NATURAL GAS LIQUID SAMPLING

LEVERAGING 60 YEARS OF EXPERIENCE IN TEXAS

Kenneth O. Thompson, Mustang Sampling

Appalachian Storage Hub Conference
South Pointe, Pennsylvania
June 5-6, 2019

Outline

Mustang Sampling®

- Introduction to Mustang Sampling®
- Global Energy & North America Natural Gas Landscape
- Determination and Product Analysis
  - Composition of Natural Gas Mixtures
  - Composition of Natural Gas Liquid Mixtures
- Standards for NGL
- Closing Comments

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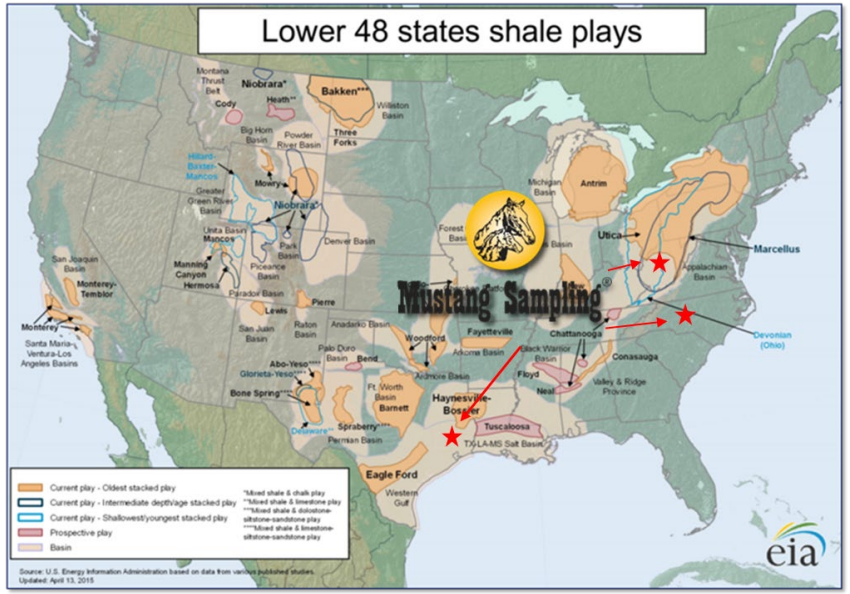
Mustang Sampling – Who We Are

- Mustang Sampling is dedicated to providing Analytically Accurate® solutions, products, systems, and services to all areas of the natural gas industry
  - Complete fiscal metering systems
    - Orifice, Ultrasonic, Coriolis, Turbine Meters
  - Sampling systems for natural gas, liquids, and LNG
  - Energy measurement systems
  - Design, Civil, Construction, Commissioning, Sales, and Maintenance support
- Product Development
  - Sampling products developed primarily from necessity
  - Virtually all products address specific customer need



Mustang Sampling Core Business

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  - Energy measurement systems
  - Design, Civil, Construction, Commissioning, Sales, and Maintenance support

Mustang Sampling's Experience

- Natural Gas Liquid Analysis is Core Competency
  - Early experience developed in Texas in and around Mont Belvieu
    - Enterprise Products
    - ONEOK
  - Used vaporizing techniques to convert liquids to gas
  - Expanded to heavier liquids than ethane and propane
  - Created Intellectual property available globally
  - Appalachian Storage Hub will be similar to Mont Belvieu

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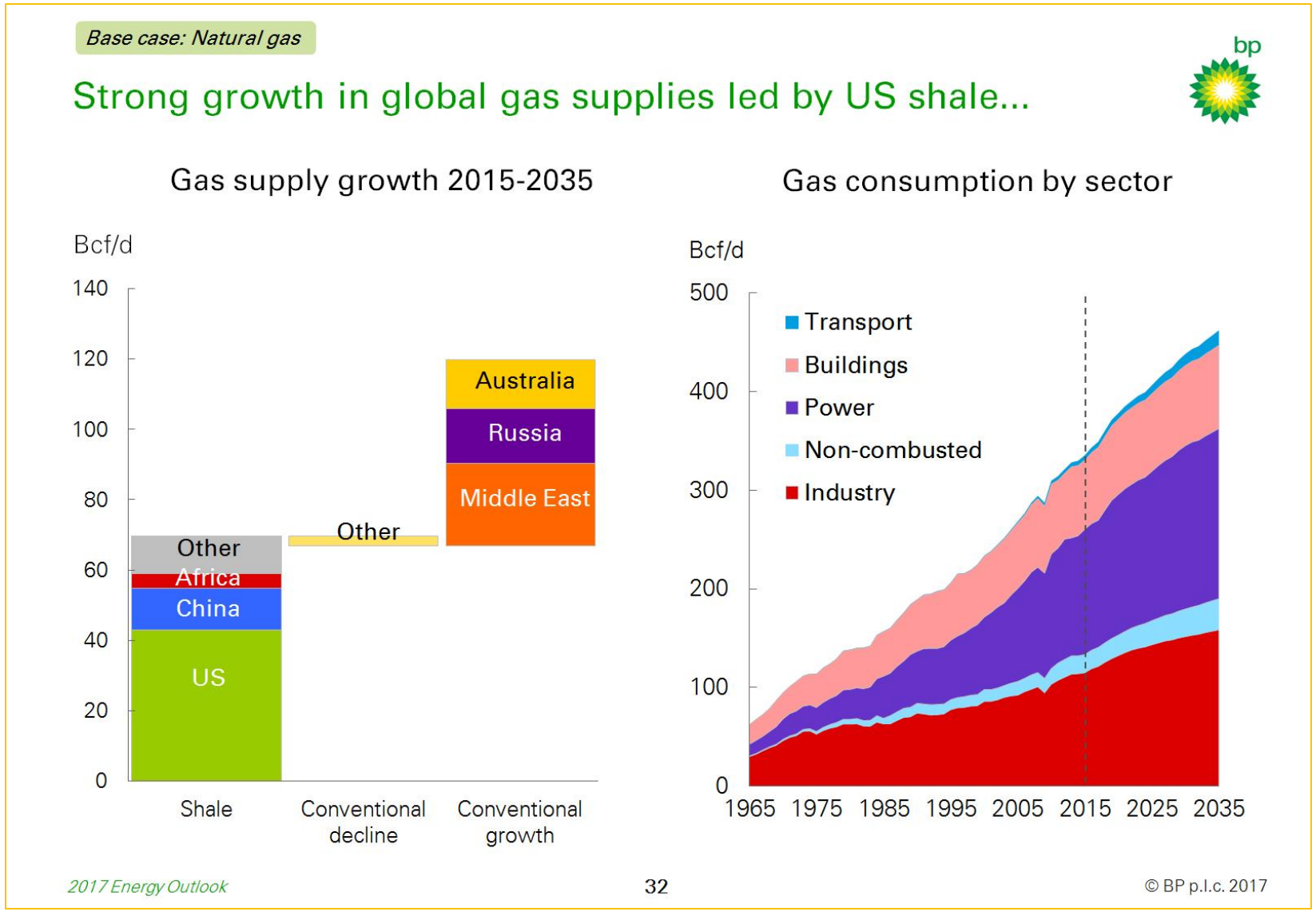
Global Natural Gas Growth Led by US Shale

Key Features (BP Report)

- Global natural gas growth will be led by US Shale
- Largest single demand growth is LNG export
- Second largest demand is electricity production
- Energy consumption will continue to grow globally for decades (or longer)
- Competition from Qatar & Australia is urging US construction
- NGL production is linked to natural gas associated deposits



Wide Distribution of Energy Values

Typical Shale Gas Heating Values

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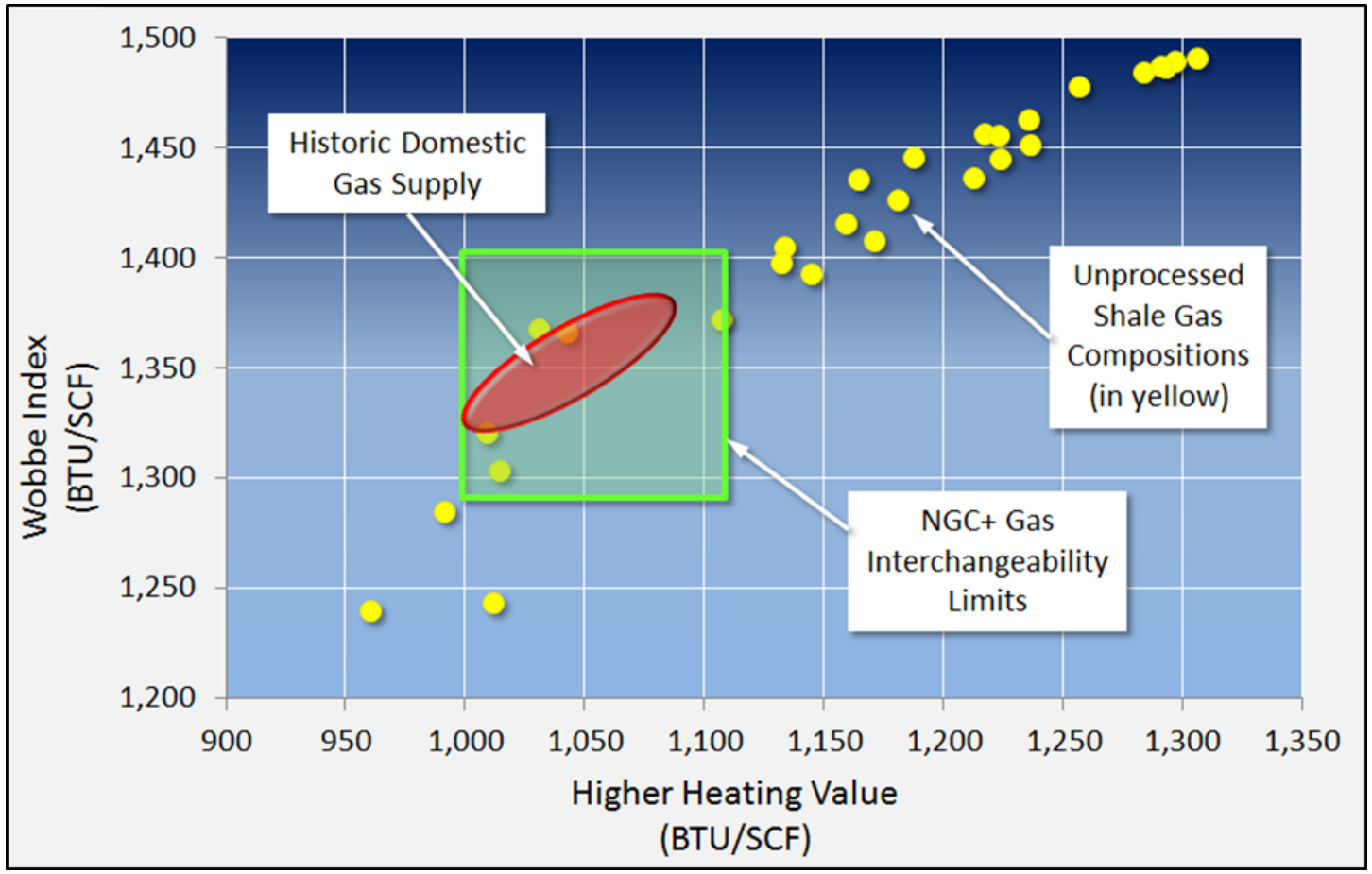
Shale Features

