
**Copper, lead, zinc and nickel
concentrates — Sampling procedures
for determination of metal and moisture
content**

*Concentrés de cuivre, de plomb, de zinc et de nickel — Procédures
d'échantillonnage pour la détermination de la teneur en métal et de
l'humidité*

iTeh STANDARD PREVIEW
(standards.iteh.ai)

ISO 12743:2006

<https://standards.iteh.ai/catalog/standards/sist/f3590df5-e081-4beb-8af2-9817e7bc93e6/iso-12743-2006>



PDF disclaimer

This PDF file may contain embedded typefaces. In accordance with Adobe's licensing policy, this file may be printed or viewed but shall not be edited unless the typefaces which are embedded are licensed to and installed on the computer performing the editing. In downloading this file, parties accept therein the responsibility of not infringing Adobe's licensing policy. The ISO Central Secretariat accepts no liability in this area.

Adobe is a trademark of Adobe Systems Incorporated.

Details of the software products used to create this PDF file can be found in the General Info relative to the file; the PDF-creation parameters were optimized for printing. Every care has been taken to ensure that the file is suitable for use by ISO member bodies. In the unlikely event that a problem relating to it is found, please inform the Central Secretariat at the address given below.

iTeh STANDARD PREVIEW
(standards.iteh.ai)

ISO 12743:2006

<https://standards.iteh.ai/catalog/standards/sist/f3590df5-e081-4beb-8af2-9817e7bc93e6/iso-12743-2006>

© ISO 2006

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either ISO at the address below or ISO's member body in the country of the requester.

ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

Published in Switzerland

Contents

Page

Foreword.....	vi
1 Scope	1
2 Normative references	1
3 Terms and definitions.....	2
4 Sampling theory.....	4
4.1 General.....	4
4.2 Total variance.....	5
4.3 Sampling-stage method of estimating sampling and total variance.....	6
4.4 Simplified method of estimating sampling and total variance	9
4.5 Interleaved sample method of measuring total variance	10
5 Establishing a sampling scheme	12
6 Mass of increment	17
6.1 General.....	17
6.2 Mass of increment for falling-stream samplers.....	17
6.3 Mass of increment for cross-belt samplers.....	17
6.4 Mass of increment for manual sampling from stationary lots.....	18
6.4.1 Primary increments	18
6.4.2 Mass of secondary and subsequent increments.....	18
6.5 Mass of increment for stopped-belt reference sampling.....	18
7 Methods of sampling from concentrate streams	18
7.1 General.....	18
7.2 Mass-basis systematic sampling.....	18
7.2.1 General.....	18
7.2.2 Sampling interval	19
7.2.3 Sample cutter	19
7.2.4 Taking of primary increments	19
7.2.5 Constitution of subsamples and lot samples	19
7.2.6 Types of division.....	20
7.2.7 Division of increments	20
7.2.8 Division of subsamples.....	20
7.2.9 Division of lot samples.....	20
7.3 Time-basis systematic sampling.....	21
7.3.1 General.....	21
7.3.2 Sampling interval	21
7.3.3 Sample cutter	21
7.3.4 Taking of primary increments	22
7.3.5 Constitution of subsamples and lot samples	22
7.3.6 Types of division.....	22
7.3.7 Division of increments and subsamples	22
7.3.8 Division of lot samples.....	22
7.4 Stratified random sampling	22
7.4.1 Fixed mass intervals.....	22
7.4.2 Fixed time intervals	23
8 Mechanical sampling of concentrate streams.....	23
8.1 General.....	23
8.2 Design of the sampling system.....	23
8.2.1 Safety of operators	23
8.2.2 Location of sample cutters	23

