Preface

This is the fourth edition of CSA B415.1, *Performance testing of solid-fuel-burning heating appliances*. It supersedes the previous editions, published in 2010 and reaffirmed in 2015 and 2020 under the same title, and published in 1992 under the title *Performance Testing of Solid-Fuel-Burning Stoves, Inserts, and Low-Burn-Rate Factory-Built Appliances*.

This Standard can be used as a stand-alone document that can be referenced by the appropriate authority having jurisdiction.

The major changes from the previous edition are as follows:

a) this Standard has been restructured to comply with current CSA requirements;

b) the general layout has been restructured to make this Standard easier to follow for each type of product covered;

c) the types of products covered by this Standard have been clarified and expanded;

d) site-built heating appliances and hybrid heaters have been added as new product types covered by this Standard;

e) definitions have been added for hybrid hydronic heaters and hybrid forced-air heaters;

f) certain definitions have been clarified and updated (e.g., factory-built fireplace, masonry heater, room heater);

g) reference publications have been updated to include their latest versions (e.g., ASTM, US EPA 40 CFR Part 60);

h) informative Annex B pertaining to the total combustible carbon method for determination of energy efficiency has been deleted;

i) for many types of appliances, content has been replaced with a referenced standard (e.g., ASTM E2515-17, ASTM E3053-17(2018e1), ASTM E2515-17), allowing for less text duplication, better harmonization with US EPA (mainly) and improved alignment with other international or regional standards;

j) this Standard now includes references and use definitions from CAN/CSA-ISO 17225 series for graded solid biofuels;

k) emission requirements have been added for hybrid hydronic heaters and hybrid forced-air heaters;

l) emission limits for room heaters have been lowered and harmonized with US EPA;

m) emission limits for forced-air furnaces and hydronic heaters have been lowered and harmonized with US EPA, with a compliance deadline of January 1, 2025, and January 1, 2024, respectively;

n) an emission cap applicable to any single test run has been added for forced-air furnaces;

o) the test method for forced-air furnaces has been clarified and improved based on lab experience since the last version of this Standard (e.g., duct velocity measurement);

p) a test method has been developed using portable flue gas analysers for measuring the gaseous emissions and thermal efficiency of site-built appliances;

q) test fuel characteristics for automatically fuelled appliances have been clarified and expanded;

r) the EN303-5:2021 certification standard has been recognized in this Standard for third-party certified automatically fed hydronic heaters with a nominal heat output between 50 kW and 500 kW;

s) an emission requirement expressed in mg/Nm^3 and a minimum delivered thermal efficiency requirement have been added for third-party certified automatically fed hydronic heaters certified to EN303-5:2021;

t) output and efficiency calculations have been modified to address appliances that generate electricity.

The Technical Committee has made every effort to make the test methodology of this Standard consistent with the United States Environmental Protection Agency's regulations, where possible. The interpretation of the EPA regulations is periodically updated by the issuance of Applicability

Determinations. Anyone using this Standard who also intends to seek EPA product approval should be fully conversant with all EPA requirements.
Emission limits are expressed in both g/h and g/MJ_{net} (output) at the option of the manufacturer. Forced-air furnaces and hydronic heaters limits are expressed in g/MJ (output) only, with the addition that indoor automatically fed hydronic heaters reports emissions in mg/Nm^3 at a delivered minimum thermal efficiency when tested to EN303-5:2021.
CSA acknowledges that the development of this Standard was made possible, in part, by the financial support of Hearth, Patio & Barbecue Association (HPBA).
This Standard is considered suitable for use for conformity assessment within the stated scope of the Standard.
This Standard was prepared by the Technical Subcommittee and has been formally approved by the Technical Committee on Performance Testing and Rating of Solid-Fuel-Burning Appliances, under the jurisdiction of the Strategic Steering Committee on Fuel Burning Equipment.
Notes:

(1) Use of the singular does not exclude the plural (and vice versa) when the sense allows.
(2) Although the intended primary application of this Standard is stated in its Scope, it is important to note that it remains the responsibility of the users of the Standard to judge its suitability for their particular purpose.
(3) This publication was developed by consensus, which is defined by CSA Policy governing standardization — Code of good practice for standardization as "substantial agreement. Consensus implies much more than a simple majority, but not necessarily unanimity". It is consistent with this definition that a member may be included in the Technical Committee list and yet not be in full agreement with all clauses of this publication.
(4) CSA Standards are subject to periodic review, and suggestions for their improvement will be referred to the appropriate committee.
(5) All enquiries regarding this Standard, including requests for interpretation, should be addressed to Canadian Standards Association, 178 Rexdale Boulevard, Toronto, ON M9W 1R3.

Requests for interpretation should
a) define the problem, making reference to the specific clause, and, where appropriate, include an illustrative sketch;
b) provide an explanation of circumstances surrounding the actual field condition; and
c) be phrased where possible to permit a specific "yes" or "no" answer.
Committee interpretations are processed in accordance with the *CSA Directives and guidelines governing standardization* and are published in CSA's periodical *Info Update*, which is available on the CSA Web site at www.csa.ca.

1 Scope

1.1 Product range

This Standard specifies requirements for performance testing of solid-fuel-burning heating appliances, including maximum emission rates.

1.2 Reporting metrics

This Standard specifies a method for determining
a) heat outputs;
b) appliance efficiencies;
c) emission levels and composition; and
d) electrical energy consumption and production

1.3 Product types

This Standard applies to
a) Type 1: Site-built heating appliances
b) Type 2: Room heaters
c) Type 3: Forced-air furnaces
d) Type 4: Hydronic heaters
e) Type 5: Hybrid heating appliances
Note*: Typically, units tested under this Standard will have outputs less than 150 kW (500 000 Btu/h).*
For the purposes of this Standard, solid-fuel-burning appliances include manually and automatically fueled systems (including add-ons and combinations).

1.4 Fuels

This Standard covers appliances that burn biomass fuels such as
a) cordwood;
b) wood chips;
c) wood pellets;
d) sawdust;
e) firelogs;
f) wood, paper, and other biomass pellets and briquettes; and
g) non-woody solid biofuels from agricultural, herbaceous and fruit origin such as kernel corn, other grains, cherry pits and pelletized or briquetted straw, hay and corn stover.

1.5 Products not covered

This Standard does not apply to
a) factory-built fireplaces intended to be used primarily for aesthetic enjoyment and not as a space heater.
b) solid fossil fuel appliances

1.6 Units

The values given in SI units are the units of record for the purposes of this Standard. The values given in parentheses are for information and comparison only.

1.7 Terms and clauses

In CSA standards, "shall" is used to express a requirement, i.e., a provision that the user is obliged to satisfy in order to comply with the standard; "should" is used to express a recommendation or that which is advised but not required; and "may" is used to express an option or that which is permissible within the limits of the standard.
Notes accompanying clauses do not include requirements or alternative requirements; the purpose of a note accompanying a clause is to separate from the text explanatory or informative material.
Notes to tables and figures are considered part of the table or figure and may be written as requirements.
Annexes are designated normative (mandatory) or informative (nonmandatory) to define their application.

2 Reference publications

This Standard refers to the following publications, and where such reference is made, it shall be to the edition listed below, including all amendments published thereto.
ASTM International
D1102-84 (2013)
Standard Test Method for Ash in Wood
D4442-20
Standard Test Methods for Direct Moisture Content Measurement of Wood and Wood-Base Materials
D5865-19
Standard Test Method for Gross Calorific Value of Coal and Coke
E711-2015
Standard Test Method for Gross Calorific Value of Refuse-Derived Fuel by the Bomb Calorimeter
E777-17a
Standard Test Method for Carbon and Hydrogen in the Analysis Sample of Refuse-Derived Fuel
E871-82 (2019)
Standard Test Method for Moisture Analysis of Particulate Wood Fuels
E1602-03 (2017)
Standard Guide for Construction of Solid Fuel Burning Masonry Heaters
E2515-17
Standard Test Method for Determination of Particulate Matter Emissions Collected by a Dilution Tunnel
E2558-13
Standard Test Method for Determining Particulate Matter Emissions from Fires in Low Mass Wood-Burning Fireplaces
E2618-13 (2017)
Standard Test Method for Measurement of Particulate Emissions and Heating Efficiency of Outdoor Solid Fuel-Fired Hydronic Heating Appliances

E2817-11 (2018)
Standard Test Method for Test Fueling Masonry Heaters
E3053-17 (2018e1)
Standard Test Method for Determining Particulate Matter Emissions from Wood Heaters Using Cordwood Test Fuel
Canadian Standard Association
CAN/CSA-ISO 16559
Solid biofuels - Terminology, definitions and descriptions
CAN/CSA-ISO 17225-1:15 (R2020)
Solid biofuels - Fuel specifications and classes - Part 1: General requirements
CAN/CSA-ISO 17225-2:15 (R2020)
Solid biofuels - Fuel specifications and classes - Part 2: Graded wood pellets
CAN/CSA-ISO 17225-3:20
Solid biofuels - Fuel specifications and classes - Part 3: Graded wood briquettes
CAN/CSA-ISO 17225-4:20
Solid biofuels - Fuel specifications and classes - Part 4: Graded wood chips
CAN/CSA-ISO 17225-5:15
Solid biofuels – Fuel specifications and classes – Part 5: Graded firewood
CAN/CSA-ISO 17225-6:15
Solid biofuels – Fuel specifications and classes – Part 6: Graded non-woody pellets
CAN/CSA-ISO 17225-7:15
Solid biofuels – Fuel specifications and classes – Part 7: Graded non-woody briquettes
CEN - European Committee for Standardization
EN 303-5:2021
Heating boilers - Part 5: Heating boilers for solid fuels, manually and automatically stoked, nominal heat output of up to 500 kW - Terminology, requirements, testing and marking.
EPA - Environmental Protection Agency
40 Code of Federal Regulations (CFR) Part 60, Subparts AAA and QQQQ Standards of Performance for New Residential Wood Heaters, New Hydronic Heaters and Forced Air Furnaces. Federal Register / Vol. 80, No. 50 / Monday, March 16, 2015 / Rules and Regulations
Appendix A:
a) Test Method 1 — Sample and Velocity Traverses for Stationary Sources http://www.epa.gov/ttn/emc/promgate/m-01.pdf
b) Test Method 2 — Determination of Stack Gas Velocity and Volumetric Flow Rate (Type S Pitot Tube) http://www.epa.gov/ttn/emc/promgate/m-02.pdf
PFI - Pellet Fuels Institute
Standard Specifications for Residential/Commercial Densified Fuel Dated November 9, 2018. Available for free at *https://www.pelletheat.org/ assets/docs/2018/2018_PFI_ Standard%20Specification.pdf*

3 Definitions

The following definitions shall apply in this Standard:
Air/fuel ratio — the ratio of the mass of dry combustion air introduced into the firebox to the mass of dry fuel consumed.
Appliance — a device that converts the energy in fuel to useful heat. It includes all components, controls, wiring, and piping required by the applicable Standard to be part of the device.
Appliance, catalytic (catalyst-equipped) — an appliance that incorporates a catalytic combustor in the combustion system.

Appliance, non-catalytic — an appliance that does not incorporate a catalytic combustor in the combustion system.
Appliance label — a permanently affixed label on an appliance that displays the information required by this Standard.
Ash — solid inert components of the fuel that remain in the appliance.
Authority having jurisdiction — the governmental body responsible for the enforcement of any part of this Standard or the official or agency designated by that body to exercise such a function.
Automatically fueled — a process in which fuel is fed to the firebox from a storage hopper by mechanical means (e.g., a pellet appliance).
Briquettes — Densified biofuel made with or without additives in form of cubiform, prismatic or cylindrical unit with a linear dimension of more than 25 mm produced by compressing milled biomass.
Burn cycle — the period of time between the loading of a fuel load and the loss of the applicable charge weight (depending on heater type), excluding ash.
Burn rate — the weight of the dry fuel load (excluding the weight of any moisture) divided by the burn cycle time.
Calorific value (Higher Heating Value) — the heat generation potential of a moisture-free fuel, including the latent heat contained in any moisture produced during burning.
Catalytic combustor — a substrate coated with a chemical substance, the presence of which results in a decrease in flue gas ignition temperature.
Charcoal — reactive components of the fuel remaining in the appliance after the volatiles have been released.
Chimney — a primarily vertical shaft enclosing at least one flue for conducting flue gases to the outside atmosphere.
Combustion chamber — See Firebox.
Cordwood — conventional firewood.
Note: *Cordwood is often referred to as "round wood", although, in practice, it is usually round wood 300 to 600 mm (11.8 to 23.6 in) long that has been split into segments. There is no equivalent SI term to the imperial volumetric measure of cord (4 × 4 × 8 ft = 128 ft3), as piled, including air space; the SI conversion factor is 3.624 556 m^3/cord.*
Delivered heat — heat supplied by a central heating appliance (furnace or hydronic heater) through the circulation of a heated medium such as air or water to areas remote from the appliance. Delivered heat does not include heat losses directly from the appliance surfaces or vent pipe to the space where the appliance is installed.
Dilution tunnel, non-condensing — an apparatus for the dilution of the flue gas flow from an appliance and for the collection on filters of all the particulates carried by a representative sample of this flow during an entire burn.
Draft — the potential for flow of air or combustion gases, or both, through an appliance and its venting system, normally measured as static pressure.
Note: *Draft is indicated by the difference between the pressure at a specified point in the appliance or venting system and the pressure of the air at the same elevation outside the appliance or venting system. The term "natural draft" signifies that no fan is used to maintain or accelerate the draft.*
Efficiency —

> **Efficiency, appliance** — the ratio of the energy output of an appliance to the total energy content of the fuel consumed.
> **Efficiency, delivered** — the percentage of energy heat available in a test fuel load that is delivered to a simulated heating load as specified in this Standard. Delivered efficiency does not account for jacket losses or transfer line losses, which will vary with the actual application.

Efficiency, overall — the ratio of the total energy content of the fuel consumed minus energy losses through the appliance vent to the total energy content of the fuel consumed.

Efficiency, combustion, η_{comb}— is a measure of how completely the fuel is burned.

Efficiency, heat transfer, η_{HT} — is a measure of how much of the heat produced from the fuel is transferred to the heated space and/or the energy distribution medium.

Energy output —

Energy output, delivered – the energy available in a test fuel load that is delivered to a simulated heating load as specified in this Standard. Delivered efficiency does not account for jacket losses or transfer line losses, which will vary with the actual application;

Energy output, overall – the total energy content of the fuel consumed minus energy losses through the appliance vent;

Excess air — air, present in the flue gas, that has been introduced into the firebox and does not participate in combustion.

Firebox — the enclosure in which the fuel is burned.

Firelog — a solid densified fuel in uniform size and weight approximating that of cordwood, formed from biomass material, and intended for use in a manually fueled system.

Note: *Firelogs can contain additives, e.g., paraffin as a binder.*

Fireplace — a solid biofuel burning appliance intended to be used for aesthetic enjoyment and may provide incidental heat to the room. It is a fireplace if satisfies the following requirements:

a) The appliance is only allowed to be operated with the doors fully open; or

b) The appliance has no user-operated controls other than flue or outside air dampers that can only be adjusted to either a fully closed or fully opened position.

Note: *The minimum burn rate of a fireplace is typically higher than 5 kg/h (11 lb/h) when tested to EPA Test Method 28A.*

Fireplace, Built-in wood heaters— Wood heaters that are intended to be recessed into the wall. These appliances generally are safety listed under UL-1482, UL-737, UL-127, ULC-S627, or ULC-S610.

Fireplace, low mass — a type of factory-built fireplace that is intended for use with the doors open or closed, or both, and is labelled accordingly.

Notes:

(1) *The minimum burn rate of low-mass fireplaces is typically higher than 5 kg/h (11 lb/h) when tested to EPA Test Method 28A.*

(2) *Low-mass fireplaces are covered by the Environmental Protection Agency's Qualified Wood-Burning Fireplace Program when tested in accordance with ASTM E2558.*

Fireplace, masonry — a fireplace (other than a factory-built fireplace) that is of masonry construction and built on site.

Note*: Prefabricated elements can be used in masonry fireplace construction.*

Fireplace insert wood heaters — Wood heaters intended to be installed in masonry fireplace cavities or in other enclosures. These appliances generally are safety listed under UL-1482, UL-737 or ULC-S628.

Flue — an enclosed passageway within an appliance for conveying combustion products and excess air. See also Vent.

Flue pipe (chimney connector or vent connector) — the conduit connecting the flue collar of an appliance to a chimney.

Forced-air furnace — an indoor or outdoor appliance that generates heat for distribution through a system of air ducts to provide space heating or process heating.

Hydronic heater — an indoor or outdoor appliance intended to supply hot water or steam for space heating, process heating, or power.

***Note**: Hydronic heaters can have a pressurized or atmospherically vented vessel containing a liquid heat transfer medium.*

Hybrid hydronic heater — an indoor solid biofuel heating appliance intended for space heating and hydronic heating. The appliance is intended to be installed within the conditioned envelope and provide useful space heating to the room which it is installed. The appliance is typically capable of delivering at least 15% of the maximum overall heat output to each end use of space heating and hydronic heating.
Hybrid forced-air heater — an indoor solid biofuel heating appliance intended for space heating and warm air distribution. The appliance is intended to be installed within the conditioned envelope and provide useful space heating to the room where it is installed. The appliance is typically capable of delivering at least 15% of the maximum overall heat output to each end use of space heating and warm air distribution.
Indoor central heating appliance — an appliance that is intended for indoor installation and is used primarily for heating spaces, other than the space where the appliance is located, by distributing a gas or fluid heated in the appliance through pipes or ducts.
Manually fueled — a process in which fuel is introduced to the firebox by the equipment operator.
Masonry heater — a vented heating system of pre-dominantly masonry construction having:
a) a mass that makes it impractical to place on a platform scale to measure the burn rate. In particular, a masonry heater is a batch loaded appliance, designed specifically to capture and store at least 50% of the heat energy in the mass of the masonry heater through internal heat exchange flue channels. It enables a batch load of solid biofuel to be supplied with an amount of air adequate to burn rapidly at a high temperature in order to reduce the emission of unburned hydrocarbons;
b) a thermal mass and surface area of such size that under normal operating conditions the external surface temperature, except in the region immediately surrounding the fuel loading door(s), does not exceed 110°C (230°F).
Note: *Masonry heaters are built in compliance with ASTM E1602.*
Moisture content, dry basis (MC_{db}) — the weight of water in wood divided by the weight of the dry wood only (oven-dry weight), expressed as a percentage.
Moisture content, wet basis (MC_{wb}) — the weight of water in wood divided by the combined weight of the water plus the wood (green weight), expressed as a percentage.
Note*: It is sometimes necessary to convert from wet basis to dry basisas follows:*

$$M_{Cdb} = \frac{M_{Cwb} \times 100}{100 - (M_{Cwb} \times 100)}$$

or from dry basis to wet basis, as follows:

$$M_{Cwb} = \frac{M_{Cdb} \times 100}{100 + (M_{Cdb} \times 100)}$$

where
MC_{db} = moisture content, dry basis, expressed as a percentage
MC_{wb} = moisture content, wet basis, expressed as a percentage
100 = factor to convert to percentage

Outdoor central heating appliance — an appliance that is intended for outdoor installation and is used primarily for heating spaces, other than the space where the appliance is located, by distributing a gas or fluid heated in the appliance through pipes or ducts. The appliance is equipped with a weatherized jacket and integral flue venting means and labelled for outdoor installation.
Particulate emissions — components of the flue gas, in solid or liquid phase (excluding water), that can be collected on a filter.
Pellets — a solid processed fuel of uniform size and intended for use in automatically fed appliances; Pellets are manufactured by densification, typically in cylindrical form, and typically 5 to 40 mm (0.2 to 1.5 in) in length and 6 mm (0.25 in) in diameter.
Notes:

(1) Feedstock includes a variety of sources and origins, e.g., sawdust from forestry operations and grain, fruit or herbaceous residues from agricultural operations.
(2) Pellets recommended for residential use are premium grade or standard grade (PFI) or Grade A1 and A2 (CAN/CSA-ISO 17225-2:15).

