Guideline for the Control of Air Emissions from Small Wood-Fired Combustors (< 3 MW)

Guideline A-14

January 2017

Ontario

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1.0 INTRODUCTION

The purpose of Guideline A-14: Guideline for the Control of Air Emissions from Small Wood-Fired Combustors (< 3 MW) is to establish the minimum expectations necessary to control air emissions from small wood-fired combustors with a nominal load heat input capacity of less than 3 megawatts (MW) in Ontario. This guideline complements Guideline A-13: Guideline for the Control of Air Emissions from Large Wood-Fired Combustors (≥ 3 MW). Together, these two air quality guidelines serve to replace the Interim Design and Review Guidelines for Wood Fired Combustors published by the Ministry in 1990.

The intended audience for this guideline includes persons applying for an environmental compliance approval (ECA) under section 20.2 of the *Environmental Protection Act,* R.S.O. 1990 (the "EPA"), persons that own or operate small wood-fired combustors, and manufacturers and distributors of small wood-fired combustors.

The intended audience for this guideline does not include a person engaging in the installation, use, operation, replacement or modification a small wood-fired combustor where that activity is a prescribed activity for the purposes of section 20.21 (1) of the EPA. Persons engaging in prescribed activities that involve the use of a small wood-fired combustor are referred to O. Reg. 01/17 "Registrations under Part II.2 of the Act – Activities Requiring Assessment of Air Emissions" made under the EPA and the EASR publication, in particular chapters 1 and 5 of the EASR publication.

During the review of an application for an ECA and when considering issuing an order, the Director[1] considers the requirements set out in relevant regulations as well as all applicable Ontario Ministry of the Environment and Climate Change (Ministry) guidelines and policies. To the extent that this document sets out that something is "required" or "shall" be done or sets out a "requirement" or "limit", it does so only to identify minimum expectations, the application of which remain subject to the discretion of the Director. The expectations set out in this guideline are compulsory to the extent that they are contained in conditions of an ECA or other legally binding instrument, such as an order. Information pertaining to the ECA process is provided in Appendix D.

As a complement to the minimum expectations for small wood-fired combustors set out in this guideline, additional technical information is provided in Appendix E. This information could be considered before purchasing a small wood-fired combustor.

While every effort has been made to ensure the accuracy of the information contained in this guideline, it should not be construed as legal advice. In the event of a conflict with requirements of the EPA, O. Reg. 419/05 or any other regulation, the legislative requirements shall determine the appropriate approach.

[1] Reference to a Director in this guideline refers to a Director appointed under section 5 of the EPA for the purpose of a section authorizing the issuance of an order or ECA.

2.0 DEFINITIONS AND ABBREVIATIONS

The following definitions apply for the purposes of this guideline:

“air pollution control equipment” means equipment that is designed to decrease emissions to the air of one or more contaminants that are present in the flue gas stream;

“CAN/CSA-ISO 17225-2:15” means the standard CAN/CSA-ISO 17725-2:15, published by the Canada National Standard/Canadian Standards – International Organization for Standardization on March 1, 2015 and entitled “Solid biofuels – Fuel specifications and classes - Part 2: Graded Wood pellets”;

“CAN/CSA-ISO 17225-3:15” means the standard CAN/CSA-ISO 17725-3:15, published by the Canada National Standard/Canadian Standards – International Organization for Standardization on March 1, 2015 and entitled “Solid biofuels – Fuel specifications and classes - Part 3: Graded Wood briquettes”;

“CAN/CSA-ISO 17225-4:15” means the standard CAN/CSA-ISO 17225-4:15, published by the Canada National Standard/Canadian Standards – International Organization for Standardization on March 1, 2015 and entitled “Solid Biofuels – Fuel specifications and classes – Part 4: Graded wood chips”;

“certified small wood-fired combustor” means a small wood-fired combustor that meets the following criteria:

1. Subject to paragraphs 2 and 3, the combustor meets the requirements of EN 303-5 (2012).
2. The combustor is designed to meet the Class 5 thermal efficiency and carbon monoxide requirements set out in EN 303-5 (2012) at nominal load and partial load heat output capacity operating conditions.
3. The combustor is designed, taking into account any air pollution control equipment specified by the manufacturer, to meet at least one of Class 3, 4 or 5 for dust (particulate matter) as set out in EN 303-5 (2012) at nominal load and partial load heat output capacity operating conditions.
4. The criteria set out in paragraphs 1 to 3 must be confirmed by a person who,
    i. does not own, operate, sell or manufacture the small wood-fired combustor, and
    ii. meets the EN ISO/IEC 17025 requirements for testing as described in EN 303-5 (2012);

“combustor” means a device in which combustible material is oxidized resulting in release of heat and products of combustion;

“commissioning period” means the 90-day period following the first start-up of a small wood-fired combustor;

“cyclone” means a piece of air pollution control equipment that uses centrifugal force to separate particulate matter from the flue gas;

“ECA” means environmental compliance approval, as defined in subsection 1(1) of the *Environmental Protection Act*;

“EN 303-5 (2012)” means European Standard EN 303-5, published by the European Committee for Standardization in June, 2012 and entitled “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”;

“existing small wood-fired combustor” means a non-reassessed small wood-fired combustor,

(a) that was installed on or before January 31, 2017, or

(b) for which an application for an ECA was made on or before January 31, 2017;

“existing ECA” means an Environmental Compliance Approval issued by the Director for a small wood-fired combustor on or before January 31, 2017;

“flue gas” means a gas that is generated from a combustion process;

“furnace” means a part of a combustor where combustion takes place and may be comprised of primary, secondary and tertiary combustion chambers;

“Guideline A-13” means Guideline for the Control of Air Emissions from Large Wood-Fired Combustors (≥ 3 MW) published by the Ministry in January 2015 (as amended);

“higher heating value” means the amount of heat released during the complete combustion of a unit quantity of fuel and includes the latent heat of vapourization of the water vapour formed by the combustion;

“mg/Rm^3” means milligrams per cubic metre at reference conditions;

“Minister” means the Minister of the Environment and Climate Change or such other member of the Executive Council as may be assigned the administration of the *Environmental Protection Act*, R.S.O. 1990 under the *Executive Council Act*;

“Ministry” means the ministry of the Minister;

“moisture content” means the total moisture content of a sample of wood fuel, as-fired, reported on a wet basis as a percentage;

“MW” means megawatt and is equal to 3,600 megaJoules per hour;

“new small wood-fired combustor” means a small wood-fired combustor, the installation of which began after January 31, 2017 and in in respect of which, no application for an ECA was made on or before January 31, 2017;

“nominal load heat input capacity” means the design capacity of a small wood-fired combustor to combust a maximum amount of wood fuel based on the physical design of the small wood-fired combustor and is calculated by multiplying the mass flow rate of the wood fuel by the higher heating value of the wood fuel;

“nominal load heat output capacity” means the maximum continuous usable heat output as determined by the nominal load heat input capacity and design of the heat exchanger;

“oxygen lambda sensor” means a device that continuously measures the concentration of oxygen in the flue gas on a wet basis and uses the resulting measurement as an input to the oxygen trim system;

“oxygen trim system” means the components of a small wood-fired combustor that dynamically control the excess oxygen level in the flue gas through the use of an oxygen lambda sensor;

“partial load heat input capacity” means the design capacity of a small wood-fired combustor to combust a minimum amount of wood fuel based on the physical design of the small wood-fired combustor, for which air emissions can be reliably measured at steady state conditions, and is calculated by multiplying the mass flow rate of the wood fuel by the higher heating value of the wood fuel;

“partial load heat output capacity” means the minimum continuous usable heat output as determined by the partial load heat input capacity and design of the heat exchanger;

“particulate matter” means particulate matter in the flue gas downstream of any air pollution control equipment, prior to discharge to the air, that has an aerodynamic diameter of less than 44 microns;

“reassessed small wood-fired combustor” means an existing small wood-fired combustor at a facility for which an application for an ECA in respect to an activity engaged in at the facility has been made after January 31, 2017;

“record” includes a written procedure, a measurement result, a written notification, a table, a report, a document, electronic data, a written practice, and an update to any of the preceding;

“reference conditions” mean conditions at which the temperature is 25 degrees Celsius and the pressure is 101.3 kilopascals;

“small wood-fired combustor” means a wood-fired combustor that has,

(a) a nominal load heat input capacity of less than three megawatts, and

(b) a nominal load heat output capacity of greater than 50 kilowatts;

“thermal efficiency” means the ratio of the delivered useful heat output to the heat input as derived from the wood fuel, expressed as a percentage;

“uncertified small wood-fired combustor” means a small wood-fired combustor that does not meet the requirements set out in the definition of a “certified small wood-fired combustor”;

“ungraded wood material” means woody biomass that has not been processed into a wood briquette, wood pellet or wood chip;

“wood briquette” means a densified wood fuel with a diameter of more than 25 millimetres produced by compressing woody biomass as defined by CAN/CSA-ISO 17225-3:15;

“wood chip” means a piece of wood within a defined size range, cut or chipped from a larger piece of wood as defined by CAN/CSA-ISO 17225-4:15;

“wood-fired combustor” means a combustion source designed to burn wood fuel and does not include a wood-fuel gasifier connected to an internal combustion engine;

“wood pellet” means a densified wood fuel made by compressing woody biomass into a cylindrical form as defined by CAN/CSA-ISO 17225-2:15.

3.0 APPLICABILITY

This guideline applies to small wood-fired combustors that are designed to burn wood fuel set out in this guideline (i.e., wood pellets, wood briquettes or wood chips[2]) rated to a nominal load heat input capacity of less than 3 MW and a nominal load heat output capacity of greater than 50 kW. This guideline does not apply to a combustor that burns ungraded wood fuel or fuel other than wood fuel (e.g. agricultural sourced biomass). Please refer to Guideline A-13 (Guideline for the Control of Air Emissions from Large Wood-Fired Combustors ≥ 3 MW) for the Ministry's expectations regarding wood-fired combustors that use ungraded wood material or up to 7.5 percent municipal waste (that is predominantly wood) material as a fuel.

Certain expectations set out in this guideline vary according to whether the small wood-fired combustor is: (i) a new small wood-fired combustor; (ii) a reassessed small wood-fired combustor; or (iii) an existing small wood-fired combustor. Unless exempt from section 9 of the EPA, it is an offence under the EPA to operate a small wood-fired combustor without an ECA and an application for an ECA should be made forthwith. It should be noted that the following are the ministry's expectations with respect to such an ECA application:

1. If the operation of the small wood-fired combustor commenced before January 31, 2017, it is expected that the person will follow the expectations set out for a reassessed small wood-fired combustor.

2. If the operation of the small wood-fired combustor commenced after January 31, 2017, it is expected that the person will follow the expectations set out for a new small wood-fired combustor.

This guideline also distinguishes between small wood-fired combustors that are certified (i.e. have been independently tested and have documentation to demonstrate compliance with European Standard EN 303-5 (2012), including Class 5 for thermal efficiency and carbon monoxide emissions and either Class 3, 4 or 5 for dust) and those that are uncertified. A certified small wood-fired combustor will be considered uncertified if it is modified to be equipped with a direct contact heat exchanger (e.g., direct contact grain dryer).

The expectations set out in this guideline for certified small wood-fired combustors also apply to a small wood-fired combustor that meets the following criteria:

- If a small wood-fired combustor has a nominal load heat output capacity of more than 500 kW, it meets all four of the criteria of the definition of "certified small wood-fired combustor" other than having a nominal load heat output capacity of less than or equal to 500 kW (note that EN 303-5 (2012) is limited to nominal load heat output capacity of up to 500 kW), and

- If the small wood-fired combustor has a non-contact air-to-air heat exchanger, the small wood-fired combustor meets the criteria set out in paragraph 1 of the definition of "certified small wood-fired combustor" and meets the criteria set out in paragraph 2 with respect to carbon monoxide and meets the criteria set out in paragraphs 3 and 4 of that definition.

[2] Please note that at the time of the writing of this guideline, the ISO wood fuel quality standard for thermally treated and densified wood fuels, such as torrified wood briquettes and pellets is under development. After the ISO fuel quality standard 17225-8 has been adopted by CSA Group, thermally treated and densified wood will be considered by the Ministry to be wood fuels and this guideline will be updated accordingly. In the interim, a small wood-fired combustor that uses thermally treated and densified wood is expected to meet the requirements of Guideline A-13.

