# INTERNATIONAL STANDARD

# ISO 9931

First edition
1991-12-15

## Coal — Sampling of pulverized coal conveyed by gases in direct fired coal systems

*Charbon — Échantillonnage de charbon pulvérisé transporté par des gaz dans des systèmes à combustion directe de charbon*



Reference number
ISO 9931:1991(E)

## Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard ISO 9931 was prepared by Technical Committee ISO/TC 27, *Solid mineral fuels*.

Annexes A, B and C of this International Standard are for information only.



International Organization for Standardization
Case Postale 56 • CH-1211 Genève 20 • Switzerland

Printed in Switzerland

## Introduction

This International Standard was developed for use in determining the distribution of pulverized coal between separate burners in a coal-fired power station.

Sampling in accordance with this International Standard can give information about performance characteristics of a pulverized coal firing system, for example

— when commissioning fuel distribution systems and firing systems with a view to equal fuel distribution to the burners;

— when monitoring and adjusting the performance of dividers and baffles in fuel distribution systems;

— when monitoring pulverizer performance for specified particle size.

NOTE 1 The sampler and the sampling method described in this International Standard were developed for the sampling of pulverized coals. However, this does not preclude this International Standard from being suitable for sampling pulverized material other than coal, conveyed by air or other gases in circular pipes. At present, however, no experience or experimental results for pulverized materials other than coal are available.

# Coal — Sampling of pulverized coal conveyed by gases in direct fired coal systems

## 1 Scope

This International Standard specifies a method which, subject to limitations imposed by the geometry of the pulverized-coal pipe, is applicable to multipoint sampling of pulverized coal suspended in air or other gases conveyed in circular pipes between pulverizer and burners in direct fired coal systems in power stations. The samples collected are used for deriving the mass distribution of coal between the burners and the particle size distribution of the coal, with the object of determining the performance of a pulverizer.

The method is suitable for sampling from vertical circular pipes at, or beyond, a specified distance from a flow disturbance when

- the maximum particle size to be sampled is less than one-third of the diameter of the sampler tip aperture, i.e. less than 1,5 mm (to ensure representative sampling and to avoid clogging of the sampler);

- sampling takes place in a circular pipe with an internal diameter between 250 mm and 700 mm;

- the air/coal ratio in the pipe is within the normal range of direct fired pulverized coal systems.

NOTE 2 If sampling access can only be made at an unsuitable position, depending upon the purpose of the measurement, the equipment may still give satisfactory results. In such positions a more detailed investigation may be necessary. This may involve taking individual samples covering the full cross-section of the pipe using some other method, including a single tip sampler.

## 2 Principle

A multipoint sampler extracts, in 4 min, one representative sample from 64 sampling points evenly distributed over a cross-section of a circular pipe. Suitable sampling positions are described. The sampler is inserted through a dustless connection into the pulverized fuel pipe. Before and after the sampling period, the sampling equipment is kept clean and heated by backblowing of heated air. The sampling gas velocity is kept constant during the sampling period. The sampled pulverized fuel is separated in a high-efficiency cyclone.

## 3 Sampling

### 3.1 Sampling equipment

The sampling equipment consists of a sampler and auxiliary equipment which shall ensure proper taking, separation and collection of the samples.

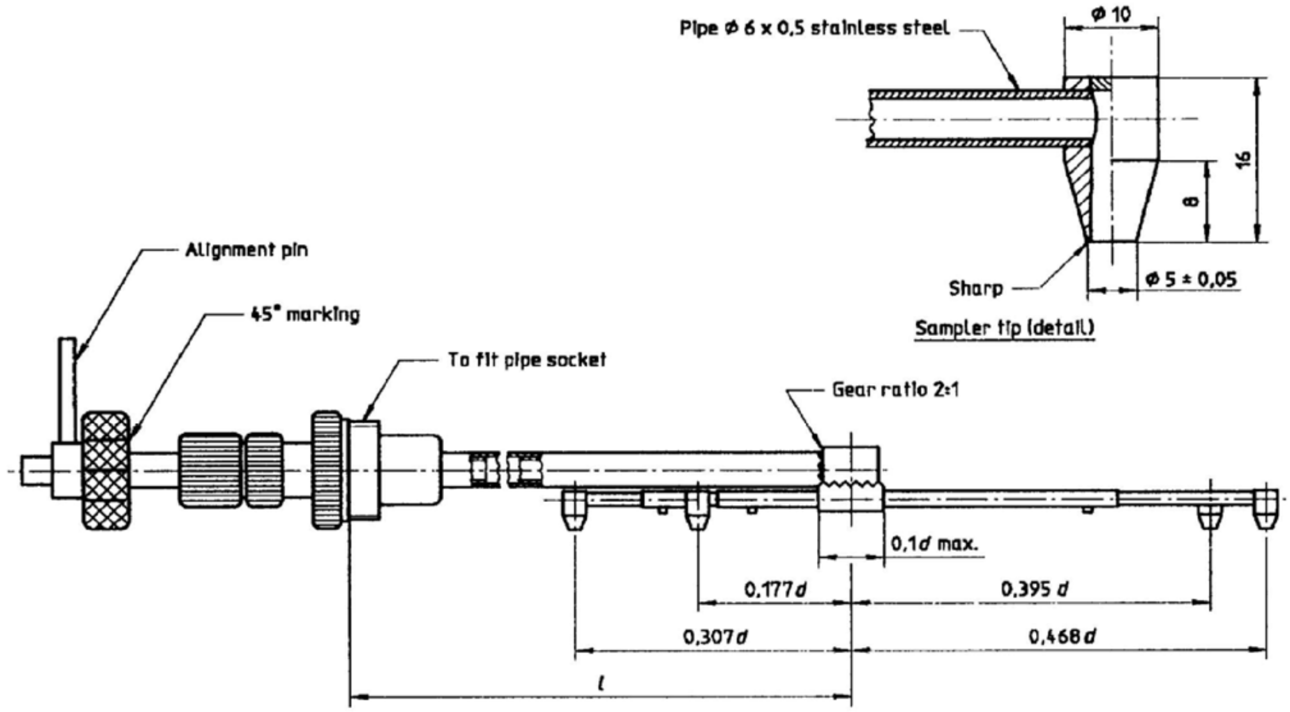
#### 3.1.1 Sampler

The sampler (see figure 1) is equipped with four sampling tips through which sample material can be simultaneously extracted. The tips are exchangeable, and if a tip is damaged, it shall be replaced.

