



Standard Practice for Determination of the Heating Value of Gaseous Fuels using Calorimetry and On-line/At-line Sampling¹

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1. Scope

1.1 This practice is for the determination of the heating value measurement of gaseous fuels using a calorimeter. Heating value determination of sample gasses containing water vapor will require vapor phase moisture measurements of the pre-combustion sample gas as well as the non-condensed gasses exiting the calorimeter. Instruments equipped with appropriate conditioners and algorithms may provide heating value results on a net or gross and dry or wet basis.

1.2 This practice is applicable to at-line and in-line instruments that are operated from time to time on a continuous basis.

1.3 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.4 *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:²

- D1070 Test Methods for Relative Density of Gaseous Fuels
- D1826 Test Method for Calorific (Heating) Value of Gases in Natural Gas Range by Continuous Recording Calorimeter
- D3588 Practice for Calculating Heat Value, Compressibility Factor, and Relative Density of Gaseous Fuels
- D3764 Practice for Validation of the Performance of Process Stream Analyzer Systems

¹ This practice 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.

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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.

D4150 Terminology Relating to Gaseous Fuels

D4891 Test Method for Heating Value of Gases in Natural Gas Range by Stoichiometric Combustion

D5287 Practice for Automatic Sampling of Gaseous Fuels

D5503 Practice for Natural Gas Sample-Handling and Conditioning Systems for Pipeline Instrumentation

D6122 Practice for Validation of the Performance of Multivariate Process Infrared Spectrophotometer Based Analyzer Systems

D6299 Practice for Applying Statistical Quality Assurance and Control Charting Techniques to Evaluate Analytical Measurement System Performance

D6621 Practice for Performance Testing of Process Analyzers for Aromatic Hydrocarbon Materials

D7164 Practice for On-line/At-line Heating Value Determination of Gaseous Fuels by Gas Chromatography

2.2 ISO Standards:³

ISO 14532 Natural gas – Vocabulary

ISO 7504 Gas analysis – Vocabulary

3. Terminology

3.1 Definitions:

3.1.1 *at-line instrument, n*—See Terminology D4150, Section 3.

3.1.2 *auto-verification, n*—an automated means of introducing Calibration Gas Mixtures or Reference Gas Mixtures into an analyzer for the purposes of verifying the analyzer response without making any adjustments to the calibration parameters of the analyzer.

3.1.3 *bypass line, n*—Line ultimately vented to the atmosphere that is used where it is impractical to provide a sufficient pressure differential.

3.1.3.1 *Discussion*—The flowrate and pressure loss in the open-ended line needs to be controlled so as to ensure that the sample accuracy is not affected from any cooling and condensation or both (reference ISO 14532 paragraph 2.3.2.9).

³ Available from International Organization for Standardization (ISO), 1, ch. de la Voie-Creuse, Case postale 56, CH-1211, Geneva 20, Switzerland, <http://www.iso.ch>.

3.1.4 *calibration gas mixture, n*—a certified gas mixture with known composition used for the calibration of a measuring instrument or for the validation of a measurement or gas analytical method.

3.1.4.1 *Discussion*—Calibration Gas Mixtures are the analogues of measurement standards in physical metrology (reference **ISO 7504** paragraph 4.1)

3.1.5 *calorimeter, n*—See Terminology **D4150**, Section 3.

3.1.6 *continuous fuel monitor, n*—an instrument that samples gas directly from a source continuously and provides an analytical result on a continuous or semi-continuous basis.

3.1.7 *direct sampling, adj*—sampling where there is a direct connection between the sample source and the analytical unit, that is, in-line or on-line instrument.

3.1.8 *dry gas, n*—See Terminology **D4150**, Section 3.

3.1.9 *fast loop/hot loop, n*—Bypass loop that returns sampled gas to the process line in a closed configuration and used for environmental and safety considerations.

3.1.9.1 *Discussion*—The loop requires a pressure differential from the collection point to the discharge point so as to ensure a constant and steady flowrate through the sampling equipment located in the loop (reference **ISO 14532** paragraph 2.3.2.8)

3.1.10 *gross heating value (also called higher heating value), n*—See Terminology **D4150**, Section 3.

