

TRACE HYDROCARBONS IN HYDROGEN, HYDROCARBON GASES, OR LPG BY GC

UOP™ Method 899-04

SCOPE

This method is for determining individual trace C₅ minus hydrocarbon impurities in hydrogen or liquefied petroleum gas (LPG), where the specific trace components are sufficiently resolved from the major components, typically propane/propylene or ethane/ethylene. Components eluting after ethyl acetylene are grouped and reported as heavies. The range of quantitation for each component is 2 to 3000 mol- (or mass-) ppm; however, the lower limit of quantitation increases when major components interfere with the resolution of the impurities.

REFERENCES

- ASTM Practice D 1265, "Sampling Liquefied Petroleum (LP) Gases (Manual Method)," www.astm.org
- ASTM Practice D 5287, "Automatic Sampling of Gaseous Fuels," www.astm.org
- Scanlon, J. T. and Willis, D. E., *Journal of Chromatographic Science*, **23**, 333-340 (1985)
- UOP™ Method 516, "Sampling and Handling of Gasolines, Distillate Fuels, and C₃-C₄ Fractions," www.astm.org
- UOP Method 999, "Precision Statements in UOP Methods," www.astm.org

OUTLINE OF METHOD

A reproducible volume of gas sample is injected into a gas chromatograph equipped with an alumina PLOT (porous layer open tubular) capillary column, a capillary injection port, a flame ionization detector (FID), and a gas or LPG sampling valve. An LPG sample may be expanded and analyzed as a vapor, or analyzed directly in the liquid phase (see *NOTE*). The concentrations of the hydrocarbon impurities are determined by the external standard method of quantitation, wherein peak areas are compared to the area of a calibration blend containing a known concentration of isobutane. For

IT IS THE USER'S RESPONSIBILITY TO ESTABLISH APPROPRIATE PRECAUTIONARY PRACTICES AND TO DETERMINE THE APPLICABILITY OF REGULATORY LIMITATIONS PRIOR TO USE. EFFECTIVE HEALTH AND SAFETY PRACTICES ARE TO BE FOLLOWED WHEN UTILIZING THIS PROCEDURE. FAILURE TO UTILIZE THIS PROCEDURE IN THE MANNER PRESCRIBED HEREIN CAN BE HAZARDOUS. MATERIAL SAFETY DATA SHEETS (MSDS) OR EXPERIMENTAL MATERIAL SAFETY DATA SHEETS (EMSDS) FOR ALL OF THE MATERIALS USED IN THIS PROCEDURE SHOULD BE REVIEWED FOR SELECTION OF THE APPROPRIATE PERSONAL PROTECTION EQUIPMENT (PPE).

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For samples containing C₅ olefins, a second analysis, under a different column temperature program, is necessary to resolve methyl acetylene from an interfering C₅ olefin.

APPARATUS

References to catalog numbers and suppliers are included as a convenience to the method user. Other suppliers may be used except as noted.

Chromatographic column, 50 m of 0.53-mm ID PLOT fused silica capillary, internally coated to a film thickness of 9-μm with alumina (GS-Alumina), J&W Scientific, Cat. No. 115-3552. Columns from other suppliers, commonly called Al₂O₃/Na₂SO₄, provide similar separation but may not be quantitative for diolefins and acetylenes, and their use is not recommended when analysis of these components is necessary.

Gas chromatograph, capable of temperature ramping, equipped with electronic pressure control, built for capillary column chromatography utilizing a split injection system, having a glass injection port insert, a heated valve box, and an FID that will give a minimum peak height response of 5 times the background noise for 2 mol-ppm of isobutane when operated at the recommended conditions, Agilent Technologies, Model 6890

Injection apparatus, gas, for injection of gas or expanded LPG samples, see Figure 1:

Fitting, internal union, for connecting injection port to 6-port sampling valve, Valco Instruments, Cat. No. ZU1T

Valve, 6-port, stainless steel, 1.59-mm (0.0625-inch) fittings, manual with standoff, Valco Instruments, Cat. No. C6UWE

Sample loop, stainless steel, 100-μL, Valco Instruments, Cat. No. SL100CUW

Tubing, stainless steel, 1.6-mm (1/16-inch) OD, 0.76-mm (0.30-inch) ID, Alltech Associates, Cat. No. 300010

Injection apparatus, LPG, for injection of LPG samples in the liquid phase, see Figure 2:

Fitting, CGA, for blend cylinder, CGA No. 510, Matheson Gas Products

Fitting, internal union, for connecting injection port to 4-port sampling valve, Valco Instruments, Cat. No. ZU1T

Fitting, reducing union, 3.2-mm (1/8-inch) to 1.6-mm (1/16-inch), Swagelok, Cat. No. SS-200-6-1

Tubing, stainless steel, 1.6-mm (1/16-inch) OD, 0.76-mm (0.30-inch) ID, Alltech Associates, Cat. No. 300010

Tubing, translucent, FEP Teflon, 3.2-mm (1/8-inch) OD, 1.6-mm (0.062-inch) ID, 3450 kPa (500 psig), Alltech Associates, Cat. No. 45740

Valve, 4-port, stainless steel, 0.5-μL internal sample volume, 1.59-mm (0.0625-inch) fittings, manual with standoff, Valco Instruments, Cat. No. CI4UWE.5

Valve, vent shut-off, Swagelok, Cat. No. SS-ORS2

Integrator, or data system, electronic, for obtaining peak areas. This device must integrate areas at a sufficiently fast rate so that the narrow peaks typically resulting from use of a capillary column can be accurately measured. ChemStation, Agilent Technologies.

LPG expansion apparatus, for quantitative expansion of LPG from a liquid to a gas phase, see Figure 3:

Fitting, male connector, stainless steel, 0.25-inch tube fitting to 0.25-inch male NPT, Swagelok, Cat. No. SS-400-1-4. Sample cylinders having an outlet fitting other than 0.25-inch female NPT will require a different fitting.

