



BSR/ASHRAE Standard 41.13P

Public Review Draft

Standard Methods for Fuel Higher Heating Value Measurement

**First Public Review (July 2022)
(Complete Draft for Full Review)**

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FOREWORD

This new standard provides methods for determining the higher heating values that are needed for performance testing of fuel-burning heating, ventilating, air-conditioning, and refrigeration systems and components under laboratory and field conditions. This standard complies with ASHRAE's mandatory language requirements.

1. PURPOSE

This standard prescribes methods for determining fuel higher heating values.

2. SCOPE

This standard applies to determining fuel higher heating values for use in testing heating, ventilating, air-conditioning, and refrigeration systems and components under laboratory and field conditions.

3. DEFINITIONS

biodiesel: a liquid fuel derived from vegetable oils or animal fats as defined by ASTM D396¹.

bio-derived gas: combustible gases produced from the microbial breakdown or thermal gasification of biomass (e.g., municipal waste, agricultural residues, and energy crops).

heating value: The amount of heat released by the combustion of a known quantity of fuel.

higher heating value (HHV): a heating value that includes the latent heat of vaporization of water and is determined when water vapor formed from the combustion of fuel is cooled and condensed at standard conditions. Higher heating value is also referred to as "gross heating value."

local conditions: the temperature, pressure, and moisture content of the fuel at the point where the higher heating value is of interest (e.g., the point where the fuel is burned, or custody transfer occurs).

lower heating value (LHV): a heating value that does not include the latent heat of vaporization of water and is determined when water vapor formed from the combustion of fuel remains in the vapor state. It is the difference between the higher heating value and the enthalpy of vaporization of water. Lower heating value is also referred to as "net heating value."

manufactured gas: combustible gases traditionally produced from the gasification of coal, coke, and oil. These gases often contain a large fraction of hydrogen, carbon monoxide, and sometimes carbon dioxide.

refuse-derived fuels (RDF): fuels that are produced from combustible components that the industry calls Municipal Solid Waste. This waste, usually taken from industrial or commercial sites, is shred, dried, baled and then finally burned.

residual moisture: water present in a sample of solid fuel after it is air dried in accordance with the sample preparation procedure prescribed by the referenced higher heating value test method.

4. CLASSIFICATIONS

4.1 Fuel Type Classification. Fuels that are within the scope of this standard are classified according to physical state: gaseous fuels, liquid fuels, and solid fuels.

4.2 HHV Test Methods and Example Fuels. Table 1 includes a list of fuels used for heating ventilation, air-conditioning and refrigeration applications, along with the corresponding higher heating value (HHV) test methods referenced by this standard. This standard applies to all fuels that fall within the scope of these HHV test methods.

Table 1 Summary of Test Methods to Determine HHV

State at Standard Conditions ^a	HHV Test Method	Technique Description	Examples of Covered Fuels
Gaseous	ASTM D3588, <i>Standard Practice for Calculating Heat Value, Compressibility Factor, and Relative Density of Gaseous Fuels</i> ²	Gas Chromatograph	Natural Gas
			Commercial Propane
Manufactured Gas			
Bio-derived gas			
	ASTM D1826, <i>Standard Test Method for Calorific (Heating) Value of Gases in Natural Gas Range by Continuous Recording Calorimeter</i> ³	Continuous Calorimeter	Natural Gas
Liquid	ASTMD240, <i>Standard Test Method for Heat of Combustion of Liquid Hydrocarbon Fuels by Bomb Calorimeters</i> ⁴	Calorimeter	Kerosine
			#2 - #6 Fuel Oil
			Biodiesel Blends
Solid	ASTM E711, <i>Standard Test Method for Gross Calorific Value of Refuse-Derived Fuel by the Bomb Calorimeter</i> ⁵	Calorimeter	Wood
			Refuse-Derived Fuel (RDF)
	ASTM D5865/D5865M, <i>Standard Test Method for Gross Calorific Value of Coal and Coke</i> ⁶	Calorimeter	Coal
			Coke

a. Standard conditions are defined in Section 5.3.

