Software Technical Summary





The KAPPA DDA suite4	En Pro
Saphir: Pressure Transient Analysis (PTA)8	KA Vis
Topaze: Production Analysis (PA) 14	Un
Rubis: History Matching (HM)20	Nu of
KAPPA Server (Ks): Reservoir surveillance of Dynamic Data26	Те

Emeraude: Production Log Interpretation (PL)	36
KAPPA Viz (Kv): Visualization and Collaboration	42
Unconventional resources	44
Numerical modeling at the heart of the KAPPA suite	46
Technical references	50

Amethyste:

Well Performance A	nalysis	(WPA).	
--------------------	---------	--------	--



For more information on the theory and practice of Dynamic Data Analysis download the KAPPA DDA book from **www.kappaeng.com**

DYNAMIC DATA: A DEFINITION

Whenever a fluid is produced or injected into the reservoir, the diffusion produces changes in pressure and temperature that may be recorded in various places. Combine this data with the production and/or injection rates and we have what we call Dynamic Data. Analysis and modeling of this data leads to a better understanding of the reservoir dynamics and the well performance, which in turn allows decision making and proper forecasting.

We need static data (seismic, logs, etc), but until we start to physically move the fluid in the reservoir and measure the response we cannot get the dynamic information that will allow us to model and predict the value of what we have.

Not so many years ago, such dynamic information was almost exclusively provided by specific field operations (well tests), that would determine important reservoir characteristics such as well productivity and sometimes reservoir boundaries, in an area around the well that depended on the duration of such operations.

For KAPPA it was the time of Saphir, our Pressure Transient Analysis software.

Today, safety and economics combined with technological developments mean that we need and are actually able to acquire, analyze, visualize and model on any scale in terms of time and dimension. We have to make use of whatever data we can get to piece together the dynamic model. Couple this with the fact that reservoirs are of increasing physical complexity, data-flow can be enormous and economics or lack of resources can limit the time spent on processing and analysis and there was a need to develop an integrated tool suite to visualize, organize and analyze dynamic data on any scale or complexity. For KAPPA it is the time of Ecrin, the integrated engineering workstation, the surveillance tool KAPPA Server and the visualization tool KAPPA VIZ.

The KAPPA suite offers a workflow from the simplest near wellbore analytical analysis to the most complex full-field numerical cases with exotic geometry and fluids. Adopted by almost all IOCs, NOCs, Service Companies and Independents the KAPPA suite is simple to use, robust and subject to an aggressive technical development program that will see it continue to develop fit for purpose tools integrated with third party workflows and massive data that face the industry.

KAPPA is 25 years old, privately owned, fiercely independent and totally committed to technical development.

The KAPPA DDA suite



Ecrin - Main window with Saphir, Topaze, Amethyste and Rubis running simultaneously

.



Originally from well tests, dynamic data analysis (DDA) comprised specialized plots and analytical models usually based on a straightforward flow followed by a shut-in period. Today the sources of dynamic data are many fold and available at various scales in time, space and volume. With complex geometry and fluids analysis is increasingly difficult. The task is to piece together a description based on these various sources.

To take a logical approach and to progressively look deeper into the reservoir we start with pressure transient analysis (PTA) usually dealing with high resolution, high frequency pressure build-ups and typically on a single well with the possible influence of nearby wells. 'Extreme near wellbore analysis' is a particular application of transient analysis applied during a Formation Test (FT) that, whilst not seeing that far into the reservoir, can provide unique vertical description.

Conversely, still using PTA, we may see much further into the reservoir using one or more build-ups separated by time and consequent material balance, by using deconvolution.

Moving yet further out into the reservoir we typically analyze low frequency, low resolution rate data with, if we are fortunate, corresponding pressure data. Using identical modeling, both analytical and numerical, to that found in PTA we use specialized plots and work on much longer time timescales attempting to reach the reservoir boundary whilst in pseudo-steady state. This is production analysis (PA). The true advantage of PA is that we model and match on what really matters, that is the production of the well, or wells, in question. On the scale and lifespan of the entire reservoir we can history match (HM) production, pressure and temperature data extending the model into true 3D. The idea of the workflow is to keep it as simple as we can. When the situation demands we add complexity.

The vertical dynamic profile of the field may be analysed with production logging (PL) and formation tests (FT). To bring all this to datum the output of a well performance analysis (WPA) tool is required.

Whatever analysis is used, the data, objects and models are shared seamlessly, the gridding is coherent between the methods and an analysis created in one module may be used, or driven, from another saving time, repetition and frustration.

In future developments the technical aim, under a complete .NET re-write, is to improve access to third party workflows, increase the use of smart automation tools and to handle increasingly massive data and well numbers.

KAPPA Server (Ks)

Permanent downhole gauges (PDG) constantly monitor downhole pressures. They provide longterm data to run production analysis (PA) and shortterm data, from incidental shut-ins, to perform single or multiple pressure transient analyses (PTA).

KAPPA Server is a client-server solution that loads, processes and shares standardized data within a workgroup and establishes real-time links with Intelligent Fields and third party databases. OpenServer APIs allow third party applications to retrieve data and analyses.

Pressures and temperatures are processed using wavelets. Rates, previously requiring extensive manual intervention to correct inaccurate reallocation processes, are solved with an algorithm that identifies shut-ins with high reliability.

Using gradient discrimination, KAPPA Server then automatically identifies shut-ins scanning years of PDG data in seconds. These identified shut-ins are then made available to the user for analysis in the PTA module (Saphir). The combination of these processes leads to perfectly synchronized pressure and rates allowing immediate single or bulk analysis.

Sharing data and technical objects

KAPPA Server and the Ecrin modules share data and analyses back and forth. This data is then available to workgroup users.

This also applies to technical objects such as PVT, reservoir maps, relative permeability tables, intake curves, IPR's, analytical and numerical models.

PVT objects may be tables, black oil correlations or an EOS. In Saphir, Topaze and Rubis this may be isothermal. In other modules Emeraude, Amethyste and Rubis, temperature dependency may be required. When dragged and dropped from one environment to another a PVT object will adapt from isothermal to non-isothermal, or vice versa.

Analytical models may be exchanged between Saphir and Topaze. It is possible to convert a whole document, with information, data and models, from PTA to PA or vice versa.





PDG processing with KAPPA Server and Ecrin

Saphir: Pressure Transient Analysis (PTA)



FEATURES

- Industry standard for Pressure Transient Analysis (PTA)
- More than 3000 active licenses worldwide
- Extensive analytical model library
- Integrated numerical model with non-linearity
- Seamless connection to KAPPA Server and other analysis modules
- Test design, QAQC and sensitivity analysis
- Deconvolution and minifrac

Saphir, the Pressure Transient (PTA) module of the Ecrin workstation, is the industry standard with over 3000 active installations. With a methodology based, since its origin, on the Bourdet derivative, Saphir offers an extensive and growing analytical model library. The Voronoi numerical model has been developed to handle the increasing complexity of producing wells, solving exactly the multi-phase and complex geometry cases for multiple wells and layers.