- Gas composition is strongly dependent on exact location and depth
- May not meet interchangeability requirements for fuel
- Liquid content has significant value
- Variations change with time from same locations

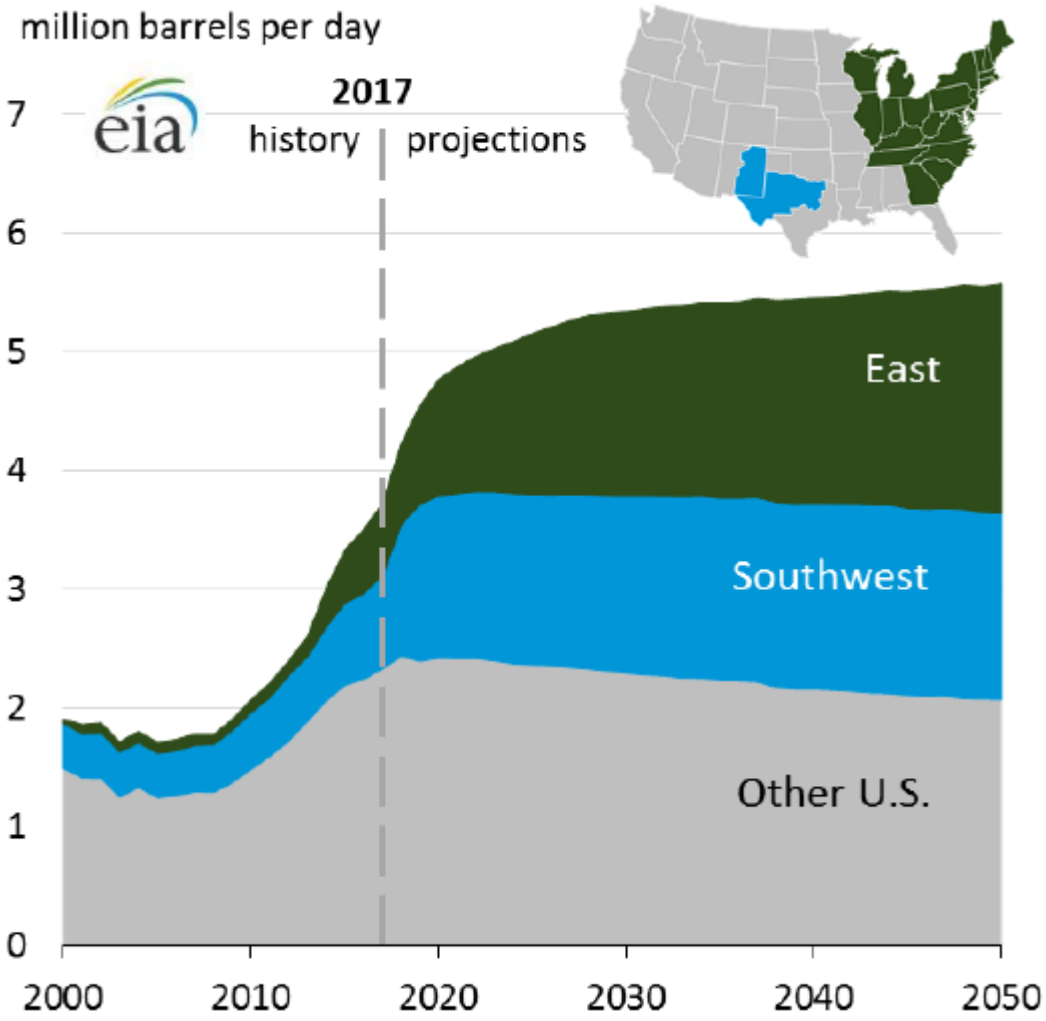


Source: Ed Bowles, 2011 PGJ Interchangeability Report

Ethane Production Forecast & Fundamentals
U.S.A. by Region

Key Features & Fundamentals (US DOE Report)

- NGL production is linked to natural gas as associated deposits along with other heavier alkanes (propane, butane, ...)
- Ethane is used almost exclusively to produce ethylene, which is used in the petrochemical industry to produce plastics
- Ethane transportation requires dedicated pipelines and is difficult to move otherwise
- Supply and demand must be closely matched (due to last two bullet points), so large supplies of domestic NGL's dictate local storage be made available
- Petrochemical industry flourishes as supply grows

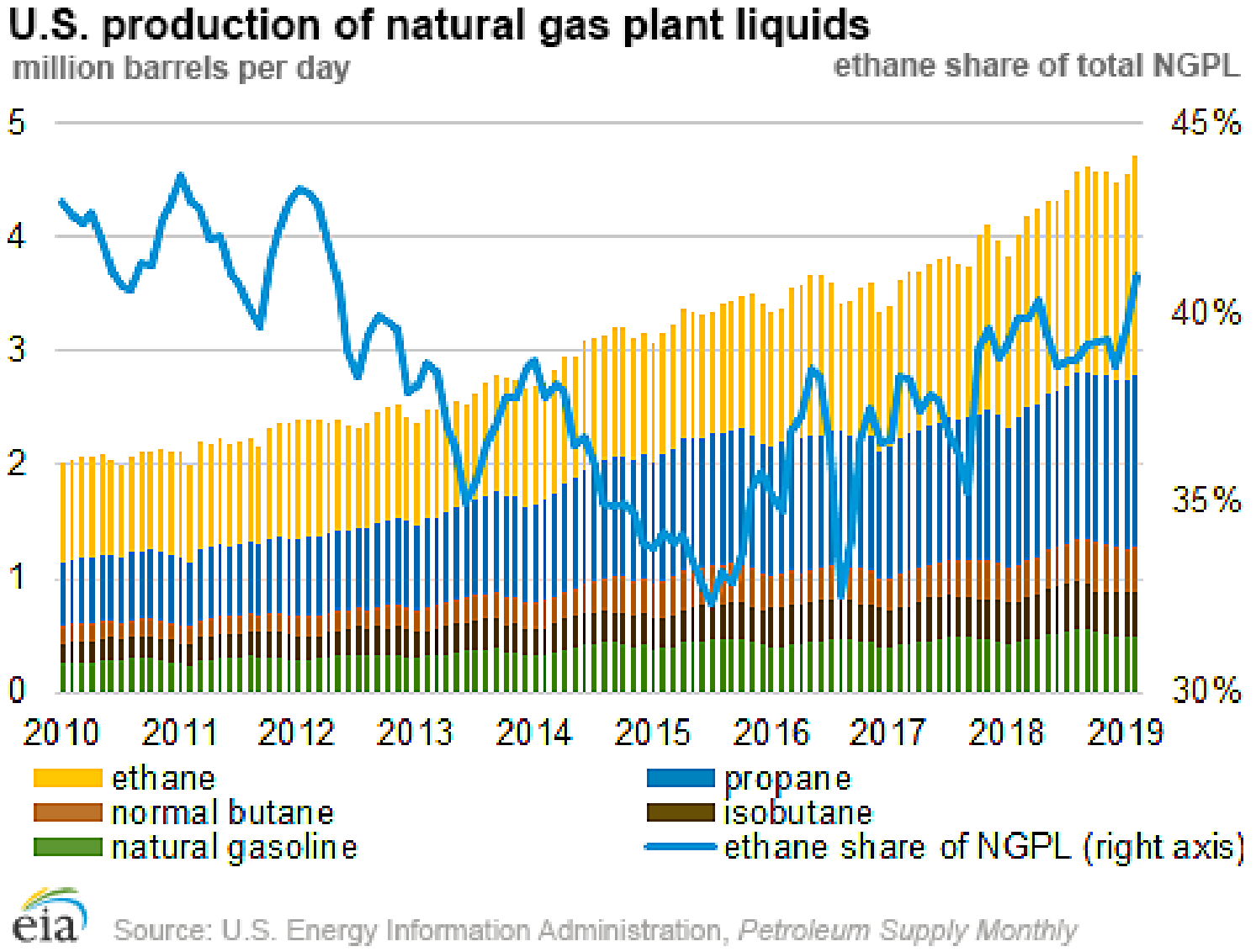


NGL Production Forecast

Production by Type

Key Features

- NGL production has continued to increase with natural gas production for almost ten years
- Ethane represents about 40% of the total NGL market by volume
- Associated liquids often dictate drilling, financial dynamics

