DRAFT FOR DEVELOPMENT

DD CEN/TS 15883:2009

Residential solid fuel burning appliances — Emission test methods

ICS 97.100.30

British Standards

National foreword

This Draft for Development is the UK implementation of CEN/TS 15883:2009.

This publication is not to be regarded as a British Standard.

It is being issued in the Draft for Development series of publications and is of a provisional nature. It should be applied on this provisional basis, so that information and experience of its practical application can be obtained.

Comments arising from the use of this Draft for Development are requested so that UK experience can be reported to the international organization responsible for its conversion to an international standard. A review of this publication will be initiated not later than 3 years after its publication by the international organization so that a decision can be taken on its status. Notification of the start of the review period will be made in an announcement in the appropriate issue of *Update Standards*.

According to the replies received by the end of the review period, the responsible BSI Committee will decide whether to support the conversion into an international Standard, to extend the life of the Technical Specification or to withdraw it. Comments should be sent to the Secretary of the responsible BSI Technical Committee at British Standards House, 389 Chiswick High Road, London W4 4AL.

The UK participation in its preparation was entrusted to Technical Committee RHE/28, Domestic solid mineral fuel appliances.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard cannot confer immunity from legal obligations.

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English Version

Residential solid fuel burning appliances - Emission test methods

Appareils résidentiels à combustibles solides - Méthodes d'essai des émissions

Häusliche Feuerstätten für feste Brennstoffe - Emissionsprüfverfahren

This Technical Specification (CEN/TS) was approved by CEN on 28 March 2009 for provisional application.

The period of validity of this CEN/TS is limited initially to three years. After two years the members of CEN will be requested to submit their comments, particularly on the question whether the CEN/TS can be converted into a European Standard.

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Foreword

This document (CEN/TS 15883:2009) has been prepared by Technical Committee CEN/TC 295 “Residential solid fuel burning appliances”, the secretariat of which is held by BSI.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

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Introduction

All the standards of CEN/TC 295 deal with the field of residential heating and cooking appliances burning solid fuels covering the standardization of appliance construction, safety and commissioning requirements and performance requirements (e.g. heat outputs, efficiency and emissions) together with supporting test methods.

This European Technical Specification (TS) deals with methods for the measurements of NO_x, and OGC/total hydrocarbons emissions and particulate and dust produced by the above mentioned heating and cooking appliances.

For the nitrogen oxides this European Technical Specification describes the ‘Chemiluminescence method’ and the ‘Non-dispersive infrared (NDIR) method’. Besides these two techniques, there are also the ‘Non-dispersive ultraviolet (NDUV) method’ and the ‘Non-extractive (in situ) method’ which are described in detail in ISO 10849:1996.

For the total hydrocarbon contents the method is described but the TS does not give any information regarding separate constituents due to the measurements being expressed as equivalents of a reference substance. In this method the measurement is continuous.

Finally, for the measurements of particulate and dust, this European Technical Specification reports, in the Annex, three official methods that coincide respectively with the combined Austrian and German method, the Norwegian method and the UK method currently in force in these countries.

1 Scope

This European Technical Specification is applicable to residential heating and cooking appliances burning solid fuels and details methods for the measurements of NO_x, and OGC/total hydrocarbons emissions and particulate and dust produced by these appliances and is to be used in conjunction with the test methods given in the European Standards covering these appliances.

This European Technical Specification covers the NO_x, and OGC/total hydrocarbons emission test methods, however it does not cover input data and detailed calculation procedures.

For the particulate and dust emissions test methods, the national documents of those countries that have a test method are reference methods which are summarised in Informative Annex A, whilst those countries that do not have a specific test method, could choose one of these methods listed in the annex.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 12815:2001, *Residential cookers fired by solid fuel — Requirements and test methods*

EN 13229:2001, *Inset appliances including open fires fired by solid fuels — Requirements and test methods*

EN 13240:2001, *Roomheaters fired by solid fuel - Requirements and test methods*

ISO 10849:1996, *Stationary source emissions — Determination of the mass concentration of nitrogen oxides — Performance characteristics of automated measuring systems*

3 Terms and definitions

3.1 Definitions

For the purposes of this Technical Specification, the following definitions apply.

3.1.1
absorption
incorporation of a substance into the body of a liquid or solid

3.1.2
calibration
set of operations that establish the relationship between values of quantities indicated by a measuring instrument or measuring system, or values represented by a material measure or a reference material, and the corresponding values realized by standards

3.1.3
dew point
temperature at, or below which, the condensation from the gas phase will occur

3.1.4
dust
particles of various shape, structure and density scattered in the gaseous phase of the flue gas

3.1.5
gas sample
portion of gaseous material on which observations can be made in order to provide data on the gaseous material from which it has been removed

NOTE A sample is taken as being representative of the gaseous material if the same observations are supplied on any other samples taken from this gaseous material to furnish the same data within preset intervals.

3.1.6
line
gas-tight system of tubing equipped with accessories such a valves, manometers, etc. enabling gas to be transported from one point to another

3.1.7
measured value
estimated value of the air quality characteristics derived from an output signal; this usually involves calculations related to the calibration process and conversion to required quantities

3.1.8
nominal heat output
declared heat output of an appliance achieved under defined test conditions when burning the specified test fuel in accordance with the European standard relevant to that appliance

3.1.9
reference material
material or substance one or more of whose property values is sufficiently homogeneous and well established to be used for the calibration of an apparatus, the assessment of measurement method, or for assigning values to materials

3.1.10
resolution
smallest difference between indications, for an identifiable component, of a recording or display device that can be meaningfully distinguished

3.1.11
sample line
line provided to remove a representative sample of a gas to be analysed and to transport it from the sample point to the analyzer

4 Emission test methods: measurements of total hydrocarbons (THC)

NOTE These methods are intended to determine the total hydrocarbon content in the flue gases from appliances burning solid fuels. The method uses an instrument equipped with a flame ionisation detector (FID). The measurement is continuous. The result obtained is expressed as equivalents of a reference substance, usually methane or propane. The measurement concerns only the total hydrocarbon content and does not give any information of separate constituents. The sampling point should be as described for the measurement section detailed in the test methods appropriate to the appliance as given in the European Standard covering the requirement and testing of these residential heating and cooking appliances burning solid fuels.

4.1 General procedure

The measurement is extractive and continuous, i.e. a sample of test gas flow is continuously extracted and is analyzed in a free-standing instrument. The sampling point shall be as described in the test methods detailed in the European Standard appropriate to the appliance being tested. If there is a damper or any other device which favours the lack of homogeneity in the flow, the measuring point shall be moved to a position where the flow is homogenous. The measuring system shall be heated to 195 °C.

4.2 Equipment

The measuring system consists of the following components.

a) *Instrument with flame ionisation detector, FID*. Measuring range, usually between 0 -10 and 0 - 100 000 ppm. The instrument shall be equipped with a heated filter.

b) *Gas probe with a cleaning filter for particulates*. The probe shall consist of a suitable material, such as corrosion resistant steel. The filter shall be heated so that condensation is avoided. This requires a temperature in the filter of 195 °C.

c) *Sample line*. The sample line shall be heated to the same temperature as the filter. The inner line shall be of PTFE and be exchangeable. The sample line shall be as short as possible.

4.3 Calculation of organic gaseous compounds (OGC)

4.3.1 This method describes how to calculate the content of organic gaseous compounds expressed in mg/Nm^3 (dry) (at normal condition[1)]) and based upon an oxygen content of 13 % in the exit flue gases. The calculation of total hydrocarbons (THC) content is based on a continuous measurement as described in 4.1.

4.3.2 Calculation assumptions

In order to undertake the calculations given in 4.3.3 the following data shall be available:

a) total hydrocarbon content in methane or propane equivalents, mean value;

b) $O_{2,m}$, $CO_{2,m}$, CO_m content, mean values;

c) carbon, hydrogen and moisture content of the test fuel (C, H and W);

d) carbon content of the residue crossing the grate referred to the quantity of the test fuel fired (C_r).