4.0 WOOD FUEL PARAMETERS

A small wood-fired combustor is expected to use the wood fuel that the manufacturer designed it to use, subject to the specifications outlined below.

4.1 Wood Fuel Specifications

New and Reassessed Small Wood-Fired Combustors
A new or reassessed small wood-fired combustor is expected to use wood fuel that meets one or more of the following specifications:

Wood pellets:

i. **CAN/CSA-ISO 17225-2:15:** Type A1, A2 or B graded wood pellets for commercial and residential applications (ISO 17225-2 has superseded EN 14961-2);
ii. **Pellet Fuels Institute:** premium or standard grade as set out in the document entitled “Pellet Fuels Institute Standard Specifications for Residential/Commercial Densified Fuel”, published by the Pellet Fuels Institute in July 2015.

Wood chips:

i. moisture content is 50 percent or less, and
ii. **CAN/CSA-ISO 17225-4:15:** Type A1, A2, B1 or B2 graded wood chips (ISO 17225-4 has superseded EN 14961-4).

Wood briquettes:

i. **CAN/CSA-ISO 17225-3:15:** Type A1, A2 or B

For wood chips, the expectation of the 50 percent or less moisture content will begin on January 31, 2017, but the specification set out in clause ii will be considered voluntary until January 31, 2027 after which compliance with the specification will be expected. Refer to Appendix F for more detailed descriptions of the above-noted wood fuel specifications.

Please note that a person responsible for a small wood-fired combustor that seeks to use a form of wood fuel other than wood briquettes, wood pellets or wood chips, when applying for an ECA on or after January 31, 2017, is expected to meet the requirements of Guideline A-13.

Existing Small Wood-Fired Combustors
For an existing small wood-fired combustor, it is considered good practice to use a wood fuel quality specification that optimizes combustion efficiency and minimizes air emissions. Using the wood fuel types described above is a recommended best practice.

4.2 Automated Wood Fuel Feed Systems for New and Reassessed Small Wood-Fired Combustors

An automated wood fuel feed system inserts wood fuel into a combustor furnace under the control of a computational algorithm that operates in conjunction with the oxygen trim system. Such a system is anticipated to assist in ensuring consistently effective combustion, as compared with manually fed systems.

Automated wood fuel feed systems have start-up and shut down procedures that control the timing sequence and amount of combustion air and wood fuel fed into the combustor. Having these procedures incorporated

into the system assists in minimizing air emissions by limiting the time for start-up and shut down as compared with manually operated systems.

Accordingly, new and reassessed small wood-fired combustors are expected to have an automated wood feed system that includes automated start-up and shutdown procedures.

4.3 Wood Fuel Management

Wood fuel quality is a critical parameter for ensuring efficient combustion and thereby minimizing air emissions. In order to ensure that each type of wood fuel being supplied to a small wood-fired combustor is of satisfactory quality and is managed in a manner that maintains the quality and characteristics of the fuel, it is expected that the person responsible for a small wood-fired combustor prepare, implement and maintain a Wood Fuel Management Plan.

New and Reassessed Small Wood-Fired Combustors

A Wood Fuel Management Plan for a new or reassessed small wood-fired combustor is expected to have the following elements:

a) A list of the type of each wood fuel that may be stored at the facility with the intent to be burned in the small wood-fired combustor (e.g., wood briquettes, wood chips, wood pellets) and which specification in Chapter 4.1 best describes the wood fuel.

b) A procedure to document the quantity of wood fuel purchased by the facility and the source from which it was purchased, and, if applicable, the quantity of wood fuel generated at the facility.

c) A procedure to document how each wood fuel, wood fuel storage area and wood fuel handling and conveyance system at the facility is inspected on a regular basis.

d) A procedure to ensure that wood fuel that is not considered acceptable for combustion at the facility is removed from the facility immediately or stored separately from the wood fuel storage until it can be removed from the facility in a timely manner. The quantity of wood fuel rejected and the reasons for the rejection should be documented.

e) A procedure to document what steps have been taken to ascertain wood fuel quality. Such steps may include laboratory testing, documentation of third party certification provided to the wood fuel supplier, and on-site testing.

f) An indication of the maximum time that each wood fuel may be stored at the facility. This maximum storage duration is intended to prevent degradation of the wood fuel before it is used as a fuel.

g) If a facility uses wood chips, a procedure to,

    i) document the wood chip pile turn-over to ensure that the wood chips that have been at the facility for the longest are used first, and

    ii) ensure that the wood chips fed into the small wood-fired combustor are delivered from either a heated indoor wood chip storage facility sufficient to store a minimum of 1.5 days of wood chip fuel supply at nominal load heat input capacity or unheated indoor storage facility sufficient to store a minimum of three days of wood chip fuel supply at nominal load heat input capacity. The wood chips may be delivered either directly from the indoor storage facility to the combustor if both are housed in one structure, or indirectly from the storage facility into the combustor fuel hopper through a conveyance system if housed in separate structures.

h) If a facility uses wood pellets or wood briquettes, a procedure to ensure that the wood pellets and wood briquettes are covered by a weather proof enclosure.

Existing Small Wood-Fired Combustors
The Ministry considers it a best practice for a Wood Fuel Management Plan pertaining to an existing small wood-fired combustor to have the elements described above.

5.0 COMBUSTOR DESIGN AND PERFORMANCE

This guideline distinguishes between small wood-fired combustors that are certified or uncertified. Note that the expectations set out in this guideline for certified small wood-fired combustors apply to a wood combustor that is described in Chapter 3.0 “Applicability”. Emission conversion and calculations are provided in Appendix C.

5.1 Design of New Small Wood-Fired Combustors

A new small wood-fired combustor is expected to have the following design elements:

a) The small wood-fired combustor is to have a multi-zone air control combustion process that includes the following elements (optional elements are noted as “good practice”):

   i) The multi-zone air control combustion process is to have a primary combustion zone with a fuel bed and is to introduce primary combustion air. The primary combustion zone is to be designed to facilitate the drying and gasification of the wood fuel. It is also to be designed to ensure that solid fixed carbon is combusted with minimal carry-over of particulate matter.

   ii) The multi-zone air control combustion process is to have a secondary combustion zone and is to introduce secondary combustion air. The secondary combustion zone is to be designed to achieve complete combustion of the volatized gases and any combustible particles that may be carried over from the primary combustion zone.

   iii) The multi-zone air control combustion process is to have an automated bottom ash removal system.

   iv) It is considered good practice for the multi-zone air control combustion process to have an automated fly ash removal system in the heat exchanger.

   v) It is considered good practice for the multi-zone air control combustion process to have a tertiary combustion zone to introduce tertiary combustion air to complete the combustion of volatilized gases.

   vi) It is considered good practice for the multi-zone air control combustion process to have a flue gas recirculation system that directs a portion of the flue gases from the outlet of the induced draft fan back into the combustion air injection points.

b) The small wood-fired combustor is to have an oxygen trim system including an oxygen lambda sensor to regulate the supply of combustion air to the primary, secondary, and, where applicable, tertiary combustion zones.

c) The small wood-fired combustor is to use a variable speed electric fan as the induced draft fan to maintain a minimum negative static pressure in the combustion zones.

d) The small wood-fired combustor is to have a monitor that measures the static pressure in the furnace or an alarm that signals when the static pressure in the furnace is positive.

e) The small wood-fired combustor is to be designed to operate in a manner that results in the concentration of particulate matter in the flue gas of the discharge stack of a small wood-fired combustor, downstream of any air pollution control equipment being less than 75 mg/Rm^3 at 11% oxygen (dry basis). The person responsible for the small wood-fired combustor is expected to obtain documentation from the

manufacturer confirming that the small wood-fired combustor (and its air pollution control equipment as described below) is capable of achieving this emission level.

f) The small wood-fired combustor is expected to have the following air pollution control equipment:

- If the combustor is a certified[3] small wood-fired combustor:
  - Where a certified small wood-fired combustor is certified to EN 303-5 (2012) Class 3 for dust,
    - if air pollution control equipment is not required to meet Class 3 dust emission level in EN 303-5 (2012), add air pollution control equipment capable of reducing the emissions of suspended particulate matter to the air by at least 50% when the small wood-fired combustor is operating at nominal load heat input capacity.
    - if air pollution control equipment is required to meet Class 3 dust emission level in EN 303-5 (2012), add an additional piece of air pollution control equipment capable of reducing the emissions of suspended particulate matter to the air by at least 50% when the small wood-fired combustor is operating at nominal load heat input capacity.
  - Where a certified small wood-fired combustor is certified to EN 303-5 (2012) Class 4 or 5 for dust, air pollution control equipment specified by the manufacturer, if necessary, to meet the Class 4 or 5 certification emission level for dust.
- If the combustor is an uncertified small wood-fired combustor, air pollution control equipment capable of reducing the emissions of suspended particulate matter to the air by at least 50% when the small wood-fired combustor is operating at nominal load heat input capacity.

g) The small wood-fired combustor is to be designed so that it is capable of measuring the process control parameters set out in Chapter 7.1.

5.2 Operation of New Small Wood-Fired Combustors

A new small wood-fired combustor is expected to operate at a load that is within an operating range specified by the manufacturer (i.e., at a load that is above the partial load and below the nominal load). Similarly a new small wood-fired combustor is expected to operate at wood fuel feed rates specified by the manufacturer and operate within the range of thermal efficiencies specified by the manufacturer. These three parameters are to be documented by the person responsible for the small wood-fired combustor, based on information received from the manufacturer.

For a certified[4] new small wood-fired combustor the partial load heat output capacity is typically 30 percent of the nominal load heat output capacity, as described in EN 303-5 (2012), and third party certification emission testing for partial load is typically conducted at 30 percent of the nominal load heat output capacity.

However, for an uncertified new small wood-fired combustor, the person responsible for the small wood-fired combustor must document, based on information received from the manufacturer, the partial load heat input and output capacity as a percentage of the corresponding nominal load heat input and output capacity. The person responsible for the small wood-fired combustor is expected to have a written record of the partial load heat input and output capacity specifications.

[3] This applies also to a wood combustor that is described in Chapter 3.0 “Applicability”.
[4] This applies also to a wood combustor that is described in Chapter 3.0 “Applicability”.

It is important to note that a new small wood-fired combustor is not to operate "in idle mode" below the partial load heat input and output capacity - it is expected to operate at or above the partial load heat input and output capacity or otherwise be shut down.

As well, a new small wood-fired combustor is expected to operate in manner that ensures that the static pressure in the furnace is negative. Ensuring the furnace is drafting air and, therefore, is negatively pressurized will prevent the migration of flue gases into the structure housing the small wood-fired combustor.

It is expected that any air pollution control equipment required to be installed as a component of the small wood-fired combustor as described in Chapter 5.1 will operate at all times while the small wood-fired combustor is operational.

5.3 Flue Gas Concentration Limits[5]

New Small Wood-Fired Combustors

The concentration of carbon monoxide in the flue gas of a new small wood-fired combustor is expected to be less than 400 parts per million by volume (ppmv) at 11% oxygen on a dry basis and reference conditions averaged over a 24-hour calendar day. When calculating the daily average carbon monoxide concentration, a person may omit up to 120 non-consecutive minutes of carbon monoxide measurements while the small wood-fired combustor is operational. As well, a person may omit any carbon monoxide measurements taken after the induced draft fan shuts off following the shutdown of a small wood-fired combustor. Records of the measurements (including those that were omitted) are to be kept at the facility for a minimum of 12 months from the date the measurement was taken (see also Chapter 7).

The concentration of oxygen in the flue gas of a new small wood-fired combustor is expected to be at least six percent by volume on a dry basis at reference conditions block-averaged over a one-hour period. Note however, that the concentration of oxygen in the flue gas of a certified[6] new small wood-fired combustor is expected to be at least 5.5 percent by volume on a wet basis averaged over a one-hour period as measured by the oxygen lambda sensor. Note that a dry oxygen measurement is not required because a continuous carbon monoxide monitor is not required for certified new small wood-fired combustors (See Chapter 7.2).

Reassessed and Existing Small Wood-Fired Combustors

It is expected that a person responsible for a reassessed or existing small wood-fired combustor will meet the flue gas carbon monoxide and oxygen limits set out in their ECA. Note that the ministry will have regard to the limits for carbon monoxide and oxygen set out above in issuing or amending ECAs after January 31, 2017. It is also expected that a person responsible for a reassessed or existing small wood-fired combustor will operate in a manner that results in the concentration of particulate matter in the flue gas of the discharge stack of a small wood-fired combustor, downstream of any air pollution control equipment meeting the limit set out in their ECA. Similarly, the ministry will have regard to a concentration limit of less than 90 mg/Rm^3 at 11% oxygen (dry basis) for particulate matter with respect ECAs issued or amended after January 31, 2017.

