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Aluminium ores — Sampling procedures

Minerais alumineux — Procédés d'échantillonnage



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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 8685 was prepared by Technical Committee ISO/TC 129, *Aluminium ores*, Sub-Committee SC 1, *Sampling*.

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

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Aluminium ores — Sampling procedures

1 Scope

This International Standard sets out requirements for the sampling of aluminium ores from moving streams and stationary situations, including stopped-belt sampling, to provide gross samples for sample preparation. Stopped-belt sampling is the reference method for collecting ore samples against which other sampling procedures may be compared. Sampling from moving streams is the preferred method. Sampling from stationary situations should only be considered when sampling from moving streams is not possible. The procedures described in this International Standard for sampling from stationary situations merely minimize some of the sampling errors.

Although this International Standard is intended to cover all aluminium ore sampling from moving streams, the procedures recommended may not be applicable in cases of extreme segregation, for example very wet ore due to its sticky nature, or very dry ore due to generation of dust. In such cases it may be necessary to revert to stopped-belt sampling.

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 565:1990, *Test sieves — Metal wire cloth, perforated metal plate and electroformed sheet — Nominal sizes of openings*.

ISO 3534:1977, *Statistics — Vocabulary and symbols*.

ISO 6138:1991, *Aluminium ores — Experimental determination of the heterogeneity of constitution*.

ISO 6139:—¹⁾, *Aluminium ores — Experimental determination of the heterogeneity of distribution of a lot*.

ISO 6140:1991, *Aluminium ores — Preparation of samples*.

ISO 9033:1989, *Aluminium ores — Determination of the moisture content of bulk material*.

ISO 10226:1991, *Aluminium ores — Experimental methods for checking the bias of sampling*.

ISO 10277:—¹⁾, *Aluminium ores — Experimental methods for checking the precision of sampling*.

3 Definitions

For the purposes this International Standard, the definitions given in ISO 3534 (including the terms "precision" and "accuracy") and the following, apply.

3.1 bias: The tendency to obtain a value which is persistently higher or persistently lower than the true value. Alternatively, the difference between the true value and the average result obtained from a large number of determinations using a biased method.

3.2 constant mass division: The method of sample division in which the retained portion from individual increments is of uniform mass.

3.3 out: A single pass of the sampling device through the ore stream.

3.4 divided increment: The quantity of ore obtained by division of the increment in order to decrease its mass.

1) To be published.

3.5 division: The process of decreasing the sample mass (without modification of the particle size of the constituent pieces) where a representative part of the sample is retained while rejecting the remainder.

3.6 fixed rate division: The method of sample division in which the retained portion from individual increments is a constant proportion of the original mass.

3.7 duplicate sampling: A particular case of replicate sampling (with only two replicate samples), for the purpose of estimating the average precision of sampling from a number of lots or sampling units.

3.8 gross sample: A sample formed when all the primary increments or subsamples, either as taken or after having been prepared individually to a particular stage of sample preparation, are combined in the correct proportions for preparation of a laboratory sample.

3.9 increment: The quantity of material extracted from the lot in a single operation of the sampling device.

3.10 lot: A quantity of ore delivered at one time for which the quality characteristics are to be determined.

NOTE 1 The lot may be composed of one or more sampling units.

3.11 isolated lot: A lot that is to be sampled without knowledge of its sampling characteristics.

3.12 manual sampling: The operation of sampling when the increments forming subsamples and gross samples are taken by human effort using a hand-held implement.

3.13 mass-basis sampling: The method of taking increments at uniform mass intervals throughout the lot or sampling unit.

3.14 mechanical sampling: The operation of sampling when the increments forming subsamples and gross samples are taken by a sampling machine.

3.15 nominal top size: The size of aperture of the finest sieve (complying with ISO 565) through which 95 % of the mass of the ore passes.

3.16 random stratified sampling: The taking of increments at irregular intervals within constant intervals of time, mass or space.

3.17 reduction (in particle size): The decrease in dimension of the pieces constituting the sample without modification of the mass or composition.

3.18 replicate sampling: The taking of increments from the lot at equal intervals of time, mass or space.

NOTE 2 The increments are placed in rotation in different containers to give several replicate samples of approximately equal mass.

3.19 sampling unit: The discrete units (e.g. trains, sections of belt, daily production) which comprise the lot.

3.20 strata: Approximately equal parts of a lot or sampling unit, based on intervals of time, mass or space.

3.21 subsample: A quantity of ore consisting of a number of increments taken from a part of the lot; also a composite of a number of increments each having been individually prepared as necessary.

3.22 systematic stratified sampling: The taking of increments at regular intervals within constant intervals of time, mass or space.

3.23 time-basis sampling: The method of taking of increments at uniform time intervals throughout the lot or sampling unit.

4 Establishing a sampling scheme

4.1 General

The basic requirement of a correct sampling scheme is that all particles in the stream have an equal opportunity of being selected and appearing in the final gross sample for analysis. Any deviation from this basic requirement can result in an unacceptable loss of accuracy and precision. No incorrect sampling scheme can be relied upon to provide representative samples.

Sampling should be carried out by systematic sampling, either on a mass basis (see clause 8) or on a time basis (see clause 9), but only when it can be shown that no systematic error could be introduced due to any periodic variation in quality or quantity which may coincide with, or approximate to, any multiples of the proposed sampling intervals.

As an example, a primary cutter may be cutting a stream of ore which is being reclaimed from a stockpile by a bucket wheel reclaimer. At both limits of the bucket wheel traverse across the ore face on the stockpile, the ore may have different properties from that of the middle of the stockpile (due to segregation). It is quite possible that every time the primary cutter makes a cut, the cut coincides with ore being delivered from the limit of a traverse of the

bucket wheel reclaimer and a systematic error could thus arise.

This same provision applies to secondary and subsequent stages of division where it is felt that a systematic error could arise, due to the manner in which the ore is handled and presented to division apparatus.

In such cases, it is strongly recommended that stratified random sampling within fixed mass or time intervals be carried out (see clause 10).

The methods for subsampling and sample preparation depend on the final choice of sampling scheme and on the steps necessary to minimize possible systematic errors arising during subsequent division steps.

4.2 Safety of operators

Due consideration shall be given to the safety of operators when employing any method of collecting samples from stationary situations. The applicable safety codes shall be respected.

4.3 General procedure for sampling

The general procedure for sampling is as follows:

- a) decide for what purpose the samples are being taken, e.g. monitoring plant performance, use in commercial transactions;
- b) identify the quality characteristics to be measured and specify the overall precision and sampling precision;
- c) identify the lot or part of the lot to be sampled;
- d) ascertain the nominal top size and particle density of the ore for the purpose of determining the minimum gross sample mass, primary increment mass and cutter opening in the case where a mechanical sampler is used, or the size of ladle in the case where manual sampling is employed;
- e) determine the increment variance, V_i , or the parameters of the variogram if the variogram method is used for the quality characteristic(s) under consideration (see ISO 6139);
- f) determine the coefficient of variation between particles, C_v , of the quality characteristic(s) under consideration (see ISO 6138);
- g) determine the minimum number of primary increments, n , and sampling units, k , required to achieve the required sampling precision (see clause 5);

- h) determine the minimum gross sample mass to achieve the required sampling variance (see clause 6);
- i) determine the minimum primary increment mass (see clause 7);
- j) determine the sampling intervals in tonnes for mass-basis systematic sampling (see clause 8) and stratified random sampling within fixed mass intervals (see clause 10), or in minutes for time-basis systematic sampling (see clause 9) and stratified random sampling within fixed time intervals (see clause 10);
- k) take primary increments at the intervals determined in step j) during the whole period of handling the lot;
- l) combine the increments (see 8.5 or 9.5) into subsamples or a gross sample (an example is given in figure 1);
- m) subsamples are usually prepared and analysed separately to improve overall precision; they may also be prepared
 - 1) for convenience of materials handling,
 - 2) to provide progressive information on the quality of the lot,
 - 3) to provide, after division, reference or reserve samples,
 - 4) to reduce any bias in the test result for the moisture content of a large lot caused by moisture loss (or gain), due to climatic conditions.

It is permissible to divide increments at step l) before constituting a gross sample or subsample, provided that the mass of the divided increment exceeds the minimum mass determined in step i). If the whole of the primary increment or divided primary increment is crushed, to enable further division it is necessary to recalculate the minimum mass of the gross sample and the divided primary increment using the nominal top size of the crushed ore.

