Sample Handling Systems Basics

SYSTEM DESIGN & BASIC SCIENCE

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Sample Conditioning System Basics

What is a Representative Sample of Natural Gas?

a **REPRESENTATIVE** sample of natural gas is in the vapor phase only, at the pressure and temperature of the gas at the point of sampling.

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Natural Gas Sampling Standards

American Petroleum Institute (API-14.1)

- Manual of Petroleum Measurement Standards Chapter 14
  - Natural Gas Fluids measurement Section 1
  - Collecting & Handling of Natural Gas Samples for Custody Transfer

Gas Processors Association (GPA 2166-05)

- 2166-05 Obtaining Natural Gas Samples for Analysis by Gas Chromatography

International Standards Organization (ISO-10715)

- Natural Gas Sampling Guidelines

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Natural Gas Sampling Standards

Scope of all three standards is for the vapor phase ONLY.

Entrained Liquids **MUST** be separated!!

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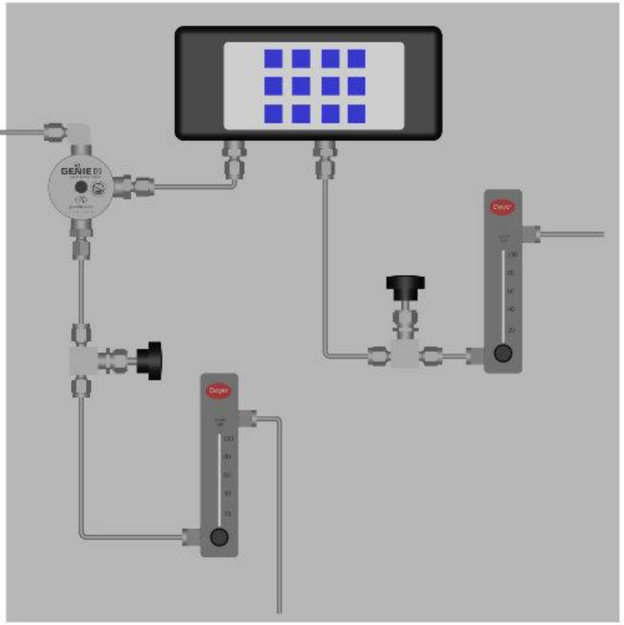
Sample Conditioning System Basics

TWO OBJECTIVES

Each is Crucial but Mutually Exclusive

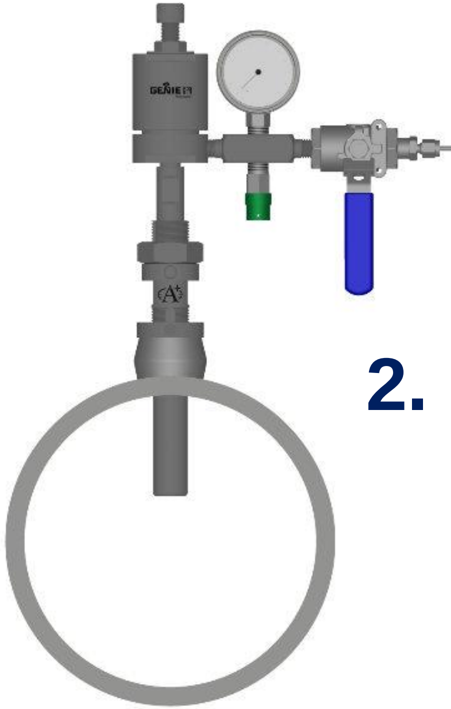
1. Deliver a **REPRESENTATIVE** sample of the actual component(s) being measured in the gas stream to the analyzer.



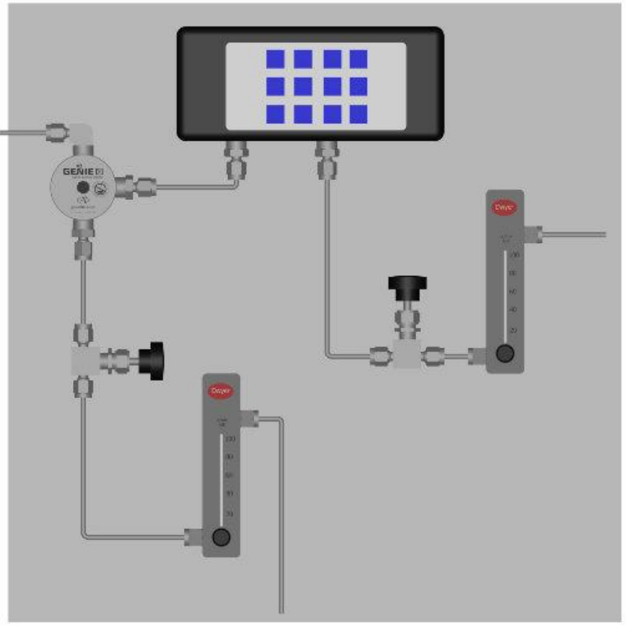
Sample Conditioning System Basics

TWO Objectives

Each is Crucial but Mutually Exclusive



2. Protect the Analyzer



Focus

FOCUS MORE ON THE SAMPLE HANDLING SYSTEM, LESS ON THE ANALYZER!

"The root cause of about **80% or more** of the **problems & errors** associated with process analyzer systems can be traced to some aspect of the **sample handling system.**"

Firmin, Mark, "Sample Extraction and Precondition for Process Analyzers"
ISA Analyzer Division Symposium, April 2016

...systems are...

...far more ...time than the...

...Tony, Industrial Sampling Systems Reliable Design & Maintenance for Process Analyzers. Copyright 2013 Swagelok Company, Printed in USA, p.6

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General Guidelines for SCS Design

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General Guidelines

The optimal sample handling system contains the **minimum number of components** that will **reliably provide timely delivery** of a **representative sample** that is **compatible with the analyzer.**

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General Guidelines

Eliminate Dead Volume

- slows response
- traps contaminants
- causes cross contamination and erroneous results

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General Guidelines

Minimize Internal Volume

quicker response

Minimize Internal Surface Area

reduces adsorption

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General Guidelines

Minimize Pressures

- safer handling
- less mass stored
- less adsorption
- quicker responses

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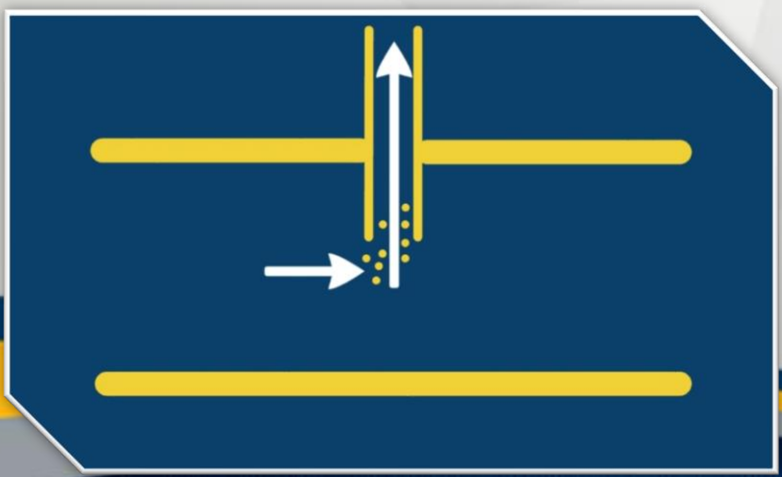
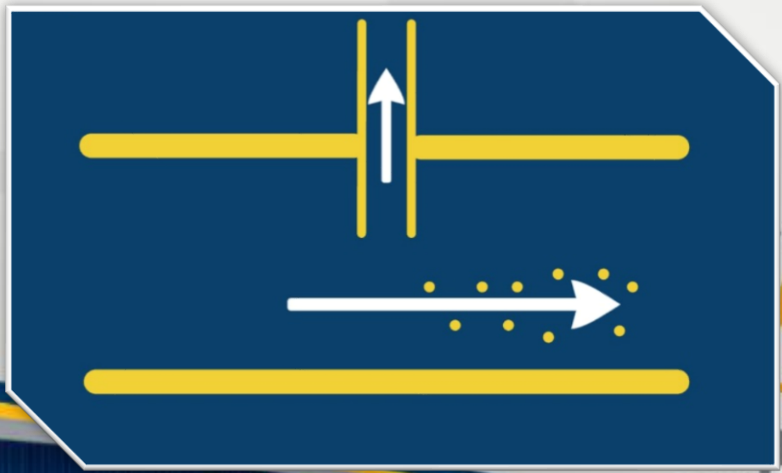
General Guidelines

