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Copper, lead, zinc and nickel sulfide concentrates — Determination of mass of contained metal in a lot

Concentrés sulfurés de cuivre, de plomb, de zinc et de nickel — Détermination de la masse de métal contenu dans un lot

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Foreword

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The committee responsible for this document is ISO/TC 183, *Copper, lead, zinc and nickel ores and concentrates*.

This second edition cancels and replaces the first edition (ISO 13543:1996), which has been technically revised.

Copper, lead, zinc and nickel sulfide concentrates — Determination of mass of contained metal in a lot

WARNING — This International Standard may involve hazardous materials, operations and equipment. It is 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 specifies the method for determining the mass of contained metal in a lot, based on the wet mass, moisture content and dry basis metal content of the lot. The procedure for estimating the variance and confidence intervals for the mass of contained metal is also specified.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. 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 12743, *Copper, lead, zinc and nickel concentrates — Sampling procedures for determination of metal and moisture content*

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

ISO 12745, *Copper, lead and zinc ores and concentrates — Precision and bias of mass measurement techniques*

3 Terms and definitions

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

3.1
lot
quantity of concentrate to be sampled

3.2
wet mass of the lot
combined mass of concentrate and moisture of the lot at the time of weighing and sampling

3.3
moisture determination
quantitative measurement of the mass loss of the moisture test portion under the conditions of drying specified in ISO 10251

3.4
chemical analysis
quantitative determination of the required chemical constituents of the analysis test portion

3.5
precision
measure of the random variations within a set of measurements

3.6
dry mass of the lot
mass of concentrate in the lot after correcting for the mass of moisture in the lot

4 Determination of mass of contained metal

4.1 General

The mass of contained metal in a lot is determined from measurements of the wet mass, moisture content and dry basis metal content.

4.2 Wet mass of the lot

The wet mass of the lot shall be determined using static scales, belt scales or draft surveys. However, due to their superior precision, static scales are recommended.

4.3 Metal content of the lot

Samples for chemical analysis shall be collected in accordance with ISO 12743 and analysed in accordance with the relevant ISO chemical analysis standards.

4.4 Dry mass of the lot

Calculate the dry mass of the lot using Formula (1):

$$m_D = m_W \left(1 - \frac{M}{100}\right) \tag{1}$$

where

m_D is the dry mass of the lot, in tonnes;

m_W is the wet mass of the lot, in tonnes;

M is the moisture content of the lot, in percent of the wet mass (mass fraction).

4.5 Mass of contained metal

4.5.1 Major elements

For the major elements copper, lead, zinc, and nickel, the mass of contained metal in the lot is given by Formula (2):

$$m_M = \frac{m_D \, a_L}{100} \tag{2}$$

where

m_M is the mass of contained metal in the lot, in tonnes;

m_D is the dry mass of the lot, in tonnes;

a_L is the metal content of the lot on a dry basis, in percent (mass fraction).

Alternatively, Formula (2) may be rewritten as Formula (3):

$$m_{\mathrm{M}} = \frac{m_{\mathrm{W}}\ F\ a_{\mathrm{L}}}{100} \tag{3}$$

where F is the moisture factor given by Formula (4):

$$F = 1 - \frac{M}{100} \tag{4}$$

4.5.2 Precious metals

For the precious metals silver and gold, the mass of contained metal in the lot is given by Formula (5):

$$m_{\mathrm{M}} = \frac{m_{\mathrm{W}}\ F\ a_{\mathrm{L}}}{1000} \tag{5}$$

where

m_{M} is the mass of contained metal in the lot, in kilograms;

m_{W} is the wet mass of the lot, in tonnes;

F is the moisture factor;

a_{L} is the precious metal content of the lot on a dry basis, in grams per tonne (mass fraction).

