

CONFIRMED
FEBRUARY 1989

Method for

Measurement of particulate emission including grit and dust (simplified method)

UDC 628.511:662.965:543.275.3

NO COPYING WITHOUT BSI PERMISSION EXCEPT AS PERMITTED BY COPYRIGHT LAW

BSI
Documents

AVA

Document Sharing Hub

Committees responsible for this British Standard

This British Standard was published under the direction of the Environmental and Pollution Standards Committee EPC/-. Its preparation was entrusted to Technical Committee EPC/28 upon which the following bodies were represented:

- Bcira
- Cement Makers' Federation
- Combustion Engineering Association
- Department of Industry
- Health and Safety Executive
- National Coal Board
- National Industrial Fuel Efficiency Service
- Oil Companies Materials Association

This British Standard, having been prepared under the direction of the Environmental and Pollution Standards Committee, was published under the authority of the Board of BSI and comes into effect on 28 February 1983

© BSI 12-1998

First published September 1961
First revision March 1971
Second revision February 1983

The following BSI references relate to the work on this standard:
Committee reference EPC/28
Draft for comment 80/52491 DC

ISBN 0 580 13046 0

Amendments issued since publication

Amd. No.	Date of issue	Comments

Contents

	Page
Committees responsible	Inside front cover
Foreword	ii
Section 1. General	
0 Introduction	1
1 Scope	1
2 Definitions	1
3 Safety	2
Section 2. Measurement	
4 Principle	3
5 Apparatus	3
6 Advance preparations	4
7 Work on site preparatory to sampling	6
8 Sampling procedure	7
9 Weighing and analysis of sample	8
Section 3. Treatment of results	
10 Method of calculation	9
11 Test report	10
Appendix A Main procedural requirements	11
Appendix B Approximate results with non-standard sampling positions	11
Appendix C Sampling apparatus	12
Appendix D Care and use of pitot-static tubes	12
Appendix E Recording and reporting procedure	13
Appendix F Bibliography	16
Figure 1 — Illustration of definitions in relation to a circular flue	17
Figure 2 — Typical access holes and fitments for sampling purposes	18
Figure 3 — Examples of locations of sampling planes in flues	19
Figure 4 — Location of sampling points in flues	20
Figure 5 — Sampling nozzles	21
Publications referred to	Inside back cover

Foreword

This revision of BS 3405:1971, having been prepared under the direction of the Environmental and Pollution Standards Committee, is the second revision of this standard. The first edition, published in 1961, provided a simplified method for the measurement of grit and dust in waste gases arising from combustion of fuel. The accuracy of results obtained was claimed to be within $\pm 25\%$, and the method was “simple” by comparison with BS 893:1940 “Methods of testing dust extraction plant and emission of solids from chimneys of electric power stations”. The 1961 edition provided a generalized description of the procedure and gave detailed procedures for a number of recommended types of apparatus.

Following the publication of the 1961 edition, the Report of the first Working Party on Grit and Dust Emission 1967 made certain recommendations and the standard was revised in 1971 to take these into account. The first revision provided only a general description of the procedure that was considered to be common to all types of apparatus, and listed a number of available types of apparatus expected to be suitable for use with the procedure.

Since the publication of the 1971 edition, BS 893 has been revised and published (in 1978) under the title “Measurement of the concentration of particulate material in ducts carrying gases”. The distinction between BS 893 and BS 3405 was reduced to a difference in the degree of sampling required and the expected accuracy. The accuracy claimed for tests according to BS 893 is $\pm 10\%$, whereas in both the 1971 and the present revision of BS 3405 the accuracy claimed is $\pm 25\%$ with the difference being essentially due to the number of sampling points used. The statutory requirements for the testing of particulate emissions in the UK have so far been satisfied with tests made using the simpler procedure of BS 3405 and no intended change in this policy has been indicated.

Experience in using the 1971 edition has provided evidence of the need to improve the detail of the procedure, and this experience has been drawn on by the committee responsible for the preparation of this revision, which also takes account of the different conditions encountered in the types of plant dealt with in the Report of the second Working Party on Grit and Dust Emissions 1974.

This revision retains the general approach of the 1971 edition in that specific apparatus is not described. The scope has been extended to cover emissions from sources other than fuel-burning plant. A suggestion that an even simpler procedure with a lower accuracy than 25% be introduced was not considered to be justified.

In view of the current emphasis placed on safety in industrial operation, clause 3 “Safety” has been introduced. The order of the text of the 1971 edition has been rearranged to align with the sequence of operations used in practice. Increased detail of some of the parts of the procedure and a tightening of certain operating conditions have been introduced. BS 3405:1971 is withdrawn.

The Technical Committee has considered carefully the lower particle size limit in the definition of “dust”, noting that with sampling apparatus that includes an inertial separator there is a marked reduction in separating efficiency for sizes less than $5\text{ }\mu\text{m}$. For sampling apparatus which contains a separator other than the inertial type, it has now provided for a higher separating efficiency than before for particles between $1\text{ }\mu\text{m}$ and $5\text{ }\mu\text{m}$. It has also defined sizes more closely than before by referring to the Stokes diameter of particles and it has eliminated the previous definition of “fines” as being solid particles less than $1\text{ }\mu\text{m}$ in diameter.

