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

UDC 662.62:697.243.3:683.93:662.613.5

Committees responsible for this British Standard

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Association of British Solid Fuel Appliances Manufacturers
British Coal Corporation
British Foundry Association
Department of Health
Department of the Environment (Her Majesty's Inspectorate of Pollution)
Department of Trade and Industry (Warren Spring Laboratory)
Low Temperature Coal Distillers' Association of Great Britain Ltd.
METCOM
Solid Smokeless Fuels Federation

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Contents

Foreword

This Part of BS 3841 has been prepared under the direction of the Solid Mineral Fuels Standards Policy Committee. Together with BS 3841-2:1994 it supersedes BS 3841:1972 which is withdrawn.

The Clean Air Act 1956 [1], modified and extended by the Clean Air Act 1968 [2], was introduced to control air pollution in the United Kingdom.

Under Section 11 of the 1956 Act, local authorities are empowered, subject to confirmation by the Minister, to set up smoke control areas in which it is an offence to emit smoke from a building. The only defences against prosecution under the Act are that the smoke is produced from an authorized fuel, that authorized fuels are not available or that the smoke is from an exempted appliance.

An exempted appliance is defined by Section 11(4) of the 1956 Act as one which can be operated for burning a fuel other than an authorized fuel without producing any smoke or a substantial quantity of smoke.

An authorized fuel is defined in Section 34(1) of the 1956 Act as a fuel declared by regulations of the Minister to be an authorized fuel for the purposes of this Act. In 1956 a number of classes of solid smokeless fuel, both manufactured and natural, which pre-dated the Act were declared to be authorized fuels.

Subsequent development of other types of manufactured smokeless fuel for domestic purposes demonstrated the need for a standard procedure to establish their potential for smoke emission and to assess whether such fuels were suitable for authorization within the terms of the 1956 Act.

For this revision, BS 3841 has been divided into two Parts, Part 1 covering the fuel combustion procedure and Part 2 describing the smoke measurement equipment and its use. The main technical changes from the previous edition are as follows:

a) extension of the test procedure to cover brown coal, lignite, peat and wood fuels;

b) widening of the permitted tolerance in the second radiation peak for valid tests;

c) modification of the refuelling procedure for long briquettes;

d) provision of a suitable aerator to enable the gas ignition burner to burn natural gas;

e) inclusion of the form of test report required;

f) specification of a sampling method in a dilution tunnel as an alternative means of smoke measurement to the electrostatic precipitator;

g) change of organic solvent for cleaning the precipitator;

h) change of procedure for conditioning the precipitator; utilizing a constant temperature room (hot room);

i) inclusion of safety precautions relating to the use of high voltage and of organic solvent in the operation of the precipitator.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 14, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

Introduction

Smoke is defined in Section 34(1) of the Clean Air Act 1956 [1] as "including soot, ash, grit and gritty particles emitted in smoke". This definition is modified by the 1968 Act [2] by the inclusion of fume. None of these terms is precisely defined within the Acts and therefore they are of little technical significance. It is clear from other parts of the Acts and related Statutory Instruments that smoke is to be assessed on the basis of its optical properties: it is often qualified by the use of "dark" or "black". However, assessment of smoke emissions purely on the basis of light obscuration depends on many parameters including the particle size distribution of the emitted particles, their chemical composition and the lighting conditions at the time when the assessment is made (if it is in the open air). Assessment in these purely subjective terms is clearly unsatisfactory. Therefore, BS 3841 describes the gravimetric measurement of the particulate emission rate during a test carried out with the fire at an average radiation heat output chosen to be reasonably representative of normal domestic usage. Subseqently, an emission limit in gravimetric terms of 5 g h was set by the Government.

The current test procedure relates particularly well to solid fuels manufactured from relatively high grade constituents. During recent years there have been many applications for the authorization of lower grade solid fuels such as peat, brown coal and fuels derived from waste materials such as wood waste, straw and paper.

This Part of BS 3841 describes a test procedure to provide the information necessary for a judgement to be made on the suitability of the fuel for classification as an authorized smokeless fuel on the basis of the 5 g/h emission limit and, if necessary, in terms of the concentration of particulate material emitted.

The procedure for authorization 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 Department of the Environment for authorization 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. The average result of replicate determinations is compared with the emission limit.

The method is not suitable as a day-to-day quality control procedure because of its time-consuming nature and the expense incurred. Other procedures which are quicker and easier to carry out but possibly less precise have been developed for quality control purposes. Such methods are not absolute: the relationship between any such method and the reference method described in BS 3841 has to be determined and periodic checks and calibrations have to be carried out for each fuel.

1 Scope

This Part of BS 3841 describes a general method of carrying out a smoke emission test from a sample of a manufactured solid fuel intended for use in domestic fires.

2 References

2.1 Normative references

This Part of BS 3841 incorporates, by dated or undated reference, provisions from other publications. These normative references are made at the appropriate places in the text and the cited publications are listed on the inside back cover. For dated references, only the edition cited applies; any subsequent amendments to or revisions of the cited publication apply to this Part of BS 3841 only when incorporated in the reference by amendment or revision. For undated references, the latest edition of the cited publication applies, together with any amendments.

2.2 Informative references

This Part of BS 3841 refers to other publications that provide information or guidance. Editions of these publications current at the time of issue of this standard are listed on the inside back cover, but reference should be made to the latest editions.

3 Definitions

For the purposes of this Part of BS 3841 the definitions given in BS 1846-1:1968, BS 6100-1.5.1:1984 and BS 3323:1992 apply.

4 Principle

A specified ignition charge of the prepared fuel, the mass depending upon its bulk density, is charged into a standard design of open fire setting and ignited with gas. As the fuel burns the radiation heat output rises to a maximum (the first radiation peak) and then starts to drop. When it has fallen to a specified level a refuelling charge, again the mass depending upon the bulk density of the fuel, is added. The radiation heat output again rises to a maximum (the second radiation peak) and then starts to drop. The setting of the air control system of the fire is adjusted so that the value of the second radiation peak falls within the range 1.80 kW to 2.30 kW.

When the radiation heat output has fallen to a specified level after the second radiation peak a second refuelling charge, equal in mass to the first, is added to the fire. If the bulk density of the fuel is below 480 kg/m^3, a third refuelling charge, of the same mass as the first and second, is added after the radiation heat output has fallen to a specified level after the third radiation peak.

