Impact of Pipeline Efficiency Improvement on Production and Reserve Estimates

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Abstract

A pipeline efficiency value of 90% is routinely used as a ***"rule of thumb"*** to estimate the production costs associated with gas-gathering systems. The 90% efficiency is appropriate for the development of new gas fields. However, conditions in mature or developing gas fields can dramatically reduce pipeline efficiency and gas-gathering system capacity. These conditions are often overlooked until a significant reduction in daily production has occurred. In order to understand the problem, field conditions that reduce the pipeline efficiency of a gas-gathering system are reviewed with respect to changes in gas production. A field study was performed to identify and correct conditions that reduce gas-gathering system efficiency. The impact of field conditions on line efficiency is examined through computer simulation. Finally, the field study is reviewed in order to show how an increase in line efficiency impacts production and reserves.

Introduction

As reservoir pressure decreases, well production rates decline. The production decline continues for the life of the field or to a point where sales revenue from the field no longer offsets the operating expenses. The life of the field can be extended by employing secondary or tertiary production methods, by optimizing the performance of producing wells, and through in-fill drilling of poorly drained areas. The deliverability of each well is optimized by well simulation, by maximizing pressure drawdown of the sand face, and minimizing pressure drops at the well and surface facilities.[1]

The development of a gas field is an extensive engineering project. Each project associated with field development is performed by discipline. The reservoir engineer estimates the gas reserves; the production engineer develops the operating scheme to optimize production. Facilities engineers design compression facilities and pipeline networks through which the gas is gathered.

A significant amount of time is spent resolving problems associated with reservoir development, drilling and completion methods, and production. Problems occur when the gas-gathering system can no longer handle production as additional wells are completed. Even though the field development program is perfect and wells are completed to perfection, if the gas-gathering system capacity does not keep pace with the production, the field development project will likely yield very disappointing results. The detailed discussion of proper techniques of designing gas-gathering systems is not the scope of this paper. This paper will show the importance of properly designing a gas-gathering system by illustrating how gas-gathering problems impact production and reserves estimates.

Gas Gathering Background

The gas-gathering system can simply be described as a network of pipelines and compression facilities connecting the gas wells to the gas processor or refinery. The operator of the gas-gathering system may be owned by the well operator or may be independent or pseudo-independent of the production companies. The gathering company may charge back to each producing well a percentage of maintenance and expansion costs. In the case of an independent or pseudo-independent gathering company, the gathering company may purchase the gas from each producer and sell to a refinery. Finally, the gathering company may charge each production company based on throughput.

Gathering system expansion must meet similar economic requirements as drilling new wells. One method of improving the economics of a gas-gathering system is by commingling wells to improve the gathering costs. The gas field and gas gathering system are generally well matched when the field is initially developed. As the field matures, original reservoirs become depleted; new high-pressure areas are found and connected to the gas gathering system along with low-pressure wells. However, with each additional well connection, the change in pressure distribution will affect the production potential of existing fields, especially the more deleted fields. The new high-pressure, high-volume wells increase line pressure and create problems for the low-pressure wells.

If the gathering company's income is derived from gas throughput, the focus of the gathering company is in maintaining the maximum efficiency of the gathering system. The justifications for improvements to the gas-gathering system are increasing system efficiency and throughput. However, any expansion or improvement must also be justified with sufficient gas reserves upstream of the pipeline to last the expected life of the gathering system.

When the gathering company purchases the gas from the producer, the gathering company's value can be based in contractually-bound reserves upstream of the gathering system. The greater the increase in reserves behind the gathering system, the greater the gathering company's value. Such a policy can negatively impact producers in pressure-depleted fields when the gathering company focuses on connecting new wells with higher-flowing pressures. The desire to connect wells with high production and vast reserves can decrease interest in producers with wells with smaller reserves and lower production, and can even decrease interest in the producers already connected.

The gathering company can make some allowances by requiring high-volume wells to be choked back to allow production from depleted wells. This production is critical in lease jeopardy or rights- of-capture situations. However, high-volume, high-pressure wells and the depleted wells are not being produced at full potential.

Condensate Problems

When reservoir and production engineers have not taken into account the impact of a production increase from worked over wells and addition of wells to the gathering system, or if facility engineers fail to design gathering system connections, well performance does not achieve the expected results. Poor results lead to a lack of confidence in larger projects that involve reservoir and facilities aspects.[2] Important aspects of the gathering system design and operation are easily overlooked. As the gas field is developed, conditions in the gathering system change. The changes include increased line pressure caused by addition of new wells, condensate in the transmission lines, deterioration of the gathering system and compression equipment, and changes in gathering system operation philosophy resulting from economics or ownership.

