INTRODUCTION TO GAS QUALITY

SEAN R. STEVENS
REPRESENTATIVE DEVELOPMENT & SUPPORT MANAGER / INSIDE SALES MANAGER
WELKER, INC.

Introduction

Natural gas product that is fed into the main gas transportation system in the United States is required to meet certain guidelines in quality. If these guidelines are not met, there can be problems ranging from small to catastrophic. This is because raw natural gas contains contaminants and natural gas liquids (NGLs) that must be removed from these high-pressure pipelines before the natural gas takes the long journey through the pipelines and, eventually, into the homes of consumers. Problems that can occur from the presence of these contaminants and liquids can be anything from an operational issue to pipeline deterioration, or even pipeline rupture.

Despite the fact that the segment of natural gas processing is seldom publicized, one can deduct that the issue of gas quality is relatively important. The primary role of these gas processing plants is to produce pipeline-quality natural gas. Pipeline-quality gas is defined on a number of different levels from one company to another, but four major areas can be identified in which the natural gas: (1) should be within a specific BTU range (1,035 BTU per cubic feet, +/- 50 BTU), (2) should be delivered at a specified hydrocarbon dew point temperature below which any vaporized gas liquid in the mix will tend to condense at pipeline pressure, (3) should contain no more than trace amounts of elements (i.e., hydrogen sulfide, carbon dioxide, nitrogen, water, or oxygen), and (4) should be free of solid particulates and liquid water that could be damaging to the operating system or the structure of the pipeline.

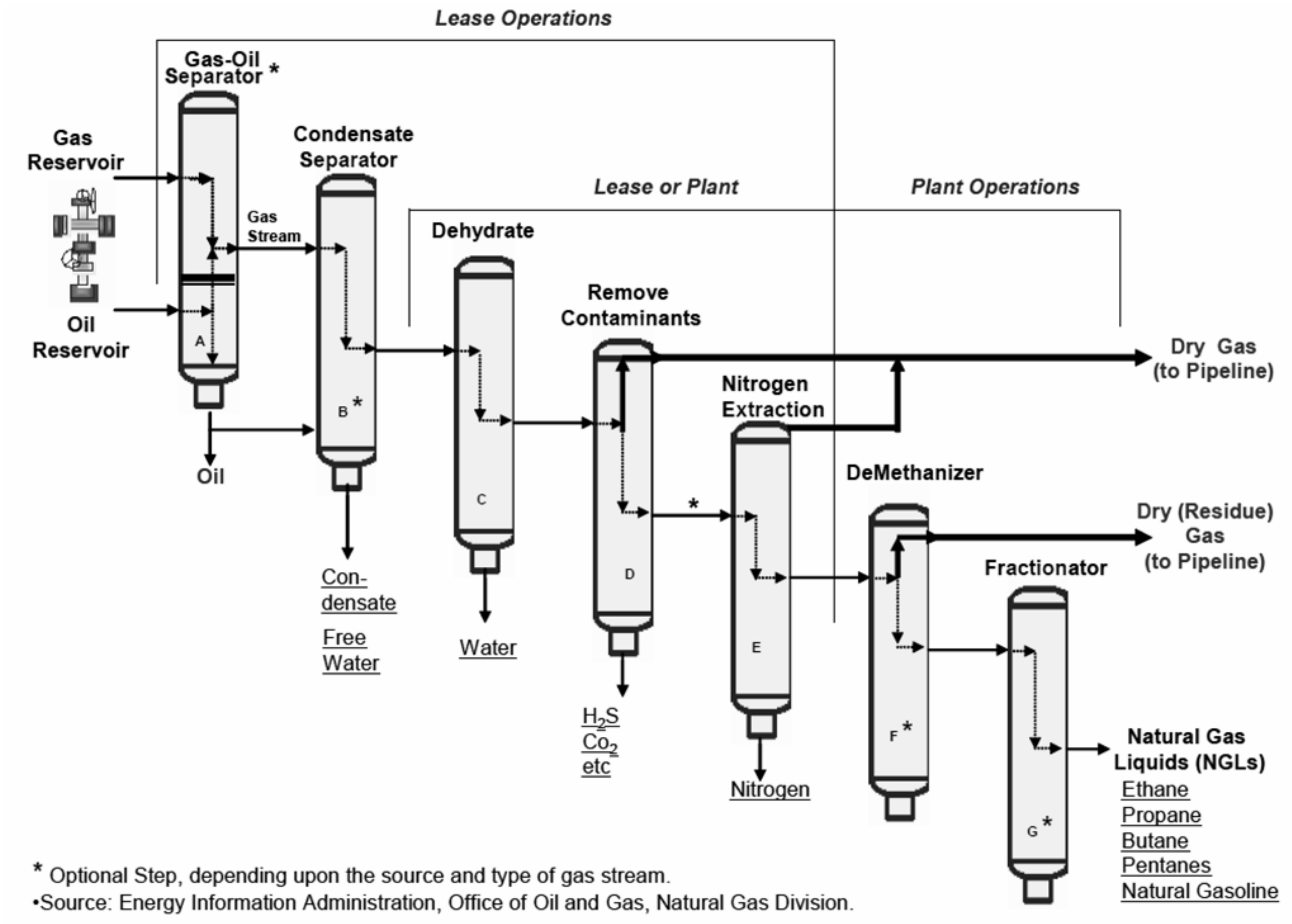
In 2009, there was approximately 26.0 trillion cubic feet (TCF) of raw natural gas being produced at the wellhead according to the Energy Information Administration. Of that, there was about 0.2 TCF being vented or flared, and roughly 3.5 TCF was being reinjected to maintain pressure within reservoirs. The remainder, 21.6 TCF, was converted into 20.5 TCF of pipeline-quality natural gas.

