

Current Trends in Reservoir Evaluation

Gary Metcalfe, Fekete's VP of Reservoir Evaluations, has been conducting economic evaluations for 20 years and, as he notes, the only constant is change. Gary has seen the enormous change in the speed that acquisition evaluations are completed. Unfortunately, in the rapid deal-making, there have been a number of "trainwrecks". The current trend is for fuller disclosure to provide investors, and particularly foreign acquirers, with a better understanding of the underlying risk factors and range of uncertainty in reserve values and production forecasts.

Dale Struksnes, of Fekete's Reservoir Evaluation Group, presented a talk to the CAPL Prospect Exchange Forum in April 2001 on the proposed revisions in public disclosure of reserve information that have been recommended by the Alberta Securities Commission (ASC) Taskforce. The Society of Petroleum Evaluation Engineers (SPEE) is currently publishing their Recommended Evaluation Practice program, which is a guide on how to treat certain reserve evaluation issues (i.e. should price hedging be included?, what BOE equivalent factor should be used?, what discount rates should be reported?). Also, the Canadian section of the SPEE is preparing a standard "Canadian Oil and Gas Evaluation Handbook".

There are a multitude of issues at stake:

- New disclosure rules to minimize "train wrecks" and protect investors.
- Treatment of uncertainty in reserves.
- Due diligence concerning sources of capital and financial ability of the client to exploit proved undeveloped and probable reserves.
- Increase emphasis on after-tax valuations.
- Phase-in of independent reserve evaluations for large (>100,000 boepd) companies.

So, what will the "new" reserve report look like? At this point, we are not anticipating a lot of changes. Our reports will continue to be documents which quantify and value reserves based on existing and factual data and which will continue to meet ASC and SEC requirements. The key intent of the new regulations is to tighten the range of reserve assignments amongst independent evaluators. Certainly there will be greater scrutiny by the evaluator on the company's financial capabilities to develop and realize cashflow from probable reserves. A company

cannot push probable reserves forward with no real capital for a development program. The BOE issue is intriguing. As companies go from a 10:1 to 6:1 factor, the reserves instantly go up (yeah!) but F&D and operating costs per BOE also go up (ouch!). People will need to learn a whole new set of benchmark metrics. We strongly recommend that abandonment/reclamation liability be included in the evaluation process.

Value Reporting

Eventually, the new regulations will prevent a repetition of past problems but do they meet the future needs of the oil companies? Companies may have exploration potential which can represent significant upside, but the hydrocarbons associated with these plays cannot be included within the constraints of the securities exchange rules for standard reserves evaluations. Remember, evaluators can not create reserves.

Borrowing a concept from the accounting profession called "Value Reporting", we recommend publishing a separate report which evaluates potential reserves and provides an independent opinion as to the upside exploration potential for undrilled lands. The value reporting concept advocates providing the investor with more than the minimal information required for public disclosure. For example, a reserve may be stranded due to lack of facilities. No economic value is given, however, there is value to our client who has a long term plan and can wait several years for the infrastructure. To some extent, annual reports and press releases are value reporting. An independent report would provide greater certainty to the investor and a firmer share price to the oil company.

New Evaluation Technology

"Straight-line" methods (decline analysis and P/Z) have, by definition, limited applicability. In particular, decline analysis assumes pseudo steady-state flow (i.e. nobody will ever drill an offset well!). Fekete is advancing rapidly with a combination of new software tools in areas of reservoir (formerly "well") testing, decline curve analysis, deliverability forecasting (incorporating multi-well pools, pipelines, plants and compressors), material balance (communicating reservoir models) and risk assessment (exploration/frontier/international plays). Our vision is an integrated asset model that will accurately and dynamically model future production.

Fishing for Deals

We have seen the "reserves are like fish" analogy. Here's some more fun. Does your acquisition team have one of these?

Accountant: will always try to spoil your fun by telling you that, including your time/gas/equipment depreciation/tirewear/etc., that fish just cost you \$500 per kilogram.

Team Player: always willing to share credit for your "catch".