The presence of liquid in a gas-gathering system is undesirable but is a common problem in most gas-gathering systems. The facilities are tailored to improve liquid-lifting capacity. The liquid-lifting problem occurs in low-volume gas wells when liquids condense on the casing surface and fall down the well. These liquids build up and increase the hydrostatic head and can ultimately kill the well.[1] When the gas velocity is high enough to lift fluids from the well bore, the fluid may condense in the flow lines. Fluid in a gas line restricts gas flow and decreases line efficiency. It is critical to have the least amount of fluid as possible in a line to avoid loss of production. The use of condensate traps (drips) and mist extractors are common for preventing liquid from entering the gathering system. Drips are containers at low spots on the line that collect fluids from the line. Mist extractors are similar to drips and are placed between the wellhead and the meter station. Once the drip or mist extractor becomes full, more fluids begin to build inside the gathering line, restricting gas flow. Since not all fields produce the same amount of fluids, a schedule is needed to pull drips and mist extractors for a particular gathering system to keep out as much fluid as possible from the gathering system.

The problem caused by liquids in a gas-gathering system is illustrated in Figure 1, which shows production and pressure rates for 1998 for one line in a gas-gathering system. An average of 4.1 MMCFD flowed through this system with an average pressure of 40 PSIA. The gathering system was modeled in a computer simulator. The simulator was run using 90% line efficiency. The simulator indicated that 5 MMCFD should be flowing through the gathering line. The results showed about 900 MCFD loss in production due to poor line efficiencies. Drips, mist extractors, blind flanges, and orifice plates were evaluated in order to determine the cause of the poor line efficiencies. In this study, the drips on a gas-gathering system were pulled three times in six to eight week increments while the mist extractors were pulled weekly. There were proration lines located at the discharge of the meter stations on most of the wells, and the main flow line had blind flanges in place. The proration lines were used when the wells were first brought on line and when the reservoir pressure was high. Six blind flanges were taken out from the meter facilities where the proration line existed. At the same time, the orifice plates were checked on the six wells and appeared to be in good working condition.

On the six wells chosen, the blind flanges and orifice plates did not appear to cause significant poor line efficiencies in the line gathering system because the production of the six wells was not enough to cause a restriction in the line. If the wells had been producing significant amounts of gas, the increase in production would have been noticed.

Based on this study, the removal of the blind flanges did not have a significant effect on production. Fluid is not present in the line allowed the line to flow at a constant rate of 4.0 MMCFD with an average pressure of 40 PSIA. If fluid is allowed to build up in the line, the fluid restricts gas flow in the line causing lower line efficiencies. The success of improving production by pulling drips and mist extractors was not obtained as expected because not all flow restrictions caused by condensation were corrected. Many of the drips were located in extremely remote locations and some of the drips removed because the wells produced only dry gas. Therefore, a major consideration for designing gas-gathering systems would be to create access to locations where condensate can be removed.

Production Backout

It is very important in this industry to continually drill and replace or increase reserves in order to maintain the overall value of a company. Any new project, such as in-fill drilling and new field developments, will affect the pressure distribution in the gathering system. This will change production potential of existing fields, especially of the more deleted fields. Commingling flowlines has been an extremely cost effective method of extending the economic life of the field. However, good initial design is required to anticipate future reservoir depletion and recompletions in order to achieve the best economic efficiency. The primary point is to anticipate future operating pressure needs and not to exceed the compressor capacity. Critical to the commingling production in a gathering system is knowledge about the location and pressure of nearby wells, flowlines, and deliverability ranges. These issues all must be considered when deciding how to optimize the utilization of existing surface facilities.[3]

An important aspect of field development that requires accurate evaluation is "back-out," the amount of production of existing fields that is lost as a result of bringing on a new project. If the current gathering system is loaded, it will hurt the company in the long run due to the fact that the new gas being brought "on-line" will back out the equivalent amount of existing gas on the system. The loss of production is directly related to the actual compressor sites which gather the gas. If the compressor is loaded and more gas is brought on the system, the line pressure of the gathering system will increase. The net system incremental capacity of a new project can be as low as 70% of the stand-alone additional capacity.[4]

Figure 2 shows a gradual increase in production from new wells; these new wells are then set to discharge down a gathering system which has no extra capacity. There is an increase of approximately 5 MMCFD onto the gathering system. However, the area's production remains constant at 74 MMCFD. This effect is observed because the system is operating at capacity, so any new gas brought onto the system essentially replaces existing gas. Therefore, any new gas being brought onto the system provides no net gain in the long run.

