Sustainable Communities and Waste

National Environmental Science Program

Emerging Priority-

Developing a real-world testing protocol for evaluating particulate and greenhouse gas emissions from Australian wood heaters

Authors: Fay H Johnston, John J Todd, Arjun Nair, Nicolas Borchers Arriagada, Eric Sivret and Amanda Wheeler

UNSW SYDNEY

CSIRO

MONASH University

Curtin University

UNIVERSITY of TASMANIA

Final Report: Developing a real-world testing protocol for evaluating particulate and greenhouse gas emissions from Australian wood heaters

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Acknowledgements

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Executive Summary

Wood heater smoke is one of the most important sources of air pollution in Australia and leads to several hundred avoidable deaths every year. (Borchers Arriagada et al., 2024)

Reducing this substantial burden requires a well-coordinated, funded and multifaceted approach. This includes the development of much safer, less polluting wood combustion appliances than those currently available (Pearce & Scott, 2021), enforcement of local environmental laws to protect neighbours affected by polluting emissions, and incentives, education and regulation to support behaviour change away from highly polluting heating choices and practices (Johnston et al., 2013; Kirkby & McNeill, 2020).

The development of safer and less polluting wood heaters requires an emissions testing protocol designed for evaluating the magnitude of polluting emissions that occur when appliances are used in the community. However, such a protocol does not currently exist in regulatory approaches in Australia. The testing protocol used in current Australian and New Zealand Standards (AS/NZS4012-4013), does not reflect typical wood heater operations in a household and as a result, grossly under-estimates emissions that occur when the appliances are used after sale (Johnston et al., 2023). Lowering of existing wood heater emission limits over many years, within the AS/NZS4012-4013 protocol, has not led to any documented reductions in community air pollution from wood heaters nor improvements in community health.

Countries in regions with similar air quality problems from wood heaters, such as New Zealand, North America, and Europe face similar problems with wood heaters and are moving towards real-world testing protocols (Marin et al., 2022; Marius et al., 2017; Schön et al.). Standards based on real world testing have been shown to result in rapid technological advancements with much cleaner, ultra-low emissions appliances. (Pearce & Scott, 2020, 2021). However, Australia cannot simply adopt these approaches. We need to develop our own testing methods due to our different dominant fuels (Eucalypt hardwoods) which burn differently to softwoods such as pine, which are largely used in NZ, North America and Europe.

Here we report on work undertaken by the University of Tasmania using their purpose-built facility in FireLab[3] for undertaking emissions and efficiency testing of wood heaters. The team have developed the Tasmania Protocol, a reproducible protocol for burning hardwoods in a wide range of heating appliances in a way that much more closely aligns with burning practices common in the community than the AS/NZS4012-4013 (Appendix 1).

Implementation of the new protocol, with appropriate independent governance and auditing and enforcement, will provide an opportunity for innovation and reform in wood heater design for vastly improved air quality and community health, enabling Australians to benefit from existing and new low emissions technologies. It will also enable more realistic characterisation of the magnitude of climate forcing emissions from wood heaters used in the community. In addition to specifying a new testing protocol, several specific recommendations are made for ongoing research, governance and enforcement of wood heater testing standards and protocols. Implementation of these procedures and protocols will enable considerably improved, and long overdue, community health protection from the harmful impacts of wood heater pollution in Australia.

Recommendations

1. The Tasmania Protocol be immediately evaluated by relevant authorities for implementation for the evaluation of emissions from all new wood heaters in Australia.

2. The primary emission metric for regulation should be $PM_{2.5}$ measured as g/kg of wood burnt.

3. A process for setting emission limits be established that is independent of the testing protocol and led by organisations with expertise in air quality and health. We recommend an initial target of 0.5 g/kg of fuel burnt.

4. In addition to setting emission limits for the average value of all complete tests, additional caps for the specific operating conditions like a slow burn rate with partially seasoned firewood should be considered. Implementation of caps for other common polluting practices should be considered.

5. The written design specification of each heater tested be verified by the testing laboratory as accurate for the model being tested. It should be lodged with an appropriate, and appropriately funded, national government agency or authority that is independent of the industry, to enable subsequent auditing of heaters.

6. An appropriate Australian government authority be funded and mandated to implement regular audits of:
   a. Testing results for individual appliances to ensure that testing protocols are being applied consistently.
   b. Design and configuration of appliances at the point of sale to ensure these have the same specifications as those documented at the time of testing.

7. Prioritise research to evaluate the climate forcing attributable to emissions from Australian wood based on real world testing or laboratory testing using the Tasmania Protocol to better characterise the role of the climate impacts of residential wood combustion in Australia.

8. Prioritise research to characterise emissions and community health impacts of nitrogen dioxide and other oxides of nitrogen from wood heaters and consider introducing standards for this pollutant.
9. Prioritise research and development of a standard for minimal indoor spillage of smoke for appliances sold in Australia.
10. Support ongoing research to refine and improve the Tasmania Protocol, for example, investigation of the influence of different hardwood densities on emissions.

