



Weatherford[®]

WellFlo[™]

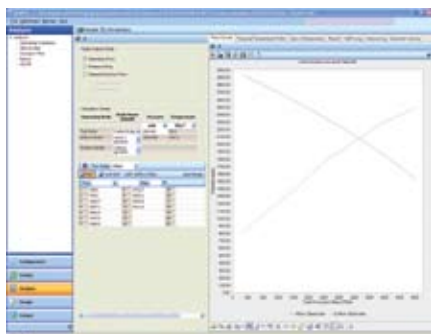
Petroleum Engineering Software



Design, model, optimize and troubleshoot naturally flowing or artificially lifted individual oil and gas wells.

WellFlo Software

Weatherford International's production optimization division provides solutions to increase production and lower lifting costs in green and brown fields. We deliver agile, well-supported products and services that foster innovative optimizing approaches for flowing wells and all forms of artificial lift. The software, hardware and completions solutions help you work better, smarter and faster.



WellFlo analysis section.

Introduction

WellFlo systems analysis software is a powerful and simple-to-use stand-alone application to design, model, optimize and troubleshoot individual oil and gas wells, whether naturally flowing or artificially lifted. With this software, the engineer builds well models, using a guided step-by-step well configuration interface. These accurate and rigorous models display the behavior of reservoir inflow, well tubing and surface pipeline flow, for any reservoir fluid. Using *WellFlo* software results in more effective capital expenditure by enhancing the design of wells and completions, reduces operating expenditure by finding and curing production problems and enhances revenues by improving well performance.

Applications

The *WellFlo* software package is a single well tool which uses nodal analysis techniques to model reservoir inflow and well outflow performance. *WellFlo* modeling can be applied to designing, optimizing and troubleshooting individual wells. Specific applications for which the software can be used include:

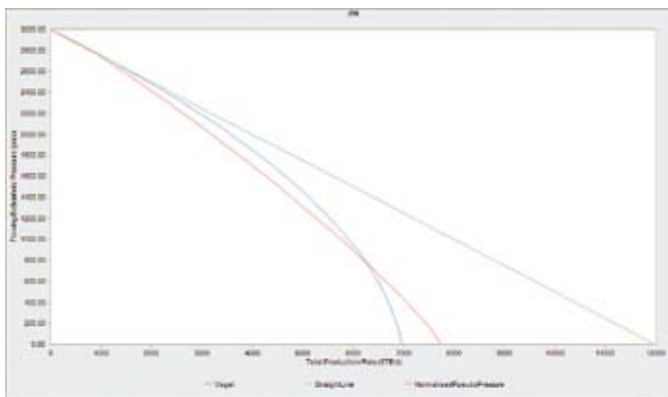
- Well configuration design for maximum performance over life of well
- Completion design to maximize well performance over the life of well
- Artificial lift design
- Prediction of flowing temperatures and pressures in wells and flowlines and at surface equipment for optimum design calculations
- Reservoir, well and flowline monitoring
- Generate vertical lift performance curves for use in reservoir simulators

As well as these applications, the software has two key internal sub-applications which can be used stand alone from the rest of the program and offer the user an excellent engineering toolkit.

- Detailed reservoir inflow performance modeling
 - Multiple completion and perforation models
 - Detailed skin analysis
- Detailed fluid PVT modeling
 - Black oil models for oil and gas
 - Equation of State models for condensate and volatile oil
 - Laboratory data matching
 - Fluid behavior prediction

