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Iron ores — Determination of the moisture content of a lot

Minerais de fer — Détermination de l'humidité d'un lot

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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.

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 3087 was prepared by Technical Committee ISO/TC 102, *Iron ore and direct reduced iron*, Subcommittee SC 1, *Sampling*.

This fourth edition cancels and replaces the third edition (ISO 3087:1998), which has been technically revised.

Introduction

Currently, large tonnages of iron ore are traded internationally and a small error in the measured moisture content [mass fraction (%)] of a lot has a considerable effect on the commercial transaction. The correct determination of moisture content of a lot is, therefore, a matter of importance for both the purchaser and the vendor.

This International Standard does not address the determination of the hygroscopic moisture content of a test sample for chemical analysis. If the hygroscopic moisture content is required to be determined, reference should be made to ISO 2596:2006, *Iron ores — Determination of hygroscopic moisture in analytical samples — Gravimetric, Karl Fischer and mass-loss methods*.

Iron ores — Determination of the moisture content of a lot

1 Scope

This International Standard specifies a method for the determination of the moisture content of a lot of iron ore. This method is applicable to all iron ores, whether natural or processed.

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 3082, *Iron ores — Sampling and sample preparation procedures*

ISO 11323, *Iron ore and direct reduced iron — Vocabulary*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 11323 apply.

4 Principle

Dry the test portion in air at 105 °C to constant mass and measure the loss in mass. Express the moisture content as the mass loss relative to the original mass of the sample as a mass fraction (%).

5 Apparatus

5.1 Drying pan, with a smooth surface, free from contamination and capable of accommodating the specified quantity of a test portion in a layer of nominal thickness not greater than 31,5 mm.

5.2 Drying oven, equipped with a temperature indicator and control apparatus capable of regulating the temperature at any point in the oven at 105 °C ± 5 °C and so designed as to maintain this temperature with a current of air to ensure efficient drying but without any loss of sample, and fitted with a fan that allows for both the circulation and change of air.

5.3 Weighing device, accurate to at least 0,05 % of the initial mass of a test portion.

The capacity of the weighing device shall be enough for the initial mass of the test portion.

6 Samples

Test samples which have been taken and prepared in accordance with ISO 3082 shall be used. The mass of a test portion, in relation to its nominal top size, is specified in Table 1, in accordance with ISO 3082.

Table 1 — Minimum mass of test portion

Nominal top size of test portion mm		Minimum mass of test portion kg
over	up to and including	
22,4	31,5	10
10,0	22,4	5
—	10,0	1

7 Procedure

7.1 Number of moisture measurements

Carry out one moisture measurement per test portion on the number of test portions specified in Table 2, according to the conditions of preparation of the test sample.

Table 2 — Number of test portions

Preparation of test sample	Number of partial samples per lot	Number of test portions to be tested
From gross sample	—	4 per gross sample
From partial sample	2	4 per partial sample
	3 to 7	2 minimum per partial sample
	≥ 8	1 minimum per partial sample
From increment	—	1 minimum per increment

In order to minimize losses of moisture to the atmosphere, it is necessary to perform all the initial weighings of the test portions as quickly as possible after obtaining those test portions.

7.2 Measurement

7.2.1 General

The moisture determination shall be measured in accordance with 7.2.2 or, alternatively, for ores with 8 % or more of combined water in accordance with 7.2.3.

When it is difficult to conduct sieving, crushing and dividing, owing to a sample being adhesive or excessively wet, the sample may be predried in accordance with the procedure in Annex A.

7.2.2 Normal method

a) Spread the test portion in a layer of nominal thickness not greater than 31,5 mm in the tared drying pan (5.1) and determine the total mass immediately. Record the total mass, the mass of the drying pan, the initial mass of the test portion (m_1) and the numerical value of 0,05 % of the initial mass of the test portion.

b) Place the drying pan with the test portion in the drying oven (5.2) set at 105 °C, and maintain this temperature for not less than 4 h. Remove the drying pan with the test portion from the drying oven and weigh it immediately while still hot in order to minimize any reabsorption of moisture. Alternatively, weigh the test portion after cooling in air in a container having a close-fitting airtight lid. In each case, report the method of weighing.

c) Once more, place the drying pan with the test portion in the drying oven, heat for a further 1 h, and then repeat the weighing.

d) Repeat the procedure described in the previous item until the difference in mass between subsequent measurements becomes 0,05 % or less of the initial mass of the test portion.