NOTE 3 When sampling an isolated lot in which the increment variance (or the variogram) and coefficient of variation between particles, C_v , of the quality characteristics under consideration are not known, it is not possible to design a sampling scheme which guarantees that the specified sampling precision will be obtained. In this situation, the number of increments to be taken and their masses should be agreed between the parties concerned. When sampling of the isolated lot has been completed, it is possible, however, to determine the overall precision obtained using the appropriate method specified in ISO 10277.

4.4 Overall variance

The overall variance, denoted by σ_{SPM}^2 , for measuring the mean value of each quality characteristic is comprised of three components, namely the variance of sampling, the variance of sample preparation and the variance of analysis. The relationship is as follows:

$$\sigma_{\text{SPM}}^2 = \sigma_{\text{S}}^2 + \sigma_{\text{P}}^2 + \sigma_{\text{M}}^2$$

where

- σ_{S}^2 is the variance of sampling;
- σ_{P}^2 is the variance of sample preparation;
- σ_{M}^2 is the variance of analysis (measurement).

The method for determining σ_{S} , σ_{P} and σ_{M} may be found in ISO 10226.

The sampling variance consists of two components, namely the short range quality fluctuation variance σ_{QE1}^2 and the long range quality fluctuation variance σ_{QE2}^2 .

The relationship is as follows:

$$\sigma_{\text{S}}^2 = \sigma_{\text{QE1}}^2 + \sigma_{\text{QE2}}^2$$

The short range quality fluctuation variance also consists of two components as follows:

$$\sigma_{\text{QE1}}^2 = \sigma_{\text{FE}}^2 + \sigma_{\text{GE}}^2$$

where

- σ_{FE}^2 is the fundamental error variance;
- σ_{GE}^2 is the segregation error variance.

Thus

$$\sigma_{\text{S}}^2 = \sigma_{\text{FE}}^2 + \sigma_{\text{GE}}^2 + \sigma_{\text{QE2}}^2$$

The fundamental error variance depends on the gross sample mass while the other two components depend on the distribution heterogeneity of the ore and the number of increments. In this International Standard, the minimum gross sample mass (see 6.1) is chosen so that

$$\sigma_{\text{FE}}^2 \leq \frac{\sigma_{\text{S}}^2}{2}$$

In the equation for σ_{SPM}^2 above, the major part of the overall variance is often due to sampling errors. However, when a very precise result is required and the sampling errors have been minimized, consideration shall be given to increasing the number of sample preparations and/or analyses performed in order to reduce these components of the overall variance. This is achieved by carrying out multiple determinations on the gross sample or preferably by dividing the lot into a number of sampling units and preparing and analysing a subsample from each sampling unit (see figure 1).

The overall variance is then given as follows.

- a) when a single gross sample is constituted for a lot and r replicate determinations are carried out on the gross sample,

$$\sigma_{\text{SPM}}^2 = \sigma_{\text{S}}^2 + \sigma_{\text{P}}^2 + \frac{\sigma_{\text{M}}^2}{r}$$

- b) when k subsamples are prepared and analysed, each constituted from an equal number of increments, and r replicate determinations are carried out on each subsample,

$$\sigma_{\text{SPM}}^2 = \sigma_{\text{S}}^2 + \frac{\sigma_{\text{P}}^2 + \frac{\sigma_{\text{M}}^2}{r}}{k}$$

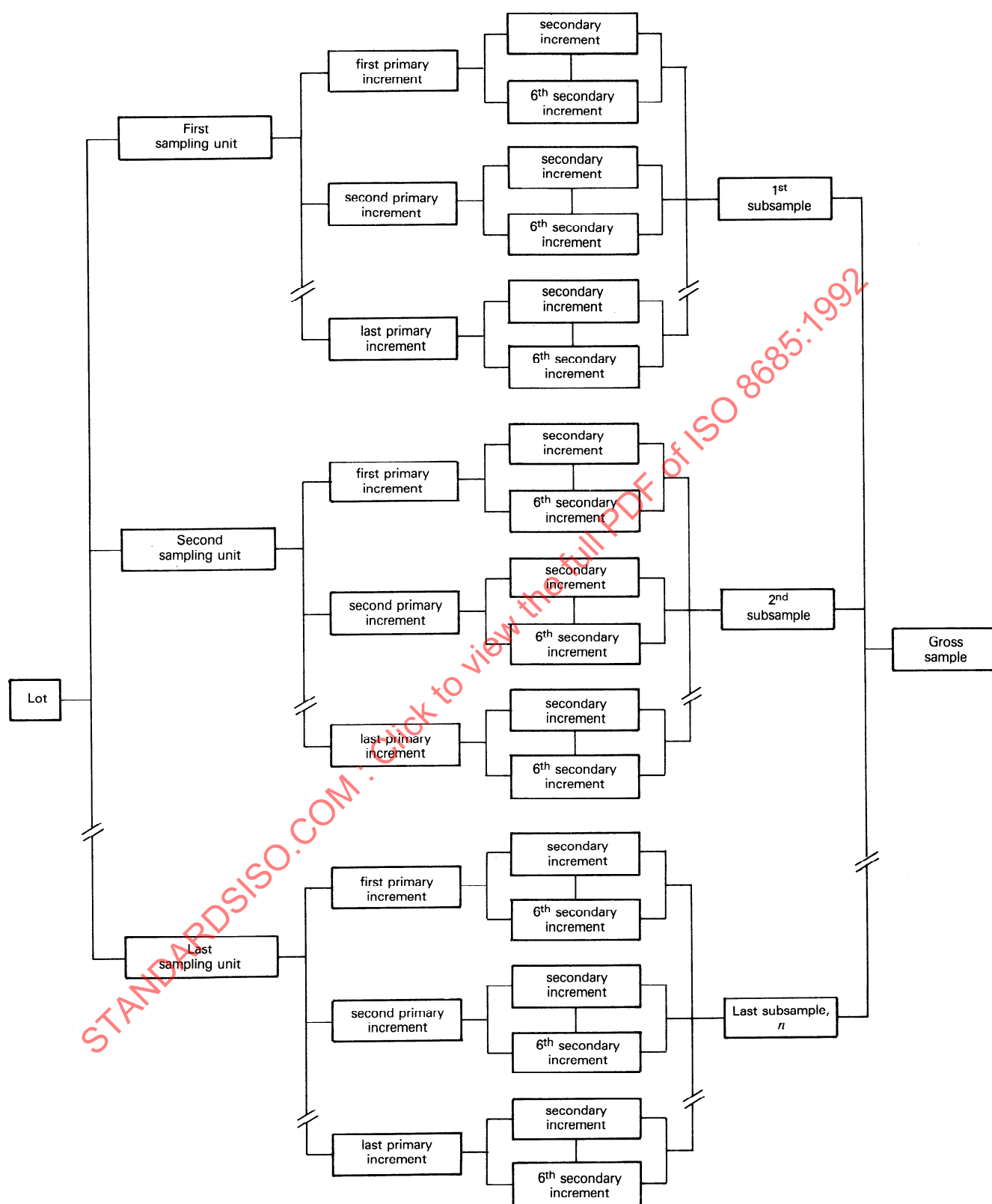


Figure 1 — Example of a sampling plan including six secondary increments

(Mixing, reduction and division steps have been omitted for simplicity.)

5 Number of primary increments and sampling units

5.1 General

The number of primary increments to be taken from a lot or sampling unit in order to attain the required sampling variance is a function of the variability of the characteristics to be determined. This variability depends on the amount of segregation present in the ore, the particle size range of the ore and the mass of the lot or sampling unit. It is determined experimentally for each type of ore and expressed in terms of either the increment variance V_I or the intercept A and slope B of the variogram in accordance with ISO 6139.

CAUTION — The determination of moisture requires special consideration due to the fact that it is extremely difficult, if not impossible, to retain the integrity of the sample over extended periods of sample collection. In such cases a bias may occur which can only be overcome by collecting moisture samples at more frequent intervals than may be dictated by a simple calculation of increment numbers of sampling units based on a certain precision. It is therefore recommended that moisture tests be carried out on a number of subsamples and the weighed mean of the test results recorded. This will reduce any bias in the test result caused by moisture loss (or gain) due to climatic conditions. It will also result in better precision.

