



Technical report on an overview of test protocols for residential appliances burning solid fuels

Summary and Key Messages of Action A3 Report

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1. Introduction

There are several testing protocols, which are used worldwide for a testing of residential appliances burning solid fuels. These protocols can be classified into two basic categories. The first category includes national standardized test protocols, which can refer to harmonized European test standards describing requirements for placing of appliances on the EU market under construction product regulation (CPR), Norwegian standards, US standards, Australian/New Zealander standards and others. The second category includes test protocols, that reflect real operation in better way such as the beReal or Blue Angel test protocol, or other protocols used in laboratories across Europe. Each test protocol has its own approach to the different burn rates, fuel arrangement, calculation of batch size, number of tests, test assembly, measured parameters, sampling duration and many other characteristics. Therefore, a selection of test protocols for the appliance testing has a major role in the measurement result. The tests with different test protocols can produce varied emission factors of pollutants due to the dissimilarities of the test protocols. It is important to make an agreement on the concept for test protocol, where the appliance is operated and tested not only at one stable nominal heat output, but also during conditions reflecting real life including the ignition phase and partial or overload operation.

2. National test protocols for a testing of residential appliances burning solid fuels

2.1. Current harmonized EN European standards for local space heaters

There are several harmonized standards used for the placing of local space heaters on EU market (under CPR regulation) which contain requirements for design, production, construction, safety and the performance:

- EN 12815:2001/A1:2004 Residential cookers fired by solid fuel
- EN 13229:2001/A2:2004 Inset appliances including open fires fired by solid fuels
- EN 13240:2001/A2:2004 Roomheaters fired by solid fuel
- EN 15250:2007 Slow heat release appliances fired by solid fuel
- EN 15821:2010 Multi-firing sauna stoves fired by natural wood logs

Several tests have to be carried out with each appliance according to these standards. One of these tests is **the test at nominal heat output**. From this test the following parameters are determined:

- The mean total efficiency (for all standards)
- The mean nominal heat output (EN 12815, EN 13229, EN 13240)
- The mean nominal heat to water, if a boiler is fitted (for all standards except EN 15250)
- The mean nominal heat to space (for all standards except EN 15250)
- The mean CO emission at 13 % O₂ (for all standards)
- The mean flue gas temperature (for all standards)
- The mean total heat output (for EN 15250 only)

The most frequently installed appliances are probably appliances falling under standards EN 13240 and EN 13229, therefore, the following text will mainly refer to the mentioned devices fired by wood logs or wooden briquettes with intermittent combustion.

Testing procedures for **nominal heat output** are very similar in both standards. The appliance under test must be placed in a trihedron (equipped with a thermocouple) which is placed on a scale. Chimney measurement section (defined in the standards) is equipped with sensors for measurement of flue draught and flue gas temperature. The flue gas analyzer is connected to this section too, together with the device used for determination of PM. The test procedure consists of ignition phase, one or more pre-test period(s) and a valid test periods (2 test periods for appliances under EN 13229 standard or 3 test periods for appliances under EN 13240).

Before the test period, sufficient basic firebed shall be established. Then, the test periods are performed. The end of test period must be recognized by the weight scale, whereas indicated mass of the firebed plus ash from the burned fuel is same as the mass at the end of the previous period. During tests, the flue draught is set in accordance with the requirement of test standard (12 Pa for nominal heat output to 25 kW) or with the requirements of producer if the flue draught must be higher, than that specified in the standard.

Test fuel (beech, birch, or hornbeam) is specified by the range of the specific components, while the fuel moisture must be from 12 to 20 %. The fuel batch is calculated from the value of nominal heat output, efficiency, refueling interval and the lower calorific value of the fuel. Size and shape of the fuel is not specified in the standards, the producer's instructions must be followed.

Test standards define requirements for the minimal efficiency and maximal CO concentration, but the Commission regulation (EU) 2015/1185 ("Ecodesign") applies from 1st January 2022 stricter requirements not only for mentioned parameters, but also for concentration of OGC, NOx and PM. All emissions are related to 13 % of O₂.

Except the test of nominal heat output, other tests must also be performed in accordance with the standard e.g. slow/reduced combustion test, recovery test, natural draught safety test etc.