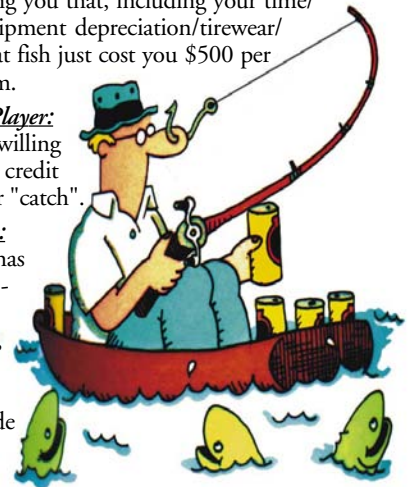
Lawyer: always has an alibi - trolling too fast, the fish are on your side of the boat.

Decision Maker: knows every reason why you are catching fish and he is not.

Scientist: decides to change lures after every two casts.

Scientist: measures air and water temperature, monitors wind speed and direction, light and water conditions, develops equations and plots on graphs and decides where to fish and what lure to use, all just in time to go home.

Enjoy your summer fishing and when you return to work this fall, remember that Fekete's economic evaluations team is at your service!



INSIDE THIS ISSUE

Reservoir Evaluations	1
Tech Talk: A Procedure for Modeling Gas Gathering Systems	2 & 3
Introducing Our Reservoir Evaluations Group	4

NEXT ISSUE

New software!



Ralph McNeil, P.Eng.
Senior Technical Advisor

A gas gathering system model allows us to investigate the complex pressure/rate interactions between reserves, sandface deliverability, wellbore dynamics and surface gathering system regimes. Fekete's engineering staff have conducted hundreds of system analyses. This paper presents a proven, systematic approach to modeling systems based on that experience. The resultant model provides an accurate, "real-life" forecast of future deliverability that is an improvement over decline analysis.

It is not uncommon to hear gas producers complain that the success they had finding gas with the drill bit never seems to be fully translated to sales. Often they will use historical references such as, "sales volumes are expected to increase by only 70%, 50%, or even 20% of the total gas volume added by new wells into the gathering system."

A gas gathering system model can be an important tool for testing the impact of various ideas proposed for optimizing a gathering system. The relationship, as shown in Figure 1, between deliverability (lower pressure to increase production) and the gathering system (increase pressure to increase capacity) is non-linear and opposing. This relationship can lead to the counter-intuitive situation where additional compression is installed to lower well back-pressures with the expectation of increased production, but the lower pipeline operating pressures reduce pipeline capacity and so the well back-pressures are only reduced minimally or worse, increased! Modeling offers the opportunity to test many ideas, virtually, before making expensive capital expenditures to lay pipeline or install compression.

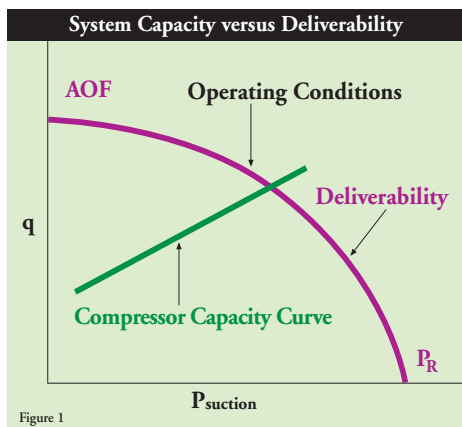


Figure 1

When attempting to build a model to replicate an existing gathering system's behaviour, it is extremely important to first "tune" the model. Tuning requires that, at a minimum, a systematic approach be used to match pipeline pressure losses, each well's deliverability relationship, and each compressor's capacity relationship to current operating conditions.

A gas gathering simulator can be a very powerful tool for evaluation of a system's components and for testing the viability of proposed enhancements, **provided it has been tuned to accurately match current operating conditions.**

The five most common mistakes made after building a model are:

- 1) not tune the model
- 2) assume all the data is representative of true conditions
- 3) assume that all pressure losses are frictional pipeline losses
- 4) not confirm that well deliverability relationships match current operating conditions
- 5) use compressor design curves without confirming their validity with current operating conditions.

