# FUEL GAS BEST MANAGEMENT PRACTICES

## Efficient Use Of Fuel Gas in Gas Gathering Systems

**MODULE 1 of 17**

SUBMITTED BY: CETAC WEST

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## Background

The issue of fuel gas consumption is increasingly important to the oil and gas industry. The development of this Best Management Practice (BMP) Module is sponsored by the Canadian Association of Petroleum Producers (CAPP), the Gas Processing Association Canada (GPAC), the Alberta Department of Energy, Small Explorers and Producers Association of Canada (SEPAC) Natural Resources Canada (NRC) and the Energy Resources and Conservation Board (ERCB) to promote the efficient use of fuel gas in gathering systems used in the upstream oil and gas sector. It is part of a series of 17 modules addressing fuel gas efficiency in a range of devices.

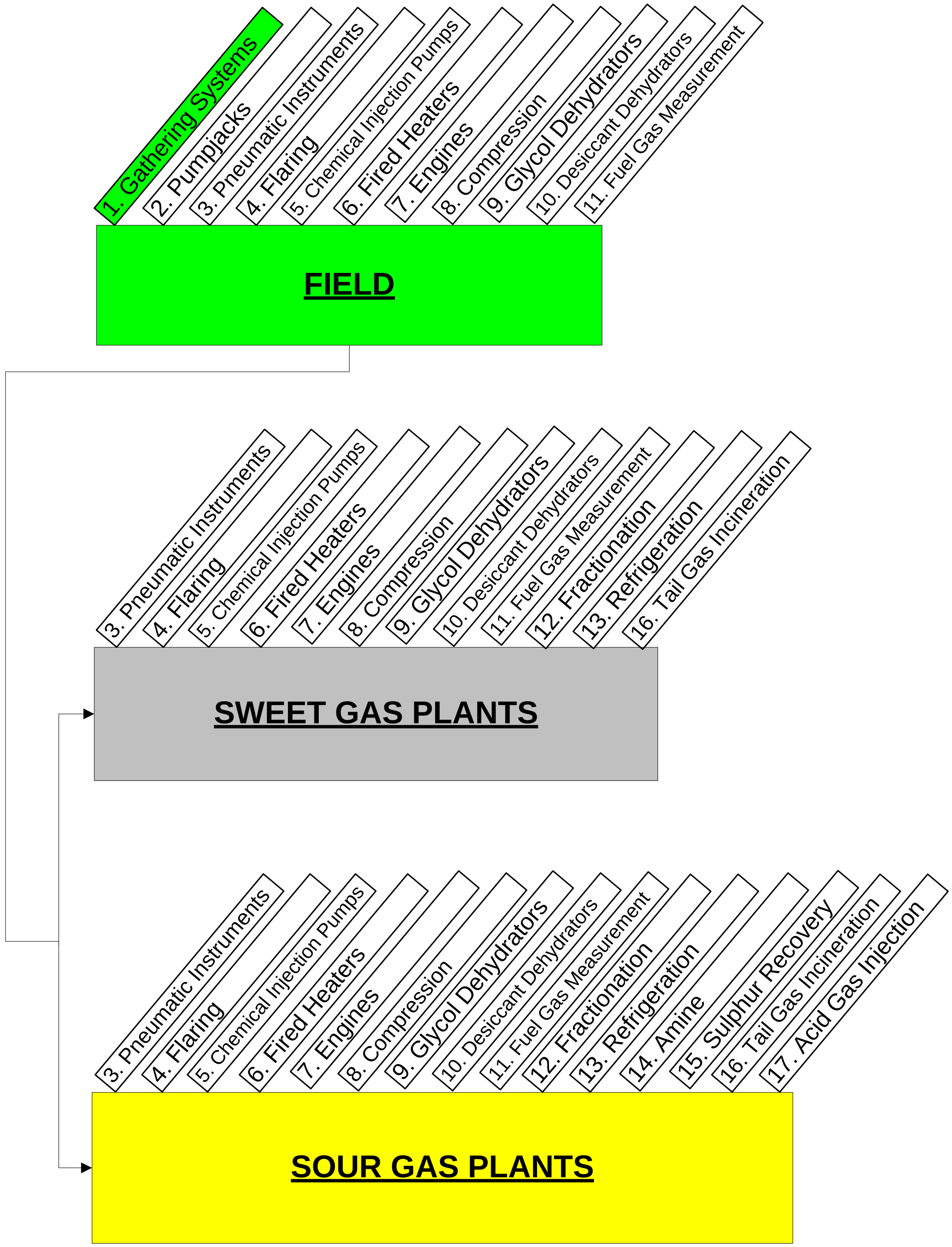
This BMP Module:

- identifies the typical impediments to achieving high levels of operating efficiency with respect to fuel gas consumption,
- presents strategies for achieving cost effective improvements through inspection, maintenance, operating practices and the replacement of underperforming components, and
- identifies technical considerations and limitations.