Platform Scale (Electronic Mass Balance) — A scale capable of weighing the test wood heater and attached chimney, including the weight of the test fuel, to within 0.05 kg (0.1 lb) or 1 % of the expected test fuel load weight, whichever is greater. (ASTM E3053-18).

Room heater – an enclosed, solid biofuel heating appliance capable of, and intended for, space heating, with or without hydronic heating and/or electrical power production. This includes free standing heaters and fireplace or wall inserts, including adjustable burn rate and single burn rate heating appliances. The appliance shall not be capable of delivering more than 15% of the maximum overall heat output as hydronic heat.

Site-built appliance – a heating appliance that has been built in the location where it operates; (also referred to as built-in-place appliance).

Sawdust — small particles of wood, typically 1 to 5 mm (0.04 to 0.2 in), produced by a saw or a planar, normally as a by-product of forestry operations.

Solid biofuels – solid fuels produced from biomass originating from forestry and arboriculture, agriculture and horticulture and aquaculture in accordance with the CAN/CSA-ISO 16559 Solid biofuels - Terminology, definitions and descriptions.

***Note**: Biomass can be plant or animal based, including but not limited to dedicated energy crops, trees, harvesting residues and processing by-products from forestry, agriculture, agricultural crops, aquatic plants, algae.*

Stove — an appliance intended for space heating or cooking, or both.

Usable firebox volume — the space within a firebox where conventional firewood might reasonably be expected to be loaded by the appliance user.

***Note**: For forced-air furnaces, the volume is not affected by any suggested loading limit marked on the appliance.*

Vent — an enclosed passageway, exterior to the appliance, for conveying combustion products and excess air to a discharge point. See also Flue.

Wood chips — small pieces of woody biomass with a defined particle size produced by mechanical treatment with sharp tools such as knives.

Note*: Wood chips have a sub-rectangular shape with a typical length of 5 mm to 50 mm and a low thickness relative to other dimensions.*

4 Requirements

4.1 General

4.1.1 Particulate matter reporting for Type 2, 3, 4 and 5 appliances

Particulate matter for solid biofuel heating appliances is reported in different metrics across jurisdictions:

a) Below a certain mass of particulate matter per unit of delivered energy output. For example, pound of particulate matter per millionth British Thermal Units of output energy [lb/mmBTU $_{out}$] or in metric units, grams of particulate matter per Mega Jules of output energy [g/MJ$_{net}$].
b) Below a certain mass of particulate matter per mass of solid biofuel burned. For example, gram of particulate matter per dry kilogram of solid biofuel burned [g/kg$_{dry}$].

c) Below a certain mass of particulate matter per unit volume of flue gases corrected to a reference condition at a delivered energy output and minimum delivered efficiency. For example, milligram particulate matter per cubic meter of dry exit flue gases corrected to a reference condition at a delivered energy output [mg/Nm^3].
d) Below a certain mass of particulate matter per hour of operation. For example, gram of particulate matter per hour of operation [g/h].

4.1.2 Manufacturer's instructions
Manufacturer's written instructions shall be provided to the test lab when the unit is sent for testing.

4.1.3 Third-party certification
Refer to Annex C.

4.1.4 CO emissions
CO emissions shall be reported according to Clause 6.1.10.10.

4.1.5 Specific requirement for catalytic combustor
If the appliance is fitted with a catalytic combustor, there shall be a centrally located temperature monitoring device fitted one inch downstream of the catalytic combustor, giving an indication of the catalytic combustor outlet gas temperature. Optionally a similarly located temperature monitoring device may be located one inch upstream of the catalytic combustor.
When tested in accordance with 6.2 to 6.6 inclusively, the monitor readings shall be recorded and reported as "The catalytic combustor indicator values" (whether a color coded or a numerical temperature).

4.2 Type 1 – Site-built appliances (Built-in-place – BIP)

Site-built appliances are exempt from all labelling requirements.
This method applies to
a) manually fed cordwood fueled appliances;
b) appliances that cannot be reasonably tested in a laboratory setting; and
c) appliances that are not designed and intended to be portable and/or removed.

4.2.1 Construction and installation
Site-built appliances of any type shall have a permanent access port or a tube not more than 260 millimetres in length built into the structure proving access to the flue, readily permitting the placement of a 10-millimetre diameter gas sampling probe into the passing gas stream. Such port shall have a replaceable cap so as to seal it during normal operation.

4.2.2 Gaseous emissions
When tested in accordance with Clause 6.2.2 the maximum average concentration of carbon monoxide (CO) in the flue gas shall be ≤1500 ppm(v) when the oxygen concentration is corrected to 11%.

4.2.3 Particulate emissions
There are no PM emission requirements for site-built appliances.

4.2.4 Thermal performance
When tested according to Clause 6.2.4 the overall efficiency shall be at least 75% (HHV).
4.3 Type 2 – Room heaters

4.3.1 Construction and installation
This Standard does not have any construction and installation requirements for Type 2 appliances.

4.3.2 Gaseous emissions
This Standard has no gaseous emission requirements for Type 2 appliances.

4.3.3 Particulate emissions
The particulate emission rate for any test run that is required to be used in determining the average emissions shall be determined in accordance with the procedures described in ASTM E2515, with the addition of ASTM E3053, E2780 or E2779.

a) for a room heater tested with cordwood, the average particulate emission rate shall not exceed:
   i) ≤2.5 g/h; or
   ii) ≤0.15 g/MJ_{net} (output).

b) for a room heater tested with crib wood or any processed solid-fuel (e.g., pellets, chips, densified log), the average particulate emission rate shall not exceed:
   i) ≤2.0 g/h; or
   ii) ≤0.15 g/MJ_{net} (output).

This limit shall apply to all room heaters manufactured after December 31st, 2022.
Note: *For converting g/MJ to yard/pound (imperial) units, the following formula may be used: 2.3254 × g/MJ = lb/mmBtu.*

4.3.4 Thermal performance
There are no thermal requirements for Type 2 appliances.
4.4 Type 3 – Forced-air furnaces

4.4.1 Construction and installation
This Standard does not have any construction and installation requirements for Type 3 appliances.

4.4.2 Gaseous emissions
This Standard has no gaseous emission requirements for Type 3 appliances.

4.4.3 Particulate emissions

a) For forced-air furnaces, the arithmetic average particulate output rate, as determined in accordance with Clauses 6.1.9 and 6.4 and Annex C, when tested with cordwood shall not exceed 0.065 g/MJ_{net} (0.15 lb/mmBtu) output.
b) For forced-air furnaces, the particulate output rate of any single test run, as determined in accordance with Clauses 6.1.9 and 6.4 and Annex C, when tested with cordwood shall not exceed 0.11 g/MJ_{net} (0.25 lb/mmBtu) output.

This limit shall apply to all forced-air furnaces manufactured after December 31st, 2024.

Note: *For converting g/MJ to yard/pound (imperial) units, the following formula may be used: 2.3254 × g/MJ = lb/mmBtu.*

4.4.1 Thermal Performance

This Standard does not have any thermal performance requirements for Type 3 appliances.

4.5 Type 4 – Hydronic heating appliances

4.5.1 Construction and installation

This Standard does not have any construction and installation requirements for Type 4 appliances.

4.5.2 Gaseous emissions

This Standard does not have any gaseous emission requirements for Type 4 appliances.

4.5.3 Particulate emissions

For central hydronic heating appliances, the arithmetic average particulate output rate, as determined in accordance with test methods ASTM E2618-13 (2017) Standard Test Method for Measurement of Particulate Emissions and Heating Efficiency of Outdoor Solid Fuel-Fired Hydronic Heating Appliances, or EPA Method 28 WHH, or EPA Method 28 WHH PTS, or EN303-5:2021 Heating boilers - Part 5 shall not exceed:

a) For hydronic heaters tested with crib wood: 0.043 g/MJ_{net} (0.10 $lb/mmBTU_{out}$) output.
b) For manually fed or automatically fed hydronic heaters tested with cordwood or graded densified logs: 0.065 g/MJ_{net} (0.15 $lb/mmBTU_{out}$) output.
c) For automatic hydronic heaters tested using any of the following graded solid biofuel (e.g., pellets, chips, densified log, briquettes):
   i) 0.043 g/MJ_{net} (0.10 $lb/mmBTU_{out}$) output, or
   ii) Class 5, 40 mg/Nm^3 of dry flue gas at a minimum 89 percent delivered thermal efficiency on an LHV basis for appliances with a nominal heat output between 50 kW to 150 kW.

For central hydronic heating appliances tested in accordance with test methods ASTM E2618-13 (2017), or EPA Method 28 WHH, or EPA Method 28 WHH PTS, the particulate output rate of any single test run used to determine the arithmetic average particulate output rate, shall not exceed 0.11 g/MJ_{net} (0.25 $lb/mmBTU_{out}$) output.

Central automatic hydronic heating appliances complying with EN303-5:2021 shall not exceed Class 5 Emissions and Performance requirements at both the minimum and the nominal delivered heat output.

For central automatic hydronic heating appliances complying with EN303-5:2021, the text in Section 5.1.4 in respect to the product range ratio and the interpolation of data for non-tested hydronic heaters within a product range is not recognized in this standard.

To be recognized under this standard, each nominal heat output of a hydronic heater shall be tested individually for emissions and energy performance.
These limits shall apply to all hydronic heater manufactured after December 31st, 2024.
Note: *For converting g/MJ to yard/pound (imperial) units, the following formula may be used: 2.3254 × g/MJ = lb/mmBTU.*

4.5.4 Thermal performance

Manually batch fed appliance fueled with cribwood biofuel do not have any thermal performance requirements under this standard.
Manually batch fed or automatically fed appliances fueled with cordwood do not have any thermal performance requirements under this standard.
Automatically fed appliances fueled with graded woody solid biofuel (including pellets or other graded non-woody or woody particulate solid biofuel) tested in accordance with the following do not have any thermal performance requirements under this standard.
a) US EPA Method 28 WHH
b) US EPA Method 28 WHH PTS
c) ASTM E2618-13 (2017)
Indoor automatically fuelled hydronic heaters fueled with graded wood solid biofuel (including graded wood pellets, graded wood chips and graded wood briquettes) tested in accordance with EN303-5:2021 shall achieve a minimum 89% thermal efficiency on an LHV basis.
4.6 Type 5 – Hybrid heaters

4.6.1 Construction and installation

This Standard does not have any construction and installation requirements for Type 5 appliances.

4.6.2 Gaseous emissions

This Standard does not have any gaseous emission requirements for Type 5 appliances.

4.6.3 Particulate emissions

The particulate emission rate for any test run that is required to be used in determining the average emissions shall be determined in accordance with the procedures described in ASTM E2515, with the addition of ASTM E3053 or E2779.
a) for a room heater, hybrid forced-air heater or hybrid hydronic heater tested with cordwood:
   i) 2.5 g/h; or
   ii) 0.15 g/MJ_{net} (output);
b) for a room heater, hybrid forced-air heater or hybrid hydronic heater tested with any processed solid biofuel (e.g., pellets, chips, densified log, briquettes):
   i) 2.0 g/h; or
   ii) 0.15 g/MJ_{net} (output);

4.6.4 Thermal performance

When tested in accordance with 6.6.4, the appliance shall be capable of delivering at least 15% of the maximum overall heat output to each end use of space heating and hydronic heating.

***Note**: Hybrid Hydronic heaters can have a pressurized or atmospherically vented vessel containing a liquid heat transfer medium.*

5 Marking and instructions

The manufacturer shall provide written set of operation, maintenance and installation instructions.
A fueling and operating protocol shall be described in the end-user's written instructions (i.e., user's manual) supplied with unit and titled "Optimum Fueling and Operating Procedures".
Visual fuel loading guidance, fuel manipulation parameters, air control, load door and bypass damper positions for achieving optimum performance shall be easily understood and performed by the end-user.
Where the efficiency is reported on a permanent label or in the operating instruction book, the permanent label shall bear the following: "The stated efficiency is based on the higher heating value of the fuel".
The lettering on the labels that provide the information specified in Clause 5 shall be at least 2 mm (0.08 in) high.
Note: *The equivalent French wording is «Le rendement annoncé est basé sur le pouvoir calorifique supérieur du combustible».*
5.1. Type 1 - Site-built appliances (Built-in-place - BIP)

5.1.1 Markings

There are no labelling requirements for site-built appliances.

5.1.2 Instructions

An owners operating instructions and maintenance manual shall be supplied. Instructions may include maximizing thermal efficiency and typical fuel load mass.

5.2 Type 2 – Room heaters

5.2.1 Markings and labeling

Each appliance shall bear a permanent label with the following information:
a) the average particulate emission rate in g/h and g/MJ_{net} (output);
b) the average efficiency of the appliance, expressed as a percentage;
c) the minimum energy output rate from a test used in determining the average emission rate;
d) the maximum energy output rate from a test used in determining the average emission rate;
e) the average electrical power consumption in kW; and
f) the average electrical power production in kW (if applicable).

5.2.2 Instructions

An owners operating instructions and maintenance manual shall be supplied.
5.2. Type 3 – Forced-air furnaces

5.3.1 Markings and labeling

Each appliance shall bear a permanent label with the following information:
a) the average particulate emission rate in g/MJ_{net} (output), based on the amount of delivered energy;
b) the average delivered efficiency of the appliance, expressed as a percentage, based on the amount of delivered energy for forced-air furnaces as per Clause 6.4.4.4;
c) the minimum delivered energy output rate from a test used in determining the average emission rate;
d) the maximum delivered energy output rate from a test used in determining the average emission rate;
e) the average overall efficiency of the appliance, expressed as a percentage, based on the overall energy output rate, determined in accordance with Clause 6.1.10.8;
f) the minimum overall energy output rate;
g) the maximum overall energy output rate;
h) the average electrical power consumption in kW; and
i) the average electrical power production in kW (if applicable).

5.3.2 Instructions

An owners operating instructions and maintenance manual shall be supplied.
5.3. Type 4 – Hydronic heaters

5.4.1 Markings and labeling

Each appliance shall bear a permanent label with the following information:
a) the average particulate emission rate in g/MJ_{net}, based on the amount of delivered energy;
b) the average delivered efficiency of the appliance, expressed as a percentage, based on the amount of delivered energy for hydronic heaters as per Clause 6.5;
c) the minimum delivered energy output rate from a test used in determining the average emission rate;
d) the maximum delivered energy output rate from a test used in determining the average emission rate;
e) the average overall efficiency of the appliance, expressed as a percentage, based on the overall energy output rate, determined in accordance with Clause 6.1.10.8;
f) the minimum overall energy output rate;
g) the maximum overall energy output rate;
h) the average electrical power consumption in kW; and
i) the average electrical power production in kW (if applicable).
Refer to Annex C for guidance on hydronic heater marking.

5.4.2 Instructions

An owners operating instructions and maintenance manual shall be supplied.
5.4. Type 5 – Hybrid heaters

5.5.1 Markings and label

Each appliance shall bear a permanent label with the following information:
a) the average particulate emission rate in g/h and g/MJ (using overall output);

b) the minimum overall heat output rate and minimum delivered heat output rate from a test used in determining the average emission rate;
c) the delivered heat output and the space heat output reported as a percentage split of overall minimum heat output (e.g., 30/70 delivered/space);
d) the maximum overall heat output rate and maximum delivered heat output rate from a test used in determining the average emission rate;
e) the delivered heat output and the space heat output reported as a percentage split of overall maximum heat output (e.g., 30/70 delivered /space);
f) the average efficiency of the appliance, expressed as a percentage, based on the overall heat output rate, determined in accordance with Clause 6.4.4;
g) the average electrical power consumption in kW;
h) the average electrical power production in kW (if applicable).

5.5.2 Instructions

An owners operating instructions and maintenance manual shall be supplied.

6 Inspection and methods of test

6.1 General

Manufacturer's written instructions shall be provided to the test lab when the unit is sent for testing. The loading and operating procedures in the manufacturer's written instructions shall reflect what the end-user is likely to be able and well-disposed to do.

6.1.1 Test room conditions and preparation for Type 2, 3, 4 and 5 appliances

Test room conditions shall be as per ASTM E2515-17 *Standard Test Method for Determination of Particulate Matter Emissions Collected by a Dilution Tunnel*. See Clause 6.1.9 for changes to this standard.

The appliance shall be assembled in accordance with the manufacturer's installation and operation instruction manual.

The flue pipe for the appliance shall be made of steel painted black or an equivalent material painted black. Any cracks or joints shall be sealed with furnace cement or equivalent. The flue pipe diameter shall match the flue collar of the appliance. A different flue pipe may be used if the appliance manufacturer's instructions require such a flue pipe.

The flue pipe shall vent into a vertical factory-built chimney having a minimum of 25 mm (1 in) of solid-pack insulating material surrounding the entire flue. The chimney shall begin 2.6 ± 0.15 m (8.5 ± 0.5 ft) above the platform on which the appliance is resting and extend to a point 4.6 ± 0.3 m (15 ± 1 ft) above the platform. Other chimney types may be used if the appliance manufacturer's instructions require such a chimney. The inside diameter of the factory-built chimney shall be in accordance with the manufacturer's instructions, except that it shall not be less than the diameter of the appliance flue collar.

An appliance shall be operated before the test procedures specified in 6.2 to 6.6 are performed, using the following:
a) for cordwood-fired appliances: the cordwood having a moisture content between 18 and 28%, dry basis; and
b) for automatically fueled appliances: the fuel recommended by the manufacturer in the written instructions accompanying the appliance.

For non-catalytic appliances, the appliance shall be operated at a medium air setting or a burn rate of Category 2 or 3 for at least 50 h.
For appliances equipped with a catalytic combustor, a new catalytic combustor shall be installed and the appliance shall be operated at least at a medium burn rate for 50 h while maintaining the catalytic combustor exit temperature above 260 °C (500°F). The hourly catalytic combustor exit temperature data (see Clause 4.1.5) and the hours of operation shall be recorded and reported.

6.1.2 Ambient air temperature for Type 2, 3, 5 and 5 appliances
The air temperature in the test room shall be measured as define in ASTM E2515-17.