By means of an angular gear mechanism with a gear ratio 2:1, the sampler tips can be rotated in concentric circles around the sampler head. A dial with eight equally distributed (45°) marks indicates the angular positions of the sampler tips at every 22,5°. When the dial is rotated twice, it gives one full turn of the sampler tips, thus giving 16 angular positions

The radial positions of the four sampling tips will ensure sampling from equal areas of the cross-sectional area of the pipe (see figure 2). The use of equal time sampling, with the sampler set at the 16 indicated angular positions, thus results in a representative sample being extracted from a total of 64 equal-sized areas of the sampling plane of the pipe

Dimensions in millimetres




**Key**

*d* Internal diameter of the pulverized-coal pipe
*l* Sampler length

**Figure 1 — Sampler**

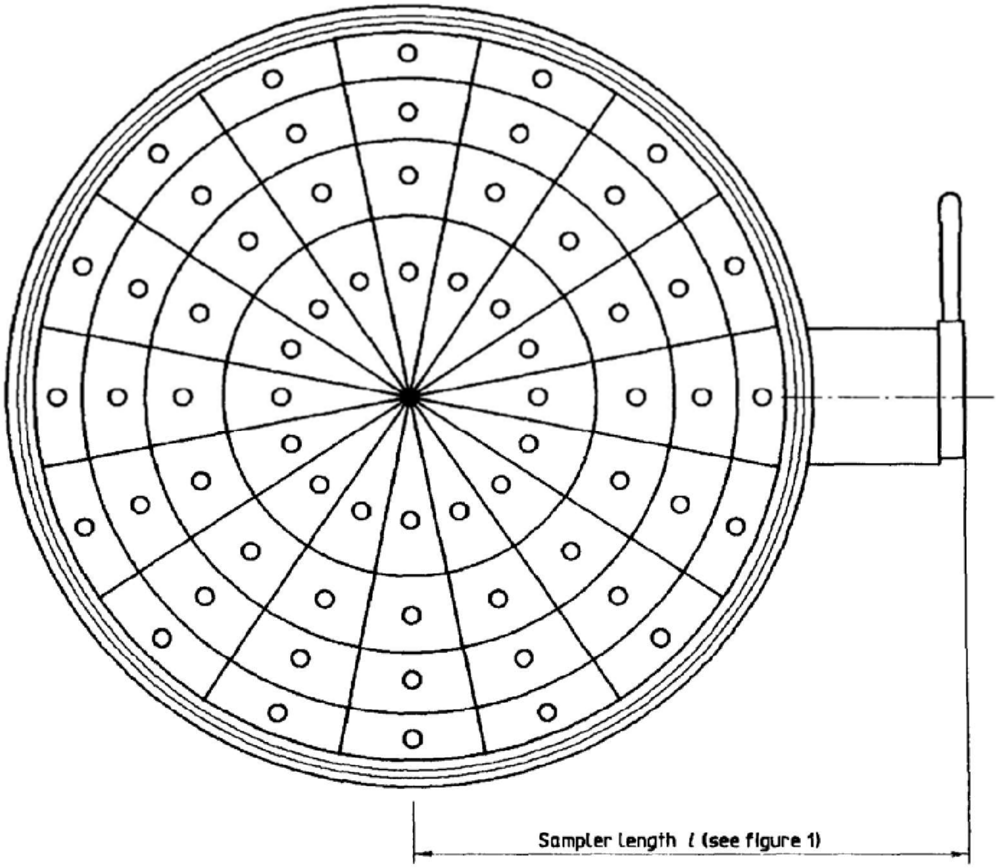



**Figure 2 — Sampling network**

The sampler is equipped with an adjusting device to ensure that the sampler head can be correctly positioned in the pipe axis during sampling. It is also equipped with extraction pipes that can be adjusted in length, in accordance with the actual pipe diameter to ensure correct sampler tip path.

In addition, the sampler is provided with an outside alignment pin perpendicular to the sampler tip plane. Thus, alignment of the pin with the pipe axis ensures a sampling plane perpendicular to the pipe.

#### 3.1.2 Auxiliary equipment

The auxiliary equipment shall have the following performance characteristics.

a) It shall measure and control the amount of extraction gas taken out during sampling.

b) It shall ensure a well-defined sampling period.

c) It shall be able to separate coal particles from the extracted sample stream with high efficiency.

d) It shall have a receiver for the separated coal sample, the receiver being just adequate to receive the maximum expected volume of sampled coal.

e) It shall ensure that no condensation takes place in the sampling system during sampling.

Suitable auxiliary equipment which meets all these requirements is described in annex A.

### 3.2 Conditions for sampling

#### 3.2.1 Selection of sampling positions

The precision of the sampling with respect to both mass and particle size distributions depends on the degree of segregation (roping) and swirling in the pipes. The occurrence of both phenomena is significant immediately downstream of a change in flow direction which happens, for example, in bends and pulverizers

In long horizontal pipe sections, the pulverized coal will tend to separate from the carrier gas thus causing the concentration to be much higher along the bottom of the pipe, with a risk of settlement.

These phenomena require careful selection of sampling positions.

The sampling positions in all pipes belonging to the same pulverizer should, if possible, be established in similar places and at the same distances from components which may create disturbances, in order to get the same bias in each of the pipes. See annex B.

The minimum distance from an upstream disturbing component to a sampling position shall be five times the internal diameter of the pipe. The minimum distance to a downstream disturbing component shall be equal to the internal diameter of the pipe. If, because of the configuration, such a sampling position is not attainable, another sampling location, using another sampling method, may be appropriate.

The pulverized coal suspension flow shall not swirl at the sampling position. Swirling can, for example, be caused by a pulverizer classifier.

Where sampling positions have been chosen, the pipes shall be equipped with a pipe socket. The socket axis shall be mounted on the pipe with a maximum deviation of $\pm$ 0,35° from radial direction. The socket shall be threaded to suit the plug and the sampler. In the case of positive pressure in the pipe, the socket should be of the dustless connection type to ensure dustfree insertions and removals of the sampler. A suitable dustless connection is described in A.1.1.