5.2 Calculation of the number of primary increments

When the variability of the ore has been determined, the number of primary increments to be taken from the lot can be calculated from the following formula at the desired sampling precision.

5.2.1 Increment variance method

$$n = \frac{V_I}{\sigma_S^2}$$

where

- n is the number of primary increments;
- V_I is the increment variance;
- σ_S^2 is the desired sampling variance.

EXAMPLE

Minimum number of primary increments for different values of V_I and σ_S

Table 1 — Minimum number of primary increments required

V_I	Sampling standard deviation, σ_S						
	0.1	0.2	0.5	0.75	1	2	3
0.25	25	7	1	1	1	1	1
1	100	25	4	2	1	1	1
4	400 ¹⁾	100	16	8	4	1	1
9	900 ¹⁾	225	36	16	9	2	1
25	2 500 ¹⁾	625 ¹⁾	100	50	25	6	3
100	10 000 ¹⁾	2 500 ¹⁾	400 ¹⁾	200	100	25	11

1) Values indicate that the specified precision may not be practically achievable. In this case, it will be necessary to adopt a poorer sampling precision than that specified in 4.3 b).

5.2.2 Variogram method

a) Systematic sampling

$$n = \frac{A + \sqrt{A^2 + \frac{2}{3} B m_L \sigma_S^2}}{2 \sigma_S^2}$$

where

- n is the number of primary increments;
- A is the intercept of the corrected variogram;
- B is the gradient (slope) of the variogram;
- m_L is the mass of the lot;
- σ_S^2 is the desired sampling variance.

b) Stratified random sampling

$$n = \frac{A + \sqrt{A^2 + \frac{4}{3} B m_L \sigma_S^2}}{2 \sigma_S^2}$$

EXAMPLE

Assume that systematic sampling is being used and that the parameters of the variogram for Al_2O_3 content, determined in accordance with ISO 6139, are as follows:

- $A = 0.3$
- $B = 0.0001$
- $m_L = 30\,000 \text{ t}$
- $\sigma_S = 0.1 \% (m/m) Al_2O_3$

Thus

$$\begin{aligned}
 n &= \frac{0,3 + \sqrt{0,09 + \frac{2}{3} \times 0,000\ 1 \times 30\ 000 \times (0,1)^2}}{2 \times 0,01} \\
 &= \frac{0,3 \sqrt{0,09 + 0,02}}{0,02} \\
 &= \frac{0,63}{0,02} \\
 &= 32
 \end{aligned}$$

5.3 Calculation of the number of subsamples

When the variances of sample preparation and measurement are known, the number of subsamples, k , can be calculated from the following formula:

$$k = \frac{\sigma_p^2 + \frac{\sigma_M^2}{r}}{\sigma_{SPM}^2 - \sigma_S^2}$$

where σ_{SPM} , σ_S , σ_p , σ_M and r are as previously defined.

Several iterations may be required to find the correct combination of σ_S and k .

6 Mass of gross samples and subsamples

6.1 Minimum mass of gross sample

It is essential to ensure that the mass of the gross sample is adequate to achieve the required sampling variance. If the gross sample mass is too small, the desired sampling variance will not be achieved, even though sufficient increments, as calculated in 5.2 may have been taken.

The minimum gross sample mass is given by the following empirical formula (see annex A):

$$m_G = \left(\frac{C_v}{\sigma_S} \right)^2 \rho g D^3 \times 10^{-6}$$

where

- m_G is the minimum gross sample mass, in kilograms;
- C_v is the coefficient of variation between particles of the quality characteristic under investigation, (according to ISO 6138);
- σ_S is the required relative sampling error (standard deviation);

- ρ is the density, in tonnes per cubic metre, of the ore particles (not bulk density);
- g is the size range factor given in table 2;
- D is the nominal top size, in millimetres, of the ore in the lot.

Table 2 — Size range factors

Size range	Value for g
Large size range ($D/D' > 4$)	0,25
Medium size range ($4 \geq D/D' \geq 2$)	0,50
Small size range ($D/D' < 2$)	0,75
Uniform size ($D/D' = 1$)	1,00
D is the nominal top size of the ore; D' is the sieve size retaining 95 % of the ore.	

The variation of minimum gross sample mass with nominal top size for various values of C_v/σ_S is shown in figures 2 and 3 (assuming $\rho = 2,5 \text{ t/m}^3$).

EXAMPLE

Take the case of sampling an aluminium ore of nominal top size 22,4 mm and of particle density 2,5 t/m³. Assume the size range is large, the coefficient of variation is 20 % and a sampling error of 0,5 % is required. The minimum mass of the gross sample is given by the following formula:

$$\begin{aligned}
 m_G &= \left(\frac{20}{0,5} \right)^2 \times 2,5 \times 0,25 \times (22,4)^3 \times 10^{-6} \\
 &= 11,2 \text{ kg}
 \end{aligned}$$

6.2 Minimum mass of subsamples

The minimum mass of individual subsamples shall be as follows:

- a) when the individual subsamples are prepared and analysed, the minimum mass of the subsample shall be not less than that of the minimum gross sample calculated in 6.1;
- b) when individual subsamples are combined to form a gross sample, the minimum mass of the subsample, m_s , shall be m_G/k where k is the number of subsamples as defined in 4.3 b).

6.3 Minimum mass of crushed gross samples and subsamples

If gross samples or subsamples are crushed to permit further division, the minimum masses may be calculated using the formula in 6.1 and 6.2, by inserting the nominal top size of the crushed ore.

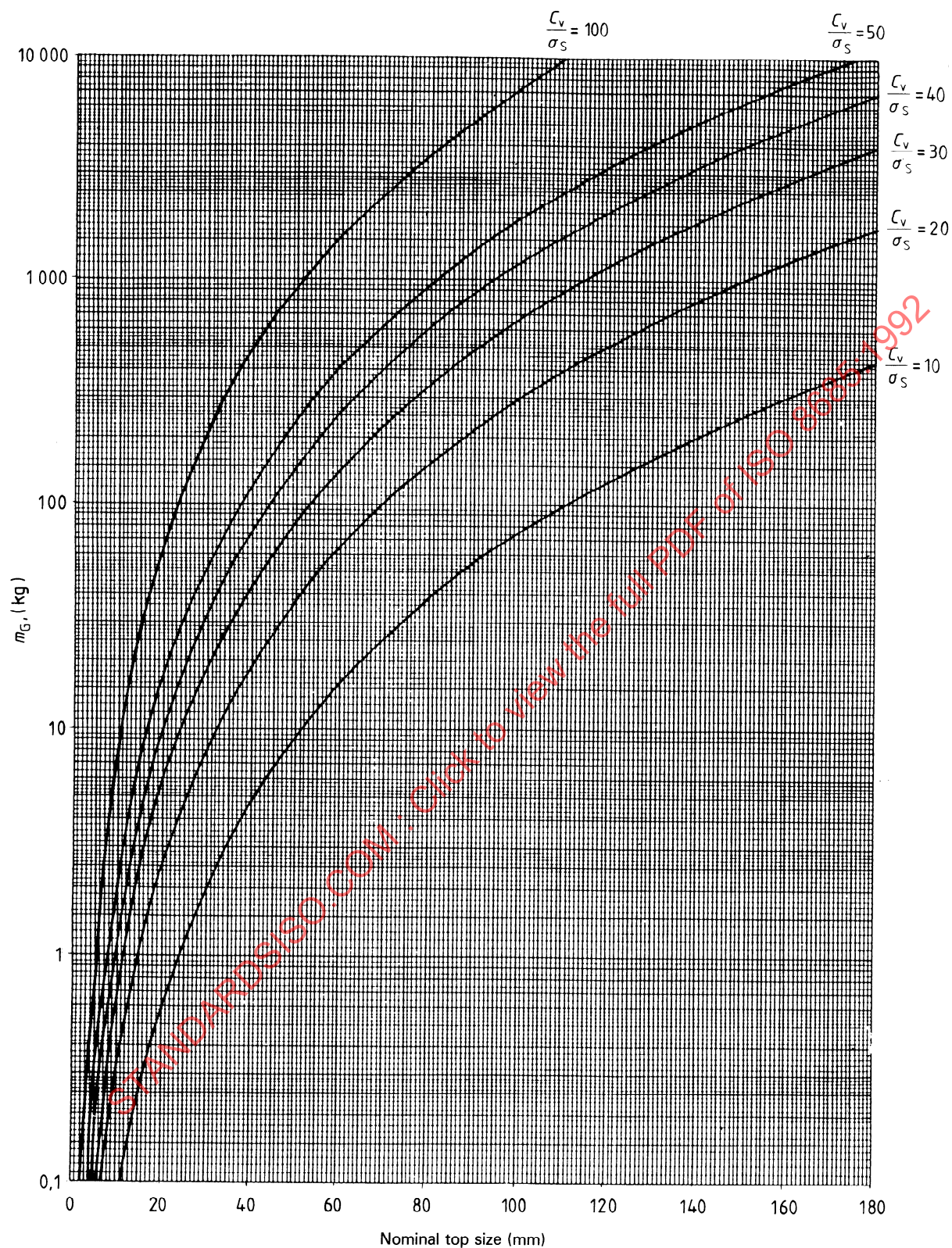


Figure 2 — Minimum gross sample mass as a function of C_v/σ_s and of nominal top size
(for a nominal density of 2,5 t/m³ and $g = 0,25$)

