Petroleum Experts

PETEX

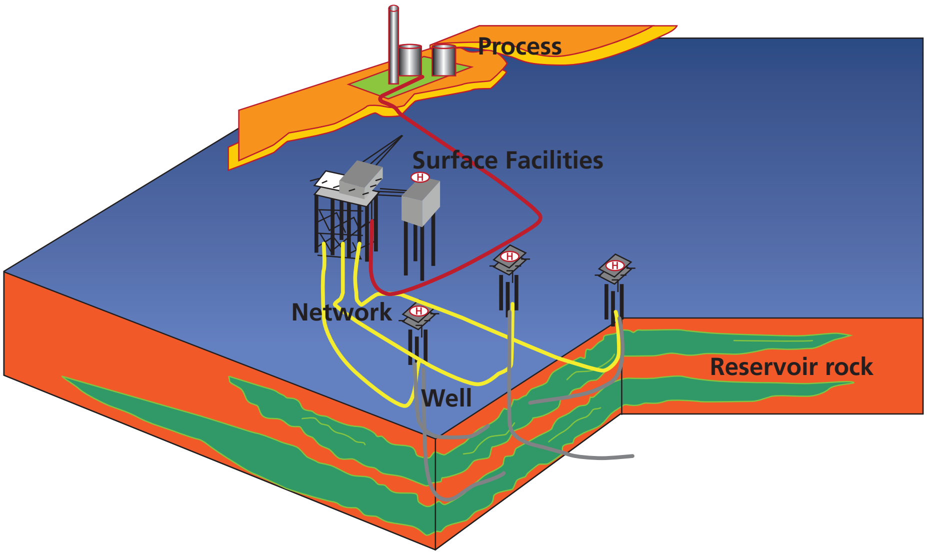
Engineering Software Development

IPM Suite

Product Information

Integrated Production Modelling

An oil or gas field is an integrated system



Oil and Gas fields worldwide **produce as integrated systems** of reservoirs, wells, pipeline networks and process facilities. Oil and Gas companies traditionally discretised the engineering analysis, breaking the system into parts and studying and solving the components individually. Each silo relied on a variety of analytical techniques which over the years evolved into distinct software products. Each product model being a calibrated mathematical representation of the physical phenomenon, with a view to maximising economic recovery from the asset. Classically, the physical models rely on boundary conditions in order for it to provide the desired results. Over time these artificial boundary conditions can become entrenched and fixed in the analysis of a model, leading an engineer of one discipline to make decisions and draw conclusions which are counter-intuitive if the whole field production system had been considered. In an oil or gas field, due to the natural integration that exists between all the elements that make up the system, **any change that is made on one part affects the behaviour of every other component that is in pressure communication with it**.

The concept of Integrated Production Modelling (**IPM**) was **pioneered by Petroleum Experts** and it involves the **elimination of artificial boundary conditions** that would be imposed by individual disciplines and facilitates the construction of models that would behave as close to reality as possible. A change that is made on a pipeline model for example, will automatically change the behaviour of the wells and reservoirs upstream of that pipe, as well as behaviour of all the elements downstream. Integrated Modelling is able to capture this behaviour, while still allowing the engineers to build models relevant to their discipline in isolation of everything else, as the benefits of integrating all the models together to replicate the natural behaviour of the field has **transformed the way companies design, operate and optimise** their assets.

Petroleum Experts (**Petex**) is a **Research and Development Company** that encapsulates innovative engineering research into software. The results of this research are implemented in a way that adhere to the principles of Integrated Production Modelling, whilst still being of practical use to the discipline in question. The following sections in this brochure describe the domain and capabilities of each product. The **IPM suite** encompasses all the engineering calculators that facilitate the formulation of solutions to challenges that engineers face. The Petex Digital Oil Field (**DOF**) **platform** includes software that facilitate rational economic decisions made through the execution of workflows in **real time**. These allow operators to understand field behaviour and replicate this in physical models which are subsequently used to **optimise production as well as ultimate recovery**.

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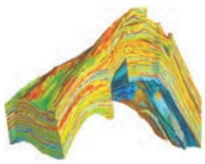
RESOLVE

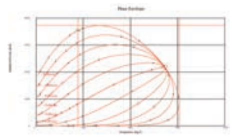
ADVANCED INTEGRATION
A VENDOR NEUTRAL SOLUTION FORMULATION PLATFORM

INTEGRATION OF SUB-SURFACE AND SURFACE MODELS

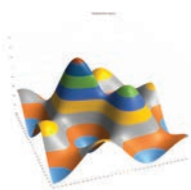


PROCESS

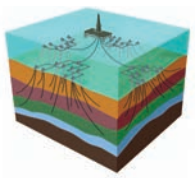
ADVANCED PVT HANDLING

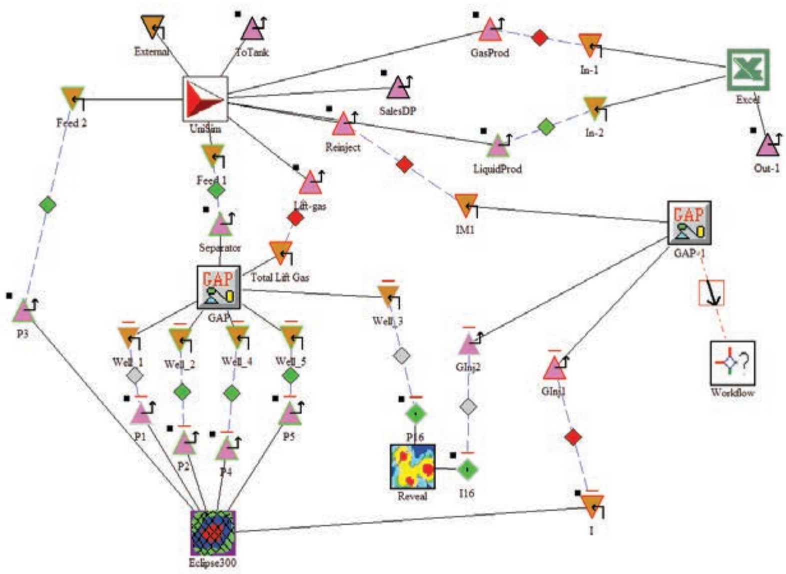


GLOBAL OPTIMISATION



WELL PERFORMANCE

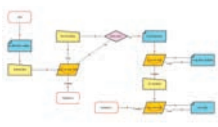




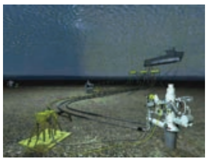
ECONOMICS

CHEMICAL DOSING

VISUAL WORKFLOWS



FLOW ASSURANCE



SCENARIO MANAGEMENT

PROBABILISTIC STUDIES

DATA OBJECTS

CLUSTERING & HYPERTHREADING

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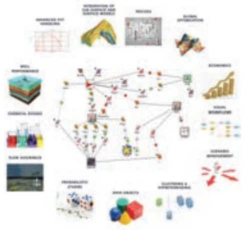


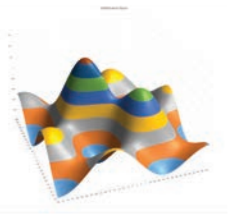
RESOLVE

ADVANCED INTEGRATION
A VENDOR NEUTRAL SOLUTION FORMULATION PLATFORM

ECONOMICS

RESOLVE has been extensively tested on many fields all over the world, and its fast calculations (e.g. tight gas, shale oil/gas etc…) have been proven time and again for field development and Economic analysis. NPV, IRR and other Economic analysis can be easily used to drive a simulation and make decisions on operational strategy.

GLOBAL OPTIMISATION

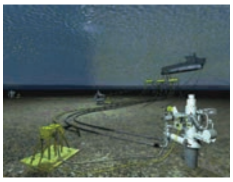


There is no "one solution fits all" optimiser algorithm that exists which can be universally applied to the upstream oil and gas system (because the problem is defined as a **Mixed Integer Non-Convex Non-Linear Optimisation** Problem). **RESOLVE** contains an SLP and Routing optimiser, combining this with the NLP optimiser in **GAP** allow for potentially a three tiered optimisation, where the user must formulate a way in which to make all of these search algorithms interact, to find the global maxima. As such **RESOLVE** has multiple levels of sophistication in the way it combines it's **multi tiered optimisation problems**, using linear, non linear and integer algorithms together to address the complexity of interaction that exist within the upstream system. All of which can be triggered and controlled dynamically from **Visual Workflows**.

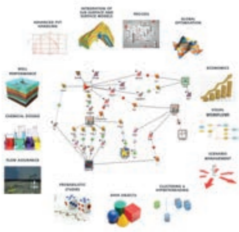
DATA OBJECTS

A number of **unique** and **efficient** computational functionalities are abundant across the **IPM** suite: this is what makes the **IPM** tools industry leading in terms of the diversity of analysis that can be performed in a single suite of applications. It is these capabilities/functionalities that have been isolated and exposed for the user as **Data Objects**: in this way all of the features are no longer native to the application in which they originated, rather they are available for a user to expose to any logic or workflow as needed. In addition to all the **IPM** calculations, there are also many other functions that are included. The list is continuously expanding, and today include data objects related to PVT, Data Stores, Maths Libraries, Wells, Tight Reservoirs, SAGD Processes, Multi-Well Allocation, Smart Well (ICD) Analysis, Probabilistic tools and Transient calculations.

FLOW ASSURANCE



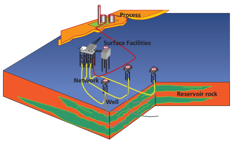
Flow assurance studies centre around the **detection** of specific phenomena that are a function of the fluid PVT or the pipeline hydraulics (e.g. Slugging, Liquid loading, Wax formation, Hydrate formation , etc.). The underlying applications detect the phenomena, whilst the controlling logic in **RESOLVE** provides the mitigation action that is in line with field strategy. **Transient hydraulic/Thermal** simulations are usually done in isolation of steady state models, using rates, pressure and PVT that may not represent the dynamically changing nature of the field. In **RESOLVE**, qualifying criteria can be setup in **Visual Workflows**, and these would then trigger the transient simulation (LedaFlow®) using consistent pressure, rates, PVT and field specific data (i.e. well/pipe deviation). Having performed the transient analysis, the steady state analysis would continue. This ensures that steady state and transient calculations are done according to where they are most useful and coupling of the two methods allows for formidable workflows to be constructed. Currently **RESOLVE** has the driver to link to the transient simulator LedaFlow®.