5. REQUIREMENTS

5.1 Requirements Plan. The requirements plan shall be one of the following documents:

- a. A document provided by the person or the organization that authorized the tests and calculations to be performed.
- b. A method of test standard.
- c. A rating standard.
- d. A regulation or code.
- e. Any combination of items a. through d.

The requirements plan shall specify the:

- a. Fuel name or composition
- b. Fuel state (solid, liquid, or gas) at the standard conditions specified in 5.3
- c. For liquid fuels, higher heating value (HHV) is to be reported on mass basis, volumetric basis, or both.

5.2 Values to be Determined and Reported if required in Section 5.1.

5.2.1 Gaseous Fuels. Fuel HHV, kJ/m³ (Btu/ft³) or MJ/m³ (Btu/ft³) at the standard conditions specified in Section 5.3.1

5.2.2 Liquid Fuels. Fuel HHV, MJ/kg (Btu/lb_m) or MJ/L (Btu/gal) at the standard conditions specified in Section 5.3.2

5.2.3 Solid Fuels. Fuel HHV, MJ/kg (Btu/lb_m) at the standard conditions specified in Section 5.3.3

5.3 Standard Conditions for Fuel Higher Heating Values.

5.3.1 Gas. Gaseous fuel HHVs are based upon these standard conditions: 15.6°C/288.75 K, (60°F/520°R), dry, and absolute pressure of 101.6 kPa (30.00 in. Hg).

5.3.2 Liquid. Liquid fuel HHVs reported on a volumetric basis are based on a temperature of 15.6°C (60°F) in these units: MJ/L (Btu/gal).

5.3.3 Solid. This standard treats the HHV of solid fuels as independent of ambient temperature and pressure.

5.4. Methods for Correcting Fuel Higher Heating Values to Local Conditions.

5.4.1 Gaseous Fuels. Apply Equation 1 to convert the HHV for a gaseous fuel at the standard conditions defined in Section 5.3.1 to local conditions.

$$HHV_2 = HHV_{sc} \times \frac{(P_b + P_2 - P_{wvl})}{(P_s - P_{wvs})} \times \frac{T_s}{T_2} \times \frac{1}{Z} \quad (1)$$

where:

HHV_2 = HHV at local conditions, MJ/m³(Btu/ft³)

HHV_{sc} = HHV at standard conditions defined in Section 5.3.1, MJ/m³ (Btu/ft³)

P_b = local barometric pressure, kPa (in. Hg)

P_s = standard absolute pressure defined in 5.3.1, kPa (in. Hg).

P_{wvl} = Partial pressure of water in fuel under local conditions, kPa, (in. Hg).

- P_{wvs} = Partial pressure of water in fuel under standard conditions, kPa, (in. Hg). Because 5.3.1 defines standard conditions as dry, P_{wvs} is = 0 kPa (in. Hg)
- P_2 = local gas pressure relative to atmosphere, kPa (in. Hg)
- T_s = standard absolute temperature defined in 5.3.1, K (°R)
- T_2 = local absolute temperature of gas, °K(°R)
- Z = Compressibility Factor defined as:
 For ideal gases, $Z= 1.0$
 For real gases, Z shall be calculated using ASTM D3588²

(Informative Notes:

- 1) For saturated gas, the partial pressure of water is equal to the vapor pressure of water at the temperature of the gas.
- 2) Commercial natural gas is generally delivered to the end user with a negligible water content, making it possible to treat P_{wvl} and P_{wvs} as zero. A notable exception is when certain types of calorimeters and gas meters are used, which saturate the gas as part of the measurement process. For this reason, it is usually possible to treat commercial natural gas as either completely dry or saturated.
- 3) Barometric pressure reported by weather forecasters and airports is generally not local but corrected to sea level. Use of such readings will yield erroneous results if the local elevation is significantly different from the source elevation.)

