WELLTEST SPECIALISTS

*i*REPORT

Welltest 106: **Impulse Testing**

Welltesting & Impulse Techniques

Responsibility Chain Management	Petroleum Reservoir and Production Engineering teams initiate hydrocarbon welltests. Well testing is first about measuring and recording pressure data. Impulse testing is done without flowing. Responsibility chain management of data requires an integrated team: from wellsite acquisition or collection; to field-office processing, data validation, and technical reporting; to engineering analysis (PTA, AOF, IPR) and legal submissions (AER, SEC). Corporate directors, managers, and stakeholders depend on reliable, traceable, advice from testing wells.
Welltesting Team	Talented and experienced wellsite equipment operators are always appreciated for safe running, installation, and recovery of scientific instruments. Knowledgeable and particular field-office technicians are valued for accurate, timely technical reporting. Engineers need to know what standards to expect, and to do whatever data processing might be required to achieve professional acceptance.
Impulse Techniques	Impulse tests can be run at surface or sandface. Drill Stem Tests (DST); Closed-Chamber Tests; Perforation Inflow, Injection, and Distribution Diagnostic tests (PID); Step-Rate, Mini-Frac', and Diagnostic Fracture Injection Tests (DFIT); and Formation Leak-off tests are all Impulse tests.
Engineering Team	Engineering is quirky: words are different, acronyms are strange, expectations are high, accuracy and precision are standard protocols. All staff in the responsibility chain need an awareness of equipment, tools, and operations. Practical knowledge about quality control, data validation, and technical reporting ensures consistent, reliable deliverables. Literacy with oil patch nomenclature (words, acronyms, subscripts, superscripts) is requisite for effective communication and comprehension.
Bridging Technical Gaps	Welltest Specialists technical training material has been written to bridge technical gaps and help new staff get up to speed with welltest engineering workflow and workspace.
Pressure Data	This *i*REPORT will focus on topics related to Impulse welltesting, exclusive of Drill Stem Testing.

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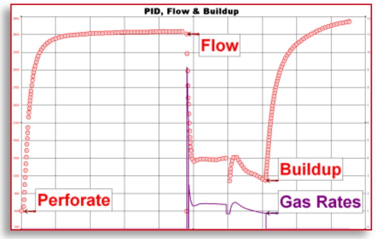
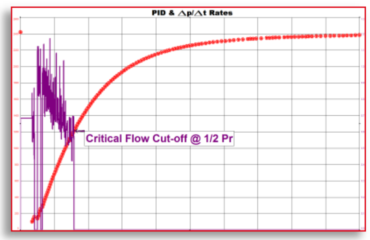
Surface Data Tests

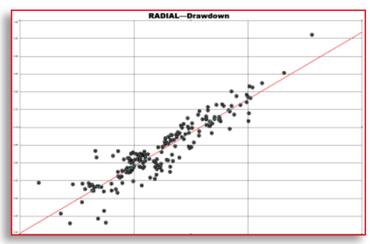


Impulse testing has been around for some time now, and analytical theory is well documented, especially for the Drill Stem Test (DST). Modern electronic surface data acquisition equipment has made impulse testing practical and economic in the Western Canada Sedimentary Basin. Issues advancing usage include under-balanced perforating, coiled tubing frac's, by-passed pay, ultimate recovery in low deliverability systems, flaring, confidentiality, and general exploitation. Order-of-magnitude reservoir flow characteristics (kh, s, q, p^*) can be estimated using both conventional and modern analytical techniques.

Perforation Inflow Diagnostic (PID) Tests—Conventional Analysis



For this test, a surface data recorder was rigged in, the well was perforated, and the resulting pressure buildup was recorded. As per accepted closed-chamber DST theory, gas inflow rates were calculated based on the change in pressure with time ($\Delta p/\Delta t$). This process can be simplified over a fixed time period (i.e. 5, 10, 30 min), or rigorously applied to each positive Δp increment, to generate an instantaneous Absolute Open Flow (AOF) value. The AOF back-pressure plot is nevertheless terminated at one-half (½) of the static reservoir pressure value, defined as the critical flow cut-off point.



Using conventional Pressure Transient Analysis (PTA) software, then, data before the critical flow cut-off can be analyzed as a pressure drawdown. Data following the cut-off point can be analyzed as a pressure buildup. Conventional pressure derivative and radial flow (semi-log) analytical techniques can be employed. Analytical models can also be employed with either regime. Corroborative analysis of conventional flow and buildup test data (as illustrated) demonstrates validity of the PID analysis technique for generating quantitative results with order-of-magnitude accuracy (kh, s, q, p*).

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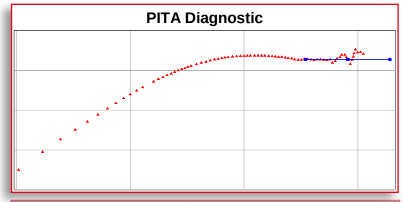
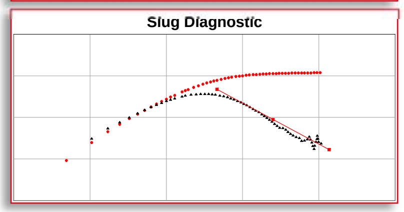
Perforation Inflow Diagnostic (PID) Tests—Modern Analysis



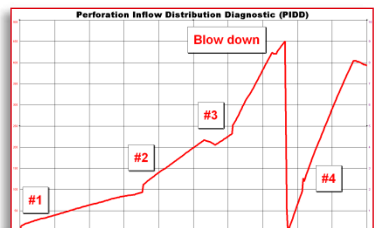


Modern analytical techniques to estimate order-of-magnitude reservoir flow characteristics (kh, s, q, p^*) have been programmed into some Welltest software (IHS). Slug, PITA, or Closed Chamber (CC) diagnostics can be performed for build-up, fall-off, or leak-off scenarios. Closed chamber analysis allows for a change in wellbore storage after setting a bridge plug to reduce wellbore volume.

