VSB TECHNICAL UNIVERSITY OF OSTRAVA | ENERGY AND ENVIRONMENTAL TECHNOLOGY CENTRE | ENERGY RESEARCH CENTRE

Comparison of existing test protocols for type testing and more real-life test protocols available on the market with focus on stoves

Kamil Krpec

26th October 2023

Real-LIFE Emissions

Introduction

There’re several approaches in Europe and other countries for testing of wood stoves:

- Type testing EN standards (hEN 13240, hEN 13229…) or EN 16510 series
- Norwegian standards
- Australian/New Zealand standards
- US EPA standards
- Test protocols reflecting real-life operation (beReal, Blue Angel)

Main characteristics of any test procedure:

1. **Test conditions –** flue gas draught, fuel mass, measured parameters, …
2. **Test assembly description –** calorimeter room, testing trihedron, dilution tunnel, etc.
3. **Fuel characteristics –** fuel type, fuel moisture, fuel granulometry, shape, dimensions, …
4. **Testing procedure –** definition of basic firebed, requirements for test duration, start and end of burning period, possibility of adjusting of combustion air during the test, burn rates categories…
5. **Measurement methods for determination of required parameters –** PM measurements methods, gaseous emission measurements methods, PAHs, heat output and efficiency determination methods, …

Each characteristic can significantly affect the results.

Type testing

Type testing in EU

- Must be done before new product is placed on the EU market
- Type testing shall guarantee a minimum product quality concerning operation characteristic, safety and construction
- Official test protocols given in **harmonized standards** offer equal opportunities for manufactures
- Product testing and assessment is done by **Notified body** and accredited laboratories
- Results shall be „**testing laboratory independent**“. Reports **shall be acepted** in the whole EU.
- 40 Notified bodies in EU for wood stoves

https://webgate.ec.europa.eu/single-market-compliance-space/#/home

European type testing standards - hEN standards / new EN 16510 series standards

- There are several harmonized European standards for testing and assessment of local space heaters fired by wood according CPR Nr. 305/2011:
  - **hEN 12815 –** Residential cookers fired by solid fuel – Requirements and test methods
  - **hEN 13240 –** Roomheaters fired by solid fuel – Requirements and test methods
  - **hEN 13229 –** Inset appliances including open fires fired by solid fuels – Requirements and test methods
  - **hEN 15250 –** Slow heat release appliances fired by solid fuel - Requirements and test methods
  - **hEN 15821 –** Multi-firing sauna stoves fired by natural wood logs – Requirements and test methods

For example - from August 2021 standards ČSN EN 12815, ČSN EN 13240, ČSN EN 13229 were cancelled in Czech republic and were superseded by EN 16510-1 standard – but these cancelled standards are still harmonized -> Notified bodies for CPR assessment have to follow cancelled standards for testing and assessment.

hEN 13240:2001 + all corrections

The main characteristics of the test procedure at NHO:

- Stove placed in **trihedron**
- **The mass of the basic firebed** is not specified in detail
- **Minimal refueling interval** is 45 min (intermittent operation) or 90 min (continuous operation)
- **Mass of fuel** is calculated from declared heat output and efficiency
- **Flue draught:** min. **12 Pa**
- **Reduced heat output is not tested**
- **Tests at nominal heat output consists of two parts:**
  - Ignition and pre-test(s) cycle(s) – preparation of firebed, heat up
  - Test cycles (efficiency, emissions, heat output are determined)

hEN 13240:2001 + all corrections

- **3 test cycles for wood logs** shall be considered for mean values (emission, heat output, efficiency). Number of test batches is not limited.
- **Test fuels for heat output tests:** beech, birch or hornbeam wood
  - **Ash:** < 1 %, **Moisture content:** (16 ± 4) %
- **Orientation, amount of logs, size** - according manufacturer's instruction
- **End of test cycle:** according weight scale
- **OGC, NOx and PM** are not mentioned in standard
- PM sampling starts after 3 min, duration 30 min, heated filter

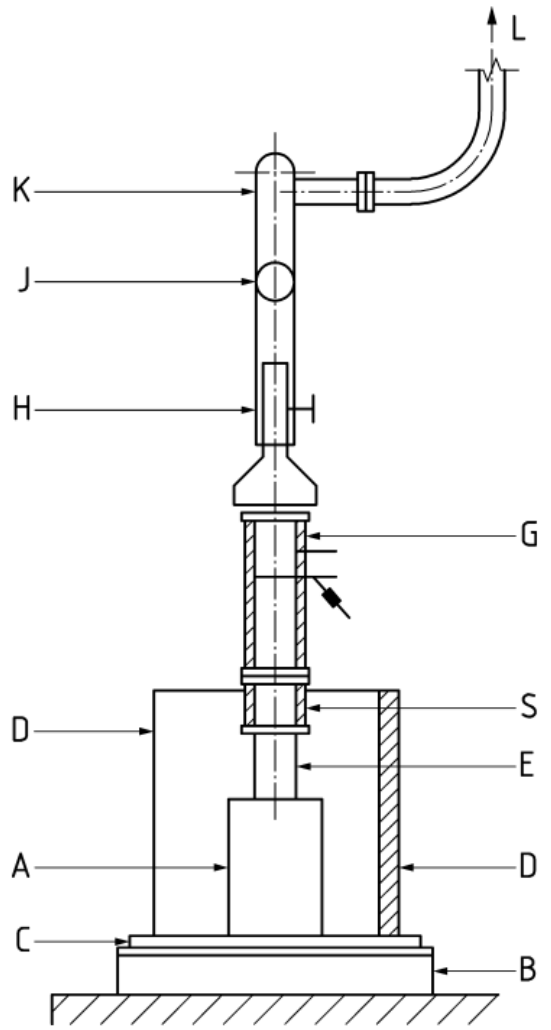
Beech logs for NHO

Fir timbers 5 x 5 cm for safety test

EN 16510-1 + EN 16510-2-1 (12/2022)

