

# **Manual of Petroleum Measurement Standards Chapter 14—Natural Gas Fluids Measurement**

## **Section 1—Collecting and Handling of Natural Gas Samples for Custody Transfer**

SIXTH EDITION, FEBRUARY 2006

REAFFIRMED, SEPTEMBER 2011



AMERICAN PETROLEUM INSTITUTE



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### **Measurement Coordination**

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# Chapter 14—Natural Gas Fluids Measurement

## Section 1—Collecting and Handling of Natural Gas Samples for Custody Transfer

### 1 Introduction

This standard concentrates on proper sampling systems and procedures. It recognizes the critical impact of hydrocarbon dew point consideration to the overall accuracy and success of these practices and procedures. Analyses of gas samples are used for many purposes and are applied to various calculations, some of which have an impact on the accuracy of custody transfer calculations (quantity and quality).

Inaccuracies can result from using:

- a. Inappropriate sampling techniques and/or equipment,
- b. Inappropriate sample conditioning and handling,
- c. Samples collected from non-representative locations and/or under non-representative operating conditions, or
- d. Inappropriate analytical methods.

Analyses from samples can be utilized in many different ways, including the following:

- a. Calculations to determine the heating value, volumetric flow rate, total energy, density, viscosity, hydrocarbon dew point, and compressibility.
- b. Calculations to determine the gallons per thousand standard cubic feet (liters per cubic meter) of recoverable liquid product from the stream.
- c. Identification of contaminants contained in the gas stream.
- d. Compositional information used for process design and to determine whether the stream meets contractual specifications.

This standard incorporates guidelines and recommendations for obtaining representative samples safely. It should be useful as a resource document for training programs as well. This standard attempts to consider both sweet and sour gas streams as well as high- and low-pressure applications. Streams at or above the hydrocarbon dew point temperature, and streams that may contain water vapor up to the point of saturation are addressed.

It is not the intent of this standard to recommend particular equipment suppliers or manufacturers.

Although economic, regulatory, compositional, and contractual considerations must always be evaluated and identified, samples should be collected on a flow-proportional or flow-weighted basis whenever practical. Spot samples, by their nature, cannot fully represent a gas stream of varying composition. Time proportional samplers, particularly if they continue to sample even when flow has stopped, are not capable of accurately characterizing natural gas streams that have variable compositions.

Sampling systems and procedures not in compliance with this guideline may result in errors. Upgrading existing facilities and practices to comply with this standard is strongly encouraged but shall be at the discretion of the parties involved.

### 2 Purpose and Scope

The purpose of this standard is to provide a comprehensive guideline for properly collecting, conditioning, and handling representative samples of natural gas that are at or above their hydrocarbon dew point.

The standard considers spot, composite, continuous, and mobile sampling systems. This standard does not include sampling of liquid streams.

This standard includes comments identifying special areas of concern or importance for each sampling method included. It is intended for custody transfer measurement systems and may be applicable to allocation measurement systems.

The accuracy of moisture determinations from samples collected using the recommendations in this standard has not been determined.

This standard does not include sampling multi-phase flow (free liquid and gas) or supercritical fluids.



### 3 Referenced Publications

The current editions of the following standards, codes, and specifications are cited in this standard:

ASTM<sup>1</sup>

D 1142 *Standard Test Method for Water Vapor Content of Gaseous Fuels by Measurement of Dew-Point Temperature*

DOT<sup>2</sup>

49 *Code of Federal Regulations*

EEMUA<sup>3</sup>

138:1988 *Design and Installation of On-Line Analyser Systems*

GPA<sup>4</sup>

Std 2166 *Obtaining Natural Gas Samples for Analysis by Gas Chromatography*

Std 2261 *Analysis for Natural Gas and Similar Gaseous Mixtures by Gas Chromatography*

NACE<sup>5</sup>

MR-01-75 *Sulfide Stress Cracking Resistant Metallic Materials for Oilfield Equipment*

### 4 Definitions

**4.1 absorption:** Occurs when natural gas constituents are dissolved into a liquid or solid that is not considered to be the mixture's liquid phase.

**4.2 adsorption:** Occurs when a thin film of molecules adheres to a liquid or solid surface.

**4.3 chilled mirror test:** Used to determine dew points (water and/or hydrocarbon) by passing the natural gas over a mirror while gradually reducing the temperature of the mirror until condensation forms. A Bureau of Mines-type of dew point apparatus is commonly used for chilled mirror tests.

**4.4 cricondenbar:** The point of maximum pressure on a hydrocarbon dew point curve. This is the highest pressure at which a hydrocarbon mixture can exist separately as gas and liquid.

**4.5 cricondenthem:** The point of maximum temperature on a hydrocarbon dew point curve. The cricondenthem is the highest temperature at which hydrocarbon vapor can condense to form liquid.

**4.6 cricondenthem pressure:** The pressure at which the cricondenthem occurs on a hydrocarbon dew point curve.

**4.7 continuous sampling systems:** Provide for an uninterrupted flow of sample.

**4.8 de-sorption:** Occurs when adsorbed or absorbed molecules are released from a liquid or solid surface.

**4.9 extension tube ("pigtail"):** A piece of tubing placed on the end of a sample container used to move the point of pressure drop (point of cooling) away from the sample being acquired.

**4.10 floating piston cylinder:** A container which has a moving piston that has its forces balanced by a pre-charge pressure.

**4.11 flow-proportional composite sampling:** The process of collecting gas over a period of time at a rate that is proportional to the pipeline flow rate.

**4.12 gas sample distortion:** Any effect that results in a sample that is not representative of the gas stream.

**4.13 gas sampling system:** The system intended to deliver a representative sample of natural gas from the pipeline to the analytical device.

**4.14 gas quality:** Refers to physical characteristics determined by the composition (including non-hydrocarbon components, specific gravity, heating value and dew points) of the natural gas mixture.

<sup>1</sup>ASTM International, 100 Bar Harbor Drive, West Conshohocken, Pennsylvania 19428-2959, [www.astm.org](http://www.astm.org).

<sup>2</sup>Department of Transportation, 400 7th Street S.W., Washington D.C. 20590, [www.dot.gov](http://www.dot.gov).

<sup>3</sup>Engineering Equipment and Materials Users' Association, 3rd Floor, 20 Long Lane, London EC1A 9HL, [www.eemua.co.uk](http://www.eemua.co.uk).

<sup>4</sup>Gas Processors Association, 6526 E. 60th Street, Tulsa, Oklahoma 74145, [www.gasprocessors.com](http://www.gasprocessors.com).

<sup>5</sup>NACE International, 1440 South Creek Drive, P.O. Box 218340, Houston, Texas 77218-8340, [www.nace.org](http://www.nace.org)

- 4.15 hydrocarbon dew point:** A temperature at a given pressure at which hydrocarbon vapor condensation begins.
- 4.16 hydrocarbon dew point curve:** A curve connecting all points on a temperature-pressure diagram where a hydrocarbon vapor begins to condense into liquid.
- 4.17 lag time in a sample system:** The time required for a molecule to migrate from the inlet of the sample probe to the inlet of an analyzer.
- 4.18 mobile sampling system:** The system associated with a portable gas chromatograph.
- 4.19 multi phase flow:** Defined as two or more phases in the stream.
- 4.20 normal condensation:** Caused by an increase in pressure or a decrease in temperature.
- 4.21 normal vaporization:** Caused by a decrease in pressure or an increase in temperature.
- 4.22 phase:** A physical state of a compound (e.g., solid, liquid, or gas). Each phase has a distinct molecular arrangement and can be readily identified (like the two phases of H<sub>2</sub>O in ice water—solid and liquid).
- 4.23 phase behavior:** Refers to the condensation and vaporization characteristics of a hydrocarbon mixture. It includes considerations such as temperature, pressure, composition, relative amounts of the liquid and gas phases.
- 4.24 pitot probe:** An impact device with an inlet and return port that provides flow to a hot loop by converting velocity into a differential pressure.
- 4.25 re-circulation region (“eddy”):** An area within a piping system where gas is not continually being replaced even though gas is flowing through the system.
- 4.26 representative gas sample:** Compositionally identical, or as near to identical as possible to the sample source stream.
- 4.27 residual impurities:** Any substances, such as air or natural gas components, that are left in a sample cylinder.
- 4.28 retrograde condensation:** Caused by a decrease in pressure or increase in temperature.
- 4.29 retrograde vaporization:** Caused by an increase in pressure or decrease in temperature.
- 4.30 sample container:** Any container used to hold a natural gas sample. Typical sample containers are constant volume cylinders or floating-piston cylinders.
- 4.31 sample loop:** Part of the sampling system that conveys the sample from the probe to the container or analytical device. It is typically external to the analysis device. This should not be confused with the sample loop that is inside an analytical device such as a gas chromatograph.
- 4.32 sample probe:** A device extending through the meter tube or piping into the stream to be sampled.
- 4.33 sample source:** Refers to the stream being sampled.
- 4.34 sampling separator:** A device in the sampling system used to collect free liquids.
- 4.35 single-phase flow:** Natural gas flowing at a temperature above the hydrocarbon dew point and free of compressor oil, water, or other liquid or solid contaminants in the flow stream.
- 4.36 slip stream (“hot loop” or “speed loop”):** Provides for a continuous flow of sample.
- 4.37 water dew point:** The temperature at a specific pressure where water vapor condensation begins.

## 5 Hydrocarbon Dew Point

The hydrocarbon dew point is a temperature at a given pressure at which hydrocarbon vapor condensation begins.

In general, when the sample system is kept above the hydrocarbon dew point temperature, all methods, when properly applied, can provide a sample that is representative of the sample source. However, it is difficult (or nearly impossible) to obtain accurate and repeatable results when the temperature of any element of the sample system falls below the hydrocarbon dew point temperature, or when sampling a stream with a temperature near the hydrocarbon dew point.



The hydrocarbon dew point for a particular gas changes with temperature and pressure. Because the hydrocarbon dew point is not constant for all pressures and temperatures, the proper application of the methods in this standard may require the use of a phase diagram. The phase diagram is particularly useful when the pressure or temperature of the gas changes during the sampling process. This tool is discussed in detail in Appendix A.

Various equation of state (EOS) computer programs are capable of calculating the hydrocarbon dew point temperature at various pressures (see References 9, 10 and 11). The accuracy of the calculated hydrocarbon dew point temperature depends on the calculation method used and on the accuracy of the gas composition that is entered into the computer program.

## 5.1 INITIAL SAMPLING OF A GAS STREAM OF UNKNOWN HYDROCARBON DEW POINT AND COMPOSITION

In order to properly apply the methods discussed in this standard, it is necessary to start with a reliable value for the hydrocarbon dew point of the stream to be sampled.

For initial sampling of a gas stream of unknown composition, the following techniques are recommended in order of preference:

- Measure the hydrocarbon dew point temperature and maintain the sample gas temperature above the measured hydrocarbon dew point temperature. NOTE: ASTM D 1142, *Standard Test Method for Water Vapor Content of Gaseous Fuels by Measurement of Dew-Point Temperature*, recommends that the sample should be 3°F (1.7°C) above the dew point. For the purposes of this standard, the sample should be maintained according to the recommendations in 6.6, *General Discussion of Heating*.

When the hydrocarbon dew point temperature is not measured,

- use a constant pressure spot sampling method while maintaining the sample gas temperature at or above the flowing gas temperature, perform an extended analysis, and calculate the hydrocarbon dew point temperature, or
- use a pressure-reducing sampling method, perform an extended analysis, and calculate the hydrocarbon dew point temperature (when using a sampling method involving a pressure reduction, provide sufficient heat, at, or prior to, the point of pressure reduction, to offset the Joule-Thomson effect), or
- use historical information, such as analyses or dew point measurements from a similar gas source, or
- take a spot sample at line pressure, heat the sample gas to at least 30°F above the flowing temperature at the time the sample was obtained, perform an extended analysis, and calculate the hydrocarbon dew point temperature. (See 6.6, *General Discussion of Heating*, for cautions regarding equipment heating.)

Once the calculated hydrocarbon dew point temperature is known, maintain the sample gas temperature at least 30°F (17°C) above the hydrocarbon dew point temperature as discussed in 6.6, *General Discussion of Heating*.

If the stream changes composition, pressure, or temperature, or if there is an indication that the hydrocarbon dew point has changed, repeat this process to ensure that the hydrocarbon dew point is known and that the gas temperature is maintained in the sampling system according to 6.6, *General Discussion of Heating*.

## 6 General Considerations for the Design of a Natural Gas Sampling System

The main consideration in the design of a natural gas sampling system is to deliver a representative sample of the gas from the sample source to an analytical device.

Issues that should be addressed when designing a sampling system include: expected gas quality, phase-change characteristics, type of sample/analysis, material to be used for sample delivery, ambient condition extremes, cleanliness, availability of power, flow rate, and transport time.

Further consideration should be given to the presence of inert compounds such as carbon dioxide (CO<sub>2</sub>) or nitrogen (N<sub>2</sub>). These compounds will not only impact the heating value and density of the gas, they also may determine the gas chromatograph carrier gas needed and whether or not the stream meets contractual specifications.

### 6.1 THE COMPONENTS OF TYPICAL SAMPLING SYSTEMS

Spot and composite sampling methods require the use of a sample container to transport the sample from the field location to the laboratory. Examples are shown in Figures 1a and 1b. Figure 1a is an example of a spot sampling apparatus employing the purging-fill and empty method. Figure 1b is an example of an application using a composite sampler.

Figure 2 shows the components in a continuous sampling system or mobile sampling system.

For specific details regarding the design of these systems, see Sections 7, *Sample Probes*, 8, *Sample Loops/Lines*, 9, *Sample Containers*, and 13, *Automatic Sampling*.

For details regarding the heating and insulating of sampling systems, see 6.6, *General Discussion of Heating*.

## 6.2 FLOW CHARACTERISTICS

### 6.2.1 General

Piping elements, such as valves and orifices, can create re-circulation regions (eddies) in the flowing sample source stream. The gas composition in these eddies may be measurably different from the gas composition of the bulk flow. The gas downstream of a gas-liquid separator will be near its hydrocarbon dew point, and a reduction in line temperature will likely cause some condensation to occur. In other cases, a pipeline may be operating with both gas and liquid continually present in the pipe. Obtaining an accurate gas sample under these conditions is difficult and outside the scope of this standard. See Appendix C, *Lessons Learned During Sampling in Hydrocarbon Saturated and 2-Phase Natural Gas Streams*. Also see Appendix B, *Fluid Mechanical Considerations in Gas Sampling* for a detailed discussion of fluid mechanics.

Users are cautioned not to interpret liquids condensed by the metering or sampling system as free liquids flowing through the pipeline.

### 6.2.2 Single-Phase Flow

Single-phase flow is natural gas flowing at a temperature above the hydrocarbon dew point and free of compressor oil, water, or other contaminants in the flowing sample source stream. In general, it is preferred that the single phase gas in the pipeline be in the turbulent flow regime, because the fluid turbulence creates a well-mixed, representative fluid.

## 6.3 CAUSES OF GAS SAMPLE DISTORTION

Since natural gas is a mixture of organic and inorganic pure gases, its integrity will be sacrificed if any components of the sample gas are depleted or augmented (e.g., air-contamination, de-sorption of hydrocarbons). This section identifies fundamental mechanisms of sample distortion. An understanding of these mechanisms will reduce the likelihood of poorly designed sampling systems.

It is important to recognize that only sample collection distortion mechanisms are identified in this section. Poor gas analysis techniques can also distort the indicated composition (see Section 16, *Guidelines for Analysis*).

### 6.3.1 Phase Changes

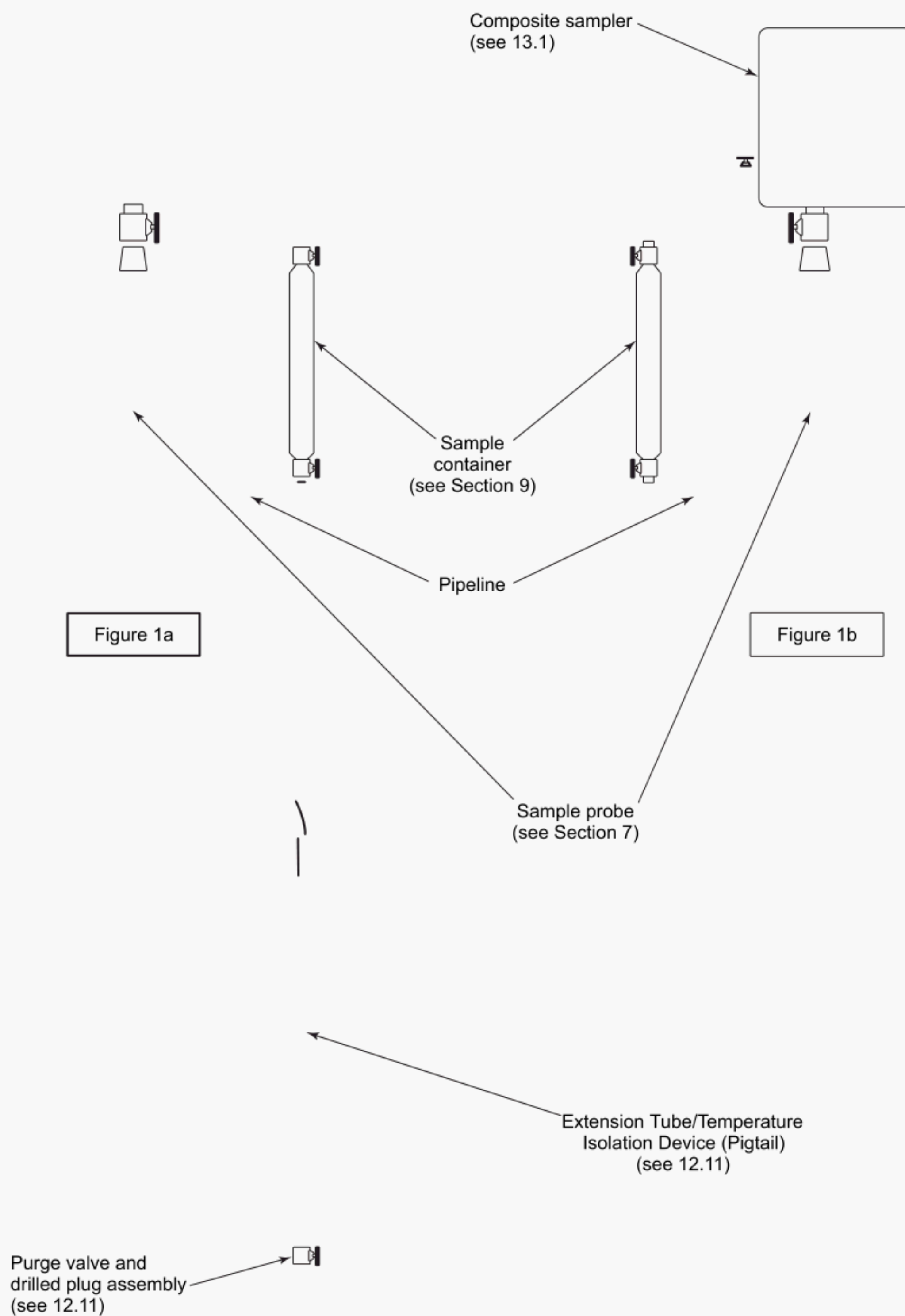
Condensation and revaporization of hydrocarbons within the sampling system can cause significant distortions in a gas sample. These types of sample distortions can occur under both flowing and non-flowing conditions (i.e., in a flowing sample delivery system or in sample containers), or if the sample comes in contact with sampling equipment that is below the hydrocarbon dew point. See Appendix A, *The Phase Diagram*, for a detailed discussion of the thermodynamics of these phase changes.

Accurate sampling from gas streams with temperatures at the hydrocarbon dew point temperature is more difficult than sampling from streams with temperatures above the hydrocarbon dew point temperature. Additionally, depending on the pipeline pressure, retrograde condensation may occur if the pressure is reduced. Some gas mixtures will have a hydrocarbon dew point that is high enough to cause condensation at ambient temperatures commonly experienced during the year. If condensation does occur, and only the gaseous phase of the partially condensed sample is analyzed, the heating value and density of the sample will be incorrect. Furthermore, the remaining sample will no longer be representative of the sample source.

The integrity of gas samples (and calibration standards) with condensed components can be recovered by revaporizing the condensed liquids, provided that no fluid (gas or liquid) has been released from the sample container prior to revaporization. See 6.4, *Revaporization*, and Appendix A, *The Phase Diagram*.

#### 6.3.1.1 Flowing and Sampling Conditions

A gas sample flowing through a sampling system may experience temperature and pressure changes. Pressure and temperature reductions occur when the gas accelerates through tubing elements within the sampling system. If the gas is near the hydrocarbon



Note: Insulation and heat tracing are not shown. See 6.6, *General Discussion of Heating* for gas temperature requirements.

