Designation: D7904 – 21

Standard Test Method for Determination of Water Vapor (Moisture Concentration) in Natural Gas by Tunable Diode Laser Spectroscopy (TDLAS)[1]

This standard is issued under the fixed designation D7904; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers online determination of vapor phase moisture concentration in natural gas using a tunable diode laser absorption spectroscopy (TDLAS) analyzer also known as a "TDL analyzer." The particular wavelength for moisture measurement varies by manufacturer; typically between 1000 and 10 000 nm with an individual laser having a tunable range of less than 10 nm.

1.2 Process stream pressures can range from 700-mbar to 700-bar gage. TDLAS is performed at pressures near atmospheric (700- to 2000-mbar gage); therefore, pressure reduction is typically required. TDLAS can be performed in vacuum conditions with good results; however, the sample conditioning requirements are different because of higher complexity and a tendency for moisture ingress and are not covered by this test method. Generally speaking, the vent line of a TDL analyzer is tolerant to small pressure changes on the order of 50 to 200 mbar, but it is important to observe the manufacturer's published inlet pressure and vent pressure constraints. Large spikes or steps in backpressure may affect the analyzer readings.

1.3 The typical sample temperature range is -20 to 65 °C in the analyzer cell. While sample system design is not covered by this standard, it is common practice to heat the sample transport line to around 50 °C to avoid concentration changes associated with adsorption and desorption of moisture along the walls of the sample transport line.

1.4 The moisture concentration range is 1 to 10 000 parts per million by volume (ppmv). It is unlikely that one spectrometer cell will be used to measure this entire range. For example, a TDL spectrometer may have a maximum measurement of 1 ppmv, 100 ppmv, 1000 ppmv, or 10 000 ppmv with varying degrees of accuracy and different lower detection limits.

1.5 TDL absorption spectroscopy measures molar ratios such as ppmv or mole percentage. Volumetric ratios (ppmv and %) are not pressure dependent. Weight-per-volume units such as milligrams of water per standard cubic metre or pounds of water per standard cubic foot can be derived from ppmv at a specific condition such as standard temperature and pressure (STP). Standard conditions may be defined differently for different regions and entities. The dew point can be estimated from ppmv and pressure. Refer to Test Method D1142 and ISO 18453.

1.6 *Units*—The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.7 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.* **Some specific hazards statements are given in Section 8 on Hazards.**

1.8 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D1142 Test Method for Water Vapor Content of Gaseous Fuels by Measurement of Dew-Point Temperature

D4150 Terminology Relating to Gaseous Fuels

D5503 Practice for Natural Gas Sample-Handling and Conditioning Systems for Pipeline Instrumentation (Withdrawn 2017)[3]

[1] This test method is under the jurisdiction of ASTM Committee D03 on Gaseous Fuels and is the direct responsibility of Subcommittee D03.12 on On-Line/At-Line Analysis of Gaseous Fuels.

Current edition approved Nov. 1, 2021. Published November 2021. Originally approved in 2015. Last previous edition approved in 2015 as D7904 – 15. DOI: 10.1520/D7904-21.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] The last approved version of this historical standard is referenced on www.astm.org.

2.2 *ISO Standards:*[4]
ISO 10715 Natural Gas Sampling Guidelines
ISO 18453 Natural Gas—Correlation Between Water Content and Water Dew Point

3. Terminology

3.1 *Definitions:* For definitions of general terms used in D03 Gaseous Fuels standards, refer to Terminology D4150.

3.1.1 *absorption spectroscopy, n*—refers to spectroscopic techniques that measure the absorption of electromagnetic radiation (such as light), as a function of frequency or wavelength, because of its interaction with a sample.

3.1.2 *adsorption, n*—adhesion of molecules to a solid surface forming a molecular or atomic film.

3.1.3 *chemometrics, n*—field of science relating measurements made on a chemical system or process to the state of the system via application of mathematical or statistical methods.