#### 3.2.2 Stability of operating conditions

During the total sampling period, the quality of the coal fed into the pulverizer and the gas and coal flow rate to the pulverizer shall be kept constant.

When sampling successively from all pipes belonging to one pulverizer, the results will only be valid if the flow conditions in all pipes are stable during the total sampling period.

#### 3.2.3 Extraction velocity

The sampling shall be carried out at a gas flow through the sampler, to give an average gas velocity through the sampling tip apertures in the range 1,1 $\pm$ 0,1 times the mean gas velocity in the coal pipe.

NOTE 3 Due to differences in particle and gas velocities, a sampling gas velocity higher than the mean carrier gas velocity is required. Experience has shown that observance of the requirement given in the previous paragraph results in better samples, both regarding mass and particle size distribution.

### 3.3 Sampling procedure

#### 3.3.1 Establishing the extraction velocity

First, calculate the mean gas velocity in the pipe at the sampling position. The calculation should be based on

- measurement of the quantity of gas supplied to the pulverizer;
- measurement or estimate of the temperature at the sampling position;
- measurement or estimate of the static pressure at the sampling position;
- estimate of the quantity of evaporated water from the coal-drying process in the pulverizer.

#### 3.3.2 Conditioning and preparation of the sampling equipment

Connect the sampler and auxiliary equipment. Clean and, to avoid condensation, heat the sampling equipment by backblowing (blowing a warm air stream in the direction opposite to that used when sampling).

Adjust the extraction pipes to the correct length according to figure 1.

#### 3.3.3 Insertion of the sampler

During insertion and fastening and until sampling starts, the intrusion of coal particles into the sampling system shall be avoided by continuous backblowing.

Adjust the sampler length ($l$ in figures 1 and 2) so that the sampler head centre is located at a distance of not more than 0,3 % of the pipe internal diameter from the pipe axis when sampling.

Before inserting the sampler, turn the sampler handwheel until the four suction pipes with the sampling tips are aligned with the sampler shaft.

Remove the plug of the sampling pipe socket. If this is a dustless connection, the plug should be removed only after compressed air has been supplied to the connection.

Carefully (to avoid damage to the tips) insert the sampler head through the socket and fasten it to the sampler shaft by means of the union nut. Check that the alignment pin is parallel to the centreline of the pipe.

Close the air supply to the dustless connection, if one is used.

NOTE 4 To ensure clearance between sampler and pipe wall, it is advisable to turn the sampler head one full turn inside the pipe and to leave the handwheel in the starting position.

#### 3.3.4 Taking of the sample

To start sampling, simultaneously start the timer and switch from backblowing to suction at the calculated velocity (see 3.3.1). Keep the extraction gas flow constant during the sampling period by adjusting it.

Sample for 15 s in the first position, turn the handwheel to the next indication mark and continue sampling for 15 s. Repeat the turning and sampling until sampling has taken place in the 16 angular positions.

NOTE 5 If preferred, sampling may also be performed by slow continuous rotation of the sampler head, for example one complete turn in 240 s.

To stop sampling, switch from suction to backblowing.

Depending on the purpose and as appropriate, duplicate samples to assess the repeatability may be taken within close time intervals and unchanged operating conditions.

If the differential pressure of the Venturi decreases during sampling, a check for blockage shall be made by increasing the suction. If the differential pressure does not increase, a blocked tip is confirmed. Abort the sampling test and clear the blockage.

#### 3.3.5 Removal of the sampler and sample

Turn the handwheel to the next indication mark in order to align the four suction pipes with the sampling tips and the sampler shaft.

When using a dustless connection, supply compressed air to it. Unscrew the sampler union nut and remove the sampler carefully. Plug the sampling socket. If this is a dustless connection, stop the air supply to it.

Stop the backblowing and remove the sample bottle from the sampler. If the sample bottle is an integral part of the sampling system, empty it carefully into a sample container.

Close the sample bottle or container with an airtight lid, and mark it for later identification.

Clean the sampling system by backblowing.

The next sample can be taken by starting the procedure from 3.3.3.

## 4 Sampling report

The sampling report shall include the following information:

a) a reference to this International Standard;

b) time and place of sampling;

c) identification of the operator;

d) sampling conditions, for example coal type, pulverizer operating conditions and readings necessary to calculate the extraction gas flow;

e) sample identification;

f) any unusual and irregular features noted during sampling.

# Annex A
(informative)

## Description and operation of suitable auxiliary equipment

This annex contains a description of suitable auxiliary equipment which meets the requirements specified in 3.1.2. It also describes the operation of the auxiliary equipment when sampling according to the procedures given in 3.3.

### A.1 Description of auxiliary equipment

The auxiliary equipment used should be suitable to withstand the pressure in the pipe at the sampling position.

The arrangement of the sampling equipment is shown in figure A.1. The sampler is described in 3.1.1.

The auxiliary equipment consists of the following parts (the numbers in parentheses refer to those used in figure A.1):

a) dustless connection (1);

b) cyclone (2);

c) sample bottle (3);

d) reinforced hose (4);

e) Venturi nozzle (5);

f) water gauge (6);

g) control valve (7);

h) ejector (8);

i) shut-off valve (9);

j) bypass valve (10);

k) filter (11);

l) air filter (12);

m) electric air-heater (13).

#### A.1.1 Dustless connection

When sampling from a pipe with positive pressure, a dustless connection should be installed to ensure dustfree insertion and removal of the sampler. A suitable dustless connection is shown in figure A.2.

#### A.1.2 Cyclone

To ensure the separation of small particles from the sampling stream, a high efficiency cyclone can be used. A suitable cyclone is shown in figure A.3.

The cut-size for the cyclone can be calculated after Perry[1] for the actual air flows. For coal particles with a density of 1 400 kg/m$^3$, the results are shown in figure A.4.

The efficiency for other particle sizes is calculated after Leith and Licht[2], and the results are shown in figure A 5.

A sample bottle lid is fastened to the lower end of the cyclone, enabling the sample bottle to be attached easily.

