Considerations for Sampling Wet, High Pressure, and Supercritical Natural Gas

Presented by: Shannon M. Bromley

Introduction

- The key to analyzer performance and accurate analysis is proper sample conditioning system (SCS) design and operation.

  - If designed incorrectly, it will result in the largest source of problems for the analyzer and compromise the integrity of the sample.

- The sample conditioning system consists of all components which contact the sample.
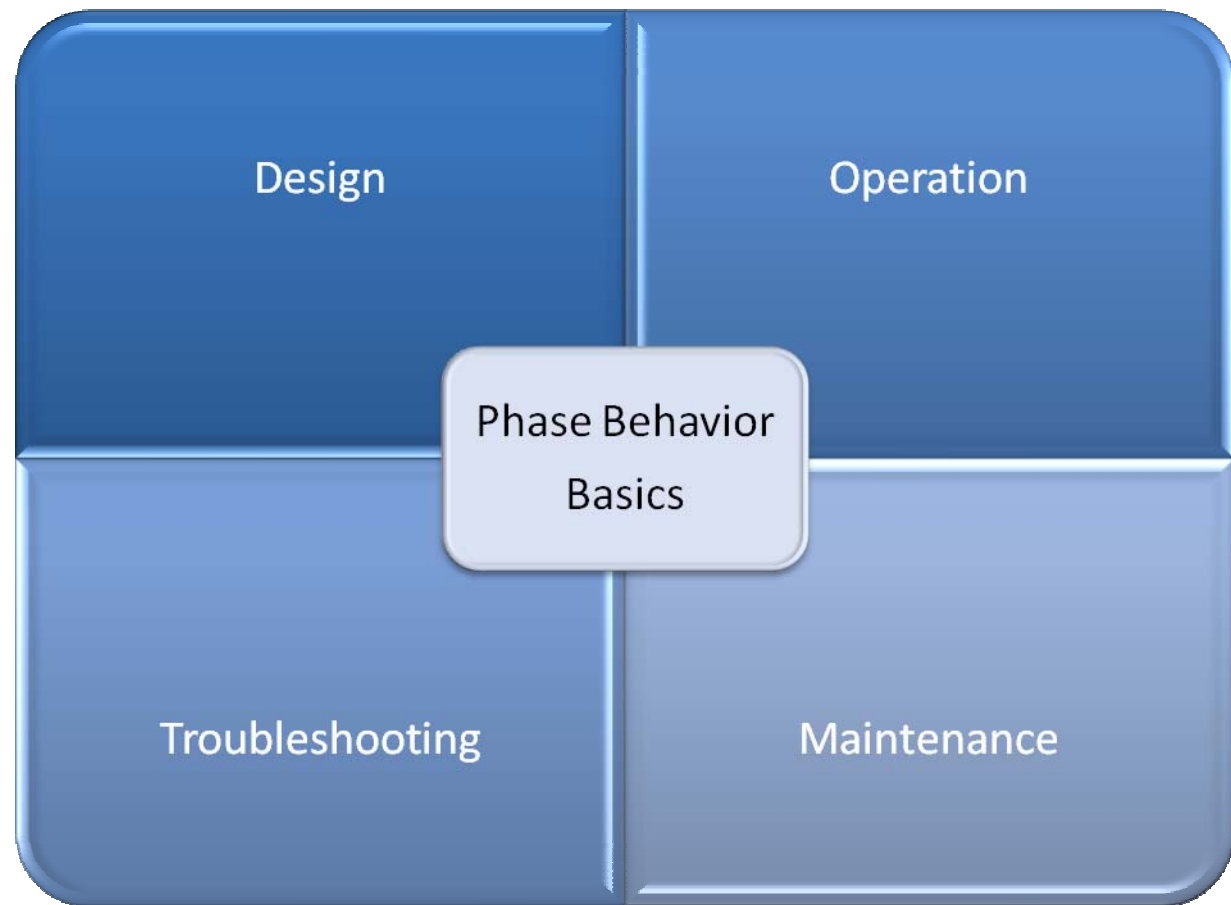
Sample Conditioning System Tasks
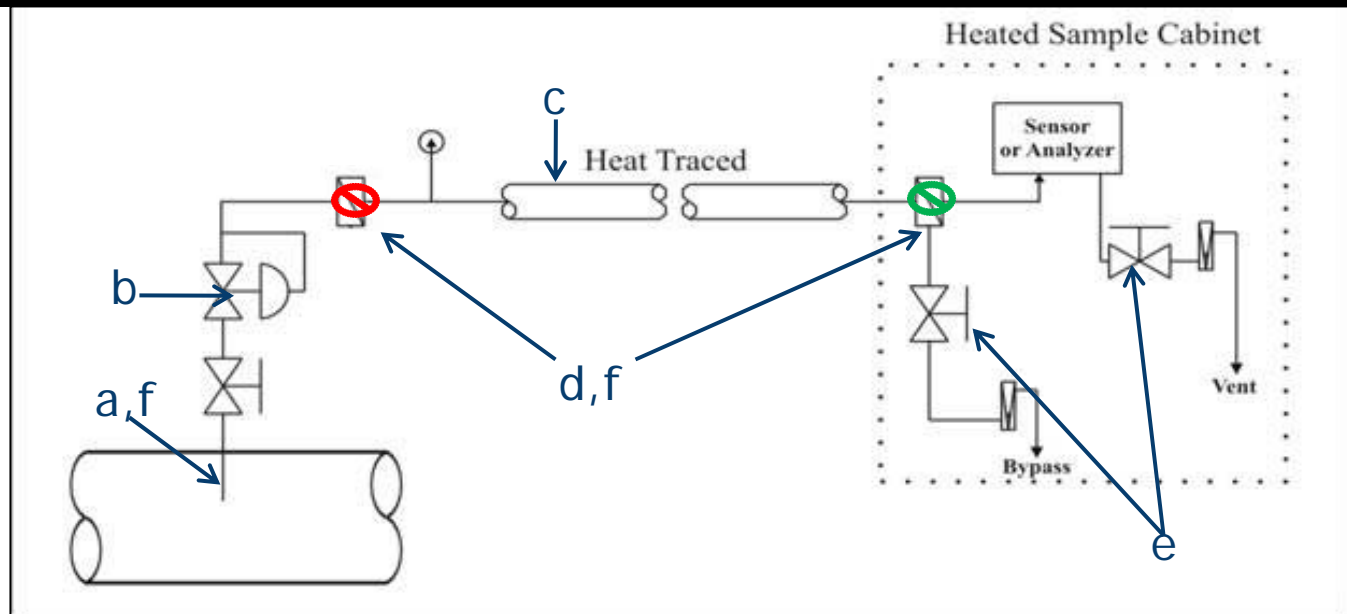
a) Extract a representative sample of the gas phase
b) Reduce (regulate) the pressure
c) Transport the sample to the analyzer without changing its composition
d) Protect the analyzer (analyzer "safety net")
e) Control flow rate
f) Remove contaminants

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Sample integrity MUST be maintained during the sample conditioning process.
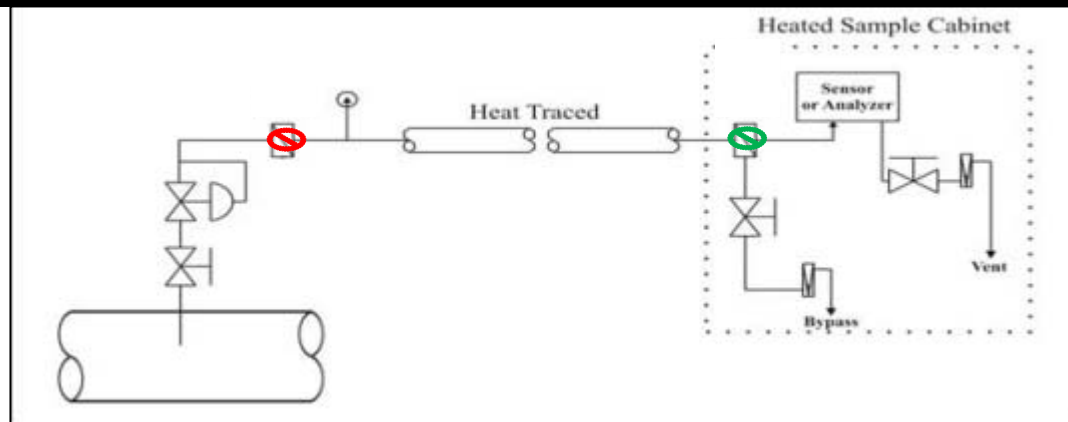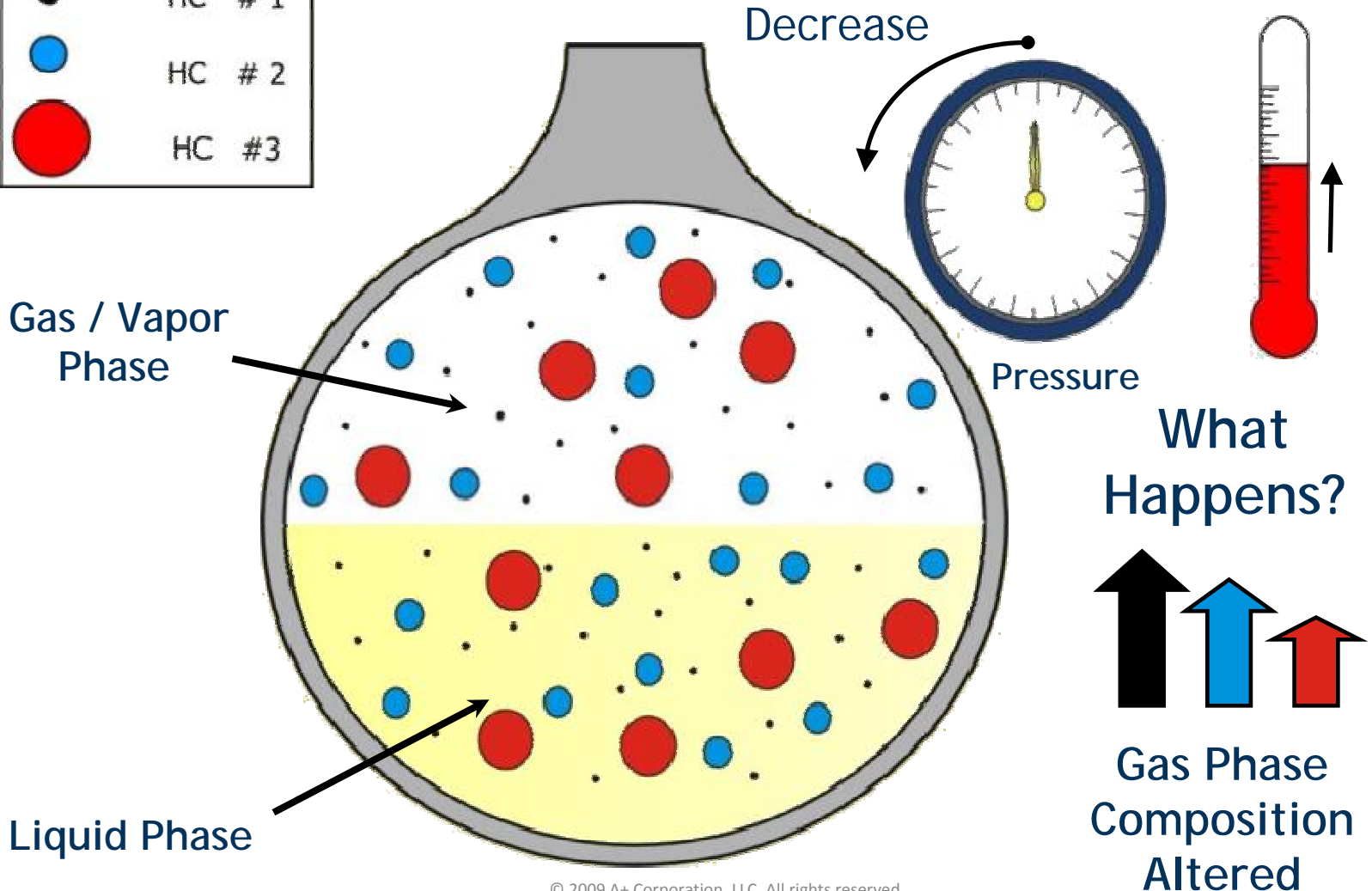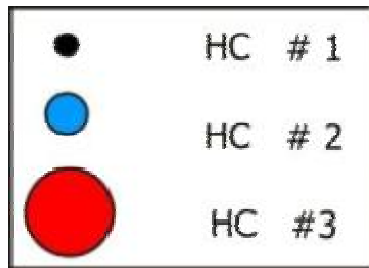