It is therefore imperative that a strict procedure be used for the construction and tuning of a gas gathering system model to ensure it will be an accurate and reliable predictive tool. The purpose of this paper is to present a modeling procedure that has proven, through extensive experience by Fekete's engineering staff, to be efficient and effective.

Define Model Objectives

The objectives of any study must be clearly defined before any work begins. It is much too easy to fall into the trap of building a model that attempts to incorporate every aspect of a gathering system, so that everyone can use it, to forecast any possible scenario. The result is usually a model that is always waiting on more data or one that is so complex and demanding of input data (especially revisions) that the quality of the model suffers to satisfy the quantity of input data! If an understanding of the pipeline pressure losses is all that is required, then there is no need to model well deliverability and reserves. If a larger tubing string is proposed for a well, a wellbore simulation is probably all that is required. Defining a set of objectives is not always an easy task.

Specific circumstances can radically change the methodology required. The process of making these decisions requires that the modeler have a thorough understanding of the theoretical and practical aspects of deliverability, reserves, single-

phase and multi-phase pressure loss, compression, and field operations. **Even more importantly, the modeler must thoroughly understand how these relationships interact with each other in a model.**

Accuracy of Data

Getting accurate data for modeling can be a frustrating experience, especially since the source of errors can be varied and hard to predict. A request for data will often pass through several people before being retrieved and returned. Each of these people will apply their own interpretation or understanding to what has been requested, and so the result may not represent the original question. The location of a measurement can have a profound impact on modeling results when the influence of a vessel or valve or other unknown effect has not been included. A common example is a suction control valve for a compressor. Suction pressure is almost always logged, but the pressure upstream of a suction control valve is rarely logged. Pressure loss between the compressor and the first wells in a gathering system can be dominated by the pressure loss taken across the control valve. If not recognized, the pipeline at the inlet to the compressor station could be considered plugged, or too small, or modeled incorrectly with a very low flow efficiency.

There are a couple of ways of dealing with this issue. The first would be to go to the field and measure everything yourself. This is not a practical solution. Another way is to use the data at hand; the daily field logs. Using this data requires a set of rules to judge its usability:

Rule 1. Data accuracy is directly related to its use in calculating other important values. Data collected to calculate revenues are usually very accurate. Data used to calculate expenses less so, and data used to monitor field operations are the least accurate.

Rule 2. Your own measurements are not perfect and you are not infallible.

Rule 3. A measurement without an estimate of its accuracy is useless. The pressure range of a gauge, its type, its condition and the stability of the system pressures are keys to estimating its accuracy.

Rule 4. There is a difference between precision and accuracy

Rule 5. Field log measurements should be used assuming an accuracy of ± 150 kpa (20 psi). The level of accuracy can be narrowed based on observations with model-calculated values while tuning, or after your own direct comparison with deadweight measurements. Measurements based on supplemental deadweight values from a field trip may be accepted as low as ± 35 kpa (5 psi). Tuning to less than ± 35 kpa (5 psi) is not practical.

Field Trip

Experience has taught us that the quickest way to get a modeling project off the ground is to gather recent copies of the Daily Field Reports for each wellsite, and the Daily Logs for pertinent system facilities, especially compressors. This data provides an excellent preliminary source of flowing pressures and gas flow rates. With this information, the modeler can develop a preliminary pipeline model match and a set of notes detailing the poorly understood portions of the gathering system. This stage should be followed up with a field trip. It is very important that the modeler take a prioritized list of objectives as there is usually only a limited amount of time available for onsite work and field staff have very little time to waste. The field trip should start with a visit to the field office. Field staff know their gathering system better than anyone else, so it is important to get their input. The modeler should be equipped with a high quality gauge appropriate for the pressure range expected (a portable electronic deadweight gauge is recommended).

Once the field trip has been completed, the model match can be finalized, and then the model converted to a “live” mode so it can be used to generate a base case forecast as well as any proposed scenarios for optimization.

Performance Tuning

The easiest way to ensure a good model match for a gathering system is to compartmentalize as much of the work as possible. A step-by-step procedure is recommended.

