INTERNATIONAL STANDARD

ISO 1953

Second edition
1994-07-15

Hard coal — Size analysis by sieving

Houille — Analyse granulométrique par tamisage

Reference number
ISO 1953:1994(E)

Hard coal — Size analysis by sieving

1 Scope

This International Standard specifies reference methods for the size analysis of coal by manual sieving (wet or dry), using test sieves of aperture sizes between 125 mm and 45 µm. A guide to sampling is given in annex A and notes on the use of mechanical sieving are given in annex B.

This International Standard is applicable to all hard coals. It is not applicable to coke or other manufactured fuels.

In the case of pulverized coal which has been ground so that a high proportion passes through the test sieve of smallest aperture size, the methods described in this International Standard will determine only the percentage oversize.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 1213-1:1993, *Solid mineral fuels — Vocabulary — Part 1: Terms relating to coal preparation.*

ISO 1213-2:1992, *Solid mineral fuels — Vocabulary — Part 2: Terms relating to sampling, testing and analysis.*

ISO 1988:1975, *Hard coal — Sampling.*

ISO 3310-1:1990, *Test sieves — Technical requirements and testing — Part 1: Test sieves of metal wire cloth.*

ISO 3310-2:1990, *Test sieves — Technical requirements and testing — Part 2: Test sieves of perforated metal plate.*

3 Definitions

For the purposes of this International Standard, the definitions given in ISO 1213-1 and ISO 1213-2 apply.

4 Apparatus

4.1 For all methods

4.1.1 Test sieves, exclusively round-hole or exclusively square-hole, complying with ISO 3310-1 or ISO 3310-2, as appropriate.

NOTES

1 The recommended series of test sieves for general purposes is 125 mm, 90 mm, 63 mm, 45 mm, 31,5 mm, 22,4 mm, 16 mm, 11,2 mm, 8 mm, 5,6 mm and 4 mm nominal aperture sizes, square-hole, or the same sizes of round-hole sieves. If this series is inadequate for the sizing of graded coals, sieves from the supplementary sizes 100 mm, 80 mm, 50 mm, 40 mm, 25 mm, 20 mm, 12,5 mm, 10 mm and 6,3 mm may be included. For samples containing pieces having a particle size greater than 125 mm, single-hole gauges of the required dimensions may be used for the larger pieces. Test sieves of nominal aperture size 4 mm and less should be of metal wire cloth; the recommended series of nominal aperture sizes is 4 mm, 2,8 mm, 2 mm, 1,4 mm, 1 mm, 710 µm, 500 µm, 355 µm, 250 µm, 180 µm, 125 µm, 90 µm, 63 µm and 45 µm.

2 When a complete size analysis is required, it is preferable, subject to the range of sieve aperture sizes available, that the mass of coal in any size fraction does not exceed 30 % of the total mass of sample being sieved. The largest aperture size sieve should be that on which not more than

5 % mass fraction of the sample is retained and the smallest aperture size sieve should be that through which not more than 5 % mass fraction of the sample passes.

3 It is important to check the sieves from time to time, by the methods described in ISO 3310-1 and ISO 3310-2, to ensure that the aperture dimensions are within the specified tolerances. Worn or damaged sieves can give rise to serious errors in size analysis and should be discarded.

4.1.2 Receivers, for collecting material passing through the sieves.

4.1.3 Weighing machine, capable of measuring the mass of the sample to be sieved to the nearest 0,1 %.

4.1.4 Three trays, smooth, of noncorrodible material, at least 400 mm × 400 mm.

NOTE 4 Glazed paper may be used if trays are not available.

4.1.5 Watch- or clock-glasses.

4.2 For dry sieving

4.2.1 Lids, to fit the test sieves.

4.2.2 Flat brush, for cleaning the sieves and for brushing dust from the trays.

4.2.3 Hardwood block, about 150 mm long with a 10 mm × 10 mm cross-section, for tapping the sieves.

4.2.4 Shovel or scoop.

4.3 For wet sieving

4.3.1 Buchner funnel.

4.3.2 Buchner flask.

4.3.3 Filter paper.

4.3.4 Oven, capable of being controlled to ± 2 °C in the range 30 °C to 110 °C.

5 Preparation of test sample

5.1 General

Drying is necessary if the coal is wet and dry sieving is to be performed. The gross sample may be divided if its mass greatly exceeds the value given in table A.1. If the gross sample is to be dried and divided, the division shall be carried out first whenever practicable. If no preparation is necessary, the test sample is the gross sample.