NOTE 1 The weighing device should be protected from the influence of heat.

NOTE 2 Drying times will be dependent on the type of ore under test. For a series of measurements carried out on a particular type of ore, the drying time of the test portion may be specified by check experiments carried out beforehand.

NOTE 3 To reduce drying time, a lower layer-thickness of the sample is recommended. It should be specified by check experiments carried out beforehand.

NOTE 4 For convenience, the test portion of mass 10 kg for ore of particle size less than 31,5 mm may be divided into two portions, each of which is subjected to moisture measurement. In calculating the results, the mean of the two values of initial mass and the mean of the two values of the drying loss in mass should be used.

7.2.3 Method for ores of high combined water content

For ores containing 8 % or more combined water, the following procedure may be applied.

a) Spread the test portion in a layer of nominal thickness not greater than 31,5 mm in the tared drying pan (5.1) and determine the total mass immediately. Record the total mass, the mass of the drying pan and the initial mass of the test portion (m_1).

b) Place the drying pan with the test portion in the drying oven (5.2) set at 105 °C and maintain this temperature for not less than 24 h. Remove the drying pan with the test portion from the drying oven and weigh it immediately while still hot in order to minimize any reabsorption of moisture. Alternatively, weigh the test portion after cooling in air in a container having a close-fitting airtight lid. Record the total mass after drying. In each case, report the method of weighing.

NOTE The notes in 7.2.2 apply to this subclause.

8 Verification

Regular checking of apparatus and procedures is essential to verify the test results. Checks shall be carried out prior to the commencement of a routine test in accordance with this International Standard and at regular intervals thereafter. The frequency of checking is a matter for each laboratory to determine. A detailed record of all verification activities shall be maintained for the following items:

a) Sprinkled water measurement

— volumenometer;

b) Rainfall measurement

— rain gauge;

c) Moisture test

— oven temperature/temperature regulation;

— circulation and change of air in oven;

— weighing device.

9 Calculation and expression of results

9.1 Test portion

The result of the determination of the moisture content, w_i, expressed as a mass fraction (%), for each test portion, is given by Equation (1) and reported to the second decimal place.

$$w_i = \frac{m_1 - m_2}{m_1} \times 100 \quad (1)$$

where

m_1 is the initial mass, in grams, of the test portion;

m_2 is the mass, in grams, of the test portion after drying.

9.2 Lot

The moisture content of a lot is given by one of the Equations (2) to (5) as the occasion may demand, and reported to the first decimal place.

Sprinkled water and/or rainwater over iron ore during loading and/or unloading operation shall be corrected according to the procedure specified in Annex B.

9.2.1 When moisture determination is conducted on the gross sample from the lot, the moisture of the lot is determined as follows.

When the range of the four test results does not exceed 1,3r as given in Table 3, the arithmetic mean, $\bar{w}$, of the four results shall be the moisture content, expressed as a mass fraction (%), of the lot as given by Equation (2).

$$\bar{w} = \frac{w_1 + w_2 + w_3 + w_4}{4} \quad (2)$$

where w_1, w_2, w_3 and w_4 are the results of the determinations of the moisture contents, expressed as a mass fraction (%), on each of the four test portions.

When the range of the four test results exceeds 1,3r as given in Table 3, the median shall be taken as the moisture content of the lot. The median of four test results is defined as the mean of the two non-extreme test results.

Table 3 — Repeatability limit of moisture determination on the gross sample

Average of moisture content $\bar{w}$ mass fraction (%)	Repeatability limit r [a] mass fraction (%)	Repeatability limit 1,3r mass fraction (%)
$\bar{w} \leq 3$	0,20	0,26
$3 < \bar{w} \leq 6$	0,25	0,33
$6 < \bar{w}$	0,31	0,40

[a] The theoretical background of the repeatability limit is shown in Annex C.

9.2.2 When mass-basis sampling has been performed and moisture determination is conducted on each partial sample, the weighted mean, $\bar{w}$, of the results from all the partial samples, considering the number of increments for each partial sample, shall be the moisture content, expressed as a mass fraction (%), of the lot, as given by Equation (3).

$$\bar{w} = \frac{\sum_{i=1}^{k} N_i w_i}{\sum_{i=1}^{k} N_i} \quad (3)$$

where

k is the number of partial samples;

N_i is the number of increments in the ith partial sample;

w_i is the result of the determination of the moisture content, expressed as a mass fraction (%), of the ith partial sample, according to Table 2 using as the number of test portions either 4 or 2.