4.3.3 Calculations of organic gaseous compounds

If the OGC content is required in methane equivalents it is determined as follows:

$$C_{OGC} = \frac{(THC \times 12)}{22{,}36} \times \frac{(21 - 13)}{(21 - O_{2,m})} \times \frac{G_W}{G_D} \tag{1}$$

Alternatively, if the OGC content is required in propane equivalents it is determined as follows:

$$C_{OGC} = \frac{(THC \times 36)}{21{,}93} \times \frac{(21 - 13)}{(21 - O_{2,m})} \times \frac{G_W}{G_D} \tag{2}$$

where

C_{OGC} is the calculated content of organic gaseous compound expressed in mg/Nm^3 dry flue gas at 13 % O_2;

[1)] Referred to 273 K and 1013 mbar.

THC is the measured total hydrocarbon content in the wet flue gas either in ppm methane equivalents or propane equivalents;

$O_{2,m}$ is the measured content of oxygen in dry flue gas expressed in % as mean value;

G_w is the actual specific wet flue gas volume expressed in Nm^3/kg fuel;

G_D is the actual specific dry flue gas volume expressed in Nm^3 /kg fuel.

The actual specific flue gas volume in wet condition is to be calculated as:

$$G_W = \frac{(C - C_r)}{(0{,}536 \times (CO_{2,m} + CO_m))} + 1{,}24 \times \frac{(9 \times H + W)}{100} \tag{3}$$

where

G_w is the specific flue gas volume in wet conditions in Nm^3/kg fuel;

C is the carbon content of the test fuel in % of mass;

C_r is the carbon content of the residue referred to the quantity of the test fuel fired in % of mass;

$CO_{2,m}$ is the measured mean content of carbon dioxide in the dry flue gas in %;

CO_m is the measured mean content of carbon monoxide in the dry flue gas in %;

H is the hydrogen content of the test fuel in % of mass;

W is the moisture content of the test fuel in % of mass.

The actual specific dry flue gas volume, G_D, is calculated as:

$$G_D = \frac{(C - C_r)}{0{,}536 \times (C_{2,m} + CO)} \tag{4}$$

where

G_D is the specific flue gas volume in wet conditions in Nm^3/kg fuel;

C is the carbon content of the test fuel in % of mass;

C_r is the carbon content of the residue referred to the quantity of the test fuel fired in % of mass;

$CO_{2,m}$ is the measured mean content of carbon dioxide in the dry flue gas in %;

CO_m is the measured mean content of carbon monoxide in the dry flue gas in %;

4.4 Uncertainty of measurement

The uncertainty of the measurement for total hydrocarbon is maximum ± 10 % of the measured value. The total uncertainty of the calculated OGC value, according to this instruction, is ± 15 % of the calculated value.

5 Emissions test methods: measurement of nitrogen oxides

NOTE The methods detailed in 5.2.1 to 5.2.3 are intended to determine the content of nitrogen oxides (NO) in flue gases from small combustion appliances. The methods are continuous. The result obtained is expressed as equivalents of nitrogen dioxide (NO_2). The sampling point should be as described for the measurement section detailed in the test methods as appropriate to the appliance as given in the European Standard covering the requirement and testing of these residential heating and cooking appliances burning solid fuels.

5.1 General procedure

The measurement is extractive and continuous, i.e. the test gas flow is extracted from the measuring point by the suction pyrometer and is analysed by an arrangement of a complete measuring system as shown in Figure 1A or Figure 1B. This system is suitable for use with all the analysers described in 5.2. The sampling point and the suction pyrometer shall be as described in the test methods detailed in the European Standard appropriate to the appliance being tested.

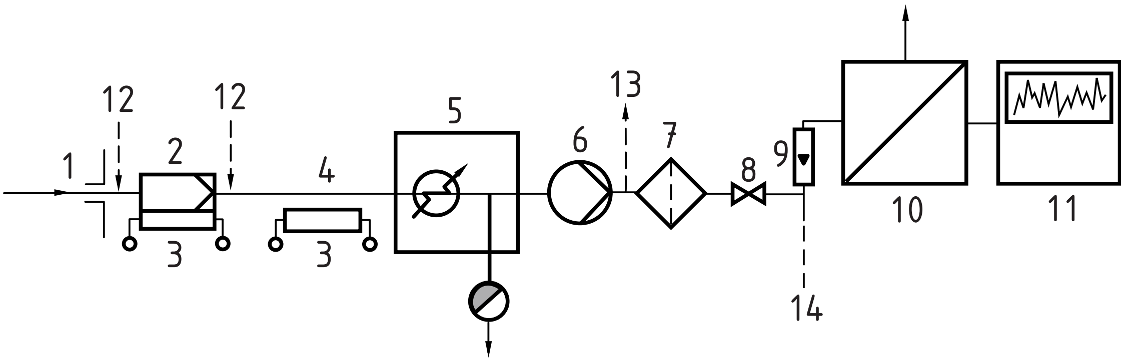


Figure 1a — NO measuring device

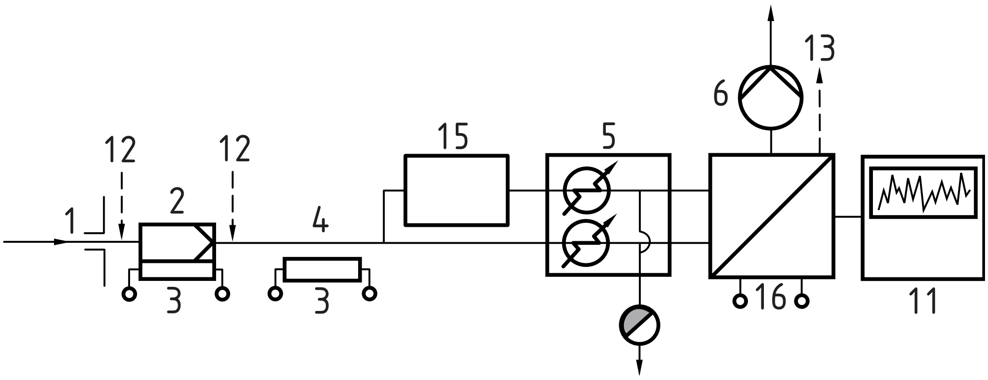


Figure 1b — NO/NO$_x$ measuring device

Key

1 Gas sampling
2 Particulate filter
3 Heating
4 Sampling line (heated if necessary)
5 Sample cooler with condensate separator
6 Sample pump
7 Filter
8 Needle valve
9 Flow meter
10 NO-analyser
11 Recorder
12 Inlet for zero and calibration gas (preferably in front of the filter) to check the complete system
13 Bypass for excess gas
14 inlet for zero and span gas to check the analyser
15 Converter
16 NO/NOx analyser

Figures 1A and 1B — Examples of the installation of the measuring devices

5.2 Measuring principles of analysers

NOTE The examples detailed in 5.2.1 to 5.2.3 describe typical principles found in existing analysers.

5.2.1 Chemiluminescence method

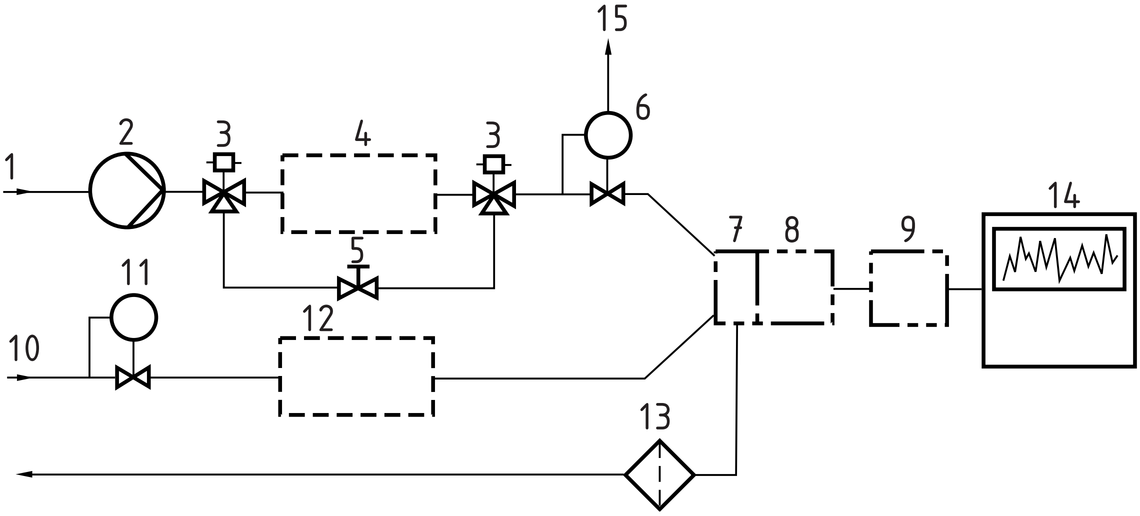
If NO reacts with ozone (O_3), NO_2 is formed. Part of the NO_2 is in a photochemical reaction state. When returning to the basic state, these NO_2 molecules can radiate light in the wavelength range of 590 nm to 3 000 nm. The intensity of this light depends on the NO content and is influenced by the pressure and presence of other gases.