Saphir connects seamlessly with the PDG surveillance tool KAPPA server and other components of Ecrin, including the Production Analysis (PA) module Topaze and allowing, through sector extraction, the run and analysis of a full-field 3D/3-phase sectors in Rubis (HM).

Recent developments include advanced work on minifrac analysis, multiple probe formation tests and deconvolution. Deconvolution, by linking buildups separated in time, allows the user to see much further into the reservoir than could be achieved by a single build-up.

'Generally we re-consider our software choices every five years. We have now been using Saphir for more than twenty years and we will certainly not change as long as you keep your enhancements, your development speed and your support as they are.' 'We are glad to see that KAPPA has not changed its technical focus since Saphir became the industry standard.'

'When you released your first numerical model in Saphir ten years ago I thought it was just a gimmick. Now I cannot imagine what I would do without it.'

'Saphir is by far the most popular software among our reservoir engineers.'

'Saphir? It just works.'



LEARN MORE

ANALYZE

Data loading and editing

Saphir can load an unlimited number of gauges, rates, pressure and other data in most formats including ASCII, Excel[™], PAS and databases via OLEDB & ODBC. Saphir has real time links with acquisition systems, data drag-drop from other modules and KAPPA Server, which can identify build-ups and initialize Saphir on a single click. Multi-layer rates may also be imported from Emeraude.



Edit rates dialog

Data QA/QC and datum correction

Saphir offers a range of interactive QA/QC tools including trends, tidal correction, gradient analysis and gauge comparison to detect sensor drift and wellbore effects.

Saphir can define or import VLPs and well intake models, either from Amethyste or standard file import. VLPs are used in conjunction with analytical and numerical models to simulate the pressure at gauge depth or at surface. Alternatively they can be used to correct pressure data to reservoir depth.

Test design

All analytical and numerical models may be used to generate a virtual gauge on which a complete analysis may be simulated. This can take into account gauge resolution, accuracy and potential drift in order to select the appropriate tools or to check if the test objectives can be achieved.



QA/QC

Extracting $\triangle P$ and deconvolution

One or several periods of interest, generally shut-ins, for one or several gauges may be extracted and used on a semi-log and loglog plot, the latter integrating the Bourdet derivative.

Deconvolution can be used to combine several successive shut-ins into a longer 'virtual production'. Available methods are (1) von Schroeter et al, (2) Levitan (with material balance correction) (3) Houzé et al and (4) a hybrid combination.



Deconvolution of two consistent build-ups (von Schroeter et al)

Specialized plots

Additional specialized analysis plots can be created with options tailored to specific flow regimes. These include very short-term tests or FasTest[™] for perforation inflow testing and predefined types such as MDH, Horner, square root and tandem root.



Classical Horner plot

Analytical models

Saphir offers a built-in analytical catalog combining well, reservoir and boundary models. External models (see pages 50–51) can be downloaded. Interactive 'pick options' are offered for most parameters for a first estimate by selecting a characteristic feature of the model on the Bourdet derivative. There is an option to use the AI package 'KIWI' as a guide. Additional capabilities include rate dependent skin, changing wellbore storage, interference from other wells, gas material balance correction, well model changing in time, horizontal and vertical anisotropy.



2-Porosity PSS - Picking the transition

Numerical models

As the case complexity increases, numerical models are used for geometries beyond the scope of analytical models. These are predominantly 2D but with 3D refinement where needed. This includes the fractured horizontal well model for unconventional resources.

These numerical models also address nonlinearity. Pseudopressures are replaced by the exact diffusion equations for real gas, non-Darcy flow, pressure related physical properties, multiphase flow, water and gas injectors, water drives, and more recently desorption models for shale gas and CBM.



Interpretation using a numerical model



Rubis sectors running in Saphir

Use of HM (Rubis) sectors

A sector of a Rubis full-field 3D reservoir model can be imported and run directly in Saphir for a given time range. The starting point is the dynamic state of the simulation at the extraction time. This enables Saphir to simulate 3D/3-phase flow with gravity and in complete coherence with the reservoir model.

Multilayer analysis

An unlimited number of commingled layers that have individual initial pressures can be modeled analytically or numerically. Connected layers can be modeled numerically. Analytical models can superpose internal or external single layer models. Stabilized or transient rates can be loaded and associated with any combination of contributing layers. Rates may be loaded directly from an Emeraude PL analysis. Optimization is performed on both pressure and layer rates.

Optimization and sensitivity analysis

Nonlinear regression is used to optimize the model parameters. This may be automatic or user controlled from a list of variable parameters, an acceptable range and weighting of the data. Optimization may be performed on the extracted period(s) or on the whole production history. Confidence intervals may be displayed. Sensitivity analysis may be performed on the same model using different parameters.

AOF / IPR

AOF and IPR analyses are available for vertical, horizontal and fractured wells. Test sequences may be flow after flow, isochronal or modified isochronal, with or without an extended stabilized flow. Transient IPRs are also available. Shape factor and average pressure can be calculated for closed and constant pressure systems. IPR facilities are shared with Amethyste.



Minifrac analysis

A workflow combines the G-function plot with derivatives to define the leakoff behavior and the closure pressure. It includes square root and after closure analysis plots.

Slug and Pulse

Processing allows a modified version of the Ramey function to match the slug pressure response of a DST with Bourdet derivative type-curves. This method can also solve for instantaneous production with wellbore storage.

Formation tests

This option enables the interpretation of any number of probes, active and interference, to discriminate vertical permeability. Models for packer-probe and probe-probe interference are included with the latter considering storage and skin. An inbuilt preprocessor handles LAS format files and calculates rates from pump volumes.

This temporary (free) Saphir module will be re-written, upgraded and removed in Generation 5 when a dedicated module will be commercially available.



Formation testers: Analysis and rates calculation from volumes

Reporting and exporting

Saphir has a range of comparison, reporting, exporting and printing capabilities. The free and unprotected Reader allows files to be read, printed and exported without the requirement for an active license. A slide presentation format is available to use on an LCD projector or to create PowerPoint[™] slides.

Topaze: Production Analysis (PA)



FEATURES

- 1400 active licenses
- Unconventional Resource modeling
- Multiwell capability
- Seamless connection to KAPPA Server and other analysis modules
- Extensive analytical model library
- Integrated numerical model with non-linearity

Moving deeper into the reservoir and typically making use of low resolution, low frequency data Production Analysis (PA) has recently come of age. Evolving from empirical decline curve methods to modern methodology that shares much with pressure transient analysis (PTA). With over 1300 commercial licenses Topaze, the Ecrin PA module, offers single and multi-well analytical and numerical analysis leading to reserves and production forecasting from the most simple to most complex multiphase case.