The aim is to provide practical guidance to operators for achieving fuel gas efficient operation while recognizing the specific requirements of individual gathering systems and their service requirements.

# EFFICIENT USE OF FUEL GAS
# IN THE UPSTREAM OIL AND GAS INDUSTRY

## MODULE 1 of 17: Gathering Systems



# 1. Applicability and Objectives

The intent of this module is to provide guidance to operating staff to identify opportunities where energy consumption associated with operating gathering systems can be reduced.

Gathering systems are networks of piping used to transport fluids produced from petroleum wells to a centralized facility for processing. These systems typically collect products from a number of wells using relatively small diameter lines (i.e. 3 to 8 NPS). Energy is consumed by pumps and compressors to overcome friction losses and by heaters used to reduce liquid viscosities or mitigate hydrate formation.

This module will focus on issues related to gathering system piping design, operation and maintenance practices that relate to energy consumption. Gathering system design strongly influences energy efficiency and while this module is not intended as a design manual, the impacts of design are discussed. The intent is to deal with operation and maintenance of existing gathering systems.

This module outlines the basic improvement strategies for reducing fuel consumption in gathering system operations and identifies sources of energy losses. Evaluation of performance using measurements to support the identification of potential reduction opportunities will also be discussed. This module will also discuss how to use a systematic and consistent approach for reduction and conservation opportunities. The final objective of this module is to outline suggestions and processes to develop an improvement program.

# 2. Basic Improvement Strategy

Achieving effective and lasting reductions to energy consumption associated with operating gathering systems requires a commitment at all levels (i.e. operations, management and corporate) to the development and implementation of a management system. This management system should be developed with an understanding of the sources of energy consumption associated with operating gathering systems and the available options for reducing this energy consumption. Implementation of the system will require periodic checks to evaluate performance and make adjustments as required, assessment of opportunities to reduce energy consumption and maintaining adequate records to support the system.

# 3. Record Keeping

Operators should have a record program to support the company's gathering system efficiency improvement program. Proper record keeping should assist in ensuring that underperforming systems are identified and that appropriate follow-up actions are implemented. This information will also assist in establishing the checking/testing frequency to achieve cost-effective reductions in energy consumption for various components of the gathering system.

Although each company will define its own record keeping system, consideration should be given to recording and retaining the following information:

- Pipe segments
  - length,
  - diameter,
  - MOP,
  - operating pressure,
  - operating temperature,
  - flow rate,
  - fluid composition,
  - elevation of pressure testing locations,
  - test records for pressure drop tests,
- Heaters
  - optimum temperature,
  - actual temperature,
- The economic analysis performed to evaluate reduction opportunities where adjustments/modifications have not been made on economic grounds.

# 4. Energy Consumption Associated With Gathering System Operations

Achieving efficiency with respect to energy consumed in operation of gathering systems requires an understanding of where energy losses occur in these systems. Energy is unnecessarily consumed by pumping equipment and compressors to overcome excessive friction losses and by heaters to raise fluid temperatures above the levels necessary to adequately reduce liquid viscosities or mitigate hydrate formation. This section discusses the various aspects of gathering system design and operation that influence energy consumption.

## 4.1 Frictional Pressure Drop

The energy lost to overcome frictional effects in a flowing fluid manifests itself as a measurable pressure drop. Some degree of loss is expected and acceptable in all gathering systems. The key to attaining efficient operation is to find the optimal balance between capital and/or operating costs required to mitigate frictional losses and the energy costs associated with those losses. Depending on the type of gathering system (i.e. gas, liquid or multiphase) various parameters can be adjusted to achieve efficient operation.

### Gas Gathering Systems

The parameters influencing frictional pressure losses in gas gathering systems are presented and discussed in Table 4.1.

