ATTACHMENT I

FORMATION PRESSURE FALL-OFF TEST

INTRODUCTION

Falloff testing is part of pressure transient theory that involves shutting in an injection well and measuring the pressure falloff. The injection well permit conditions require a falloff test per Code # 146.13.

UIC Class 1 Well Regulatory Requirements

• §146.13 Operating, monitoring and reporting requirements (d)(1) …At a minimum, the Director shall require monitoring of the pressure buildup in the injection zone annually, including at a minimum, a shut down of the well for a time sufficient to conduct a valid observation of the pressure falloff curve."

1. GENERAL PREPARATION

Factors that will be considered prior to performing a pressure fall-off test:

- Adequate storage for the injection liquid needs to be ensured for the duration of the test.
- Offset wells completed in the same formation as the test well will be shut-in prior to and during the test. If this cannot be accomplished then a low, constant injection rate into the offset injection wells will be maintained prior to and during the test, if feasible.
- The location of the shut-in valve to cease flow to the well for the shut-in portion of the test will be located at or near the wellhead. The shut-in will be accomplished as instantaneously as possible to prevent erratic pressure behavior during the test.
- Facility wastewater or plant water supply will be used for the test.
- A surface readout downhole pressure gauge will be used. The capability to produce plots necessary to analyze the test data will be available at the well site to help insure valid test data is obtained and false test runs are quickly identified and aborted. The gauge will be configured to obtain pressure data ~~more frequently in the early portion of the test when~~ the rate of pressure decline is greater. Larger time increments will be used to obtain data later in the test when the rate of pressure decline is less.

2. CONDUCTING THE FALL-OFF TEST

The following EPA recommended procedure will be used for conducting the test. Alternative procedures that will produce valid test results and which will satisfy the requirements of the USEPA and the regulations may be presented to the UIC for authorization, in advance of the test.

1 The depth to any fill in the well will be tagged and recorded.
The surface readout downhole pressure gauge will be located at or near the top of the injection interval, unless previous testing indicates a more appropriate location. A surface readout will be provided to allow flexibility in determining appropriate pressure measuring and recording time intervals and to ensure valid test data is generated and false testing runs can be identified and aborted.

2 The injection rate and injection liquid density for the test will be held constant prior to shut-in. The injection rate will be high enough and continuous for a period of time sufficient to produce a pressure buildup that will result in valid test data. The injection rate will result in a pressure buildup such that a semilog straight line can be determined from the Horner plot. The injection rate will be the maximum injection rate that can be feasibly maintained constant in order to maximize pressure changes in the formation and provide valid test results, but will not exceed the daily injection volume limit of the UIC Permit.

3 The injection rate and the density (chloride concentration, total dissolved solids concentration, conductivity or pH are also acceptable) of the injection fluid will be periodically measured and recorded to insure these parameters remain constant.
4 If the stabilization injection period is interrupted, for <u>any</u> reason and for <u>any</u> length of time, the stabilization injection period will be restarted.
5 The well will be shut-in at the <u>wellhead</u> or as near to the wellhead as feasible in order to minimize wellbore storage and afterflow. The shut-in will be accomplished as instantaneously as possible to prevent erratic pressure behavior during the test.
6 The fall-off portion of the test will be conducted for a length of time sufficient such that the pressure is no longer influenced by wellbore storage or skin effects and enough data points lie within the infinite acting period and the semilog straight line is well developed.

3. EVALUATION OF THE TEST RESULTS

A licensed geologist or licensed professional engineer, licensed by the California Board of Professional Geologists or Engineers to practice geology or engineering in California and knowledgeable in the methods of pressure transient test analysis, will evaluate the test results.

