Fekete NEWS

Engineering and Business News from Fekete Associates Inc. Winter 2004

Additions to F.A.S.T. RTA™

We have numerous new features slated for the next release of F.A.S.T. RTA™. Among them are numerical models, wavelet decomposition smoothing and enhanced results visualization (mapping).

AUTHOR

Dave Anderson is a senior technical advisor at Fekete and leads the F.A.S.T. RTA™ development team.

Numerical modeling capability will complement our extensive suite of analytical models and allow the user yet another method with which to compare results in an advanced decline analysis scenario. Traditionally, numerical modeling of reservoir flow has been the sole territory of reservoir simulation. However, with recent advancements in automatic gridding and ever increasing computing power, numerical models are becoming as practical and efficient for single well production history matching as their analytical counterparts. In particular, numerical models offer more versatility in modeling of asymmetrical

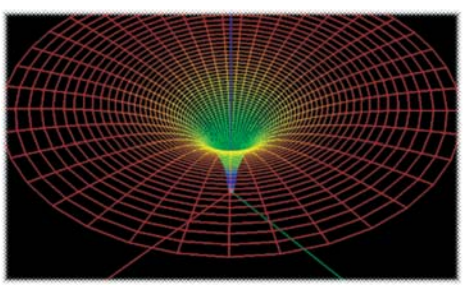

Fig. 1 | Pressure Profile from Numerical Model

boundaries, reservoir heterogeneities and multi-phase reservoir flow. In addition to numerical models, three new analytical models will be available: radial composite, multi-layer and dual porosity.

Wavelet decomposition is a cutting edge technology used in signal processing. It has proven application for noise reduction of well test data. Our new and highly visual "Smoothing and Filtering" section will allow the user to easily and efficiently apply wavelet techniques to smooth the production data signal

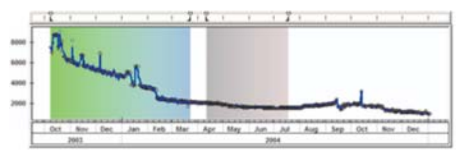

Fig. 2 | Filtered Data

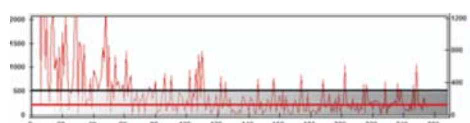

Fig. 3 | Wavelet Decomposition

(both rates and pressures), prior to analysis. Wavelets also work excellently as an "outlier detection" tool, which allows the user to quickly and automatically identify and eliminate "off trend" data points.

Visualization of results is a new enhancement that allows the user to quickly access visual F.A.S.T. RTA™ results on a field-wide basis. Consider the power of being able to rapidly produce colour permeability gradient maps, or drainage area bubble maps (to name a few) for a 100 well project in which you have just completed the rate transient analyses. Use bubble and gradient maps in combination with

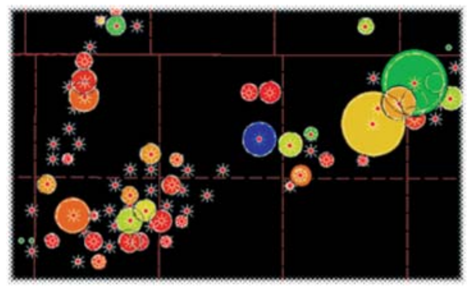

Fig. 4 | Visualization of Results

geological and pipeline maps to identify drilling targets. Since the mapping follows performance-based reservoir analysis, it offers a quick insight into potential field optimization and development.

Some additional features planned for the release include :

- Gas condensate recombination.
- Flowing Material Balance for solution gas drive reservoirs.
- Time re-initialization for type curve analysis.
- Enhancements to Traditional Page (segmented analysis, group production decline plots).
- Calculation of abandonment pressure, EUR and critical liquid lift rates for advanced methods.
- Wellbore enhancements (allow flow path variation with time, fluid levels for pumping wells). ■

INSIDE THIS ISSUE

TECH TALK: Gas Gathering System Model of a Coalbed Methane Field

AUTHOR

Trevor Thompson is a project engineer at Fekete and leads the F.A.S.T. CBM™ development team.