5.2 Drying

Air-dry the sample either at ambient temperature or at an elevated temperature not exceeding 50 °C. Cool, if necessary, and allow the moisture content to come to equilibrium with the laboratory atmosphere.

NOTE 5 If caking or swelling tests are to be carried out subsequently on the sample, the drying temperature should not exceed 40 °C.

5.3 Division (other than wet coal of nominal top size less than 4 mm)

Provided that the sample does not contain pieces of particle size greater than 16,0 mm, divide the sample by means of a suitable mechanical sample divider or riffle, which will not give biased divided samples, avoiding size degradation and loss of dust. If the sample contains pieces of particle size greater than 16,0 mm, use either the flattened heap method or the strip mixing and splitting method described in ISO 9411-1. Weigh all the coal not included as part of the test sample and retain it until all analyses and calculations are complete.

5.4 Division of wet coal of nominal top size less than 4 mm

Spread the gross sample on a clean flat surface, form into a cake 15 mm to 25 mm thick and extract a 2 kg divided sample by taking not less than 50 increments, evenly spread over the cake, using an appropriate sampling scoop. If further division is necessary, air-dry the divided sample first, as described in 5.2 and then proceed as described in 5.3.

6 Procedure

6.1 General

The analysis shall be carried out by dry sieving (6.2) or by wet sieving (6.3).

If the mass of the undersize greatly exceeds the value given in table A.1, divide it by means of a suitable mechanical sample divider or riffle, which will not give biased divided products, or by the flattened heap method or the strip mixing and splitting method described in ISO 9411-1, avoiding size degradation and loss of dust.

NOTES

6 In general, dry sieving is suitable for most types of coal but wet sieving should be used if particles tend to agglomerate.

7 A combination of wet sieving (to remove fine material) and dry sieving may be appropriate and an example is given in annex C.

8 The range of sieves used will depend on the type of coal and the purpose of the test. For example, a complete size analysis may be required for a run-of-mine coal or, in the simplest case, the amount of undersize in a graded product may be required. If the results are to be presented graphically, the range of sieves should comprise at least five different aperture sizes.

9 During sieving it may be convenient either to weigh separately each container with its size fraction and to subtract the mass of the empty container or to weigh one container with the fraction corresponding to the largest aperture size and to add successively all the other fractions, noting the cumulative mass after each addition. The first technique is preferred for samples having a maximum particle size of 4 mm, so that the endpoint of sieving may be checked. The second technique is normally used for samples containing pieces having a particle size greater than 4 mm. However, if a detailed analysis of the individual size fractions is required, it is essential to use the first technique.

10 A preliminary sieving on the smallest aperture size sieve is recommended when the sample contains a large proportion of very fine material.

6.2 Dry sieving

6.2.1 Sample of maximum particle size greater than 45 mm

Weigh the sample to the nearest 0,1 %. Position the 45 mm aperture size sieve (4.1.1) over an empty receiver (4.1.2) so that the free fall of coal passing through the sieve into the receiver does not exceed 150 mm. Place the coal on the sieve and move the coal by hand until no more passes through the sieve. Hand place the particles which still remain on the sieve.

NOTE 11 "Hand placing" refers to the operation defined in ISO 1213-2:1992, 3.73.

Resieve the oversize from the 45 mm aperture size sieve, in the same fashion, on the larger aperture size sieves in the set (4.1.1), starting with the largest aperture size and working down to the smallest. Collect each size fraction in a weighed empty receiver and reweigh to obtain the mass of each individual fraction.

Sieve the undersize from the 45 mm aperture size sieve as described in 6.2.2.

6.2.2 Sample of maximum particle size between 4 mm and 45 mm

Weigh the sample to the nearest 0,1 %. Position the largest aperture size sieve in the set (4.1.1) over an empty receiver (4.1.2). Move the sieve horizontally to and fro, with the displacement not exceeding 100 mm in either direction, so as to cause the pieces of coal to tumble or roll on the sieve.

NOTE 12 When using square-hole sieves, the sides of the holes should be parallel to the direction of the sieving motion.

Continue the sieving motion until eight movements in each direction (a total of sixteen movements) have taken place after the last undersize piece passes through the sieve. Avoid any impact when stopping the motion.

Place the coal remaining on the sieve in a weighed receiver and reweigh to obtain the mass of the size fraction.

