Natural Gas Sampling System Components

Introduction

A well-designed sample handling system is essential to the accuracy and reliability of instrumentation used in the natural gas industry. Approximately 80% of the problems encountered with instrumentation is associated with the sample handling system. There is no doubt that proper operation and accuracy of any instrument depends on the ability to obtain a representative sample from the pipeline. To ensure a valid representative sample, the sampling system must be designed to efficiently extract the sample, transport it, and condition it. This must be done while allowing for the effects of sample composition, pipeline pressure and temperature, ambient temperature, and contaminants present.

What is a Sampling System?

The sample handling system must extract a representative sample from a flowing pipeline, transport the sample to the analyzer, condition the sample to be compatible with the analyzer, and resist the corrosive nature of the sample.

The sampling system can best be described as a collection of components that:

- extracts the sample from the pipeline
- reduces the sample pressure
- filters the sample
- heats the sample
- delivers the sample to the analyzer.

This application note discusses the important aspects of a sampling system and its major components.

Sample Probe

The sample probe is typically a hollow, rigid tube that extends into the center one-third of the pipeline. Positioning it in this way allows the sample to be extracted without including contaminants that exist along the inside wall of the pipe. Sample probes come in various lengths and with various pressure connections. In most cases, the probes are typically made from 316 stainless steel in accordance with NACE specifications. Two types of sample probes exist: a simple sample probe, and a combination probe and pressure regulator. The simple probe consists of a length of tubing that extends into the pipeline and a threaded NPT connection for the pipeline. The combination probe performs the same function except that the sample pressure is reduced within the probe at pipeline temperature thereby reducing the chance of sample condensation due to pressure reduction (***Joule Thompson*** effect). The following rules apply for the use of sample probes:

- The tip of the sample probe must be positioned in the center one-third of the pipeline away from the pipeline wall where large particles accumulate.
- The probe must not be positioned in a "***dead end***" zone where positive flow does not exist.
- The probe should be a minimum of five pipe diameters downstream from any device that could produce aerosols or significant pressure drop such as elbows, orifice meters, control valves, etc.
- The sample probe should not be located within a defined meter tube region.
- The sample probe should be mounted vertically from the top of horizontal pipelines. It should not be located on vertical pipelines.

Pressure Regulator

A pressure regulator is used to reduce the sample pressure to the inlet pressure requirements of the analyzer. In many cases, the inlet pressure is less than 50 PSIG (344.75 kPa). An additional pressure regulator is not required if a combination probe/regulator is being used. The pressure regulator must accept pipeline pressures and reduce the sample pressure without condensing the sample. To meet this requirement, many regulators, know as ***two-stage regulators***, reduce the pressure in two steps. The regulator body may require heating to prevent condensation in cases where the ambient temperature is similar to water or hydrocarbon dew point of the sample line at line pressure. The regulator body and internal diaphragm should be manufactured from 316 stainless steel to resist corrosive attack from the sample.

Sample Filters

The sample filter removes the particulates and liquids that may be entrained with the sample. In all cases, filters must be chosen which will not change the composition of the sample except by removing contaminants which would be harmful to the analyzer. Various types of filters exist. The most common described below.

In-Line Filter

Unlike some of the other filter types, with the in-line filter, all of the sample passes through the filter. The active filter elements are available in a variety of materials including stainless steel (Figure 1).

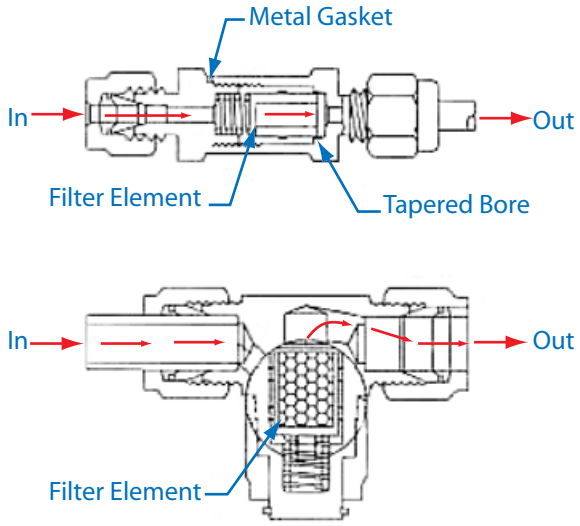


Figure 1. In-Line Filter.