Fitting, port connector, stainless steel, 0.25-inch tube fitting, Swagelok, Cat. No. SS-401-PC, 2 required

Fitting, union tee, stainless steel, 0.25-inch, Swagelok, Cat. No. 400-3

Tubing, stainless steel, Type 304, 0.25-inch OD x 0.210-inch ID, Alltech Associates, Cat. No. 30301

Vacuum pump, capable of achieving a vacuum of 0.1-mm Hg, Fisher Scientific, Cat. No. 01-115-2

Valve, stainless steel, 0.25-inch, Swagelok, Cat. No. SS-1RS4

LPG expansion cylinder, sample cylinder for containing expanded LPG sample:

Cylinder, 4- x 6-inch, 316 stainless steel, 1380 kPa (200 psi) internal pressure, double connection, 0.25-inch pipe hex bored through, Arthur Harris, Cat. No. B-270

Fitting, hex nipple, stainless steel, 0.25-inch NPT, Swagelok, Cat. No. SS-4-HN, 3 required

Fitting, tee, stainless steel, 0.25-inch NPT, Swagelok, Cat. No. SS-4-T

Gauge, stainless steel, vacuum-pressure, -100 to +200 kPa gauge (-15 to +30.0 psig) range, Matheson Gas Products, Cat. No. 63-2204

Valve, stainless steel, 0.25-inch NPT inlet, 0.25-inch tube fitting outlet, Whitey, Swagelok, Cat. No. SS-1RM4-S4, 2 required

Regulator, air, two-stage, high purity, delivery pressure range up to 690 kPa (100 psi), Matheson Gas Products, Model 3122-590

Regulator, helium, two-stage, high purity, delivery pressure range up to 690 kPa (100 psi), Matheson Gas Products, Model 3122-580

Regulator, hydrogen, two-stage, high purity, delivery pressure range up to 690 kPa (100 psi), Matheson Gas Products, Model 3122-350

Regulator, nitrogen, two-stage, high purity, delivery pressure range up to 690 kPa (100 psi), Matheson Gas Products, Model 3122-580

REAGENTS AND MATERIALS

References to catalog numbers and suppliers are included as a convenience to the method user. Other suppliers may be used.

Air, zero-gas, total hydrocarbons less than 2 ppm as methane

Calibration blend, gas, quantitative, primary standard, to contain from 250 to 500 mol-ppm isobutane in helium, Matheson Gas Products

Calibration blend, LPG, quantitative, primary standard, to contain from 250 to 500 mass-ppm isobutylene in *n*-butane, in cylinder with eductor tube, Matheson Gas Products

Gas purifier, helium, used to remove oxygen and moisture from carrier gas, Mat/Sen, Cat. No. P-100-1

Helium, zero-gas, total hydrocarbons less than 0.5 ppm as methane

Hydrogen, zero-gas, 99.95% minimum purity, total hydrocarbons less than 0.5 ppm as methane

Nitrogen, zero-gas, 99.99% minimum purity, total hydrocarbons less than 0.5 ppm as methane

Tape, Teflon, thread seal, Fisher Scientific, Cat. No. 14-831-300B

PROCEDURE

Sampling

Obtain the sample by following the procedures described in ASTM Practice D 1265, "Sampling Liquified Petroleum (LP) Gases (Manual Method)," ASTM Practice D 5287, "Automatic Sampling of Gaseous Fuels," UOP Method 516, "Sampling and Handling of Gasolines, Distillate Fuels, and C₃-C₄ Fractions," or other reliable technique.

Chromatographic Technique

The analyst is expected to be familiar with the technique of gas chromatography and the equipment being used.

Quantitative results are based on the injection of a reproducible volume of both sample and calibration blend.

1. Install the gas purifier in the supply line between the carrier gas source and the carrier gas inlet on the gas chromatograph.
 - Column life is significantly reduced if the gas purifier is not used.
2. For gas phase analysis, install the 6-port gas sampling valve in the valve box of the instrument and the fused silica capillary column as shown in Figure 1. For liquid phase analysis, install the 4-port LPG sampling valve external to the GC near the split injection system. Connect the related apparatus as shown in Figure 2.
3. Establish the recommended operating conditions as given in Table 1.
 - For samples containing C₅ olefins, a second analysis, under a different column temperature program, is necessary to resolve methyl acetylene from an interfering C₅ olefin.
 - Other conditions may be used provided they produce the required sensitivity and chromatographic separations equivalent to those shown in the Typical Chromatogram, Figure 4.

Table 1
Recommended Operating Conditions

	<u>Standard Conditions</u>	<u>Modified for Methyl acetylene</u>
Carrier gas	helium	
Column head pressure @ 35°C, constant flow mode	70 kPa (10 psig)	
Equivalent flow	10 mL/min	
Equivalent linear velocity	59 cm/sec	
Split flow rate	150 mL/min	
Injection port temperature	200°C	
Valve box temperature	100°C	
Electronic pressure control	constant flow on	
Column temperature program		
Initial temperature	35°C	100°C
Initial time	2 min	17 min
Programming rate	10°C/min	10°C/min
Final temperature	190°C	190°C
Final time	10 min	19 min
Detector	FID	
Detector temperature	200°C	
Hydrogen flow rate*	30 mL/min	
Air flow rate*	350 mL/min	
Makeup gas	nitrogen	
Makeup gas flow rate*	30 mL/min	
Sample size, gas phase	100µL repeatable	
Sample size, liquid phase	0.5µL repeatable	

*Consult the manufacturer's instrument manual for suggested flow rates.

4. Condition the column according to the manufacturer's instructions.
5. Cool the column oven to a stabilized initial temperature of 35°C.
6. Proceed to Step 7 if the sample is in the gas phase. If not, LPG must be carefully expanded into the gas phase to ensure that a representative sample is analyzed. Proceed to *LPG Sampling, gas phase analysis*. Alternatively, LPG may be injected as a liquid following the procedure in *LPG Sampling, liquid phase analysis*.
7. Set the gas sampling valve in the sample purge position. Purge the sample loop with the sample to be analyzed for approximately one minute. Turn off the sample purge, allow several seconds for the pressure to equilibrate and inject the sample by rotating the gas sampling valve to the inject position.
8. Start the integrator and the column temperature programming sequence.