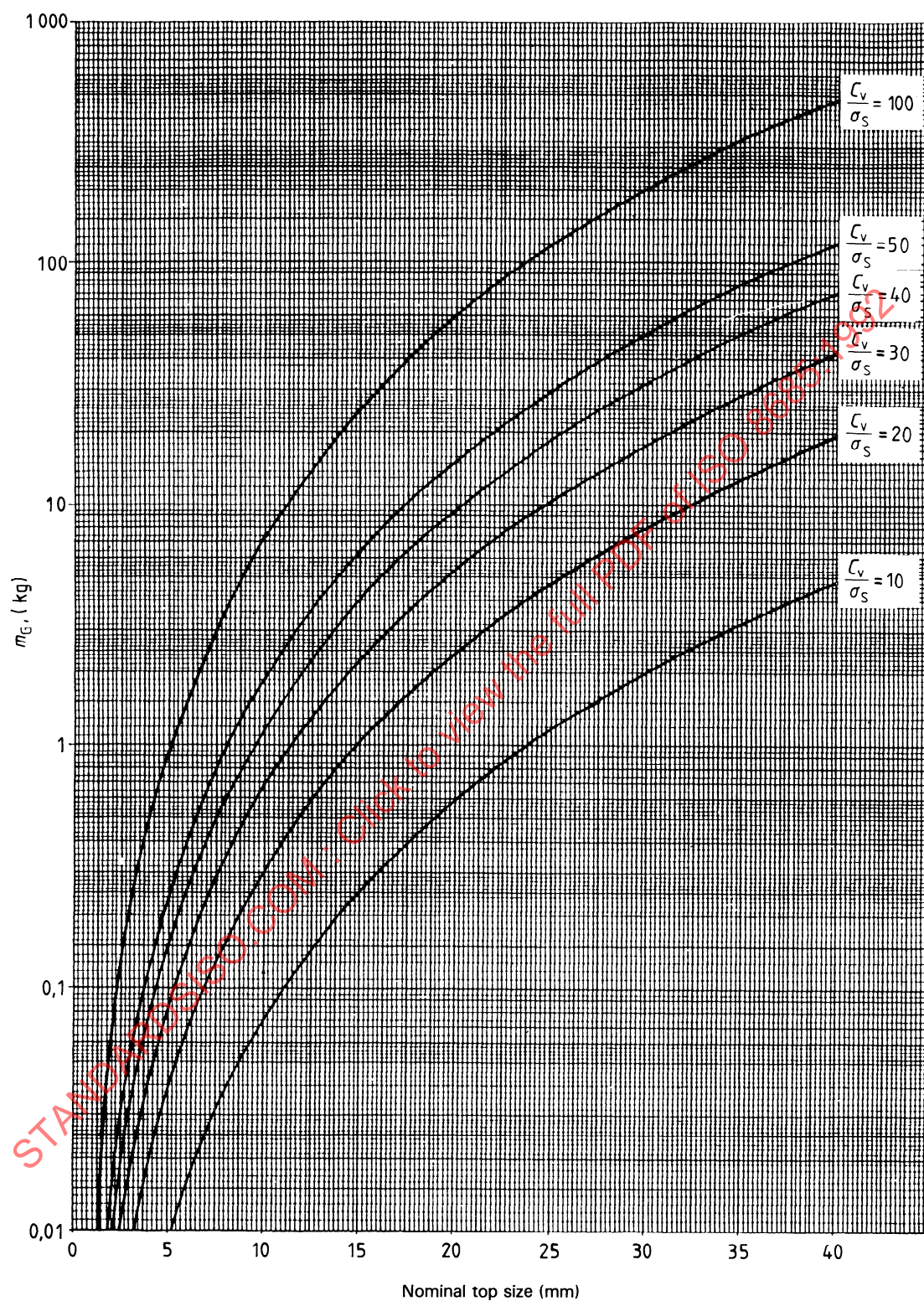


Figure 3 — Minimum gross sample mass as a function of C_v/σ_s and of nominal top size
(for a nominal density of 2,5 t/m³ and $g = 0,25$)

7 Mass of increment

7.1 Minimum mass of primary increment

Although the concept of minimum increment mass is not absolute, the increment mass must be large enough to ensure that the minimum sample masses specified in 6.1 and 6.2 are exceeded. Thus, the minimum mass of a primary increment, m_i , is given by the following formula:

$$m_i = \frac{m_G}{n} = \left(\frac{C_v}{\sigma_s} \right)^2 \frac{\rho g D^3}{n} \times 10^{-6}$$

where n is the number of primary increments calculated in 5.2.

This ensures that the gross sample or subsample, consisting of the combination of primary increments, is always of sufficient mass.

The minimum mass of primary increments or the number of primary increments will need to be increased accordingly if subsamples are prepared or if separate gross samples or subsamples are required for chemical analysis, moisture determination and physical testing.

7.2 Actual mass of increment for sampling from moving streams

The actual mass of increment taken by a cutter-type sampler from the ore stream at the discharge end of a moving stream may be calculated using the following formula:

$$m_A = \frac{q_m b_c}{3,6 v_c}$$

where

- m_A is the actual mass, in kilograms, of increment;
- q_m is the flow rate, in tonnes per hour, of ore stream;
- b_c is the cutting aperture, in metres, of the sampler;
- v_c is the cutter speed, in metres per second, of the sampler.

When the flow rate is high, the actual mass of a primary increment will nearly always greatly exceed the value obtained from the formula in 7.1. In fact, it is determined by the minimum cutting aperture determined in 11.3.1 and the maximum cutter velocity specified in 11.3.2. Unless these two conditions are respected, the increment may not be representative of the ore from which it was taken.

7.3 Subdivision of large primary increments

The method for subdivision of large increments is specified in 8.10 and 9.8.

The apparatus for division may be coupled automatically to the mechanical sampling equipment, but all of the processes after collection, including storage, shall be carried out in enclosed and draught-proof conditions to minimize changes of moisture content.

Secondary and subsequent sample dividers which are on-line shall have cutting frequencies which are not in phase with the primary sampler or with each other and shall operate continuously throughout the whole sampling period.

7.4 Minimum mass of crushed increments

If the primary increment is crushed to permit further division, the minimum mass of the divided primary increment may be calculated using the formula in 7.1 by inserting the nominal top size of the crushed ore.

NOTE 4 The minimum mass of any increment is never to be less than 100 g in order to maintain the integrity of the increment as it passes through the sampling system.

8 Mass-basis sampling

8.1 General

Mass-basis sampling may be used irrespective of flow rate variations. When sampling from moving streams which show a wide variation in feed rate (i.e. greater than 20 % from the nominal rate), it is the preferred basis for sampling.

Mass-basis sampling involves the following two steps.

- a) Spreading the number of primary increments required on a uniform tonnage basis throughout the mass to be sampled.
- b) Extracting from each tonnage interval an almost uniform mass of ore [at either the primary (preferred) or secondary division steps] to give an almost uniform mass of sample reporting to the gross sample or subsample.

"Almost uniform mass" means that the coefficient of variation of the increment masses shall be less than or equal to 20 %. For example, when the average mass of increments is to be 40 kg, the increments shall be taken in such a manner that 95 % of the increments vary between 24 kg and 36 kg with an average of 40 kg.