- Preserve sample integrity by:
  - Removing contaminants (solids and liquids), when present, in the pipeline.
  - Reducing (regulating) the pressure <u>without traversing the phase envelope.</u>
  - Maintaining the sample in the gas phase at all times after extraction.
    - At least 30°F of de-saturation is required by the API 14.1 standard to keep away from the hydrocarbon dew point (HDP).

In order to design, operate, and troubleshoot sample conditioning systems one must know some basic Chemistry & Physics related to sample conditioning.

Vapor/Liquid Equilibrium

HC #1
HC #2
HC #3

Gas / Vapor Phase

Liquid Phase

Decrease

Pressure

What Happens?

Gas Phase Composition Altered

6

Vapor/Liquid Equilibrium

HC #1
HC #2
HC #3

Gas / Vapor Phase
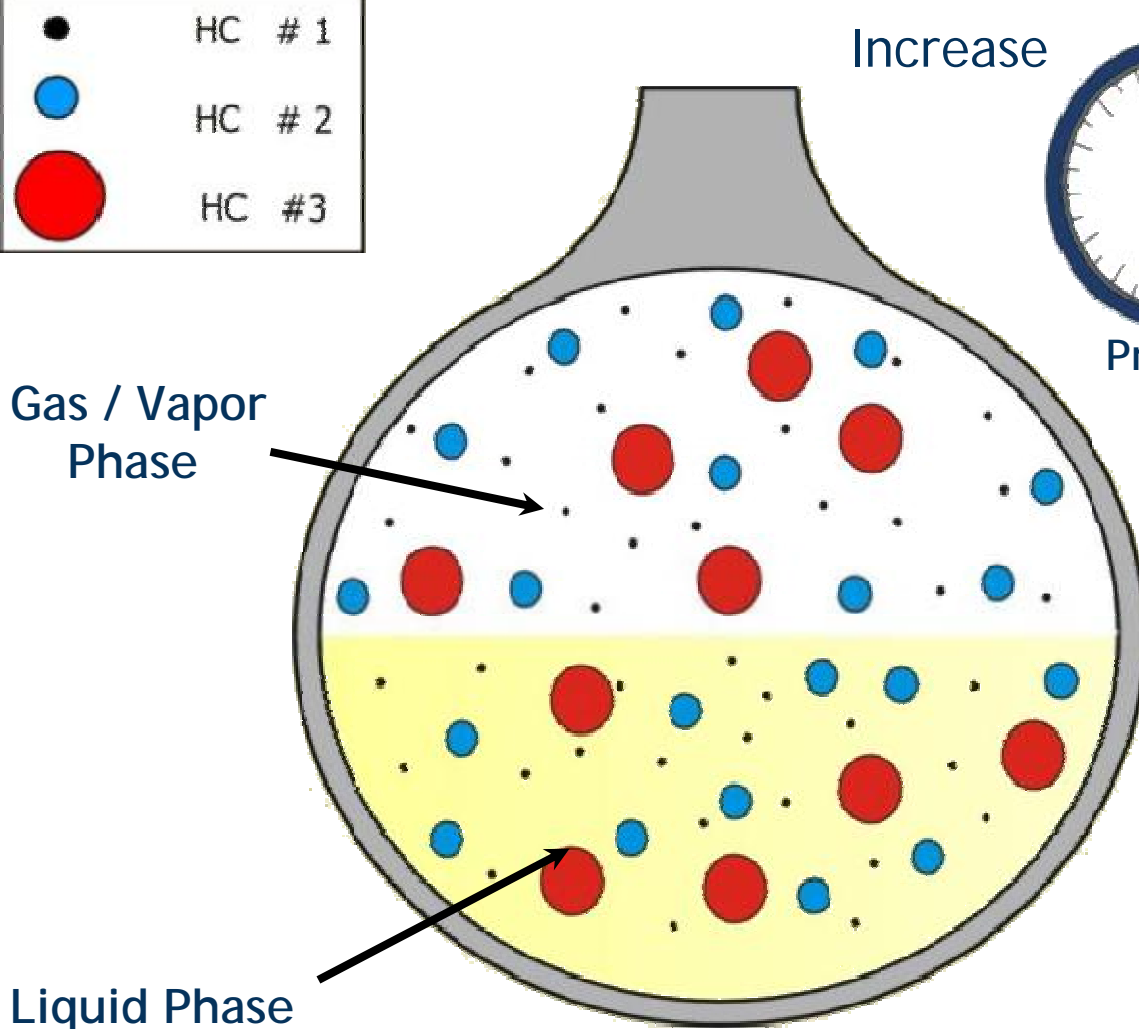
Liquid Phase
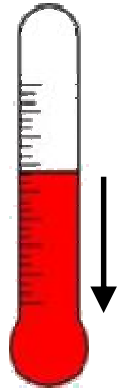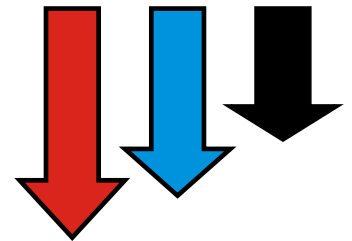
Increase
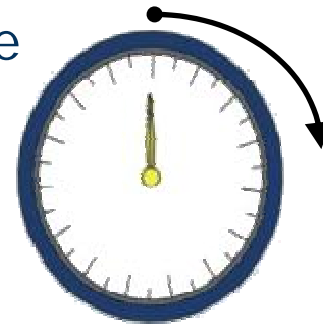
Pressure

What Happens?

Gas Phase Composition Altered

Key Point:

When liquid is entrained in the source gas, changes in either the pressure or the temperature will change the gas phase composition.