8.2.3	Provision for interleaved sampling	23
8.2.4	Provision for stratified random sampling.....	24
8.2.5	Checking precision and bias	24
8.2.6	Avoiding bias	24
8.2.7	Minimizing bias	24
8.2.8	Configuration of the sampling system	24
8.3	Sample cutters.....	24
8.3.1	General	24
8.3.2	Design criteria	25
8.3.3	Cutter speed	26
8.4	Mass of increments.....	27
8.5	Number of increments	27
8.6	Sampling interval	27
8.7	Routine checking	27
9	Manual sampling of concentrate streams	28
9.1	General	28
9.2	Choosing the sampling location.....	28
9.3	Sampling implements	28
9.4	Mass of increments.....	28
9.5	Number of increments	28
9.6	Sampling interval	28
9.7	Sampling procedures	29
9.7.1	General	29
9.7.2	Full stream cut from a falling stream	29
9.7.3	Partial stream cuts from a falling stream	29
9.7.4	Sampling from moving conveyor belts.....	30
10	Stopped-belt reference sampling.....	30
11	Sampling from grabs	31
11.1	General	31
11.2	Mass of primary increments.....	31
11.3	Number of primary increments.....	31
11.4	Method of sampling	31
11.5	Constitution of subsamples and lot samples	31
12	Sampling from trucks, railway wagons and sampling hoppers.....	32
12.1	General	32
12.2	Mass of primary increments	32
12.3	Number of primary increments.....	32
12.4	Method of sampling	32
12.5	Constitution of subsamples and lot samples	32
13	Sampling of concentrate in bags or drums.....	35
13.1	General	35
13.2	Mass of primary increments	35
13.3	Number of primary increments.....	35
13.4	Method of sampling	36
13.4.1	General	36
13.4.2	Sampling during filling or emptying	36
13.4.3	Spear sampling	36
13.5	Constitution of subsamples and lot samples	36
14	Sampling of stockpiles	37
15	Methods of comminution, mixing and division.....	37
15.1	General	37
15.2	Comminution	37
15.2.1	General	37
15.2.2	Mills	37
15.3	Mixing	38
15.3.1	General	38

15.3.2	Methods of mixing	38
15.4	Division	40
15.4.1	Chemical analysis samples	40
15.4.2	Moisture samples.....	40
15.4.3	Number of increments for division	40
15.4.4	Minimum mass of divided sample	40
15.4.5	Rotary sample division.....	41
15.4.6	Cutter-type division	42
15.4.7	Manual increment division.....	43
15.4.8	Spear division	43
15.4.9	Fractional shovelling.....	44
15.4.10	Ribbon division	45
15.4.11	Riffle division	47
16	Sample requirements	49
16.1	Moisture samples.....	49
16.1.1	Mass of test portion.....	49
16.1.2	Processing of samples.....	49
16.2	Chemical analysis samples	49
16.3	Physical test samples.....	50
17	Packing and marking of samples	50
Annex A	(normative) Sampling stage method of estimating sampling and total variance	51
Annex B	(informative) Estimation of total variance — Barge unloading using a grab	58
Annex C	(informative) Mechanical sample cutters	62
Annex D	(informative) Checklist for mechanical sampling systems	67
Annex E	(normative) Manual sampling devices.....	71
Annex F	(informative) Apparatus for manual sampling of concentrates from stopped belts	73
Annex G	(informative) Sampling of stockpiles	74
Annex H	(normative) Increment division scoops for conducting manual increment division	76
Bibliography	77

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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. 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.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 12743 was prepared by Technical Committee ISO/TC 183, *Copper, lead, zinc and nickel ores and concentrates*.

This second edition cancels and replaces the first edition (ISO 12743:1998), which has been technically revised. The principal change is the extension of the scope to cover the sampling of nickel concentrates.

iTeh STANDARD PREVIEW
(standards.iteh.ai)
ISO 12743:2006
<https://standards.iteh.ai/catalog/standards/sist/f3590df5-e081-4beb-8af2-9817e7bc93e6/iso-12743-2006>

Copper, lead, zinc and nickel concentrates — Sampling procedures for determination of metal and moisture content

WARNING — This International Standard may involve hazardous materials, operations and equipment. It is the responsibility of the user of this International Standard to establish appropriate health and safety practices and determine the applicability of regulatory limitations prior to use.