6.1.3 Flue gas analysis for Type 2, 3, 4 and 5 appliances
The flue gas temperature shall be measured by a Type K sheathed thermocouple or equivalent located in the centroid of the stack 2.44 m ± 150 mm (8.0 ± 0.5 ft) above the platform scale.
The percentage of carbon monoxide (CO) and carbon dioxide (CO_2) in the flue gas shall be measured by a continuous infrared analyzer or equivalent. Continuous analyzers (or equivalent) shall have maximum zero and span drift, over a 24 h period, of 1% of full scale.
Gas samples shall be taken by a probe inserted at the centreline of the chimney 50 mm (2 in) above the thermocouple measuring flue gas temperature.
Continuous analyzers (or equivalent) shall be arranged so that they are synchronized to reach 90% of their final reading within 30 s when beginning at ambient levels and responding to a calibration gas that contains at least 80% of full-scale value of the constituent being measured. The calibration gas for this test shall be introduced through the sampling probe.

6.1.4 Determination of calorific value
The calorific value of a representative sample of the fuel to be used in each appliance test series shall be determined in accordance with ASTM D5865 or ASTM E711 or CSA-ISO 18125.
Note*: Uncontaminated sawdust resulting from cutting charge pieces may be used for determining the calorific value.*

6.1.5 Electrical power production and consumption

6.1.5.1 Supply voltage
The supply voltage to the appliance or component part shall be maintained as follows for the duration of the test:
a) within ± 1.0% of the rated voltage (nameplate voltage);
b) if a voltage range is specified on the nameplate, within ± 1.0% of the midpoint of the nameplate voltage range; or
c) if dual-voltage operation is specified on the nameplate, within ± 1.0% of the highest voltage specified.

6.1.5.2 Measurements
The electrical power production and consumption shall each be measured by a wattmeter, watt-hour meter, or equivalent meter with a resolution of:
a) 0.01 W or better for power measurements of 10 W or less;

b) 0.1 W or better for power measurements greater than 10 W and less than 100 W; and
c) 1 W or better for power measurements greater than 100 W.
For appliances connected to more than one phase, the meter shall be equipped to measure the total power of all phases connected.
Production shall be measured over the duration of the test and reported by kilowatt-hours [kWh].
Consumption provided external from the appliance (i.e., grid power) shall be measured over the duration of the test and divided by the test duration to determine an average value [W].
Power production shall be measured at the output of the device (i.e., useful external power).

6.1.5.3 Electrical connections

Single- and three-phase electrical power monitoring connections shall be arranged as shown in Figures 1,2 and 3, respectively.

Figure 1 Connection of measurement devices (single-phase)46

(See Clause 6.1.5.3)

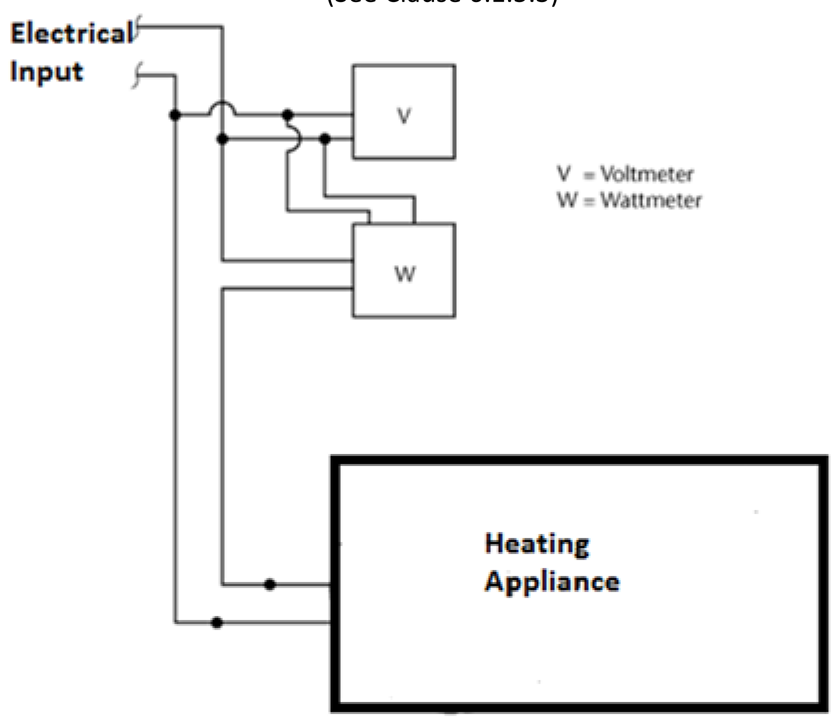


Figure 2 Connection of devices (single-phase) for measuring electrical power production from the heating appliance 47

(See Clause 6.1.5.3)

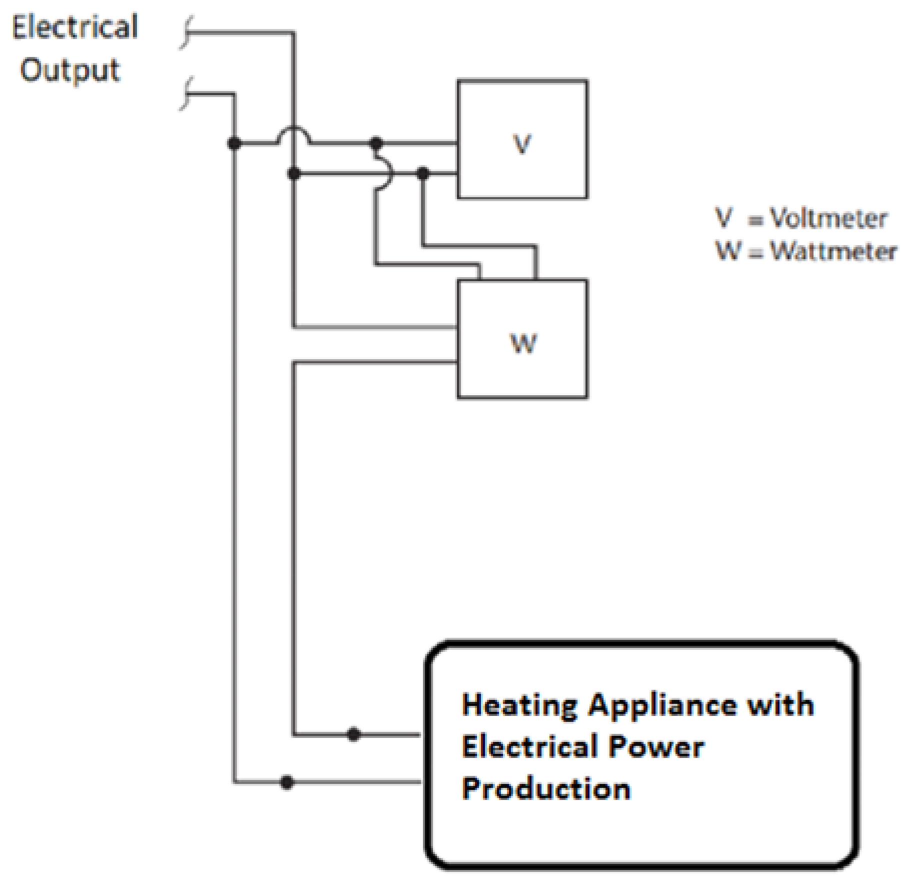
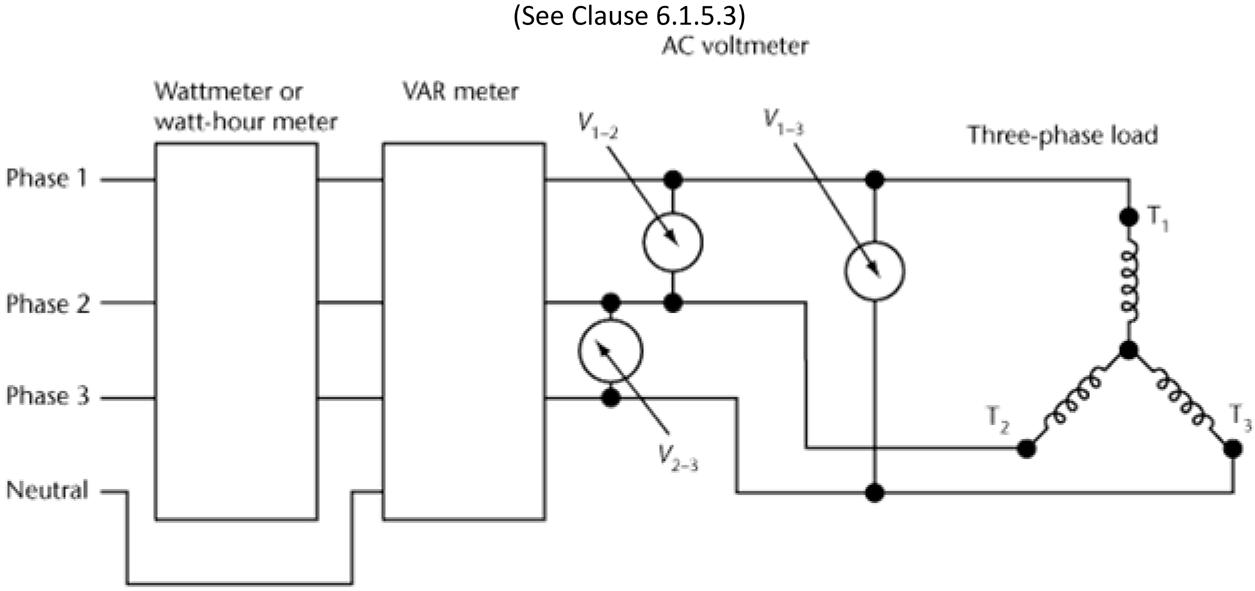


Figure 3 Connection of measurement devices (three-phase)47

(See Clause 6.1.5.3)



Legend:
T = terminal
Vx–y = voltage between phase *x* and phase *y*

Note: *A separate single- or three-phase wattmeter and/or VAR (volt-amp reactive) meter might be necessary for power monitoring of a second load such as a power burner, induced draft fan, or auxiliary component.*

6.1.5.4 Standby electrical power consumption

Electrical energy consumption on standby (EST), expressed in watts, shall be determined when the appliance has cooled down after testing.

After the appliance has been activated and been on standby (i.e., when the main burner and/or appliance operational functions are off), and allowed to stabilize for at least 5 min, the average measured power consumption (in watts) over a period of at least 5 min shall be recorded.

Stable conditions shall be indicated by a variation of less than 5% in the measured power consumption over 5 min.

For appliances with more than one low-power or standby operating state, measurements shall be taken at each of the low-power (standby) states.

If a default value is used, it shall be based on the sum of the V•A ratings of all permanently powered transformers, as follows:

EST default value = 0.2 W for every 1 V•A rating of permanently powered transformers

6.1.6 Calibration

Instruments shall be calibrated in accordance with the manufacturer's instructions and accuracy verified as required. Wherever possible, calibration shall be traceable to National Research Council Canada primary standards or equivalent.

6.1.7 Particulate sampling for Type 2, 3, 4 and 5 appliances

Particulate emissions should be measured in accordance ASTM E2515 with the following changes:

a) The filter temperature shall be maintained between 80 and 90 degrees F during testing.

b) Filters shall be weighed in pairs to reduce weighing error propagation; see ASTM E2515, Section 10.2.1 Analytical Procedure.

c) Sample filters shall be Teflon-coated glass fiber, and of 47 mm, 90 mm or 110 mm in diameter.

Note*: Pall TX-40 has been found acceptable for this purpose.*

d) Only one point is allowed outside the ± 10 percent proportionality range per test run.

6.1.8 Data collection and recording for Type 2, 3, 4 and 5 appliances

6.1.8.1 General

For each test run, the required data shall be recorded. All data required for the determination of total particulate matter emissions shall be recorded as defined in ASTM E2515-17, Sections 9 and 10. In addition, the data required for calculation of the stack loss efficiency shall be recorded at least every 10 min during the test run:

a) flue gas temperature;

b) ambient temperature;

c) weight on the platform scale;

d) CO_2 level; and

e) CO level.

6.1.8.2 Beginning of the test

The following shall be recorded once at the beginning of the test program:
a) A description of the appliance;
b) Firebox dimensions;
c) Air introduction systems dimensions of openings (minimum, maximum, fixed);
d) Baffle(s) dimensions and location;
e) Refractory material dimensions and location;
f) Insulation dimensions and location;
g) Catalyst combustor dimensions and location;
h) Catalyst bypass mechanism and catalyst bypass gap tolerances (when bypass mechanism is in closed position) dimensions, cross-sectional area, and location;
i) Flue gas exit dimensions and location;
j) Door and catalyst bypass gaskets dimensions and material;
k) Outer thermal shielding and thermal coverings: Dimensions and location;
l) Fuel feed system (for automatically fueled appliance); and
m) Forced-air combustion system description (power output, flow rate, dimensions).

6.1.8.3 Each test run

The following information shall be recorded for each test run:
a) Test fuel load information (including weight, length and moisture content of every fuel piece).
b) A description of the test fuel loading configuration;
c) Times at which any fuel is added;
d) Any adjustments to controls made during test preparation and operation; and
e) Final appliance control settings.

6.1.9 Pressure and Humidity

The ambient pressure and relative humidity shall be determined at the beginning and the end of the test. The measurements shall be averaged.

6.1.10 Efficiency and carbon monoxide

Overall efficiency shall be determined using the procedure specified in Clauses 6.1.10.1 to 6.1.10.5 The overall efficiency calculations may be performed using the Microsoft Excel® spreadsheet linked to this Standard (see Annex A).

6.1.10.1 Initial values

6.1.10.1.1 Wood fuel based tests

For wood fuel based tests, the initial values shall be determined using the following equations:
The initial dry weight of the fuel load shall be determined as

$$Wt_{do} = Wtm \times [1 - (0.01 \times MC_{wb})]$$

where

Wt_{do} = *initial dry weight of the fuel load, kg*
Wt_m = *initial wet weight of the fuel load, kg*
MC_{wb} = *initial moisture content of the fuel load, %*

The current dry weight of the fuel load shall be determined as

$$Wt_{dn} = W_t \times [1 - (0.01 \times MC_{wb})]$$

where

Wt_{dn} = *current dry weight of the fuel load, kg*
W_t = *current wet weight of the fuel load, kg*
MC_{wb} = *initial moisture content of the fuel load, %*

The moisture content of the burning fuel (% wet basis) shall be determined as

$$M_{wb} = MC_{wb} \times R$$

where

M_{wb} = *moisture content of the burning fuel (% wet basis)*
MC_{wb} = *initial moisture content of the fuel load, %*
R = *portion of the original wood moisture content that is being evaporated at the moment of sampling*

The moisture content of the burning fuel (% dry basis) shall be determined as

$$M_{db} = 100 \times \frac{M_{wb}}{100 - M_{wb}} \backslash$$

where

M_{db} = *moisture content of the burning fuel (% dry basis)*
M_{wb} = *moisture content of the burning fuel (% wet basis)*

The percentage of carbon in the dry burning fuel, CA, shall be the percentage of carbon in the fuel at the beginning of the burn cycle (using 48.73 for Douglas fir and the actual measured carbon content for other fuels).

The percentage of hydrogen in the dry burning fuel, HY, shall be the percentage of hydrogen in the fuel at the beginning of the burn cycle (using 6.87 for Douglas fir and the actual measured hydrogen content for other fuels).

The percentage of oxygen in the dry burning fuel shall be determined as

$$OX = 99.5 - (CA + HY)$$

where

OX = *percentage of oxygen in the dry burning fuel*
CA = *percentage of carbon in the dry burning fuel*
HY = *percentage of hydrogen in the dry burning fuel*

The fuel shall be assumed to contain 0.5% ash. For fuels with a higher ash content, the calculation of OX shall be adjusted accordingly.

The dry calorific value (Higher Heating Value) of the burning fuel, CV, shall be the dry calorific value of the fuel at the beginning of the burn cycle (using 19,810 kJ/kg for Douglas fir and the actual measured dry calorific value content for other fuels).

6.1.10.1.2 Tests conducted with particulate automatically fed fuels

For tests conducted with particulate automatically fed fuels, the values of Mwb, CA, HY, OX, and CV shall be those determined in accordance with Clause 6 for each appliance type for the sample of the fuel used in the test run.

6.1.10.2 Combustion equation

The results calculated shall be based on the following chemical equation modelling the wood combustion:

$$wC_aH_bO_c + uO_2 + 3.77uN_2 = dCO_2 + eCO + gO_2 + hN_2 + jH_2O + kCH_4$$

where

w = moles of dry fuel per 100 moles of dry flue gas

a = fraction of carbon atoms in the fuel

b = fraction of hydrogen atoms in the fuel

c = fraction of oxygen atoms in the fuel

u = moles of oxygen entering per 100 moles of dry flue gas

d = moles of CO_2 *per 100 moles of dry flue gas*

e = moles of CO per 100 moles of dry flue gas

g = moles of O_2 *per 100 moles of dry flue gas*

h = moles of N_2 *per 100 moles of dry flue gas*

j = moles of H_2O *per 100 moles of dry flue gas*

k = moles of CH_4 *per 100 moles of dry flue gas*

The stack oxygen concentration, g, shall be determined as

Determine the ultimate CO_2 for fuel composition:

$$CO_{2Ult} = \left\{ \frac{a}{a + 3.77\left[\frac{2a + b/2 - c}{2}\right]} \right\} \times 100$$

= 19.64% for Douglas fir using the composition specified in Clause 6.1.10.1.1

For each reading interval, calculate the excess air ratio, EA, as

$$EA = CO_2Ult/(d + e)$$

where

d = *CO_2 concentration for each reading interval*

e = *CO concentration for each reading interval*

For each reading interval, calculate the total oxygen concentration, O_2Total, as

$$O_2Total = [CO_2Ult + (EA - 1) \times 20.94]/EA$$

For each reading interval, calculate the oxygen concentration, g, as

$$g = O_2Total - (d + e/2)$$

6.1.10.3 Fuel constituents ratio

The following values (see Clause 6.1.10.1) shall be determined as

$a = CA/12$

$b = HY/1$

$c = OX/16$

where

CA = *percentage of carbon in the dry burning fuel*

HY = *percentage of hydrogen in the dry burning fuel*

OX = *percentage of oxygen in the dry burning fuel*

12 = *molecular weight of carbon*

1 = *molecular weight of hydrogen*

16 = *molecular weight of oxygen*

6.1.10.4 Mass balance

The masses of the elemental constituents shall be balanced as

The carbon balance shall be determined as follows:

$$aw = d + e + k$$

where

a = fraction of carbon atoms in the fuel

w = moles of dry fuel per 100 moles of dry flue gas

d = moles of CO_2 per 100 moles of dry flue gas

e = moles of CO per 100 moles of dry flue gas

k = moles of CH_4 per 100 moles of dry flue gas

The hydrogen balance shall be determined as follows:

$$bw = 2j + 4k$$

where

b = fraction of hydrogen atoms in the fuel

w = moles of dry fuel per 100 moles of dry flue gas

j = moles of H_2O per 100 moles of dry flue gas

k = moles of CH_4 per 100 moles of dry flue gas

The oxygen balance shall be determined as follows:

$$cw + 2u = 2d + e + 2g + j$$

where

c = fraction of oxygen atoms in the fuel

w = moles of dry fuel per 100 moles of dry flue gas

u = moles of oxygen entering per 100 moles of dry flue gas

d = moles of CO_2 per 100 moles of dry flue gas

e = moles of CO per 100 moles of dry flue gas

g = moles of O_2 per 100 moles of dry flue gas

j = moles of H_2O per 100 moles of dry flue gas

The nitrogen balance shall be determined as follows:

$$3.77u = h$$

where

u = moles of oxygen entering per 100 moles of dry flue gas

h = moles of N_2 per 100 moles of dry flue gas

The sum of the dry products shall be determined as follows:

$$d + e + g + h = 100$$

where

d = moles of CO_2 per 100 moles of dry flue gas

e = moles of CO per 100 moles of dry flue gas

g = moles of O_2 per 100 moles of dry flue gas

h = moles of N_2 per 100 moles of dry flue gas

Solving the following equations yields values for the unknowns *h, u, w, k,* and *j*:

The moles of nitrogen per 100 moles of dry flue gas shall be determined as follows:

$$h = 100 – d – e – g$$

The moles of oxygen entering per 100 moles of dry flue gas shall be determined as follows:

$$u = \frac{h}{3.77}$$

The moles of dry fuel per 100 moles of dry flue gas shall be determined as follows:

$$w = \frac{(8d + 4g + 6e - 4u)}{(4a - b + 2c)}$$

The moles of hydrocarbon (expressed as CH_4) per 100 moles of dry flue gas shall be determined as follows:

k = aw – d – e

the moles of water per 100 moles of dry flue gas shall be determined as follows:

$$j = \frac{bw - 4k}{2}$$

This Clause allows the weight of dry wood input per 100 moles of dry flue gas, and the moles of flue products per unit weight of dry wood input, to be determined.