Introduction

Production engineers have always been faced with the challenge of trying to design or optimize pipeline systems for gas fields. Although this can be a difficult process in conventional gas fields, it is often more difficult in coalbed methane (CBM) fields. CBM fields present different challenges, which are related to the following:

- Gas storage mechanism
- Water production
- Isotherm/desorption pressure
- Relative permeability of gas and water

The gas storage mechanism of CBM reservoirs is significantly different from that of conventional gas reservoirs. Gas in conventional reservoirs is stored in the pore space and can often be modeled using tank-type or transient models. In CBM reservoirs, the gas storage mechanism is adsorption and most of the gas is stored within the 'matrix', not the pore space (cleats).

In an undersaturated coalbed methane reservoir, the pore space (cleats) of the coal is initially filled with water. Before any gas can be produced from the reservoir, it must be depressured by producing water. Even after sufficient water has been produced to reach the desorption pressure, the reservoir must continue dewatering in order to produce gas. This phase of dewatering is often called the 'negative decline'. During the negative decline period, gas fills up the pore space, displacing water to the wellbore. As the proportion of gas increases in the pore space, the gas rate increases because gas becomes more mobile and water becomes less mobile. Relative permeability curves denote the mobility of gas and water at different saturations. Fig. 1 shows the lifecycle of an undersaturated CBM well.

Although many conventional gas reservoirs produce water, the rate of water production from these reservoirs tends to increase near the end of the well's lifecycle. This contrasts with CBM reservoirs where the water rate decreases continuously. Water production from conventional wells is often assumed to be constant when modeling conventional gas gathering systems. During the initial production phase, an undersaturated CBM reservoir will only produce water.

The isotherm controls the pressure at which the gas is released from the coal (desorption pressure) and the quantity of gas that will be released from the coal. Once desorption pressure is reached, gas will be released from the coal and into the cleats. In a conventional tank-type reservoir, the recovery of gas as a function of pressure tends to be linear, or very close to linear. The isotherm for a CBM reservoir can be very non-linear, and the quantity of gas released (per unit drop in pressure) can be much larger at lower reservoir pressures. Fig. 2 demonstrates the effect of the isotherm on gas recovery.

Fekete's F.A.S.T. CBM™ software incorporates the aforementioned characteristics of CBM wells, and can be used to predict future gas and water production at any specified flowing pressure. With the increased demand for modeling CBM gas gathering systems, Fekete has integrated the CBM reservoir model into our in-house version of FAST Piper™ (gas gathering system modeling program). The integration of the CBM module with F.A.S.T. Piper™ software now allows us to predict interactively the total gas and water production of an interconnected network of CBM wells, while incorporating compressor capacity curves, facility losses, and pipeline friction losses.

One of our largest and most complex CBM projects was recently modeled using our CBM module with F.A.S.T. Piper™ software. This article describes the project, the methodology used to complete the project and the benefits of using our analytical CBM model in F.A.S.T. Piper™.

