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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.

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## Contents

Page

Foreword .....	3
Introduction .....	4
1 Scope .....	5
2 Normative references .....	5
3 Terms and definitions .....	5
3.1 Definitions .....	5
4 Emission test methods: measurements of total hydrocarbons (THC) .....	6
4.1 General procedure .....	6
4.2 Equipment .....	7
4.3 Calculation of organic gaseous compounds (OGC) .....	7
4.4 Uncertainty of measurement .....	8
5 Emissions test methods: measurement of nitrogen oxides .....	8
5.1 General procedure .....	8
5.2 Measuring principles of analysers .....	9
5.2.1 Chemiluminescence method .....	9
5.2.2 Non-dispersive infrared (NDIR) method .....	10
5.2.3 Other methods .....	11
5.3 Calculation method .....	11
Annex A (informative) .....	12
A.1 Austrian and German particle test methods .....	12
A.1.1 General .....	12
A.1.2 Dust measuring equipment .....	12
A.2 Norwegian particle test methods .....	13
A.2.1 The test methods for particle emissions .....	14
A.3 UK particle test methods .....	16
A.3.1 Background to legislation and basis of testing .....	16
A.3.2 Measurement of smoke emission from Fuels: summary of the BS 3841 Test Procedure .....	17
A.3.3 Measurement of Smoke Emission from a Smoke Reducing Appliance .....	18
A.3.4 Brief summary of BS 3841 smoke measurement apparatus .....	19
Bibliography .....	25

## 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.

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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<sub>x</sub>, 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<sub>x</sub>, 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<sub>x</sub>, 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 as 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<sup>3</sup> (dry) (at normal condition<sup>1)</sup>) 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<sub>2,m</sub>, CO<sub>2,m</sub>, CO<sub>m</sub> 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<sub>r</sub>).

### 4.3.3 Calculations of organic gaseous compounds

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

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

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

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

where

C<sub>OGC</sub> is the calculated content of organic gaseous compound expressed in mg/Nm<sup>3</sup> dry flue gas at 13 % O<sub>2</sub>;

<sup>1)</sup> 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:

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

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:

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

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  $\pm 10$  % of the measured value. The total uncertainty of the calculated OGC value, according to this instruction, is  $\pm 15$  % 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<sub>2</sub>). 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.