Introduction

The national problem of woodsmoke

Impacts on community health

Wood heaters significantly contribute to air pollution in urban, regional, and rural communities across Australia, New Zealand (NZ) and many other parts of the world (Bailey et al. 2019; Chafe et al. 2015). Exposure to smoke from wood heaters increases the risk of developing many serious health problems including lung diseases (Dai et al., 2021), heart diseases (Huynh et al., 2018), pregnancy complications (Assibey-Mensah et al., 2019), and deaths (Johnston et al., 2013). As a result, wood heater emissions are responsible for a substantial community health and economic burden (Borchers Arriagada et al., 2020). In Australia the annual death toll from wood heater smoke is currently estimated to be more than 700 per year, with an associated economic impact in excess of $3.6 billion per year, making this one of the most important sources of air pollution-related deaths in the country (Borchers Arriagada et al., 2024). For example, in Sydney only 4-8% households heat with wood (Romanach & Frederiks, 2021), yet wood smoke is the largest single source of fine particulate air pollution ($PM_{2.5}$) and is associated with more premature deaths each year than the corresponding estimates for emissions from power stations or motor vehicles (Broome et al., 2020; Environment and Heritage, 2023).

Impacts on climate

Wood heater emissions contribute to climate change through emissions of particles and gases, especially carbon dioxide (CO_2), carbon monoxide (CO) and methane (CH_4) (Savolahti et al., 2019). For example, each tonne of firewood burnt in existing Australian heaters produces on average, 7.9kg of particles, 11.9kg of methane, and 141kg of carbon monoxide (Todd, 2023). Cleaner heaters, developed from meeting strict emission standards when measured using real-world testing protocols, could potentially reduce climate forcing emissions from this source (Todd, 2023).

The challenges of creating standards for wood heaters

Despite increasingly stringent emission limits for wood heaters in Australia, there has been frustratingly little progress in reducing ambient air pollution from this source. This is because testing protocols designed for evaluating the performance of an appliance in a reproducible way in laboratory settings do not provide robust information about the amount of pollution the appliance will add to the atmosphere when used in homes in the community. For example, the existing standards for wood heater testing in Australia and New Zealand, the AS/NZS4012-4013, excludes the most polluting stage of a burn cycle, i.e. the start-up, because emissions during this stage are highly operator dependent, and do not include common operating practices that increase pollution (Pearce and Scott 2021). For example, householders are advised to leave the air control fully open for 15 to 20 minutes after refuelling because it leads to much less smoke, but the available evidence suggests that this is unlikely to happen consistently in practice. Indeed, a national study found that in almost one in every five times a heater is refuelled the combustion air is *immediately* set to minimum. (Todd 2008).

Potential solutions – standards based on realistic testing protocols

The New Zealand province of Canterbury made progress in overcoming these limitations through the development of a simulated real life testing protocol known as Canterbury Method One (CM1) (Pearce and Scott 2021). Incorporation of CM1 into regulatory requirements in the Canterbury region led to rapid innovation in the design of wood heaters that can reliably produce low emissions (e.g. less than 1 g/kg) when operated under realistic household conditions (Pearce and Scott 2021), known as ultra-low emission burners (ULEBs).

In New Zealand, where the CM1 was developed, softwoods like pine are the main fuels used for home heating. However, in Australia hardwood fuels, mostly eucalypts, are more typically used. The differences in density, flammability and charcoal structure between hardwoods and softwoods, and the resulting differences in patterns of homeowner operation mean different testing protocols are required. Appliances and protocols designed for one type of fuel will not necessarily be optimal for the other. Our previous feasibility study demonstrated that:

- It is possible to adapt the pioneering approach of the CM1 to Australian hardwoods; and
- Hardwood fuelled Ultra-low Emission Burners (ULEBs) as defined by the NZ CM1 testing protocol could produce substantially lower pollution emissions (by almost 90%) than existing hardwood burners used in Australia (Johnston et al 2023).

Project aim

To develop a real-world testing protocol for evaluating particulate and greenhouse gas emissions from Australian wood heaters that is fit for purpose and ready for review with a view to adoption by Standards Australia.

Methods

We used the purpose-built emissions testing laboratory at the University of Tasmania, FireLab[3] which is configured in a manner consistent with the requirements of the existing AS/NZS4012-4013 standard.

The approach was designed to be practical, requiring (1) the same laboratory configuration as needed for the existing AS/NZS4012-4013 standard; (2) similar testing time to the AS/NZS4012-4013 of approximately one week per heater; and (3) generation of reproducible results when testing according to the protocol, similar to or better than the uncertainty in the current AS/NZS4012-4013 .

The methodological steps were as follows:

1. A review of national and regional surveys of wood heater operation in Australia was conducted. Real world operation was primarily informed by National Wood Heater Operation and Firewood Parameters Study (Todd, 2008) also smaller recent surveys (Nwachukwu, 2025), of how wood heaters are used. Specifically:
    - The configuration of fuel when lighting a fire (newspaper vs firelighters, kindling materials, inclusion of larger logs or not).
    - The timing of refuelling
    - The number and weight of logs inserted when refuelling
    - The time from refuelling to closing the air intake
2. Adaptation of the draft hardwood protocol from our pilot studies based on previous results (Johnston et al., 2023). We focussed on evaluating the feasibility of using different fuel configurations and operational practices during testing.
3. Implementation of multiple testing cycles on heaters with a wide range of sizes, shapes and designs to ensure the Protocol is reproducible for implementation on diverse heaters.
4. Presentation of the draft protocol and rationale to stakeholders including representatives from Standards Australia, the wood heater industry, environment and health agencies, and consumer representatives for feedback to incorporate final refinements.