The mass of smoke emitted during the burning of the two, or three, refuelling charges is determined by one of the methods described in BS 3841-2 or by any other method which has been demonstrated to give equivalent results. The duration of the test period is taken as the time interval between the addition of the first refuelling charge and the falling of the radiation heat output to the level which is specified for refuelling, after the third or fourth radiation peak (depending upon whether there have been two or three refuelling charges). The result is expressed as the mass of smoke emitted per unit time, averaged over the duration of the test period.

NOTE Further information on the basis of the test method is given in Annex A.

5 Apparatus

5.1 *Smoke measurement equipment*, as required for the method of measurement of smoke emission rate (see **10.3.3**).

5.2 *BCURA (British Coal Utilization Research Association) quadrant radiometer*[1)], for measuring the radiation heat output from the fire. The radiometer shall consist of the upper section of a hemispherical cage fitted with a matched set of radiometer elements. The calibration factor *F*, in kilowatts per millivolt, is initially provided by the supplier of the radiometer and shall be redetermined at intervals not exceeding 24 months.

5.3 *Balance*, for weighing the fuel, with a capacity of at least 10 kg and an accuracy of ± 0.01 kg.

5.4 *Calibrated dry gas meter,* for measuring the total volume of gas supplied to the ignition burner, with an accuracy of ± 0.1 dm^3. The calibration shall be traceable to national standards and shall be carried out under the pressure conditions of the test.

5.5 *Indicating gas flowmeter,* for checking the rate of flow of gas supplied to the ignition burner, with a range of 0.04 dm^3/s to 0.4 dm^3/s.

5.6 *Manometer,* for measuring the pressure of the gas supply to the ignition burner, with a range covering 0 kPa to 2.5 kPa and an accuracy of ± 0.0025 kPa.

5.7 *Thermocouple or other temperature measurement device,* for measuring the temperature of the gas supply to the ignition burner, with a calibration traceable to national standards.

5.8 *Poker,* for de-ashing the fire, with a diameter of not more than 10 mm at the end which is inserted into the fire.

5.9 *Timing device,* accurate to within ± 1 s over the duration of the test.

6 Test chimney and setting

6.1 Test chimney

The test chimney shall be constructed in accordance with Figure 1. The chimney shall terminate within the test laboratory at a height of 4 570 mm ± 25 mm above finished hearth level.

An extraction system shall be provided for collecting the flue gas from the top of the chimney and discharging it to outside air.

NOTE The design of the system depends on the method of smoke measurement: the arrangements when using the electrostatic precipitator and dilution tunnel methods are described in **3.2.1** and **4.2.11** respectively of BS 3841-2:1994.

6.2 Test setting

The test setting shall be constructed as shown in Figure 2. The fireback shall conform to BS 1251:1987.

NOTE 1 The number of parts of the fireback is left to individual choice.

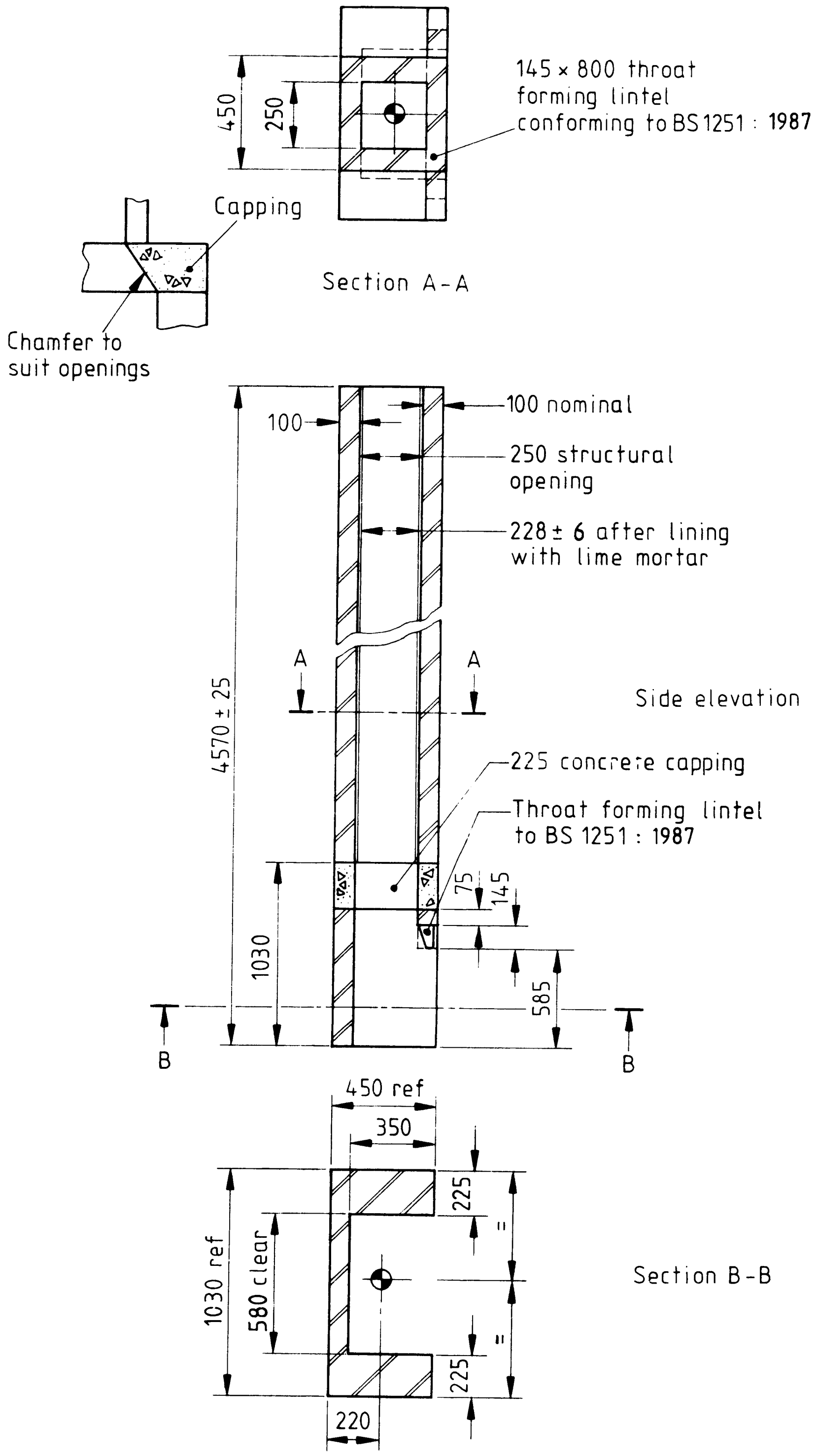
The rear surface of the throat shall be formed above the fireback in the manner shown in Figure 2, i.e. without a smoke shelf. The line of the upper surface of the fireback shall be followed for approximately 100 mm and the throat then sloped off at an angle of approximately 45° to meet the brickwork at the rear of the chimney, yielding a throat width of approximately 115 mm.