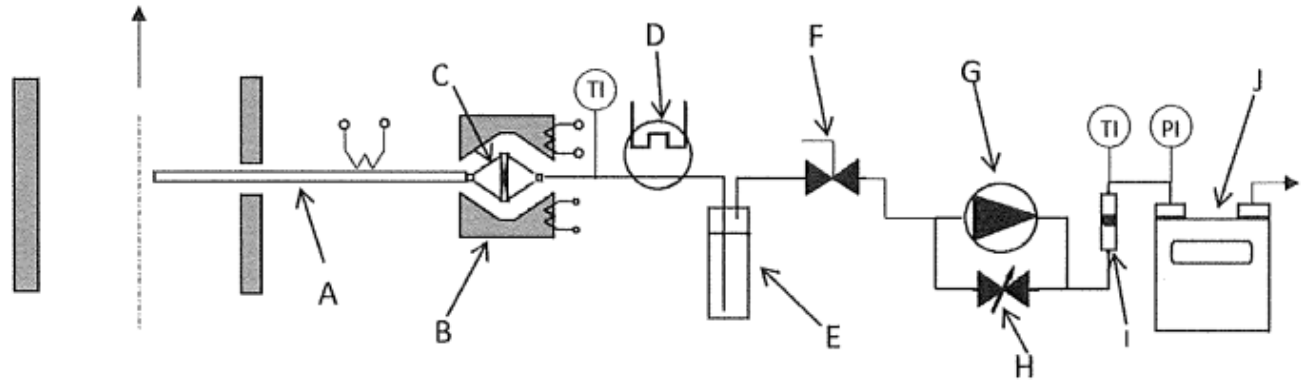
The main characteristics of the test procedure:

- Stove placed in **trihedron**
- **Flue draught:** min. **12 Pa** for test of nominal heat output, min. **6 Pa** for test of reduced heat output
- **3 cycles for wood logs** shall be considered for mean values (emission, heat output, efficiency), **2 of these shall be consecutive**. Number of test batches is not limited.
- **The mass of the basic firebed** for the nominal heat output shall be specified by the manufacturer in instructions (if not then 10 % of the mass of the batch ± 50 g)
- **Tests at NHO, PHO (if specified) consist of two parts:**
  - Ignition and pre-test(s) cycle (s) – preparation of firebed, heat up
  - Test cycles (efficiency, emission, heat output are determined)
- **Up to 3 minutes after loading is permissible to adjust air controls for achieve proper ignition**



EN 16510-1 + EN 16510-2-1 (12/2022)

- **Test fuels for heat output tests:** beech, birch or hornbeam wood
  - **Ash:** < 1 %, **Moisture content:** (15 ± 3) %
- **Orientation, amount of logs, size according manufacturer's instruction**
- **Minimal refueling interval: 40 min** for intermittent operation, **90 min** for continuous operation (for PHO not defined)
- **End of test cycle:** according weight scale or CO_2 (level of CO_2 for refueling must be specified by manufacturer)
- **OGC, NOx and PM** are mentioned in standard
- PM measured with heated probe and filter (180 °C = solid fraction, 90 ° non-isokinetic, **full cycle**) – ENPME method



Norwegian standards

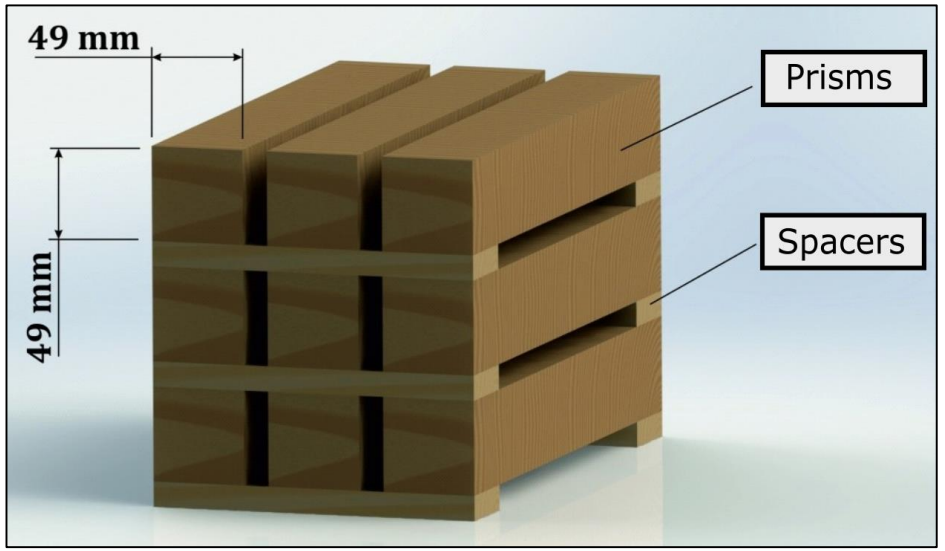
- **NS 3058:1994 - Enclosed wood heaters, Smoke emission**
  - **Part 1 –** Test facility and heating pattern
  - **Part 2 –** Determination of particulate emission
  - **Part 3 –** Determination of organic micro contaminations (PAH)
  - **Part 4 –** Determination of content of CO and CO_2 in flue gas
- **NS 3059:1994 –** Enclosed wood heaters, Smoke emissions, Requirements

