



**Weatherford**<sup>®</sup>

# PanSystem<sup>®</sup>

## Well Test Analysis Software

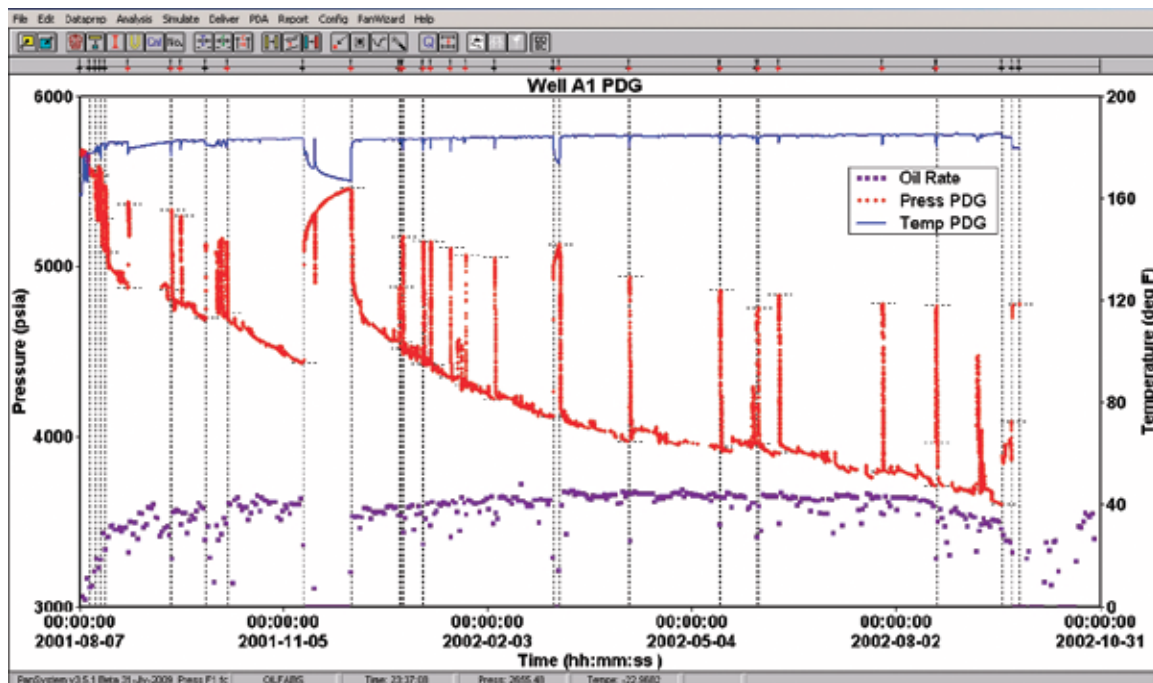


Robust, easy-to-use software tool provides multiple options for pressure transient models and analysis.

*PanSystem* software has been the industry's leading well test analysis program for more than 20 years. It is a robust yet easy-to-use software tool that provides multiple options for models and analysis. These options include industry standards as well as user-defined models for additional flexibility. Ultimately, the *PanSystem* application provides a way to simplify complex transient well testing through detailed analysis, simulation, and reporting.

*PanSystem* software is dedicated to transient well testing, a key technical function in the oil and gas industry. A pressure transient well test has the unique ability to obtain information from within the reservoir surrounding the well and with appropriate testing and analysis techniques can provide a wealth of data:

- Permeability of the reservoir-at-large and, in some cases, the near-wellbore region
- Completion efficiency, effective open interval size (over the life of the well)
- Reservoir structure (boundaries, heterogeneities)
- Reservoir pressure
- Nature of any pressure support
- Drainage area, connected pore volume, and initial hydrocarbons in place
- Vertical permeability, vertical communication in layered systems
- Well performance (over the life of the well)
- Communication between wells
- Deliverability and production forecasts



*Typical permanent downhole gauge record spanning 15 months of rate changes and shut-ins, planned and unscheduled.*

## Typical Applications

The task of designing, executing, and analyzing a well test depends on operating conditions as well as completion and reservoir type. *PanSystem* software analyzes a wide range of situations and asset types.