Results and discussion

Based on more than one hundred testing cycles on seven different wood heaters we developed the **Tasmania Protocol** (hereafter called the Protocol). To the best of our knowledge, this is the first documented testing approach for defining a hardwood ULEB. The Protocol is specified in detail in Appendix 1.

Testing was conducted at University of Tasmania's FireLab[3] on four existing New Zealand ULEBs, (Pyrofires Pyroclassic, Woodsman Serene, Blaze King Sirocco20, and Tropicair Rua), and three common Australian heaters: an older Jindara Hammersley, representative of the current stock of heaters in the community, the Nectre N15, a popular current Australian model, and a Yunca Monty, a newer model currently being marketed in Australia as a ULEB.

Similar to the CM1, we developed protocols for three stages of testing. The start-up phase, a high burn rate phase, and a low burn rate phase. Each testing cycle requires four replicates with minor variations to encompass user practices including start up with different fuel configurations, and one burn cycle using unseasoned wood. (Appendix 1).

We have chosen common 'moderately poor' operating practices as distinct from less common 'extremely poor' practices (such as the burning of waste and very wet fuels) to incorporate into the Protocol. The value of including extremely poor operating practices into the Protocol would be a useful focus for future research in this area.

The Protocol does not specify a numerical pass/fail value for emissions because it is appropriate that this be set by government agencies responsible for maintaining healthy air quality independently from the testing protocol itself. However, we note that many wood heaters that are rated as ultra-low emission burners in New Zealand have emissions of less than 0.5g/kg and believe this would be a reasonable target for hardwood ULEBs. As wood heaters put out a large amount of heat, thermal efficiency is much less of a concern than pollution emissions, and we have recommended that a limit based on pollution measured as g/kg is a more appropriate metric to regulate than one that also includes efficiency such as mg/MJ.

Key elements of the Protocol

The Protocol has six sections. Section 1 covers the scope of the test method, Section 2 defines the test facilities, Section 3 describes firewood specifications, Section 4 deals with various combustion-air controls on the appliance, Section 5 specifies wood heater operation during testing and Section 6 deals with test laboratory reporting requirements.

The research we conducted mainly informed Section 3 (Firewood specifications) and Section 5 (Wood heater operation during testing) and a summary of key outcomes from those areas is provided in the following sections.

Test fuel parameters (Section 3)

<u>Source of fuel</u>

The testing laboratory must use commercially available firewood as this best represents what consumers use after sale. Logs with bark attached and/or knots are included, while logs with decay are excluded. This is replicate the type of firewood used in the community.

Density

The Protocol specifies a density range of 500 to 800 kg/m^3 (oven dry wood) to reflect the available range across Australia (Clause 3.1). Ideally this should have further research and refinement as density is likely to have a significant impact on emissions. However, further testing across a range of eucalypt densities to determine the influence on emissions was beyond the scope of the current project.

Log length

The length of each piece is specified to be 300±20mm which covers 50% of logs sampled across four Australian States and the ACT (Todd, 2008). However, provision is made for combustion chambers that are too small to accommodate this length (Clause 3.2). While the AS/NZS4012-4013 uses different length logs for each heater model depending on the dimensions of the combustion chamber base, the national survey showed little correlation between heater dimensions and firewood log lengths. A standard length that can be scaled to smaller heaters if needed simplifies the protocol.

Moisture content

The Protocol specifies a moisture content for ‘seasoned’ logs in the range of 12% to 20% on a wet-weight basis (Clause 3.3). This is wider than the range allowed in AS/NZS4012-4013 (12% to 16%) to reflect common patterns of moisture in seasoned wood used in the community. The Protocol also includes the method used to determine the moisture content by random selection of 10 logs per tonne of firewood and oven drying the selected logs to constant weight. Furthermore, one test cycle includes ‘partially seasoned’ firewood with moisture in the range of 30% to 40% (wet weight) to be used in the slow burn stage, the stage most likely to be adversely impacted by burning partially seasoned firewood.

Operation during testing (Section 5)

The draft protocol requires four days of testing, with each day including three stages. This requires similar testing time to AS/NZS4012-4013, which involves a total of nine separate tests, three each at high burn rate, minimum burn rate, and a medium burn rate that usually takes 3 or 4 days to implement.

Emissions from each stage are measured (i.e. filters are changed for each stage). Each set of three stages involves changes to the firewood added and/or changes to the way the heater is operated. This provides an indication of how the heater model being tested will perform across a range of firewood and operation parameters. While the overall average is suggested to be used to determine if it achieves an acceptable emission performance, consideration should be given to introducing an additional cap for certain operating conditions. As an example, while the average value might be acceptable, if the slow burn with partially seasoned firewood exceeds the associated cap, the heater would not meet the Protocol standard.