Resieve the undersize by repeating the above process for each sieve down to and including the 4 mm aperture size sieve. If analysis of the undersize from the 4 mm aperture size sieve is required, proceed as described in 6.2.3.

6.2.3 Sample of maximum particle size less than 4 mm

6.2.3.1 Weigh the sample to the nearest 0,1 %. If the sample contains a large proportion of fine dust, remove the dust by proceeding as described in 6.2.3.2 to 6.2.3.6 and then continue as described in 6.2.3.7. Otherwise, proceed as described in 6.2.3.7.

6.2.3.2 Place the smallest aperture size sieve in the set (4.1.1) on a receiver (4.1.2), brush the sample onto the sieve, fit the lid (4.2.1) and sieve continuously for 5 min, as described in 6.2.3.3, to remove the undersize. If the sample is large, sieve it as separate portions so that not more than 75 % of the area of the sieve is covered at the end of each sieving operation.

6.2.3.3 Hold the receiver, fitted with the sieve and its lid, in the left hand so that the surface of the sieve is inclined downwards towards the left at an angle of about 30° to the horizontal. Tap the higher side of the sieve frame six to eight times with the hardwood block (4.2.3). While maintaining the inclination of the sieve, shake the assembly to and fro several times, also rotating it in the plane of the sieving surface through an angle of approximately 60°.

NOTE 13 During the shaking operation the assembly should be held loosely between the hands, the movement of the arms being from the elbow joints. It will then be possible to rotate the sieve with the fingertips whilst it is being shaken.

Continue the operations of tapping and shaking alternately for 5 min.

6.2.3.4 At the end of the 5 min sieving period allow the suspended dust to settle for 2 min, carefully remove the lid and lift the sieve from the receiver. Invert the sieve over a tray (4.1.4), tap the side of the frame with the hardwood block and carefully brush the uppermost surface of the inverted sieve with the flat brush (4.2.2). Turn the sieve the right way up and add any loose particles dislodged during brushing to the oversize on the tray.

6.2.3.5 Invert the receiver over a second tray (4.1.4), tap the receiver with the hardwood block and brush out any adherent dust.

6.2.3.6 If fine dust is still visible in the oversize, replace the sieve on the receiver, transfer the oversize from the first tray to the sieve, replace the lid and resieve as described in 6.2.3.3 for a further 5 min. Separate the sieve and the receiver and again clean the sieve as described in 6.2.3.4. Add the dust to the material which passed through the sieve during the first 5 min period.

NOTE 14 In most cases the sample will now be sufficiently free from dust to allow a complete size analysis to be carried out rapidly.

6.2.3.7 Assemble the appropriate sieves (4.1.1) in a nest, in descending order of aperture size, and fit a receiver (4.1.2). Place the sample, or the oversize from the process described in 6.2.3.2 to 6.2.3.6, on the top sieve. Shake the nest of sieves for a period of 5 min.

6.2.3.8 At the end of the 5 min period clean each sieve in turn, starting with the smallest aperture size sieve, by inverting it over a tray (4.1.4), tapping the side of the frame with the hardwood block (4.2.3) and carefully brushing the uppermost surface of the inverted sieve with the flat brush (4.2.2). Turn the sieve the right way up and add any loose particles dislodged during the brushing to the oversize on the tray. Return the sieve to the nest and transfer the material on the tray back to the sieve.

6.2.3.9 Repeat the process described in 6.2.3.7 and 6.2.3.8 twice, but after the final cleaning of the sieves transfer the material from the trays to the watch- or clock-glasses (4.1.5) and determine the mass of each size fraction. Add the undersize obtained from the initial separation to that from the final sieving before weighing.

6.2.3.10 After weighing, return each individual size fraction to the corresponding sieve, repeat the sieving cycle described in 6.2.3.7 and 6.2.3.8 and then reweigh each size fraction as described in 6.2.3.9. Continue this process until the difference between the two weighings for any size fraction, after consecutive sieving cycles, does not exceed 0,2 % of the total mass of coal being sieved.

6.3 Wet sieving

6.3.1 Support the largest aperture size sieve in the set (4.1.1) over a receiver (4.1.2), transfer to it about 30 g of the sample and thoroughly wash this portion with a jet of water. Inspect the portion for the presence of aggregated particles and, if these are detected, spray vigorously to effect their breakdown but take care not to overspray, thus causing the disintegration of shale. Add the remainder of the sample to the sieve in approximately 30 g increments, washing the undersize in each portion through into the receiver. Check whether all the fines have been washed through the sieve by collecting some of the washings in a second receiver and examining them closely. If any solids are present, add them to the first receiver and continue the washings until all the fines have been washed through.