- **Low pressure reservoirs, heavy oil:** Wellbore fill-up and leak-off tests, steam injection tests
- **Pumping wells:** Acoustically-derived pressures and rates
- **Medium oil reservoirs:** Conventional drawdown and build-up tests
- **Gas wells:** Conventional analysis using real gas pseudo-pressure, turbulent skin analysis for high-rate wells, and gas well deliverability by empirical (C-and-n) and LIT methods (in depletion scenarios, gas properties are revised as reservoir pressure declines)
- **Volatile oil/condensate reservoirs:** Conventional analysis techniques or use of multiphase pseudo-pressure to model phase behavior and its effect on relative permeability (in particular, liquid dropout or gas breakout around wellbore)
- **Hydrothermal wells:** Steam production, water injection
- **Gas and water injection wells:** Injection and fall-off tests, including multi-region analysis to allow for mobile phase changes and temperature effects
- **Interference tests:** Inter-well permeability and  $\Phi Ct$  product from type-curve analysis and/or history matching by simulation
- **Multi-layered reservoirs:** Conventional analysis or specialized testing technique (MLT) using selective flowmeter data
- **Varying rate tests:** Rates measured on surface or with a downhole flowmeter
- **Permanent downhole (or surface) gauges:** Special pressure decline analysis (PDA) section to analyze long-term pressure and rate records for hydrocarbons in place; deconvolution to reveal nature of the reservoir and boundary models otherwise obscured by rate changes and shut-ins
- **Wireline formation tests:** Analysis of pre-test, pump-out, mini-DST, and vertical interference tests using dual- and packer-probe analytical models (including special LAS and DPK format data import)

From large scale reservoir characterization to monitoring of individual well performance, *PanSystem's* well test analysis provides information for many important operational decisions.

- **Workover:** Completion efficiency from skin factor and early time derivative shape; open interval length for stimulation or reperforation; fracture quality
- **Reservoir characterization:** Horizontal permeability (from kh); vertical permeability; boundaries and heterogeneities; gas cap/aquifer support; pressure support from a second compartment; layering for reservoir model refinement and field development planning
- **Reserves estimation:** Extended production test; long-term flowing pressure record (with permanent downhole gauge); build-up testing for reservoir model refinement and field development planning
- **Production performance prediction:** Single well forward prediction with material balance included for field development planning
- **Reservoir pressure decline:** for field development planning





PanQL log-log plot: radial flow line and flow regime are fitted automatically to derive  $k$  and  $S$ .  $P^*$  is obtained from a Horner plot.

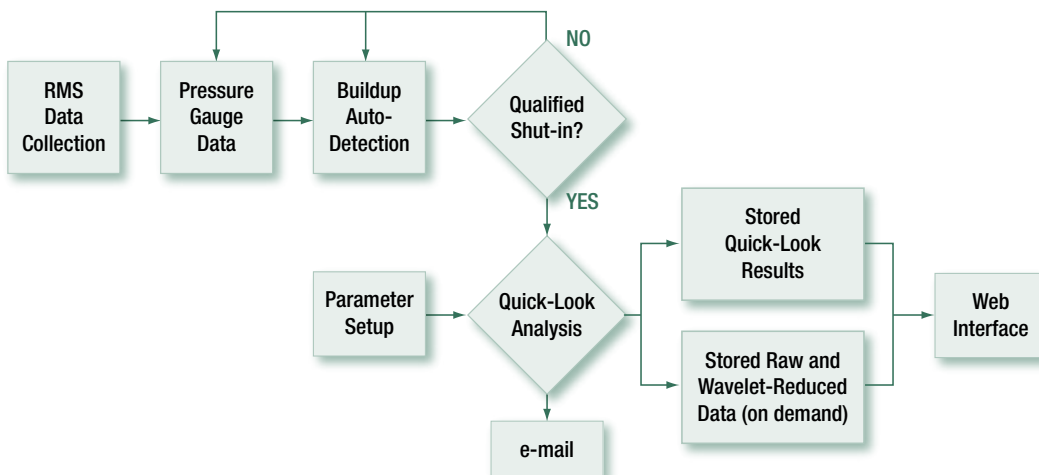
## Permanent Downhole Gauge Data – From PanQL™ Software to In-Depth Analysis

The *PanQL* module is a subset of *PanSystem* software that has been implemented in Weatherford's reservoir monitoring system (RMS) and data acquisition unit. The *PanQL* application will perform an automatic transient analysis quick-look on unscheduled buildups from wellhead or downhole gauge data and will e-mail the results to the reservoir engineer.

