Step Rate Testing

Injecting at pressures significantly below the parting pressure results in reduced oil recovery rates whereas injecting at pressures above the parting pressure may result in loss or misdirection of the injection fluid and reduced oil recovery. Step rate testing (SRT) is the primary method used to determine the maximum safe injection pressure without fracturing the reservoir rock.

The test procedure requires the test well to be either shut in or stabilized at a reduced but constant injection rate prior to the start of the step rate test. Ideally, the shut-in period should be long enough so that the bottom-hole pressure is near the static formation pressure. Alternatively, if the well is stabilized at a reduced injection rate, the stabilization period should be long enough to achieve a steady-state or pseudosteady-state condition. The step rate test consists of a series of constant-rate injections with rates increasing from low to high in a step wise fashion. Each constant-rate step is normally of equal time length. Below is a graph (Fig. a) of injection rate versus time. The intended rate of injection is depicted as the solid lines.

![Schematic of a typical STEP-RATE procedure.](Fig. a)

In practice, a totalizer gives the total volume of water injected in each interval. The recorded volume is then divided by time to give an average injection rate. In contrast to the flow totalizer, the SPIDR® gauge measures the flow rates continuously throughout the test. The SPIDR® gauge has shown the rate does not always remain constant. It often decreases with increasing well-head pressure, as shown by the dashed lines in the SRT graph (Fig. a). Experience with the SPIDR® gauge in the step rate tests have shown that it is often difficult to control injection rate. The pressure increase for a constant injection rate is shown in the SRT graph (Fig. a) with the solid line, whereas the dashed line shows the pressure increase for a falling injection rate.

A Cartesian plot of pressure vs. injection rate is made from the step rate test data. When the injection pressure exceeds parting pressure, the resulting fracture acts as an additional fluid conductor. This
reduces the slope of the pressure vs. rate curve as illustrated in this graph. The pressure corresponding to the point where the two lines intersect is interpreted as the formation parting pressure (FPP). The graph shows FPP at 1,975 PSI. The maximum injection rate can now be obtained by staying under this pressure value during injection. The SPIDR® gauge has shown that control of injection rate in step rate tests is often inadequate. The results are under-estimated formation parting pressure and therefore lower than optimum injection and production rates.

It is advisable to observe surface pressure readings while the test is in progress to detect formation parting pressure as soon as possible. By using the SPIDR® gauge, the change in slope can be detected earlier, resulting in a shorter test duration. The recorded pressure and flow data can be viewed at anytime during the test without interrupting SPIDR® gauge operation or removing the data from memory. Optimum injection rates to a well may be obtained using the measurement and monitoring capabilities of the SPIDR® gauge.

If accurate pressure and injection rate data are recorded, multi-rate pressure transient analysis techniques can also be applied to step rate tests. Formation flow capacity, KH, and well bore skin, S, can be determined and the injection falloff test may not be needed to determine formation properties.