Figure 1a—Typical Spot Sampling System  
Figure 1b—Typical Composite Sampling System



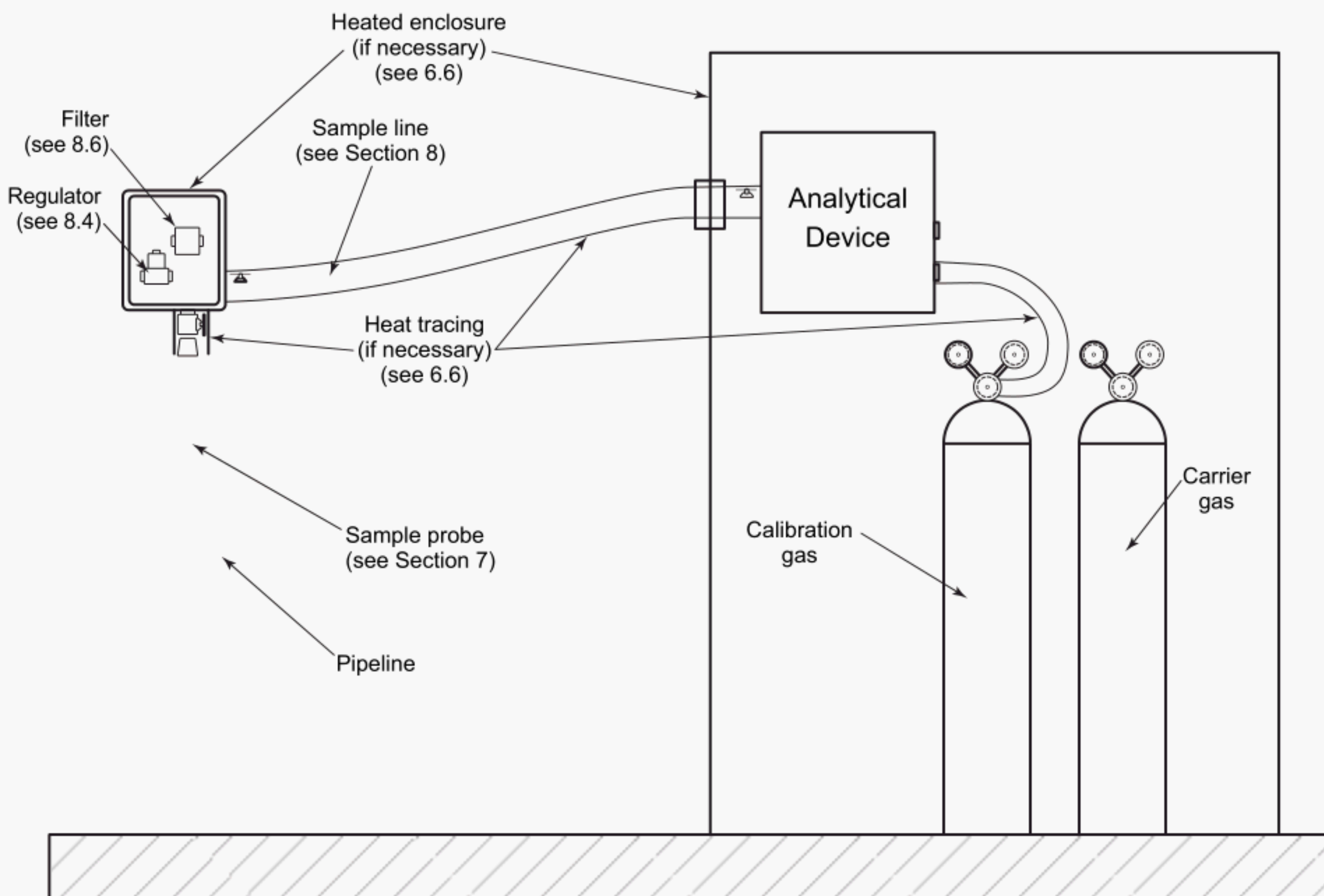


Figure 2—Typical Continuous (On-Line) Sampling System/Mobile Sampling System

dew point, condensation may occur, causing gas sample distortion. It is important to be aware of the fittings and elements within a flowing sampling system, particularly those that cause significant pressure drop.

For example, consider natural gas flowing through a restriction such as a partially closed valve or regulator. If the hydrocarbon dew point curve for a gas being sampled is represented by Figure 3, condensation could occur as the pressure of the gas is reduced from 1500 psia to 900 psia (10.3 MPaabs to 6.2 MPaabs) (path 1–2, Figure 3). It is possible to avoid condensation if the sample gas temperature is maintained above the hydrocarbon dew point. The gas temperature must be high enough to offset the reduction in temperature associated with the pressure reduction (path 1–3, Figure 3). See 6.6, *General Discussion of Heating* and Appendix A, *The Phase Diagram*, for further information.

### 6.3.1.2 Sample Conditions

When a non-flowing gas sample, such as a sample contained in a sample cylinder, is subjected to a temperature below the hydrocarbon dew point temperature, condensation (and, therefore, sample distortion) will occur.

A gas sample could condense in the sample cylinder while it is being transported or awaiting analysis in a laboratory. Consider a natural gas with the phase diagram shown in Figure 3 and contained within a sample cylinder. Path 4–5 shows that the sample can condense if the cylinder is exposed to an ambient temperature below the hydrocarbon dew point temperature.

If it is necessary to transfer a small representative sample from a large accumulator, care must be taken to insure that any condensation that may have occurred has been revaporized prior to and during transfer and that the sample is well mixed. This is not a recommended practice because it is very difficult to transfer a representative sample from one cylinder to another if the gas is at or near the hydrocarbon dew point.



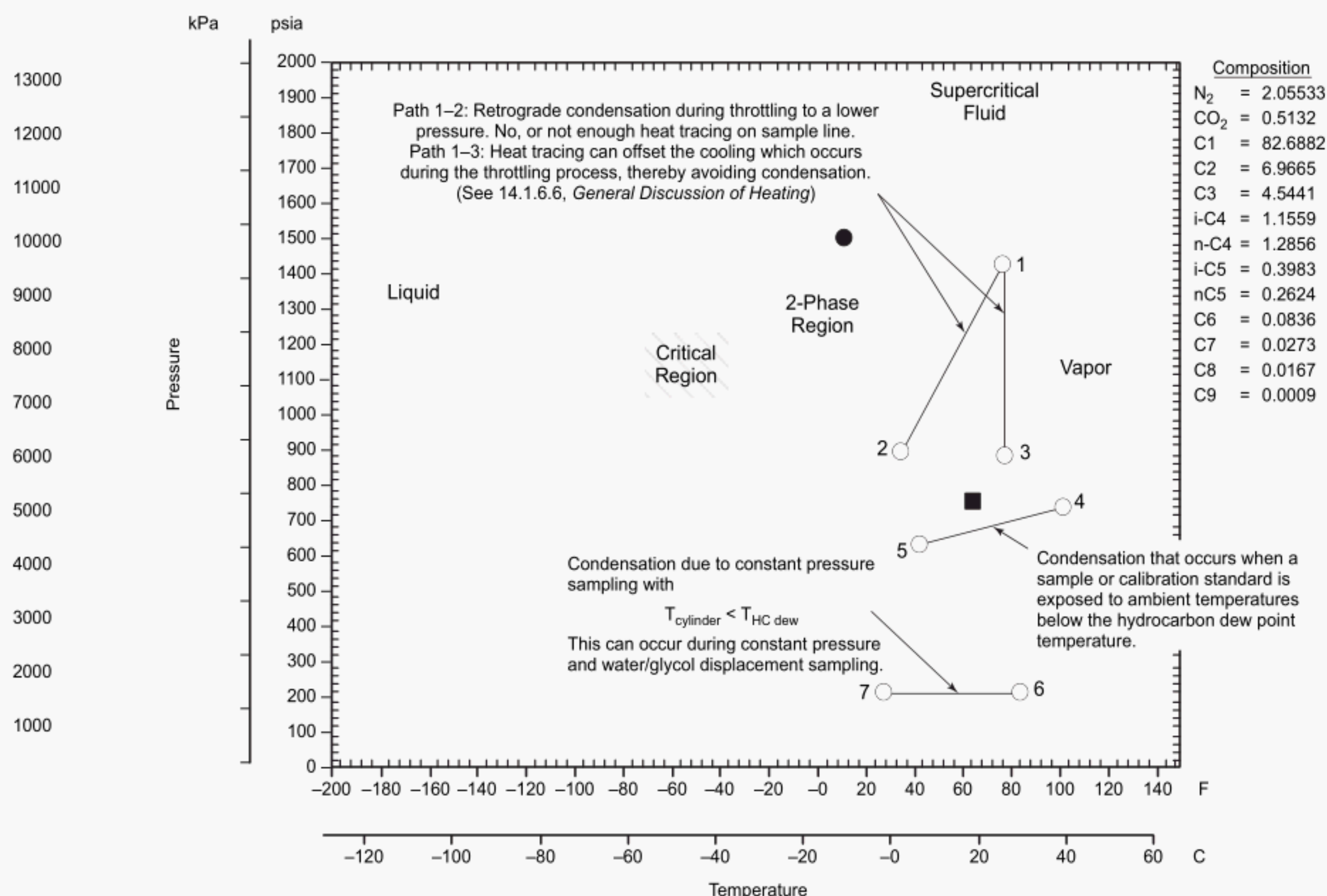


Figure 3—Examples of Thermodynamic Processes Associated with Sampling System Design and Sampling Methods

Gas sample containers and the lines to an analysis device should always be heated prior to analysis. Heating times and temperatures should be sufficient to ensure that any condensed hydrocarbons are revaporized before an analysis is started. See 6.6, *General Discussion of Heating*, and Appendix A, *The Phase Diagram*, for further information.

### 6.3.1.3 Cold Sampling Equipment

If the sample stream comes in contact with sampling equipment that is at a temperature below the hydrocarbon dew point, condensation, and therefore, sample distortion can occur. Consider the natural gas mixture represented by Figure 3. If the temperature of the sampling equipment is below the hydrocarbon dew point temperature, condensation can occur even when sampling at constant pressure (path 6–7). See 6.6, *General Discussion of Heating*, and Appendix A, *The Phase Diagram*, for further information.

### 6.3.2 Surface Effects

There are three important surface effects that have been identified for gas sampling.

1. Clean, solid surfaces are subject to adsorption (sticking) and de-sorption (unsticking) of gas molecules.
2. Some liquids may dissolve gas molecules, or they may yield certain gas molecules if the liquid already contains significant amounts of dissolved gas molecules.
3. Porous surfaces can cause gas sample distortions.

The first two effects tend towards an equilibrium that is dependent on pressure and temperature. If the temperature and/or pressure of the sampling system changes, hydrocarbons could be removed from or released into the sample stream. This will cause an incorrect determination of heating value and density.

Sampling systems should incorporate clean, inert and non-porous materials and sufficient temperature control to remain above the hydrocarbon dew point if the surface effect errors are to be avoided.



See 6.5, *Cleanliness*, 8.3, *Tubing Materials*, 6.6, *General Discussion of Heating*, Section 10, *Materials for Sweet and Sour Gas Service*, and Appendix A, *The Phase Diagram*, for further information.

### 6.3.2.1 Adsorption

Adsorption occurs both chemically and physically. Chemical adsorption is due to a reaction between the gas molecules and the solid surface molecules.

Physical adsorption occurs because free surfaces, such as the inner surfaces of tubing or sample containers, tend to attract gas phase molecules. For a given surface and gas molecule, the extent of physical adsorption depends on the amount of surface area and the pressure and temperature. Changing the pressure and/or temperature could either adsorb or de-sorb gas molecules.

Sample distortion due to chemical and physical adsorption can be minimized by prudent selection of sampling system materials. In general, materials and coatings that are chemically inert and of minimum porosity are the best choices.

### 6.3.2.2 Liquid/Gas Interfaces

Another surface effect that causes gas sample distortion occurs between gas molecules and the surfaces of some liquids. Hydrocarbon liquids can dissolve significant amounts of natural gas components. This is especially important if the sampling system or sample container has been exposed to liquid hydrocarbons.

Proper cleaning procedures will minimize the potential for this problem. See 6.5, *Cleanliness*.

### 6.3.2.3 Plastic Tubing

With the exception of Nylon 11 or equivalent, most plastic tubing tends to cause gas sample distortion and is not recommended as a gas sample conduit for hydrocarbon analysis.

**CAUTION:** Be careful not to apply direct heat or high temperature heat tracing to any plastic tubing, including Nylon 11.

### 6.3.3 Residual Impurities

Gas sample distortion can be caused by residual impurities such as air or previous samples and they may be difficult to detect. For example, a gas chromatograph not configured to detect oxygen will show a residual of air as increased nitrogen. This type of impurity might not be detected. If a small amount of the previous gas sample was left in the sampling system or sample container, it might not be detected either.

Strategies for removing residual impurities involve purging, evacuating and repeated fill/empty cycles. Sample distortion due to the presence of residual impurities may be a problem if any of these methods are performed poorly. If there are leaks in any valves or seals these methods may not work, even if the procedures are performed correctly.

## 6.4 REVAPORIZATION

Section 6.3.1, *Phase Changes*, identifies a phase change as one cause of gas sample distortion. This type of sample distortion will have a significant impact on the integrity of the gas sample.

If the gas phase of a partially condensed sample contained in a sample container is analyzed, the heating value and density of the sample will be biased and the remaining sample will no longer be representative of the sample source.

If a gas chromatograph's calibration gas standard experiences a phase change and calibration occurs while the calibration gas is still in two phases, all analyses performed from that point forward will be biased. Furthermore, the composition of the calibration gas standard will have changed.

The integrity of the sample (and the calibration standard) can be recovered by heating the containers if no fluid (gas or liquid) is withdrawn prior to revaporization. Care must be taken to ensure that all condensed gases are revaporized when a gas sample is analyzed in a laboratory.

Section 6.6, *General Discussion of Heating*, provides guidelines for heating samples and calibration standards, and for revaporizing condensed samples and calibration standards.

## 6.5 CLEANLINESS

The impact of liquid hydrocarbon residues is discussed in 6.3.2.2, *Liquid/Gas Interfaces*. Proper cleaning procedures must be followed in order to remove liquid hydrocarbon residues and other impurities (e.g., water or glycol residue) that may exist.

Sample systems should be designed so that they may be thoroughly and easily cleaned. A procedure for cleaning sample systems and sample containers is essential for good gas sampling practices.

Sample containers must be purged and cleaned prior to each collection of sample, unless they are special passivated cylinders used to sample streams containing highly reactive components. The most effective cleaning agent is wet steam. Steam cleaning is acceptable only if the steam is clean and does not contain corrosion inhibitors, boiler water treating chemicals or other substances that may contaminate the sample cylinder.

Solvents, such as acetone and liquid propane, that do not leave a residue after drying are generally acceptable for removing most heavy ends contamination, although they may sometimes present hazards such as flammability and toxicity. Decon Contrad<sup>®6</sup> 70 washing also produces acceptable results that compare well to the solvents. Other solvents chemically equivalent to Decon Contrad<sup>®</sup> 70 can reasonably be expected to produce acceptable results, however, their effectiveness must be tested prior to use.

Supercritical carbon dioxide cleaning produces acceptable results, in spite of the fact that some dirty hydrocarbon spot trails may be left in the cylinder after it is cleaned.

**WARNING: Using supercritical carbon dioxide to clean cylinders can be hazardous due to the physical properties of the fluid and the high pressures and low temperatures involved and should be used with great caution.**

Sample containers must be dried and purged after wet cleaning procedures (e.g., wet steam). Evacuating the cylinder to 1 millimeter of mercury absolute (133 Paabs) (near perfect vacuum) or less will eliminate the residual liquid. Nitrogen, helium and dry instrument quality air are good examples of gases that may be used to dry or purge cylinders that are free of deposits and heavy hydrocarbon contamination.

Many laboratories leave a blanket of nitrogen, helium or other gases in sample cylinders in order to protect the cylinder from air contamination. Blanket gases and gases used to pre-charge sample cylinders must be carefully selected so that, should leakage occur within the cylinder or should the sample be contaminated by these gases, the chromatograph will not interpret the contamination as a part of the sample being analyzed. For example, a chromatograph using helium as a carrier gas will not detect helium gas left over from the pre-charge of a single cavity cylinder or helium leaking by the piston in a constant pressure cylinder.

Many sulfur species will be readily absorbed by general purpose sample cylinders. The resulting analysis will dramatically understate sulfur levels. Samples to be analyzed for sulfur content need to be collected in clean and dry specially-lined or passivated cylinders dedicated for that purpose. The entire wetted surface of the sample container and its secondary components (e.g., valves, fittings or relief devices) should be non-reactive to sulfur or sulfur-containing compounds.

Note: Interaction with water and other components present in the sample gas may degrade the sulfur content regardless of the cylinder material. The sample loop, including any separator in the system, must be thoroughly purged and be cleared of contaminants and accumulated liquids prior to sample collection.

## 6.6 GENERAL DISCUSSION OF HEATING

Condensation may occur in composite, spot, mobile or on-line sampling systems. If any part of the sampling process causes the sample to fall below the hydrocarbon dew point, scattered and biased analytical results and non-representative samples are likely to result. In order to avoid this problem, the sample gas temperature must remain above the gas hydrocarbon dew point during sampling. This can be accomplished by heating sample probes and by heat tracing lines, regulators and sample cylinders or by employing some other means of delivering heat to the fluid in the sampling system.

Due to the uncertainty in measuring or calculating the hydrocarbon dew point, it is recommended that the gas being sampled be maintained at least 30°F (17°C) above the expected hydrocarbon dew point throughout the sampling system. This operating temperature margin may be reduced for gas compositions where data (see References 9, 10 and 11) exists to show that differences between calculated dew points and measured hydrocarbon dew points are less than the 30°F recommendation. If ambient temperatures are above the hydrocarbon dew point, heating may not be required. When the sampling process involves a pressure reduc-

<sup>6</sup>This term is used only as an example only, and does not constitute an endorsement of this product by API.



tion, provide sufficient heat at or prior to, the point of pressure reduction to offset the Joule-Thomson effect (approximately 7°F (3.9°C) per 100 psi (690 kPa) of pressure reduction).

### 6.6.1 Heat Tracing

Heat tracing methods most commonly used are steam, hot water and electrical.

Electrical heat tracing is normally used in remote locations or in locations where it is difficult to use steam or hot water. Electrical heat tape should be self-limiting or controlled with temperature-limiting devices.

**Electrical heat tracing and all electrical equipment must meet the electrical codes for the intended service area. These requirements ensure that a heating element does not overheat if a failure in the electrical components occurs. Overheated electrical components could cause injury or an explosion in a natural gas application.**

Sampling systems on residue gas lines on the outlet of gas plants should be heat traced to insure that liquids do not condense in the sample system during plant upsets. Once these liquids accumulate in a sampling system, it may take days after the process is operating normally before representative samples are collected from the system. Purging the entire system may be required.

### 6.6.2 Catalytic Heater

A catalytic heater produces heat through an exothermal reaction between a combustible gas, such as natural gas, oxygen and a catalyst. The heat given off by the reaction can be adjusted by varying the rate of gas flow to the catalyst. The heat released by the reaction is well below the ignition temperature of the natural gas.

**Electrical heat tracing and all electrical equipment must meet the electrical codes for the intended service area. These requirements ensure that a heating element does not overheat if a failure in the electrical components occurs. Overheated electrical components could cause injury or an explosion in a natural gas application.**

### 6.6.3 Insulation

Insulation is used to protect the flowing stream from cold ambient conditions or covering heat tracing around the external portions of the probe assembly, regulator and sample line. It will help ensure that the stream being sampled remains above the hydrocarbon dew point during the sampling process.

### 6.6.4 Sample Containers

During sampling, the cylinder temperature must be kept above the hydrocarbon dew point. If the sample cylinder is exposed to temperatures below the hydrocarbon dew point after the sample has been collected, the sample can be recovered by heating it to a minimum of 30°F (17°C) above the flowing temperature at the time the sample was obtained and maintaining the sample cylinder at that temperature for at least 2 hours **prior to analysis**. If a sample is collected at a pressure other than line pressure at the time of collection, the sample must be heated at least 30°F (17°C) above the calculated hydrocarbon dew point of the sample at conditions in the sample cylinder at the time of collection. (See 6.6 for additional guidance regarding the operating temperature margin of 30°F above the calculated hydrocarbon dew point.)

Sample containers can be heated using a water bath, heating blankets, heat tape or a heated chamber as long as the temperature of the heating medium is controlled. Heat lamps and similar devices are not recommended since it is difficult to control the temperature of the cylinder. **Any method used for heating the sample cylinders must meet the requirements of all applicable codes and regulations.**

Whenever a sample cylinder assembly is heated above 125°F, special care must be taken to consider the effect of the heat on seals and other materials. Use the label to verify that the contents of the container will not overpressure the sample cylinder when heated. Exercise care to avoid heating cylinders filled with liquids, as the cylinder may be overpressured.

### 6.6.5 Pressure Regulators and Regulating Probes

The gas temperature must be maintained at a temperature high enough to offset the reduction in temperature associated with pressure regulation (approximately 7°F [3.9°C] per 100 psi [690 kPa] of pressure reduction). If necessary, heat the regulator or regulating probe and the associated tubing (where exposed to ambient conditions) to maintain the gas temperature at least 30°F (17°C) above the calculated hydrocarbon dew point temperature as discussed in 6.6, *General Discussion of Heating*.

### 6.6.6 Composite Sampling Systems

It is recommended that these systems, including the sample container, be maintained above the hydrocarbon dew point to ensure the composite sample is representative of the flowing gas stream. Tests conducted under actual field operating conditions have shown that composite sampling systems do not consistently provide representative samples when exposed to ambient temperatures below the sample gas hydrocarbon dew point.

Note: No tests were conducted with sample containers below the hydrocarbon dew point and all other components of the composite sampling system above the hydrocarbon dew point.

### 6.6.7 Calibration Standards

The calibration standard shall be heated for a minimum period of 4 hours after the skin temperature of the cylinder reaches a temperature at least 30°F (17°C) above the calculated hydrocarbon dew point as discussed in 6.6, *General Discussion of Heating*. The intent of this requirement is to ensure that the core temperature of the calibration standard has reached a temperature of at least 30°F (17°C) above the calculated hydrocarbon dew point of the calibration gas. Vaporization of the heavy components will occur more rapidly at higher temperatures above the calculated hydrocarbon dew point. It is generally not necessary to exceed 50°F (27.8°C) above the calculated hydrocarbon dew point. Heating the calibration standard for a longer period or continuously will not cause deterioration of the standard. The sample lines from the calibration standard to the chromatograph and any regulators in the system must also be maintained at a temperature at least 30°F (17°C) above the calculated hydrocarbon dew point.

For details regarding condensation and vaporization of natural gas, see 6.3, *Causes of Gas Sample Distortion*, and Appendix A, *The Phase Diagram*.