Background

Various types of processing plants have been utilized since as early as the mid-1850s to remove liquids, such as natural gasoline from crude oil. However, for many years, natural gas was not a sought-after source of fuel. It wasn't until the 20th Century that the need for an alternative fuel source was realized.

Most natural gas production contains small (one to six carbons) hydrocarbon molecules. These gasses may exist at a gaseous state underground, but at normal atmospheric pressures, they can exist in a liquid state. When a gas becomes a liquid at atmospheric pressure, it is commonly

Figure 1. Generalized Natural Gas Processing Schematic



referred to as a natural gas liquid or NGL. In some cases, natural gas may come out of the formation with crude oil mixed in. This is known as "associated-dissolved" natural gas. It is also commonly, within the industry, referred to as gaseous crude. When the natural gas from the well is not found with crude oil, it is known as "non-associated". This non-associated natural gas comprises 75 percent of the U.S. natural gas production.

Natural Gas Processing

The process of transforming raw natural gas into pipeline-quality natural gas is a long one with multiple stages (see Figure 1). The total number of stages in the process of conversion of raw natural gas into pipeline-quality natural gas depends on the composition of the gasses generated by the wellhead production. In some cases, several stages may be integrated into one operation. In other cases, it may not be required at all.

Gas-Oil Separation

The first stage of natural gas processing consists of converting associated-dissolved natural gas into non-associated natural gas. In this stage, the oil will be removed from the raw natural gas (NOTE: if the natural gas is non-associated, this stage will not be necessary). The separation of gas and oil is done by utilization of a gas-oil separator. Gas-oil separators are commonly cylindrical containers in a vertical configuration with inlets at one end and an outlet at the top for the gas to be removed, while also utilizing an outlet at the bottom for the oil to be removed from the separator. Separation is done utilizing gravity as a means of separating oil from gas through a process of heating and cooling of the product. During this stage, some water or condensate may also be removed.

Condensate Separation

The second stage of natural gas processing is the separation of NGLs from the gas stream. This is often the first stage in the process since only 25 percent of wellheads require the use of gas-oil separators. The gas enters through a slug catcher, which removes free water, then is routed to a condensate separator. The condensate extracted is sent to on-site storage tanks and the gas continues its process.

Dehydration

The third stage of the process is the drying of the gas or dehydration. This is the process of removing the free liquids and water that can cause hydrates, which are small ice crystals generated when the gas reaches certain temperature or pressure conditions. Dehydration can be handled using few different methods. Some companies choose to inject ethylene glycol (also known as glycol injection) as a way to absorb the water. Other companies choose to use dry-bed dehydrator towers, which contain desiccants, like silica gel or activated alumina to remove the liquids.