The entire process is automated so that no user interaction is required and no valid buildup, no matter how short, is missed.

- The *PanQL* program is triggered when a shut-in is detected and the pressure change and duration constitutes a valid dataset for interpretation. This is determined by a smart acquisition routine based on defined parameters.
- The following information is obtained from the quick-look analysis:
  - $k$ : the effective permeability of the formation
  - $S$ : skin factor: the near-wellbore damage or improvement
  - $p^*$ : the extrapolated formation static pressure (from the Horner plot)
- A synopsis of the *PanQL* results is then sent to the reservoir engineer via e-mail.
- If the reservoir engineer wishes to further investigate the quick-look, he or she may log in to the system via a web interface, look at the plots and results, and determine whether or not to download raw data or a wavelet reduced dataset for in-depth investigation.
- As successive test results are accumulated in the database, these parameters can be graphed against time to reveal trends.

A wide range of reservoir and boundary models, diagnostic plots, line-fit options, type-curves and simulation are available in *PanSystem* software should a more rigorous analysis be required.



PanQL workflow.

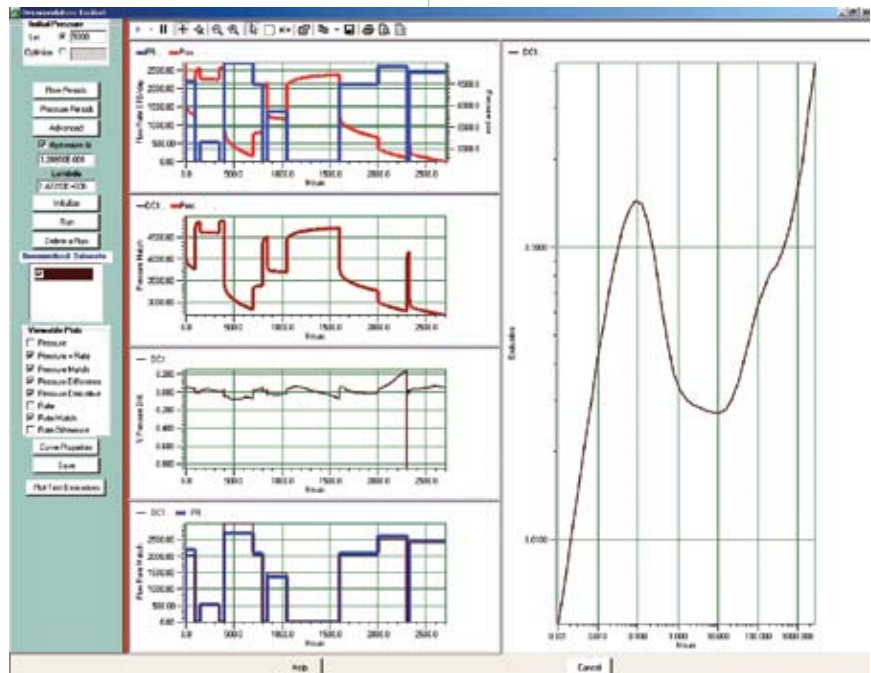
## Permanent Downhole Gauge Data – Long-term Data Analysis

PanSystem software can be used to analyze an entire permanent downhole gauge record or sections of it rather than just individual buildups. This takes advantage of the huge radius of investigation implicit in any long-term pressure record at a constant rate (ideally) or at different rates interspersed with shut-ins, as is more usually the case to identify remote boundaries, closure, drainage area, pore volume, etc.

Three techniques are available in the pressure decline analysis (PDA) module of PanSystem software.