6.1.10.5 Moisture in fuel

Additional moisture is present as water in the fuel load. The weight of water per unit weight of fuel shall be calculated using the equation in Clause 6.1.10.1 for *Mwb*. Since this weight is unchanged by the reaction, it is also present in the flue gas and shall be added to the *j* term to obtain the total water in the flue gases.

6.1.10.6 Heat content

Given the weight of fuel consumed over any time interval, the number of litres of product may be calculated using the values specified in Clauses 6.1.10.1 to 6.1.10.4 If the moles of product are determined for the fuel input over the interval, the instantaneous vent losses may be calculated as follows:

$l_i = \Sigma[Moles_{product} \times (Heat_{contentvent} - Heat_{contentambient})]$

where

l_i = sum of the enthalpies of the flue products over any portion of the run

$Moles_{product}$ = number of litres of product

$Heat_{contentvent}$ = enthalpy, latent heat (water), and heating value (CO and CH_4) of product at vent temperature

$Heat_{contentambient}$ = enthalpy of product at ambient temperature

The heat content in joules/mole shall be calculated as follows:

$$\text{sensible and latent loss rate} = \sum_{j=1}^{6} n_i \times \left(\left(\left(C_{p-i,TS} + C_{p-i,TR}\right)/2\right) \times \left(T_S - T_R\right)\right) + n_{H_2O} \times 43\,969$$

$$\text{chemical loss rate} = n_{CO} \times 282\,993 + n_{CH_4} \times 890\,156$$

where

nCO = molar flow rate of carbon monoxide

n_{CH_4} = molar flow rate of hydrocarbons

ni = molar flow rate of species i

Cp–i,TS= specific heat of species i at vent temperature, joules/mole•K

Cp–i,TR = specific heat of species i at room temperature, joules/mole•K

TS = vent temperature in K (°C + 273.15)

TR = ambient temperature in K (°C + 273.15)

nH_2O = molar flow rate of water vapour

The specific heat of species *i* at temperature *T* shall be determined as follows:

$CP\text{–}CO$ = 0.0056 × T + 27.162

$CP\text{–}CO_2$ = 0.029 × T + 29.54

$CP\text{–}H_2O$ = 0.0057 × T + 32.859

$CP\text{–}O_2$ = 0.009 × T + 26.782

$CP\text{–}N_2$ = 0.0062 × T + 26.626

$CP\text{–}CH_4$ = 0.056 × T + 18.471

where

T = temperature in K (°C + 273.15)

6.1.10.7 Total overall heat losses

The total overall heat losses shall be calculated as follows:

Lchem = Σ(lchem × dw)/W

Lsens & lat = Σ(lsens & lat × dw)/W

where

Lchem = total chemical loss due to unburned fuel, MJ

Ichem = chemical energy of the unburned flue products over any portion of the run

dw = dry weight interval between measurement of flue products

W = total dry weight loss during the sampling period

Lsens & lat = total sensible and latent losses, MJ

Isens & lat = sum of the enthalpies and latent heat of the flue products over any portion of the run

6.1.10.8 Heat output and efficiency

The overall heat output of the appliance, *Eo* , shall be calculated as follows:

Eo = I – Lsens & lat – Lchem

where

I = total weight of fuel burned during the test period multiplied by the calorific value of fuel per unit weight

Lsens & lat = total sensible and latent heat losses determined in accordance with Clause 6.1.10.7

Lchem = total chemical heat losses determined in accordance with Clause 6.1.10.7

Combustion efficiency, η_{comb}, shall be calculated as follows:

$$\eta_{comb} = \left[\frac{I - L_{chem}}{I}\right] \times 100$$

where

I = total energy input, MJ

Due to uncertainties in determining the ultimate analysis of the fuel and flue gas composition, the combustion efficiency calculation for very-clean-burning appliances can exceed 100%. When this occurs, the combustion efficiency shall default to 99.5% and this value shall be used to calculate the chemical losses as follows:

Lchem = 0.005 × I

The overall efficiency of the appliance shall be calculated as

$$\eta_r = 100 \times \frac{I - L}{I}$$

where

η_r = *overall efficiency, %, for test run r*

I = total energy input, MJ

L = Lsens & lat + Lchem

= total vent losses, MJ

Heat transfer efficiency shall be calculated as follows:

$\eta_{HT} = \eta_r /(\eta_{comb} /100)$

where

η_{HT} = *heat transfer efficiency, %*

η_r = *overall efficiency, %*

η_{comb} = *combustion efficiency, %*

For forced-air furnaces, the delivered efficiency of the appliance shall be calculated in accordance with Clause 6.4.4.

For hydronic heaters, delivered heat output shall be calculated in accordance with Clause 6.5.1; the delivered efficiency of the appliance shall be calculated as follows:

$\eta_{dr} = 100 \times (E_d + 3.6 \times \text{Power\_Output}) / I$

where

η_{dr}= *delivered efficiency, %, for test run r*

E_d = *delivered heat output, MJ*

Power_Output = electrical power output produced during each test run, kWh, where applicable. It is measured in accordance with Clause 6.1.5.

I = total energy input, MJ

6.1.10.9 Average vent temperature

The average vent temperature for the burn shall be calculated as follows:

$$T = \sum_{i=1}^{tot} \left(\frac{t_i \times \Delta w_i}{W} \right)$$

where

T = *average vent temperature, °C*

t_i = *vent temperature for interval i, °C*

Δw_i = *dry fuel weight loss for interval i, kg*

W = *total dry fuel weight loss during the sampling period, kg*

6.1.10.10 CO emissions

The CO emissions shall be determined as follows:

a) For Type 1 appliances:

Convert the measured CO concentration to a reference oxygen dilution according to equation n.n.

$CO_R = 20.95 – O_{2Reference} \times CO_{Measured}$ [ppm(v)]

(Eq. n.n)

$20.95 – O_2Measured$

where

CO_R = *CO corrected to O_2Reference*

20.95 = oxygen concentration in air

$CO_{Measured}$ = *average measured concentration of carbon monoxide in flue gas [ppm(v)]*

$O_{2Reference}$ = *11%*

$O_{2Measured}$ = *average measured oxygen content in flue gas (%)*

b) For Type 2 and Type 5 appliances:

$$W_{CO} = \left(\sum_{i=1}^{tot} n_{CO,i} \times 28 \times \Delta w_i\right) / E_o$$

where
Eo is as specified in Clause 6.1.10.7

c) For Type 3 and Type 4 appliances:

$$W_{CO} = \left(\sum_{i=1}^{tot} n_{CO,i} \times 28 \times \Delta w_i\right) / E_d$$

where
W_{CO} = *total CO emissions over the burn, g/MJ*
$n_{CO,i}$= *moles of CO over weight interval i*
28 = molecular weight of carbon monoxide
Δw_i = *dry fuel weight loss for interval i, kg*
E_d = *delivered heat output, MJ/h*

6.1.11 Particulate emission rate, total particulate emissions, and particulate emission factor

The particulate emission rate for each test run shall be determined as follows:
a) if measured in g/h:
$E_r = C_s Q_{sd}$
b) if measured in g/MJ:
E_r = 100CsQsd /BRr × CV × η+ (3.6 (Power_Output)]
where
E_r = *particulate emission rate for each test run, g/h or g/MJ*
C_s = *concentration of particulate matter in the vent gas, dry basis, corrected to standard conditions, g/m³ dry*
Q_{sd} = *average gas flow rate in the dilution tunnel, determined in accordance with Environment Canada Report EPS 1/RM/8, m³ dry/h*
BR_r = *dry fuel burn rate for each test run, kg/h*
CV = calorific value (Higher Heating Value) of the test fuel, MJ/kg dry fuel, determined in accordance with Clause 6.1.4
η = efficiency of the appliance, %
= η_{dr} *for central heating appliances, determined in accordance with Clause 6.4.4.4.3 or 6.5*
= η_r *for appliances other than central heating appliances, determined in accordance with Clause 6.1.10*

Power_Output = electrical power output produced during each test run, kWh, where applicable.

It is measured in accordance with Clause 6.1.5.

The total particulate emissions for each test run shall be determined as follows:

$E_t = 60E_rT_r$

where

E_t = total particulate emissions, g

E_r = particulate emission rate for each test run, g/h

T_r = total time of test run, min

The emission factor for each test run shall be determined as follows:

$E_{wt} = E_t / W_{tdo}$

where

E_{wt} = emission factor for each test run, g/kg dry fuel

E_t = total particulate emissions, g

W_{tdo} = initial dry weight of the fuel load, kg

6.2

Type 1: Site-Built Appliances

For appliances with unusual design or operational characteristics that make the application of these procedures impractical, these procedures may be suitably modified, provided that the modifications conform to the intent of this Standard.

6.2.1 Test apparatus

6.2.1.1 General

Follow the recommendations of the manufacturer for calibration.

For CO measurement, the instrument shall meet or exceed the following minimum specification:

a) Measurement range: ≥8,000 ppm

b) Resolution: 1 ppm

c) Accuracy:

  i) ±5 % of measured value (≤ 2000 ppm)

  ii) ±10 % of measured value (≥ 2001 ppm)

For O_2 measurement, the instrument shall meet or exceed the following minimum specification:

a) Measurement range: 0% to ≥21% volume

b) Resolution: ≤ 0.1% volume

c) Accuracy: ± 2% of measured value

For CO_2 measurement, the instrument shall meet or exceed the following minimum specification:

a) Measurement range: 0 – 20% volume

b) Resolution: ≤ 0.1% volume

c) Accuracy: ±5 % of measured value

Note*: When performing a site acceptance test, using a portable handheld combustion gas analyzer that has been designed for solid biofuel burning devices is important due to the presence of particulate matter. Examples of appropriate portable flue gas analyzers include a Testo 350, Enerac 500/700, Ecom EN2, E-Instrument E4500 or equivalent.*

6.2.1.2 Fueling

6.2.1.2.1 Batch fueled appliances

Test fuel shall comply with manufacturer’s written specifications, in absence of manufacturer fuel specification, refer to ASTM E2817-18 Annex A1 or CSA-ISO17225 part 5.

Fueling procedure shall comply with manufacturer’s written instructions, in the absence of clear instructions from the manufacturer, refer to ASTM E2817-18 for masonry heaters and ASTM E2558-13 (2021 Annex A1) for masonry fireplaces. For masonry heaters:

a) A batch load of fuel is stacked in the firebox according to the manufacturer's written instructions.

b) The manufacturer’s written instructions shall specify a minimum and a maximum initial fuel load.

c) Manufacturer's written instructions may specify one or more batch reloads. No batch reload may be less than 25% of the manufacturer's specified maximum total fuel load for a heating cycle. Heating cycles are typically in the range of 8 to 24 hours.

d) For an efficiency test, use the manufacturer's specified maximum fuel load

6.2.1.2.2 Non-batch fueled appliances

Test fuel shall comply with manufacturer’s written specifications. Fueling procedure shall comply with manufacturer’s written instructions.

6.2.2 Gas emissions and measurements

6.2.2.1 General

The general requirements are as follows:

a) The test is started from cold, no previous fire in the appliance for at least 12 hours before test

b) Begin taking samples (at least 30 min after ignition)

c) Sample CO and O_2 emissions for 30 continuous minutes or until end of yellow flaming, whichever comes first. If yellow flame is reached before 30 minutes, minimal sample time of 15 minutes.

d) Set the instrument sample frequency to a maximum of 30 seconds.

e) Sample location can be anywhere within the flue discharge stack downstream of the combustion chamber

f) The probe shall be inserted to take sample measurements approximately at the center of the flue pipe.

g) Apply the CO reference value conversion found in Clause 6.1.10.10

h) Check for compliance with Clause 4.1

i) If the appliance does not meet the requirement of Clause 4.1, a second test shall be performed to confirm the negative result. If the result of the second test meets the requirement of Clause 4.1, the appliance shall be deemed acceptable.

6.2.2.2 Flue gas measurements for thermal efficiency

The following instructions shall be followed:

a) Begin stack gas measurements no more than two minutes after ignition

b) Take readings every 5 minutes or less

c) Combustion air control, if present, is set to maximum setting for the duration of the burn.

d) There may be one adjustment of the fuel pile at any time during the test run, with a maximum of 30 seconds permitted for adjustment
e) End of Burn is defined as when either 4% CO_2 or 25% of the observed maximum CO_2 value is reached, whichever is lower

6.2.3 PM emissions test

There are no PM emissions requirements for site built appliances.

6.2.4 Thermal efficiency test

For efficiency determination using averaging of fuel consumption rather than on a scale use the Excel efficiency calculation spreadsheet of Annex A modified as described below:
a) Clean out firebox
b) Weigh fuel load before loading
c) Enter fuel weight into first cell of "Fuel Weight Remaining" column
d) At End of Burn remove and weigh fuel residue.
e) Subtract ash weight from fuel residue at a default value of 0.5% of initial fuel weight (dry basis)
f) Decrement the column labelled "Fuel Weight Remaining" linearly by equal fuel mass at 5-minute time intervals (i.e., full firebox to fuel residue, if any, less ash, in 5-minute intervals).
g) The fuel weight values to be input to the Fuel Weight Remaining section of the CSA B415.1 calculation spreadsheet shall be altered as follows: the remaining test fuel load weight at End of Burn shall be subtracted from the test fuel load weight input at each time increment in the spreadsheet including the zero-time value.

6.3 Type 2: Room heaters

For appliances with unusual design or operational characteristics that make the application of these procedures impractical, these procedures may be suitably modified, provided that the modifications conform to the intent of this Standard.

6.3.1 Installation of apparatus for testing room heaters

Refer to Clause 6.3.3.

6.3.2 Gas emissions and measurements

Refer to Clause 6.1.10.

6.3.3 Particulate matter measurements

6.3.3.1 Manually fueled room heaters — Testing with cribs

Appliance to be tested with cribs test fuel shall use the test method described in ASTM E2780-10 “Standard Test Method for Determining Particulate Matter Emissions from Wood Heaters". Annex A1 for cordwood fueling and operation shall not be used.

6.3.3.2 Manually fueled Room heaters — Testing with cordwood

Appliance to be tested with cordwood test fuel shall use the test method described in ASTM E3053-18 "Standard Test Method for Determining Particulate Matter Emissions from Wood Heaters Using Cordwood Test Fuel". Adjunct Excel spreadsheet "Adjunct to E3053, Excel files for Cordwood Calculator and Wood Heater Cordwood Test Summary" shall be used for wood load calculation and for data reporting with the following changes:

h) Alternative criteria for Section 8.5.9.5 (2) may be used. The test fuel load pieces also may be adjusted once (that is, repositioned) during a test run if more than 60 % of the initial test fuel load weight has been consumed and more than 10 min have elapsed without a 0.1 lb (0.05 kg) weight loss. Provide a detailed written description or photograph or video of the fuel load in the firebox before and after it is adjusted.

i) Alternative criteria for Section 8.6.12 Low and Medium Fire Test Run Completion may be used.

   i) Low and Medium Fire Test Run Completion — The test run is completed when the scale indicates the remaining weight of the test fuel load is 0.0 lb (0.00 kg) or less for 30 s OR if at least 90 % of the test fuel load weight has been consumed and weight loss is <0.1 lb (0.05 kg) for at least 30 min.

   ii) At the end of the test run, the particulate sampling per Test Method ASTM E2515-17 and CSA B415.1 sampling shall be stopped, and the final fuel weight, the run time, and all final measurement values recorded. See ASTM E3053-18 Section 9.2 for calculation procedure.

   iii) The total test run duration for purposes of determining emission rate equals the time from the beginning of the test load time per Section 8.6.9.1 to the test run completion.

j) For purposes of determining emission factor, the total fuel weight burned shall equal the test fuel load weight, less the ending weight at the test run completion, on a dry basis. For purposes of this test method, the moisture content of the charcoal bed at the beginning of the test run and any remaining fuel at the end of the test run shall be assumed to be 0%.

k) Alternative criteria for and Section 8.6.13 Invalid Test Run may be used.

l) Invalid Test Run—The test run shall be considered invalid if less than 90% of the test fuel load weight has been consumed when weight loss is <0.1 lb (0.05 kg) for at least 30 min.19.

6.3.3.3 Automatically fueled room heater — Specific requirements

6.3.3.3.1 Fuel

For wood pellet-burning appliances, the test fuel shall meet the specifications of Grade A1 and A2 wood pellets, targeting residential market specifically, as defined in the CAN/CSA-ISO 17225-Part 2:2015 of graded wood pellets.

For wood briquettes burning appliances, the test fuel shall meet the specifications of Grade A1 and A2, wood briquettes as defined in the CAN/CSA-ISO 17225 Part 3:2015.

A representative fuel sample shall be taken in accordance with ISO 21945 and analyzed for the following fuel properties using the test methods:

a) Higher heating value in accordance with CSA-ISO 18125

b) Ash composition in accordance with CSA-ISO 18122

c) Carbon, hydrogen and oxygen in accordance with CSA-ISO 16948

d) Moisture content in accordance with CSA-ISO 18134-3

6.3.3.3.2 Appliance operation

For pellet burning appliances, the appliance shall be operated in accordance with ASTM E2779-10 (2017). For single burn rate pellet burning appliances that are not automatically controlled, the appliance shall be operated for the same total sampling interval specified in ASTM E2779-10 (2017).
Non-pellet burning appliances shall be tested at the burn rates specified in ASTM E2779-10 (2017) in a single test run, as with pellet burning appliances. For appliance which burns larger fuel piece sizes, it may be necessary to apply a scaling factor to the test interval times specified in ASTM E2779-10 (2017) in order to achieve acceptable repeatability. See Annex B for optional procedure.
For non-pellet burning single burn rate appliance, the appliance shall be operated for the same total sampling interval specified in ASTM E2779-10 (2017). For non-pellet burning single burn rate appliance that is automatically controlled to achieve a targeted average heat output by cycling on and off, follow the operating procedure specified in paragraph 9.4.1.4 of ASTM E2779-10 (2017).
At the end of the test period, particulate sampling shall stop and the final fuel weight, and all other final measurement values shall be recorded.
The burn rate shall be determined in accordance with ASTM E2779-10 (2017). Alternative means of determining the burn rate may be used, provided that they have the required accuracy.