Step 1. Concentrate on matching the pipeline pressure losses to ensure that all excessive pressure losses are understood and modeled appropriately. It is important to remember that pressure loss correlations, especially those for single-phase gas, were developed to calculate pressure losses relatively accurately. Tuning factors such as relative roughness, flow efficiency, effective length and effective diameter can be used to finely adjust those results but must be used with care. Extreme use of tuning factors may result in an excellent match at current conditions but will seriously undermine a correlation’s capacity to predict pressure loss at other conditions. In many situations, excessive pressure losses are not an indicator that the correlation is faulty but that the modeler hasn’t yet figured out the source of the pressure loss. Examples include inaccuracies in the pressure measurements, confusion over the location of the measurement, incorrect pipeline diameters and buildup of non-moving liquids in low-lying portions of the pipeline system.

Step 2. Evaluate well deliverability to ensure the method of calculation chosen actually produces

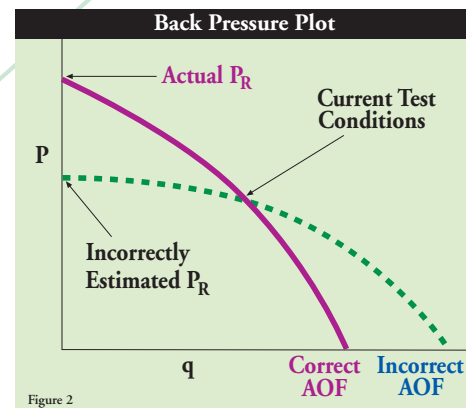
similar if not the same gas flow rates at current flowing pressures as that reported in the Daily Field Reports. There are two main reasons why deliverability is not represented correctly in a model; use of inaccurate or unstabilized deliverability constants and poor estimates of current reservoir pressure. Recent deliverability tests, if properly conducted, and expertly interpreted, can be an excellent source of deliverability constants. However, it is not practical to expect that a recent deliverability test will be available for every well in the system. Therefore, deliverability is best estimated using current flowing conditions rather than using old formal test data that may no longer be representative of current conditions. It is imperative that all deliverability calculations include an accurate estimate of current reservoir pressure. Otherwise, predictions of gas rates at any flowing pressures could be significantly different from reality (Figure 2).

Step 3. Compare compressor design curves with actual performance by plotting current gas throughput and suction pressure on a plot of the capacity curves to ensure modeled compressors match actual field performance. If current conditions do not plot on the capacity curve plot, then the reason must be understood, and a revised set of curves developed that accurately reflect the current operation of the compressor. Common reasons for current conditions not matching design curves are: compressor is run at significantly different conditions than the original design, compressor cylinders were replaced with a larger or smaller set, head-ends have been deactivated for a double-acting reciprocating compressor, multiple compressors may exist in parallel where the curves supplied are for one unit only.

Step 4. All the aforementioned work should be completed separately. After each component is complete, the model can be finalized and checked to ensure it matches current field conditions. If it does not match current conditions reasonably well, then a mistake was made in the process of evaluating each component or in the process of putting all the finalized components together. It is important to not finalize the model until it is capable of reasonably replicating current conditions.

Step 5. If a prediction of future deliverability is required, then a fifth step can be added. Run a Base Case forecast using the finalized model with current estimates of reserves (Initial Gas-In-Place, Cumulative Production, Initial Reservoir Pressure, etc. required to model reservoir depletion), and graph the production forecast of each well on historical production plots. The forecast decline should match the historical decline quite closely.

If it does not, then the reserve calculations should be revisited. Many gas gathering system models have been discounted after much good work because no one took the time to verify that the reserves given would yield a realistic prediction of future gas rates!



Conclusion

A gas deliverability model is a very powerful tool for investigating the impact of various system design changes for a new or existing gathering system. Its optimum usage demands several things:

- The modeler must have a solid theoretical and practical understanding of reservoir, production, pipeline and compression engineering.
- The modeler must define the project objectives very clearly, and only make the model as complicated as is absolutely required.
- The modeler must use a defined procedure that compartmentalizes the work, and includes checks to ensure the finalized model is truly representative of the actual gathering system.
- The modeler should make at least one trip to the field and take pertinent measurements to resolve questions raised by the modeling effort.
- The modeler must have an appreciation for the level of accuracy that comes with each piece of data.