[1)] For information on the availability of BCURA radiometers and calibrated radiometer elements write to Customer Services, Information, BSI, Linford Wood, Milton Keynes MK14 6LE.

NOTE 2 This may be done by the use of either brick with a lime mortar lining or precast concrete.

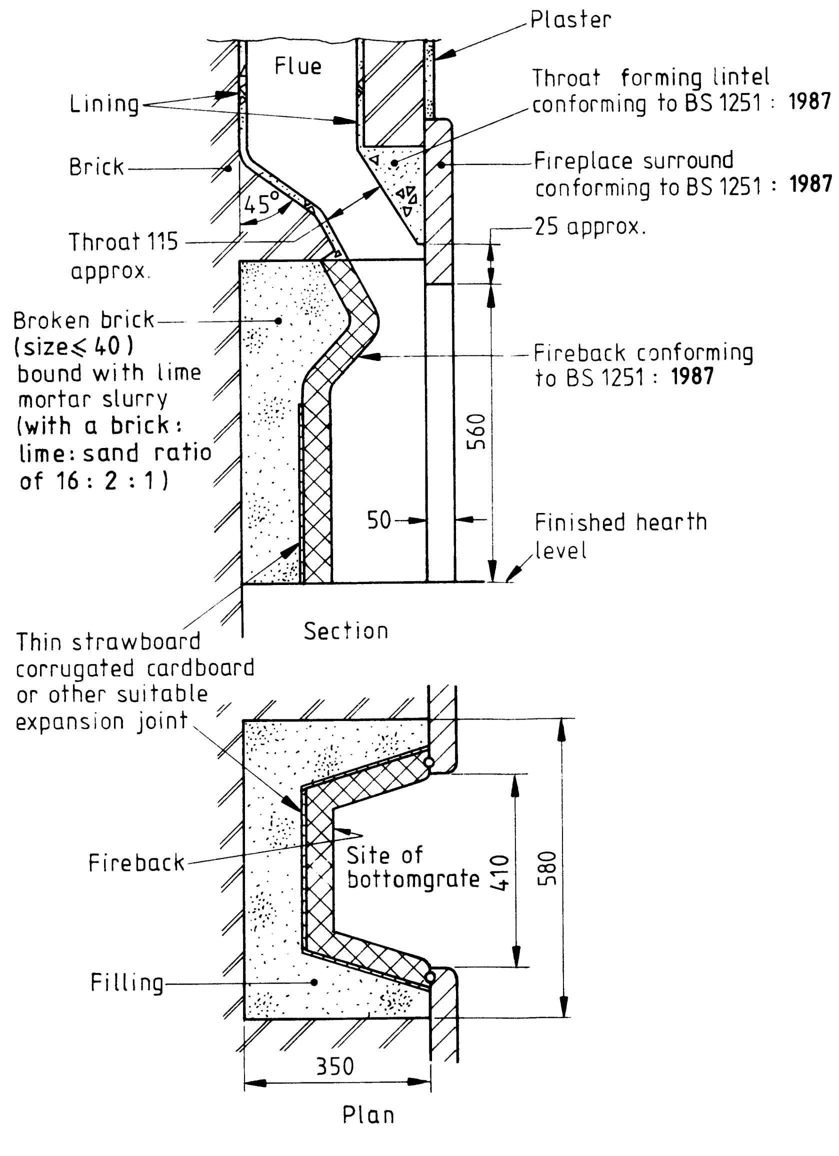
A fireplace surround comforming to BS 1251:1987 shall be fitted, of overall size 1 m high by 1 m wide by 50 mm thick and with the fireplace opening measuring 410^{+10}_{0} mm wide and 560^{0}_{-5} mm high. The surround shall be flat, i.e. the back of the surround at its periphery and around the fireplace opening shall be in the same plane. The front of the surround shall be faced with light-coloured matt tiles.

Directly and centrally in front of the chimney the concrete hearth shall be faced with light-coloured matt tiles or finished in a light-coloured matt paint, to match the front of the fireplace surround, over a sufficient area to cover a semicircle of 760 mm radius, on which the base of the radiometer cage (**5.2**) stands when in position for measurement of the radiation heat output.



NOTE The chimney shown is purely for test purposes and does not relate to modern practice of chimney construction. All dimensions are in millimetres.

Figure 1 — Test chimney



All dimensions are in millimetres.

Figure 2 — Test setting for installation of 400 mm inset open fire

7 Open fire and gas ignition burner

7.1 Appliance

The test appliance[2)] shall be as shown in Figure 3. The appliance is a 400 mm (nominal) inset open fire fitted with a cast iron bottomgrate having air spaces of 16 mm ± 1 mm between the bars. It shall be used without deepening bar or deepening plate but with its ashpan in position.