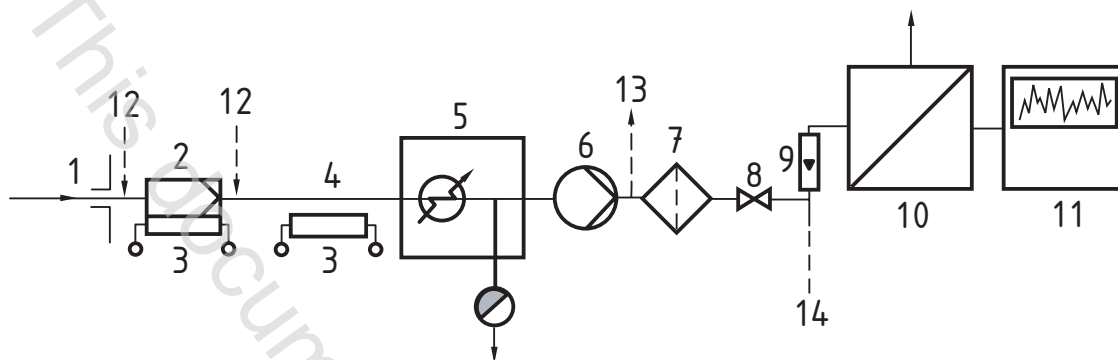


Figure 1a — NO measuring device

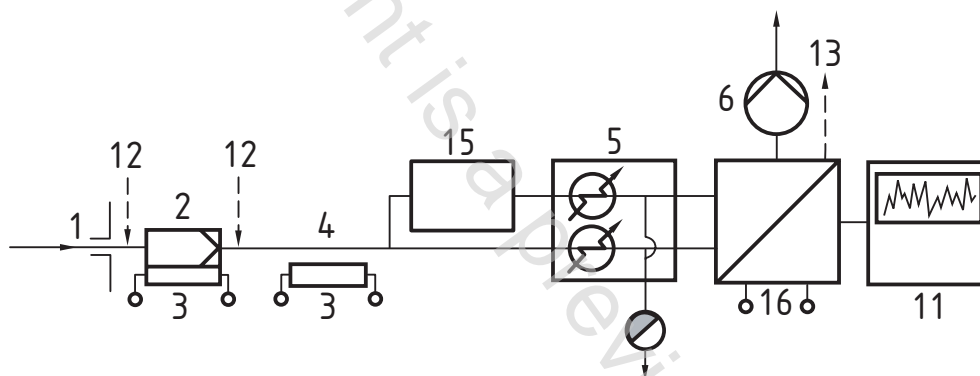


Figure 1b — NO/NO<sub>x</sub> measuring device

#### Key

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

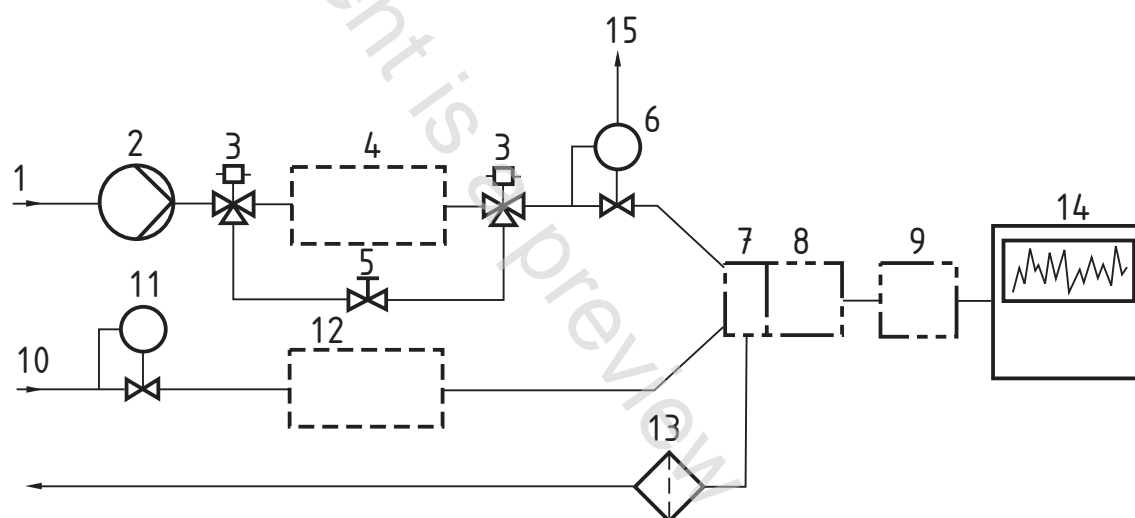
If NO reacts with ozone ( $O_3$ ),  $NO_2$  is formed. Part of the  $NO_2$  is in a photochemical reaction state. When returning to the basic state, these  $NO_2$  molecules can radiate light in the wavelength range of 590 nm to 3 000 nm. The intensity of this light depends on the NO content and is influenced 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<sub>2</sub>) in the sample gas is possible, particularly in the presence of water vapour, due to the quenching of the chemiluminescence. The extent of the quenching depends on the CO<sub>2</sub> and H<sub>2</sub>O 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<sub>2</sub> as the sample gas.

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

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<sub>2</sub>/NO converters and owing to their structure, give signals for NO, NO<sub>x</sub>, and NO<sub>2</sub> 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 <sub>2</sub> /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  $\nu_{\max} = 1.876 \text{ cm}^{-1}$  ( $= 5,3 \text{ }\mu\text{m}$ ) 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.