The abundance of data from permanent gauges has meant that users are able to obtain answers that were previously only available from transient tests. This information has the advantage that it is available at no extra cost and with no deferred production. As the long-term production is modeled, the evolution in time of the well productivity may also be quantified. Finally, forecasting is based on a real model as opposed to an empirical function.

Unique features include a total compatibility with the Ecrin PTA module (Saphir) data and models, an extensive analytical model catalog and a unique numerical capability that allows reliable history matching and forecasting, even in the case of shale gas and CBM produced by fractured horizontal wells. Its multiwell capability allows very fast full-field decline analysis and forecasting. A field production profile generator is also integrated. *With decent rate data, permanent gauge pressure data and Topaze I can make the data dance.*

'Other tools process bulk data efficiently, but when I need to be sure my analysis is not based on any old line I use Topaze to be really sure of the model.'

'You may not like what you see, but the data is the data and it is telling you what is happening. If that is the model then, like it or not, you have to live with it. The data never lies.'

'Why should I be surprised when the rates and the pressures tell me the same thing? It is the same reservoir. Just a different scale and way of looking at things.'





Loading and editing data

Load and edit an unlimited number of gauges, rates, pressure and other data in almost any format including ASCII, Excel[™], PAS, DMP2, Merak and databases via OLEDB & ODBC. Real-time links with various acquisition systems, and data drag-drop from other modules or from KAPPA Server.

Classical PA diagnostics

Multiple variants of the Arps plot. Fetkovich type-curves P-Q plots, to discriminate between transient and boundary dominated flow Normalized rate cumulative plot A variation of the Agarwal-Gardner Flowing material balance Square root plot Power law loss ratio plot



Arps multiple scale analysis



Flowing material balance plot

Well intake correction

When pressures are acquired at surface, or at any point other than the sandface, they can be corrected to datum using well intake models created by Topaze, imported from third party software or from Amethyste.

Modern PA diagnostics

The three main and complementary diagnostics used in Topaze are the rate and pressure history match, the loglog plot and the Blasingame plot. The Blasingame plot displays, on a loglog scale, the instantaneous and average productivity index, with derivative versus material balance time. Type-curves are also available. For gas material balance, the time is replaced by the material balance pseudotime. The simulated model can be compared to the data on these three plots.



Fetkovich

Analytical models

Topaze uses well, reservoir and boundary models listed on pages 50–51. Topaze can simulate pressures from rates, rates and cumulative production from pressures, or both. History matching is obtained by nonlinear regression of the model on pressures, rates, cumulative production or any weighted average.



Blasingame type-curve with data overlay



Model match on Blasingame plot

Numerical models

In more complex cases Topaze numerical models are used to generate geometries beyond the scope of analytical models. This is predominantly 2D, but with 3D refinement where needed. The horizontal multifractured well for unconventional resources is included. Numerical models also address nonlinearities, replacing the linear diffusion used in analytical model by the real diffusion equations solving for real gas, non-Darcy flow, pressure related physical properties, multiphase flow, water drives, and desorption based on the Langmuir isotherm, for shale gas (single phase) and coalbed methane (2-phase water-gas).



Numerical model with multiple wells



3D model



Water influx





Topaze multiwell display and dialog

Multiwell processing

The multiwell mode of Topaze facilitates the analysis of the production of multiple wells. The production data can be loaded simultaneously in formats including DMP2, Merak, or by drag-drop from KAPPA Server. It is then possible to view this data together in a browser, and conduct quick or detailed analysis of all wells or groups of wells. The results are viewed as tables or bubble maps as required and then it is a single step to construct a field profile from any extension of the selected diagnostic, be it a decline curve or a complex model.





Bubble map in Topaze

Changing well conditions

The numerical module simulates multiple well production where individual wells can be pressure or rate controlled. There is 2D and 3D visualization of the well drainage areas and their evolution with time. If the simulation deviates from the data and indicates a change in the well productivity index the user may assign individual skin values to different production periods. Nonlinear regression is then applied on all skins, resulting in a relationship between mechanical skin and time.

Production forecast

Without data, or after history matching, a production forecast for any model may be run based on the anticipated producing pressure. Sensitivity to production improvement or decay can be simulated.



Production forecast

Production profile generator

This tool provides a uniform and standardized approach to obtaining quick production estimates for new fields and incremental recovery studies. Valid for oil, gas and condensate the user can model water or gas drive taking into account all producing and or injecting wells. It allows the input of an unlimited number of various well-type profiles and generates a field production profile consistent with the drilling and workover schedule and facility constraints. The profile generator can use a multiwell field profile as a baseline for an incremental study.



Production profile generator

Reporting and exporting

Topaze has a range of comparison, reporting, exporting and printing capabilities. The free and unprotected Reader allows files to be read, printed and exported without the requirement for an active license. There is a slide presentation format for LCD projector or copy/paste into PowerPoint[™].

Rubis: History Matching (HM)



FEATURES

- Simple, interactive 3D click and draw build process
- Automatic gridding
- Full compatibility with Saphir, Topaze and Amethyste modules
- Direct PDG (KAPPA Server) data link
- GRDECL and CMG import
- Build and run in minutes
- Sectors run from Pressure Transient Analysis (Saphir)

Rubis, the full-field numerical module of the Ecrin workstation, offers the specialist and non-specialist alike, an easily built click-and-draw model in minutes as opposed to hours or days. Multiple forecasts, reserves and investigation of possible intervention opportunities can be run and history matched in a very short time frame.

Rubis sits between single cell material balance and massive simulation models. It replaces neither, but does much of the work of both. It offers full-field, 3D, multiwell, multiphase with gravity capability. It was developed after seeing engineers labor with spreadsheets or conventional simulators to solve dayto-day problems.

The basic premise is that the grid is a necessary evil that should not dominate the problem solving process, so it is built automatically. Of real interest is the physical problem we want to simulate. We want this to be complex enough to reproduce the main drives of the reservoir that will affect production, but simple enough to be run with a very short time cycle that is usable; in hours, not days.

Recent developments in Rubis have focused on unconventional resources with multiple-fracture horizontal wells and wells with arbitrary trajectories; the Wriggly wells. 'Just before lunch the reservoir manager walked in and asked me to run a few scenarios for the next well placement. I had the answers on his table by close of business that day.'

'I will never use Rubis to replace my current model. It has taken so long to build it makes little sense to do so. What I can do though is run my cases in Rubis and it gets me very close to what I think is happening. This drastically saves time in advancing the full model.'

'I should not say this, but working with Rubis is fun. It is the way it should be.'

LEARN MORE







Rubis workflow

The grid is built automatically as a final step after the physical problem has been defined by the input of the PVT, the geometry, the wells and the reservoir static properties.

Defining the PVT

The numerical solver is compositional, however the PVT used is black-oil or modified black-oil. The Rs and rs relations are turned into a composition ratio, providing the grounds for a compositional formulation. Internal correlations can be used and tuned to match measured values. Alternatively, tables can be loaded.