Tests shall be carried out within each of the four burn rate categories (dry basis)

	Burn rate category 1	Burn rate category 2	Burn rate category 3	Burn rate category 4
Grade 1	< 0.80 kg/h	0.80 – 1.25 kg/h	1.26 – 1.90 kg/h	> 1.90 kg/h
Grade 2	< 1.25 kg/h	1.25 – 1.90 kg/h	1.91 – 2.80 kg/h	> 2.80 kg/h

Norwegian standards - Fuel

- Test fuel is **air-dried spruce**
- **Fuel moisture:** 16 to 20 % (wet basis)
- **Cross section 49 x 49 mm of wood pieces** stitched together with steel stitcher and spacers
- Length and width of batch are calculated according to combustion chamber volume:
  - Weight of the test fuel charge acc. specific fuel charge density 112 ± 11 kg/m^3.



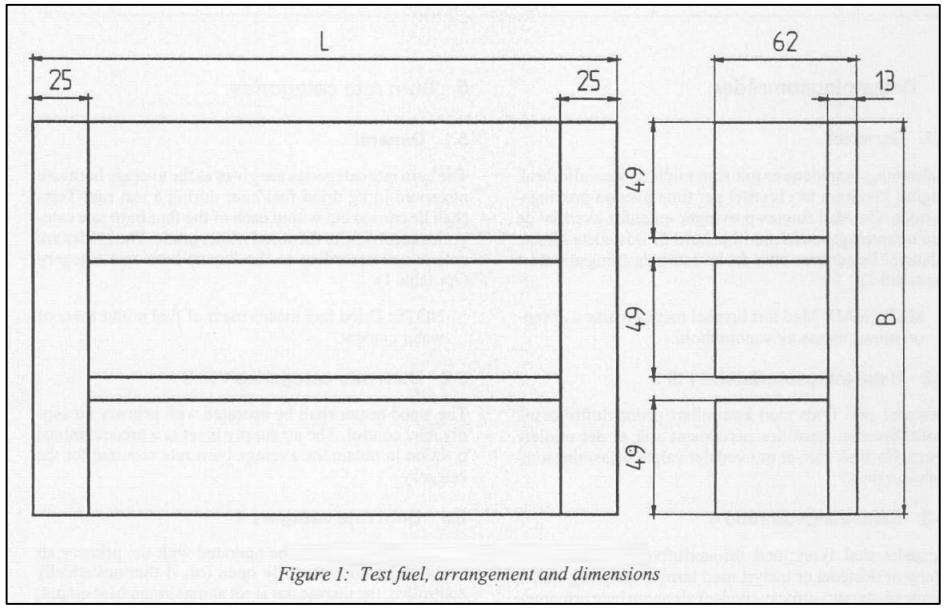
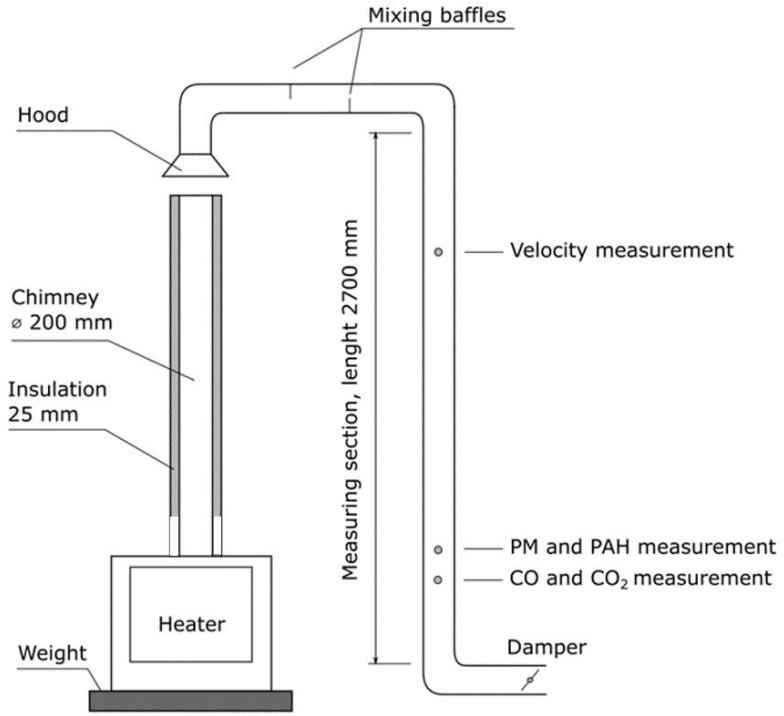


