

PVTsim Technical Overview

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■ INTRODUCTION

I WHAT IS PVTSIM?

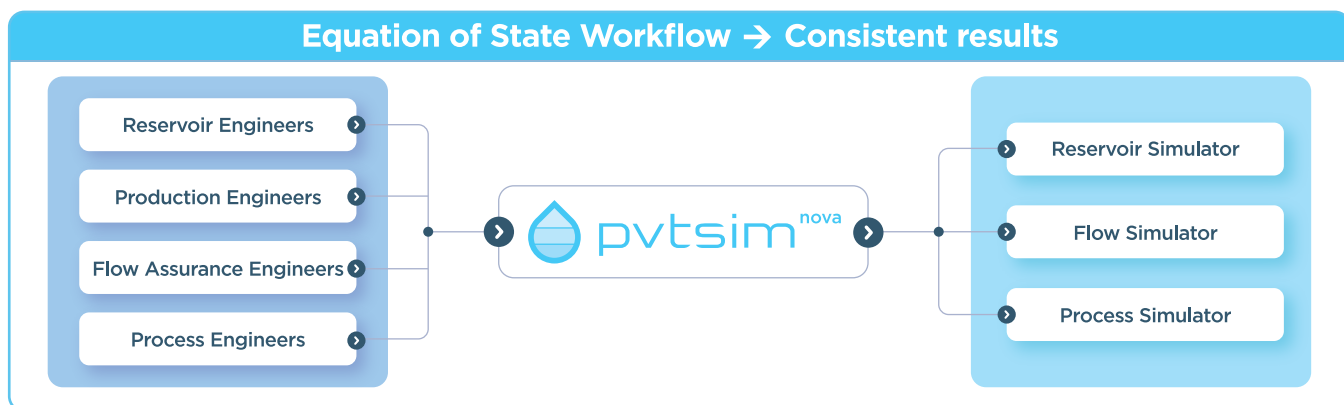
PVTsim is a versatile equation of state (EoS) modeling software that allows the user to simulate fluid properties and experimental PVT data. PVTsim is the primary commercial software owned, marketed, and developed by Calsep, thereby ensuring continued

and long-term improvements to the software. PVTsim is divided into a number of modules, interfaces and apps. Clients can purchase PVTsim Packages tailored for different application areas, or customize a package according to their engineering requirements.

I WHY CHOOSE PVTSIM?

First released in 1988, PVTsim is being used by over 300 of the world's leading oil & gas companies and PVT lab specialists. More than 35 years of extensive data collection and joint industry projects has made PVTsim one of the most versatile and reliable petro-

leum fluid simulators. PVTsim is a single tool which can be used by engineers from different disciplines for the life-cycle of a hydrocarbon reservoir fluid, thereby achieving consistency in PVT calculations across different engineering domains.



Distinguishing PVTsim features include:

- Reliable & predictive reservoir fluid characterization with flexible component lumping
- Automated import of PVT reports (Energetics PRODML 2.2 xml format and Calsep Excel format)
- Separate input mode for extended GC analyses with option to lump C7+ isomers with carbon number fractions
- Automatic fluid composition quality check (QC) with auto-correction capability
- Equations of State: Nine variations of cubic EoS's, PC-SAFT, and GERG-2008
- Model polar components using popular cubic EoS models SRK or PR with Huron-Vidal, CPA, or Classical mixing rule
- Plus fluid regression that adjusts property correlations to actual fluid PVT data
- Automated EoS builder including detailed tracking of regression settings and results for complete transparency
- Preservation of results in PVTsim after re-opening the program
- Regression history and audit trail automatically cataloged
- Characterization of multiple fluids to a common EoS, with and without regression
- Compositional variation with depth considering impact of a vertical temperature gradient
- Fully compositional simulation of wax deposition along pipelines
- Viscosities of gas, oil, water, oil with suspended wax, and water-oil emulsions
- Export to over 30 of the most popular reservoir, pipeline, and process simulators for consistent fluid description across disciplines. Import of EoS models from: Eclipse Comp, Intersect Comp, PVTi, tNavigator Comp, Comptrack, LedaFlow Comp Tracking, CHC, Prosper EoS, GEM and Winprop
- Cloud Flash API that allows flash calculations fully consistent with PVTsim to be carried out from 3rd party software
- In an effort to continue providing the most advanced and accurate models, Calsep periodically updates models and parameters. Verification reports are published and are available upon request. Examples of available verification reports include: Hydrate Verification, Mutual Solubility of Water-Hydrocarbon Mixtures, and Velocity of Sound

Please visit our website www.calsep.com for more information on PVTsim licensing and training courses.

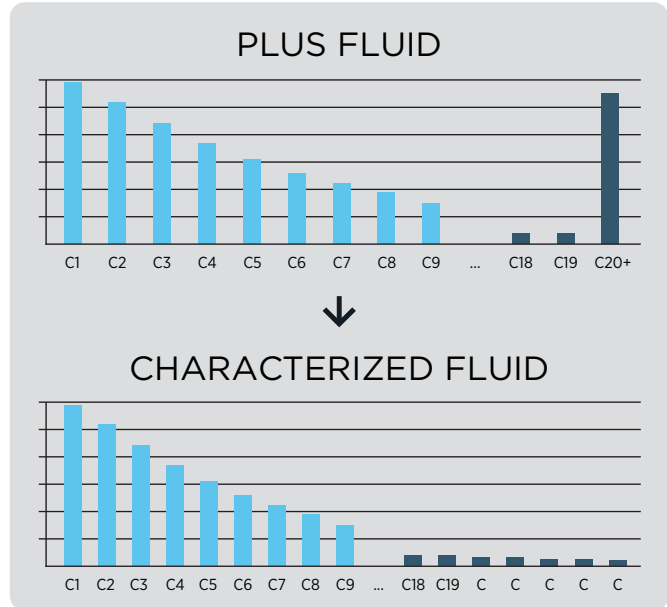
PVTsim MODULES

I BASE

PVTsim provides three different compositional input options. One is the classical molar or weight-based fluid compositions with molecular weights and densities input for each C7+ fraction. Another input mode is for extended GC fluid analyses, which may count several C7+ isomers, but lack detailed molecular weight and density data for the heavy fractions. A True Boiling Point (TBP) Analysis for a stable oil may be converted into a molar composition and used in simulations, possibly after recombination with a gas composition to create the full reservoir fluid composition.