9. Identify the components of interest by comparing the chromatogram obtained to the Typical Chromatograms (Figures 4 and 5).
 - The PLOT columns will overload easily, which causes retention times to shift, and, depending upon component concentrations, some very large components will mask smaller ones. Care should be taken when identifying these components. A typical chromatogram of an expanded LPG sample containing some high concentration level components is included for reference (Figure 5).
 - Neopentane elutes between 1-butene and isobutylene. In high concentrations it will interfere with the 1-butene. A C₅ olefin, if present, co-elutes at the methyl acetylene site. If C₅ olefins could be present in the sample, reanalyze the sample for methyl acetylene only using the modified operating conditions listed in Table 1. A typical chromatogram is shown in Figure 6. The instrument must be recalibrated under these conditions. C₅ olefins and C₆ hydrocarbons, if present, may also cause interference at the vinyl acetylene and ethyl acetylene sites. Prepare or purchase qualitative blends containing the relevant compounds, analyze them, and adjust instrument conditions so as to eliminate the interferences.
10. Sum the peak areas of the unidentified components eluting after ethyl acetylene to obtain the peak area of the heavies composite.

LPG Sampling, for gas phase analysis

LPG must be carefully expanded to ensure that a representative sample is analyzed. Various procedures are used to quantitatively expand LPG from a liquid phase into a representative gas phase prior to analysis. The following is the recommended procedure that has been proved to be satisfactory.

1. Assemble the LPG expansion cylinder consisting of a small stainless steel expansion cylinder, a stainless steel gauge with a reading range from vacuum to 200 kPa gauge and two stainless steel shut-off valves (see Figure 3).
 - Some expansion cylinders have two valves (C and D) as shown in Fig. 3, some have only one (Valve C). The version shown in Figure 3 is easier to clean, but either may be used.
2. Connect the apparatus to the vacuum system and evacuate the cylinder assembly to 0.013 kPa (0.1-mm Hg).
3. Connect two small pieces of clean stainless steel tubing, a tee and valve B to the evacuated cylinder as shown in Figure 3 (LPG Expansion Apparatus).
4. Place the LPG sample cylinder in a vertical position in a hood or well-vented area. If the cylinder has an outage tube, the outage tube must be at the top. Briefly open the bottom valve (A) to check that no water or sediment is present in the LPG. If water or sediment is determined to be present, discontinue the analysis and obtain a clean sample.
 - LPG samples are usually contained in a cylinder having valves on both ends or, in some cases, a cylinder where one of the valves is connected to an eductor tube. If the sample cylinder contains an eductor tube, invert the cylinder (both valves on the bottom) and briefly open the valve not connected to the eductor tube to check that no water or sediment is present.
5. Connect the bottom valve or the valve connected to the eductor tube of the LPG sample cylinder with a stainless steel tubing connector to the expansion apparatus. Fully open Valve B in Figure 3.
 - The exact length of the connecting tubing to be used is determined in Step 8, below. A 25-cm length is a good starting point.
6. Rapidly open Valve A, about 1/4 turn, on the sample cylinder until only liquid comes out of Valve B. *Important:* The valve must be opened wide enough so that a portion of liquid sample

enters the stainless steel tubing before it vaporizes. Fractionation must not take place at the valve, or the composition of the sample will change.

7. Close Valve B and then Valve A and open Valve C (Fig. 3).
8. Close Valve C on the apparatus and disconnect the LPG Expansion Cylinder from the apparatus. A positive pressure of 70 to 100 kPa gauge (10 to 15 psig) should be displayed on the expansion cylinder gauge. If not, repeat Steps 1 through 8 with a longer or shorter piece of stainless steel tubing in the expansion apparatus. The cylinder now contains a gas phase sample that is representative of the LPG sample in the original pressurized cylinder.
9. Inject the expanded sample following Steps 7 through 10 under *Chromatographic Technique*.

LPG Sampling, for liquid phase analysis

1. Place the LPG sample cylinder in a vertical position in a hood or well-vented area. If the cylinder has an outage tube, the outage tube must be at the top. Briefly open the bottom valve to check that no water or sediment is present in the LPG. If water or sediment is determined to be present, discontinue the analysis and obtain a clean sample.
 - LPG samples are usually contained in a cylinder having valves on both ends or, in some cases, a cylinder where one of the valves is connected to an eductor tube. If the sample cylinder contains an eductor tube, invert the cylinder (both valves on the bottom) and briefly open the valve not connected to the eductor tube to check that no water or sediment is present.
2. Pressurize the LPG cylinder containing the sample to approximately 1400 to 2000-kPa gauge (200 to 300-psig) with nitrogen or helium.
3. Mount the cylinder in a vertical position. If the cylinder has an outage tube, the outage tube must be at the top. Connect the bottom valve to the sample injector valve inlet tubing.
 - If the cylinder is fitted with an eductor tube, connect the eductor tube outlet to the sample injection inlet tubing in such a manner that the eductor tube is sampling liquid LPG.
 - The connecting tubing between the cylinder and the injector valve must be as short as possible.
4. Place the injection valve in the fill position.
5. Ensure that the vent shut-off valve is closed.
6. Fully open the bottom valve, or eductor valve, of the sample cylinder.
7. Partially open the vent shut-off valve to permit LPG flow through the sampling system.
8. Continue the flow until no entrained bubbles are observed through the translucent tubing.
 - **CAUTION:** Inspect the translucent tubing regularly. Replace at first signs of wear or kinking. Pressure on the translucent tubing must never exceed 2000 kPa (300 psig).
9. Stop the sample flow by closing the vent shut-off valve.
10. Inject the sample immediately by switching the inject valve to the inject position, and start the integrator and the column temperature programming sequence.
 - The injection valve remains in the inject position for the duration of the sample run.