3.1.4 *desorption, n*—phenomenon whereby a substance is released from a surface (the opposite of adsorption).

3.1.5 *heat trace, n*—ribbon-shaped tape that uses electrical resistance or steam to generate heat.

3.1.5.1 *Discussion*—Heat trace tape is attached to sample tubing and other sample conditioning components to avoid condensation and stabilize the temperature of the wetted components and the gas stream.

3.1.6 *selectivity, n*—refers to the extent to which TDLAS can detect moisture in gas matrices without significant interferences from other components in the mixture.

3.1.7 *tunable diode laser absorption spectroscopy, TDLAS, n*—technique for measuring the concentration of a specific component, such as water vapor, in a gaseous sample by absorption spectrometry using tunable diode lasers.

[4] Available from International Organization for Standardization (ISO), 1, ch. de la Voie-Creuse, CP 56, CH-1211 Geneva 20, Switzerland, http://www.iso.org.

4. Summary of Test Method

4.1 A representative sample of the gas is extracted from a process pipe or pipeline and is transferred by a sample transport line through an appropriately designed sampling system to the inlet of a moisture analyzer. The sample must be conditioned with a minimum, preferably negligible, impact on the moisture concentration. The gas flows continuously through the analyzer and is vented to atmosphere, or to flare, or back to the process stream depending on application and regulatory requirements.

4.2 The gas sample stream flows through the measurement cell. An overall diagram of the system is shown in Fig. 1. A solid state laser with a narrow wavelength range is used as a light source. Electronics drive the laser and a thermoelectric cooler, which precisely stabilizes the laser temperature. The laser generates a near-infrared beam of light that passes through the cell window, is typically reflected using a mirror (or mirrors) within the cell, and then returns back through the window and into a photodiode detector. The photodiode signal is used to determine how much light is absorbed at specific wavelengths.

4.3 Fig. 2 is a graph of typical regions in the near-infrared spectrum where water will be absorbed. In the graph, the *x*-axis indicates the wavelength. The *y*-axis indicates the "transmission" of light where 1.0 (or 100 %) is the maximum. Where the transmission is less than 1.0, absorbance by water is indicated. The vertical lines within the graph indicate the magnitude of absorption at specific wavelengths. Each individual absorption line can be potentially utilized for TDLAS moisture measurement. The actual wavelength used will vary based on manufacturer, background composition, measurement specification requirements, and laser availability.

4.4 The sensitivity of the measurement is determined by the absorption as well as the length of the laser beam path (path length) within the sample cell. The path length is fixed and can

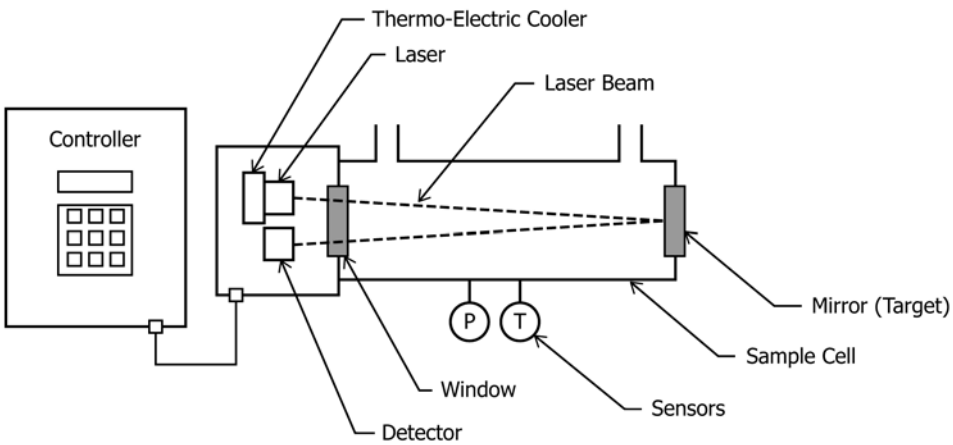

FIG. 1 Main Components of the TDLAS System