3.1.11 *heating value, n*—the amount of energy per volume transferred as heat from the complete, ideal combustion of the gas at standard temperature.

3.1.12 *in-line instrument, n*—See Terminology **D4150**, Section 3.

3.1.13 *net heating value (also called lower heating value), n*—See Section 3 entitled Terminology, of **D4150**.

3.1.14 *on-line instrument, n*—See Terminology **D4150**, Section 3.

3.1.15 *reference gas mixture, n*—a certified gas mixture with known composition used as a reference standard from which other compositional data are derived.

3.1.15.1 *Discussion*—Reference Gas Mixtures are the analogues of reference standards (**ISO 7504** paragraph 4.1.1)

3.1.16 *wet gas, n*—See Terminology **D4150**, Section 3.

3.2 *Acronyms:*

3.2.1 *SOP, n*—Standard Operating Procedure.

3.2.2 *QA, n*—Quality Assurance.

4. Summary of Practice

4.1 A representative sample of the gaseous fuel is extracted from a process pipe, a pipeline, or other gaseous fuel stream and is transferred to an analyzer sampling system. After conditioning that maintains the sample integrity, the sample is introduced into a calorimeter. Excess extracted process or sample gas is vented to the atmosphere, a flare header, or is returned to the process in accordance with applicable economic and environmental requirements and regulations. Post-combustion gasses from the calorimeter are typically vented to the atmosphere.

4.2 The heating value is calculated based upon the instrument's response to changes in the heating value of the sample gas using an algorithm.

4.3 Calibration (7.1), maintenance (Section 10), and performance (Section 9) protocols provide a means to validate and assess operation of the analyzer.

5. Significance and Use

5.1 On-line, at-line, in-line and other near-real time monitoring systems that measure fuel gas characteristics such as heating value are prevalent in various gaseous fuel industries and in industries either producing or using gaseous fuel in their industrial processes. The installation and operation of particular systems vary depending on process type, regulatory requirements, and the user's objectives and performance requirements. This practice is intended to provide guidance for standardized start-up procedures, operating procedures, and quality assurance practices for calorimeter based on-line, at-line, in-line and other near-real time heating value monitoring systems. Users employing gas chromatographic based instrumentation for measurement of gaseous fuel heating value are referred to Practice **D7164**.

6. Apparatus

6.1 *Instrument*—Any instrument of standard manufacture, with hardware necessary for interfacing to a fuel gas pipeline and containing all the features necessary for the intended application(s) can be used.

6.1.1 *Combustion System*—Operating parameters employed must be capable of converting all of the volatile combustible chemical species in the sample into carbon dioxide, water, nitrogen, nitrogen dioxide, and/or sulfur dioxide, using a dry, hydrocarbon-free oxidant which is typically air. A change of less than or equal to 1,000 ppm/wt in the moisture content of instrument air between calorimeter calibrations is acceptable to maintain a statistically insignificant $\pm 0.1\%$ heating value accuracy as denoted in Practice **D4891**. The less than 1,000 ppm/wt moisture content control value is easily achieved using desiccant or refrigerant air dryers when the air dryers are maintained according to the manufacturer's recommendations. Instrumentation must satisfy or exceed analytic performance characteristics for accuracy and precision for the intended application without encountering unacceptable interference or bias. In addition, components in contact with sample streams such as tubing and valving must be constructed of suitable inert or passivated materials to ensure that the composition of the sampled gas is not altered.

6.2 *Sample Probes/Sample Extraction*—The location and orientation of sampling components are critical for ensuring that a representative sample is analyzed. The locations and orientation of sampling components should be selected based upon sound analytic and engineering considerations. Sampling practices for gaseous fuels can be found in Practice **D5287**.

6.3 *Sample Inlet System*—An automated gas sampling valve is required in many applications. All sampling system components in contact with the fuel stream must be constructed of inert or passivated materials. Care should be taken to ensure that the extracted sample is maintained in a single clean gaseous phase. The addition of heat at the point of pressure reduction or along the sample line to the analyzer may be required to ensure that the sample is maintained in the gas phase. The need for heat tracing and the extent to which it is