The following information and evaluations must be provided with the test report:

1 A log-log plot with a derivative diagnostic plot must be used to identify flow regimes. The wellbore storage portion and infinite acting portion of the test must be identified on the plot. Type curves must be used to verify results.
2 A Horner plot must be used to calculate the kh/u product and to determine P*. An expanded Horner plot containing the entire infinite acting portion must be reproduced in order to permit a closer inspection of the semilog slope and any data fluctuations. The slope used to calculate the kh/u product and to determine P* must be drawn on both Horner plots. In addition, the wellbore storage portion and infinite acting portion of the test must be identified on both plots.
3 The "h" value (injection interval thickness) used must be agreed upon between the UIC and the permittee. For formations with characteristics such as the Arbuckle Formation, the injection interval should be considered the entire thickness of the injection formation in the area. A reliable literature value can be used if site specific data is not available.
4 The viscosity used in analyzing the test must be that of the liquid through which the pressure transient was propagating during the infinite acting portion of the test. The information used to determine the viscosity must be provided.
5 Any test that was not shut-in long enough to develop an infinite acting period, or cannot be properly analyzed for the kh/u group of parameters using the Horner method, should be rerun, using a procedure that will result in valid test results, unless other arrangements have been made with UIC.
6 All equations used in the analysis must be provided with the appropriate parameters substituted in them.
7 Tests conducted in relatively transmissive reservoirs are more sensitive to the temperature compensation mechanism of the gauge, because the pressure buildup response evaluated is smaller. For this reason, the plot of the temperature data should be reviewed. Any temperature anomalies should be noted to determine if they correspond to pressure anomalies.
8 Explain any anomalous data responses. The analyst should investigate physical causes other than reservoir responses.

4. REPORT COMPONENTS

The report to UIC will include general information and an overview of the test, present and analyze the test data, summarize the results of the test and compare the results with previous test results, where appropriate. The report will be submitted to UIC within 30 days of test completion. The report will include the following:

a. The facility name, location, well identification number and UIC Permit number of the test well.

b. A well schematic depicting current completion and location of the pressure measuring tool during the test.
c. Test well information including wellbore radius, completed interval and type of completion.
d. The distance between the test well and offset wells completed in the same injection interval and the status of the offset wells during both the injection and shut-in portion of the test. Describe the impact, if any, the offset wells had on the test.
e. Chronological listing of the daily testing activities.
f. A description of the surface readout downhole pressure gauge used including manufacturer and type, resolution, calibration certificate and the manufacturer's recommended frequency of calibration.
g. Date of test.
h. Location of the shut-in valve used to cease flow to the well for the shut-in portion of the test.
i. Time of injection period, type of injection liquid, final injection pressure and temperature.
j. Total shut-in time, final static pressure and temperature.

Calculations for the following; including equations used, the equations with the appropriate parameters substituted in them, description of values used in calculations and equations and references for values used:

- Radius of test investigation.
- Time to beginning of the infinite acting portion of the test.
- Horner time to the beginning of the infinite acting portion.
- Slope or slopes determined from the Horner plot.
- The value for kh/u (transmissibility).
- Permeability.
- Skin.
- Pressure drop due to skin.
- Flow efficiency.
- Flow capacity.
- P1hr (pressure at 1hr).
- Explanation for any pressure or temperature anomaly.
- Description of whether system is completion or reservoir dominated and whether the system is homogeneous or heterogeneous, including an explanation of how this was determined.
- The following graphs must be provided:
- Cartesian plot, pressure and temperature versus time.
- Cartesian plot of injection rate versus time.
- Log-Log and derivative plots with the flow regions identified (must identify radial flow).
- Semi-log Horner and expanded Horner plots with flow regions indicated (must identify radial flow), the semilog straight line drawn, P* (extrapolated pressure) and P- 1hr (extrapolated pressure at 1hr).
- A comparison of permeability, Kh/u, skin, P and fill up with the same values determined from fall-off tests previously conducted.
- A statement that the raw test data generated by the test will be kept on file by the ECGS for a period of not less than 3 years and will be made available to the UIC Program Director upon request during this time period.

Step Rate Test (SRT)

For

Maximum Surface Injection Pressure (MSIP)

The ECGS will notify the California UIC Program so the SRT can be witnessed by an EPA inspector or representative.