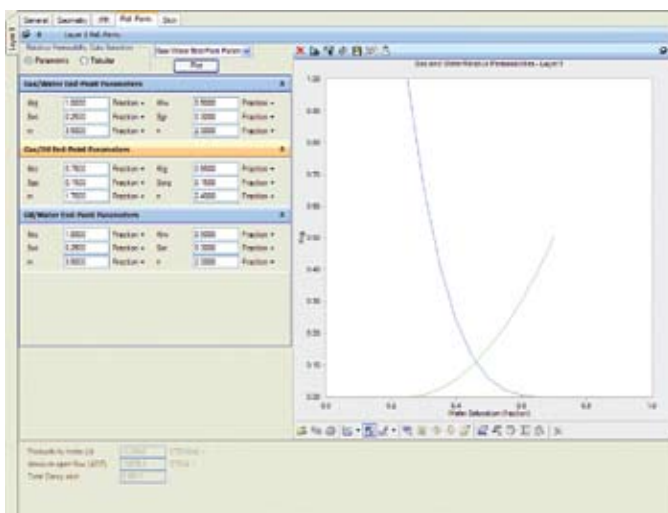
Inflow and Completion Modeling

Well inflow is an important factor in a well's performance. The *WellFlo* interface allows you to enter a PI, reservoir pressure and inflow model such as Vogel, if your information is limited. Alternatively, detailed completion data including damaged zone, well deviation, partial penetration, perforating specification, gravel pack information and fracture geometry can all be entered to predict the effect on well deliverability (this can be done for both vertical and horizontal wells).



Inflow performance plot comparing multiple IPR methods.

A multilayer model is included for composite systems, with each layer having its own fluid, completion and inflow model. This benefits petroleum engineers who are designing new completions or diagnosing problems in performance. A sophisticated constant mass flow rate inflow model can be used to include relative permeability effects. These can be entered through tables or Corey coefficients. This provides an extremely accurate technique for performance forecasting in condensate and gas cap drive reservoirs, and is especially useful in predicting performance as reservoir conditions and phase fractions change in these fields.



Relative permeability interface.

New to *WellFlo* 4.0 Software

This new version represents a major step forward in systems analysis, providing a new level of power, sophistication, flexibility and ease of use. All of this in a modern, intuitive, workflow-based user interface. The following is a sampling of features that users will find in the latest release.

- Completely new graphical interface
- Data input de-coupled from creation of nodes
- Improvements to temperature model
- Major enhancements to equipment catalogs
- Internationalization support which provides easy translation to any language
- All new, interactive gas lift design tool incorporating true valve performance
- Improvements to reporting and plotting
- Ability to retain and organize any report or plot for future reference
- Dashboard showing overview of well parameters and model selections
- Sachdeva choke model
- support for OLGAS 2000 steady-state multiphase flow correlation
- Enhancements to liquid loading calculations including addition of Coleman method
- Pressure and temperature survey matching
- Tuning of inflow performance relationship to measured data, including THP to BHP calculation
- Tuning of PVT parameters
- Tuning of well parameters to match well performance measurements
- Ability to import and filter data from Excel spreadsheets
- COM interface to external utilities and engineering applications
- Ability to create custom charts from calculated profiles including wellbore flow regime distribution



PVT Modeling

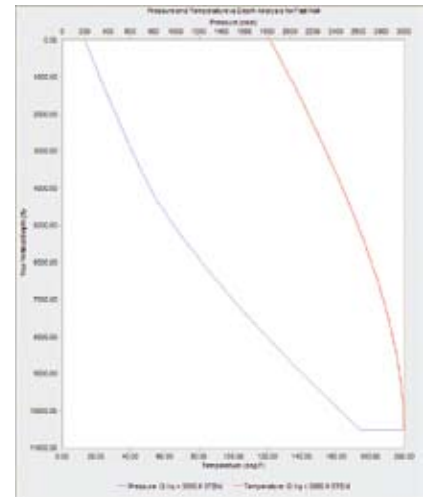
All pressure and flow modeling in hydrocarbon systems relies on accurate modeling of fluid properties as they vary with pressure and temperature. The *WellFlo* PVT package includes the important standard black oil correlations and allows these to be tuned to honor observed data. The tuned correlation is then used throughout the program to calculate fluid properties. As a result, you can rely on the accuracy of the software's performance predictions and optimization operations which often depend on accurate calculations of fluid properties.