Start-up stage

The Protocol requires three variations to the lighting stage: (a) firelighters igniting kindling with slightly larger logs added in two steps; (b) newspaper igniting kindling with slightly larger logs added in two steps; (c) firelighters igniting kindling plus small logs without any more logs then added (Clause 5.2). The reason for this approach is that firelighters are commonly used for fire lighting because many households no longer receive daily newspapers. However, some households do still use newspapers, and our tests have shown that this may lead to significantly higher emissions. Some households build the fire by adding small loads until the fire is well alight, others put a mix of logs and kindling in at the start which creates a good fire for adding larger logs later (Nwachukwu, 2025). All these approaches are included over the four testing cycles.

High burn rate stage

The combustion air control is left fully open, either one or two seasoned firewood logs of specified weights are added, the door is immediately closed and latched (Clause 5.3). In almost all cases this type of operation has very low emissions. It is included because it represents a typical real-world operation, i.e. getting the living space warmed up as quickly as possible. The end of the stage is determined by the weight of fuel remaining in the combustion chamber. By the end of this stage the heat output has passed its peak and heat output is falling, but there is still some flame and a good charcoal bed for the next addition of firewood.

Slow burn rate stage

This is a critical part of the test and one of the most important differences with the AS/NZS4012-4013 test method. Wood heater operation has a very high influence on emissions in this stage. The AS/NZS4012-4013 requires the combustion air control to be left fully open until mass of fuel has dropped by 20%. This period of maximum combustion air for 10 to 20 minutes (depending on the heater model) allows the new fuel load to get well alight, and increases the combustion chamber temperature, resulting in much lower emissions. However, despite many community education programmes urging 'correct' heater use, approximately half of all fuel loadings in people's homes at medium or low burn rates are not done like this (Todd, 2008). To better reflect community practices in the Protocol, the air control is set to minimum as soon as the fuel load for a slow burn rate is added (Clause 5.4). The testing carried out so far in FireLab[3], using commercial eucalypt firewood, clearly showed that the New Zealand ULEB approved wood heaters can achieve low emissions when the air control is immediately set to minimum during the slow burn-rate tests. This demonstrates that it is possible, through more robust wood heater design, to inherently mitigate increases in pollution emissions due to operator behaviour instead of depending on operators to consistently change their behaviour to manage the device in a manner that reduces emissions.

The slow burn-rate stage in the Protocol includes two further design challenges. One is to delay the fuel loading until the fire in the high burn rate stage has burnt slightly longer. This means the combustion chamber has cooled a little before the slow burn test begins. This variation is used in one of the four full tests. The second is the use of partially seasoned firewood in another one of the four tests, similar to the CM1. Most households burn firewood that is well seasoned (say less than 20% moisture (wet weight). Available information on firewood moisture suggests around 5 to 10% of household firewood moisture is above $30\%_{ww}$ (Todd, 2008). While it is a relatively uncommon practice, the combustion of wetter wood has an extremely large influence on emissions (Fachinger et al., 2017). While most people are likely to be aware that wetter wood does not burn so well, they are often unable to easily determine the water content of purchased firewood.

Management of remaining charcoal

Any charcoal remaining at the end of a full test is to be removed and weighed. Using a common energy content for dry charcoal of 31MJ/kg (common range is 30 to 33MJ/kg), the energy in the residual charcoal is calculated and subtracted from the energy input from the mass of firewood added during the full test (Clause 5.5). This energy correction is small, often negligible, but it is simple to do and enables more accurate calculation of the wood heater's efficiency. While we did not find any charred logs remaining at the end of any ULEB-design heater tests, further research could be needed for ways to estimate the energy content of charred logs if this is a common outcome in testing Australian heaters.

Calculating thermal efficiency

Calculation of the efficiency of the heater is done over a full test (i.e. stages 1,2 and 3). The total measure heat output into the calorimeter room (including an estimate of the 'tail' at the end of the slow burn) is divided by the total calculated energy input in the firewood minus the small charcoal correction (Clause 5.6). In a person's home the heater may operate for long periods of maximum burn rate, in which case the efficiency would probably be a bit lower as there is more heat lost up the flue. Alternatively, if the heater is run for long periods on medium or slow burn rates the efficiency would probably be a bit higher. However, introducing testing for such variations would introduce complexity, time and expense for the marginal benefit of having a range of efficiencies quoted for every heater.

Calculating emissions

The Protocol requires calculation and documentation of: (1) the emission rate for all stages (expressed as g of particles per hour, g/h), and (2) the overall emission expressed as both the g/kg (the average of g of particles emitted across the 3 stages divided by the calculated oven-dry mass of firewood loaded into the heater over the full test), and the g/MJ (grams of particles emitted divided by the calculated total heat output). The latter is a measure of emissions per unit of heat delivered into a household (Clause 5.7).

Reporting

The Protocol includes a list of information that the manufacturer/importer must supply to the testing laboratory (Clause 6.1) and a list of the information that the testing laboratory must send to the authority that certifies the wood heaters meet the requirements of the relevant legislation (Clause 6.2). These may need refinement once the procedures for certifying ULEB wood heaters in Australia established.

Other areas for research

While beyond the scope of this project we identified three areas requiring urgent research for understanding and improving the safety of wood heaters.

