

# SAMPLING AND CONDITIONING OF NATURAL GAS CONTAINING ENTRAINED LIQUIDS

Class 303

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## Introduction

Hydrocarbon liquids, entrained in natural gas, have been the source of many sampling problems. The primary problem is lack of agreement in the natural gas industry on the fundamental issue of "should entrained liquid be included or excluded from sample gas". Standard practices issued by industry organizations are generally more applicable to natural gas that is free of liquid. The current standard practices provide minimum guidance in dealing with entrained liquids. Most of the current research in this field relates to techniques for sampling rich gas sources that contain no liquid.

A second problem involving liquids in natural gas is the definition of terms. For example the term "free liquid" is defined by some as liquid in the form of surface film, pool, or liquid stream. This definition treats liquid in the form of small droplets or aerosol as an included part of the gas phase. Yet others refer to gas containing entrained liquids in any form as "wet gas". However, wet gas is interpreted by some as gas having a high water vapor content. Before these liquid related problems can be solved or discussed it will be necessary to adhere to specific definitions of the frequently used terms. The definition of terms used by the author in this presentation can be found in the "Glossary".

A third problem is that no distinction is made between "entrained" liquid and "condensed" liquid. Whether the liquid was present (entrained) in the source or is the result of condensation during the sampling process has a large bearing on the sampling procedure.

Entrained liquid in a natural gas pipeline can be present in the form of a pool, film, small droplets or aerosol. It is highly probable that the forms are in a constant state of change as a result of internal pipeline geometry and gas velocities. For example, liquid film can be sheared into small droplets or aerosols as it flows across a sharp surface, only to be impinged and coalesced upon a downstream surface, such as a pipe bend. It is highly probable that this constant change in liquid form is a major

contributor to the vast differences of opinion on what are suitable sampling techniques for natural gas.

Yet a fourth problem is the fact that entrained liquid is not always easy to detect. In some cases entrained liquid is detected not by sight but rather by its impact on analysis of the gas phase. It is the author's opinion that in many cases where the following situations arise, entrained liquid is the culprit:

- (a) Erratic composition reported by an on-line gas chromatograph, especially if the normalization factor is also erratic.
- (b) Large differences in composition noted for the same gas at different sample points.
- (c) Large differences between lab and "on-line" analyzer analysis of gas from the same source.

It must be remembered that a small volume of liquid is equivalent to several hundred times that volume of gas. Therefore, even microscopic amounts of hydrocarbon aerosol droplets, which may be difficult or impossible to detect visually, can have a significant impact on composition and heating value of natural gas.

Gas phase components of a natural gas sample can condense as a result of temperature and/or pressure changes. This is most likely to occur in "rich" gases. It is often difficult to determine if the source of liquid was entrainment or condensation. However, the proper method for prevention or elimination of the liquid will very much depend on its origin.

This presentation discusses the previously described problems in the context of "current state of art methods" and newly developed technology.

## Physical properties of fluids which influence gas sampling techniques

A keen understanding of the physical relationships between liquids, gases and vessel surfaces that contain them, is a must for anyone attempting to solve natural gas sampling problems. Some of the most important of these physical relationships and

their impact on composition and BTU value are summarized below:

- (a) Pressure and temperature changes in a gas containing a mixture of liquids alter the gas phase composition. Pressure increases typically reduce liquid vapor concentrations in the gas phase while decreases of pressure have the opposite effect. Even minor alterations of the liquid vapor content have measurable impact on the heating value (BTU) of the gas.
- (b) Adsorption and desorption of components by containment surfaces can alter the composition of the gas phase. With a given surface and gas composition, increases of pressure and decreases in temperature increase surface adsorption. Decreases of pressure and increases of temperature have the opposite effect. The gas and surface material compositions determine the degree to which adsorption occurs at any condition of pressure or temperature.
- (c) Changes of pressure can shift the hydrocarbon dew point of a gas. The effect can be bi-directional. For example an increase of the pressure may reduce the hydrocarbon dew point of one gas composition and increase it in another composition.
- (d) Reduction of pressure cools a gas due to a phenomenon known as the Joules-Thompson effect. The cooling effect may lower the gas temperature below its dew point. When the temperature of a gas drops below its hydrocarbon dew point condensation occurs. This in turn causes changes in the gas phase composition and BTU value.
- (e) Raising the gas pressure and/or reducing its temperature increases the water vapor absorption capacity of glycol. Lowering gas pressure and/or raising its temperature has the opposite effect.
- (f) The acid gas ( $H_2S$  or  $CO_2$ ) absorption capacity of amines is affected by temperature and pressure in a manner similar to that of water vapor absorption by glycol.
- (g) Internal surfaces of sample systems contaminated by glycol or amines will alter the concentration of water vapor or acid gases respectively, in

response to even slight pressure or temperature changes in sample gas. Additionally the response to changes in the concentration of water vapor or acid gas can be significantly dampened by glycol or amine contamination.