11. Close the LPG cylinder valve and immediately open the vent shut-off valve to vent the sampling system.
12. Follow Steps 9 and 10 under *Chromatographic Technique*.

Calibration, gas phase analysis

Since it may be difficult to purchase and maintain a calibration blend that contains all components of interest, a blend containing a known concentration (250 to 500 mol-ppm) of isobutane in helium is used as a quantitative standard.

1. Analyze the quantitative standard, in triplicate, as described under *Chromatographic Technique* each time samples are analyzed. If the modified conditions for methyl acetylene resolution are also being used, perform a second calibration under these conditions.
2. Identify the isobutane peak and average the peak area from the triplicate runs.
 - Peak areas from each of the triplicate runs should not deviate from the average by more than 5% of the value. If greater deviations occur, make certain that there are no problems with the equipment, then make additional runs until the required repeatability is obtained on three consecutive runs.
3. Determine the response factor relating the mol-ppm concentration of isobutane in the calibration blend to unit peak area using Equation 1.

$$K = \frac{P}{A} \quad (1)$$

where:

- A** = average peak area of isobutane
K = response factor for isobutane
P = isobutane concentration in blend, mol-ppm

4. Determine the response factors relative to isobutane to relate the peak areas of the other hydrocarbon components to mol-ppm using Equation 2.

$$F = \frac{C}{D} \quad (2)$$

where:

- C** = molecular weight of isobutane, g/mole
D = molecular weight of the component of interest, g/mole
F = relative response factor for the component of interest

The molecular weight of *n*-hexane is used when calculating the factor for the heavies component. See Table 2 for examples of the calculated relative response factors.

Calibration, liquid phase analysis

Since it may be difficult to purchase and maintain a calibration blend that contains all components of interest, a blend containing a known concentration (250 to 500 mass-ppm) of isobutylene in *n*-butane is used as a quantitative standard.

Table 2
Calculated Mole Response Factors Relative to Isobutane

Methane	3.62	Neopentane	0.81
Ethane	1.93	Isobutylene	1.04
Ethylene	2.07	<i>cis</i> -2-Butene	1.04
Propane	1.32	Isopentane	0.81
Cyclopropane	1.38	<i>n</i> -Pentane	0.81
Propylene	1.38	1,2-Butadiene	1.07
Isobutane	1.00	1,3-Butadiene	1.07
<i>n</i> -Butane	1.00	Methyl acetylene	1.45
Propadiene	1.45	Vinyl acetylene	1.12
Acetylene	2.23	<i>n</i> -Hexane	0.67
<i>trans</i> -2-Butene	1.04	Ethyl acetylene	1.07
1-Butene	1.04		

1. Analyze the quantitative standard, in triplicate, as described under *Chromatographic Technique* each time samples are analyzed. If the modified conditions for methyl acetylene resolution are also being used, perform a second calibration under these conditions.
2. Identify the isobutylene peak and average the peak area from the triplicate runs.
 - Peak areas from each of the triplicate runs should not deviate from the average by more than 5% of the value. If greater deviations occur, make certain that there are no problems with the equipment, then make additional runs until the required repeatability is obtained on three consecutive runs.
3. Determine the response factor relating the mass-ppm concentration of isobutylene in the calibration blend to unit peak area using Equation 3.

$$L = \frac{Q}{B} \quad (3)$$

where:

- B** = average peak area of isobutylene
L = response factor for isobutylene
Q = isobutylene concentration in blend, mass-ppm

CALCULATIONS

Gas Phase Analysis

Calculate the mol-ppm of any component or composite of interest in the sample to the nearest mol-ppm below 100 mol-ppm, or to the nearest 10 mol-ppm at or above 100 mol-ppm, using Equation 4.

$$\text{Component, mol-ppm} = BFK \quad (4)$$

where:

- B** = peak area of the component or composite of interest
F = relative response factor, previously defined (Equation 2)
K = response factor of isobutane, previously defined (Equation 1)

Liquid Phase Analysis

Mass response factors of other hydrocarbon components relative to isobutylene are listed in Table 3. These were calculated using the effective carbon number (ECN) concept as described by Scanlon and Willis.

Calculate the mass-ppm of any component or composite of interest in the sample to the nearest mass-ppm below 100 mass-ppm, or to the nearest 10 mass-ppm at or above 100 mass-ppm, using Equation 5.

$$\text{Component, mass-ppm} = \text{BGL} \quad (5)$$

where:

- B** = peak area of the component or composite of interest
- G** = relative response factor of component, from Table 3
- L** = response factor of isobutylene, previously defined (Equation 3)

Table 3
Calculated Mass Response Factors Relative to Isobutylene

Methane	1.11	Neopentane	1.00
Ethane	1.04	Isobutylene	1.00
Ethylene	1.10	cis-2-Butene	1.00
Propane	1.02	Isopentane	1.00
Cyclopropane	0.98	n-Pentane	1.00
Propylene	1.01	1,2-Butadiene	0.99
Isobutane	1.01	1,3-Butadiene	0.99
n-Butane	1.01	Methyl acetylene	0.77
Propadiene	0.98	Vinyl acetylene	0.80
Acetylene	0.70	n-Hexane	1.00
trans-2-Butene	1.00	Ethyl acetylene	0.82
1-Butene	1.00		

NOTE

Expansion of LPG samples may be more convenient, particularly if both gas phase and LPG samples are analyzed on the same apparatus. However, if heavy (C₅ plus) material is present in the sample, and accurate quantitation of that material is needed, the sample must be injected as a liquid under pressure.

PRECISION

Precision statements were determined using UOP Method 999.

Repeatability and Intermediate Precision

A nested design was carried out for determining components in three hydrocarbon samples with two analysts in one laboratory. Each analyst carried out tests on two separate days, performing two tests each day. The total number of tests for each component was eight. The precision data are summarized in Tables 4 and 5. Two tests performed by the same analyst on the same day should not differ by more than the repeatability allowable difference with 95% confidence. Two tests performed

in one laboratory by different analysts on different days should not differ by more than the intermediate precision allowable difference with 95% confidence.