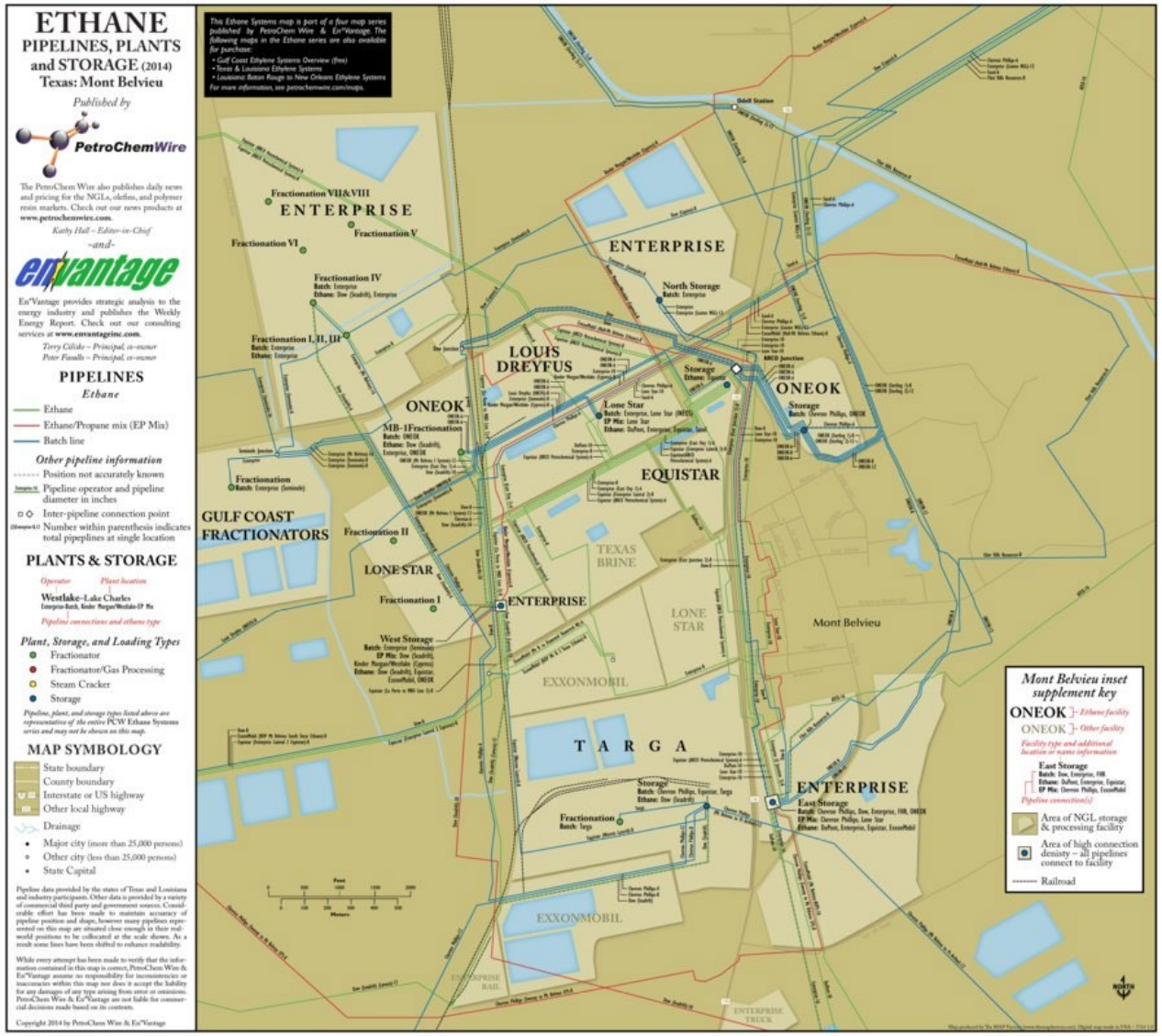


eia Source: U.S. Energy Information Administration, *Petroleum Supply Monthly*

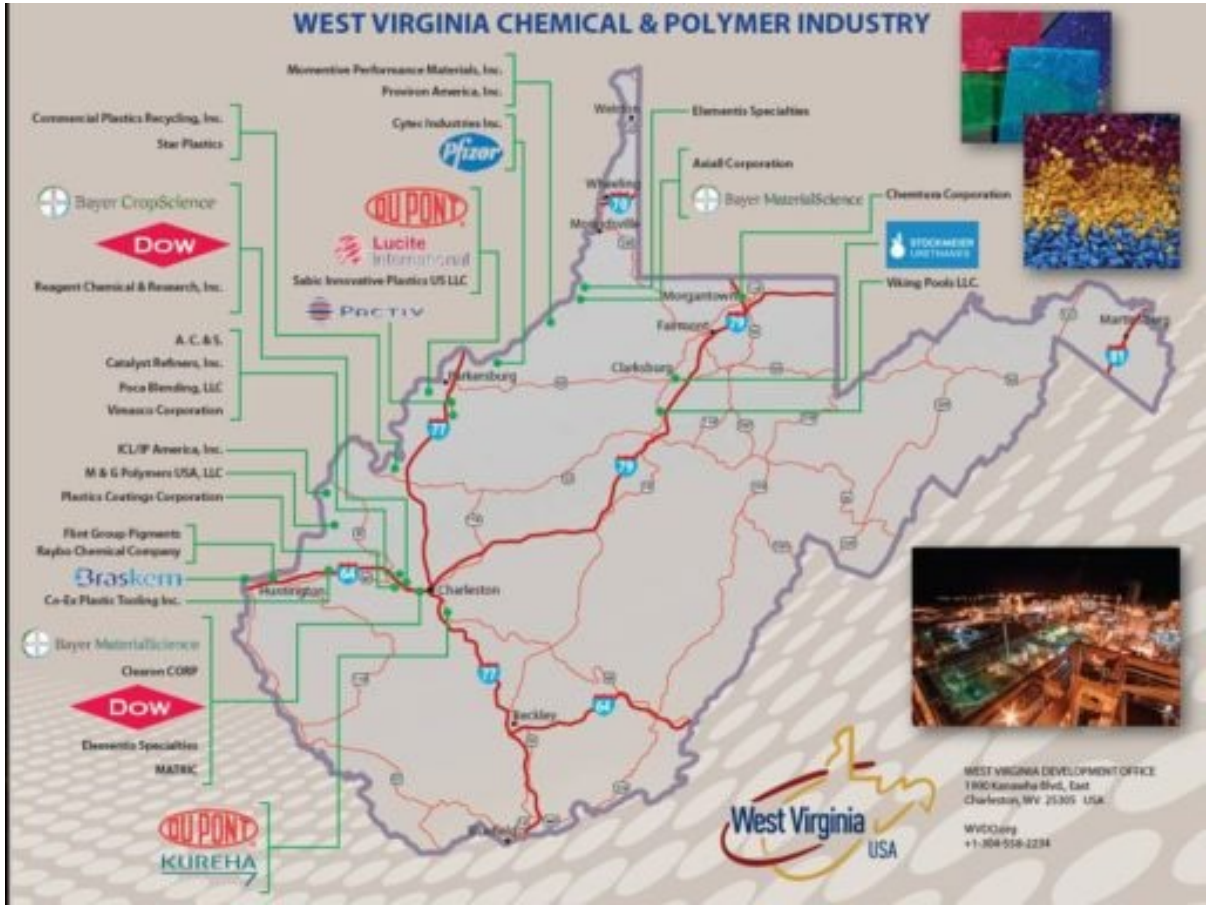
Mont Belvieu, TX Storage Hub

Key Features Associated with NGL

- Map is approximately 10 square miles
- Facility has roots more than 60 years old
- Enterprise, ONEOK, Lone Star NGL, & Targa Resources have major facilities
- Area includes Natural Gas Processing Plants, Fractionation Plants, NGL Pipelines, NGL Storage, Import & Export Facilities, Rail & Truck Facilities
- Facility is located within 30 miles of Houston, Texas (4.7M people)
- Facility is often confused with Strategic Oil Reserve due to its size and location



Potential & Existing Ethane Impact in Appalachian Valley



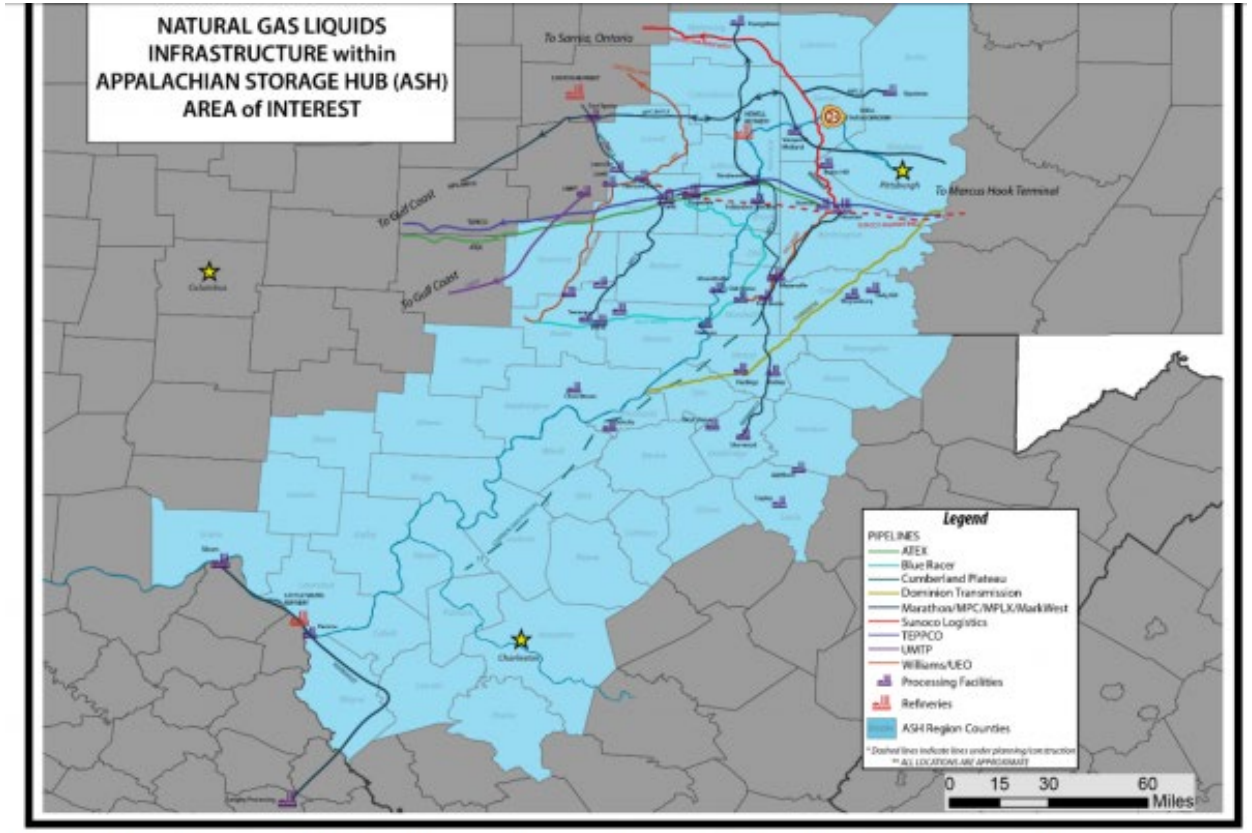


Figure 4-26. Natural gas liquids infrastructure (existing and planned) within the AOI. All locations are approximate.

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What is Natural Gas?
And Why is the Composition Important?

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Natural gas is a naturally occurring hydrocarbon gas mixture consisting primarily of methane, but commonly including varying amounts of other higher alkanes, and sometimes a small percentage of carbon dioxide, nitrogen, hydrogen sulfide, or helium (Petro-wiki)

- Natural gas is not all the same. Natural gas components vary with location, depth, and time.
- The behavior of natural gas depends on the composition and conditions of the gas.
- The value of individual components within natural gas are different, so more valuable components are often stripped from the mixture to sell separately (e.g. propane)
- The energy value of natural gas depends on the composition of the gas. Generally, higher methane values equate to lower energy values.
    - Monetization of natural gas requires full knowledge of the composition.
- Natural gas composition measurement is required for safety and compliance.