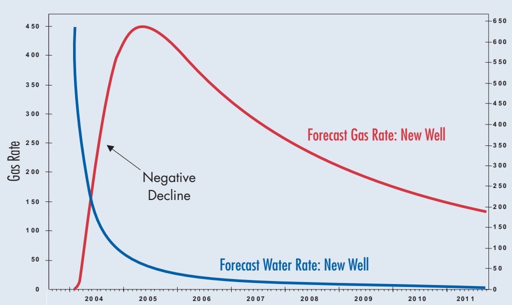

Fig. 1 | Gas & Water Rates vs. Time

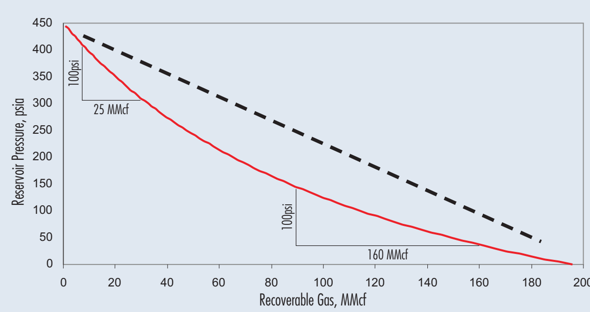

Fig. 2 | Non-Linear Gas Recovery

General Project Description

The project consists of 400 wells that are connected by 200 miles of pipeline. Most of the gas is compressed at a central compressor station using five 3-stage compressors. Within the field, there are 3 field compressor stations that take gas out of the gathering system and send it to an adjacent field.

The object of the project was to determine existing bottlenecks in the gathering system, and estimate future compression and pipeline requirements for a 200-well drilling program.

Reservoir Characteristics

The wells in this field normally produce from 3 coal zones, the upper zone is 500-800 feet deep, the middle zone between 900-1400 feet, and the lower zone is 1200 and 1800 feet. The upper and middle zones are the most prolific zones in the field. The lower zone tends to have much less permeability and does not contribute significantly to production.

Because of the large separation between zones, the reservoir pressure and the gas content for each of the zones varies greatly.

CONTINUED...

During a preliminary review of the production data, several wells exhibited production profiles indicative of multi-layer production. Fig. 3 is an example of this behavior.

In Fig. 3, at the point where flowing pressure increases by 80 psi (as a result of a rising fluid level), the gas production decreases by approximately 40%. The data indicates that the flowing pressure increased to a pressure higher than the desorption pressure of the middle zone, while it remained below the desorption pressure of the other two layers.

Fig. 3 shows that : a) the middle zone is not producing at all during this period, b) the high pressure lower zone is hardly affected and is still contributing (though only to a small degree, because of its much lower permeability) and c) the low pressure upper zone is producing the majority of the gas. This behavior shows the significant effect that a change in flowing pressure can have on a well's production characteristics, and demonstrates

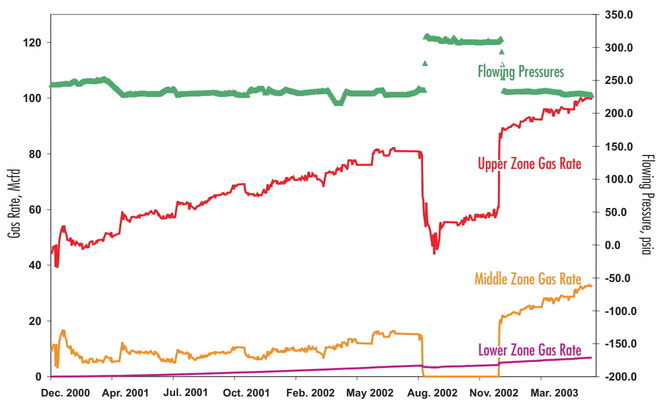

Fig. 3 | Historical Rates vs. Time

the need for watching the line pressures during field development.

Reservoir Methodology

This CBM field is relatively new and little reservoir modeling had been conducted in the area prior to this project. Although the client supplied much of the data, some key parameters had to be determined by conducting a preliminary reservoir study. One of the more important parameters that needed to be determined was the relative permeability curves.

To successfully accomplish the history matching process, we started in an area where some of the wells had been completed in only one zone. These wells allowed us the opportunity to isolate the production characteristics for each of the zones, and thereby determine the reservoir parameters for the individual zones. A production characteristic that was particularly helpful in establishing reservoir parameters was a gas rate that was declining as a result of depletion. Wells that had sufficient permeability and production to establish a pattern of drainage areas, allowed us to obtain an unique solution, and thereby establish confidence in the relative permeability curves and porosity.