6.3.4 Thermal efficiency
Refer to Clause 6.1.10.

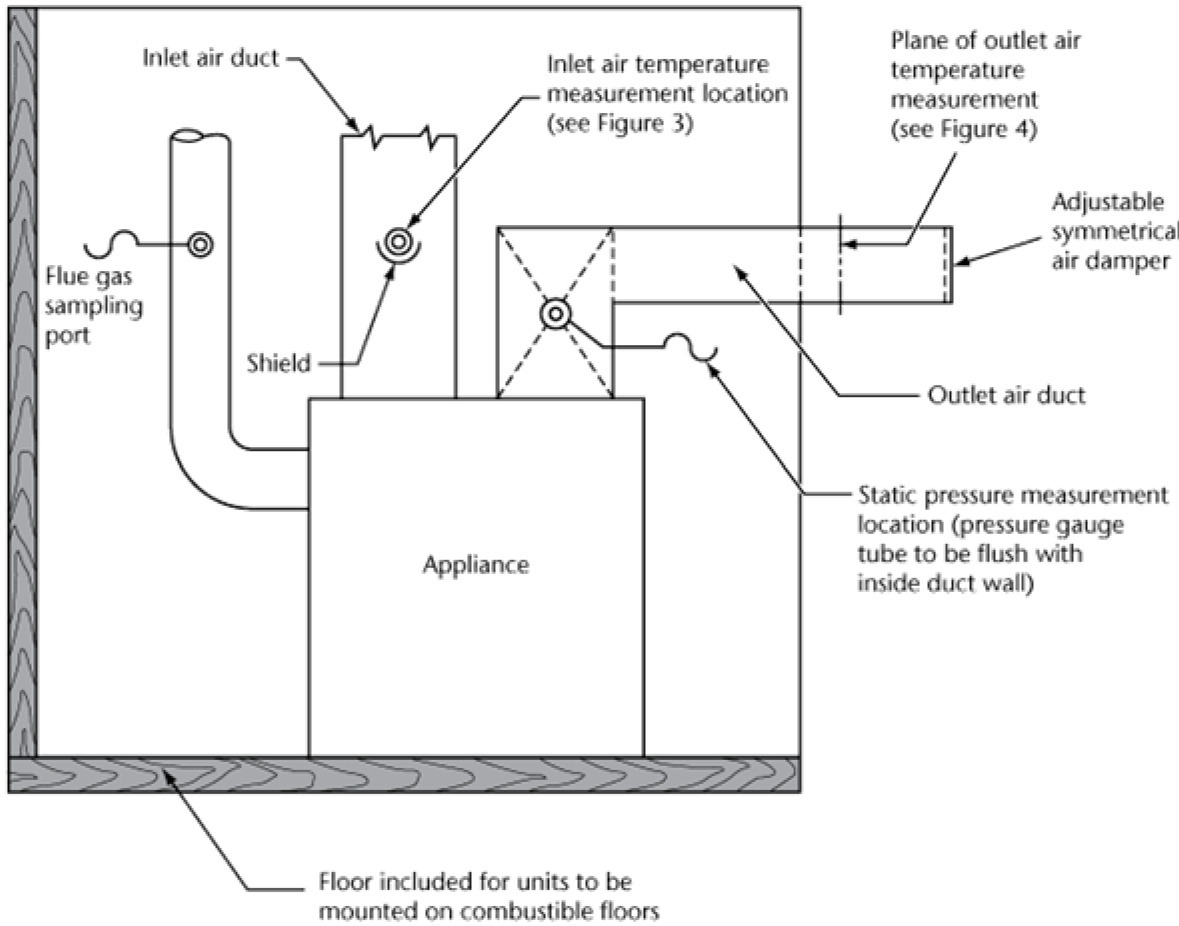
6.4

Type 3: Forced-air furnace

6.4.1 Installation instructions
Forced-air furnaces in which the burn rate is intended to be controlled by a thermostat or other remote device designed to cycle the furnace between the high and low fire condition shall be installed and adjusted in accordance with Clauses 6.4.1.1 to 6.4.1.5. Typical installation schematics are shown in Figures 4 and 5.

Figure 4 Duct, air temperature, and test point locations for in-line central furnaces (side view)44

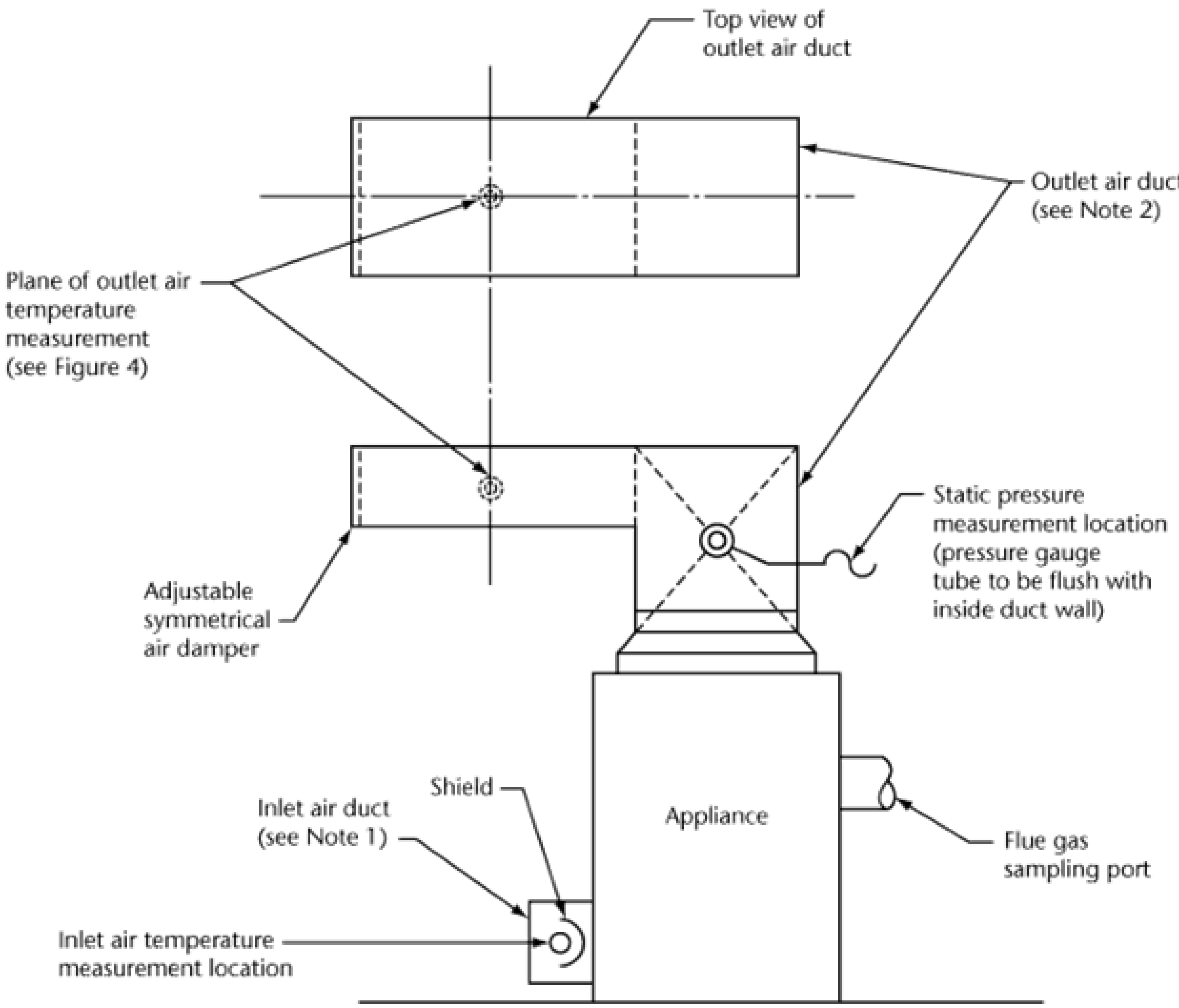
(See Clause 6.4.1)



Note: *The appliance is shown in a standard test enclosure.*

Figure 5 Duct, air temperature, and test point locations for upflow central furnaces45

(See Clause 6.4.1 and Figure 4)



Notes:

(1) The inlet air ducts for downflow, closet, alcove, and horizontal appliances shall extend at least *300 mm* (12 in) outside the enclosure wall or ceiling.

(2) The outlet air ducts for all installations shall extend at least *600 mm* (24 in) outside the enclosure.

6.4.1.1 Ducting Characteristic – Outlet duct

Appliances shall be fitted with an outlet air duct. If necessary for installation, an outlet air plenum shall also be fitted.

The outlet plenum and ductwork shall:

a) be insulated with at least the equivalent of 1.5 cm (0.6 in) fiber glass insulation;

b) provide a flow velocity sufficient for measurement with an accuracy of ± 5% at all fan operating speeds;

c) be of adequate cross-sectional area to allow a static pressure in the duct at or below that specified in Table 1;

Table 1 External static pressures for the rated output capacity test40

(See Clauses 6.4.1.1)

Rated output capacity, kW (Btu/h)	**External static pressure, Pa (in wc)**
≤47 (≤160 000)	50 (0.20)
> 47 and ≤ 88 (> 160 000 and ≤ 300 000)	62 (0.25)
> 88 (> 300 000)	As specified by the appliance manufacturer

d) provide for measurement of flow velocity and temperature at a point at least eight duct diameters downstream of the duct inlet or flow straighteners, and continuing at least two duct diameters past the measuring point or a sufficient distance to minimize the impact of the outlet air on test enclosure temperatures. See Equation (E-2) for equivalent diameter for rectangular duct; and

e) be fitted with adjustable restrictors at the duct exit to allow a static pressure in the duct in accordance with this Standard’s test requirements.

The outlet duct shall have a length of at least ten duct diameters (or the equivalent, for non-circular ducts).

To improve air flow characteristics, flow straighteners may be fitted in the beginning of the outlet air duct.

The outlet air duct may exit vertically from the furnace, in which case care shall be taken to shield the temperature-measurement thermocouples specified in Clause 6.4.1.3 from the furnace.

The flow restrictors (see Clause 6.4.1.1.e) at the outlet of the warm air duct shall be adjusted to obtain the external static pressure specified in Table 1 when the circulating blower is operated at its highest setting and with the circulating air at room temperature. For inputs greater than 88 kW (300 000 Btu/h), the static pressure shall be specified by the appliance manufacturer.

6.4.1.2 Ducting characteristic – Inlet duct

An inlet air duct at least 0.5 m (1.6 ft) long shall be fitted. Where the manufacturer’s installation instructions to the end-user provide for various inlet plenum locations, the location for testing shall be as specified by the manufacturer.

6.4.1.3 Furnace duct temperatures

The inlet air temperature shall be measured by a 24 AWG Type J thermocouple or equivalent. The thermocouple shall be located in the center of the inlet air duct and shielded to prevent a direct line-of-sight between the thermocouple and any part of the furnace.

The outlet air temperature shall be measured by a thermocouple array. The number and location of thermocouples shall meet the requirements for determination of velocity traverse points specified in Clause 6.4.4.4.2. The array shall be located approximately eight duct diameters downstream in the warm air duct and at least 20 mm (0.8 in) downstream of the velocity measurement probe. 2

The accuracy of the thermocouples (or equivalent) shall be ± 1.5% of absolute temperature.

6.4.1.4 Furnace duct velocity

During particulate sampling tests, the duct velocity when the blower is on shall be determined by a single point measurement near the centroid of the duct, with the actual flow rate determined by

applying a correction factor obtained from a duct velocity traverse as per Clause 6.4.4.4.2. The use of a standard type Pitot tube is adequate for this measurement.
Prior to run the test, a calibration run using an air velocity sensing device, such as a vane anemometer, shall be made at the duct outlet when the distribution blower is off as per Clause 6.4.4.4.1. The flow determined shall be used in the heat output calculations when the distribution blower is not running.

6.4.1.5 Furnace external static pressure

The static pressure in the warm air plenum or duct shall be measured by an inclined manometer or equivalent device having an accuracy of ± 2.5 Pa (± 0.01 in wc). The static pressure tube shall consist of a length of 6.4 mm (1/4 in.) OD tubing soldered to the surface of the duct, and centered over a hole of 1 mm (0.04in.) in diameter drilled through the duct. The tube shall be located in the supply plenum as shown in Figures 4 and 5. The end of the tube shall be flush with the plenum casing and the inside surface of the measurement hole shall be free from burrs and irregularities.

6.4.2 Forced-air furnace output rates

Appliances that do not have any means of controlling the output rate shall be tested and the emissions shall be reported based on the average of at least three test runs.
For appliances not covered by the first paragraph of this Clause, different output rates as required by the third paragraph of this Clause shall be achieved using the control settings as required in Clause 6.4.2.1 and 6.4.2.2, consistent with the manufacturer's written instructions supplied to the end-user with the unit. If these instructions recommend manual adjustment after refuelling, such adjustments shall be performed during the first 5 min of the burn cycle only.
One emission test run shall be required in each of the output rate categories in Table 2:

Table 2 Burn-rate categories for forced-air furnaces 42

(See Clause 6.4.2)

	Category 1	Category 2	Category 3	Category 4
% of manufacturer's rated output	< 35	≥35 and < 53	53–76	Rated output (maximum)

The first test run shall produce a heat output rate that is within 10 % of the manufacturer's rated heat output (Category 4). If the appliance is not capable of producing a heat output within these limits, the manufacturer's rated heat output is considered not validated and testing is to be terminated. In such cases, the tests may be continued using the heat output as measured as the Manufacturer's Rated Heat Output if requested by the manufacturer.

6.4.2.1 Manually controlled burn rate

The following requirements shall apply to appliances in which the output rate is intended to be set manually using a control located on the appliance:

a) Category 1: Needs to be the minimum primary air control opening and the lowest achievable output rate (Btu/h).

b) Category 2 and 3 output rates: the appliance shall be operated with the primary air control or other control device set at the predetermined position necessary to obtain the average output rate required for the category.
c) Category 4 output rate: during the entire test run the appliance shall be operated with the primary air controls fully open and needs to be the maximum achievable output rate.

For all output rates, if an auxiliary appliance temperature-sensing control is fitted, it shall be allowed to operate in accordance with the manufacturer's instructions.

6.4.2.2 Thermostatically controlled burn rate

For central forced-air furnaces in which the output rate is intended to be controlled by a thermostat or other remote device designed to cycle the appliance between the high and low fire condition, one emission test run shall be required in each category. The target set points in Table 3 may be used:

Table 3 Target set points for forced-air furnaces 42

(See Clause 6.4.2.2)

	Category 1	Category 1	Category 3	Category 4
Target set point (% of maximum output)	Minimum achievable (always off)	44 nominal (35 to 53 actual)	65 nominal (53 to 76 actual)	Maximum achievable (always on)

The target set point needs to be inside the range of the category. The same target set point shall be used for the whole test run. The target set point is used to switch the thermostat to the "on" and "off" position in function of the integrated heat output rate. The integrated heat output rate is the average heat output rate from the start of the run.

Switching the thermostat "on" and "off" at the target set point may result in an integrated heat output rate above or below the category range during the test run due to the furnace's thermostat response lag time. However, the integrated heat output rate shall be in the range of the category at the end of the test run. See the note below.

Note*: Example of furnace rated at 50 000 BTU/h.*

Category 2 with set point at 50% (25 000 BTU/h). The range (35 to 53%) is from 17 500 to 26 500 BTU/h. At the start, thermostat is "on". At 15 minutes, the integrated heat output rate is 24 800 BTU/h. At 16 minutes, the integrated heat output rate is 26 100 BTU/h. The thermostat is turned "off". At 45 minutes, the integrated heat output rate is 32 000 BTU/h. At 3h30, the integrated is 25 500 BTU/h. At 3h31, the integrated heat output rate is 24 900 BTU/h. The thermostat is turned "on". At the end of the test, the finale integrated heat output rate is 19 200 BTU/h.

This test is compliant because:

The set point used was inside the range of the category (50 % is between 35% and 53%)

The thermostat was turned on & off using the same target of 50% (25 000 BTU/h) during the whole test

The integrated heat output rate at the end of the test is inside the range because 38.4% (19 200 BTU/h) is between 35% and 53%.

For all output rates, if an auxiliary appliance temperature-sensing control is fitted, it shall be allowed to operate in accordance with the manufacturer's instructions.

The Category 2 and 3 outputs shall be achieved by setting the remote control to the "on" position at the beginning of the run and keeping it at this setting until the average heat output from the start of the run, as determined by measurement of the outlet plenum air flow rate and temperature rise across the appliance, exceeds the target percentage of maximum output. The remote control shall then be set to the “off” position and remain at that setting until the average output from the start of the run drops below the target percentage of maximum output. At that point the remote control shall again be switched to the “on” position until the average output from the start of the run exceeds the target output. This process shall be continued until the run is completed. Measurements shall be taken at intervals of 1 min or less between readings. Outputs shall be determined using the procedure specified in Clause 6.4.4.4.

While power output measurements shall be made in an interval of 1 minute or less, proportionality measurement of the particulate matter sampling can still be measured in an interval of 10 minutes or less.

The Category 4 output shall be achieved by leaving the remote control in the “on” position throughout the test.

Appliances with control systems other than those described in Clause 6.4.2.2 shall be tested in a manner consistent with the intent of Clause 6.4.2.2.

6.4.3 Manually or automatically fueled cordwood forced-air furnace — Specific requirements

Appliances shall be tested in accordance with Clauses 6.4.3.1 to 6.4.3.4 For appliances with unusual design or operational characteristics that make applying the test procedure specified in Clauses 6.4.3.1 to 6.4.3.4 impractical, the test procedure may be suitably modified, provided that it conforms to the intent of this Standard.

6.4.3.1 Firebox measurement

The volume of a rectilinear firebox shall be the product of the firebox length, width, and height. Determine the firebox volume in cubic feet or cubic meter. Firebox volume shall include all areas accessible through the fuel loading door where firewood could reasonably be placed up to the horizontal plane defined by the top of the loading door. A drawing of the firebox showing front, side and plan views or an isometric view with interior dimensions shall be provided by the manufacturer and verified by the laboratory. Calculations for firebox volume from computer aided design (CAD) software programs are acceptable and shall be included in the test report if used. If the firebox volume is calculated by the laboratory the firebox drawings and calculations shall be included in the test report.