The content of NO in the gas sample is determined by the measurement of the intensity of the radiated light.

Interference due to carbon dioxide (CO_2) in the sample gas is possible, particularly in the presence of water vapour, due to the quenching of the chemiluminscence. The extent of the quenching depends on the CO_2 and H_2O concentrations and on the type of analyser used. Any necessary corrections shall be made to the analyser output either by reference to correction curves supplied by the manufacturers or by a calibration of the gases which contain approximately the same concentration of CO_2 as the sample gas.

The measuring range of chemiluminescence analysers used for emission measurements extends from 10 mg/m^3 to 20 000 mg/m^3.

Figure 2 shows an example for the basic arrangement: there are atmospheric pressure and low pressure analysers depending on the pressure in the reaction chamber. Some analysers have built-in NO_2/NO converters and owing to their structure, give signals for NO, NO_x, and NO_2 either simultaneously or in sequence.



Key

1	Sample inlet	9	Electronics
2	Sample pump	10	Oxygen inlet
3	Magnetic valve	11	Pressure regulator
4	NO_2/NO converter	12	Ozone regulator
5	Flow regulator	13	Ozone inlet
6	Pressure regulator	14	Signal
7	Reaction chamber	15	Bypass
8	Photomultiplier		

Figure 2 — Example for an arrangement of a chemiluminescence analyser

5.2.2 Non-dispersive infrared (NDIR) method

The most common application of the IR method are analysers working according to the NDIR method (see Figure 3). Gases, which consist of molecules of different atoms, absorb light of the characteristic wavelength in the infrared spectral region. With the NDIR method, spectral analysis of the IR radiation is omitted and the total absorption of the NO molecule at v_{max} = 1.876 cm^{-1} (= 5,3 µm) is used for the measurement.

The radiation emitted from the IR source is divided into two beams and then modulated: one beam passes through the measuring cell, the other through the reference cell containing an IR inactive gas, usually nitrogen. If the sample gas contains NO, some of the IR energy is absorbed and the difference in IR energy reaching the detector is proportional to the amount of NO present. The detector is designed to be sensitive only to the NO-specific wavelengths. A special arrangement of the NDIR method is the gas filter correlation method. Interference is possible, particularly with water vapour.

5.2.3 Other methods

Beside the two methods mentioned in 5.2.1 and 5.2.2 above, there are the Non-dispersive ultraviolet (NDUV) method and the Non-extractive (in situ) method. These methods are described in detail by ISO 10849:1996.

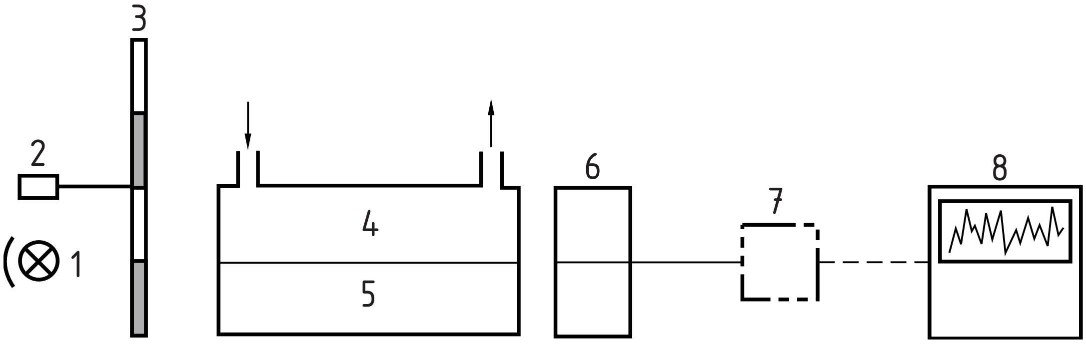
5.3 Calculation method

The measured mean NO content (NO_{avg}) shall be converted to a NO_2-content value based on a standardised oxygen content of 13 % in the flue gas according to the following equation:

$$NO_{2content} = NO_{avg} \times \frac{21 - O_{2s\tan dardizes}}{(21 - O_{2avg})} \times d_{NO_2} \qquad (5)$$

where

$NO_{2content}$	is the NO2 content calculated to the standard oxygen content of 13 %;
NO_{avg}	is measured mean content of NO in the dry flue gas in %;
d_{NO2}	density of NO_2 at 13 % oxygen content in kg/m^3_n [$\Rightarrow$ 2,05 kg/m^3_n];
$O_{2standardised}$	is the standardised oxygen content which is taken as 13%;
O_{2avg}	is the measured mean content of oxygen in the dry flue gas in %.



Key

1	Light source	5	Reference cell
2	Chopper motor	6	Detector
3	Chopper wheel	7	Electronics
4	Measuring cell	8	Signal

Figure 3 — Example of a typical NDIR analyser

Annex A
(informative)

NOTE This Informative Annex contains three different methods that coincide respectively with the combined Austrian and German method, the Norwegian method and the UK method currently called up in National Legislation in these countries. For a full description of a particular method reference may have to be made to the relevant National Standard.

A.1 Austrian and German particle test methods

A.1.1 General

Particulate emissions are measured during type testing according to EN 13240:2001 A.4.7, EN 13229:2001 A.4.7 and EN 12815:2001 A.4.9 (nominal heat output test) parallel to CO measurement.

The measurement position for particle measurement is arranged upstream of measurement positions of CO, CO_2, NO_x and C_nH_m. Measurement of particulate emissions have to be started 3 minutes after the fuel load is added.

The duration of measurement is 30 minutes.

A.1.2 Dust measuring equipment

The measuring arrangement is illustrated in Figure A.1. The sampling tube with a diameter of 8 mm widens out to 9,74 mm at the specimen inlet.

The sampling equipment shall be designed so that in a sampling period of 30 minutes a waste gas volume of 270 ± 13,5 litres relative to normal conditions (273 K, 1013 hPa) is extracted. During the sampling, it shall be possible to control the volume flow by means of a volume flow measurement.

The sampling probes shall be designed for flue gas temperatures of 325 °C and a waste gas speed of approx. 4 m/s at 1013 Pa under the conditions described above.

NOTE In the interests of simplifying the measuring method, individual measurement of the flow velocity and subsequent matching of the inlet cross-section are dispensed with. In order to carry out the measurement, the sampling probe is centred in the exhaust-gas cross-section, using a threaded cone.

The attachment for the filter sleeve shall be designed so that the filter cannot be damaged during handling and structurally attached to exclude the possibility of dust entering the pump unit. The measuring filter is inserted in a filter holder at the end of the sampling probe.