The analysis started by history matching the data using the analytical CBM reservoir model. Several wells were history matched simultaneously to determine the porosity, drainage area, relative permeability and absolute permeability. This process resulted in a single set of relative permeability curves, and a consistent value for porosity, that we could use for all of the wells in the area. By using the established relative permeability and porosity across the entire field, we were able to history match all 400 wells. The results demonstrated consistency, and several permeability trends could be observed throughout the area.

and a consistent value for porosity, that we could use for all of the wells in the area. By using the established relative permeability and porosity across the entire field, we were able to history match all 400 wells. The results demonstrated consistency, and several permeability trends could be observed throughout the area.

The drainage areas determined via history matching were also consistent with the drilling spacing for the area. Fig. 4 shows these drainage areas for the upper zone, and the colour coding represents the permeability of each area.

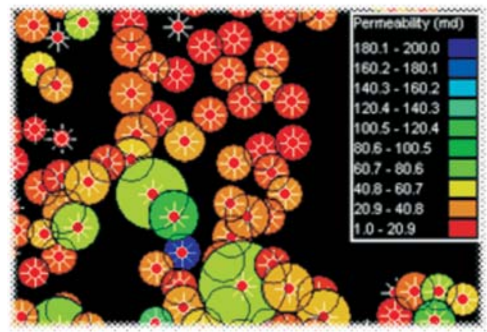

Fig. 4 | Drainage Areas and Permeability

Wells that were still in the early phases of production, and had not yet experienced a decline in gas rate, were assigned a drainage area equivalent to their respective drilling spacing. Fig. 5 is an example of a well that has not reached peak gas rate. The forecast shows that the gas production will continue to increase for a year and a half, as the well continues to de-water.

Forecasting

With the completion of the history matching exercise, all of the reservoir information was automatically imported, seamlessly, from F.A.S.T. CBM™ into F.A.S.T. Piper™. This included the isotherm data, initial gas contents, initial pressure, porosity, permeability, relative permeability, drainage area and cumulative gas and water production.

A base case forecast was generated to determine how the field would perform with the current pipeline and compressor capacity. This base forecast was validated by comparing it to the historical gas and water production for each well.

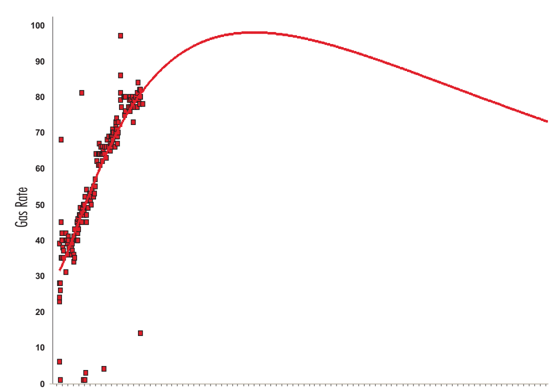

Fig. 5 | Gas Rate vs. Time

CONTINUED...

After confirming that the model was producing the expected results, three additional scenarios were conducted. These scenarios included the same 200-well proposed drilling program. However each case incorporated different compression and pipeline scenarios. Fig. 6 shows the resulting forecasts. Some interesting observations can be noted from these development scenarios:

- Gas production rates continue to increase *after* the drilling program has ended (Jan. 2005), even though no new wells are added and no new optimization is performed on the system. This increase in gas rate reflects the continued dewatering of new drills (the mechanism of Fig. 5). This continual increase in gas rate *after* the end of drilling contrasts the behaviour of conventional gas reservoirs (where decline sets in immediately).