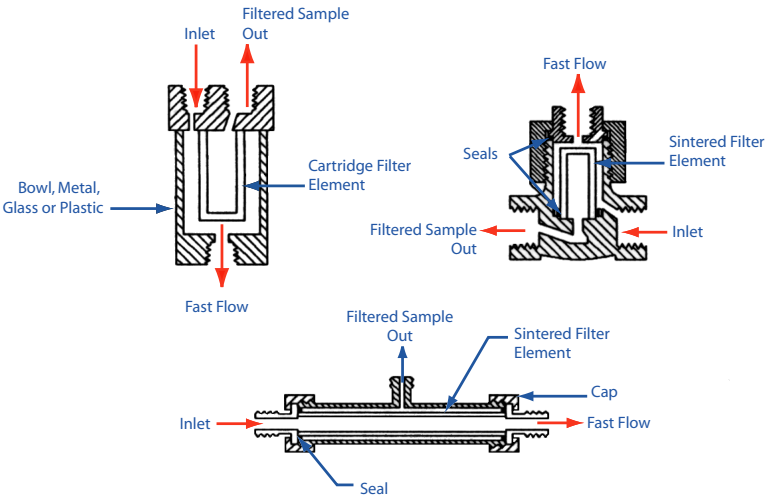


Figure 2. Bypass Filter.

Bypass Filter

Only a small portion of the sample passes through a bypass filter, while a majority of the sample passes across the surface of the filter element. The filtered sample is connected to the analyzer and the bypass port is used to maintain a high sample flow rate. The active filter element is either a disposable cartridge or a reusable sintered metal element (Figure 2).

Coalescing Filter

Coalescers are used to force liquid aerosols to combine into larger liquid droplets so they can be separated by gravity. The liquid is drained from the bottom port and the filtered gaseous sample exits the top port. The flow rates out the top and bottom are critical for proper operation (Figure 3).

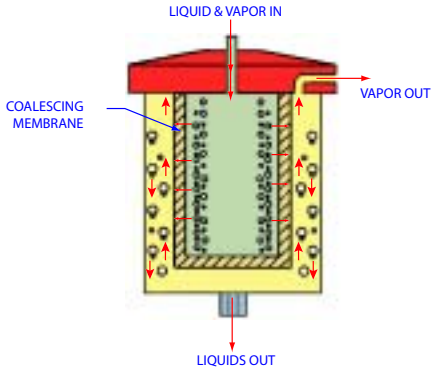


Figure 3. Coalescing Filter.

Membrane Filter

Membrane filters are considered to be liquid separators. The separator consists of a housing with a porous membrane sandwiched between its two halves. The housing typically have ports labeled Inlet, Bypass, and Outlet. The Inlet and Bypass ports are located on the upstream side of the membrane, while the Outlet port is on the downstream side. Gas sample enters through the Inlet port, flows through the membrane and exits the Outlet port. Any liquid that may be present cannot flow through the membrane and so it exits the Bypass port. If particulate is present, it is retained on the membrane. This membrane is supported by a sintered porous disk, located on the Outlet side of the housing (Figure 4).