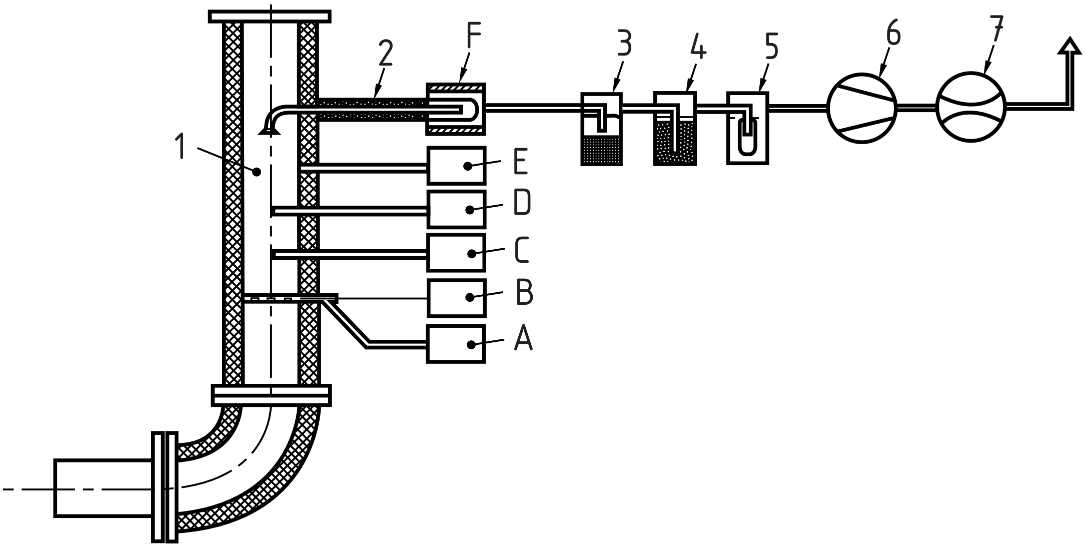
The sampling system shall be designed so that a controlled probe heating system excludes the possibility of falling below the dew point in front of or in the filter sleeve. Here, the temperature in the sleeve area shall be maintained at a constant 70 °C, under sampling conditions.

In the event of the waste gas inlet temperature exceeding a value of 225 °C, a cooling apparatus shall be provided to ensure that a temperature of 70 °C is maintained in the sleeve area. The design of the cooler shall not have any negative influences on the result of the measurement.

Suitable measures shall be employed to protect the pump and the volume flow control or limiting device against the action of dust and accumulated condensate.

Taking the complete measuring procedure into account, in the concentration range of the dust limit value of 0,15 g/m^3, the measuring system shall be able to guarantee that the results of the measurement will have a resolution of ± 0,03 g/m^3.

The mechanical stability of the dust collecting sleeve shall be retained even at temperatures of 160 °C and the collecting sleeves shall not suffer mass losses greater than 2 mg.



Key

1 measurement section
2 gas sampling probe and line for particles measurement (heat-insulated)
3 water separator
4 silica gel filter
5 superfine filter
6 pump
7 gas flow meter
A CO_2 and CO measurement
B Flue gas temperature t_a measurement
C NO_x measurement
D C_nH_m measurement
E Flue Draught measurement
F Particles filter (off-line gravimetric measurement)

Figure A.1 — Measurement section (including NO_x, C_nH_m, Particles measurement)

A.2 Norwegian particle test methods

NOTE The Norwegian Pollution Authority (SFT) has done several investigations in different areas in Norway of the air pollutions. They have found that wood stoves are one of the greatest contributors to air pollutions. Numbers from SSB (Statistisk sentralbyrå) says that 65 % of the particles (PM_{10}) are emissions from wood combustion in Norway. SFT has given the National Office of Building Technology and Administration the authority to give requirements for particle emission from appliances fired by solid fuel. The Norwegian legislation for particle emission is given in the Building Regulations. The legislation is connected to the standard NS 3059 *Enclosed wood heaters — Smoke emission — Requirements*.

NS 3059 tells how to calculate the reported particle emission based upon 4 runs in accordance to NS 3058, part 1 and 2. *NS 3058-1 Enclosed wood heaters — Smoke emission — Part 1: Test facility and heating pattern* gives detailed restrictions how to prepare and run the test and NS 3058-2 *Enclosed wood heaters — Smoke emission — Part 2: Determination of particulate emission* gives detailed restrictions how to prepare and do particle emission measurements when firing in accordance to NS 3058-1.

A.2.1 The test methods for particle emissions

Appliances for solid fuel are tested with natural draft with dilution tunnel and sampling on a plane filter with porosity of 1 μm.

The test fuel shall consist of air-dried spruce with dimension 49 × 49 mm and moisture between 16 to 20 % on wet basis. The distance between the logs shall be 10 mm (see Figure A.2). The fuel charge density shall be between 101 to 123 kg/m^3 of burning chamber volume.

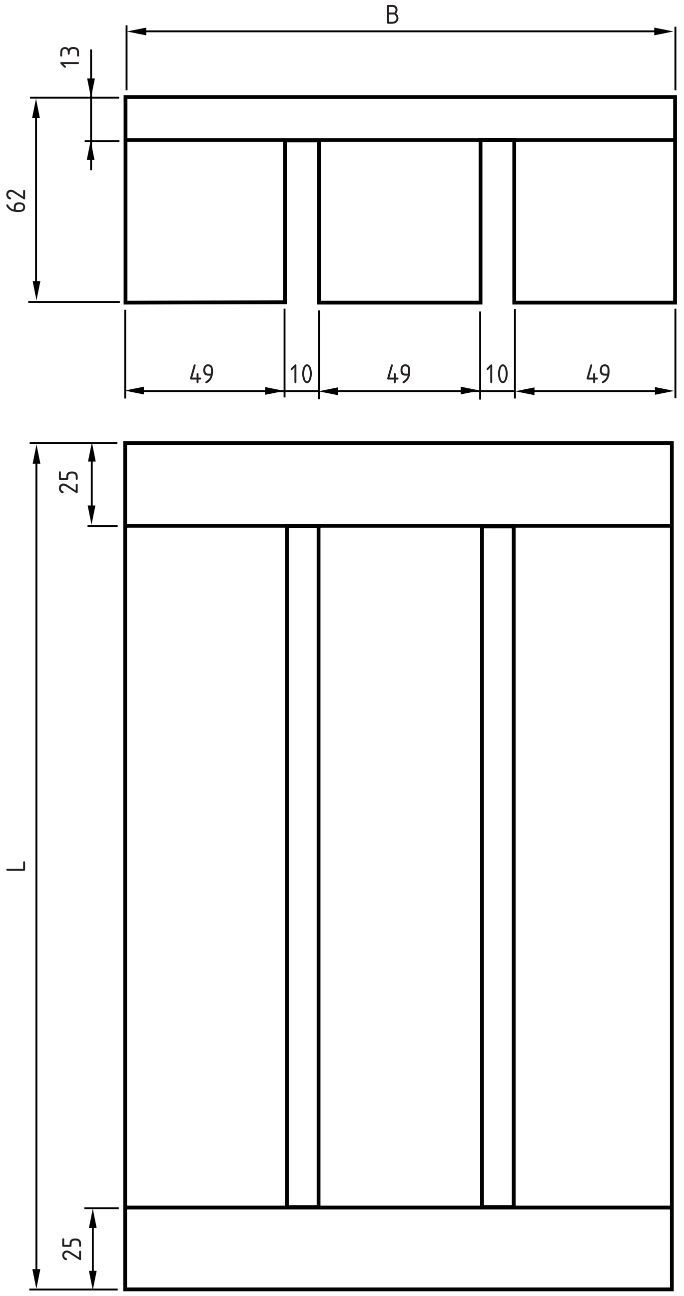


Figure A.2 — Test fuel, arrangements and dimensions

The burning rate is not given by the producer but is fixed in four burning categories, see Table A.1 below.