RESOLVE

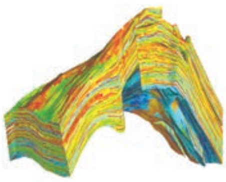
ADVANCED INTEGRATION
A VENDOR NEUTRAL SOLUTION FORMULATION PLATFORM

OIL AND GAS FIELDS ARE NATURALLY INTEGRATED



The concept of Integration was pioneered by Petroleum Experts in 1990 and it involves the elimination of artificial boundary conditions that would otherwise have existed if engineers study each individual element of a field in isolation. The same concept is expanded in **RESOLVE** as a vendor neutral system, by enabling the link between any application (from any vendor) that describes a part of the system to other software in a dynamic and fully integrated fashion. Reservoir simulators can therefore be connected to well models, surface facilities, process, re-injection and any other element that the user requires as part of their formulation. As part of this process, PVT handling, physical models of correcting IPRs, a variety of coupling schemes and other means that ensure that these connections are not only mechanically simple, but physically robust and efficient were invented by Petex and are available to the users as part of the unique collection of features of **RESOLVE.** Integration is the starting point of formulating robust **solutions** to petroleum engineering challenges and this is the base level of the capabilities of **RESOLVE** and the starting point of using the other features available.

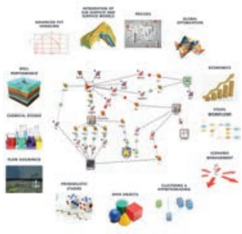
INTEGRATION OF SUB-SURFACE AND SURFACE MODELS



RESOLVE has **proprietary algorithms** to perform the **physically consistent** coupling between reservoir simulators to well, network and process models (referred to as **IPR Scaling**). Commonly used techniques in the industry, such as the iterative Newton coupling, are computationally expensive, inflexible and restrictive. The Petex IPR scaling method allows for multiple simulation models from multiple vendors to be part of the model, being connected to a surface network that can include multiple levels of optimisation. Adaptive time-stepping allows the granularity in calculations when events occur in the field to be captured. The result is that mass and pressure balance exist across the system, irrespective of the underlying simulators, using fundamentally different physical principles at their core. Currently the following simulators can form part of a **RESOLVE** model: Eclipse (E100, E300), IMEX, GEM, PUMAFLOW, PSIM, NEXUS, VIP, tNavigator and TEMPEST (with more currently under development). In addition, many clients have created connections that are proprietary to their companies and the tools that they use internally.

PROCESS

Complex facilities, compression trains, and heat exchange processes (among others) ready the fluid for export are best captured in process simulators. In reality these systems are directly connected to the upstream system and any change in the feed composition and conditions will have a direct impact on the performance of the process. As such, **RESOLVE** allows the full downstream response, to be captured over time by the integration of these models with the upstream process systems including UniSim, HySys and ProII. As thermodynamic consistency is key to ensuring these dynamic connections happen in a physically consistent manner, **RESOLVE** includes unique **Lumping/Delumping** algorithms that allow the orchestration of PVT transfers between applications. Black Oil models can be delumped to fully compositional descriptions and vice versa, so that the PVT requirements of each engineering application are satisfied.



RESOLVE

ADVANCED INTEGRATION
A VENDOR NEUTRAL SOLUTION FORMULATION PLATFORM

RESOLVE INTEGRATED MODEL

RESOLVE is a platform designed for the engineer to express the engineering ideas and formulate solutions as integrated engineering studies in a vendor neutral environment. The software, commercialized in 2002 as a strategic advancement in the concept of Integrated Production Modelling (**IPM**), moved the development of models from the Petex domain to a vendor neutral platform. From the outset of **IPM** the intention was to expand the capabilities of the tool in such a way that engineers would be able to express their ideas in an easy to use platform that would require no coding at all. Today, **RESOLVE** encompasses many **unique capabilities** listed in this document, including nested optimisation, visual workflows, advanced PVT handling, data objects etc. Each of these items encompasses decades of research and petroleum engineering experience. This ensures that solutions are formulated easily and include the optimum level of physical interactions between each element of the system.

SCENARIO & PROBABILISTIC STUDIES

Within **RESOLVE** the **Scenario Management** capability allows multiple realisations of field strategies or underlying model setup to be run in parallel or on separate nodes using the clustering/hyper threading capabilities built into the tool. There is often a degree of uncertainty in the field information and the operating strategies. For instance reservoir volumes, or well deliverability are assessed on a P10, P50 and P90 basis, and there are many field development scenarios that satisfy the design criteria. The response of the integrated system will change depending upon which assumptions are considered, and these can all be assessed using a combination of the Scenario Manager and the relevant Data Objects (Sensitivity Tools, the Case Manager and links to **CrystalBall**™ and **@Risc**™ among others).

CLUSTERING & HYPERTHREADING

For efficient processing and faster calculations times **hyperthreading** and **clustering** capabilities are part of **RESOLVE**. In the former the parallelisation of solver algorithms have been implemented, and the use of local (multi core processing) or network (remote machines) computing clusters is available. In the latter context the PXCluster (Petroleum Experts clustering) has been designed to distribute computations over multiple computational nodes.

VISUAL WORKFLOWS

Petex's **Visual Workflows** are a natural evolution of the **Event driven scheduling functionality** (existed in **RESOLVE** for over a decade now), which allow engineers to seamlessly create controlling logic that drives the development and management of the field without entering a single line of code. Logic can be implemented (using Visual Workflows) to control the simulation, and perform additional calculations to assess the likelihood of certain events (e.g. hydrate formation), and even propose mitigation actions (e.g. chemical dosing of MEG to the pipelines). All of this can be automated in a workflow to be dynamically assessed at each timestep.

GAP

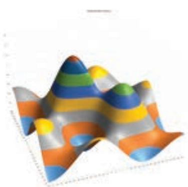
MULTIPHASE NETWORK MODELLING AND OPTIMISATION

INTEGRATED PRODUCTION AND INJECTION NETWORKS

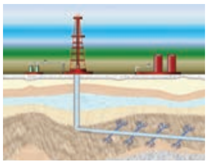
EQUATIONS BASED SOLVER

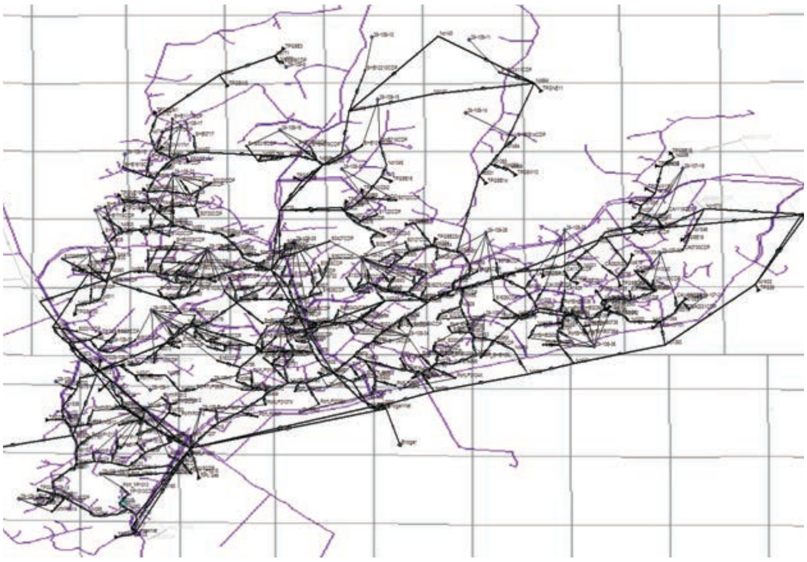
$$\begin{bmatrix} a_{1,1} & a_{1,2} & a_{1,3} & \cdots & a_{1,n} \\ a_{2,1} & a_{2,2} & a_{2,3} & \cdots & a_{2,n} \\ \cdots & \cdots & \cdots & & \cdots \\ a_{m,1} & a_{m,2} & a_{m,3} & \cdots & a_{m,n} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \end{bmatrix} = \begin{bmatrix} b_1 \\ b_2 \\ b_3 \\ b_4 \end{bmatrix}$$

NON-LINEAR OPTIMISATION



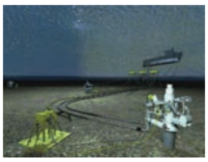
UNCONVENTIONALS



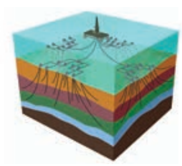


RULE BASED CONSTRAINTS

FLOW ASSURANCE

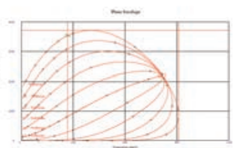


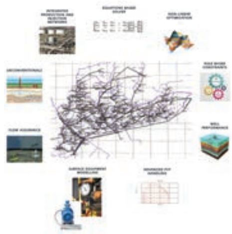
WELL PERFORMANCE



SURFACE EQUIPMENT MODELLING

ADVANCED PVT HANDLING





GAP

MULTIPHASE NETWORK MODELLING AND OPTIMISATION

INTEGRATED PRODUCTION AND INJECTION NETWORKS

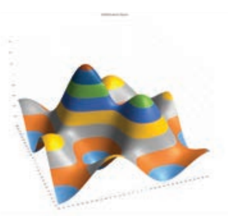
Petex was created in 1990 with the objective of providing best in class software that would allow various disciplines to perform studies in understanding the behaviour of fields as well as design systems and optimise production. GAP was designed to eliminate artificial boundary conditions in reservoir, well and surface network models, through the creation of integrated models using Petex tools. It is able to consider the multiphase network response of multiple wells (with different PVT) producing into a common production system, where the response of one well would affect production of another (i.e. back pressure response). Today GAP is the **most sophisticated steady state multiphase network optimiser** that exists in the industry, with many **proprietary features** that allow engineers to maximise production from oil and gas fields all over the world. GAP has been the tool of choice for over 420 oil companies in over 80 countries and the corporate standard for all of the super majors in the area of integrated modelling. Year on year new features are added and improvements are made based on the development strategy of Petex and the requests from clients presented at the user meeting.

EQUATIONS BASED SOLVER

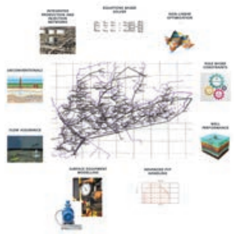
$$\begin{bmatrix} a_{1,1} & a_{1,2} & a_{1,3} \\ a_{2,1} & a_{2,2} & a_{2,3} \\ \cdots & \cdots & \cdots \\ a_{m,1} & a_{m,2} & a_{m,3} \end{bmatrix}$$

The objective of GAP is to capture the full field response of a hydrocarbon field using physical descriptions of each item that will affect production. The fundamental calculations done in GAP relate to balancing pressure, flow and temperature from all items in a system based on a single boundary condition at the end point (for production networks) or starting point (for injection networks). The solver being used is an **equation-based proprietary engine** that has been specifically designed and built for solving integrated oilfield networks. Starting points are internally evaluated and decades of research have allowed this to be the **fastest network solver** in the industry today (independently verified in tests by various oil companies). The solver takes into account all the physics that are present in the system and works by drawing information from all parts of the system, by performing dynamic calculations on the physical models (for pipelines, chokes, wells, compressors etc), or by using pre-calculated responses (for example lift curves).