#### **Current state of art for sampling natural gas containing entrained liquid**

There is a lack of suitable technology for extracting a natural gas sample containing any form of liquid in proportion to the liquid load of a source gas. Some of the standard industry practices specifically state that it cannot be achieved. Other standard practices state that liquid should be separated in the source gas, measured and accounted for separately from the gas phase.

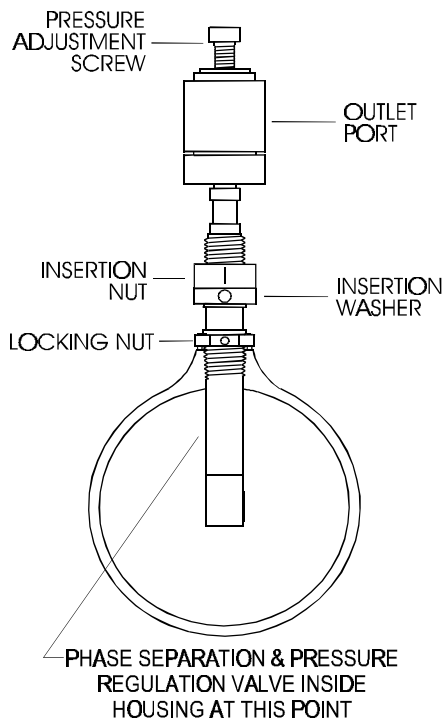
After reviewing the nature of problems associated with hydrocarbon liquids present in natural gas and the physical relationships between liquids, gases, and surfaces, the following conclusions can be drawn:

- (a) The most practical approach to consistent sampling is to extract a sample representative of the gas phase composition as it exists at the source.
- (b) If the source contains entrained hydrocarbon liquid, then the liquid should be excluded from the sample gas at the prevailing pressure and temperature of the source. This will prevent temperature and pressure related alteration of the gas phase during sample conditioning and transportation.
- (c) Pressure reduction, with entrained hydrocarbon liquids present, will alter the gas phase composition. If entrained liquid enters a pressure regulator, whether it is externally mounted or inserted into the pipeline, gas phase composition and BTU changes will occur.
- (d) Heating a natural gas sample, which does **not** contain entrained liquid is an acceptable method for **preventing** condensation.
- (e) Heating a sample gas when **entrained liquid** is present will alter the gas phase composition and heating value.
- (f) Glycol liquid entering a gas sample train will distort the water vapor composition of the sample gas.

- (g) Amine liquid entering the sample train will distort the acid gas composition of the sample gas.
- (h) All liquids entering the sample train may either alter sample composition and/or damage “on-line” analyzers.

**New technology is developed**

A technology has been recently developed which makes it possible to extract a representative gas phase sample from a source of natural gas that contains entrained liquid. The new technology also provides a means for preconditioning the sample gas in a manner that reduces the risk of condensation while the sample gas is transported to an analyzer. The hardware developed for utilization of the technology can be employed for composite sampling, spot samples, portable analyzers, and “on-line” analyzers. It is applicable to natural gas that contains entrained liquids, rich natural gas that is free of liquid, and lean gas.