## 7 Sample Probes

### 7.1 GENERAL DESIGN CONSIDERATIONS

Sample probes are designed for the purpose of directing a representative portion of the natural gas sample source in the pipeline to the sampling system. The probe extends into the pipeline to ensure a representative sample that is free of unwanted contaminants that may have collected on the interior pipe wall. Sample probes may be designed as fixed or as insertable and retractable units. The probe and associated valving should not restrict the sample outlet flow. A well-designed sampling system requires the use of a properly installed sample probe. There are several designs of sample probes available. The design must also consider the possibility of resonant vibration being induced in the probe by high flowing velocities in the pipeline. Gas lines with streams free of entrained liquids and at flowing conditions well above their dew point temperatures may be sampled with any probe design. Lines that are operating at or near the gas stream's dew point may require special probes designed to overcome the problems of condensation in the gas. In selecting a sample probe, the first step is to determine sampling conditions and then to determine the proper sample probe for the application. See Section 6, *General Considerations for the Design of a Natural Gas Sampling System*.

### 7.2 APPLICATION

Sample probes and other components of sampling systems must be designed to deliver a representative sample of the sample source.

### 7.3 TYPES

#### 7.3.1 Straight Tube Probes

The most basic sample probe design is the straight tube probe shown in Figure 4. The probe may be attached to a fixed coupling assembly or to one that allows the probe to be removed completely. All fittings installed in the sampling system should be non-restrictive and must be rated for the intended line pressure and temperature. The materials must be suitable for use with the product, its contaminants and ambient conditions. Modifications to this basic design are numerous. Filters and screens added to the collecting end of the probe may reduce the possibility of small liquid particles entering the probe. This practice must not alter the composition of the sampled gas. Some filters or screens may encourage the creation of liquids not otherwise present in the stream. Inappropriate probes or filters could alter gas streams that are very close to the hydrocarbon dew point. The collection end of the probe may be straight or angle-cut. Straight-cut probes are preferred over beveled probes.



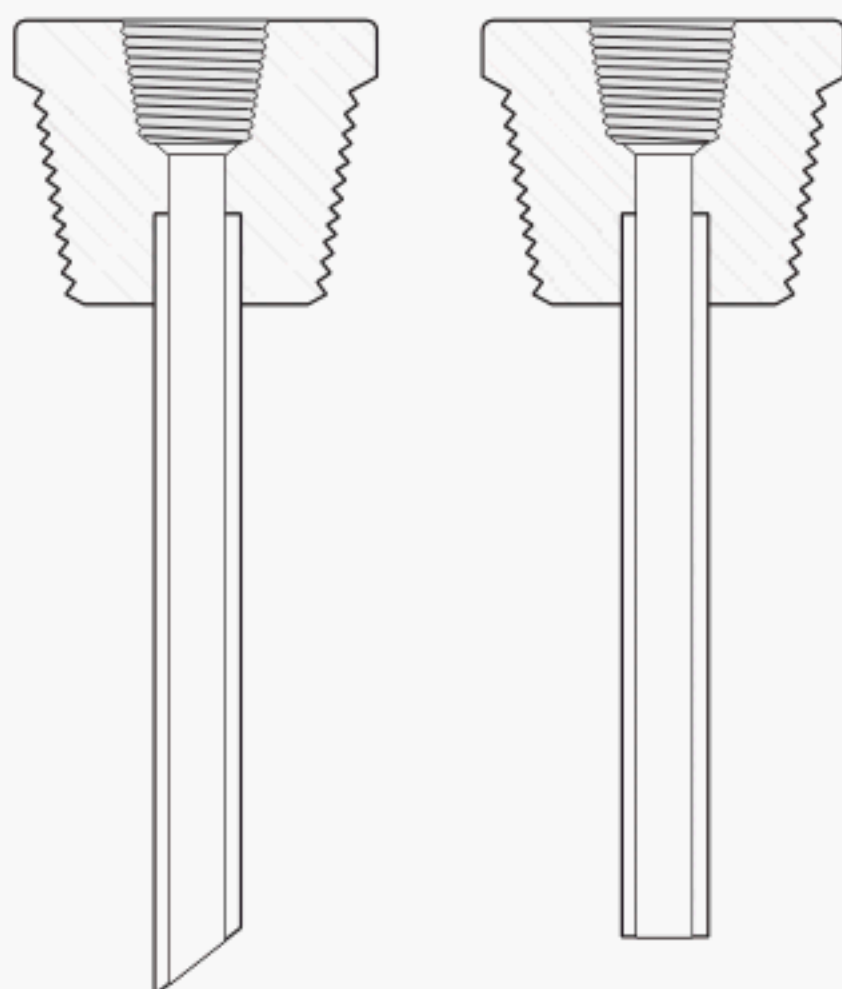


Figure 4—Straight Tube Sample Probe

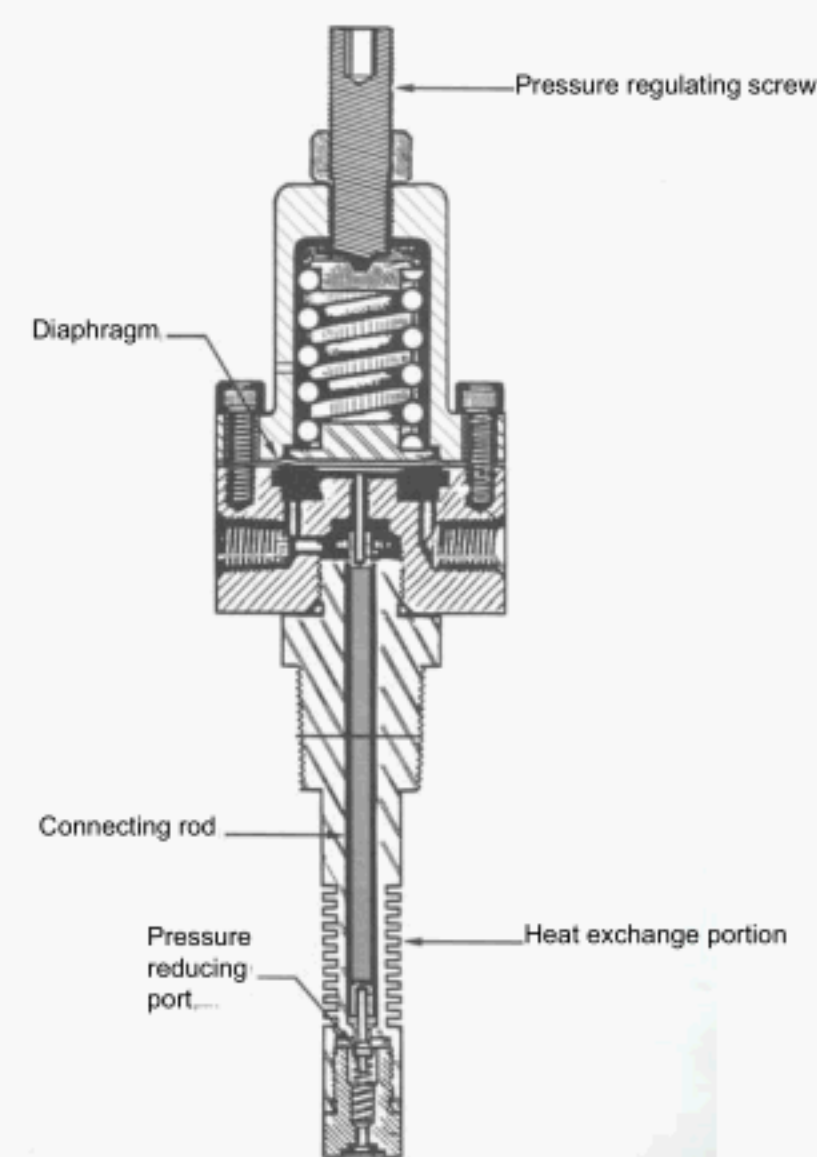


Figure 5—Typical Regulated Sample Probe

### 7.3.2 Regulating Probes

Regulating probes are commonly used with continuous sampling systems designed to deliver gas to the sampling system at reduced pressure. An illustration of a typical probe is shown in Figure 5. The probe's most basic form is a straight tube with an integral regulating mechanism. If retrograde condensation is possible, then condensation of the sample gas could occur in the probe after the pressure is reduced, and a non-representative sample will result. Fins may be used on the probe to improve heat transfer with the sample gas to prevent condensation. Care must be taken to minimize the effect of thermally coupling the probe to the pipe carrying the sample source stream. See 6.6, *General Discussion of Heating*, 6.3, *Causes of Gas Sample Distortion*, and Appendix A, *The Phase Diagram*, for further information.

### 7.3.3 Pitot Probes/Dual Probes

A Pitot probe can be used, provided the gas velocity in the pipeline is sufficient to drive the flow throughout the entire loop, or two straight tube probes can be installed across a differential pressure point, assuring flow throughout the system.

Note: Adequate data is not available to make recommendations regarding the performance of Pitot probes.

## 7.4 PROBE INSTALLATION

### 7.4.1 Sample Probe Length

A probe configuration such as discussed in 7.3, *Types*, should be used for all sampling techniques. It is industry practice that the collection end of the probe be placed within the approximate center one-third of the pipe cross-section. While it is necessary to avoid the area most likely to contain migrating liquids, the pipe wall, it may also be necessary to limit the probe length to ensure that it cannot fail due to the effects of resonant vibration.

Resonant vibration can occur when the vortex shedding frequency resulting from a probe inserted into a flowing fluid is equal to or greater than the probe's natural resonant frequency. Table 1 provides maximum recommended probe lengths for typical diameters based on a maximum natural gas velocity of 100 ft/sec (30.48 m/sec):

Table 1—Maximum Recommended Probe Lengths

Probe Outer Diameter inches (cm)	Recommended Max Probe Length inches (cm)
0.25 (0.64)	2.00 (5.08)
0.375 (0.95)	3.25 (8.26)
0.50 (1.27)	4.25 (10.80)
0.75 (1.91)	6.50 (16.51)

Calculations were based on a maximum recommended probe length Strouhal Number of 0.4, a 0.035 in. (0.089 cm) wall thickness, and 316 stainless steel probe construction. For conditions other than these use the formula below to calculate the maximum recommended probe length.

The probe length is defined as the distance between the probe tip and its point of attachment. The probe depth is the distance between the probe tip and the inner pipe wall (Figure 6).

### Equation for Maximum Recommended Probe Length

#### SI System

$$L = \left[ \left[ (F_m \times 4.38 \times OD \times 10) / (S \times V) \right] \times \left[ (E/\rho) \times (OD^2 + ID^2) \right]^{1/2} \right]^{1/2} \text{ (Reference 16)}$$

where

$L$  = Recommended Probe Length (mm)

$F_m$  = Virtual mass factor – a constant to take account of the extra mass of the cylinder due to the fluid surrounding it & vibrating with it. For a gas,  $F_m = 1.0$  and for water & other liquids,  $F_m = 0.9$

$OD$  = OD of Probe (mm)

$ID$  = ID of Probe (mm)

$S$  = Strouhal number = dependent on the Reynolds No. & shape of the cylinder, but can be taken as 0.4 for worst case or 0.2 as suggested by API Chapter 8.

$V$  = Velocity of fluid (m/sec)

$E$  = Modulus of Elasticity of probe material (kg/cm<sup>2</sup>)

$\rho$  = Density of probe material (kg/m<sup>3</sup>)

#### American Engineering System

$$L = \left[ \left[ (F_m \times 1.194 \times OD) / (S \times V) \right] \times \left[ (E/\rho) \times (OD^2 + ID^2) \right]^{1/2} \right]^{1/2} \text{ (Reference 16)}$$

where

$L$  = Recommended probe length (inches)

$F_m$  = Virtual mass factor – For a gas,  $F_m = 1.0$  and for water and other liquids,  $F_m = 0.9$

$OD$  = OD of probe (in.)

$ID$  = ID of probe (in.)

$S$  = Strouhal Number = Use 0.4 as worst case

$V$  = Velocity of fluid (ft/sec)

$E$  = Modulus of elasticity of probe material (psi)

$\rho$  = Density of probe material (g/cc)



### 7.4.2 Location

Probes should be mounted vertically at the top of a straight run of horizontal pipe. For gas streams not near the hydrocarbon dew point, essentially any probe location will suffice as long as it does not interfere with the performance of a primary metering element (see appropriate reference standards for guidance).

For streams that are at or near their hydrocarbon dew point (either continuously or only during process upsets), the probe should be at least 5 diameters (of the maximum diameter of the disturbing element) downstream of that disturbance. For major disturbances that change the flow profile of the flowing stream (such as orifice plates, elbows, tees, reduced-port valves, flow conditioners, filters, strainers, etc.), the diameter of the disturbance shall be considered to be the inside pipe diameter at the disturbance. This requirement is intended to avoid the effects of liquid droplets or liquids formation due to the impact of the flowing stream on the disturbing element. Similar precautions should be taken for streams with liquid contaminants such as glycols, amines, compressor oils, corrosion inhibitors, etc.

Note: Probes should not be installed in any “dead-end” section of pipe, where gas is not continually flowing or where there may be recirculation regions or “eddies.” See 6.2, *Flow Characteristics*, Appendix B, *Fluid Mechanical Considerations in Gas Sampling*, and Appendix C, *Lessons Learned During Sampling in Hydrocarbon Saturated and 2-Phase Streams*, for more information.

## 8 Sample Loops/Lines

### 8.1 GENERAL DESIGN CONSIDERATIONS

The sample loop (slip stream) is the part of the sampling system that delivers the gas from the sample probe to the inlet of the sampler or analysis device and then to a lower pressure point. Sample loops should be designed to deliver a representative sample of the sample source gas that is flowing in the pipeline. The velocity of the gas flowing in the sample line and the volume of the sample system determine how often a new representative sample can be obtained. It is preferred that the sample line be sloped upward from the sample probe to the sample extraction point. This will minimize the accumulation of liquid in the loop.

In order to obtain a representative sample, the loop must be designed to ensure that the volume of gas in the sample loop is replaced between samples. This requires the sample loop flow rate to be relatively high and the volume of the loop to be small. Excessively high flow rates may cause liquid particles present in the pipeline to be drawn into the sample probe. Sample loops that purge to the atmosphere can cause unacceptable amounts of gas waste and violate environmental regulations. In addition, a large pressure loss in a sample loop may cause cooling and condensation which will affect the accuracy of the sample.

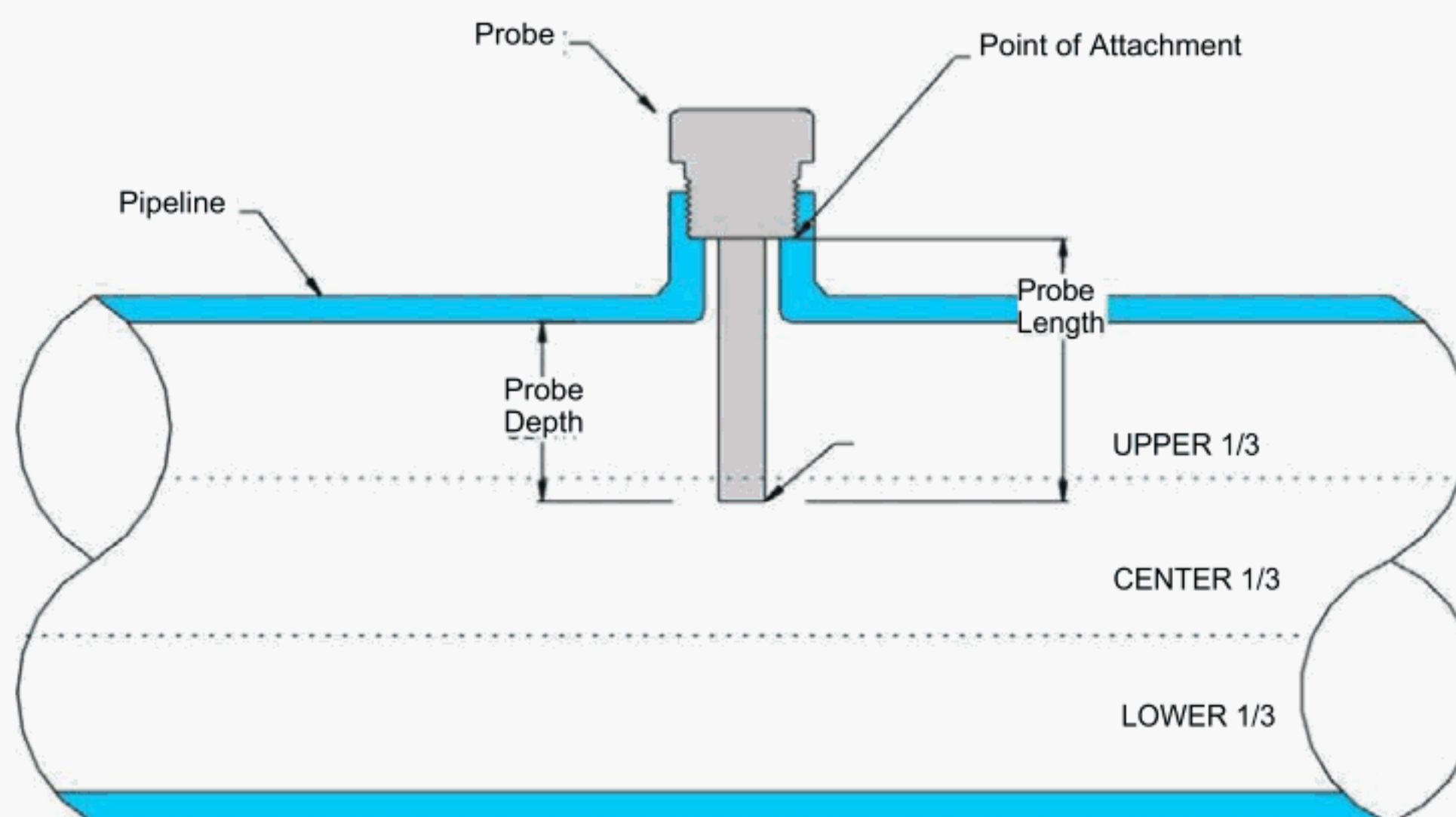


Figure 6—Probe Dimensions Used to Determine Maximum Recommended Probe Length



## 8.2 PRESSURE DROP IN A SAMPLE LOOP

Proper operation of a sample loop requires a pressure differential from the collection end to the discharge end. This pressure differential may be produced with an orifice plate, regulator, or pump. Attaching the ends of a sample loop across a flow restriction will provide a pressure differential to the sample loop that is proportional to the flow rate squared. This arrangement will provide a flow in the sample loop that is proportional to the flow through the orifice. Custody transfer meters cannot be used for this application because the flow through the sample loop will bypass the meter and result in a biased flow rate measurement.

## 8.3 TUBING MATERIALS

304 or 316 stainless steel tubing is the recommended material for the sample loop under most conditions. Other tubing materials, such as Nylon 11 or an equivalent, can be used if the product sampled adversely affects or is affected by the stainless steel tubing.  $\frac{1}{16}$ ,  $\frac{1}{8}$ , and  $\frac{1}{4}$  in. (1.59, 5.08, and 6.35 mm, respectively) stainless steel tubing have relatively small volumes per unit length that allow free liquids to be more easily swept out of the loop. If mechanical security is a concern, the tubing can be encased in larger tubing or pipe.

All sample loop tubing must be steam cleaned and dried before installation. Any oil left in the tubing from the manufacturing process must be removed. This oil can retain or release some of the heavier hydrocarbon components. The amount of components retained or released depends on their concentration in the sample gas, the sample loop temperature, the flowing pressure and the amount of the tubing coated with oil.

Nylon 11 tubing, or an equivalent, can be used effectively in certain applications where excessive heat is not required. It is particularly useful when checking for the presence of free liquids. The sample loop must be cleaned if free liquids have or are suspected to have contaminated the system (see 6.5, *Cleanliness*).

## 8.4 PRESSURE REGULATORS

Pressure regulators are often required at the point where the gas sample is withdrawn from the sample loop, to reduce the gas pressure from pipeline pressure to a usable pressure for the sample container or analysis device. Specialized pressure regulators that are inserted into the pipeline to take advantage of the flowing gas temperature are available (see 7.3.2, *Regulating Probes*). Insertion type regulators that incorporate integral filtration to remove free liquids are also available. Pressure regulators must have a pressure rating that exceeds the maximum expected line pressure of the gas sampling system. Regulators should be constructed of materials that are not reactive with the gas being sampled.

Care must be taken when using any type of regulator, to ensure that the gas does not condense. Retrograde condensation may occur even if the gas is maintained at pipeline temperature. If the gas changes phase and condensation does occur, a representative sample will not be obtained.

One method of reducing the possibility of heavy end condensation in a pressure regulator is to use a heated regulator. This type of regulator should be designed to supply enough heat during the pressure reduction to avoid condensation. Another method of reducing the possibility of condensation is heat tracing. In general, the amount of heat energy required to offset the effect of the pressure drop will depend on the gas composition, pressure, temperature, pressure drop and hydrocarbon dew point. The gas temperature must be maintained at a temperature high enough to offset the temperature reduction associated with the pressure reduction.

See 6.3, *Causes of Gas Sample Distortion*, 6.6, *General Discussion of Heating*, and Appendix A, *The Phase Diagram*, for further information.

## 8.5 PUMPS

Pumps may be used to provide sufficient gas flow through a sample loop. The pump should be installed to provide steady flow without significant pulsation or flow interruptions. The pump produces the best results when it is installed downstream of the sample container or analysis device. The pump and the sample loop line size must be properly matched to assure that pump damage will not occur. The preferred pump for the application is a centrifugal pump.

## 8.6 FILTERS

Particulate filters are used to remove solid, abrasive particles from the sample source stream. This is primarily intended to protect the analysis equipment. Typical filter sizes are 2 to 7  $\mu$  (0.08 to 0.28 mils) and generally do not affect analytical results more than  $\pm 0.25\%$ .

Be sure to change filters regularly and insure condensation does not occur within them.

Multiple streams, with different heating values, flowing through the same filter, may cause sample distortion and should be avoided.

## 8.7 SEPARATORS

The standard does not recommend the use of the separator referred to in the GPA Standard 2166 when sampling single-phase streams. Heat transfer may cause condensation or vaporization when the gas temperature is depressed below, or elevated above the hydrocarbon dew point.