2.2 New EN 16510 series standards for local space heaters

This series of standards superseded old standards in 2023, and they have been harmonized for CPR by the European Commission's implementing decision (EU) 2023/2461. The coexistence period with old standards will span two years, starting on November 9, 2023 and concluding on November 9, 2025.

- EN 16510-1: 2022 Residential solid fuel burning appliances - Part 1: General requirements and test methods
- EN 16510-2-1:2022 Residential solid fuel burning appliances - Part 2-1: Roomheaters
- EN 16510-2-2:2022 Residential solid fuel burning appliances - Part 2-2: Inset appliances including open fires
- EN 16510-2-3:2022 Residential solid fuel burning appliances - Part 2-3: Cookers
- EN 16510-2-4:2022 Residential solid fuel burning appliances - Part 2-4: Independent boilers – Nominal heat output up to 50 kW

- EN 16510-2-6:2022 Residential solid fuel burning appliances - Part 2-6: Mechanically by wood pellets fed roomheaters, inset appliances and cookers

New standards already cover emission and efficiency requirements given by “Ecodesign”.

To be able to compare old and new standards the following text will be focused on the test of roomheaters and inset appliances at nominal heat output. Tested appliances must still be tested in trihedron, requirements for measuring devices are very similar to old standards, but in new standard, detailed description of PM measurement (hot filter method) is included. For the recognition of the end of test period, weight criterion is still used. Only when weighing of whole setup is an issue, CO₂ criterion can be used (but level of CO₂ at refueling must be defined by producer) e.g. if heavy roomheaters are tested. The testing procedure again consists of ignition and pre-test cycle(s) and test cycles. At least 2 consecutive cycles shall be considered for the calculations of relevant parameters (for wood logs - 3 cycles are needed for calculations, whereas 2 of them must be consecutive). There is no difference in calculation of fuel batch and requirements given for flue draught. Test fuel shall have moisture in range 12 to 18 %mass (size and shape of test fuel are still not specified). New standards allow to adjust air controls in the first 3 minutes after fuel loading to achieve proper ignition of the fuel. PM is sampled over the whole test cycle, while previously, PM sampling started 3 minutes after loading of fuel into the combustion chamber and the duration of sampling was 30 minutes.

New standards also contain the description of safety tests and tests at partial heat output (if it is specified by producer of appliance).

3. Norwegian standards, Australian/New Zealand standards, U.S. standards

Testing (certification) of wood heaters in the mentioned countries is done differently than in EU countries. Generally, wood heaters are tested not only at nominal heat output, but are tested at so called burn rates, which should cover various ways of usage of wood heaters in real houses. Burn rates are specified by fuel consumption and the results (mostly PM and CO emissions) are afterwards expressed as emission factors weighted over all burn rates.

3.1. Australian/New Zealand standards

There are following standards for the type testing of heaters burning wood:

- AS/NZS 4012:2014 Domestic solid fuel burning appliances – Method for determination of power output and efficiency
- AS/NZS 4013:2014 Domestic solid fuel burning appliances – Method for determination of flue gas emission

AS/NZS 4014 series:

- AS/NZS 4014-1:1999 Domestic solid fuel burning appliances - Test fuels – Hardwood

- AS/NZS 4014-2:2016 Domestic solid fuel burning appliances - Test fuels - Part 2: Softwood

The tested appliance is placed in the calorimeter room (with internal volume not less than 15 m³) over a number of burn cycles at specific burn rates. The usage of a calorimeter room makes it possible to measure appliance's heat output and efficiency using a direct method, which is a big difference from the procedures used in the EU, where the heat output is calculated from efficiency, which is calculated indirectly from heat losses.

Fuel batch is calculated by the usable volume of the firebox, wood logs should have approximately cylindrical shape, cross section of the logs is defined. Length and the number of logs is given by the size of firebox. Moisture of the fuel shall be 12-16 %.

Appliances are tested at high burn rate, low burn rate and medium burn rate, where burn rates are set by the combustion rate controls. Three burn cycles are required at each burn rate. Mass of firebed is defined in the standard and the end of burn cycles is determined by weight scale. Natural draught is used for the tests, 4.6 m chimney is required. PM sampling is done in dilution tunnel. Limits for PM are given in g/kg and are different for appliances with or without catalytic combustor.

3.2. U.S. standards, Norwegian standards

Standards (methods) used in both countries are very similar, because Norwegian method originate from U.S. Method 28/2017.