[5] Note that air standards in Ontario Regulation 419/05 are also applicable.
[6] This applies also to a wood combustor that is described in Chapter 3.0 "Applicability".

6.0 INSTALLATION AND SOURCE TESTING

6.1 Installation Test for New Small Wood-Fired Combustors

During the 90-day period following the first start-up of a new small wood-fired combustor it is expected that an installation test be performed to ensure the small wood-fired combustor was installed and is operating according to the manufacturer's design. As part of the installation test, the person responsible for the small wood-fired combustor is to ensure that a technician trained by the manufacturer inspects how the small wood-fired combustor was installed and observes the operation of the small wood-fired combustor to determine if any problems occur. The person responsible for the small wood-fired combustor is to ensure that the technician corrects any problems and is to document the work done by the technician upon successful completion of the installation test.

When performing the installation test, it is expected that the person responsible for the small wood-fired combustor ensures that the technician determines if the performance monitoring equipment (as described in Chapter 7) is functioning properly. The monitoring equipment is to be assessed for a minimum of three continuous hours at each of the following operating conditions: (i) at nominal load heat input and output capacity and (ii) at partial load heat input and output capacity. The data generated by the process monitoring devices described in Chapter 7.1 are expected to be recorded as part of the installation test. This test is intended to ensure the satisfactory performance of the performance monitoring equipment and to demonstrate that the equipment is ready to operate at steady state conditions for subsequent source testing as described in Chapter 6.2 below.

The installation test is to be performed for each type of wood fuel that is intended to be used in the small wood-fired combustor (i.e., wood pellets, wood chips and/or wood briquettes). For a small wood-fired combustor that may use wood pellets or wood briquettes, the installation test is to be performed using wood pellets or wood briquettes with the highest ash content that may be used in the small wood-fired combustor. For a small wood-fired combustor that may use wood chips, the installation test is to be performed using wood chips with the highest moisture content and ash content that may be used in the small wood-fired combustor.

As part of the installation test, the person responsible for the small wood-fired combustor must ensure that the technician uses a calibrated portable combustion gas analyzer to measure and record carbon monoxide and oxygen emission levels in the flue gas for each three-hour period concurrent with the assessment of the performance monitoring equipment at nominal load and partial load heat input and output capacity. As such, it is recommended that all new small wood-fired combustors have readily accessible emission testing ports to allow for the use of a calibrated portable combustion gas analyzer.

It is expected that the concentration of carbon monoxide measured during the installation testing be: (i) less than 100 ppmv at 11% oxygen for nominal load heat input and output capacity, and (ii) less than 200 ppmv at 11% oxygen for partial load heat input and output capacity. It is expected that the concentration of oxygen in the flue gas measured during installation testing be at least 5.5 percent by volume.

The person responsible for the small wood-fired combustor is to ensure that the technician compares the measurement results to the limits set out above and any other applicable limits (e.g. in an ECA). The person responsible for the small wood-fired combustor is to ensure that the technician makes any necessary adjustments or repairs to ensure that the measurement results are compliant with the limits set out above. If the small wood-fired combustor has a continuous carbon monoxide or oxygen monitor, the person responsible for the small wood-fired combustor must ensure that the technician compares the measurement results of the portable combustion gas analyzer to the measurements of the continuous monitor.

The person responsible for the small wood-fired combustor is to ensure that the technician reviews and correlates the results of the measurements described above from the process monitoring devices and combustion gas analyzer, subject to any adjustments or repairs, to determine if the small wood-fired combustor is performing well in accordance with the manufacturer's recommendations.

It is expected that the person responsible for the small wood-fired combustor will document the results of an installation test and that a report be prepared and retained at the facility for a period of five years after the date on which the small wood-fired combustor ceases to be used at the facility. The report shall include the calibration records of the portable combustion gas analyzer.

6.2 Source Testing for Small Wood-Fired Combustors

In this guideline, a source test generally means the measurement of carbon monoxide, oxygen and particulate matter in the flue gas of the discharge stack of a small wood-fired combustor, downstream of any air pollution control equipment.

A source test is to be performed for each type of wood fuel that is intended to be used in the small wood-fired combustor at the facility (i.e., wood pellets, wood chips and/or wood briquettes). For a small wood-fired combustor that may use wood pellets or wood briquettes, the source test is to be performed using wood pellets or wood briquettes with the highest ash content that may be used in the small wood-fired combustor. For a small wood-fired combustor that may use wood chips, the source test is to be performed using wood chips with the highest moisture content and ash content that may be used in the small wood-fired combustor.

The source test report is to include a summary of the process control monitoring data described in Chapter 7 that was measured during the source test.

New Small Wood-Fired Combustors

A source test is expected to be performed no later than six months after the completion of an installation test with respect to a new small wood-fired combustor.

The source test is to measure particulate matter, carbon monoxide and oxygen in the flue gas of the new small wood-fired combustor. These parameters are to be measured at both nominal load heat input and output capacity and partial load heat input and output capacity[7]; however, a certified new small wood-fired combustor need only measure carbon monoxide and oxygen at nominal load heat input and output capacity and partial load heat input and output capacity.

It is expected that the concentration of particulate matter, as measured in the flue gas after the air pollution control equipment during source testing, be less than 75 mg/Rm^3 at 11% oxygen (dry basis) averaged over a period determined in accordance with the Ontario Source Testing Code.

It is expected that the concentration of carbon monoxide measured during source testing be: (i) less than 100 ppmv at 11% oxygen on a dry basis and reference conditions averaged over a one-hour period for nominal load heat input and output capacity, and (ii) less than 200 ppmv at 11% oxygen on a dry basis and reference conditions averaged over a one-hour period for partial load heat input and output capacity.

It is expected that the concentration of oxygen in the flue gas measured during source testing be at least six percent by volume on a dry basis and reference conditions averaged over a one-hour period. Note that measuring the concentration of oxygen on a dry basis enables the oxygen correction of the carbon monoxide

[7] Chapter 5.2 sets out that the partial load heat input capacity is to be set out in a written record for uncertified small wood-fired combustors.

measurements. The dry oxygen level determined during source testing must be measured separately from the wet oxygen level determined by the oxygen lambda sensor.

If a new small wood-fired combustor undergoes a significant modification, it is expected that the person responsible for the small wood-fired combustor would seek an amendment to the ECA, after which another source test will be completed according to the requirements set out in the ECA.

Reassessed and Existing Small Wood-Fired Combustors
Source testing at nominal load heat input and output capacity operating conditions is expected to be performed, in accordance with the terms and conditions of an ECA. Note that for ECAs issued or amended after January 31, 2017, the ministry will have regard to the following expectations:

(i) if it has been five years (or more) since the last source test was conducted for the small wood-fired combustor at the time when it is reassessed, source testing may be required no later than six months after the issuance of an ECA pertaining to the reassessed combustor, or

(ii) if the small wood-fired combustor has been modified in such a way that it no longer conforms to the existing ECA conditions and requires an amendment to the ECA (e.g., change induced draft fan size, flow or pressure ratings, change wood fuel type and associated feed system), source testing may be required no later than six months after the commissioning period of the modified combustor, or

(iii) with respect to an application for an ECA with respect to an existing small wood-fired combustor that has been operating without an ECA, where one is required, source testing is expected to be performed no later than six months after the issuance of an ECA pertaining to the existing small wood-fired combustor.

It is expected that the concentration of particulate matter in the flue gas measured downstream of any air pollution control equipment during source testing be less than 90 mg/Rm³ at 11% oxygen (dry basis) averaged over a period determined in accordance with the Ontario Source Testing Code.

It is expected that the concentration of carbon monoxide measured during source testing be less than 100 ppmv at 11% oxygen on a dry basis and reference conditions averaged over a one-hour period.

It is expected that the concentration of oxygen in the flue gas measured during source testing be at least six percent by volume on a dry basis and reference conditions averaged over a one-hour period.

A summary of the source testing expectations are provided in Appendix A.

7.0 PERFORMANCE MONITORING

7.1 Process Control Monitoring for Small Wood-Fired Combustors

New Small Wood-Fired Combustors
The Ministry expects that certain process control parameters will be monitored and recorded while a new small wood-fired combustor is operating. For the purposes of data recording, the process control monitors should measure and record for a minimum of two hours after a shutdown procedure has commenced.

The Ministry expects the following parameters to be measured continuously and that the measurements be block-averaged over every five minute period:

1. The concentration of oxygen in the flue gas as measured by the oxygen lambda sensor (percent by volume on a wet basis)
2. An induced draft fan parameter (e.g., fan speed or percent of maximum)
3. A fuel input or energy output parameter (e.g., percent of nominal load to ensure that the small wood-fired combustor does not operate below the partial load heat input capacity – see Chapter 5.2)
4. The flue gas temperature.

The Ministry expects that each measurement be recorded and retained at the facility for at least 12 months from the date the measurement was taken.

Reassessed and Existing Small Wood-Fired Combustors
The Ministry considers it a best practice for a reassessed or existing small wood-fired combustor to have process control monitoring as described above.

7.2 Flue Gas Monitoring for Small Wood-Fired Combustors

New Small Wood-Fired Combustors
A new small wood-fired combustor is to be equipped with a monitor that continuously measures and records the concentration of carbon monoxide and oxygen in the flue gas. **Note that such monitoring is not expected if the new small wood-fired combustor is certified.**

In particular, it is expected that the following parameters be measured continuously and that the measurements be block-averaged over every five minute period:

1. The undiluted concentration of carbon monoxide, reported on a dry basis and corrected to 11 percent oxygen and reference conditions, in the flue gas.
2. The undiluted percentage of oxygen by volume, reported on a dry basis and reference conditions, in the flue gas.

For new uncertified small wood-fired combustors, it is recommended that the measurements of oxygen and carbon monoxide are conducted at the same location and that the carbon monoxide monitor be configured as a dual range application with automatic range change capabilities to accurately measure emissions during both start-up and shut down operations as well as normal operations.

The process control monitoring data is intended to assist in interpreting this flue gas emission monitoring data. As such, it is expected that the times and dates for each monitor and data recording system (for both flue gas and process control monitors) be synchronized to within one minute of each other.

The Ministry expects that each carbon monoxide and oxygen measurement be recorded and retained at the facility for at least 12 months from the date the measurement was taken.

Prior to installing a new uncertified small wood-fired combustor, it is strongly recommended that a person submit a plan for the installation, operation and maintenance of the above-noted continuous flue gas monitoring devices to the Manager of Technology Standards Section, Standards Development Branch at the Ministry.

Reassessed and Existing Small Wood-Fired Combustors
The Ministry expects that a person responsible for a reassessed or existing small wood-fired combustor will comply with the terms and conditions of their ECA with regards to flue gas monitoring. Note that for ECAs issued or amended after January 31, 2017, the ministry will have regard to the expectation that a small wood-

fired combustor be equipped with a monitor that continuously measures and records the concentration of carbon monoxide, oxygen and temperature in the flue gas. The Ministry also expects that each carbon monoxide, oxygen and temperature measurement be recorded and retained at the facility for at least 12 months from the date the measurement was taken.

7.3 Routine Inspections or Remote Connection

New and Reassessed Small Wood-Fired Combustors
To minimize the potential for operational malfunction of a small wood-fired combustor and associated air emissions, it is expected that new and reassessed small wood-fired combustors be (i) inspected regularly or (ii) equipped with a remote connection.

If the small wood-fired combustor is to be inspected regularly, it is expected that the routine physical inspections be performed at least once per week in accordance with recommendations of the manufacturer by a person who has received training for the purposes of conducting such inspections. The Ministry expects the results of each inspection to be recorded and maintenance activities to be performed as needed.

If a small wood-fired combustor is to be equipped with a remote connection, it is expected that the small wood-fired combustor be equipped with a 24-hour per day remote connection to either a designated facility staff member or service contractor. The remote connection should communicate error or fault alarms, messages and notifications from the facility in the event of a malfunction to enable a response in a timely manner to trouble-shoot and correct the malfunction by either attending to the combustor in person or engaging in two-way communication remotely with the combustor. The Ministry expects the results of each remote communication to be recorded and maintenance activities to be performed as needed.