**Table 4.1**
**Parameters Influencing Frictional Pressure Losses in Gas Gathering Systems**

| Parameter | Description | Approx. $\Delta P \alpha$ | Importance |
|---|---|---|---|
| Diameter | Pipe diameter has the most significant impact on pressure drop due to friction for gas gathering systems because of the approximate fifth power inverse relationship. For example doubling the line size reduces the pressure drop due to friction by a factor of 32. Large diameter lines are desirable for energy efficient operation. | $1/D^5$ | High |
| Flow | Flow can have a significant impact on pressure drop due to the approximate second power relationship. For example doubling the flow increases the frictional pressure drop by a factor of four. Low flow rates are desirable for energy efficient operation. | $Q^2$ | High |

| Parameter | Description | Approx. $\Delta P \alpha$ | Importance |
|---|---|---|---|
| Pressure | Pressure has an approximate inverse relationship with frictional losses. For example doubling the pressure approximately decreases the frictional losses by a factor of two. High pressures are desirable for energy efficient operation. | 1/P | High |
| Length | Length has an approximate direct relationship with frictional losses. For example doubling the length approximately doubles the frictional pressure drop. Short lengths are desirable for energy efficient operation. Length has a lower priority because this parameter is fixed by design and cannot typically be manipulated. | L | Low |
| Friction Factor | The friction factor is directly related to the frictional losses. For example doubling the friction factor doubles the pressure drop. The friction factor has less importance than other directly related parameters like operating pressure because the range of values in narrow (i.e. typically 0.015 to 0.060 for conditions encountered in gas gathering systems). Low friction factors are desirable (i.e. smooth pipes under turbulent flow) for energy efficient operation. | F | Low |
| Temperature | Absolute temperature is approximately inversely related to pressure drop. For example doubling the absolute temperature approximately doubles the pressure drop due increased flow velocities and increased viscosity of the gas. The temperature is less important than other directly related parameters like operating pressure because the range of values encountered in gas gathering systems is narrow (e.g. when the temperature changes from 0 C to 100 C the absolute temperature has only increased by a factor of 1.37). Low temperatures are desirable for energy efficient operation. | 1/T | Low |

For gas transmission systems the optimum frictional pressure drop has been shown to be 15 - 25 kPa/km [1]. Others recommend a pressure drop of 21 - 43 kPa/km for low pressure gathering system. The optimum pressure drop will generally be system specific but these values can be used as guidelines.

**Liquid Gathering Systems**

The parameters influencing frictional pressure losses in liquid gathering systems are presented and discussed in Table 4.2.

**Multiphase Gathering Systems**

Multiphase gathering systems are less efficient at transporting produced fluids than single phase liquid or gas systems. In straight sections of pipe, frictional losses are greater because of slippage between the two phases and additional losses are introduced to overcome elevation changes in undulating terrain. Multiphase lines may also be less desirable from an operating standpoint because liquid holdup may necessitate frequent pigging and large liquid slugs might initiate process upsets at upstream facilities.

The treatment of multiphase flows is more complex than single phase flow and generally requires computer simulation. A number of commercial software packages and consulting firms are available to assist with this task.

Unlike in single phase flows, decreasing the flow velocity of a multiphase flow (e.g. increasing the pipe diameter, reducing the flow rate, increasing pressure, etc.) will not necessarily correspond to a reduction in total pressure loss. This is because the unrecoverable elevation losses tend to decrease with increased flow velocity whereas frictional losses exhibit an opposite effect. The net result of these counteracting effects is an optimum operating point where pressure losses in multiphase lines traversing undulating terrains are minimized. In order to reach this optimum point it may actually be appropriate to increase flow velocities (e.g. reduce line sizes, increase flow rates, decrease operating pressure, etc.) in some cases.

## 4.2 Heating Losses

Heaters are frequently used to reduce the viscosity of liquid or to mitigate hydrate formation. This is often necessary energy consumption. However, heating fluids beyond the levels required to achieve optimal viscosity reductions or to inhibit hydrate formation represent inefficiencies.