List of Norwegian standards *:

- NS 3058:1994 Enclosed wood heaters, Smoke emission (Part 1- Part 4)
- NS 3059:1994 – Enclosed wood heaters, Smoke emissions, Requirements

List of U.S. standards

- Method 28r:2019 Certification and auditing of wood heaters

Appliance is placed on the weight scale and tested at four burn rate categories. Fuel batch is calculated from the combustion chamber volume. Spruce (Norway) and Douglas fir (U.S.) are used as fuel. A fuel batch is inserted into the combustion chamber in so called test fuel crib, where particular "logs" have a square shape with defined dimensions and are specifically stitched together with steel stitchers and spacers. The moisture of the fuel must be 16-20 %.

Tests are done at natural draught (4.6 m chimney). In the first 5 minutes of the test cycle the air supply can be adjusted. PM is measured in dilution tunnel. No calculation of heat output is done during the tests, OGC, NO_x are not measured, CO is measured but there is no limit. Limits for PM are expressed in g/kg.

* Since 1st January 2022, EU standards for type testing of wood stoves are used in Norway

4. Test protocols reflecting real-life operation of local space heaters

In previous chapters standards used for type testing (certification) were briefly described, but these standards do not reflect real-life operation of installed appliances and therefore measured emission parameters are underestimated. There are two test protocols developed which should show more realistic results of emissions: beReal protocol and Blue Angel protocol. Real-Life test protocols are not standardized and not used for type testing.

4.1 beReal test protocol for wood stoves

beReal test protocol was developed within EU FP7 project. It consists of eight consecutive batches and cooling down phase:

- Batch 1: one initial batch at cold stage for ignition and starting the fire
- Batch 2 to Batch 5: four batches at nominal load (100 % mass and air settings according to nominal load)
- Batch 6 to Batch 8: three batches at 50 % fuel load and air setting for partial load
- Cooling down phase with air settings for stand-by

As a fuel, beech or birch wood is used and draught of 12 Pa is used over the test. Gaseous emissions (CO, OGC, NO_x, O₂, CO₂) are measured from the ignition of the fuel to the end of the cooling down phase (temperature of flue gas 50 °C). PM (hot filter) is measured from batches number 1, 3, 5 and 7, and the CO₂ concentration is used as a refueling criterion. Emission results are calculated as volume weighted averages for the whole test procedure. No limits for emissions are defined by beReal. A version of beReal test protocol exists also for pellet stoves.

4.2 Blue Angel – eco label scheme

The Blue Angel eco-label scheme for wood stoves has been introduced in 2020. It defines testing procedure for stove testing:

- Phase 1: initial phase (first batch for ignition at cold stage and one additional batch at nominal load, both batches are measured with one PM sampling), starting at natural draught (4 m chimney).
- Phase 2: nominal load phase (three batches with PM sampling each) at 12 Pa, PM starts 3 minutes after reloading and is terminated after 30 minutes.
- Phase 3: partial load phase (two batches with PM sampling each), if the manufacturer does specify partial load operation, nominal load operation shall again be applied, chimney draught shall be set according to manufacturer, but if they are not specified 6 Pa shall be applied.

The gaseous components in the flue gas shall be detected continuously starting right after ignition and lasting until the reloading criteria of the seventh batch is reached. As a refueling criterion can be used concentration of CO₂ or weight scale. Fuel is beech wood with moisture in the range of 12-18 %. PM is measured by hot-filter method. Adjustment of air controls is not allowed during phase 1 and 2.

Blue Angel defines limits (much stricter than required by Ecodesign) for concentration of CO, OGC, NO_x and PM (mass and number concentration). Nowadays, there are only a few appliances on the market which have Blue Angel eco label.

5. Summary

There are many test procedures used for the testing of local heating appliances worldwide. Harmonized EU standards provide operational characteristics near to steady-state operation, but don't reflect ignition and cooling down phases. U.S. (and similar) testing procedures are somewhere in the middle between EU standards and real-life test protocols. Real life test protocols reflect realistic operation of the wood stoves, but they cannot be currently used for type testing. The aim of the project Real-LIFE Emissions is to prepare a new real-life test protocol, which will be evaluated and suggested for use in future standards.



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Harmonizing reliable test procedures representing real-LIFE air pollution from solid fuel heating appliances - **Real-LIFE Emissions** project.

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- University of Eastern Finland (UEF)
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