Minimize Flow

- less pressure required
- less contamination ingested
- less to filter

Longer Service – Smaller Components – Lower Life Cycle Cost



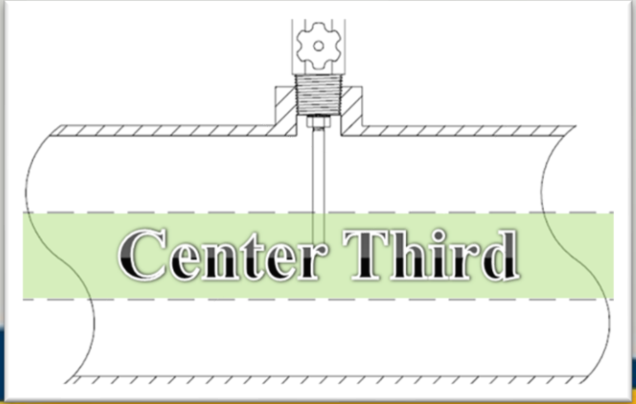


Sample Probe Depth

Probe depth is from point of attachment to probe tip:

Standards recommend the maximum insertion depth be based on probe design and source gas velocity.

Newer probe designs are exempt from the calculations and can withstand both low and high velocities (up to 150-200 ft/sec).



API 14.1 and GPA 2166 industry practice of center 1/3:

- **Common practice, but not required.**
- **Max 10” insertion depth.**

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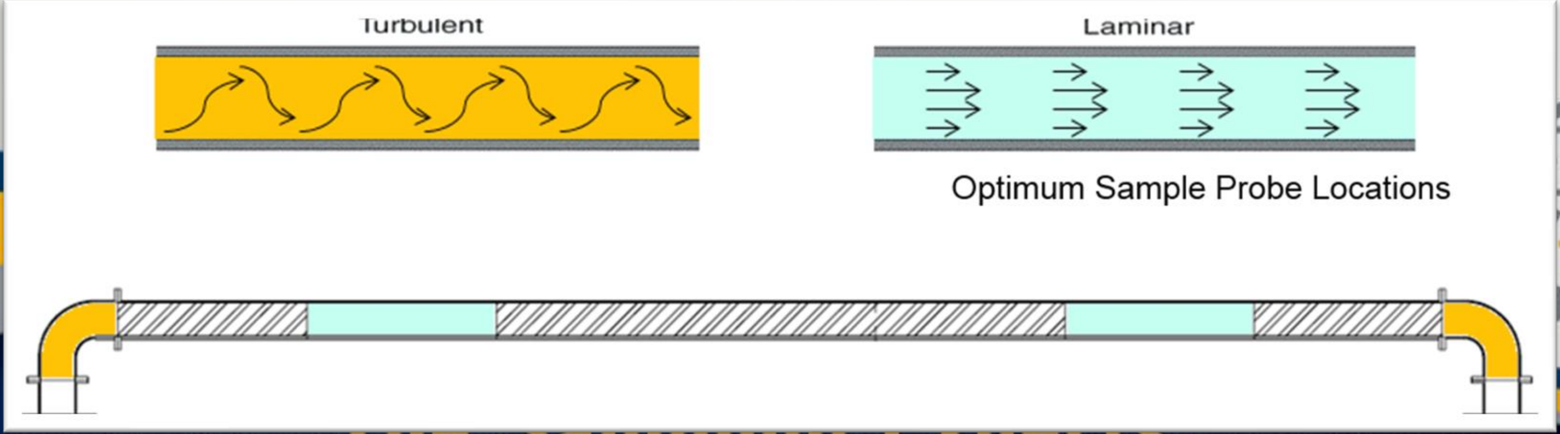
Sample Probe Location

- **Vertical tap at top of a straight run of horizontal pipe to allow gravity to assist with draining liquids.**
- **Avoid dead-end pipe section where gas is not flowing continuously. Resulting turbulence can stir liquids into aerosols that result in liquids finding their way into the sample.**
- **At least 5 diameters downstream of a disturbing element:.**

Eg. 1: For a tube like protrusion like a 1” OD thermowell, the tap should be located 5” downstream (5 x 1”) of the thermowell

Eg. 2: For a 20” orifice plate or 20” pipe elbow, the tap should be located 100” (8’,3”) downstream of the sample tap



Sample Conditioning System Basics

Almost always a custom design.

Products recommended for one situation may not be appropriate for another.

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Sample Conditioning System Basics

Proper design is key to analyzer performance & accurate analysis.

- Leading cause of sample distortion & analyzer problems = Incorrect SCS Design
- Represents greatest challenge to all involved.

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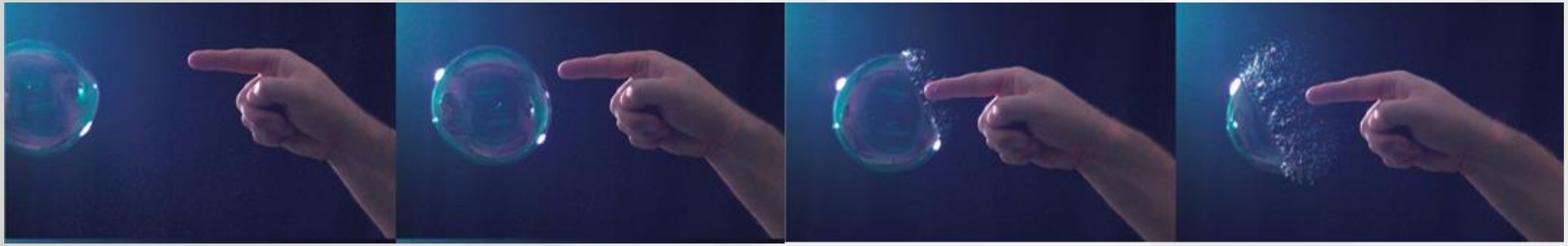
Importance of Accurate Analysis for Custody Transfer

Once a composition is changed, it cannot be restored



A bubble cannot be "unpopped"

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Science of Sampling

Vapor Liquid Equilibrium - The number of vapor molecules that condense is statistically equal to the number of liquid molecules that vaporize.