Nine variations of the Peng-Robinson (PR) and Soave-Redlich-Kwong (SRK) cubic equations of states (EoS) are supported with the option to use constant or temperature dependent volume translation. The PC-SAFT EoS is available for general flash and PVT simulations as well as in Asphaltene simulations. For high-accuracy gas property predictions such as gas Z-factors and dewpoints, the GERG-2008 EoS is available with flash calculations, phase envelope, property generator and OLGA interface.

EoS models developed for reservoir fluids using a standard cubic equation of state can be readily extended to also handle water, hydrate inhibitors, and other polar components. An additional polar model can be selected from a separate drop-down menu.



Both the SRK and PR EoS models can be used to model polar components using Huron-Vidal, CPA, or Classical mixing rule. Separating the model with polar components from the non-polar allows the user to first tune the fluid using the standard cubic EoS of choice followed by application of the desired polar component model.

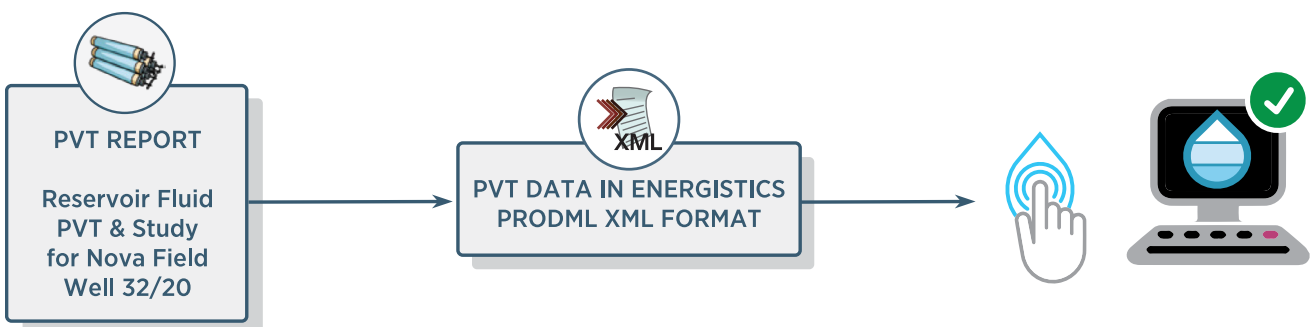
Key features included with the BASE module are:

- Fluid database that stores reservoir fluids, water analysis fluids, and field data
- Input of plus, no-plus, or characterized fluid compositions
- Copy PVT data between fluids
- Flexible lumping options and preset lumping schemes
- Recombination of separator oil & gas. Mix or weave up to 100 different fluids
- Conversions from a standard water analysis to salt composition in mol%
- Phase envelope and 2-phase flash calculation
- Help system with video tutorials

I IMPORT PVT REPORT (XML AND EXCEL FORMAT)

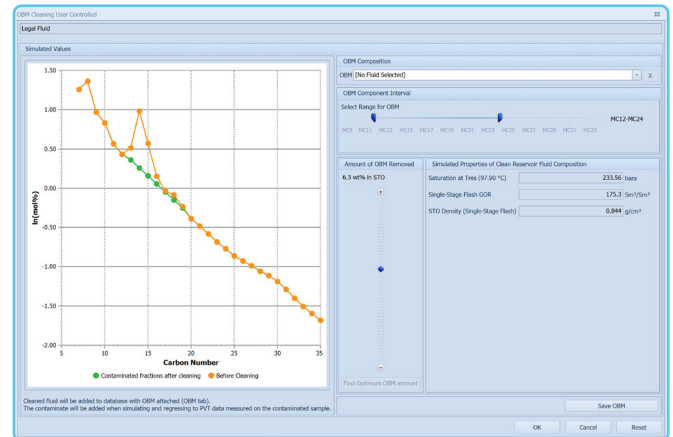
It is possible to import one or more lab PVT reports into PVTsim with a single-click. Normally this step of data input is done manually by the engineer, and is

often time consuming and may lead to incorrect data being input. The import feature in PVTsim uses the PRODML schema from Energetics.



OBM CLEANING

Reservoir fluid samples taken for lab analysis are sometimes contaminated with oil-based drilling mud. The Oil Based Mud (OBM) Cleaning option in PVTsim will numerically remove OBM contaminate to generate a clean reservoir fluid with the associated mud attached. PVTsim will estimate the OBM contaminate composition when it is not available. The user can also customize PVTsim's estimate by adjusting the OBM range and/or the amount of OBM removed. PVT data measured on the contaminated fluid sample may be input with the contaminated fluid. The mud will be mixed in when simulating and regressing to experimental PVT data measured on the contaminated fluid. The resulting cleaned and regressed fluid can be saved and used for reservoir fluid simulation studies. Building a common EoS is possible for several contaminated samples.



QC (QUALITY CHECK)

Ensure the fluid data is reliable before characterization using this comprehensive tool, which generates a straightforward and easy to read Word report listing possible reasons for fluid quality failure. Because the reliability of the results obtained in PVTsim depends on the quality of input fluid data, it is critical to ensure the input data is accurate and representative of the de-

sired fluid. In case of failure, it is possible to have reasons for failure and suggested cures printed to a QC report. QC evaluations include: single-phase sample check, oil-based mud contamination, thermodynamic equilibrium of separator samples, and mass-balance of separator samples.

Information required by the QC Module is:

- Fluid sample type: Bottomhole or Separator
- Compositional analyses of the fluid samples
- Gas/oil ratio and STO oil density
- Fluid sample type: Gas, gas condensate, near-critical, oil, or heavy oil

A fully automated QC feature is also available under the APPS section.