Fundamentals of Sampling
Analytically Accurate® Methods & Processes for Gas

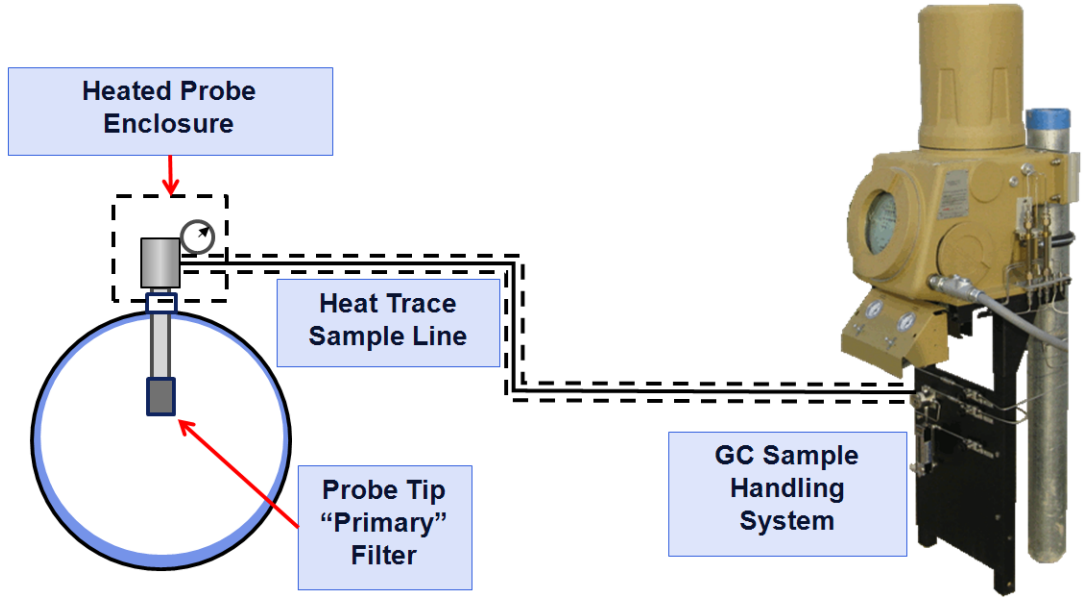
Mustang Sampling®

Fundamentals of Sampling

Sampling allows the user to understand the content of their vessel or pipeline

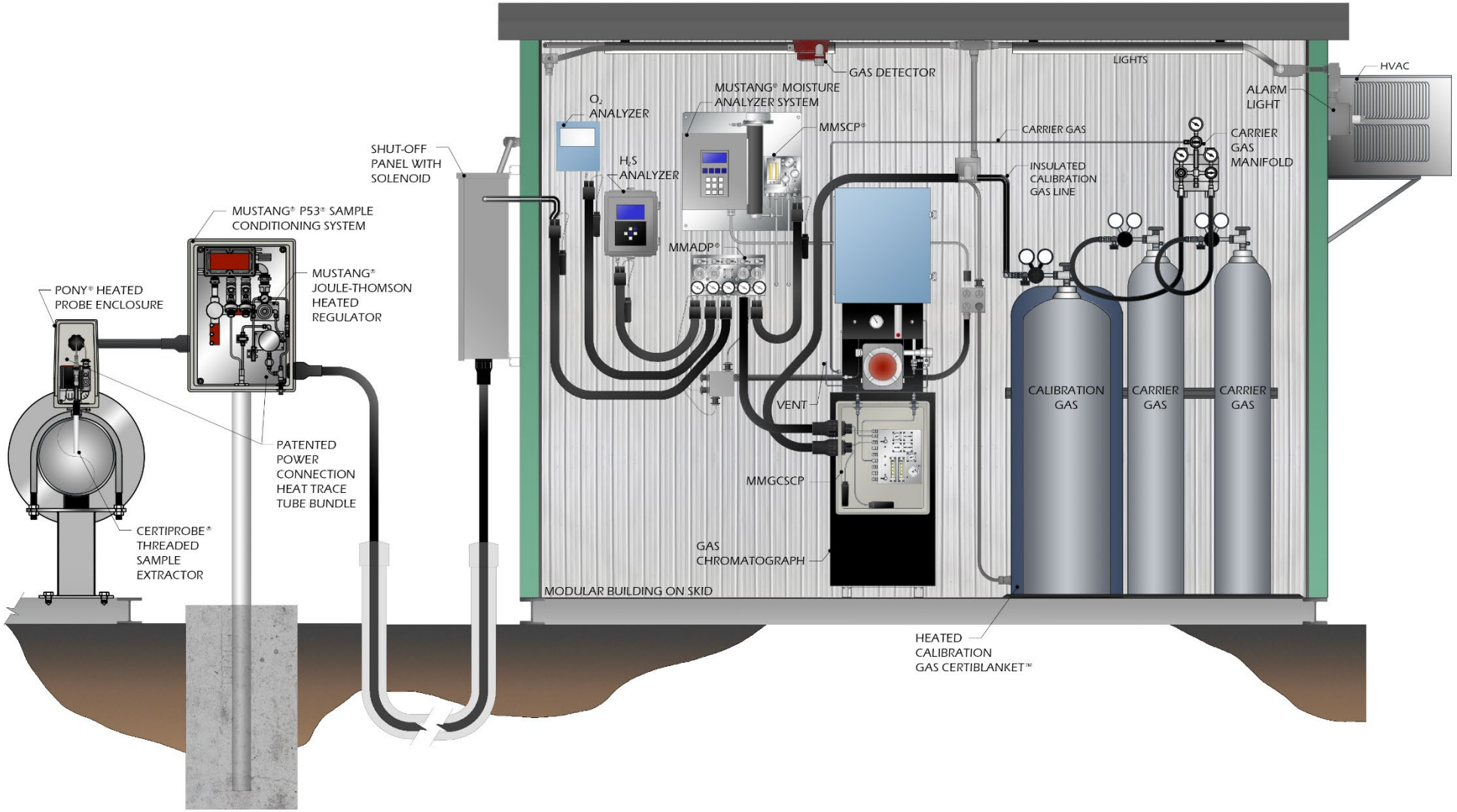
Analytically Accurate sampling requires all of the following:

- Tapping sample from reservoir contained in vessel or pipeline
- Extraction of a representative sample from a vessel or pipeline
- Transportation of sample to sample conditioning system
- Adjustment of sample pressure and temperature
- Transformation to gas phase of sample if needed
- Delivery of sample to analyzer



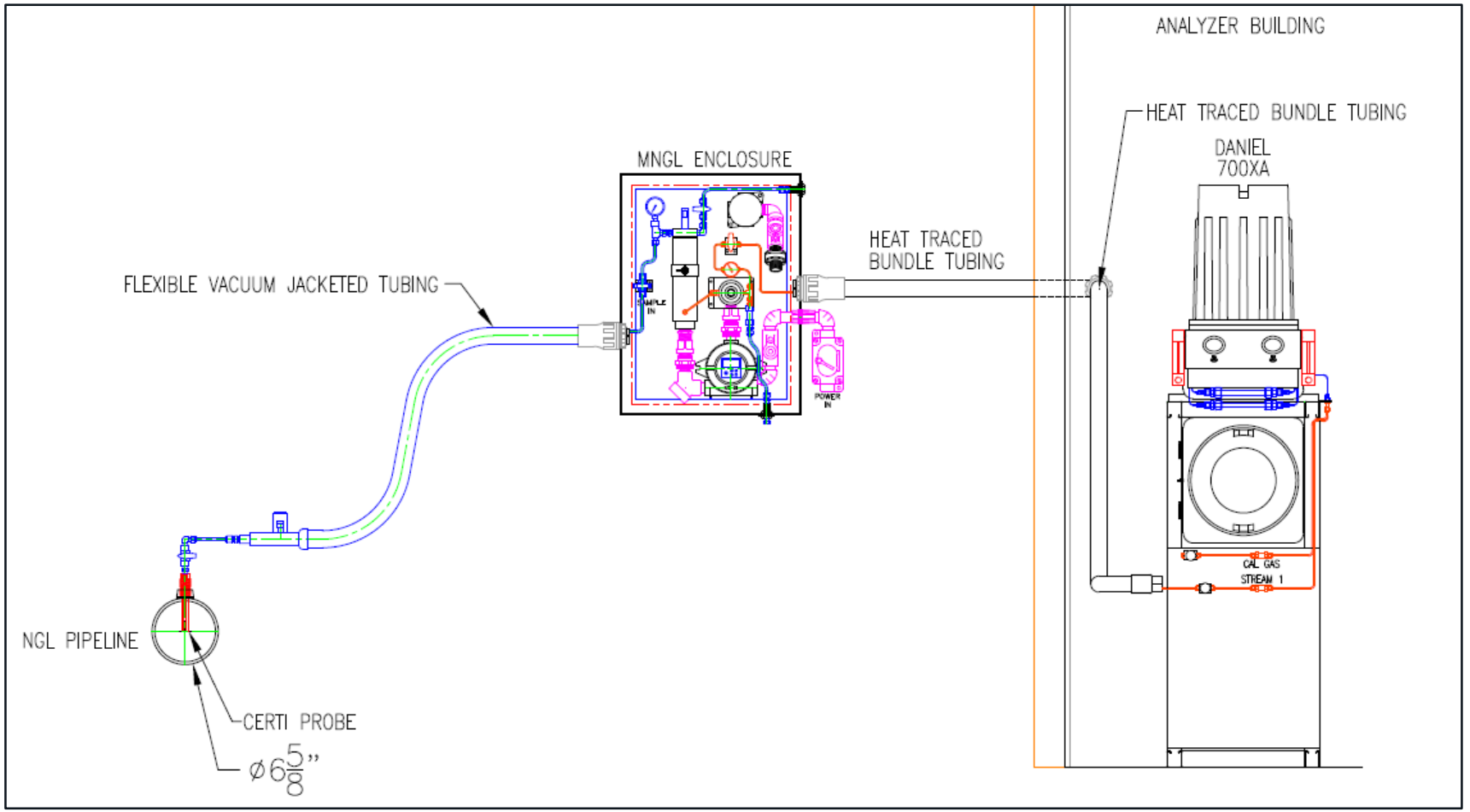
Sampling & Analysis of Natural Gas

Analytically Accurate® Methods & Processes



Sampling & Analysis of Natural Gas Liquid

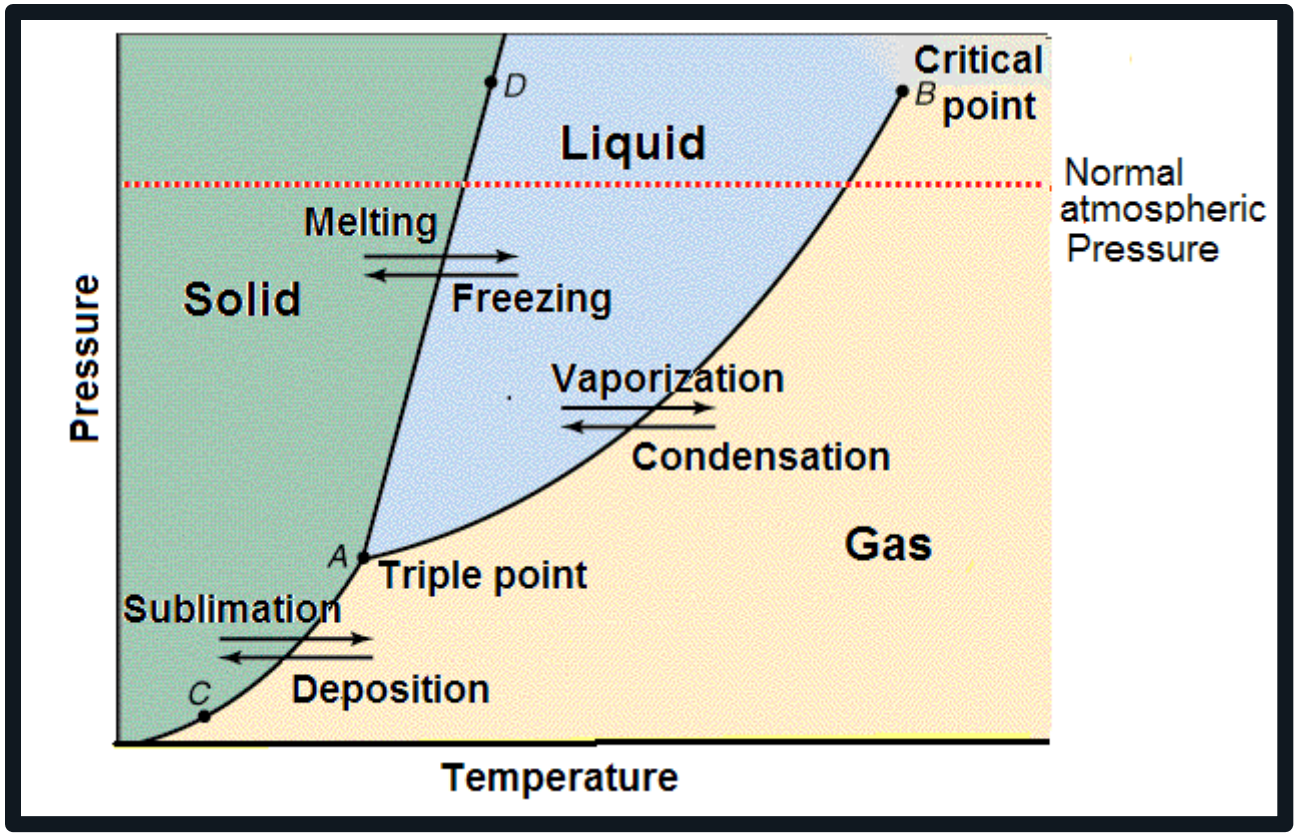
Analytically Accurate® Methods & Processes