Smoke spillage requires a standard

An important determinant of the safety of wood burning appliances is the amount of smoke that spills indoors during lighting and reloading. This could be an important factor contributing to the higher rates of some cancers observed in people who regularly operate wood heaters (Mehta et al., 2023; White & Sandler, 2017). Pulling the door open very quickly is likely to drag some smoke out with it. But if the door is opened slowly, as most wood heater instructions suggest, it will only allow smoke-spillage in badly designed wood heaters. How does one define a slow door opening? Currently there are no standards for evaluating woodsmoke spillage in Australian heaters. This requires further research to identify a reproducible and meaningful test method.

The community health impacts of gaseous emissions

The current emissions testing is restricted to particulate matter only. It is well recognised that wood smoke contains many toxic gases important for community health and wellbeing. Although beyond the scope of the current project, further research is needed to characterise the community air quality impacts of emissions of toxic gases especially oxides of nitrogen, given the large health impacts in the community (Boningari & Smirniotis, 2016).

The climate impacts from wood heater emissions

The escalating climate crisis is having multiple impacts on human health and wellbeing globally. Although beyond the scope of this project research is urgently needed to characterise the climate impacts of wood heater use in Australia, taking into account the source of firewood (sustainable or not), particles, carbon dioxide and other greenhouse gases such as methane. Preliminary data suggest that when taking short lived climate forcing agents into account the carbon dioxide equivalents of firewood emissions are almost double that of the carbon dioxide alone (Savolahti et al., 2019; Todd, 2023).

Governance and transparency

A rigorous testing protocol alone is not sufficient to ensure that safer products are designed and made available to the Australian public. Appliance testing also requires processes for independent monitoring and verification of performance, documentation of design specifications, and enforcement to ensure the safety of the Australian community. We have made recommendations for establishing systems for these wider functions, which are not presently occurring in Australia.

Conclusions and recommendations

Our results confirmed that a heater testing protocol to define hardwood burning ultra-low emission wood heaters is practical and feasible for Australia using existing laboratory facilities. We make the following recommendations for the next steps towards implementing the protocol to reduce the current high burden of illness and death from wood heater generated air pollution in Australia.

1. The Tasmania Protocol be immediately evaluated by relevant authorities for implementation for the evaluation of emissions from all new wood heaters in Australia.
2. The primary emission metric for regulation should be $PM_{2.5}$ measured as g/kg of wood burnt.
3. A process for setting emission limits be established that is independent of the testing protocol and led by organisations with expertise in air quality and health. We recommend an initial target of 0.5 g/kg of fuel burnt.
4. In addition to setting emissions limits for the average value of all complete tests, an additional cap for the specific operating conditions of a slow burn rate with partially seasoned firewood should be considered. Implementation of caps for other common polluting practices should be considered.
5. The written design specification of each heater tested be verified by the testing laboratory as accurate for the model being tested. It should be lodged with an

appropriate, and appropriately funded national government agency or authority that is independent of the industry, to enable subsequent auditing of heaters.

6. An appropriate Australian government authority be funded and mandated to implement regular audits of:
    a. Testing results for individual appliances to ensure that testing protocols are being applied consistently.
    b. Design and configuration of appliances at the point of sale to ensure these have the same specifications as those documented at the time of testing.

7. Prioritise research to evaluate the climate forcing attributable to emissions from Australian wood based on real world testing or laboratory testing using the Tasmania Protocol to better characterise the role of the climate impacts of residential wood combustion in Australia.

8. Prioritise research to characterise emissions and community health impacts of nitrogen dioxide and other oxides of nitrogen from wood heaters and consider introducing standards for this pollutant.

9. Prioritise research and development of a standard for minimal indoor spillage of smoke for appliances sold in Australia.

10. Support for ongoing research to refine and improve the Protocol such as investigation of the influence of different hardwood densities on emissions.

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Appendix 1.

The Tasmania Protocol

Test method for defining ultra-low emission wood heaters for hardwoods

[Version 1.1 November 2025]

FIRELAB[3]
Bushfires, Bioenergy, Emissions

UNIVERSITY of TASMANIA | MENZIES

History	Date	Changes
Version 1.0	August 2025	Original protocol
Version 1.1	November 2025	Minor updates - Correction of minor typographical errors, additional explanatory text Table1, clarification clause 5.4

1 Introduction

1.1 Intent

This test method is for performance and emissions from wood heaters burning commercial eucalypt firewood. The operation of the wood heater during testing includes a lighting stage, a high burn rate stage and a slow burn rate stage. This provides performance and emission measurements that better reflect real-world emissions from wood heaters than AS/NZS4012/4013.

1.2 Scope

The test method applies to residential wood burning heaters, fuelled manually. This includes free-standing wood heaters and wood heaters installed in masonry fireplaces or other enclosures.

It does not apply to:

- wood-pellet burning heaters,
- cooking stoves with hotplate(s) plus oven(s) which have a volume not less than 28L,
- central heaters, where heat is transferred to the living area by means of ducted hot air, or hot water,
- site built masonry space heaters,
- appliances intended solely for water heating,
- appliances that, when fired at the high burn rate [see Clause 5.3] prescribed in this test method, have a maximum carbon dioxide output from the combustion chamber of less than 5% by volume with any optional doors fitted and closed.

1.3 Limitation

This Protocol only tests performance and emissions. All safety issues including minimum clearances, flue materials and flue installation clearances, minimum flue height, and constraints on flue discharge location must comply with AS/NZS 2918:2018, or a more recent issue of this Standard

2 Test Facilities

2.1 Performance Testing Facility

The performance testing facility shall comply with Section 3 (Test Enclosure and Flue) of AS/NZS 4012:2014, or a more recent issue of this Standard.