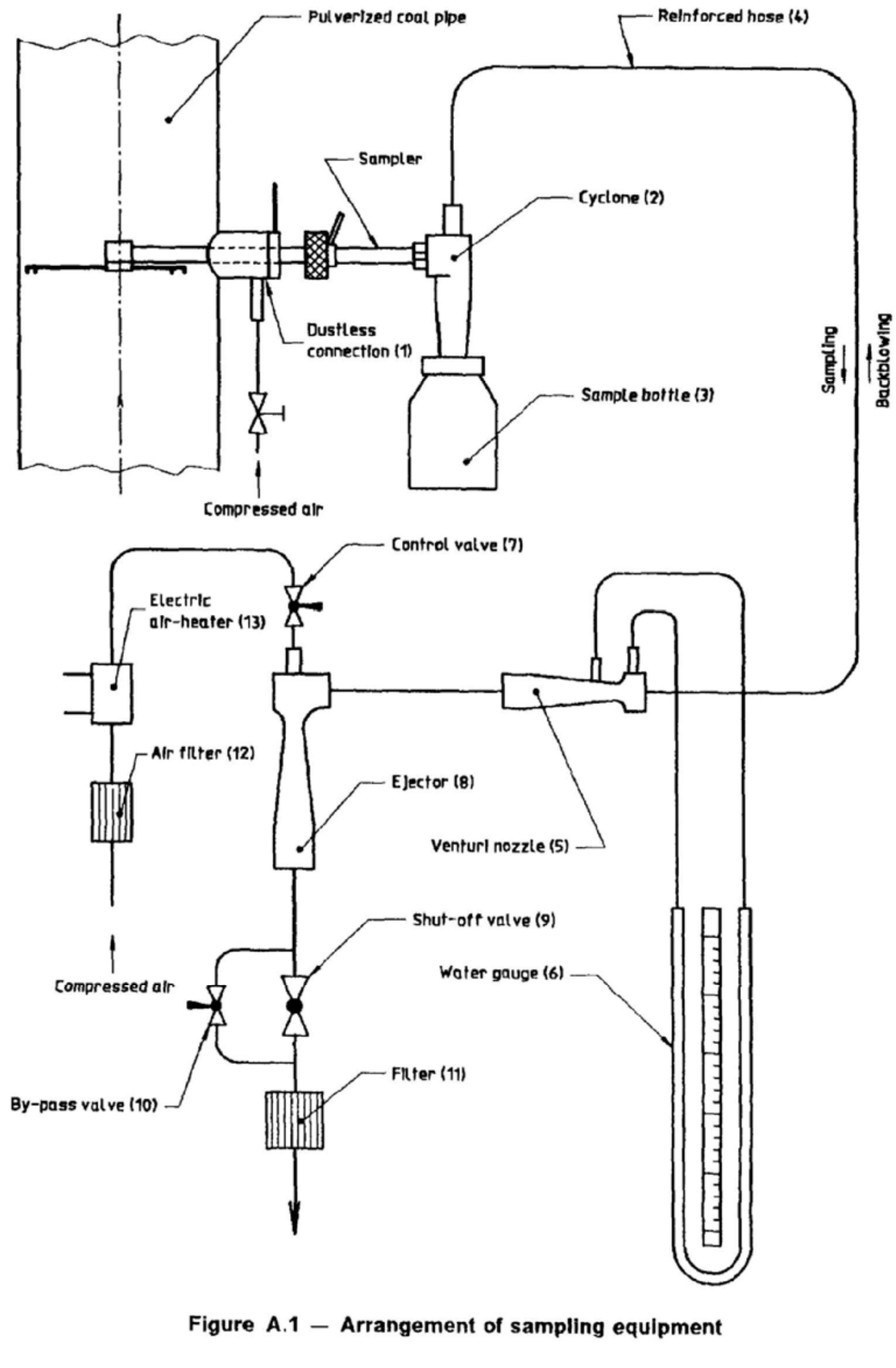



**Figure A.1 — Arrangement of sampling equipment**

### A.1.3 Sample bottle

A 500 ml polyethylene bottle is suitable for use as a sample bottle for most applications.

### A.1.4 Reinforced hose

The hose connects the cyclone and the Venturi nozzle [see figure A.1, (5)]. It should be as short as possible (2 m to 3 m) to avoid condensation, and the internal diameter should be 10 mm to 13 mm to give little pressure drop but sufficient transport velocity. The reinforcement prevents the hose from collapsing due to negative pressure.