## Table 4.2
### Parameters Influencing Frictional Pressure Losses in Liquid Gathering Systems

| Parameter | Description | Approx. $\Delta P \alpha$ | Importance |
|---|---|---|---|
| Diameter | Pipe diameter has the most significant impact on pressure drop due to friction for liquid gathering systems because of the approximate fifth power inverse relationship. For example doubling the line size reduces the pressure drop due to friction by a factor of 32. Large diameter lines are desirable for energy efficient operation. | $1/D^5$ | High |
| Flow | Flow can have a significant impact on pressure drop due to the approximate second power relationship. For example doubling the flow increases the frictional pressure drop by a factor of four. Low flow rates are desirable for energy efficient operation. | $Q^2$ | High |
| Friction Factor | The friction factor is a directly related to the frictional losses. For example doubling the friction factor doubles the pressure drop. The friction factor more important in liquid gathering systems than in gas gathering systems because a high range of values can be encountered (i.e. from 0.012 for low viscosity flows in smooth pipes to 0.1 or greater for high viscosity fluids). Low friction factors are desirable (i.e. smooth pipes under turbulent flow) for energy efficient operation. | F | High |
| Density | Density has a direct relationship with frictional pressure drop. For example doubling the density doubles the frictional pressure drop. On a work per unit volume basis low density fluids are preferred. However on a work per unit mass basis the effect of lowering the density to lower the frictional losses is directly canceled by increases to the pumping work. | $\rho$ | N/A |
| Length | Length has an approximate direct relationship with frictional losses. For example doubling the length approximately doubles the frictional pressure drop. Short lengths are desirable for energy efficient operation. Length has a lower priority because this parameter is fixed by design and cannot typically be manipulated. | L | Low |

## Viscosity Reduction

Although temperature has little direct influence on the frictional pressure losses in liquid systems because liquid volumes do not change appreciably with temperature, fluid temperature can have an appreciable impact on the friction factor via changing a fluid's viscosity. The viscosity of a liquid decreases with temperature allowing the fluid to flow more freely. For this reason heaters are sometimes used to reduce the viscosity of oils. This has the added advantage of helping to mitigate fouling by reducing wax precipitation. Reductions in viscosity only correspond to reductions in the friction factor up to the point where fully turbulent flow is developed. After the onset of complete turbulence further reductions to viscosity will not result in decreases to the friction factor. Also, the optimum operating temperature may be reached before turbulent flow is developed. Generally, temperature increase should not be pursued past the point where energy consumed to increase the fluid temperature is directly offset by pumping cost reductions.

## Hydrate Mitigation

Hydrates are a crystalline structure consisting of water and hydrocarbons which can form in natural gas and NGL systems. Their accumulation on pipe walls can create severe flow restrictions or completely block the flow.

One method of preventing hydrate formation is to maintain the pipeline temperature above the hydrate formation temperature. This is accomplished by using line heaters. Inefficiencies can result if the process fluid is heated above the temperature required to safely mitigate hydrate formation.

Other means of controlling hydrate formation are to either provide field dehydration, inject methanol into the gas stream or some combination thereof. Methanol Injection is effective suppressing hydrate formation in gas systems low in water and condensate. In the presence of high water and/or condensate gas systems, engineering and economical evaluation are strongly recommended.

# 5. Measuring Losses

Actual site measurements are beneficial for identifying substandard performance and evaluating opportunities to improve energy efficiency in gathering system operations. Measurements should be taken periodically and documented to track performance of the gathering system.

## 5.1 Pressure Drop

Pressure losses per unit length of pipe can be tracked over time and compared to identify reduction opportunities. Measuring the pressure drop requires sectioning the gathering system into segments of pipe that contain a constant flow (i.e. no tie-ins) and have an upstream and downstream point that is accessible for taking a pressure measurement (i.e. the line is not buried and there are sufficient fittings available to mount a pressure gauge). In addition to documenting the upstream and downstream pressures, elevations, segment length, pipe diameter, flow rate, temperature and product composition should also be recorded.

Permanently mounted pressure gauges typically found at wellheads and risers may not have sufficient resolution and the measurement agreement between upstream and downstream gauges may be insufficient for assessing pressure drops. The use of a portable high resolution pressure gauge is preferred for taking upstream and downstream measurements to establish the pressure drop across a segment of the gathering system.

Correction for elevation differences between upstream and downstream measurement locations must be made when comparing pressure drops per unit length for different liquid lines. Gas lines do not require this correction. In multiphase lines the potential energy losses due to elevation increases are not completely recoverable so no correction should be made. In fact, it is difficult to compare different multiphase lines but measurements can still be compared to past measurements on the same line to identify changes.

## 5.2 Heaters

The process fluid inlet and outlet temperatures at line heaters should be measured periodically to ensure agreement with required values.

# 6. Reduction Opportunities

When evaluating reduction opportunities it is important to base decisions on reliable data using a systematic and consistent approach. Any case where there is an excessive frictional pressure loss or overheating of a fluid represents an opportunity to conserve energy by correcting the deficiency. Correction of the deficiency may include operational or design changes.