5.4.2 Liquid Fuels. The HHV method in Section 7.2 determines liquid fuel HHV in units of energy per unit mass. To determine HHV on a volumetric basis, determine the density of the fuel using ASTM D4052⁷ at the standard temperature 15.6°C (60°F) as stated in Section 5.3.2. Volumetric HHV is then determined using Equation 2.

$$HHV_V = HHV_m \times \rho \quad (2)$$

where:

HHV_V = HHV on a volumetric basis, MJ/L (Btu/gal)

HHV_m = HHV on a mass basis, MJ/kg (Btu/lb_m)

ρ = Density, kg/L (lb_m/gal) at standard temperature of 15.6°C (60°F) as stated in Section 5.3.2.

5.4.3 Solid Fuels. The HHV methods in Section 7.3 determine solid fuel HHV in units of energy per unit mass, where the unit mass includes residual moisture contained in the fuel. The residual moisture content of the fuel shall be measured and reported using the test method referenced Section 7.3. Apply Equation 3 to calculate the moisture content at local conditions.

$$HHV_2 = HHV_{SC} \left[\frac{(100-MC_2)}{(100-MC_{SC})} \right] \quad (3)$$

where:

HHV_2 = HHV at local conditions, MJ/kg (Btu/lb_m)

HHV_{SC} = HHV at the residual moisture reported with the HHV, on a mass basis, MJ/kg (Btu/lb_m)

MC_2 = Moisture content at local conditions by mass, %

MC_{SC} = Residual moisture content reported with the HHV by mass, %

(Informative Note: The total moisture content of solid fuels may change significantly from the value measured when the HHV was determined during subsequent storage and transport of the fuel. It is therefore important to measure the moisture content and correct the HHV in accordance with the equation above, at the time and place of use or custody transfer.)

6. INSTRUMENTS

6.1. Instrumentation Requirements for All Measurements

6.1.1 Instruments and data acquisition systems shall be selected to meet the requirements specified in the corresponding Test Method referenced in Section 7.

6.1.2 Measurements from the instruments shall be traceable to primary or secondary standards calibrated by the National Institute of Standards and Technology (NIST) or to the Bureau International des Poids et Mesures (BIPM) if a National Metrology Institute (NMI) other than NIST is used. Instruments shall be recalibrated on regular intervals that do not exceed the intervals prescribed by the instrument manufacturer and calibration records shall be maintained. Instruments shall be installed in accordance with the instrument manufacturer's requirements, or the manufacturer's accuracy does not apply.

7. METHODS FOR DETERMINING FUEL HIGHER HEATING VALUES

The fuel higher heating values (HHVs) determined by using the methods in this section are at the standard conditions that are defined in Section 5.3. To correct the resulting fuel HHVs at standard conditions to local conditions, apply the correction methods that are specified in Section 5.4.

7.1 Gaseous Fuels.

7.1.1 The HHV of gaseous fuels shall be measured in accordance with ASTM D3588². The resulting HHV shall then be corrected to the standard pressure shown in 5.3.1 using the following equation:

$$HHV_{SC} = HHV_{3588} \times \frac{14.735}{14.696} \quad (4)$$

where:

HHV_{sc} = HHV at standard conditions defined in Section 5.3.1, MJ/m³ (Btu/ft³)

HHV_{3588} = HHV determined using ASTM D3588², MJ/m³ (Btu/ft³)

14.735 = Standard absolute pressure defined in 5.3.1 (psia).

14.696 = Base absolute pressure defined in Section 1.1 of ASTM D3588² (psia)

7.1.2 Measurement of the HHV of ideal natural gas using ASTM D1826³ shall be permitted in place of ASTM D3588². The HHV obtained using ASTM D1826³ is based on the standard pressure in 5.3.1 and Equation 4 shall not be used.

7.2 Liquid Fuels. The HHV of liquid fuels shall be measured in accordance with ASTM D240⁴. Where HHV is to be reported on a volumetric basis, density shall be measured in accordance with ASTM D4052⁷ and the volumetric HHV at the conditions specified in Section 5.3.2 calculated in accordance with Section 5.4.2.