FLASH & UNIT OPERATIONS

Plot phase envelopes including the option to search for 3-phase regions or capture up to 5 phases in a color-coded grid using Phase Mapping. There are several different flash operations available, including:

- PT (Pressure, Temperature) including options for non-aqueous fluids, aqueous fluids, or multi-phase (up to 5 phases)
- PH (Pressure, Enthalpy)
- PS (Pressure, Entropy)
- VT (Volume, Temperature)
- UV (Internal energy, Volume)
- HS (Enthalpy, Entropy)
- PT (Pressure, Temperature) with solids. Up to 5 phases in addition to pure solid phases
- K-factor (Specify K-factors)
- Split-factor (Specify split factors)
- P-Beta (Pressure, Vapor mole fraction of non-aqueous phases)
- T-Beta (Temperature, Vapor mole fraction of non-aqueous phases)
- Saturate with water (Saturate the current fluid with water at given pressure and temperature)

The PT non-aqueous, K-factor, and Split-factor flash options consider only non-aqueous components and two phases (gas and oil). The PT multiphase option considers up to five fluid phases. The PT flash with solids option considers up to five fluid phases in addition to pure solid phases. The remaining flash options consid-

er gas, oil, and aqueous phases. Simulation results are presented in a tabular format that can be exported to a built-in worksheet where the data may be manipulated and plotted inside PVTsim or the output data can be exported to Excel®.

Output from a flash calculation includes:

- Phase amounts and compositions
- Molar volume, density, and Z-factor
- Enthalpy, entropy, Cp and Cv
- JT coefficient and velocity of sound
- Viscosity, thermal conductivity, and surface tension
- Fugacity and partial molar volumes
- Ability to save phase compositions for use in new simulations

Accurate gas simulations in PVTsim:

- Gas Quality (GPA and ISO 6976:2016)
- H₂S partitioning (gas/oil/aqueous)
- Mercury partitioning (gas/oil/aqueous)

Volumetric properties in the output are derived from the selected equation of state. Thermal properties are derived from a combination of separate ideal gas models and the selected equation of state. If water is present, the aqueous phase properties can be calculated using the Water Package or the PC-SAFT model as an alternative to the selected EoS model. Viscosity and thermal conductivity are calculated using either a corresponding states model (Pedersen modification) or the Lohrenz-Bray-Clark correlation.

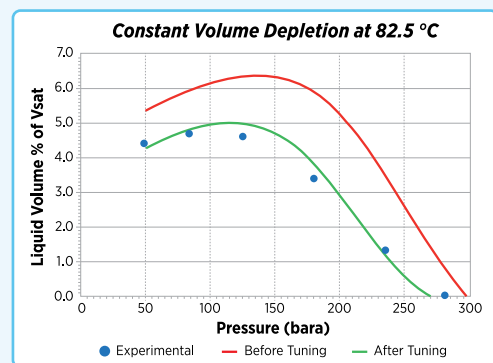
It is possible to calculate viscosities of water-in-oil and oil-in-water emulsions at specified temperatures and pressures. Users can select from the available Rønningesen (default) or Pal and Rhodes models. For each pressure and temperature input, plots will be shown of viscosity versus water volume fraction.

The Flash & Unit Operations module also includes simulation capabilities for various unit operations such as compressor (classical/polytropic), expander, cooler, heater, pump, valve, and 3-phase separator which allows input of oil production rate at standard conditions.

BASIC PVT SIMULATION & REGRESSION

Simulate standard experiments carried out in PVT laboratories including:

- Constant mass (or composition) expansion (CME or CCE)
- Dry Gas CME (pVTZ)
- Constant volume depletion (CVD)
- Differential liberation (DL)
- Separator test
- Viscosity experiments



Up to five data sets for each type of experiment may be stored with each fluid composition. The data input includes measured phase compositions for experiments where phase compositions are reported. The user may define the standard (stock tank) conditions compliant with the actual PVT experiments.

In the PVT simulation input menus, the entered temperatures and pressures are shown as default values when the experiments are simulated and plots compa-

ring experimental and simulated data are shown. However, it is important to note that no experimental data is required to simulate these experiments.

Input menus for storing the PVT data are arranged to comply a standard PVT reports, allowing for direct cut and paste of data from PVT reports available as soft copy.

To get a more representative simulation of the reservoir production process, it is possible to include separator corrected values with the CVD, DL, and Depth Gradient simulations.

The output results are presented in a user-friendly format and can be exported to a worksheet where the data may be manipulated and plotted inside PVTsim or the output data can be exported to Excel. Detailed output of physical properties and compositions at each pressure stage may optionally be shown.

The extensive data output allows the user to cross check the experimental data with simulated values. PVTsim can generate a comparison of all experimental and simulated PVT data input for a fluid in one click using the Compare with Experimental PVT Data option. Plots and tables comparing simulated and measured PVT data and equilibrium phase compositions along with percent deviation are provided as output.

It is also possible to perform a mass balance check on experimental data for the Separator Test, DL, Equilibrium Contact, and Multiple Contact experiments by using the Material Balance Check option. The output from a Material Balance Check is a report providing Component Molar Balance tables which compare the difference in inlet and outlet molar compositions, and Overall Mass Balance tables comparing the mass in at the first pressure stage vs. summed mass out at each subsequent pressure stage and the mass of stock tank oil in the last stage.

Regression may be needed when developing an EoS model to match available PVT data. This is a primary step for a heavily lumped fluid model to be exported to a compositional reservoir or flow simulator. Regression in PVTsim may start with a plus fluid composition or an already characterized composition. Fluid regression results in a tree structure in the database where regressed fluids are child fluids of the original root fluid. This process allows the user to keep track of the history of tuned fluids. The child fluid is indexed in the database through a multilevel list where the result of a regression of fluid #2 would be a child fluid indexed as fluid #2.1, and so on.

After each regression, the result is stored as a temporary fluid. This allows the user to compare all the regressions, decide which one provides the best match, and save it in the database. In addition, the regression history of a fluid, including the adjusted parameters and the selected weighting, is automatically saved with a fluid in the Reg History tab. This audit history allows for tracking the fluid from the plus fluid to the final EoS model.

PVTsim also provides an automated EoS modeling tool, which implements fluid characterization, regression, and lumping in one single step. This menu is detailed in the APPS section.