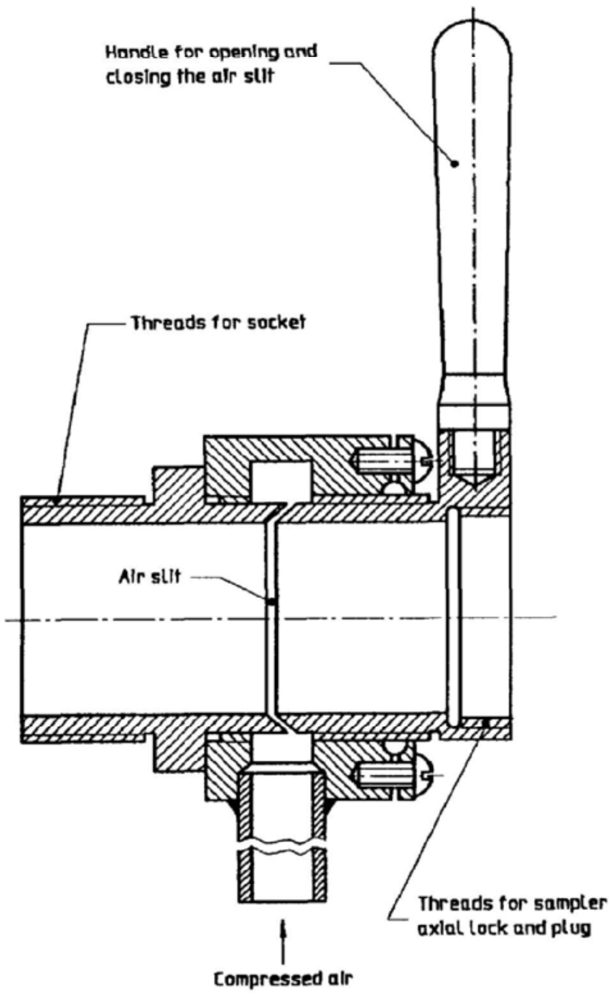



**Figure A.2 — Dustless connection**

Dimensions in millimetres

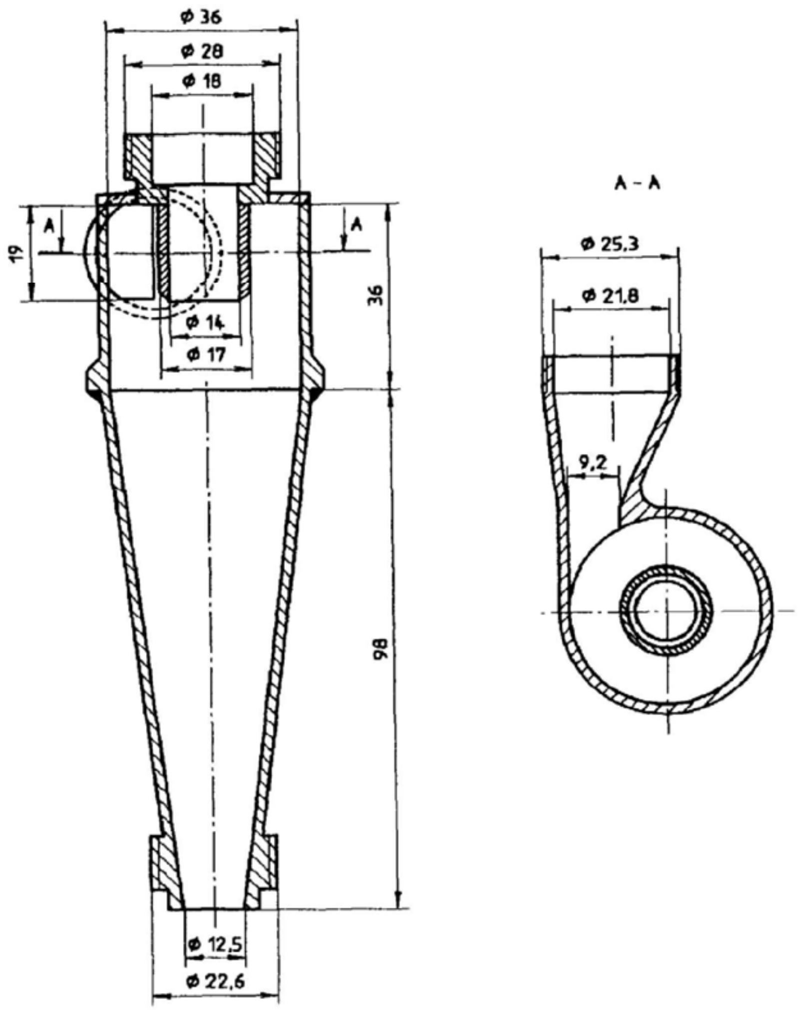



**Figure A.3 — Dimensioned drawing of a cyclone** (See, for example, BS 3405[4].)

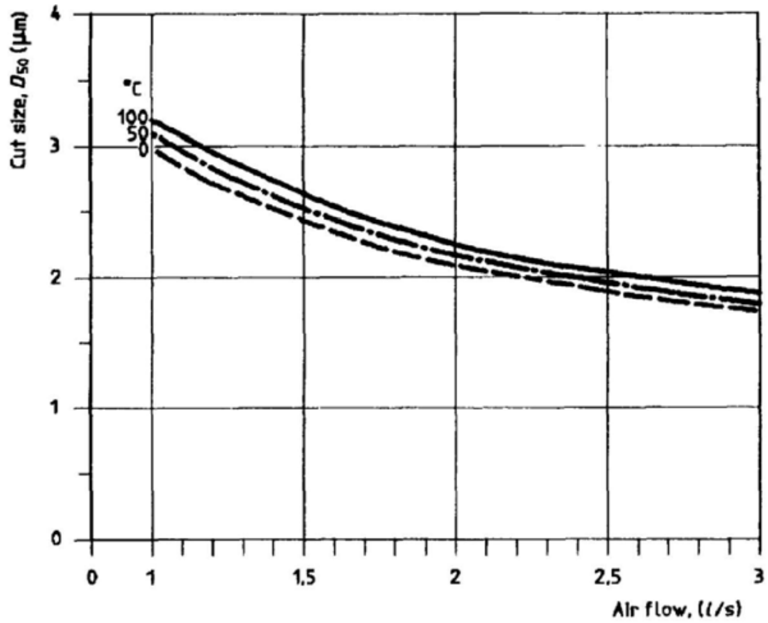



Figure A.4 — Cut size ($D_{50}$) for cyclone in figure A.5

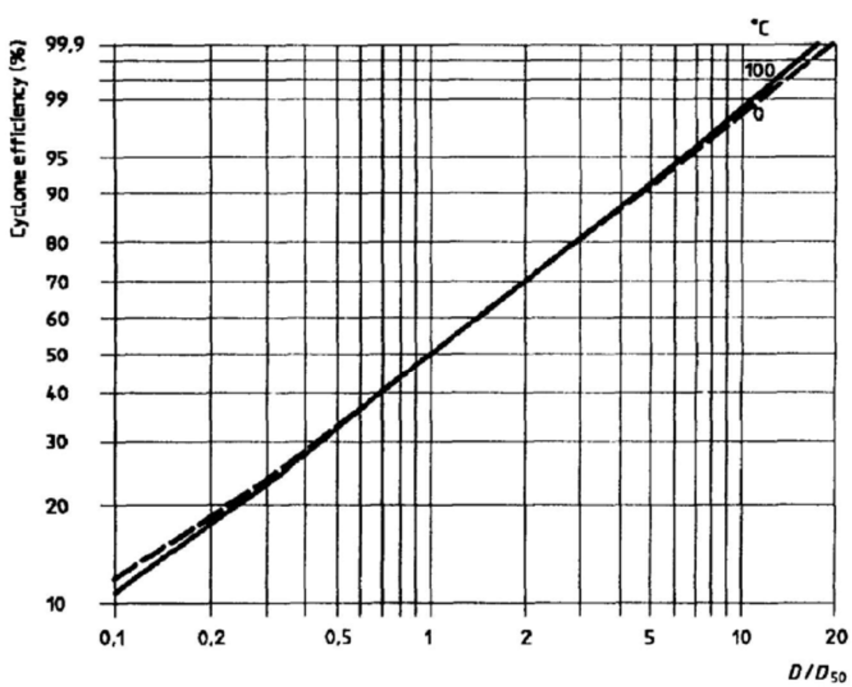



Figure A.5 — Cyclone efficiency for particle sizes other than $D_{50}$

### A.1.5 Venturi nozzle

A Venturi nozzle can be used to measure the air flow during sampling. A suitable Venturi nozzle is shown in figure A.6 and a calibration chart for it is shown in figure A.7.