Defining the reservoir geometry

The user defines the areal perimeter of the reservoir and the number of geological layers. Individual layer volumes are defined by drawing or importing horizons and thickness fields. Internal faults can be defined. Scarce information is compensated for by kriging or linear interpolation. Vertical cross-sections can be created and viewed.

Defining the reservoir properties

Reservoir properties that include petrophysical, relative permeability, capillary tables and fluid contacts may be defined by layer or areas or a combination of both. In addition, non-Darcy flow, double-porosity, vertical and horizontal anisotropy may be specified. Each segment of the reservoir boundary can be set individually to sealing, constant pressure, or connected to various types of aquifers.

Importing geometry and properties

The interactive build may be replaced by an import from a geomodeler or another simulator using GRDECL or CMG format including the net-to-gross. It is also possible to drag-drop a case, or part of a case, from another Rubis document or from a Saphir or Topaze numerical model.

Defining the well geometry

A well in Rubis may be either vertical, vertical with a hydraulic fracture, horizontal or slanted. The 'wriggly well' can follow any trajectory and cross any stratigraphy. Perforations are unlimited with opening and closing times defined individually. Each perforation may have a discrete skin which may be constant, rate or time dependent. Because a wellbore model can be coupled with options including classical empirical, mechanistic and drift flux models, the well definition is not limited to its actual path in the reservoir. It is therefore possible to define the complete well trajectory from surface.



Using an Amethyste wellbore model in Rubis

Defining the well data and constraints

Real well pressure and rate data can be loaded and edited. PDG and production data may be used and dynamically updated from KAPPA Server. The user can define an individual well model or import it from Amethyste. Controls can be constant or time dependent. Abandonment rates may be specified.

Building the grid

The unstructured Voronoi numerical model is common to Saphir, Topaze and Rubis with only local grid refinement around the wells. The grid forms automatically and with the minimum number of cells. However, if required, the user may take full control.



Typical Rubis grid



Example of coning in a limited entry well

Running the simulation

The user can override the default time range, solver settings, list of output results and frequency of the simulation restarts. Required output plots are created, pressure and saturation fields are initialized, and the individual well indices are calibrated from a hidden PTA grid. The simulation is then started and may be paused at any time. Individual plots are updated whilst the simulation is running. Information on the simulation process is displayed in the lower message window.

Display during and after the simulation

Individual well production and pressures, together with reservoir statistical information, are displayed on a dedicated versus time plot and updated in real time during the simulation. In playback mode, a vertical line highlights the active replay time.

Static fields such as permeability or porosity and dynamic fields, such as pressures and saturations, can be displayed in 3D or 2D with vertical or horizontal cross-section.

A simulated production log, per well, showing the contribution by phase and zone is generated and time stepped in playback mode.

All data, input and stored, is organized in a hierarchical data browser. Any number of runs can be stored in a given session to enable 'what-ifs?' to be run.



Rubis simulation window





Multifrac horizontal well model



Rubis Sectors

Shale gas, shale oil and CBM

The multi-fractured horizontal well with stress dependency and adaptive gridding to handle local diffusivity and the expected time step is included. The model includes desorption for CBM.

Sending a Rubis sector to Saphir

When a shut-in has been identified in the pressure history, usually from a PDG measurement, the user may select a period of time and a section of the reservoir that will be transferred to Saphir. The starting point is not the equilibrium, but the 'real' state of the reservoir properties.

A complete Saphir document is initiated and the extracted build-up can be analyzed using the standard tools including specialized plots, the analytical model or built-in numerical model or driving the complex three-phase, 3D model, including gravity.



Injection / warmback simulation in Rubis

Thermal model and Network

There is a temporary, experimental implementation of a full field thermal model developed in cooperation with TOTAL. Furthermore, a surface network module is included. These are for evaluation purposes only and can be activated for interested users by contacting KAPPA.

KAPPA Server (Ks): Reservoir surveillance of Dynamic Data



FEATURES

- Extensive global deployment
- Unlimited gauge and data capability
- Seamless connection to KAPPA workstation analysis modules
- Mathpack, alarms and auto-update
- Automatic PBU identification and rate allocation
- Smart filtering and de-noising
- Shared data, object and analysis environment

Permanent gauges are a wonderful, data-rich witness of reservoir behavior, but without organization they only add to the end-user feeling of data overload and at best the ROI will be limited.

KAPPA Server addresses the issue of capturing massive PDG data in a useable, smart-filtered form for transient/production analysis and history matching. It automates, alarms and connects seamlessly with KAPPA workstation and third party platforms and workflows helping to transform PDG data into valuable information such as productivity, wellbore performance, reserves and forecasts in a seamless environment.

KAPPA server represents the next generation of massive dynamic data management and replaces Diamant Master.

'Since we installed the system we have not needed to perform a single planned shut-in'.

'This has become the eyes of the reservoir'

'We thought this would all be about build-ups, it is, but it has also given us an unexpected visualization on the interconnectivity of wells'

'The flow of data we get from Diamant Master is of strategic value to our business'.



LEARN MORE

ORGANIZE



Typical PDG data response gathered over two weeks

Handling PDG data

PDGs acquire pressure data at high frequency and over a long duration capturing build-ups as 'free' well test candidates for PTA. The long term response can be used in association with the well production to perform production analysis and/or history matching.

The data is vast with a single gauge typically generating 3 to 300 million data points. It is often difficult to locate and when used requires a different emphasis; short-term high frequency data for PTA and long-term low frequency data for PA.

Wavelet filtering

To perform a PTA or PA analysis typically requires 100,000 data points, but it is a different 100,000 from the same dataset. To obtain both, KAPPA Server (Ks) uses a wavelet algorithm. This may be described as a 'smart' filter with a threshold. For each point the local noise is estimated for different frequencies. If the local noise is above threshold, as occurs for pressure breaks when the well is shut-in this is considered significant and retained. The wavelets act as a high-pass filter. Conversely, if the noise level is below threshold, this is noise and it is filtered out. The wavelets act as a low-pass filter. As a result, producing pressures will be filtered out and reduced to a few points per day, while all early shut-in data will be preserved.



Wavelets decomposition and denoising algorithm



Wavelets denoising: (1) raw data = 10,000 points; too low (2), too high (3) and selected (4) thresholds; (5) post-filtration; (6) filtered data = 70 points

KAPPA Server/KAPPA Client (Ks/Kc) workflow

KAPPA Server runs continuously on Windows Server[™] and is controlled using KAPPA client (Kc) or a WEB client. Data tags in the historian are persistently connected from which data is sequentially mirrored, filtered and presented to the user in a logical userdefined hierarchy. Updates, filtering and specific selection may be user-controlled or automatic.

The filtered data is stored in the local database to be subsequently sent to the KAPPA analysis modules on a single drag-drop or to third party workflows.

KAPPA Server stores KAPPA technical objects and files to be shared by the analysis modules.