NON-LINEAR OPTIMISATION



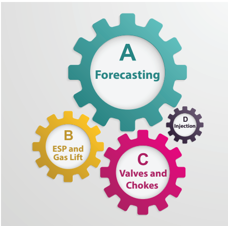
Once physical models are in place as an integrated system, optimisation algorithms can be used with the objective of increasing hydrocarbon recovery. For the past 20 years, one of the biggest areas of research in Petex has been on a mathematically rigorous ***global non-linear optimisation algorithm that is proprietary and unique in the industry***. The user does not have to provide starting points and intelligence built into the system allows for selecting the appropriate technique depending on the problem at hand. Local optimisation techniques like BFGS, Fletcher Reeves, Rank1 and various others are nested within the structure of the optimiser and are coupled with a proprietary global optimum search engine that searches the whole production and injection space for the best possible solution. The control settings that will satisfy constraints as well as maximise production are then presented to the user in the form of choke settings, artificial lift quantities, compressor speed and any other control that may exist in the field and has been allowed to be considered in the optimisation problem.



GAP

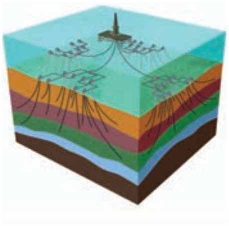
MULTIPHASE NETWORK MODELLING AND OPTIMISATION

RULE BASED CONSTRAINTS



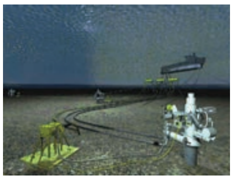
GAP is often used for **long term planning activities** and for testing various **strategies** through long term forecasting. The objective in this context is not to optimise production on a day to day basis, but rather to honour constraints and evaluate long term production goals. This is achieved by using the **Rule Based Network Solver** functionality. The model is setup in the same way as it is to achieve optimisation objectives, the difference being in the fact that the constraints are met through a set of well defined rules that are adjusted by the user depending on the problem at hand. As this algorithm is extremely fast, forecasts can be obtained quickly and can include artificial lift individual well production maximisation (equal slope techniques for gas lifted wells for example).

WELL PERFORMANCE



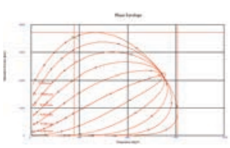
The performance of wells is typically handled by embedding PROSPER models in the integrated system, although dynamic well models can be captured through native GAP calculations. Wells can therefore be **evaluated and optimised** over time with respect to the back pressure response of the entire network. Design and performance can be assessed through the life span of each well, considering artificial lift (pumps, gas lift, etc.) or any other type of intervention. **Flow assurance** analysis features very strongly in well modelling, with dynamic calculations as well extended lift curves being used to assess the safe flowing envelopes that pressures, temperatures and rates will allow. Diagnostics of any proposed/existing design and how it handles future production conditions are at the centre of evaluation workflows in the tool.

FLOW ASSURANCE

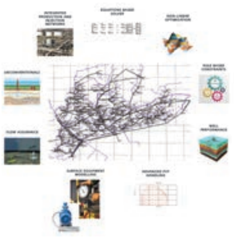


Flow assurance studies centre around the **detection** of specific phenomena that are a function of the **fluid PVT** or the **pipeline hydraulics** (e.g. **Slugging, Liquid loading, Wax** formation, **Hydrate** formation, etc.). GAP harnesses all the existing functionality from PVTp and PROSPER to detect these phenomena across the entire surface network, and provide information that will address flow assurance challenges over time. Moreover, workflows can be setup in RESOLVE so that all the native functionality in GAP can be used as part of a bigger solution formulation scheme, going as far as performing calculations in real time for any objective the client wishes to embed in support of their field management activities.

ADVANCED PVT HANDLING



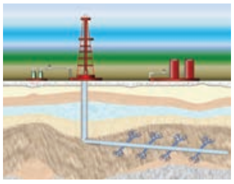
GAP has been designed to be able to handle different PVT descriptions that are used in the reservoir, wells and surface network. For instance, a fully compositional reservoir simulator will typically contain no more than 6-8 components, and everything downstream of this will usually contain more. GAP can use the **lumped** composition, and perform the **delumping** to a larger component composition. The Black Oil to Compositional feature in GAP was created to enhance the performance of these integrated models. This was achieved by using the EOS to generate the inputs of Black oil model, and using both descriptions in tandem. The consequence is a fluid description that harnesses all the advantages of EOS and black oil descriptions, without any of the weaknesses.



GAP

MULTIPHASE NETWORK MODELLING AND OPTIMISATION

UNCONVENTIONALS



GAP is often used for **long term recovery estimates** and testing the intended field. In recent years the production of unconventional reservoirs has become more viable and as such the need to capture the inflows, system response and PVT of **coal bed methane** (CBM), **tight, shale** and **heavy oil** reservoirs has increased. GAP has extended its functionality into this domain, allow the dewatering cycles and production cycles of CBM to be captured. The tight reservoir and shale inflow response is captured in REVEAL, but the multiphase flow in the well, and surface network is analysed in GAP.

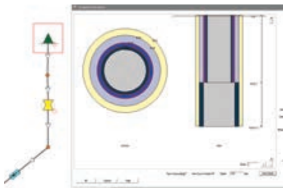
SURFACE EQUIPMENT MODELLING

As exploration focuses on more remote inaccessible locations, long trunklines to transport fluids back to processing facilities are common place as are the use of various **turbo-machinery** to supplement the production efforts. In GAP **compressors** (single and **tandem screw compressors, reciprocating** and **multiphase**) and pumps (**performance curves, jet pumps** and **bespoke multiphase**) can all be modelled. Their response in time as production conditions change can also be assessed, thus making GAP an invaluable design tool in this context.

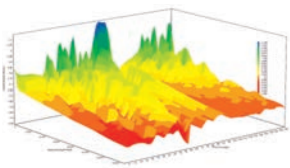
GAP Transient

TRANSIENT MULTIPHASE NETWORK MODELLING

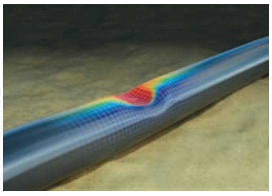
TRANSIENT THERMAL MODELLING



TRANSIENT MULTIPHASE NETWORK FLOW

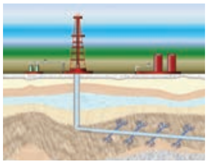


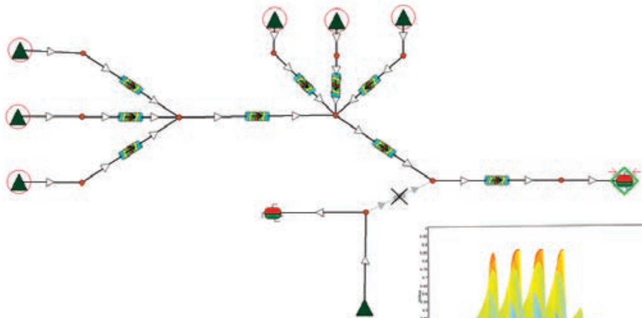
FLOW ASSURANCE STUDIES

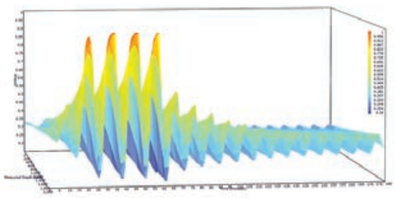


VISUAL WORKFLOW INTEGRATION

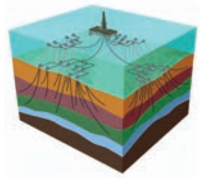
TRANSIENT RESERVOIR PERFORMANCE





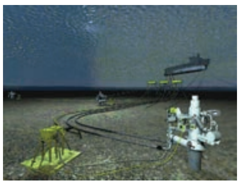


INTEGRATION WITH STEADY-STATE

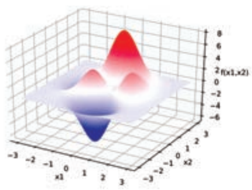


EQUIPMENT INTEGRITY

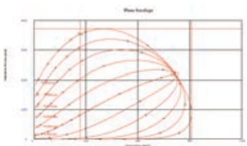
INTIALISATION FROM FIELD CONDITIONS



RULE-BASED CONSTRAINTS



ADVANCED PVT HANDLING



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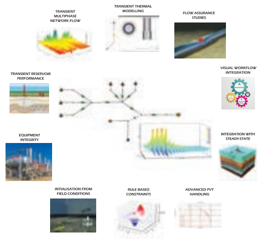
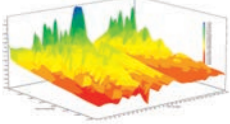


GAP Transient

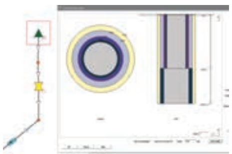
TRANSIENT MULTIPHASE NETWORK MODELLING

TRANSIENT MULTIPHASE NETWORK FLOW



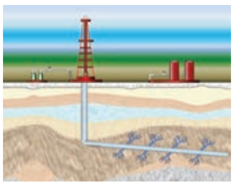
Transient multiphase flow modelling studies are typically performed by specialist teams and software in ad-hoc studies if/when there are specific flow assurance aspects that are suspected. **GAP Transient** extends the production engineering toolkit allowing a seamless integration between the state-of-the-art integrated modelling capabilities of the **IPM tools** and transient multiphase flow models. **GAP Transient** ensures that the relevant boundary conditions and physics are fully captured; integrating the knowledge and experience of the specialist transient modelling studies in one place for field management, optimisation, forecasting and development studies. This allows **GAP Transient** to bring transient modelling into the everyday tasks which are performed in the industry standard **IPM toolkit**.

TRANSIENT THERMAL MODELLING



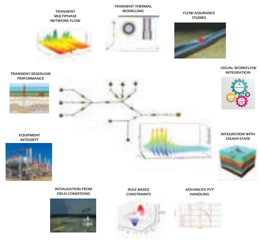
When working in short timescales (as is required in transient flow calculations), it becomes vital to capture the complex exchange of heat between the fluid and the surroundings in a more detailed manner. **GAP Transient** harnesses all the existing functionality of **PVTp** and **PROSPER** to model complex fluids as well as the ability to model detailed well and pipeline completions. Detailed annuli, insulation, burial and annular fluid descriptions allow the physics critical to the thermal response of the well to be calculated. The results of these calculations, such as pressurisation of the annulus during well start-up, can be captured and included in well integrity calculations.

TRANSIENT RESERVOIR PERFORMANCE



Transient wellbore and flowline models require accurate boundary conditions to capture the physics and changes which will happen in the field. Using the Transient Inflow Performance Relationship models which are used throughout the **IPM suite**, the transient multiphase flow models in **GAP Transient** can be integrated directly to the transient reservoir response.