- **Deconvolution:** The deconvolution module processes any multi-rate test sequence including flowing periods and shut-ins and, without any prior assumptions regarding models, presents the data in the form of a constant rate drawdown response, from which it is more straightforward to extract the underlying reservoir and boundary models. The module also has the option to minimize errors in flowrate measurements by making adjustments.
- **Agarwal-Gardner type-curves:** These type-curves are intended primarily for assessment of drainage area and pore volume in semi-steady state systems, but also cover the early transient period.
- **Equivalent constant rate (ECR) method:** Primarily for semi-steady state analysis, this is a relatively simplistic process which, like deconvolution, converts the data to an equivalent constant rate drawdown.

The powerful wavelet-based advanced data conditioning module has been implemented in the dataprep section to facilitate reduction and denoising of large datasets and to detect rate change events automatically.



Deconvolution module, showing raw data, a sequence of flowing and shut-in periods (upper left); the deconvolved constant rate derivative (right); flowrates before and after adjustment, an optional part of the deconvolution process (lower left).

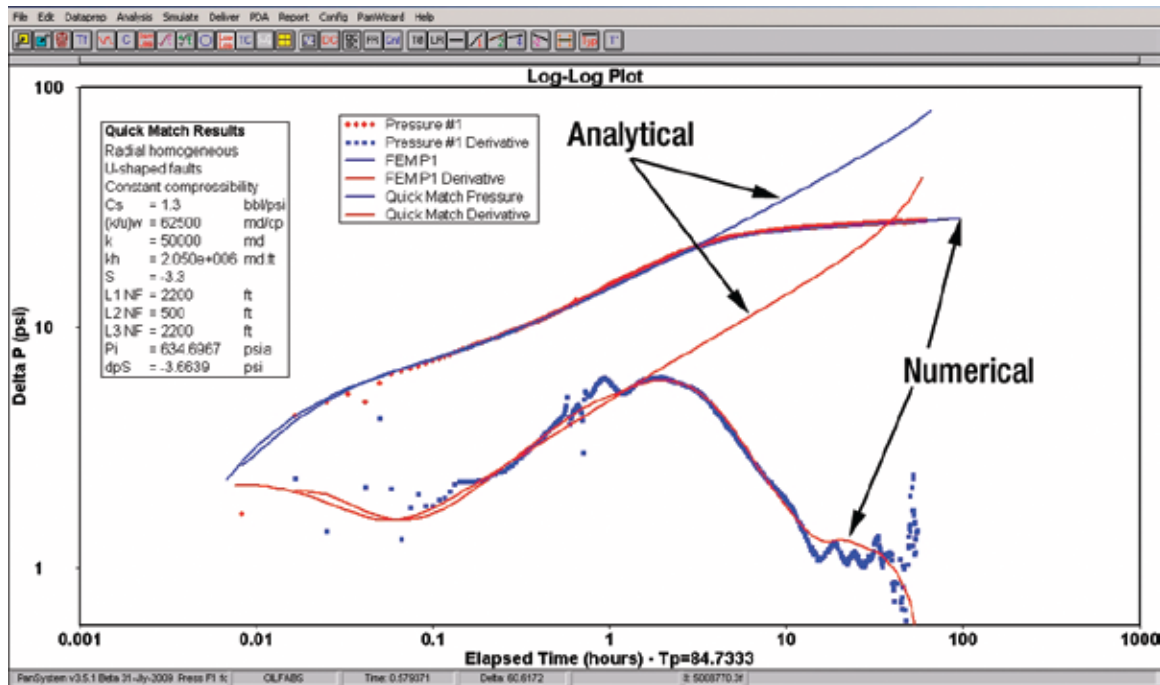
## The Power of Numerical Simulation

The use of a numerical simulator enables the well test analyst to reach beyond the limits of analytical simulation in terms of complexity of reservoir structure and completion design.

- True 3-dimensional well test simulator
- Complex boundary geometries, irregular shapes
- Multiple layers, multiple completions
- Heterogeneities (rock and fluid)
- Pressure vs. time at any point in the reservoir

The **PanMesh™** module is fully integrated into *PanSystem* software. It fulfills the same basic simulation objectives as the analytical quick match and advanced simulators available in the *PanSystem* application in terms of model validation and test design, and occupies a similar place in the workflow, but has a far greater modeling capability.