Table A.1 — Burn rate categories (average burn rate in kg/h)

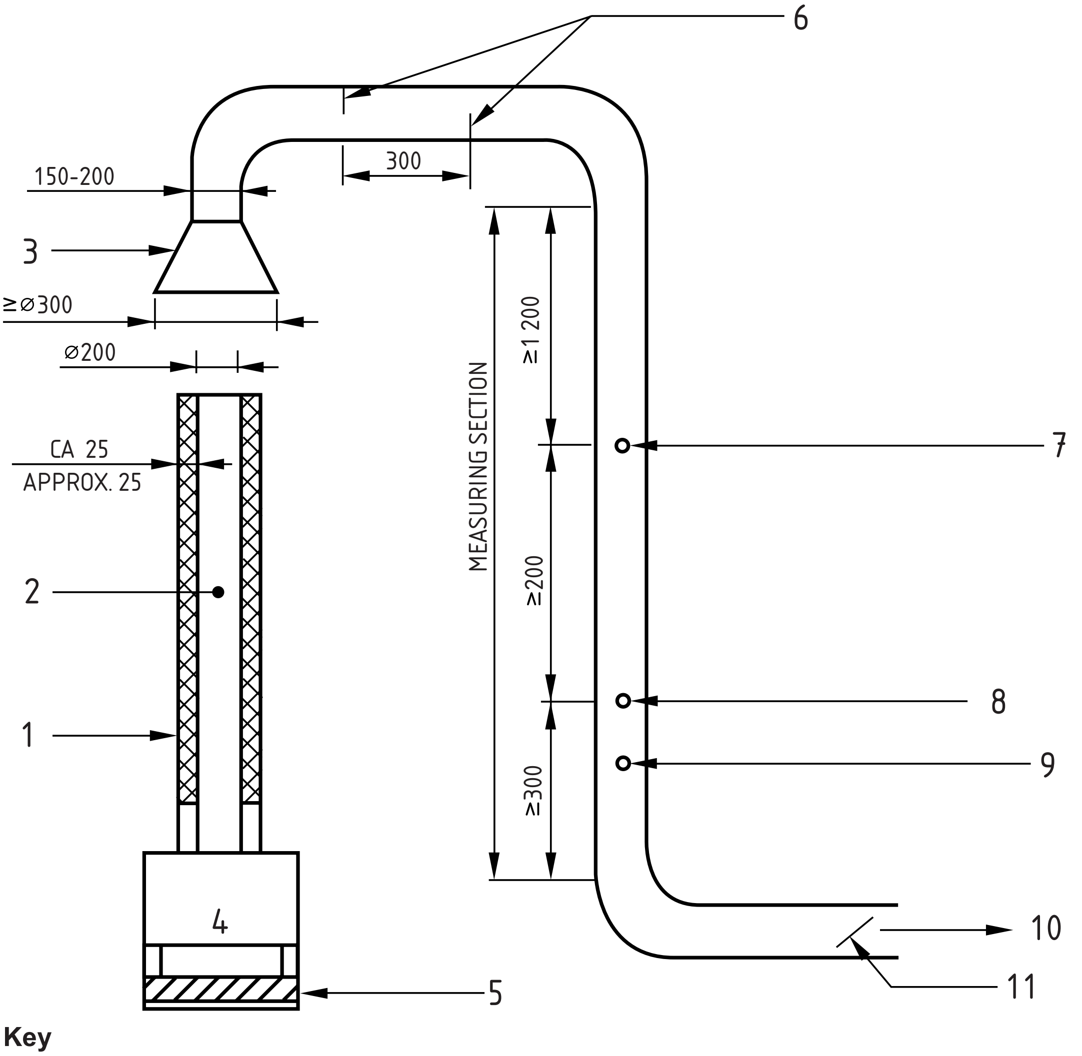
	Burn rate category 1	Burn rate category 2	Burn rate category 3	Burn rate category 4
Grade 1	< 0,80	0,80-1,25	1,26-1,90	>1,90
Grade 2	< 1,25	1,25-1,90	1,91-2,80	>2,80

Grade 1 is meant for heating of small rooms and grade 2 for heating of larger rooms. The particulate emission is measured isokinetic in a dilution tunnel (see Figure A.3).

The test runs are done from preheated wood heater and the average value of surface temperatures can differ up to 70 °C from start to end of the test run, but not higher. The result is calculated as gram emission per kilogram of fuel on dry basis (g/kg).

The reported emission value is calculated in accordance to NS 3059 based upon 4 runs.

All dimensions in milimeters



Key

1	Insulation	7	Velocity measurement
2	Chimney	8	Particulates and PAH measurement
3	H000	9	CO and CO_2 measurement
4	Heater	10	Probe
5	Weight	11	Damper
6	Mixing baffles		

Figure A.3 — Dilution tunnel with wood heater and chimney

A.3 UK particle test methods

A.3.1 Background to legislation and basis of testing

The need for a 'British Standard Smoke Test' for solid fuels arose from the implementation of the Clean Air Act of 1956 [1], which was introduced to control air pollution in the United Kingdom. The Clean Air Act 1956 was subsequently modified and extended by the Clean Air Act 1968 and both have currently been consolidated into the Clean Air Act 1933 (c11). This act lays down legislative requirements regarding emissions from solid fuels and solid fuel fired appliances in the UK. Under the Clean Air Act local authorities are empowered, subject to confirmation by the Minister, to set up smoke control in which it is an offence to emit smoke from a building.

Section 1 (1) of the UK 1993 Clean Air Act states "Dark smoke shall not be emitted from a chimney of any building, and if, on any day, dark smoke is so emitted, the occupier of the building shall be guilty of an offence." The 1993 Act in Section 20(4) (prohibition of smoke emissions in smoke control area) states "...it shall be a defence to prove that the alleged emission of smoke was not caused by the use of any fuel other than a *Authorized Fuel*."

Additionally, Section 21 of the 1993 Act states "The Secretary of State may by order exempt any class of fireplace, upon such conditions as he may specify in the order, from the provisions of Section 20 (prohibition of smoke emissions in smoke control area), if he is satisfied that such fireplaces can be used for burning fuel other an authorised fuels without producing any smoke or a substantial quantity of smoke." Thus the only defences against prosecution under the Act are that the smoke is produced from an *Authorized Fuel*, that authorised fuels are not available or that the smoke is from an *Exempted Fireplace*.

Smoke, in Section 34(1) of the Clean Air Act 1956 (now Section 64(1) in the 1993 Act) is defined as 'including soot, ash, grit and gritty particles emitted in smoke'. This definition was modified by the 1968 Act; by the inclusion of fume. To assist in implementing the legislation and to develop a standard test procedure, a small electrostatic precipitator was developed in the early 1960's to measure domestic smoke emission under laboratory conditions (see section A.3.4 below for further detail). The investigations led to the formulation of the test method for manufactured smokeless fuels detailed in BS 3841-1:1994 *Determination of smoke emission from manufactured solid fuels for domestic use Part 1 General method for determination of smoke emission rate* and BS 3841-2:1994 *Determination of smoke emission from manufactured solid fuels for domestic use Part 2 Methods for measuring the smoke emission rate* which together with BS PD 6434:1969 *Recommendations for the Design and the Testing of Smoke Reducing Solid Fuel Burning Domestic Appliances* enabled realistic standards to be set for permitted levels of smoke emission in Smoke Control Areas.

NOTE BS 3841 — Part 2:1994 now gives a specification of a sampling method in a dilution tunnel as an alternative to the preferred electrostatic precipitator method (see section A.3.4 below for further detail).

In assessing an *Authorised Fuel* the Minister as stated that one of the conditions to be satisfied is that the fuel when tested in an open fire in accordance with BS 3841 shall not emit more than 5 g/h of solid particle matter. Once authorised by the Secretary of State the fuel may than be burned in any domestic heating appliance without further assessment of its use on a specific appliance.

In assessing a domestic fireplace (e.g. stove, room heater or boiler etc.) for exemption (an *Exempted Fireplace*) the tests and emission guidelines of BS PD 6434 are employed and cover the measurements and evaluation of the desirable limits of emissions of solid particles at high, intermediate and low output and under conditions of misuse to ensure compliance under all possible continuously operating conditions and outputs.

A.3.2 Measurement of smoke emission from Fuels: summary of the BS 3841 Test Procedure

A.3.2.1 Summary of the BS 3841 Test Procedure

The procedure for authorisation of a solid fuel is now well established. When a new solid smokeless fuel intended for use in a smoke control area has been developed, application is made to the government department responsible, DEFRA Air Quality Division, for authorisation as a smokeless fuel. At this stage the smoke emission characteristics of a representative sample of the fuel would be determined in accordance with the procedure described in BS 3841 Parts 1 and 2 by an independent Testing Station.