6.4.3.2 Fuel placement and load density

Pieces shall be placed in the firebox parallel to the longest firebox dimension or in the direction specified in the manufacturer’s printed operating instructions. When test fuel is loaded, no effort shall be made to stack fuel pieces either tightly or loosely with respect to one another.

The wet weight of test fuel loads shall be determined by multiplying the firebox volume determined in accordance with Clause 6.4.3.1 by 162 kg/m^3 (10 lb/ft^3), or by a higher load density as recommended by the manufacturer’s printed operating instructions. The number of pieces of fuel that most nearly match this target weight shall be selected. When the manufacturer’s printed instructions specify fuel loading to a specific level, the firebox shall be loaded with fuel as specified in Clause 6.4.3.3 to the specified level and the weight of the fuel load shall be recorded. This weight shall then be divided by the firebox volume and the resulting loading density shall be recorded. If the loading density is less than 162

kg/m^3 (10 lb/ft^3), all tests shall be run with fuel load densities of 162 kg/m^3 (10 lb/ft^3), even if this necessitates loading to a level higher than specified in the manufacturer's instructions.

6.4.3.3 Fuel characteristics

The weight of fuel consumed during a burn shall be determined using a device capable of measuring to within ± 0.05 kg (± 0.10 lb) or 1% of the initial test fuel load weight, whichever is greater.
Moisture content shall be determined as follows:

a) the test fuel moisture content shall be measured with a calibrated electrical resistance moisture meter not more than 4 h before the test run;
b) the fuel moisture for each fuel piece shall be determined by averaging at least three moisture meter readings, one from each of three sides, measured parallel to the wood grain;
c) the moisture content shall be measured within 50 to 75 mm (2 to 3 in) of each end and at the centre of each piece;
d) the readings for each fuel piece in the test fuel load shall be averaged for each piece; and
e) the moisture meter's insulated electrodes shall penetrate at least 19 mm (0.75 in) into each fuel piece in the test charge.

The test fuel load shall be a species of cordwood with a specific gravity of 0.60 to 0.73 (see Table 4) on a dry basis and a moisture content of 18 to 28% on a dry basis when measured in accordance with the second paragraph of this Clause. Piece length shall be 508 ± 102 mm (20 ± 4 in) (see Figure 6).

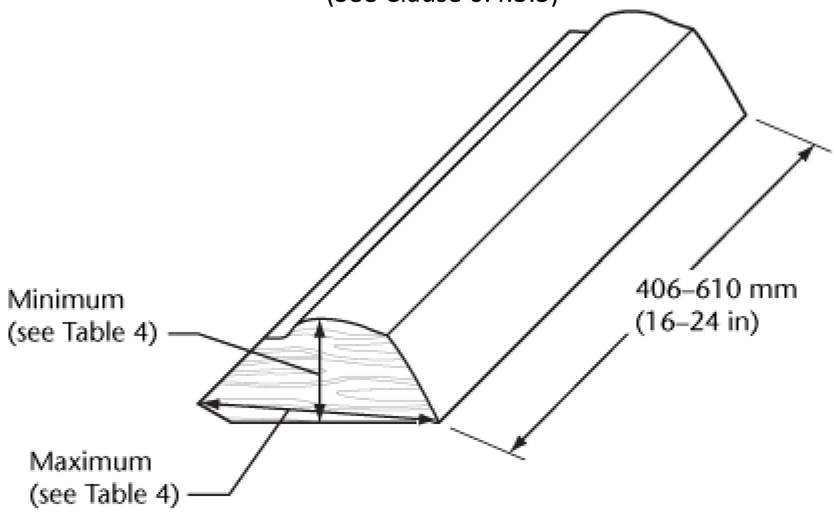
Table 4 Specific gravity of commercially important species of wood based on oven-dry weight and oven-dry volume42

(See Clause 6.4.3.3)

Species	**Specific gravity**
Ash, white	0.63
Beech	0.67
Birch, sweet	0.71
Birch, yellow	0.65
Elm, rock	0.67
Maple, hard (black)	0.60
Maple, hard (sugar)	0.67
Oak, red	0.66
Oak, white	0.71
Pecan	0.73
Pine, southern, longleaf	0.64

Figure 6 Dimensions of test fuel pieces47

(See Clause 6.4.3.3)



Only cordwood pieces that are free of decay, fungus, and loose bark shall be used. Test loads shall be made up of fuel pieces as specified in Table 5.

Table 5 Firebox volume and cross-section, weight, and number of cordwood pieces42

(See Clause 6.4.3.3 and Figure 6)

Firebox volume, m3 (ft3)	Cross-section of piece, mm (in)		Minimum weight of piece, kg (lb)	Maximum weight of piece, kg (lb)	80% piece weight range, kg (lb)	Number of pieces
	Minimum	Maximum				
< 0.11 (< 4)	51 (2)	152 (6)	1 (2.2)	6 (13.2)	1.5–5 (3–11)	4–7
≥0.11 and < 0.28 (≥4 and < 10)	64 (2.5)	203 (8)	2 (4.4)	8 (17.6)	3–7 (6.7–15.5)	5–10
≥0.28 and < 0.56 (≥10 and < 20)	76 (3)	254 (10)	3 (6.7)	10 (22)	4–9 (9–20)	8–15
≥0.56 (≥20)	76 (3)	305 (12)	4 (9)	12 (27)	4–10 (9–22)	> 12

6.4.3.4 Forced-air furnace operation

The pretest fuel load pieces shall be cordwood meeting the requirements of Clause 6.4.3.2 and 6.4.3.3, in approximately the weight ratio used for the test fuel load. Crumpled newspaper and kindling may be used to help ignite the pretest fuel.

The air inlet supply control(s) may be set at any position that will maintain combustion of the pretest fuel load. At least 1 h before the start of the test run, the air supply controls shall be set at the approximate positions desired for the test run. In the case of a Category 2 of a thermostatically controlled forced-air furnace, set the heat demand to OFF. For a category 3, set the demand to ON. Adjustment of the air supply controls, addition of fuel, and raking out of the bottom of the firebox (including stirring the coals, breaking the burning fuel into smaller pieces, moving fuel pieces from positions of poor combustion, and checking for the condition of uniform charcoalization) shall be recorded and kept to a minimum but may be performed up to 15 min prior to the start of the test run. Fuel weight data and wood heater temperature measurements shall be recorded at intervals of not more than 10 min during the pretest ignition period. During the 15 min prior to the start of the test run, the wood heater loading door shall not be open more than a total of 1 min. Raking out the bottom of the firebox shall be the only adjustment allowed during this period.

The weight of pretest fuel remaining at the start of the test run shall be determined as the difference between the weight of the appliance with the remaining pretest fuel and the tare weight of the cleaned and dry appliance, with or without dry ash or sand (added in a manner consistent with the manufacturer's instructions and the owner's manual). The tare weight of the appliance shall be determined with the appliance and ash, if added, in a dry condition.

Note: *One purpose of the pretest ignition period is to achieve uniform charcoalization of the test fuel bed prior to loading the test fuel load. Uniform charcoalization is a general condition of the test fuel bed characterized by an absence of large pieces of burning wood in the burning material on the bottom of the firebox and the brittleness of remaining fuel pieces, such that they can be broken into smaller charcoal pieces with a metal poker. Manipulations of the fuel bed prior to the start of the test run should be carried out to achieve uniform charcoalization while maintaining the desired burn rate. In addition, some appliances (e.g., high-mass units) can require extended pretest burn time and fuel additions to reach an initial average surface temperature.*

When the kindling and pretest fuel have been consumed to leave a fuel weight between 10 and 25% of the weight of the test fuel load, the weight of the remaining fuel shall be recorded and the test run shall be started. All individual appliance surface temperatures and catalytic combustor temperatures, and any initial sampling method measurement values, shall be recorded. Particulate emission sampling shall then begin.

The maximum allowable time for loading the main fuel load following the start of the test run shall be equal to 700 s/m^3 (20 s/ft^3) of usable firebox volume but shall not be less than 1 min. Within the maximum allowable load time, the test fuel load weight shall be recorded, the appliance door shall be opened, and the test fuel load shall be loaded.

The maximum start-up time shall be equal to 3530 s for each cubic metre (100 s for each cubic foot) of usable firebox volume but not less than 5 min. The appliance door may remain open and the air supply controls may be adjusted within the maximum start-up time to adjust the test fuel load and ensure that ignition of the test fuel load has occurred. Within the maximum start-up time, the appliance door (and catalytic-combustor bypass damper, if present) shall be closed and the air supply controls adjusted to the position determined to produce the desired burn rate. The air supply controls and test fuel load shall not be adjusted after the maximum start-up time. A record shall be made of the length of time the appliance door remains open, the adjustments to the air supply controls, and other operational adjustments.

The test fuel load may be adjusted (i.e., repositioned) once during a test run if more than 60% of the initial test fuel load weight has been consumed, and if more than 10 min have elapsed with a weight change of less than 0.05 kg (0.10 lb). The time used to make this adjustment shall be less than 30 s.

Provide a detailed written description or photograph or video of the fuel load in the firebox before and after it is adjusted.
The test run shall be considered completed when the remaining weight of the test fuel load is zero. The test run shall end when the scale indicates a test fuel load weight of 0.00 kg (0.00 lb) or less for 30 s. Particulate sampling shall stop and the run time and all final measurement values shall be recorded.
The appliance shall be cleared of ash and charcoal after not more than four test charges. The procedure described in Clause 6.4.3.4 shall be repeated prior to further tests. If the manufacturer’s instructions recommend a bed of inert material, this inert material shall be replaced to the recommended minimum level.

6.4.4 Automatically fueled forced-air furnace — Specific requirements

6.4.4.1 General

Test procedures for automatically fueled appliances shall be based on the procedures for cordwood-fired appliances as modified by Clauses 6.4.4.1.1 and 6.4.4.1.2 For appliances with unusual design or operational characteristics that make the application of these procedures impractical, these procedures may be suitably modified, provided that the modifications conform to the intent of this Standard.

6.4.4.1.1 Fuel characteristics

Fuel shall meet the specification in Clause 6.3.3.3.1.

6.4.4.1.2 Appliance operation

The fire shall be started in the unit in accordance with the manufacturer’s written instructions, with the controls adjusted to achieve the desired burn rate. The appliance shall be operated at the desired burn rate until all test parameters have stabilized, but not less than 1 h, before the start of the test run.
Fuel shall be added to the supply hopper as necessary to complete the test run. The weight of the fuel in the supply hopper shall be determined and the test run shall be started. Additional fuel shall not be added to the hopper during the test run. Manual adjustments shall not be made to the appliance air supply or wood supply rate during the test run.
Appliance testing shall continue for at least two hours. At the end of the test period, particulate sampling shall stop and the final fuel weight, run time, and all other final measurement values shall be recorded.
The burn rate shall be determined using the difference between the initial and final fuel weights, and the burn time. The burn rate may be determined by dividing the difference between the weight of the fuel hopper at the beginning and end of the test period by the burn time, if practicable. Alternatively, the burn rate may be determined by marking the supply hopper in a manner that allows determination of the volume of fuel at the beginning and end of the burn and weighing a quantity of fuel sufficient to determine its density under conditions of packing similar to those in the hopper. Alternative means of determining the burn rate may be used, provided that they have the required accuracy.

6.4.4.2 Gas emissions and measurement

Refer to Clause 6.1.10.

6.4.4.3 Particulate measurements
Particulate measurement shall be conducted in accordance with Clause 6.1.7.

6.4.4.4 Direct measurement of the output and efficiency
A forced-air furnace uses a blower to move air over a firebox/heat exchanger. An insulated outlet duct is installed on the furnace with flow restrictors to create a target static pressure in the duct. Temperature, air flow rate, and static pressure in the duct are determined in accordance with recognized procedures Clause 6.4.1. The inlet air barometric pressure, temperature, and moisture content are also determined. From these, the amount of heat added to the airstream by the furnace can be determined. This measurement can be integrated to determine the heat output over any time interval. It can also be integrated over the course of the burn and compared to the heat content of the fuel load to determine the delivered efficiency of the furnace over the complete burn.
Direct output measurement allows real-time determination of the instantaneous and integrated heat output rate of a furnace. By comparing actual heat output rate to a target heat output rate, the control settings of the furnace can be adjusted to attempt to maintain the target heat output rate in a manner consistent with normal operation. The overall heat output rate, and hence delivered efficiency, of the furnace can be determined.

6.4.4.4.1 Measurement procedure of duct velocity when the blower is off
To evaluate the energy distribution when the blower is off, a calibration run, prior to the test program, shall be performed. The calibration run is a complete test run in which the blower is off for the longest period of time. The heat output shall be set to Category 1. On that calibration run, a supplemental smaller section is to be added to the duct outlet to allow an adequate measurement of the velocity without obstructing the natural convective flow.
Note*: This calibration run can be counted as part of the conditioning pre-burn of the furnace.*
The velocity shall be measured using an air velocity sensing device, such as a vane anemometer, capable of measuring air velocity as low as 60 ft/min. It is recommended to use a vane anemometer that can be recorded for a long period of time to better evaluate the energy distribution over time. It is also recommended to use a vane anemometer with a large vane diameter to minimize flow interference from the anemometer body on the readings.
To perform the calibration run, a downward flowing circular calibration duct shall be fitted to the exit of the duct outlet. The calibration duct shall have a length of at least 2.5 duct diameters after the last cross-sectional area change. If the outlet duct is circular, a 90° elbow of the same diameter of the duct outlet may be fitted, followed by an assembly of one or multiple reducers. If a rectangular outlet duct is used, a conversion duct having a pyramidal or conical shaped shall be fitted to the outlet to convert from rectangular to circular duct. The biggest possible 90° elbow shall be fitted on the conversion duct, followed by an assembly of one or multiple reducers. The calibration duct shall be fitted to last reducer. Figure 7 and 8 present an example of calibration duct installed.

Figure 7

Forced-air furnace with calibration duct for blower off flow rate measurement
(See Clause 6.4.4.4.1)

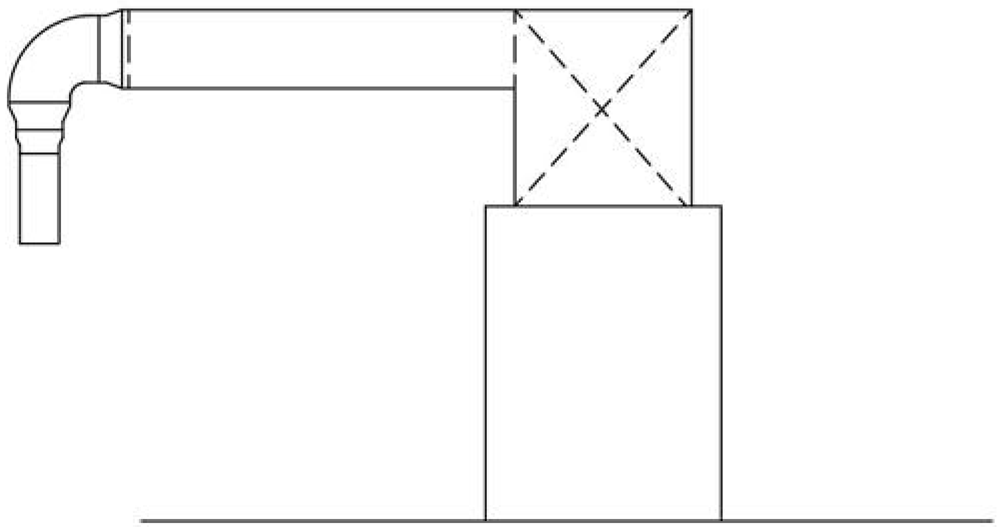
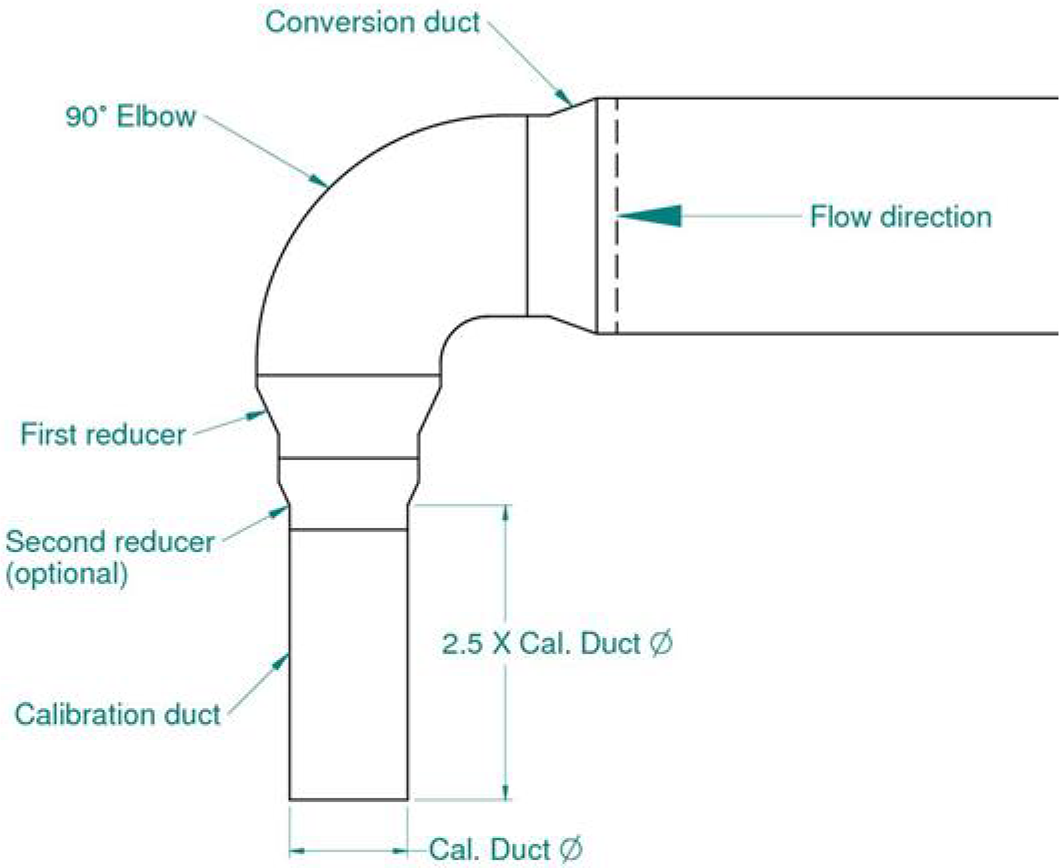


Figure 8

Detailed view of the calibration duct for blower off flow rate measurement
(See Clause 6.4.4.4.1)



The diameter of the calibration duct shall be sized to allow a vane anemometer to read a velocity between 1.5 and 3 times the minimum velocity measurement while measuring the blower off velocity at the warmest temperature condition as per Clause 6.4.4.4.1.e.