*PanMesh's* color visualization facility offers a deeper understanding of the nature of the transient response by tracking the pressure transient as it propagates through the reservoir. This enables the analyst to see how changes in the model structure correlate with changes in the pressure derivative.

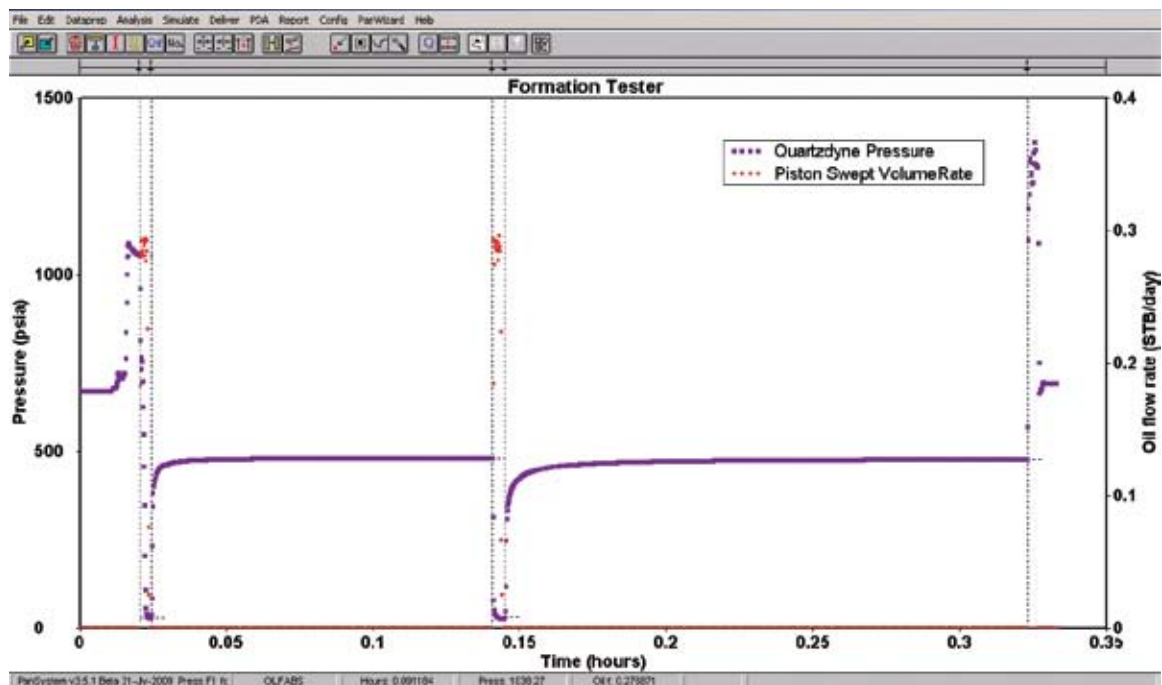


The fault structure encountered by this fall-off test could not be modeled analytically in its entirety. The numerical model, which was based on the fault map and created in the PanMesh module, delivered a good pressure and derivative match, confirming the correctness of the map.