If the coefficient of variation of the mass of individual primary increments is greater than 20 %,

- 1) each primary increment shall be subjected separately to division (according to the rules of division) and determination of its quality characteristics, or
- 2) primary increments shall be subjected to constant mass division prior to combining into subsamples or a gross sample.

8.2 Sampling interval

The interval between taking primary increments by mass-basis sampling shall be determined from the following formula:

$$\Delta m_i < \frac{m_L}{n}$$

Δm_i is the mass interval, in tonnes, between taking primary increments;

m_L is the mass, in tonnes, of the lot or sampling unit;

n is the number of primary increments calculated in 5.2.

8.3 Cutter

Either of the following cutters may be adopted:

- a) a fixed-speed cutter whose cutting speed is constant during the course of handling the entire lot;
- b) a variable-speed cutter whose cutting speed is constant while cutting the stream but can be regulated, primary increment by primary increment, corresponding to the flow rate of the ore on the conveyor belt.

8.4 Taking of primary increments

Each primary increment shall be taken by a single pass of the sampling device so that a full cross-section of the stream is taken.

The first primary increment shall be taken at a random mass less than Δm_i (see 8.2).

Thereafter, the required number of primary increments shall be taken by systematic stratified sampling on a mass basis, i.e. at a fixed mass interval Δm_i , and this interval shall not be changed during the entire course of sampling of a lot.

The mass interval between primary increments should be smaller than that calculated from the number of primary increments determined in 5.2, in

order to ensure that the number of primary increments to be taken will be larger than the minimum number required.

If the planned number of primary increments has been taken and the handling has not been completed, additional increments shall be taken at the same mass interval until the handling operation is completed.

8.5 Constitution of a gross sample or subsample

A gross sample shall comprise all the primary increments or subsamples, either as taken or after having been prepared individually to a particular stage of sample preparation and then combined in the correct proportions.

If the coefficient of variation of the masses of primary increments is greater than 20 %, the primary increments as taken shall not be combined into subsamples or a gross sample, and the requirements given in 8.1 b) [1) and 2)] shall be observed.

A subsample shall comprise consecutive primary increments, either as taken or after having been prepared individually to a particular stage of sample preparation and then combined in the correct proportions. Each of a series of subsamples for a lot should be made up of an equal number of consecutive primary increments.

CAUTION — Care should be taken not to attribute the precision of a test result from a lot to the test result from an individual primary increment or subsample formed in the above manner. The test result from an individual primary increment or subsample cannot be used to characterize the lot or the sampling unit.

8.6 Method of division

Constant-mass division is a method of obtaining divided subsamples or gross samples having almost uniform mass $C_v \leq 20$ % regardless of the variation in the masses to be divided. Cutter-type dividers with variable cutting speeds can be used for this type of division.

Fixed-rate division is a method obtaining divided subsamples or gross samples having masses proportional to the varied masses to be divided. Rotary sample dividers or slotted belts can be used for this type of division.

8.7 Division of increments

Where increments are divided and subsamples or a gross sample constituted from such divided increments, the division shall be carried out as follows:

- a) if the coefficient of variation for the masses of increments is greater than 20 %, the division shall be carried out on an increment-by-increment basis using constant-mass division;
- b) if the coefficient of variation is less than or equal to 20 %, either constant-mass or fixed-rate division can be used.

The number of cuts and their minimum masses shall be as specified in 8.10.

8.8 Division of subsamples

Where subsamples are divided and a gross sample constituted from the divided subsamples, the division shall be carried out as follows:

- a) when the coefficient of variation of the masses of subsamples is less than or equal to 20 % and the subsamples consist of an equal number of increments, both constant-mass and fixed-rate division may be used;
- b) If the subsamples consist of different numbers of increments, fixed-rate division shall be used.

The number of cuts and their minimum masses shall be as specified in 8.10.

8.9 Division of gross samples

Normally the gross sample is subjected to sample preparation in accordance with the procedures given ISO 6140. However, where division of the gross sample is carried out in an on-line situation, the number of cuts and their minimum masses shall be as specified in 8.10.

8.10 Number of cuts for division

The minimum number of cuts and their minimum masses shall be as follows.

- a) Where all increments or subsamples have been combined and mixed to form a gross sample from a lot or sampling unit; a minimum of 20 cuts of minimum mass $m_G/20$, where m_G is the minimum gross sample mass calculated in 6.1.
- b) Where several increments have been combined and mixed to form a subsample for analysis; a minimum of 10 cuts of minimum mass $m_G/10$.
- c) Where individual primary increments are to be divided; a minimum of 6 cuts of minimum mass $m_G/6n$, where n is the number of primary increments.
- d) Where individual secondary and subsequent increments are to be divided; a minimum of 1 cut

per secondary or subsequent increment of minimum mass m_G/np , where n is the number of primary increments and p is the final number of subsequent cuts per primary increment.

For constant-mass division, the interval between taking cuts shall be made variable according to the mass of the gross sample, subsample or increment to be divided in accordance with the principles of 8.2. The first cut shall be taken at random within the first mass interval.

For fixed-rate division, the interval between taking cuts shall be constant regardless of the mass of the gross sample, subsample or increment to be divided, in accordance with the principles of 9.2. The first cut shall be taken at random within the first time interval.

NOTE 5 The division of divided gross samples, subsamples or increments below their minimum masses at any stage requires particle size reduction before division. The minimum gross sample mass, m_G , should then be recalculated as specified in 6.3.

9 Time-basis sampling

9.1 General

Time-basis sampling may be used when sampling from moving streams which preferably do not show a wide variation in feed rate, i.e. less than or equal to 20 % variation from the nominal rate.

9.2 Sampling interval

The interval between taking primary increments by time-basis sampling shall be determined from the following formula:

$$\Delta t < \frac{60m_L}{q_m n}$$

where

- Δt is the time interval, in minutes, between taking primary increments;
- m_L is the mass, in tonnes, of the lot;
- q_m is the conveyor load rate, in tonnes per hour;
- n is the number of primary increments calculated in 5.2.

9.3 Cutter

The cutter shall be a fixed-speed cutter whose cutting speed is constant during the course of handling the entire lot.

9.4 Taking of primary increments

Each primary increment shall be taken by a single pass of the sampling device.

The first primary increment shall be taken at a random time less than Δt (see 9.2).

Thereafter, the required number of primary increments shall be taken by systematic stratified sampling on a time basis, i.e. at a fixed time interval Δt , and such an interval should not be changed during the entire course of sampling of a lot.

The time interval between primary increments should be smaller than that calculated from the number of primary increments calculated in 5.2, in order to ensure that the number of primary increments to be taken will be larger than the minimum number of primary increments specified.

If the planned number of primary increments has been taken and the handling has not been completed, additional primary increments shall be taken at the same time interval until the handling operation is completed.

9.5 Constitution of gross sample or subsample

Primary increments may be combined to form gross samples or subsamples in either of the following ways.

- a) The primary increments as taken may be combined into subsamples or a gross sample irrespective of the variation of masses of the primary increments.

NOTE 6 When subsamples are analysed to determine the quality characteristics for the lot, the mass of subsample, or the mass of sampling unit from which the subsample has been taken, should be determined in order to obtain the weighted mean of the quality characteristic for the lot.

- b) Primary increments may be divided by fixed rate division and the gross sample or subsample may be prepared by combining divided increments, provided that the mass of the divided increment is proportional to that of the primary increment, so that the weighted mean of the quality characteristic for the lot is retained.

9.6 Division of increments and subsamples

After time-basis sampling, division of increments and subsamples shall be carried out by fixed-rate division. The number of cuts and their minimum masses shall be as specified in 9.8.

9.7 Division of gross samples

Normally the gross sample is subjected to sample preparation in accordance with the procedure given in ISO 6140. However, where division of the gross sample is carried out in an on-line situation, the number of cuts and their minimum masses shall be as specified in 9.8.

9.8 Number of cuts for division

The minimum number of cuts and their minimum masses shall be as follows.

- a) Where all increments or subsamples have been combined and mixed to form a gross sample from a lot or sampling unit, a minimum of 20 cuts of minimum mass $m_G/20$, where m_G is the minimum gross sample mass calculated in 6.1.
- b) Where several increments have been combined and mixed to form a subsample for analysis; a minimum of 10 cuts of minimum mass $m_G/10$.
- c) Where individual primary increments are to be divided; a minimum of 6 cuts of minimum mass $m_G/6n$, where n is the number of primary increments.
- d) Where individual secondary and subsequent increments are to be divided; a minimum of 1 cut per secondary or subsequent increment of minimum mass m_G/np , where n is the number of primary increments and p is the final number of subsequent increments per primary increment.