Connecting to data

There is no standard way to store PDG data. Almost every vendor has its own data model, and OPCOs routinely have several providers as well as their own data model. Each data model requires an adaptor to navigate and access data. An API permits the development and connection to customized adaptors that are automatically downloaded. Connection is therefore very straightforward.

Data processing

When connecting to a new tag KAPPA Server proceeds with a quick data scan of one point in every ten thousand to preview the data and help in spotting anomalies and gross errors. A user defined data window can immediately discard obvious outliers. A first series of points, typically 100,000, or one week of data, is then used in an interactive session for the engineer to adjust the wavelet setting and data post-filtering, based on a maximum Δt and Δp . Upon user acceptance the filtering is performed using overlapping increments the size of the initial sample.

Derived channels (Mathpack)

These are user defined and permit mathematical operations on data channels with a comprehensive formulae package. The outcome may be another data set or a Boolean function of time that may be used to create an alarm. The outcome of the alarm is to display, in the KAPPA client window, the execution of an alarm E-mail, or the call of a user defined DLL.



Automatic Shut-in identification in KAPPA Server



Multiple build-up analysis in Saphir



History matching in Topaze



Build-ups indentified in KAPPA Server ready to send to Saphir

Automatic shut-in identification

KAPPA Server automatically identifies shut-ins. Years of PDG data can be scanned in seconds and build-ups made available to the user for analysis in Saphir. The times of these shut-ins may be used to modify the production history in order to honor both shut-in periods and cumulative production. Hence rate synchronization is automated.

Transferring data to the analysis modules

Filtered data can be transferred to any analysis module by drag-drop. Shut-ins are analyzed and compared using Saphir, producing rates and pressures can be analysed and matched by Topaze and filtered data may also be used to constrain Rubis models.





Express shut-in(s)

With the transients identified and daily rates correctly allocated and cleaned, shut-in data can be sent, en masse or individually, to a Saphir document. The result can be the latest shut-ins or a cloud of transients from previous years that may be analysed together, as a selected group or discretely.

WEB access and administration

KAPPA Server is a seamless way to handle data, technical objects and files when using KAPPA applications. However, these can also be accessed from an Internet browser by connecting to the KAPPA Server IP address or its name in the domain. The engineer can view the status of the different processes, access the data tables and technical objects and recover the filtered data in Excel[™] format without using the workstation. An ActiveX control can also be loaded to navigate the data structure in the same environment as KAPPA Server.

Amethyste: Well Performance Analysis (WPA)



FEATURES

- Seamless connection to other workstation analysis modules
- Multiple models and sensitivities
- Well sketch
- ...free!

The Well Performance Analysis (WPA) module (Amethyste) is seamlessly integrated in the workflow to simplify processes involving wellbore modeling and IPR calculations. Although there are some fine packages on the market the WPA module was developed to speed up and allow unique workflows and to ensure a consistency of approach. The WPA module is free of charge, included with the package

The WPA module corrects for less than optimal gauge placement, including at surface. It allows full drag and drop, back-and-forth integration with PTA, PA and HM (Saphir, Topaze and Rubis) where it can be run dynamically with complete control and without blind table interpolation.

Multiple pressure drop models may be defined and compared with unlimited sensitivity studies. User data can be added to the model for comparison. Correlation between resulting rates and the sensitivity parameters can then be displayed, as can the evolution of the productivity index as a function of the time as the reservoir starts to deplete.

Wellbore and flow line can be treated independently or together. A well sketch is available for graphical display using a library of pre-defined completion components. Lift curves can be generated in Eclipse[™] format for third party software.

LEARN MORE



ANALYZE

WPA Workflow

The workflow is similar to other modules, with a control panel guiding the engineer through the default steps; defining the problem, input PVT, define the well, calculate the VLP and the IPR and run sensitivity analyses.

Defining the problem and PVT

The user defines the type of well, producer or injector, the reference phase and the PVT is the same standard black oil PVT used in other modules.

Defining the well

Wellbore and flow line can be treated independently or together. Wellbore flow may be tubular or annular, with trajectory, ID, roughness, detailed completion with any number of restrictions included. A well sketch uses a library of pre-defined completion components.

Vertical Lift Profile (VLP)

Multiple pressure drop models may be defined with one required as the reference. Each model can be assigned factors to honor observed data. A temperature profile must be loaded or calculated. The built-in temperature model uses a segmented model incorporating convection, conduction, and thermal compressibility effects.

The VLP option generates traverses (p vs. depth) and VLP plots (p vs. q). For each scenario user data can be input manually, from a file, or picked from production data. On validation, each scenario is run and the corresponding plot built. The plot content can be customized interactively.



Well sketch

Inflow Performance Relationship (IPR)

An IPR study performed with Saphir may be dragdropped into Amethyste and the IPR part of the analysis is immediately complete. Alternatively, test data can be loaded or drag-dropped into Amethyste. The IPR option, which is identical to that in Saphir, is used to define a single, or composite layer IPR. Multiple models can be selected and compared from which one is selected as reference. For those models using a skin, the user can input a total skin or calculate the skin components using a completion model. User data can be added for comparison with the model(s). An IPR plot is created that can be customized interactively.



Sensitivity Analysis

Well Performance Analysis (WPA)

The VLP and the IPR overlay intersection provides the solution for a given set of surface conditions.

Running sensitivity

An unlimited number of sensitivity studies may be performed. A given study will correspond to a set of user-controlled values for an IPR parameter, a VLP parameter or both. A cross-correlation between the resulting rates and the sensitivity parameters can then be displayed. The evolution of the productivity index as a function of the time as the reservoir starts to deplete can be shown.

Report, export and plot

Amethyste has an extensive range of reporting, exporting and printing capabilities. Lift curves can be generated in Eclipse[™] format for third party software.

The browser can be used to drag-drop components between analyses or between other modules. In particular, a whole VLP object can be dropped into Saphir, Topaze, or Rubis and run from those modules with the possibility of changing any model parameter, post-transfer.

Emeraude: Production Log Interpretation (PL)



FEATURES

- Industry standard PL platform
- Used by all major service companies and most major OPCOs
- Full multi-probe tool MPT
- (MAPS[™] and FSI[™]) capability
- Choice of processing; zoned and continuous
- Temperature quantitative interpretation
- Pulsed Neutron (PNL) interpretation
- No black boxes

With over 1,100 active licenses, KAPPA Emeraude is the industry standard software platform for production log interpretation, shared between all major service companies, most operating companies and independent contractors worldwide. Data from any PL string can be analyzed; from the simplest injector to the most complex multi-probe strings run in multiphase horizontal wells.

Recent years have seen a step change in the complexity of wells with multiple zones, phases and deviation ranging from vertical to horizontal. This has led to the development of esoteric logging tools with multiple arrays attempting to describe complex flow regimes by giving a spatial mapping of the flow characteristics. Masses of data are created that need visualization, QA/QC and analysis. It is not a straightforward process. It is easy to succumb to the temptation of a 'black box' that will do some clever statistical stuff to produce a solution that matches perfectly all data to hand. With the complexity of the physical problem, and the simplicity of the models, a perfect match only means that a trick is used internally by means of additional degrees of freedom, not necessarily obvious to the user. Production log interpretation is not rate measurement. The key to the process is in the name: Interpretation. Engineers interpret, machines do not. The engineer must control the software not the other way around.