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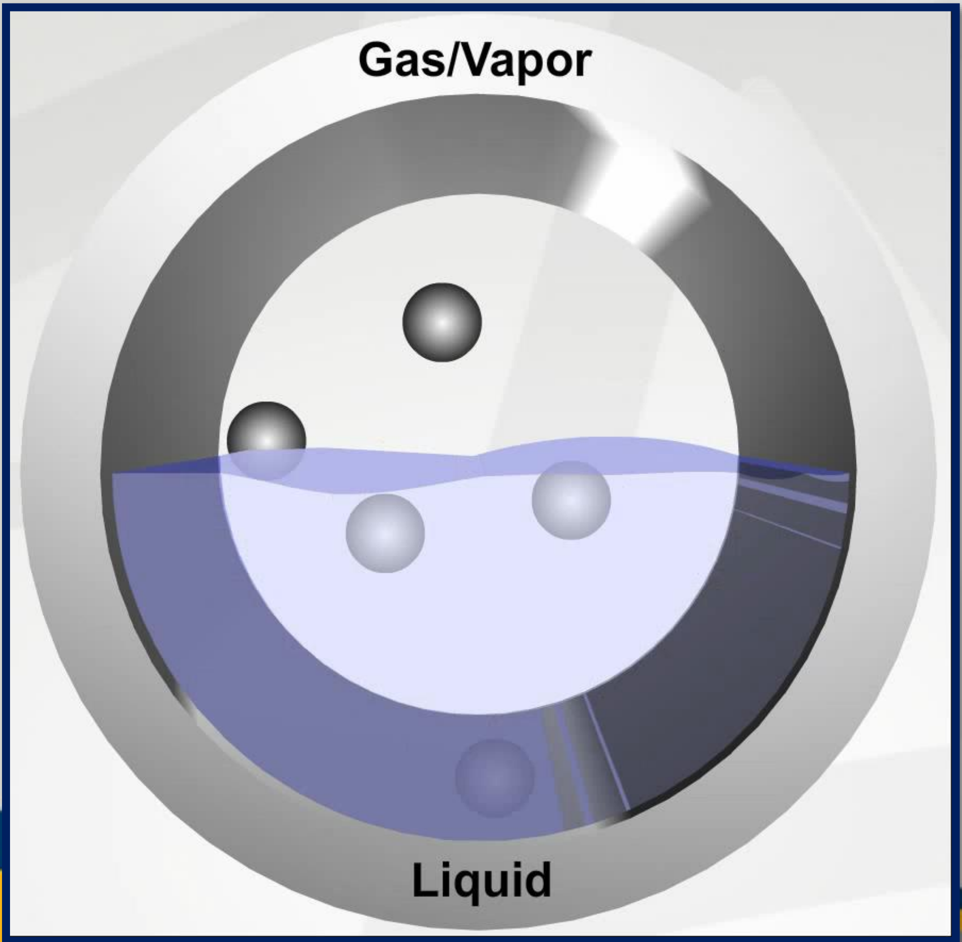
Science of Sampling



VLE Single Component

- The presence, not amount, of liquid is what's important!
- Equilibrium disturbed by changing temperature or pressure.
- How would a 2 component mixture differ from a single substance?

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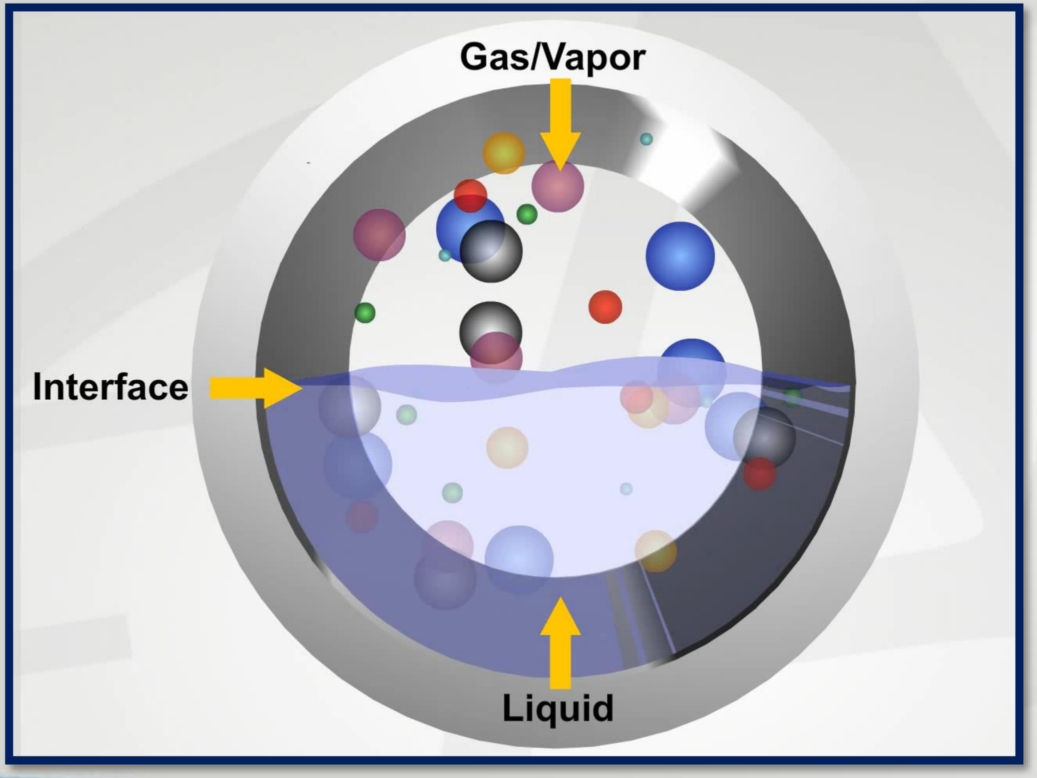
Science of Sampling



VLE of a Mixture

- Vapor pressure of each component varies with temperature.
- Concentration of each component depends on the systems pressure and temperature.

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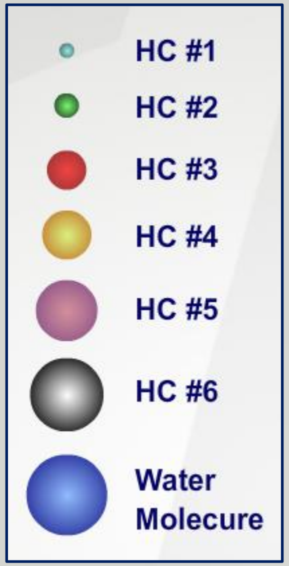
Vapor Liquid Equilibrium



...are there equal parts in the vapor phase?

If there are equal parts in the liquid phase....

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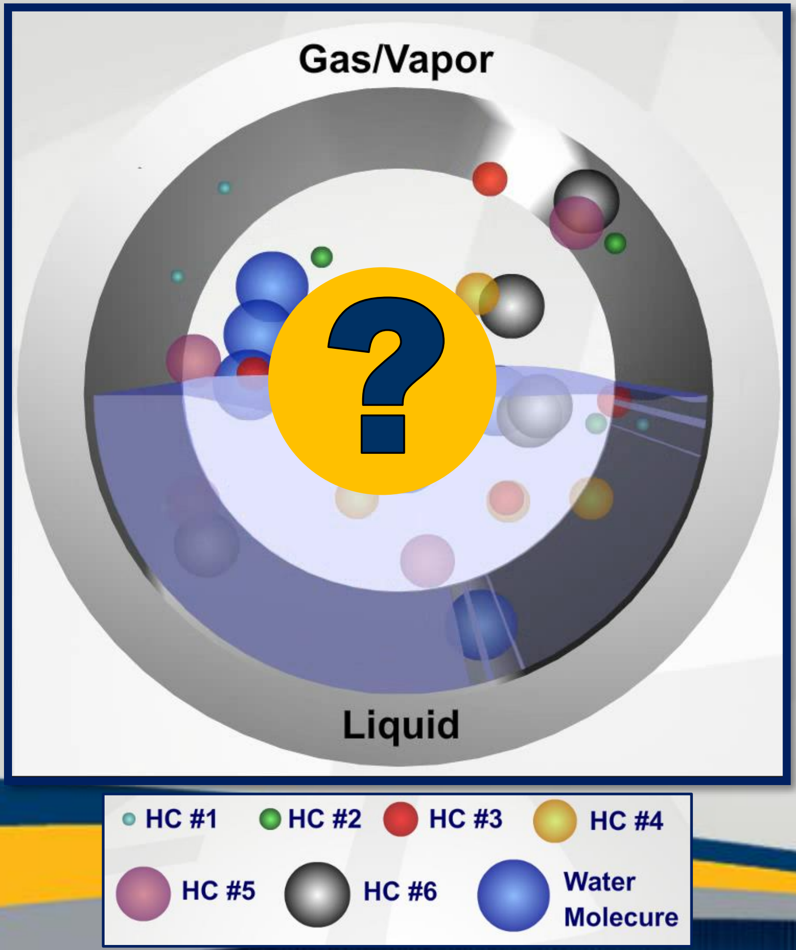
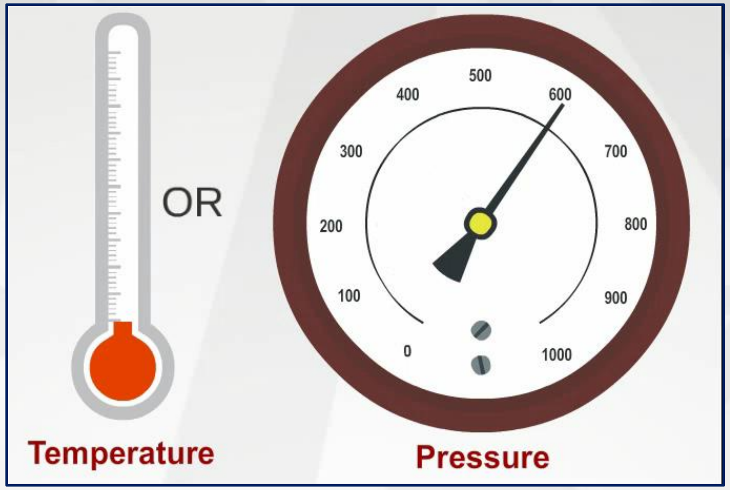
Vapor Liquid Equilibrium