BS 3841 requires the fuel to be burned on a typical UK design of inset open fire, without a boiler, installed in accordance with British Standard Codes of Practice beneath a 4.6 m high test chimney. The open fire is fitted with a specially designed air inlet plate to enable fine adjustment of the primary air opening between one test and another.

Smoke is measured with the electrostatic precipitator and the radiation output from the fire is measured with an instrument known as the BCURA quadrant cage radiometer, which is widely used in the UK for domestic solid fuel appliance testing.

The firing cycle consists of an ignition period and two refuel periods (three refuel periods for fuels of low bulk density). Smoke is measured during the refuel periods only and not during the ignition period.

The aim of the BS 3841 test is to measure the smoke emission with the primary air opening adjusted to give an average radiation output over the refuel periods of approximately 1.75 kW, a value typical of UK domestic usage with an open fire. For experimental convenience, however, test limits are set in terms of the peak in radiation output in the first refuel period.

The criteria for refuelling the fire, in terms of both the amount of fuel added and the radiation output when the refuels are made, are also typical of domestic usage.

For ignition, a mass of fuel corresponding to 7 dm^3 (0.25 ft^3) is lit by an integral gas burner.

The radiation output rises to the first peak then falls, and the precipitator is weighed and put in position shortly before the first refuel is due. When the radiation output has fallen to 1.47 kW, a refuel charge of mass corresponding to 5 dm^3 (l/6 ft^3) is added and the high voltage is applied to the precipitator. The radiation rises to a second peak which must be between the specified limits of 1.9 kW to 2.2 kW and, when it falls again to 1.47 kW, a second refuel charge equivalent to 5 dm^3 is added. The test period ends when the radiation output has risen to a third peak then fallen again to 1.47 kW (or after a third refuel period, if the fuel has a bulk density of less than 480 kg/m^3). The high voltage supply is then turned off and the precipitator is removed and weighed again. The mass of the smoke in grams is obtained from the gain in weight of the precipitator.

A.3.2.2 Evaluation of BS 3841 Results

The smoke emission is expressed in grams per hour, averaged over the duration of the test period. The mean result of replicate determinations is compared with the maximum emission limit of 5 g/h for a fuel to be declared by the regulations of the Minister as an authorised fuel. In addition DEFRA would also require a specification of the fuel and would recommend that the total sulphur content of the fuel should not exceed 2.0 % 'dry basis'. They would also expect some form of quality control checks to ensure the original specification is maintained during continued production.

A.3.3 Measurement of Smoke Emission from a Smoke Reducing Appliance

A.3.3.1 Basis of test procedure

The principles for the testing of appliances for smoke emission are given in BS document PD 6434 which deals with ‘Recommendations for the Design and Testing of Smoke Reducing Solid Fuel Burning Domestic Appliances’. Whilst PD 6434 gives guidance on appliances which are designed primarily to burn bituminous coal with reduced smoke emission, it acknowledges that there is no reason why appliances designed to burn other solid fuels, such as wood or peat, should not be considered. The recommendations in the document have been deliberately phrased to present the principles of testing and design as broadly as possible, supplemented by guidance notes where necessary.

It is usual for a representative sample of the appliance to be examined on behalf of DEFRA by an independent Testing Station whose responsibility is to agree and carry out a series of tests, within the framework of the basic principles of PD 6434, and which are adequate to establish the capabilities of the appliance with respect to smoke reduction.

PD 6434 adopts the BS 3841 electrostatic precipitator method of smoke collection and measurement but the refuelling interval and firing procedure for fuels is replaced by the refuelling and firing procedure given in the relevant Standard Specification against which the thermal performance and efficiency of the appliance is assessed in accordance with the manufacturer’s declared heat output and the appliance’s operating instructions. Whilst the smoke is collected and measured by means of an electrostatic precipitator the optical density of the smoke is also monitored by a suitable form of meter, working across the chimney.

PD 6434 tests are carried out with the appliance being operated in accordance with the manufacturer's instructions at high (rated) output and at the low end of its output range. If necessary tests are also made at one or more intermediate levels of output to check that the smoke is within the recommendations of the PD 6434 standard over the full range of performance of the appliance.

In general five repeat tests are carried out under each output condition and the emission is again expressed in grams per hour averaged over each test period. The heat output from the appliance over the test period is also measured and the average is reported in kW. If the tests confirm that the appliance can operate continuously without undue trouble to the user, and is likely to be so operated, then ignition smoke is ignored.

In addition to the smoke emission tests described above, PD 6434 recommends that checks are made to establish the extent to which the smoke-reducing characteristics of the appliance depend intrinsically on the design rather than on the way in which it is operated.

These checks involve the Test Station in carrying out misuse tests to find the effect of diverging from the manufacturer's operating instructions, which some householders might be expected to adopt, having regard to the particular form which the appliance controls assume. The tests will vary depending upon the nature and operation of the appliance.

However some typical conditions which represent misuse would be:

I. firebed not de-ashed before refuelling;

II. refuelling on to a low firebed;

III. refuelling door closed but not secured;

IV. ashpit door/cover not on properly.

Each type of misuse test is generally carried out in duplicate using the test fuel that gave the highest smoke emission under normal operation.

A.3.3.2 Evaluation of PD 6434 Results

PD 6434 recommends standards against which the performance of the appliance should be assessed in the main tests, i.e. those made under the conditions of operation recommended by the manufacturer (rated output, low output etc).

For each of the mean values obtained from the five repeat tests the mean smoke emission should not exceed 0.1 g/h for each 0.3 kW of the corresponding mean heat output plus 5.0 g/h.

It is also recommended that no individual smoke measurement in each set of five should be more than 50 % greater than the permitted mean result for the set; any such result will be reported separately as well as being included in the calculated mean.

The optical density of the smoke, as recorded throughout each test, is examined to check that, in addition to the average rate of smoke emission being within acceptable limits, the emission over short periods, for example at the times of refuelling or de-ashing, does not reach objectionably high levels.

It should be borne in mind that the standards given in PD 6434 are regarded as desirable limits of smoke emission, but failure to comply with them in all respects does not necessarily constitute an automatic reason for the rejection of the appliance. Each case is judged by DEFRA on its merits, due consideration being given to any significant contribution the appliance might make to clean air.

In general, if an appliance is found to have some 'good' and some 'bad' features in its performance, it will be necessary for the Testing Station to submit to DEFRA the best assessment it can of the overall merits of the design.

NOTE Whether comparing different fuels by BS 3841 or different appliances by PD 6434 it should be noted that the grams per hour basis at a particular heat output is regarded to be better for assessing pollution than expressing the smoke emission as a percentage of the weight of fuel burned and comparing values at similar burning rates, as it makes due allowance for variations in calorific-value and thermal efficiency.

In addition to and to complement the laboratory tests it is usual practice for a DEFRA representative to visit site installations to observe the smoke emission from the appliance operating in the 'field' under a range of running conditions. Bearing in mind the laboratory test results and their observations of the appliance operating in the 'field' DEFRA would judge whether to recommend exemption of the appliance to the Minister.

A.3.4 Brief summary of BS 3841 smoke measurement apparatus

A.3.4.1 Electrostatic Precipitator

Figure A.4 shows the general arrangement of the electrostatic precipitator and Figure A.5 shows the electrostatic precipitator in position at the top of a chimney developed for domestic-smoke measurement. The mass of smoke collected is determined by weighing the precipitator on a suitable balance at the beginning and end of a test period.

The precipitator was preferred to alternative methods of smoke measurement as it collected the particulate matter from the total volume of the flue gas produced during the test, has a high collection efficiency for small particles, has a low resistance to flow and obviates sampling errors.