It should be noted that in streams outside the scope of this standard, GPA separators may be used to prevent free liquids from entering the section of the sampling system downstream of the separator. Refer to GPA Standard 2166 for guidance in the use of the separator.

# 9 Sample Containers

## 9.1 GENERAL DESIGN CONSIDERATIONS

A sample container stores a gas sample in a protected and secure state until the gas composition can be determined. The container should not alter the gas composition in any way nor affect the proper collection of the gas sample. The materials, valves, seals, lubricants and other components of the sample container must all be specified with this major consideration in mind. In addition to the mechanical components of the container, the cleaning, prior to each use, and handling of the container must be carefully performed to ensure that no contamination of the gas sample will occur. See 6.5, Cleanliness.

Sample containers should be labeled with an identification number and maximum working pressure. If required, the date of the last physical inspection must either be included on a cylinder label or be filed in readily accessible records. If the container is to be transported, it must meet U.S. DOT (CFR 49) specifications. See Section 15, *Safety, Labeling, Handling, and Transportation of Cylinders*.

## 9.2 TYPES OF SAMPLE CONTAINERS

A general description of sample containers may be found in the latest revision of GPA Standard 2166.

### 9.2.1 Single- and Double-Valve Standard Cylinders

These cylinders are also known as constant volume cylinders, single cavity cylinders, and “spun” cylinders. An example is shown in Figure 7.

Use sample containers that are designed to safely meet the anticipated operating extremes for their intended service and are corrosion resistant to the product being sampled. Stainless steel containers are recommended to minimize problems of absorption and/or adsorption of heavy components (hexanes and heavier components) and to minimize the reaction of contaminants with the container. If the container is to be transported, it must meet DOT specifications and be labeled according to DOT hazardous materials regulations and applicable state regulations. See Section 15, *Safety, Labeling, Handling, and Transportation of Cylinders*.

The container may be of the one-valve or two-valve type (depending upon the sampling procedure selected). Sample containers and valves must have a working pressure equal to or exceeding the maximum pressure anticipated in sampling, storage or transportation of the sample container. Soft-seated valves are preferable to those having metal-to-metal seats. All valves and safety devices must meet the appropriate material and pressure requirements for safe design. The pressure relief valves may be of spring or rupture-disc type. These allow a partial or complete loss of contents due to thermal expansion or overpressurization. Should relieving occur, the sample is likely to be compromised and must be discarded. The size of the container depends both upon the amount of sample required for the laboratory tests that are to be made and the volume required to obtain a representative sample from composite sampling systems based on time or flow. Smaller containers will be easier to handle.

Figure 7—Typical Double Valve Sample Cylinder

### 9.2.2 Floating Piston Cylinders

These cylinders are also known as constant pressure cylinders. An example is shown in Figure 8.

A floating piston cylinder container is constructed of metal tubing, honed and polished on the inside surface. The cylinder should be closed with removable end caps to provide access to remove and service the moving piston. The end caps are drilled and tapped for valves, gauges, and relief valves. The complete cylinder assembly must be designed to withstand the maximum pressure and temperature anticipated during sampling, transportation and analysis and to be non-reactive to (a) materials being sampled; (b) the pressurizing fluid; (c) the cleaning solvents; and (d) the expected corrosives. The volume of the cylinder will depend on the amount of sample needed for the laboratory analysis. If the container is to be transported, it must meet DOT specifications and be labeled according to the federal hazardous materials regulations and applicable state regulations. See Section 15, *Safety, Labeling, Handling, and Transportation of Cylinders*.

The cylinder itself contains a moving piston equipped with O-rings, PTFE (Teflon®) rings or other devices to effect a leak-free seal between the sample and the inert, back-pressure gas and still allow the piston to move freely within the cylinder. The use of guide rings is recommended to ensure smooth piston travel. The piston and sealing device must be nonreactive to (a) the sample; (b) the back-pressure gas; (c) the cleaning solvents; and (d) expected corrosive components in the gas.

All valves and safety devices must meet the appropriate material and pressure requirements for safe design. The pressure relief valves may be of spring or rupture-disc type. These allow a partial or complete loss of contents due to thermal expansion or over-pressurization. Should relieving occur, the sample is likely to be compromised and must be discarded.

Some piston-type cylinders are fabricated from nonmagnetic materials such as 300 Series Stainless Steel. The piston, likewise, is fabricated of stainless steel, but has magnets attached to the precharge side of the piston. As the piston moves the length of the cylinder, the magnetic field generated by the magnets flips a series of bicolored flags. This system (or systems of similar configurations) indicates the piston position and volume of sample in the cylinder.

Some piston-type cylinders are fabricated with a rod attached to the piston that extends through the end cap on the inert gas back-pressure chamber with appropriate sealing devices to prevent the inert gas back-pressure from leaking. The travel rod provides an indication of the piston position and the volume of the cylinder filled with the sample. Again, some modifications of this style may exist.

Some types of constant pressure cylinders are equipped with electronic tracking devices to provide for local and/or remote indication of the piston's position relative to full/empty.

Other types of floating piston cylinders are available which have no visual method of determining the sample volume directly. For these cylinders, a magnet or some other type of locating device is necessary to follow the movement of the piston.



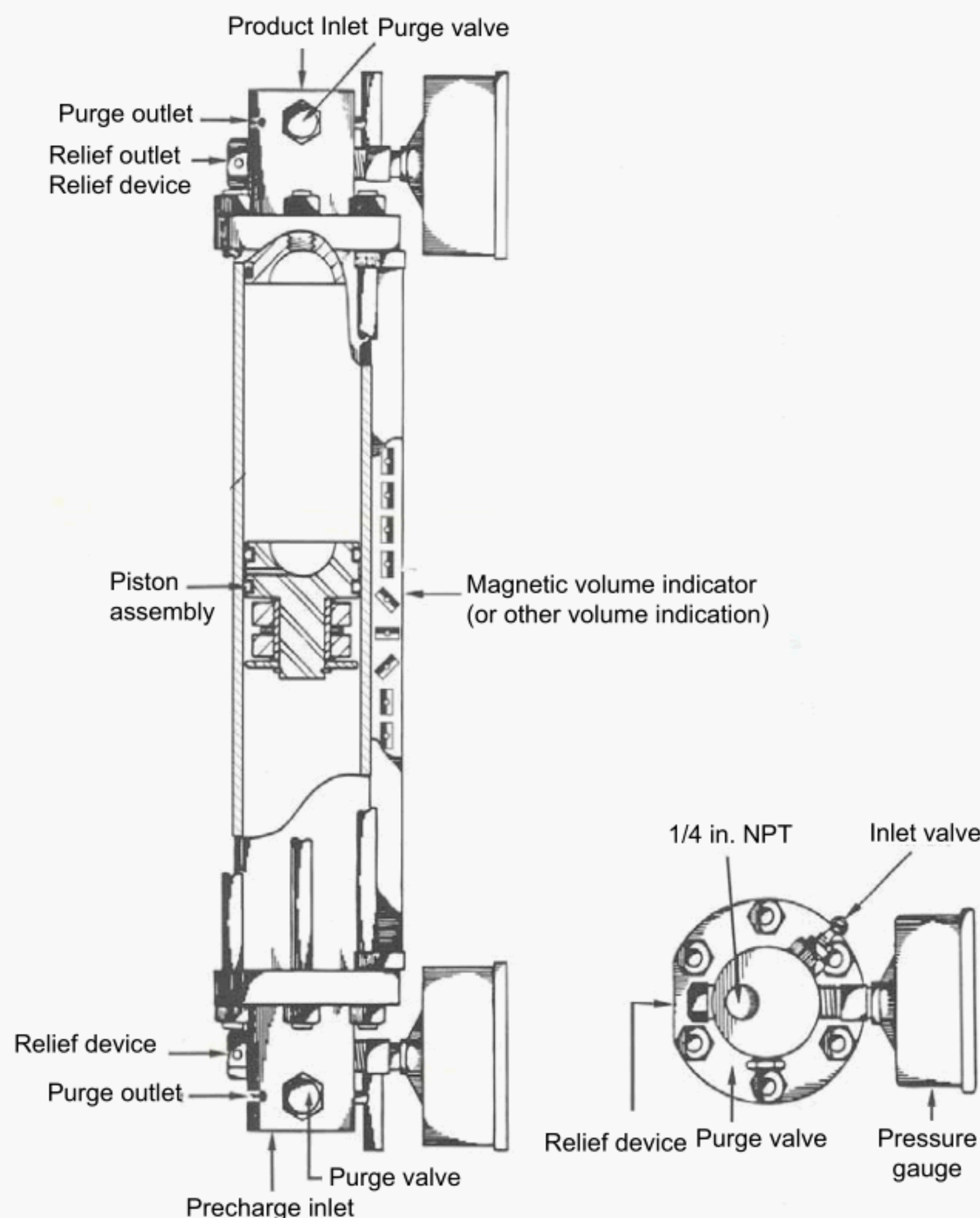


Figure 8—Typical Floating Piston Cylinder

## 10 Materials for Sweet and Sour Gas Service

### 10.1 GENERAL CONSIDERATIONS

The types of materials used in a sample system will depend on the gas being sampled. Generally, it is recommended that 304 or 316 stainless steels be used for all wetted surfaces. Valve seats, O-rings and piston seals should be made of elastomers appropriate for the intended service. Sampling of  $H_2S$ ,  $CO_2$ , wet- and high-temperature gases, present additional material problems. These types of gases will sometimes require special materials and coatings in the sampling system.

It is recommended that sample cylinders used in sour and/or corrosive gas service should be specially-lined or coated (e.g., epoxy). Occasionally, sample cylinders may be glass or ceramic-lined, however, such cylinders may be absorptive or adsorptive under certain conditions. Other coating materials and/or passivation may be acceptable. Very reactive components, such as hydrogen sulfide ( $H_2S$ ), should be analyzed on-site when practical since even coated containers may not eliminate all absorption or reaction of the contaminants.

The use of soft metals such as brass, copper, and aluminum (except hard anodized) should be avoided in a sample system, because of excessive corrosion rates and other metallurgical and sampling problems. Corrosion rates and the possibility of sulfide stress corrosion cracking for each sampling system must be considered and the service life of the equipment reduced to account for corrosion. NACE standards or other appropriate standards for materials should be applied to the containers and sampling systems.

## 10.2 CARBON STEEL

Carbon steel and other relatively porous materials may retain heavier components and contaminants such as CO<sub>2</sub>, N<sub>2</sub>, and H<sub>2</sub>S in the natural gas sample source stream and should not be used in a sampling system. Reaction of carbon steel with the components frequently found in natural gas will cause errors in the gas analysis. Sample valves and cylinders made from this material display dangerously high corrosion rates. These problems are particularly acute in wet sour gas sampling. Corrosion rates in a carbon steel sample system may be sufficient to cause particulate contamination of the sampling system valves, filters and analysis equipment.

## 10.3 DISSIMILAR MATERIALS

Using dissimilar materials in a sample system may cause increased rates of corrosion and may result in sampling errors. When taking several samples of a gas for comparative analysis, the same cylinder material should be used. Using the same material reduces the likelihood that the gas will react differently with each sample cylinder, but does not guarantee that the sample will not be distorted.

# 11 Other Apparatus

## 11.1 TIMERS

Timers are used on time-proportional sampling systems to actuate the sample system and collect a sample at the desired intervals. See 14.2, *Composite Sample Intervals*.

## 11.2 FLOW COMPUTERS

Flow computers or flow indicators may be used on a sample system to provide an indication of the flow rate to a flow-proportional sample system. Flow computers and flow indicators must meet all appropriate electrical standards for the areas of their intended use.

## 11.3 POWER SUPPLIES

Systems requiring a power supply must meet appropriate electrical standards and should have a backup power source available in case the primary power source fails.

## 11.4 PRESSURE GAUGES

Gauges should be calibrated or compared to a certified pressure standard on a regular schedule to ensure accuracy. This is particularly important in reduced pressure sampling methods.

# 12 Spot Sampling Methods

## 12.1 GENERAL

The standard procedures recommended for spot sampling are contained in the latest revision of GPA Standard 2166. The scope of GPA Standard 2166 does not include composite gas sampling, on-line gas sampling, or mobile gas sampling. GPA Standard 2166 allows eight different methods that, with certain comments and cautions, are accepted by API. SAMPLE CYLINDERS SHOULD BE CLEAN PRIOR TO EMPLOYING ANY OF THE METHODS. See 6.5, *Cleanliness*, for more information.

The methods are:

- a. Evacuated container method.
- b. Reduced pressure method.
- c. Helium pop method.
- d. Floating piston cylinder method.
- e. Water displacement method.
- f. Glycol displacement method.
- g. Purging—fill and empty method.
- h. Purging—controlled rate method.



The evacuated container method, the reduced pressure method, and the helium pop method all require evacuating the sample container to 1 mm Hg ( $1/2$  in. H<sub>2</sub>O or 3.39 kPaabs) or less, absolute pressure. See 2.2, *Evacuated Container Method*; 2.3, *Reduced Pressure Method*; and 2.4, *Helium Pop Method*.

The floating piston cylinder method, the glycol displacement method, and the water displacement method are constant pressure methods, and are good choices when the pressure within the sample cylinder must remain equal to the stream pressure during the sampling procedure. See 2.5, *Floating Piston Cylinder Method*, 2.6, *Water Displacement Method*, and 2.7, *Glycol Displacement Method*.

The user must expect degradation in accuracy with any of the methods when the temperature of the source gas stream and/or all parts of the sampling system are not at or above the hydrocarbon dew point temperature. See Appendix C, *Lessons Learned During Sampling in Hydrocarbon Saturated and 2-Phase Natural Gas Streams*.

## 12.2 EVACUATED CONTAINER METHOD

The evacuated container method requires a vacuum of 1 mm Hg ( $1/2$  in. H<sub>2</sub>O or 3.39 kPaabs) or less, absolute pressure. When using the evacuated container method, the valves and fittings on the sample cylinder must be in good condition and there must be no leaks in either the evacuated or pressurized states.

This method has produced results to within  $\pm 0.14\%$  of the reference gas mixture heating value (HV) and density value when the sample gas temperature and all parts of the sampling system are maintained according to 6.6, *General Discussion of Heating*.

## 12.3 REDUCED PRESSURE METHOD

The reduced pressure method is similar to the evacuated container method except that instead of allowing the cylinder to come up to line pressure, it is slowly filled to a point approximately one-third line pressure.

This method has produced results to within  $\pm 0.12\%$  of the reference gas mixture HV and density values when the sample gas temperature and all parts of the sampling system are maintained according to 6.6, *General Discussion of Heating*.

Since the hydrocarbon dew point temperature of the gas changes with pressure, filling the cylinder to one-third line pressure does not guarantee that there will be no condensation. Consider a cylinder at a temperature of 20°F (−7°C), used to sample an unknown stream at a pressure of 1500 psig (10.3 MPa). The reduced pressure method specifies filling the cylinder to approximately 500 psig (3.4 MPa). However, the mixture may still condense at a pressure of 500 psig (3.4 MPa), and a temperature of 20°F (−7°C).

## 12.4 HELIUM POP METHOD

The helium pop method requires preparing the cylinder by evacuating the sample container to 1 mm Hg ( $1/2$  in. H<sub>2</sub>O or 3.39 kPaabs) or less, absolute pressure. The helium pop method is similar to the evacuated container method except that a helium charge is used to keep the container free of air prior to sampling.

Use of the Helium Pop method will reduce the un-normalized total percent that is calculated during a gas chromatographic analysis. Therefore, the un-normalized total percent cannot be used as a gas chromatograph diagnostic when employing this method.

This method has produced results to within  $\pm 0.15\%$  of the reference gas mixture HV and density values when the sample gas temperature and all parts of the sampling system are maintained according to 6.6, *General Discussion of Heating*.

## 12.5 FLOATING PISTON CYLINDER METHOD

The constant pressure cylinder is designed to maintain the sample at pipeline pressure. The sample cylinder should be reheated in the laboratory to a temperature necessary to ensure complete vaporization of any liquids in the cylinder as described in 6.6.4, *Sample Containers*. It is also critically important to ensure that the cylinder is properly cleaned before sampling, particularly if there is a suspicion that previous samples condensed within the cylinder, or if the cylinder made contact with any liquid hydrocarbons such as slugs or compressor oil (see 6.5, *Cleanliness*).

The piston sealing mechanism (normally o-rings or lip seals) requires that the piston totally separate the sampled natural gas from the pre-charge gas. The material used for the sealing mechanism and the lubricant used must not adsorb or in any other way distort any of the components in the natural gas mixture. Adsorption or absorption of hydrocarbon components can cause leakage and/or seal failure.

This method has produced results to within  $\pm 0.14\%$  of the reference gas mixture HV and density values when the sample gas temperature and all parts of the sampling system are maintained according to 6.6, *General Discussion of Heating*.

Floating piston cylinders should have the following features (see 9.2.2, *Floating Piston Cylinders*):

- a. They must be of sturdy construction and non-absorptive to the sample. Their design pressure rating should exceed the highest pressure available at the facility where they may be used.
- b. A piston position indicator, which is a method to detect leakage of precharge gas, must be provided.
- c. PTFE (Teflon<sup>®</sup>) seals or equivalent, which require no grease for sealing or smooth operation of the floating piston, should be used.
- d. Silicon grease or other piston lubricants that may absorb or contaminate the sample should not be used.
- e. The precharge side of the cylinder should be charged to a pressure equal to or greater than line pressure. The piston should be flush with the inlet end cap. It is recommended that the precharge side be charged with an inert gas that is different from the components in the stream being sampled. This will not affect analytical results should a leak occur.

Before the sampling operation is begun, the associated sample inlet piping should be purged through the end cap purge valve on the inlet side of the piston cylinder. If the cylinder is not equipped with a purge valve, a “purge-valve tee” arrangement should be installed to allow purging the inlet piping and valving. Care should be taken to avoid condensation and contamination during the purge procedure.

## 12.6 WATER DISPLACEMENT METHOD

**CAUTION:** For the water displacement method, water may absorb or desorb CO<sub>2</sub>, H<sub>2</sub>S, and other components depending on the water quality and the contact time. Using distilled water will prevent de-sorption, but not absorption, of CO<sub>2</sub> or other components. The displacement fluid may also contaminate the chromatograph sample systems and columns. This method should not be used when sampling for water content determination or when the ambient temperature is below 32°F (0°C).

This method has produced results to within  $\pm 0.13\%$  of the reference gas mixture HV and density values when the sample gas temperature and all parts of the sampling system are maintained according to 6.6, *General Discussion of Heating*.

## 12.7 GLYCOL DISPLACEMENT METHOD

Note: A 50/50 mixture of glycol and water is commonly used with this method.

**CAUTION:** For the glycol displacement method, water may absorb or desorb CO<sub>2</sub>, H<sub>2</sub>S, and other components depending on the water quality and the contact time. Using distilled water will prevent desorption, but not absorption, of CO<sub>2</sub> or other components. The displacement fluid may also contaminate the chromatograph sample systems and columns. This method should not be used when sampling for water content determination.

This method has produced results to within  $\pm 0.10\%$  of the reference gas mixture HV and density values when the sample gas temperature and all parts of the sampling system are maintained according to 6.6, *General Discussion of Heating*.

## 12.8 PURGING—FILL AND EMPTY METHOD

The purging—fill and empty method requires several cycles of filling and emptying the sample cylinder in order to remove residual impurities. Table 2 shows the number of fill and empty cycles required to sufficiently remove residual impurities from the cylinder. This method has produced results to within  $\pm 0.12\%$  of the reference gas mixture HV and density values when the sample gas temperature and all parts of the sampling system are maintained according to 6.6, *General Discussion of Heating*.

This method requires that:

1. The cylinder is coupled to the sample point as shown in Figure 9.
2. A “pigtail” with a flow restriction at the end is attached to the outlet of the cylinder as shown in Figure 9. The key consideration is that the cooling produced by the Joule-Thomson effect should be located at the end of the “pigtail.”
3. The cylinder is purged of residual impurities using the correct number of fill and empty cycles (Table 2).

## 12.9 PURGING—CONTROLLED RATE METHOD

The controlled rate method described in GPA Standard 2166 employs a continuous purge.



Table 2—Fill and Empty Purge Cycles

Maximum Gas Pressure in Container, psig (kPa)	Number of Fill and Empty Cycles
15 – 29 (100 – 200)	13
30 – 59 (200 – 405)	8
60 – 89 (405 – 615)	6
90 – 149 (615 – 1025)	5
150 – 500 (1025 – 3450)	4
>500 (>3450)	3

This method has produced results to within  $\pm 0.18\%$  of the reference gas mixture HV and density values when the sample gas temperature and all parts of the sampling system are maintained according to 6.6, *General Discussion of Heating*.

**CAUTION:** For the purging—controlled rate method—liquid may accumulate in the sample cylinder and in the coiled extension tubing on the outlet of the sample cylinder. This will cause an enrichment of the gas sample and thereby an overstatement of the heating value and density of the gas in the pipeline. This liquid accumulation should not occur if all parts of the sampling equipment are kept above the hydrocarbon dew point temperature in accordance with 6.6, *General Discussion of Heating*.

## 12.10 VACUUM—GATHERING SYSTEM METHOD

In rich, low-pressure, or vacuum-gathering systems, the use of a vacuum pump is recommended. One method involves a pump drawing gas from the sample point and discharging into the sample system (see Figure 10a). An alternate method, not evaluated in the research program (see Figure 10b), involves drawing the sample through a helium-filled sample cylinder with the pump. With either method, before the sample is collected, both the oxygen content and the relative density of the stream should be measured using a portable oxygen analyzer and a portable gravimeter to ensure the sample is representative of earlier samples and free of air contamination due to leaks. For the method shown in Figure 10a, once the oxygen and gravity values are recorded and accepted, the sample is collected using any of the following GPA Standard 2166 methods:

- Fill and Empty,
- Evacuated Container,
- Helium Pop, or
- Glycol Displacement.