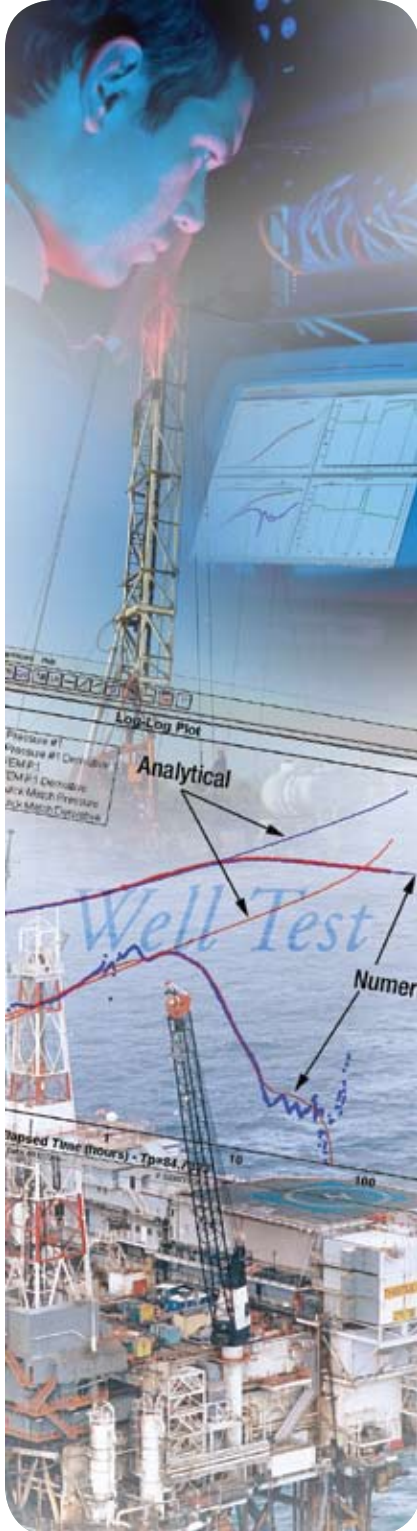
## Wireline Formation Testing

The *PanSystem* application will import wireline formation tester data in conventional LAS format and in Weatherford's DPK format. Automatic identification of flow periods based on piston movement makes for rapid data preparation.

Models have been implemented for the analysis of probe and dual-packer configurations used for pre-test, pump-out, and mini-DST tests. In addition, active and interference signals from a dual- or packer-probe combination can be processed simultaneously to optimize results.



*Pre-test data from a wireline formation tester with probe. PanSystem software has models to interpret the active and interference signals from a dual or packer-probe combination.*



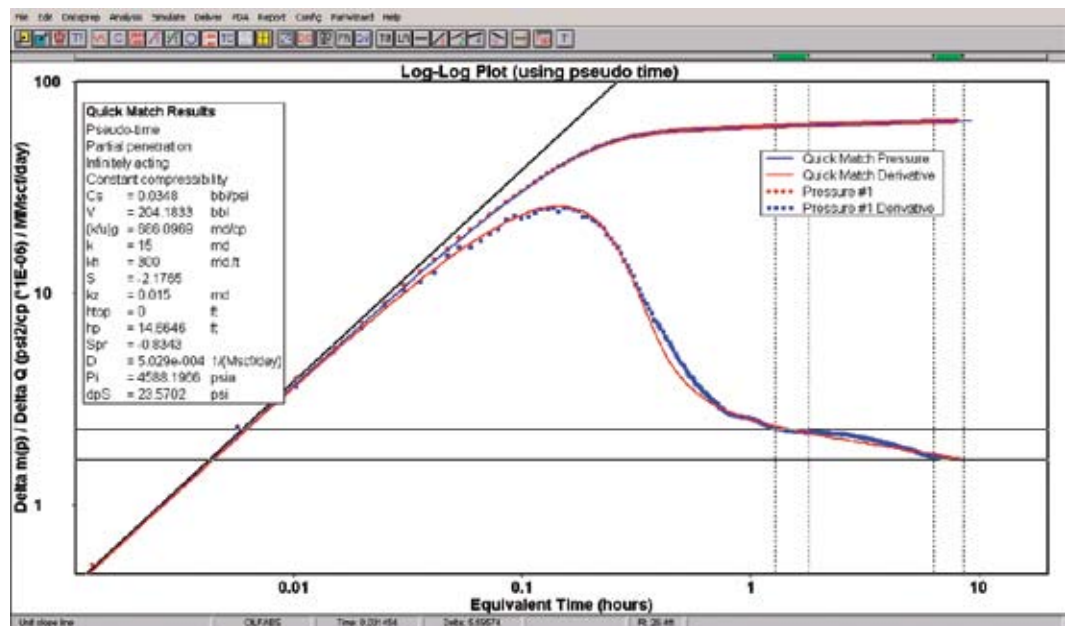
## Key Technical Features

*PanSystem* software's graphical interface offers the user an efficient workflow. Its versatile data processing and analysis capabilities meet the challenges presented by the high performance of modern pressure gauges and the large volumes of data which they can acquire.

