Step Rate-Falloff Test Guidelines to Determine Fracture Initiation Pressure and Reservoir Properties

- Submittals including, but not limited to, the proposed testing procedure, analysis and report must be prepared by or under the direct supervision of a **licensed Professional Engineer (P.E.) in good standing with the Louisiana Professional Engineering and Land Surveying Board**. Submittals must be sealed, signed, and dated by the licensed professional.
- Before proceeding, have a reasonable idea of what the injection sand formation permeability and the in-situ stresses are in order to plan the Step Rate Test.
- Provide the name of the sand formation to be tested/injected into.
- Provide the stabilized reservoir pressure.
- Has the injection sand formation ever been stimulated? If so, the Step Rate – Falloff Test may measure the fracture extension pressure instead of the fracture initiation pressure.
- Submit Form UIC-17 or Form UIC-2 MASIP (whichever is appropriate) with the Step Rate – Falloff Test proposal which – at a minimum – must include the information found below.
- A Conservation Enforcement Specialist (CES) must be given the opportunity to witness the test.
- *****IMPORTANT***** If multiple sand formations are perforated, block off the lower formations so that you are only injecting into the uppermost perforated sand formation.
- Prior to the test, the well must be shut-in long enough (*minimum of 48 hours*) for the Bottom-Hole pressure to equalize with the shut-in formation pressure.
- *****IMPORTANT*** You will be performing an *initial* Step Rate Test followed immediately by a Falloff Test then *repeating* the Step Rate Test followed immediately by another Falloff Test.** Ensure an adequate supply of water is available and ready to go for the entire test since it could potentially last for a couple of hours. Several hundred barrels of water may be required.
- Ensure that the injection pump is capable of handling the full range of injection rates expected during the test. The pump must be able to pump smoothly and reliably.
- Test fluid weight must be held constant and verified throughout testing. Fluid analysis will be required.
- Gauge the inside diameter (ID) of the tubing - from top to bottom - to ensure uniform ID (and no obstructions) all the way down and also verify the entire length of the tubing.
- Must include running **both a continuous readout *Surface* pressure gauge and a continuous readout *Bottom-Hole* pressure gauge** (as close as possible to top perforation). Ensure that the pressure gauges are recently calibrated and able to accommodate the full range of expected pressures.
- Injection rates should be controlled with a constant flow regulator that has been tested prior to use. Do not use a throttling device in place of the constant flow regulator. Flow rates should be measured with a recently calibrated turbine flowmeter capable of accommodating the full range of expected flow rates.
- First step must begin at **¼ bpm**. Rates for subsequent steps (Step 2 and beyond) may be adjusted with the goal of achieving at least three to four rates *below* fracture initiation pressure and at least three rates *above* fracture initiation pressure. Each step must reach radial flow and last a minimum of 30-minutes per step. **IMPORTANT:** If a step takes longer than 30-minutes to reach radial flow, all subsequent steps should last for that amount of time, e.g. if step 3 takes 45-minutes to reach radial flow, all steps after that must be performed for a minimum of 45-minutes; then, if a subsequent step takes 55-minutes to reach radial flow, all steps after that must be performed for a minimum of 55-minutes; and, so on.
- **If stabilized pressure values are not achieved during each time step or if the data does not definitively show the "fracture initiation" pressure, the Injection and Mining Division (IMD) may deem the test results inconclusive.**

- After the final three Step Rate-time increments have been performed (*knowing that the formation fracture initiation pressure has been exceeded*) and after the pressure has stabilized, injection must be immediately stopped by instantaneously closing the line valve (at the wellhead) and allowing the pressure to bleed-off into the formation. You should observe a significant instantaneous pressure drop (Instantaneous Shut-In Pressure or ISIP), after which the pressure should level out. This ISIP value must be read and recorded. This will conclude the *initial* Step Rate – Falloff Test.
- ***IMPORTANT*** Once you have successfully completed the *initial* Step Rate – Falloff Test, **REPEAT the Step Rate – Falloff Test again.**
- After the final three Step Rate-time increments have been performed during the *repeated* Step Rate Test (*knowing that the formation fracture extension pressure – in this case – has been exceeded*), injection must be immediately stopped by instantaneously closing the line valve (at the wellhead) and allowing the pressure to bleed-off into the formation. You should once again observe a significant instantaneous pressure drop (Instantaneous Shut-In Pressure or ISIP), after which the pressure should level out. This ISIP value must be read and recorded and may be considered to be the minimum pressure required to hold open a formation fracture at this particular injection well. The *repeated* Step Rate – Falloff Test can be considered completed once the ISIP is obtained.
- ***IMPORTANT*** At the conclusion of both Step Rate – Falloff Tests, you must run a Radioactive Tracer Survey (RTS) with Time Drive Supplement in accordance with the IMD's RTS and Time Drive Supplement guidelines to prove there is no damage to the cement which may result in vertical migration of injection fluid.
- Submit the RTS with Time Drive Supplement and Form UIC-WH1 to the IMD along with a report that includes in-depth analysis of the Step Rate – Falloff Tests and interpretation of all graphs and data.
- **For both Step Rate – Falloff Tests, provide the following plots and additional data**:
    - Cartesian Plot of Surface Pressure, Bottom-Hole Pressure, Temperature and Injection Rate plotted versus Time.
    - Cartesian Plot of Bottom-Hole Pressure (y-axis) versus Rate (x-axis).
    - Cartesian Plot of Surface Pressure (y-axis) versus Rate (x-axis).
    - Log-Log Diagnostic Plot showing Pressure and Semi-Log Derivative curves. Identify the radial flow regime.
    - Superposition Semi-Log Plot (use Horner Plot if single rate change precedes a step; multi-rate superposition if several rate changes precede the step). Identify the radial flow portion.
    - Calculate the following: Transmissibility, kh/μ; Skin Factor, s; Skin Pressure Drop, ΔP_{skin}; Radius of Investigation, r_i.
    - Analysis of test fluid - include chloride (mg/l), TDS (mg/l), density (ppg) or SG, and temperature.
    - Provide an explanation of any anomalous data or results.
- Provide all raw data in digital format.
- **Do not resume injection** into the well until the IMD has reviewed the data and, if necessary, re-calculated the Maximum Authorized Surface Injection Pressure (MASIP).
- The MASIP will be re-calculated based on the results from the two Step Rate – Falloff Tests.
- ***IMPORTANT*** **It is ultimately up to the Operator and/or the Third-Party conducting the Step Rate – Falloff Tests to ensure accurate, analyzable data and test results. The IMD cannot guarantee an increased MASIP. If this Office fails to see the "fracture initiation" pressure or if there are unexplainable anomalies in the data, the test may be deemed inconclusive. If the "fracture initiation" pressure is determined to be lower than expected, the currently-assigned MASIP will be reduced. Furthermore, if the RTS and/or Time Drive Supplement indicate that the cement sheath has been compromised or that vertical migration of fluid has occurred outside of the approved injection interval, a Plan of Corrective Action must be submitted and evaluated by the IMD.**