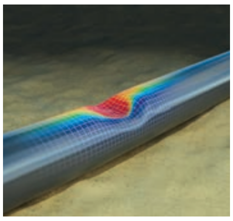
This integration allows the early-time response of the reservoir to be modelled more accurately providing more accurate results in transient flow models as this early-time response can dominate the timescales of the transient model.



GAP Transient

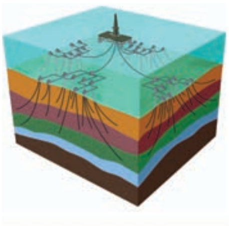
TRANSIENT MULTIPHASE NETWORK MODELLING

FLOW ASSURANCE STUDIES



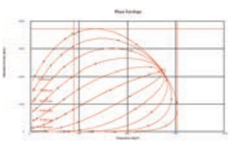
Flow assurance studies centre on the detection of specific phenomena that are a function of the fluid PVT or pipeline hydraulics (e.g. terrain induced or hydro-dynamic slugging, liquid loading, wax or hydrate formation etc.). **GAP** utilises the existing functionality of the IPM suite to detect these phenomena across the entire surface network and provide information that will address flow assurance challenges over time. **GAP** (using steady-state) can very quickly and easily be converted into transient models to be run using **GAP Transient** which extends this functionality into the realm of dynamic multi-phase flow modelling; seamlessly switching between steady-state and transient modelling to allow the engineer to optimise and forecast using the state-of-the-art integrated modelling capabilities of **GAP** and then evaluate the dynamic response of any optimisation strategies that are determined or flow assurance aspects that are predicted.

INTEGRATION WITH STEADY-STATE

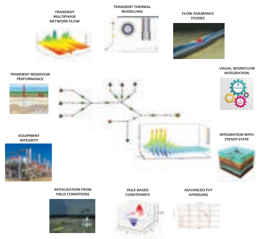


The different time-scales used in transient (minutes/hours/days) and steady-state (weeks/months/years) modelling tools mean that the two approaches can be complementary when used correctly. Models in **GAP** (using steady-state) can very quickly and easily be converted into transient models to be run using **GAP Transient**. This allows transient flow calculations to be triggered at different points within a longer scale steady-state run and use the conditions calculated by the steady-state model (such as fluid and reservoir conditions) to be used as the conditions of the transient model. Late life flow assurance studies (such as riser stability) can therefore be more accurately modelled due to the complementary use of the two approaches.

ADVANCED PVT HANDLING



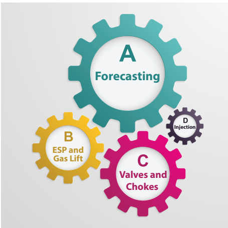
GAP Transient has been designed to handle different PVT descriptions that are used in the reservoir, wells and surface network. In addition to both Black Oil and Equation of State models, **GAP Transient** can utilise the Black Oil Compositional Lumping/Delumping PVT model to exploit the advantages of both the EOS and black oil models without their inherit weaknesses.



GAP Transient

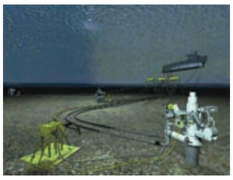
TRANSIENT MULTIPHASE NETWORK MODELLING

VISUAL WORKFLOW INTEGRATION



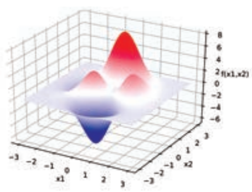
GAP Transient can be integrated with **RESOLVE** and the **Digital Oilfield** to add field management logic to models and real-time systems. Using the cutting edge **Visual Workflow** platform, field logic can be added to control the model without the need for any programming or coding by the engineer. Actions (such as opening of new well or rerouting of a pipeline) can be performed based upon the results of the dynamic calculations. This allows, for example, for a new well to be unloaded into a test separator before a **Visual Workflow** will re-route it to the main flowline when the kill fluid has been fully removed.

INTIALISATION FROM FIELD CONDITIONS



GAP Transient calculations can be initialized from both steady-state or static conditions depending upon the scenario being run. Different parts of the model can be initialised from different states if required. For example, if the start-up of a new well is being evaluated, then the current network (of both wells and pipelines) can be initialized from steady-state while the new well can be initialized from static conditions.

RULE BASED CONSTRAINTS

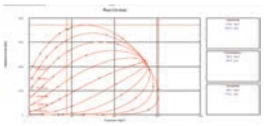


GAP Transient has access to the Rule Based Network Solver (RBNS) which is used extensively within **GAP** to control models to meet certain constraints applied to the system. This allows the engineer to place constraints on the model and have **GAP Transient** find the controls required to meet these targets for the duration of the transient simulation.

PROSPER

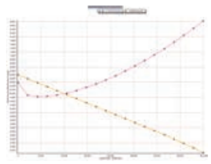
MULTIPHASE WELL AND PIPELINE NODAL ANALYSIS

FULLY COMPOSITIONAL

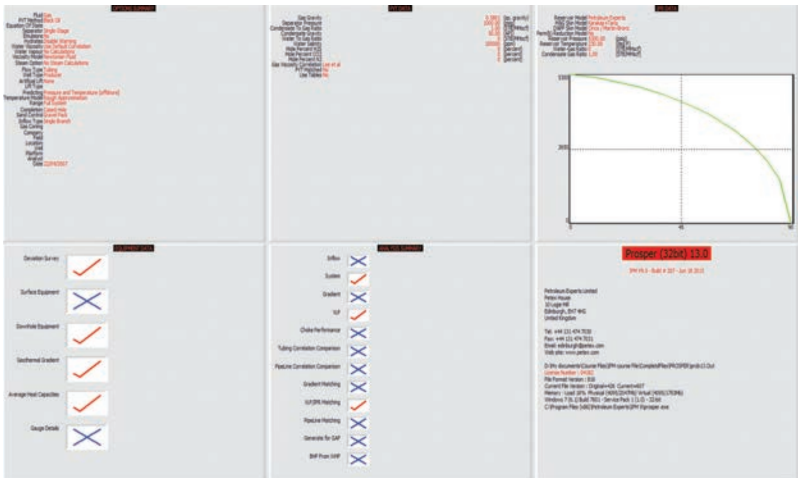


WELL AND PIPELINE MODELS

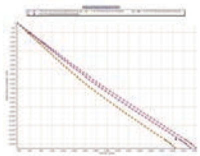
INFLOW/OUTFLOW RESPONSE



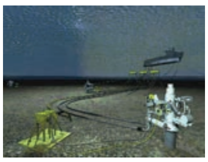
STEAM WELLS



OUTFLOW (VLPs) MODELS

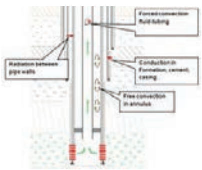


FLOW ASSURANCE

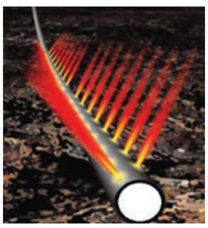


ARTIFICAL LIFT SYSTEMS

THERMAL MODELLING

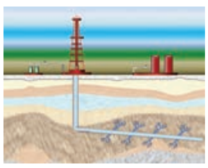


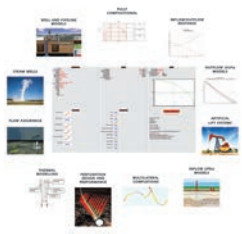
PERFORATION DESIGN AND PERFORMANCE



MULTILATERAL COMPLETIONS

INFLOW (IPRs) MODELS





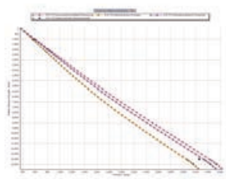
PROSPER

MULTIPHASE WELL AND PIPELINE NODAL ANALYSIS

WELL AND PIPELINE MODELS

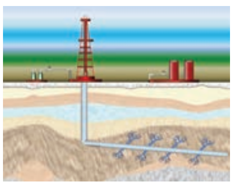
PROSPER was commercialised in the early 90's and has been the subject of ongoing research and development for over two decades. Each year, new models and functionalities are added to the already extensive list of options in the program. There are over three million combinations of options that can be used to describe the vast majority of physical phenomena happening in wells and pipelines. In spite of the large number of situations that can be modelled, the adaptive interface only presents the user with the relevant input fields and menus according to the selections made in the options menu, keeping the model building effort at a minimum. PROSPER has evolved into the industry standard for well and pipeline modelling due to it's unrivalled sound technical basis and unique modelling capabilities. The program today forms one of the foundation stones of the Digital Oil Field system, and the calculation engine is utilised by numerous workflows in real time on hundreds of fields world-wide.

OUTFLOW (VLPs) MODEL



As part of the package of unique features available in PROSPER, research being conducted since Petex was founded has resulted in the creation of a number of proprietary multiphase flow pressure drop models (both empirical and mechanistic). The objective of this research has been to create fundamentally rigorous models that overcome the limitations of traditional models available in the industry. Petex is uniquely placed to have access to data from all over the world and over the years, a comprehensive database of pressure drop measurements has been created, which allows our researchers to compare novel physical models to real world information. Independent comparisons done by industry experts in multiphase flow have proven the reliability and consistency of the Petroleum Experts pressure drop models, to the point where these models are being widely used to quality check measurements obtained in the field. As part of a clearly defined well test quality check workflow, users have the ability to compare and contrast the behaviour of traditional pressure drop models with the ones uniquely available in PROSPER in order to assess suitability and consistency over the life of a well. Should users choose to use third party pressure drop models such as OLGAS or LEDAFLOW, these are also available as plug-ins, provided that the relevant licenses from the third party vendors are put in place.

INFLOW (IPRs) MODEL

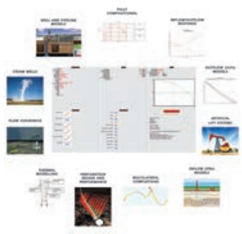


A comprehensive set of inflow models complement the multiphase flow capabilities in PROSPER, enabling Nodal Analysis calculations to be done for virtually any type of well. There are over 20 inflow models that have been developed over the years, that can be applied to horizontal, vertical, deviated, multilayer and multilateral geometries. Furthermore, novel development has seen the realisation of unique inflow models that account for changing PVT conditions in the well drainage area as well as in multiple zones. This allows re-perforation studies, analysis of skin, the application of sand control measures and many other sensitivities to be conducted easily.

MULTILATERAL COMPLETIONS

Alongside all of the analytically derived Inflow Performance Relationships available in PROSPER, the Multi-Lateral IPR model is the culmination of extensive research and has been designed specifically for complex well completions that have undulating trajectories across multiple producing zones. This is the most advanced analytical IPR that exists in the industry today and can only be found in PROSPER as another one of the many unique features in the program.