If it is impracticable to sample the lot as a whole, or desirable to sample a lot in separate parts of unequal mass as in the case of time-basis sampling, the moisture content of each part shall be determined independently and the weighted mean, $\bar{w}$, of the results, expressed as a mass fraction (%), of the lot calculated from the individual results using Equation (4).

$$\bar{w} = \frac{\sum_{i=1}^{k} m_i w_i}{\sum_{i=1}^{k} m_i} \quad (4)$$

where

k is the number of partial samples;

m_i is the mass of the ith part;

w_i is the result of the determination of the moisture content, expressed as a mass fraction (%), of the ith part.

9.2.3 When moisture determination is conducted on each increment, the arithmetic mean, $\bar{w}$, of the results for all increments obtained according to 9.1 shall be the moisture content, expressed as a mass fraction (%), of the lot as given by Equation (5).

$$\bar{w} = \frac{\sum_{i=1}^{n} w_i}{n} \quad (5)$$

where

n is the number of increments;

w_i is the result of the determination of the moisture content, expressed as a mass fraction (%), of the ith increment.

10 Test report

The test report shall contain the following information. Examples of test reports are shown in Annex D.

a) A reference to this International Standard, i.e. ISO 3087:2011;

b) details necessary for the identification of the sample;

c) result of the test;

d) reference number of the result;

e) any characteristics noticed during the determination, and any operation not specified in this International Standard which may have had an influence on the results.

Annex A
(normative)

Determination of moisture content of adhesive or wet iron ores

Introduction

When it is difficult to conduct sieving, crushing and dividing, owing to a sample being adhesive or excessively wet, the sample may be predried until preparation can be conducted without difficulty.

In this case, the moisture content of the lot shall be obtained by using the predrying method according to the procedure specified in this annex. In handling the test sample and weighing the initial mass and predried mass of the test sample, attention shall be paid to ensuring the measurement precision of the predried moisture content.

A.1 Determine the initial mass of the test sample.

A.2 Spread the test sample in a uniform thickness and dry it in air or in a drying apparatus at a temperature no higher than 105 °C. The choice of temperature and time for this predrying stage shall not exceed a point where an ore is likely to reabsorb moisture during subsequent processing.

A.3 After predrying, again determine the mass of the test sample.

A.4 Calculate the predried moisture content, w_p, expressed as a mass fraction (%), of the test sample using Equation (A.1).

$$w_p = \frac{m'_1 - m'_2}{m'_1} \times 100 \qquad \text{(A.1)}$$

where

m'_1 is the initial mass, in grams, of the test sample;

m'_2 is the mass, in grams, of the test sample after predrying.

A.5 Prepare the test portions for moisture measurement from the predried sample according to the procedure in ISO 3082.

A.6 Determine the drying loss of the test portion in accordance with 7.2 and calculate the additional moisture content, expressed as a mass fraction (%), in accordance with 9.1.

A.7 Calculate the total (as received) moisture content, w_{pd}, expressed as a mass fraction (%), of the test sample using Equation (A.2).

$$w_{pd} = w_p + \frac{100 - w_p}{100} \times w_d \qquad \text{(A.2)}$$

where w_d is the additional moisture content obtained in accordance with 9.1 after predrying, expressed as a mass fraction (%).

A.8 Determine the moisture content, as a mass fraction (%), of the lot in accordance with 9.2.

A.9 If the mass of the moisture sample is not large, the entire quantity of the sample may be dried in order to conduct the moisture determination according to the method specified in the body of this International Standard.

Annex B
(normative)

Corrections for sprinkled water and/or rainwater

Introduction

Nowadays, in many countries, strict environmental regulations must be observed in the iron ore and steel industry. When water is sprinkled over iron ore during loading and/or unloading operations to prevent dust evolution, the moisture content of a lot shall be corrected, according to the procedure specified in this annex, for the mass of water sprinkled.

This annex also describes a method for correcting the moisture content of a lot containing rainwater.

B.1 General

B.1.1 Water is sprinkled for the following reasons:

a) environmental regulations at loading and/or unloading ports;

b) difficulty of handling iron ores due to ore characteristics, weather conditions, handling equipment, etc.

B.1.2 Correction for rainwater shall be made whenever rainfall occurs during the loading or unloading operations, and the moisture content of the lot is known to have been affected.