1 Scope

This International Standard sets out the basic methods for sampling copper, lead, zinc and nickel concentrates from moving streams and stationary lots, including stopped-belt sampling, to provide samples for chemical analysis, physical testing and determination of moisture content, in accordance with the relevant International Standards. Where the concentrates are susceptible to significant oxidation or decomposition, it is necessary to use a common sample for moisture determination and chemical analysis to eliminate bias (see ISO 10251). In such cases, the common sample must be sufficiently representative, i.e. unbiased and sufficiently precise, for chemical analysis and determination of moisture content. Any large agglomerates (> 10 mm) present in the primary sample should be crushed prior to further sample processing. Sampling of concentrates in slurry form is specifically excluded from this International Standard.

Stopped-belt sampling is the reference method for collecting concentrate samples against which mechanical and manual-sampling procedures may be compared. Sampling from moving streams is the preferred method. Both falling-stream and cross-belt samplers are described.

Sampling from stationary lots is used only where sampling from moving streams is not possible. The procedures described in this International Standard, for sampling from stationary lots, only minimize some of the systematic sampling errors.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 10251, *Copper, lead, zinc and nickel concentrates — Determination of mass loss of bulk material on drying*

ISO 12744, *Copper, lead, zinc and nickel concentrates — Experimental methods for checking the precision of sampling*

ISO 13292, *Copper, lead, zinc and nickel concentrates — Experimental methods for checking the bias of sampling*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1 representative sample
quantity of concentrate representing a larger mass of concentrate with both precision and bias within acceptable limits

3.2 lot
quantity of concentrate to be sampled

3.3 lot sample
quantity of concentrate representative of the lot

3.4 sub-lot
subdivided parts of a lot which are processed separately, each of them producing a subsample which is analysed separately, e.g. for moisture determination

3.5 subsample
quantity of concentrate representative of the sub-lot

3.6 sampling
sequence of operations aimed at obtaining a sample representative of a lot

NOTE It comprises a series of sampling stages, each stage usually comprising operations of selection and preparation

3.7 selection
operation by which a smaller quantity of concentrate is taken from a larger quantity of concentrate

3.8 increment
quantity of concentrate selected by a sampling device in one operation

3.9 increment selection
selection process that consists of extracting from the lot, or from an intermediate sample, successive increments which can be combined to constitute a sample

3.10 division
operation of decreasing sample mass, without change of particle size, where a representative part of the sample is retained

3.11 constant-mass division
method of division in which the retained portions from individual increments or subsamples are of uniform mass

iteh STANDARD PREVIEW
(standards.iteh.ai)
ISO 12743:2006
<https://standards.iteh.ai/catalog/standards/sist/15590415-c081-40e0-8a2-9817e7bc93e6/iso-12743-2006>

3.12**proportional division**

method of division in which the retained portions from individual increments or subsamples are a constant proportion of their original mass

3.13**preparation**

nonselective operation without division such as sample transfer, drying, comminution or homogenization

3.14**sample processing**

whole sequence of selection and preparation operations which transforms a stage i sample into a test sample

3.15**comminution**

operation of reducing particle size by crushing, grinding or pulverisation

3.16**stage i sample**

sample obtained at the i th stage of the sampling scheme

3.17**moisture sample**

representative quantity of concentrate from which test portions are taken for moisture determination

NOTE

Alternatively, the whole moisture sample may be dried to determine its moisture content

3.18**laboratory sample**

sample that is processed so that it can be sent to the laboratory and used for further processing and selection of one or more test samples for analysis

3.19**common sample**

representative quantity of concentrate which is dried to determine its mass loss and subsequently used for further processing and selection of one or more test samples for chemical analysis

3.20**test sample**

representative quantity of concentrate obtained from a laboratory sample when additional preparation, such as drying or hygroscopic moisture determination, is needed prior to the selection of one or more test portions

3.21**test portion**

representative quantity of concentrate taken from a moisture sample, a laboratory sample or a test sample which is submitted to moisture determination or analysis in its entirety

3.22**systematic sampling**

selection of increments in which the concentrate being sampled is divided into equal strata and the first increment is taken at random within the first stratum, the interval between subsequent increments being equal to the stratum size

3.23**stratified random sampling**

selection of increments in which the concentrate being sampled is divided into equal strata, each increment being taken at random within each stratum

3.24

homogenisation

preparation operation which reduces the distribution heterogeneity of the concentrate

3.25

agglomerate

cluster of particles that are held together by chemical or physical phenomena

3.26

nominal top size

aperture size of a test sieve that retains 5 % of the mass of concentrate

3.27

moisture determination

quantitative measurement of the mass loss of the moisture test portion under the conditions of drying specified in ISO 10251

3.28

chemical analysis

quantitative determination of the required chemical constituents of the analysis test portion

3.29

error

in any quantitative measurement, the difference between the true value and the value obtained for an individual measurement

iTeh STANDARD PREVIEW
(standards.iteh.ai)

3.30

bias

statistically significant difference between the mean of the test results and an accepted reference value

See also ISO 13292.