Emeraude offers the user the choice of both zoned and continuous processing. Data from the simplest injector string to the most complex multiprobe tools (MPT), such as Schlumberger FSI[™] and GE Sondex MAPS[™], are handled in an open, streamlined workflow with an unparalleled range of tools for displaying, editing and handling data. There are no 'black boxes' no hidden processing. Recent additions include an 'energy' temperature model to simulate reservoir thermal behavior; this can be applied to steam injection tests, leak detection design and DTS data interpretation. Additional options include multirate PL and SIP, water saturation (PNL) monitoring, permeability correction, formation test QA/QC and multilayer rate export to Saphir.

'Having the software on my workstation has meant service companies know I can look very closely at the data. It has meant a significant increase in log analysis quality. It is now a common platform of communication between us.'

'The continuous processing is something some clients insist upon. I really did not want to purchase and learn another package. Now I have the choice of processing in one software.'



ANALYZE



Display

Data load and display

Load logs and stationary data from LIS, LAS, and ASCII files. Automatic tracks are built to give an instant view of the log data, whilst customized views can be created. A well sketch can be built by completion component drag-drop. All display settings can be customized and templates created.

Data structure, browser, and editing

The hierarchical documents contain an unlimited number of surveys and interpretations. The browser contains a wide range of editing options: lateral average, depth stretch, shift, data cut and fill, merging, splicing, derivative, sampling, user-formula module, additional functions through external DLL's. Stations can be displayed vs. time.



Data browser

Spinner calibration and apparent velocity

Multiple spinners can be handled simultaneously, in particular for Multi-Probe Tools (MPT). Various calibrations and editing may be performed on user defined spinner calibration zones. Apparent velocity channels are then calculated for each pass and each spinner.

Single and zoned PVT

Black-oil PVT offers a wide choice of correlations, which can be viewed and matched to user-defined measurements. PVT tables may also be loaded. If the PVT is zoned, properties are redefined for each inflow zone. A steam-water model is available to analyze steam injection wells.

Zone: 1	Model	3 Phase	:LG]	14.02	-	100
	Correlation I-g	Duk!	er.		*		E spir	nner reapon	ac al
	Correlation W-O:	Choque	tte		•]			
Qw: 0.014	m3/sec		Do: 0.009761	11)g: 0.08	m3/sec	
Qws.c.: 0.013	3 m3/sec	Que	.c.: 0.006170	51		Que	c. 16.5	1 m3/sec	
Yw: 0.137	7	1000	Yo: 0.09				Ya: 0 773		
Denne Aberl		-				~	0.100		
regime: Mist/	Annuar	SID	ar: o m/sec	ç	8	SID 0-	W; 0.100	m/sec	
Matched	Measured	Shift	Calculated	Error %	Fit	W	leight	Vpcf	-
VASPN, m/sec	5.8727	>	5.8418	0.5294	J	All 1	A	0.8948	
WFDE, kg/m3	361.498	>	371.212	2.687	9	AI 1	A	N/A	
Yw-DFHM	0.1692	>	0.1369	3.2316	모.	A1 1	A	N/A	
Yg-GHHM2	0.7357	>	0.7732	3.7558	P	A1 1	A	NA	
(* Table							-		
C Plot									
			10232	0		-	67 U.S		1
			1 No form	- E4	1	882	e le	Incore	0

Regression in Zoned / Continuous analysis

Rate calculation is treated as an optimization problem using nonlinear regression, with full flexibility in the type and number of input measurements, as long as they are in sufficient number and include apparent velocity, density, pressure gradient, capacitance, phase holdup, phase velocity, phase rate, temperature, etc. Calculations may be zoned or continuous. The zoned calculation focuses on user defined intervals. The continuous method seeks agreement everywhere on the logs, and the holdups are treated as variables, allowing a possible deviation from the slip model. The zoned method works well most of the time and it is very fast. The continuous method may provide a better answer in complex cases and when attempting to match the temperature. The user has the choice.

Local vs. global regression

The local regression in the zoned method calculates cumulative rates on selected intervals. This may also be the starting point for the continuous method, where a global regression solves for the contributions of the inflow intervals. Such regression solves for the entire well at once using user-defined constraints such as the contribution sense, surface rates, etc. It is also possible to fix any particular contribution to a fixed or null value.



Continuous analysis results



Interpretation models

Emeraude offers a complete range of flow models from single to 3-phase. Specific models are provided to handle flow re-circulation and standing water columns. Three and two-phase liquid-liquid stratified models for horizontal and highly deviated wells are available. It is possible to connect user models through an external DLL interface.



FSI processing







Interpretation including temperature

Multiple Probe Tool (MPT) processing

Emeraude includes specific treatment for the Schlumberger PFCS, GHOST, and FSI, and the GE Sondex MAPS suite: the CAT, SAT and RAT tools. Image views are created and cross sections displayed at any depth and for any combination of passes. A process fits the discrete measurements with relevant 2D models, contingent to user-defined constraints on segregation, phase presence or other tools. The output can be presented for QA/QC and results compared with the raw data. Average values of phase holdups, mixture velocity, and phase rates are produced and serve as input to the interpretation.

Pulsed Neutron Log (PNL) interpretation

Clean formation and shaly single / dual water models are available. Channels may be estimated from correlations or loaded from other openhole interpretations. Classical crossplots can be created to obtain or correct estimates. Time-lapse presentation can be generated.

Selective Inflow Performance (SIP)

SIP can be made with a few clicks. Pseudopressures are used for gas. An unlimited number of SIP's can be created and compared. Each zone can be assigned a different model: straight line, c&n, or Jones. The SIP can use the total rate, a phase rate, or the total liquid rate. Data may be downhole or from surface. Pressure datum correction and composite IPR's are available.

Temperature models and DTS

Emeraude offers a segmented model and an energy model. The analytical segmented model accounts for enthalpy balance in front of inflow zones, and conduction / convection between. Joule-Thomson effects are calculated from a user estimated pressure drop. The numerical energy model solves the full energy equation in the wellbore and the reservoir, accounting explicitly for the thermal effects within the reservoir. Both models can be used for the analysis of DTS data, standalone temperature logs, or to replace a faulty or blinded spinner.

Test design

Tool responses can be modeled for any particular flow scenario. The simulated channels take into account the tool specific response, its resolution and the noise. Packer leaks and steam injection can be simulated.

Formation test data QAQC

Reservoir pressure, permeability and mobility may be loaded. Quality indicators can be added at any depth. Lines can be calculated or drawn, gradients and fluid contacts can be calculated.