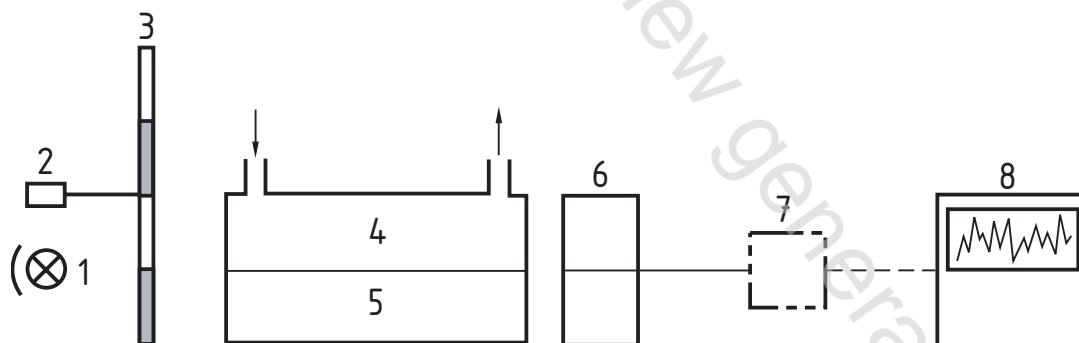
## 5.3 Calculation method

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:

$$NO_{2content} = NO_{avg} \times \frac{21 - O_{2standardised}}{(21 - O_{2avg})} \times d_{NO_2} \quad (5)$$

where

$NO_{2content}$  is the  $NO_2$  content calculated to the standard oxygen content of 13 %;  
 $NO_{avg}$  is measured mean content of NO in the dry flue gas in %;  
 $d_{NO_2}$  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<sub>2</sub>, NO<sub>x</sub> and C<sub>n</sub>H<sub>m</sub>. 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  $270 \pm 13,5$  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.

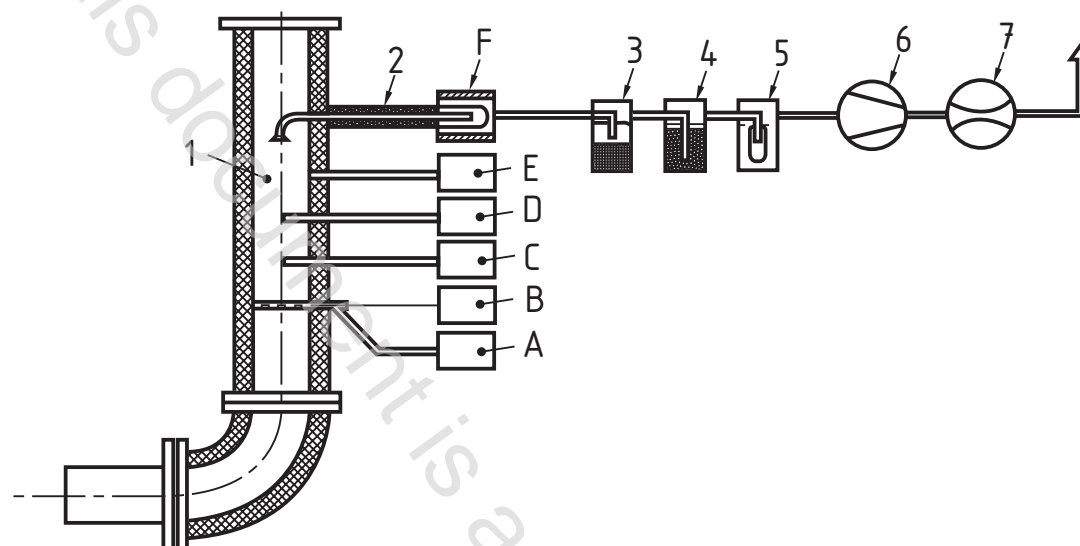
The sampling system shall be designed so that a controlled probe heating system excludes the possibility of falling below the dew point in front of or in the filter sleeve. Here, the temperature in the sleeve area shall be maintained at a constant 70 °C, under sampling conditions.

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  $0,15 \text{ g/m}^3$ , the measuring system shall be able to guarantee that the results of the measurement will have a resolution of  $\pm 0,03 \text{ g/m}^3$ .

The mechanical stability of the dust collecting sleeve shall be retained even at temperatures of  $160^\circ\text{C}$  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  $\text{CO}_2$  and CO measurement
- B Flue gas temperature  $t_a$  measurement
- C  $\text{NO}_x$  measurement
- D  $\text{C}_n\text{H}_m$  measurement
- E Flue Draught measurement
- F Particles filter (off-line gravimetric measurement)

**Figure A.1 — Measurement section (including  $\text{NO}_x$ ,  $\text{C}_n\text{H}_m$ , 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 ( $\text{PM}_{10}$ ) 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