WELLTEST SPECIALISTS

*i*REPORT

# Welltest 102: **Production Testing**

## *Welltesting & Production Testing*

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|---|---|
| Responsibility Chain Management | Petroleum Reservoir and Production Engineering teams initiate hydrocarbon welltests. Well testing is about measuring and recording flow rate and pressure data. Production Testing services clean up and flow test the well. 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. |
| Production Team | Production testing teams operate a range of equipment from simple one-man flow provers to complicated four-stage separation and multi-phase metering manned 24/7 by tandem crews. |
| 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. |
| Production Data | This *i*REPORT will focus on operations, quality control, data reporting, and data validation topics related specifically to production evaluation and welltesting. |

## Production Testing

**Principals** Production testing is a generic term for any flow through portable facilities. Usually production testing is done prior to tie-in for commercial operations. Production testing operations are for:

- Fracture stimulation treatments; sand, fluid, and load gas clean-up operations
- Acid wash or squeeze stimulation treatments; caustic fluid clean-up operations
- Various well workover, clean-up, swab, and evaluation operations
- Single point and multi-point flow test operations
- Underbalanced drilling; where the well is allowed to flow while drilling

**Objectives** Production testing operations usually have two main objectives: first is to clean up the wellbore after completion, workover, and stimulation/wash/wax treatments; second is to evaluate flow potential (productivity in oil, deliverability in gas). Note that all flow from a well is critical with respect to welltest interpretation, analysis, engineering, and regulatory submission (AER).

**Load Fluids** Load fluids are pumped from surface during completion and workover operations. Load fluids must be cleaned up, out of the well, with accurate field note differentiation from reservoir fluids. Load fluids include: drill and kill fluids; frac' water, oil, and gas; and spent acid wash water.

**Completion** Completion operations prepare drilled and cased wellbores for commercial production of oil and gas. Vertical and deviated wellbores are usually perforated and stimulated, whereby kill fluids, frac' fluids and sand, or spent acid water require cleaning up before insitu reservoir flow becomes economic. Horizontal and multi-lateral wells are usually stimulated via large hydraulic fracture treatments (frac'd) which require flow-back to clean up carrier water or gas ($N_2$, $CO_2$).

**Workover** Workover operations may be to re-complete wellbores for production in alternate formations (abandoning original zones), re-stimulate or acid wash wellbores that have become damaged, clean out wax or scale deposits, or change out equipment (rods and pumps, bumper springs).

**Swabbing** Swabbing is a method of mechanically removing (cleaning up) overbalanced completion and workover liquids (kill fluids) from a wellbore to allow insitu reservoir flow. Swabbing operations are performed by the wireline team (Welltest 101) while the production team operates facilities and records flow, volume, and pressure data in field note software. In oil wells swabbing often continues for inflow evaluation of reservoir liquids. In gas wells swabbing operations must be suspended as soon as the well begins to flow gas-to-surface.

## Production Testing

**Clean-up**

Clean-up operations try to remove as much load fluid as possible before commencing other tasks or testing. Frac' sand is abrasive, flow back can wash out equipment, so sand returns must be zero before pulling the completion/workover string and installing production tubing. Sand returns must also be zero before welltesting, which involves running subsurface pressure recorders into the hole by the wireline team (pressure recorders sanded into the hole is an expensive problem, washed out they are costly scrap).

**Inflow Testing**

Inflow testing or flow evaluation commences after clean-up. Subsurface pressure recorders are usually installed by the wireline team. Note the pressure recorder clock time ◷ defines the test time standard – which *must **never** be changed* despite a test spanning Daylight Savings Time switches. In Canada oil wells do not usually flow to surface on their own (they have to be pumped) so the evaluation finishes, and the well is shut-in, as swabbing is terminated.

**Single Point Test**

Gas wells are usually flow tested with a Single Point Test – one flow rate for a designated time period (24 h and 72 h extended rates are typical). The objective is to try and establish a steady flow, in terms of both rate and drawdown (pressure). Good luck with that!

**Multi-Point Test**

High deliverability gas wells may require a multi-point test in which flow rates are incremented from low to high in equal time intervals. Flow-after-flow tests usually have four (4) steps up in 2 h or 4 h intervals. Modified Isochronal tests have four (4) flow rate steps with an equal time shut-in between each step (i.e. flow 4 h, shut-in 4 h, flow 4 h, shut-in 4 h…).