In view of the predominant use of apparatus containing an inertial separator, the Technical Committee considers that there is a strong case for redefining the lower particle size limit for “dust” as 5 µm but it has not taken this step in the present revision.

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 to iv, pages 1 to 22, 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.

Section 1. General

0 Introduction

This British Standard describes a method for use when an accuracy of $\pm 25\%$ suffices. The main procedural requirements of this standard are summarized in appendix A. This standard does not supersede BS 893 and the testing procedure specified in that standard should be followed in all cases where greater accuracy is necessary. However, as such tests are more lengthy and complicated in practice and may involve considerably greater expense to carry out, BS 3405 may be used if both parties to a contract agree that the lower degree of accuracy is acceptable.

By the procedure of this standard it is reasonable to expect that, with two experienced operators, the required velocity measurements and sampling can be completed within about 3 h.

Where the tests are carried out to meet statutory requirements or contractual obligations, the period of sampling should comply with the appropriate regulations or with the terms of the contract. Chapter 1, paragraph 13, of the Report of the first Working Party on Grit and Dust Emissions 1967 recommends that the period of sampling should be selected to embrace conditions described as “normal” and should include periods when customary peak loads on the plant obtain.

It is not generally practicable to arrange a sampling schedule that will give adequate significance to short periods of high rates of emission such as may occur, for example, during periods of soot blowing. Attempts to include them in the period of sampling could well render it impossible to get the required degree of agreement between repeat tests. It is therefore desirable to exclude such periods when taking samples to determine “normal” rates of emission. Where it is necessary to assess the importance of short-term peak emissions they should be made the subject of a special study by a team skilled in dealing with this particular aspect.

Requirements for sampling position are given in 6.3. In the design of new plant it is recommended that provision be made for suitable sampling positions. On some existing plants it may be found impracticable to choose a sampling position that satisfies all the requirements. For such cases, appendix B sets out certain deviations from the sampling position requirements that allow measurements to be made to assess the approximate level of emissions. Any report or statement of results using such sampling positions should state clearly that the results are determined at sampling positions that do not comply with the requirements of BS 3405 and that the accuracy of the results cannot be assured (see clause 11). Appendix B should not be used to determine the location of sampling positions prior to the construction of any new plant (cf. B.1).

1 Scope

This British Standard describes a method for measuring, with an accuracy of $\pm 25\%$ under defined conditions, the concentration of particulate matter, including grit and dust in the gases, and the total mass of these solids carried in unit time by gases passing through a flue or discharging from a chimney.

It also sets out requirements for the design features of apparatus, by the proper use of which such determinations can be made, and indicates basic requirements for the positioning of sampling facilities.

NOTE The titles of the publications referred to in this standard are listed on the inside back cover.

2 Definitions

For the purposes of this British Standard, the following definitions apply.

2.1

access fitment

a tube or socket installed at an access hole, of suitable size and shape to hold the sampling probe (see Figure 1 and Figure 2)

2.2**access hole**

a hole in the flue at the extremity of a sampling line, through which the sampling probe is inserted (see Figure 1 and Figure 2)

2.3**cumulative sampling**

the collection of a single composite sample obtained by sampling for the required period at each sampling point in turn

2.4**diameter**

the internal diameter of a circular duct or the hydraulic diameter (four times the duct area divided by the duct perimeter) of a non-circular duct

2.5**dust**

solid particles that are smaller than grit but above 1 µm in Stokes diameter¹⁾

2.6**flue**

a duct or other enclosed structure through which gases travel from one point to another (e.g. the interior of a chimney)

2.7**grit**

solid particles retained on a sieve of aperture size 75 µm complying with BS 410

2.8**incremental sampling**

the collection and removal of individual samples from each sampling point

2.9**isokinetic sampling**

sampling at a rate such that the average velocity of the gas entering the sampling nozzle is the same as that of the gas in the flue at the sampling point

2.10**sampling line**

the line in the sampling plane along which the sampling points (see 2.12) are located (see Figure 1)

2.11**sampling plane**

the plane normal to the centreline of the flue at the sampling position (see Figure 1 and Figure 3)

2.12**sampling point**

specific location on a sampling line at which a sample is extracted (see Figure 4)

2.13**sampling position**

a suitable location in the flue system for carrying out sampling operations

2.14**site**

works or plant where sampling is to be carried out

3 Safety

3.1 General. Sampling operations may involve a variety of hazards depending on the circumstances. All concerned, e.g. management, sampling operators and control authorities, shall consider them adequately beforehand.

If hazards cannot be eliminated, appropriate safety arrangements shall be made having regard to any specific regulations before sampling operations commence.

Hazards most likely to be encountered and their means of reduction include those given in 3.2 to 3.4.