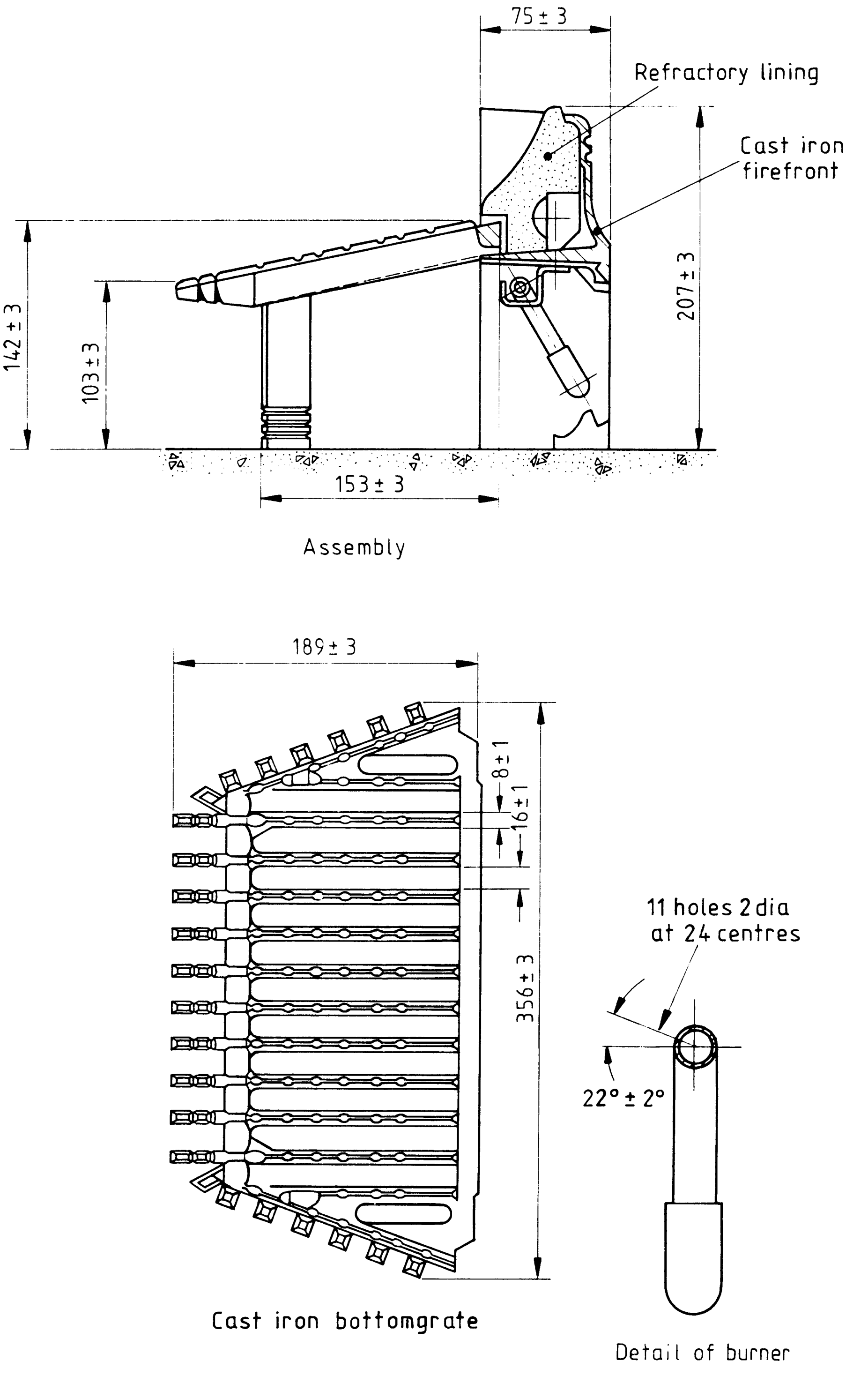
An air inlet plate constructed as shown in Figure 4 shall be used instead of the normal ashpit cover, to enable the amount of combustion air to be more accurately set and reproduced.

7.2 Ignition burner

The appliance shall incorporate the integral gas ignition burner shown in Figure 3, positioned so that the holes align with the spaces between the grate bars, and this shall be provided with the aerator/flow restrictor shown in Figure 5 for conversion to burning natural gas.

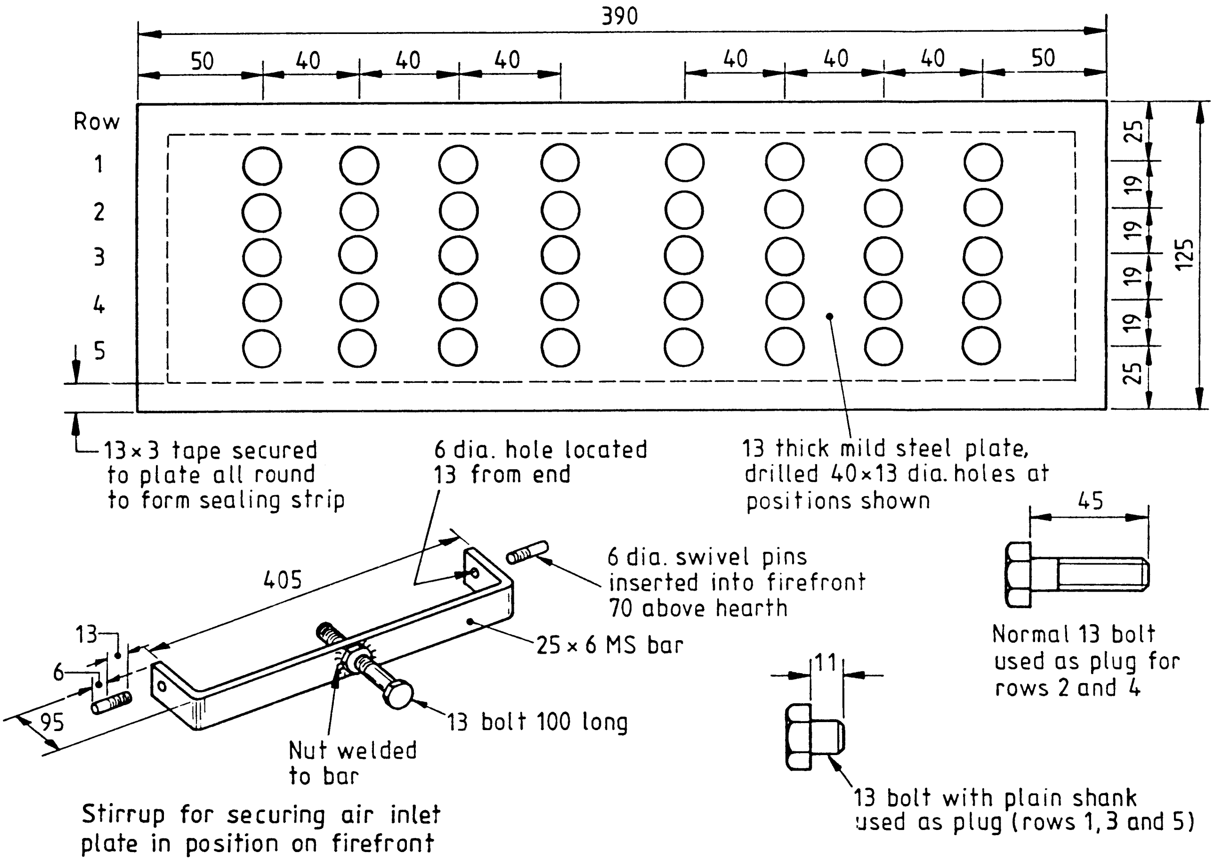
[2)] For information on the availability of the test Services appliance, write to Customer Services, Information, BSI, Linford Wood, Milton Keynes MK14 6LE.

The dry gas meter (**5.4**), gas flowmeter (**5.5**), manometer (**5.6**) and temperature measurement device (**5.7**) shall be incorporated in the gas supply line to the aerator/flow restrictor and ignition burner, as shown in Figure 6.