**Effluent Sampling**

Production testers usually take effluent samples just before final shut-in (gas, oil, water, sand). Samples are sent to hydrocarbon testing labs for composition analysis. The final production test technical report will require certain composition parameters for accurate gas flow rate and volume calculations. Testers (and wireline) may also help lab personnel on site take bottomhole samples (insitu pressure and temperature samples for PVT analysis).

**Pressure Build-up Test**

With subsurface pressure recorders in the hole, final shut-in initiates the pressure build-up test, ending production testing operations (except maybe to record build-ups for a few hours while equipment is rigged out).

**Facilities**

Test facilities range from essentially none (blowing a gas well to atmosphere) to sophisticated, high pressure, heated, multi-phase sand/liquid/gas separation equipment. Production testing can be continuous for several days, even weeks, sometimes months. Companies will thus set up a small camp (trailer) for crews on 24/7 h shifts.

## Production Testing

**Sample Production Test**

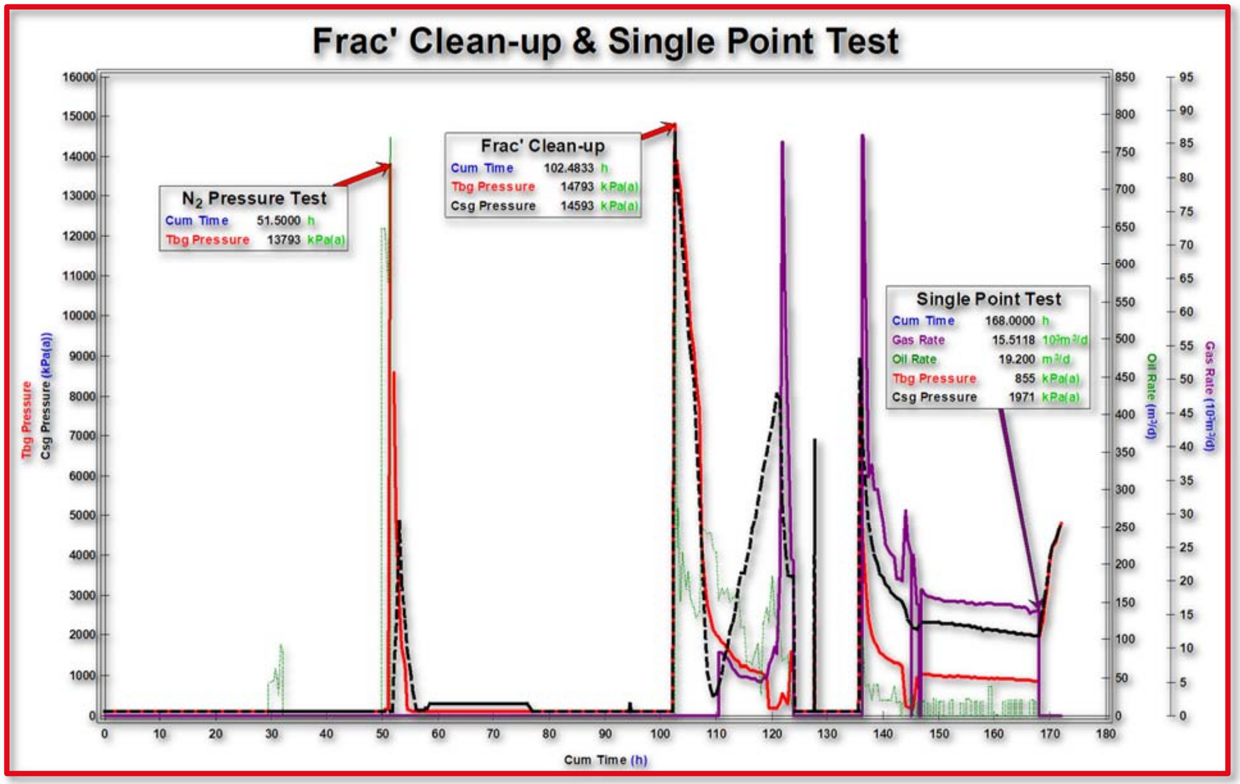
Illustrated below is the field notes software Cartesian plot from a typical production test in Alberta, Canada. At 30 h the well was swabbed down, with very little inflow, and completion tubing was installed. At 50 h an $N_2$ unit rigged in to blow out the well and pressure test the system. Before 100 h the well was fracture stimulated (frac'd) with a Nitrogen gas ($N_2$) carrier fluid. Clean-up opening pressure after the frac' was 14 793 $kPa_a$. The well flowed gas to surface immediately with a light oil, no water. Not too bad a gas well here…