Removal of Contaminants

The fourth stage of natural gas processing is the removal of contaminants. Natural gas may contain trace elements, such as hydrogen sulfide, carbon dioxide, helium, oxygen, and water vapor. The most common method is by introducing the gas flow through a tower containing an amine solution. Amines absorb sulfur from natural gas and are reusable. After the sulfur has been removed, the flow is redirected through filter tubes. As the velocity of the gas reduces, heavier particles fall out due to gravity. Smaller particles combine with other particles to make larger particles, which are continually filtered through the filter tubes. In addition to the filtration, centrifugal motion helps eliminate liquids.

Removal of Nitrogen

The fifth stage of natural gas processing is the removal of nitrogen. The nitrogen is removed by routing the gas flow through a Nitrogen Rejection Unit (NRU), where it is absorbed using molecular sieve. During this process, the gas is also routed through a column and a brazed aluminum plate fin heat exchanger. Through a thermodynamic process, the nitrogen is cryogenically separated and vented to atmosphere.

Separation of Methane

The sixth stage of natural gas processing is the separation of methane. The removal of methane is commonly executed by the introduction of cryogenic temperatures (usually -120 degrees Fahrenheit). During this change in temperature, the heavier hydrocarbons are converted into a liquid state, while the methane remains gaseous. This is typically accomplished by using the turbo expansion process, whereby external refrigerants are used to chill the gas. This process is the most effective at removing lighter hydrocarbons.

Another method for the separation of methane is with the use of lean absorbing oil. When the gas passes through the absorption tower, the oil soaks up the NGLs. Once the NGLs have been absorbed, the oil will then be referred to as enriched oil. The oil is then sent to distillers, where it is heated to a boiling point of the NGLs. In the process, the NGLs are vaporized and the oil remains fluid. The NGLs are cooled and routed to a fractionation tower, while the oil is recycled. In some cases, the cryogenic and absorption methods are combined using a refrigerated oil absorption, which can enhance recovery.

Fractionation

The seventh and final stage of natural gas processing is the fractionation process. During this process, the NGLs still present in the raw natural gas are heated to the vapor points of the respective hydrocarbons. The process occurs where the gas rises through several towers where heating raises the temperature of the gas, causing the liquids to separate into specific holding tanks.

Determining Natural Gas Quality

During the process of converting raw natural gas to pipeline-quality natural gas, there will be many times where the product changes hands from one company to another. Today, many companies operate in specific areas of the industry, including production, transmission and distribution. However, most companies do not operate in all of those areas, so raw natural gas will be sold multiple times before it ever reaches the consumers, like you and me. The price varies based on the natural gas composition because, in the 1970s, the government decided that natural gas sales would be conducted on the basis of BTU value rather than volume. As the number of carbons in the carbon-chain goes up, so does the BTU value.

The quality of natural gas can be determined through sampling of the product under flowing conditions. Once a sample is obtained, it will then be analyzed using a gas chromatograph to determine the components of the gas. Typically, the gas chromatograph is found in a laboratory setting, but as times have changed, many gas chromatographs can be found near the pipeline. This is often referred to as online chromatography. The sampling process is an important one. It requires care in obtaining the sample in order to receive accurate results from the gas chromatograph. Improper methods or handling of samples or lack of care can result in invalid samples or even harm to individuals.

Proven Natural Gas Sampling Standards

There are many ways to sample natural gas, but not all are accepted. When choosing how to sample, one should refer to a proven, accepted method. This can be done by following proven standards. Within the natural gas industry there are experts that examine methods of sampling and test them for accuracy. Through this process of examination, the industry has produced proven sampling standards. A proven sampling standard is defined as a sample method that has been shown to be accurate, reproducible, and repeatable in proving that a known composition of natural gas can be gathered using the specified method of sampling. This is accomplished by attempting to prove a sample of a known composition by means of different sampling methods. Those that produce the accuracy, repeatability and reproducibility of the sample are considered proven.