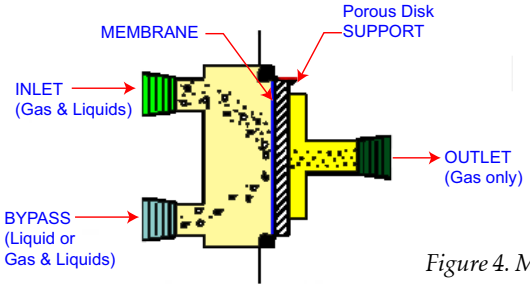


Figure 4. Membrane Filter.

Sample Tubing

The sample tubing is used to connect the components of the sampling system and to deliver the sample to the analyzer. The choice of sample tubing must be based on internal volume and chemical compatibility with the sample. In most cases, the tubing should be 316 stainless steel with a diameter of 1/4" (6mm) or smaller to minimize the total volume of the system. The sample tubing may require heating depending on the ambient temperature and the composition and pressure of the sample. This tubing, known as ***heat-traced tubing***, is used to prevent condensation of water or hydrocarbons due to ambient temperature below the sample dew point.

Lag Time

Although each case tends to be different, the sampling system must be designed to minimize the time required to deliver the sample to the analyzer. This time, known as ***lag time***, is minimized by reducing the internal volume of the sampling components and maintaining a high sample flow rate from the pipeline to the analyzer.

The calculation of lag time involves determining the total volume of the sampling system and the volumetric flow rate of the sample through the system. To determine the volume of the sampling system, use the following equation for the tubing volume.

$$\text{Tubing Volume} = 3.14 \times \frac{\text{Inside Diameter}^2}{4} \times \text{Length}$$

From the vendor literature, determine or estimate the internal volume of additional components such as filters, valves, etc. Add these volumes to the total volume of the tubing.

Use a flow meter to measure the continuous flow rate of the sample through the analyzer at the vent port. The flow meter must be calibrated to indicate flow rate at standard pressure (14.7 PSIA, 1 bar). Since the sample pressure leading to the analyzer is above atmospheric pressure, the actual volumetric flow rate must be determined. This is needed for determining the lag time since the volumetric flow rate varies with line pressure. The flow rate at low pressure is much larger than the flow rate at a high pressure. Use the following equation to calculate the sample flow rate at the pressure in the sampling system.

$$\text{Actual Flowrate} = V \times \frac{P_{base}}{P_{actual} + P_{base}}$$

where,

V = the sample flow rate at standard temperature and pressure

P_{actual} = the sampling system pressure

P_{base} = the base pressure (14.7 psia, 1 bar)

