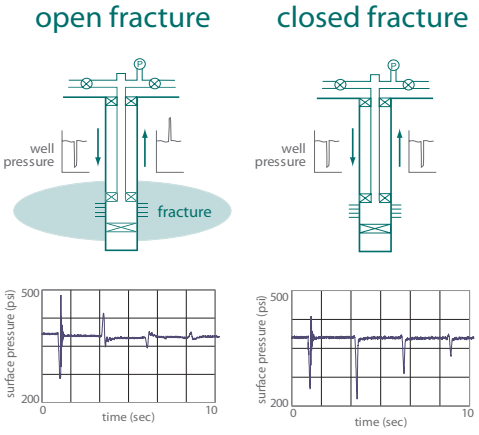
HIT—Hydraulic Impedance Testing

Pinnacle

GET RESULTS

- Determine Fracture Presence
- Pinpoint Fracture Location
- Measure Closure Stress
- Determine Critical Injection Rate



If there is an open fracture, the signal peaks change polarity from negative to positive, but if there is no fracture, the peaks are the same polarity—all negative.

Hydraulic Impedance Testing (HIT) is a Pinnacle Technologies fracture diagnostic service which determines if a fracture is present in a well and if so, the location of the fracture(s). It is a completely non-invasive method, using only surface equipment to perform downhole fracture measurements. HIT also provides an accurate measurement of formation closure stress (minimum in-situ stress) following a diagnostic breakdown or minifrac injection.

HOW HIT WORKS

Hydraulic Impedance Testing creates a pressure wave in the wellbore and we measure the reflections of this wave at the surface. An open fracture causes a reflected pressure wave that is inverted with respect to the original pressure wave (see figure below, left). If there is no fracture, the bottom of the wellbore reflects the pressure wave without any polarity changes (see figure below, right). Also, reflections come from changes in the wellbore diameter. We can simulate the complete HIT trace, both with and without a fracture. In this way it is easy to discern the fracture reflections, even for complicated wellbores.

In order to create the pressure wave, a computer-controlled valve is connected to a wellbore under pressure. The computer pulses the valve open and closed quickly,allowing a small amount of fluid to exit the wellbore. This release of fluid causes the pressure to drop at the surface. This pressure drop propagates down the wellbore,creating a small “water hammer“ as the pressure “bounces “ up and down along the wellbore. A high frequency pressure gauge records the surface reflections at up to 1000 samples/sec.

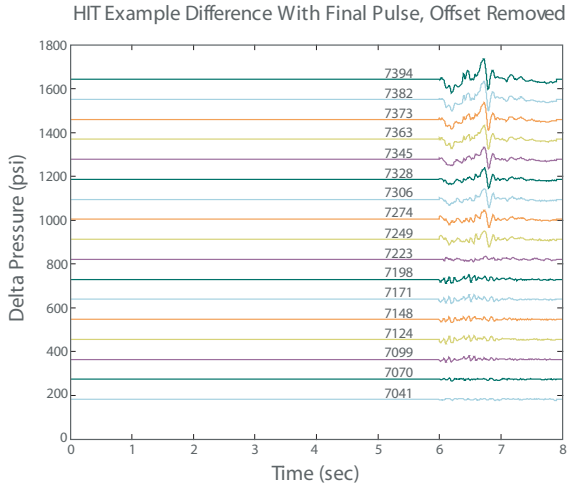
HIT APPLICATIONS

In water injection wells, it is important to know whether the injection is taking place under fracturing conditions. By observing the reflected pulses at the surface, one can determine whether or not there is an open fracture.

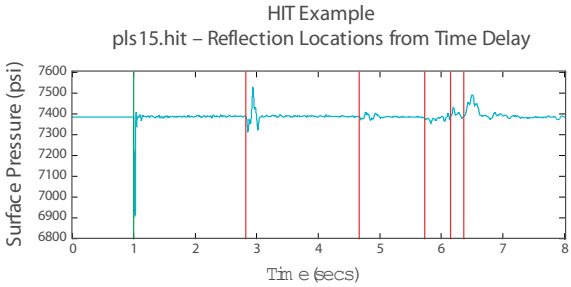
Additionally, HIT can locate a fractured injection zone in open hole or multiple zone completions by measuring the two-way travel time to the fracture and its reflection back to the surface. The velocity of the pressure wave in the wellbore is calibrated using the known depths of any diameter changes. Multiplying the delay time by the velocity gives the depth to the fracture. Using this same method, obstructions blocking the wellbore can also be located.

Fracture closure stress is a critical variable for fracture pressure analysis. HIT is valuable for accurate determination of fracture closure pressure. Normal pressure decline analysis does not always provide a clear indication of closure stress. By performing repeated HIT pulses during pressure fall-off, the transition from an open to a closed fracture may be detected by observing the change in polarity of the reflected pressure wave.

The analysis at the top of the next page illustrates the “Difference “approach to measuring fracture closure pressure where the change in amplitude illustrates the pressure at which the fracture closed. Once the amplitude reaches a constant value, this indicates that the fracture has closed and the effective closure stress has been reached.



This example of HIT analysis using the "Difference" approach indicates a clear fracture closure between 7223 and 7249 psi.



Example of reflection location analysis.

Reflection Locations
Origin for Delay Calculation = 1.000 sec

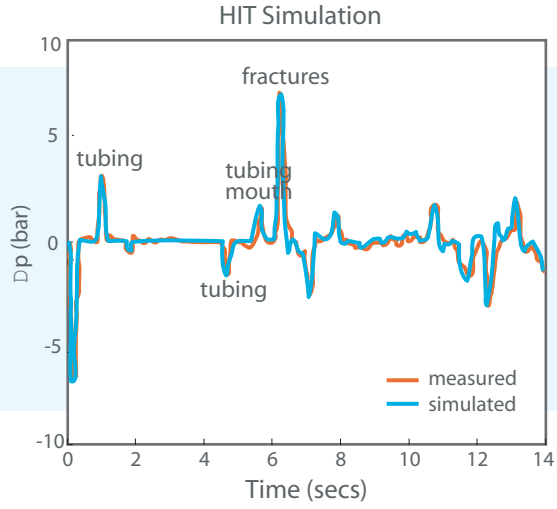
Reflection #1 = 4800 (ft)	Delay Time #1 = 1.823 sec
Reflection #2 = 9623 (ft)	Delay Time #2 = 3.666 sec
Reflection #3 = 12415 (ft)	Delay Time #3 = 4.734 sec
Reflection #4 = 13496 (ft)	Delay Time #4 = 5.147 sec
Reflection #5 = 14059 (ft)	Delay Time #5 = 5.362 sec

The HIT example at middle left shows how various changes in pipe i.d. are determined and their locations calculated from the two way travel time. Five different reflections are seen illuminating a couple of open fractures and several changes in wellbore i.d.

Hydraulic Impedance Testing answers these questions:

- Is there a fracture present in my well?
- Where is the fracture located?
- At what pressure does the fracture close?
- At what rate can I inject and not extend the fracture?

Already a HIT with many operators in the Middle East, North Sea, and U.S., you can answer these questions without putting any tools into the well and without spending a lot of money. Please contact us to learn how Pinnacle's fracture diagnostics can help you.



Adjacent left figure shows a comparison of a simulation with the actual HIT measurement, using the tubing/casing profile and matching fracture reflections by adjusting the fracture location and width. The simulation can be used to infer the fracture parameters and as a pre-job model to determine in advance the effectiveness of HIT on a case-by-case basis.

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