The first step in sampling natural gas is the extraction process
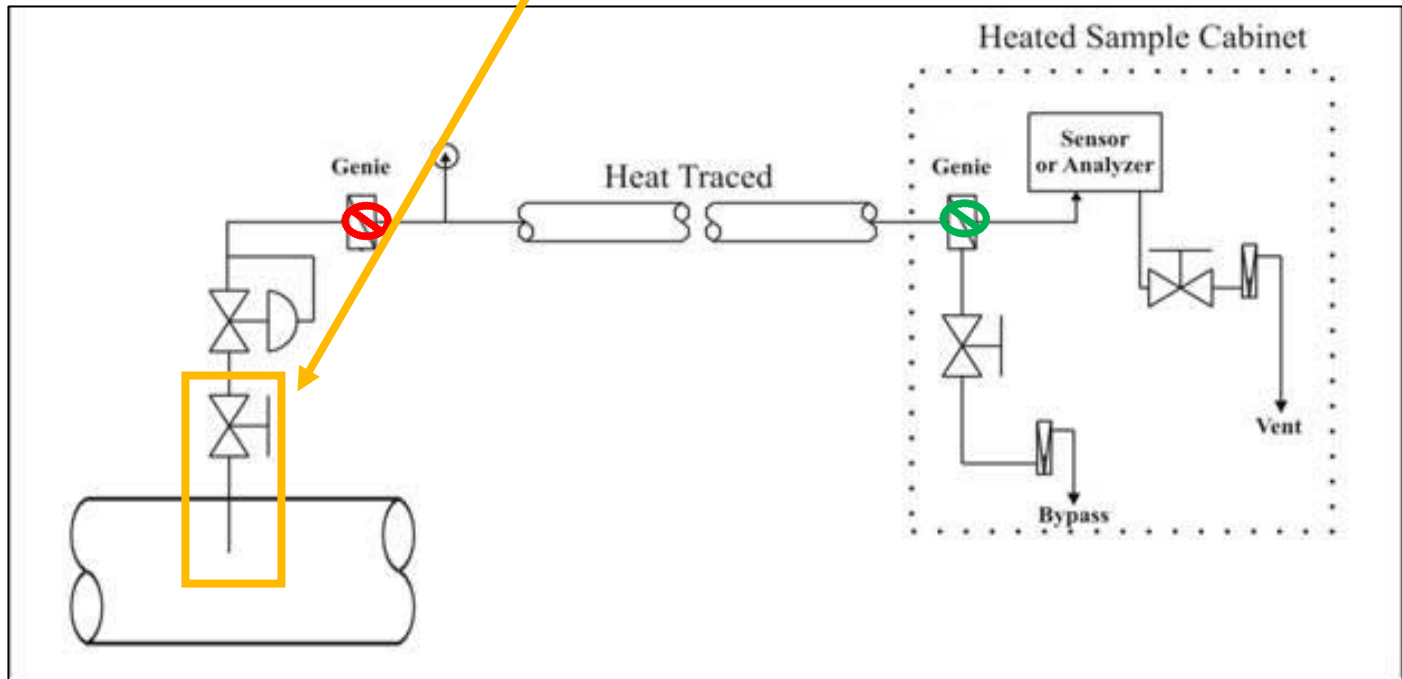
- The most severe problems are encountered during sample extraction.

What is a "representative" sample?

- Industry standards are not absolutely clear on the definition of "representative" when liquid is present in the source gas.

  - There is also a lack of clear consensus in the industry on this subject.

- There is NO industry standard that covers the sampling of wet or supercritical gases.

- How we define a representative sample is the key to how the sample is conditioned.

How do the industry standards define what a "representative" sample is?

- The standards imply that a representative natural gas sample when liquid is present in the source consist of:

  - "The gas phase at the prevailing pressure and temperature of the source gas at the point of sampling."

Entrained liquid must be separated

- No technology is available for extracting a gas sample containing a representative amount of entrained liquid

  - Making matters more difficult is the fact that liquid is constantly changing forms in the pipeline.

- This is backed by the API 14.1 standard (Appendix B, Section B.3 - "Multi-phase flow")

  - It states, in summary, that current sampling technology is not sufficiently advanced to obtain a sample representing both phases.

When liquids are present, we CANNOT:

Heat tracing (or ambient warmer than gas)

Gas warmer than ambient

Can't heat

Can't cool

Can't ignore the liquid!

Can't drop pressure internally

Can't drop pressure externally

# Since we cannot ignore the liquid, what can we do?

1. Separate the liquid from the gas phase at line conditions of pressure and temperature.

    - Use a membrane tipped probe inserted vertically into the sample source to accomplish this task.

2. Take steps to "de-saturate" the sample.

    - Drop the pressure

    - Increase the temperature

Caution: Improper Sequence of events

- If steps to de-saturate (pressure reduction and heating) the sample were taken BEFORE liquid was separated at line conditions, the following are likely to occur:

  - Liquids (an arbitrary amount) would become vaporized

  - Vapor composition is altered (ie-richer)
    - BTU value is increased

  - Physical constants calculated from the composition are incorrect
    - Flow (volume) calculations are incorrect

  - Monetary value assigned to Natural Gas is incorrect

Phase Separation Membrane

Phase Separation Membrane

Gas   Flows Through Freely
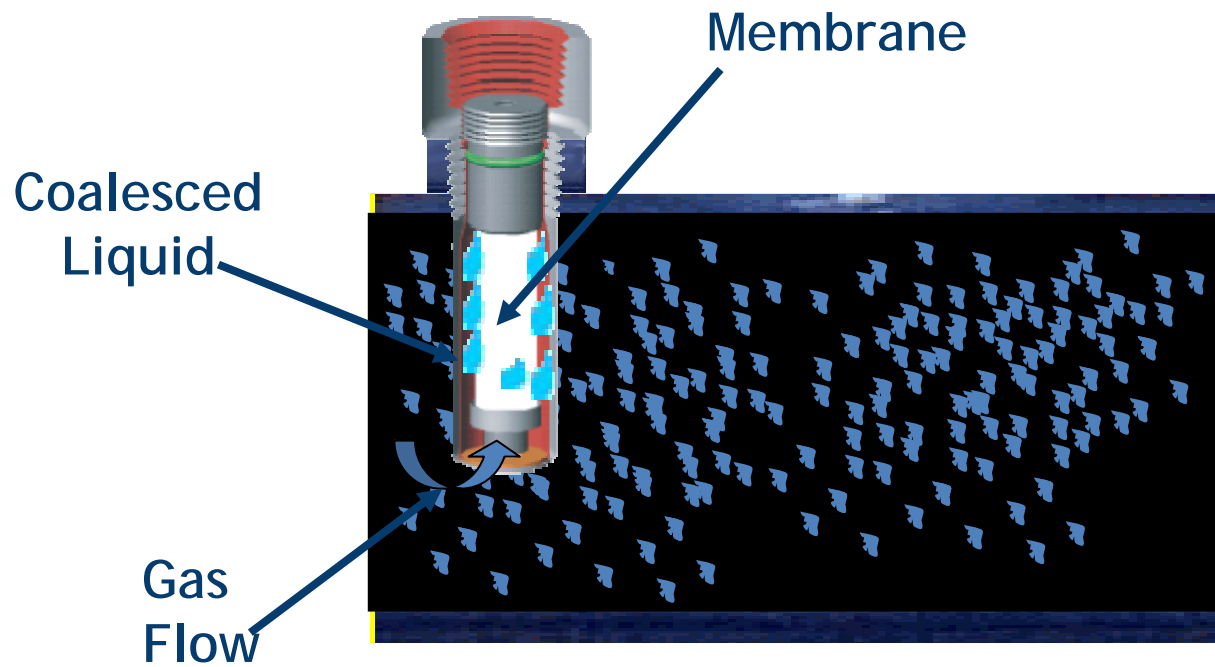
Liquid
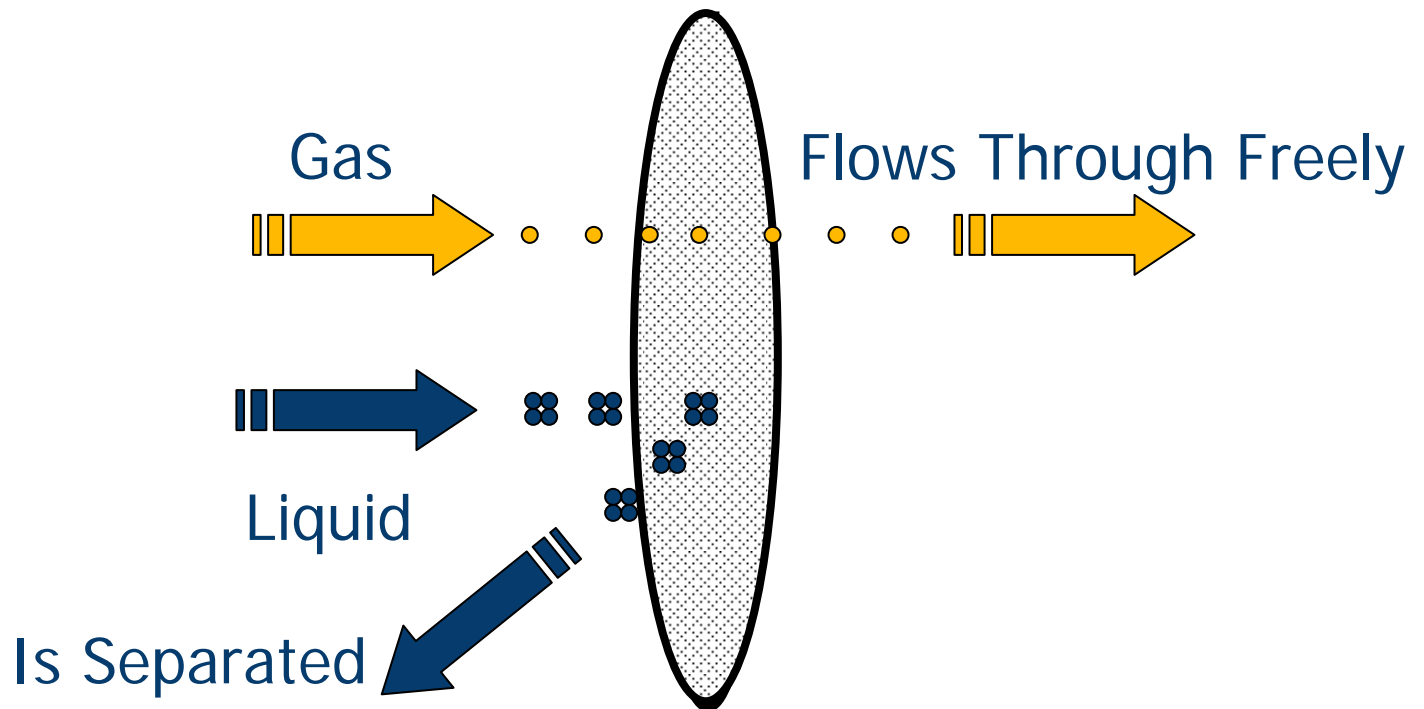
Is Separated

Chemically inert, NOT chemically selective

GPA 2166 & Membrane Separation

- ## Section 7.3.3

  - "An acceptable method for removal of unwanted contaminants is a membrane filter inserted directly in the line."