For fixed-rate division, the interval between taking cuts shall be constant regardless of the mass of the gross sample, subsample, or increment to be divided, in accordance with the principles of 9.2. The first cut shall be taken at random within the first time interval.

NOTE 7 Division of divided gross samples, subsamples or increments below their minimum masses at any stage requires particle size reduction before division. The minimum gross sample mass, m_G , should then be recalculated as specified in 6.3.

10 Stratified random sampling at fixed mass or time intervals

10.1 Stratified random sampling at fixed mass intervals — General procedure

The procedure shall be as specified in clause 8 except that, when the mass interval has been set, the sample divider or cutter is programmed to take one primary increment at any point at random within this mass interval. This is achieved by use of a random number generator, capable of giving a random mass

number anywhere within the mass interval (determined in 8.2), which activates the sampling device at the mass corresponding to the mass number generated.

10.2 Stratified random sampling at fixed time intervals — General procedure

The procedure shall be as specified in clause 9 except that, when the time interval has been set, the sample divider or cutter is programmed to take one primary increment at any point at random within this time interval. This is achieved by use of a random number generator, capable of giving a random time number anywhere within the time interval (determined in 9.2), which activates the sampling device at the time corresponding to the time number generated.

11 Mechanical sampling from moving streams

11.1 General

There are a number of different mechanical sampling devices and hence it is not possible to specify any particular type which should be used for specific sampling applications. Annex B shows examples of sampling devices in common use and should be taken as a guide in the choice of suitable equipment.

This International Standard deals only with mechanical samplers which take a complete cross-section of the ore stream in one pass of the sampling device. Mechanical sampling devices taking only a part of the stream in one operation are not recommended.

11.2 Design of the sampling system

11.2.1 Location of sampling equipment

The location of the sampling equipment shall be chosen according to the following criteria:

- the sampling equipment shall be located at a point which affords access to the complete ore stream;
- sampling shall be performed as close as possible to that point in the materials handling system where it is desired to determine the composition of the ore (e.g. immediately prior to ship loading);
- sampling shall be performed at a point in the handling system where there is no apparent visual segregation of the material stream and where there is no apparent risk of errors due to

a systematic variation in material feed rate or composition;

- to permit performance of the checks specified in 11.2.3, provision should be made for stopped-belt sampling adjacent to the automatic sampler;
- sample collection points shall be located to provide easy access for operator convenience, and preferably as close as possible to the last division stage.

11.2.2 Provision for duplicate sampling

It is recommended that the system provided be capable of processing the primary increments to constitute pairs of subsamples A and B, by combining the increments alternately. Procedures for carrying out duplicate sampling are described in the appropriate International Standard.

11.2.3 System for checking the precision and bias

When a mechanical installation is commissioned or when principal parts are modified, check experiments for precision and bias shall be carried out for the installation as a whole.

The methods of checking precision and bias, described in ISO 10277 and ISO 10226, respectively, shall be carried out preferably by comparison with stopped-belt sampling as described in clause 13.

11.2.4 Minimizing bias in the sample

The installation shall be designed in such a manner as to minimize

- spillage of the sample;
- impedance of the flow of the sample material through the equipment;
- retention of residual material;
- contamination of the sample;
- degradation of the constituent particles if a sample is taken for size determination;
- any variation of moisture content.

Secondary and subsequent sample dividers which are on-line shall have cutting frequencies which are not in phase with the primary sampler.

11.2.5 Arrangement of sampling system

The installation should be arranged in such a way that the principal units can be operated individually for testing and maintenance.

11.3 Sample cutters

11.3.1 Design criteria

In order to minimize bias in the taking of increments, the sample cutter should, in addition to incorporating the requirements specified in 11.2.4, fulfil the following criteria.

- a) The sample cutter shall be of the self-cleaning type.
- b) There shall be no introduction of materials other than the sample into the sample cutter. This applies particularly to material from belt scrapers and dust accumulating in the cutter in the park position.
- c) The cutter shall cut a complete cross-section of the ore stream, both the leading and trailing edges clearing the stream in one path.
- d) The cutter shall cut the ore stream either in a plane, or along an arc, normal to the mean trajectory path of the stream.
- e) The cutter shall travel through the ore stream at a speed constant within $\pm 5\%$.
- f) The geometry of the cutting aperture of the sampler shall be such that the cutting time of each point in the stream is constant within $\pm 5\%$.
- g) The minimum dimensions of the cutting aperture of the sampler shall be at least 3 times the nominal top size of the ore being sampled.
- h) The minimum aperture of any cutter shall be 30 mm.
- i) The cutter shall be of sufficient capacity to accommodate the increment mass obtained at maximum flow rate of ore.

11.3.2 Cutter velocities

In the designing of a mechanical sampling device, one of the most important design parameters is the cutter velocity. Too high a cutter velocity will lead to a biasing of the sample due to deflection of the larger particles and may also lead to shock load problems and difficulties in maintaining constant velocity while cutting the material stream. It could also cause excessive turbulence which should be

avoided to minimize the risk of rebounding particles and dust causing a biasing of the sample.

Experimental work undertaken by Gy²⁾ shows that for sampling heterogeneous material streams of low belt loading (stream density) where the particle size distribution is very narrow, significant bias may be introduced when the cutter velocity exceeds 0,6 m/s or the cutter aperture is less than 3 times the nominal top size of the ore.

On the basis of this evidence, the cutter velocity should not exceed 0,6 m/s for cutters that cut normal to the ore stream, with cutter aperture, b_c , equal to 3 times the nominal top size of the ore (see figure 4). The same maximum cutter velocity applies to cutters which do not cut normal to the ore stream (see figure 5), provided that the "effective cutter aperture", b_0 , is a minimum of 3 times the nominal top size. Cutters which cut normal to the stream may cut in either direction or in both directions. Cutters which cut other than normal to the stream may cut in one direction only.

For cutters where the aperture b_c is in excess of 3 times the nominal top size D , the maximum velocity allowed, v_c , may be increased in accordance with the following formula:

$$v_c = 0,3 \left(1 + \frac{b_c}{b_1} \right)$$

where

v_c is the maximum velocity, in metres per second;

b_c is the actual width of cutter aperture;

b_1 is equivalent to three times the nominal top size ($b_1 = 3D$).

However, the maximum velocity shall not exceed 1,5 m/s.

NOTE 8 Velocities higher than 0,6 m/s at a cutter aperture of $3D$ may be used only if experimental evidence proves that no significant bias is introduced.

11.4 Mass of increments

In all cases the minimum mass of each increment obtained in one pass of the sample cutter shall comply with 7.1.

11.5 Number of increments

The number of increments shall be in accordance with 5.2, 8.10 and 9.8.

2) See GY P., *Sampling of particulate materials — Theory and practice*, Elsevier Publishing Co., 1982.