## 6.1 Operation

There are a number of operating considerations that can lead to more energy efficient gathering systems. These include frequent pigging, implementing a corrosion mitigation program, adjusting the temperature of line heaters, using viscosity reduction agents, using methanol injection and field dehydration to mitigate hydrate formation.

**Pigging**

Pigging is used as a maintenance practice to remove liquids from gas and multiphase gathering systems and reduce wax buildup in oil gathering systems. This is an important practice in many gathering systems and adequate facilities should be installed to accommodate pigging where appropriate.

This practice is beneficial in gas and multiphase gathering systems as removal of liquids from gas systems can significantly reduce pressure drops and helps to mitigate corrosion (see Section 5.1). Even in gas gathering systems where liquids are removed at the wellhead there is still potential for condensation to occur in the pipeline which may lead to an accumulation of liquids over time. In oil gathering systems pigging is used to remove wax build up from the pipe walls. This wax buildup increases pressure losses by increasing the friction factor and reducing the effective internal diameter of piping.

The effectiveness of pigging at reducing pressure losses can be assessed by measuring the pressure drop for a section of pipeline before and after being pigged. Pressure drop measurements should also be taken periodically between pig runs to establish an optimum pigging schedule.

**Corrosion Mitigation Program**

In addition to being a potential requirement for the safe operation of a pipeline [2,3] corrosion mitigation is also good practice to reduce frictional losses in gathering systems. Corroded pipelines have rough walls which increases the flowing friction factor. For example, the frictional factor for fully developed turbulent flow in a rusted steel (i.e. relative roughness of 2 mm) NPS 2 standard wall pipe are expected to be 3.3 times the friction factor for a new steel (i.e. relative roughness is 0.047 mm) NPS 2 standard wall pipe under fully turbulent flow. Corrosion can be managed by separating liquids from gas pipelines, frequent pigging and/or using corrosion inhibitors.

**Heater Adjustments**

Heaters are used in the operation of many gathering systems to prevent hydrate formation and reduce liquid viscosity. These units should be periodically checked and adjusted to ensure the process fluid is not being heated above the levels required.

For line heaters used to mitigate hydrate formation the discharge temperature of the line heater must be high enough to ensure the process stream is maintained above the hydrate formation temperature at the inlet of the next line heater or processing facility. The hydrate formation temperature depends on the gas composition, water content and pressure. Adequate temperatures can be established through operating experience or predicted from theory. A methodology for estimating hydrate formation temperatures is presented in *Gas Processors Suppliers Association, Engineering Data Book, Twelfth Edition* [4]. Most process simulators used in the design of gathering systems are able to provide this information as well.

Liquid systems using heaters to reduce viscosity should not be operated where the energy consumed in increasing the fluid temperature is directly offset by pumping cost reductions. This can be estimated from the fluid properties (i.e. viscosity-temperature relationship, specific heat capacity and flow rate) and pipe attributes (diameter, length, roughness) or determined based on operation experience.

**Viscosity Reduction Agents**

Alternatives or supplements to using heaters to achieve viscosity reductions include blending product with diluents or using chemical additives. Diluents are low viscosity hydrocarbons (e.g. usually butanes or condensates) that are blended with viscous oils to reduce pumping requirements. There are also chemicals on the market that can be added to liquids and gases to reduce viscosity. These options may be an efficient means of reducing pumping costs in some circumstances and should be considered.

**Using Methanol to Inhibit Hydrate Formation**

Methanol can be injected into the pipeline as an alternative to using line heaters to inhibit hydrate formation. The energy consumed is minimal compared to a line heater and depending on chemical use and recovery rates may be an economic alternative. It is important to understand the required injection rates (accounting for seasonal variability) when evaluating methanol injection. Methanol recovery should also be considered as a viable option to reduce the cost of methanol injection. Methanol is a liquid and as such may accumulate in low points throughout the gathering system causing additional pressure drops and requirements for pigging.

## 6.2 Designing and Upgrading Gathering Systems

Many gathering systems are currently experiencing suboptimal efficiencies because they are being operated outside of their original design conditions. This phenomenon occurs for a number of reasons including:

- the gathering system was designed to accommodate gas from the originally targeted deep high pressure formations but is now being used to collect fluids from shallower low pressure formations.