- ## Appendix B.1.8

  - To effectively separate unwanted liquids, the device must be operating at flowing temperature and pressure conditions.

Membrane Tipped Probe

Membrane

Coalesced Liquid

Gas Flow

Topic

THE USE OF PHASE DIAGRAMS IN THE DESIGN & OPERATION OF A NATURAL GAS SYSTEM

Calculate   Print   Copy   Edit Titles   Edit Points   Transpose

Select Diagram

P-T Phase Diagram
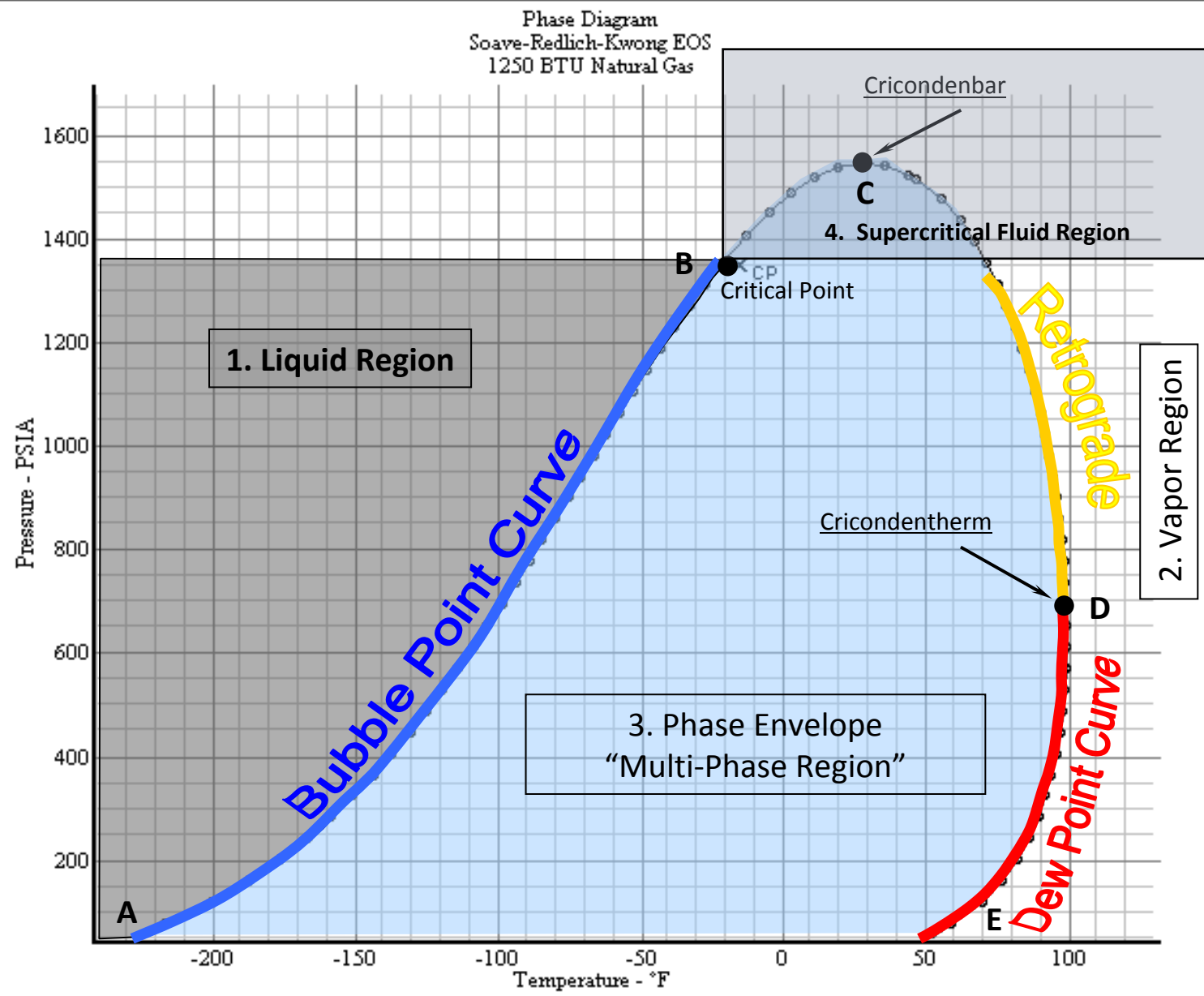Vapor Density
Liquid Density
Vapor Volume
Liquid Volume
Vapor Enthalpy
Liquid Enthalpy
Vapor Entropy
Liquid Entropy
Vapor Heat Capacity
Liquid Heat Capacity
Vapor Viscosity
Liquid Viscosity
Vapor Therm Conductivity
Liquid Therm Conductivity
Surface Tension

Diagram Constant

◉ Pressure
◯ Temperature

14.70   PSIA

Diagram Options

Phase Diagram
Soave-Redlich-Kwong EOS
1250 BTU Natural Gas

Cricondenbar

C

4. Supercritical Fluid Region

B

CP
Critical Point

1. Liquid Region

Retrograde

2. Vapor Region

Cricondentherm

D

Bubble Point Curve

3. Phase Envelope
"Multi-Phase Region"

Dew Point Curve

A

E

1600

1400

1200

1000

800

600

400

200

Pressure - PSIA

-200   -150   -100   -50   0   50   100

Temperature - °F

DEFINING THE "PRACTICAL" TEMPERATURE

Insertion Pressure Regulators are not 100% effective in preventing J-T cooling

- Note that insertion pressure regulators are designed to "offset" or prevent excessive Joule-Thomson (J-T) cooling during pressure reduction.

  - This is accomplished by having the pressure reduction valve located in a section of the sample probe which is inside of the pipeline. This allows the sample gas to be "heat sinked" to the process gas.

Insertion Pressure Regulators are not 100% effective in preventing J-T cooling (continued)

- Experience has shown the actual "practical" temperature achieved during pressure reduction with an insertion regulator to be near the midpoint of the adiabatic (no heat transfer) and isothermal (without temperature change) temperature points.

    - The "practical" temperature point will be used in this discussion for guidance in the design and operation of sample systems.

Defining the practical temperature
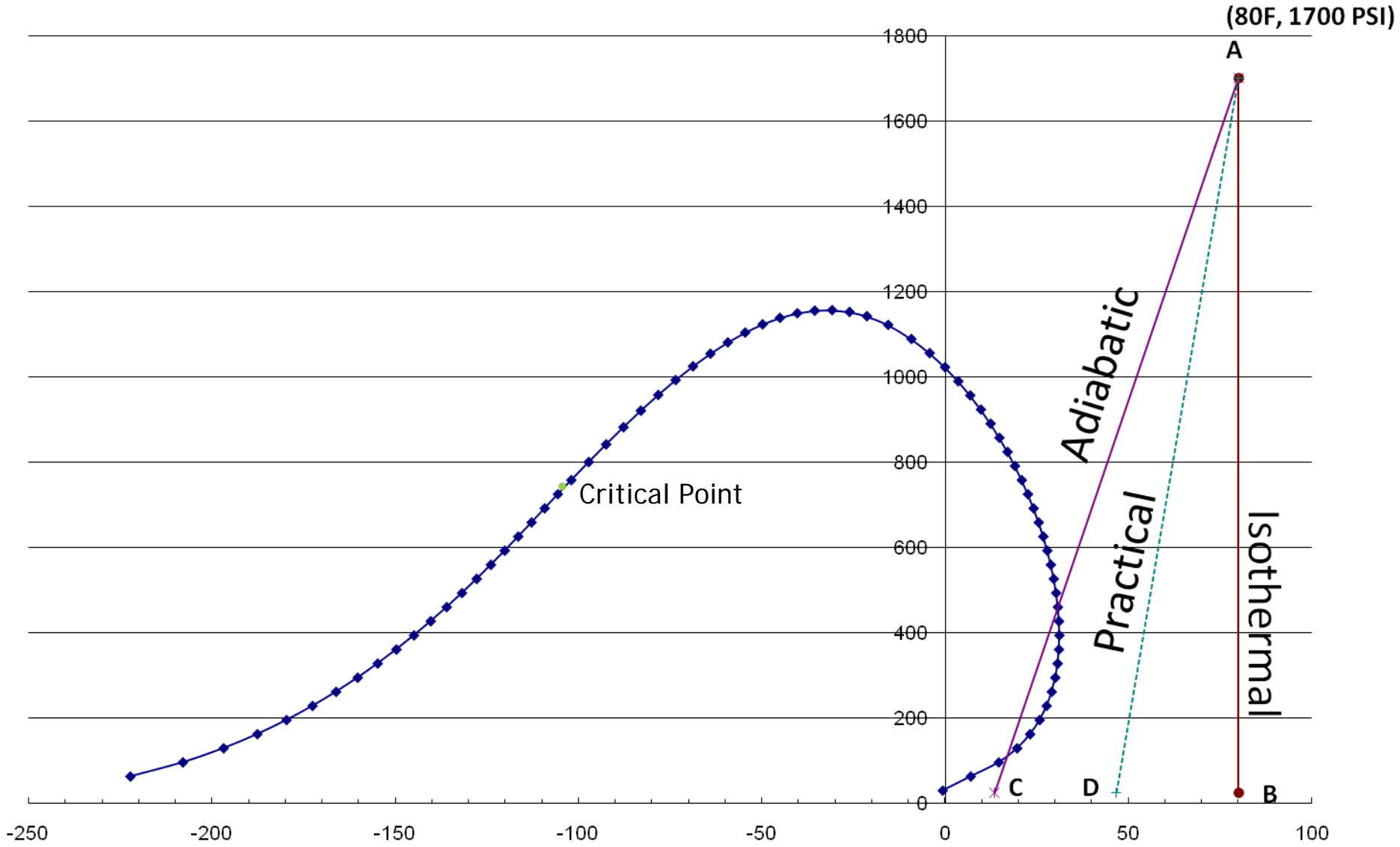
Topic