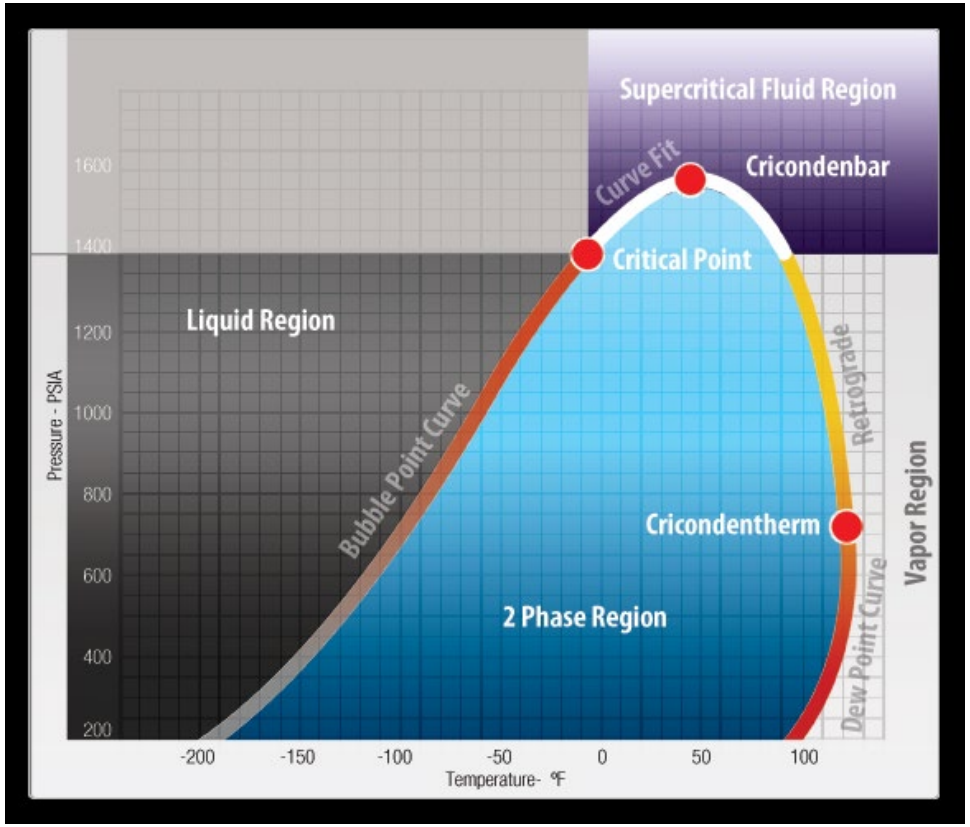


Phase Curve Elements

Pure Substance vs. Mixture

Mustang Sampling®



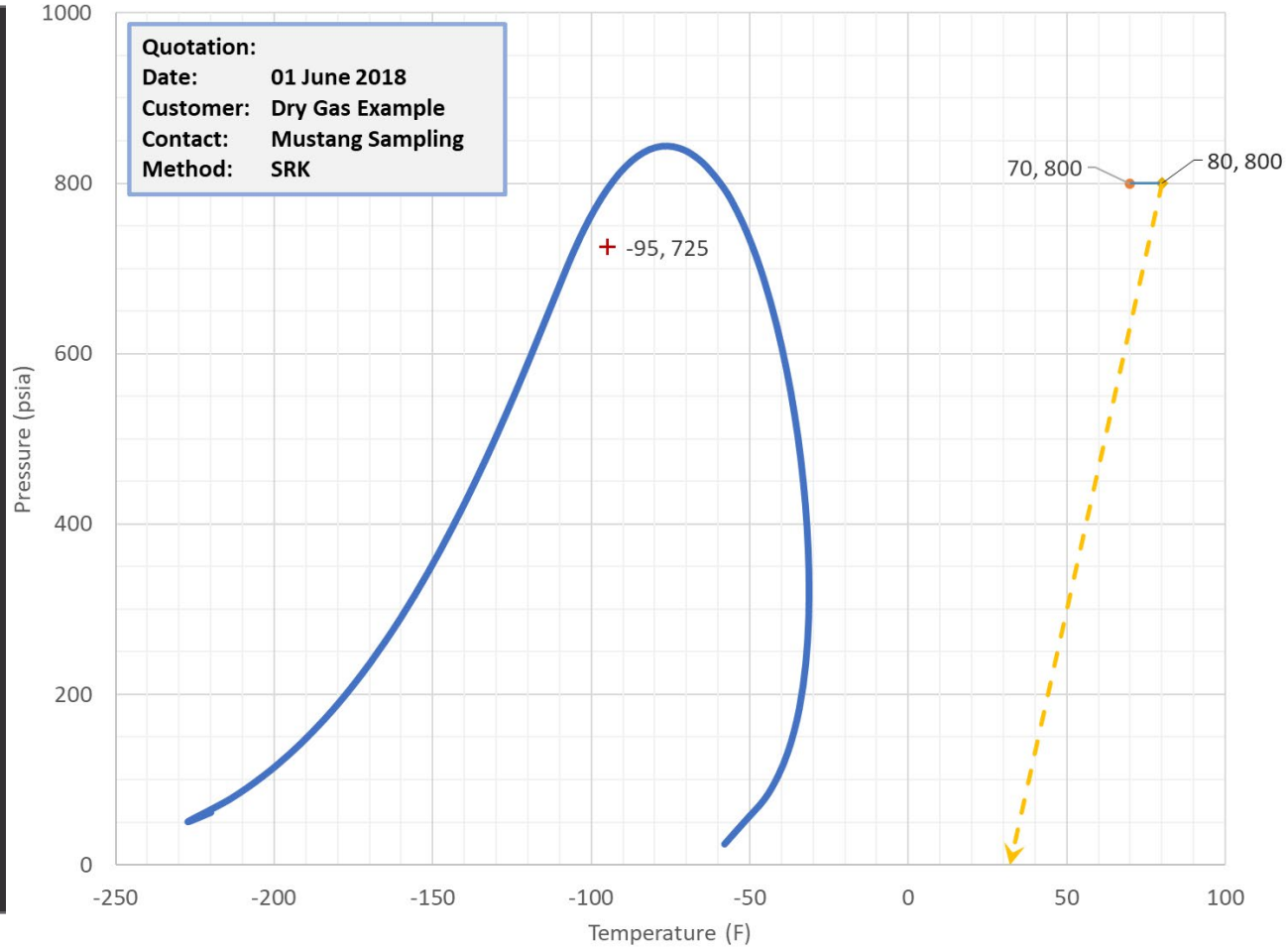


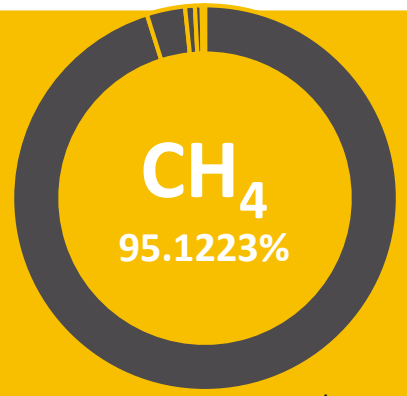
Phase Curve – Dry Gas

Mustang Sampling®

Phase Curve with Mustang® Heated Regulator at 80° F

- Sample point
- Critical point
- Mustang Sampling Point





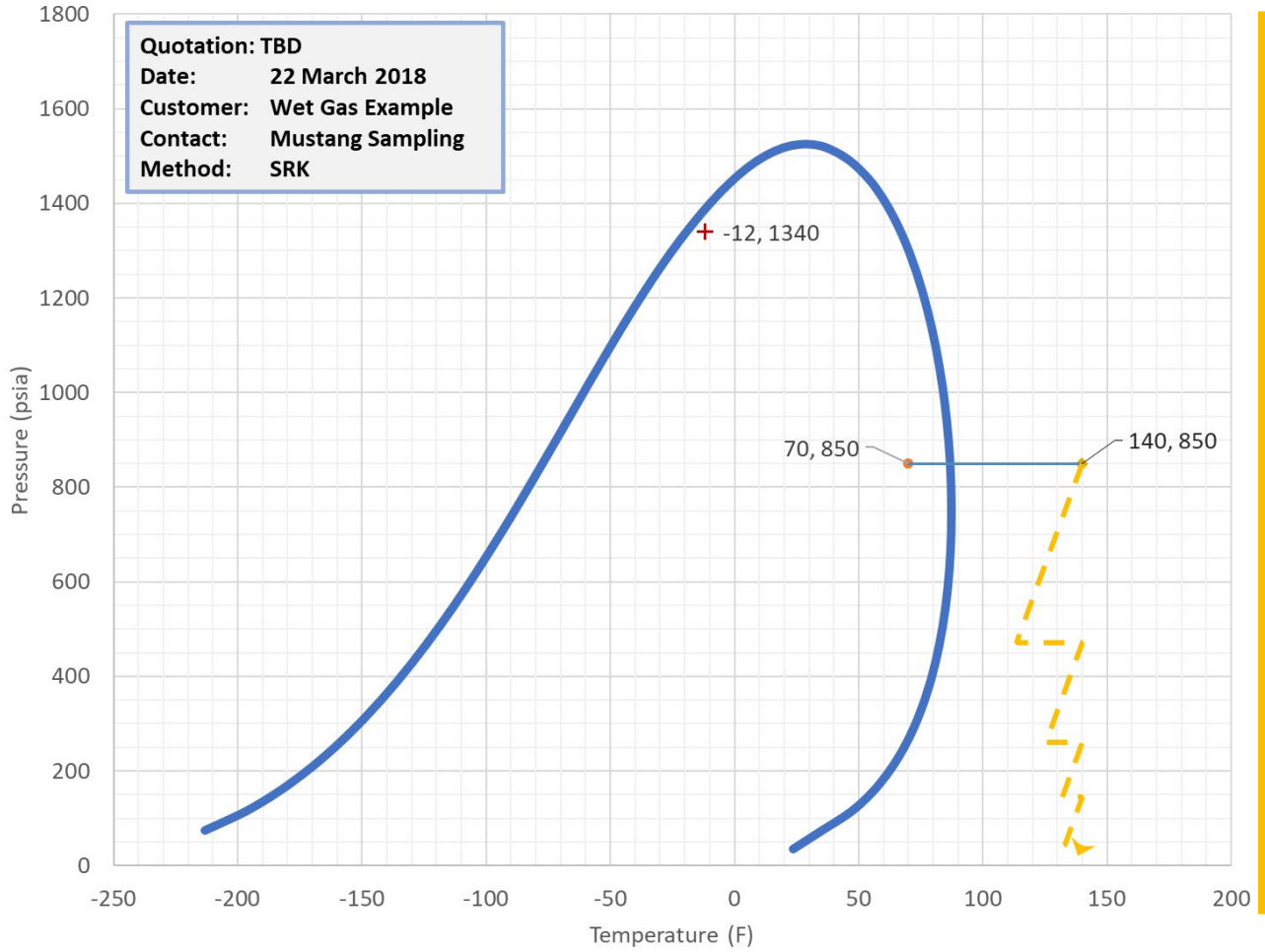
No.	Name	Formula	Molar %
1	Methane	CH4	95.1223
2	Ethane	C2H6	3.2142
3	Carbon Dioxide	CO2	0.8215
4	Nitrogen	N2	0.5663
5	Propane	C3H8	0.1977
6	n-Butane	C4H10	0.0263
7	Isobutane	C4H10	0.02385
8	Isopentane	C5H12	0.00885
9	n-Hexane	C6H14	0.00809
10	n-Pentane	C5H12	0.00536
11	n-Heptane	C7H16	0.00405
12	n-Octane	C8H18	0.00135