*Field Notes Cartesian Plot*

*Note tubing/casing differential during clean-up illustrates liquid load-up in the annulus*

*In between clean-up and testing the wellhead was installed*

*During the single point test the well loaded up and was swabbed back in*



## → Facilities—Basic

Dry, Sweet Gas

The most basic of production tests is to blow a well to atmosphere through a bean choke or critical flow prover. A small water knock-out separator can be added for minor liquids. See production nomenclature at the end.

## ⇆ Facilities—Intermediate

Sweet Gas & Liquids

Intermediate facilities include a header or manifold, water/oil/gas multi-phase cold separator, orifice meter or vortex meter, backpressure valve, and flare stack. Tanks can be added to hold liquids.

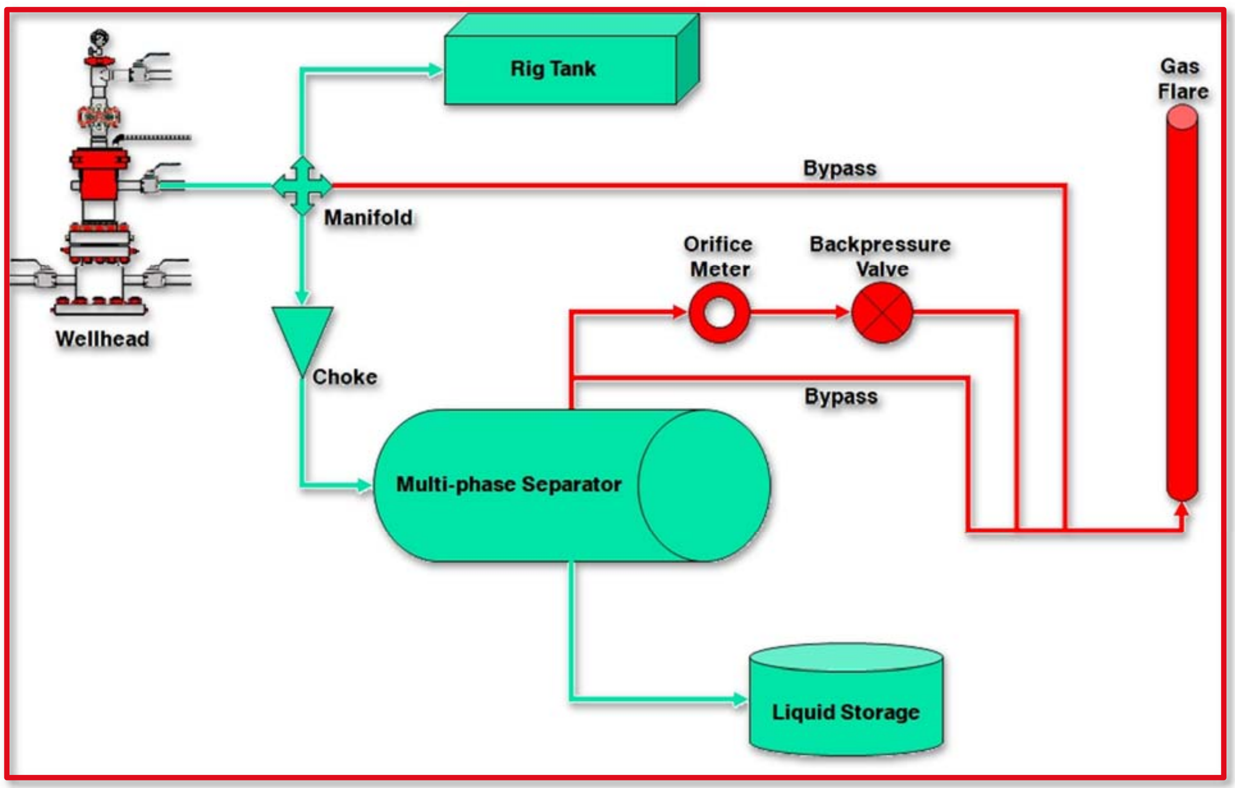
*Flow diagram illustrating intermediate equipment*