6.3.2 Place the sieve and its contents on a tray (4.1.4) and dry as described in 5.2. When dry, tap the sieve two or three times and transfer any material which collects on the tray to the next sieve (with a smaller aperture size) in the set. Brush out both the top and bottom of the first sieve, collecting the oversize on a tared watch- or clock-glass (4.1.5). Reweigh the watch- or clock-glass to obtain the mass of the size fraction.

6.3.3 Support the next sieve in the set over another receiver and pour the contents of the first receiver onto it. Wash any solids remaining in the first receiver onto the sieve, using a jet of water. Continue washing the material on the sieve until all the fines appear to have been washed through. Check whether this is so, as described in 6.3.1, then proceed as described in 6.3.2.

Repeat this process with each of the remaining sieves in turn.

Should the quantity of water in the washings become excessive, allow the solids to settle and decant a portion of the water. Examine the decanted water to

ensure that it contains no solid material before discarding it.

6.3.4 Add a flocculating agent to the final washings and allow the solids to settle. Decant and discard as much of the water as possible and filter through a weighed filter paper (4.3.3) using the Buchner funnel (4.3.1) into the Buchner flask (4.3.2). Dry the filter paper and its contents to constant mass in the oven (4.3.4) controlled at a temperature of 105 °C to 110 °C. Subtract the original mass of the filter paper to obtain the mass of the fine material.

NOTE 15 When the total mass of the sample is known, this determination of the undersize serves as a useful check on the efficiency of the sieving and should, therefore, be carried out whenever possible (see also note 4 to 6.1).

7 Expression of results

7.1 Calculation

Calculate the mass of the size fraction retained on each of the different sieves as a percentage of the total mass of the test sample.

Record the percentages, to the nearest 0,1 %, both fractionally and cumulatively. In most cases it will be most convenient to commence with the fraction of largest size but for a sample for which there is particular interest in the amount passing through the sieves, it may be preferred to start with the fraction of smallest size. If the analysis has been performed on a number of replicate samples, calculate the mean percentage of each size fraction.

Adjust the mass of the smallest size fraction to take account of any loss or gain in the total mass of the test sample after sieving. If, however, in any test the loss or gain in mass exceeds 1 % of the total mass of the test sample, reject the results of that test.

If, during the course of a size analysis, the mass of undersize is reduced by sample division, calculate the mass of each of the subsequent fractions as a percentage of the total mass of undersize at the time of division. An example of the calculation of a size analysis involving sample division is given in table 1 and the sieving procedure is shown schematically in figure 1.

If replicate sampling of an isolated consignment has been carried out, calculate the precision achieved in accordance with ISO 1988:1975, C.4.4.

7.2 Graphical presentation

The presentation of fractional size analyses in graphical form presents difficulties in interpretation, in that the size range of each fraction is seldom uniform. If graphical presentation is required, it is recommended that the cumulative percentage of material remaining on each sieve is plotted, as ordinate, against sieve aperture size, as abscissa.

Linear scales are not usually satisfactory except when the size range is less than two orders of 10. A logarithmic abscissa scale or a Rosin–Rammler type of plot should be used whenever possible. The ordinate for a Rosin–Rammler plot is lg (lg 100 – lg R), where R is the cumulative percentage of material remaining on each sieve, and the abscissa is the logarithm to base 10 of the sieve aperture size. None of the graphs should be extrapolated outside the experimental range. An example of a Rosin–Rammler plot, using the data in table 1, is given in figure 2.

8 Test report

The test report shall include the following information:

a) the identification and mass of the sample;

b) a reference to this International Standard;

c) details of any sample preparation carried out;

d) details of the test sieves used;

e) whether dry sieving or wet sieving was carried out;

f) the percentage mass, or the mean percentage mass, in each size fraction;

g) if replicate sampling of an isolated consignment has been carried out, the precision achieved;

h) any operation not included in this International Standard, or regarded as optional;

i) the date of test.