Figure 1: Test fuel, arrangement and dimensions

Norwegian standards – Test procedure

- Ignition according to manufacturer's instruction
- **The weight of basic firebed shall be from 20 to 25 % of the fuel charge** loaded at the start of the test run
- **Test run** begins immediately after the test fuel has been loaded
- **5 minutes allowed** for adjusting of air supply
- **Secondary** air can be adjusted once during test run (manufacturer's instruction)
- **The average value of the surface temperatures can differ up to 70 °C** from the start to the end of the test run (thermal balance)
- **PM measured in dilution tunnel** (solid + condensables), calculated by specific calculation mode based on measurement of each burn rate
- **OGC, NOx** – not determined, **CO** measured but no limit
- **End of test run** – weight scale
- **Natural draught** (chimney 4.5 m)



From 01/01/2022 – hEN standards

	Max. allowable emission for one test	Maximum weighted mean value
Catalyst-equipped wood heater	10 g/kg	5 g/kg
Non-catalyst wood heaters	20 g/kg	10 g/kg

Australian/New Zealand standards

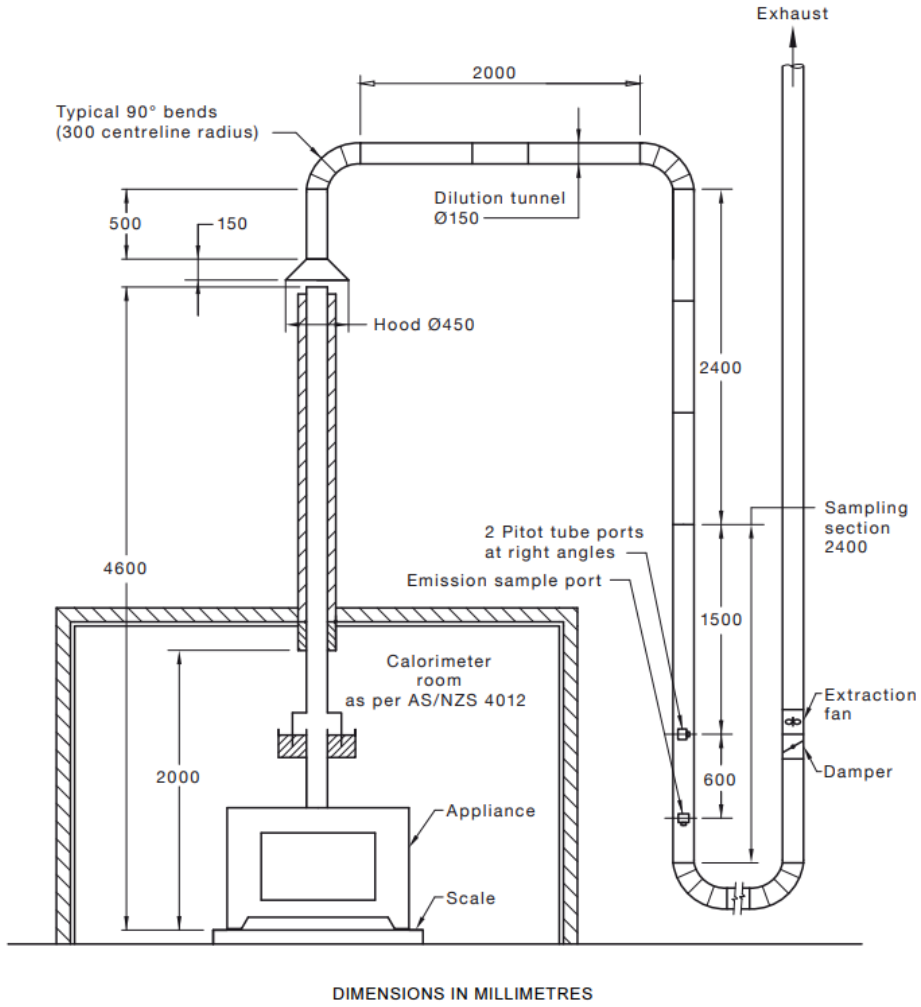
- **AS/NZS 4012:2014 -** Domestic solid fuel burning appliances – Method for determination of power output and efficiency
- **AS/NZS 4013:2014 -** Domestic solid fuel burning appliances - Method for determination of flue gas emission
- **AS/NZS 4014 and parts -** Domestic solid fuel burning appliances – Test fuels

Limits for **PM** and **efficiency** (new for version from 2014)

Test methods apply to domestic solid fuel burning appliances :

- Space-heating appliances
- Space-heating appliances that include water-heating devices

Is not intended for site-built masonry appliances, central heating appliances, cookers, …



Australian/New Zealand standards – Test fuel load

- The size of the **test fuel load determined by the volume of the firebox** of the appliance.
- **Test fuel load nominal volume shall be 16.5 % of the fuel chamber useable volume**
- **Test fuel without bark (any hard wood, moisture 12-16 % wet basis)** shall be cut to approx. **cylindrical shape**
- **Cross section of wood between 75 and 110 mm**, length and number of pieces calculated according firebox dimension