For near critical fluids, where the black oil correlations are unreliable, an equation-of-state technique is incorporated in the software with tuning facilities to allow accurate modeling of these fluid types. This approach holds great advantages because it requires only the limited data needed for a black oil model while retaining the higher accuracy of full compositional modeling.

Pressure Traverse and Temperature Calculations

The pressure drop and temperature change between the bottom of the well and the surface is normally the largest drop in the system. *WellFlo* pressure drop analysis incorporates all the important correlations for this calculation. The temperature modeling options include manual definition of temperature at each node, calculated and calibrated heat loss models and a coupled temperature-pressure model. This allows you to define heat loss factors either through the system's calculation or by direct input.

Plots of measured data and predictions can be shown simultaneously on-screen allowing rapid matching. When performing pressure traverse calculations you have the option to capture other data instead of pressure and temperature, such as in situ phase densities and velocities, flow regime, and hold-up plus the gravitational, frictional and acceleration terms of the pressure drop. This data can be very useful in determining, for example, if erosional velocity limits are being exceeded.



Pressure and temperature versus depth analysis for a gas lift well.

Tuning of Well Models

In order to be certain that analysis results can be trusted to match reality, users need a way to tune their well model to measured data. With many software packages, this task can prove to be labor-intensive and challenging. In the redesigned *WellFlo* 4.0 software release, this task has been greatly simplified through the development of an all-new tuning mode. In this mode, users are able to tune PVT correlations using PVT data; they can use flowing pressure gradient surveys to tune their outflow performance model; they can use production well test data, at either surface or downhole conditions, to tune their inflow performance model and they can use multi-rate well test performance data to tune a variety of well parameters. In each of these cases, data can either be entered manually or imported from an external source through a wizard-based data import tool. Once the measured data is entered, it can then be used to tune a variety of parameters using a powerful non-linear regression algorithm. This ensures that well models will be as accurate as possible with a minimum of effort from the user.

Data Export and Import

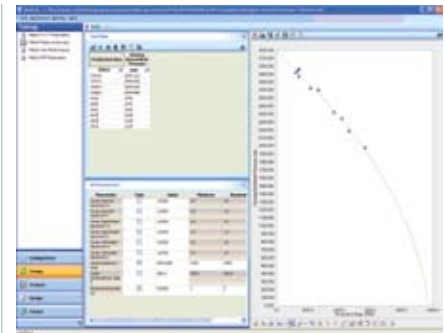
WellFlo data export tools generate vertical flow table data in DOS or UNIX format for use in Eclipse™, VIP® and other reservoir simulators. These files are simply pasted into the control decks for the simulator. Therefore, it becomes practical to generate a vertical flow profile table for every well in a field appropriate to that particular well. Without this direct link to simulators, a 'typical' table is used for all wells due to the sheer impracticality of generating one table per well.

Report files can be generated in tab-separated form to allow easy export of data to word processing and spreadsheet packages. The ability to 'cut and paste' in the Windows® environment allows very efficient generation of reports including graphs and other screen captures. A graphics export option also allows plots to be saved directly to file in a number of formats.

- UNIX and DOS flowing pressure file generation for Eclipse, VIP, CHEARS™, SimBest™ I and II, IMEX™, MoReS™, GCOMP, COM4, sensor reservoir simulators and a multi-well batch mode is available for some outputs
- Key-worded file output available for data transfer to other applications
- Graphics export facility saves plots directly to file (BMP, GIF, JPG and TIF formats)
- Reports can be opened directly in Word, Excel, etc.

Measured pressure-depth or pressure and rate data can be imported into the *WellFlo* data repository and plotted on the same graphs as the model's prediction. This significantly reduces the time taken to produce a matched data model. An auto-regression option will estimate the optimum flow correlation tuning factor by a least-squares fit to the measured data.

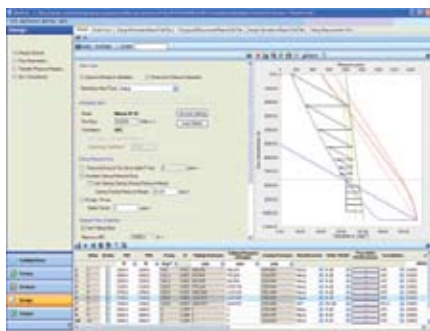
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Tuning inflow performance relationship to measured data.