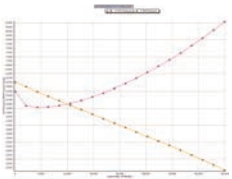
e-mail: **edinburgh@petex.com**



PROSPER

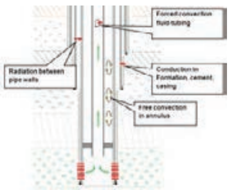
MULTIPHASE WELL AND PIPELINE NODAL ANALYSIS

INFLOW/OUTFLOW RESPONSE



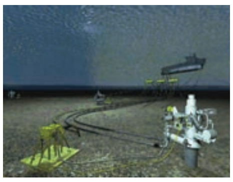
The rigorous multiphase pressure drop models and unique list of inflow performance relationships come together to form system calculations for well and pipeline models. This allows for assessing the productivity of oil, gas and condensate wells to be performed, both for production and injection scenarios, with or without artificial lift. Sensitivities can be conducted through a simple interface that allows the investigation of virtually all parameters that are inputs to the models and the matching workflows allow for comparisons to be done between the results predicted by the models and the measurements obtained for these wells if they are already operational.

THERMAL MODELLING



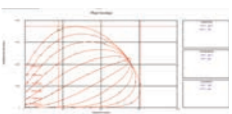
PROSPER is capable of modelling thermal profiles in wellbores using multiple methods, ranging from a constant rate of heat transfer (Rough Approximation) through to a detailed and rigorous full energy balance (Enthalpy Balance) that considers the forced and free convection, conduction and radiation heat transfer mechanisms. The latter considers a detailed materials specification, and to aid with this PROSPER has been furnished with a database of common casing, tubing, cement and mud descriptions with their associated heat transfer properties. Users can also take advantage of a hybrid thermal calculation technique that was developed by Petex (Improved Approximation). This allows for Joules-Thomson effects to be captured in the well, while at the same time enabling multiple heat transfer coefficients with depth to be used.

FLOW ASSURANCE

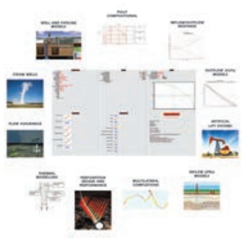


Flow assurance studies are an integral part of any pipeline and well analysis, done both for designing and troubleshooting purposes. In PROSPER many years of research have been dedicated to addressing these issues and users can study either hydraulic flow assurance challenges, or issues related to the thermodynamic behaviour of fluids. Hydraulic investigations can be conducted on flow regimes, erosional velocities, superficial velocities, wellbore stability analysis (liquid loading), slug catcher sizing and many others. Thermodynamic calculations can include studies on hydrate formation, waxing, salt precipitation and others. PROSPER will indicate where in the system these issues might occur and the user has options to consider intervention (e.g. hydrate inhibition, surfactants, etc.) or changing the operational conditions (wellhead pressure).

FULLY COMPOSITIONAL



As is the case with all the programs developed by Petex, PROSPER uses a powerful thermodynamics engine to complement the traditional black oil models that provide all the thermodynamic properties needed for the pressure drop, flow assurance and inflow calculations. In fully compositional mode, PROSPER allows users to take advantage of advanced hydrate prediction and mitigation calculations, salt deposition, special handling of CO2 for dense and light phases and many other functionalities. In black oil mode, a large number of correlations are available that can be compared and matched to lab data. Special correlations for heavy oils have been implemented and these, coupled with an emulsion model as well as special heavy oil pressure drop models, make PROSPER unique in being able to deal with such fluids and the intricacies of producing them. Another feature that is widely used is the ability to predict the vaporised water that is produced from gas wells. This is based on industry standard calculations that have been modified based on data received from clients to create a uniquely accurate model for analysing this situation.



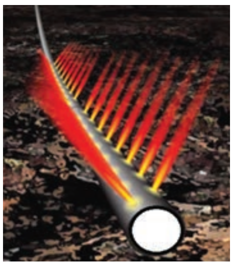
PROSPER

MULTIPHASE WELL AND PIPELINE NODAL ANALYSIS

ARTIFICAL LIFT SYSTEMS

Artificial lift design and troubleshooting has been an area where PROSPER has offered unparalleled modelling capabilities to the user community for many years. Gas Lift, ESPs, HSPs, Coil Tubing Gas Lift, PCPs, Jet Pumps, Sucker Rod Pumps are only a few of the many lift mechanisms that can be evaluated for new and existing installations. With every new release of the program, one or more methods are added and the capability of the existing methods are enhanced. A database of equipment (Pumps, valves, motors etc) is available and is being updated every year as new descriptions become available. Unique features include the Quicklook troubleshooting workflows, minimum energy methodologies for HSP wells, designs that consider the inflow performance and many others. The latest addition to the list is a Fully Transient Gas Lift Simulator, which simulates the unloading phase of gas lifting and allows users to assess the stability of such wells. All the artificial methods available can be made part of a bigger network model (GAP) for full field optimisation as well as the Digital Oilfield systems where they can form the basis of any workflow that users wish to automate (for surveillance, diagnostics and others).

PERFORATION DESIGN AND PERFORMANCE



As part of the philosophy of sharing knowledge among operators in the industry, Shell has contributed their proprietary perforation optimisation tool (SPOT) which can now be found as part of the standard toolkit of calculations in PROSPER. The objective of this module is to allow engineers to compare the perforation charge performance and assist in selecting the optimum perforation gun. This can be done through the charge properties, rock properties (averages of obtained from logs), fluid properties and by using appropriate drilling mud invasion models. It can handle open hole completions as well as cased hole completions. The implementation in PROSPER allows the output of SPOT to be directly combined with the vertical lift performance models to predict the complete well performance, therefore eliminating the artificial boundary conditions that would need to be put in place if only the inflow part of the well was considered.

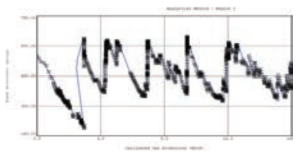
STEAM WELLS

Steam injection wells (SAGD, Huff and Puff, Direct Steam Injection) are becoming more common in the industry and modelling of such systems can be done through a variety of tools in the IPM Suite, primarily REVEAL. PROSPER is also steam enabled and if the wells to be modelled relate to steam injection systems, then lift curves can be generated that can be used to model steam distribution systems (in GAP). In creating integrated steam injection systems models, the efficient designs of the network, analysing the operating envelope limits, evaluating energy management and the economics are now feasible for what have traditionally been a costly operation.

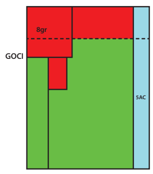
MBAL

ANALYTICAL RESERVOIR ENGINEERING TOOLKIT

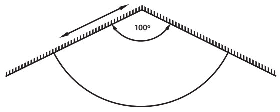
HISTORY MATCHING



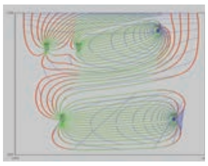
MATERIAL BALANCE

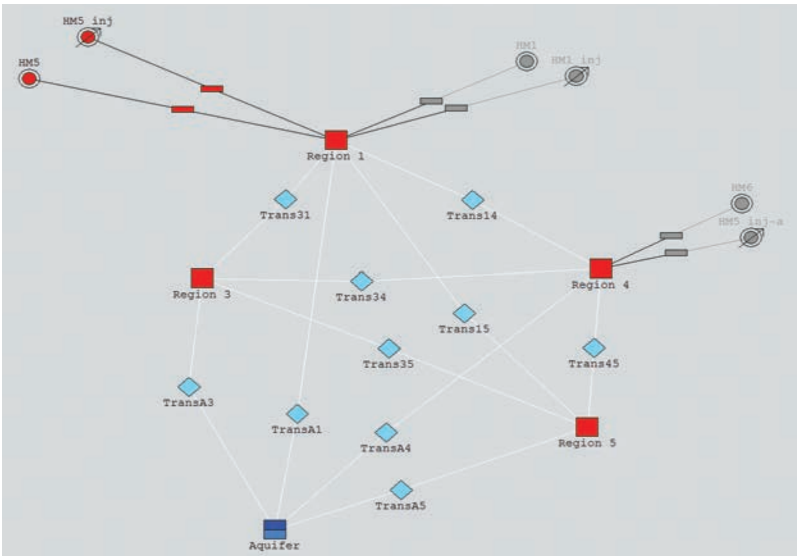


AQUIFER MODELLING

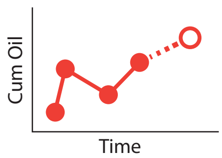


STREAMLINES

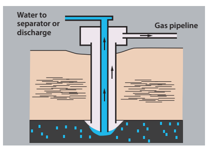




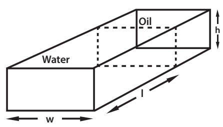
FORECASTS



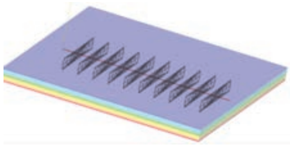
COAL BED METHANE



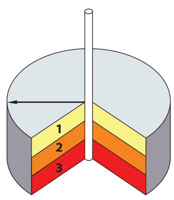
1D MODEL



TIGHT RESERVOIRS



MULTILAYER PRODUCTION



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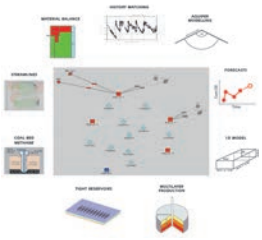


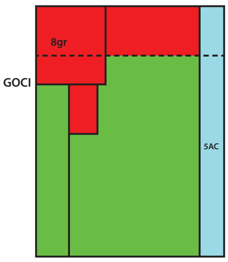
MBAL

ANALYTICAL RESERVOIR ENGINEERING TOOLKIT

MBAL

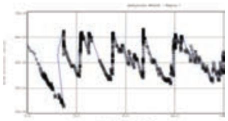
MBAL- commercialised in the early 1990s- is a reservoir engineering tool kit that is intended to assist reservoir engineers in their analytical studies of the reservoir. This includes, but is not limited to, material balance calculations. Aside from **Material Balance**, other tools also available are **Decline Curve Analysis, 1D model, Monte Carlo Simulations, Coal Bed Methane, Reservoir Allocation, Tight Reservoir Modelling** and **Streamlines**. All available techniques can be used in isolation or in combination to achieve engineering objectives. As the name of the program suggests, Material Balance calculations are a core functionality and includes many advancements on the classical Material Balance concept found in literature. Aside from allowing engineers to estimate the oil or gas originally in place and understanding ***drive mechanisms***, many novel approaches such as performing predictions using relative permeability curves and multi-tank modelling ensure that MBAL can provide a solid platform on which reservoir physics and production plans can be studied in detail.

