A Procedure for Modelling Gas Gathering Systems

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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 Often they will use historical references such as, “sales volumes are expected to increase by only 70%, 50%, or even 20% of the total gas volume added by new wells into the gathering system.” In severe cases, new high-pressure wells can cause older wells, especially those with liquid production problems, to shutdown. Operators quickly learn to avoid this situation by choking the new wells. In many situations, this is the best they can do, but it raises a big flag for anyone monitoring daily field logs. Inevitably, the question is asked, “Why are these wells choked?” Unfortunately, the operator can only say that this is what he has to do to avoid killing other wells, whereas, those monitoring the field’s production cannot reconcile why all the new gas added to the system doesn’t show up in the sales reports.

This is a classic case of the confusion that often exists between office and field personnel. It is also a case that could be simulated using a gas gathering system model. A model could be used to demonstrate why new wells may need to be choked but more importantly, it can be used to test ideas for optimizing system production rates.

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, 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! Modelling offers the opportunity to test many ideas, virtually, before making expensive capital expenditures to lay pipeline or install compression that may not increase gas volumes appreciably. Consequently, proposals can be put to the test and can be quantified in terms of incremental gas rates and incremental recovery of reserves.

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. 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, and 5) use compressor design curves without confirming their validity with current operating conditions.

If a model is not tuned then no conclusions about the gathering system’s current operating status can be ascertained, and any forecasts generated from it can only be used for qualitatively predicting production trends. If all pipeline pressure losses are assumed to be frictional, then pipelines may be judged to be operating inefficiently when they are, in fact, operating efficiently, and predicted flowing pressures can be grossly overestimated or underestimated. If deliverability is not modelled correctly, then predictions of deliverability under the proposed scenarios can also be grossly overestimated or underestimated. If compressors are modelled using compressor capacity curves that do not replicate current operating conditions, then suction pressures and throughput volumes can be very difficult to replicate and so future forecasts will not accurately predict throughput volumes and suction pressures.

A gas gathering system 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. 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 work is to present a modelling procedure that has proven to be 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 deliv-
erability and reserves. If a larger tubing string is proposed for a well, a wellbore simulation is probably all that is required. A model should always be constructed to include only those components that are absolutely required to model the key behaviour. Defining a set of objectives is not always an easy task.

A commonly requested objective is to model the impact of adding a booster compressor to lower suction pressures, and consequently increase deliverability and reserve recovery. In this type of case, many of the capabilities of a simulator will need to be used. The key to completing the task in a reasonable time frame and still be accurate, is to know what needs to be modelled very accurately and what needs to be “close enough.” The compressors downstream of the proposed booster must be modelled accurately and must include compressor curves that span all the proposed new operating conditions. The booster can initially be modelled relatively simply as, the objective is to determine its volumetric and driver requirements. Pressure losses in the pipeline system must be very well understood and modelled well enough to replicate pressure losses under proposed new conditions reasonably accurately. In most cases, deliverability can be modelled at the wellhead and the reservoir can be modelled using gas depletion drive. These are general comments on what is commonly done. Specific circumstances can radically change the methodology required. The process of making these decisions requires that the modeller has 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 modeller must thoroughly understand how these relationships interact with each other in a model.

**FIGURE 2: System capacity vs. deliverability.**

Accuracy of Data

Getting accurate data for modelling can be a frustrating experience, especially since the source of errors can be varied and hard to predict. A request of 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 modelling 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 well in a gathering system can be dominated by the pressure loss taken a control valve. If not recognized, the pipeline at the inlet to the compressor station could be considered plugged, or too small, or modelled 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 generally recommended.

**Performance Tuning**

Experience has taught us that the quickest way to get a modelling 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 modeller 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 modeller take a prioritized list of objectives as there is usually only a limited amount of time available for onsite work and field staff has 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. They also need to know when you are in the field, and can alert you to any pertinent situations in the gathering system that may affect your work such as a compressor that went down overnight. The modeller should be equipped with a high quality gauge appropriate for the pressure range expected (a portable electronic deadweight gauge is recommended) and should be directly involved with taking appropriate onsite pressure measurements. 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.

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

**Step 1**

Concentrate on matching the pipeline pressure losses to ensure that all excessive pressure losses are understood and modelled 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 modeller 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 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. Most tests were probably conducted many years ago (five to ten years ago is not unusual) and many were not run long enough to accurately determine stabilized conditions. 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.

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 modelled 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.

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.

If a prediction of future deliverability is required, then a fourth step can be added. Run a Base Case forecast using the finalized model (after completion of the previous three steps) 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 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:

• It requires that the modeller have a solid theoretical and practical understanding of reservoir, production, pipeline and compression engineering.

• It also requires that the modeller define the objectives of the project very carefully, and only make the model as complicated as is absolutely required.

• The modeller 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 modeller should make at least one trip to the field and take pertinent measurements to resolve questions raised by the modelling effort.

• The modeller must have an appreciation for the level of accuracy that comes with each piece of data.

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