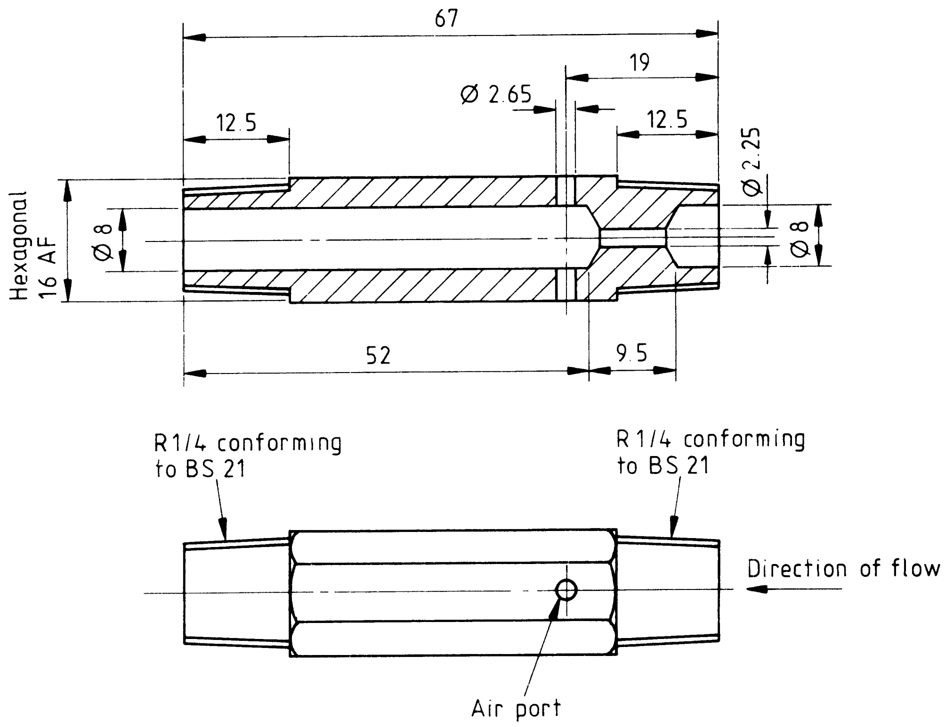
All dimensions are in millimetres.

Figure 3 — Test appliance: 400 mm (nominal) inset open fire



All dimensions are in millimetres.

Figure 4 — Air inlet plate for use with 400 mm inset open fire



NOTE All drilled holes shall be free from burrs. A
All dimensions are in millimetres.

Figure 5 — Aerator/flow restrictor device for natural gas ignition burner

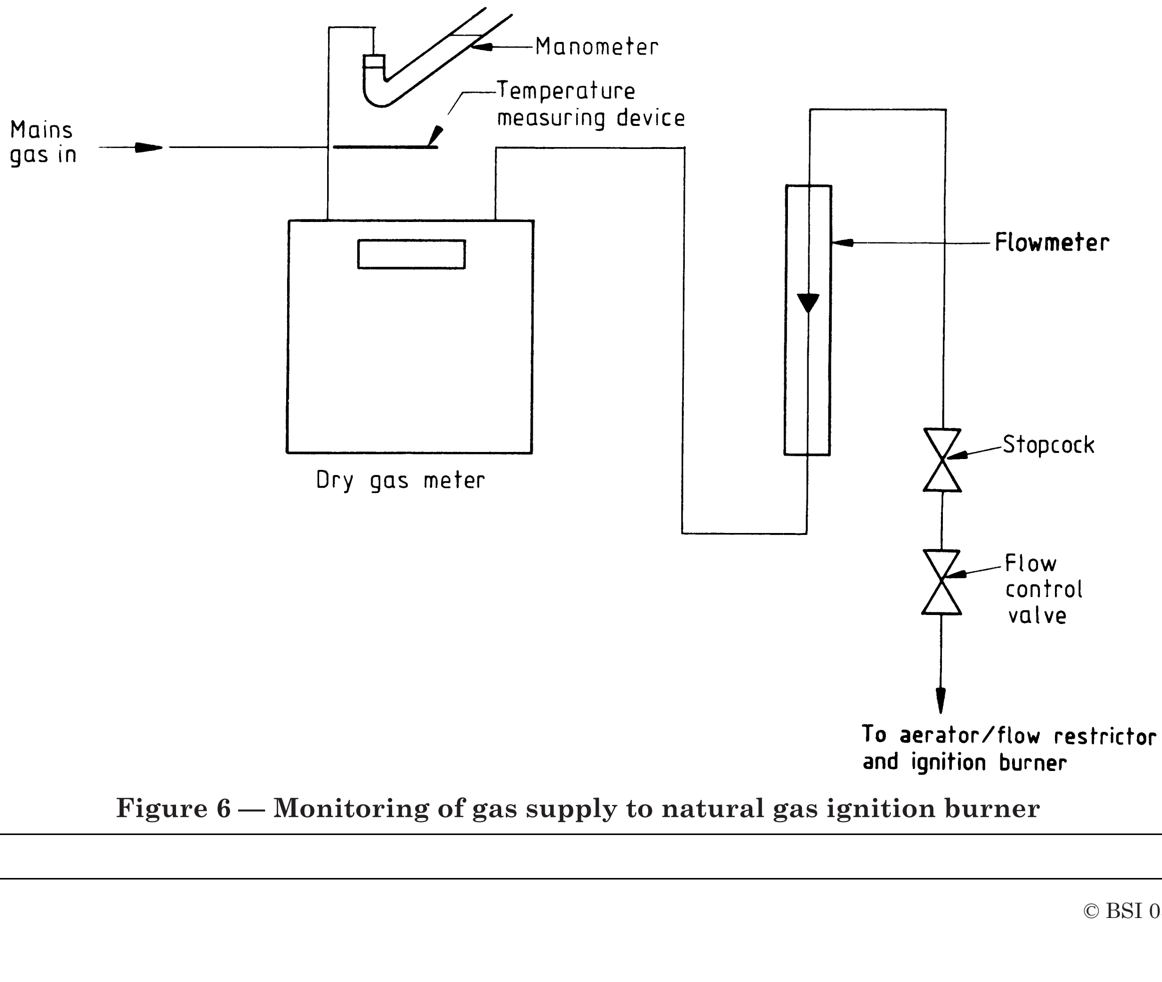


Figure 6 — Monitoring of gas supply to natural gas ignition burner

7.3 Installation

The fire shall be set back as far as possible in the fireplace opening. The firefront shall be rigidly fixed to the hearth and its vertical sides sealed against the front edges of the fireback by means of non-combustible, non-asbestos tape or string, tightly packed and faced off with refractory cement. The sealing strip along the bottom of the firefront shall be sealed to the hearth with refractory cement.