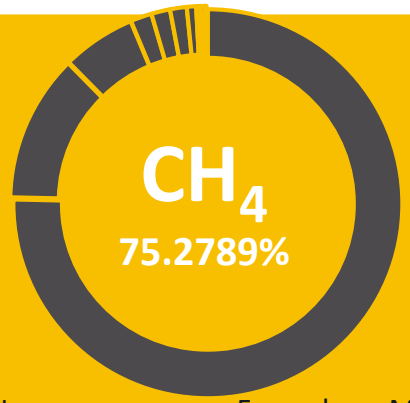
Phase Curve – Wet Gas

Mustang Sampling®

Phase Curve with Vaporizer and Mustang® Heated Joule-Thomson Regulator at 140° F

- Sample point
- Critical point
- Mustang Sampling Point





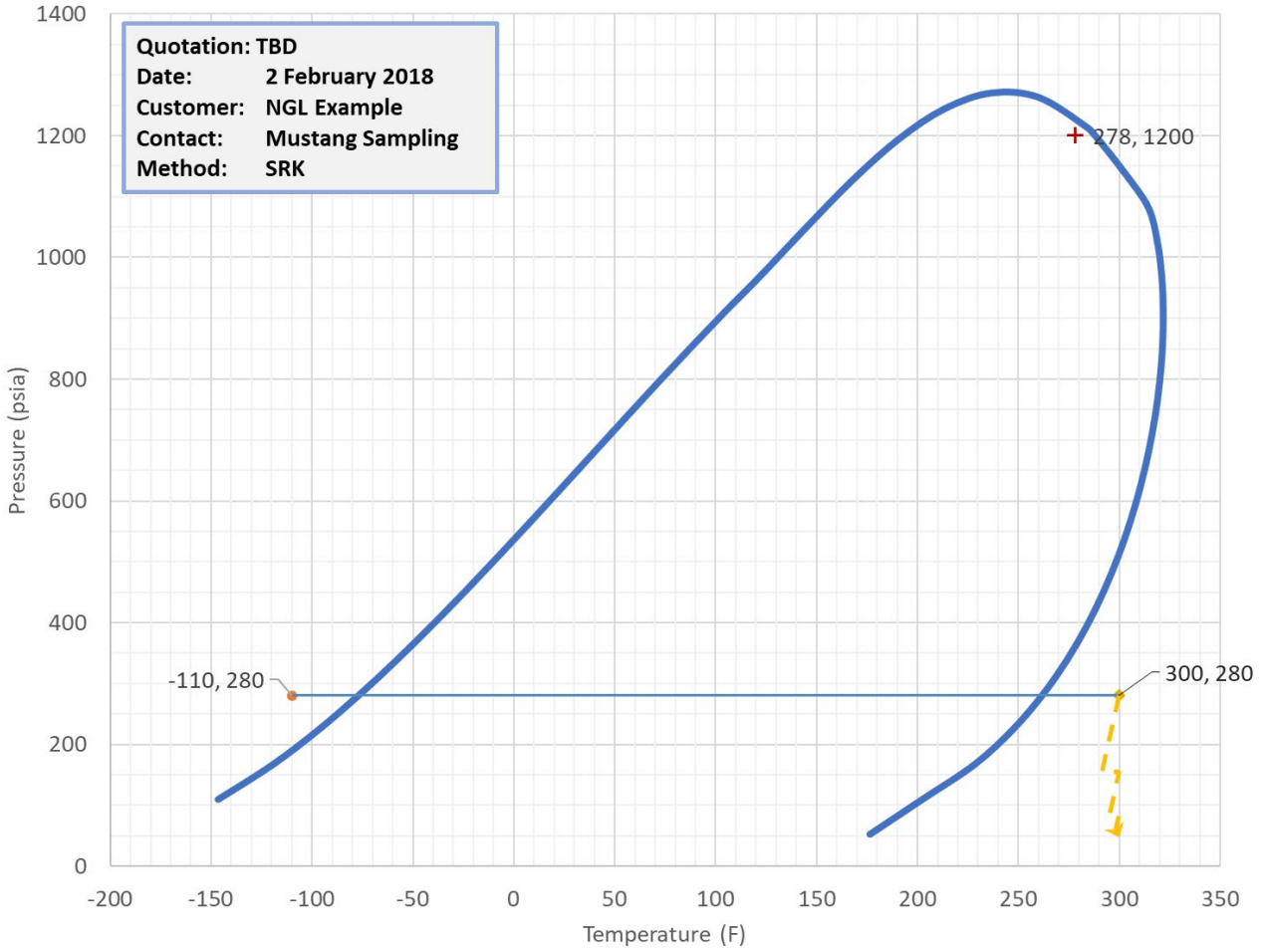
No.	Name	Formula	Molar %
1	Methane	CH4	75.2789
2	Ethane	C2H6	12.2447
3	Propane	C3H8	6.0996
4	n-Butane	C4H10	1.7576
5	Carbon Dioxide	CO2	1.5436
6	Nitrogen	N2	1.3748
7	Isobutane	C4H10	0.7644
8	Isopentane	C5H12	0.354
9	n-Pentane	C5H12	0.354
10	n-Hexane	C6H14	0.00536
11	n-Heptane	C7H16	0.0834
12	n-Octane	C8H18	0.0429

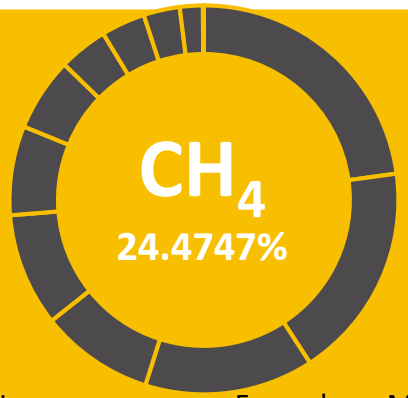
Phase Curve – Natural Gas Liquids

Mustang Sampling®

Phase Curve with Vaporizer and Mustang® Heated Joule-Thomson Regulator at 300° F

- Sample point
- Critical point
- Mustang Sampling Point

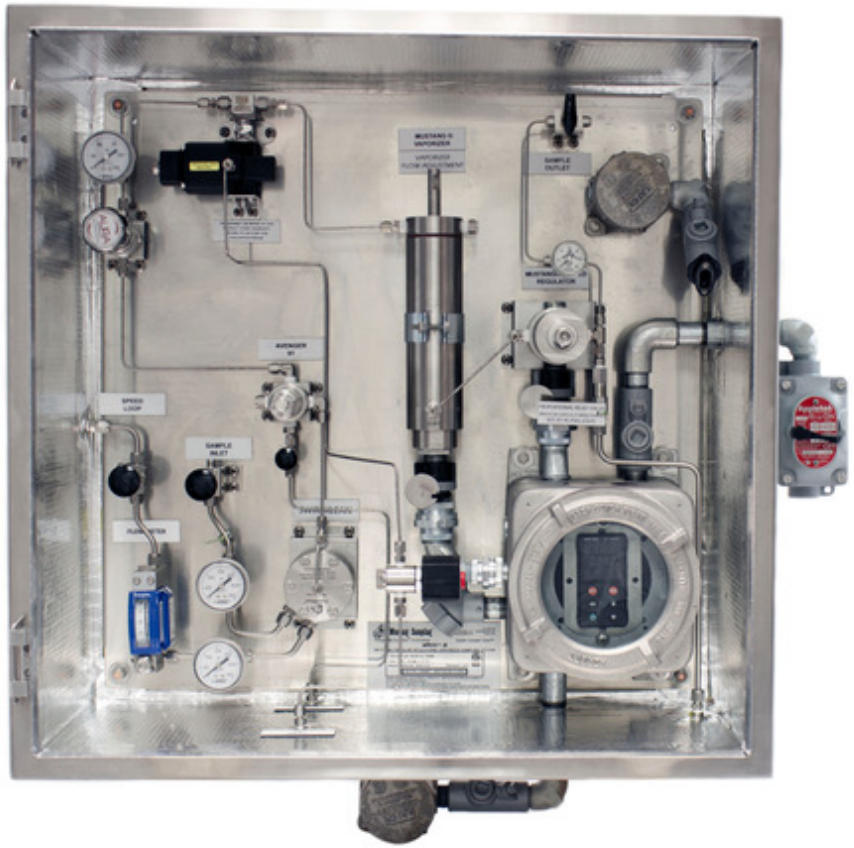




No.	Name	Formula	Molar %
1	Methane	CH4	24.4747
2	Propane	C3H8	19.2648
3	Ethane	C2H6	15.0653
4	n-Hexane	C6H14	10.1277
5	n-Butane	C4H10	10.0901
6	Hydrogen Sulfide	H2S	7.95
7	n-Heptane	C7H16	6.5355
8	n-Pentane	C5H12	4.3673
9	Isopentane	C5H12	3.9252
10	Isobutane	C4H10	3.2224
11	Carbon Dioxide	CO2	2.0488
12	Nitrogen	N2	0.0652
13	Water	H2O	0.0241

NGL Sample Conditioning

- Vaporization is necessary for heavy or liquid samples
  - Boiling point determines requirement
  - Line between liquid and vapor not clear
- Required temperature may exceed limits of equipment in some cases
- Sample points may not be ideal
  - Sample point often inside two phase envelope
  - Liquid volume fractions fluctuate widely near critical points



Mustang® Vaporizer – MV™

The Mustang Vaporizer (MV) flash vaporizes liquid samples for introduction into gas analysis systems. Liquid samples are maintained near line conditions until reaching a flash chamber within the vaporizer, preventing pre-vaporization. The energy for vaporization is provided by an electric cartridge heater with sufficiently large surface area to maintain a stable gas temperature throughout the process.