Note: *For example, if the minimum measurable value of the vane anemometer is 50 ft/min, the maximum measured value shall be 150 ft/min (3 x 50 ft/min) and the minimum measured value shall be 75 ft/min (1.5 x 50 ft/min). If a calibration duct of 5 inches is used, and the measured value is at 175 ft/min, a larger duct shall be used to prevent flow obstruction. If an 8 inches duct is used for the same flow rate, the velocity would drop to 68 ft/min, which is below the minimum measurement value. In that case, the use of a 6 inches duct would give a velocity of 122 ft/min which complies with the requirement.*

The following procedure shall be performed to generate the data needed to create an equation that relates temperature and flow rate when the blower is off. This procedure may be suitably modified to fit to different furnaces, provided that the modifications conform to the intent of this Standard.

a) Light kindling as per Clause 6.4.3.4.

b) Add preload as per Clause 6.4.3.4.

c) Tare the scale and load the fuel pieces as per Clause 6.4.3.4.

d) Operate the furnace to achieve Category 1 per Clause 6.4.2.2.

e) When the fire is at its maximum flue temperature (flaming period, during the first hour), the blower shall be forced off for a period of at least 10 min. The velocity measurements and the temperature measurement of the thermocouple array shall start 1 minute after the blower is turned off.

f) Measurement shall be taken at a time interval of 1 minutes or less.

g) After the forced 10-minute period, the blower shall function as designed until all fuel is consumed.
h) If a vane anemometer with recording is used, measurement shall be made at an interval no more than 1 minute.
i) If a vane anemometer without recording is used, the interval shall be every 15 minutes when the blower is cycling on and off, and every 30 minutes if the blower is off without the possibility to be turned on again.
j) The calibration run ends when all the fuel is consumed. Record the last velocity and temperature measurement.

6.4.4.4.1.1 Recommended procedure to extract data from calibration run

All data gathered is used to find the equation that best fits the flow rate of when the blower is off as function of the thermocouple array temperature. The following steps may be used:
a) Filter the data to keep only the values when the blower is off.
b) If the off-period is longer than 1 min, remove the first off minute of the period to avoid transition conditions.
c) Calculate the flow rate for every time step. A velocity profile factor of 0.95 shall be applied. See equation E-3
d) Plot the flow rate of when the blower is off as a function of the thermocouple array temperature.
e) Find the equation of the trendline that fits the best (highest R^2).
f) Use that equation to calculate the real-time flow rate of the blower off period as a function of the thermocouple array during the test program.

6.4.4.4.1.2 Example of calibration run

Figure 9 shows all data gathered in an example of calibration test run expressed as calibration duct velocity as a function of the average duct temperature. First step is to filter and remove the flow of when the blower was on.

Figure 9

Graphical presentation of a calibration run
(See Clause 6.4.4.4.1.2)

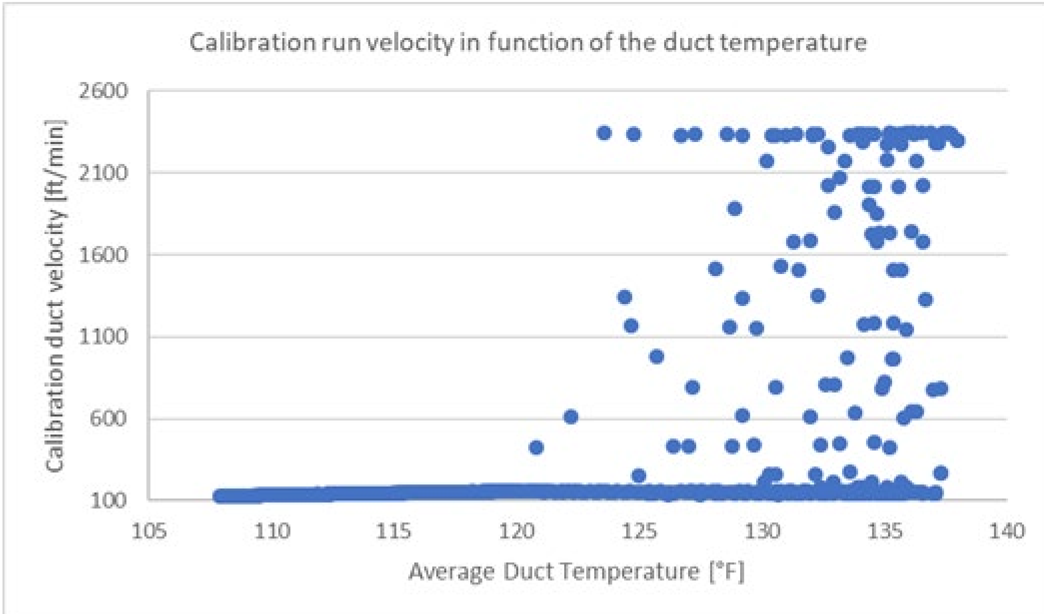


Figure 10 shows the same data, without all velocity above 180 ft/min. On this figure, it is possible to see two distinct behaviors: the right-hand side portion is a cycling portion, while the left hand side portion is when the blower was off for the last time, until the end of the calibration run. In that case, the best is to have 2 different equations for the two-distinct period.

Figure 10

Graphical presentation of a calibration run with filtering on data
(See Clause 6.4.4.4.1.2)

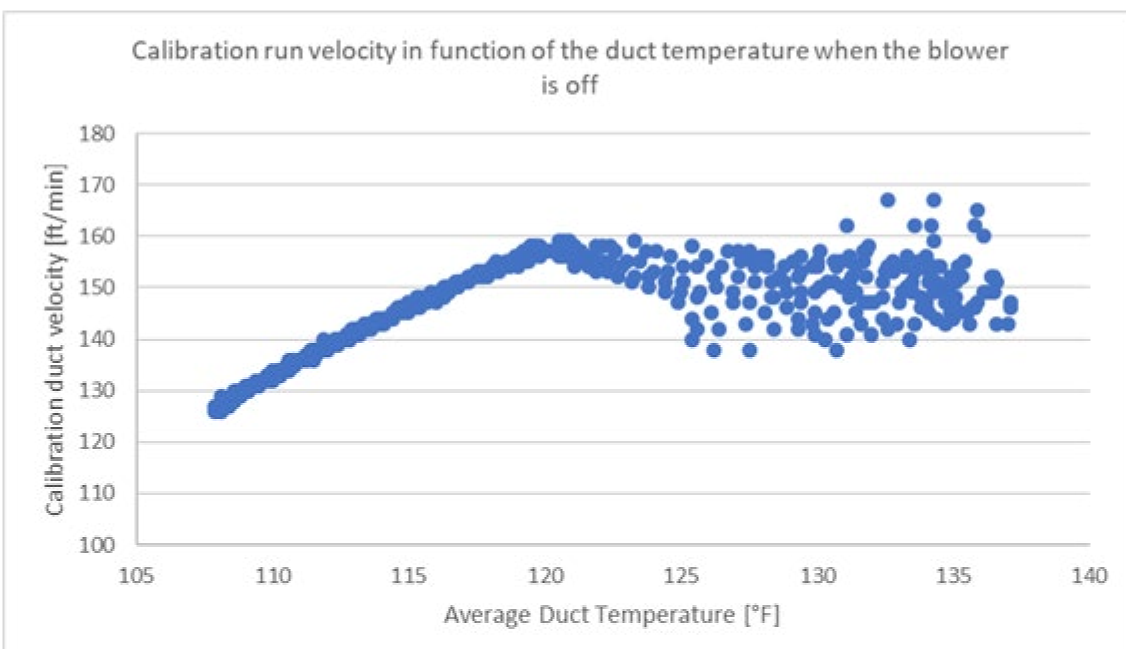


Figure 11 shows the portion when the blower was still cycling. This portion does not have a clear tendency due to the frequent cycling of the blower.

Figure 11

Graphical presentation of a cycling portion of the calibration run with filtering on data
(See Clause 6.4.4.4.1.2)

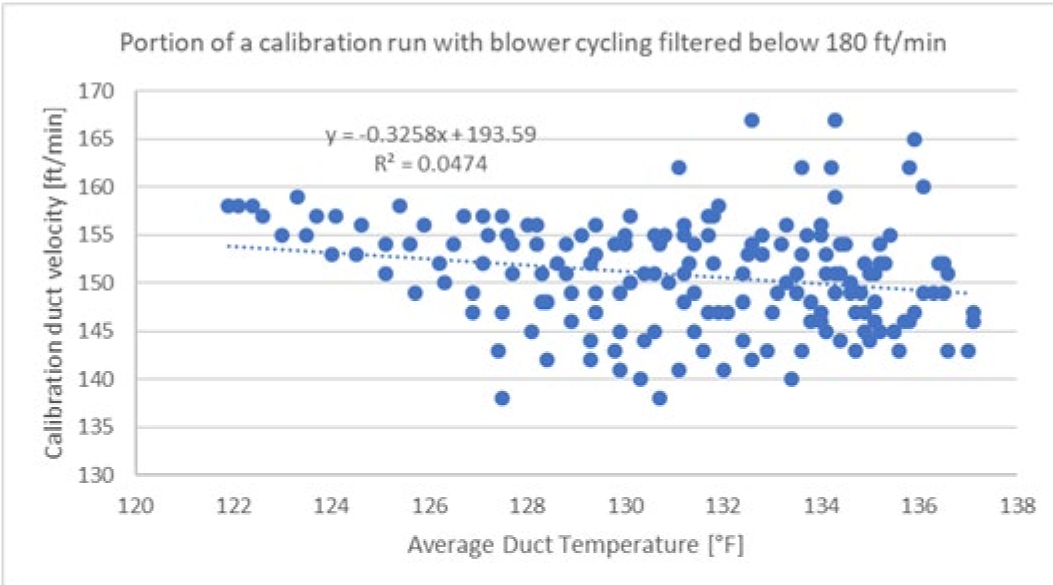
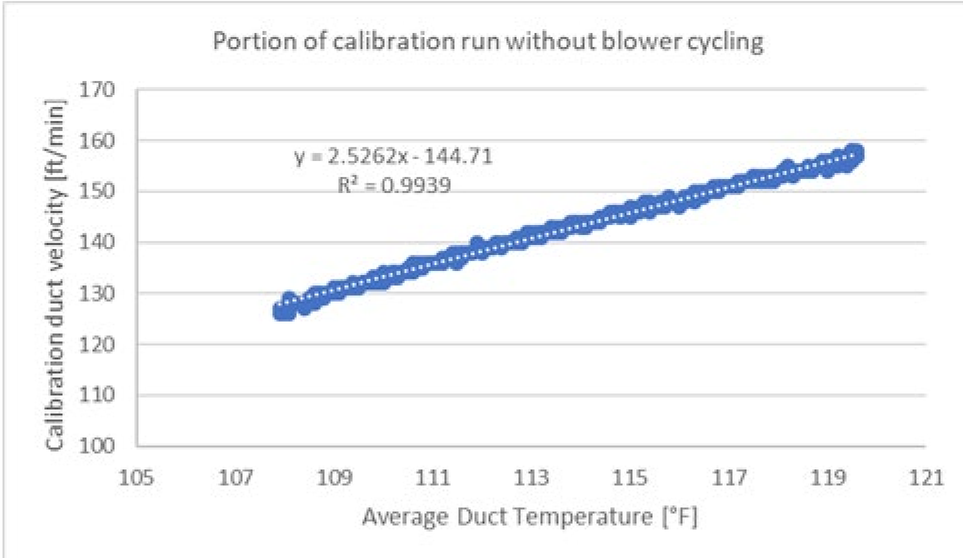


Figure 12 shows the portion where the blower stopped for the last time until the end of the run. On that portion, the flow is more stable, and a relationship can be observed. The trendline gives a linear equation that should be implemented in the calculation of the heat output rate while doing the official test runs.

Figure 12

Graphical presentation of a portion of the calibration run with blower always off
(See Clause 6.4.4.4.1.2)



6.4.4.4.2 Measurement procedure of duct velocity when the blower is on

The velocity of air flow in the warm air duct at each fan setting to be used in testing shall be determined using a velocity traverse. The velocity traverse gives a correction factor, called *Pitot factor*, to apply to the centroid velocity in order to calculate a flow rate that takes the velocity profile into account. When testing for emissions and efficiency, the Pitot Factor shall be applied to every time intervals and shall be adjusted to the correspondent fan speed.

Note: *The Pitot factor is not the calibration factor of the pitot tube.*

Duct velocity traverse measurement shall be done:

g) in a warm condition during the pretest fuel combustion as per Clause 6.4.3.4;
h) before every test run;
i) with all components of the furnace installed;
j) on the same vertical plane where the pitot tube will be installed for measurement during the test run (8 duct diameters downstream of any duct area change);
k) using the same pitot tube used for measurement during the test run.

If an air filter holder comes with the furnace, or as option, all the tests shall be performed with an air filter. The air filter specification, such as material and size, shall be included in the test report. After loading the pretest fuel load and before the last hour of the pretest fuel load end point, conduct a velocity traverse as define in Clause 6.4.4.4.2.1 or 6.4.4.4.2.2., in the duct to determine the Pitot Factor (Fp). After the velocity traverse is done, the Pitot tube shall be placed at the center of the duct for measurement during the test run.

6.4.4.4.2.1 Velocity traverse of round ducts

a) Measure the diameter of the duct at the velocity traverse port location through both ports. Calculate the duct area using the average of the two diameters. Place the standard Pitot tube at the center of the duct in either of the velocity traverse ports. Seal any gap between the velocity traverse port in the duct and the Pitot tube and seal the unused velocity traverse port to prevent any air leakage into the duct. Continue to read the velocity head (Dp) and temperature until the velocity has remained constant (less than 5 % change) for 1 min. Once a constant velocity is obtained at the center of the duct, perform a velocity traverse as specified in Clause 6.4.4.4.2.1.f.

b) Ensure that the proper differential pressure gauge is being used for the range of Dp values encountered. If it is necessary to change to a more sensitive gauge, do so, and re-measure the Dp and temperature readings at each traverse point. Conduct a post-test leak-check (mandatory), as described in Clause 6.4.4.4.2.1.d and e, to validate the traverse. Measure the Dp and duct temperature at each traverse point and record the readings.

c) Calculate the total air flow rate using calculations contained in Clause 6.4.4.4.3, using the velocity traverse points in accordance with Clause 6.4.4.4.2.1.f, excluding the center readings.

d) Pitot Tube leak test — A leak test of the Pitot tube lines is mandatory at the conclusion of each velocity traverse. The lines shall pass this leak-check in order to validate the velocity head data. The test run is invalid if this leak test is failed.

e) A leak-check of Pitot lines using the following procedure is recommended (a) blow through the Pitot impact opening until at least 7.6 cm (3.0 in.) water velocity head registers on the manometer; then, close off the impact opening. The pressure shall remain stable for at least 15 seconds; (b) do the same for the static pressure side, except using suction to obtain the minimum of 7.6 cm (3.0 in.) water.

Note*: A lower pressure may be used, provided that it is not exceeded during the test. It is recommended to use a pressure at least twice the pressure measured when the blower is running at the maximum speed, at room temperature.*

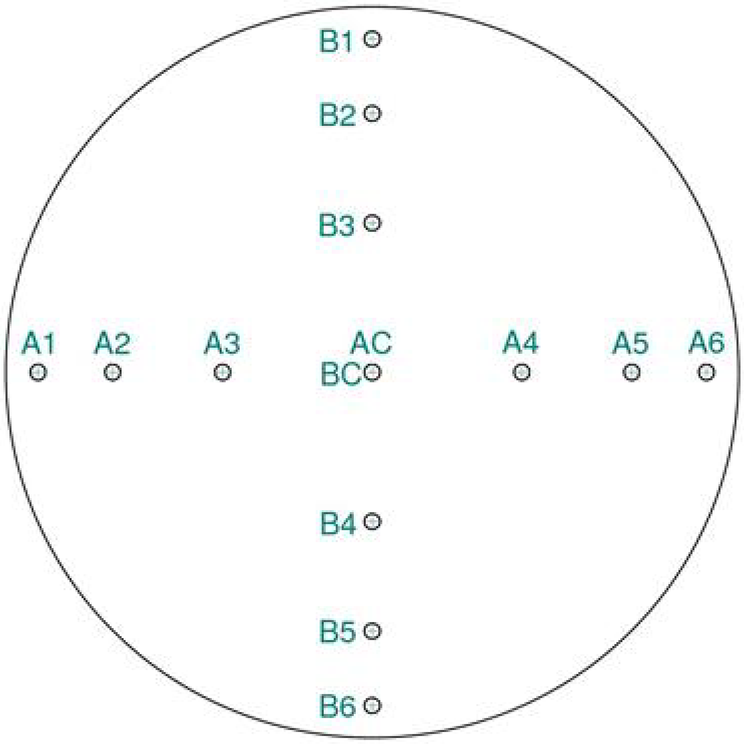
f) Velocity Traverse Measurements—Measure and record the velocity head and temperature at the traverse points specified as follows:

  i) For duct diameters equal to or greater than 0.3 m (12 in.) locate the traverse points on two perpendicular diameters according to the example shown in Figure 13.

  ii) For duct diameters less than 0.3 m (12 in.) locate the traverse points on two perpendicular diameters according to the example shown in Figure 14.

Figure 13

Traverse point position for duct equal of greater than 12 inches
(See Clause 6.4.4.4.2.1.i)



For duct with diameter ≥ 12 in	
Traverse Point	% of diameter
1	4.4
2	14.6
3	29.6
Center	50
4	70.4
5	85.4
6	95.6

Figure 14

Traverse point position for round duct less than 12 inches
(See Clause 6.4.4.4.2.1.ii)

For duct with diameter less than < 12 in	
Traverse Point	% of diameter
1	6.7
2	25
Center	50
3	75
4	93.3

6.4.4.4.2.2 Velocity traverse of rectangular duct

Determine the number of traverse points and determine the grid configuration using Table 6. Divide the duct cross-section into as many equal rectangular elemental areas as traverse points, and then locate a traverse point at the centroid of each equal area according to the example in Figure 15.

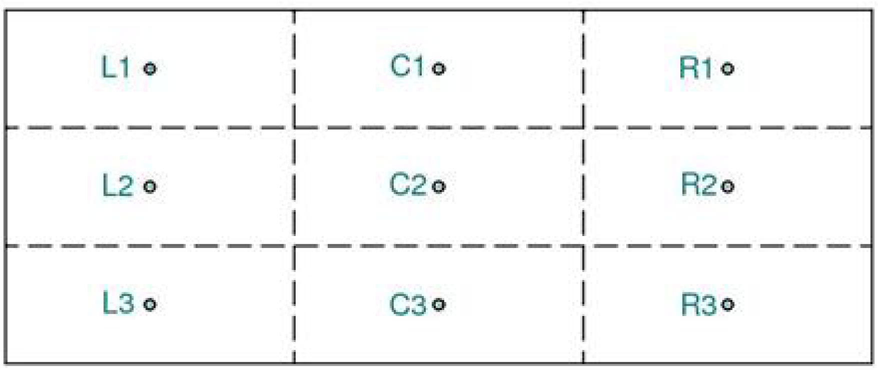
Table 6

Rectangular traverse point specification
(See Clause 6.4.4.4.2.2)

Equivalent duct diameter	Minimum number of traverse point	Grid configuration
> 0.61 m (24 inches)	12	4 x 3
≤ 0.61 m (24 inches)	9	3 x 3

Figure 15

Example of traverse point configuration for equivalent duct diameter below 24 inches
(See Clause 6.4.4.4.2.2)



Follow indications in Clause 6.4.4.4.2.1 except that in Clause 6.4.4.4.2.1.a, measure the area or the inner rectangle instead of the diameters, and except in Clause 6.4.4.2.1.f, measure the traverse point as defined in first paragraph of this Clause.