MATERIAL BALANCE

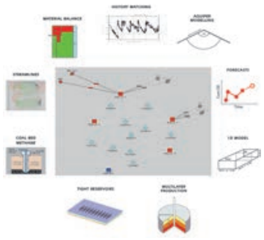


MBAL allows non dimensional reservoir analysis to be conducted throughout the life of the field, whether this is in early field life when limited data is available, or even in mature fields where more certainty exists. As such, this straightforward but powerful reservoir toolkit can be applied throughout the life of the reservoir, and is often used in conjunction with numerical simulators as a quality check of history matching, and/or as a proxy model for fast calculations. Using limited data (PVT and cumulative production) the engineer is well equipped to find the amount of oil in place, and any associated drive mechanisms. Unlike the classical theory, MBAL can be used to describe any hydrocarbon fluid (Oil, Gas or condensate) using either Black oil or compositional descriptions in scenarios where variations in PVT with depth occur (Compositional gradient are important in high relief reservoirs). Moreover, compartmentalised reservoirs with partially sealing faults, or pressure activated faults can be modelled and history matched by creating multi-tank models with transmissibilities. This evolution of the material balance concept is another innovation from Petroleum Experts, and extends the range of applicability to full field life.

HISTORY MATCHING



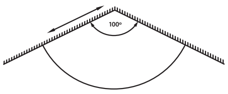
MBAL's progressive menu options lead the engineer logically through the history matching process, which is performed graphically using industry standard techniques (e.g. **Cole, Campbell, P/Z plots**) and allows the identification of drive mechanisms in place, and whether the measured data entered is to be trusted. Having used the analytical methods available in MBAL to history match the analytical model, a simulation is run of the history, and yields two valuable results: Firstly, by running the historical period in a simulation, the user can compare the production profiles predicted from the model and the data entered (a close match indicating a good history match). Secondly, by running the history as a prediction, MBAL will calculate all the historical production profiles, saturations and reservoir pressures in the historical period. This can be used to create custom relative permeability curves and **calibrate** these to the History matched model. The historical data can be entered on a tank basis, or in a well by well basis, in the latter context the Relative Permeability curves can be generated for the draining area of each well using the approach described above. It is this innovative capability that allows the analytical model to approach the response of reality and is a departure from classical literature based models.



MBAL

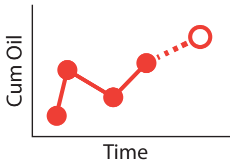
ANALYTICAL RESERVOIR ENGINEERING TOOLKIT

AQUIFER MODELLING



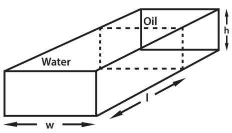
For existing reservoirs where the PVT and historical production is known, MBAL provides extensive matching facilities and the ability to model the **size** and **strength** of **drive mechanisms**. Both **steady state** and **transient responses** can be modelled in MBAL, using the industry standard and Petroleum Experts Modified models. The sizing of the aquifer (based upon its pressure support response) provides a way of calibrating known physics against production data, which once calibrated can be used to forecast.

FORECASTS



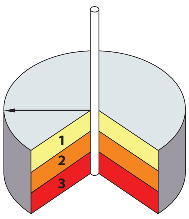
MBAL can be used to carry out forecasting/predictions in two ways, (i) as a reservoir tool in an integrated model or (ii) as a standalone reservoir analysis tool kit. In both cases MBAL can perform **fast calculations** honouring the history matched **aquifer** and **relative permeability's** as the basis for predictions. Using the history matched model **relative permeability curves** are generated. These curves -which are physically representative - describe how one phase flows relative to the others in the well drainage area. Implicit to these curves is **well positioning** in the reservoir, and allows **two wells in a single homogenous tank** to exhibit different production profiles (e.g. if one well is closer to the **Oil-Water Contact** its production history will give different Relative Permeability curves). The creation of bespoke relative permeability curves for each well based upon historical production, is **novel** and a departure from classical theory. Combined with **GAP**, full field development planning is possible. When run standalone, MBAL can be used to analyse the saturations and pressure decline over time. Using a **multi-tank** system with **transmissibilities** can be used to model **partially sealing faults** and **pressure activated faults** where production from one compartment (**compartmentalised reservoirs**) initiates flow from one part of the reservoir to another as production occurs in the forecast.

1D MODEL

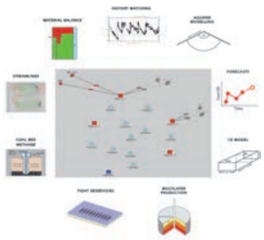


The **1D Model** allows the study of the displacement of oil by water using fractional flow and Buckley Leverett equations for a single layer. In the Multi layer context, the **Multi-Layer tool** allows the creation of a set of Relative Permeability curves for each layer using the immiscible placement theories of **Buckley Leverett, Stiles, Communicating Layers** (using theory from **L.P Dake**) and simple (single cell simulation). Having generated the profiles, these can then be seamlessly brought to the material balance tool for further matching and analysis.

Multilayer Production



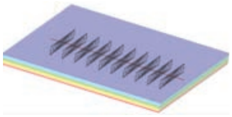
Often wells can be completed in multiple layers, and production from several producing intervals can be achieved in the field. In this context it is customary to measure the production rates at the surface rather than on a layer by layer basis, and the classical method of allocating production was on the basis of permeability and pay height. The **Reservoir Allocation tool** is a novel modification to this allocation method, and uses IPRs to perform this back allocation. Once allocated the rates can then be brought from the **Reservoir allocation tool**, to the **Material Balance** tool, and a history match performed as usual. This can be performed iteratively until a history match is achieved. Alongside the multi layer systems, **multi-tank** systems, **gas recycling, inter-tank transmissibility's** can all be captured in MBAL.



MBAL

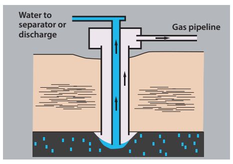
ANALYTICAL RESERVOIR ENGINEERING TOOLKIT

TIGHT RESERVOIRS



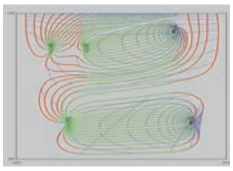
Steady state IPRs assume that the reservoir boundary “feels” the production in a negligible amount of time. In **tight reservoir** plays this assumption breaks down as these conditions are reached in the time span of decades rather than days: as such it has been conventional to use **type curves** (from Pressure transient analysis) to try and predict the gas in place. MBAL has **Blasinghame** and **Agarwal-Gardener** type curves that allows the engineers to find GIIP, however these types curves have a geometry implicit within their formulation. These type curves have been implemented in MBAL for some time now, allowing MBAL to generate unconventional IPR responses, that can later be used for predictions and forecasting. These have been essentially superseded by the novel $P_D T_D$ approach in RESOLVE, but are still used as a cursory quality check of production data prior to performing the analysis in RESOLVE.

COAL BED METHANE



There are no real limitations (besides the fundamental material balance assumptions) on which fluid or reservoir types that can be modelled: **Oil, gas, tight gas, condensate, Coal Bed Methane** (using the **Langmuir Isotherm**), **multi tank systems** can all be modelled. In the **Coal Bed Methane** context MBAL can be used to model the release of methane gas from the coal bed using either the **Langmuir** or modified **Langmuir isotherms**. Using these isotherms, predictions of the **dewatering** phase and **production** phases can be captured and integrated with the well and surface network response.

STREAMLINES



One of the investigations reservoir engineers typically perform relates to the determination of breakthrough time and evolution of watercuts (especially important in water flooded reservoirs). Material balance can be used to perform these forecasts, but necessitate production history data, which is not always available: this is where the **streamlines** functionality comes in. The streamlines module in MBAL allows a quick 2-dimensional simulation to estimate (I)**Sweep efficiencies** and (II) producing well **fractional flows** for a set well pattern of producers and injectors. This is not intended to replace the reservoir, rather allow a quick analysis of different well patterns and the overall effect on recovery. This 2D streamline tool allows the engineer to understand how the flood path of an injection well supports the producing well, determining **water breakthrough time** and **evolution of watercuts** (especially important in water flooded reservoirs). The streamlines tool is to be used when the Material balance and numerical simulation approaches are not adequate (i.e. MBAL will need history, and numerical simulations are computationally expensive when considering multiple producer injector patterns) and a fast way of finding breakthrough and watercut profiles is required.

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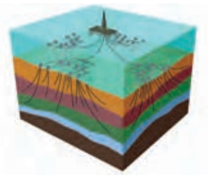
REVEAL

SIMULATOR FOR SPECIALISED RESERVOIR STUDIES

ADVANCED WELLS

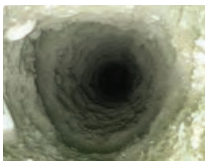


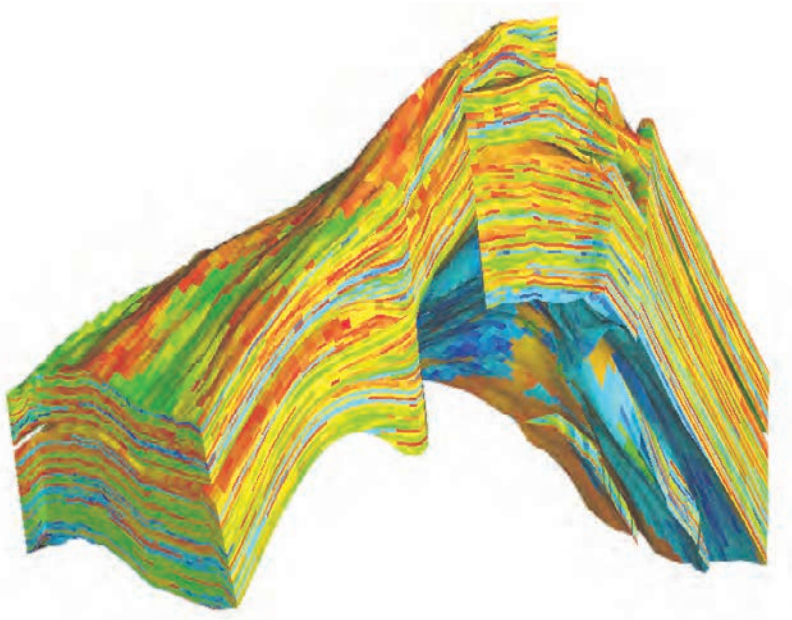
TEMPERATURE

COMPLEX FLUIDS

GEO-MECHANICS AND FRACTURES

SCALE





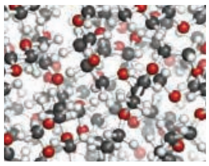
ROCK FAILURE AND SAND GENERATION

WATER CHEMISTRY

FILTERCAKE

STEAM

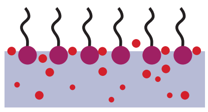
POLYMERS / GELS

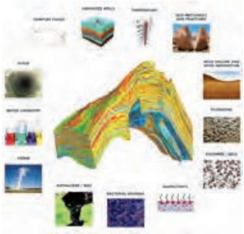


ASPHALTENE / WAX

BACTERIAL SOURING

SURFACTANTS

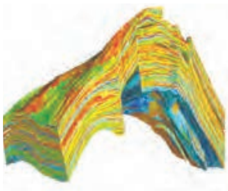




REVEAL

SIMULATOR FOR SPECIALISED RESERVOIR STUDIES

SPECIALISED RESERVOIR STUDIES



REVEAL is a specialised reservoir simulator that enables integrated reservoir and production studies to be performed. The key role of REVEAL is to bridge the gap between reservoir simulation and specialised studies that have traditionally been done in isolation of mainstream reservoir engineering domains. Such studies include thermal fracturing, production chemistry, solid transport, EOR and many others. The advantage of integrated studies lays in understanding the impact of production on reservoir performance and therefore overall field management. REVEAL can import and use existing reservoir simulation models as starting points for integrated studies. Links to surface network models through RESOLVE allow REVEAL to be part of a vendor neutral integrated model, as well as to take advantage of workflows that can operate on the reservoir model and dynamically utilise variables for advanced decision making processes. The uniqueness of REVEAL lies in the ability to model all of the effects described in the sections below in a single model. This is done by having all models activated working together to replicate reality as closely and consistently as possible.