Table 1 — Example of the calculation of a size analysis involving sample division

Sieve aperture size	Initial sample		First sample division			Second sample division			Third sample division			Size analysis	
	Mass	% of test sample	Mass	% of sub-sample	% of test sample	Mass	% of sub-sample	% of test sample	Mass	% of sub-sample	% of test sample	Fractional	Cumulative oversize
mm	kg		kg	(1)	(2)	g	(3)	(4)	g	(5)	(6)	%	%
63	19,5	3,1										3,1	3,1
45	32,1	5,1										5,1	8,2
31,5			8,0	8,3	7,6							7,6	15,8
22,4			13,1	13,6	12,5							12,5	28,3
16			10,8	11,2	10,3							10,3	38,6
11,2			14,0	14,5	13,3							13,3	51,9
8						561,7	21,8	10,5				10,5	62,4
5,6						545,6	21,2	10,2				10,2	72,6
4						379,8	14,8	7,1				7,1	79,7
2,8									88,7	32,5	6,6	6,6	86,3
2									56,4	20,7	4,2	4,2	90,5
1,4									41,7	15,3	3,1	3,1	93,6
1									34,9	12,8	2,6	2,6	96,2
< 1												3,8	100,0
Total retained on sieves (A)	51,6	8,2	45,9	47,7	43,8	1 487,1	57,8	27,8	221,7	81,3	16,5		
Passing finest sieve (B)	576,4	91,5	50,2	52,1	47,8	1 079,7	42,0	20,2	50,0	18,3	3,7		
Sample used (C)	629,7	100,0	96,3	100,0	91,8	2 573,0	100,0	48,1	272,8	100,0	20,3		
Loss (D)	1,7	0,3	0,2	0,2	0,2	6,2	0,2	0,1	1,1	0,4	0,1		
Passing + loss ($B + D$)		91,8			48,1			20,3			3,8		
Reduction factor $F = (B + D)/100$	$F_1 = 0{,}918$		$F_2 = 0{,}481$			$F_3 = 0{,}203$							

NOTE — The data in columns (2), (4) and (6) are obtained by multiplying the corresponding data in columns (1), (3) and (5), respectively, by the reduction factors F_1, F_2 and F_3.