Existing Small Wood-Fired Combustors
The Ministry considers it a best practice to adopt a routine inspection program or remote connection as described above for existing small wood-fired combustors.

8.0 PERFORMANCE ASSESSMENT

New and Reassessed Small Wood-Fired Combustors
The Ministry expects that the person responsible for the small wood-fired combustor will ensure that a technician who is competent in heating, ventilation, and air conditioning (HVAC) technologies conducts a performance assessment at least once per year with respect to a new or reassessed small wood-fired combustor. The performance assessment is expected to include the following actions:

1. Inspection of the following items while the small wood-fired combustor is not operating,
    i. fuel conveyance and handling equipment (e.g., is the wood fuel conveyance equipment visibly damaged?),
    ii. indoor wood fuel storage area (e.g., is the indoor wood fuel storage area dry or is there evidence of water leaking in from the outdoors?),
    iii. heat exchanger, air pollution control equipment, combustion air and flue gas ductwork (e.g., are the heat exchanger tubes free of corrosion and fly ash deposits, and is the ductwork free from leakage due to rust or holes?),
    iv. fans and dampers (e.g., are any of the fans or dampers visibly damaged?),

v. continuous monitoring devices (e.g., is the oxygen lambda sensor installed correctly or has it been removed?),

vi. combustion chamber air injection nozzles, grates and refractory (e.g., is there surplus bottom ash on the grate that has not been removed in a timely manner?), and

vii. bottom ash and fly ash (e.g., does the bottom ash contain a significant amount of blackened fuel particles that still have a recognizable shape because they did not burn completely?).

2. While the small wood-fired combustor is operating at or between nominal and partial heat load, measure the carbon monoxide and oxygen emission levels in the flue gas of the small wood-fired combustor over at least a 30-minute period using a calibrated portable combustion gas analyser and record the levels of those parameters.

3. Complete any necessary adjustments or repairs to ensure that the measurements obtained in accordance with paragraph 2 indicate the following concentrations:

   i. the concentration of carbon monoxide averaged over the test period described in paragraph 2 is less than 100 parts per million by volume (ppmv) corrected to 11 percent oxygen, and

   ii. the concentration of oxygen averaged over the test period described in paragraph 2 is at least 5.5 percent by volume.

4. Determine if the small wood-fired combustor is performing well by reviewing:

   i. the results of the measurements required by paragraph 2, subject to any necessary adjustments or repairs, and correlating those results with the results of the measurements obtained in accordance with Chapter 7.1 over the same period;

   ii. the maintenance, inspection and calibration records for each piece of continuous monitoring equipment mentioned in Chapter 7.1.

If the determination described by paragraph 4 above indicates that the small wood-fired combustor is not performing well, the person responsible for the small wood-fired combustor must ensure that necessary adjustments or repairs are made in a manner that will ensure the small wood-fired combustor is operating in accordance with the manufacturer's recommendations and the requirements of any conditions of an ECA or other legally binding instrument.

For greater certainty, the actions described above do not replace any inspection or preventative maintenance program recommended by the manufacturer and such recommendations are expected to be implemented in addition to the actions described above. Also, the actions expected to be performed while the small wood-fired combustor is operating can be performed on a different day than the actions expected to be performed while the small wood-fired combustor is not operating, within the same year.

The person responsible for the small wood-fired combustor is expected to ensure that a record of the results of each performance assessment is created and retained for a five-year period after the record is completed. A record created is expected to include the date on which the performance assessment is performed, the observed conditions of the items to be inspected while the small wood-fired combustor is not operating, the measurements made while the small wood-fired combustor is operating, a summary of the determination made as to whether the small wood-fired combustor is performing well and a description of any adjustments or repairs made to correct the small wood-fired combustor so that it does perform well.

Existing Small Wood-Fired Combustors

The Ministry considers it a best practice to perform performance assessments for existing small wood-fired combustors as described above.

9.0 DOCUMENTATION

This chapter sets out the information that is expected to be submitted in an ECA application and, with respect to a new small wood-fired combustor, documented prior to the installation of a new small wood-fired combustor. The following information on wood fuel parameters, combustor design and performance will assist the Director in assessing whether the small wood-fired combustor meets the expectations set out in this guideline (where applicable):

a) A tabulated summary of the types and specifications of wood fuels that are proposed to be stored and intended to be used at the facility (see expectations set out in Chapter 4.1).

b) A tabulated summary of the design, operating and performance monitoring aspects of the small wood-fired combustor and air pollution control equipment (see expectations set out in Chapters 5 and 7).

c) A side-sectional schematic of the combustor including an illustration of the automated method of introduction of wood fuel into the furnace that meets the expectations set out in Chapter 4.2; the combustion zones (e.g., primary, secondary) and identification of points of introduction of combustion air and, where applicable, flue gas recirculation air (see expectations set out in Chapter 5).

d) A copy of the original equipment manufacturers combustor design and operating documentation[8] that includes the following information (where available):

   i) The make and model number and nominal load heat input and output capacity and other related design features such as the air pollution control equipment (e.g., cyclone).

   ii) The partial load heat input and output capacity as a percent of the nominal load heat input and output capacity.

   iii) The types of wood fuels capable of being used in the unit, including wood briquettes, pellets and/or chips with a provision for wood chip units that the maximum fuel moisture content is 50%.

   iv) A description of the automated start-up and shutdown procedures.

   v) A description of the combustion process control parameters outlined in Chapter 7.1, including the data acquisition system capabilities.

   vi) Specifications for the oxygen lambda sensor.

   vii) The design operating range for excess oxygen in the flue gas and how the oxygen trim system maintains the excess oxygen at the desired level.

   viii) Recommendations for operator training, routine visual inspections, remote connections and monitoring, preventative maintenance plans, spare parts, trouble-shooting, operational adjustment either on-site or remotely and periodic combustor cleaning, maintenance and tune ups.

e) A tabulated summary of the expected air emission performance of the small wood-fired combustor for both nominal load and partial load heat input and output operating conditions (see expectations set out in Chapters 5.2 and 5.3), that includes the following information:

   i) Range of anticipated 1-hour block average oxygen concentrations (percent by volume, dry and wet basis) in the flue gas and typical set-point for each wood fuel proposed for use at the facility.

   ii) Maximum anticipated 24-hour daily average carbon monoxide concentration (ppmv, dry basis at 11% oxygen and reference conditions) in the flue gas.

   iii) Maximum anticipated flue gas concentration of particulate matter (mg/Rm³ at 11% oxygen, dry basis) measured at a point after any air pollution control equipment.

[8] If the manufacturer's documentation is not available, a copy of the tender documents used to procure a small wood-fired combustor may be submitted instead.

f) Air emission documentation that validates the above-noted maximum anticipated outlet concentrations of carbon monoxide and particulate matter for the small wood-fired combustor and air pollution control equipment that is to be included in the application for ECA. In particular:

   i) For a certified[9] small wood-fired combustor at least one of the following is considered acceptable if it identifies the emissions of dust (particulate matter) and demonstrates compliance with the requirements of EN 303-5 (2012) Class 5 for thermal efficiency and carbon monoxide as well as Class 3, 4 or 5 for dust at both nominal load and partial load heat input and output capacity operating conditions:

      1. the manufacturer's guaranteed emission limits,
      2. a copy of an independent testing agency's report.

   ii) For an uncertified small wood-fired combustor, an air emission test report from an operating small wood-fired combustor in another jurisdiction that has been accepted by an environmental regulatory agency (e.g., an American State or Canadian Provincial regulator) is preferred over published emission factors. Emission data at nominal load heat input and output capacity is expected and emission data at partial load heat input and output capacity is also desired where available.

g) Documentation summarizing the proposed continuous flue gas monitoring devices, installation location, operation and maintenance for uncertified small wood-fired combustors (see expectations set out in Chapter 7.3).

Refer to Table A-1 in Appendix A for a summary of the expectations for new and reassessed small wood-fired combustors. Table A-1 includes related notes to distinguish expectations based on certification status. Refer also to Table B-1 in Appendix B for an example of a format that would assist in providing the above-listed information.

[9] This applies also to a wood combustor that is described in Chapter 3.0 "Applicability".

APPENDIX A

Tabulated Summary of Guideline A-14 Expectations

Table A-1: Summary of Expectations for Small Wood-Fired Combustors

A person responsible for a small wood-fired combustor that has an ECA must meet the requirements set out in the ECA. For existing small wood-fired combustors that have an ECA the items listed in Table A-1 under the column entitled “Reassessed” are considered best practices. Please refer to the notes below Table A-1 with regards to distinguishing expectations for certified new small wood-fired combustors.

	Parameter	Guideline A-14 Expectations	
		New	Reassessed
	Wood Fuel		
1.	Select wood fuel specifications	Yes	Yes
2.	Develop wood fuel management plan	Yes	Yes
3.	Automated start-up, shut down and feed system	Yes	Yes
	Design Parameters		
4.	Nominal load heat input capacity	<3 MW	<3 MW
5.	Partial load heat input capacity (% of nominal load)	As provided by the manufacturer [A]	N/A
6.	Air Pollution Control Equipment	Yes [E]	N/A
7.	Multi-zone air control with oxygen trim system	Yes	N/A
8.	Maximum particulate matter in the flue gas, downstream of any air pollution control equipment [D]	< 75 mg/Rm³	< 90 mg/Rm³ [F]
	Flue Gas Limits		
9.	Minimum oxygen (1-hour block average)	> 6.0% dry basis [B]	> 6.0% dry basis
10.	Maximum carbon monoxide (daily average) [D]	< 400 ppmv	< 400 ppmv
11.	**Installation Test**	Yes	N/A
	Source Testing Objectives		
12.	Particulate Matter – nominal load [D]	< 75 mg/Rm³ [C]	< 90 mg/Rm³
13.	Particulate Matter – partial load [D]	< 75 mg/Rm³ [C]	N/A
14.	Carbon Monoxide – nominal load (1-hour average) [D]	< 100 ppmv	< 100 ppmv
15.	Carbon Monoxide – partial load (1-hour average) [D]	< 200 ppmv	N/A
16.	Minimum oxygen (1-hour average)	> 6.0% dry basis	> 6.0% dry basis
	Performance Monitoring		
17.	Oxygen lambda sensor (% by volume, wet basis)	Yes	Best Practice
18.	Induced draft fan parameter	Yes	Best Practice
19.	Fuel input or energy output (% of nominal load)	Yes	Best Practice
20.	Flue gas temperature	Yes	Yes
21.	Carbon monoxide (ppmv) [D]	Yes [C]	Yes
22.	Oxygen (% by volume, dry basis)	Yes [C]	Yes
23.	Retain performance monitoring data for at least 12 months (maximum 5-minute block averaging)	Yes	Yes
	Inspection and Maintenance		
24.	Routine inspection log and/or remote connection	Yes	Yes
25.	Performance assessment	Yes	Yes

Notes:

[A] The partial load heat capacity for a new certified small wood-fired combustors is typically tested at **30%**.

[B] The minimum excess oxygen (1-hour block average) for a new certified small wood-fired combustor may be **5.5% on a wet basis** as recorded by the oxygen lambda sensor**.**

[C] Not applicable for a new certified small wood-fired combustor.

[D] Corrected to 11% oxygen, dry basis, reference conditions.

[E] Refer to Chapter 5.1 (f) for details of air pollution control equipment expectations, depending on the EN 303-5 (2012) Class 3, 4 or 5 rating for dust (particulate matter) and whether air pollution control equipment is required to meet the dust Class rating as specified by the manufacturer.

[F] This limit for particulate matter is a flue gas limit for reassessed small wood-fired combustors, not a design parameter, but it is shown here for ease of comparison with new small wood-fired combustors.