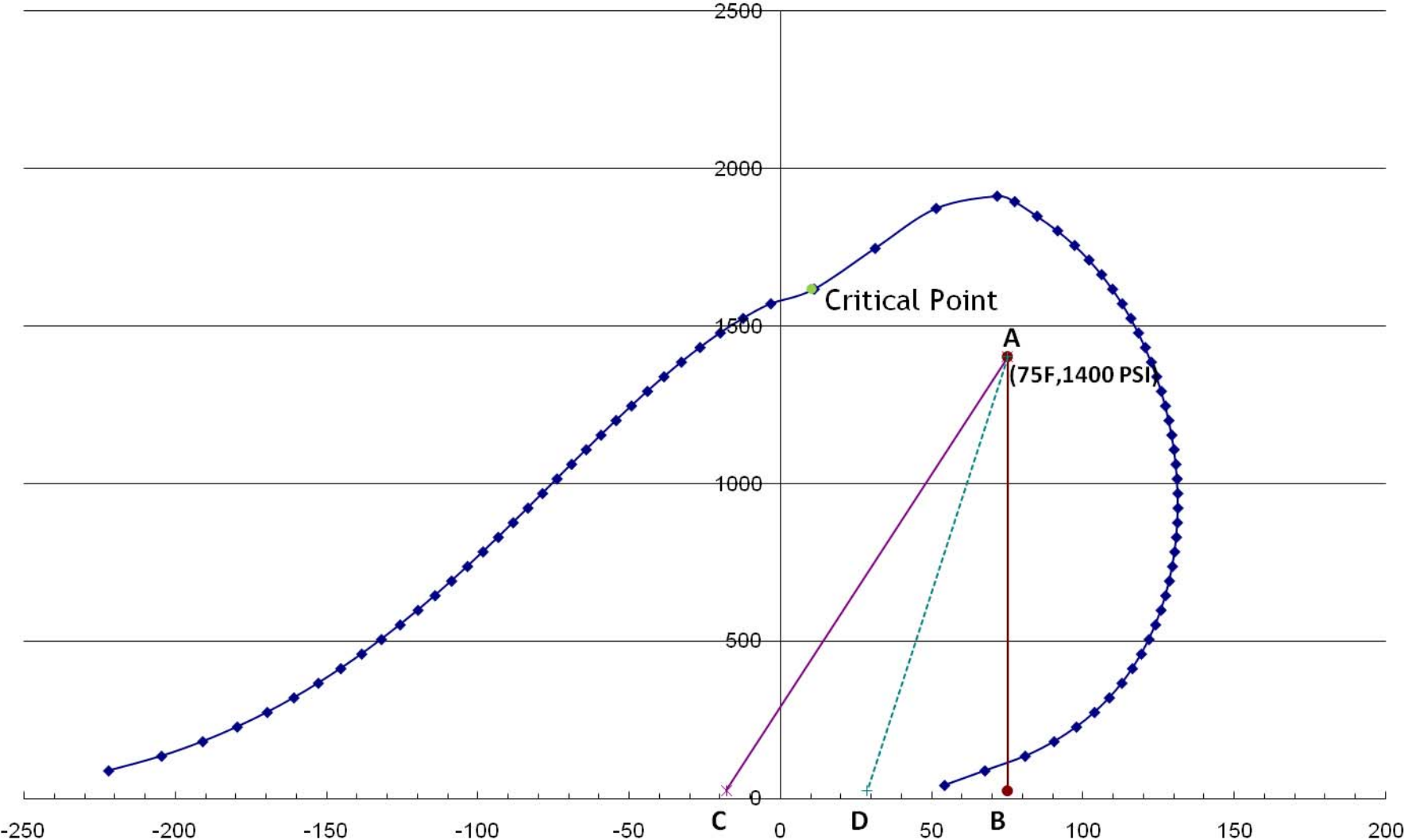# PROBLEMS ENCOUNTERED WHEN SAMPLING & CONDITIONING WET, HIGH-PRESSURE, AND SUPERCRITICAL NATURAL GAS & SOLUTIONS

Problem # 1

How does one extract & condition a "representative" sample when liquid in any form is present in the gas sample (i.e.- "wet" gas)?

Source gas contains entrained liquid ("wet" gas)

In order to arrive at a solution, one must determine the following:

- Determine what type of probe should be used

- Determine if internal or external pressure regulation is required

- Determine if heating is required
  - In order to make these determinations, a phase diagram for the <u>gas</u> composition to be extracted should be utilized.

Solution for "wet" gas

1) Separate liquid inside of the pipeline

- A "phase separation" membrane tipped probe may be used for this purpose.

- Removing liquid externally is not practical because line conditions would have to be maintained EXACTLY as they are in the pipeline.
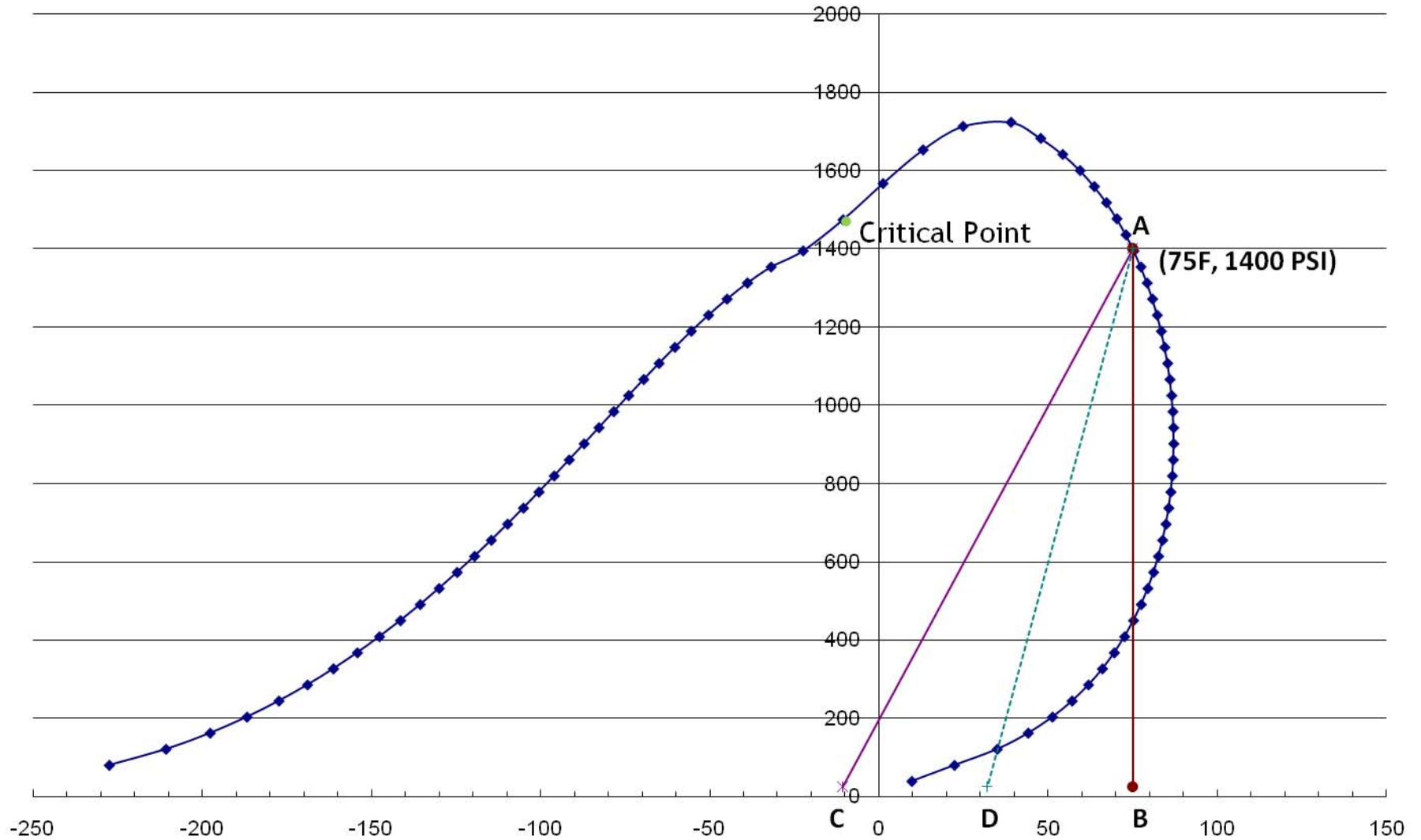
Source gas contains entrained liquid ("wet" gas)
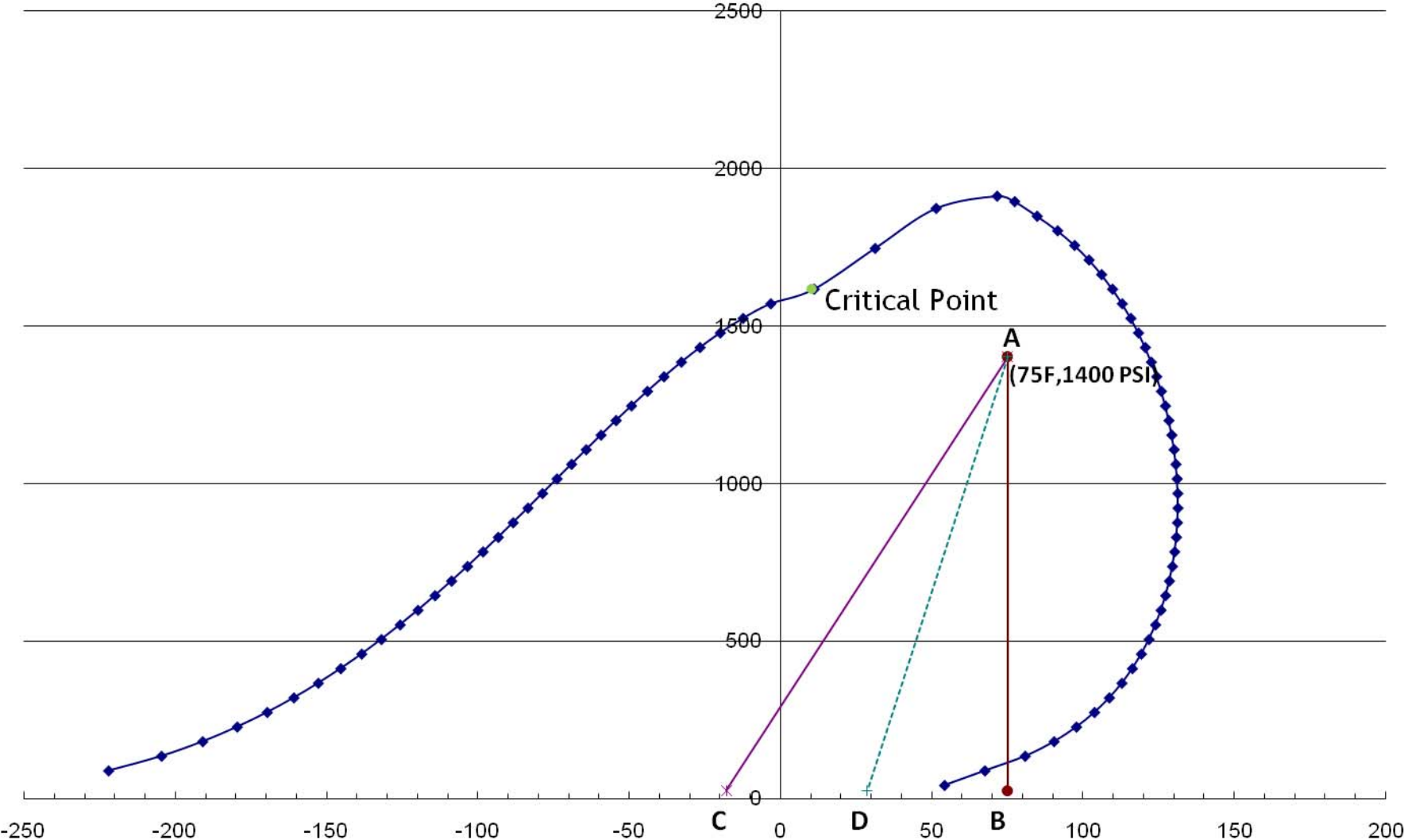
Gas Phase Composition of "Wet" Gas
Will an insertion regulator work?