Australian/New Zealand standards – Test procedure

- **Three burn rates with at least 3 tests required:**
  - **High burn rate** – combustion rate controls fully open;
  - **Low burn rate** – controls adjusted to the minimum setting;
  - **Medium burn rate** – combustion rate controls adjusted to ± 20 wt.-% of the midpoint of average high and low burn cycle times with maximum variation from the midpoint of 30 min;
  - At low and medium burn rate, controls shall be fully open till the fuel mass drops down by 20 %, then set to appropriate position
- **Firebed** – 24 to 26 wt.-% of test fuel load;
- **Burn cycle** is complete when mass balance is reached / ± 0.5 wt.-% of the mass of the test fuel load
- **Natural draught** (chimney 4.6 m), **direct method** for determination of heat output (calorimeter room)
- **PM sampling** (solid + condensables) in dilution tunnel (non-isokinetic, 90 °), calculation of appliance emission factor (from all burn rates)

	Australia	New Zealand*
Efficiency	60 %	65 %
PM	1.5 g/kg (without catalytic combustor) 0.8 g/kg (with catalytic combustor)	1.5 g/kg

* Appliances installed on properties less than 2 hectares in size

U.S. EPA standards (2017)

- **Method 28/2017 –** Certification and auditing of wood heaters
- Very **similar to Norwegian** standards
- Wood heaters are tested with **test fuel crib**
- **Material:** air-dried squared Douglas fir with moisture 16 – 20 %
- **Dimension of Douglas timber:** 2 x 4 or 4 x 4 inches (50 x 100 or 100 x 100 mm) acc. firebox volume
- **Test fuel loading density shall be 112 ± 11.2 kg/m³** of usable firebox volume, wet basis
- **Dimension, placement of fuel load according volume of the combustion chamber**
- **Length of the used timber pieces is 5/6 of the length of the combustion chamber**

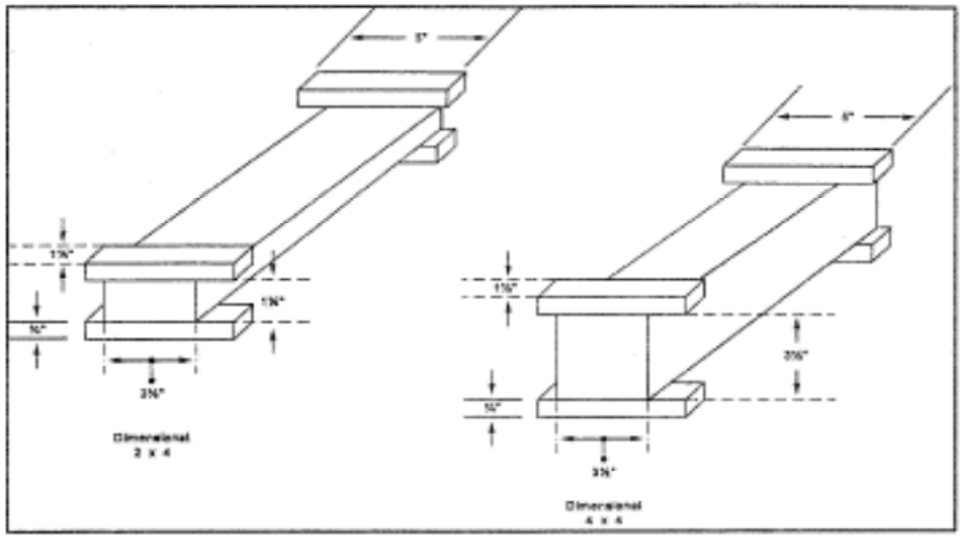
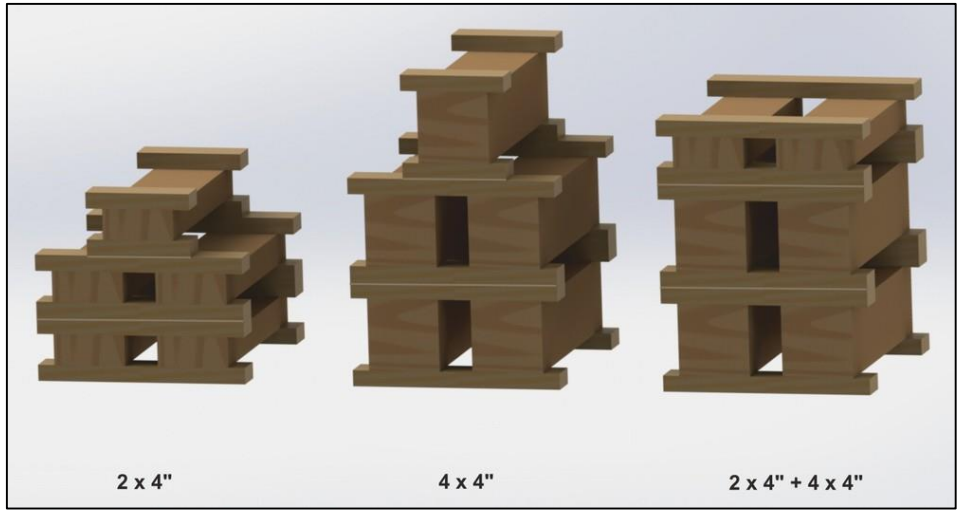


Figure 28-2. Test Fuel Spacer Dimensions.