#	Well	Test	Fluid	Sample	Text	Type	Lumping	#Comps	PVT Tuned	Visc Tuned	EoS	Polar
1	NS23z	1st A	Gas Cond	Sep Mass Balance	Sep Test, CVD, CME	Plus	PVTsim default	24				
2	Sep Gas	PT1	SEPGAS	BOTTLE A#16000	PVT LAB	No-Plus	PVTsim default	14				
3	Sep Liq	PT1	SEPLIQ	BOTTLE #K6000	PVT LAB	Plus	PVTsim default	14				
4	VO-6056	1B	Vol Oil	BH	Crit Pnt, Sep, DL, Visc	Plus	PVTsim default	43				
5	TEST 4	BHS	OIL	Sampling Data	OIL LAB	Plus	PVTsim default	14				
6	TEST	A	OIL	Diff Lib Mass Balance	DIFF LIB+VISC+CME	Plus	PVTsim default	24				
7	TEST	B	Condensate	CVD DATA	CVD LAB w/GAS COMPS	Plus	Lumped gas condensate	11				
7.1	TEST	B	Condensate	CVD DATA	CVD LAB w/GAS COMPS	Characterized		7	Yes	No	SRK Peneloux	
7.1.1	TEST	B	Condensate	CVD DATA	CVD LAB w/GAS COMPS	Characterized		7	Yes	No	SRK Peneloux	
8	TEST	B	Natural Gas 90.4...	GERG	GAS LAB	No-Plus	PVTsim default	10				
9	TEST	A	Sales Gas	GERG	GAS LAB	No-Plus	PVTsim default	10				
10	TVAR	3X	Cyl 1A	Biodegraded Oil	Heavy Oil Char (T)	Plus	PVTsim default	37				

The composition varies with depth in a reservoir. Based on a sample composition, sample depth, and PT-conditions, PVTsim simulates the variation with depth in composition, pressure, GOR and a number of physical properties along with the location of the gas-oil contact, if such exists. Simulations may be carried out isothermally or accounting for a vertical temperature gradient modeled using the theory of irreversible thermodynamics.

The increased compositional grading caused by viscosity effects (SPE-205887-MS) may also be included in the simulation.

For fluids with asphaltene components, the Asphaltene Tar Mat option calculates the variations in composition, saturation point, and asphaltene onset point with depth and identifies the location of a possible tar mat.

EOR, MULTIFLUID PVT & REGRESSION

Experiments used to study gas injection and miscibility of fluids are time consuming and expensive. Careful planning of which experimental conditions to use is therefore important. Standard EOR lab experiments available for simulation in PVTsim include:

- Swelling test
- Equilibrium contact
- Multiple contact
- Minimum Miscibility Pressure (Analytical method)
- Slim tube (1-D flow simulation, and Method-of-Characteristics)

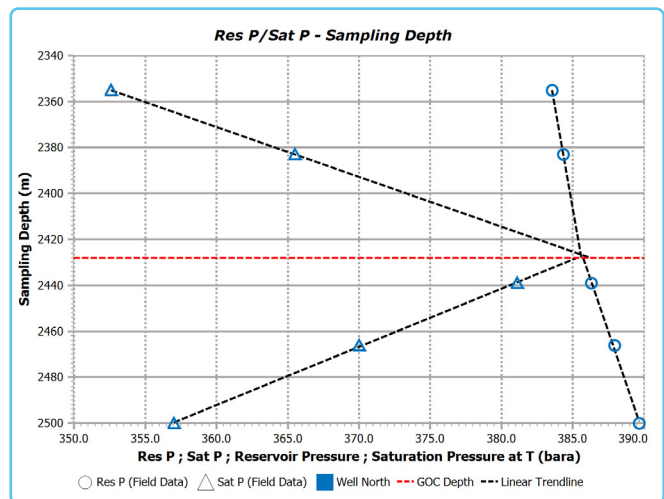
Injection gases used in EOR PVT experiments can be entered with a fluid and assigned to a particular EOR PVT experiment. A swelling test may be performed to simulate the swelling of a reservoir fluid during gas injection. It is possible to include CME and viscosity data for the mixture at each stage and use this data for regression. The critical point can be input with the swelling data and used for regression. A slim tube experiment can be simulated and provide results for recovery and composition of the produced fluid at the actual reservoir pressure. The Method-of-Characteristics slim tube option is a fast, approximate alternative to the traditional cell-to-cell slim tube simulation and it includes the option to see a video of how the oil saturation changes in the slim tube as gas is injected. The multi-component MMP option gives a fast and reliable answer about the minimum pressure required to develop a miscible drive.

In many cases, it is desirable to make a single EoS model for multiple fluids, also known as a Common EoS model (or a field-wide or basin-wide EoS model). In a Common EoS model, multiple fluids utilize the exact same EoS parameters and differ only by the molar amounts of each component. For example, fluid compositions will vary with horizontal location and depth in the reservoir. If these fluids are from the same reservoir, though they may vary by molar composition, each fluid can be represented using the same equation of state model. With the Common EoS option in PVTsim, it is possible to characterize 2 to 100 different plus and/or no-plus fluids to a Common EoS. When developing the Common EoS model, it is possible to regress to PVT data for each of the individual fluid compositions. Common EoS models for fluid samples at varying depths can also be tuned to match the measured compositional gradient, saturation pressure gradient, and gas-oil contact depth.



The results from a Common EoS model can be compared in one-click using the Multifluid Compare with Data menu. The data for multiple fluids is collated in a summary document by way of tables and plots for easier inter-fluid comparison. A separate comparison of measured and simulated PVT data for each fluid is also provided.

The Data Visualization Tool allows for the rapid visualization of key fluid property trends versus depth. Fluid data can be integrated with field data, such as reservoir temperature, reservoir pressure, or saturation pressure without requiring a compositional sample. This data can be plotted versus depth or used in cross plots to visualize and estimate fluid property trends in the reservoir.



COMPOSITION ESTIMATION

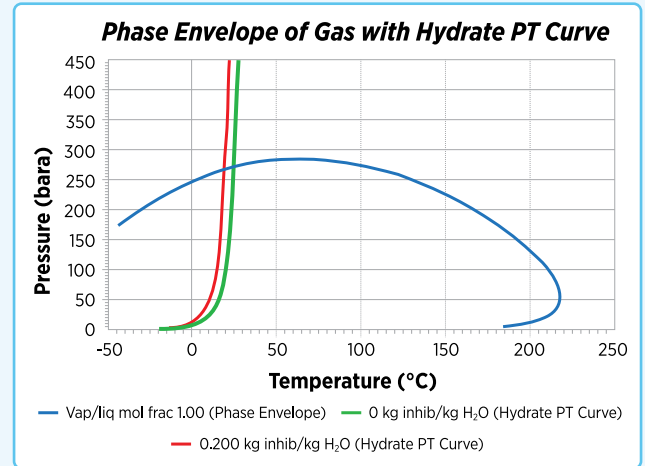
It is often a challenge to know the reservoir fluid composition in shale oil and gas fields due to limited availability of samples and uncertainty in the sampling process. Starting from one or more reference compositions, the Composition Estimation module in PVTsim uses advanced chemical reaction equilibrium theory

to estimate shale reservoir fluid compositions from simple input of the reservoir temperature and pressure. The output from the module is a Plus composition of the reservoir fluid, which can be characterized and used for simulations throughout PVTsim.