Figure 3 shows the same production rates as Figure 2, with one exception. The total production shown does not include the increase in production from the new wells. This figure will help to show the "one-for-one" back-out situation that occurs in a gathering system operating at capacity. Figure 3 shows the new production increasing with approximately the same slope as the decreasing area production. Thus, for each MCFD that is brought onto the gathering system, one MCFD is backed out from existing production.

In Figures 2 and 3, the total area production is measured to determine the effects new gas has on existing production. Figure 4 shows the production from the actual booster on the gathering system. The figure, is intended to show that no matter how much new gas is added onto the gathering system, there is no increase in gas out of the system. Figure 4 shows that, with the exception of the down compressor coming back "on-line," there is no new gas being discharged from the booster. Essentially, a material balance can be run showing that, if there is no net gas out of the system, there is no net gas into the system. It is therefore important to consider the gathering system every time a new well is drilled. If possible, costs for taking the new gas to a system that is not operating at capacity, or setting wellhead compression so the new gas can be discharged downstream of the existing boosters should be considered

An important issue in the development plan is how to minimize or even avoid significant back-out effects. An important consideration in gas-field development is the maximization of available gathering system capacity, since this is linked directly to allowable sales volume. Since capacity decline within a group field can vary significantly, maximization of long-term system capacity can be achieved by giving priority to fields that have the lowest decline in capacity unit produced. Rerouting projects reduces pressure drops, whereas looping relevant lines is being considered as an alternative to installing additional compression.[4] Other studies have shown that compression upgrades will initially increase field deliverability by 10% and can defer workover activity for up to 5 years.[1]

The dynamics of production forecasting and reserve estimates requires consistency in the knowledge of the gathering system pressure. The gathering system pressure controls the abandonment pressure (reservoir pressure at which flow rate is below the rate necessary to meet operating expenses). The impact is seen in production back-out. The impact of a reduction in line pressure is also observed in production reserve estimates.

Production and Reserve Estimates

The value of a production company is based on the production and reserves. These values must be accurate for proper reservoir management and field development. The reserve and production estimates incorporate minimum economic flow rates or abandonment pressures. The gathering system pressure frequently controls these values. However, as additional wells are connected to the gathering system, the pressure in the gathering system changes. Even though the properties are subjected to regular testing and review, changes in the field limit the accuracy of reserve and production forecasts. The problem grows more complex if competing production companies are developing the same field. This section discusses the gathering system's line pressure on production and reserve estimates.

The following equation is used to illustrate the impact wellhead flowing pressure (WHFP) has on the given well's production.

$$Q = C \times \left(\frac{\left(WHSIP^2 - WHFP^2\right)}{1000} \right)^n \tag{1}$$

where:

- Q = Flow Rate (MCFD)
- C = C-Factor (MCFD/psia^2)
- WHSIP = Wellhead Shut-in Pressure (psia)
- WHFP = Wellhead Flowing Pressure (psia)
- n = Exponential Factor

The C-factor for each well is determined from a "back-pressure" curve which plots gas rate (independent axis) vs. ($WHSIP^2 - WHFP^2$)/1000 (dependent axis). Once the data is plotted, a curve is fit and the x-value where the curve intersects the y = 1 line on the y-axis is the well's C-factor. The C-factor is then adjusted slightly in order to match current operating conditions. The slope of the curve gives the exponential factor (n) for each well. The value of "n" varies between 0.5 and 1, where a value of 1 is for darcy flow.

Equation 1 is used to estimate gas-well deliverability. If gas production depends on wellhead compression, or if the gathering system is on vacuum, the WHFP is the line pressure. While each field has a unique "n" exponent, a sensitivity analysis of Equation 1 reveals that the gas-well production potential decreases up to 10% for a 20-psi increase in line pressure.

The reserve estimates are made by material balance methods using P/Z plots and by decline curve analysis using log/log type curves and semi-log plots. As a rule of thumb, reliable reserve estimates require at least six months of data. Therefore, production data were reviewed on a similar field in which in-fill drilling occurred with accompanying modifications to the gas-gathering system. The modifications included adding extra compression and looping or rerouting of gas pipelines. The P/Z plot of wells indicated that, on average, each 5-psi decrease in line pressure yielded a 5% increase in reserves. The impact on reserve estimations from the decline curves had a 20% per well average increase in reserves. One well in the field increased production from 200 to 450 MCFD, and after three years the production was over 300 MCFD. The semi-log analysis for well had reserves increasing threefold. Since adding compression, four new wells were connected to the gathering system, and no significant negative production impact has been detected. The marked difference between this field and the previously mentioned field is the added gathering system capacity. The effort was made to anticipate future compression requirements as the field developed.