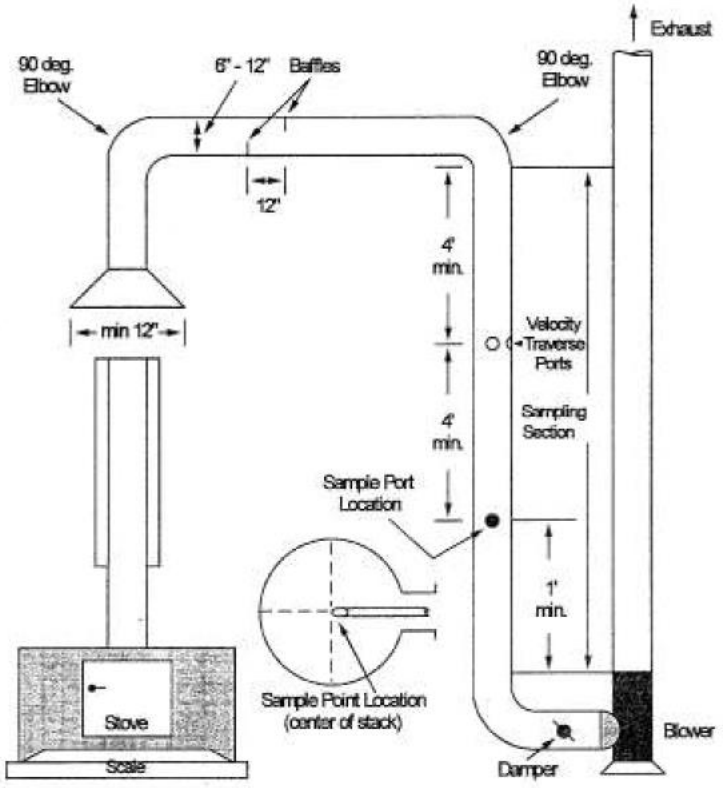


U.S. EPA standards

- **Stoves ageing** – 50 h for catalyst-equiped stoves, 10 h other stoves
- Natural draught (chimney 4.6 m)
- The appliance is operated at four burn rates achieved by adjustment of air supply

Category 1	Category 2	Category 3	Category 4
< 0.8 kg/h	0.8 to 1.25 kg/h	1.25 to 1.90 kg/h	Maximum burn rate
< 1.76 lb/hr	1.76 to 2.76 lb/hr	2.76 to 4.19 lb/hr	

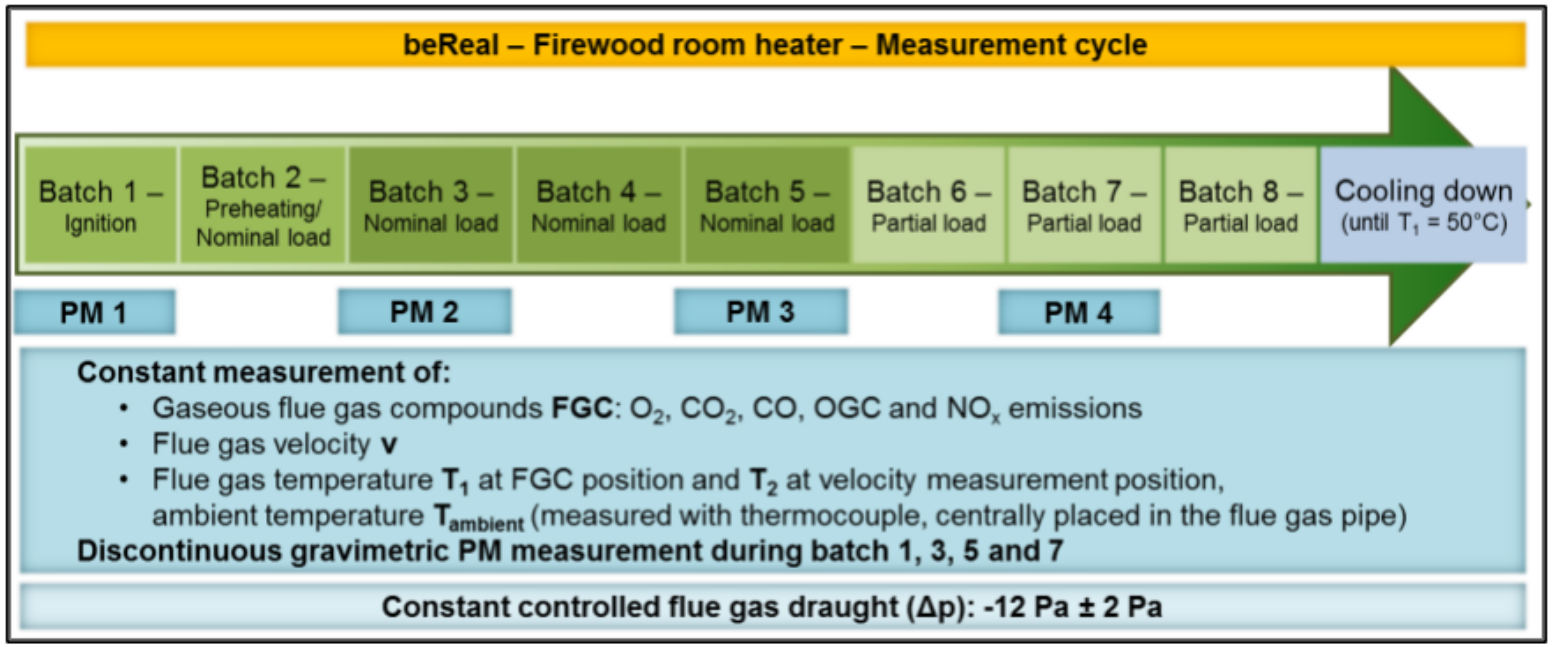
- **5 min** for combustion air adjustment
- Particulate emissions are determined (**solid + condensables**):
  a) in cold and diluted flue gas according **Method 5G** (preffered, non-isokinetic, 90 °)
  b) in hot and undiluted flue gas according **Method 5H** (optional, complicated)
- **PM limit**: 2.0 g/h of operation for catalytic and noncatalytic stoves