The data in Tables 4 and 5 are a short-term estimate of repeatability. When the test is run routinely, a control standard and chart should be used to develop a better estimate of the long-term repeatability.

Table 4
Repeatability and Intermediate Precision, mol-ppm

<u>Sample Component</u>	<u>Mean Conc.</u>	<u>Repeatability</u>		<u>Intermediate Precision</u>	
		<u>Within-Day esd</u>	<u>Allowable Difference</u>	<u>Within-Lab esd</u>	<u>Allowable Difference</u>
Propylene feed, gas sample					
Methane	33	0.4	1	0.6	3
Ethane	734	7.8	23	12.3	48
Cyclopropane	1174	14.6	44	16.6	57
Isobutane	197	0.8	2	6.6	30
<i>n</i> -Butane	34	0.5	1	1.0	3
Propylene feed, LPG sample, expanded					
Cyclopropane	61	1.1	3	2.1	7
Isobutane	783	33.9	101	39.4	132
<i>n</i> -Butane	4	0.5	1	0.8	3
1-Butene	34	0.5	1	1.1	4
Methyl acetylene	6	0.0	0	0.5	2

Table 5
Repeatability and Intermediate Precision, mass-ppm

<u>Sample Component</u>	<u>Mean Conc.</u>	<u>Repeatability</u>		<u>Intermediate Precision</u>	
		<u>Within- Day esd</u>	<u>Allowable Difference</u>	<u>Within- Lab esd</u>	<u>Allowable Difference</u>
Mixed butanes, LPG sample, injected as liquid under pressure					
Propane	442	11.1	34	18.7	63
<i>trans</i> -2-Butene	217	5.9	18	7.7	26
1-Butene	16	0.6	2	0.6	2
Isobutylene	20	0.6	2	0.6	2
<i>cis</i> -2-Butene	134	3.4	10	5.2	17

Reproducibility

There is insufficient data to calculate reproducibility of the test at this time.

TIME FOR ANALYSIS

The elapsed time for one analysis (or calibration) is 0.8 hour. The labor requirement is 0.8 hour. The elapsed time for one modified analysis is 1.2 hour. The labor requirement is 0.8 hour.

SUGGESTED SUPPLIERS

Agilent Technologies, 2850 Centerville Rd., Wilmington, DE 19808-1610 (302-633-8000)
www.chem.agilent.com

Alltech Associates, 2051 Waukegan Rd., Deerfield, IL 60015 (847-948-8600) www.alltechweb.com

Arthur Harris and Co., 210 N. Aberdeen St., Chicago, IL 60607 (312-666-6832)
www.arthurharris.com

Fisher Scientific, 711 Forbes Ave., Pittsburgh, PA 15219-4785 (412-562-8300) www.fishersci.com

J&W Scientific, 91 Blue Ravine Rd., Folsom, CA 95630-4717 (916-985-7888)
www.chem.agilent.com

Matheson Gas Products, Inc., 166 Keystone Dr., Montgomeryville, PA 18936 (215-641-2700)
www.mathesontrigas.com

Mat/Sen, 26272 Twelve Trees #C, Poulsbo, WA 98370 (360-697-9199) www.vici.com

Swagelok Company, 29500 Solon Rd., Solon, OH 44139 (440-248-4600) www.swagelok.com

Valco Instrument Co., Inc., P.O. Box 55603, Houston, TX 77255 (713-688-9345) www.vici.com