NOTE On every occasion, plant management and plant operators should be aware that sampling operations are taking place. Management should consider what appropriate safety procedures, e.g. work permits, should be adopted and ensure that they are understood by all those likely to be concerned.

3.2 Hazards to sampling operators

- a) Working at heights or under difficult access conditions. Consider means of escape, guard rails (see 6.4), warning systems, etc.
- b) Exposure to toxic, corrosive or hot gases or dusts from the access holes or from elsewhere in the process plant. Consider circumstances, monitoring or warning systems, personal protective equipment, etc.
- c) Electrical hazards, from electrical equipment or from electrostatic charge. Consider equipment protection, earthing, etc.
- d) Noise and heat from plant or equipment. Consider protective measures.
- e) The handling of heavy or bulky equipment. Consider arrangements.

3.3 Hazards to other personnel

- a) Objects falling from platform. Consider warning signs, barricading, etc.
- b) Presence of temporary equipment, e.g. cables causing trip hazards. Consider warning signs, etc.

3.4 Hazards to plant

- a) Ignition of flammable gases. Consider using non-sparking equipment, etc.
- b) Equipment dropping into flue system. Consider likelihood of hazard.

¹⁾ See the foreword and reference (1) of appendix F.

Section 2. Measurement

4 Principle

A sharp-edged nozzle is positioned in the duct facing into the moving gas stream and a sample flow of the gas is extracted through it, at the same gas velocity as that in the duct, for a measured period of time. To allow for non-uniformity of distribution, samples are taken at four or eight stated positions in the duct cross section. The particulate matter entrained in the gas sample is separated for weighing. Its mass, multiplied by the ratio of the cross-sectional area of the duct to that of the sampling nozzle, is taken as the mass flow rate of particulate matter in the duct.

5 Apparatus

5.1 General. Different types of sampling apparatus may have particular features that render them suitable only for selected applications (e.g. only for the normal range of boiler flue gas temperatures, or for low concentrations of particulate matter, or for a certain size of duct). Where this is so, the limitations stated in the instructions and descriptive literature shall be observed when proceeding in accordance with this standard.

Operating instructions of sufficient detail to enable the user to carry out the procedure described in this standard shall be obtained from suppliers of apparatus offered for testing in accordance with BS 3405.

Sampling and flow measuring apparatus to be used for testing in accordance with this standard shall be suitable for use through a 100 mm nominal (4 in) BSP socket complying with the requirements of BS 1740-1 (see Figure 2), and shall wherever practicable include facilities for securing the apparatus in the access hole and for minimizing the ingress of air or the escape of gases through the access hole.

The operating voltage for all portable electrical apparatus shall not exceed 110 V.

Apparatus required for this standard shall comprise that described in 5.2 to 5.5.

NOTE Appendix C lists some available apparatus assemblies that have been found suitable for use in conjunction with this standard.

5.2 Gas velocity measuring equipment

5.2.1 General. The equipment shall consist of means for measuring the velocity of the flue gases at the sampling point, as described in 5.2.2 to 5.2.4.

5.2.2 A pitot-static tube of appropriate length, constructed in accordance with BS 1042-2A, or another velocity measuring device or pitot tube calibrated against a measuring device constructed in accordance with BS 1042, in velocity conditions corresponding to those of the test.

NOTE Appendix D provides guidance on the care and use of pitot-static tubes.

5.2.3 A differential pressure measuring device such as an inclined-tube manometer, capable of measuring pressure in the range 4 Pa to not less than 300 Pa with a sensitivity of not less than ± 1 Pa.

NOTE The range may, if necessary, be covered by more than one instrument.

5.2.4 A temperature measuring device capable of measuring the temperature of the flue gases with an accuracy of ± 5 °C.

5.3 Isokinetic sampling equipment

5.3.1 General. The equipment shall consist of means for isokinetically withdrawing a sample volume of the flue gas, together with its associated particulate matter, as described in 5.3.2 to 5.3.7. Each item shall be made of material suitable to withstand the conditions of test having regard to its position in the assembly.

5.3.2 A sampling nozzle of circular cross section, the inlet end having a wall thickness a not exceeding 1.3 mm. The inclinations of this wall and of the other internal and external surfaces shall be as shown in Figure 5. When the apparatus is assembled, the clearance around the centre-point of the nozzle opening shall be as shown in Figure 5. A set of nozzles of different diameters, each suitably identified, shall be provided.

5.3.3 A probe tube to position the sampling nozzle at each of the sampling points, and to convey the sampled gas. If the separating device (5.4.2) is mounted outside the flue, provision shall be made for

- a) maintaining the probe tube at a temperature sufficient to prevent condensation, and
- b) the recovery of any solids that are deposited within the probe tube.

A pointer or similar device shall be incorporated to indicate the facing direction of the sampling nozzle.

5.3.4 A gas flow rate measuring device capable of determining the rate of flow of the gas sample with an accuracy of ± 5 %.

If the gas sample flow rate is measured at a point outside the flue, a means for measuring the temperature of the gas sample flow at that point to an accuracy of ± 5 °C shall be provided.