The electrostatic precipitator is approximately 640 mm high and 360 mm in diameter and weighs approximately 8.5 kg. It is made up essentially of a honeycomb of 85 hexagonal aluminium alloy tubes, giving a large area for smoke collection, with a stainless steel wire down the centre of each tube. When a voltage of 7 kV to 8 kV is applied to the frames which support the wires, there is a ‘corona' discharge of electrons from the wires to the earthed tubes. The electrons charge the smoke particles, which then drift in the electrical field towards the tube surface, where the smoke is retained. Various ancillary equipment is required for use with the precipitator, including an EHT supply unit and either a 'hot room' or large drums containing silica gel for storing the precipitators and minimising moisture absorption.

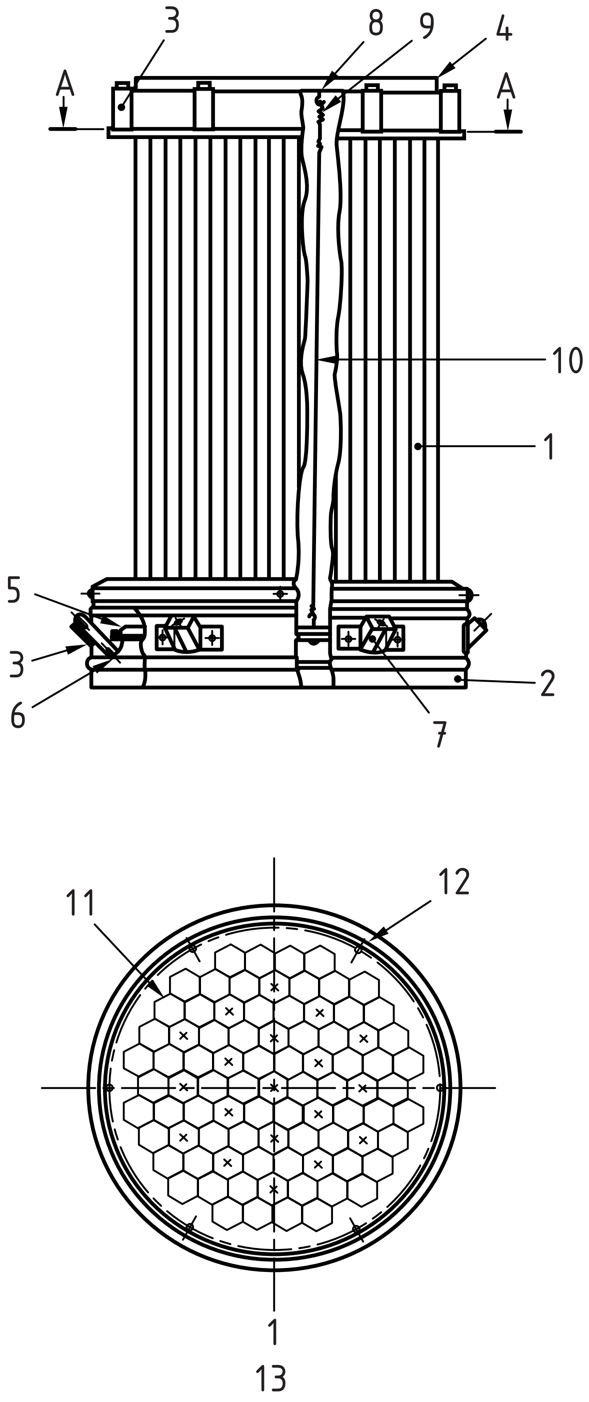
After use the precipitator is cleaned by firstly removing loose particulate matter by means of a high pressure water lance and then by immersion in a bath containing dichloromethane with a water seal. The solvent is then evaporated by heating the precipitator in a well ventilated oven at approx 100 °C. The precipitator is then stored for use either in a drum containing silica gel or else in a 'hot-room' maintained at about 30 °C, to prevent moisture absorption on the precipitator surfaces.

Safety procedures have to be observed in operating the high voltage and in handling the organic solvents.

A.3.4.2 Dilution tunnel

The dilution tunnel method involves sampling isokinetically from a duct above the test chimney. The flue gas from the top of the test chimney is mixed with ambient air in a dilution tunnel. A sample of the diluted gas is withdrawn through the sampling train in which the particulate matter is collected on a glass fibre filter maintained at 70 °C. The mass of particulate matter collected is determined. The smoke emission rate is then calculated in grams per hour using the volume of the gas sampled and the volume flow rate of the tunnel gas.

Figure A.6 shows the general arrangement of the dilution tunnel and sampling train whilst Figure A.7 shows the suggested arrangement of the dilution tunnel filter housing.



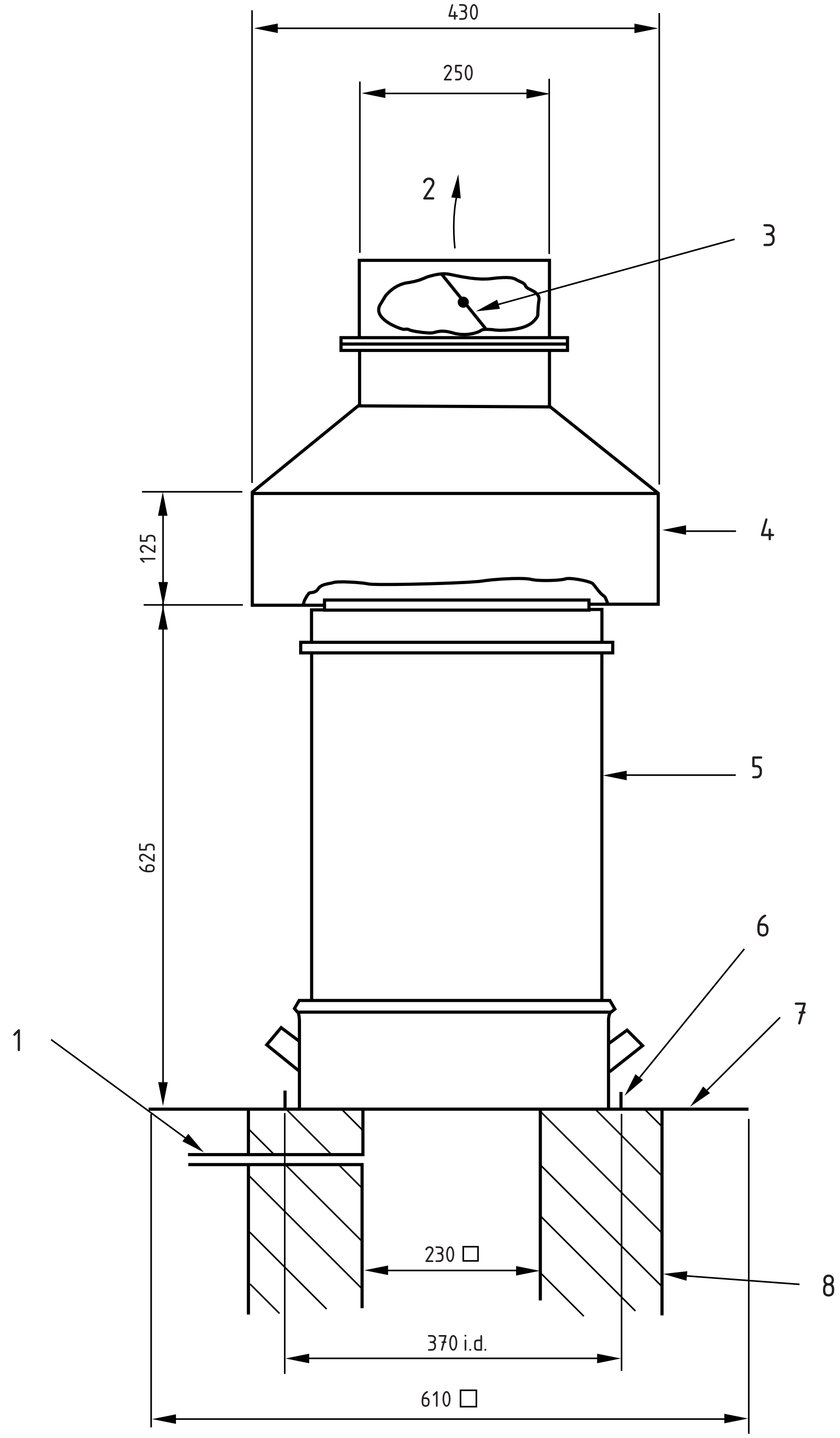
Section A-A

Key

1	Collecting electrodes	8	Suspension hook
2	Skirt	9	Tension spring
3	Insulators	10	Charged electrodes (spring-loaded stainless steel wire)
4	Upper end frame (see figure 2)	11	Main frame made from aluminium alloy hexagonal tubes welded at the ends and to the dished end pieces (66 off)
5	Lower end frame (see figure 2)		
6	Inner mounting bracket	12	6 × 4BA clearance holes equi-spaced on a 314.3 PCD
7	Outer mounting bracket	13	Tubes are omitted from positions marked X