- Versatile data preparation
  - Easy entry of basic rock and fluid parameters
  - Import of raw data
    - ODBC databases supported (Weatherford RMS, any standard SQL)
    - Import from file or Microsoft® Excel® spreadsheet
    - Import from LAS or DPK files (wireline formation tester)
    - More than adequate capacity (20 million data points)
    - Append new data to existing data, including quasi-real-time acquisition through the ODBC facility
  - Data processing
    - Wavelet transform filter for outlier removal, denoising, reduction, and event detection
    - Large choice of alternative data reduction and smoothing algorithms
    - Data manipulation (function, difference, shift, copy, paste, merge, resample, and tidal filter)
  - Flow rates
    - Manual and automatic identification of rate change events (with a choice of simplistic and wavelet-based options)
    - Flow rate averaging from long-term production records
    - Wavelet filter reduces size of rate data channel while honoring cumulative production
    - Option to compute sandface flow rate from  $dp/dt$
  - Wellhead-to-bottomhole flowing pressure conversion using VFP format flowing pressure files, Weatherford's **WellFlo**® application, or a simplified dry gas model

## Key Technical Features (continued)

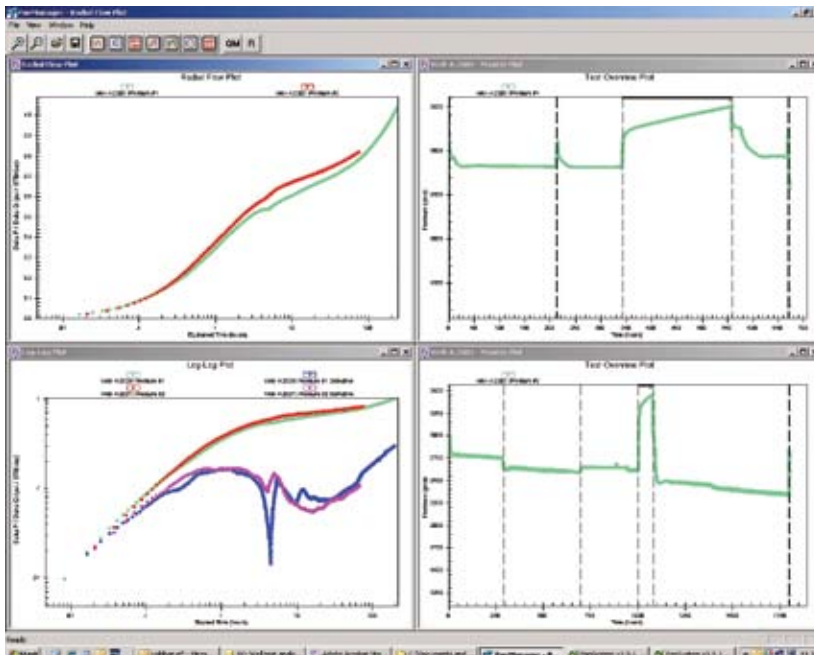
- Analysis
  - Wide range of wellbore, reservoir, and boundary models
  - User-defined models can be easily integrated via dynamic link library
  - Up to six different models can be investigated in a single file
  - Diagnostic plots include log-log with selection of pressure derivatives, rate normalization and superposition/convolution, line-fitting, and type-curve matching
  - Deconvolution module extracts underlying reservoir and boundary models from a multi-rate test sequence including flowing periods and shut-ins, without any prior assumptions regarding models and has the option to minimize errors in flow rate measurements
  - Quick single-well simulation allows rapid validation of selected storage, reservoir and boundary models, and parameters
  - Auto-regression for automatic parameter optimization
  - PDA facility for the analysis of long-term flowing pressure and rate (or cumulative) data to estimate hydrocarbons in place using:
    - Agarwal-Gardner type-curves
    - Weatherford's equivalent constant rate (ECR) deconvolution method



PanSystem software provides many complementary tools for well test interpretation. This figure shows a gas well buildup test with flow regime markers, straight line derivative diagnostics, and a simulated analytical model response whose parameters are displayed in the box at left.