Legend: Phase Envelope • Insertion Regulator Adabiatic • Insertion Regulator - Isothermal • Insertion Regulator- Practical Temp.
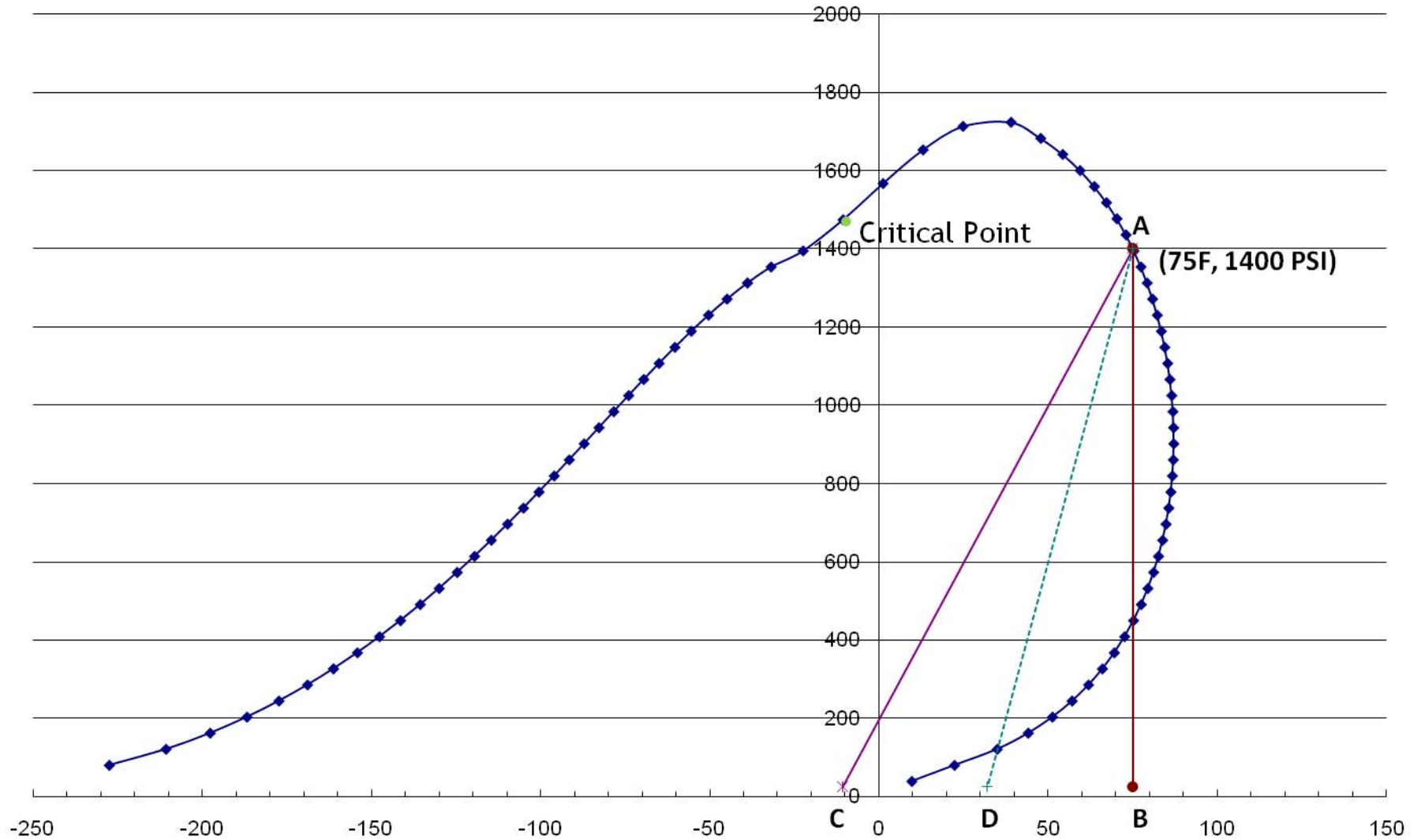
Solution for "wet gas" (continued)

2) Plot a new phase diagram using ONLY the GAS PHASE composition to determine if an insertion regulator can be used or if a heated regulator is required.

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Gas Phase Composition of "Wet" Gas
Will an insertion regulator work?

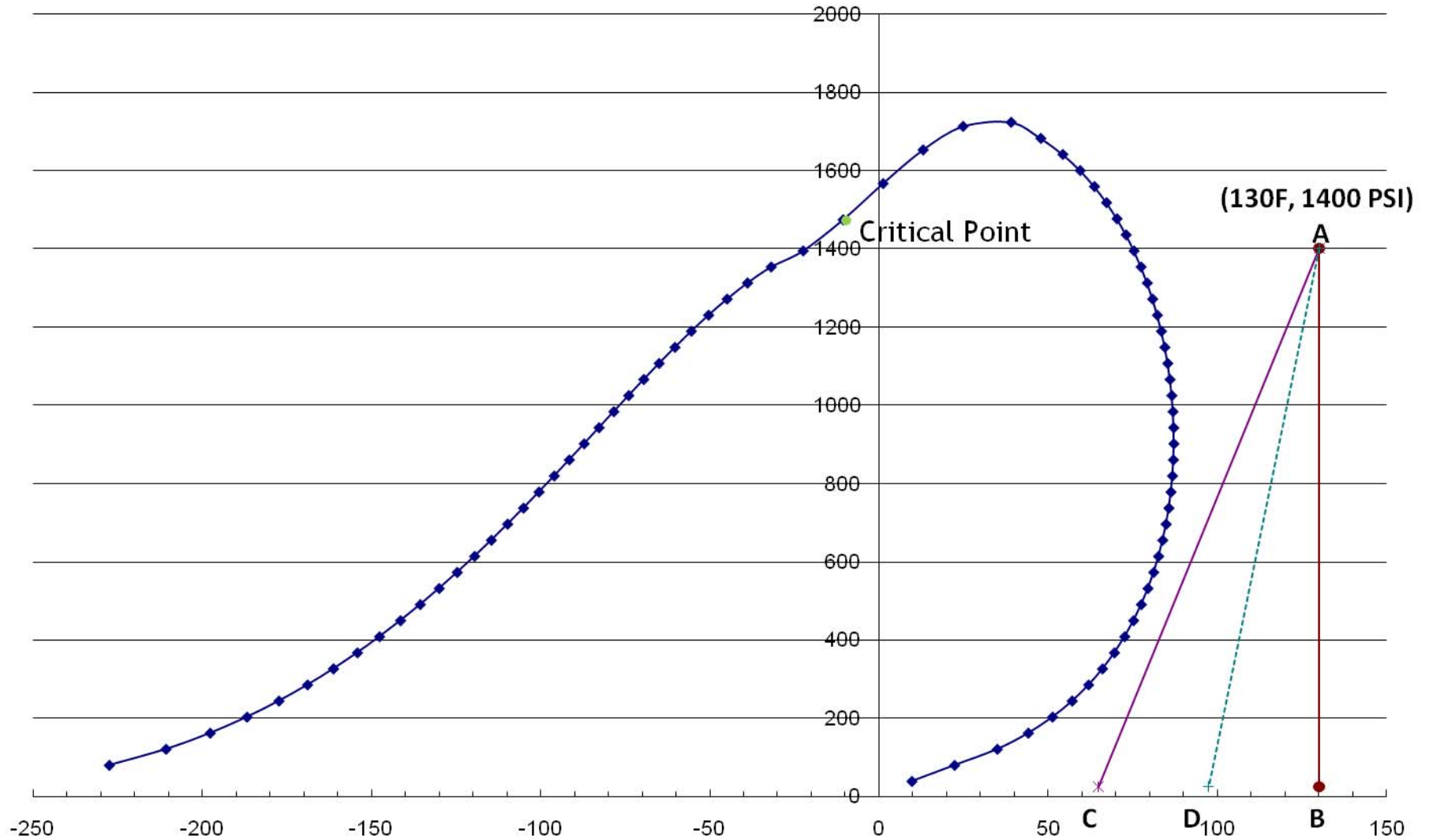# Gas Phase Composition of "Wet" Gas
Will a heated, single-stage regulator work?