Temperature or Pressure Changes





What Happens?

Gas Phase Composition Altered

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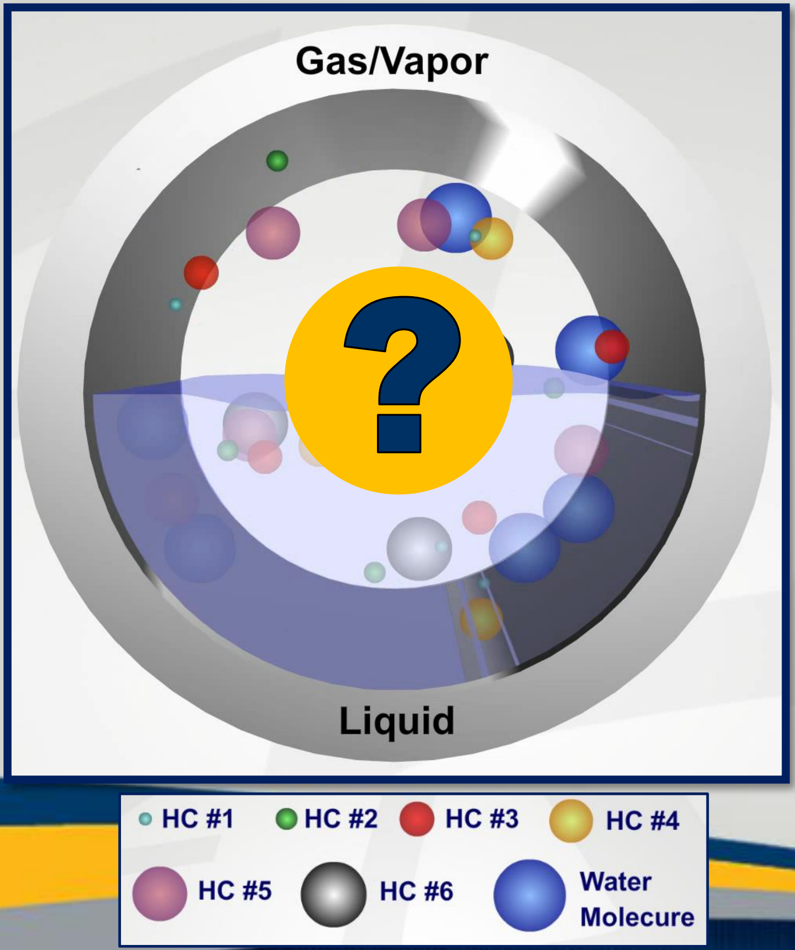
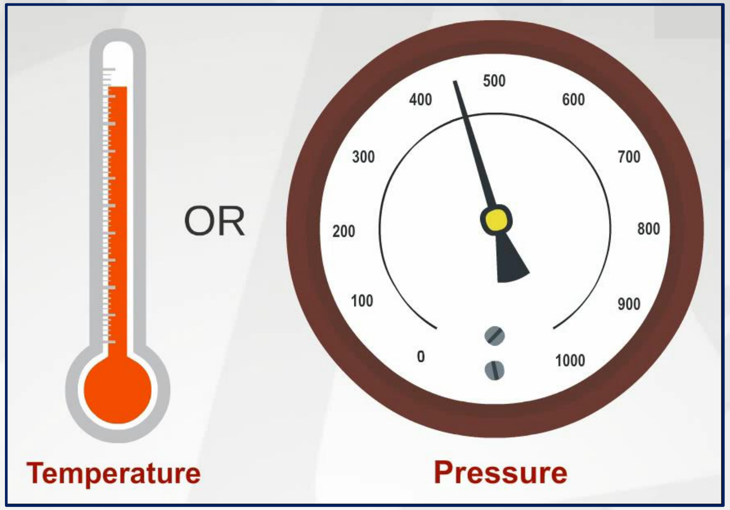
Vapor Liquid Equilibrium

Temperature or Pressure Changes





What Happens?

Gas Phase Composition Altered

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With or w/o liquids present, we cannot:

Use Bare Tubing (especially if ambient is colder than gas)

(1 of 4)

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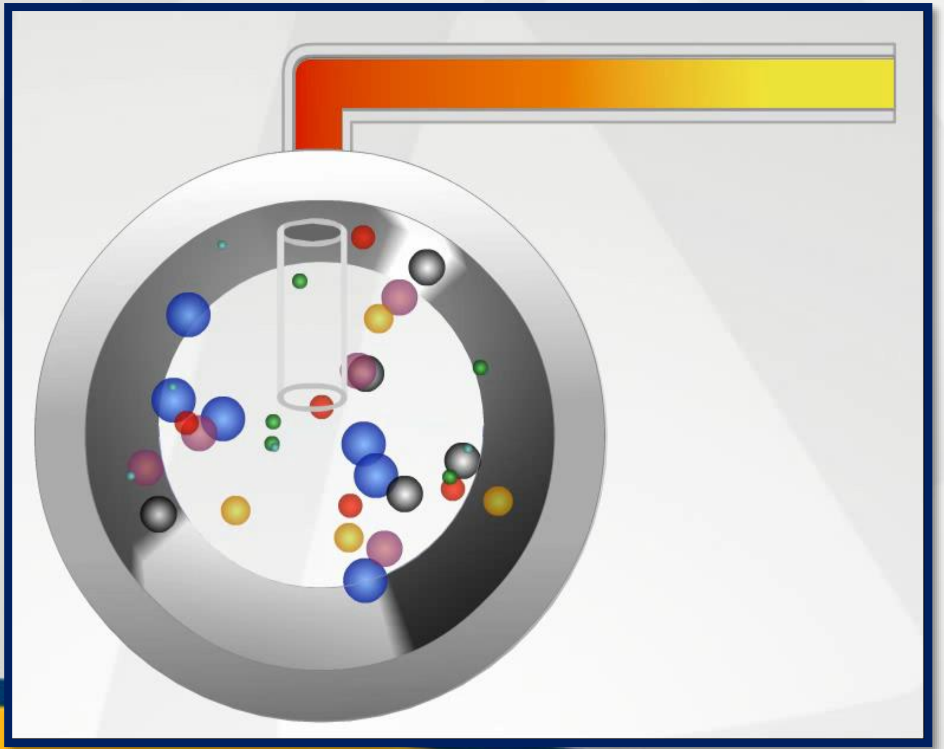
With liquids present, we cannot:

Heat Trace (or ambient warmer than gas)



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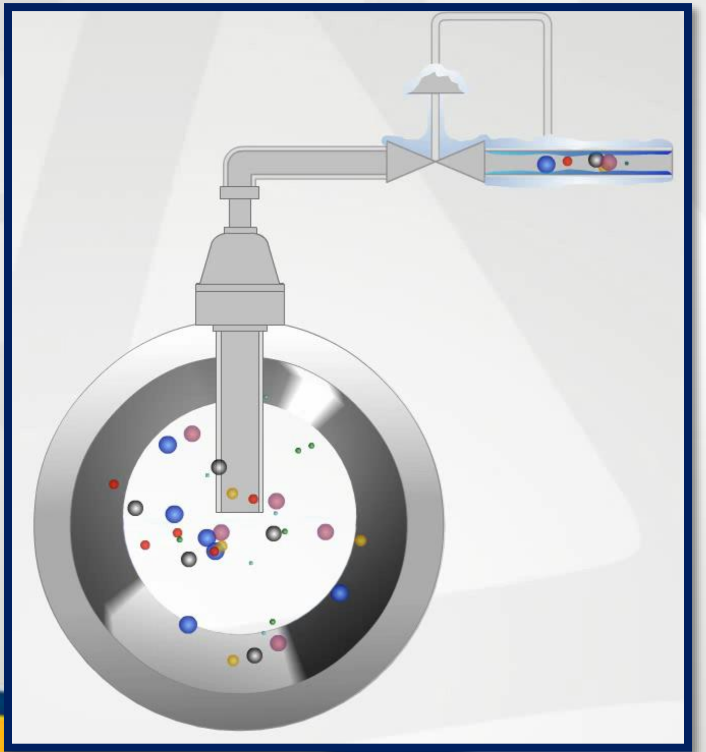
With liquids present, we cannot:

Reduce Pressure Externally



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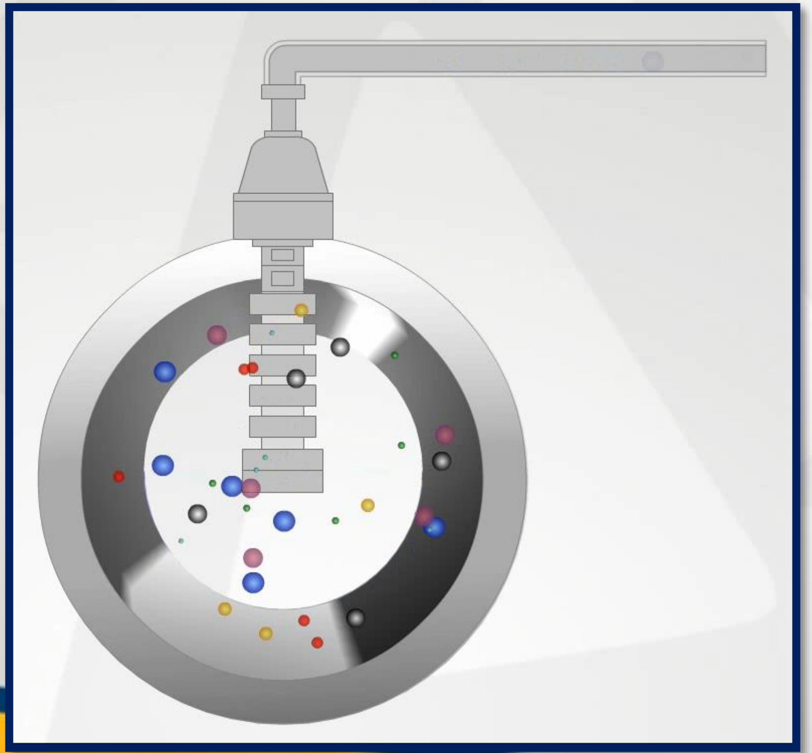
With liquids present, we cannot:

Reduce Pressure Internally



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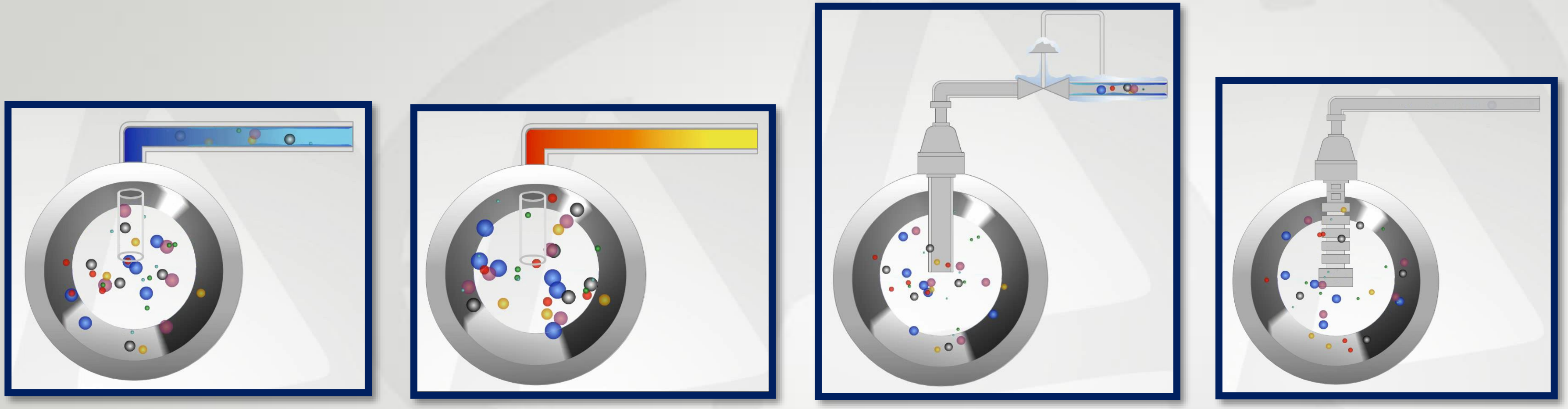
With liquids present, we cannot:



What CAN we do?

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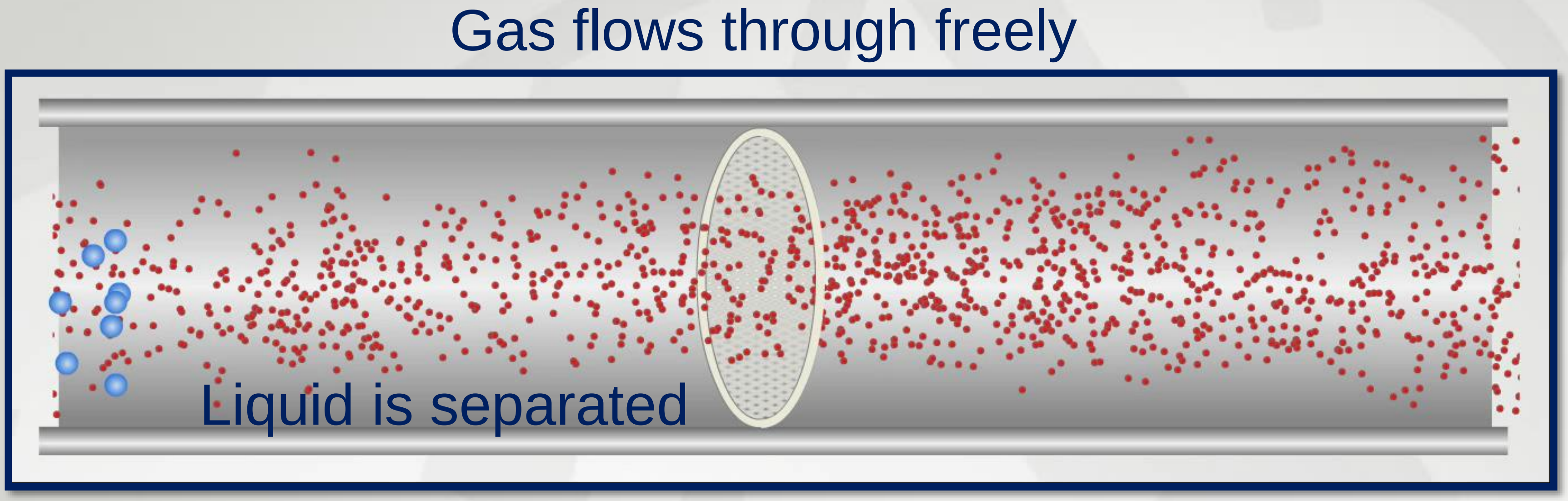
Phase Separation Membrane Technology



- Chemically inert, not chemically selective.
- Liquids are separated because of cohesion.