## Key Technical Features (continued)

- Simulation
  - In addition to the quick simulation for model validation, *PanSystem* software contains multi-well, multi-layer simulators to generate pressure from flow rate (advanced simulation) and, less conventionally, flow rate from pressure (the **PanFlow™** module). In layered reservoirs, layer offtake and crossflow are modeled. *PanMesh* software, *PanSystem's* companion numerical well test simulator, gives the user access to more complex well and reservoir configurations which are beyond the capabilities of analytical models.
- Deliverability and Production Forecasting
  - Using the results of transient well test analysis or from direct measurements of flowing pressures and rates
    - Conventional IPR for oil or water
    - Empirical C-and-n and rigorous LIT methods for gas and condensate wells
  - Production forecasting module forward simulates the production profile through transient, semi-transient, semi-steady, or steady state phases to abandonment
    - Constant bhfp option or constant thfp (using a VFP format file for tubing performance)
    - Reservoir pressure is computed versus time in depletion cases
- Test Design
  - Well test design module includes testing time and flow rate advisors
  - Predicted pressure response generated by advanced simulation can include gauge resolution, noise, and drift

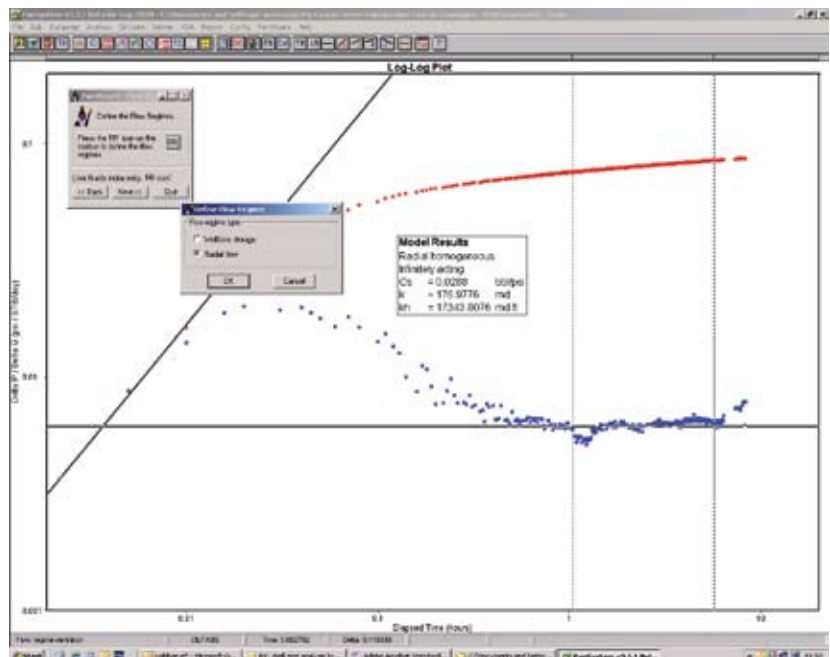


Comparison of buildup tests run in the same well in 2007 and 2009 using PanManager software.

## Key Technical Features (continued)

- **PanManager™** Software
  - Opens multiple *PanSystem* files for comparison of gauge datasets and interpretations
    - Well tests run in same well at different times
    - Well tests run in different wells
    - Different interpretations of one well test
- Reporting
  - User-configurable report format can be stored as a template
  - Output to printer or to Microsoft Word
  - Version 4 of the regulatory Pressure ASCII Standard (PAS) format of the Alberta EUB is supported for TRG.PAS
- **PanScan™** Software
  - Utility to digitize scans of mechanical gauge records (strip charts) ready for import into *PanSystem* software
- Help
  - Interactive **PanWizard™** module guides the new or infrequent user through the workflow
  - Detailed help documentation for technical and functional issues
  - Support desk offers technical advice by e-mail or phone

The *PanWizard* module guides the user step-by-step through the analysis workflow.



## PanSystem Well Test Analysis Software

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