HYDRATE

PVTsim can accurately simulate hydrate formation conditions of gas and oil mixtures. Depression of hydrate formation temperature of the most commonly used hydrate inhibitors (MeOH, EtOH, MEG, DEG and TEG) can be simulated as well as the loss of inhibitors to the hydrocarbon phases.

- Hydrate formation conditions
- Amount of hydrates formed
- Amount of inhibitor needed to suppress formation
- Effect of salts on hydrate formation
- PT & PH flash options

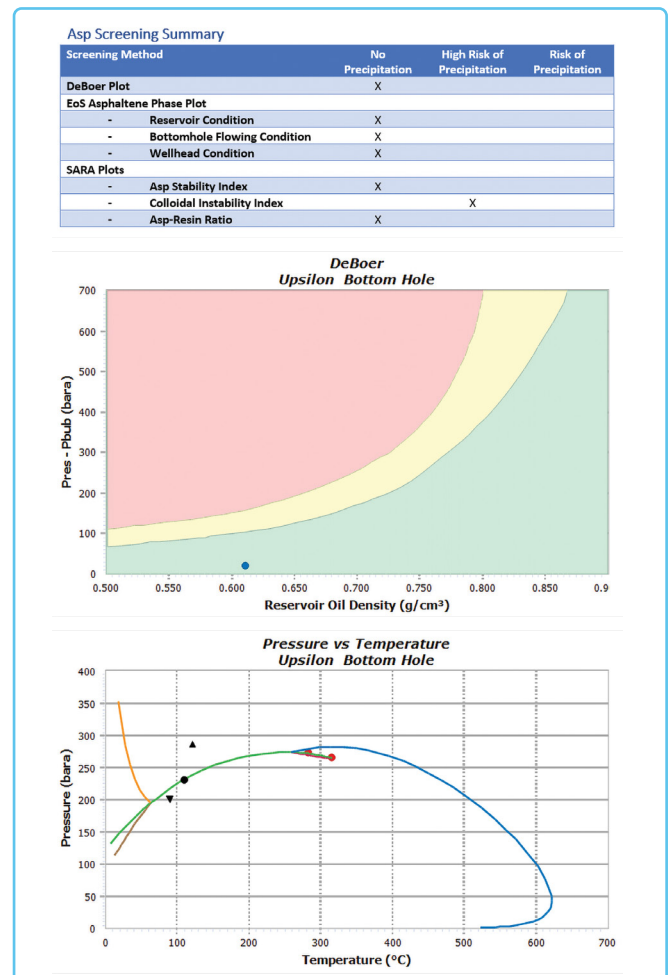


The flash options automatically provide amounts and types of hydrates (structures I, II and H) as well as hydrocarbon and aqueous phases, solid salt phases,

es, and ice. The Hydrate module supports all cubic equations and the CPA model.

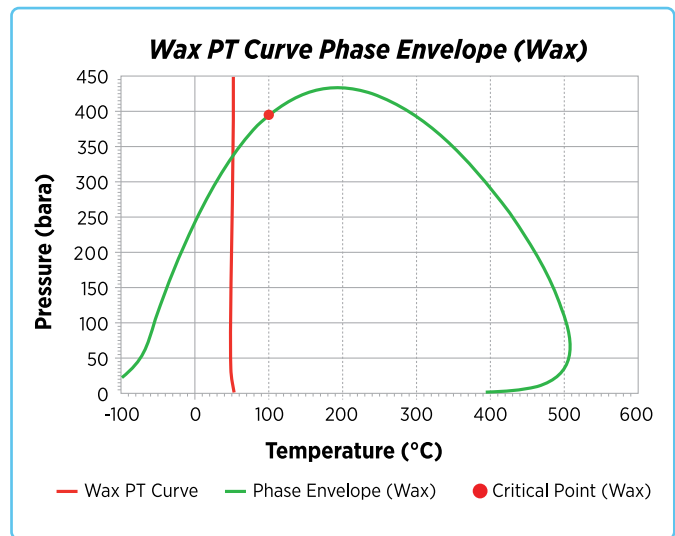
ASPHALTENE

Screen fluid compositions for risk of asphaltene precipitation. The Asphaltene Screening tool evaluates asphaltene risk in reservoir, flowing bottomhole and wellhead conditions and compiles a summary report with De Boer plots and analyses performed on SARA data saved on the fluid. Simulate the conditions at which asphaltene precipitates for a given fluid composition, tune to asphaltene onset pressure, perform a PT flash, and determine weight % of asphaltene components in stock tank oil (STO). This module allows calculation of the entire asphaltene phase envelope for the complete PT spectrum. For a given temperature, you may also determine the pressure range at which asphaltene precipitation occurs for various amounts of injection gas. The effect of gas injection on the asphaltene precipitation conditions can be studied using a Px-curve option. The asphaltene model has been developed based on experimental live oil asphaltene precipitation data and supports all Cubic EoS models, PC-SAFT, and the CPA model.



WAX

Evaluate wax formation conditions from an ordinary compositional analysis or, if available, the n-paraffin distribution may be entered with the fluid. Using the wax module, it is possible to quantify the amount of wax precipitate, run flash calculations, and plot wax formation conditions through PT curves. If data is available, it is also possible to tune the wax model to experimental wax data, stored on the fluid (WAT, Wax in STO and Solid Wax vs. Temp.). The amount of wax precipitate may be calculated as a function of P for constant T or as a function of T for constant P and quantitative flash calculations will consider gas, oil and wax. Additionally, there is an option to account for the influence of wax inhibitors. Oil with suspended wax particles, which exhibits a non-Newtonian viscosity behavior, can be modeled with PVTsim. Viscosity plots can be made of wax in oil suspensions for varying shear rates. Fluids tuned in the wax module may be used in the PVTsim DepoWax module, a pipeline simulator considering wax deposition and the effect on viscosity of wax particles suspended in the oil phase.