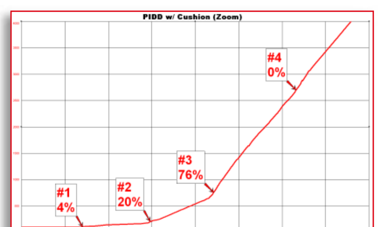
Florin Hategan suggests that formation net pay (h) be replaced by effective perforated pay (h_p) thus generating formation permeability (k_f) such that formation flow capacity becomes ($kh = k_f \bullet h$) (unpublished, but it makes sense, and empirically appears more correct).

Subsurface PID tests have proven very economical and effective for compliance with Alberta AER Initial Pressure Gas and, especially, Initial Pressure Oil requirements.

Perforation Inflow Distribution Diagnostic (PIDD) Tests



PIDD Without Cushion



PIDD With Cushion

The PID test is analogous to production logging when two or more intervals are perforated. Based on changes to the $\Delta p/\Delta t$ slope, gas inflow and AOF ratios can be estimated. Starting with the interval of least anticipated influx potential, multiple perforation runs are conducted. Subsequent to each perforation run, pressures are allowed to build up for a set period of time, being a function of permeability (k) and rate of pressure increase. It may be necessary to blow down the well if pressures exceed the critical flow cut-off point of one-half (½) the static reservoir pressure.

The first example illustrates four intervals perforated with no cushion. Perforated intervals two and three obviously exhibited an increment in slope, contributing respectively higher gas inflow ratios. Perforation interval number four did not exhibit an increment in slope and thus contributed negligible gas.

The second example illustrates four intervals perforated with a cushion. Again, perforated intervals two and three exhibited an increment in slope, contributing respectively higher gas inflow ratios. Perforation interval number four did not exhibit any increment in slope and thus contributed negligible gas.

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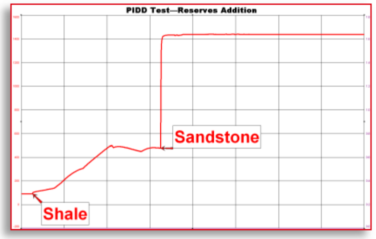
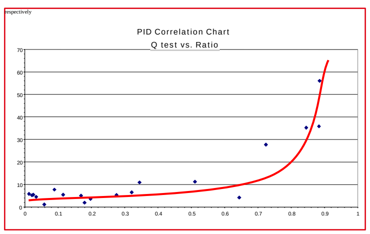
Proving Movable Reserves



In this example a high permeability (k) sandstone overlaid a shale zone. Decline curve analysis indicated reserves greater than volumetrics could justify. It was hypothesized that the shale gas reserves migrated vertically, due to pressure differential, to be produced with the sandstone gas reserves. The shale was perforated first and exhibited a pressure increase, thus proving additional movable reserves. The second perforation response was from the high permeability sandstone. The PID has also proven incremental by-passed reserves in Alberta's east-central tight gas sands (Milk River/Medicine Hat/Second White Specks).

$ Exploitation Correlations



Exploitation correlation plots can be developed for specific fields and pools. Enough tests and end-results need to be monitored so correlations can be observed. Eventually these plots are used for making on-site real-time tie-in or fracture treatment decisions. In some documented cases tie-in decisions were literally being made five minutes after perforating a well by plotting a hand-held pressure point (dimensionless) on the correlation chart. In-line deliverability tests (AOF) were conducted later for AER regulatory compliance. This not only saved thousands of dollars by not testing, but also retained the value of gas not flared.

Other Applications

Surface Casing Vent Tests — Surface casing-vent tests can be conducted using the closed-chamber method.

Drill Stem Tests — Closed-chamber Drill Stem Tests (DST). A specialized topic on it's own.

Fracture Evaluation — Pre-frac' evaluations, Mini-Frac' falloff tests, Diagnostic Fracture Injection Tests (DFIT).

AER Initial Pressure Requirements — Alberta AER Initial Pressure requirements can be achieved with a variety of subsurface pressure PID techniques:

- Recorders on bottom before perforating (used with TCP guns)
- Recorders attached to the drop bar (use a spring to dampen impact on gauges)
- Recorders on bottom after perforating (may have wellbore storage issues)
- Recorders on bottom below a WR bridge plug (limits wellbore storage issues)
- Horizontal well, multi-stage frac' string installed, run recorders, blow open toe port
  - Becomes a Formation Leak-off test

☑ *Impulse Test Data Qualification*

Qualify Your Application

This *i*REPORT is provided as a means of disseminating thoughts, information, knowledge, and experience. The very nature of well testing is interpretative, as much art as science, such that there are no definitive answers. The magnitude of impact on quantitative results must also be qualified. Open discussion of the topics presented herein is encouraged.

ⓘ *Selected Reference*

Information Source

Portions of this *i*REPORT were derived from the technical paper CIM 2000–80 *"Impulse, Perforation and Closed Chamber Testing: Simple, Quick Cost-effective Snapshots of Reservoir Inflow Characteristics"* by David Leech, Robert V. Hawkes, Paul Storey and Sharyda Brown.

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