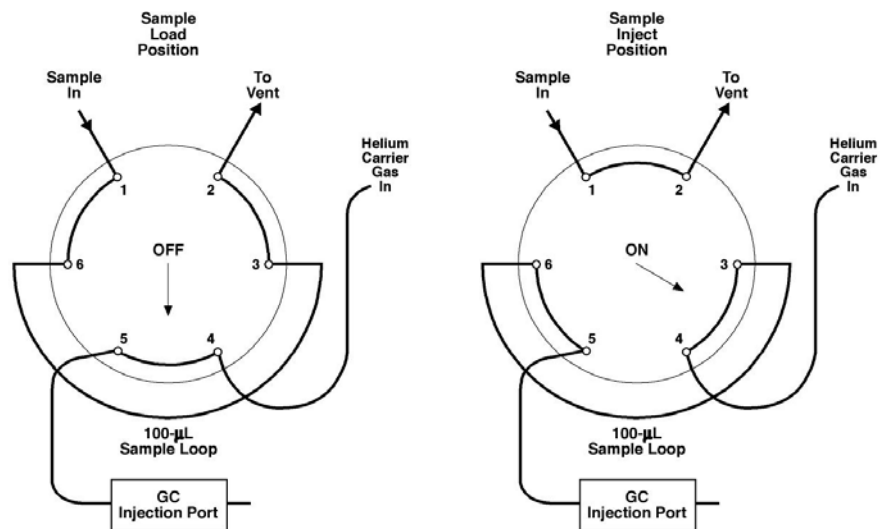


Figure 1
Sample Valve Flow Diagram

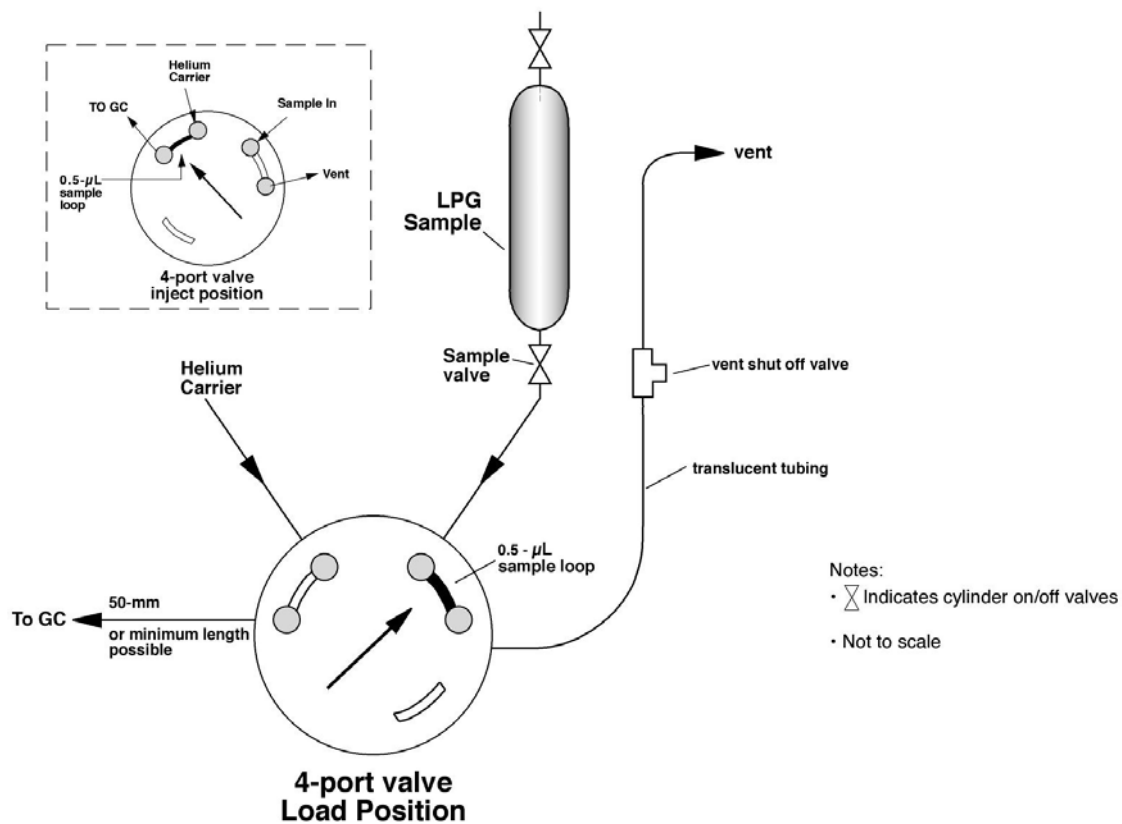


Figure 2
LPG Sampling System

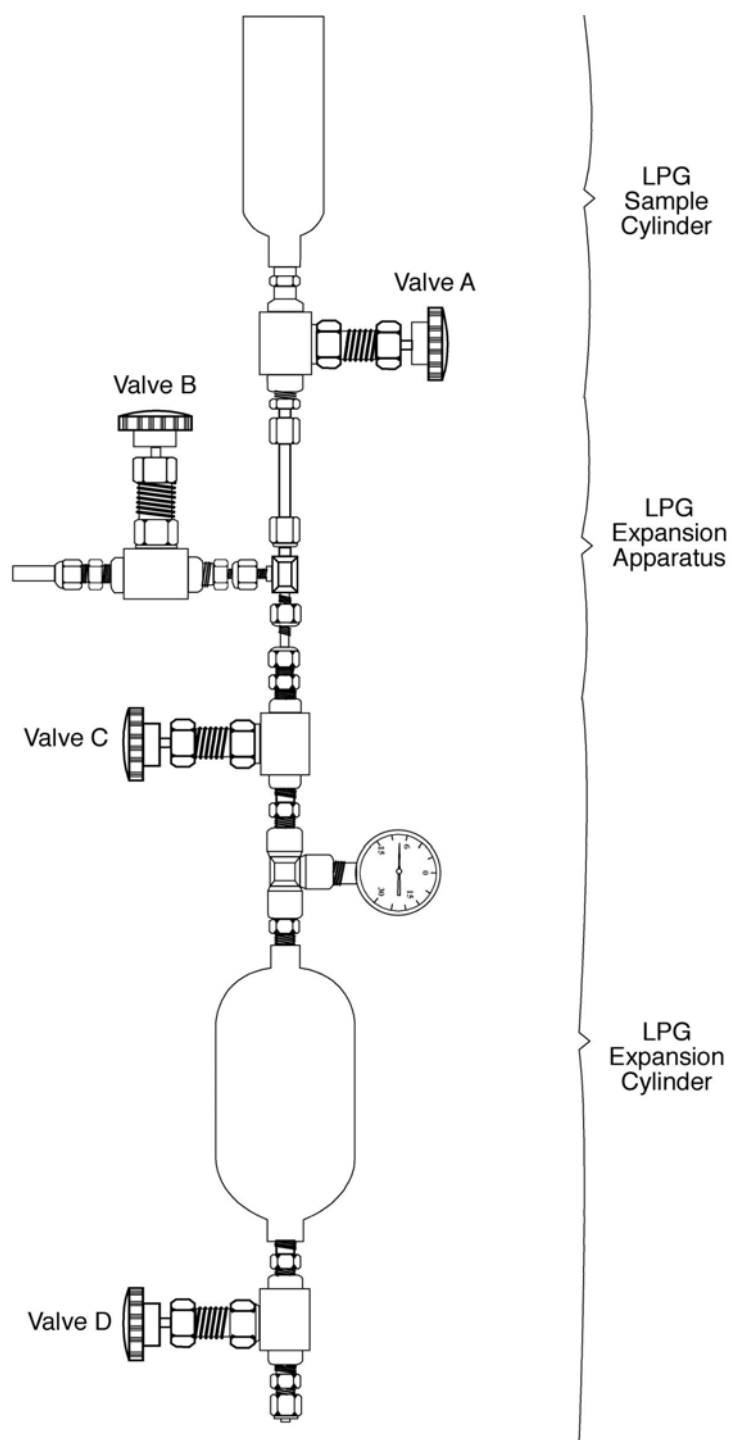