- the original development forecasts used to design the system were overly optimistic or pessimistic; or

- the gathering system was constructed in a piecemeal fashion often by many different operators with different objectives at the time than the current operator has today.

This section discusses some design changes that can be implemented to address suboptimal performance.

**Eliminate Multiphase Flows**

Multiphase flow lines are not conducive to efficient fluid transport and should be avoided whenever possible. The following are preferable alternatives to multiphase flow lines that should be considered:

- Separation and storage of liquids – in this scenario, liquids are removed at the well head using a separator. Gas is transported by pipeline to a central processing facility and liquids are stored onsite in a tank for pickup by truck. Because of the potential for flashing losses this option is generally only used when produced liquid are stable (e.g. water). For condensates and crude oils, flashing losses can be significant and will typically negate any gains in transport efficiently. However, if vapour recovery can be implemented this can also be a viable option for flashing products.
- Separate liquid and gas pipelines – in this scenario, products are again separated at the wellhead and are transported using dedicated liquid and gas pipelines.

If multiphase flow cannot economically be avoided centralized facilities for separation and vapour recovery for should be placed as close as practical to the wells to limit the piping distance of multiphase flow.

## Loop Flow Lines

There are often instances where higher than acceptable pressure drops occur because parts of the gathering system are undersized for the current flow conditions. In gas gathering systems this can be addressed by increasing the system pressure. However, it may not always be possible or desirable to increase the operating pressure of a gas gathering system to overcome losses associated with undersized flow lines. This is especially true when only short segments of the system are undersized. In these cases line looping is a viable option to address excessive frictional pressure drops. In liquid systems line looping is often the only viable option to address excessive frictional losses resulting from undersized lines.

## Added Compression

The distance gas is transported at low pressure should be minimized as much as possible. Adding compression upstream in a gathering system can improve transportation efficiencies and increase system capacity. However, an excess of field compressors should also be avoided.

In maturing fields it is common practice to increase production and alleviate liquid loading by adding wellhead compression. Unfortunately, these units are typically sized for current demands and quickly begin to operate outside of their optimum efficiency range as the wells decline. In these compressor systems there is a lack of redundancy so wells are subject to reduced flows and liquid loading issues when compressors are down. Furthermore, these compressors do not typically boost gas pressures to levels that are conducive to efficient transportation. Improvements in production from wells featuring these units are often realized at the expense of the other wells in the gathering system. Wellhead compressors are justified in some instances but the use of centralized compression is preferred.

Centralization of compression can improve operating efficiency and create redundancy. Compression loads can be shared over several units which can be put online or taken offline as required to maximize efficiency with changing demands. Centralized compression allows compressors to be taken offline for servicing without causing flow reductions and liquid loading at the wells. Ideally the station should be designed for a high discharge pressure to promote efficient gas transportation to the subsequent processing facility.

The upstream gathering system should be considered when evaluating the feasibility of a centralized compressor station. As the pressure of the gathering system is drawn down the pressure losses will increase. Restrictions in upstream flow lines may make it impossible to achieve desired wellhead pressures using a centralized compressor scheme. In these cases line looping should be considered to eliminate upstream restrictions. If line looping is not a viable option wellhead compression may be considered.

**Gas Dehydration/Sweetening**

Alternatives to mitigating hydrate formation by using line heaters to maintain the process above the hydrate formation temperature include: adequately dehydrating the gas to preclude hydrate formation or sweetening the gas to increase the hydrate formation temperature. These options are preferable to line heaters because the gas must eventually undergo these processes anyway. The use of a dehydrator or sweetening system should be evaluated as an alternative to line heaters for gathering systems where hydrate formation potential exists.

**Design with the Future in Mind**

The optimum wellhead flowing pressure for individual wells varies as the reservoir is depleted and is the key consideration when designing a gathering system. Knowledge of the reservoir inflow potential and reservoir tubulars can be used to predict the behavior of a well throughout the depletion process. This information is invaluable when evaluating options for designing or expanding a gathering system.

It is important to consider the current and future operating conditions of all existing and planned wells when designing or upgrading a gathering system. This is a complicated task and the use of integrated modeling software which considers compression, pipeline, wellbore and reservoir is recommended.

When all assets in a field are owned by a single company long term planning is simplified. However, this is not normally the case. Multiple companies with competing interests often operate in the same fields. Stakeholders should evaluate opportunities for improving efficiency by sharing infrastructure and equipment. Industry consultation is required by the ERCB[2] for energy developments.

# 7. References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