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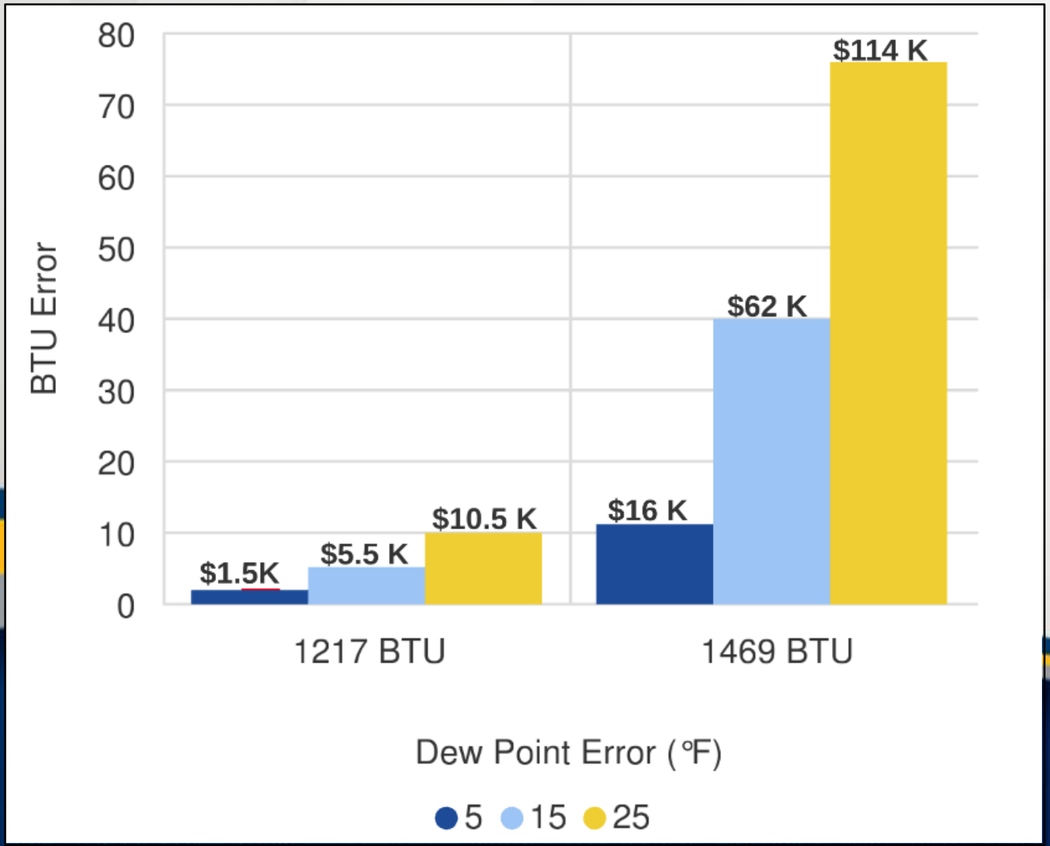
Importance of Accurate Analysis for Custody Transfer

Monthly Financial Impact of Sampling Error

(10MMSCF/Day flow rate @ $2.00 MMBTU)



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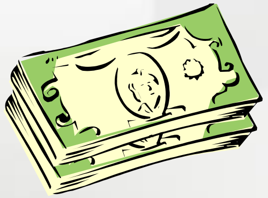
Vapor Liquid Equilibrium

VLE Conclusions

- Liquid present in gas sample + pressure or temperature changes = change in gas phase composition.
- If BTU value & flow rate calculation are inaccurate, the monetary value assigned to the gas will be as well.
- Compositional errors are costly!



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Natural Gas Phase Diagram

Help to determine:

- Hydrocarbon Dew Point
- Presence of Liquid (Source & Sample)
- Hardware Requirements
- Heating Requirements

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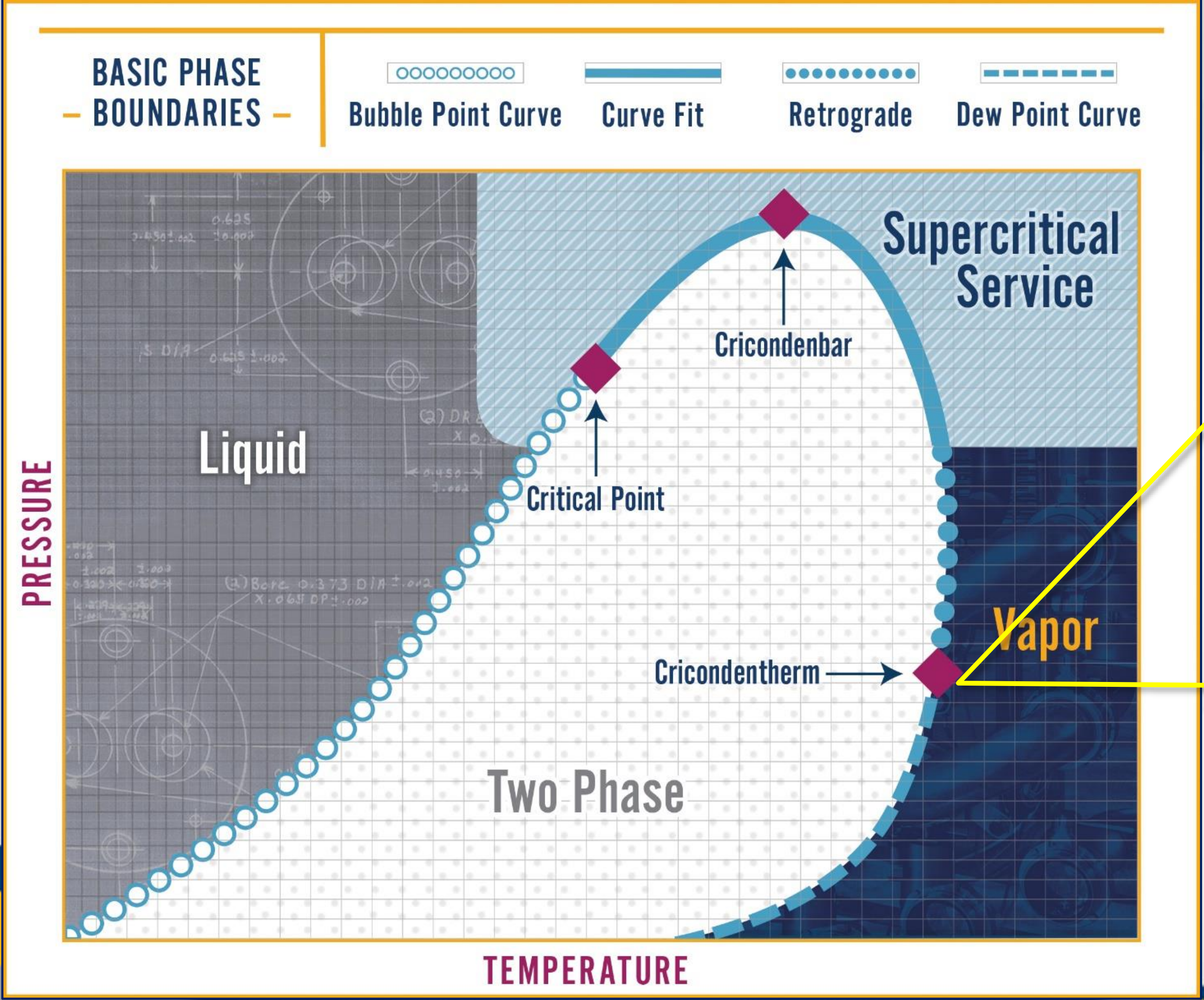
Phase Diagram



For natural gas there is approximately 7° F of cooling for every 100 PSI dropped. This is Joule-Thomson Cooling we will talk about later but this idea causes us to operate with a 30-degree cushion from the dew point and retrograde curves.