APPENDIX B

Tabulated Summary of Documentation Expectations

Table B-1: Summary of Documentation Expectations regarding Combustor Design and Performance

1	**Make and Model Number of Small Wood-Fired Combustor:**	
2a	**Certified[10] to EN 303-5 (2012) Class 5 for Thermal Efficiency and Carbon Monoxide (Yes/No):**	
2b	**Certified to EN 303-5 (2012) Class 3, 4 or 5 for Dust (Yes/No, if Yes specify):**	
3a	**Identify whether Guideline A-13 or Guideline A-14 applies to the small wood-fired combustor:**	
3b	**If Guideline A-14 applies, identify whether the small wood-fired combustor is existing, reassessed or new:**	
4	Wood Fuel Type(s) (Pellet, Briquette and/or Wood Chip):	
5	Wood Fuel Specification(s):	
6	Equivalent days of indoor storage for wood chips at nominal load (heated or unheated):	
7	Maximum Wood Fuel Moisture Content for each intended fuel type:(% by weight, wet basis):	
8	Maximum Wood Fuel Ash content according to specification for each intended fuel type (% by weight, if applicable):	
9	Maximum fuel flow at nominal load operating condition for each intended fuel type (kg/hr):	
10	Maximum fuel flow at partial load operating condition for each intended fuel type (kg/hr):	
11	Nominal Load Heat Input and Output Capacity (kW):	
12	Partial Load Heat Input and Output Capacity (% of Nominal Load):	
13a	Testing report/documentation compliant to	

[10] This applies also to a wood combustor that is described in Chapter 3.0 “Applicability”.

	EN 303-5 (2012) Class 5 for Thermal Efficiency and Carbon Monoxide (Yes/No):	
13b	Testing report/documentation compliant to EN 303-5 (2012) Class 5 for Carbon Monoxide, equipped with an air-to-air heat exchanger (Yes/No):	
13c	Testing report/documentation compliant to EN 303-5 (2012) Class 3, 4 or 5 for Dust (Yes/No, if Yes specify):	
14	Includes multi-zone air control (Yes/No):	
15	Includes oxygen trim system? (Yes/No):	
16	Includes tertiary combustion air (Yes/No):	
17	Includes flue gas recirculation (Yes/No):	
18	Side-sectional schematic of combustor included (Yes/No):	
19a	Oxygen lambda sensor type and operating range (% by volume – wet):	
19b	Induced draft fan parameter and operating range:	
19c	Fuel input or energy output parameter and operating range:	
19d	Flue gas temperature measurement operating range:	
20	Maximum anticipated suspended particulate matter outlet concentration (mg/Rm^3 @ 11% O_2-dry):	
21	Maximum anticipated carbon monoxide outlet concentration at nominal load, partial load and 24-hour daily average (ppm-v @ 11% O_2-dry):	
22	Includes air pollution control equipment specified by combustor manufacturer (Yes/No) if yes please describe:	
23	Includes other air pollution control equipment as described in Chapter 5.1 (f) (Yes/No) if yes please describe:	
24	Supporting documentation included for	

	anticipated outlet concentrations of particulate matter and carbon monoxide (Yes/No):	
25	Includes testing port(s) for particulate matter and carbon monoxide emission testing (Yes/No):	
26	Supporting documentation included for flue gas emission monitoring devices (where applicable) (Yes/No):	

Notes:

i) mg/Rm^3 @ 11% O_2-dry means milligrams per reference cubic metre corrected to 11% by volume (dry basis) oxygen content in the flue gas;
ii) ppm-v @ 11% O_2-dry means ppmv corrected to 11% by volume (dry basis) oxygen content in the flue gas; and
iii) reference conditions are 25 degrees Celsius and 101.3 kilopascals atmospheric pressure.

APPENDIX C

Emission Conversions and Calculations

Table C-1: Conversion Between Imperial and Metric Systems

From	To	Multiply by	References
Btu	J	1055.1	Perry's Chemical's Engineer Handbook (50th Anniversary Edition, 1984) Table 1-6, pages 1-15 to 1-17.
Btu/hr	kJ/hr	1.0551	
Btu/hr	W	0.29307	
MM Btu/hr	MW	0.29307	
Pounds-mass	Kilograms	0.45359	

Notes:

i) MM = 1 million in US customary units and Imperial British Units (e.g., 1 MM Btu = 1 million Btu).
ii) M = 1 million in metric units (e.g., 1 MW = 1 megawatt or 1 million watts).
iii) G = 1 billion in metric units (e.g., 1 GJ = 1 billion Joules).

Table C-2: Emission Conversions

a. Converting from parts per million by volume of a gaseous contaminant to milligrams per cubic metre at the same Conditions:

$$\text{Emission Concentration (mg/m}^3\text{)} = 21.9 \times [\text{ppmv}] \times \frac{MW}{(1.8 \times T + 492)}$$

T is the temperature, in °C, of the flue gases that corresponds to the (ppmv) measurement
MW= Molecular weight of contaminant

Note: In the above-noted formula, the converted emission concentration (mg/m^3) is on the same dry or wet basis and at the same flue gas conditions (e.g., % oxygen and/or % carbon dioxide) as the measured concentration (ppmv).

b. Converting from parts per million by volume of a gaseous contaminant to pounds per cubic foot at the same Conditions:

$$\text{Emission Concentration (pounds/ft}^3\text{)} = [\text{ppmv}] \times \frac{1.369 \times MW}{[1E6 \times (T + 460)]}$$

T is the temperature, in °F, of the flue gases that corresponds to the (ppm-v) measurement
MW= Molecular weight of contaminant

Note: In the above-noted formula, the converted emission concentration (pounds/ft^3) is on the same dry or wet basis and at the same flue gas conditions (e.g., % oxygen and/or % carbon dioxide) as the measured concentration (ppmv).

c. Converting from pounds per standard cubic foot of a gaseous contaminant to milligrams per reference cubic metre at the same oxygen level and same wet/dry basis:

$$\text{Emission Concentration (mg/Rm}^3\text{)} = [\text{pounds/Scf}] \times (35.315/2.2046) \times (1E6) \times (20+273)/(25+273)$$

$$\text{Therefore, Emission Concentration (mg/Rm}^3\text{)} = [\text{pounds/Scf}] \times (1.575E7)$$

Notes:
i) Standard conditions (with respect to "standard ft^3" or Scf) are at 68 °F or 20 °C and reference conditions (with respect to Rm^3) are at 25 °C.
ii) In the above-noted formula, the converted emission concentration (mg/Rm^3) is on the same dry or wet basis and at the same flue gas conditions (e.g., % oxygen and/or % carbon dioxide) as the measured concentration (pounds/Scf).

d. Converting a measured concentration from one level of volumetric percentage of oxygen-dry in flue gas to a different volumetric percentage of oxygen in flue gas:

$$\text{Emission Concentration}_B = [\text{Original Concentration}]_A \times \frac{(20.9 - \%O_{2B})}{(20.9 - \%O_{2A})}$$

$\%O_{2B}$ = percent, by volume-dry, oxygen at the new concentration
$\%O_{2A}$ = percent, by volume-dry, oxygen at the original concentration

Example: converting 80 ppmv (dry) at 3% oxygen-dry to a concentration at 11% oxygen-dry:

Emission concentration at 11% oxygen = (80 ppmv-dry) x [(20.9-11)/(20.9-3)] = 44 ppmv-dry

e. Converting a measured concentration from one level of volumetric percentage of carbon dioxide-dry in flue gas to a different volumetric percentage of carbon dioxide in flue gas:

$$\text{Emission Concentration}_B = [\text{Original Concentration}]_A \times \frac{(\%CO_{2B})}{(\%CO_{2A})}$$

$\%CO_{2B}$ = percent, by volume-dry, carbon dioxide at the new concentration
$\%O_{2A}$ = percent, by volume-dry, carbon dioxide at the original concentration

Example: converting 100 ppmv-dry at 10% by volume-dry carbon dioxide to a concentration at 12% carbon dioxide:

Emission concentration at 12% carbon dioxide = (100 ppmv-dry) x [(12)/(10)] = 120 ppmv-dry

f. Converting a measured concentration (in mg/m^3) from one flue gas temperature to another:

$$\text{Emission Concentration}_B = [\text{Original Concentration}]_A \times \frac{(T_A+273)}{(T_B+273)}$$

T_B = Temperature, in °C, at the new concentration
T_A = Temperature, in °C, at the original concentration

Example: converting 10 mg/m^3 at 0 °C to a concentration at 25 °C

Emission Concentration at 25 °C = (10 mg/m^3) x [(0+273)/(25+273)] = 9.2 mg/m^3

Note: There is no need for a temperature correction for a concentration in ppmv because both the numerator and denominator are volume-based.

g. Converting from pounds per million Btu (a common emission factor metric used in the United States) to milligrams per reference cubic metre

When measurements of contaminant concentration (F_d) and oxygen ($\%O_{2d}$) are both on a dry basis, then the following conversion formula can be used:

Note: This involves the following two step conversion process:

i) First, converting from pounds per million Btu to pounds per standard cubic foot where standard conditions are defined as 68 °F (ie., 20 °C) and 760 mm Hg (ie., 101.3 kPa); and
ii) Second converting pounds per standard cubic foot to milligrams per Reference cubic metre where, for the purposes of this document, reference temperature and pressure are defined as
25 °C and 101.3 kPa.

Step 1: Convert pounds per million Btu to pounds per standard cubic foot:

$$C_d = [\text{Emission Factor in pounds per million Btu}] \times [(20.9 - \%O_{2d})/(20.9 \times F_d)]$$

- **C_d:** contaminant concentration, dry basis, pounds per standard cubic foot
- **$\%O_{2d}$:** percent by volume oxygen, dry basis, that corresponds to the contaminant concentration, C_d
- **F_d:** Fuel factor (volumes of combustion components per unit heat content)

$$F_d = \frac{[1E6] \times [3.64\times(\%H) + 1.53\times(\%C) + 0.57\times(\%S) + 0.14\times(\%N) - 0.46\times(\%O)]}{HHV}$$

%H: percent by weight hydrogen (as-fired, from ultimate analysis of fuel)
%C: percent by weight carbon (as fired, from ultimate analysis of fuel)
%S: percent by weight sulphur (as fired, from ultimate analysis of fuel)
%N: percent by weight nitrogen (as fired, from ultimate analysis of fuel)
%O: percent by weight oxygen (as fired, from ultimate analysis of fuel)
HHV: Higher heating value of fuel, as fired, Btu/lb

Step 2: Convert pounds per standard cubic foot to milligrams per reference cubic metre

$$C_d \text{ in mg/Rm}^3 = [C_d \text{ in lb/Scf}] \times (35.315/2.2046)\times(1E6)\times(273+20)/(273+25)$$

$$Cd \text{ in mg/Rm}^3 = [C_d \text{ in lb/Scf}] \times (1.575E7)$$

Where, standard conditions (with respect to Scf) are at 68 °F or 20 °C and reference conditions (with respect to Rm^3) are at 25 °C.

Table C-3: Summary Table of Typical Fuel Factors (F_d):

Fuel Type	F_d (dry standard cubic foot/million Btu heat input)
Coal:	
Anthracite:	10,100
Bituminous:	9,780
Lignite:	9,860
Oil:	9,190
Gas (natural gas, propane, butane):	8,710
Wood:	9,240
Wood Bark:	9,600
Municipal Solid Waste:	9,570

Note: The above fuel factors (F_d) are determined at standard conditions:
20 °C (68 °F) and 101.3 kPa (760 mm Hg)

Reference for Fuel Factor Conversion Information and Typical Fuel Factors:

- **US EPA, Method 19 – Determination of Sulphur Dioxide Removal Efficiency and Particulate Matter, Sulfur Dioxide and Nitrogen Oxide Emission Rates**
- **See http://www.epa.gov/ttn/emc/methods/method19.html**

Appendix D

Information Pertaining to Environmental Compliance Approvals Process

The websites listed below may contain information that may assist proponents to develop a small wood-fired combustor project in Ontario.

Environmental Compliance Approval in Ontario
https://www.ontario.ca/page/environmental-compliance-approval

Guide to applying for Environmental Compliance Approval
https://www.ontario.ca/document/guide-applying-environmental-compliance-approval

Checklist of technical requirements for completing an Environmental Compliance Approval submission
https://www.ontario.ca/document/checklist-technical-requirements-complete-environmental-compliance-approval-submission

Guideline A-10: Procedure for preparing an Emission Summary and Dispersion Modelling (ESDM) report
https://www.ontario.ca/document/guideline-10-procedure-preparing-emission-summary-and-dispersion-modelling-esdm-report

Guideline A-11: Air dispersion modelling guideline for Ontario
https://www.ontario.ca/document/guideline-11-air-dispersion-modelling-guideline-ontario

Acoustic Assessment Report checklist
https://www.ontario.ca/document/acoustic-assessment-report-checklist

APPENDIX E

Additional Technical Information

During the development of this guideline, a significant amount of technical information was reviewed that was not used to develop regulatory instruments but may improve project performance if considered before purchasing a small wood-fired combustor. The additional technical information is summarized below for information purposes and may assist a person considering the use of a small wood-fired combustor. The rationale document prepared to accompany this guideline also contains a significant amount of technical and jurisdictional information that may be informative.