This paper was reprinted with permission of the Journal of Canadian Petroleum Technology, January 2001

Ralph McNeil, P.Eng. is a Senior Technical Advisor at Fekete Associates Inc. He is currently the technical lead of the F.A.S.T. Piper™ Support, Training & Development Team. Ralph has over 20 years of petroleum experience in reservoir engineering, gas gathering system modeling and property evaluations.

Introducing - Reservoir Evaluations Group

In this edition, we would like to introduce the Calgary members of our Reservoir Evaluation Group, who combine their individual expertise in solving a wide diversity of reservoir projects.

Rob Henderson is a core member of Fekete's Reservoir Evaluations group. His primary responsibility is oil and gas property evaluations. He is highly experienced in decline analysis, material balance analysis, waterflood evaluations, deterministic and probabilistic reserve assignments and cashflow forecasts.

Steve Lawton has just recently moved to Calgary from Fekete's office in Australia where he has been for the last 4 years. Steve brought with him practical experience in a variety of projects, including field reserves studies and full-field deliverability studies using analytical and numerical simulation. He has significant expertise in surface facility modelling.

Chad Thompson is responsible for conducting oil and gas property evaluations. He has also undertaken the role of technical support for third party software applications that the group requires to conduct their business. He is involved in the task of taking the evaluations group into the 21st century by keeping up with the new technologies and incorporating them in the day to day activities of the group.

Gary Metcalfe is our Vice President of Engineering and is responsible for Fekete's reservoir engineering and economic evaluation projects. Gary's responsibilities include supervision and preparation of corporate reserve evaluations, acquisition/divestiture evaluations, assessment of development drilling projects including infill/horizontal wells, waterflood studies and performance reviews, gas storage studies and reservoir studies.

Lori Malcolm has just recently joined us as a project technician for the Reservoir Evaluations Group. Lori has worked for several engineering firms throughout her career, and brings her diverse skill set to Fekete.

Dale Struksnes initially worked in Fekete's Production Optimization group for four years, preparing regulatory applications and field studies. Dale moved into the Reservoir Evaluations group last fall, where he conducts oil and gas property evaluations.

Jim Lee, is the Geology Manager at Fekete. His specialities include log evaluation, reservoir modelling, property evaluation, resource assessment and risk analysis.

David Dunn is a Partner and Vice President of Fekete Associates Inc. He is responsible for coordinating and directing Fekete's Reservoir Evaluation and Production Optimization groups as well as overall business development. His hands-on approach and ability to sort through information results in identifying and resolving complex reservoir issues.

Chris May is the newest member of the group with three years of experience. He is conducting petrophysical analysis, pool mapping and reserve assignments for corporate evaluations.

Linda Greig is our reservoir technician, and is responsible for compiling data and

maps for economic evaluations of oil and gas properties and generating the economics.



*Back row: Dales Struksnes, Jim Lee, David Dunn, Chris May, Linda Greig
Front row: Rob Henderson, Steve Lawton, Chad Thompson, Gary Metcalfe, Lori Malcolm.*

With its diverse skills, integrated approach and state-of-the art software, Fekete's reservoir evaluation group is ready to handle everything from your corporate evaluation to waterflood design to acid gas disposal. Call David Dunn or Gary Metcalfe at 213-4200.

FEKETE ASSOCIATES INC.

2000, 540 - 5th Avenue S.W.
Calgary, Alberta, Canada T2P 0M2
Ph: (403) 213-4200 Fax: (403) 213-4298
U.S.A. : 1-800-625-2488
E-Mail: fast@fekete.com

FEKETE AUSTRALIA PTY. LTD.

7, 66 Mill Point Road
South Perth, WA
Australia, 6151
Ph: 08-9474-9622 Fax: 08-9474-9633
E-Mail: fast@fekete.com.au