(130F, 1400 PSI)

Critical Point

A

C   D 100   B

- ◆ Phase Envelope
- ✳ Heated Regulator Adabiatic
- ● Heated Regulator - Isothermal
- +--- Heated Regulator- Practical Temp.

Source gas contains entrained liquid ("wet" gas)
If source conditions were at Point B instead of Point A,
would an insertion regulator work?

Critical Point

A
(75F,1400 PSI)

B
(82F, 600 PSI)

C   0   D   50   B   100

Legend:
- Phase Envelope
- Insertion Regulator Adabiatic
- Insertion Regulator - Isothermal
- Insertion Regulator- Practical Temp.

WORLDWIDE

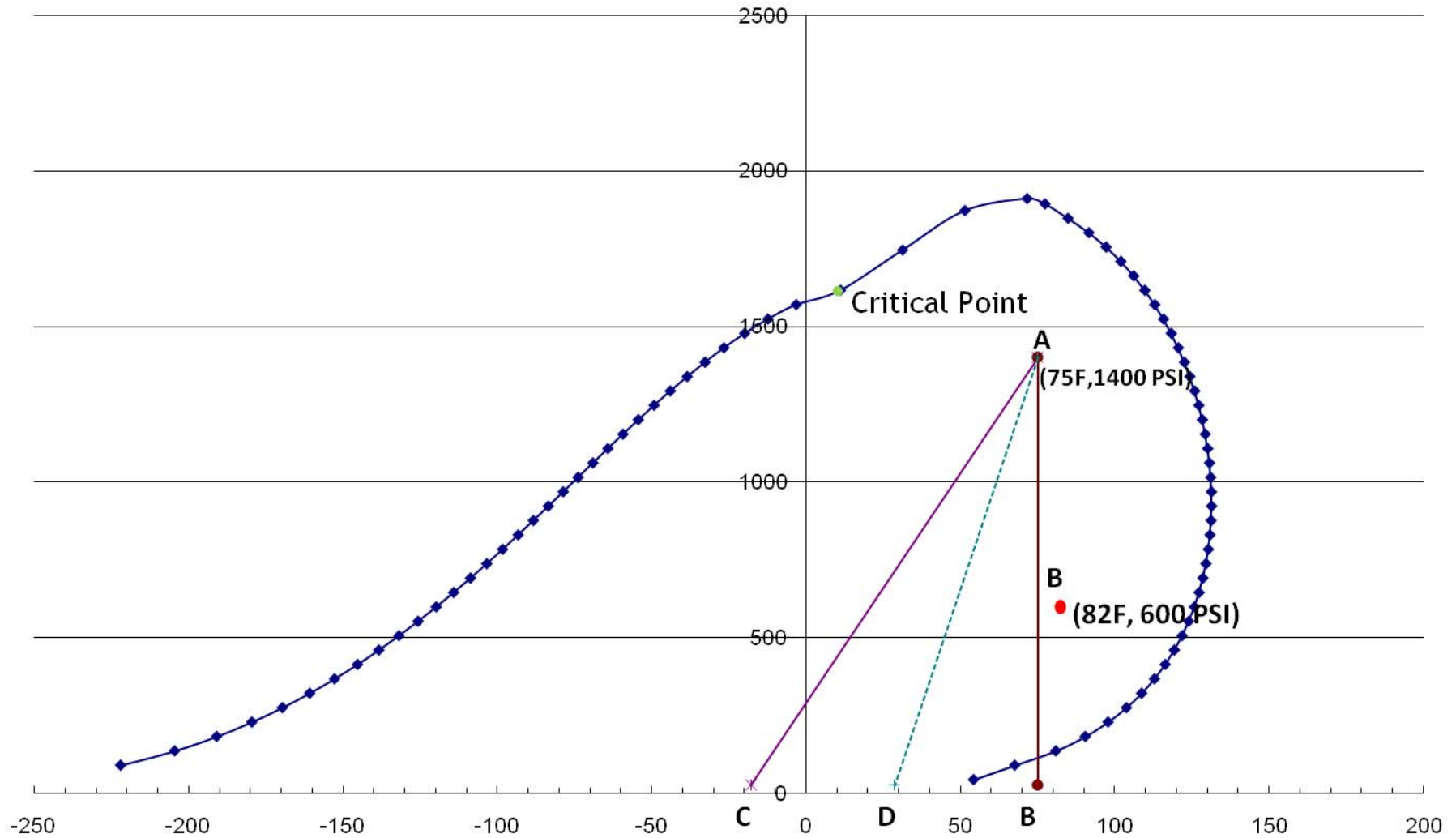# Gas Phase Composition of "Wet Gas"
Will an insertion regulator work?

Legend: Phase Envelope · Insertion Regulator Adabiatic · Insertion Regulator - Isothermal · Insertion Regulator- Practical Temp.

Labeled point: B (82F, 600 PSI)
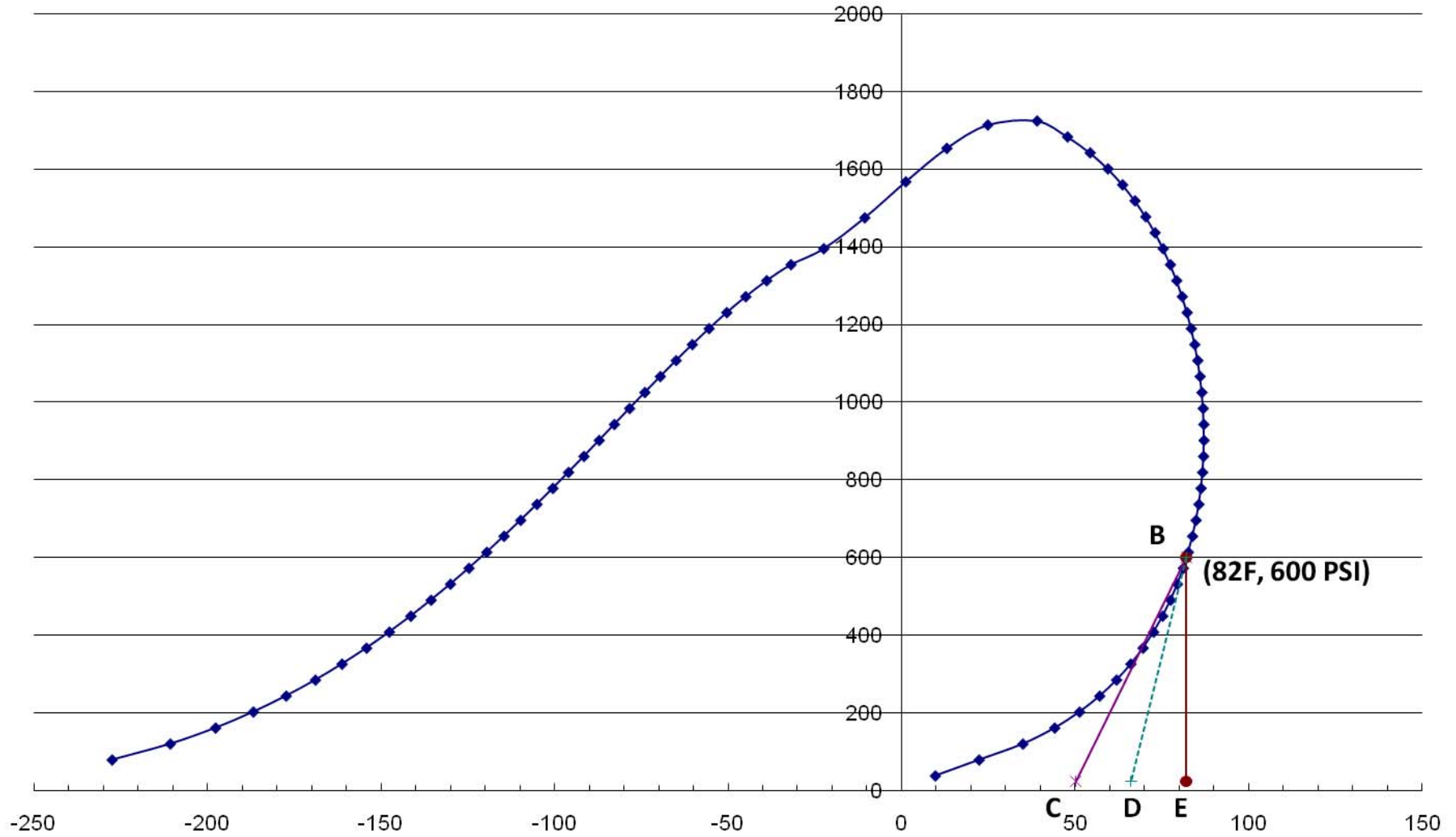
Problem # 2

How does one extract & condition a "representative" sample from a supercritical or high pressure natural gas source, even though it does not contain entrained liquid?