1. Reference documents such as “Biomass Heating Project Analysis Chapter” (RetSCREEN®), “Biomass Heating” (CIBSE AM15:2014), “Emission Controls for Small Wood-Fired Boilers” (RSG Inc./BERC, May 2010) and “Particulate Matter Emissions-Control Options for Wood Boiler Systems” (BERC, 2011) are freely accessible on the internet.
2. Where available, wood fuel with independent, third-party certification is preferred. Retaining documentation from a wood fuel supplier demonstrating compliance with a fuel standard is one approach to complying with this guideline.
3. A project proponent should assess the availability of wood fuel and associated quantity and quality guarantees in their area. For example, having more than one wood fuel supplier within 100 km of a project site would be considered prudent if a facility does not produce its own wood fuel.
4. For facilities seeking to use wood chips as a fuel, it is recommended that an on-site testing capability be developed to measure the moisture content of the wood chips on a periodic basis. The purpose of developing this capability is based on the fact that wood fuel moisture can be lost during sample storage and transit before analysis at an off-site laboratory and the moisture content no longer represents the “as fired” reported basis. The most widely used approach in Europe consists of using an aluminum foil pan, small oven and scale. Retaining documentation of periodic on-site wood fuel moisture tests is one approach to complying with this guideline. Refer to Figure E1 below for a description of a procedure used to measure the moisture content of wood fuel prepared by FPInnovation.
5. Wood chips that have been dried or “seasoned” to a moisture content of 25 to 35 percent typically have better combustion properties as compared with wet or “green” wood chips at 50 percent moisture content.
6. A small wood-fired combustor designed to burn 50 percent moisture content wood chips may be able to burn lower moisture content wood chips with high efficiency but a combustor designed to burn 35 percent moisture content wood chips may encounter operational difficulties if 50 percent moisture content wood chips are used as a fuel.
7. A combustor designed with automated continuous de-ashing is preferred, as compared with automated batch de-ashing designs, as they don’t require the combustor to temporarily cease operating to open the grate(s) to discharge the bottom ash. The automated batch de-ashing designs may emit increased levels of carbon monoxide when the grate(s) are open.
8. To accommodate the installation of appropriate emission testing port(s) the minimum exhaust stack inner diameter should be no less than 0.15 m and a minimum diameter of 0.20 m is preferred. The Ontario Source Testing Code (June 2010, as amended) contains information pertaining to the design configuration of emission testing ports as a component of an exhaust stack.
9. When performing a site acceptance test or tune-up, using a portable hand held combustion gas analyzer that has been designed for solid fuel burning devices is important due to the presence of particulate matter. An example of this type of analyzer is the Testo 380 that has been designed specifically to accommodate particulate matter in the flue gas.
10. Air emissions from small wood-fired combustors can increase at partial load operation and during start-up and shut down conditions. As such, it is desirable to maintain steady state operation at or near the nominal load heat input capacity as much of the time as possible. To achieve this objective, the heating system design of a facility should be considered beyond just the small wood-fired combustor. A heating system

design should include a description of how the integrated heating system components at the facility are designed to operate to meet the peak heat load as well as non-peak heat loads. This could be achieved by dividing the peak heat load into two small wood-fired combustors and/or using other devices that operate in conjunction with the small wood-fired combustor(s), such as a thermal storage tank, an auxiliary heating system and/or a peaking heating system. The description should include the estimated peak heat load served by the small wood-fired combustor(s) and the estimated monthly design heat loads to demonstrate how the small wood-fired combustor(s) is/are anticipated to modulate between nominal and partial loads or otherwise be shut down when the thermal storage tank is full or when the auxiliary heating system is operating.

11. Certified[11] small wood-fired combustors are tested at partial load, which typically represents 30% of the nominal load according to EN 303-5 (2012). This emission data is informative because small wood-fired combustors used for comfort heating in a building will typically experience variable heat load demand and should be able to modulate the heat input capacity between nominal and partial load without creating significant increases in air emissions.

[11] This applies also to a wood combustor that is described in Chapter 3.0 “Applicability”.

Figure E1: Procedure to Measure Wood Fuel Moisture Content

Analyzing the Moisture Content of Biomass Samples

Objective: to find the moisture content percentage *mc* (%) (% by weight, wet basis) of a biomass sample.

Work space: This procedure should be performed in laboratory conditions.

Materials and equipment:

- ☐ Digital scale with a capacity of at least 2000 g and accuracy of 0.1g (from $350)
- ☐ Forced air convection oven (from $700)
- ☐ Clean sample weighing tray, able to hold at least 300 g of biomass
- ☐ 6 L (>1 kg) of biomass sample (3 replicates of at least 300 g each)

Procedures:

Step 1
Follow the procedures for *Separating Biomass Samples* to separate 3 replicates of at least 300 g each from one sample of at least 1 kg of biomass.

Step 2
Weigh the empty sample tray and record its weight (*tare*) m_t

Step 3
Load the material of a replicate into a weighing tray. Weigh the loaded tray and record the weight m_{wet}.

Step 4
Load the tray into the oven and set to 105°C.
Keep the tray in the oven until constant mass is obtained[1].

Step 5
Weigh the loaded tray and record the weight of the dry material m_{dry}.

Step 6
Calculate moisture content *mc* (%) according to the following formula:
$mc\ (\%) = [(m_{wet} - m_{dry}) / (m_{wet} - m_t)] \times 100$

Step 7
Analyze the 3 replicates and report the average.

[1] Mass constancy is obtained when the mass lost between two weights taken 60 minutes apart is not exceeding 0.2% of the total lost in mass (EN-TS 14774-1:2009). The drying time will depend on the particle size and the thickness of the sample in the tray, and may vary between 5 and 24 hours (overnight).

APPENDIX F

Summary of Wood Fuel Specifications and NRCan Bulletins

WOOD PELLETS

STANDARDS

CAN/CSA-ISO 17225-2:15, as amended

Solid biofuels – Fuel Specifications and classes – Part 2: Graded wood pellets – standard must be purchased.

This standard is a voluntary National Standard of Canada that is produced by the CSA Group. The standard was adopted without modification from the International Organization for Standardization's Standard 17225-2:2014, first edition 2014-05-01. It is intended to be used in conjunction with CAN/CSA-ISO 17225-1:15 (as amended), Solid biofuels - Fuel specifications and classes – Part 1: General requirements (adopted from ISO 17225-1:2014).

Accessed through the CSA Group's website: http://shop.csa.ca/en/canada/fuel-burning-equipment/cancsa-iso-17225-215/invt/27038012015 (accessed November 2015).

United States Pellet Fuels Institute (PFI) Standards Program

PFI is a non-profit North American trade association that represents the densified biomass fuel industry. The PFI Standards Program is available for voluntary use in Canada. It is a third party accredited program that provides specifications for residential and commercial-grade fuel.

Documents that outline the PFI Standards Program can be accessed through the PFI website: http://www.pelletheat.org/ (accessed November 2015)

CERTIFICATION SYSTEMS

The Wood Pellet Association of Canada (WPAC) is the Canadian Licensor for the ENplus wood pellet certification system. The CANplus wood pellet trademark is owned by WPAC and was launched in 2013. The CANplus system is to certify wood pellets developed in Canada. Third party certification is recognized in Canada, the United States and Europe.

Details of each certification system are summarized in handbooks which can be accessed through WPAC's website: http://www.pellet.org (accessed November 2015).

WOOD CHIPS

STANDARDS

CAN/CSA-ISO 17225-4:15, as amended

Solid biofuels - Fuel specifications and classes - Part 4: Graded wood chips – standard must be purchased.

This standard is a voluntary National Standard of Canada that is produced by the CSA Group. It is an adoption without modification of the identically titled International Organization for Standardization's Standard 17225-4, first edition, 2014-05-01. It is intended to be used in conjunction with CAN/CSA-ISO 17225-1:15 (as amended), Solid biofuels - Fuel specifications and classes – Part 1: General requirements (adopted from ISO 17225-1:2014).

Accessed through the CSA Group's website: http://shop.csa.ca/en/canada/fuel-burning-equipment/cancsa-iso-17225-415/invt/27038032015 (accessed November 2015).

WOOD BRIQUETTES

STANDARD

CAN/CSA-ISO 17225-3:15, as amended
Solid biofuels - Fuel specifications and classes - Part 3: Graded wood briquettes – standard must be purchased.

This standard is a voluntary National Standard of Canada that is produced by the CSA Group. It is an adoption without modification of the identically titled International Organization for Standardization's Standard 17225-4, first edition, 2014-05-01. It is intended to be used in conjunction with CAN/CSA-ISO 17225-1:15 (as amended), Solid biofuels - Fuel specifications and classes – Part 1: General requirements (adopted from ISO 17225-1:2014). Requires payment.

Accessed through the CSA Group's website: http://shop.csa.ca/en/canada/fuel-burning-equipment/cancsa-iso-17225-315/invt/27038022015 (accessed November 2015).

NATURAL RESOURCES CANADA SOLID BIOFUELS BULLETINS

The NRCan bulletins for wood pellets, wood chips and wood briquettes are included in the following pages of this appendix, and all seven bulletins are available through the NRCan website:

https://www.nrcan.gc.ca/energy/renewable-electricity/bioenergy-systems/19069 (accessed October 2016)

Natural Resources Canada
Ressources naturelles Canada

Solid Biofuels Bulletin No. 4

GRADED WOOD PELLETS

This bulletin, fourth in a series of bulletins, introduces the different grades of wood pellets, their appropriate use and the important parameters that can affect the fuel characteristics. It provides information on the graded wood pellets as specified in the CAN/CSA-ISO 17225 Part 2: Graded wood pellets.

Wood pellets are a highly consistent biomass fuel allowing for easy handling and storage, as well as efficient energy conversion.

As a globally traded commodity, wood pellets are used for space heating in residential appliances, boilers, district heating plants and for electricity generation in large coal-burning power plants.

Wood pellets are small densified cylindrical granules produced by compression of sawdust. As a result, wood pellets are a consistent fuel that can easily be transported and suited to automated fuel handling systems.

Origins and Sources

Wood pellets are mainly produced from the by-products of traditional forest operations such as sawmills and finished wood products manufacturing. Harvest residues are also used as raw material though to a much lesser extent. The highest quality sources tend to come from mill and manufacturing residues with little or no bark or ash content.

The CAN/CSA-ISO 17225 Part 2 Standard[1] classifies several grades of wood pellets based on the origins and source of raw materials. Raw biomass used in the production of high grade wood pellets, Grades A1 and A2 (residential or commercial applications), primarily comes from mill residues including sawdust, shavings and cut-offs (classification 1.2.1) and stem wood (classification 1.1.3). In addition to the above sources, Grade A2 allows for the use of logging residues (classification 1.1.4) and whole trees without roots (classification 1.1.1)[2].

Sources of the raw biomass impacts fuel specifications. For example, A1 grade wood pellets contain low ash and nitrogen contents, while Grade A2 wood pellets have slightly higher ash and nitrogen content.

Grade B wood pellets are manufactured from more diverse sources, over and above those used for Grade A wood pellets, and can include bark (classification 1.1.6), residues from thinning, pruning, and arboriculture operations in city parks (classification 1.1.7), and chemically untreated used wood (classification 1.3.1).

Wood Pellets

Canada

The CAN/CSA-ISO 17225 Part 2 Standard also specifies Industrial Grade (I1, I2, I3) wood pellets based on origins, sources and properties, but these are outside the scope for this bulletin.

Both softwood and hardwood tree species can be sourced for wood pellets. It is anticipated that purposely grown woody crops such as poplar and willow grown on marginally productive land may be sourced for wood pellet production in the future. For further details on the origins and sources, refer to Natural Resources Canada Solid Biofuels Bulletin No.2 – Primer for Solid Biofuels[2].

Key Properties

The production of pellets starts with size reduction (if necessary) of the raw biomass source followed by drying. The material is then extruded under high pressure in pellet machines coming out as small cylinders typically with a 6 or 8 mm diameter, and a length of up to 40 mm. Small amounts of additives and binders can be blended with biomass material to improve the quality of wood pellets, but this is not common in Canada.