*Rig tanks are open to atmosphere*

*Separators start simple for gas, working up to heated high pressure multi-phase sand separators*

*Liquid storage tanks are enclosed*

*Gas flare may include incineration for sour gas*



## Facilities—Advanced

**Sour Gas, Sand & Liquids**

Advanced facilities include a header or manifold, line heater, high pressure multi-phase sand/water/oil/gas separator (four-stage), orifice or vortex meter, backpressure valve, flare stack, and incineration gas (propane) metering and injection. Tanks can be added to hold liquids and sand. Underbalanced drilling applications may include additional, highly specialized equipment, for the circulation gas ($N_2$ or air).

## Flow Meters

**Parameters**

Gas metering requires measurement of several parameters to solve the equation-of-state: temperature, static pressure, and differential pressure. Gas gravity (density), composition ($H_2S$, $CO_2$, $N_2$) and critical properties (${}_pP_c$, ${}_pT_c$) should also be known for accurate technical reporting. Compositional analysis of effluent (gas, oil, water) is not usually known until after test samples have been analyzed by a lab. Samples are usually taken at the end of testing.

**Flow Prover**

Critical flow provers are simple gas flow meters using orifice plate theory. Gas is blown to atmosphere, so the differential pressure is assumed: seal level standard atmospheric pressure is 101.325 kPa, but Alberta, Canada is at a higher elevation so the standard pressure for AER submissions is 93 kPa.

**Orifice Meter**

The most common type of gas flow meter is in-line, with differential pressure controlled by the backpressure valve. Orifice plate theory is employed for velocity and rate calculations.

**V-Cones**

V-Cones are simply the opposition of an orifice (hole) whereby an obstruction is placed in the flow stream. Parameters are the same as for orifice meters.

**Vortex**

Vortex meters are being used more often. These place a bar in the flow path, creating flow eddies or vortices. Frequency is an input parameter. Vortex meters shouldn’t be used for frac’ sand flow back because abrasives wash out the bar.

**Incineration**

Hydrogen sulfide ($H_2S$) content may require gas incineration. Propane is used as a volatile gas additive. Be sure to use correct physical properties for flow volume calculations. The relative density ($\partial$) of propane ($C_3H_6$) is **1.45** vs. field note software default of **0.65** for natural gas. Using $\partial = 0.65$ for propane metering would *overestimate injection rates for incineration by nearly 50 %!*

## ☑ Test Considerations

**Clean-up** Sand returns (an abrasive) should be eliminated before wireline installs pressure recorders. Load fluids should be minimized, before conducting a production test. Clean-up gas volumes are important for welltest analysis such that technical reports of results should be provided.

**Interruptions** Flow interruptions (choke changes, backpressure adjustments, orifice plate changes, well shut-ins) should be minimized throughout single point or extended production flow tests. Modified isochronal tests should have consistent flow/shut-in periods, without changes.

## Technical Reporting

**Gas Properties** Sampled gas properties should be input for correct gas flow rate and volume calculations. Be sure to use reservoir gas properties, as sampled, not 'acid gas free' which is 'sales' gas.

**Absolute Pressures** Pressure data should be converted from field measured gauge pressure to absolute pressure for engineering purposes (93 kPa is Alberta regulation).

**Flow Time & Volume** Incremental and cumulative flow time should be shown on the table for data quality control, confirming flow time calculations, and analytical usage. Meters must be zeroed appropriately for correct gas volume and flow time calculations.

**Load Fluids** Load Fluids Left to Recover (LFLTR) should be tracked carefully for government reporting and engineering pressure transient analysis (PTA) purposes.

**Daylight Savings Time Changes** Note the subsurface pressure recorder clock time 🕒 defines the test time standard – which *must* ***never*** *be changed* despite a test spanning Daylight Savings Time switches.