Pressure within the sample cylinder is maintained at less than 20 psig (13.8 kPa). **Without sufficient heat input, increased sample pressure may cause condensation to occur.** Sample cylinders larger than 300 cm<sup>3</sup> (18 in.<sup>3</sup>) may be required to contain enough material to analyze. It is extremely important that samples from such streams be heated in accordance with the recommendations in 6.6, *General Discussion of Heating*, if analytical results are to be repeatable and reproducible. Refer to Appendix A, *The Phase Diagram*, for general discussion of phase changes due to pressure increases.

Samples of compositions characteristic of vacuum-gathering systems (very high HV content) demonstrate a greater degree of uncertainty in the analytical results due to the susceptibility of the heavy ends to condense.

## 12.11 USE OF THERMAL ISOLATION AND THROTTLING DEVICES

The purpose of thermal isolation and throttling devices is to prevent cooling of the sample cylinder during the purging process. Refer to Figure 9. Throttling the sample gas downstream of the cylinder outlet valve reduces both the pressure drop across the sample cylinder valves and the resulting Joule-Thomson cooling effects caused by upstream restrictions. Thermal isolation of the throttling device from the cylinder prevents cooling of the cylinder.

When performing the fill-and-empty spot sampling procedure, use an extension tube (“pigtail”) of 1/4 in. (0.635 cm) ID and at least 36 in. (91.4 cm) in length extending from the sample cylinder outlet valve to the purge valve/throttling assembly on the end of the pigtail (Figure 9). The pigtail is intended to provide thermal isolation between the throttling device and the sample container outlet valve. Refer to GPA standard 2166 for details.

The throttling device utilized shall have a flow coefficient (Cv) ranging from 0.09 to 0.53. This corresponds to orifice diameters ranging from 1/16 in. to 1/8 in. (0.16 cm to 0.32 cm). A standard 1/16 in. to 1/8 in.-port (0.16 cm to 0.32 cm-port) multi-turn sample valve has also been shown to work well in this application. Other devices or combinations of devices are acceptable if they pro-

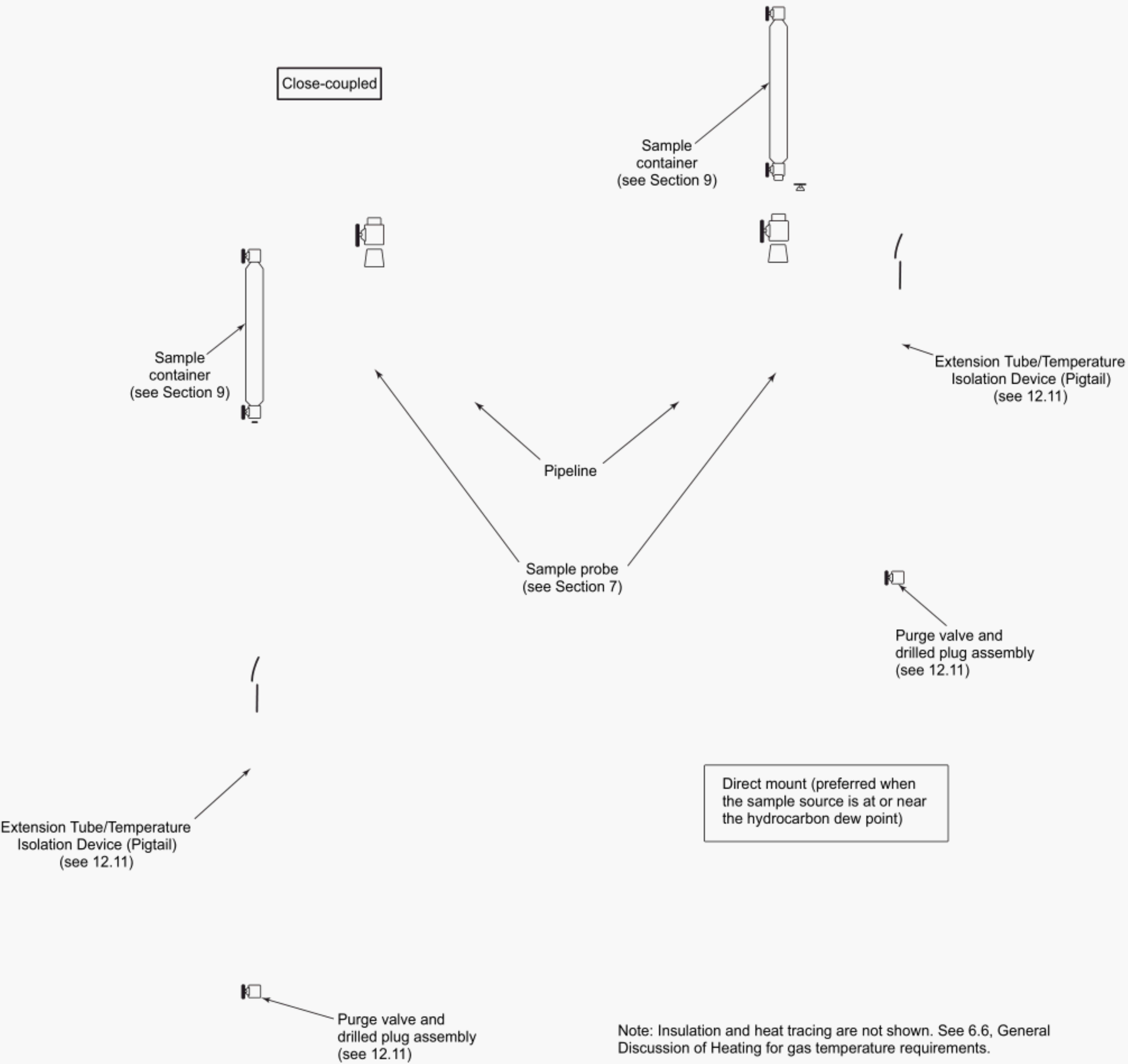


Figure 9—API Recommended Spot Sampling Apparatus for Fill and Empty Method. Close-Coupled and Direct Mount

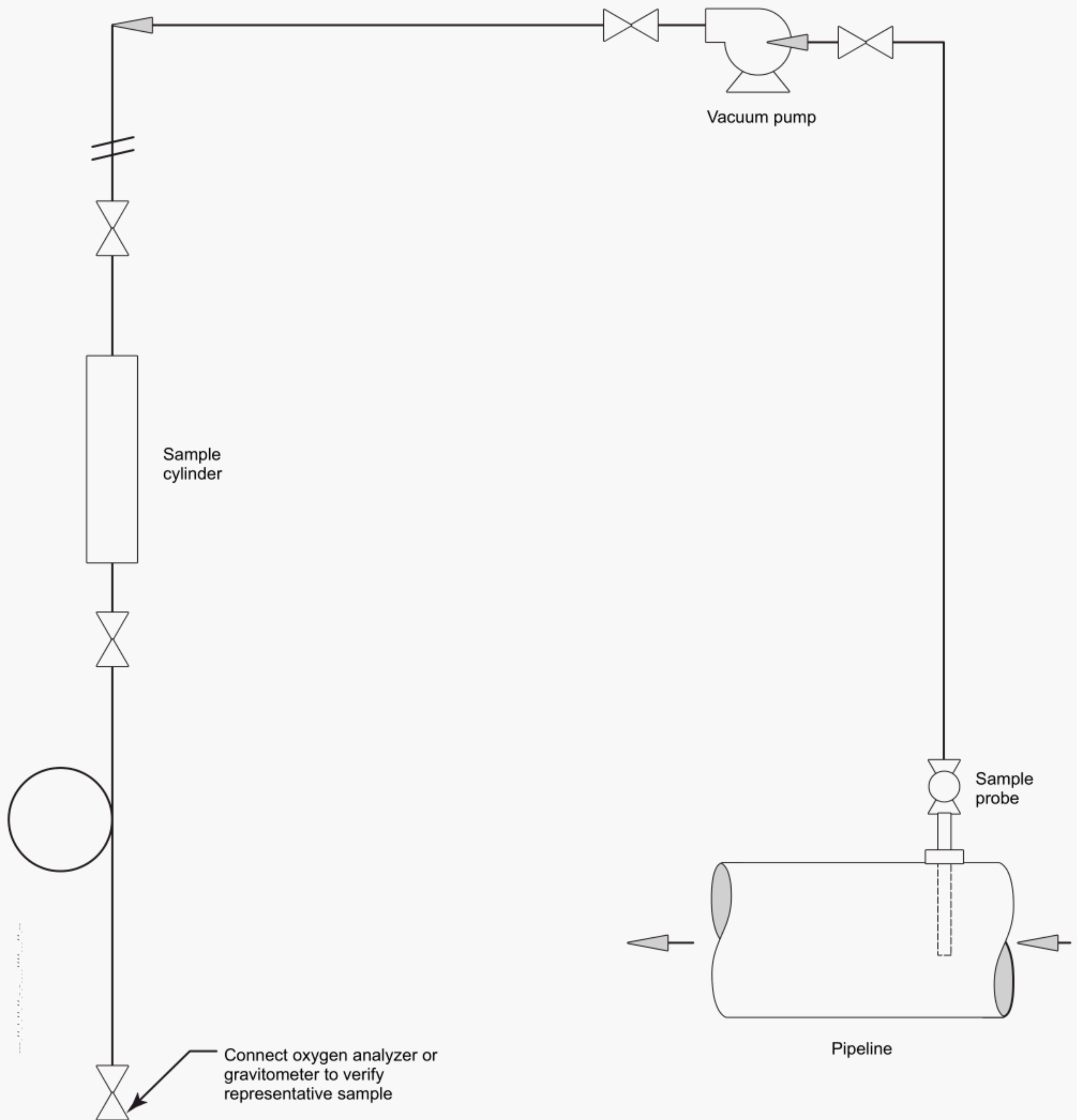


Figure 10a—Vacuum Gathering System Model

vide temperature isolation and throttling of the sample gas flow equal to or exceeding that of the “pigtail” and throttling devices described above.

Increasing the flow restriction will lengthen the purge time. In ambient temperature conditions at or below the hydrocarbon dew point of the flowing stream, the purge time may be lengthened to a point where the ambient air cools the sample cylinder more than the fill and empty purging process can warm it. Insufficient throttling may cause excessive cooling of the sample gas at points of restriction upstream of the throttling device, allowing the gas sample to cool below its hydrocarbon dew point temperature. Allowing the gas sample to cool below its hydrocarbon dew point temperature may cause it to become non-representative.

## **13 Automatic Sampling**

### **13.1 COMPOSITE SAMPLERS**

#### **13.1.1 General**

Composite samples are automatically taken over an extended period of time with the sampling rate proportional to flow rate or time. There are several composite samplers commercially available. For streams with variable flow rate and composition, a flow-proportional sampler is recommended.

Condensation in the sample system must be avoided. Tests conducted under actual field operating conditions have shown that composite samplers cannot be reasonably expected to provide representative samples when exposed to ambient conditions below the sample gas hydrocarbon dew point. See 6.6, *General Discussion of Heating*, for further information.

#### **13.1.2 Regulator Samplers**

A specially designed pressure regulator increases the delivery pressure of the sample to the sample cylinder from atmospheric pressure to a maximum of line pressure during the sample period. Regulator samplers are not recommended for low-pressure lines or variable flow rates.

#### **13.1.3 Displacement Samplers**

A positive displacement pump extracts a sample at line pressure and discharges it into a sample cylinder during the sampling period.

#### **13.1.4 System Considerations**

The sample line between the sampling device and the collection cylinder should be of minimum length. Heat and insulation may be required to avoid condensation. If the sample system does not provide a continuous flow of sample, the sampler should purge itself prior to pumping a sample increment into the collection cylinder. (See section 6.6, *General Discussion of Heating*, and Appendix A, *The Phase Diagram*, for further information.)

When using displacement samplers, either constant volume or constant pressure cylinders may be used. When using regulator samplers, constant volume cylinders are required.

### **13.2 CONTINUOUS SAMPLING SYSTEMS FOR ON-LINE ANALYZERS**

#### **13.2.1 General**

For on-line analyzers, such as chromatographs and gravimeters, the sample system will consist of components to extract, condition and deliver a representative sample of natural gas to the analyzer. The sample delivery system must not interfere with the integrity of the primary metering system. To avoid the possibility of system interference, it is generally recommended that on-line sampling systems be dedicated to a single device.

#### **13.2.2 System Considerations**

The sample lines should be kept as short as possible.

The sample delivery system must meet the requirements of 6.6, *General Discussion of Heating*, which may require heating and insulation to avoid sample condensation. The system should also be designed to facilitate cleaning. See section 6.5, *Cleanliness*, and Appendix A, *The Phase Diagram*, for further information. The flow rate through the sample system should be designed to



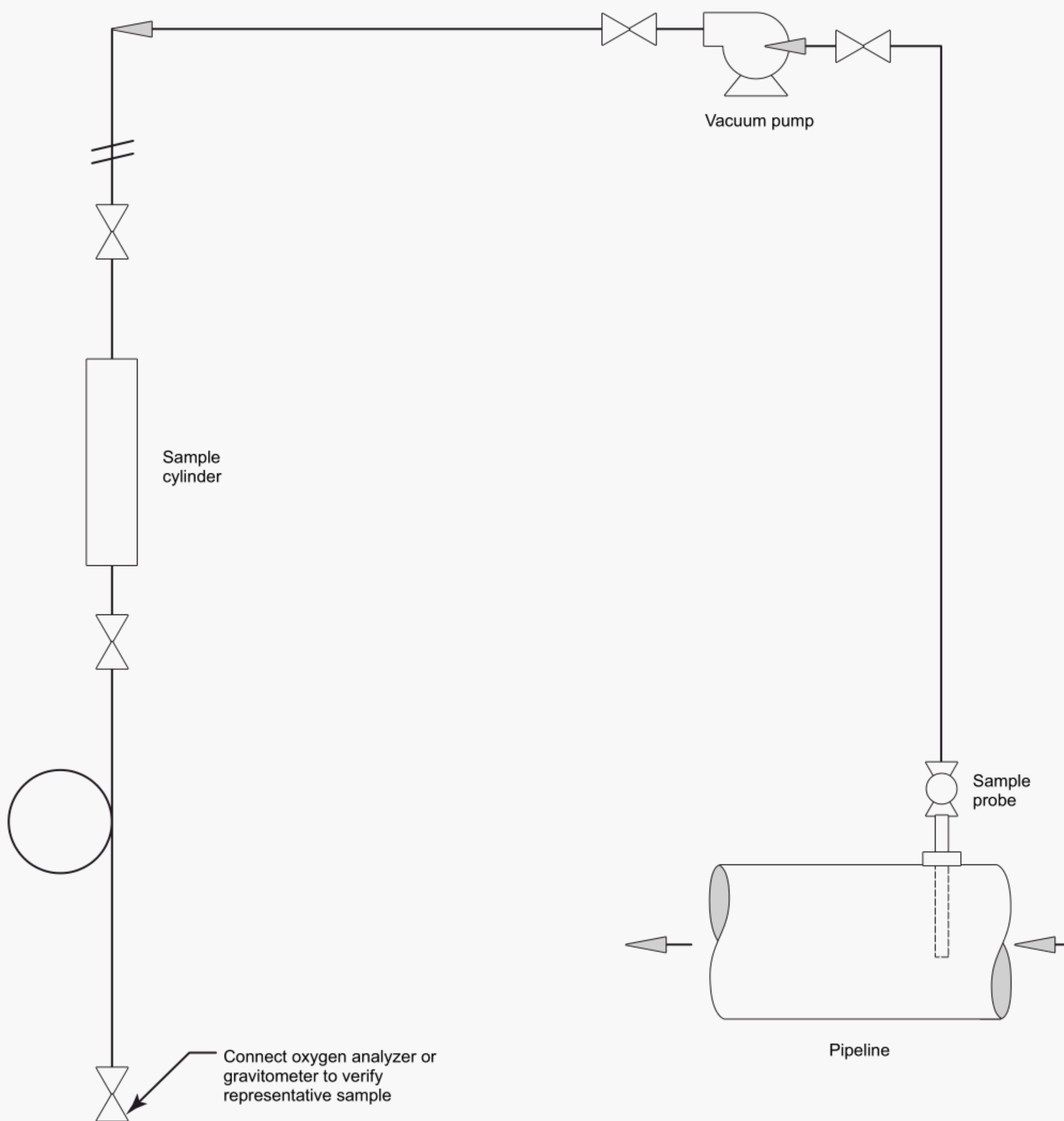


Figure 10b—Alternate Method of Sampling from a Vacuum-Gathering System

achieve the appropriate lag time in the system. For example, in real time process control, the lag time must be very short relative to the requirements for a monthly average analysis.

## 14 Sampling Intervals

### 14.1 GENERAL CONSIDERATIONS

A sampling system should provide a sample representative of the gas flowing in the pipeline. Since pipeline flow rates and compositions may vary with time, a sampling interval, time or flow proportional, should be carefully chosen so that the collected sample reflects these variations.

### 14.2 COMPOSITE SAMPLE INTERVALS

In choosing the method to be used in pacing the sampler, the sample source stream is the primary concern. Flow proportional composite sampling systems are most likely to produce a representative sample. If the stream has a constant composition or flow rate, a time pacing mechanism may be used. Provisions in time based systems must be made to stop sampling when there is no flow.

### 14.3 SPOT SAMPLING INTERVALS

Generally, gas pipeline composition will have daily, monthly, semi-annual, and seasonal variations. Compositional variations will also occur because of surface equipment and gas reservoir changes. All of these environmental and operational considerations must be taken into account when selecting a sampling interval for a spot sample. Spot samples will produce accurate and representative compositions only if the product composition is stable within the accounting time frame.

## 15 Safety, Labeling, Handling, and Transportation of Cylinders

### 15.1 SAFETY

**Precaution should be taken to ensure that safe practices are employed. All applicable Occupational Safety and Health Administration (OSHA) and DOT regulations should be consulted.**

Sample probes, cylinders, lines, sampling separators and valves must have working pressures above the sample source pressure. The material used in the construction of each of the components in the sample system must not be affected by the components in the gas sampled. Pressure and velocities in the flowing pipeline must be carefully considered when specifying hardware for the sampling system. Copper tubing and fittings can be hazardous and should be avoided. If copper tubing and fittings are used, they must be used with caution and inspected frequently for bad connections, flattening, and kinks. Systems with pressures over 1,000 psi (6.9 MPa) or gas containing hydrogen sulfide ( $H_2S$ ) should be constructed with stainless steel or other appropriate tubing, fittings and components.

**During sampling, sample transfer and especially during purging, a total commitment to safety precautions is mandatory. Smoking, open flames, vehicles with motors running, use of matches and use of non-explosion proof electrical devices in the area is not permitted. Caution must be exercised when purging and sampling to prevent forming a hazardous atmosphere. Special precautions should be taken if hydrogen sulfide ( $H_2S$ ) is present (see Appendix D, *Hydrogen Sulfide Warning*).**

The transportation and construction of the sample cylinder is strictly regulated by DOT, 49 *Code of Federal Regulations*, the U.S. Coast Guard, the Federal Aviation Administration and various other regulatory agencies. **TRANSPORTATION OF THESE CYLINDERS MUST ADHERE TO THE GUIDELINES SET FORTH IN THEIR REGULATIONS.**

**Inhalation of hydrogen sulfide ( $H_2S$ ) at certain concentrations can lead to injury or death.  $H_2S$  is an extremely toxic, flammable gas which may be encountered in the production and processing of gas well gas, high-sulfur-content crude oil, crude oil fractions, associated gas and associated waters. Since  $H_2S$  is heavier than air, it can collect in low places in still air. It is colorless and has a foul, rotten-egg odor. In low concentrations, it is detectable by its characteristic odor. Smell cannot be relied upon to forewarn of dangerous concentrations however, because exposure to high concentrations of the gas (greater than 100 parts per million) rapidly paralyzes the sense of smell. A longer exposure to lower concentrations has a similar desensitizing effect on the sense of smell. If the sense of smell is rendered ineffective by hydrogen sulfide ( $H_2S$ ), the result can be an individual failing to recognize the presence of dangerously high concentrations. Utilize  $H_2S$  monitoring systems to accurately determine  $H_2S$  levels. Excessive exposure to hydrogen sulfide ( $H_2S$ ) causes death by poi-**

**soning the respiratory system at the cellular level.** There is some indication that the presence of alcohol in the blood aggravates the effects of H<sub>2</sub>S in acute poisoning cases. At low concentrations (10 to 50 parts per million), H<sub>2</sub>S is irritating to the eyes and respiratory tract. Closely repeated, short-term exposures at low concentrations may lead to irritation of the eyes, nose and throat. Symptoms from repeated exposures to low concentrations usually disappear after not being exposed for an appropriate period of time. Repeated exposures to low concentrations that do not produce effects initially can eventually lead to irritation if the exposures are frequent.

## 15.2 LABELING

Labels or tags must be completed and attached to each sample cylinder with the following information:

- Cylinder contents: natural gas,
- Sample source,
- Sample collection method,
- Pressure and temperature of the sampled source stream near the sample point,
- Date and time of collection,
- Field technician name.

Additional information may be required, such as:

- Hydrocarbon dew point,
- Water dew point,
- Flow rate,
- Relative density,
- Oxygen concentration,
- CO<sub>2</sub> concentration,
- H<sub>2</sub>S concentration.

Labels or tags must be securely attached to the sample cylinders, but should not interfere with the utilization of the cylinder. Figure 11 gives an example of typical label information.

US DOT *CFR* 49 includes specific requirements for labeling.

## 15.3 HANDLING AND TRANSPORTATION OF CYLINDERS

**Sample cylinders containing natural gas samples must be handled carefully due to their pressure, flammability and/or contents.**

The following actions shall be performed in conjunction with handling and transporting a sample:

- Check valves and fittings for leaks,
- Inspect, repair or replace valves as required,
- Plug or cap sample cylinder inlet and outlet valves prior to transportation,
- Avoid creating an unsafe situation due to over-tightening valves. Hand tightening of valves is sufficient,
- Protect sampling equipment from damage,
- Properly restrain sample containers during transport.