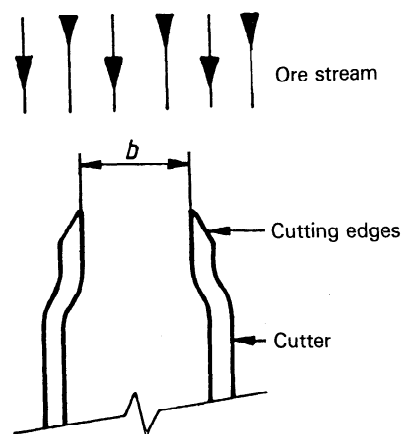
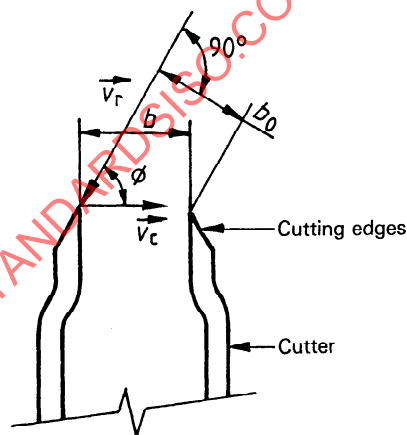
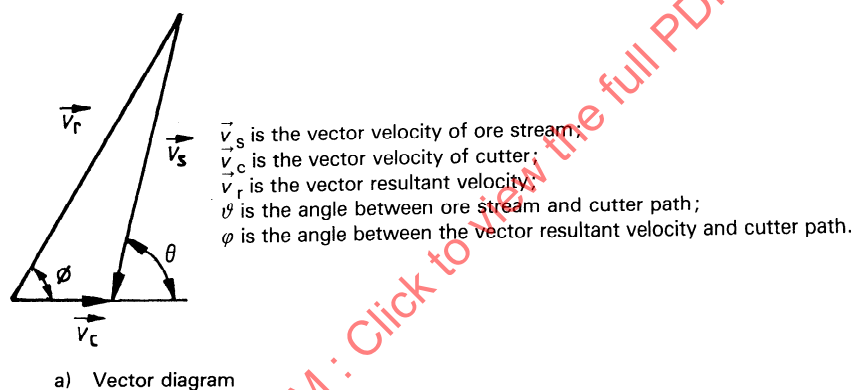


Figure 4 — Cutters with cutting edges designed to cut normal to the ore stream



b) Cutters with cutting edges normal to the cutter path

Figure 5 — Cutters with cutting edges designed to cut other than normal to the ore stream

11.6 Routine checking

Maintenance and inspection of the installation shall be carried out at regular intervals, and verification shall be carried out when any modifications are made or a change suspected.

12 Manual sampling from moving streams

12.1 General

Mechanical sampling from moving streams is the recommended method because it provides more reliable data than manual sampling. However, where no mechanical sampling device is available, manual sampling may be performed, provided that access is available to the complete ore stream and that there is no risk to the safety of the operator. In relation to the safety of operators, the applicable safety codes of the Regulatory Authorities shall be respected.

NOTE 9 Manual sampling from moving streams should not be used for the sampling of ore of nominal top size greater than 31,5 mm. In this case, stopped-belt sampling should be used.

12.2 Choosing the sampling location

The sampling site shall

- afford complete operator safety;
- afford access to the complete ore stream;
- show minimum segregation of the ore stream, e.g. in size distribution or moisture content;
- be as close as possible to the load or discharge point where the quality is to be determined.

In most conveying systems the only sampling location which satisfies the above requirements is at a transfer point. Sampling from the top surface of a moving conveyor belt shall be avoided at all times.

12.3 Sampling implements

Sampling shall be performed using ladles of the type specified in annex C.

The capacity of the implement chosen shall be in accordance with the requirements of clause 7 and table C.1.

12.4 Minimum of increments

The minimum mass of each increment shall comply with the requirements of 7.1.

1	6	3	8
5	2	7	4

Figure 6 — Plan view of ore stream with recommended positions-sequence for taking increments manually

12.5 Number of primary increments

The number of primary increments taken shall comply with the requirements of 5.2.

12.6 Sampling procedures

12.6.1 Single operation of the ladle

It is preferable to take the increment in a single pass, moving the ladle across the full width of the stream at a uniform rate and taking care that the ore does not overflow before the ladle leaves the ore stream. Alternate increments should be taken by crossing the stream in opposite directions.

12.6.2 Multiple operations of the ladle

In some cases it will not be possible to obtain a complete cross-section of the ore stream in one pass of the ladle.

In such cases the ladle shall be placed in the stream in a manner so as to systematically draw samples from across the whole ore stream in a number of discrete operations. An example is given in figure 6.

Assuming that the ladle is only capable of taking a representative amount from one eighth of the ore stream [see any of the areas (1 to 8) indicated in figure 6] in one operation, the ladle shall be systematically moved to each remaining area in each subsequent operation so that after eight operations the complete cross-section of the ore stream has been sampled to give one increment.

The actual number of operations that may be required in order to obtain an increment from a complete cross-section of the falling stream will depend on the stream geometry and density and the dimensions of the ladle.

The ladle should be inserted upside-down into the stream, inverted and allowed to fill, then withdrawn from the stream.

Notwithstanding any of the above, the following two further cautions should be observed in drawing a manual sample:

- when a subsample is to be constituted from a number of increments, each subsample or gross

sample shall contain increments which represent a complete cross-section of the stream (i.e. each gross sample shall be complete in itself and should not represent only a part of the stream);

- b) the ladle shall not be overfilled as this may lead to a bias in the sample (i.e. larger particles will tend to roll off a heaped ladle).

13 Stopped-belt sampling

Stopped-belt sampling is the preferred method for collecting a reference sample against which other sampling procedures may be compared. The procedure for sampling from a stopped belt shall be as follows.

- a) Determine the parameters for sampling.
- b) Stop the belt at the predetermined time or mass intervals.
- c) At each stoppage, place a suitably profiled sampling frame (see annex D), with minimum internal dimensions of three times the nominal top size of the ore, across the width of the stationary belt and insert it through the ore so that it is in intimate contact with the belt across its full width.
- d) Should any large pieces of ore obstruct insertion of the frame, push those at the left-hand edge of the frame into the increment and those at the right-hand edge of the frame out of the increment.
- e) Remove the ore within the sampling frame, ensuring that all ore particles in this area are included in the increment by sweeping the belt and deposit each increment in a suitable container. If the increment is to be used for moisture determination, the container should be sealed to prevent moisture loss (or gain) due to climatic conditions.
- f) Combine the increments as follows.
 - 1) Time-basis sampling. The increments as taken may be combined into subsamples or a gross sample irrespective of the variation in the masses of the increments. If the masses of the increments are too large, the increments shall be divided by fixed rate division prior to combination.
 - 2) Mass basis sampling. If the coefficient of variation of the increment masses is greater than 20 %, the increments as taken shall not be combined into subsamples or a gross sample. Either each increment shall be subjected separately to division and determination of

quality characteristics, or increments shall be divided by constant mass division prior to combination at the appropriate stage of division into subsamples or a gross sample.

- g) Store the subsamples or gross samples in labelled containers as specified in clause 15.

14 Sampling from stationary situations

14.1 General

This clause specifies procedures for sampling aluminium ore from stockpiles, wagons and ships' holds. In this case, the lot or sampling unit shall be divided into n strata (n is the number of increments calculated in 5.2) spaced evenly by position or mass.

Sampling shall be systematic, but only when it can be shown that no systematic error could be introduced by any periodic variation in quality or quantity which may coincide with, or approximate to, any multiple of the proposed sampling interval.

If there is a risk that systematic errors could be introduced by periodic variations in quality or quantity, it is suggested that stratified random sampling be used.

In some cases, if all increments are to be combined, the total mass of the combined increments may be so large that division of the increments may be necessary prior to combination to form subsamples or a gross sample. In such cases, the procedure for increment division specified in ISO 6140 shall be followed respecting the requirements of clause 6 of this International Standard.

14.2 Uniformity of primary increment mass

All primary increments taken for combining into gross samples or subsamples shall be of almost uniform mass, i.e. they shall not vary by more than 20 %.

14.3 Bias testing

Procedures for checking bias in sampling are given in ISO 10226.

14.4 Sampling implements for stockpiles, wagons and ships' holds

14.4.1 Shovels

Sampling ore with shovels usually produces a biased sample because it does not fulfil the fundamental principle of sampling that the whole of the lot shall be equally accessible. The ore in the top layer of a stockpile or wagon is almost always different from the rest due to exposure, segregation and

other causes. Therefore sampling with shovels is not recommended. The following procedures merely minimize errors.

Where sampling by shovelling is unavoidable, increments shall be taken from positions spaced as evenly as possible over the surface of the ore to be sampled, ensuring that each increment contains all sizes of ore represented in that portion of the ore. The recommended shovel dimensions are given in table D.1.

The procedure for sampling using a shovel shall be as follows.

- a) Dig a hole to a depth of at least 300 mm in the ore bed, ensuring that the ore dug out of the hole is thrown clear of the hole. The angle of the sides of the hole should be selected to prevent the ore rolling down the sides of the hole and causing further bias in the sample.
- b) Take an increment of the appropriate mass from the bottom of the hole in either single or multiple operations of the shovel, as appropriate.
- c) Place the increments into labelled containers as specified in clause 15.

Ensure that the shovel is never over-filled. After each hole has been dug, the shovel should be inserted nearly horizontally into the top layer of ore, so that it is never buried completely. The natural instinct to thrust a shovel at a steep angle into the ore and lever or lift it out should be avoided as this will inevitably lead to over-filling.