APERM

This method corrects, with the PL interpretation, the open-hole effective permeability. It uses an IPR relationship where the relevant reservoir or perforation parameters are defined zone by zone. The method is implemented for single-phase liquid, liquid mixture, or for gas using pseudopressures.

Steam-injection

This special analysis uses a dedicated 2-phase steam-water PVT for the design of steam-injection tests. The temperature, pressure, holdup, and velocity profiles are calculated from surface, to come up with the property of the injected fluid in each zone. Relevant slip models are considered.

Output / Export

Emeraude log channels can be exported in LIS, LAS, or ASCII format. Log tracks and X-Y plots can be copied to the clipboard as a bitmap or a Windows Metafile. Fonts, scales and grid lines can be modified. API logs can be produced. A built-in report can be printed and previewed that includes predefined sections. It is possible to produce a report in MS-Word[™] using the OLE[™] interface of Emeraude. A template MS-Word[™] report is installed and can be customized as required. All reporting and exporting features are accessible with the free reader.

KAPPA Viz (Kv): Visualization and Collaboration





FEATURES

- 3D visualization of any reservoir and well object from the seismic block through to wells, simulations and logs.
- Collaboration in virtual rooms
- Massive objects handled over narrow bandwidths
- Animation of time dependent properties
- Works on Windows[™] and iPad[™]

KAPPA-Viz is the virtual visual meeting place for any 3D object generated by KAPPA or any third party application. This Client-Server solution offers virtual rooms where Giga or Terrabyte objects can be shared between PC and iPad users over an intranet or very narrow internet bandwidths.

KAPPA-Viz can handle objects of any size and format from any source. KAPPA objects, such as numerical models from Rubis, Topaze and Saphir, or production logs from Emeraude are imported by a single drag-drop either locally from Ecrin or from KAPPA Server. Third party objects, such as seismic blocks, geomodels, simulations and logs are handled by a series of plug-ins. The massive processing is handled on the KAPPA-Viz server, the manipulation and visualization is handled 'light and local'.

When a new object is imported, whatever the size, KAPPA-Viz will create a low-resolution 3D rendering. In the hands of the user this allows smooth manipulation of the actual massive object. It is simplified as much as possible, but no further. There is just sufficient information to manipulate the object in 3D, although many orders of magnitude more data are held in store that is equally accessible and useable. When the manipulation ceases the full high resolution image is populated by the server and immediately presented to the user. Users, wherever they are, enter virtual rooms where they can share, overlay, manipulate and animate any object or objects describing the reservoir in real time on iPad or PC. When the object is a KAPPA analysis a handle appears on the relevant well(s) that opens the corresponding analysis on a click or touch.

LEARN MORE



VISUALIZE

Unconventional resources



FEATURES

- Shale gas, shale oil and CBM
- Analytical horizontal multifrac models
- Numerical non-linear model
- KAPPA Unconventional Resources Consortium (KURC)

Unconventional Resources occur in ultra-tight formations in which we need to create a large interface area by massive fracing. Simultaneously the PVT behaviour is exotic with extreme pressure gradients and compressibility changes. 'All' the industry needs to do is model these mechanisms to accurately book reserves and predict production.

KAPPA is the first to admit it does not have all the answers. Nobody has.

Unconventional Resource modeling is a key R&D focus for KAPPA. Currently available in the suite are both analytical and numerical horizontal fractured well models. The latter includes adaptive superfine gridding and non-linearity. However, to believe that what exists now is the model on which to base all future predictions would be foolish.

Research is underway in partnership with more than twenty of the major OPCOs and Service Companies in the KAPPA Unconventional Resources Consortium (KURC). This is a not-for-profit group that has brought together the best experience and practise in the industry to move the development of tools forward and test them against real data as it becomes available. Membership of the consortium brings a three-year exclusivity on developments.

LEARN MORE



ANALYZE

Numerical modeling at the heart of the KAPPA suite



FEATURES

- Interactive build tools
- Automatic grid
- Flexible, coherent upscaling on any time scale (PTA/PA/full field)
- Horizontal well model; any trajectory, any layering

A numerical model should be quick and intuitive to build, allowing users to solve day-to-day problems without deep specialist simulation knowledge. Developed at the core of the workstation the automatic unstructured Voronoi grid tips conventional model building on its head. The model is simple to build using interactive geometry tools or by importing from geomodelers. The grid is then filled automatically into the created space, freeing the mind to concentrate on the physical problem with a turn around of minutes rather than hours or days.

By using flexible upscaling the same grid can be used at the different time scales demanded by transient, production and full field analysis. This, for example, allows the user to grab a sector from the full field model for transient analysis or transfer the model between various analyses by seamless drag-drop.

Using the same grid we can therefore progressively see from extremely close to the wellbore, as in a formation test or unconventional resource analysis, progressively deeper into the reservoir to observe the effect of other wells and the boundaries, all with perfect coherence.

In the latest development the Voronoi grid has been adapted to extreme geometries to enable the analysis of true horizontal wells. The wriggly well model handles any well trajectory across any stratigraphy. Numerical models may be exchanged between Saphir, Topaze and Rubis with the model grid dynamically adapting to its new environment. Although analytical models are still an integral part of the workflow and remain under active development, numerical models are at the core of the suite and of increasing importance. Without the numerical capability rigorous treatment of certain cases, especially unconventional resources, would not be possible.

Well models calculated by Amethyste can be sent to and used by Saphir, Topaze and Rubis.

The KAPPA numerical model

The basic premise of the Voronoi numerical model is that the grid is a necessary evil and that the engineer's focus is the physical problem. We simplify and automate as far as possible. The sequence shows the workflow in this example of building a simple 2D model that might be utilized in Saphir and Topaze.

- 1. Define the reservoir boundary, the wells and faults using interactive drawing tools overlaying a scaled bitmap representing the reservoir.
- 2. Define composite zones, thickness, porosity and permeability fields
- 3. The grid fills the area automatically.
- 4. During and post-simulation the static and dynamic properties can be visualized and animated in 2D, pseudo-3D and 3D.
- 5. At each well, the 2D unstructured grid is replaced by a 3D unstructured grid as needed, for example, in the case of a limited entry or horizontal well.
- Vertical and horizontal anisotropy can be introduced.

When extending into 3D in the Rubis model, strata and gravity are added. Alternatively horizons, volumes and static properties can be directly imported from Geomodelers such as Petrel[™] using GRDECL or CMG formats. By extension, the numerical model is the tool for the non-linear case in PTA and PA including real gas diffusion, multiphase flow, water and gas injectors, water drives, non-Darcy flow (Forscheimer), unconsolidated formations, desorption and extreme compressibility environments found in unconventional resources.

The KAPPA numerical modules use the same technical kernel and the same basic reservoir grids with flexible upscaling adapted to very different requirements around the well.

Considering the case of a horizontal well, PTA needs very significant refinement, with around two thousand cells to perfectly simulate the different 3D flow regimes on a loglog scale. PA only requires a detailed 2D or limited 3D representation with around 300 cells around the well. Whilst HM time steps, being days or weeks, require very coarse grid with only six cells being sufficient.