TEMPERATURE

Temperature of injected fluids can have a significant impact on flow paths, recovery factors, rock mechanics, EOR mechanisms and many other physical processes that take place in a reservoir. These effects have not traditionally been captured when isothermal simulators are used. REVEAL is a fully thermal finite difference numerical simulator and as such, convective and conductive heat transport, as well as Joule-Thompson effects are included as part of the coupled pressure-flow-temperature equations that are solved. This enables REVEAL to be the ideal tool for understanding the effects of injection, where the temperature of the injected fluid is different to that of the reservoir.

GEO-MECHANICS AND FRACTURES

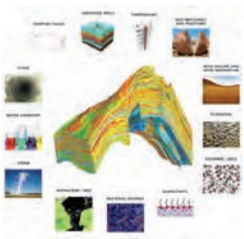
A reduction in temperature due to cold water injection will cause a reduction in stress that may cause thermal fractures. Similarly, increase of injection pressures will cause hydraulic fractures. To address this phenomena, rock mechanics calculations are coupled with flow and temperature calculations by directly linking a numerical finite-element model for fracture initiation and propagation to the finite-difference 3D simulation engine. Production fractures can also be modelled. The thermal fracture model is based on the pressure balance within the fracture and the reservoir stress field, including poro-elastic and thermo-elastic stress change effects. The elasticity of the rock determines the ability of the fracture to propagate, once the rock's critical stress intensity is overcome.

ROCK FAILURE AND SAND GENERATION

As a direct result of the rock mechanics calculations, criteria for shear and plastic failure modes exist in REVEAL that enable sand generation, transport and trapping calculations to be performed. The transport and trapping of sand is dependent on sand particle size and pore throat distribution of the rock. The solid trapping of the sand can also occur in the production wells, causing building up of skin.

FILTERCAKE

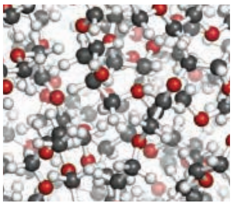
The Filtercake model enables the study of injection damage resulting from particulates in the injected fluid. The build-up of filter cake is calculated for the injection wells and associated fractures.



REVEAL

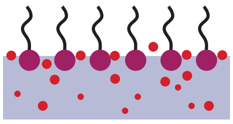
SIMULATOR FOR SPECIALISED RESERVOIR STUDIES

POLYMERS / GELS



Injection of polymers and gels is an important mechanism for controlling thief zones in reservoirs with layers of varying permeability. Thermal viscosity effects are essential in understanding performance of these techniques. REVEAL is able to assist in these studies through its ability to model gel, polymer, chelating agent, cross-linker and foam mobility control of the aqueous phase. The model captures kinetics, salinity, pH and temperature dependence, and the degradation of these agents.

SURFACTANTS



If a surfactant is injected, the interfacial tension between the water and oleic phases will reduce and an intermediate phase may be generated. This may favourably increase the mobility of heavy oils and produce residual oil. This is modelled in REVEAL by calculating an effective salinity resulting from the concentrations of the surfactant, polymer, alcohols, temperature and equivalent alkane number, then using a ternary diagram to calculate the phase saturations and concentrations of all components within the phases. The Alkaline Surfactant Polymer (ASP) process can also be modelled (using the water chemistry model available) which models the combined polymer and surfactant floods.

BACTERIAL SOURING

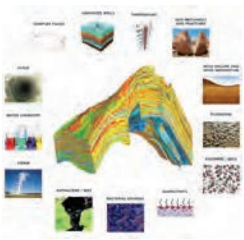
Sulphur reducing bacteria can thrive in an oil reservoir, provided the right conditions are present. This will give rise to H_2S production, that can have a significant impact in production processes. A souring model, catalysed by bacterial action, with partitioning of H_2S between the aqueous and oleic phases is present in REVEAL that can assist in analysing this phenomenon. Growth and respiration effects of the bacteria are based on carbon source and bacterial activity. H_2S can then partition and be transported in oil and water, enabling engineers to understand the severity of the challenge and what mitigating action to take.

ASPHALTENE / WAX

Wax deposition can create significant problems in fields where fluids have the potential to drop out paraffinic compounds. This depends on the the pressure and temperature conditions of flow and being able to understand this behaviour and create suitable operating envelopes is paramount in such situations. Wax and asphaltene precipitation (and consequent permeability reduction) is modelled by defining solubility characteristics (based on temperature) and plugging effects within the reservoir, according to pore throat size distribution.

WATER CHEMISTRY

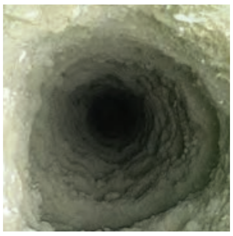
REVEAL's comprehensive water chemistry capability with a large database of reaction species and reaction pathways allows to model reactive transport processes. Water chemistry calculations are used for many pH dependent processes such as ASP and polymer kinetics. The prediction of mineral dissolution and precipitation is modelled as the chemical species are transported and mixed within the reservoir. REVEAL also includes a water chemistry calculator, which allows batch water chemistry calculations to quality check brine composition and identify key species and minerals. REVEAL can accurately calculate the thermophysical properties of CO_2—brine mixtures over a wide range of pressure, temperature and salinity envelopes.



REVEAL

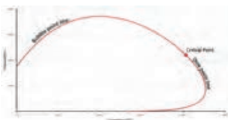
SIMULATOR FOR SPECIALISED RESERVOIR STUDIES

SCALE



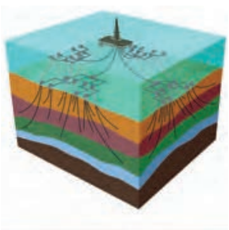
The mixing of incompatible waters due to water injection may result in scale deposition. Water chemistry calculations allows to identify scaling potential. Scale inhibitor and reversible/irreversible adsorption models are present to study the inhibitor squeeze treatments.

COMPLEX FLUIDS



REVEAL has a detailed PVT description which includes black oil and compositional complex hydrocarbon fluids such as retrograde condensates and non-hydrocarbon fluids such as CO_2 and N_2. Non-Newtonian fluids, where the apparent viscosity reduces with applied shear stress can also be modelled.

ADVANCED WELLS



Complex wells that include ICVs, ICDs, equaliser and other flow control mechanisms are being used extensively in the industry. Designing and being able to predict the behaviour and optimisation of these wells is an important aspect that engineers study in relation to these types of wells. Complex well geometries, including extended reach wells and multilateral wells with detailed well completions including annular flow, dual string completions, coiled tubing, inflow control devices, inflow control valves, isolation packers, gravel packs can be modelled in REVEAL. Friction losses and temperature changes along the wellbore are calculated and heat exchange (current and counter current) between the reservoir and the different components of the well is captured. REVEAL also allows the complex control of the wells such as fluid circulation in the well. Well geometry is independent of gridding and wells are coupled to fractures if present.

STEAM

A fully implicit steam injection model is present to model huff and puff and SAGD processes. REVEAL models can be created with the SAGD data object through RESOLVE, ensuring an appropriate gridding of the reservoir and linking of well pair to the reservoir grid. This auto generated models include a pre-heating and production schedule with control script to ensure automatic sub-cool control of the wells. The emphasis is given to production with the dynamic coupling and control of wells.

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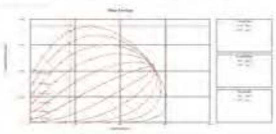
PVTP

THERMODYNAMICS FLUID CHARACTERISATION PACKAGE

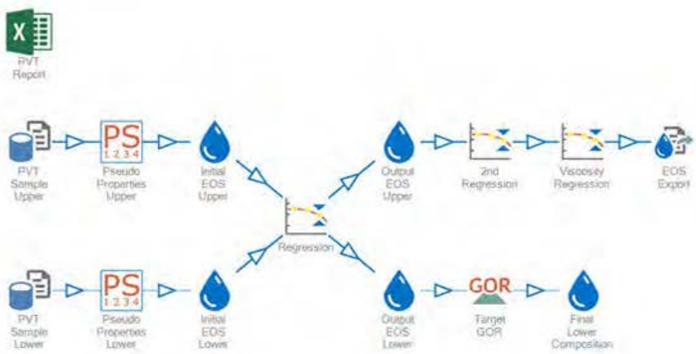
MATCHING ON LAB EXPERIMENTS

FLUID CHARACTERISATION



LUMPING /DELUMPING

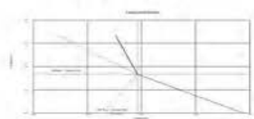
HYDRATES



CARBON DIOXIDE

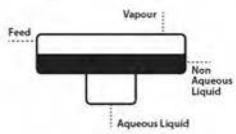
SALT PRECIPITATION

COMPOSITIONAL GRADIENTS



WAX FORMATION

3-PHASE FLASH CALCULATIONS



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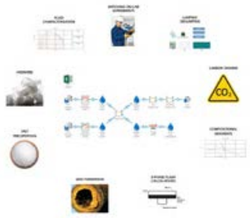
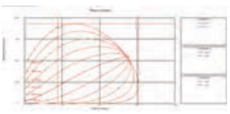


PVTP

THERMODYNAMICS FLUID CHARACTERISATION PACKAGE

FLUID CHARACTERISATION



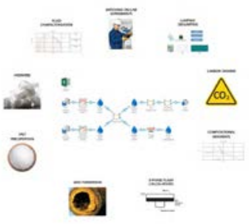
The IPM suite of applications was created to allow for integrated systems to be constructed, therefore eliminating artificial boundary conditions that engineers would have to impose on models of individual parts of any production or injection system. The basis of any integrated model is a solid and consistent PVT definition, which respects the behaviour of any fluid when it flows in the reservoir, in wells, in pipes and beyond. Traditional approaches of modelling each part of the system in isolation relied on PVT models that were bespoke and created for a single specific use. Integrated Models present challenges of not only ensuring that the same description is valid for any part of the system, but also in a vendor neutral environment, ensuring that different software from different vendors communicate dynamically and receive or pass PVT information that works for their own domain. An integrated model with reservoir simulation, facilities and process models from three or more vendors needs to ensure that the limited number of components or black oil models used in the reservoir simulator are translated into full blown compositions of large component numbers used in process models.