Within the natural gas industry, there are four proven natural gas sampling standards. Those standards are Gas Processors Association (GPA) 2166, American Petroleum Institute (API) Chapter 14.1, American Society for Testing of Materials (ASTM) D-4177 or International Organization for Standardization (ISO) 10715. Many of these standards are similar or identical in their teachings. Those wishing to determine which standards should be used, should consult their company's list of gas quality standards utilized.

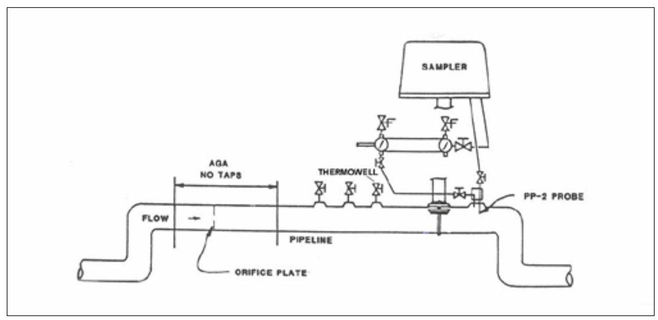
Information to Consider Before Sampling

Since the natural gas being sampled may not have reached the pipeline-quality level at which point it is sampled, one must take special precautions when performing the sample extraction. It is important to note that the heavier components of raw natural gas, will tend to stay in a liquid phase and travel against the pipeline walls.

In most cases, 316 stainless steel is the accepted material for sampling equipment. Viton® seals are a common source of elastomer material for equipment requiring o-rings or seals. Finally, for regulation of pressure (where applicable), the use of Teflon® or Kel-F® seats is typically utilized. It is important to note that some natural gas contaminants, such as hydrogen sulfide, can be damaging to the material used to design the sampling equipment. In these case, contact the manufacturer of the sampling equipment to determine the most appropriate material necessary. Most manufacturers have optional metals, such as Inconel and Hastelloy, that can be used in conjunction with other sealing compounds, such as Kalrez®, to ensure the life of the sampling equipment. Be prepared to show your known components with the manufacturer when deciding to purchase sampling equipment.

The sampling method chosen will determine which equipment to use. However, when taking a sample, there is something all standards agree on—place a sample probe in the center one-third of the pipeline at least five pipe diameters from any flow restriction. Flow restrictions can be headers, bends, elbows or other equipment in the pipeline that can alter the flow of the natural gas. These flow restrictions create turbulence in the pipeline and cause heavier components, like water or NGLs to be moved into the flowing stream. Capturing these liquids in your sample will give you inaccurate sample results.

Figure 2. Sample Probe Location



Accepted Sampling Methods

Within the industry, there are three primary methods of sampling. The first, on-line analyzing (using a gas chromatograph), has already been mentioned. The second accepted method is spot sampling. Spot sampling is defined as taking the sample of a specified volume at a specific point in time. Spot sampling is basically taking a "snapshot" of the natural gas in the pipeline. The third, and most common method of sampling, is composite sampling. In composite sampling, a sample of a specified volume is collected in small increments over a period of time. To decide on the appropriate method of sampling, one should consult his/her company's manual. Many companies vary on the sampling method based on the volume of natural gas flowing through the pipeline.

Spot Sampling

Spot sampling collects a full sample at one point in time. Spot sampling equipment typically consists of a sample probe, with a fully-ported hand valve, a sight glass, and a sample cylinder as well as stainless steel tubing (see Figure 3). There are six different methods for spot sampling. The three most common methods used are the evacuated cylinder, the helium pop, and the fill-and-empty methods. Each method requires the sample probe be placed in the center one-third of the pipeline, so as to ensure a proper sample is obtained from the pipeline. After a full-ported valve is connected to the probe, a piece of tubing connects the valve to the sight glass. The sight glass is in place to see if liquids are forming, since liquid in the sample is undesirable. Next, there is a sample cylinder utilizing isolation valves and a relief device. Most cylinders are rated to 1,800 PSI and have Department of Transportation (DOT) exemption. Depending on the method being used, a pig-tail and GPA plug may be used (fill-and-empty method only).