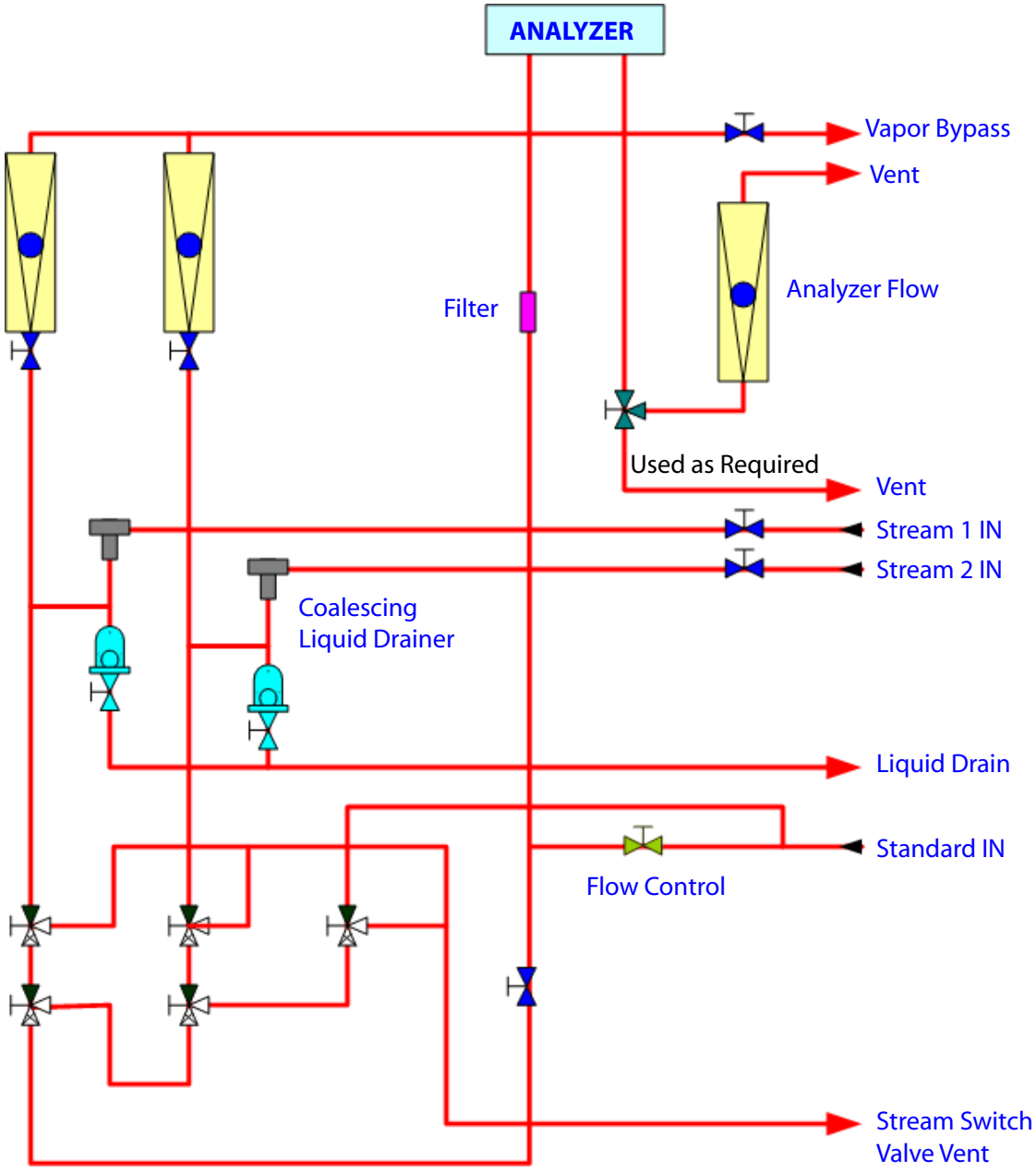
For example, with a volumetric flow rate of 1000 mL/ min at standard temperature and pressure, the actual flow rate at a line pressure of 30 PSIG is 329 mL/min. However, the actual flow rate at a line of pressure of 1,000 PSIG is only 14.5 mL/ min. Obviously the pressure in the sampling system will affect the actual sample flow rate to the analyzer and the lag time.

Once the actual flow rate is known, the lag time is calculated as follows:

$$\text{Lag time} = \frac{\text{Total volume}}{\text{Actual flowrate}}$$

Using the previous example, the lag time with a 50 mL total volume, and a pressure of 30 PSIG is 9.1 seconds. With a pressure of 1,000 PSIG, the lag time increases to 207 seconds. As the example indicates, it is advantageous to reduce the pressure at the pipeline probe to increase the flow rate in the sampling system to reduce the lag time. The reduced pressure also reduces the chance of moisture or hydrocarbon condensation since the dew point will occur at a lower temperature.

Many analyzers require low sample flow rates. To ensure continuous flow in the sampling system and to reduce lag time, systems are designed with a parallel ***speed loop*** or ***bypass loop*** that is operated at a greater sample flow rate compared to the analyzer flow rate. In this way, the lag time is minimized and the analyzer uses a fresh sample for each analysis cycle.



A typical natural gas sampling system is illustrated above. Note the use of sample and calibration gas selection solenoid valves in the ***Double Block and Bleed*** (DBB) configuration. The internal DBB valving prevents mixing of sample from the previous stream that was sampled.