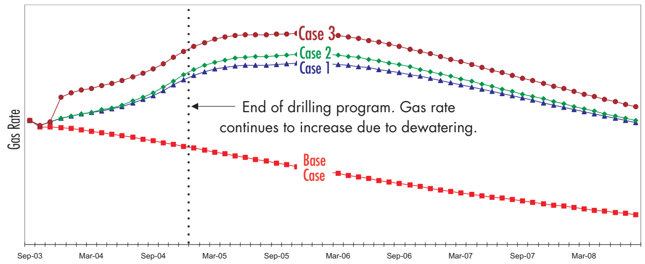

Fig. 6 | Development Scenarios

- The only difference between Case 1 and Case 2 is the addition of compression. There is an obvious uplift in gas rates due to compression, and this uplift demonstrates the link between the reservoir model and the gathering system model. This uplift is easily quantified for economics.
- The difference between Case 2 and Case 3 illustrates the effect of wellbore optimization. Case 3 is the same as Case 2 but the fluid level in the wellbore is lowered by more effective pumping of the water. The economic benefits of wellbore optimization can now be quantified.

Modeling Conclusions

The benefits of coupling the analytical F.A.S.T. CBM™ reservoir module with the F.A.S.T. Piper™ gathering system software are:

- A stand-alone analytical CBM reservoir simulator is maintained. This easy-to-use module allows you to focus on the reservoir and understand its characteristics, without having to worry about the complexities and variability of the gathering system.
- Data transfer from the CBM reservoir module into the gathering system model is seamless, and speeds up the project.
- The integration of F.A.S.T. CBM™ and F.A.S.T. Piper™ allows you to simulate the complexities of field operations. The sensitivity of production forecasting to variations in pressure is easily evaluated. All aspects of a CBM system can be accounted for (i.e. compressor capacity, friction losses, facility losses, and wellbore optimization).
- Incremental gas production can be easily quantified for economics evaluation.
- Prior to incorporating the analytical F.A.S.T. CBM™ module into F.A.S.T. Piper™, a CBM gathering system of this size could not be easily modeled. Incorporating the F.A.S.T. CBM™ module into the F.A.S.T. Piper™ program has helped us significantly reduce the time that it would normally take to model such a large CBM field.

What's News at Fekete

Fekete Technical Video Series

In December 2003, Fekete mailed out, to more than 10,000 engineers and technologists, a CD that included a technical talk on wellbore dynamics. The talk was given by Louis Mattar, president of Fekete Associates. We received many positive comments from viewers, and are happy to announce the development of more videos in the near future.

The next video in the Fekete Technical Video Series is a talk presented by Dave Anderson, a senior technical advisor at Fekete. Dave has been involved in the development of the F.A.S.T. RTA™ software since its inception, and has taught a number of courses on advanced decline analysis. His talk looks at the differences between pressure transient analysis, traditional decline analysis, and advanced decline analysis. He examines the benefits and limitations of each method and lays out a strategy to incorporate all three data evaluation processes. Dave's talk is entitled "Getting The Most Out Of Your Production Data".

If you missed Louis' video and would like a copy, or wish to ensure that you are on our mailing list to receive future videos, please contact Amanda Potts, Fekete's customer service representative, at 1-800-625-2488.

Here We Grow Again!

In response to the ever growing needs of our clients, Fekete Associates now employs over 100 people. With growth in every group in the company, the Regulatory Applications group has seen the largest growth over the past three months. This increase is attributed to the high activity level in the industry as energy prices remain strong.

Another high growth area is the Pipeline Modeling group. Dave Lillico and his staff have travelled across North America completing studies from 50 to 2500 wells. With many clients running aggressive drilling programs, Dave's group ensures that pipeline and compression requirements are determined before wells come on production.

For more information on any of Fekete's engineering services, contact David Dunn at 1-800-625-2488.

Course Schedule

The 2004 Fekete software course schedule is now available. There are twenty public courses available throughout the year in Calgary, Denver, and Houston. Our courses are taught by Fekete engineers who are exposed to the research, development, and use of the software with their everyday project work.

More information is available on Fekete's website at www.fekete.com, where you can register for courses online. If you have any questions, e-mail us at courses@fekete.com.

Fekete Associates Inc.
Suite 2000, 540 - 5th Avenue S.W.
Calgary, Alberta, Canada T2P 0M2

Phone: 403 213 4200
Fax: 403 213 4298
Toll Free: 800 625 2488
Email: fast@fekete.com
Web: www.fekete.com