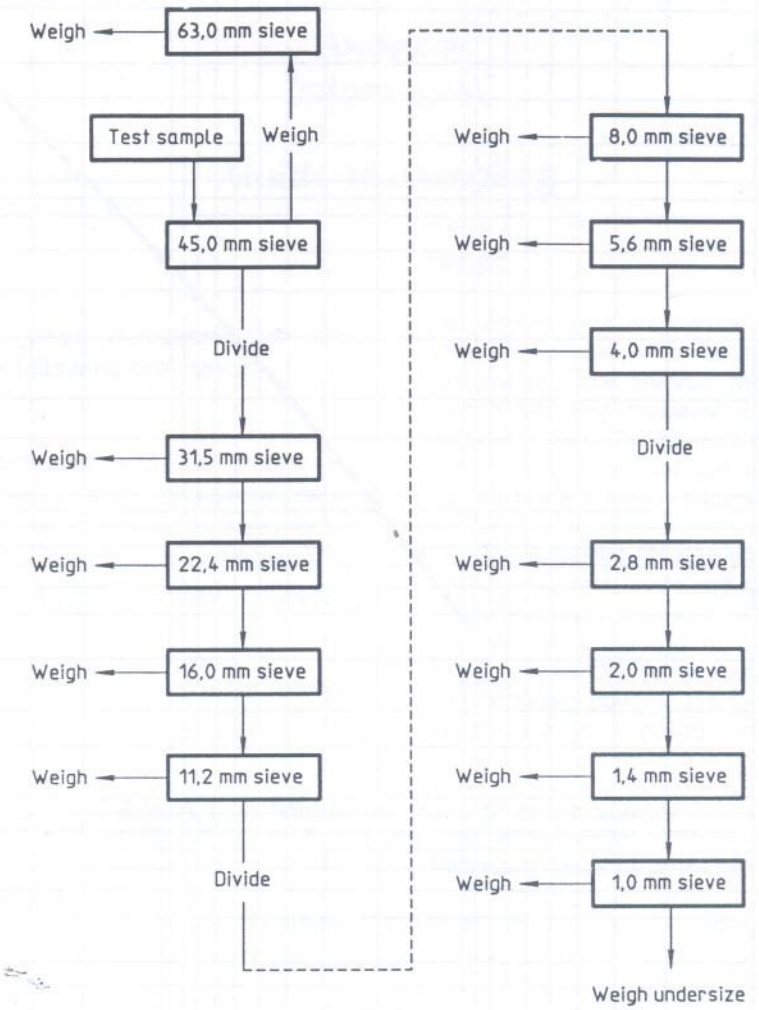

Figure 1 — Schematic diagram of a sieving procedure

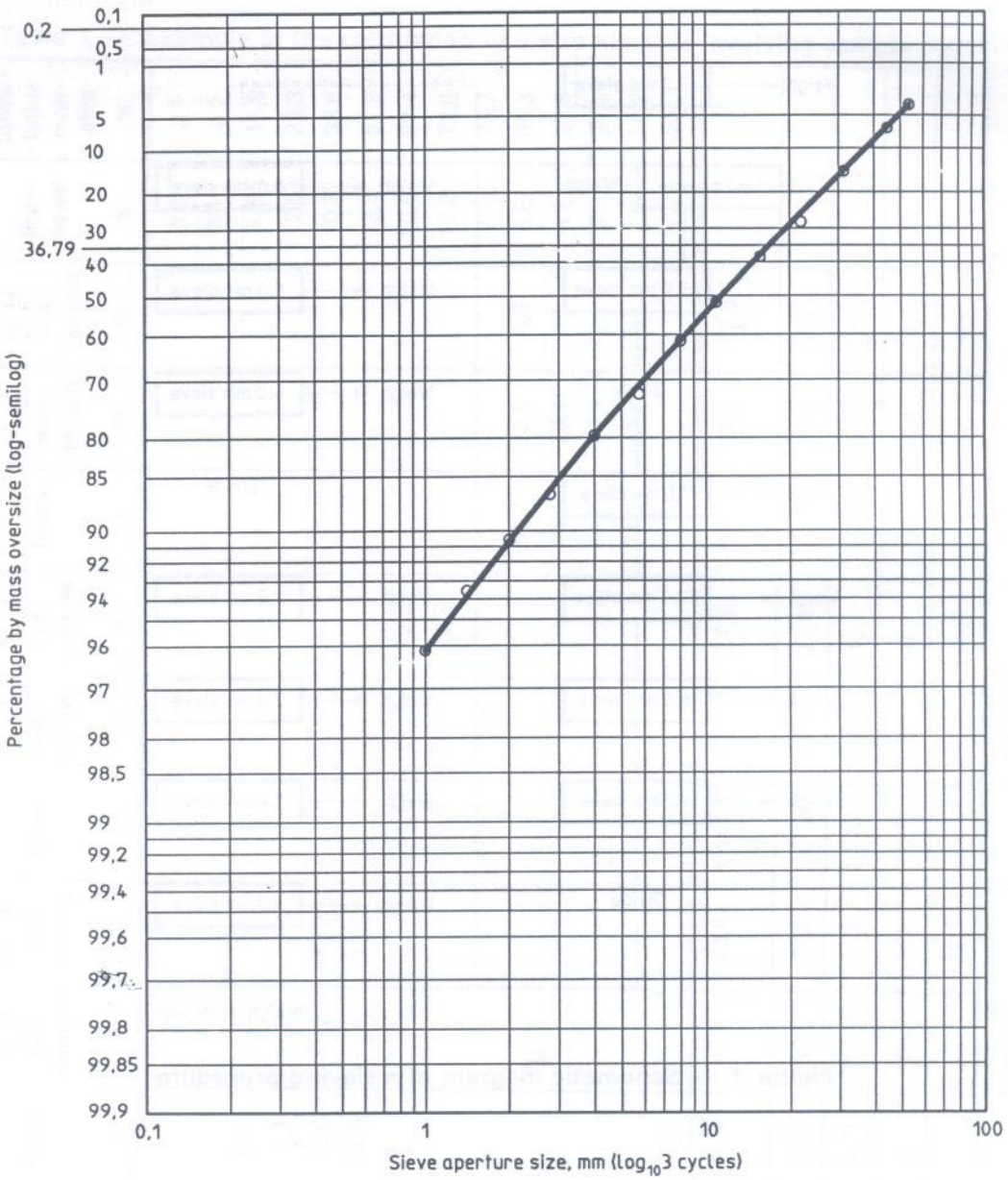

Figure 2 — Graphical presentation of a size analysis

Annex A
(informative)

Guide to sampling

A.1 General

The sample should be taken in accordance with ISO 1988, subject to the following provisions:

a) the number of increments and the increment masses, for both manual and mechanical sampling, should comply with the requirements of ISO 9411-1:—, *Solid mineral fuels — Mechanical sampling from moving streams — Part 1: Coal.*

b) the minimum mass of the gross sample should comply with table A.1.