Figure 3
Sample Expansion
Setup

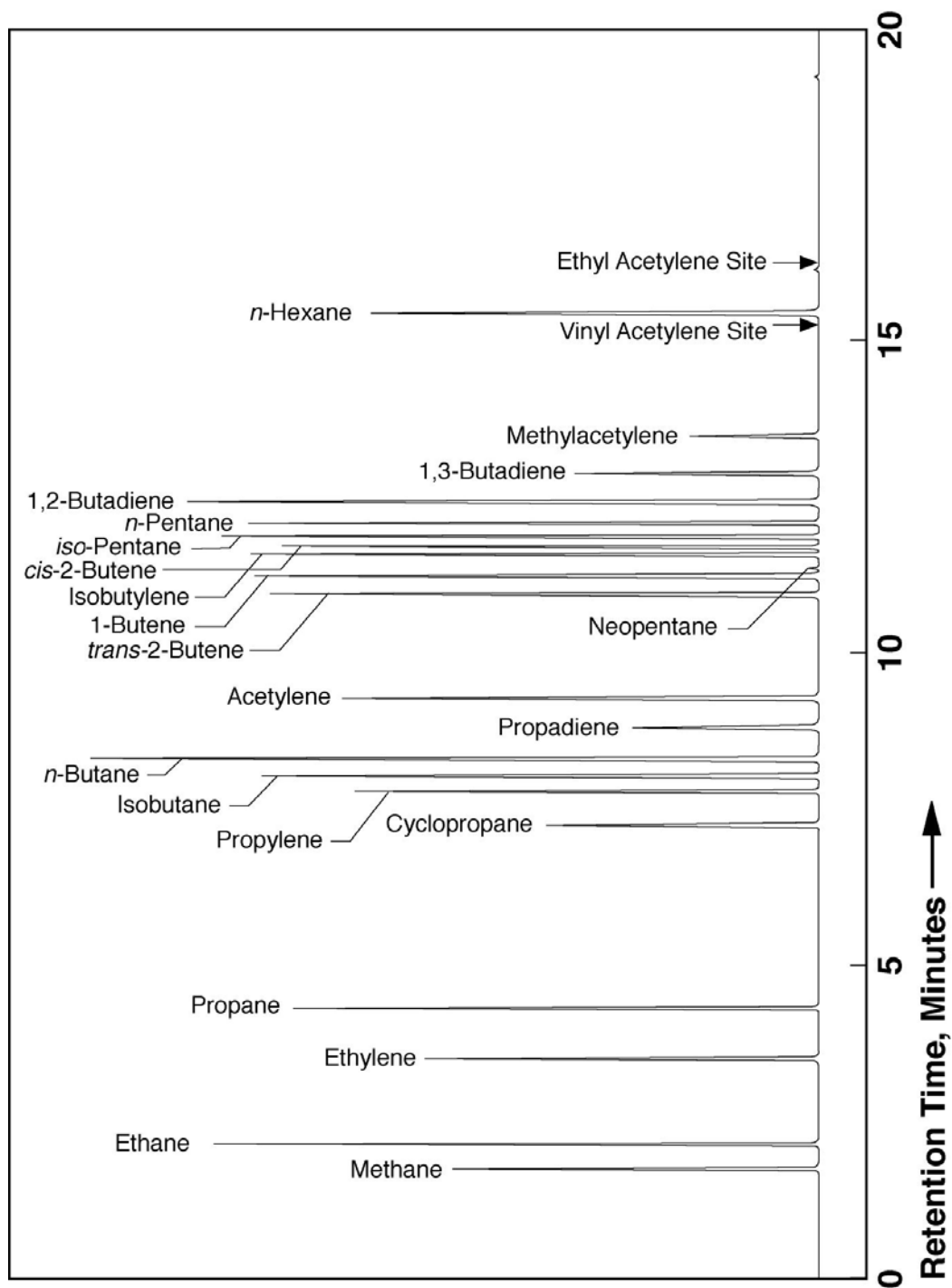


Figure 4
Typical Chromatogram

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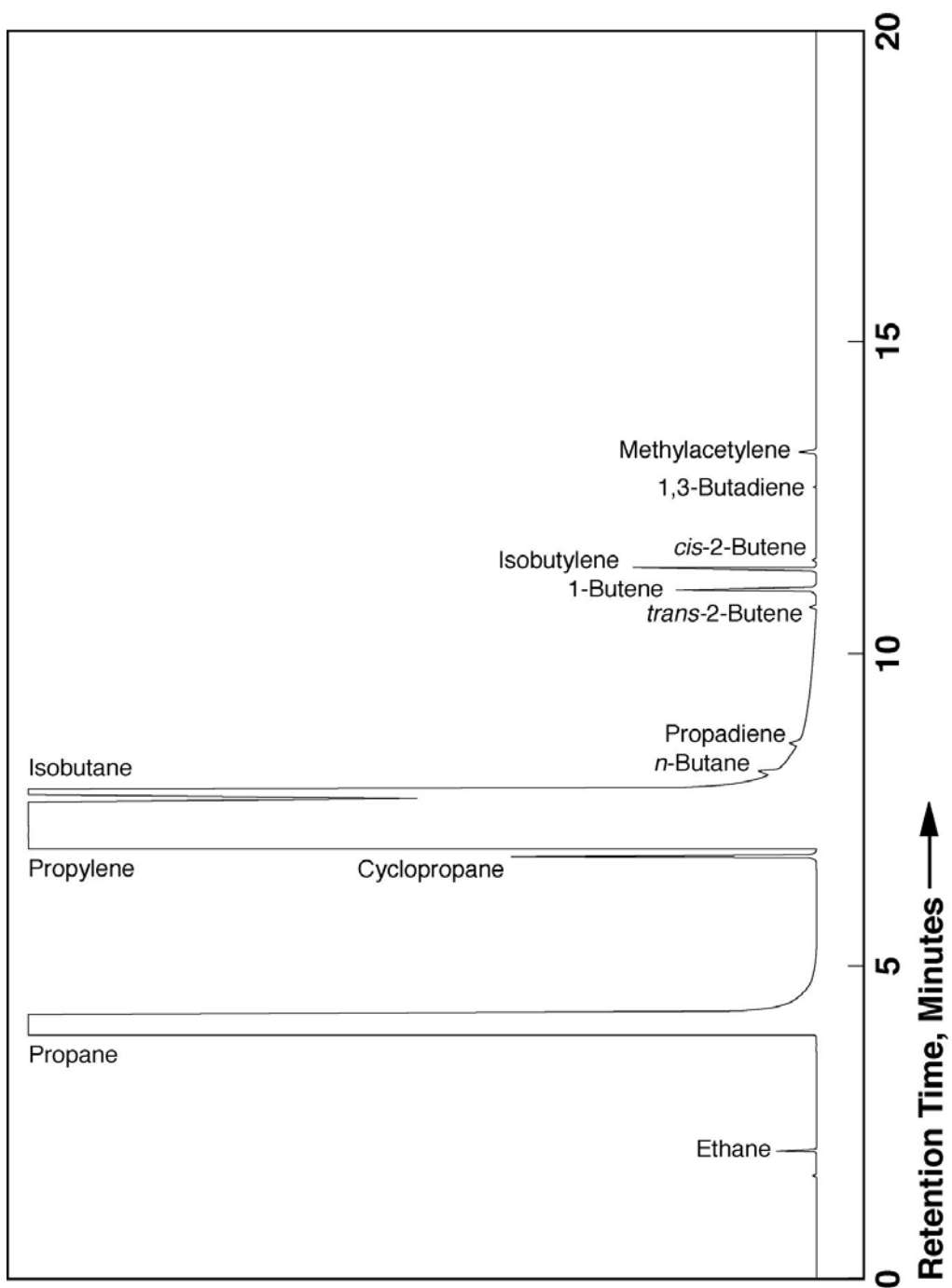