**Consider that depressurizing sample containers may produce low temperatures, high fluid velocities and hazardous vapors.**

It is recommended that all sample cylinders incorporate an over-pressure relief device, approved by the appropriate regulatory agency. The transportation and construction of the sample container is strictly regulated by the DOT, 49 *Code of Federal Regulations*, the U.S. Coast Guard, the Federal Aviation Administration and other regulatory agencies. **TRANSPORTATION OF THESE CYLINDERS MUST ADHERE TO THE GUIDELINES SET FORTH IN THEIR REGULATIONS.**

## 16 Guidance for Laboratory Analysis

All laboratories shall meet the operational requirements of the GPA or other recognized standards organizations for the type of gas analysis configuration being used. All analyses shall be performed in accordance with procedures set forth in GPA publications or other accepted industry standards.



SAMPLE FORM	
Facility Name: _____	
Company Name: _____	
Agreement Number: _____	
Sample Location: _____	
Sampled By: _____	
Date: _____	
Time: _____	
Sampled From:	Composite _____ Pipeline _____ Storage _____ Other _____
Sample Conditions:	Pressure _____ Temperature _____ Relative Density (Specific Gravity) _____ BTU _____ (If Known)
Sampling Method:	Purge/Fill _____ Waterdraw _____ Piston _____ Other _____
The following information to be filled out by laboratory:	
Name of Laboratory: _____	
Date Sample Received: _____	
Date Sample Analyzed By: _____	
Sample Condition: _____	
Witnessed By: _____	

Figure 11—Typical Sample Form

The API Laboratory Inspection Checklist developed by the API Chapter 14.1 Working Group is a useful tool for evaluating the performance and systems of analytical laboratories (See Appendix E).

A critical part of evaluating a lab's performance involves using calibration gas standards to calibrate or verify the calibration of analytical systems. This section of Chapter 14.1 offers recommendations for using calibration gas standards. Sections 16.2 and 16.3 cover preparing those standards for service.

## 16.1 USE AND HANDLING OF CALIBRATION GAS STANDARDS

The recommendations in this section presume that the calibration gas standard has been handled properly from the time of preparation to its removal from service.

It is important to read and follow all manufacturers' precautionary labels and Material Safety Data Sheets (MSDS) before heating a compressed gas cylinder.

The calibration standard shall be heated for a minimum period of 4 hours after the skin temperature of the cylinder reaches a temperature at least 30°F (17°C) above the hydrocarbon dew point calculated at the cylinder fill pressure using common equations of state (such as Peng-Robinson or SRK) and standard interaction parameters. (See 6.6 for additional guidance regarding the operating temperature margin of 30°F above the calculated hydrocarbon dew point.) If the fill pressure of the cylinder is above the cricondenthem pressure of the gas blend, the standard shall be heated to a temperature at least 30°F (17°C) above the calculated cricondenthem, so that as gas is withdrawn from the cylinder and the cylinder pressure drops, the gas blend does not undergo phase change. In no case should the cylinder temperature exceed the temperature limit of the cylinder. The intent of this requirement is to ensure that the core temperature of the calibration standard has reached a temperature of at least 30°F (17°C) above the calculated hydrocarbon dew point of the calibration gas. Vaporization of the heavy components will occur more rapidly at higher temperatures above the calculated hydrocarbon dew point. It should not be necessary to exceed a temperature of 50°F (27.8°C) above the calculated hydrocarbon dew point. The pressure and temperature at which a calibration standard blend was prepared may also be referenced when heating the standard before analysis. When the sample is withdrawn for injection, the cylinder should be oriented vertically. It is recommended that a standard be replaced or statistically reverified annually. Reverification requires the use of an independent gravimetrically prepared calibration gas standard to determine whether or not the analytical device as calibrated using the existing calibration gas standard can meet industry standard criteria for both reproducibility and repeatability (see Appendix E). Care should be taken to insulate the calibration gas cylinder from cold surfaces (floors, walls, etc.)

The sample lines from the calibration standard to the chromatograph and any regulators in the system shall also be maintained at a temperature at least 30°F (17°C) above the calculated hydrocarbon dew point plus the expected temperature reduction due to pressure regulation (approximately 7°F (3.9°C) per 100 psi (690 kPa) of pressure regulation), not to exceed the rated temperature of the equipment. See 6.6, *General Discussion of Heating*, for further guidance.

It is recommended that a calibration gas standard be analyzed as an unknown on a chromatograph of known good calibration and performance before it is first used.

## 16.2 ACCURACY REQUIREMENTS FOR PREPARATION OF CALIBRATION STANDARD GAS BLENDS

As a minimum, calibration standard gas blends shall be gravimetrically prepared and traceable by weight to the National Institute of Standards and Technology (NIST), or equivalent standards body. Standard gas blends prepared using only analytical methods will typically have higher composition uncertainties than standards prepared gravimetrically, and are not recommended for calibration purposes. All facilities that prepare calibration standards shall meet the requirements of GPA 2198 or other applicable standards for the preparation, validation and care of natural gas reference standards.

Raw materials used in the preparation of calibration standard blends shall be screened for impurities when first received, and periodically during their use. Any impurities shall be considered in the compositional analysis of the final blend.

Uncertainty analyses of the final compositions of each calibration standard gas blend shall include, as a minimum, the following sources:

- Precision uncertainty of instruments used in the preparation process.
- Bias errors observed during calibration of instruments.

Other sources of uncertainty, such as composition uncertainties and impurities in raw materials, shall be included if excluding them will result in errors exceeding the mole percent repeatability limits in Appendix E. Analytical compositions of reference gases obtained using gas chromatography may be used to verify the gravimetric compositions, but are not recommended for use as the final certified composition.

Certificates of composition should include the calculated uncertainties in each component, either in mole % or in percent of value. The confidence level of the uncertainty figures (1-sigma, 95%, etc.) should also be included on the certificate. Accuracies for calibration standard gas blends shall meet the following requirements of GPA 2198:

Table 3—Required Blending Accuracy  
(from GPA 2198-98)

% of concentration	% accuracy
0.00 to 0.099%	5% relative
0.10 to 9.999%	2% relative
10.0% to 100%	1% relative

### 16.3 BEST PRACTICES FOR PREPARATION OF CALIBRATION STANDARD GAS BLENDS

Raw materials used in the preparation of calibration standard blends shall be screened for impurities when first received, and periodically during their use. Any impurities shall be considered in the standard preparation process. Raw materials shall be replaced when they have reached their expiration dates, or when analysis shows they no longer meet specifications.

Mixing new lots of raw materials with old lots is discouraged. When an empty raw material storage vessel is to be reused, precautions are encouraged to avoid contamination of the new contents of the vessel with the previous contents. Examples of such precautions include heating the empty vessel under vacuum to remove the previous contents, or dedicating the vessel to the storage of a single raw material.

Materials used in containers, valves, and transfer lines shall be compatible and non-reactive with the components they come in contact with. Sample transfer lines made of stainless steel or Nylon 11 are recommended; other plastics are not recommended for use as transfer lines. Pressure and flow regulators containing neoprene seals are not recommended. If lubricants are used, no component of the raw material or final product should be soluble in the lubricant. Cleaning agents, or agents used to purge storage vessels and transfer lines, shall not cause contamination of the raw materials or final product. The practice of cleaning new storage vessels, transfer lines, and other equipment before using them for the first time is encouraged.

Environmental controls are encouraged to keep raw materials in storage stable and at the desired conditions. Materials sensitive to light, heat, or moisture shall be kept in appropriate containers. Storage in inert or temperature-controlled environments for reactive materials is encouraged.

Where balances are used to determine the mass of components added to a blend, precautions shall be taken to ensure consistent measurements. Examples of such precautions include placing enclosures around balances to stabilize the local environment, and the use of “targets” on the balance to ensure that equipment is weighed in the same position each time. Other methods to ensure consistent measurements may be found in ISO 6142. The use of statistical process control or quality control charts, as discussed in GPA 2198, is encouraged to identify inconsistencies in balance measurements.

The possibility of condensation of mixtures of hexanes and heavier hydrocarbons at valves or throttles, caused by Joule-Thomson cooling, should be investigated. If the possibility of fractionation exists, precautions shall be taken to prevent raw materials from condensing within transfer lines upstream of the blending location. All components other than hexane and heavier hydrocarbons shall be added as pure components, not as part of mixtures.

All Department of Transportation (DOT) regulations and International Air Transport Association (IATA) regulations shall be followed when shipping or transporting reference gas blends.

### REFERENCES

1. ASTM D 1142, *Standard Test Method for Water Vapor Content of Gaseous Fuels by Measurement of Dew-Point Temperature*, American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania, 19428-2959.
2. DOT (U.S. Department of Transportation), *Code of Federal Regulations*, Title 49 – Transportation, U.S. Government Printing Office, Washington, D.C. 20001.



3. GPA 2166-05, *Obtaining Natural Gas Samples for Analysis by Gas Chromatography*, Gas Processors Association, 6526 E. 60th Street, Tulsa, Oklahoma 74145.
4. GPA 2261-00, *Analysis for Natural Gas and Similar Gaseous Mixtures by Gas Chromatography*, Gas Processors Association, 6526 E. 60th Street, Tulsa, Oklahoma 74145.
5. NACE Standard MR-01-75, *Sulfide Stress Cracking Resistant Metallic Materials for Oilfield Equipment*, National Association of Corrosion Engineers, 1440 South Creek Drive, Houston, Texas 77218-8340.
6. *Metering Research Facility Program: Natural Gas Sample Collection and Handling-Phase I*, Behring, K.A. III and Kelner, E., GRI Topical Report No. GRI-99/0194, Gas Technology Institute, 1700 South Mount Prospect Road, Des Plaines, Illinois 60018-1804.
7. *Metering Research Facility Program: Natural Gas Sample Collection and Handling-Phase II*, Kelner, E., Britton, C. L., Behring, K.A. III and Sparks, C. R., GRI Topical Report No. GRI-01/0069, Gas Technology Institute, 1700 South Mount Prospect Road, Des Plaines, Illinois 60018-1804.
8. *Metering Research Facility Program: Natural Gas Sample Collection and Handling-Phase III*, Kelner, E., Sparks, C. R., and Behring, K.A. III, GRI Topical Report No. GRI-01/0070, Gas Technology Institute, 1700 South Mount Prospect Road, Des Plaines, Illinois 60018-1804.
9. *Metering Research Facility Program: Natural Gas Sample Collection and Handling-Phase IV*, George, D. L., Barajas, A. M., Kelner, E., and Nored, M., GRI Topical Report No. GRI-03/0049, Gas Technology Institute, 1700 South Mount Prospect Road, Des Plaines, Illinois 60018-1804.
10. *Metering Research Facility Program: Natural Gas Sample Collection and Handling-Phase V*, George, D. L., Burkey, R. C., and Morrow, T. B., GRI Topical Report No. GRI-05/0134, Gas Technology Institute, 1700 South Mount Prospect Road, Des Plaines, Illinois 60018-1804.
11. *Measurements of Hydrocarbon Dew Points of Rich Natural Gases*, George, D. L. and Burkey, R. C., Final Report to U.S. Department of Energy, May 2005.
12. *Hydrocarbon Phase Behavior*, Ahmed, T., Gulf Publishing Company, Houston, TX, 1989.
13. *The Properties of Petroleum Fluids*, McCain, W.D. Jr., PennWell, Tulsa, Oklahoma, 1990.
14. *Introduction to Fluid Mechanics*, Fox, R.W and McDonald, A.T., Wiley & Sons, New York, 1973.
15. *Prediction of Horizontal Tubeside Condensation of Pure Components Using Flow Regime Criteria*, Breber, G., Palen J.W., Taborek, J. Presented at the 18th National Heat Transfer Conference, San Diego, 1979. Also published in *Condensation Heat Transfer*, ASME Publication No. 100123.
16. EEMUA 138:1988, *Design and Installation of On-Line Analyser Systems*, The Engineering Equipment and Materials Users Association, 20 Long Lane, London EC1A 9HL, United Kingdom.

## ADDENDUM

There is a theoretical possibility for auto-ignition of natural gas and air mixtures in gas sample cylinders if improperly filled (rapidly pressurized).

If natural gas is introduced into the sample cylinder at sonic velocity (the speed of sound), it is theoretically possible that the shock wave produced by the gas entering the cylinder will act like a piston. The air/gas mixture could compress so rapidly that the mixture could reach its auto-ignition temperature. If the mixture is within the range of air/gas ratios that support combustion, a fire inside the cylinder or an explosion could occur. For such an event to occur under these circumstances, the inlet valve would have to have a relatively large opening and be opened very quickly, as might occur with a quarter-turn, full-port valve.

API is not aware of any incidents of this type occurring during the filling of natural gas sample cylinders, but cautions users of the standard of the theoretical possibility.

To mitigate the theoretical possibility of this occurring, either the air/oxygen must be removed from the cylinder or the maximum velocity of the gas entering the cylinder must be below sonic velocity. This must be accomplished in a manner that does not introduce sample distortion.

Although there are no reports of this type of incident occurring during the filling of natural gas sampling cylinders, users should be aware of the theoretical possibility and exercise due caution.

## APPENDIX A—THE PHASE DIAGRAM

### A.1 Phase Changes in General

The importance of avoiding condensation during gas sampling is discussed throughout this standard because phase changes have a significant impact on the accuracy of a gas sample. When a hydrocarbon mixture undergoes a phase change process during sampling, the composition of the collected sample will not be the same as the composition of the flowing gas stream. The errors in composition resulting from a phase change can be large.

The phase diagram is a useful tool for modeling the phase behavior of a hydrocarbon mixture. The phase diagram illustrates the change in dew point and bubble point temperatures with changes in the gas pressure.

Since pressure changes are impossible to avoid during the sampling process (i.e., getting a sample of gas from the source, to the analyzer), an understanding of the gas mixture's phase behavior provides guidance in the design and application of sampling systems and sampling methods.

For the purposes of this discussion, only liquid and gas phases are considered.

### A.2 Single Component Phase Behavior

Consider the piston-cylinder device shown in Figure A1 and filled with a single component (e.g., CO<sub>2</sub>, N<sub>2</sub>, He) in the gaseous phase. The pressure, temperature, and volume of the substance are represented by the letter A. If the substance is compressed isothermally (i.e., at constant temperature, T<sub>1</sub>), there will be a decrease in the cylinder volume. This decrease in volume and the associated increase in pressure will continue until liquid begins to condense. The pressure at which condensation begins is called the dew point, and is shown in Figure A1 as point B.

Once condensation begins, additional decreases in volume produce more and more condensation (C and D) until only an infinitesimal amount of gas remains in the mixture. This pressure is called the bubble point pressure. In Figure A1, it is point E. For a single component, the dew point pressure is equal to the bubble point pressure when the temperature is held constant. The substance is entirely in the liquid phase at volumes below the bubble point volume.

If this process is repeated for a temperature, T<sub>2</sub> greater than T<sub>1</sub>, similar pressure—volume behavior occurs. This can be repeated at higher and higher temperatures until no distinct phase-change occurs. This happens at the critical temperature. The pressure associated with the critical temperature is called the critical pressure. The critical point (CP) is the intersection of the critical temperature and critical pressure. Gas and liquid cannot coexist above the critical point of a single component.

When connected, the dew points, bubble points, and critical point form a region called the 2-phase region. In this region, liquid and gas coexist in relative quantities ranging from just under 100 percent gas, to just under 100 percent liquid.

If the dew point and bubble point pressures and temperatures are plotted on a pressure—temperature diagram, the result is a single line known as the P-T diagram, phase diagram, or vapor pressure curve. Figure A1 shows a typical vapor pressure curve for a single component. The upper section corresponds to the liquid phase and the lower section corresponds to the gaseous phase. Gas and liquid will coexist at the pressure/temperature points on the curve. The vapor pressure curve for a single component does not show the relative amounts of each phase.

### A.3 Mixture Phase Behavior

Now consider the piston-cylinder device filled with a mixture of components, such as hydrocarbons. If the mixture is compressed isothermally, as in the previous example, the mixture will go from a gaseous phase, to a mixture of gas and liquid, then to liquid, as shown on the T<sub>1</sub> isotherm of Figure A2. This can be repeated at progressively higher temperatures until the critical temperature is reached. The line connecting the dew points, bubble points and the critical point forms the 2-phase region.

The general phase behavior of a mixture, such as a hydrocarbon mixture, is similar to that of a single component, with two important exceptions. First, the dew point pressure does not equal the bubble point pressure at a given temperature. Second, gas and liquid can coexist at pressures and temperatures above the critical point of a mixture.

If the dew point and bubble point pressures and temperatures are plotted on a P-T diagram as shown in Figure A2, the result is the mixture phase diagram. The region enclosed by the bubble points and dew points is the 2-phase region, also known as the phase envelope.



Natural gas engineering is primarily concerned with mixture temperatures that are above the critical temperature.

## A.4 Retrograde Condensation and Vaporization

The vapor pressure curve for a single component was discussed earlier and is shown in Figure A1. This curve represents the pressures and temperatures where 2-phases of a single component coexist. At a given temperature, the phase change process for a single component occurs at a constant pressure.

Mixture phase behavior is different than single component phase behavior. There is a pressure change during the phase change process. This pressure change appears on the phase diagram (P-T curve) as two saturation pressures for a given temperature (Figure A2).

Focusing on the section of the phase diagram with temperatures above the critical temperature (Figure A3), one can see that during an isothermal pressure drop, from point A to point E, the mixture starts completely in the gas phase, then begins to condense as it reaches the point labeled as the “upper dew point.” This “retrograde” condensation is counter to the behavior that occurs with a single component.

As the pressure continues to drop, more of the mixture condenses, until the percent of condensed liquid in the mixture reaches a maximum (determined by the composition of the original mixture). Once the maximum is reached, further pressure reduction causes a vaporization of the liquid until the “lower dew point” is reached. The mixture is entirely in the gas phase at pressures below the lower dew point pressure.

The opposite will occur during an isothermal pressure increase. It may also occur when gas from a vacuum-gathering system is compressed into the sample cylinder.

Retrograde phase changes can also occur when the temperature is changed at pressures above the critical pressure and within the phase envelope.

## A.5 Natural Gas Mixture Phase Diagrams

Figure A4 shows a phase diagram for a typical natural gas mixture. Several sections of the curve are labeled. The composition of the hydrocarbon mixture being modeled is also shown.

The line A-B is the section of the phase diagram known as the bubble point curve. When the pressure is lowered isothermally to the bubble point, an infinitesimal amount of gas begins to evolve. As the pressure is reduced further, more and more gas is liberated from the mixture, increasing the total concentration of gas in the 2-phase mixture.

The line B-E is the dew point curve. This section of the phase diagram represents the pressures and temperatures associated with the condensation of an infinitesimal amount of liquid from the gas mixture.

The line C-D is sometimes referred to as the retrograde dew point line. The dew points along line C-D are referred to as the upper or retrograde dew points.

The line D-E is sometimes referred to as the normal dew point curve. The dew points along line D-E are referred to as the lower or normal dew points.

Point C is the cricondenbar. It is the highest pressure on the phase envelope. Point D is the cricondentherm. It is the highest temperature on the phase envelope.

## A.6 Limitations of the Phase Diagram

The accurate determination of a hydrocarbon mixture’s phase behavior depends on the accuracy of the compositional analysis, the equation of state used, the amount of “heavy” (C6+) fractions, and the accuracy of physical properties such as the critical temperature and critical pressure.

These limitations must be considered when using a phase diagram for gas sampling system or method design.