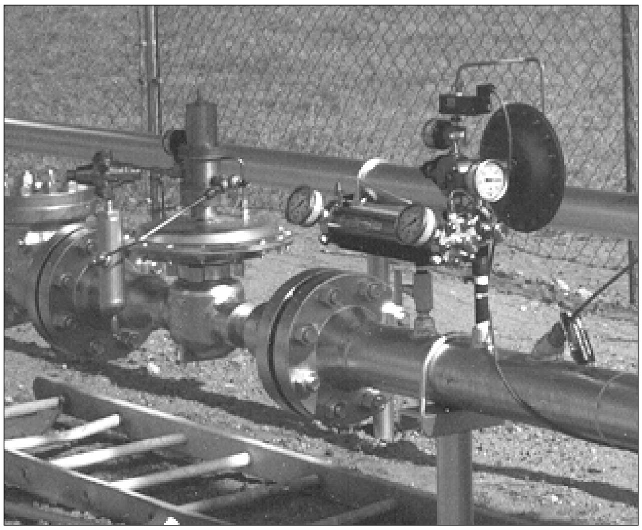
Composite Sampling

Composite sampling of natural gas is the method of sampling that gathers a specified volume of natural gas over a period of time. This differs from spot sampling in that multiple gas samples in small increments are taken rather than one large sample. Composite sampling requires different equipment than spot sampling, but taking a composite sample still requires the use of a sample probe and correct probe placement. The other components required are a sample pump, sample controller, and sample cylinder as well as stainless steel tubing. A common configuration for a composite sample system can be seen in Figure 4. This configuration consists of the sample probe outlet being tubed to the sample pump, which is operated by a sample controller, and the sample pump outlet being tubed to the sample cylinder. Using the sample controller, a field technician can operate the sampler based on the volume required for sampling (typically 80% of maximum cylinder volume is used), the sample period, and the size of sample per actuation of the pump. It is important to note that most sample pumps on the market utilize a design that allows for the last sample to be purged through the pump. This allows new, fresh sample to be taken with

Figure 3. Spot Sampling Equipment

each pump actuation, an important component of composite gas sampling.

Figure 4. Composite Sampling System



Sample Cylinder Selection

Proper selection of sample cylinders is an important part of sampling. Generally, there are two types of sample cylinder designs. The sample cylinder can be either a single cavity cylinder (sometimes referred to as a sample bomb) or a constant pressure (also known as a floating piston cylinder). The determination of which cylinder to use depends on the BTU content of the gas being sampled. It is common practice to use a constant pressure cylinder when BTU values are in excess of 1,050 BTU. The reason is because as the BTU value increases, it is a result of heavier hydrocarbons, some of which can be in a liquid state at atmospheric pressures and ambient temperatures. Having a gas sample with liquids is not desirable, as these liquids will raise the BTU value and can damage the gas chromatograph. When choosing a cylinder, it is important to know if it will be transported to a lab for analysis. If so, a DOT exempt cylinder should be chosen in the design required to keep the gas in the gas phase during collection and analysis.

On-Line Analysis

In some cases, an on-line gas chromatograph is used to determine the gas composition in real-time. On-line analysis is becoming more common with the introduction of explosion-proof analyzers and the drop in prices of these units.

On-line analyzers can only process a low pressure rate (typically 15-25 PSI). Therefore, it is necessary to lower the pipeline pressure of the gas flowing to the analyzer. This can be accomplished by utilizing a probe regulator, which combines a sample probe with an instrument regulator. A probe regulator is more effective at resisting the Joule-Thompson effect, which is the drop in temperature of the natural gas as the pressure drops. The correlation is that for every 100 PSI of pressure that drops, the natural gas temperature will drop by 7 degrees Fahrenheit. The pressure drop can cause gasses to convert into liquids. However, gas chromatographs, whether on-line or in the lab, cannot process liquids. Therefore, it is important to utilize liquid removing products. Many manufacturers offer liquid removing solutions in the form of filtering devices and some offer flow shut-off devices in the instance that some liquid makes it past the filter.

Reaching Pipeline-Quality

Deciding which stages of gas quality are necessary is very much contingent on the type of sample you receive. As the natural gas goes from the production stage, in which it is raw, it will continually be refined using the methods discussed in this paper. To ensure that pipeline-quality is being met, it is important to sample the product as it travels through the many processes in the industry. Once the natural gas has reached the distribution stage, in which it is to be distributed to consumers, it will be of pipeline-quality.

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