Figure 5
Propylene Feed Typical Chromatogram

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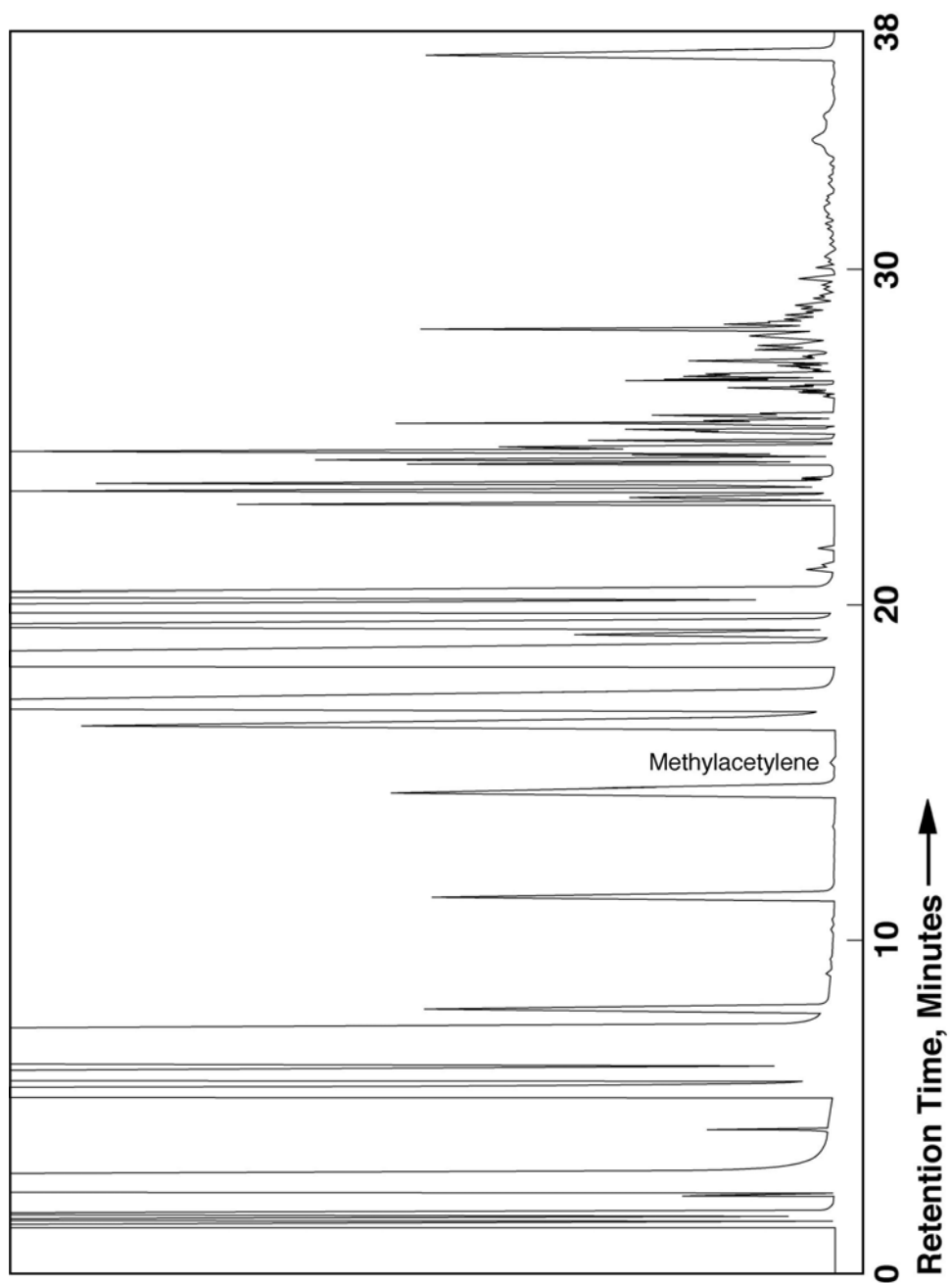


Figure 6
Typical Chromatogram
Conditions for Methylacetylene in the Presence of C₅ Olefins

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