B.2 Corrections for sprinkled water

B.2.1 General

In the case of unloading a lot, sprinkled water refers to water sprinkled (or sprayed) in the vessel holds and/or on any sections extending to a point where samples are taken. In the case of loading of a lot, sprinkled water refers to water sprinkled in the holds and/or on the loading conveyors located after the point where moisture samples are taken.

Two methods of correction for sprinkled water are mentioned in this clause. One refers to water added before the sampling point during unloading operations, the other to water added after the sampling point during loading operations.

B.2.2 Measurement of sprinkled water

The measurement of sprinkled water shall be made with a volumenometer having an accuracy of $\pm$ 5 %. The volume obtained shall be converted to a mass, m_3, in tonnes, by multiplying it by the density of the sprinkled water.

NOTE Fresh water is assumed to have a density of 1 t/m^3.

B.2.3 Mass of lot

The mass of the lot, m_4, in tonnes, as received or as despatched without sprinkled water or rainwater, or the mass of the lot, m_5, in tonnes as received or as despatched containing sprinkled water or rainwater, should be determined by draught survey or by other internationally recognized means, such as weightometer or weigh hopper.

NOTE In the examples given in B.2.4, B.2.5, B.3.6, B.3.7, B.4 and B.5 below, it is assumed that the mass of the lot has been determined by draught survey. In these instances, the determination of mass is conducted either before any sprinkled water or rainwater is added (unloading operations) or after all sprinkled water or rainwater has been added (loading operations).

If a weightometer or weigh hopper is used, special care must be taken to ensure that corrections take into account the relative position of the weighing device and the sampling point. For example, during unloading operations, if sampling is conducted immediately after the weighing device, no corrections for sprinkled water or rainwater are necessary. However, corrections may be necessary if the sampling point is remote from the weighing device.

B.2.4 Calculation of moisture content corrected for sprinkled water added during unloading operations prior to taking moisture samples

The moisture content of the lot, w_s, expressed as a mass fraction (%), corrected for sprinkled water is given by Equation (B.1) and reported to the first decimal place.

$$w_s = \bar{w} - (100 - \bar{w}) \frac{m_3}{m_4} f \tag{B.1}$$

where

$\bar{w}$ is the mean value of the moisture content, expressed as a mass fraction (%), of a sample taken containing sprinkled water, calculated to the second decimal place;

m_3 is the mass, in tonnes, of sprinkled water;

m_4 is the mass, in tonnes, of the lot as received without sprinkled water, as determined in B.2.3;

f is a predetermined factor to correct for water lost during sprinkling.

NOTE In determining a suitable f factor, the following factors are considered on a case-by-case basis:

a) atmospheric conditions

— humidity;

— air temperature;

— wind effects;

— rainfall;

b) ore type/ore characteristics

— sizing;

— mineralogy;

— porosity/texture;

— moisture content;

c) sprinkler arrangement/geometry;

d) chemical reagents/additives in water.

B.2.5 Calculation of moisture content corrected for sprinkled water added during loading operations after taking moisture samples

The moisture content of the lot, w_s, expressed as a mass fraction (%), corrected for sprinkled water, is given by Equation (B.2) and reported to the first decimal place.

$$w_s = \bar{w} + (100 - \bar{w}) \frac{m_3}{m_5} f \quad \text{(B.2)}$$

where

$\bar{w}$ is the mean value of the moisture content, expressed as a mass fraction (%), of a sample taken prior to sprinkled water, calculated to the second decimal place;

m_3 is the mass, in tonnes, of sprinkled water;

m_5 is the mass, in tonnes, of the lot containing sprinkled water, as determined in B.2.3;

f refer to the note in B.2.4.

B.3 Corrections for rainwater

B.3.1 General

The moisture content of the lot shall be determined from the as-tested moisture content by allowing for the influx of rainwater into the vessel's hold(s), and/or onto the handling equipment during both loading and unloading operations.

Two methods of correction for rainwater are mentioned in this clause. One refers to rainwater influx before the sampling point during unloading operations, the other to rainwater influx after the sampling point during loading operations.