## Government Regulations

**Regulatory Boards** In Canada, petroleum well testing is controlled by provincial boards, each with a variety of rules, regulations, and submission requirements:

1. Alberta Energy Regulator (AER, has also been known as ERCB & AEUB)
2. British Columbia Oil and Gas Commission (BC-OGC)
3. Saskatchewan Industry and Resources (SIR)

## 1 *Alberta Requirements*

**Act & Regulations** Alberta has the most stringent requirements and one should be thoroughly familiar with Oil and Gas Conservation Act 151/71, AER published guides and directives G3, G5, G40, & G60 as well as General Bulletins 2003-01, 2003-05, and especially 2003-15 (the PAS file mnemonic guide).

**AER.pas Files** All clean-up and production test data are required to be submitted to the AER, in electronic format, via their web site, as PRD.pas files (pressure ASCII standard). Appropriate electronic files are expected by all welltest engineers (i.e. root software files or CSV files).

## 2 *British Columbia Requirements*

**Regulations** All test data and applicable analyses must be submitted, as per requirements of Section 95 of the *Drilling and Production Regulation*. Well testing requirements are further detailed in Section 6.7 of the *British Columbia Oil and Gas Handbook*.

**Submissions** Welltest submissions to the BC-OGC are Zipped PRD.pas files via e-mail. Reports should be prepared by qualified welltest interpretation experts. Underbalanced drilling, clean-up, and production data are documented on the Well Deliverability Test Report (OGC-062-AOF form).

## 3 *Saskatchewan Requirements*

**Submissions** Welltest submissions to the SIR are still via paper copy. Absolute Open Flow (AOF) reports should be prepared by qualified welltest interpretation experts, with the accompanying ERCB-EG-32 form (predating AER.pas electronic files).

## ⓘ *Contact*

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## Production Nomenclature

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|---|---|
| **Facilities** | **Equipment used for production test facilities** |
| Wellhead | Capping the wellbore, wellheads allow access to tubing and casing (annulus) flow. |
| Manifold | Allows control and diversion of flow stream to different places (rig tank, separator, bypass). |
| Rig Tank | An open-air tank with the service rig to hold load fluids. |
| Choke | Bean chokes or adjustable chokes control the flow volume. |
| Separator | Two-phase (gas, water), three-phase (gas, oil, water) or multi-phase separation of well effluent. |
| Cold Unit | Most common, non-heated separator. |
| Line Heater | Warms the gas to reduce hydrating problems (freezing due to JT cooling). |
| P-Tank | Separator built to handle high pressure gas, usually multi-phase. |
| Backpressure Valve | Special valve to hold back pressure on the orifice meter/separator. Mimics line pressure. |
| Flare Stack | For igniting and burning off gas production. A propane source can be added for incineration. |
| **Meters** | **Parameters and flow meter parts** |
| Orifice | Hole in an orifice plate. Meters have a variety of orifice plates to use, each with a specific hole ID size. |
| Static Pressure | Pressure immediately upstream, or more commonly, downstream of the orifice plate. |
| Differential Pressure | Difference in pressure across the orifice plate. With the common in-line meter, this is controlled by the backpressure valve and measured. With a critical flow prover, the differential is assumed between static pressure (upstream) and atmospheric pressure (AER standard barometric pressure = 93 $kPa_a$). |
| BS&W | Base Sediment and Water. From a "grind-out" or centrifuged sample. Subtracted from total liquids to estimate water rates and volumes. |
| LFLTR | Load Fluid Left To Recover. After recovery of load fluids, liquids are considered to be "new". |
| **Pressures** | **Clarification of pressure standards** |
| Gauge Pressure | Measurements of closed systems (i.e. wellhead, pipeline, separators) are exclusive of atmospheric influence. Gauge pressures ($kPa_g$) must be converted to absolute values during the technical reporting process for engineering use (AER standard barometric pressure = +93 $kPa_a$). |
| Absolute Pressure | Open-air pressure measurements include atmospheric or barometric pressure. Wireline pressure recorders measure absolute pressures ($kPa_a$). Engineering standard is to use absolute pressures. |