8 Gas supply to ignition burner

The gas for ignition shall be natural gas having a calorific value between 38.0 MJ/m^3 and 39.0 MJ/m^3, calculated at 15 °C and 101.325 kPa. The supply pressure shall be capable of being regulated at 2 kPa above atmospheric pressure.

9 Fuel sample preparation and bulk density determination

9.1 Initial preparation

Take a sample of at least 100 kg for a single determination or at least 200 kg for a series of replicate determinations (see **10.4**).

Mix the whole sample thoroughly and spread it out evenly in a thin bed on a hard dry surface under cover.

9.2 Subsample for determination of moisture content

Obtain a subsample of approximately 15 kg of fuel by taking 12 increments of 1.0 kg to 1.5 kg, spaced uniformly along the prepared bed of fuel (see **9.1**), using a large shovel. Mix the subsample thoroughly then screen the fuel on a 19 mm test sieve conforming to BS 410:1986, rejecting the undersize material.

9.3 Moisture determination

Take approximately 1 kg of the prepared subsample of fuel and crush it to less than 10 mm. Place approximately 0.5 kg of the crushed fuel on a tray and measure its mass m_1 in grams, using a balance of capacity 1.0 kg and accurate to within ± 0.05 g. Place the tray in an oven whose temperature is thermostatically controlled at 103 °C ± 2 °C and through which a flow of air is maintained. Weigh the sample, hot, after 2½ h. Return the sample to the oven and weigh it, hot, at intervals of 30 min until successive results differ by no more than 0.1 g. Record the final mass m_2 of the sample in grams.

Calculate the total moisture content of the sample, as a percentage by mass, from the expression:

$$M = \frac{m_1 - m_2}{m_1} \times 100$$

where

- M is the total moisture content of the sample [expressed as % (*m*/*m*)];
- m_1 is the initial mass of the crushed fuel (in g);
- m_2 is the final mass of the crushed fuel, after drying to constant mass (in g).

9.4 Drying

9.4.1 ***Fuels manufactured from anthracite, low-volatile coal or bituminous coal***

If the total moisture content is above 5 % (*m*/*m*), dry the fuel at a temperature not exceeding 30 °C to a total moisture content of 5 % (*m*/*m*) or less.

9.4.2 ***Fuels manufactured from brown coal, lignite, peat and wood***

If the total moisture content is above 20 % (*m*/*m*), dry the fuel at a temperature not exceeding 40 °C to a total moisture content of 20 % (*m*/*m*) or less.

9.5 Bulk density

NOTE See clause **11** for determination of bulk density of long briquettes.

Determine the bulk density of the fuel (of total moisture content as given in **9.4.1** or **9.4.2** as appropriate) in accordance with BS 1016-108.3:1991 but using a container having a capacity of 57 dm^3, i.e. with sides of 384 mm. Obtain the subsample for this determination as described in **9.2** but with sufficient increments to fill the container with screened fuel.

When the bulk density has been determined, either return the fuel to the bed or divide it into approximately 15 kg subsamples for use in the determination of smoke emission (see **9.6**).

9.6 Subsample for smoke emission determination

For each determination of smoke emission, obtain a subsample of about 15 kg of fuel, as described in **9.2**.

NOTE For convenience it is recommended that a number of 15 kg subsamples should be taken by the above procedure at the same time, each being stored in a sealed container until it is required.

Return to the bed any fuel which remains unused at the end of a smoke emission determination.

10 Procedure

NOTE See clause **11** for modifications to the procedure for long briquettes.

10.1 Adjustment of air inlet plate

Perform a preliminary test as described in **10.2** and **10.3**, without measuring the smoke given off, to establish by trial and error the correct air inlet opening for the particular fuel under test. Repeat the procedure after adjusting the air inlet plate until the second radiation peak lies within the range 1.80 kW to 2.30 kW.

To obtain increasing amounts of primary air by means of the air inlet plate (see **7.1**), open the holes in the plate in the following order. Commencing with the next to bottom of the five rows of holes, open the central holes and then work outwards until all the holes in the row are open. Repeat this procedure with the holes on the next to top row, then on the bottom row, then on the middle row and finally on the top row.

Do not alter the air inlet setting during the smoke emission determination.

10.2 Preparation

Carry out the following operations before each determination.

a) Fully open the stopcock in the gas supply to the ignition burner (see Figure 6) and measure the pressure and temperature of the gas, using the manometer (**5.6**) and temperature measurement device (**5.7**) in the supply line. Calculate from the following equation the gas volume flow rate that corresponds to a heat input rate of 7.5 kJ/s ± 0.3 kJ/s.

$$V' = \frac{101.325H'(273 + t_1)}{288C(p + 2)}$$

where:

- V' is the volume flow rate corresponding to the required heat input rate (in dm^3/s);
- H' is the required heat input rate (in kJ/s);
- C is the calorific value of the natural gas supply (in $MJ/m^3 \equiv kJ/dm^3$), calculated at 15 °C and 101.325 kPa;
- t_1 is the temperature of the gas supply (in °C);
- p is the atmospheric pressure (in kPa).

Adjust the flow control valve in the gas supply line to give the required flow rate, measured using the calibrated dry gas meter (**5.4**) and the timing device (**5.9**). Note the reading on the indicating flowmeter (**5.5**). Check that the static pressure in the supply line is 2 kPa above atmospheric pressure (see clause **8**) and adjust the mains gas pressure regulator as necessary.

Repeat the measurements and adjustments of the gas volume flow rate and the static pressure until both requirements are met. Close the stopcock, leaving the flow control valve in the set position.

b) Remove the air inlet plate, clean the fireplace and remove all ash. Place the empty ashpan in position under the bottomgrate.

10.3 Firing cycle

10.3.1 *General*

The firing cycle shall consist of an ignition period followed by a test period in which either two or three refuelling charges are added.

10.3.2 *Ignition period*

Take the ignition charge from the 15 kg subsample of fuel and spread it evenly on the grate. The specified ignition charge shall be the mass of fuel corresponding to 7 dm^3, as determined from the bulk density (see **9.5**), or 3.2 kg, whichever is the greater. The actual mass of this charge shall be within 30 g of the specified charge. Unless testing is carried out on the same day as sample preparation, take 0.5 kg from the subsample of fuel for determination of the total moisture content, to confirm that this is within the limits given in **9.4**.