A buyer or user of graded wood pellets should consider several quality characteristics:

- **Diameter and Length (D and L) –** tested in the lab or production site. Two alternative diameters are produced: 6 mm and 8 mm (± 1 mm). The length of the individual wood pellets should be larger than 3.15 mm, and less than or equal to 40 mm ($3.15 < L \leq 40$ mm) with the maximum length not exceeding 45mm. The quantity of pellets longer than 40 mm can be 1% in weight. The quantity of pellets shorter than 10 mm (weight %) is stated by the producer.
- **Durability (DU) and Fines (F) –** determined in the lab by tumbling and screening the pellets. After tumbling, the quantity of pellets (in weight %) staying on the screening with the screen opening size greater than 3.15 mm determines the durability. The quantity of pellets passing through the screen with less than 3.15 mm opening size is defined as fines. Pellets handled in large quantities (bulk) experience some attrition, resulting in higher content of fines.
- **Bulk Density (BD) –** tested in the lab to provide guidance for sizing the storage space based on energy consumption needs. Minimum bulk density should be greater than or equal to 600 kg/m^3. The actual bulk density of the pellets is often stated by the producer on the packaging. Rough estimates of bulk density can be made by weighing a known volume. When testing density, attempts should be made to minimize the void space between pellets by shaking and tapping pellets well.
- **Calorific value (Q) and Moisture Content (M) –** measured by lab testing. All grades of wood pellets must have moisture content less than 10% and a high calorific value greater than or equal to 18.6 MJ/kg (or low heating value of greater than or equal to 16.5 MJ/kg).
- **Ash Content (A) –** tested in the lab. For residential and commercial applications, ash content is low and increases from Grade A1 to A2 to B (Table 1). For residential stoves, furnaces and boilers, it is recommended to use wood pellets with low ash content.

TABLE 1. Key specifications of graded wood pellets based on the CAN/CSA-ISO 17225 Part 2 Standard

Property Class	Unit	Grade A1*	Grade A2*	Grade B*
Diameter, D	mm	6 ± 1 or 8 ± 1	6 ± 1 or 8 ± 1	6 ± 1 or 8 ± 1
Length**, L	mm	3.15 ≤ L ≤ 40	3.15 ≤ L ≤ 40	3.15 ≤ L ≤ 40
Moisture, M	% of weight	≤ 10	≤ 10	≤ 10
Ash, A	% of weight	≤ 0.7	≤ 1.2	≤ 2.0
Durability, DU	% of weight	≥ 97.5	≥ 97.5	≥ 96.5
Fines Content, F	% of weight	≤ 1	≤ 1	≤ 1
High Calorific Value, Q	MJ/kg	≥ 18.6	≥ 18.6	≥ 18.6
Bulk Density, BD	kg/m^3	600 ≤ BD ≤ 750	600 ≤ BD ≤ 750	600 ≤ BD ≤ 750

* Suitable for residential and commercial applications.
**Maximum length of wood pellets shall be ≤ 45 mm. Amount of pellets longer than 40 mm can be 5% weight.

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Further restrictions may be stipulated by the supplier of the combustion equipment regarding ash characteristics of the pellets, such as ash melting temperature, to minimize damage to equipment.

Specifications of Properties for Graded Wood Pellets

Graded wood pellets conform to specific feedstock sources as well as the quality requirements as stipulated in the CAN/CSA-ISO 17225 Part 2 Standard. Table 1 shows various properties and specifications for Graded wood pellets as detailed in the CAN/CSA-ISO 17225 Part 2: Graded wood pellets. A family of CAN/CSA-ISO testing standards is available to confirm compliance of the wood pellets with the grade, see Bulletin No.7 – CAN/CSA-ISO Solid Biofuels Standards[2].

Certification of Wood Pellets

The European certification ENplus[3] for wood pellets was adopted in Canada in 2013 under the acronym CANplus[4]. The ENplus and CANplus seals account for the whole wood pellet supply chain, from production to delivery to the final customer, to ensure high quality. Both ENplus and CANplus schemes define wood pellet quality classes following the ISO 17225 Part 2 Standard: A1, A2 and B. Examples of the two certification system logos are shown below:

Pellet Fuel Institute (PFI) in the USA has also developed standard specifications for residential and commercial grade wood pellets[5]. The PFI wood pellet standard forms the basis of a third party accredited certification program. The certification under ENplus and CANplus are currently voluntary in Europe and Canada, while the PFI certification is mandatory in the USA.

Safe Handling and Storage of Wood Pellets

Wood pellets require closed storage, such as silos or storage tanks to keep them dry. During storage, chemical, physical and biological processes can take place including water absorption, off-gassing, oxygen depletion and self heating. Off-gassing can lead to production of toxic gases including carbon monoxide (CO) which is a poisonous, odorless, tasteless and non-irritating gas. As a result, bulk storage spaces need to be well ventilated with exhaust away from areas where people are present. As additional safety measure, CO detectors should be installed in and around the storage area. Personal protective equipment should be worn if entry into large storage areas is necessary.

Temperature measurements in large storage piles are recommended to monitor heat build up.

Dust can be generated while handling wood pellets. In large volumes dust may cause respiratory problems if inhaled, and constitutes a risk for fires and explosions. An extensive Safety Data Sheet (SDS) is available for wood pellets in bags and there is a separate SDS for wood pellets in bulk. SDS documents contain information on the potential hazards (health, fire reactivity and environmental) and how to work safely with wood pellets.

Standards and guidelines for safe handling and storage of wood pellets of all scales are currently under development by ISO/Technical Committee 238[6].

References & Links

1. CSA Group - www.csagroup.org for the CAN/CSA-ISO 17225 Solid Biofuels-Fuel specifications and classes – Part 1 General Requirements and Part 2 Graded wood pellets.
2. Natural Resources Canada – www.nrcan.gc.ca for the Solid Biofuels Bulletins Series.
3. European Pellet Council http://www.pelletcouncil.eu
4. Wood Pellet Association of Canada http://www.pellet.org
5. Pellet Fuels Institute http://www.pelletheat.org
6. ISO Technical Committee 238 Solid Biofuels http://www.iso.org/iso/iso_technical_committee%3Fcommid%3D554401

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Solid Biofuels Bulletin No. 5

GRADED **WOOD BRIQUETTES**

This bulletin, fifth in a series of bulletins, introduces different grades of wood briquettes, their appropriate use and the important parameters that can affect the fuel characteristics. The information on the graded wood briquettes is based on the CAN/CSA-ISO 17225 Part 3: Graded wood briquettes.

Wood briquettes for heat generation have been used in residential space heaters, boilers and in district heating for several decades.

Wood briquettes come in a variety of dimensions depending on the manufacturer. In general, they can be found in two sizes: larger, such as bricks or logs, and smaller, such as pucks (which fit in your hand) or cubes. As a densified fuel product, briquettes are a consistent solid biomass fuel similar to wood pellets. In comparison to wood pellets, briquettes are less dense, constituent particles are larger and typically require less drying leading to less power consumption in manufacturing and hence lower cost.

Various shapes and sizes of wood briquettes

Origins and Sources

CAN/CSA-ISO 17225 Part 3 Standard[1] classifies three grades of wood briquettes based on origins and sources: Grades A1 and A2 are intended for heating of residential and commercial buildings; Grade B briquettes are for larger-scale combustors, such as district heating and electricity production.

Raw biomass used to produce Grade A2 briquettes include sources used for Grade A1 and residues left behind from logging operations (tree tops, branches and low grade small dimension logs – classification 1.1.4) and whole trees without roots (classification 1.1.1)[2]. Raw biomass used to produce Grade A2 briquettes include sources used for Grade A1 and residues left behind from logging operations (such as tree tops and branches and low-grade small dimension logs—classification 1.1.4) and whole trees without roots (classification 1.1.1)[2]. Grade A1 briquettes contain low ash and nitrogen levels, while Grade A2 have slightly higher ash and nitrogen content.

Grade B further expands the briquette source material[2] to include residues from tree thinnings, prunings and arboriculture operations in city parks (classification 1.1.7), bark (classification 1.1.6), and chemically untreated used wood (classification 1.3.1). Grade B also includes chemically treated wood by-products (classification 1.2.2), as long as they do not contain heavy metals or halogenated organic compounds from treatment with wood

TABLE 1. Key specification of graded wood briquettes based on the CAN/CSA-ISO 17225 Part 3 Standard

Property Class	Unit	Grade A1	Grade A2	Grade B
Moisture, M	% of weight	≤ 12	≤ 15	≤ 15
High Calorific Value, Q	MJ/kg as received	≥ 17.5	≥ 17.3	≥ 16.8
Ash, A	% of weight	≤ 1.0	≤ 1.5	≤ 3.0
Particle Density, DE	g/cm^3 as received	≥ 1.0	≥ 0.9	≥ 0.9

preservatives or coatings. Sources are expected to be free of contaminants such as stones, glass, metal, sand, plastics and rubber.

Both softwood and hardwood species can be sourced for wood briquettes. It is anticipated that purposely grown woody crops, such as poplar and willow, grown on marginally productive land will be sourced for wood briquettes production in the future. For further details on the origins and sources, refer to Natural Resources Canada Solid Biofuels No.2 – Primer for Solid Biofuels[2].

Key Properties

The production of briquettes starts with size reduction of the raw feedstock and drying. Next, the material is compressed or extruded under high pressure in briquette machines before coming out in a variety of shapes and sizes as logs, bricks, cylinders, nuts or pucks. In Canada, additives and binders blended with biomass material to improve the quality of wood briquettes are not common.

Wood briquettes are distributed and transported in large plastic bags or stacked on pallets with plastic wrapping or cardboard packaging for distribution by truck or by shipping containers.

Wood briquettes, like wood pellets, are a highly consistent biomass fuel type which allows easy handling and storage, as well as efficient energy conversion.

A buyer of/user of wood briquettes should consider several quality characteristics, the most important of which are as follows (see Table 1):

- **Moisture content (M) and calorific value (Q) –** measured by lab testing.
- **Ash content (A)** – any restrictions regarding ash content and ash melting temperature as stipulated by the supplier of the combustion equipment need to be considered to minimize combustion equipment operational issues (clinker/slagging).
- **Particle density (DE) –** depending on the physical shape of the briquettes, particle density is used by some suppliers in lieu of bulk density to assist in estimating storage volume required.
- **Physical size of the briquettes –** recommended by the equipment supplier to avoid clogging the hoppers and augers that are used to feed the briquettes in automated systems.

Specifications of Properties for Graded Wood Briquettes

The term “graded” means that the feedstock as well as the quality of the briquettes have to comply with certain requirements as stipulated in the CAN/CSA-ISO 17225-3 Standard[1]. Table 1 is an excerpt from the CAN/CSA-ISO 17225 Part 3: Graded wood briquettes. It provides standards for three graded property classes: A1, A2 and B. The source materials as well as the briquettes are tested for compliance in accordance with a family of CAN/CSA-ISO testing standards, see NRCan Solid Biofuels Bulletin No.3 – CAN/CSA-ISO Solid Biofuels Standards[2].

For example, a label stating wood briquettes’ specifications of M9.0, A2.5 and Q17.0 indicates that the wood briquettes contain ≤ 9% moisture, ≤ 2.5 ash with a minimum calorific value of 17 MJ/kg. Based on these fuel property values, this wood briquettes is classified as Grade B.

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Safe Handling and Storage of Wood Briquettes

Wood briquettes need to be kept dry during storage to maintain their mechanical integrity and fuel quality.

Bulk storage spaces should be well ventilated and away from areas where people are present.

Dust can be created during handling of large volumes of briquettes, which may cause respiratory problems if inhaled, and increase risk of fires and explosions. Wood briquettes piles may self-heat, and temperature measurements in large storage spaces are therefore recommended to monitor heat build up.

A Safety Data Sheet (SDS) for wood briquettes is available with information on the potential hazards (health, fire, reactivity and environmental) and how to work safely with wood briquettes.

References & Links

1. CSA Group - www.csagroup.org for CAN/CSA-ISO 17225 Solid Biofuels-Fuel specifications and classes – Part 1: General requirements, and, – Part 3: Graded wood briquettes.

2. Natural Resources Canada – www.nrcan.gc.ca for the Solid Biofuels Bulletins Series.

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Solid Biofuels Bulletin No. 6

GRADED WOOD CHIPS

This bulletin, sixth in a series of bulletins, introduces the different grades of wood chips, their appropriate use and the important parameters that can affect the fuel characteristics. It provides information on graded wood chips as specified in the CAN/CSA-ISO 17225 Solid Biofuels—Fuel specifications and classes—Part 4 Graded Wood Chips.