As an alternative to a calibration chart, the following equation, which is derived from the calibration data in figure A.7, can be used:

$$p = \frac{0{,}856v^2}{273 + t}$$

where

- $p$ is the differential pressure, in kilopascals;
- $v$ is the extraction velocity, in metres per second;
- $t$ is the extraction gas temperature, in degrees Celsius.

### A.1.6 Water gauge

The water gauge is connected to the Venturi nozzle. It should be able to measure 4 kPa to avoid blow-through of the gauge.

### A.1.7 Control valve

The control valve is used

a) for adjustment of the extraction gas velocity by throttling compressed air to ejector [see figure A.1, (8)], and

b) for backblow control.

### A.1.8 Ejector

The ejector supplies suction for the sampling system. It shall be dimensioned to yield sufficient vacuum, depending on the static pressure at the sampling points.

### A.1.9 Shut-off valve

The shut-off valve is used for fast switches from sampling to backblowing and vice-versa.

### A.1.10 Bypass valve

The bypass valve is used to prevent pressurization of the sample bottle and hose during changes from suction to backblowing

### A.1.11 Filter

The filter, for example a vacuum cleaner paper bag, captures the fine coal dust which escapes from the cyclone.

### A.1.12 Air filter

The air filter ensures that compressed air entering the sampling system is free from oil and water.

### A.1.13 Electric heater

The electric heater heats the compressed air, thus preventing condensation in the sampling system. Normally, a power of 0,5 kW is sufficient. The air temperature should be controlled to avoid overheating of the auxiliary equipment.

Dimensions in millimetres

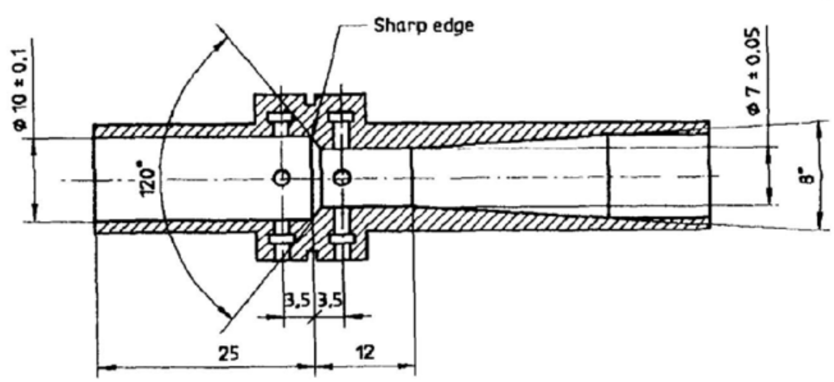



**Figure A.6 — Example of a suitable Venturi nozzle**

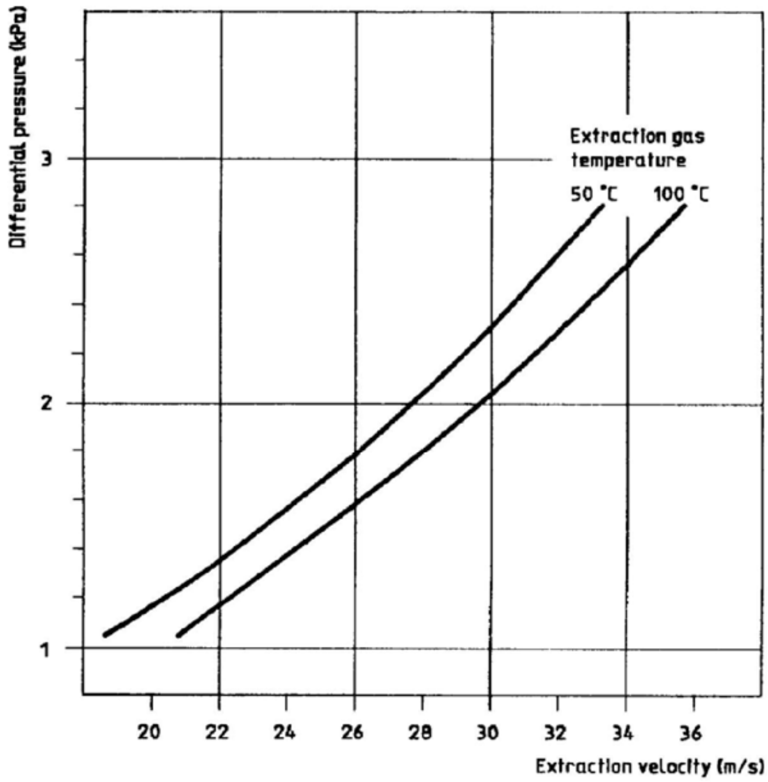



**Figure A.7 — Calibration chart for the Venturi nozzle shown in figure A.6**

## A.2 Operation

When sampling, the auxiliary equipment described is used in the following manner. (The numbers in parentheses refer to those used in figure A.1.)

### A.2.1 Establishing the extraction velocity (see 3.3.1)

When the extraction gas velocity has been calculated, the corresponding water gauge (6) reading may be found using the Venturi nozzle calibration data (see figure A.7) or the equation in A.1.5.

### A.2.2 Conditioning and preparation of the sampling equipment (see 3.3.2)

The sampling equipment is heated (to avoid condensation) and cleaned in the following way.

The air-heater (13) is switched on and the temperature set to between 80 °C and 85 °C. A spare sample bottle is fitted to the cyclone (2). Compressed air is connected and backblowing established by closing the shut-off valve (9) and opening the control valve (7).

Sampling can be started when the cyclone (2) and the sampler (see 3.1.1) are hand-warm. The heating system shall be switched on during the whole sampling period.

The control valve (7) is closed while a clean sample bottle is fitted to the cyclone (2).

Before insertion of the sampler, an approximate setting of the control valve (7) is found by an open-air suction test with the required extraction velocity. A leak test of the equipment is performed by placing the finger tips over the four sampling nozzles to check that the Venturi differentials drop to zero. The bypass valve (10) is also adjusted to avoid extreme pressurization during backblowing.