Figure A.4 — General arrangement of electrostatic precipitator

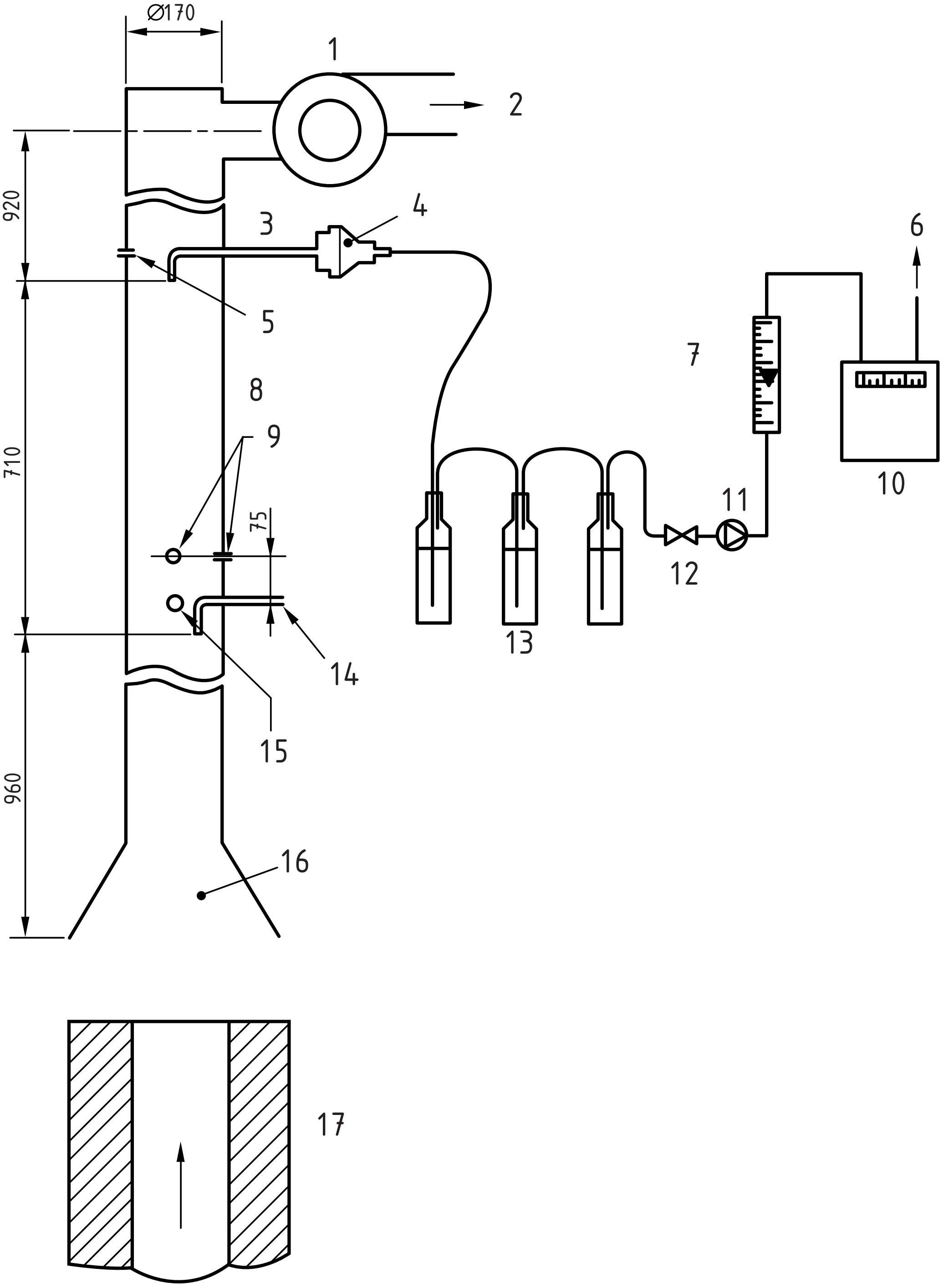
All dimensions are in millimeters



Key

1	Pressure tapping	5	Electrostatic precipitator
2	To fan and outside air	6	Locating ring
3	Draught control damper	7	Base plate of safety cage
4	Hood	8	Chimney

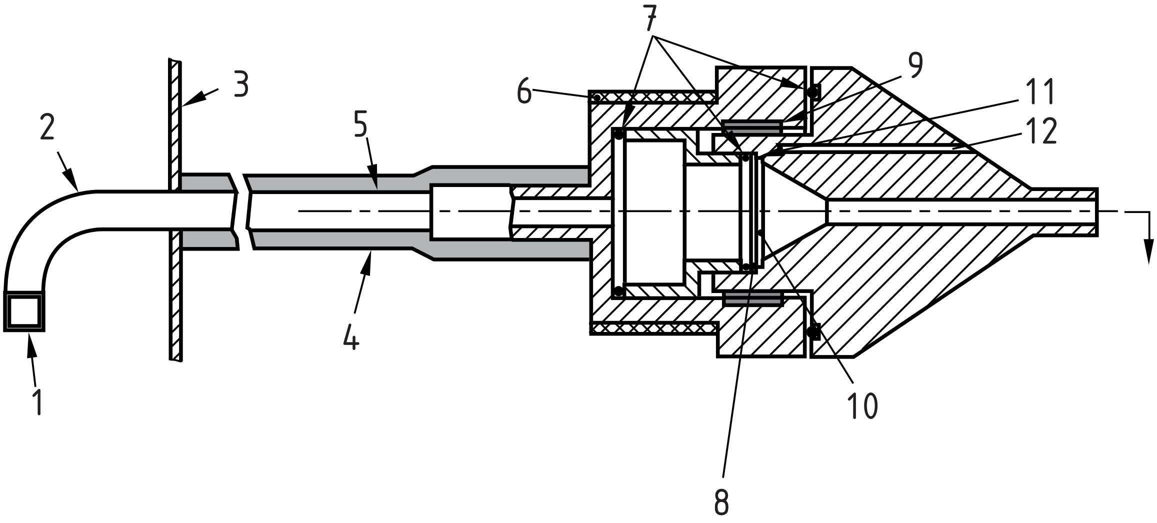
Figure A.5 — Electrostatic precipitator positioned for smoke collection



Key

1	Fan	10	Dry gas meter
2	Exhaust	11	Pump
3	Sampling probe	12	Flow control valve
4	Heated filter housing	13	Dreschel bottles
5	Additional Pitot port	14	Pitot static tube
6	Exhaust	15	Additional pitot port
7	Indicating gas flowmeter	16	Collecting cowl
8	Sampling section	17	Chimney
9	Ports for temperature measuring device		

Figure A.6 — General arrangement of dilution tunnel and sampling train



Key

1	M12 threaded end for nozzle attachment
2	Stainless steel tubing
3	Dilution tunnel wall
4	Insulation
5	Sampling probe
6	Heater band
7	O-ring seals
8	Ø 44 × 1.5 thick perforated support disc with 109 × Ø 2.2 equi-spaced holes on triangular pitch
9	Threaded
10	Ø 47 × 0.4 thick perforated filtered support disc with Ø 0.55 equi-spaced hols on triangular pitch
11	Filter Ø 47
12	Thermocouple

Figure A.7 — Suggested arrangement of dilution tunnel filter housing

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