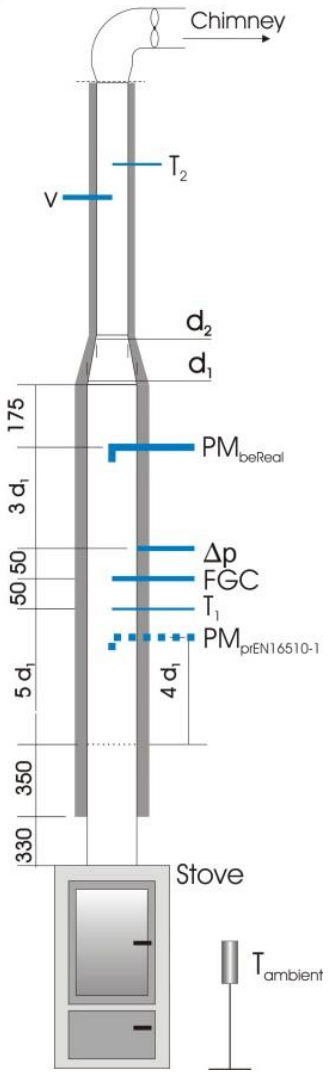


Standard	Tested heat output/burn categories	Measured main parameters	Cold starting batch included?	Used fuel	Mass of fuel	Fuel shape and moisture	Flue gas draught	PM measurement	Refuelling criterion
Current harmonized European standards like EN 13240, EN 12815, EN 13229 and others	Nominal heat output	Efficiency, CO	No	Primarily hard wood (beech, birch, hornbeam)	Calculated from heat output defined by manufacturer	Shape is not defined, water content 16 ± 4 % on wet basis	Controlled flue gas draught 12 ± 2 Pa	Not defined	Scale criterion
New EN 16510 series from 2022	Nominal heat output Partial heat output (if specified by manufacturer)	Efficiency, CO, NO_x, OGC and PM Limits given by EU1185/2015	No	Primarily hard wood (beech, birch, hornbeam)	Calculated from heat output defined by manufacturer, PHO calculated acc. to formula of EN 16510-1:2022	Shape is not defined, water content 15 ± 3 % on wet basis	Controlled, 12 ± 2 Pa (Nominal heat output) 6 ± 1 Pa (Partial heat output)	EN-PME method in measurement section behind appliance	Scale or CO_2 criterion
Norwegian standards NS 3058-1 to 4:1994	4 burn rate categories in two grades	PM	No	Air-dried spruce	112 ± 11 kg/m^3 of the usable volume of the firebox	Prisms 49 x 49 mm, water content 16-20 % on wet basis	Natural flue gas draught	PM measurement in dilution tunnel	Scale criterion
Australian/New Zealand standards AS/NZS 4012:2014 AS/NZS 4013:2014 AS/NZS 4014-1:1999 AS/NZS 4014-2:2016	High burn rate Low burn rate Medium burn rate	Efficiency, PM	No	Hard wood	Nominal volume shall be 16,5 % of the fuel chamber usable volume	Cylindrical shape, cross section from 75 to 110 mm, 12 to 16 % on wet basis	Natural flue gas draught	PM measurement in dilution tunnel	Scale criterion
US standard EPA Method 28	4 burn rate categories in one grade	PM	No	Douglas fir lumber	112 ± 11 kg/m^3 of the volume of combustion chamber	Prisms 50 x 100 or 100 x 100 mm, water content 16-20 % on wet basis	Natural flue gas draught	PM measurement in dilution tunnel	Scale criterion

Real-life test protocols

beReal





- Includes **ignition and cooling down** phases
- **Hardwood** (beech or birch)
- Refueling criterium – **CO_2**
- **PM (solid)** measured in hot flue gases isokinetically (whole cycle, EN 16510-1:2018)
- **Results** – volume weighted averages for the whole measurement cycle
- **Partial load** = 50 % of fuel mass for nominal load
- Quick user guide (brief instructions about fuel preparation, settings the air, lightning, recharging…)
- Never used for product labeling, no limits defined