6.4.4.4.3 Calculations

Depending on the degree of accuracy desired and equipment used, the calculations in this Clause may be modified. The moisture content of the circulating air (kg/kg) shall be determined using a sling psychrometer and psychrometric charts or an equivalent procedure.
The change in enthalpy of the circulating air shall be calculated using the moisture content and temperature rise of the circulating air, as follows:

$$\Delta h = \Delta t\,(1.006 + 1.84x) \qquad \text{(E-1)}$$

where
Δh = change in enthalpy, kJ/kg
Δt = temperature rise, °C
1.006 = specific heat of air, kJ/kg °C
1.84 = specific heat of water vapor, kJ/kg °C
X = humidity ratio, kg/kg

The mass airflow in the duct (kg/h) is determined using a Pitot tube to measure velocity pressure along with measurement of duct static pressure, barometric pressure, and duct cross-sectional area to calculate the air flow rate in standard cubic meters per hour. Pitot tube measurements shall be made in a straight section of duct at least eight duct diameters downstream and two upstream from any change in area or flow direction. For rectangular ducts, the equivalent duct diameter calculated in accordance with Equation 2 (E-2) shall be used to determine the location of velocity and temperature measurements. Flow straighteners should be used if the flow is not relatively uniform. The air flow rate is multiplied by the standard air density to determine the mass flow rate.

Note*: A Pitot array using multiple impact and static pressure taps distributed in the duct has been found to provide a stronger and more stable velocity pressure signal than a single Pitot tube. Other flow measuring systems of at least equal accuracy may be used.*

The equivalent duct diameter shall be calculated as follows:

$$ED = \frac{2HW}{H+W} \qquad \text{(E-2)}$$

where

ED = equivalent duct diameter

H = duct height, m

W = duct width, m

The air flow rate when the blower is off (F_{off}) (m^3/s) shall be calculated as follows: (E-3)

$$F_{off} = V_{off} \times 0.95 \times \frac{ID_{cd} \times \pi}{4}$$

where

V_{off} = velocity measured by the vane anemometer (m/s)

ID_{cd} = Inner diameter of the calibration duct (m)

The Pitot factor can be calculated as follows: (E-4)

$F_p = V_{strav} / V_{scent}$

where

V_{strav} = Average air velocity calculated after the multipoint Pitot traverse

V_{scent} = Average air velocity at the center of the warm air duct calculated after the Pitot tube traverse

V_{strav} and V_{scent} can be calculated using the following equation (E-5) by ignoring F_p.

The air flow velocity shall be calculated as follows:

$$V = F_p \times C_p \times 34.97 \times \sqrt{\Delta P} \times \sqrt{\frac{T}{28.56\,(P_{Baro} + P_s)}} \qquad \text{(E-5)}$$

where

V = velocity, m/s

F_P = Pitot factor determined from velocity traverse measurements, dimensionless

C_P = Pitot tube coefficient, dimensionless

= 0.99 for a standard Pitot tube or as determined by calibration for a Type S Pitot tube

34.97 = Pitot tube constant

Note*: The Pitot tube constant is determined on the basis of the following units:*

$$\frac{m}{s}\left[\frac{g/g\ mole\ (mm\ Hg)}{(K)(mm\ H_2O)}\right]^{0.5}$$

where

ΔP = velocity pressure, mm H_2O

T = temperature, K

28.97 = molecular weight of air

P_{Baro} = barometric pressure, mm Hg

P_s = duct static pressure, mm Hg

The mass flow rate shall be calculated as follows:

$m =$

$3600 V A \rho$ (E-6)

where

m = mass flow rate, kg/h

V = air flow velocity, m/s (from Equation (E-5))

3600 = number of seconds per hour

A = duct cross-sectional area, m^2

P = density of air, kg/m^3

$$= \frac{p_d M_d + p_v M_v}{RT}$$

where

p_d = partial pressure of dry air, Pa

T = outlet duct temperature, K (°C+273.15)

p_v = pressure of water vapor, Pa

M_d = molecular weight of dry air, 28.97 g/mol

M_v = molecular weight of water vapor, 18.02 g/mol

R = universal gas constant, 8314.5 J/(kg*mole*K)

with

$p_d = p - p_v$

where

p = absolute pressure, Pa

$= P_{bar} + p_g$

with

P_{bar} = barometric pressure, Pa

P_g = duct static pressure, Pa

and

$p_v = \phi p_{sat}$

where

ϕ = relative humidity (0.0 – 1.0, may be the average throughout the test)

p_{sat} = saturation vapor pressure, Pa

$= 610.78 \times 10^{7.5T/(T+237.3)}$

where

T = outlet duct temperature, °C

The rate of heat release into the circulating air shall be calculated using the air flow and change in enthalpy, as follows:

$\Delta e = \Delta h \times m$

(E-7)

where

Δe = rate of heat release into the circulating air, kJ/h

Δh = change in enthalpy of the circulating air, kJ/kg

m = mass air flow rate, kg/h

The heat output over any time interval shall be calculated as the sum of the heat released over each measurement time interval, as follows:

$Et = \Sigma(\Delta e \times i)$

for $I = t1$ to $t2$ (E-8)

where

Et = delivered heat output over any time interval $t2–t1$, kJ
i = time interval for each measurement, h

The average heat output rate over any time interval shall be calculated as follows:

$et = Et\ /t$

(E-9)

where

et = average heat output, kJ/h

t = time interval over which the average output is desired, h

The total heat output during the burn shall be calculated as the sum of all the heat outputs over each time interval, as follows:

$Ed = \Sigma(Et)$

for $t = t0$ to $tfinal$ (E-10)

where

Ed = heat output over a burn, kJ/h (Btu/h)

Et = heat output during each time interval, kJ/h (Btu/h)

The efficiency shall be calculated as the total heat output divided by the total energy input, expressed as a percentage as follows:

Efficiency (ηdr), % =

$100 \times Ed\ /I$ (E-11)

where

Ed = total heat output of the appliance over the test period, kJ/kg

I = input energy (fuel calorific value as-fired times weight of fuel load), kJ/kg (Btu/lb)

6.4.4.4.4 Results

If more than one test run is conducted within a specified burn rate category, the results from at least two-thirds of the test runs in that category shall be used in calculating the average values. Measurement data and results of all test runs shall be retained regardless of which values are used in calculating the weighted average.

Note*: Compliance with US EPA. If more than one test run is conducted within a specified category, the results from at least two thirds of the test runs in that category shall be arithmetically averaged in calculating the emission rate for that category. Runs that are above the EPA emissions limit shall be treated as valid runs.*

6.4.4.4.4.1 Burn rate

The burn rate, BR_r, for each test run, r, shall be calculated as

$$BR_r = \left(\frac{60 \times W_{wd}}{T_r}\right) \times \left(\frac{100 - M_{Cwb}}{100}\right)$$

where

BRr = dry fuel burn rate for each test run, kg/h

60 = number of minutes in an hour

Wwd = total mass of wood burnt during the test run, including weight of moisture in wood, kg

Tr = total time of test run, min

100 = factor to convert from percentage to a fraction

$MCwb$ = initial moisture content of the fuel load, %

6.4.4.4.4.2 Average particulate emission rate

For forced-air furnace, the average particulate emission rate, Ew, shall be the arithmetic average of the particulate emissions from each burn rate range. If the results from more than one test are used in a given burn rate range, the arithmetic average for this range shall be determined and used in determining the average particulate emission rate.

6.4.4.4.4.3 Average efficiency

For forced-air furnace, the average efficiency, η, shall be the arithmetic average of the particulate emissions from each burn rate range. If the results from more than one test are used in a given burn rate range, the arithmetic average for this range shall be determined and used in determining the average efficiency.

6.5

Type 4: Hydronic heaters

6.5.1 General

Hydronic heaters shall be tested to the applicable requirements of this Standard in accordance with ASTM E2618-19, EPA Method 28 WHH, EPA Method 28 WHH-PTS or EN303-5:2021.

6.5.1.1 Fuel characteristics

Indoor hydronic heaters that are automatically fueled and are tested in accordance with Clause 4.5 shall be tested using at least one the following biofuels:

a) using wood pellets conforming to the Pellet Fuels Institute (PFI) Standard Specifications for Residential/Commercial Densified Fuel dated November 9, 2018; or
b) using biogenic fuels conforming to Section 1.2 Fuels and Table 9 of EN303-5:2021 Heating boilers - Part 5: Heating boilers for solid fuels, manually and automatically stoked, nominal heat output of up to 500 kW - Terminology, requirements, testing and marking; or
c) using solid biofuels conforming to the origin, source and classification in CAN/CSA-ISO 17225-1:15 (R2020) Solid biofuels - Fuel specifications and classes - Part 1: General requirements.

6.5.2 Installation instructions

Refer to Clause 6.5.1.

6.5.3 Gaseous emissions

Refer to Clause 6.1.10.

6.5.4 Particle measurements

Refer to Clause 6.5.1.

6.6 Type 5: Hybrid heating appliances

For appliances with unusual design or operational characteristics that make the application of these procedures impractical, these procedures may be suitably modified, provided that the modifications conform to the intent of this Standard.
Appliance shall be operated in accordance with manufacturer's recommended operating instructions.
Hybrid forced- air furnaces heaters shall be tested in accordance with Clause 6.3 with the addition of Clauses 6.4.1 and 6.4.4.4.
Hybrid hydronic heating appliance shall be tested in accordance with Clause 6.3 with the addition of Clauses 6.6.1 and 6.6.4.
Note*: Hybrid Hydronic heaters can have a pressurized or atmospherically vented vessel containing a liquid heat transfer medium.*

6.6.1 Test apparatus

6.6.1.1 Hybrid forced-air heater

For hybrid forced-air heater, test apparatus shall be in accordance with Clause 6.4.1 with the following exceptions:

a) Instead of a restrictor, a floor register or other device intended to be used with the heater shall be installed at the outlet.
b) Rigid pipe shall be used to measure flow rate and the minimum length shall be 10 duct diameters or equivalent duct diameters.
c) The duct system shall be installed as recommended by the manufacturer in the owner's manual.

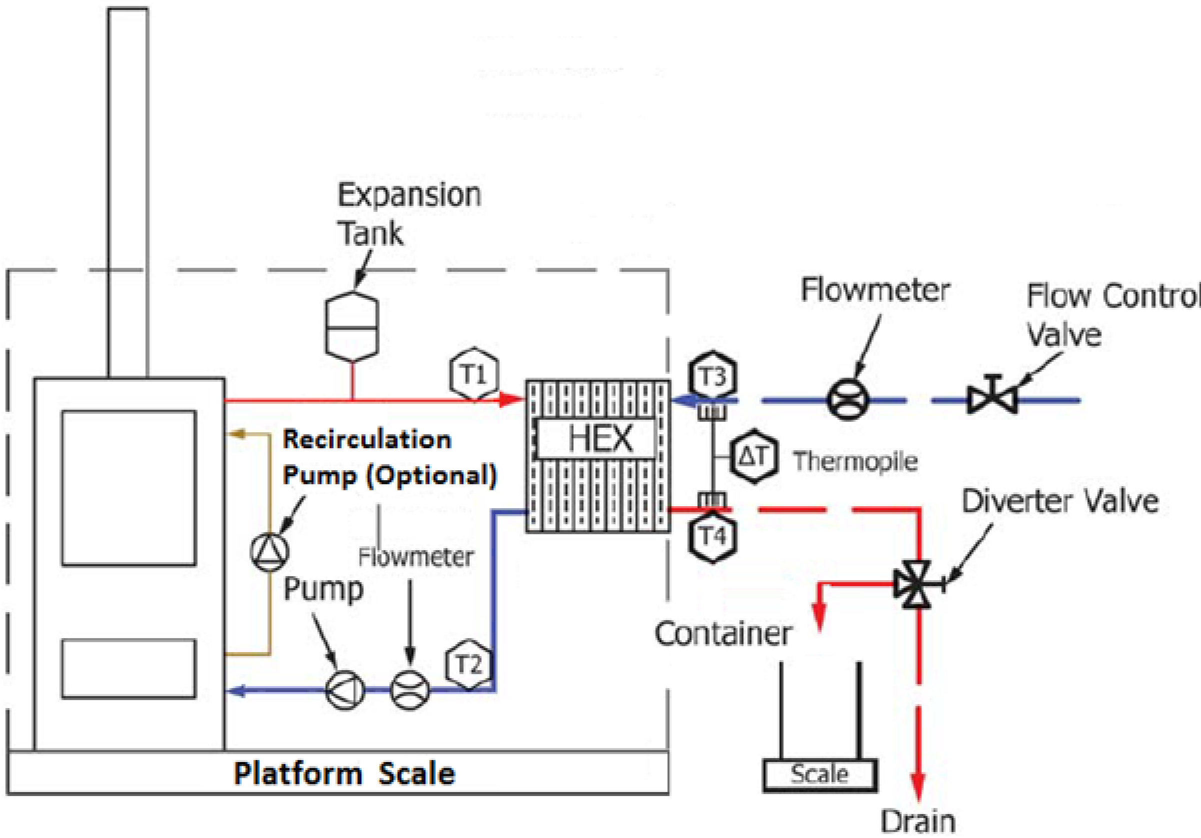
6.6.1.2 Hybrid hydronic heater

For hybrid hydronic heater, test apparatus shall be in accordance with ASTM E2618-19 Standard Test Method for Measurement of Particulate Emissions and Heating Efficiency of Solid Fuel-Fired Hydronic Heating Appliances Sections 6, 7, 8, 9 & 10, 12.2.14, with the following exceptions:

a) The appliance, heat exchanger, and all components on the closed loop between the appliance and heat exchanger shall be placed on a scale capable of weighing the appliance fully loaded with a minimum accuracy of ±0.1 lb (±0.05 kg) or 0.5% of load weight, whichever is greater, as shown in Figure 16.

Figure 16

Test Apparatus Schematic
(See Clause 6.6.1.2.a)



Note: *Illustrated appliance pump location and flow path through the appliance are generic and may vary based on the unit being tested.*

6.6.2 Gaseous emissions test

Refer to Clause 6.3.

6.6.3 PM test

Refer to Clause 6.3.

6.6.4 Thermal efficiency test

6.6.4.1 Determining delivered heat output

6.6.4.1.1 Hybrid forced-air heater

Delivered heat output shall be determined in accordance with Clause 6.4.4.4 with the following exceptions:

a) Delivered heat may only be measured when the fan is turned on. Fan off measurement is optional.

b) Static pressure needs to be measured, but there is no target value.

6.6.4.1.2 Hybrid hydronic heater

Hydronic heat output shall be determined in accordance with ASTM E2618-13 (2019) Standard Test Method for Measurement of Particulate Emissions and Heating Efficiency of Solid Fuel-Fired Hydronic Heating Appliances Sections 6, 7, 8, 9 & 10, 12.2.14, 13.4.1, with the following deviation from ASTM E2618, Section 9.5.6:

a) The reported efficiency and delivered heat output rate shall be based on measurements made on the load side of the heat exchanger (See Figure. 16).

The minimum delivered heat output rate shall be determined from a low fire test run used in determining the average emission rate.

The maximum delivered heat output rate shall be determined from a high fire test run used in determining the average emission rate.

6.6.4.2 Determining space heat output

Space heat output shall be determined by subtracting the delivered heat output from the overall heat output;

$E_{space} = E_o - E_d$

where

E_{space} = space heat output rate

E_o = overall heat output rate as determined by Clause 6.1.10.8

E_d = delivered heat output rate as determined by:

Clause 6.4.4.4.3 for hybrid Forced-air heater (see equation E-10).

Clause 6.6.4.1 for hybrid hydronic heater

Note: *The minimum 15% space heat output shall be determined using a high fire test run used in determining the average emission rate.*

Annex A (Informative)

Spreadsheet for calculating the energy efficiency and heat output of solid-fuel-burning heating appliances

Note: *This Annex is not a mandatory part of this Standard.*

The energy efficiency and heat output of solid-fuel-burning heating appliances may be calculated using the Microsoft Excel® spreadsheet linked to this Standard.

***Note**: Authorized use of the Excel spreadsheet is subject to the terms and conditions of the “Legal Notice for Standards” accepted upon the loading of this Standard. The spreadsheet is a stand-alone calculator. The user assumes full responsibility for the use or application of the spreadsheet and CSA accepts no responsibility whatsoever arising in any way for any use or reliance thereon.*

Annex B (Informative)

Automatically fueled appliances which burn fuels larger than wood pellet

Note: *This Annex is not a mandatory part of this Standard.*

For automatically fueled appliances which burn fuels larger than wood pellet size as define in CAN/CSA-ISO 17225-Part 2:2015, it is possible to use the procedure below:

Set the heater at the maximum burn rate and burn for at least 2 hours. If the combustion cycles (for example, due to the feeding system or the nature of the fuel), the high fire shall burn for at least 2 hours AND at least 3 complete burn cycles. Cycling can be determined with flue temperature variation or, with flue gas composition variation. Low and medium burn rate test shall burn at least the same amount of fuel burned in the high fire test. The resultant of the dry medium burn rate shall be smaller than the mid-point between the dry burn rates for the low fire and high fire test runs.

If the procedure is different than the one described here, the rationale shall be detailed in the test report.

Annex C (Informative)

Recognition of EN303-5:2021 third-party certified automatic appliances in CSA B415.1

Note: *This Annex is not a mandatory part of this Standard.*

It is recommended to incorporate Class 5 emission requirements to the new version of the CSA B415 for automatically fueled hydronic heaters from 50 kw to 150 kw heat output. Products should obtain certification by an agency recognized by Standards Council of Canada and show an accepted product certification mark. By recognizing the EN303-5 standard for emissions and performance, Canada facilitates the replacement of outdated fossil fuel hydronic heating equipment in rural and remote areas.

It is recommended for the AHJ (authority having jurisdiction) such as Chief Building Officials under National Building Code of Canada that automatic hydronic heaters complying with EN303-5 be certified by a recognized Canadian third party in lieu of manufacturer self-declaration. This is because many self-declared units have not demonstrated similar operational performance levels in the field compared to in-house laboratory test results. There are cases where self-declared Class 5 automatic hydronic heaters have passed the US EPA NSPS QQQQ Step 1 emission limits, but have failed to pass lower, mid or nominal heat output emission limits required in Step 2.

For example, the United Kingdom does not allow self-declared products either. For solid biofuel hydronic heaters sold and used in the United Kingdom, product approval is conducted under the Microgeneration Certification Scheme (MCS) 008; Product Certification Scheme Requirements: Biomass. The MCS is an internationally recognised quality assurance scheme to promote renewable technologies. Approved products for biomass heating appliances are provided by HETAS. HETAS are authorised by the United Kingdom Accreditation Services (UKAS) under EN-ISO/IEC 17065 to conduct quality assurance programs and provide a certification mark valid in UK. Certified hydronic heater models are listed here: https://www.hetas.co.uk/find-appliance/.

Note: *In Canada, accreditation of laboratory and certification bodies is undertaken by the Standards Council of Canada.*