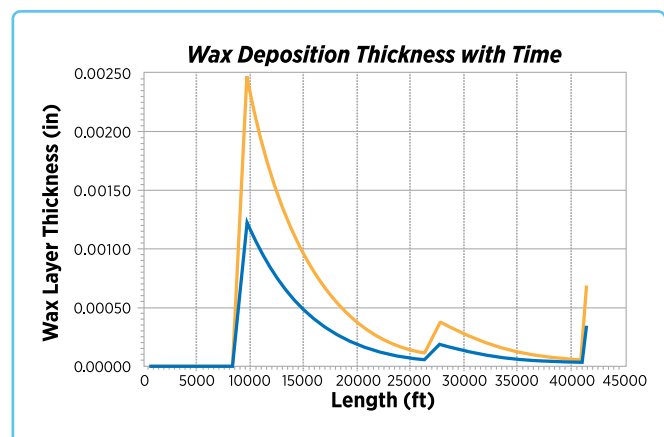


DEPOWAX

Analyze the nature and extent of wax deposition along a pipeline by calculating pressure drops, temperature profile, position and thickness of wax deposited with a fully compositional profile. Wax appearance temperature, wax amount, and wax viscosity can be tuned in the wax module prior to initiating a wax deposition simulation. The RRR (Rygg, Rydahl, Rønningsen) and Matzain wax deposition models are available. Being fully compositional, DepoWax is well suited for pipelines with multiple inlets and commingled fluids.

With the fluid properly characterized, all the user has to input is pipeline geometry, (xy-coordinates, inner diameter, roughness, ambient temperature, and insulation) inlet P&T, and inlet flow rate. Other properties have default parameters which may be modified.

The simulation results give information with respect to time for pressure drop, temperature profile, and position and thickness of deposited wax.



SCALE

Determine the amount of scale (salt precipitate) that will emerge from formation water and seawater mixtures. Formation water and seawater can easily be selected for simulation from the stored water analyses in the database. This module takes into account CO₂ and

H₂S equilibrium pressures in the water, pH, as well as the effect of the other ionic species (primarily NaCl, CaCl₂, and KCl).

The PVTsim scale module considers precipitation of the most common salts including:

- BaSO₄
- SrSO₄
- FeS
- CaSO₄
- CaCO₃
- FeCO₃

Pitzer's activity coefficient model is used. The risk of scale formation over an entire PT grid can be viewed through 2D and 3D plot options.

PROPERTY GENERATOR

Customize fluid property tables to investigate trends in specific properties as a function of pressure and temperature, or generate property input for a pro-

gram to which PVTsim has no dedicated interface. Fluid properties available through the Property Generator include:

Molar Volume	Enthalpy	Velocity of Sound
Density	Entropy	Viscosity
Z-factor	Heat Capacity (Cp)	Thermal Conductivity
Molecular Weight	Heat Capacity (Cv)	Interfacial Tension
Internal Energy	Kappa (Cp/Cv)	Compressibility
Molar Internal Energy	JT Coefficient	Bulk Modulus

ALLOCATION

Allocate the export streams of gas, oil, and water (aqueous) back to 2 - 100 production streams. Export flow streams are reported at reference conditions, which by default are the selected standard conditions.

PVTsim APPS

PVTsim APPS are designed to optimize and automate the EoS modeling steps, enabling users to generate a robust EoS model in a short time frame.

COMPOSITION PREPARATION FOR AUTO EOS

Most of today's compositions come from Gas Chromatography analyses where plus fraction properties are not directly measured. This practice can result in a high degree of uncertainty on reported plus fraction properties. The process for evaluating and correcting reported compositional data has been automated into a single step, which checks whether the reported plus fraction properties of a fluid are consistent with the

rest of the reported data for the fluid. In the event of failure, the composition is automatically adjusted with details of the performed correction reported in the output datasheet. A new corrected fluid is added to the database and selected for simulations while the original fluid is preserved in the database.

AUTO EOS

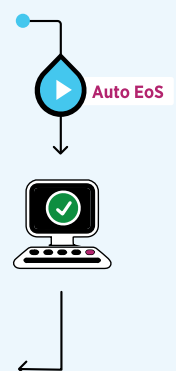
With a plus fluid in the database, Auto EoS will deliver a fully tuned and lumped EoS model. Select from a list of available EoS models, define the final number of components for the model, and PVTsim will automatically include and rank available experimental PVT data for tuning. PVTsim can add an estimated critical point as an additional data point in the regression, which is useful for gas injection modeling. For complete transparency, the Auto EoS regression steps are reported in detail including plots and datasheets illustrating parameters adjusted and the match before and after tuning.

INPUT

- Plus fluid composition
- Experimental PVT data
- Number of components

OUTPUT

- EoS model matching PVT data
- Lumped appropriately
- Full report with regression steps



SEPARATION & SEPARATOR OPTIMIZATION

Simulate an overall separation process in a way that is true to the actual facility design without requiring the level of detail needed for most process simulators. A characterized fluid and the temperatures and pressures of each separation stage are the only required input. It is also possible to define component-split separators where the input is either the K-factors or Oil Recovery Factors of each component. Two inlet fluids can be provided. Generated output includes for-

mation volume factors (Bo, Bg), process GOR, stream compositions and PVT properties. Once a process flowsheet is created, it can be saved and accessed in several PVTsim menus (for example, Diff lib, CVD) and be used to generate black oil tables with accurate gas and oil properties. Separator temperatures and pressures can be optimized to create a separation process with the maximum liquid production.

INSITU FLUID

It is often desired to create the original reservoir fluid composition from a depleted sample. The InSitu Fluid option uses a depleted sample together with information about the original reservoir fluid (either original Sat P or original GOR) to recreate the original reservoir fluid composition. For depleted oil samples, a simula-

tion process is used to add/remove gas in small steps to match the original reservoir fluid input. For depleted gas condensate samples, equilibrium liquid is added/removed in small steps to match the original reservoir fluid input.