Calculate the volume of natural gas that corresponds to a heat input of 4 220 kJ ± 170 kJ from the following equation.

$$V = \frac{101.325H(273 + t_1)}{288C(p + 2)}$$

where:

- V is the total volume corresponding to the required total heat input (in dm^3);
- H is the required total heat input (in kJ);
- C is the calorific value of the natural gas supply, calculated at 15 °C and 101.325 kPa (in $MJ/m^3 \equiv kJ/dm^3$);
- t_1 is the temperature of the gas supply (in °C);
- p is the atmospheric pressure (in kPa).

With the air inlet plate removed from the grate, light the ignition charge with the required volume of gas, measured by the dry gas meter (**5.4**). Check periodically that the indicating gas flowmeter is at the previously determined value [see **10.2** a)].

Measure the radiation heat output with a BCURA quadrant radiometer (**5.2**).

NOTE As the radiometer is sensitive to radiation falling on the back of the elements when in use, take care that this is prevented. Also, take care to ensure that the radiometer is protected from draughts.

Place the radiometer in front of the fire with the bottom members of the cage framework resting on the hearth and the outer surfaces of the front tubular structure touching the surround. Locate the cage symmetrically in relation to the vertical centre-line of the fireplace opening.

Record the output of the radiometer in millivolts, either continuously or at regular intervals of not more than 5 min, using a potentiometric recorder or data logger.

Calculate the radiation heat output from the fire, which at any instant is given by the following equation:

$$R = FL$$

where

- R is the radiation heat output (in kW);
- F is the calibration factor of the BCURA quadrant radiometer (in kW/mV) (see **5.2**);
- L is the measured output from the radiometer (in mV).

If the radiation heat output of the fire fails to reach 1.15 kW within 50 min from the time the gas is lit, the test is invalid and shall be terminated; in all subsequent tests on the sample of fuel concerned, use a volume of gas corresponding to a heat input of 7 375 kJ ± 300 kJ for ignition.

When the measured radiation heat output from the fire reaches 1.15 kW, place the air inlet plate in position, with the appropriate air inlet opening (see **10.1**).

When the radiation heat output from the fire has passed the first radiation peak and fallen to 1.45 kW or to three-quarters of the value of the first radiation peak, whichever is the smaller, remove the radiometer and carefully de-ash the firebed. Using the poker (**5.8**), clear all the firebar slots from the top of the grate, working from front to back and inserting the poker so that it protrudes through the firebars; level the firebed off. Allow a period of 20 s to permit all the fly-ash to clear the chimney before commencing smoke measurement.

10.3.3 ***Test period***

Measure the smoke emission rate during the test period by one of the methods described in BS 3841-2:1994, or by any other method which has been demonstrated to give equivalent results, using the appropriate equipment (**5.1**).

NOTE In Annex A of BS 3841-2:1994 it is demonstrated that the electrostatic precipitator method and the dilution tunnel method give equivalent results.

Immediately following de-ashing at the end of the ignition period, add the first refuelling charge to the fire, spread it evenly and replace the radiometer. Each refuelling charge shall be the mass of the fuel corresponding to 5 dm^3, as determined from the bulk density (see **9.5**). Where practicable the actual mass of the refuelling charge shall be within 15 g of the specified charge; where this is not practicable the masses of successive charges shall be adjusted so that the mean mass of the refuelling charge falls within the specified limits. Note the time when the first refuelling charge is added to the fire; this is the commencement of the test period.

Measure the radiation heat output as described in **10.3.2**.

If the second radiation peak occurs between 1.80 kW and 2.30 kW, continue with the test; otherwise the test is invalid and shall be terminated. When the radiation heat output has passed the second radiation peak and fallen to 1.45 kW, remove the radiometer and de-ash the firebed in accordance with **10.3.2**. Immediately following this de-ashing, add the second refuelling charge to the fire, spread it evenly and replace the radiometer.

For fuels of bulk density 480 kg/m^3 or greater complete the test period when the radiation heat output falls to 1.45 kW after the third radiation peak. For fuels of bulk density less than 480 kg/m^3, remove the radiometer and de-ash the firebed again in accordance with **10.3.2**, add a third refuelling charge, spreading it evenly on the fire, and replace the radiometer. In this case, complete the test period when the radiation heat output has passed the fourth radiation peak and has fallen to 1.45 kW.

Note the time at which the test period is completed.

10.4 Number of valid determinations

NOTE The number of valid determinations to be carried out will depend on the purpose of the test; the maximum number of valid determination is five. Assessments based on a single determination are not in general recommended but may be acceptable in some circumstances, e.g. as a basis of periodic checks on production of an authorized fuel.

An individual determination shall be valid if the second radiation peak falls within the range 1.80 kW to 2.30 kW.

In addition, for a series of replicate determinations to be valid, the mean value of the second radiation peaks for the individual determinations shall lie within the range 1.95 kW to 2.15 kW.

If for a series of less than five replicate determinations the mean value of the second radiation peaks falls outside the range 1.95 kW to 2.15 kW, a further replicate determination shall be carried out and the series shall be considered valid if the mean then falls within the range. This procedure shall be repeated until the mean value falls within the range or until five replicate determinations have been carried out, whichever is the sooner.

If five replicate determinations have been carried out and the mean value of the second radiation peaks is higher than 2.15 kW, the highest value shall be rejected and a further replicate determination shall be carried out. If five replicate determinations have been carried out and the mean value is less than 1.95 kW, the lowest value shall be rejected and a further replicate determination shall be carried out. In both cases, the series shall be considered valid if the mean value then falls within the range 1.95 kW to 2.15 kW. This procedure shall be repeated until the mean value of five replicate determinations falls within the range.

11 Modifications to the procedure for long briquettes

The following modifications apply, as appropriate, to briquettes longer than 150 mm.

If the briquettes are longer than 250 mm and the manufacturer's instructions state that refuellings should be made with a single whole briquette, perform the determinations with $1\frac{1}{2}$ briquettes broken into quarter lengths for the ignition charge and a single whole briquette for the refuelling charge.