2.2 Emission Testing Facility

The emission testing facility shall comply with Section 3 (Configuration of Test Equipment) of AS/NZS 4013:2014, or a more recent issue of this Standard.

3 Firewood Specifications

3.1 Commercial Firewood

Firewood must be sourced from a commercial firewood supplier. Tests may be carried out with any eucalyptus firewood species provided the oven-dry density is within the range 500 to 800 kg/m^3.

The logs used for wood heater testing may include bark and knots, but logs with visible decay or mould should not be used.

3.2 Firewood length

All firewood logs shall have a length of 300±20mm. The only exception is for heaters where the dimensions of the base of the combustion chamber are too small to accommodate this length. In this case the logs shall be 20mm shorter than the longest dimension of the combustion chamber measured horizontally perpendicular or parallel to the plane of the fuel loading door.

3.3 Firewood moisture

3.2.1 Seasoned Firewood

Seasoned firewood shall be in the moisture range 12 to 20%ww based on 10 randomly selected logs, per tonne of firewood, collected when the commercial firewood is delivered. (See Note A at the end of this document for more detail). Six samples selected for density determination may be included in the 20 sampled for moisture measurements. The 20 samples shall be oven dried to constant weight in a ventilated oven at 100 to 105°C. Moisture shall be determined on a wet-weight basis using the formula:

Moisture %ww = (seasoned wood weight – oven-dry wood weight)/seasoned wood weight x 100

All 20 samples must lie in the specified moisture range.

On the same date as samples are collected for moisture determination, an additional 10 randomly selected logs shall be weighed and labelled and retained in the stacked store of seasoned firewood. These 10 logs shall be periodically reweighed (but not oven-dried), and the date and percent weight loss recorded. The average weight loss of these 10 labelled logs shall be used to recalculate the average moisture content of logs at the date of sampling.

3.2.2 Partially Seasoned Firewood

As for 3.2.1 except range is 30 to 40%ww

Note: partially seasoned firewood will dry significantly within a month or two if left in ambient air. Once the moisture range of a load of partially seasoned wood has been measured, each log should be labelled and weighed. Then the logs should be placed in air-tight containers or bags. Before using, the log should be weighed to see if it has lost any moisture. If it is still within the allowable range, it can still be used.

4 Wood Heater Operating Procedures

4.1 Wood Heater Conditioning

Before commencing performance and emission testing the wood heater shall be conditioned by operating it at high heat output, with combustion air fully open and firewood added every hour, for two six-hour periods.

4.2 Maximum Heat Output Setting

As part of the wood heater conditioning, or in a separate preliminary test, the heat output of the wood heater shall be measured under high burn rate settings. If the heat output exceeds the maximum calibrated range of the calorimeter room, an appropriate mark on the combustion air control shall be made which corresponds to the heat output to that of the maximum calibrated value ±1kW. This setting shall be used for all Stage 2 testing where 'maximum' combustion air settings are required.

Stage 1, start-up, testing shall be done with the wood heaters actual maximum air setting.

4.2 Automatic Controls

If a wood heater has automatic controls, these shall be allowed to operate normally during the tests. If automatic controls require periodic battery replacement, or require mains electricity, the control must default to maximise combustion air in the event that there is no power.

4.3 Multiple Controls

If a wood heater more than one control for the primary combustion air, the controls shall be operated in accordance with the manufacturers' instructions. The manufacturers' instructions for controls should be classified by the testing laboratory as being one of (1) clear and simple, (2) complex but clearly explained (3) complex but not clearly explained. This opinion shall be included in the final report to the certifying authority.

If the wood heater only has one control that is used when lighting the heater the manufacturers' instructions shall be followed. Leaving the fuel loading door open after lighting and/or refuelling the fire is not considered a control, and the Protocol should be followed in favour of any such instruction.

4.4 No Adjustable Controls

If the wood heater has no adjustable controls then all tests shall be carried out with the single, fixed setting.

4.5 Convection Fan

If a wood heater is fitted with a convection fan, the fan shall be run on its high setting throughout the full test. Any automatic controls on the fan shall be allowed to operate normally.

5 Wood Heater Operation During Testing

Emission and performance testing involves a continuous sequence of three stages: a start-up stage where the wood heater is lit at room temperature and heats up to the point where larger logs are added; a high burn rate stage where the combustion air control is left fully open; and a slow burn stage where the combustion air control is set to minimum. A new pair of particulate filters is used for each stage. The pair of filters capturing the smoke particles are swapped for a clean pair just before the next stage commences. The new filters will capture any smoke resulting from the refuelling-door opening and loading the next fuel load.

Four tests, each with three stages, are required for certification testing. As detailed below, some light-up stages are carried out using firelighters and some using newspaper; one slow burn stage uses partially seasoned firewood; and one slow burn stage involves refuelling with a smaller remaining fuel load in the combustion chamber.

5.1 Lighting, firewood moisture, and scales reading for refuelling for each test

The four tests below are labelled A, B, C and D but they may be carried out in any order. The variations from one test to the next are shown in Table 1.