NOTES

10 It is best to use, whenever possible, the shovel size which allows the increment to be taken in a single pass.

11 When the increments are so large that it is not possible to use the largest shovel in a single pass, the increment may be taken in several passes.

14.4.2 Augers

These implements are used when the primary increments are to be collected from the body of a stockpile but, as with shovels, they tend to produce a biased sample as they do not guarantee an equal probability of selection of all particles. The samples obtained will at best be representative of the depth of ore to which the implement penetrates. The use of an auger can cause particle breakage and therefore affect size distribution and bulk density of the ore sample. Therefore sampling with augers is not recommended.

The diameter of the auger shall be at least three times the nominal top size of the ore or 30 mm, whichever is the greater.

When sampling ore with a nominal top size of less than 25 mm, the increment may be taken with an auger but care must be taken to ensure that the full column of ore is taken out and that no particles are lost when the probe is being extracted.

When sampling ore with a nominal top size greater than 25 mm, auger sampling may be found to be impossible unless mechanical apparatus is used. Where mechanical apparatus is used, the amount of material taken will usually exceed that required. It will then be necessary to take the increment by the procedure indicated in 14.4.1.

The procedure for sampling using an auger shall be as follows.

- a) Take increments from positions spaced as evenly as possible over the surface of the ore to be sampled, ensuring that each increment contains all sizes of ore represented in that portion of the ore.
- b) Ensure that wet ore is not allowed to adhere to the outside of the implement when it is withdrawn, and that wet ore is not left adhering to the inside of the implement when extracting the increment. An auger must not be heated to stop wet ore from adhering to it.
- c) Place the increments into labelled containers as indicated in clause 15.

14.4.3 Ladles

Ladles may only be used for sampling of ore in falling streams. The procedure for the use of ladles is given in 12.6.

14.5 Samples from stockpiles

14.5.1 General

Sampling aluminium ore from a stockpile generally presents difficulties in obtaining a representative sample and therefore is not a recommended procedure. A sample taken from the top or sides only of a stockpile cannot be regarded as being representative of the whole stockpile, particularly when the stockpile is composed of ore from more than one source.

The only really effective and recommended method for sampling ore in a stockpile is by sampling during the building up or the breaking down of the stockpile. However, a representative sample can be taken from a stockpile, provided that the sampling device used is capable of penetrating the full depth of the stockpile at each point to be sampled, and extracting the whole column of ore. It is realized that this is rarely feasible. It must be remembered that, in all cases, a sample can represent only that part and

that depth of the ore from which it is collected. For example, if increments are taken by an auger that can penetrate to a depth of 2 m only, the results of tests on the sample(s) can be regarded as being representative of the quality of ore in the stockpile down to that depth only. In effect a 2 m thick shell has been sampled. Thus, if such an implement is used to sample a 20 m high stockpile, only the ore contained in the top 2 m can be taken as the quantity of ore for which the final result is possibly valid.

Some sampling implements may cause degradation of the ore and care shall be taken to ensure that the properties of ore deemed critical are not affected by the sampling implement.

14.5.2 Selection of sampling points

Determine the layout of the stockpile and make a plan of the stockpile. On the plan, divide the stockpile into areas containing approximately equal masses of accessible ore, and number each area. The size of these areas should be such that they are easy to locate on the stockpile.

14.5.3 Method

Take the samples from the stockpile in the following way.

- a) Determine the sampling parameters indicated in 4.3.
- b) Take samples by one of the methods described in 14.4.1 or 14.4.2.

14.6 Sampling from wagons or trucks

14.6.1 Sampling from the top

WARNING — For reasons of safety, sampling from the top of wagons must be carried out with extreme caution. It is essential that the wagons are not moved during the sampling operation.

Sampling from the tops of wagons or trucks is not recommended; however, if no other means are available, it should be carried out in the following way.

- a) Determine the sampling parameters indicated in 4.3.

- b) Take samples by one of the methods described in 14.4.1 or 14.4.2.

14.7 Sampling from wagons during bottom discharge or trucks during tailgate discharge

It is preferable to take a sample during discharge by the procedure specified in clause 11. However if this is not possible, the ore should be discharged into an accessible location (normally a stockpile), and a sample taken by sampling the ore in accordance with one of the procedures described in 14.4.1 or 14.4.2.

14.8 Sampling from ships' holds

Sampling from ships' holds is not recommended; however, if no other means is available, the procedure specified in 14.4.1 should be followed.

15 Packing and marking of samples

Samples obtained for subsequent sample preparation, moisture testing or analysis, which are to be carried out remote from the sampling plant, shall be placed in air-tight containers. The relevant information shall be shown on the label and on a card placed in the container. Examples of the information required are as follows:

- a) type, grade and nominal top size of the ore and name of the lot (identity of ship or train, etc);
- b) mass of the lot or sampling unit;
- c) sample number or portion of lot or sampling unit that the sample represents;
- d) place and date of sampling;
- e) moisture content (if known);
- f) method of sampling (e.g. mass basis, time-basis, manual or mechanical);
- g) nominal top size of the sample;
- h) special purpose or test for which the sample is taken (e.g. bias test, size analysis).

Annex A (informative)

Derivation of equation for minimum gross sample mass

Let s be the standard deviation of the required quality characteristic between individual ore particles. The variance V_s of quality characteristic in a sample consisting of N particles is therefore given by the following equation:

$$V_s = \frac{s^2}{N} \quad \dots (A.1)$$

This is the variance associated with selecting a sample of N particles.

Expressing this in terms of the percentage relative error gives the fundamental error variance, σ_{FE}^2 , due to the heterogeneity of constitution, i.e.:

$$\sigma_{FE}^2 = \frac{s^2}{Nc^2} \times 10^4 \quad \dots (A.2)$$

where c is the value of the quality characteristic, i.e. concentration.

Let the total relative error, expressed as a percentage, allowable for the whole sampling operation be σ_s . Thus in accordance with the assumption made in 4.4,

$$\sigma_{FE}^2 \leq \frac{\sigma_s^2}{2} \quad \dots (A.3)$$

Combining equation [formula (A.2)] and condition [formula (A.3)], gives

$$\frac{s^2}{Nc^2} \times 10^4 \leq \frac{\sigma_s^2}{2} \quad \dots (A.4)$$

Thus

$$N \geq \frac{2s^2}{c^2\sigma_s^2} \times 10^4 \quad \dots (A.5)$$

The number of particles in the gross sample must therefore exceed the minimum given in condition [formula (A.5)].

In order to calculate the minimum sample mass m_G , in kilograms, assume the particles are spherical of diameter D , in millimetres, and density ρ , in tonnes per cubic metre.

Then

$$m_G = N \frac{4}{3} \pi \rho \left(\frac{D}{2} \right)^3 \times 10^{-6}$$

i.e.:

$$m_G = N \frac{\pi}{6} \rho D^3 \times 10^{-6} \quad \dots (A.6)$$

Combining condition [formula (A.5)] and equation [formula (A.6)] gives

$$m_G \geq \frac{2\pi}{6} \left(\frac{s}{c} \times 100 \right)^2 \frac{\rho D^3 \times 10^{-6}}{\sigma_s^2}$$

i.e.:

$$m_G \geq \frac{2\pi}{6} \left(\frac{C_v}{\sigma_s} \right)^2 \rho D^3 \times 10^{-6} \quad \dots (A.7)$$

where

m_G is the minimum mass, in kilograms, of the gross sample;

$C_v = s/c \times 100$, i.e. the coefficient of variation of the required quality characteristic between individual particles;

ρ is the particle density, in tonnes per cubic metre;

D is the nominal top size, in millimetres.

Thus

$$m_G \approx \left(\frac{C_v}{\sigma_s} \right)^2 \rho D^3 \times 10^{-6} \quad \dots (A.8)$$

Approximation [formula (A.8)] assumes that all particles in the sample are of nominal top size. Because this is rarely the case, conservative values for sample mass are obtained. This can be overcome by introducing the size range factor g suggested by Gy [see bibliographic note 2) to 11.3.2 and table 2] Approximation [formula (A.8)] then becomes

$$m_G \approx \left(\frac{C_v}{\sigma_s} \right)^2 \rho g D^3 \times 10^{-6} \quad \dots (A.9)$$