<https://standards.iteh.ai/catalog/standards/sist/f3590df5-e081-4beb-8af2-9817e7bc93e6/iso-12743-2006>

3.31

precision

closeness of agreement between independent test results obtained under stipulated conditions

See also ISO 12744.

3.32

interleaved samples

samples constituted by placing consecutive primary increments alternately into two separate sample containers

4 Sampling theory

4.1 General

The basic rule for a correct sampling method is that all possible increments from the concentrate stream or stratum shall have the same probability of being selected and appearing in the sample. Any deviation from this basic requirement can result in a bias. An incorrect sampling scheme cannot be relied on to provide representative samples.

Sampling should preferably be carried out on a systematic basis, either on a mass basis (see 7.2) or on a time basis (see 7.3), but only where it can be shown that no systematic error (or bias) could be introduced due to any periodic variation in quality or quantity that may coincide with, or approximate to, any multiples of the proposed sampling interval. In such cases, it is recommended that stratified random sampling within fixed time or mass intervals be carried out (see 7.4).

The methods for sampling, including sample processing, depend on the final choice of the sampling scheme and on the steps necessary to minimize possible systematic errors. The aim is always to reduce the total variance to an acceptable level, while at the same time eliminating any significant biases, e.g. minimizing degradation of samples used for determination of size distribution.

Moisture samples shall be processed as soon as possible and test portions shall be weighed immediately. If this is not possible, samples shall be stored in impervious airtight containers with a minimum of free air space to minimize any change in moisture content, but should be prepared without delay.

4.2 Total variance

The general aim of a sampling scheme is to provide one or several test portions, sufficiently representative of a lot, for determination of the quality characteristics of the lot. The total variance of the final result, denoted by s_T^2 , consists of the variance of sampling (including sample processing) plus the variance of analysis (chemical analysis, moisture determination, determination of particle size distribution, etc.) as follows:

$$s_T^2 = s_S^2 + s_A^2 \quad \dots(1)$$

where

s_S^2 is the sampling variance (including sample processing);

s_A^2 is the analytical variance.

In Equation 1, the sampling variance includes the variances due to all sampling (and sample processing) steps, except selection of the test portion. The variance due to selection of the test portion is included in the analytical variance, s_A^2 , which is determined in accordance with ISO 12744, because it is difficult to determine separately the "true" analytical variance.

Often replicate analyses of quality characteristics are carried out, which reduces the total variance. In this case, if r replicate analyses are made.

$$s_T^2 = s_S^2 + \frac{s_A^2}{r} \quad \dots(2)$$

The estimation or measurement of the total variance can be carried out in several ways, depending on the purpose of the exercise. In many respects, the different approaches are complementary.

The first method, which was developed by Gy^[3, 4], is to break up the sampling variance into its components for each sampling stage (see Annex A). The total variance is then given by:

$$s_T^2 = s_{S_1}^2 + \dots + s_{S_i}^2 + \dots + s_{S_{u-1}}^2 + \frac{s_A^2}{r} \quad \dots(3)$$

where

$s_{S_1}^2$ is the sampling variance for stage 1, i.e. the primary sampling variance;

$s_{S_i}^2$ is the sampling variance for stage i ;

$s_{S_{u-1}}^2$ is the sampling variance for stage $u - 1$, the second last stage;

u is the number of sampling stages, stage u corresponding to selection of the test portion.

This is referred to as the “sampling stage” method (see 4.3) and provides very detailed information on the variance components, which is particularly useful for designing and assessing sampling schemes. However, to obtain maximum benefit, it is necessary to collect data at each sampling stage.