7.3 Solid Fuels.

7.3.1 Wood and Refuse-Derived Fuels (RDF).

7.3.1.1 HHV. The HHV of wood and refuse derived fuels shall be measured and reported in accordance with ASTM E711⁵.

7.3.1.2 Moisture. The residual moisture content of wood and refuse derived fuels shall be measured in

accordance with ASTM E790⁸ and reported with the HHV.

7.3.2 Coal.

7.3.2.1 HHV. The HHV shall be measured in accordance with ASTM D5865/D5865M⁶.

7.3.2.2 Moisture. The residual moisture content of coal shall be measured in accordance with ASTM D3173/D3173M⁹.

8. RESULTS. The following information shall be reported:

8.1 Fuel name or composition.

8.2 Date of analysis.

8.3 Name of person responsible for the analysis.

8.4 Name and location of laboratory performing the analysis.

8.5 Test method or methods used.

8.6 Fuel Higher Heating Value:

- a. For a gaseous fuel, report the higher heating value (HHV), kJ/m^3 (Btu/ft³) or MJ/m^3 (Btu/ft³) at the standard conditions specified in Section 5.3.1
- b. For a liquid fuel, report the HHV, MJ/kg (Btu/lb_m) or MJ/L (Btu/gal) at the standard conditions specified in Section 5.3.2
- c. For a solid fuel, report the fuel HHV, MJ/kg (Btu/lb_m) at the standard conditions specified in Section 5.3.3 and residual moisture content.

9. REFERENCES

1. ANSI/ASTM D396-21. *Standard specification for fuel oils*. American Society for Testing and Materials, West Conshohocken, PA. See note 1.
2. ASTM D3588-20, *Standard Practice for Calculating Heat Value, Compressibility Factor, and Relative Density of Gaseous Fuels*, American Society for Testing and Materials, West Conshohocken, PA. See note 2.
3. ASTM D1826-94 (2017), *Standard Test Method for Calorific (Heating) Value of Gases in Natural Gas Range by Continuous Recording Calorimeter*, American Society for Testing and Materials, West Conshohocken, PA. See note 3.
4. ASTM D240-19, *Standard Test Method for Heat of Combustion of Liquid Hydrocarbon Fuels by Bomb Calorimeters*, American Society for Testing and Materials, West Conshohocken, PA. See note 4.
5. ASTM E711-87 (2004), *Standard Test Method for Gross Calorific Value of Refuse-Derived Fuel by the Bomb Calorimeter*, American Society for Testing and Materials, West Conshohocken, PA. See note 5.
6. ASTM D5865/D5865M-19, *Standard Test Method for Gross Calorific Value of Coal and Coke*, American Society for Testing and Materials, West Conshohocken, PA. See note 6.
7. ASTM D4052-18a, *Standard Test Method for Density, Relative Density, or API Gravity of Liquids by Digital Density Meter*, American Society for Testing and Materials, West Conshohocken, PA. See note 6.
8. ASTM E790-21, *Standard Test Method for Residual Moisture in Refuse-Derived Fuel Analysis Samples*, American Society for Testing and Materials, West Conshohocken, PA. See note 7.
9. ASTM D3173/D3173M-17a, *Standard Test Method for Moisture in the Analysis Sample of Coal and Coke*, American Society for Testing and Materials, West Conshohocken, PA. See note 8.

Notes:

1. This reference is only required if the fuel is an oil.
2. This reference is only required if the fuel is a gas and the gas chromatograph technique is applied.
3. This reference is only required if the fuel is a gas and the continuous calorimeter technique is applied.
4. This reference is only required if the fuel is a liquid.
5. This reference is only required if the fuel is wood or a refuse-derived fuel.
6. This reference is only required if the fuel is coal or coke.
7. This reference is only required if the fuel is a liquid.
8. This reference is only required if the fuel is wood or a refuse-derived fuel.
9. This reference is only required if the fuel is coal or coke.