- Thermal cutoff
- Versatile conduit connections
- Integral heater and controller
- Integral flow restrictor on inlet

Mustang Vacuum Jacketed Tubing – VJT®

This highly efficient design of the Mustang Vacuum Jacketed tubing utilizes multilayered material within a vacuum-sealed space for efficient insulation of the inner liquid transfer line.

Non-conductive spacers are utilized for the inner line which reduces heat transfer. This flexible stainless steel tubing is custom-designed to meet individual project needs for inner pipe size and overall length. Flow and various application requirements are considered with each engineered unit for continuity of quality.

- Multi-layered insulation
- Non-conductive spacers
- Flexible stainless steel tubing
- Patented gas-line probe adapter for connecting vacuum jacketed tubing

Mustang Certiprobe® Threaded Sample Extractor

The threaded Mustang Certiprobe is the initial access point for a sampling system within a natural gas, natural gas liquid, chemical process, or biogas pipeline or vessel. The Certiprobe is available in a variety of lengths, materials, and pressure ratings to accommodate a wide range of applications in threaded configurations.

The Certiprobe sample extractor design includes Nondestructive Examination (NDE) of Positive Material Identification (PMI) and Dye Penetrant Inspection (DPI) for all welds. Stress analysis is performed, using pipeline conditions, prior to pipeline installation.

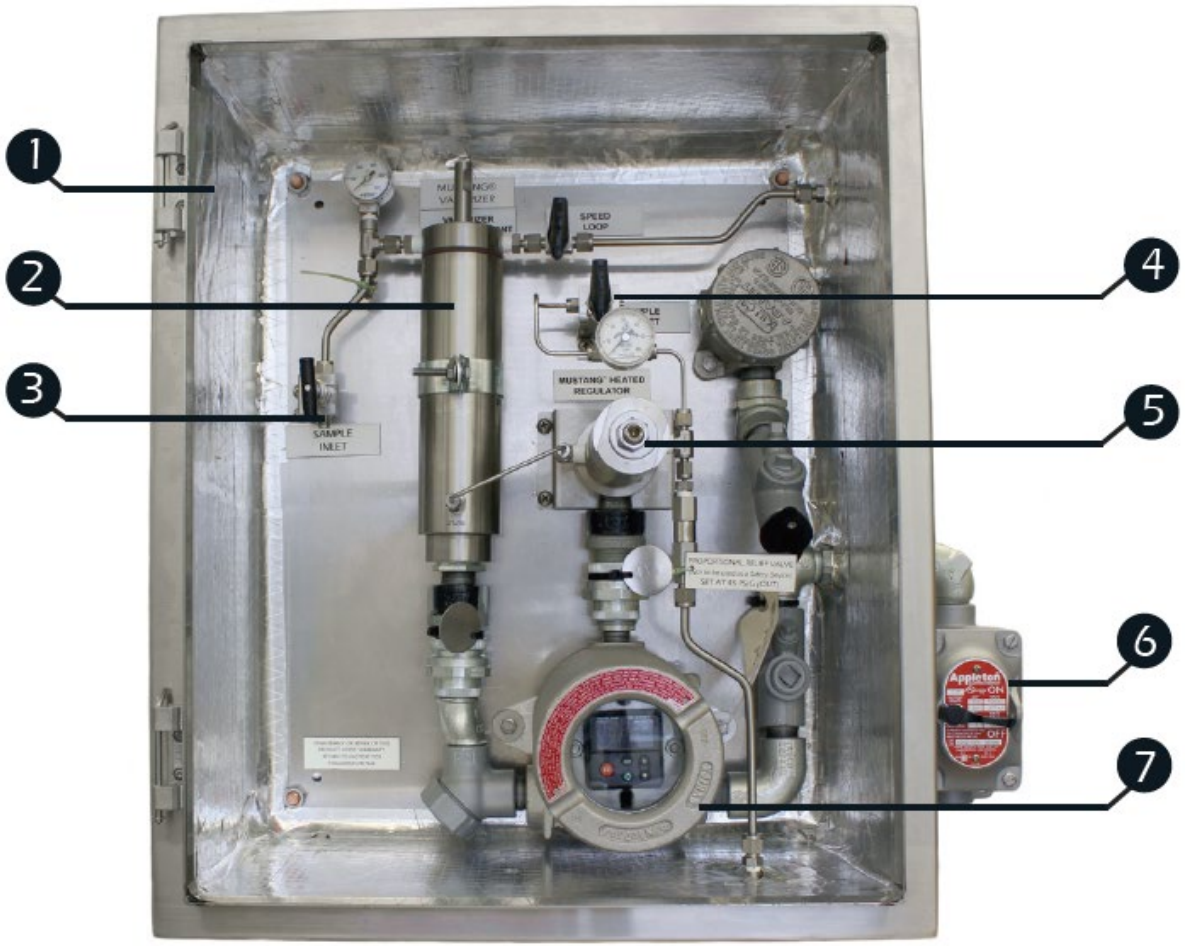
- Customer-specified metallurgy & rating
- Includes NDE, Dye Penetrant (PT),
- Hydrotest, and PMI (if requested)
- Threaded design
- Large bore diameter
- Designed for high velocity gas stream

Mustang® NGL Sample Conditioning System – MNGL®

Mustang Sampling®

SINGLE TEMPERATURE CONTROLLER

Item Number	Description
1	Stainless Steel Insulated Enclosure
2	Mustang® Vaporizer
3	Sample Inlet (from process)
4	Sample Outlet (to analyzer(s))
5	Single or Multi-Stage Mustang® Heated Regulator
6	Power Switch
7	PID Temperature Controller

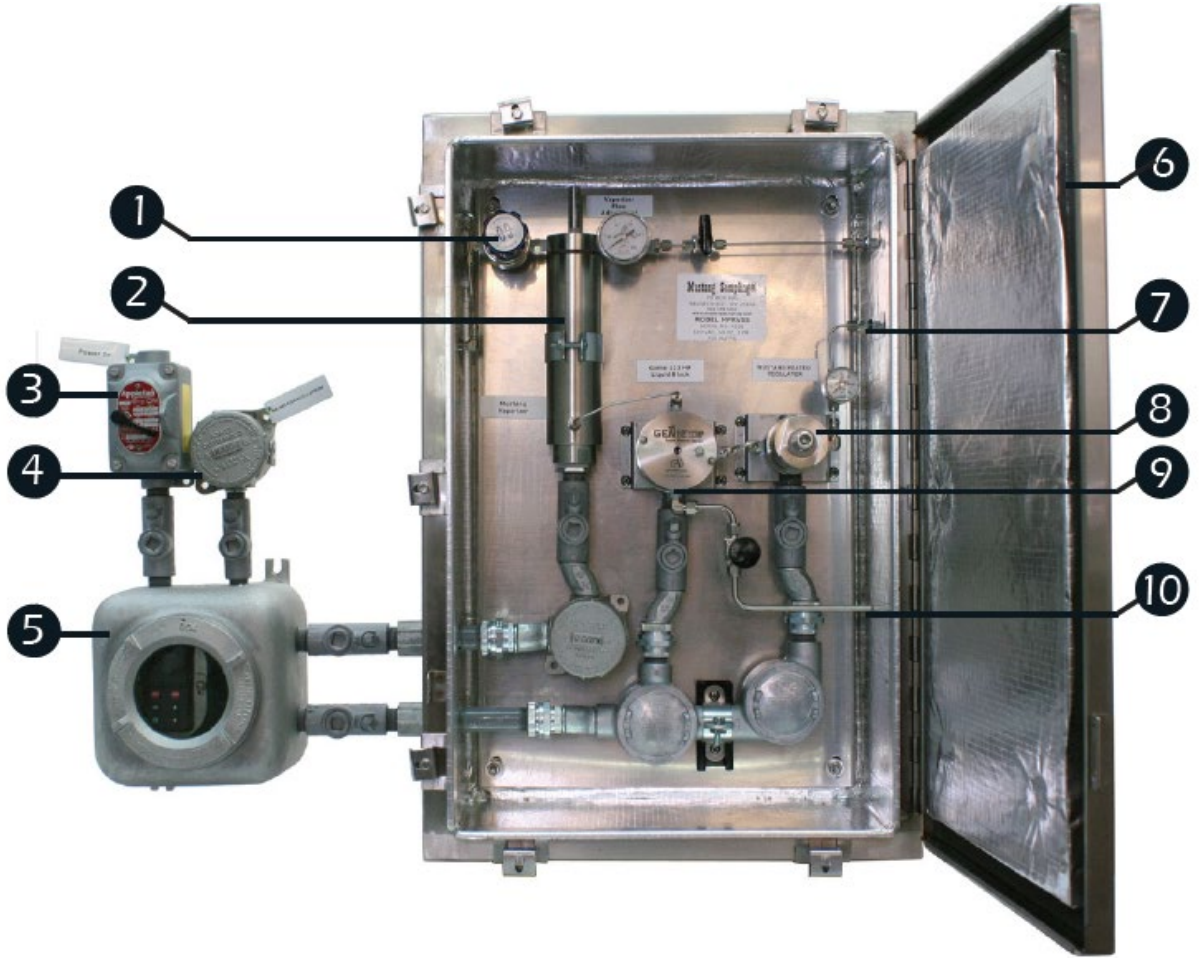


Mustang® NGL Sample Conditioning System – MNGL®

Mustang Sampling®

DUAL TEMPERATURE CONTROLLER

Item Number	Description
1	Manual Liquid Pressure Regulator
2	Single Path Mustang® Vaporizer
3	Power Switch
4	RS-485 Communications
5	Dual PID Temperature Controller
6	Stainless Steel Insulated Enclosure
7	Sample Outlet
8	Single or Multi-Stage Mustang® Heated Regulator
9	Heated Liquid Block
10	Drain