FLUID INCLUSION SIMULATOR

Hydrocarbons hosted in fluid inclusions in sediments represent trapped material that was present in the hydrocarbon system in the past. Laboratory-measurements of homogenization temperature and volume% gas allow for the estimation of the fluid composition

and trapping conditions. The Fluid Inclusion Simulator option in PVTsim calculates the optimal hydrocarbon composition which is consistent with the measured data.

PVTSIM NOVA CCS

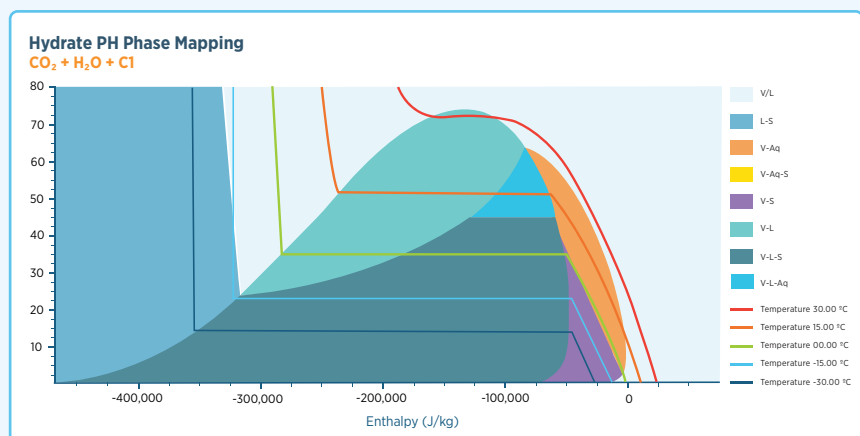
The PVTsim Nova CCS module offers specialized models to simulate and understand complex phase equilibrium problems related to Carbon Capture and Storage (CCS). This includes analyzing the phase equilibrium challenges that CO₂-rich fluids with impu-

rities will face during transport in pipelines, through the well, and into the depleted reservoir or saline aquifer. The PVTsim Nova CCS module provides features that make it a one-stop solution for modeling and evaluating CO₂-rich systems.



KEY FEATURES

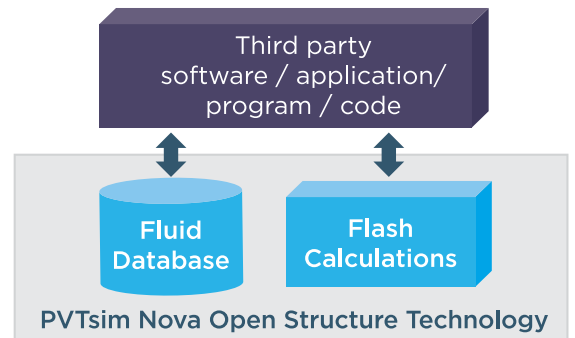
- Pure CO₂
- Impact of impurities
- CO₂ hydrate
- CO₂-brine solubility
- SO_x, NO_x, NH₃
- PH phase mapping
- CO₂ density tuning
- Pure hydrogen
- Reliable & validated simulations



■ OPEN STRUCTURE

I OPEN STRUCTURE

Open structure is an API which gives access to the PVTsim thermodynamics and fluid databases without opening the PVTsim graphical user interface. Open structure can be accessed via code written in most common programming languages including Visual Basic, Python, Matlab, C++, and C#. PVTsim Open Structure modules include Flash, Hydrate and Wax. All open structure calculation options are fully consistent with calculations carried out in PVTsim directly.



I FLASH OPEN STRUCTURE

Flash Open Structure allows the following flash calculations: PT (including aqueous phase flash and multiphase flash), PH, PS, VT, UV, HS, K-factor, Split factor, P-Beta, and T-Beta.

I HYDRATE OPEN STRUCTURE

Hydrate Open Structure gives access to the following calculation options: PT hydrate flash, Hydrate formation PT curve, Hydrate formation pressure, Hydrate formation temperature, and Minimum inhibitor.

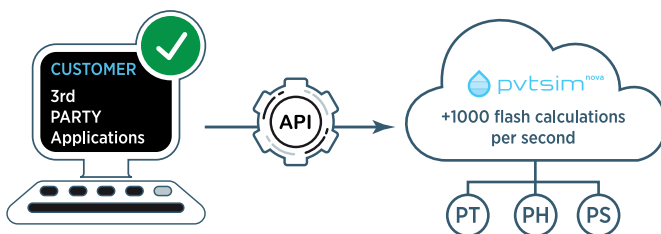
I WAX OPEN STRUCTURE

Wax Open Structure gives access to the following calculation options: PT flash, Wax formation PT curve, and Wax formation temperature.

■ CLOUD FLASH API

Calsep has released the Cloud Flash API, which allows fast and robust thermodynamic simulations in the cloud using PVTsim Nova technology. It can be used to build applications that require access to volumetric, thermal and transport properties of all types

of reservoir fluid compositions. The Cloud Flash API is developed and designed for implementation in high performance solutions that can require more than 1000 flash calculations per second.



A Software Development Kit (SDK) is available for the Cloud Flash API in both Python and C#. The SDK shows how to set up a call to the Cloud Flash API and how to access the available functions. A full documentation of the API functions is provided together with the SDK.

• PYTHON SDK

• C# SDK

The Cloud Flash API is ideal for real-time or batch calculations. Examples of applications include:

- Real-time allocation of produced fluids using the data from multiphase flow meters
- Real-time simulation of a separation process
- Phase behavior in a transient flow system

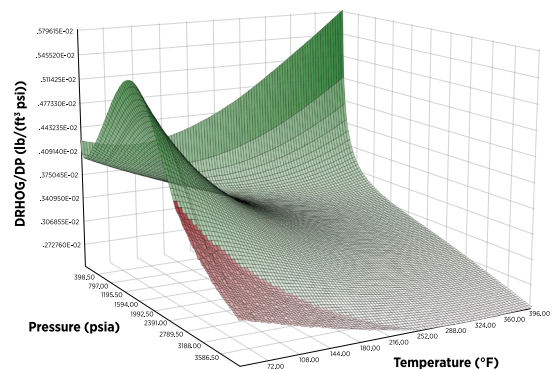
The Cloud Flash API can be delivered both as a public cloud solution or a private cloud solution (on-premise), see www.calsep.com/calsep-cloud/ for more information on how to get access to Calsep's Flash API.