5 Determination of variance of mass of contained metal

The variance of the mass of contained metal in the lot may be determined from Formula (3) by taking the partial derivatives with respect to the wet mass, the moisture factor and the metal content of the lot as given in Formula (6):

$$s_{\mathrm{M}}^2 = \left(\frac{\partial m_{\mathrm{M}}}{\partial m_{\mathrm{W}}}\right)^2 s_{\mathrm{W}}^2 + \left(\frac{\partial m_{\mathrm{M}}}{\partial F}\right)^2 s_{\mathrm{F}}^2 + \left(\frac{\partial m_{\mathrm{M}}}{\partial a_{\mathrm{L}}}\right)^2 s_{\mathrm{T}}^2 \tag{6}$$

where

s_{M}^2 is the estimated variance of the mass of contained metal in the lot;

s_{W}^2 is the estimated variance of the wet mass of the lot;

s_{F}^2 is the estimated total variance of the moisture factor = $(s_{\mathrm{H}}/100)^2$ with s_{H} being the total precision (one standard deviation) of moisture determination;

s_{T}^2 is the estimated total variance of the metal content of the lot.

NOTE The estimated total variances of the moisture factor and the metal content include the contributions from primary sampling, sample processing and analysis.

Determining the partial derivatives and substituting them into Formula (6) gives Formula (7):

$$s_{\mathrm{M}}^{2} = \left(\frac{F a_{\mathrm{L}}}{100}\right)^{2} s_{\mathrm{W}}^{2} + \left(\frac{m_{\mathrm{W}}\ a_{\mathrm{L}}}{100}\right)^{2} s_{\mathrm{F}}^{2} + \left(\frac{m_{\mathrm{W}} F}{100}\right)^{2} s_{\mathrm{T}}^{2} \qquad (7)$$

Formula (7) may be simplified as Formula (8):

$$s_{\mathrm{M}}^{2} = m_{\mathrm{M}}^{2}\left[\frac{s_{\mathrm{W}}^{2}}{m_{\mathrm{W}}^{2}} + \frac{s_{\mathrm{F}}^{2}}{F^{2}} + \frac{s_{\mathrm{T}}^{2}}{a_{\mathrm{L}}^{2}}\right] \qquad (8)$$

Formula (8) is applicable to both the major elements and the precious metals.

The variance of the wet mass of the lot shall be determined in accordance with the procedures specified in ISO 12745 for estimating the precision of mass measurement techniques. The variances of the moisture factor and the metal content of the lot shall be determined according to the procedures specified in ISO 12744. The analyses shall be carried out according to the methods prescribed in relevant International Standards.

6 Examples of calculation of contained metal and its variance

6.1 Static scale

6.1.1 General

Assume a 500 t lot containing a mass fraction of 30 % copper, a mass fraction of 10 g of gold/t and a mass fraction of 8 % moisture is weighed using a static hopper scale with a capacity of 25 t, i.e. 20 hopper loads. The precision (one standard deviation) of the hopper scale is 0,1 % relative. The lot is divided into 10 sub-lots and a single moisture determination is carried out on each subsample. A single lot sample is constituted for chemical analysis. The total precisions of the copper, gold and moisture determinations (one standard deviation) are mass fractions of 0,05 % copper, 0,5 g of gold/t and 0,1 % moisture absolute, respectively.

6.1.2 Mass of contained copper

$m_{\mathrm{W}} = 500$ t

$$s_{\mathrm{W}}^{2} = \left(\frac{25 \times 0{,}1}{100}\right)^{2} \times 20 = 0{,}012\,5$$

$$F = 1 - \frac{8}{100} = 0{,}92$$

$$s_{\mathrm{F}}^{2} = \frac{\left(0{,}1/100\right)^{2}}{10} = 0{,}000\,000\,1$$

$a_{\mathrm{L}} = 30$ % copper

s_T^2 = (0,05)² = 0,002 5

Formulae (3) and (8) give

$$m_M = \left(\frac{500 \times 0,92 \times 30}{100}\right) = 138 \text{ t copper}$$

$$\begin{aligned} s_M^2 &= 138^2 \times \left(\frac{0,012\,5}{500^2} + \frac{0,000\,000\,1}{0,92^2} + \frac{0,002\,5}{30^2}\right) \\ &= 138^2 \times \left(0,000\,000\,05 + 0,000\,000\,12 + 0,000\,002\ 78\right) \\ &= 0,000\,95 + 0,002\ 3 + 0,052\ 9 \\ &= 0,056 \end{aligned}$$

Calculation of the standard deviation s_M gives

s_M = 0,24 t copper

Hence, at the 95 % confidence level (i.e. two standard deviations), the mass of contained copper metal is

m_M = 138 ± 0,5 t copper (i.e. ±0,4 % relative)

The 95 % confidence range is 137,5 t of copper to 138,5 t of copper.