Conclusion

The causes for some types of reductions in gas-gathering system efficiency are difficult to correct, or the immediate impact of corrective efforts is not always observed. However, corrective efforts must continue. The impact-trapped liquids in the pipelines, need for improvements to the gas gathering system, and need for additional compression can be determined by first observing daily production and then comparing production data with baseline results from computer simulations of the gas-gathering system. The wells can be drilled and completed; but if the gathering system does not have the capacity to carry gas from the well to the refinery, the maximum economic benefit to the producer will not be achieved. Cooperation is required between engineering disciplines to properly manage the reservoir, identify surface facility problems, and develop the best solutions.

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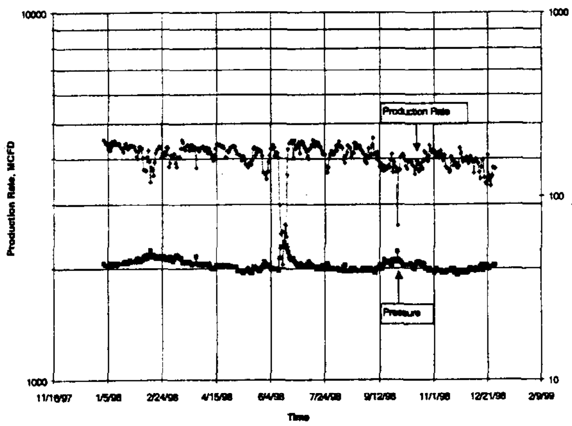

Figure 1 - Line Production History

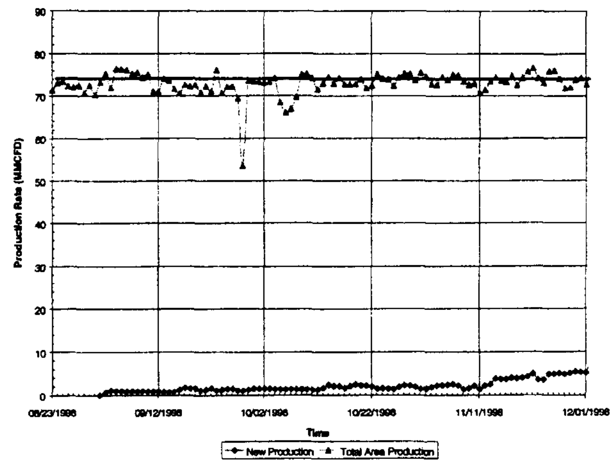

Figure 2 - Total Area Production

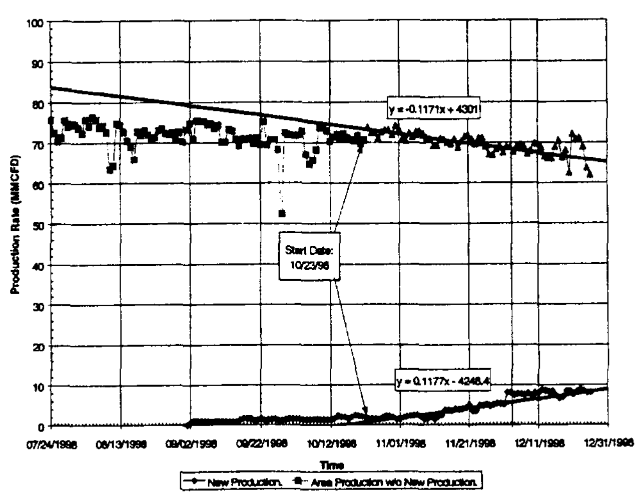

Figure 3 - Total Area Production

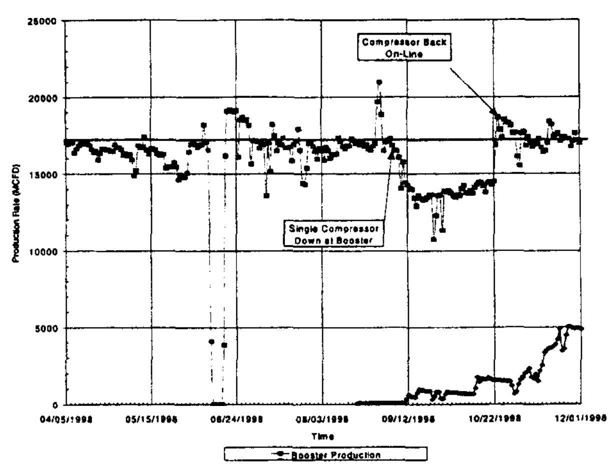

Figure 4 - Gathering System Booster Production