For other long briquettes the procedure for determining the bulk density and charging the briquettes to the fire specified in **9.5** and **10.3** respectively shall the modified as follows.

a) Determine the bulk density of the briquettes with the briquettes placed in the bulk density container so that their longitudinal axes are as near to horizontal as is practicable and they are otherwise randomly packed.

b) Calculate the required mass of briquettes corresponding to 7 dm^3 for the ignition charge and 5 dm^3 for the refuelling charge. Determine the actual mass of the charge to the nearest whole briquette.

c) For the ignition charge, divide the briquettes into between two and four pieces, depending on their length and any natural points of cleavage. Spread the broken briquettes evenly on the grate.

d) If preliminary tests show that it is impossible to achieve second radiation peaks within the required limits (see **10.3.3**) by adjustment of the air inlet plate, increase the ignition charge to 8.5 dm^3, to raise the peak, or decrease it to 5.5 dm^3, to lower the peak.

e) For the refuelling charge, place the briquettes on the fuel bed with their longitudinal axes as near to horizontal as is practicable and otherwise randomly placed.

f) If the manufacturer's written instructions describe a different method of packing the briquettes from that given in item e), perform additional tests with the stated method of packing.

12 Calculation of results

For each determination calculate the smoke emission S (in g/h) using the appropriate equation for the method of smoke measurement (see **3.5** and **4.5.5** of BS 3841-2:1994 for the electrostatic precipitator and the dilution tunnel methods).

If replicate determinations have been carried out calculate the arithmetic mean, S_m, of the values of S from the individual determinations and round the result to the nearest 0.1 g/h.

13 Test report

The test report shall include the following information:

a) a reference to this British Standard, i.e. BS 3841-1:1994;

b) identification of the fuel sample;

c) the bulk density of the fuel (in kg/m^3);

d) the purpose of the tests, e.g. candidate fuel for authorization;

e) the method of smoke measurement used, i.e. electrostatic precipitator method, dilution tunnel method or other;

f) for each determination, the smoke emission rate S (in g/h) and the value of the second radiation peak (in kW);

g) for replicate determinations, the mean value of the smoke emission rate S_m (in g/h) and the mean value of the second radiation peak R_m (in kW) from the individual determinations;

h) details of any unusual features noted during the test.

NOTE For record purposes, it is recommended that the following information also be included:

1) the primary air opening (in mm^2);
2) the volume of gas for ignition (in dm^3);
3) the duration from the start of ignition to achieving a radiation heat output of 1.15 kW (in min);
4) the value of the first radiation peak (in kW);
5) the total mass of smoke (in g);
6) the duration of the test (in h).

Annex A (informative) Basis of test method

The purpose of the test procedure for measuring the smoke emission of a manufactured fuel is to enable the smoke characteristics of different fuels to be compared. For such a comparison to be fair it has to be made between equivalent amounts of fuel, i.e. between amounts which will give the same heat service to the user. This implies that smoke emission should be measured as the mass produced per unit time, at a particular level of the average radiation heat output of the fire in which the fuel is burned for the purposes of the test.

From investigations which have been made [3] on a number of manufactured solid fuels it seems that the relationship between the smoke emission, as defined in the preceding paragraph, and the average radiation heat output at which the smoke is measured is not the same for all fuels. For most manufactured fuels the rate of smoke emission is very nearly constant for different outputs; however, in some cases the smoke increases, and in others it decreases, as the average radiation heat output increases. It is consequently essential that the level of average radiation heat output which is chosen for the purpose of the test should be one which is reasonably characteristic of normal domestic usage.

NOTE These investigations were not carried out by the method described in this standard, but by what is commonly referred to as the "one-and-a-half hourly refuel" method. It would be expected, however, that the conclusions drawn would be equally applicable to both methods.

The practical design of the lest needs to be such as to ensure that combustion takes place under conditions which are as nearly as possible reproducible from test to test and from fuel to fuel. To get such truly comparable and reproducible conditions for different fuels it has been concluded that the amounts of fuel which are used, both for producing an established fire (the ignition charge) and for giving the smoke which is determined (the refuelling charge), should be defined by their volumes and not by their masses, so that a fire of substantially the same physical size is obtained irrespective of the bulk density of the fuel. The rate at which the refuelling charge is burned is governed by the amount of undergrate air admitted to the fire and, for experimental convenience, it is arranged that it is the peak value of the radiation heat output which is controlled. The value chosen for this peak is 2.05 kW, which experimental investigations have shown leads to an average radiation heat output of approximately 1.75 kW. These figures are considered to be reasonably characteristic of nominal domestic usage. For practical purposes it is necessary to allow a tolerance of 0.25 kW on the control level in individual tests. Usually a series of replicate determinations will be carried out and the individual measurements averaged to obtain an evaluation of the smokiness of a given fuel. It is clear that there is the possibility of bias in the final result in such a series if the determinations are all made near one of the extremes of the range 1.80 kW to 2.30 kW. To deal with this it is required that, in such a series of determinations, the average value of the peak radiation heat outputs in the individual determinations lies within the range 1.95 kW to 2.15 kW.

In general, for the types of smokeless fuel likely to be tested in accordance with this Part of BS 3841, one refuelling charge does not give sufficient smoke for accurate weighing. Thus two refuelling charges are added in succession, the smoke from the two being collected and weighed together. In the case of fuels of low bulk density, a third refuelling charge is added, for the same reason.

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List of references

Normative references

BSI standards publications
BRITISH STANDARDS INSTITUTION, London

BS 410:1986, *Specification for test sieves.*
BS 1016, *Methods for analysis and testing of coal and coke.*
BS 1016-108, *Tests special to coke.*
BS 1016-108.3:1991, *Determination of bulk density (small container).*
BS 1251:1987, *Specification for open-fireplace components.*
BS 1846, *Glossary of terms relating to solid fuel burning equipment.*
BS 1846-1:1968, *Domestic appliances.*
BS 3323:1992, *Glossary of terms relating to sampling, testing and analysis of solid mineral fuels.*
BS 3841, *Determination of smoke emission from manufactured solid fuels for domestic open fires.*
BS 3841-2:1994, *Methods for measuring the smoke emission rate.*
BS 6100, *Glossary of building and civil engineering terms.*
BS 6100-1, *General and miscellaneous.*
BS 6100-1.5, *Operations; associated plant and equipment.*
BS 6100-1.5.1:1984, *Coordination of dimensions; tolerances and accuracy.*

Informative references

[1] GREAT BRITAIN. Clean Air Act 1956. London: HMSO.
[2] GREAT BRITAIN. Clean Air Act 1968. London: HMSO.
[3] DICKINSON, R. Measurements of domestic smoke emission and their application to clear air legislation, *Journal of the Institute of Fuel.* March 1970, **43**, 75 – 81.

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