Well	Flow Rate	Gas Lift	Gas Rates	Pressure	Water Content
1	146.8	8	4702.7	32	
2	674.2	8	3298.2	32	
3	1859.7	12	3898.8	37	
4	2227.2	12	4612.8	37	
5	2852.8	12	5412.8	37	
6	3478.3	12	6212.8	37	
7	4103.8	14	7012.8	37	

Data export interface.



Gas-lift design section showing gas-lift valve spacing and valve calculations.

Gas Lift Design and Analysis

Using the program's specialized capabilities for gas lift, engineers can design and model gas-lift installations and determine the number and position of the gas-lift valves, as well as the optimum injection rate taking account of the available injection pressure.

Gas-lift design and diagnosis is a particular strength of the software making it (with its link to the only commercially available dynamic gas-lift simulator, Weatherford's **DynaLift™** program) a uniquely powerful gas-lift system. This is critical in a tool used for full gas-lift system modeling and optimization.

This program will allow you to incorporate gas injection rate or gas-liquid ratio terms as preferred. Together with the casing head pressure, these factors are input as sensitivity variables. For every rate specified, the program will determine which valve is being used for gas injection so that the system's predictions are always accurate.

WellFlo features include the following modes of operation for analyzing and designing gas-lift systems:

- Continuous gas-lift design—deepest point of injection
- Gas-lift design—valve spacing for continuous and intermittent gas-lift installations
- Gas-lift design—valve sizing
- Gas-lift performance analysis—for continuous gas lift
- Advanced gas-lift valve modeling (AGVM)—for continuous gas lift, true valve performance

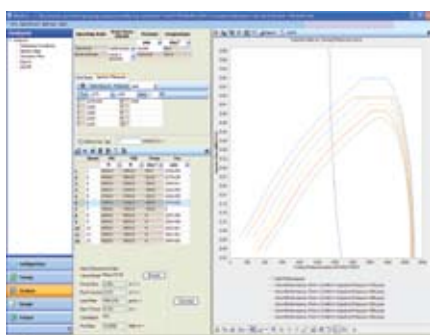
Advanced Gas-lift Valve Modeling

The pressures at which gas-lift valves allow gas to pass and the amounts of gas they pass depend upon the way they are constructed.

Orifice valves are simple: if there is sufficient pressure in the casing to reach the valve, then the major limitations on how much gas can be passed through the valve are the port size and the casing pressure.

Pressure controlled, or live, valves open at a pressure that is dependent upon overcoming a resisting force (bellows or spring). These mechanisms also allow the valve to be fully or partially open and to pass variable amounts of gas depending upon the balance of tubing and casing pressures and the valve port size.

The AGVM facility in the software introduces true valve performance into the computation of operating points.



AGVM injection pressure sensitivity for an IPO valve.

Electric Submersible Pumping Systems

Weatherford engineers have worked extensively with pump suppliers to ensure that the calculations performed by *WellFlo*-ESP software are rigorously accurate. The program has a complete database of pump performance curves for all the models from leading manufacturers. These performance curves are used as the basis for the head calculations which are then adjusted for fluid density, pump frequency, number of stages and other system variables. This means that a reliable calculation of pump performance is performed at all operating conditions. The benefit of including pump modeling within the software is that it allows a pump to be modeled as installed in the real well, such as in a horizontal well, with a particular fluid type. This is more accurate than modeling the pump performance without considering other well characteristics.

Pseudo-Pressure File Generator (PPFG)

The multiphase PPFG (link with third-party physical vapour transport (PVT) packages) is an additional application which creates a table of multiphase pseudo-pressure from the customer's own PVT. This allows the client to use his own PVT modeling package where he prefers to do so. The multiphase pseudo-pressure generated by PPFG can then be imported into *WellFlo* software for use in IPR calculations.