The precision of the measured copper content of the lot is the major contributor to the uncertainty in the mass of contained metal. The uncertainty can be reduced by carrying out additional analyses on the lot sample, or, in future, by analysing each sub-lot separately.

6.1.3 Mass of contained gold

m_W = 500 t

$$s_W^2 = \left(\frac{25 \times 0,1}{100}\right)^2 \times 20 = 0,012\,5$$

$$F = 1 - \frac{8}{100} = 0,92$$

$$s_F^2 \frac{\left(0,1/100\right)^2}{10} = 0,000\,000\ 1$$

a_L = 10 g of gold/t

$$s_T^2 = \left(0,5\right)^2 = 0,25$$

Formulae (5) and (8) give

$$m_M = \left(\frac{500 \times 0,92 \times 10}{1000}\right) = 4,6 \text{ kg gold}$$

$$s_M^2 = 4,6^2 \times \left(\frac{0,012\,5}{500^2} + \frac{0,000\,000\,1}{0,92^2} + \frac{0,25}{10^2} \right)$$
$$= 4,6^2 \times \left(0,000\,000\;\;05 + 0,000\,000\;\;12 + 0,002\;\;5\right)$$
$$= 0,000\,001\,1 + 0,000\,002\,5 + 0,052\,9$$
$$= 0,053$$

Calculation of the standard deviation s_M gives

s_M = 0,23 kg gold

Hence, at the 95 % confidence level, the mass of contained gold is

m_M = 4,6 ± 0,5 kg gold (i.e. ±11 % relative)

The 95 % confidence range is 4,1 kg of gold to 5,1 kg of gold.

The precision of the measured gold content of the lot is the major contributor to the uncertainty in the mass of contained metal. Once again, the uncertainty can be reduced by carrying out additional analyses on the lot sample, or, in future, by analysing each sub-lot separately.

6.2 Draft survey

Assume a lot containing a mass fraction of 30 % copper and 8 % moisture has a wet mass of 25 000 t. If the wet mass is determined by draft survey with a relative precision (one standard deviation) of 1 % and the copper and moisture content of the lot have been determined with total precisions (one standard deviation) of mass fractions of 0,05 % copper and 0,1 % moisture absolute respectively, then

m_W = 25 000 t

$$s_W^2 = \left(\frac{25\,000 \times 1}{100} \right)^2 = 62\;\;500$$

$$F = 1 - \frac{8}{100} = 0,92$$

$$s_F^2 = \left(\frac{0,1}{100} \right)^2 = 0,000\,001$$

a_L = 30 % copper

$$s_T^2 = \left(0,05\right)^2 = 0,002\,5$$

Hence, Formulae (3) and (8) give

$$m_M = \left(\frac{25\,000 \times 0,92 \times 30}{100} \right) = 6\,900\text{ t copper}$$

$$s_M^2 = 6\,900^2 \times \left(\frac{62\,500}{25\,000^2} + \frac{0{,}000\,001}{0{,}92^2} + \frac{0{,}002\,5}{30^2} \right)$$
$$= 6\,900^2 \times (0{,}000\,1 + 0{,}000\,001\,2 + 0{,}000\,002\,8)$$
$$= 4\,761 + 57 + 133$$
$$= 4\,951$$

Calculation of the standard deviation s_M gives

s_M = 70 t copper

Hence, at the 95 % confidence level, the mass of contained copper metal is

m_M = 6 900 ± 140 t copper (i.e. ±2,0 % relative)

The 95 % confidence range is 6 760 t of copper to 7 040 t of copper.

Clearly, the precision of mass determination is the major contributor to the uncertainty in the mass of contained metal. This situation is typical when the wet mass of the lot is determined by draft survey, which is much less precise than using weigh hoppers.

Bibliography

[1] ISO 10258, *Copper sulfide concentrates — Determination of copper content — Titrimetric methods*

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[3] ISO 10469, *Copper sulfide concentrates — Determination of copper — Electrogravimetric method*

[4] ISO 11441, *Lead sulfide concentrates — Determination of lead content — Back titration of EDTA after precipitation of lead sulfate*

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[6] ISO 13291, *Zinc sulfide concentrates — Determination of zinc — Solvent extraction and EDTA titrimetric method*

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