Calculate   Print   Copy   Edit Titles   Edit Points   Transpose

Select Diagram

P-T Phase Diagram
Vapor Density
Liquid Density
Vapor Volume
Liquid Volume
Vapor Enthalpy
Liquid Enthalpy
Vapor Entropy
Liquid Entropy
Vapor Heat Capacity
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E

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1600
1400
1200
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200

-200   -150   -100   -50   0   50   100

Temperature - °F

In order to arrive at a solution, one must determine the following:

- Determine what type of probe should be used

- Determine if internal or external pressure regulation is required

- Determine if heating is required

  - In order to make these determinations, a phase diagram for the gas composition to be extracted should be utilized.

Source pressure and temperature conditions (Point A) of this composition are in a supercritical condition. A pressure reduction without heating will cause the sample to traverse the phase envelope.
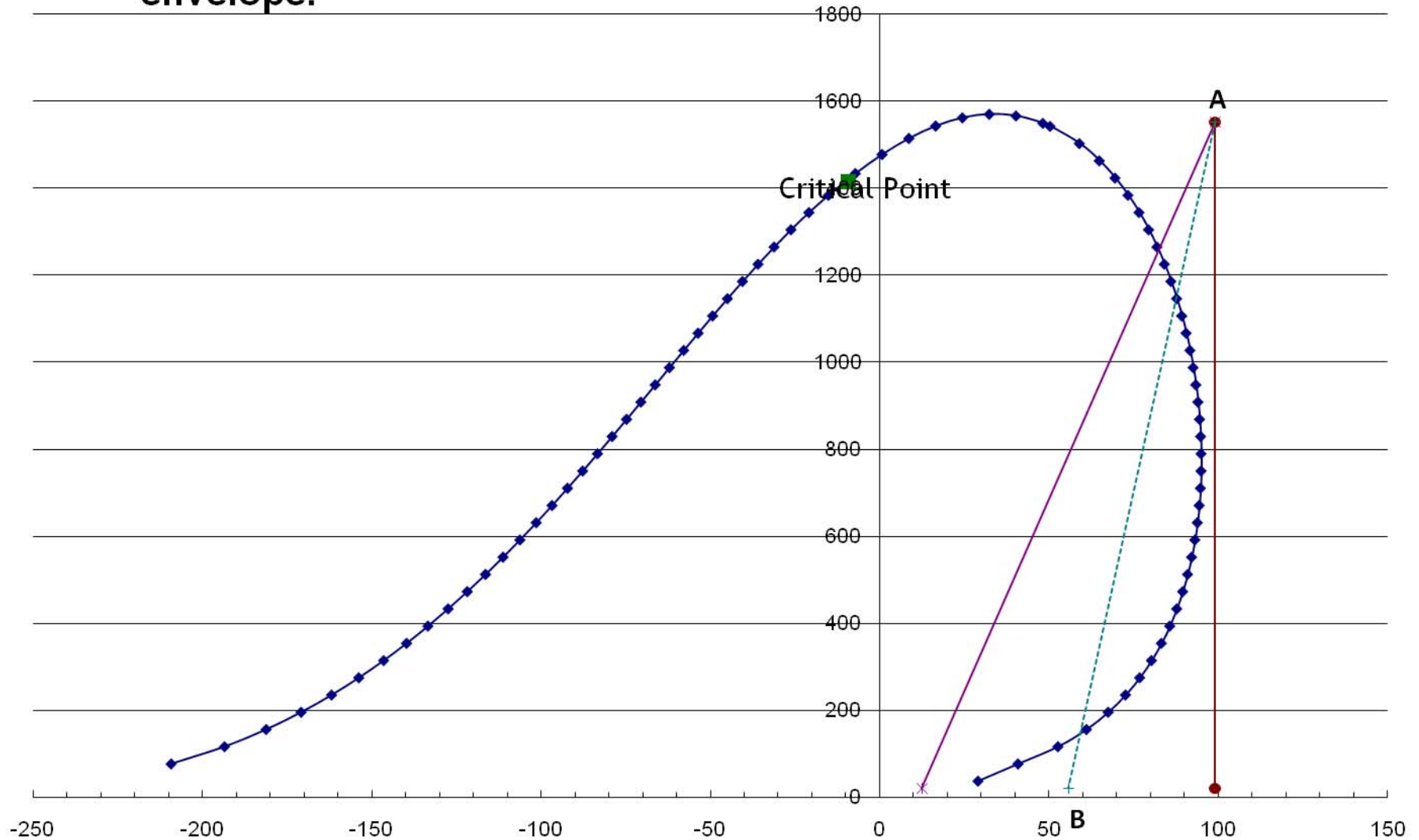

Critical Point

A

B

Phase Envelope — Insertion Regulator- Adabiatic — Insertion Regulator - Isothermal — Insertion Regulator - Practical Temp. — Critical Point

Solution for extracting & conditioning the supercritical natural gas sample on previous slide

- Extract the sample under conditions which ensure the pressure and temperature changes do not allow the sample to change from its supercritical state.

- Transfer the sample to an external heated multi-stage regulator through a sample line heated at least 30°F above the cricondentherm temperature.

  - Multiple stages of pressure regulation, with re-heating of the sample gas between stages is recommended

Multiple stages of pressure regulation, with reheating of the sample gas between stages is recommended
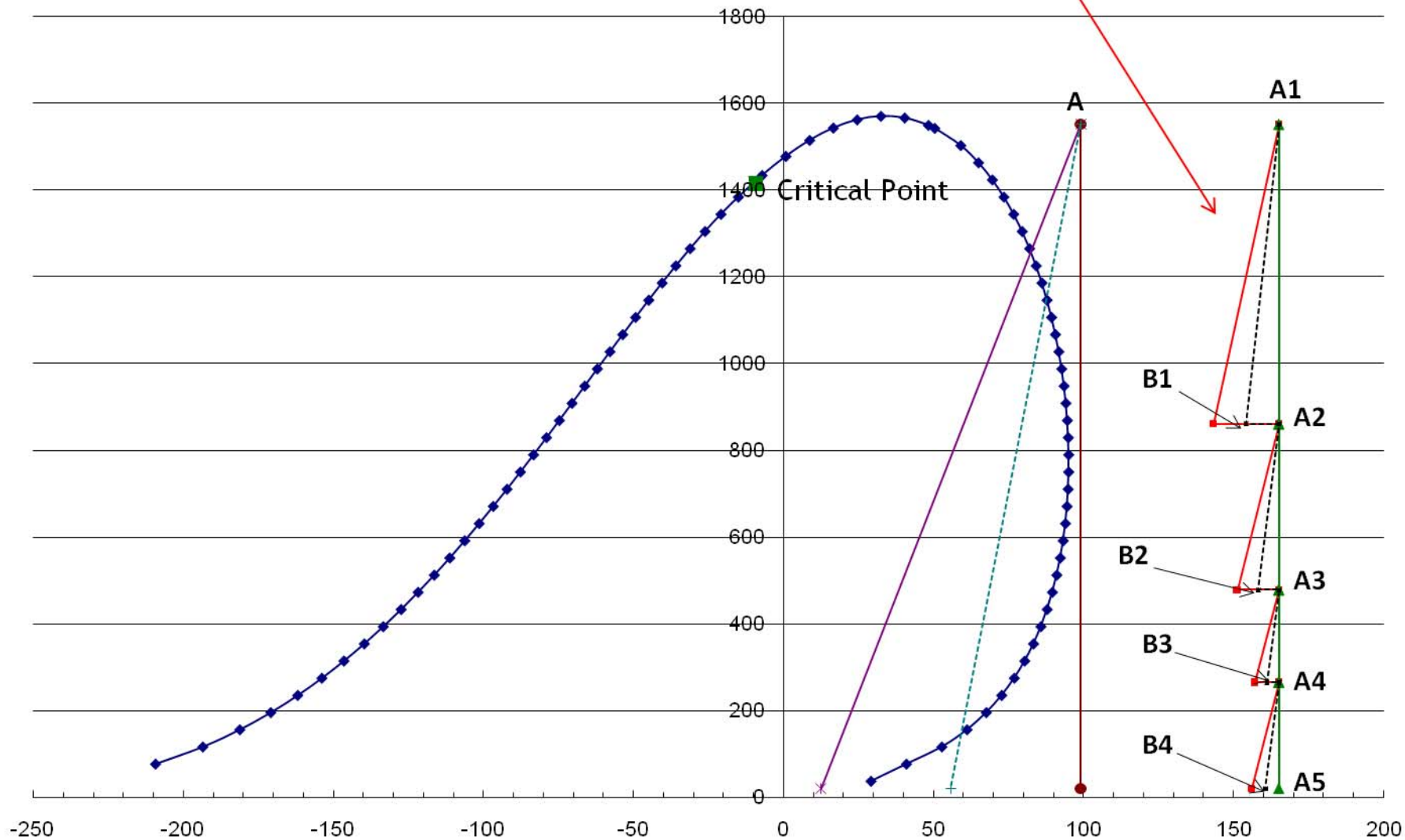
Sampling High Pressure Gas

○ Although the focus of the last example was on sampling a supercritical gas (also high pressure), the considerations are the same for a high pressure gas. The following will need to be determined:

- Determine what type of probe should be used
- Determine if internal or external pressure regulation is required
- Determine if heating is required
  - In order to make these determinations, a phase diagram for the gas composition to be extracted should be utilized.

Summary

- The recommendations in this presentation are based on experience in similar circumstances.
- The sample extraction process for high pressure, wet, or supercritical gases is the most critical step in the analytical process.
  - Sample will be invalid if this step is performed incorrectly
- Another key step is pressure regulation

Summary

- Design or operation of a sample system for wet, high pressure or supercritical natural gas requires a basic knowledge of thermodynamics

- Understanding phase diagrams is a "must" for making sample conditioning decisions.

- The API 14.1 standard is a good reference even though its scope is limited to gases at or above their hydrocarbon dew point.