The PVT data are generated by the user's preferred PVT package and supplied to the software in the form of an ASCII file containing a table of phase properties versus pressure at a specified (reservoir) temperature. Properties required are viscosity, density and, for oil and condensate systems, gas mass fraction.

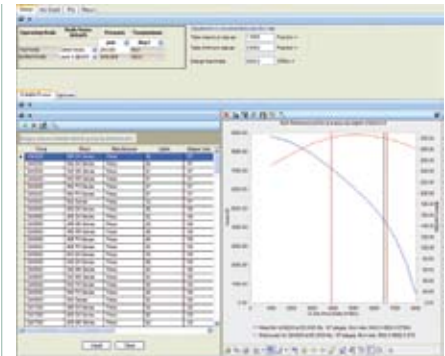
PPFG interfaces with *WellFlo* software via an external API link to extract the relative permeability data which is part of the well and reservoir model contained in the well file.

The generator then creates a multiphase pseudo-pressure file. This can be imported into the software and used as the basis for layer IPR calculations. The use of external PVT data is an alternative to the use of the software's own internal PVT models (4-component EoS, black oil correlations, etc).

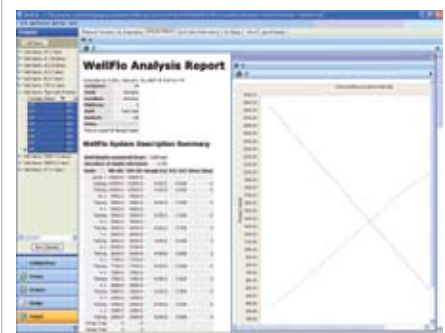
Each layer in the *WellFlo* model can be assigned its own pseudo-pressure file and each pseudo-pressure file can be generated from a different set of PVT data so the accurate modeling of variations in fluid properties with depth and their effect on IPR becomes possible.

Document Management

The latest software version addresses one of the most important, yet often-overlooked, tasks facing users of the program, through the development of a unique document management system. Upon completion of an analysis or design, users generally want to display and then save their work in the form of a chart or report. Unfortunately, most software packages do not provide an easy way of doing this. In most cases, the chart or report is only available for viewing for as long as it is displayed on the screen. The creators of the *WellFlo* systems analysis platform have developed a new feature called Output, which addresses this need. Users can now save and organize any chart or report that is generated in the software. Once the item is saved, it is available for viewing in the Output section, where it can easily be recalled using the document management feature that is provided. This means that users can easily display, print or e-mail any analysis results from any well model, regardless of which model is active at the time. This can save the user hours of frustration and wasted effort while providing a seamless way of viewing the results of prior analysis runs.



ESP design mode.



Output mode.

WellFlo Software

Conclusion

The *WellFlo* well analysis package is a sophisticated well modeling tool with a wide application to all producing or injecting oil wells. With more than a decade of use in applications in all major hydrocarbon producing regions it has benefited from the wide range of technical environments in which it has been used. *WellFlo* 4.0 software builds on this pedigree, providing a new level of sophistication, flexibility and ease-of-use. As the product matures and future enhancements are made, this robust analysis tool will continue to provide unsurpassed capabilities for well modeling and optimization.

The software is part of Weatherford's suite of production optimization software that includes:

- *DynaLift* dynamic gas-lift simulator
- **Field Office**™ real-time production optimization software
- **LOWIS**™ life of well information software
- **MatBal**™ reservoir analysis and production forecasting software
- **PanSystem**™ well test analysis software
- **PanManager**™ multiple well testing software
- **PanMesh**™ numerical simulator for well test analysis
- **ReO**™ network management optimization software
- **ReO Forecast**™ production forecasting and field planning software
- **RigPlan**™ resource scheduling software
- **Verge**™ production surveillance software
- **Well Service Manager**™ production optimization software
- **WellScribe**™ mobile data collection software
- Intelligent daily operations (**i-DO**™) system



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