The second method, called the “simplified” method (see 4.4), is to break up the total variance into primary sampling, sample processing and analytical variances only as follows:

$$s_T^2 = s_{S_1}^2 + s_P^2 + \frac{s_A^2}{r} \quad \dots(4)$$

where

$s_{S_1}^2$ is the primary sampling variance;

s_P^2 is the variance due to all subsequent sampling steps, i.e. sample processing, except selection of the test portion;

s_A^2 is the analytical variance, including selection of the test portion (at stage u in Equation 3).

The primary sampling variance is identical to the sampling variance for stage 1 in Equation 3, while s_P^2 is equal to the total sampling variance for the remaining sampling stages, except for selection of the test portion which is included in the analytical variance. The relative magnitudes of the variance components in Equation 4 indicate where additional effort is required to reduce the total variance. However, it is not possible to separate the variances of the separate sample-processing stages. This method is suitable for estimating the total variance for new sampling schemes based on the same sample-processing procedures, where the numbers of primary increments, sample processings and analyses are varied.

Finally, the total variance s_T^2 can be estimated experimentally by collecting interpenetrating duplicate samples (see 4.5). This is called the “interleaved sample” method and gives valuable information on the total variance actually achieved for a given sampling scheme with no extra effort provided facilities are available for collecting duplicate samples (Merks^[5]). It gives no information on variance components, but the total variance can be compared with the analytical variance to ascertain whether the sampling scheme used was optimized or not. It is therefore of limited use for designing sampling schemes, but it can be used to monitor whether a sampling scheme is in control.

4.3 Sampling-stage method of estimating sampling and total variance

The sampling variance for stage i is given by (see Annex A):

$$s_{S_i}^2 = \frac{s_{b_i}^2}{n_i} \quad \dots(5)$$

where

$s_{b_i}^2$ is the variance between increments for stage i ;

n_i is the number of increments for stage i .

The variance between increments for stage i , $s_{b_i}^2$, can be estimated using the following equation:

$$s_{b_i}^2 = \frac{\sum_{j=1}^n (x_j - \bar{x})^2}{n_i - 1} - s_{PA}^2 \quad \dots(6)$$

where

x_j is the test result for increment j ;

\bar{x} is the mean test result for all increments;

s_{PA}^2 is the variance of subsequent sample processing and analysis.

The variance of subsequent sample processing and analysis of each increment, s_{PA}^2 , has been taken into account in Equation 6 to obtain an unbiased estimate of $s_{b_i}^2$.

NOTE Care is needed in subtracting variances. The difference is significant only when the F ratio of the variances being subtracted is statistically significant.

Remembering that the variance due to selection of the test portion is included in the analytical variance s_A^2 , the total sampling variance is given by:

$$s_S^2 = \sum_{i=1}^{u-1} \frac{s_{b_i}^2}{n_i} \quad \dots(7)$$

Combining Equations 2 and 7 gives the total variance, s_T^2 as follows:

$$s_T^2 = \sum_{i=1}^{u-1} \frac{s_{b_i}^2}{n_i} + \frac{s_A^2}{r} \quad \dots(8)$$

For a three-stage sampling scheme (including selection of the test portion), Equation 8 reduces to:

$$s_T^2 = \frac{s_{b_1}^2}{n_1} + \frac{s_{b_2}^2}{n_2} + \frac{s_A^2}{r} \quad \dots(9)$$

The best way of reducing the value of s_T^2 to an acceptable level is to reduce the largest terms in Equation 8 first. Clearly $s_{b_i}^2/n_i$ for a given sampling stage can be reduced by increasing the number of increments n_i or reducing $s_{b_i}^2$ by homogenizing the concentrate prior to sampling. The last term can be reduced by reducing the particle size prior to selection of the test portion, or performing replicate analyses. Selecting the optimum number of increments n_i for each sampling stage may require several iterations to obtain the required total variance s_T^2 .