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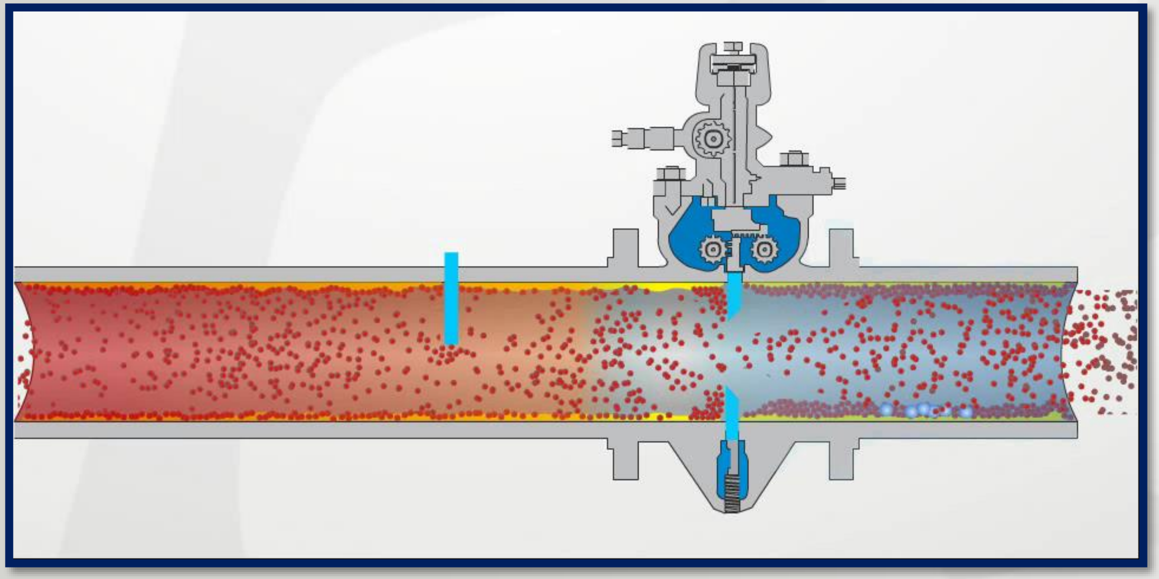
Joule-Thomson Cooling vs. Latent Heat of Vaporization

Joule-Thomson (JT) Cooling



- Cooling that occurs when a highly compressed gas is allowed to expand in such a way that no external work is done.

- This cooling sometimes lowers the gas temperature below its dew point temperature causing condensation.

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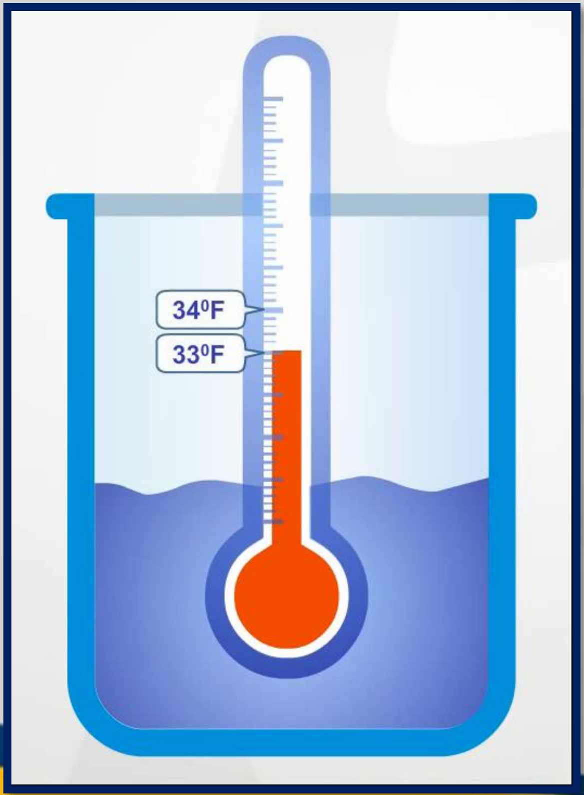
Joule-Thomson Cooling vs. Latent Heat of Vaporization

Sensible Heat vs. Latent Heat



SENSIBLE HEAT- The thermal energy absorbed or transmitted by a substance during a change of temperature which is not accompanied by a change of state.

One BTU = energy to change 1lb of H_2O by 1ºF

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Joule-Thomson Cooling vs. Latent Heat of Vaporization

Sensible Heat vs. Latent Heat

LATENT HEAT OF VAPORIZATION -The heat required to change a liquid to a gas or vapor, without a change of temperature. It is also the heat released in the reverse process.

To warm 1lb of water from freezing 32°F to boiling 212°F takes 180 BTU's sensible heat / lb of H2O.

Nearly 1000 BTUs of latent heat to vaporize 1lb of H2O.

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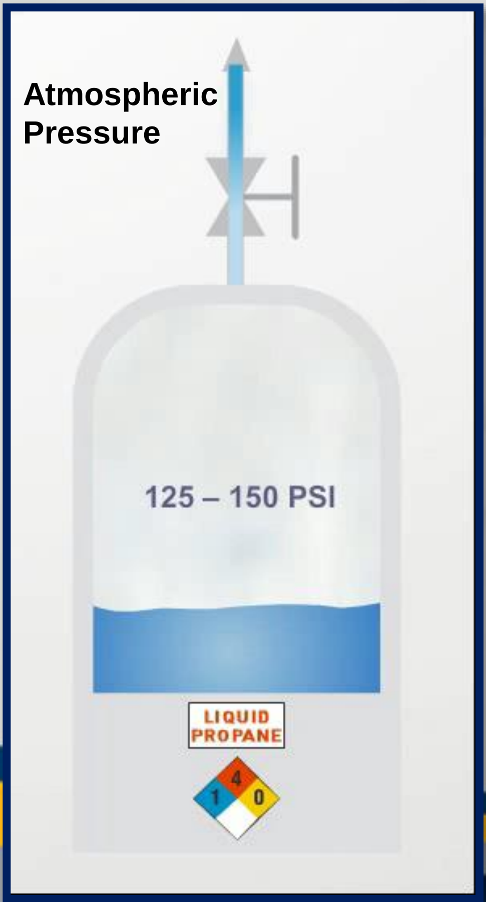
Joule-Thomson Cooling vs. Latent Heat of Vaporization

Joule-Thomson Effect Demonstration



For natural gas: Approximately 7° F of cooling for every 100 PSI dropped

The temperature of gas, after pressure drop, is lowered slightly by the JT effect.

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Joule-Thomson Cooling vs. Latent Heat of Vaporization

Joule-Thomson Effect Demonstration

The temperature of gas, after liquid vaporizes, is substantially lower.