Comparing these three different refinements on a loglog scale shows that all responses merge on a reference analytical model after a time adapted to the required minimum time steps. The 'trick' is that rather than using an analytical well index, before any run coarse grids are calibrated with a refined PTA grid with a small single phase simulation around each well. The value of the coarse grid well index is adjusted to match the long-term productivity of the refined grid. Numerical problems can therefore be transferred between modules, upscaled or downscaled, whilst remaining consistent.











E < 0 &

Visualization options

Technical references

PVT correlations

Gas	Z	Dranchuk, Standing, Beggs & Brill, Hall-Yarborough, Dranchuk & Abou-Kassem, Span-Wagner (CO2)		
	Viscosity	Lee et al., Carr et al., Lee compositional		
	Pb & RS	Lasater, Vasquez & Beggs, Standing, Glaso non volatile, Glaso volatile, Lasater-Standing, Petrosky & Farshad, Kuparuk, South brae		
Oil	Bo Standing, Vasquez & Beggs, Glaso, Petrosky & Fa Kuparuk, South brae			
	Со	Petrosky & Farshad, Vasquez & Beggs		
	Viscosity	Beggs & Robinson, Beal		
	Rsw	Katz, Meehan & Ramey, Spivey, Haas, Culberson & McKetta		
14/	Bw	Gould, McCain, Meehan & Ramey, Spivey		
water	Cw	Dodson & Standing, Osif		
	Viscosity	Van-Wingen & Frick, Meehan & Ramey, Helmholtz, Matthews & Russel		

Pressure drop correlations

Artep	Liquid-Gas	Mechanistic	Any angle
Aziz & Govier	Liquid-Gas	Mechanistic	Vertical
Beggs & Brill	Liquid-Gas	Empirical	Any angle
Brauner	Liquid-Liquid stratified	Mechanistic	Deviated
Choquette	Liquid-Liquid	Empirical	Vertical
Dukler-Eaton	Liquid-Gas	Empirical	Horizontal
Duns & Ros	Liquid-Gas	Empirical	Vertical
Hagedorn & Brown	Liquid-Gas	Empirical	Vertical
Kaya et al	Liquid-Gas	Mechanistic	Any angle
Orkiszewski	Liquid-Gas	Empirical	Vertical
Petalas&Aziz	Liquid-Gas	Mechanistic	Any angle
Stanford	Liquid-Gas & 3-Phase	Drift flux	Any angle
Taitel & Dukler	Liquid-Gas	Mechanistic	Vertical
Zhang	3-Phase stratified	Mechanistic	Deviated
Baxendell & Thomas	Liquid-Gas	Empirical	Vertical
Chierici et al	Liquid-Gas	Empirical	Vertical
Cornish	Liquid-Gas	Empirical	Vertical
Fancher & Brown	Liquid-Gas	Empirical	Vertical
Gray	Liquid-Gas	Empirical	Vertical
Griffith et al	Liquid-Gas	Empirical	Vertical
Poetmann & Carpenter	Liquid-Gas	Empirical	Vertical
Reinickle & al	Liquid-Gas	Empirical	Vertical
Hasan & Kabir	Liquid-Liquid	Mechanistic	Deviated

Built-in analytical models

	No storage
Wellbore	Constant storage
models	Changing storage (Fair, Hegeman, Spivey packer, Spivey fissures)
	Finite radius
	Fracture - uniform flux
	Fracture - infinite conductivity
	Fracture - finite conductivity
Well	Horizontal
models	Limited entry
	Slanted fully penetrating
	Slanted partially penetrating
	Multi-fractured horizontal
	Time dependent
	Constant
Skin	Rate dependant
models	Time dependant
	Homogeneous
	2-porosity P.S.S.
	2-porosity transient sphere
Reservoir	2-porosity transient slab
models	2-layer with X-flow
	Radial composite
	Linear composite
	Areal anisotropy
	Infinite
	Single sealing fault
	Single constant pressure fault
	Closed circle
Boundary	Constant pressure circle
models	2 parallel faults
	2 intersecting faults with any angle Rectangle
	Composite rectangle
	Leaky fault
M 14:1	Commingled production
Multilayer	Layered pi
	Packer-probe interference with storage and Skin
Formation Testers	Probe-probe interference (0, 90, 180 °) with storage and Skin
	Probe-probe and packer-probe interference in multi-layer reservoirs

External analytical models (download)

2-layers with X-flow & radial composite
2-layers with X-flow & 2-porosity
2-porosity & radial composite
2-porosity with Skin at matrix blocks
3-porosity (1 fissure and 2 matrices)
3-layers & 4-layers with X-flow
4-layers with X-flow in closed system
Slanted well in multi-layer reservoir
Conductive fault
Horizontal well with finite conductivity
Fractured horizontal well (identical of different fracs)
Multi-lateral well
Reservoir pinchout
3 & 4 zones radial composite, infinite or closed circle
Multi-zone linear composite
Limited entry fracture
Radial composite fracture (with fracture extending beyond
the composite zone)
Triple porosity + double porosity model
Triple porosity and limited entry flow model
Fractal reservoir

Built-in numerical models

User defined reservoir contour in the X-Y plane
Any contour segment sealed or at constant pressure
Inner faults with individual leakage factor
True double-porosity model (duplication of grids)
Composite regions with associated diffusivity,
storativity & individual double-porosity models
Horizontal & vertical anisotropy
Varying thickness, porosity and permeability fields
Conductive faults
Multiple wells with flexible upscaling
Optimal upscaling
Fractured well with finite & infinite conductivity
Limited entry vertical well
Fractured well with limited entry
Fractured horizontal well
Changing wellbore storage (Saphir only)
Time-dependent & rate-dependent Skin
Saphir and Topaze: slightly compressible liquid
Non-Darcy flow for gas (NL)
2-phase W-O and W-G (NL)
Real gas diffusion (NL)
Water influx (NL) : Carter-Tracy, Fetkovich, Pot,
Shiltius, Numerical
Multilayer : crossflow, multiwell, partial completion
Horizontal and limited entry wells in multilayer
Fractured well in multilayer
Composite multilayer
Gas desorption (with or without diffusion)
Unconsolidation in fractures and/or matrix
Thermal single phase & multiphase modeling (Rubis)

www.kappaeng.com

Corporate office

France - Sophia Antipolis Support and Development KAPPA Engineering SA TEL: +33 4 8986 9600 support@kappaeng.com

Sales, Training and Consulting

UK - Reigate

KAPPA TCS Ltd TEL: +44 1737 245444 sales@kappaeng.com tcs@kappaeng.com

Regional offices

USA & Latin America - Houston KAPPA North America Inc. TEL: +1 713 772 5694

Middle East Asia - Bahrain KAPPA MEA W.L.L. TEL: +973 17 229 803

Russia - St Petersburg KAPPA FSU OOO TEL: +7 812 332 2005