B.3.2 Effective area caught in the rain

The effective area exposed to the rain shall be calculated by summation of the areas specified below, rounded to the nearest square metre.

a) *Hatch(es)* The open area, in square metres, of the hatch(es) through which the lot is exposed to the rain shall be calculated on the basis of the drawings provided on board the carrying vessel.

b) *Surge hopper(s)* The open area, in square metres, of the hopper(s) used during handling the lot and exposed to the rain shall be calculated on the basis of drawings of the hopper(s).

c) *Belt conveyor(s)* The open area, in square metres, of the belt conveyor(s) shall be calculated by multiplying the effective belt width by the length exposed to the rain during transportation of the lot between the vessel and the point where moisture samples are taken.

B.3.3 Duration of rainy periods

The duration of rainy periods shall be determined from the time of the opening of the hatches to completion of sampling.

B.3.4 Amount of rainwater

The amount of rainwater shall be determined by means of an approved rain gauge placed close to the loading or the unloading port. The amount of rainwater shall be measured to the nearest millimetre.

B.3.5 Mass of rainwater

The mass, m_R, in tonnes, of rainwater is given by Equation (B.3), and rounded off to the nearest unit.

$$m_R = \frac{ARρ}{1\,000} \tag{B.3}$$

where

A is the effective area, in square metres, exposed to the rain, as calculated in B.3.2;

R is the quantity, in millimetres, of rainwater obtained in B.3.4;

$ρ$ is the density, expressed in tonnes per cubic metre, of rainwater (usually $ρ = 1$ t/m^3).

B.3.6 Calculation of moisture content corrected for rainwater ingress during unloading operations prior to taking moisture samples

When a lot is partially or totally exposed to the rain during unloading operations prior to taking moisture samples, the moisture content, w_R, expressed as a mass fraction (%), of the lot corrected for rainwater is given by Equation (B.4) and reported to the first decimal place.

$$w_R = \bar{w} - (100 - \bar{w})\frac{m_R}{m_4} \tag{B.4}$$

where

$\bar{w}$ is the mean value of the moisture content, expressed as a mass fraction (%), of a sample taken containing rainwater, calculated to the second decimal place;

m_R is the mass, in tonnes, of rainwater;

m_4 is the mass, in tonnes, of the lot as received without rainwater, as determined in B.2.3.

B.3.7 Calculation of moisture content corrected for rainwater ingress during loading operations after taking moisture samples

When a lot is partially or totally exposed to rain during loading operations after taking moisture samples, the moisture content, w_R, expressed as a mass fraction (%), of the lot corrected for rainwater is given by Equation (B.5) and reported to the first decimal place.

$$w_R = \bar{w} + (100 - \bar{w})\frac{m_R}{m_5} \tag{B.5}$$

where

$\bar{w}$ is the mean value of the moisture content, expressed as a mass fraction (%), of a sample taken prior to rain, calculated to the second decimal place;

m_R is the mass, in tonnes, of rainwater;

m_5 is the mass, in tonnes, of the lot containing rainwater, as determined in B.2.3.

B.4 Corrections for both sprinkled water and rainwater ingress during unloading operations prior to taking moisture samples

The corrected moisture content, w_o, expressed as a mass fraction (%), of a lot which has been wetted with both sprinkled water and rainwater prior to taking moisture samples, is given by Equation (B.6) and reported to the first decimal place.

$$w_o = \bar{w} - (100 - \bar{w}) \frac{(m_3 f + m_R)}{m_4} \tag{B.6}$$

where f, m_3, m_4, m_R and $\bar{w}$ are as previously defined.

B.5 Corrections for both sprinkled water and rainwater ingress during loading operations after taking moisture samples

The corrected moisture content, w_o, expressed as a mass fraction (%), of a lot which has been wetted with both sprinkled water and rainwater after taking moisture samples is given by Equation (B.7) and reported to the first decimal place.

$$w_o = \bar{w} + (100 - \bar{w}) \frac{(m_3 f + m_R)}{m_5} \tag{B.7}$$

where f, m_3, m_5, m_R and $\bar{w}$ are as previously defined.

Annex C
(informative)

Precision of moisture measurement

This International Standard assumes that single test results have the precision shown as β_{PM} in Table C.1.

When two test portions have been prepared from a single test sample and subjected to moisture measurement in the same laboratory, the test results will generally agree to within the repeatability limit which is given as r in Table 3 and which may be calculated as $\sqrt{2}\beta_{PM}$.

Table C.1 — Precision of moisture measurement

Average moisture content $\bar{w}$ mass fraction (%)	Precision β_{PM} mass fraction (%)
$\bar{w} \leq 3$	±0,14
$3 < \bar{w} \leq 6$	±0,18
$6 < \bar{w}$	±0,22