test should only be used to determine if the well has a significant skin and to provide a rough estimate of permeability. Another use of a 2-rate test is to estimate the reservoir pressure by assuming a constant PI (productivity index) and plotting \( (P_{initial} - P_{well \ flowing})/Q \). However, this technique is only valid in high-permeability reservoirs.

One of the difficulties in a rate-after-rate test is that some of the rate changes may not be large enough to create a new transient in the reservoir. To ensure a new transient is created each time the rate is changed, the new rate should be double the previous rate. If this is not the case, boundaries may affect the pressure decline differently for different rates, which often leads to an underestimation of the well's PI. To mitigate this problem, isochronal tests may be performed.

Isochronal (Modified) Tests

Isochronal tests (and Modified Isochronal tests) provide more accurate deliverabilities than those provided by a rate-after-rate test and also permit evaluation of rate-dependent skin. After a stabilized SIBHP is achieved, the well is produced in the same sequence as a rate-after-rate test, except that at the end of each rate, the well is shut-in. In an Isochronal test, the well is shut-in until the SIBHP stabilizes; in a Modified Isochronal test, the well is shut-in for the length of time of the previous flow period. The last flow period is generally 4-6 times the length of the other flow periods. After the final flow period, the well
may be shut-in again, especially if the initial shut-in data were not gathered. In practice, modified isochronal tests are performed much more often than regular isochronal tests, since they are less open-ended (fixed shut-in times), take less time and provide equivalent results. Deliverabilities are determined in a similar fashion to rate-after-rate tests, except that the final shut-in pressure prior to the rates is used to calculate the effective ΔP across the reservoir, instead of a fixed P*.

In general, the only drawback to a multi-rate test is that it has to be executed properly to get meaningful results. All flow periods must be the same length of time except the final "stabilized flow" period which should be 2-3 times the length of the previous flow periods for a rate-after-rate or 4-6 times the flow period for Isochronal tests. Rate-after-rate tests should have at least 3 rates and Isochronal tests should at least 4. Most importantly, each successive flow rate should be HIGHER than the previous rate.

Summary

- Multi-rates are useful for completion and reservoir evaluation, regulatory testing and AOF or deliverability of the well.
- A "rule of thumb" for drawdown testing (after shut-in) is that it is usually believable up to 2 TIMES the length of the previous shut-in. Therefore if the well has been shut-in for 2 days prior to the drawdown the first 4 days of the drawdown are typically reliable information.
- Constant Choke, not constant rate
- Simultaneously test while selling gas
- Multi-rate or flowing tests are typically not well-suited for type-curve analysis methods.

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