Table 1. Configuration and testing requirements for each of the four test cycles
(see clause 5.2 for lighting methods 1 and 2)

Test	Lighting Stage	High Burn Rate Stage	Slow Burn-Rate Stage
A	Firelighters (fuel loading method 1)	Seasoned firewood 1 log	Refuelled at* 1kg, seasoned firewood
B	Newspaper (fuel loading method 1)	Seasoned firewood 2 logs	Refuelled at 1kg, seasoned firewood
C	Firelighters (fuel loading method 1)	Seasoned firewood 1 log	Refuelled at 0.7kg, seasoned firewood
D	Firelighters (fuel loading method 2)	Seasoned firewood 1 log	Refuelled at 1kg, partially seasoned firewood

- “Refuelled at’ refers to the mass of wood/charcoal remaining in the firebox as measured by the scales under the wood heater.

5.2 Start-up Stage

(1) Lighting: Fuel Loading Method 1

The wood heater, installed in the calorimeter room, shall be at ambient temperature (5°C to 20°C), ash shall be removed, the scales recording the wood heater mass shall be zeroed, the firelighters (2 each weighing 5±1g), or newspaper (5 sheets) (see Table 1), shall be placed in the combustion chamber and 15 pieces of split seasoned eucalypt kindling weighing a total of 1kg ± 0.02kg shall be placed in a criss-cross manner above the firelighters/newspaper.

The combustion air control shall be fully open throughout the start-up stage. With the smoke capture hood in place, dilution tunnel operating, filters in place and the sample train operating, light the fire using a match or cigarette lighter. Immediately close and latch the fuel loading door.

Eight minutes after lighting the fire add 3 small split seasoned firewood logs with a total weight of 1kg ± 0.04kg. Place the small logs on top of the burning kindling so that they do not roll towards the fuel loading door where they might block incoming combustion air. Close and latch the fuel loading door.

When the scales indicate 0.70kg add 2 small, seasoned firewood logs each weighing 1.0kg ± 0.05kg. The logs should be placed on top of the burning fuel load in such a way that they do not roll forward and block the incoming combustion air. Close and latch the fuel loading door.

(2) Lighting: Fuel Loading Method 2

The wood heater, installed in the calorimeter room, shall be at ambient temperature (5°C to 20°C), ash shall be removed, the scales recording the remaining fuel load shall be zeroed, the firelighters (2 each weighing 5±1g), shall be placed in the combustion chamber.

Two logs, each weighing 1.0kg± 0.05kg shall be placed in the combustion chamber, perpendicular to the fuel loading door, and positioned centrally with a 150mm gap between the logs, or so the two logs are touching the sides of the combustion chamber if the combustion chamber is too narrow to achieve a 150mm gap. 15 pieces of split seasoned eucalypt kindling weighing a total of 1kg ± 0.02kg shall be placed in a criss-cross manner above the firelighters. Three small split seasoned firewood logs with a total weight of 1kg ± 0.04kg shall be placed on top of the kindling.

The combustion air control shall be fully open throughout the start-up stage. With the smoke capture hood in place, dilution tunnel operating, filters in place and the sample train operating, light the fire using a match or cigarette lighter. Immediately close and latch the fuel loading door.

5.3 High Burn Rate Stage

When the scales indicate 1.1kg, stop the filter train, replace the 2 filters with 2 clean filters and restart the filter train sampling. When the scales indicate 1.0kg, add one large, seasoned firewood log weighing 3kg ±0.2kg, or 2 seasoned firewood logs each weighing 1.5kg ±0.1kg (see Table 1). Close and latch the fuel loading door. The combustion air control remains fully open.

If the maximum heat output rate exceeds the calibrated range of the calorimeter room the maximum combustion air setting shall be reduced, for high burn rate tests only, to a setting that restricts the maximum heat output to within 10% of the maximum of the calibrated rage.

5.4 Slow Burn Stage

When the scales indicate 1.1kg, stop the filter train, replace the 2 filters with 2 clean filters and restart the filter train sampling.

When the scales indicate 1.0kg or 0.7kg (see Table 1), add one large seasoned or partially seasoned log weighing 3kg ±0.2kg (see Table 1), and immediately close and latch the fuel loading door and set the combustion air control to its minimum air setting.

When the measurement of heat output drops below 1kW, stop the sample train and remove filters for drying. The measurement of heat output may continue until the heat output drops to zero.

If all visible flame disappears within 30 minutes of refuelling in Stage 3, the test shall continue for a further 120 minutes. During this period, if the heat output drops below 1kW without flame reappearing, the test may be terminated, and the wood heater is considered to have failed the certification process. If flames become visible within this 120 minute period the test continues uninterrupted.

5.5 Charcoal

Lumps of charcoal remaining after the wood heater has cooled to ambient temperature shall be removed before starting the next test. The charcoal shall be weighed immediately and the mass recorded. The energy content of the charcoal shall be calculated using the formula:

Energy content of charcoal (kJ) = mass of charcoal (g) x 30 (kJ)

The energy content of the charcoal (i.e. the charcoal residue of the just completed test) shall be subtracted from the energy content of the firewood burnt in that test (see clause 5.6).

If the residue includes any partially carbonised firewood, samples shall be tested for their calorific values in order to determine the total energy content of the residue.