EXAMPLE Consider a four-stage sampling scheme for determining the metal content of a copper concentrate containing 31,2 % Cu. Assume that the concentrate is being conveyed at 500 t/h on a conveyor belt, that the lot size is 500 t, and that the following parameters have been determined using Equation 6 where appropriate:

$$s_{b_1} = 0,3 \text{ \% Cu}$$

$$s_{b_2} = 0,2 \text{ \% Cu}$$

$$s_{b_3} = 0,1 \text{ \% Cu}$$

$$s_A = 0,05 \text{ \% Cu}$$

NOTE Many measurements may be required to obtain good estimates of s_{b_1} , s_{b_2} , s_{b_3} and s_A .

Stage 1

Assume that the primary cutter takes increments of 12 kg mass at 2 min intervals. Thus:

$$n_1 = 30$$

Primary sample mass = 360 kg

Equation 5 gives:

$$s_{S_1}^2 = (0,3)^2/30 = 0,003 0$$

Stage 2

The primary increments are collected in a hopper, and then fed to the secondary cutter at a rate of 360 kg/h. Secondary increments of 0,01 kg are taken at 30 s intervals. Thus:

$$n_2 = 120$$

Divided sample mass = 1,2 kg

$$s_{S_2}^2 = (0,2)^2/120 = 0,000 333$$

Stage 3

iTeh STANDARD PREVIEW
(standards.iteh.ai)

The 1,2 kg sample is transported to the sample-processing laboratory and fed through a rotary sample divider with a sample-collection canister divided into 8 equal sectors rotating at 30 rev/min (0,5 s⁻¹). Sample division takes 2 min. Thus:

<https://standards.iteh.ai/catalog/standards/sist/f3590df5-e081-4beb-8af2-9817e7bc93e6/iso-12743-2006>
ISO 12743:2006

$$n_3 = 60$$

Divided sample mass = 150 g

$$s_{S_3}^2 = (0,1)^2/60 = 0,000 167$$

Stage 4

Dry the sample and then pulverize it to 150 µm. Select a 1 g test portion, by taking 10 increments of 0,1 g with a spatula, and conduct a single analysis. Thus:

$$s_A = 0,05 \% \text{ Cu}$$

Total variance

The total variance is given by:

$$\begin{aligned} s_T^2 &= s_{S_1}^2 + s_{S_2}^2 + s_{S_3}^2 + s_A^2 \\ &= 0,003 0 + 0,000 333 + 0,000 167 + 0,002 5 \\ &= 0,006 \end{aligned}$$

Hence:

$$s_T = 0,077 \% \text{ Cu}$$

In this example, the largest components of variance are due to primary sampling and analysis. Consequently, the total variance can be reduced by increasing the number of primary increments and conducting replicate analyses.

An example of the application of the sampling-stage method of estimating total variance to sampling from grabs is given in Annex B.

4.4 Simplified method of estimating sampling and total variance

While it is not possible to partition, i.e. separate, the variances of the individual sample-processing stages, the simplified method is suitable for estimating the total variance for new sampling schemes based on the same sample-processing procedures, where the numbers of primary increments, sample processings and analyses are varied.

Using Equation 5, the primary sampling variance $s_{S_1}^2$ is given by:

$$s_{S_1}^2 = \frac{s_{b_1}^2}{n_1} \quad \dots(10)$$

where

n_1 is the number of primary increments;

$s_{b_1}^2$ is the variance between primary increments determined using Equation 6.

The primary sampling variance can be reduced by increasing the number of primary increments n_1 .

The sample-processing variance s_P^2 and analytical variance s_A^2 are determined experimentally by duplicate sample processing and determination of quality characteristics in accordance with ISO 12744. The analytical variance s_A^2 can also be obtained by carrying out duplicate analyses on test samples.

Multiple sample processings and analyses are often carried out to reduce the total variance. In this case, combining Equations 4 and 10 gives the following.

a) Where a single sample is constituted for the lot and r replicate analyses are carried out on the test sample:

$$s_T^2 = \frac{s_{b_1}^2}{n_1} + s_P^2 + \frac{s_A^2}{r} \quad \dots(11)$$

b) Where the lot is divided into k sub-lots, a subsample is constituted for each sub-lot, and r replicate analyses are carried out on each resultant test sample:

$$s_T^2 = \frac{s_{b_1}^2}{n_1} + \frac{s_P^2}{k} + \frac{s_A^2}{rk} \quad \dots(12)$$