### A.2.3 Insertion of the sampler (see 3.3.3)

Backblowing with the control and bypass valves, (7) and (10), in the preset positions is continued during this operation until sampling starts. It should be noted that the Venturi nozzle/water gauge cannot be used for measurements during backblowing.

### A.2.4 Taking of the sample (see 3.3.4)

Sampling is started by opening the shut-off valve (9). The extraction gas flow is adjusted to the appropriate reading on the water gauge (6) using the control valve (7). During the sampling period, the extraction gas flow is kept constant by adjusting the control valve. The bypass valve (10) is kept in the preset position.

Sampling is stopped by closing the shut-off valve (9), which changes the operation from suction to back-blowing.

### A.2.5 Removal of the sampler and sample (see 3.3.5)

Backblowing is continued during removal of the sampler, but stopped before removal of the sample bottle (3) by closing the control valve (7).

# Annex B
(informative)

# Flow distribution and correction factors

## B.1 Flow distribution

During transportation of pulverized coal conveyed by gases in pipe systems, some segregation of the pulverized coal from the carrier gas will take place.

Due to centrifugal forces on the particles in, for example, classifiers, bends and splitters and also due to gravitational forces when the flow is passing long horizontal sections, this segregation results in high concentration areas, so-called ropes, at the pipe walls.

In the vertical pipe section which follows, these ropes will gradually be dissolved, the particles again becoming evenly distributed in the carrier gas.

Figure B.1 shows the segregation that occurs in a typical pipe system caused by a bend, and the subsequent dispersion in the vertical pipe section.

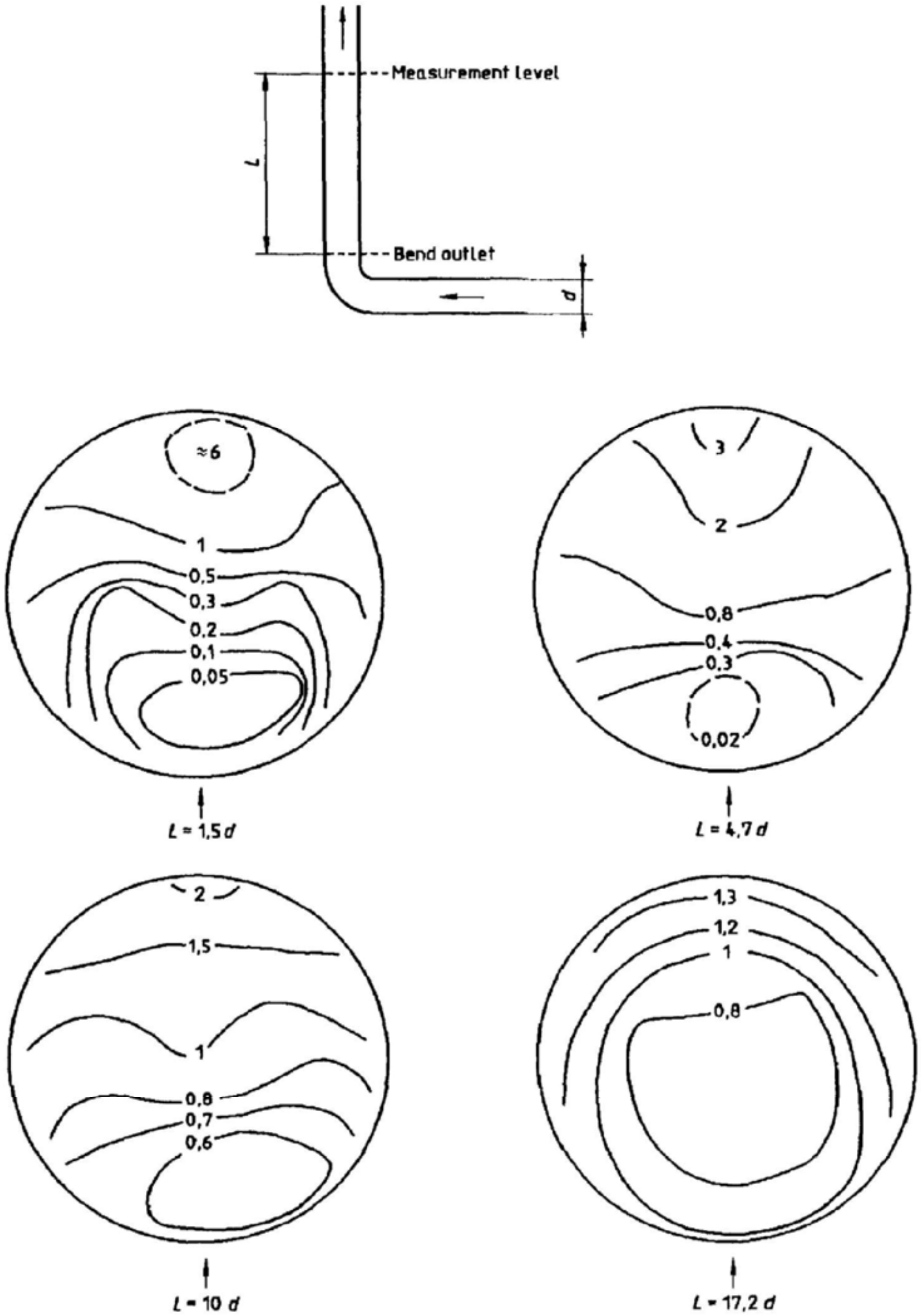
It can be inferred from figure B.1 that roping is a major problem in obtaining a representative sample.

In order to obtain a quantitative impression of this problem, experiments were carried out in a pilot plant with one pulverized coal pipe, and the impact made on sample mass and fineness by a 90° bend was investigated for different sampling positions.

The results obtained can be expressed as a set of correction factors for sample mass and fineness, in relation to the upstream distance from the sampling positions to the bend.

Experiments show that the mass of the sample taken is smaller than that of a sample from an ideal sampling position, and also that the extracted pulverized coal is finer than that of a sample from an ideal sampling position.