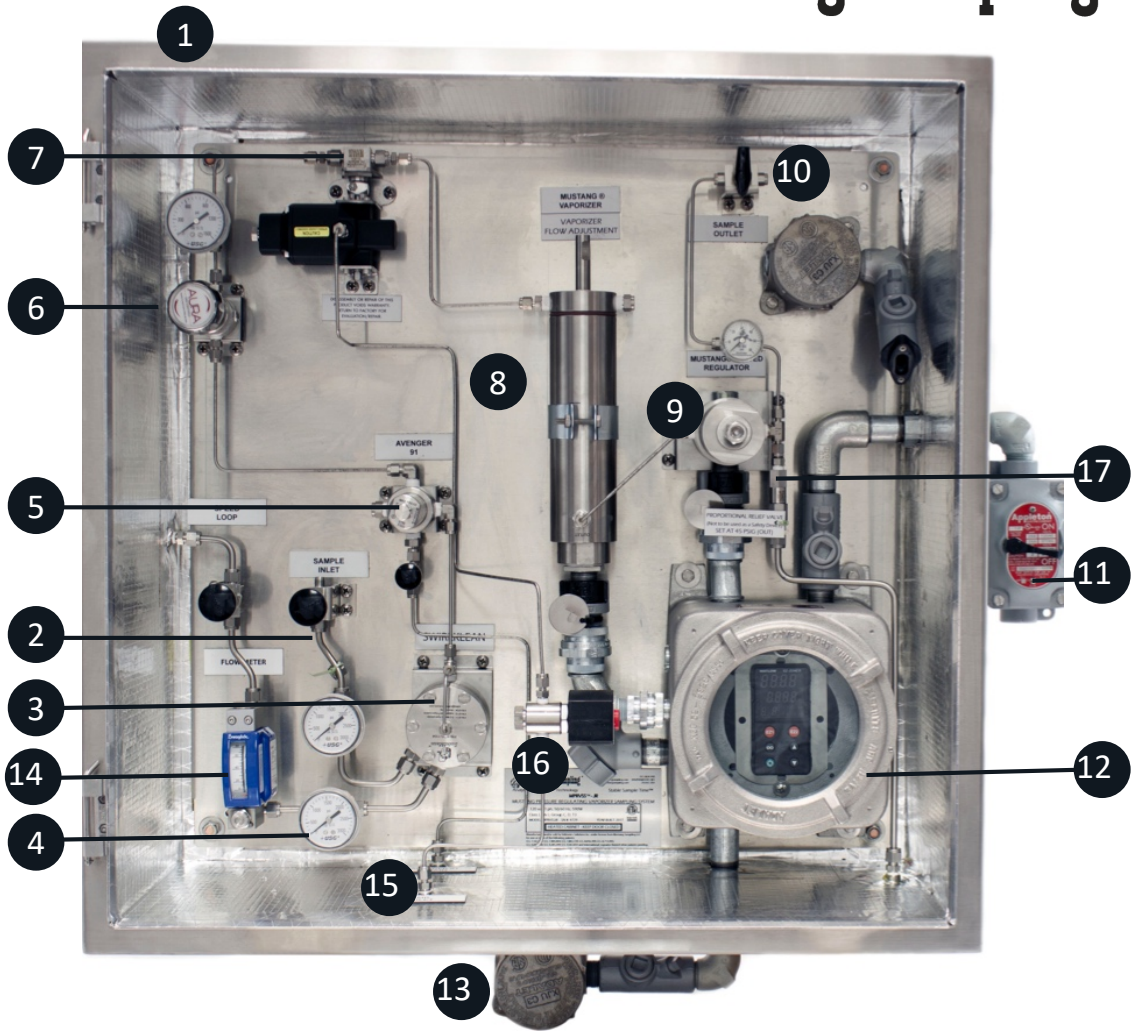


Mustang® NGL Sample Conditioning System – MNGL®

DUAL TEMPERATURE CONTROLLER with FILTRATION & SHUT DOWN

#	Description
1	Stainless Steel Insulated Enclosure
2	Sample Inlet (from process)
3	Particulate Filter
4	Filter Drain to Speed Loop
5	Coalescing Filter
6	Manual Liquid Regulator
7	Shut-off Valve
8	Single Path Mustang Vaporizer
9	Single or Multi-stage Mustang Heated Regulator

#	Description
10	Sample Outlet (to analyzer)
11	Power Source Switch
12	Dual PID Temperature Controller
13	Communications Port
14	Armored Flow Meter
15	Liquid Drain
16	Thermal Shut-off Valve
17	Relief Valve



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NGL Specification (Y-Grade)

Mustang Sampling®

Lone Star NGL Pipeline LP
Lone Star NGL Mont Belvieu LP
Lone Star NGL Fractionators LLC

Version: November 16, 2012

Y-GRADE PRODUCT SPECIFICATIONS

Acceptable Y-Grade shall be a mixture of constituents or component products of natural gas liquids (NGLs) composed principally of ethane, propane, butane and natural gasolines, meeting the following product specifications:

CHARACTERISTIC	PRODUCT SPECIFICATIONS	TEST METHOD
Composition: Methane, maximum Aromatics, maximum Olefins, maximum	 See Note 1 See Note 2 1.0 L.V. %	 GPA 2177 GPA 2186 GPA 2186
Carbon Dioxide: PPM by Volume in Liquid	500 maximum	GPA 2177
Vapor Pressure: psig at 100° F	600 maximum	ASTM D-6378
Corrosiveness: Copper strip at 100° F	No. 1	ASTM D-1838
Total Sulfur: PPM by weight, maximum	150	ASTM D-2784
Hydrogen Sulfide: Pass/Fail	Pass	ASTM D-2420
Distillation: End point at 14.7 psia, maximum See Note 3	375.0° F	ASTM D-7344
Color: Saybolt Number, minimum See Note 3	+25.0	ASTM D-6045
Existing Gum: Washed Unwashed	 <=1mg/100ml <=1mg/100ml	ASTM D-381
Dryness: Free Water at 34° F	None	Visual Inspection
Product Temperature: Minimum Maximum	 60° F 100° F	

Note 1: Methane not to exceed either 0.5 L.V. % of the total stream or 1.5 L.V. % of the ethane content. For accounting purposes a maximum of 1.5 L.V. % methane in the ethane will be considered ethane. Any excess above this specification shall not be accounted for.

Note 2: Aromatics not to exceed either 1.0 wt. % in the total stream or 10 L.V. % in contained natural gasoline

Note 3: Distillation and Color to be run on that portion of the mixture having a boiling point of 70° F and above at atmospheric pressure.

General Contaminants Note: The Y-Grade shall be commercially free from sand, dust, gums, gum-producing substances, oil, glycol, inhibitors, amine, caustics, chlorides, oxygenates, heavy metals, any other contaminants that make it unfit for its commonly used applications and any compound added to the product to enhance the ability to meet these specifications.

Abbreviations: ASTM = American Society for Testing and Materials, Standard Test Procedures; **° F** = Degrees Fahrenheit; **GPA** = Gas Processors Association; **L.V. %** = liquid volume percent; **mg** = milligrams; **ml** = milliliters; **PPM** = Parts per Million; **psia** = pounds per square inch absolute; **wt. %** = percentage by weight.

The aforementioned specifications may be modified from time to time in the sole discretion of the issuing entity.

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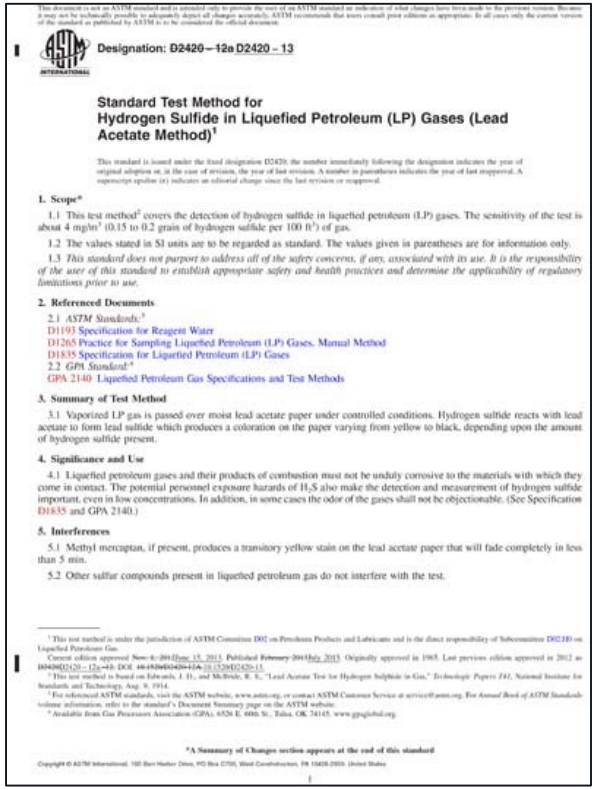
Vapor Pressure: psig at 100° F	600 maximum	ASTM D-6378
Corrosiveness: Copper strip at 100° F	No. 1	ASTM D-1838
Total Sulfur: PPM by weight, maximum	150	ASTM D-2784
Hydrogen Sulfide: Pass/Fail	Pass	ASTM D-2420
Distillation: End point at 14.7 psia, maximum See Note 3	375.0° F	ASTM D-7344
Color: Saybolt Number, minimum See Note 3	+25.0	ASTM D-6045

Standards for NGL Measurement

Combination of API, GPA, & ASTM Standards



Designation: D2420 – 12a D2420 – 13

Standard Test Method for
Hydrogen Sulfide in Liquefied Petroleum (LP) Gases (Lead Acetate Method)[1]

1. Scope*

1.1 This test method[2] covers the detection of hydrogen sulfide in liquefied petroleum (LP) gases. The sensitivity of the test is about 4 mg/m³ (0.15 to 0.2 grain of hydrogen sulfide per 100 ft³) of gas.

1.2 The values stated in SI units are to be regarded as standard. The values given in parentheses are for information only.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[3]
D1193 Specification for Reagent Water
D1265 Practice for Sampling Liquefied Petroleum (LP) Gases, Manual Method
D1835 Specification for Liquefied Petroleum (LP) Gases
2.2 *GPA Standard:*[4]
GPA 2140 Liquefied Petroleum Gas Specifications and Test Methods

3. Summary of Test Method

3.1 Vaporized LP gas is passed over moist lead acetate paper under controlled conditions. Hydrogen sulfide reacts with lead acetate to form lead sulfide which produces a coloration on the paper varying from yellow to black, depending upon the amount of hydrogen sulfide present.

4. Significance and Use

4.1 Liquefied petroleum gases and their products of combustion must not be unduly corrosive to the materials with which they come in contact. The potential personnel exposure hazards of H_2S also make the detection and measurement of hydrogen sulfide important, even in low concentrations. In addition, in some cases the odor of the gases shall not be objectionable. (See Specification D1835 and GPA 2140.)

5. Interferences

5.1 Methyl mercaptan, if present, produces a transitory yellow stain on the lead acetate paper that will fade completely in less than 5 min.

5.2 Other sulfur compounds present in liquefied petroleum gas do not interfere with the test.

*A Summary of Changes section appears at the end of this standard

Technical Publication
TP-31

GPA 2261 and GPA 2177 Methods
Precision Statements Calculation

Gas Processors Association

Obtaining Liquid Hydrocarbons Samples
For Analysis by Gas Chromatography

Designation: D 1266 – 98 (Reapproved 2003)ε1

Designation: 107/86

Standard Test Method for
Sulfur in Petroleum Products (Lamp Method)[1]

1. Scope

1.1 This test method covers the determination of total sulfur in liquid petroleum products in concentrations from 0.01 to 0.4 mass % (Note 1). A special sulfate analysis procedure is described in Annex A1 that permits the determination of sulfur in concentrations as low as 5 mg/kg.

2. Referenced Documents

3. Summary of Test Method

Outline

Mustang Sampling®

- Introduction to Mustang Sampling®
- Global Energy & North America Natural Gas Landscape
- Determination and Product Analysis
  - Composition of Natural Gas Mixtures
  - Composition of Natural Gas Liquid Mixtures
- Standards for NGL
- Closing Comments

Mustang Sampling®

THANK YOU.