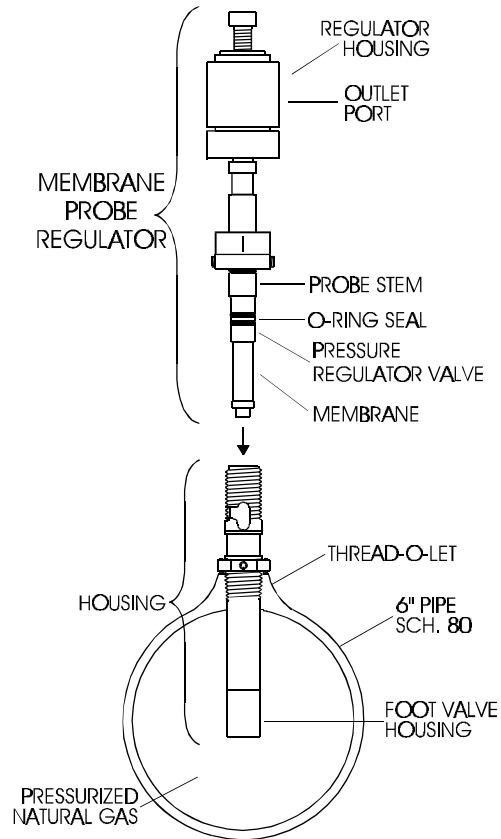
**FIGURE 1 - INSTALLED HOUSING & MEMBRANE PROBE REGULATOR**

**What is the new preconditioning technology?**

The new technology consists of first removing entrained liquid from sample gas followed by immediate pressure reduction to reduce condensation risk during transportation. This is accomplished

*inside* the pipeline. The hardware consists of a small cylindrical housing and a probe having a cylindrical, phase-separating membrane and pressure regulator (Fig.1). The housing is inserted through a thread-o-let into the pipeline and the probe is inserted into the housing. Once the housing is installed in the pipeline, the probe can be easily retracted/inserted in order to maintain the membrane and regulator (Fig.2). This can be accomplished quickly and safely at line pressures up to 1500 PSI.

**Detailed hardware description**



**FIGURE 2 - INSTALLED HOUSING & RETRACTED MEMBRANE PROBE REGULATOR**

The housing is constructed of an open tube terminated by a foot valve at its lower end. A sturdy poppet and stem comprise the foot valve. The valve-sealing element is a well-protected “O” ring. A heavy spring holds the poppet in a closed position when the probe is retracted from the housing. Pipeline pressure provides additional force for closing.

The probe consists of a phase-separation membrane and pressure regulation valve in its lower end, with a pressure regulator housing at its upper end. The regulator diaphragm is located in the housing and the pressure regulation valve is positioned immediately above the membrane. When the probe is fully

inserted into the housing, the membrane and pressure regulation valve are positioned inside the pipeline. The housing protects the membrane from direct exposure to the pipeline gas.

As the probe is being inserted into the housing, “O” rings form a seal between the housing and probe, prior to the foot valve being opened. Clockwise turning of the insertion nut on the threaded upper end of the housing forces the probe downward. Lowering the probe also pushes the valve stem downward to an “open” position. This allows source gas to flow into the membrane probe.

### **Operation**

In operation, gas from the pipeline enters the housing through the foot valve located on the bottom end of the housing. Sample gas then flows through the cylindrical membrane. Any entrained liquid present in the sample gas is rejected and coalesced on the membrane surface. The coalesced liquid then returns to the pipeline by gravity-induced flow. Since the membrane is located inside the pipeline, separation and removal of liquid is accomplished under the prevailing pipeline pressure and temperature conditions. These conditions are an absolute must to prevent gas phase composition changes during the removal of entrained liquid. The phase-separation membrane was specifically designed for removing entrained liquids from natural gas samples, without altering gas-phase composition.

Gas flowing through the membrane continues upward through the pressure regulation valve, probe stem, regulator housing and then enters the external sample transport system. This action regulates the sample gas to the desired pressure. Since the pressure drop during regulation occurs in the pipeline heat is transferred from the source gas to the regulator. This method prevents excessive Joules-Thompson cooling from occurring which could otherwise cause gas phase components to condense.

### **Applications**

The membrane probe regulator is an ideal “front end conditioner” for on-line analyzers (Fig.1). In that application it will precondition the sample, prevent sample system contamination, and protect the analyzer against damage by liquids.

A housing can be installed at each desired sample point along a pipeline. Thereafter, a single

membrane probe regulator can be employed to precondition sample gas for a portable analyzer (Fig.3).

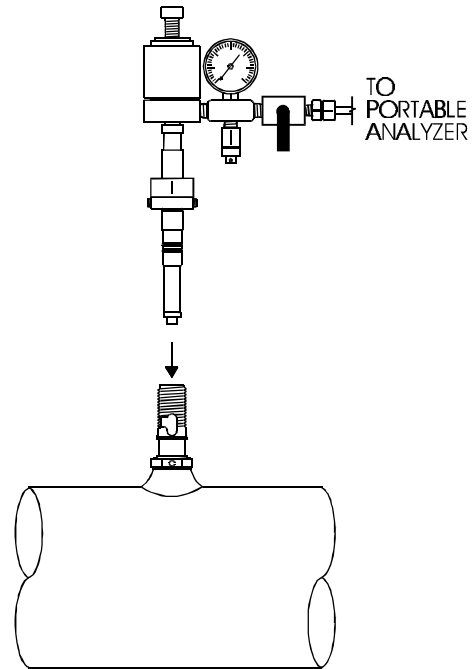


FIGURE 3 - INSTALLED HOUSING & RETRACTED MEMBRANE PROBE

In cases where pressure regulation is not required, a probe, having only a phase-separation membrane, is inserted into the housing (Figs. 4 & 5). Such may be the case where this technology is employed for spot or composite sampling (Fig.6). Some types of composite samplers may be mounted directly to the upper end of the probe.