Wood chips have been widely used as fuel for space heating in buildings for several decades. As a locally available fuel with minimal processing, wood chips offer a less costly fuel option compared to wood briquettes or pellets.

Wood chips are typically produced by grinding or chipping operations followed by screening and air drying of the chips. Screening is necessary to produce the desired wood chip quality (particle size, ash and fines content).

Origins and Sources

The major sources for wood chips are by-products and residues from wood processing operations in the forest sector (slabs, bark or shavings). The highest quality wood chip sources tend to be from milling and manufacturing operations. According to the CAN/CSA-ISO 17225 Part 4 Standard[1], classification is based on origins and sources and provides for four different grades of wood chips. Grade A (A1 and A2) are high quality wood chips that are sourced primarily from stem wood (classification 1.1.3) and by-products and residues from milling (classification 1.2.1) and logging operations (classification 1.1.4). A1 grade wood chips are dried and contain lower ash and no or little bark. A2 grade contains slightly higher ash and/or moisture content.

Sources for Grade B1 wood chips include materials from tree trimmings, prunings and arboriculture operations in city parks (classification 1.1.7).

In addition to the sources that are used for Grades A and B1, sources for Grade B2 wood chips include chemically treated by-products and residues from wood processing facilities (classification 1.2.2) and chemically untreated used wood (classification 1.3.1). B2 grade wood chips do not contain heavy metals or halogenated organic compounds from wood preservatives or coatings. For further details on classification by the origin and sources, refer to Natural Resources Canada Solid Biofuels Bulletin No.2 – Primer for Solid Biofuels[2].

Hog fuel – coarse and varying in size wood chips

High grade wood chips (pulp chips)

Canada

Grade A classified wood chips are suitable for smaller bioenergy systems (assuming they meet the equipment's specifications) used in schools, public and commercial buildings. Larger bioenergy systems typical of industrial operations (such as sawmills, pulp mills, commercial greenhouses and large district energy systems) are able to use the lower quality Grade B1 and B2 wood chips.

Key Properties

While a number of different parameters are important for small-scale bioenergy systems, the most critical properties to consider when buying and using wood chips are moisture content (M), particle size (P), and ash content (A) (Tables 1 and 2)[2]. Bark content, extraneous material (stones, sand, and dirt) and contamination (such as glass, metal, plastics) lead to an increase in ash content causing higher equipment maintenance costs. Particle size specifies both the acceptable size range for the diameter and length of wood chips and the minimum allowable amounts of acceptable sized material (main fraction in weight %). Each grade of wood chips also defines specific limits for the amounts of both undersize (fine fraction) and oversize materials (coarse fraction). Fines are defined as particles less than 3.15 mm (less than 1/8 inch). Increased amount of fine and/or coarse fractions can have a significant impact on the fuel handling and operation (efficiency and emissions) of the bioenergy system.

It is highly recommended that the moisture, size and ash properties be tested on a regular basis to confirm contractual requirements for wood chips quality are met. This will also ensure that the biomass fuel is appropriate for efficient and economical operation of the heat or energy system.

It is possible to determine particle size using a sieve test. A hand-held moisture meter can be used to quickly measure moisture; however, an oven-dry analysis gives more accurate measurement and is preferred.

The standard test methods for determining moisture content and particle size distribution are provided in the CAN/CSA-ISO 18134-1 or -2 and CAN/CSA-ISO 17827-1, respectively. The detailed list of testing protocols is available in Natural Resources Canada Solid Biofuels No.3 – CAN/CSA-ISO Standards for Solid Biofuels.

Table 1. Key specifications of properties for graded wood chips based on CAN/CSA-ISO 17225 Part 4

Property Class	Unit	Grade A1	Grade A2	Grade B1	Grade B2
Moisture (M)	weight %	M10 ≤10 M25 ≤25	M35 ≤35	Maximum value to be stated	Maximum value to be stated
Ash (A)	weight %, dry	A1.0 ≤1.0	A1.5 ≤1.5	A3.0 ≤3.0	A3.0 ≤3.0

Table 2. Classification of particle sizes for graded wood chips based on CAN/CSA-ISO 17225 Part 4*

Particle Size (P)	Main Fraction (min. 60 % weight)	Fine Fraction weight %, (≤ 3.15 mm)	Coarse Fraction weight % (length of particle)	Max. Length of Particle
P16S	3.15 mm to 16 mm	≤ 15 %	≤ 6 % (>31.5 mm)	≤ 45 mm
P31S	3.15 mm to 31.5 mm	≤ 10 %	≤ 6 % (> 45 mm)	≤ 150 mm
P45S	3.15 mm to 45 mm	≤ 10 %	≤ 10 % (> 63 mm)	≤ 200 mm

* Test method for determining particle size is ISO 17827-1 or -2

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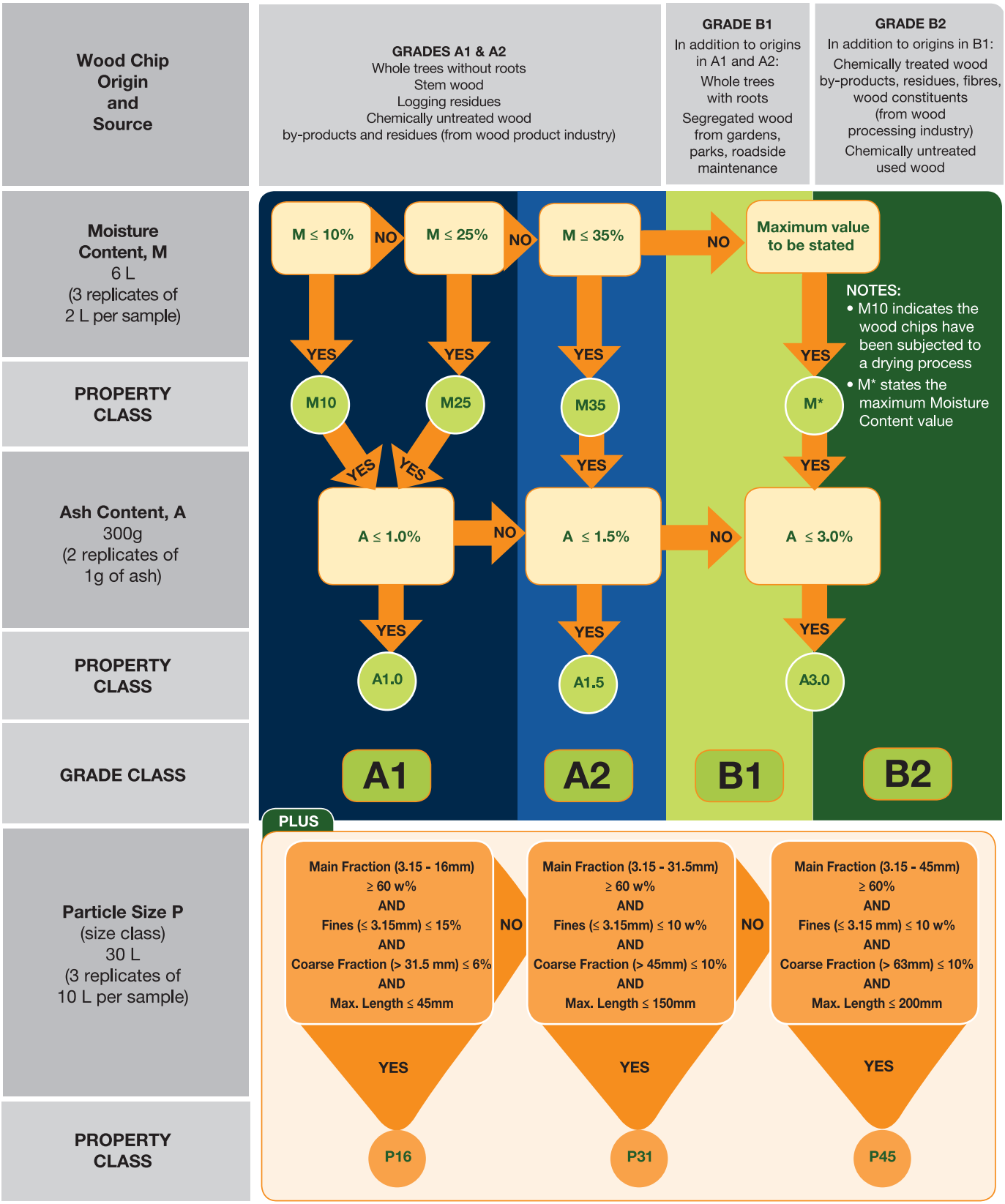

NOTES:
- This diagram highlights the most critical wood chip property classes. Other classes exists that were not included, such as: bulk density and chemical composition.
- A classification code may be generated using these classes, such as: A1-P16, B2-P31, etc.
- An appropriate wood chip sample amount should be separated from the wood chip lot (e.g., pile, chip van) for which the classification is done. The sample amount required for analysis depends on the attributes being tested, and indicated under each attribute title. For sample collection procedures, refer to ISO 17827-1 for Particle Size (P); ISO18134-1, ISO18134-2 for Moisture Content (M); and ISO 18122 for Ash Content (A).

Figure 1. Wood Chip Classification Diagram, prepared by FPInnovations based on the CAN/CSA-ISO 177225 Part 4: Graded Wood Chips.

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Figure 2. Covered storage for wood chip piles

Specifications of Properties for Graded Wood Chips

The use of common names (such as hog fuel, shavings) is neither quantitative nor sufficiently specific, and should not be used when developing biomass fuel supply agreements. CAN/CSA-ISO 17225 Part 4 provides measurable parameters for the sale of wood chips (Tables 1 and 2).[1] Current forestry by-products and residues commonly sold as wood chips may not meet grade specifications without further processing and may not be appropriate for a specific bioenergy application. Variability of wood chips should be minimized to ensure proper bioenergy system operation.

When sourcing wood chips, the nomenclature should include at minimum source class, particle size (P), moisture content (M) and ash content (A). For example, wood chips specification label would show:

Origin: Logging residues (1.1.4).

Properties: Dimensions P45S, Moisture M40, Ash A1.5.

This label states that the minimum 60% weight of the wood chips is sized between 3.15 mm and 45 mm, has moisture content of less than 40% and contains less than 1.5 % ash. Figure 1 is a schematic diagram of specifications of properties for graded wood chips.

Safe Handling and Storage of Wood Chips

Protection of the wood chips pile from rain and snow with covered storage is critical to maintain fuel quality (Figure 2).

During storage of wood chips, chemical, physical and biological processes can occur. Microbial activities might be cultivated, dry fuel mass might degrade and the pile can heat up. In the worst case this can lead to self ignition. Particle size within a pile of wood chips affects rate of moisture absorption, heat build-up and heat dissipation. Large amounts of fines in a pile causes greater amounts of water to be absorbed, leading to faster heat up and even possibly spontaneous combustion. In contrast, large wood chunks heat up more slowly due to large void volumes between particles allowing more air flow. Microbial action also takes place at lower rates. To minimize the impact of these processes on the quality of the wood chips, it is highly recommended the storage period is kept to minimum.

The Ontario Office of the Fire Marshal has a technical guideline that recommends maximum sizes for outdoor piles of wet wood chips from storm debris[4]. For wood chips to be stored for more than three months, the recommended maximum height, width, and volume are 4 meters (13 feet), 8 meters (26 feet), and 1000 cubic meters (1,300 cubic yards), respectively. For periods less than three months, the recommended maximum height is 7.5 meters (25 feet).

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Maintaining a low moisture and fines content in the wood chip pile will help minimize the risks of microbial activity, composting and self ignition. Storing low moisture pile under covered area is therefore a good practice.

To minimize the possibility of inadvertently transporting invasive species, care should also be taken when sourcing wood chips from other locations.

References & Links

1. CSA Group – www.csagroup.org for the CAN/CSA-ISO Standard 17225 Solid biofuels – Fuel specifications and classes Part 4: Graded wood chips, and, – Part 1: General requirements.
2. Natural Resources Canada – www.nrcan.gc.ca for the Solid Biofuels Bulletins Series.
3. FPInnovations, "Basic procedures for sampling and analyzing woody biomass", Advantage report Vol. 15, No.5, 2015.
4. Ontario Office of Fire Marshal Technical Guideline for wood chips storage, www.mcscs.jus.gov.on.ca/english/firemarshal/legislation/technicalguidelinesandreports/TG-1998-03.html.

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