Figure B.1 shows mass flow contours in a vertical pipe of diameter 150 mm containing pulverized coal particles of mean diameter 35 µm, density 1 380 kg/m$^3$ (interpolated from the data of Zipse[3]), velocity 14 m/s, and air to solids ratio 1,7. The mass flows are relative to each centre-point value.




**Key**

*d* Internal diameter of the pipe
*L* Sampling position distance from upstream disturbant components

**Figure B.1 — Example of segregation in a vertical pipe system**

## B.2 Correction factors

### B.2.1 Correction for sample mass

For pulverized coal samples taken according to this International Standard, the relative mass flow distribution to each pipe belonging to the same pulverizer can be calculated immediately without using a correction factor.

Experiments show that an approximation to the actual pulverized coal mass flow in each pipe, i.e. the mass which could be extracted under optimum sampling conditions, can be estimated by using the following equation:

$$m_a = g \cdot m_s$$

where

$m_a$ is the actual sample mass;

$m_s$ is the measured sample mass; and

$g$ is the mass correction factor obtained from table B.1, where $L/d$ is the ratio between $L$, the sampling position distance from upstream disturbant components, and $d$, the internal pipe diameter.

Table B.1 gives the corresponding mass correction factors for different values of $L/d$.

**Table B.1 — Mass correction factor ($g$)**

| $\frac{L}{d}$ | 5 | 6 | 8 | 10 | 15 | 20 | 30 | 40 |
|---|---|---|---|---|---|---|---|---|
| $g$ | 1,12 | 1,11 | 1,10 | 1,08 | 1,06 | 1,04 | 1,03 | 1,02 |

### B.2.2 Correction for particle size distribution

Particle size distribution is normally reproduced in a Rosin-Rammler chart, showing sieve passing mass percentages as a function of sieve apertures.

Experiments show that an approximation to the actual particle size distribution, i.e. the particle size distribution which would appear under optimum sampling conditions, may be found by displacing the particle size distribution parallel to the right in the Rosin-Rammler chart (see the example given in figure B.2). This is expressed by the following equations:

$$A(x_2) = M(x_1) \text{ and } x_2 = fx_1$$

where

$A$ is the actual particle size distribution, i.e. sieve passing as a function of sieve aperture;

$M$ is the measured particle size distribution, i.e. sieve passing as a function of sieve aperture;

$x$ is the sieve aperture;

$f$ is the particle size distribution correction factor obtained from table B.2, where $L/d$ is the ratio between $L$, the sampling position distance from upstream disturbant components and $d$, the internal pipe diameter.

**Table B.2 — Particle size distribution correction factor**

| $\frac{L}{d}$ | 5 | 6 | 8 | 10 | 15 | 20 | 30 | 40 |
|---|---|---|---|---|---|---|---|---|
| $f$ | 1,10 | 1,09 | 1,08 | 1,07 | 1,04 | 1,03 | 1,02 | 1,01 |

EXAMPLE — A sample is taken in a vertical pipe at a distance of $10 \times d$ from a 90° bend which is upstream.

The particle size distribution, $M$, of this sample is found to have a passing of 70 % through a sieve with an aperture of $x_1 = 75$ µm (point 1 in figure B.2) and a slope, as shown, in the range of 75 µm.

Using the correction factor for $L/d = 10$ from table B.2, the actual particle size distribution, $A$, will then have a passing of 70 % through a sieve with an aperture of $x_2 = 75 \times 1,07 = 80$ µm (point 2 in figure B.2).

The actual particle size distribution, which has the same slope as that of the sample taken, is then found to have a passing of 66 % through the 75 µm sieve (point 3 in figure B.2).

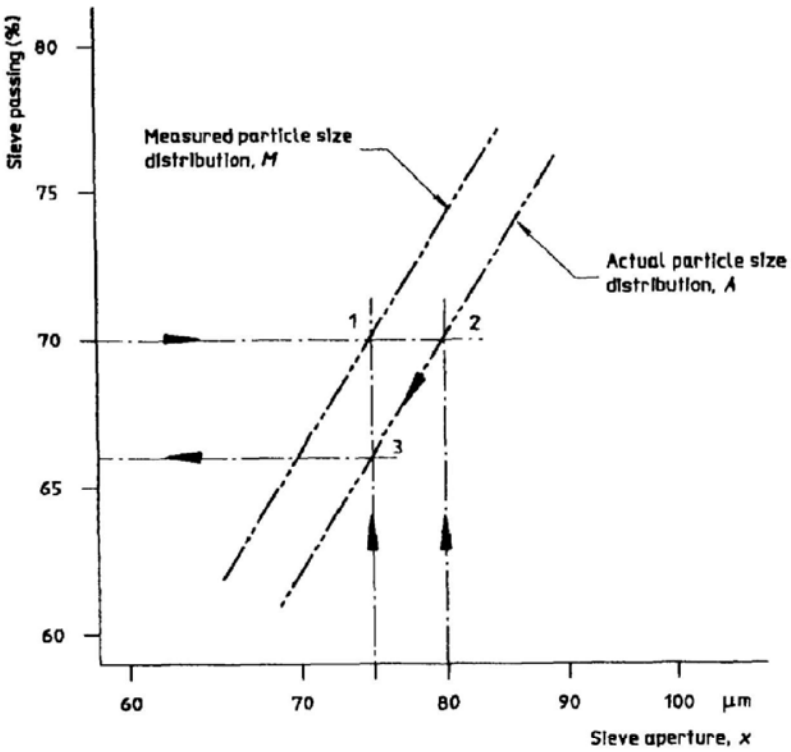



**Figure B.2 — Example of correction for particle size distribution (part of Rosin-Rammler chart)**

# Annex C
(informative)

## Bibliography

[1] PERRY, J.H., *Chemical Engineers Handbook* (1963), McGraw-Hill Book Company.

[2] LEITH, and Licht, *AIChE Symposium Series*, **68** (1972), p. 196.

[3] ZIPSE, G., The mass flow density distribution in pneumatic transport of powders and the influence on it by inserts in the piping. Fort.-Ber. VDI-Z., Series 13, No. 3, (1966).

[4] BS 3405:1983 *Method for measurement of particulate emission including grit and dust (simplified method)*.

**UDC 662.87:620.11**

**Descriptors**: solid fuels, coal, powdery materials, sampling, electric power generation, pneumatic conveyors, crushers, furnaces.

Price based on 18 pages