### **Safety**

After the housing is installed into the pipeline it is locked firmly to the top surface of the thread-o-let. This is accomplished by a locking nut, and set screw which locks the nut to the housing. Additional set screws lock the nut and housing to the upper surface of the thread-o-let.

A second safety feature prevents the removal of the probe from the housing so long as the housing is pressurized. Mechanical stops require the housing to be depressurized in order for the probe to be pushed downward and turned manually as required for its retraction.

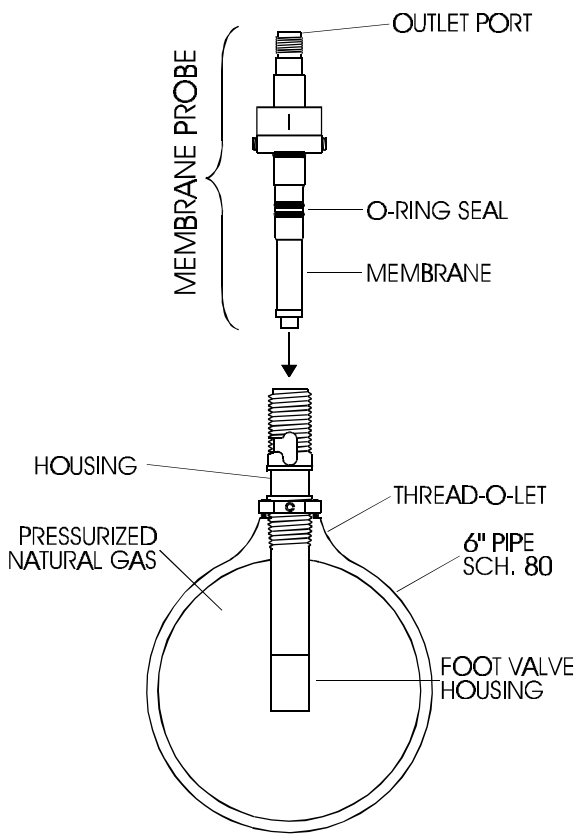


FIGURE 4 - INSTALLED HOUSING & RETRACTED MEMBRANE PROBE

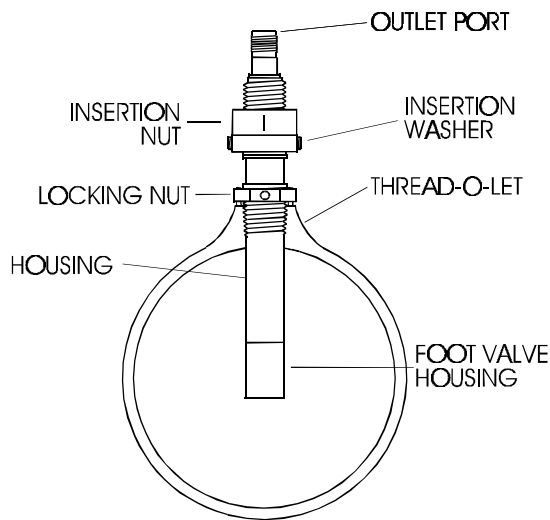


FIGURE 5 - INSTALLED HOUSING & MEMBRANE PROBE

#### Conclusion:

Obtaining a representative gas phase sample of natural gas sources containing entrained liquid has caused many problems. A new technology was developed which consists of a technique and hardware for sampling natural gas having entrained liquid. It removes the liquid under pipeline pressure and temperature conditions thereby preventing gas phase composition changes that would otherwise occur. After the liquids are removed the pressure is regulated in a manner which prevents excessive cooling and possible condensation of some gas phase components. The hardware can be inserted/retracted at normal pipeline pressures to facilitate maintenance.