NOTES

16 When using mechanical samplers, there is a risk of breakage of coal whilst collecting the sample. Therefore, samples for size analysis should preferably be taken by manual sampling. However, if manual sampling is impracticable or unsafe, the method of mechanical sampling used should be checked for bias in accordance with ISO 1988 using size distribution as the variable.

17 The sampling for size analysis of stationary coal contained in wagons, ships and stockpiles, especially that having a nominal top size greater than 80 mm, is not recommended. Reliable results can only be obtained by taking the sample during loading or unloading, or building up or breaking down in the case of stockpiles, using one of the methods for sampling from a stream of coal.

Table A.1 — Minimum mass of gross sample

Nominal top size of coal	Minimum mass of gross sample	
	Absolute precision ± 1 %	Absolute precision ± 2 %
mm	kg	kg
125	4 000	1 000
90	1 500	400
63	500	125
45	200	50
31,5	65	15
22,4	25	6
16	8	2
11,2	3	0,70
8	1	0,25
5,6	0,50	0,25
4	0,25	0,25
2,8	0,25	0,25

NOTE — The minimum masses have been calculated on the basis of the precision of the determination of oversize, i.e. the amount of coal larger than the nominal top size. The precision for other size fractions will usually be better.

A.2 Handling and transport of samples

Since the size distribution of coal changes during conveying, screening and loading, it is important to take the sample at the point in the operations at which the size analysis is required. If the result of the analysis of a sample is to be representative of the size distribution of the lot, it is essential that breakage during the handling and transport of the sample be minimized. Increments shall be placed gently in rigid containers and the handling of these containers during transport shall be as gentle as possible.

Large coal is particularly susceptible to breakage and the methods employed for transporting and sieving the sample will have a marked influence on the size analysis. The bias due to breakage can be reduced by grading the larger pieces, having a particle size greater than 45 mm, at or near the point of sampling by the method described in 6.2.1.

Annex B
(informative)

Use of mechanical sieving

If mechanical sieving is to be used, it is important to demonstrate that this method is free from bias when compared to the method (manual sieving) described in this International Standard.

The following recommendations apply to mechanical sieving.

a) A satisfactory sieving action should be achieved that maintains the particles in movement over the entire sieving area with minimum breakage.

b) The sieves should be shaken in nests only for an initial period of 5 min.

c) The undersides of the sieves should be cleaned after the initial 5-min period.

d) Thereafter, the sieves should be shaken individually for periods of 2 min, with the undersize being added to the next smaller aperture size sieve in the set.

e) Sieving should be continued until the change in mass for any size fraction after two consecutive cycles does not exceed 0,2 % of the total mass of coal being sieved.

Annex C
(informative)

Example of removal by wet sieving of fine material from a sample having a maximum particle size less than 4 mm

C.1 Disperse the sample in about 400 ml of water in a suitable vessel (for example, a beaker), making sure that the sample is thoroughly wetted.

NOTE 18 It is usually necessary to use a small amount of wetting agent.

Support the smallest aperture size sieve in the set (4.1.1) on a suitable receiver (for example, a large beaker). Pour the dispersed sample onto the sieve and wash any residue in the vessel onto the sieve with clean water. Thoroughly wash the material on the sieve with a jet of water whilst tapping the sieve frame with a piece of wood. Check whether all the fines have been washed through the sieve by collecting some of the washings in a second receiver and examining them closely. If any solids are present, add them to the first receiver and continue the washings until all the fines have been washed through.

C.2 Carefully place the sieve and its contents on a tray (4.1.4) and dry in the oven (4.3.4) controlled at a temperature of 50 °C. When dry, invert the sieve over the tray and clean as described in 6.2.3.8. Sieve the contents of the tray as described in 6.2.3.7 to 6.2.3.10, the bottom sieve in the nest being that on which the wet sieving was carried out.

NOTE 19 Any material which passes through the bottom sieve should be added, just prior to weighing, to the fine material which is recovered as described in C.3.

C.3 Add a flocculating agent to the washings containing the undersize material from the wet sieving and allow the solids to settle. Filter, dry and weigh the fine material exactly as described in 6.3.4.