PVTP was created with the objective of not only creating thermodynamically consistent and precise Equation of State models for fluids, but also to deliver these models in ways that can satisfy the vendor neutral principles of integrated modelling. Unique lumping/delumping algorithms have been embedded into the program which satisfy this role and enable engineers to create integrated systems in a straight forward manner and with confidence that consistency in fluid thermodynamics is achieved.

MATCHING ON LAB EXPERIMENTS

PVT analysis and EOS creation is based on lab experiments and PVTP enables the user to perform these tasks by matching compositions to data available on CCE, CVD, Differential Liberation, Separator Tests and many others. Special treatment of pseudo components exists with quality checks that enable a consistent set of parameters to be used along the process. The program has been designed with flexibility in mind, so that procedures different companies rely on as standards in their organisation can be accommodated for. When matching the EOS models to lab data, PVTP offers a variety of regression techniques. The ones Petex recommends ensure monotonicity in the properties of the components being regressed on, so that consistency in the results can be guaranteed. Unique features in this domain include, but are not limited to:

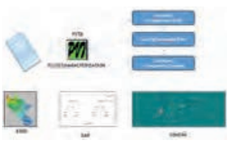
- Proprietary database of component properties
- Preconditioning of Pseudo properties based on Standing-Katz or Costald models
- Special models for BI coefficients (reliable for pseudo components)
- Proprietary algorithms for pseudo component splitting or lumping
- Volume shift initialisation based on component densities
- Ability to invoke either traditional EOS based or black oil models for viscosity
- Advanced phase detection calculations
- Modifiers that overcome traditional limitations of EOS models in CO2 rich fluids



PVTP

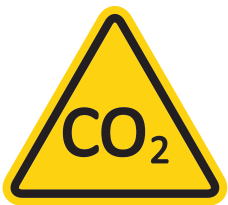
THERMODYNAMICS FLUID CHARACTERISATION PACKAGE

LUMPING /DELUMPING



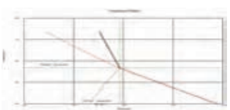
As mentioned at the introduction of this document, the foundations of an integrated model rely on a strong PVT definition that holds across applications from multiple vendors. The role of PVTP has always been as a platform that not only provides the engine for PVT calculations for all the Petex software, but also to facilitate characterisations that are applicable in such integrated modelling efforts. To this end, proprietary Lumping/Delumping schemes have been developed, uniquely associated with the implicit generation of rules that enable the recipient software to either lump or delump compositions that can seamlessly be used from reservoir to process. Traditional techniques (such as using marker components) for the same purpose have been of limited use and only work in certain conditions. The novel approach used in PVTP allows the resulting compositions to carry with them the rules by which they were created. These same rules can then be used by the recipient programs (such as RESOLVE) to have the fundamental methods by which the full compositions have been lumped and as such, enable delumping to be done in a consistent and generic fashion.

CARBON DIOXIDE

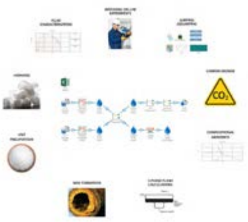


The Peng Robinson and SRK EOS models in their original form have well known limitations when dealing with polar molecules, such as water and CO2. For CO2 in particular, normal practice in the industry has traditionally been to use bespoke equations of state for 100% C02 (e.g. Span and Wagner). This approach has severe limitations for field applications, as mixtures are not handled and also, many recipient programs (such as reservoir simulators) only work with traditional EOS descriptions. To overcome these limitations, Petex spent a considerable amount of time in researching how traditional EOS models could be modified to predict accurately properties of CO2 and the result of this has been to create a unique correction that is now available to all the IPM software when the Peng-Robinson EOS model is used. PVTP can model all of the properties of C02 up to 20,000psig, in line with the NIST data, and capturing both dense and light phases depending on pressure and temperature.

COMPOSITIONAL GRADIENTS



In reservoirs with significant pay thickness, gravity segregation of components will cause a change in fluid properties with depth. This will in turn lead to the reservoir pressure and the bubble point of the fluid being different from the top to the bottom of the structure. As samples depend on the depth from which the fluid is obtained, models need to take into account how the fluids change with depth, not relying on a fixed description obtained at the sampling depth. The compositional gradient function in PVTP, allows the user to characterise the equation of state based on the sample characteristics, and then using this description, to generate a variable composition and hence properties with depth. This can then be fed directly into the reservoir model, giving a more accurate fluid characterisation over the whole reservoir.



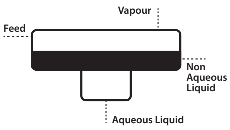
PVTP

THERMODYNAMICS FLUID CHARACTERISATION PACKAGE

WAX FORMATION

Wax deposition can create significant problems in fields where fluids have the potential to drop out paraffinic compounds. This phenomena depends on the the pressure and temperature condition of flow. Being able to understand this behaviour and create suitable operating envelopes is paramount in such situations. PVTP includes models that can predict wax deposition envelopes as well as amount of wax to be deposited at a given set of conditions. The models are based on Won's original work, which analyses the behaviour of a fluid based on a thermodynamic cycle and the changes in Gibbs free energy along various paths. Various modifications to this model have been proposed, improving on the assumptions made by Won and these are also included in PVTP. These include the Won model with solubility parameters, two versions of a model by Chung and also the wax model by Pedersen.

3-PHASE FLASH CALCULATIONS



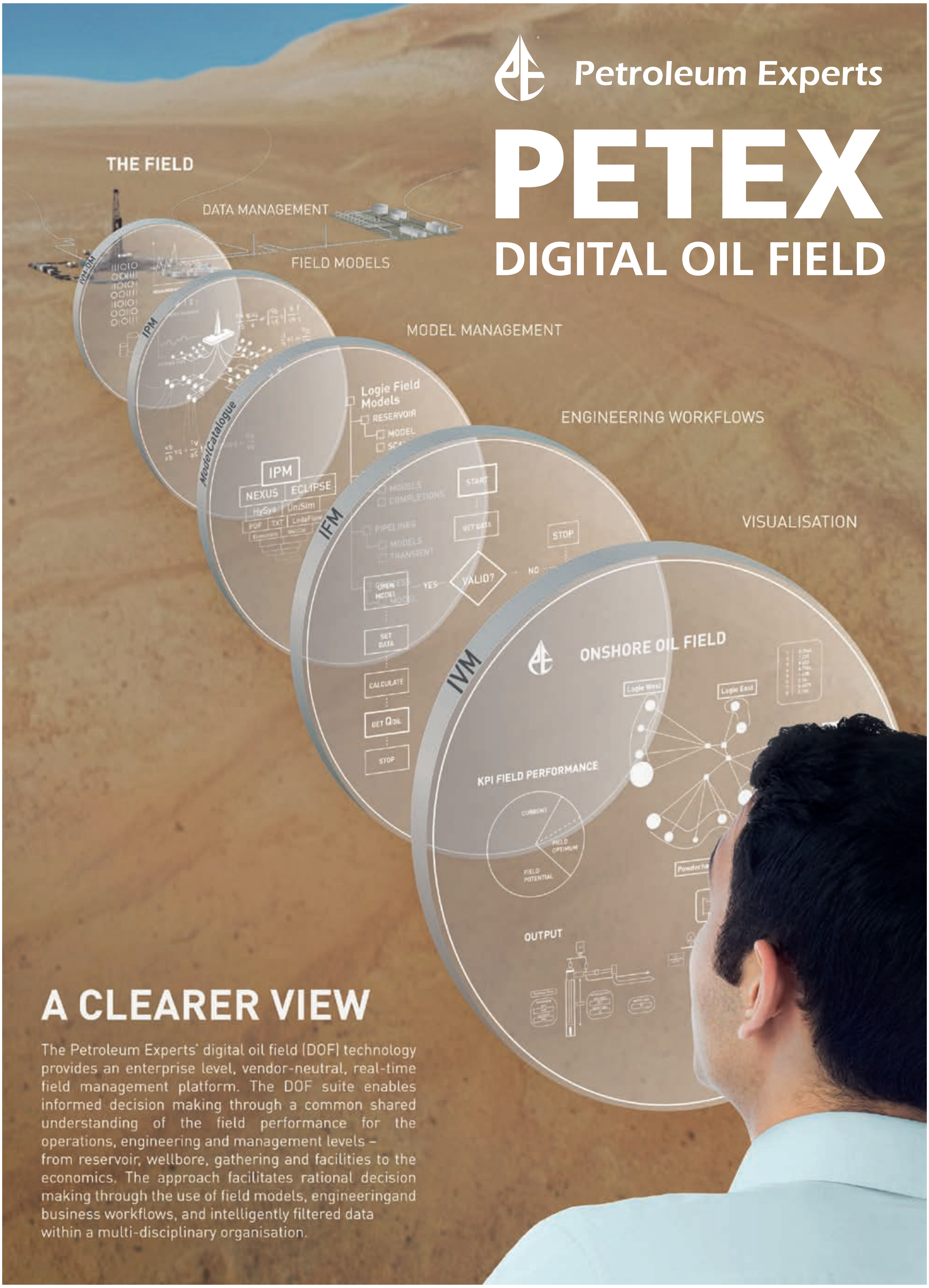
PVTP includes two and three phase flash engines that facilitate a range of calculations depending on the desired outcome. The Soreide and Whitson method provides the basis of the three phase flash with two more models being available from Hydrafact (Cubic and Cubic Pus Association). The speed penalty that has traditionally restricted the use of these models to very specialised domains, can be overcome by using a proprietary algorithm, referred to as "Pseudo Multi Phase". This is the result of internal research on speeding up three phase flashes and achieves very similar results as the full thermodynamic models but at a fraction of the time they would require.

SALT PRECIPITATION

Salt deposition is increasingly becoming a topic that engineers in the industry are concerned with, especially when expensive offshore wells have been compromised by salt that deposits and inhibits production. This is especially relevant in wells producing gas from reservoirs that include water saturated with salts. A drop in pressure while the gas is being produced means that more water will saturate the gas, leaving the rest of the water being unable to dissolve the salt, hence the deposition in the reservoir or the wells. PVTP allows the user to study this phenomena and understand at which conditions salts will deposit as well as the amount. This can either be done from the water composition itself, or through the salinity of the water.

HYDRATES

Complementing all the flow assurance calculations in PVTP, the hydrate modelling capabilities in PVTP include both industry wide available models (such as Munc) as well as models created from research done in Hydrafact and JIPs with Heriot Watt University (Hydrafact Modified Cubic and Hydrafact CPA). Operating envelopes that would enable safe conditions of flow can be created. In the event of inhibitors needing to be introduced, the calculations allow for evaluations to be done on which inhibitor would be most effective and at what quantity it would need to be injected.



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