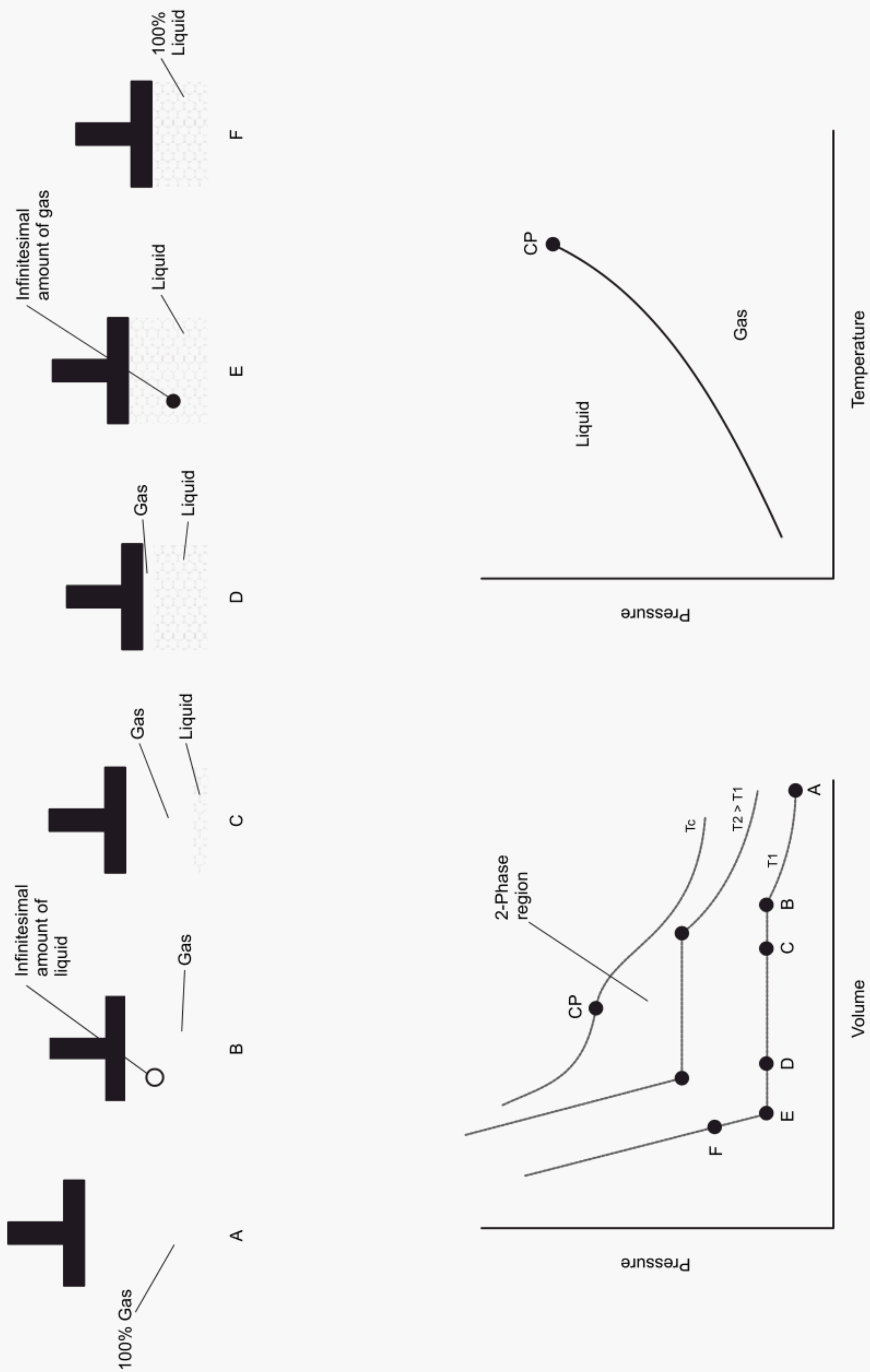


Figure A1—Pressure—Volume and Pressure—Temperature Diagrams for a Pure Component

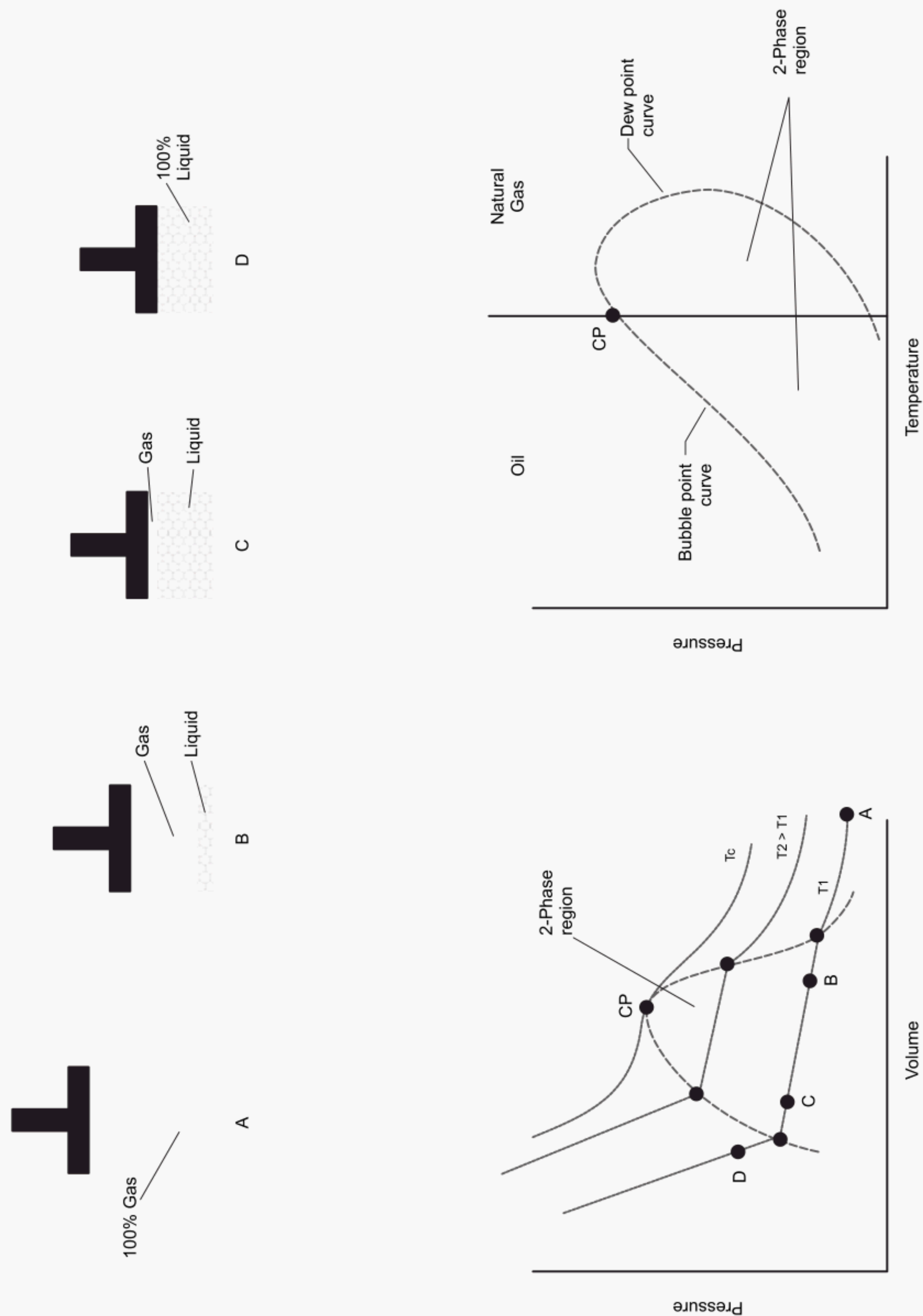


Figure A2—Pressure—Volume and Pressure—Temperature Diagrams for a Mixture



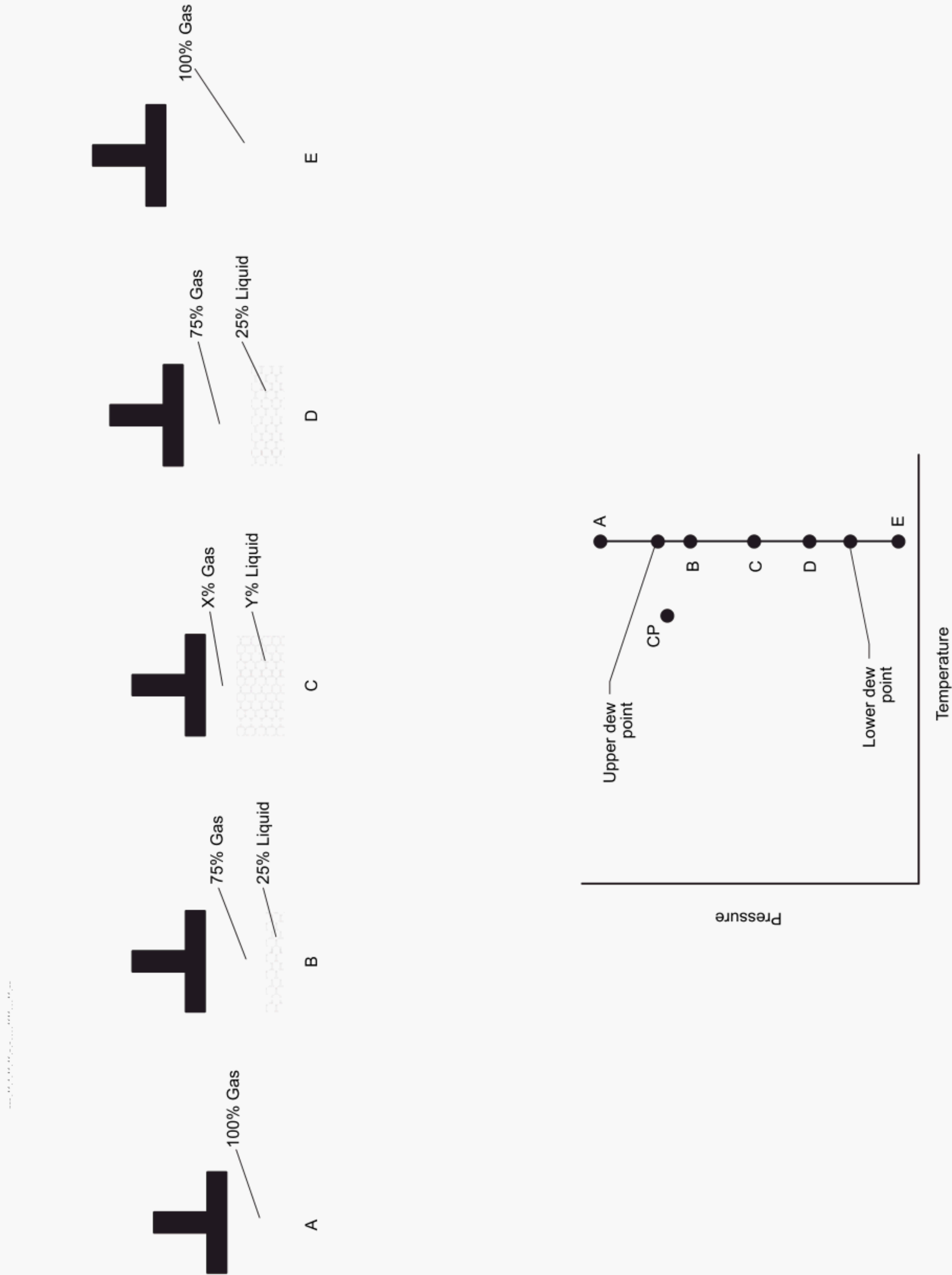


Figure A3—Retrograde Condensation

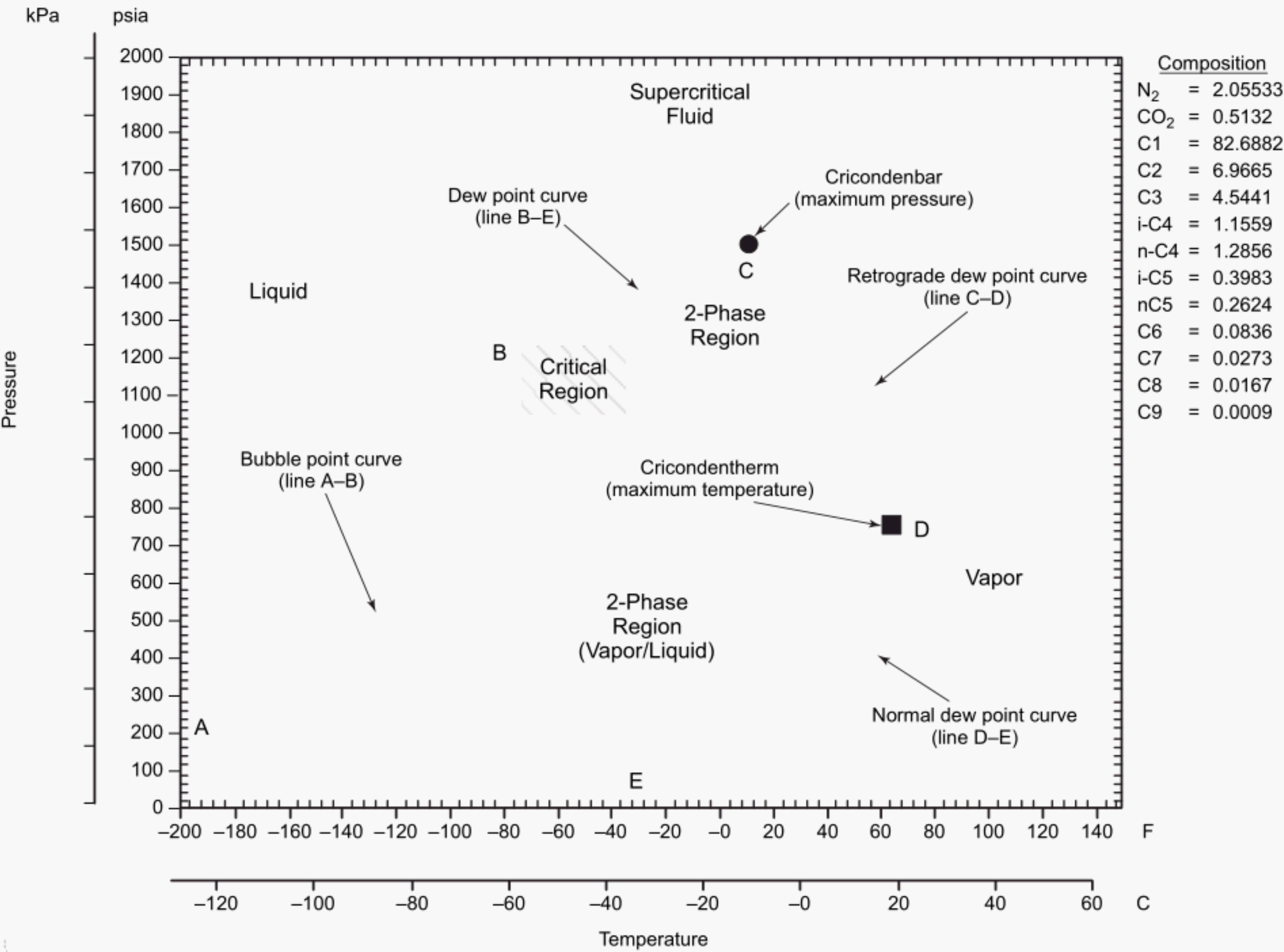


Figure A4—Examples of Thermodynamic Processes of Natural Gas

## APPENDIX B—FLUID MECHANICAL CONSIDERATIONS IN GAS SAMPLING

### B.1 General

It is important to understand the types of flow perturbations that can occur in a pipeline and how these can affect the accuracy of a gas sample. For instance, some piping elements or configurations can create re-circulation zones or eddies in the flow stream. The zone immediately downstream of an orifice plate is a prime example. The gas composition in these eddies may be measurably different from the gas composition of the bulk flow. Other types of flow restrictions or expansions can create localized thermodynamic changes in the gas stream. An example would be the flow from a gas-liquid separator. In that case, the gas will be near its hydrocarbon dew point and a reduction in line temperature will likely cause some condensation to occur, resulting in the flow becoming two phases. In other cases, a pipeline may be operating in a multiphase equilibrium, in which case both gas and liquid are continually present in the pipe. Obtaining an accurate gas sample under these conditions can be quite challenging.

It is not the objective of this document to explain in full detail how flow effects can adversely affect the gas sampling process. There is a large body of information on this subject available in the open literature, to which the reader is referred (see References). Instead, the following general overview seeks to make the reader aware of potential flow-related problems that may need to be addressed when selecting appropriate gas sampling locations or troubleshooting existing sampling sites.

### B.2 Single-Phase Flow

The preferred flow regime is single-phase, turbulent flow away from major restrictions to the flowing stream that might produce condensation. Single-phase flow is natural gas flowing at a temperature at or above the hydrocarbon dew point and free of compressor oil, water or other contaminants in the flow stream. In general, it is preferred that the single phase gas in the pipeline be in the turbulent flow regime, because the fluid turbulence creates a well-mixed, representative fluid.

Laminar flow is not normally found in gas pipeline applications because the gas viscosity is relatively low and the gas velocity is usually high enough to ensure that this flow regime does not occur. However, depending on the design of the gas sampling system, laminar flow can occur in low-flow-rate sampling lines.

Laminar flow is the simplest class of pipe flow, in which streamlines form an orderly, flow pattern. A streamline is the trajectory traced out by a moving fluid particle. In laminar flow, viscous forces control the movement of the gas as it moves through the pipe. The gas may be thought of as flowing along in a series of layers or laminates, with smoothly varying velocity from laminate to laminate. There is also no macroscopic mixing of adjacent fluid layers. To illustrate, if a thin film of dye were to be injected into a laminar flow, the dye would appear to be a single line, with no dispersion of the dye throughout the flow field (except for slow dispersion due to molecular motion).

Figure B1 qualitatively illustrates laminar flow at the entrance region of a pipe. In this example, the flow velocity ( $U_0$ ) is uniform at the pipe entrance. The velocity of the gas at the wall of the pipe is always zero and the pipe wall exerts a retarding shear force on the flowing gas. The result is that the gas velocity near the pipe wall is reduced in the axial direction and the effect of the pipe wall is felt farther out in the flow stream as the gas progresses downstream. This phenomenon creates a boundary layer along the pipe wall. At some distance downstream of the pipe entrance, the boundary layer grows to the point that it reaches the pipe centerline. The length required for the boundary layer to reach the pipe centerline is called the entrance length. Beyond the entrance length, the velocity profile does not change with increasing distance and the flow is said to be fully developed. The velocity profile of fully-developed laminar pipe flow has a parabolic shape.

Turbulent flow in a pipe is generally characterized by a general swirling nature in the flow field involving indistinct lumps of fluid called eddies or vortices. There is typically a very wide range in the size of the eddies occurring at the same time or at the same place in the turbulent region. The instantaneous boundary region between the turbulent core flow region and non-turbulent flow region near the pipe wall is sharp. Turbulent flow is also a randomly unsteady process, with effective frequencies ranging over several orders of magnitude. The irregular variations in the motion of the gas stream are not small with respect to either time or space. Furthermore, the turbulence is always three-dimensional, even if the bulk flow is two-dimensional. To illustrate, if a dye filament were to be injected into a turbulent flow, the dye would break up into myriad entangled threads and disperse quickly throughout the entire flow field.

Figure B2 illustrates the differences in velocity profiles for laminar and turbulent pipe flow. In this case, the pipe Reynolds number (i.e., the non-dimensional ratio of inertial to viscous forces) is  $4 \times 10^3$ . Both profiles have the same average velocity and, thus,



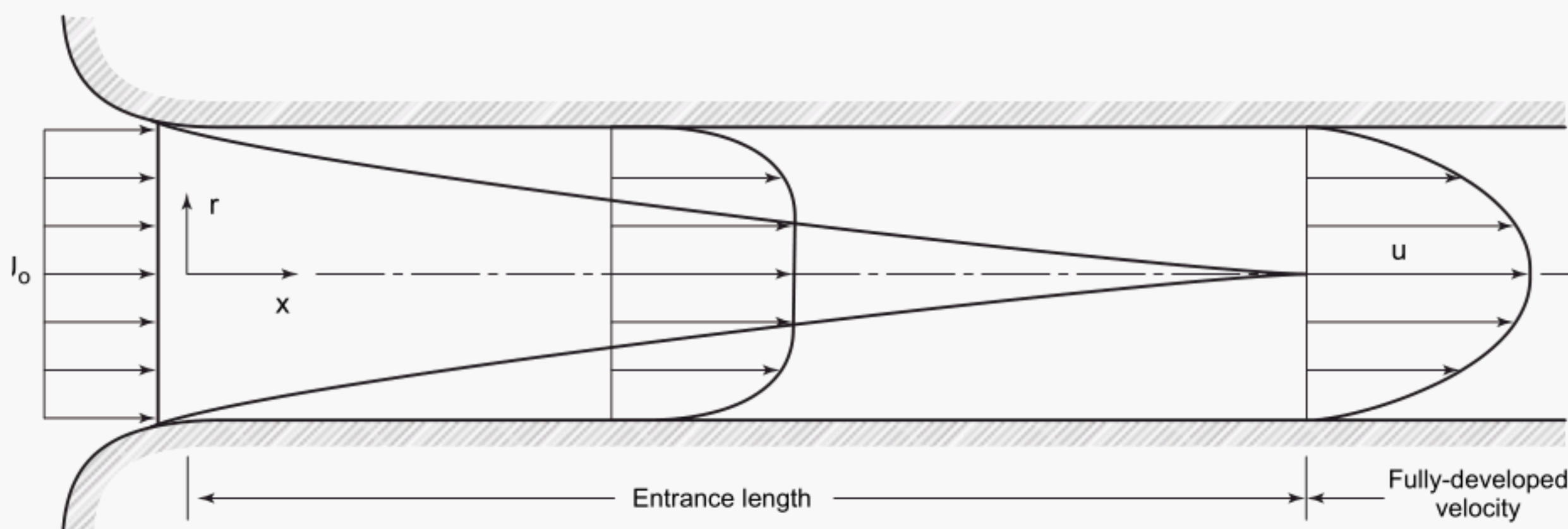
the same flow rate. Notice, however, that the laminar and turbulent velocity profiles do not have the same centerline velocity and that the turbulent profile has a much steeper profile near the wall of the pipe.

Some piping configurations (e.g., headers, single elbows, multiple elbows in series, etc.), flow control elements (e.g., valves, regulators, filters, etc.), or flow metering devices (e.g., orifice flow meters, turbine flow meters, etc.) may distort the gas flow field in a pipe, producing velocity profile asymmetry, swirl, a combination of profile asymmetry and swirl or a phenomenon known as flow separation. Flow separation occurs when the momentum of the fluid in the boundary layer is insufficient and the fluid layers adjacent to the solid surface (e.g., the pipe wall or an obstruction protruding in the pipeline, such as a reduced port valve, flow regulator, or an orifice plate) separate from the surface. Separation results in the formation of a relatively low pressure region downstream of the separation point or behind the obstruction that produces the flow separation. This low-pressure region is called the wake. Large scale eddies or flow re-circulation zones often develop in wake regions that form in a pipe flow.

These flow distortions may also produce thermodynamic changes (e.g., pressure or temperature changes) that result in non-equilibrium conditions. For instance, thermodynamic effects may cause phase changes in the gas mixture. Care should be taken to select gas sampling locations that are free of flow distortion, since these distortions may cause compositional changes in the gas mixture.

