# FINAL

SUBJECT: Guidance for Pressure Fall-off Testing In Class I UIC Wells

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Revised:


PURPOSE: To provide guidance to Class I Underground Injection Control (UIC) well operators on methodology to employ in planning, performing and reporting the results of a pressure fall-off test.

BACKGROUND: OAC Rule 3745-34-57(J)(1) states, in part, that, "(t)he Director shall require monitoring of the pressure buildup in the injection zone annually including, at a minimum, a shutdown of the well for a time sufficient to conduct a valid observation of the pressure fall-off curve". This guidance outlines procedures which will aid in performance of a valid pressure fall-off test.

The purpose of the required injection well testing is three-fold:

1. Reservoir pressure increases associated with long-term fluid injection can be estimated.

2. Estimates of average reservoir pressure obtained through this testing can be compared to modeled predictions of injection interval pressure thereby allowing a post-audit of models used in "no-migration" petitions.

3. The testing permits determination of reservoir characteristics including permeability and skin (formation damage or enhancement near the wellbore) as well as identification of fracturing and changes in these characteristics over time.

The minimum and most common means of testing to satisfy the regulatory requirements is the pressure fall-off test. A typical test consists of injection into a well at a constant rate for a period of time followed by shut-in of the well and monitoring of the pressure decline. At the Director's discretion, additional testing may be required. In any case, the plan for this testing requires Ohio EPA approval. This guidance should be considered in the development of the plan for testing but the plan should not merely reference the guidance. Facility-specific issues should be identified and addressed. Further, this guidance does not cover alternate means of compliance with OAC Rule 3745-34-57(J)(1), such as pressure build-up tests, nor does it imply that a pressure fall-off test will be an appropriate means of compliance with this rule for all wells.

GUIDANCE: **Testing Procedures**

Pretest Considerations: In order to prevent flow rate fluctuations in nearby injection wells from impacting the pressure fall-off test, these wells should be shut in no later than the time injection into the tested well begins and should remain shut-in during the fall-off period. If these offset wells cannot be shut in, they should be operated at a constant rate (no more than 5% variation, where possible) for this same time period. Ideally, offset wells would be shut down several days prior to initiation of injection into the tested well and would remain shut-in for the duration of the fall-off period.

Injection Period: An injection period in excess of 48 hours prior to shut-in will maximize the reservoir pressure increase and the radius of investigation thus improving the potential for calculation of representative reservoir characteristics. It can be expected that the period of valid fall-off data will be shorter than the injection period. Further, well bore storage effects impact data for approximately 50 times (1.5 log cycles) the period of total well bore storage domination (a unit slope line on the log-log plot). Thus, if well bore storage effects are expected to be apparent for more than 1.5 hours, a period of injection longer than 72 hours may be necessary. Injection at the highest rate possible without exceeding injection pressure limits will further maximize the reservoir pressure increase thereby overcoming "noise" in the reservoir. The injection rate in the tested well should vary by no more than 5% and the tested well should be shut in at the wellhead to minimize wellbore storage effects.

Fall-off Period: Ideally, the pressure data would be analyzed in the field as it is recorded to ensure collection for an adequate but not excessive fall-off period. The fall-off period should be of sufficient duration to reflect a period of radial flow in the reservoir. Such data would result in a relatively flat pressure derivative curve on the log-log plot and a straight line of slope, m, on a semilog plot. However, if the data represent linear flow or are obscured by well bore storage, well interference or other phenomena, these indicators may not be evident.

Data Acquisition: Pressure data should be recorded at not less than the following frequencies during various time intervals of the fall-off period:

1. For the first ten minutes: at least every five seconds (a higher frequency may be necessary to acquire meaningful data);

2. For the next twenty minutes: at least every thirty seconds;

3. For the remainder of the fall-off period: at an interval which allows a 1% pressure change. However, the interval between two successive measurements should not exceed fifteen minutes. Ohio EPA has observed that tests can generally be discontinued when the bottom hole pressure decline is less than two psi per hour.

**Reporting**

The time frame for report submission is specified in the UIC permits to operate. The following information should be included in each report submitted.

Pressure Data The required report should include a complete hard copy of pressure and time data and, if possible, a copy of the data on a computer diskette in a LOTUS 123, dBASE III, dBASE IV, Excel or Supercalc spreadsheet or an ASCII text file. It is preferred that time data reflect elapsed time since shut-in, in decimal hours.

Data Plots The report should include all plots used in the data analysis including a Cartesian plot and a log-log plot showing the pressure derivative curve. Semilog plots should show the best-fit straight line of slope, m, representing radial flow. The report should also contain a summary of data derived from these plots, e.g., slope (m) and $p_{1hr}$, and subsequently used in calculation of reservoir characteristics such as permeability and skin. The value obtained for "false pressure" (pressure at infinite shut-

in time, or p*) should be reported. If type curve matching is used in data analysis, the appropriate type curves and match point data should be submitted.

Additional Data The report should include all pertinent data used in the calculation of reservoir characteristics. These data include pre-test injection period, volume injected, well or open-hole radius, injection interval thickness, formation porosity, total system compressibility, viscosity of the fluid through which the pressure transients are propagating, viscosity of the injected fluid, specific gravity of the injected fluid and gauge depth.

The report should also provide the following information where applicable:

1. The duration of shut-in of the tested well prior to initiating pre-test injection;

2. The volume injected and the time elapsed since the last shut-in which allowed for a significant pressure decline (if the tested well was not shut-in prior to pre-test injection);

3. The injection rate history for offset injection wells operating during the pre-test injection period and/or fall-off period.

Discussion and Interpretation The report should identify the equations used in calculations of reservoir characteristics and discuss the applicability of the equations to the data interval selected to represent radial flow (if present). The use of curve matching, modelling and superposition techniques (including computer simulations) should be described as appropriate. The presence or absence of linear flow and the influence and duration of well bore storage effects should be discussed. Further, the influence of boundary conditions, partial well penetration and slanted boreholes on the data should be noted. Finally, the results obtained in the current analysis should be compared to results obtained in previous testing and a textual interpretation provided.

## References


Earlougher, Robert C., 1977. Advances in Well Test Analysis, Monograph Volume 5 of the Henry L. Dougherty Series, Society of Petroleum Engineers of AIME, New York.

Lee, W. John, 1982. Well Testing, SPE Text Book Series Volume 1, Society of Petroleum Engineers of AIME, New York.

Nowak, J. T. And Lester, G. W., 1954. "Analysis of Pressure Fall-off Curves Obtained in Water Injection Wells to Determine Injective Capacity and Formation Damage", Pressure Analysis Methods, SPE Reprint Series No. 9, Society of Petroleum Engineers of AIME, New York.

U.S.EPA, Region V, 1990. "Regional Guidance #6."

U.S. EPA, Region VI, 1993. "Pressure Falloff Testing Guideline, First Revision."