Interpreting Pressure Transient Tests

There is a lot of information present in a pressure transient test, and it is the reservoir engineer’s job to correctly interpret that information in order to make the proper decisions regarding the production of the well being tested. One of the most useful plots that one can make from a pressure transient test is the pressure derivative plot. From this plot one can get an idea of the amount of skin damage around the wellbore, reservoir permeability, the reservoir geometry, and if there are any limits or boundaries nearby. Additionally, most commercially available analysis software utilizes Derivative Type Curve matching for pressure transient analysis. At Halliburton we test several hundred wells every year, and as such have seen a wide variety of datasets illustrating different reservoir behavior. In this article, we will present a few of these derivative plots to show the valuable information that can be obtained through well testing. It is also important to note that all of these tests were conducted from surface.

The first example, which is the most basic plot, is of infinite-acting radial flow, as shown in Figure 1.

![Figure 1) Infinite-Acting Radial Flow](image)

As can be seen in the plot, the slope is zero during radial flow. During this time there are no effects seen from boundaries of any kind, and essentially the reservoir is seen as “infinite” in size. The permeability is determined from this plot. Also, the amount of skin damage can be inferred from this plot, as the amount of separation between the two curves is directly related to the amount of skin damage.

The next example shows a type of limit contact where the well exhibits channel behavior during the pressure transient test. This can be seen in Figure 2 and Figure 3 below.
Figure 2) Channel Behavior

Figure 3) Channel Behavior on a Square Root of Time plot
Channel behavior, which is linear flow between two parallel boundaries, shows up on the derivative plot as a half slope sometime after radial flow. The width of the channel can also be interpreted from this plot, as the distance between the two curves during channel behavior is directly related to the width of the channel. Additionally, during channel behavior a linear plot of the pressure against the square root of shut-in time will yield a straight line, as shown in Figure 3.

Horizontal wells also have their own unique signature to pressure transient tests. Figure 4 below shows a derivative plot from a horizontal well.

![Figure 4) Horizontal Well](image)

There is a lot of valuable information about the horizontal well available from this pressure transient test. During the early (vertical) radial flow (ERF) the vertical permeability ($k_z$) (around the wellbore) and skin damage around the wellbore can be determined. Here, the length of the horizontal section should be used in place of the net pay as used in traditional pressure transient analysis. During the pseudo (horizontal) radial flow (PRF) the horizontal permeability ($k_{xky}$) (along the wellbore) and effective skin can be determined. Here, the true vertical net pay should be used.

One issue commonly seen on wells making a considerable amount of water is liquid re-injection after the well has been shut-in. An example of this is presented below in Figure 5 and Figure 6. The Semilog plot is also shown to aid in illustrating when liquid re-injection ends.
Figure 5) Liquid Re-injection Derivative

Figure 6) Liquid Re-injection Semilog
When testing from surface, it is important that the well be flowing at a high enough rate to bring all produced fluids to the surface naturally. Liquid re-injection occurs when a well is shut-in, and the water which before was being carried out of the wellbore falls back to the perforations, and is then re-injected back into the formation as pressure increases. During this time of re-injection, the reservoir response is being masked at the surface, and as such it is important to only do an analysis on the data after the re-injection is finished. It is also important to note that downhole gauges can also be subject to liquid re-injection issues as they are often set some distance above the perforations. Once the liquid level drops below the gauge, the reservoir response is masked until the liquid is fully re-injected.

The final example shows wellbore storage during a pressure transient test, as seen in Figure 7 below.

![Figure 7) Wellbore Storage](image)

Wellbore storage shows up as a unit slope during the start of the pressure transient test. The longer wellbore storage lasts, the farther along in the plot the unit slope extends before breaking over and going into radial flow. Wellbore storage is the after-flow of fluids into the wellbore after the well is shut-in at the wellhead. During wellbore storage, reservoir effects are masked or distorted. Wellbore storage effects last until pressure is equalized between the well bore and formation. It is a common and incorrect belief that only surface testing is subject to wellbore storage concerns. In fact, downhole gauges are just as subject to wellbore storage effects as a surface gauge. The only way to minimize wellbore storage is by shutting in downhole.

Halliburton conducts several hundred well tests every year. We have seen a wide variety of test data, and have a large knowledge base in regards to well test planning and test analysis, in addition to our ability to accurately convert surface pressures to bottom-hole conditions. Please contact us in the future with any test planning or interpreting questions you may have. Our consultation in these matters is always free of charge.

© 2012 Halliburton. All Rights Reserved