INTERFACES

PVTsim includes modules to generate PVT input tables to a number of external (non-Calsep) programs. Tables may contain physical, compositional, or black oil properties. The Interfaces can be purchased individually or in packages and provide easy export to the following widely used reservoir, process, and flow assurance programs:

<h3>Eclipse</h3> <ul style="list-style-type: none"> Eclipse Black Oil Eclipse Black Oil Rs/Rv vs Depth Eclipse Black Oil API vs Depth Eclipse Black Oil Corr Eclipse GI Eclipse Comp Eclipse Comp Import Eclipse Thermal Plot Eclipse Black Oil File 	<h3>CMG</h3> <ul style="list-style-type: none"> IMEX GEM STARS GEM Import <h3>tNavigator</h3> <ul style="list-style-type: none"> tNavigator Black Oil tNavigator Comp tNavigator Comp Import 	<h3>OLGA</h3> <ul style="list-style-type: none"> OLGA TAB OLGA Data Plotting Tool OLGA Comp Tracking OLGA Comp Tracking Import OLGA Wax OLGA Batch <h3>Leda Flow</h3> <ul style="list-style-type: none"> LedaFlow LedaFlow Comp Tracking LedaFlow Comp Tracking import 	<h3>IPM</h3> <ul style="list-style-type: none"> Prosper MBAL Prosper EoS Prosper EoS Import Reveal <h3>Process</h3> <ul style="list-style-type: none"> PRO/II HYSYS UniSim
<h3>Intersect</h3> <ul style="list-style-type: none"> Intersect Intersect Black Oil Intersect Comp 	<h3>VIP</h3> <ul style="list-style-type: none"> VIP Black Oil VIP-Comp 	<h3>Pipesim</h3> <ul style="list-style-type: none"> Pipesim 	<h3>Multiphase Meter</h3> <ul style="list-style-type: none"> MPM
<h3>Nexus</h3> <ul style="list-style-type: none"> Nexus Black Oil Nexus Comp 	<h3>OPM Flow</h3> <ul style="list-style-type: none"> OPM Flow 	<h3>Pipephase</h3> <ul style="list-style-type: none"> Pipephase 	<h3>Turbulent Flux</h3> <ul style="list-style-type: none"> Turbulent Flux
<h3>MORE</h3> <ul style="list-style-type: none"> MORE Black Oil MORE EoS 	<h3>PVTsim JSON EoS</h3> <ul style="list-style-type: none"> Limited (Flash API) Complete (Incl. PVT data) 	<h3>Other</h3> <ul style="list-style-type: none"> Saphir WePS WELLCAT Harmony 	

It is possible to visually observe trends and identify potential problem areas in the tables/black oil files for the reservoir simulators Eclipse, tNavigator, IMEX and Nexus and for the multiphase flow simulator OLGA using the available plotting tools in PVTsim. The plotting tool for the OLGA interface allows plotting in 2D and 3D formats and provides a summary of any illegal or non-numerical values. In the plots, real data is marked with a green color, while imaginary data is marked with a red color.



OLGA Plotting Tool

LICENSING & MAINTENANCE

PVTsim licenses are available as Site licenses, which are convenient for multiple users at the same Site who can access a license server on the network. Site licenses are run using the FLEXlm license manager. Stand-alone licenses are also available as a dongle that can be plugged into the USB port of a computer.

fixes, access to Client Area on Calsep.com and superior technical support from Calsep consultants. To run PVTsim, minimum hardware requirements include: 1 GB RAM and 1 GB free disk space, a minimum resolution of 1920 x 1080 with 125% scaling, 64-bit Windows 10 or Windows 11.

Calsep offers a maintenance arrangement for an annual fee. This fee covers any updates in PVTsim, bug

■ STANDARD PVTsim PACKAGES

Popular PVTsim modules and interfaces have been collected into standard packages offered for a lower price when compared to purchasing each module individually. The different packages target the needs of different engineering areas. The following table summarizes the modules and interfaces included with each package:

MODULES	Basic PVT	PVT Lab	Reservoir	PVTsim for OLGA/ LEDAFLOW	Flow Assurance	Premium PVT	Full Package
BASE	✓	✓	✓	✓	✓	✓	✓
OBM CLEANING		✓	✓		✓	✓	✓
QUALITY CHECK (QC)		✓	✓			✓	✓
FLASH & UNIT OPS				✓ ²	✓	✓	✓
BASIC PVT SIMULATION & REGRESSION	✓	✓	✓			✓	✓
EOR AND MULTIFLUID PVT & REGRESSION		✓	✓			✓	✓
PROPERTY GENERATOR		✓	✓		✓	✓	✓
COMPOSITION ESTIMATION			✓			✓	✓
HYDRATE				✓	✓	✓	✓
WAX					✓	✓	✓
ASPHALTENE					✓	✓	✓
SCALE					✓	✓	✓
ALLOCATION						✓	✓
DEPOWAX							✓
CCS						✓	✓
OPEN STRUCTURE							
OPEN STRUCTURE FLASH							✓
OPEN STRUCTURE HYDRATE							✓
OPEN STRUCTURE WAX							✓
INTERFACES							
RESERVOIR INTERFACES			✓ ¹				
ONE RESERVOIR INTERFACE	✓						
OLGA				✓			
LEDAFLOW				✓			
FLOW ASSURANCE INTERFACES					✓ ³		
ALL INTERFACES							✓ ⁴

1. Includes interfaces for ECLIPSE, INTERSECT, CMG, tNavigator, PROSPER/MBAL

2. Includes only the 3-phase aqueous flash

3. Includes interfaces for OLGA, LEDAFLOW, PIPESIM and PIPEPHASE.

4. Includes interfaces for ECLIPSE, INTERSECT, MORE, CMG, NEXUS, PROSPER/MBAL, REVEAL, SAPHIR, VIP, tNavigator, OPM, HARMONY, OLGA, LEDAFLOW, PIPESIM, MULTIPHASE METERS, Turbulent Flux, HYSYS, PRO/II, UNISIM DESIGN, PIPEPHASE, WEPS and WELLCAT.



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