1. Preparation & Ignition

- Clean and open the grate and empty the ash box
- Properties of used firewood:
  - Length of firewood pieces: **30 cm**
  - Total batch mass, nominal load: **1,5 kg**
  - Use only dry and natural firewood pieces
- Ignition batch:
  - **2 pieces** of firewood, each 0.5 kg, placed on the bottom of the combustion chamber. (Figure 1)
  - **8 pieces** of kindlings (total mass: 1,0 kg) stacked crosswise in **3 layers** atop (3 pieces, 2 pieces and 3 pieces) of the 2 wood pieces on the bottom. (Figure 2-4) Place the **starting aid** atop of the second layer (Figure 2)
  - Whole mass of the ignition batch has to be **2.0 kg** (1,0 kg firewood and 1,0 kg kindling) (Figure 4)
- **Air inlet flap settings for ignition:**
  - Air supply: At **full position** 100% open (Figure 5)
- Lighting of **starting aid** (placed atop of the 2nd layer – Figure 2)
- Close the combustion chamber door immediately after lighting the starting aid.


Figure 1


Figure 2


Figure 3


Figure 4


Figure 5

2. Recharging at Nominal Load

- Recharge when **flames extinguished** or **only little flames** are visible.
  - Firewood: 2 pieces, each 0.75 kg, total batch mass **1.5 kg** (placement according to Figure 6)
- **Air inlet flap settings:**
  - Air supply: At **full position** 100% open (Figure 5 & Figure 7)


Figure 6


Figure 7

3. Recharging at Part Load

- Recharge when **flames extinguished** or **only little flames** are visible.
  - Firewood: 2 pieces, each 0.375 kg, Total batch mass **0.75 kg** (placement according to Figure 8)
- **Air inlet flap settings:**
  - Air supply: Set the damper from the full position to 60% (from right to left) (Figure 9)


Figure 8


Figure 9

4. Finishing heating operation

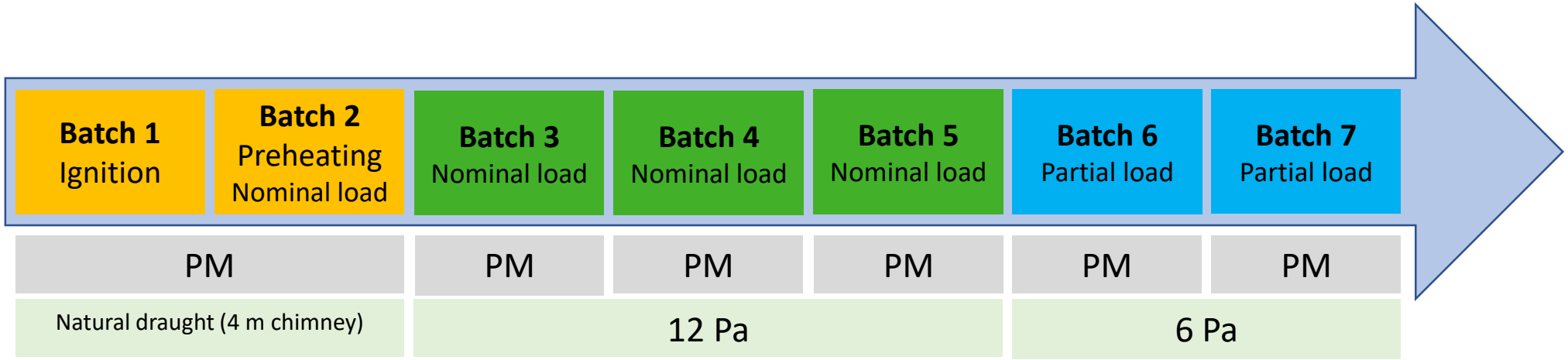
- Close the damper (0% – Figure 11) after finishing heating operation (Figure 10).


Figure 10


Figure 11

Blue Angel – German eco label

- https://www.blauer-engel.de/
- Ecolabeling under the German Federal Government
- 8 general areas
- Heating / Energy -> Air Conditioners, Climate-Friendly Grocery Stores, Energy Meters, **Stoves for wood**
- 6 producers, about 6 awarded stoves (mostly equipped by catalytic converter and ESP)



- **Hardwood** (beech with moisture 15±3 %)
- Refuelling criterium – **CO_2 (4 %) or weight**
- **PM (solid)** measured in hot flue gases (EN 16510-1:2018), Ignition phase – whole, other phases – after 3 min + 30 min
- Air adjustments – in accordance to the manual, nominal + partial load – not allowed
- Quick user guide

Parameter	Blue Angel limit *	Ekodesign limit *
Dust – PN [#/cm^3]	5x10^6	-
Dust – mass [mg/Nm^3]	15	40
CO [mg/Nm^3]	500	1500
OGC [mg/Nm^3]	70	120
NOx [mg/Nm^3]	180	200

* Dry flue gases, 0 °C, 101 325 Pa, 13 % O_2

- PN (CPC) - solid particles after volatile particle remover, limit valid from 01/01/2024)

Summary

- There is any universal testing procedure for wood stoves
- EN standards, provide operational characteristic near to steady-state operation
- Typical real-life operation shows higher emissions and lower efficiency in comparison with results from type-testing

The choice of test protocol significantly affects the results of determining the appliance characteristics. Results obtained by different test procedures are not comparable.

Thank you for attention

VSB - Technical University of Ostrava
Energy and environmental Technology Centre, Energy research center

Kamil Krpec
kamil.krpec@vsb.cz