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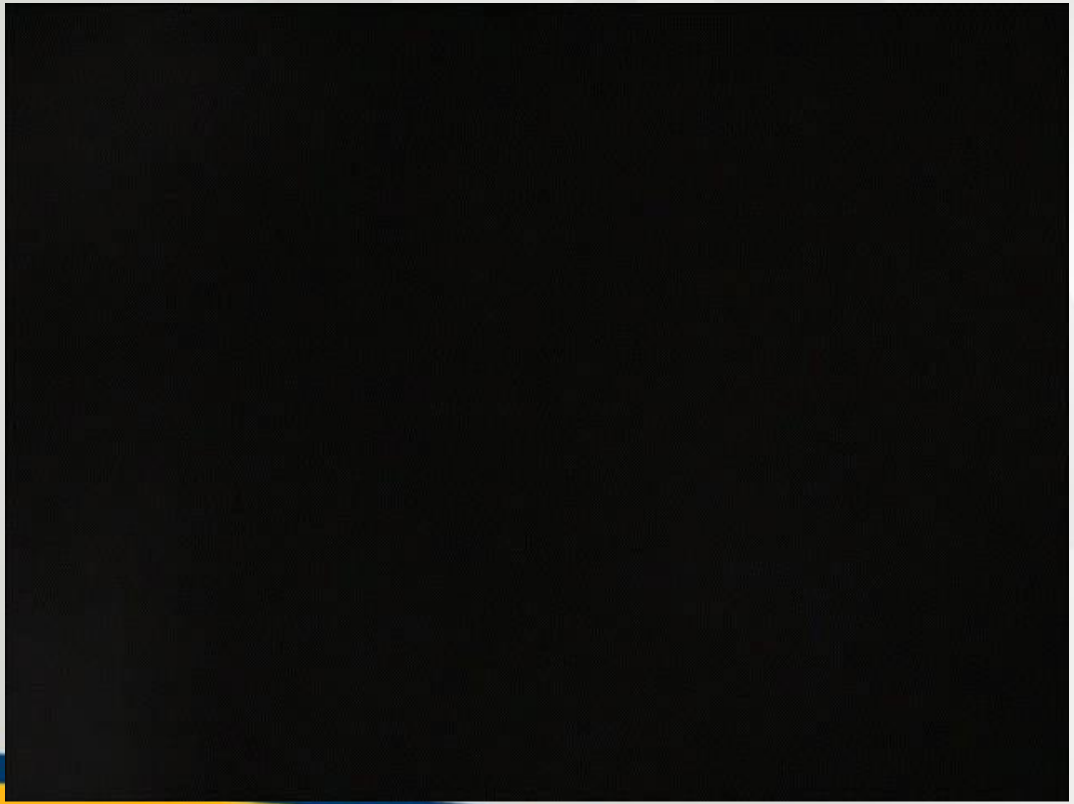
Joule-Thomson Cooling vs. Latent Heat of Vaporization

Joule-Thomson Effect Demonstration



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Joule-Thomson Cooling vs. Latent Heat of Vaporization

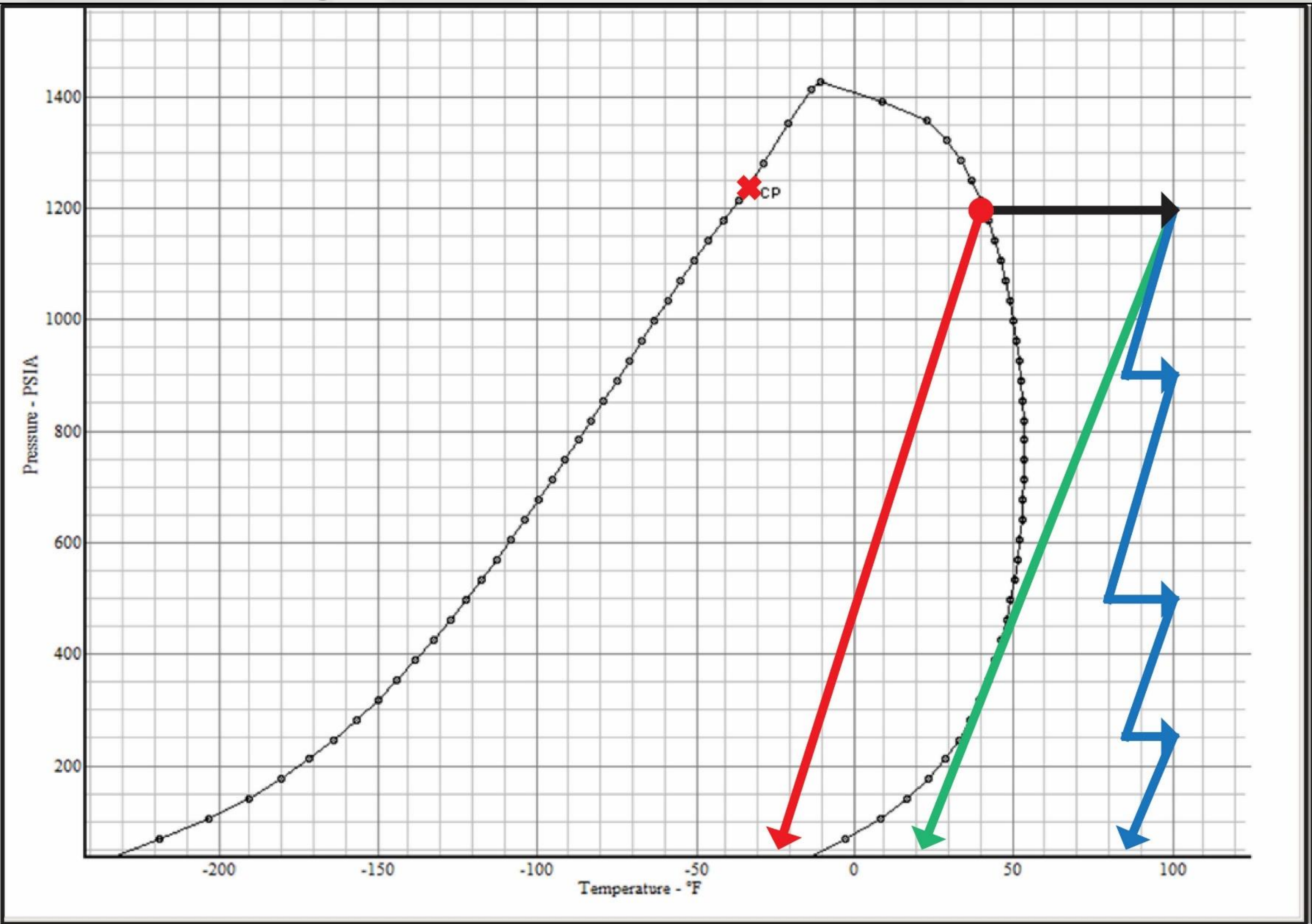
Phase Diagram

Legend

- ✖ Critical Point
- ● Source Conditions
- ➡ Probe Regulator JT
- ➡ 1 Stage Heated Regulator JT
- ➡ 4 Stage Heated Regulator JT

Composition

Components	Mole %
Carbon Dioxide	2.0971
Nitrogen	1.9316
Methane	77.7356
Ethane	11.1812
Propane	5.3681
Isobutane	0.2902
n-Butane	0.8487
Isopentane	0.1244
n-Pentane	0.1359
n-Hexane	0.2872



Joule-Thomson Cooling vs. Latent Heat of Vaporization

JT CONCLUSIONS

- Valve & regulator freeze-ups are usually caused by Latent Heat of Vaporization, not Joule-Thomson cooling, especially in sample systems.

- Those freeze-ups are an indication that liquid is likely present.

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Sample Conditioning System Basics

Almost always a custom design.

- Information matters!
  - Slight differences in composition and/or conditions could mean big differences in the solution recommendation.
- Compositional analysis saves the end user time & money.
- The more you do on the front end, the less you have to do on the back end.

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