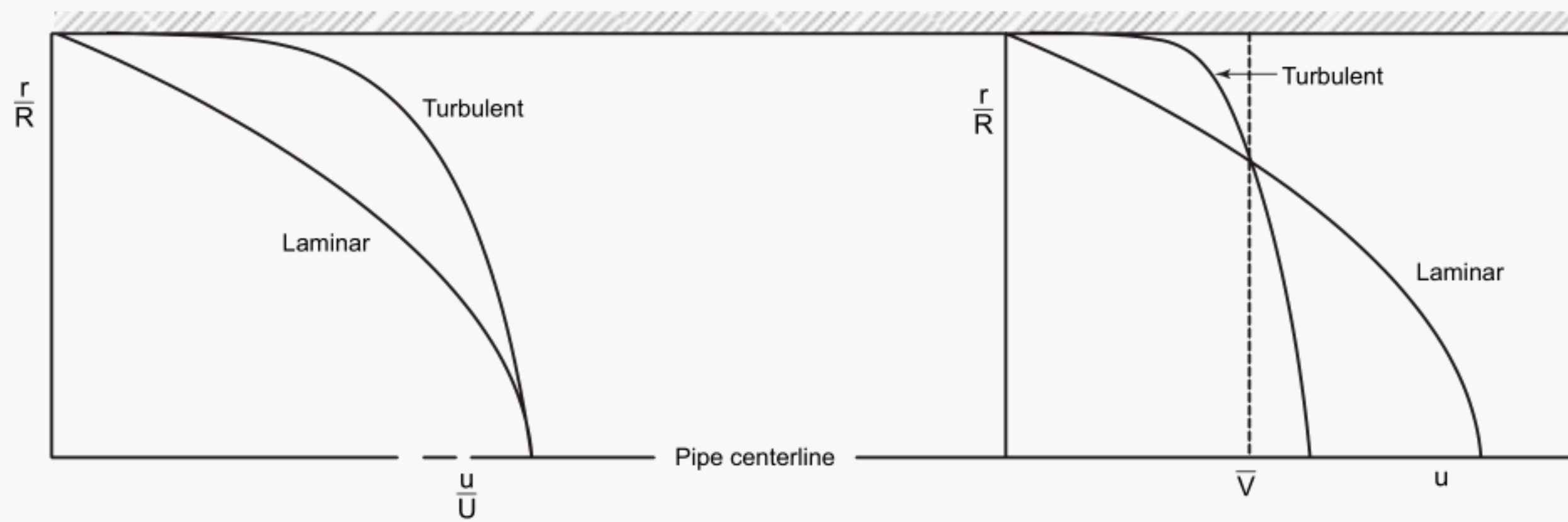
### B.3 Multiphase Flow

Sampling of multiphase flow is outside the scope of this standard. Sampling of multiphase (gas and liquid) mixtures is not recommended and should be avoided if at all possible. In the multiphase flow, the ideal system would mix the gas and liquid flows uniformly and collect a sample of the true mixture flowing in the line by using a properly designed sample probe and an isokinetic sampling system. Current technology of natural gas sampling is not sufficiently advanced to accomplish this with reasonable accuracy. When sampling a multiphase liquid-gas flow, the recommended procedure is to eliminate the liquid from the sample. The liquid product that flows through the line should be determined by another method. The liquid fraction of the multiphase flow may contain water and hydrocarbons. The hydrocarbons can contribute significantly to the energy (measured in British thermal units) content of the gas and their presence in the gas line must not be overlooked.



Note: Figure excerpted from *Introduction to Fluid Mechanics*, Fox and McDonald.

Figure B1—Laminar Flow in the Entrance Region of the Pipe



Note: Figure excerpted from *Introduction to Fluid Mechanics*, Fox and McDonald.

Figure B2—Comparison of Laminar and Turbulent Velocity Profiles for Flow in a Pipe





## APPENDIX C—LESSONS LEARNED DURING SAMPLING IN HYDROCARBON SATURATED AND 2-PHASE NATURAL GAS STREAMS

During the late 1980's, industry made a commitment to the BLM to complete a full set of consensus standards covering all the measurement-related practices in common use by the industry for custody transfer measurement. As a result of this commitment, several new standards were developed and several existing standards were upgraded. Examples include standards covering Allocation Measurement, Electronic Gas and Liquid Measurement, Coriolis Meters, Natural Gas Sampling, Inferred Mass Liquid Measurement, etc.

As a part of the effort, API Chapter 14.1 was expanded during the early 1990's to include composite sampling of natural gas. During the drafting of the upgraded standard, the Working Group realized that many of the consensus recommendations contained in the standard for both spot and composite sampling were not well supported by sufficient documented and qualified data. Following the balloting and approval of the standard in 1992, a research project was eventually defined and implemented to produce enough high-quality data to make future recommendations technically defensible.

As originally scoped, the research project was to consist of two basic test phases. The Laboratory Phase, conducted at the Southwest Research Institute, was intended to evaluate spot sampling methods under carefully controlled conditions. The Field Phase was intended to evaluate the performance of the most promising sampling methods identified during the Laboratory Phase at actual operating locations. The Field Phase was to be conducted twice, once during Summer conditions, then again under Winter conditions. The Field Phase was to contain evaluations for composite sampling as well.

Once the project had begun, Colorado Engineering Experiment Station, Inc. (CEESI) commissioned a wet-gas flow facility that offered the Working Group the option of performing the Field Phase under more controlled conditions, but still at operating conditions typical of many field locations. The facility offered the option of performing tests with the flowing stream at, above or below the hydrocarbon dew point of the stream.

The CEESI wet-gas loop provided the ability to blend different compositions of gas in order to evaluate both the repeatability and accuracy of various sampling methods. The gas blends were generally prepared using pipeline gas, then weighing-in additional heavy components as required.

Since the project intended to evaluate methods in the wet-gas loop that were often below the hydrocarbon dew point, many of the data sets were collected under severe operating conditions where it was fully expected that achieving good repeatable analytical results was not likely. The Working Group intentionally designed the tests to penetrate the phase boundary and enter the two-phase region, resulting in entrained and free liquids sometimes being present in the flow loop.

The final scope of the project does not include recommendations for sampling in the two-phase region. The test plan defined by the Working Group for CEESI was performed under such severe conditions in the hope that recommendations could be made concerning the best methods to be used at or near the phase boundary. The data indicated that some methods might be capable of allowing sampling below the hydrocarbon dew point, but with higher uncertainties. The data also clearly demonstrated that under some severe operating conditions, when free liquids are present, none of the current methods are capable of obtaining a representative sample.

Other areas investigated during the course of the research included probe location, spot and composite sampling system design, heating and insulation requirements, laboratory inspection procedures and performance criteria, GPA separators and visual observation of free liquids (when operating the loop below the hydrocarbon dew point).

The work at CEESI showed that probe location is not critical if flow is single-phase (above the hydrocarbon dew point). For flow conditions at or near the hydrocarbon dew point, the probe location should not be placed within or immediately following flow disturbances.

The uncertainty of a portion of the Field Phase data is high, especially when the gas stream was below the hydrocarbon dew point. However, some data during these periods did reflect a general trend. For example, the constant pressure displacement method tended to be biased slightly low, the fill and empty method appeared to work fairly well as much as 10°F (5.6°C) below the hydrocarbon dew point and the helium pop method had a slight negative bias compared to the reference.

In spite of the best intentions of the Working Group and CEESI, there were difficulties in collecting and interpreting the data. Examples include:

- Some of the test procedures were found to involve more than one uncontrolled variable,

- Changes in the reference sample point location during the investigations into sample point location and sample method tests,
- Calibration problems with the online gas chromatograph (peak gates not set properly during the initial test series),
- Unstable chromatographic results during consecutive analyses (analyses that failed to reach equilibrium and/or analyses that exhibited poor repeatability),
- Large variations in the analyzed nitrogen concentration during various series of analyses,
- Sample size variations during analysis, due to atmospheric pressure variations and wind effects during the initial test series,
- Portions of a single test series being run with the flowing stream at times above and at times below the hydrocarbon dew point temperature,
- Not knowing exactly how the operating conditions related to the phase boundary at different locations within the flow loop during some tests.

Conclusion:

- When the simulated field conditions were below hydrocarbon dew point, it was difficult to draw clear conclusions from the data. The Helium pop and fill and empty methods showed promise under these adverse conditions.
- Trends reflected in the laboratory results were also generally reflected in the simulated field studies, even though the absolute values exhibited a higher uncertainty due to the differences between the reference point and the spot sample method caused by operating below the hydrocarbon dew point in the sample loop.

## APPENDIX D—HYDROGEN SULFIDE WARNING

Inhalation of hydrogen sulfide ( $\text{H}_2\text{S}$ ) at certain concentrations can lead to injury or death.  $\text{H}_2\text{S}$  is an extremely toxic, flammable gas that may be encountered in the production and processing of gas well gas, high-sulfur-content crude oil, crude oil fractions, associated gas and associated waters. Since  $\text{H}_2\text{S}$  is heavier than air, it can collect in low places in still air. It is colorless and has a foul, rotten-egg odor. In low concentrations it is detectable by its characteristic odor. Smell cannot be relied upon to forewarn of dangerous concentrations however, because exposure to high concentrations of the gas (greater than 100 parts per million) rapidly paralyzes the sense of smell. A longer exposure to lower concentrations has a similar desensitizing effect on the sense of smell.

**Utilize  $\text{H}_2\text{S}$  monitoring systems to accurately determine  $\text{H}_2\text{S}$  levels.**

Excessive exposure to hydrogen sulfide ( $\text{H}_2\text{S}$ ) causes death by poisoning the respiratory system at the cellular level. There is some indication that the presence of alcohol in the blood aggravates the effects of  $\text{H}_2\text{S}$  in acute poisoning cases. At low concentrations (10 to 50 parts per million),  $\text{H}_2\text{S}$  is irritating to the eyes and respiratory tract. Closely repeated, short-term exposures at low concentrations may lead to irritation of the eyes, nose and throat. Symptoms from repeated exposures to low concentrations usually disappear after not being exposed for an appropriate period of time. Repeated exposures to low concentrations that do not produce effects initially can eventually lead to irritation if the exposures are frequent.

The sense of smell may be rendered ineffective by hydrogen sulfide ( $\text{H}_2\text{S}$ ), which can result in an individual failing to recognize the presence of dangerously high concentrations.





## APPENDIX E—API LABORATORY INSPECTION CHECKLIST

<b>Lab Number:</b>	<b>Date:</b>
<b>Survey Team Members:</b>	

Sample Handling & Conditioning	YES	NO
Are sample cylinders heated?		
If sample cylinders are heated, to what temperature?		
Is the sample cylinder temperature monitored?		
Is the sample cylinder cleaned and purged before use?		
Is the sample heated for at least 2 hours?		
Is time monitored for sample cylinder heating?		
What is the length of time used for heating sample cylinders? (# hours)		
Are samples taken immediately from heater to analyzer if manually transferred?		
What method is used to insulate heated sample cylinders during analysis?		
Insulated Blanket		
Heated Cabinet		
Other (Specify in Comments)		

Physical Facility	YES	NO
Is the analyzer room heated?		
Is the analyzer room air-conditioned?		

Filters, Connections, and Hardware	YES	NO
Are filters used between sample and analyzer?		
Type:		
Size:		
Replacement Interval:		
What are the size, length and material of sample line and fittings?		
Are connections, lines, and hardware between sample cylinder and analyzer insulated?		
Are connections, lines & hardware between sample cylinder and analyzer heated?		
Sample loop size is: 0.25 cc		
0.50 cc		
1.00 cc		
Other (specify size)		

Injection System	YES	NO
Is the sample system a vacuum injection system?		
Is the sample system a purge injection system?		
If purge injection system, is there back pressure?		
Can the purge rate be read or measured?		
What is the purge rate?		

<b>Analyzer</b>	<b>YES</b>	<b>NO</b>
What is the analyzer brand?		
What is the analyzer model?		
What is the analyzer's serial number?		
Is this an isothermal run?		
If "YES," record temperature in °F (°C)		
If "NO," secure a copy of the temperature program.		
Are the columns configured per GPA 2261?		
If "NO," list the configuration		
Integration method is:	Peak Height:	
	Area:	
	Data logging:	
	Manual:	
	Electronic:	
Highest carbon number component analyzed is:		
C6		
C6+		
C7		
C7+		
Other (Specify)		
Calibration schedule is:		
Daily		
Weekly		
Monthly		
Other (Specify)		
Analysis frequency is:		
Daily		
Weekly		
Monthly		
Other (specify		

<b>Carrier Gas</b>	<b>YES</b>	<b>NO</b>
What is used as the carrier gas?		
What is the purity of the carrier gas?		
Is the carrier gas pressure monitored?		
Is the carrier gas flow rate monitored?		
If yes, carrier gas flow rate in cc/minute:		
Is a carrier gas drier used?		
If yes, type of drier material used:		
Replacement interval of carrier gas drier material:		



Calibration Standard Gas	YES	NO
Manufacturer of calibration standard		
Is calibration standard age less than a year old?		
If "NO," list the date blended		
Is the calibration standard heated continuously?		
If no, list the length of time heated before use:		
To what temperature is the calibration standard heated?		
Is an insulation blanket or heated cabinet used for the calibration standard?		
Can the cylinder pressure of the calibration standard be monitored?		
If yes, record the pressure in psig (kPa) before and after each test.		
Does the lab have calibration standards required for the test program?		
Is the hydrocarbon dew point for the calibration standard available?		
If yes, hydrocarbon dew point:		
Has or could the calibration standard ever been exposed to a temperature below the hydrocarbon dew point?		

Calculation	YES	NO
Are the component constants used in accordance with the latest GPA 2145?		
If "NO," what constants are used?		
Can the constants be verified?		
Are the calculations performed in accordance with the latest version of GPA 2172?		
Other methods used:		
Values for C6+ or other heavy fraction:		
C6		
C6 +		
C7		
C7 +		
Other (Specify)		
Composition of fraction:		
C6		
C7		
C8 +		
Other (Specify)		

Quality Control Program	YES	NO
Does a Quality Control Program exist?		
Can a copy of the Quality Control Program be obtained?		

NOTE: Rating by Team

<b>Documentation</b>	<b>YES</b>	<b>NO</b>
Secured area counts and response factors?		
Secured chromatograms and results?		
Secured copy of analysis report for calibration standards?		
Secured relative density?		
Secured HV—saturated and unsaturated both real and ideal?		
Secured mol% both normalized and unnormalized?		
Secured starting and ending pressures for both lab's calibration standard and audit group's standards.		
NOTE: Normal heating time for sample cylinders is 24 hr ( $\pm$ 2hr)		

### Repeatability and Reproducibility

The table below lists API-recommended laboratory repeatability and reproducibility criteria. The repeatability is defined, using the API definition, as the comparison of back to back runs, using the same sample, chromatograph and operator. Reproducibility can be defined in two ways, using either the API definition of reproducibility as the comparison of results between two labs on the same sample, or using “Warren Reproducibility,” which is defined as the comparison between the gravimetrically determined composition of the calibration standard and the analysis from the lab.

Table E1—Laboratory Repeatability and Reproducibility Criteria

Repeatability Criteria		Reproducibility Criteria (Using API or Warren Definition)	
Mol % Concentration	Max. Allowed Deviation ( $\pm$ Mol%)	Mol % Concentration	Max. Allowed Deviation ( $\pm$ Mol %)
0 to 1	0.02	0 to 1	0.04
> 1 to 5	0.10	> 1 to 5	0.13
> 5 to 15	0.18	> 5 to 15	0.26
> 15 to 30	0.28	> 15 to 30	0.38
> 30 to 50	0.40	> 30 to 50	0.50
> 50	0.52	> 50	0.63





## APPENDIX F—NEW SPOT OR COMPOSITE SAMPLE METHOD PERFORMANCE VERIFICATION PROCEDURE

Testing will be limited to a single-phase gas stream at or above its hydrocarbon dew point (HCDP). Multi-phase fluid sampling is not within the scope of this procedure. Laboratory practices described in this document should not be interpreted to be required procedures for normal sampling and analysis.

### **Procedure**

1. The same chromatograph used to analyze the sample stream is to be used to analyze the spot or composite samples to eliminate the error of using different chromatographs. It is preferable to use chromatographs for testing that are capable of producing an extended analysis (C9+) accurate within the API Chapter 14.1 guidelines for repeatability and reproducibility. The use of analyzers limited to a C6+ output may provide test results that indicate that the sampling method is acceptable for the application tested; however, method approval from such results should not be extrapolated to include applications where a more extended analysis is required.
2. Establish that the online or portable chromatograph and sample delivery system complies with API Chapter 14.1. See Appendix E for repeatability and reproducibility criteria and inspection checklist. The same calibration method and calibration standard is to be used for all chromatographs used for testing. The GC should be calibrated in the same environment in which it is used to analyze samples, so as to eliminate bias in the analysis.
3. Calibration standards must be prepared in accordance with the requirements in API Chapter 14 Section 1 (paragraph 16), maintained in accordance with the requirements in GPA Standard 2198-03, and verified by a laboratory independent of the blender. Verification of the calibration standard must comply with API Chapter 14.1 Appendix E repeatability and reproducibility criteria.
4. Establish that the complete sampling system (chromatograph, cylinders, tubing, etc.) is clean and free of any contaminants prior to calibrating and testing. Verify that the sample delivery system and chromatograph are clean by analyzing a sample of ultra-high purity (UHP) helium. Verify the cleanliness of the sample cylinders by charging them with 50 psig (345 kPa gauge) of UHP helium, heating to 125°F (52°C) for 2-4 hrs, and then analyzing the helium. No peaks should be produced during these procedures.
5. If the sample method is tested under controlled laboratory conditions (as in 5a), performance verification is recommended on multiple gas blends. If the method is tested on a single flowing gas composition at an established metering location (as in 5b), the results may not apply to a broad spectrum of gas compositions.

The protocol is intended to evaluate the performance of new or proposed sampling systems and procedures under both ideal conditions and under those conditions when only the best current methods will succeed. For example, in a case where two gases are used during the evaluation, the lean gas may be used to verify good performance when the gas is far from its hydrocarbon dew point (HCDP) and ambient temperatures (real or induced) are higher than the flowing temperature of the stream. The richer gas, during the same evaluation, would be used to evaluate the performance of the new or proposed sampling system and procedure when the ambient temperature is colder than the flowing temperature of the stream and the measured hydrocarbon dew point of the stream, and the flowing stream is at a temperature very near its HCDP.

- a. Verify the method on at least two and preferably three gas blends that represent a broad spectrum of gas compositions commonly encountered in gas gathering and transportation operations. For example, a three-gas test might use blends that produce gross heating values of 1000 Btu/scf, 1175 Btu/scf, and 1350 Btu/scf (37.3, 43.8, and 50.3 MJ/std m<sup>3</sup>).
  - b. Select a location for sampling that has a steady flow rate and a stable gas composition. Verification of stability will be established before sampling is conducted. Stability is defined as the repeatability of consecutive analyses as defined by API Chapter 14.1 Appendix E.
  - c. To fully confirm the suitability of new or proposed sampling systems and procedures, it is recommended that the flowing stream during one phase of the evaluation program be within 5°F (2.8°C) of its' measured HCDP and that the ambient temperature (actual or induced) be at least 20°F (11.1°C) colder than the flowing temperature of that stream.
6. Measure the HCDP using the following steps. See Reference 9 for further guidance.
    - a. Use a Bureau of Mines-type dew point apparatus with a NIST-traceable temperature-measuring device, preferably with a video attachment.
    - b. Heat the sample line and the Bureau of Mines-type dew point apparatus to at least 20°F (11.1°C) above the temperature of the flowing stream or gas source.

- c. c) The dew point is to be measured before, during and after the sampling procedure tests.
- 7. Determine the composition of the flowing stream using the following steps:
  - a. Verify and document the stability of the composition of the flowing gas stream using a portable or on-line chromatograph.
  - b. The chromatograph is to be analyzing the stream during sampling procedures.
  - c. The chromatograph software will be required to archive and time- and date-stamp the chromatograms, composition, and the corresponding heating value. The methods and calibration chromatograms used for each testing procedure shall be saved.
- 8. Also capture and record sufficient data to demonstrate the stability of the dynamic flowing conditions of the stream during the sampling tests. All instruments that record data with time stamps, such as flow meters, gas chromatographs or data loggers, should be synchronized to avoid errors in data comparisons.
- 9. Conduct sampling method using the following steps:
  - a. A minimum of five (5) samples shall be obtained for each method tested.
- 10. Analysis Requirements
  - a. Each cylinder shall be heated to 50°F (27.8°C) above the HCDP for a period of 4 hours before analyzing.
  - b. Each cylinder is to be analyzed a minimum of three times to establish repeatability as defined by API Chapter 14.1 Appendix E.
- 11. Data Requirements
  - a. The data shall be in tabular form and in a format that is easy to read and understand.
  - b. The data shall be available for public review.
  - c. The spot sample analysis report shall reference the corresponding online or portable gas analysis report.
  - d. On-line chromatograph data for comparison with composite samples shall be averaged for the same time period as the composite samples.
- 12. Verification of sampling procedure: Sample heating values shall agree within the greater of the tolerances described below or those defined by API Chapter 14.1 Appendix E.
  - a. Review the data to ensure that the accuracy of the spot or composite sample method complies with the repeatability and reproducibility for each component as stated in API Chapter 14.1 Appendix E.
  - b. The three successive analyses of each test cylinder must repeat within one (1) Btu per cubic foot (37.3 kJ/m<sup>3</sup>).
  - c. Each test cylinder must reproduce within three (3) Btu per cubic foot (111.7 kJ/m<sup>3</sup>) of the online or portable chromatograph.
  - d. Analyses of each composite sample cylinder must reproduce within (3) Btu per cubic foot (111.7 kJ/m<sup>3</sup>) of the average of the online chromatograph for that sampling period.



**Record the Following Information:**

Description of the sample method:

Description of the test used to evaluate the sample method:

Date of test:

Location of the Test:

Personnel conducting the tests:

Personnel witnessing the tests:

Pipeline Pressure:

Pipeline Size:

Piping Configuration (Upstream and Downstream):

Sample probe style and description:

Sketch or photo of the piping scheme for the test site:

Description or photo of the test method equipment and physical installation used in test:

Description of the flowing gas stream, i.e., well head, separator, distribution system, meter run, gathering system, etc.:

Ambient Temperature:

Pipeline Flowing Temperature:

Sampling Apparatus Temperature for sample method and reference analyzer. As a minimum, include the temperature at the sample probe and at the exit point of the sample delivery system.:

Description of temperature control equipment (i.e. insulation, heater, steam):

Hydrocarbon Dew Point:

Cylinder Style:

Cylinder Size:

Sampler style (if applicable) and description:

Timed or Proportional to flow:

Sample volume size:

Approximate elevation of the test location:

GC Description:

Last calibrated and how, relative to test data:

Provide records for calibrations performed immediately before, during and after the testing, including response factors and repeatability data.

***Record test data on a spreadsheet and provide as much additional information as possible, including copies of analyses from labs.***



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