STEP-RATE TEST PROCEDURE:

1) The injection well will be shut in long enough prior to testing such that the bottom hole pressures approximate shut-in formation pressures. If the shut-in well flows to the surface, the wellhead injection string will be equipped with a gauge and the static surface pressure read and recorded.

2) A series of successively higher injection rates will be determined using the guidelines below, and the elapsed time and pressure values will be read and recorded for each rate and time step. Each rate step will last exactly as long as the preceding rate. If stabilized pressure values are not obtained within the rate steps suggested below, the test results will be considered as inconclusive.

   Injection rates for Step Rate Test as a percentage of the anticipated maximum injection rate; 5%, 10%, 20%, 40%, 60%, 80%, 100%.

3) Injection rates will be controlled with a constant flow regulator that has been tested prior to use.

4) Flow rates will be measured with a calibrated turbine flowmeter.

5) Injection rates will be record using a chart recorder or a strip chart.

6) Pressures will be measured with a down hole pressure bomb. If a surface gauge is used, the test pressures will be corrected for the estimated friction loss at each particular flow rate.

7) Injection pressures will be measured and recorded with a gauge or recorder (for immediate test results). The records will show each time step and corresponding pressure.

8) A plot of injection rates and the corresponding stabilized pressure values will be graphically represented as a constant slope straight line to a point at which the formation fracture, or “breakdown”, pressure is exceeded. The slope of this subsequent straight line will be less than that of the before-fracture straight line.

9) If the formation fracture pressure has definitively been exceeded, as evidenced by at least two injection rate-pressure combinations greater than the breakdown pressure, the injection pump will be stopped, and the line valve closed and pressure allowed to bleed-off into the injection zone. There will be a significant instantaneous pressure drop (Instantaneous Shut-in Pressure or ISIP), after which the pressure values will level out. The ISIP value will be read and recorded. The ISIP obtained in this manner will be considered to be the minimum pressure required to hold open a fracture in this formation at the well.

10) Once the ISIP is obtained, the SRT is field activity will be considered complete.

11) If the breakdown pressure was not obtained at the maximum test injection pressure, the test results may indicate that the formation is accepting fluids without fracturing.

STEP RATE TEST DATA

*Well:*_____ *Date:*_____ *Operator* _____

STEP #1 Test Rate (*5%* *of maximum rate*) _____ (*bbl/min*)

Time (*min*) :	_____	_____	_____	_____	_____	_____	_____
Pressure (psi):	_____	_____	_____	_____	_____	_____	_____

STEP #2 Test Rate (*10%* *of maximum rate*) _____ (*bbl/min*)

Time (*min*) :	_____	_____	_____	_____	_____	_____	_____
Pressure (psi):	_____	_____	_____	_____	_____	_____	_____

STEP #3 Test Rate (*20%* *of maximum rate*) _____ (*bbl/min*)

Time (*min*) :	_____	_____	_____	_____	_____	_____	_____
Pressure (psi):	_____	_____	_____	_____	_____	_____	_____

STEP #4 Test Rate (*40%* *of maximum rate*) _____ (*bbl/min*)

Time (*min*) :	_____	_____	_____	_____	_____	_____	_____
Pressure (psi):	_____	_____	_____	_____	_____	_____	_____

STEP #5 Test Rate (*60%* *of maximum rate*) _____ (*bbl/min*)

Time (*min*) :	_____	_____	_____	_____	_____	_____	_____
Pressure (psi):	_____	_____	_____	_____	_____	_____	_____

STEP #6 Test Rate (*80%* *of maximum rate*) _____ (*bbl/min*)

Time (*min*) :	_____	_____	_____	_____	_____	_____	_____
Pressure (psi):	_____	_____	_____	_____	_____	_____	_____

STEP #7 Test Rate (*100%* *of maximum rate*) _____ (*bbl/min*)

Time (*min*) :	_____	_____	_____	_____	_____	_____	_____
Pressure (psi):	_____	_____	_____	_____	_____	_____	_____

ISIP : _____ (psi)

Test Run / Witnessed By: _____