#### Glossary

The definitions of words and terms in this glossary were purposefully narrowed for their application to the sampling of natural gas.

absorption – the act of taking up or assimilating

adsorption – attraction of a thin layer of gas or liquid molecules to a surface

aerosol - a microscopic droplet of liquid suspended in a gas

BTU - British thermal unit. A unit for measuring the heating value of natural gas

condense – to change from a gas or vapor to a liquid

condensed liquid – liquid originating from the condensation of a vapor or gas

desorption – to release from a condition of being absorbed or adsorbed

droplet - a small drop of liquid

entrained liquid – liquid in any form carried along or suspended in a stream of natural gas

fluid - anything that flows in any way, either a liquid or a gas

free liquid – liquid in any form – A microscopic aerosol droplet exhibits the same characteristics as a large pool of liquid.

gas - any substance that has no shape or size of its own and can expand without limit

gas phase – a phase consisting exclusively of gas and/or vapor – Liquid in any form, even though it may be suspended in a gas is not a part of the “gas phase”.

hydrocarbon dewpoint – the temperature, at any given pressure, at which hydrocarbon liquid initially condenses from a natural gas mixture

lean gas – gas containing a relatively small quantity of heavy hydrocarbon vapor and having an average or low BTU value

liquid - a liquid is composed of molecules that move freely over each other so that it has the shape of its container, like a gas, but, unlike a gas it has a definite volume

liquid forms – the geometric shape that liquid may be found in natural gas such as film, droplet or aerosols and pools

liquid phase – a phase consisting of liquid in any form – even microscopic aerosol droplets, suspended in a gas phase, are a part of the liquid phase

liquid vapor – see vapor

membrane – a thin sheet of semipermeable synthetic or natural material

natural gas – a naturally occurring mixture of hydrocarbon and nonhydrocarbon gases found in porous geological formations. Its main constituent is methane.

phase - a state of matter such as solid, liquid, gas or vapor

phase-separating membrane – a membrane adapted for separating entrained liquid in any form from gases. Gas passes readily through membrane leaving behind any liquid that may have been entrained.

rich gas – natural gas containing a large amount of heavy hydrocarbon vapor and having an evaluated BTU value

sample train – see sample system

sample transport system – all associated pipe, tube, fittings and hardware such as filters rotameters, etc. which transport a gas sample from its source to an intended destination such as an analyzer or sample cylinder

sample system – all components associated with extracting, transporting, and conditioning of a natural gas sample

vapor - a substance, which is normally liquid at ambient temperature and atmospheric pressure but becomes a gas at elevated temperature or lower pressures

wet gas – a gas which contains a high concentration of water vapor

3. Upp, E.L., Fluid Flow Measurement: A Practical Guide to Accurate Measurement, Gulf Publishing Company, Houston, Texas, 1993.
4. Hodgman, Charles D., editor, Handbook of Chemistry and Physics, 40<sup>th</sup> edition, Chemical Rubber Publishing Company, Cleveland, OH, 1959.
5. The World Book Dictionary, 1977 edition, Volume A-K, Doubleday & Company, Chicago, IL, 1977.
6. American Petroleum Institute Manual of Petroleum Measurement Standards, Chapter 14, Natural Gas Fluids Measurement, Section 1, Collecting and Handling of Natural Gas Samples for Custody Transfer, fourth edition, August 1993.
7. Behring, Kendricks A., "Accuracy of Natural Gas Sampling Techniques, and the Impact of Composition Measurement Errors on Flow Rate and Heating Value Determination", Flomeko '98, The 9<sup>th</sup> International Conference on Flow Measurement, Lund, Sweden, June 1998.
8. Behring, Kendricks A., "Lessons Learned from the API 14.1 Gas Sampling Research Project", American School of Gas Measurement Technology, 1998, Pages 193-203.
9. Houser, E. A., Principles of Sample Handling and Sampling Systems Design for Process Analysis, UMI, Ann Arbor, MI, 1997.
10. Gas Processors Association, Standard 2166, "Obtaining Natural Gas Samples for Analysis by Gas Chromatography".
11. Gas Processors Association, Standard 2261, "Analysis for Natural Gas and Similar Gaseous Mixtures by Gas Chromatography".

## **References**

1. ASTM Designation: D 5503-94, "Standard Practice for Natural Gas Sample-Handling and Conditioning Systems for Pipeline Instrumentation", American Society for Testing and Materials Standards, 1915 Race St., Philadelphia, PA.
2. ASTM Designation: D 4150-94, American Society for Testing and Materials Standards, 1915 Race St., Philadelphia, PA.