5.6 Calculation of Wood Heater Efficiency

The heater efficiency is calculated by dividing the total heat output (MJ) over the three Stages (measured, plus an extrapolation if required) divided by the energy (MJ) in the total fuel load (over all three Stages) minus the energy content of any residual charcoal when the test is complete. The efficiency shall be expressed as a percentage (calculated total energy into the calorimeter room divided by the total fuel energy input x 100). The overall efficiency is the average of the 4 efficiency measurements obtained in the testing.

5.7 Calculation of Emissions

The following calculations shall be carried out on completion of each wood heater test:

- The emission rate (mg/h) for Stage 1 and Stage 2 shall be calculated for each test and an overall average calculated for Stages 1 and 2 on completion of the four tests (A, B, C, and D).
- The emission factor (g/kg) shall be calculated for each test (sum of emissions for Stages 1, 2 and 3 divided by the oven dry weight of all firewood burnt during the test). The weight of charcoal remaining at the end of the test shall not be subtracted from this weight. The overall emission factor is the average of the four emission factors calculated (tests A, B, C and D).
- The emission factor expressed as mg/MJ shall be calculated for each test (sum of emissions for Stages 1, 2 and 3 divided by the energy in all the firewood burnt in the test minus the energy in any residual charcoal expressed in MJ), and the overall average of the four tests (tests A, B, C and D).

6 Test laboratory Reporting

6.1 Information to be submitted to the test laboratory

In submitting a wood heater for test, the manufacturer/importer shall make available to the test laboratory:

(i) Such documents that identify the type and model of wood heater to be tested;

(ii) The names and physical addresses of the manufacturer and the applicant;

(iii) Design drawings with tolerances stated and a detailed description of the appliance (and water booster if fitted including part identification numbers) as specified in section 8 of the AS/NZS 4013:2014 which match the specifications of the test model to the production model;

(iv) Minimum combustion air openings (mm^2);

(v) Sales brochure if available;

(vi) Current operating and installation instructions;

(vii) Proposed authorisation label.

6.2 Test laboratory Report

The test laboratory report shall include the following:

(i) The details as noted in 6.1

(ii) The name and address of the testing agency and the name of the person responsible for the test.

(iii) A list of the dates and times for the test.

(iv) Whether the appliance being tested is a prototype or a production model.

(v) A statement that the burner tested complies fully with the scaled assembly drawings.

(vi) Whether any variations from this test Protocol were required and, if so, details of the procedure followed.

(vii) Photographs of the wood used for test showing extent of bark, knots and resin in the wood.

The following data shall be included in the test report for each Stage of each test:

- The weight of each fuel load added, in kg
- The average moisture content of each fuel load, % wet basis
- The flue gas temperature immediately prior to each refuelling, °C
- The average flue gas temperature for each output setting, °C
- The average burn rate for each output setting, kg/h
- The charcoal weight at the end of the test

- Heat output measurements
- The average heat output for each burn phase
- The maximum heat output for each burn phase
- All data relating to the dilution tunnel and particulate measuring train as required in AS/NZS 4013:2014
- The total particulate emission, in grams, g/kg fuel (dry weight basis) and g/h for each of start-up, high burn rate, low burn rate, seasoned hardwood and partially seasoned hardwood phases, and for the mass weighted average of start-up, high burn rate and low burn rate phases combined, for each day of testing.
- The overall efficiency based on gross calorific value for each day of testing and for the four days combined.
- The average emission factor expressed as mg/MJ of total useful heat for each day and for both days combined.
- The estimated uncertainty in emission factor measurements and the basis for the estimate.
- The use of any convection fans or automatic devices fitted to the appliance or the use of any ancillary features as described in clauses 4.2 to 4.5.
- Any routine maintenance requirements for the wood heater.
- In an attachment to the main report, the test laboratory shall provide comment on any of the following that are relevant.

    a) the potential for tampering with components of the wood heater that may influence emissions, in particular whether it appears easy for an untrained person to adjust the minimum air supply or draught due to the design of the wood heater;

    b) aspects of the wood heater design that have tight tolerances and may influence emissions (e.g. narrow slots between two components which are used as primary or secondary air supply);

    c) the need for routine maintenance of emission reduction components of the wood heater, in particular cleaning of emission scrubbing devices (if fitted);

    d) the complexity and potential for failure or incorrect use of automatic controls; and

    e) other features of the wood heater that influence emissions and might be subject to failure or poor user practices.

Appendix Note A

Sampling requirements for establishing firewood moisture

Ten randomly selected firewood pieces per tonne which are free of bark, knots and decay shall be collected when commercial firewood is delivered. The sampled logs are then oven-dried to constant weight at a temperature of 100 to 105°C. The density is determined either by:

(1) cutting a cube of wood from the dry log, weighing the cube and measuring the dimensions; or
(2) weighing the dry log, immersing the log in a totally full container of water such that water spills into a measuring vessel. The volume of water collected is an indicator of the volume of the log.

The density is determined by the measured weight (kg) divided by the measured volume (m^3).
An error analysis of the calculated density shall be carried out. The uncertainties in measuring the volume and the weight shall be included. The uncertainty of density measurement must be less than 5%.
All density measurements must lie within the specified density range.