



**International
Standard**

ISO 17544

**Carbonaceous materials used in
the production of aluminium —
Cold and tepid ramming pastes —
Determination of rammability of
unbaked pastes**

*Produits carbonés utilisés pour la production de l'aluminium —
Pâtes de brasquage froides et tièdes — Détermination de
l'aptitude au brasquage des pâtes non cuites*

**Second edition
2024-08**

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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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 226, *Materials for the production of primary aluminium*.

This second edition cancels and replaces the first edition (ISO 17544:2004), which has been technically revised.

The main changes are as follows:

- the mass of the falling weight and the ramming rate have been corrected.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

The bottom of aluminium electrolysis cells is lined with cathode blocks that are sealed with a ramming paste to avoid any leakage. When lining a cell, the green paste is directly rammed between the cathode blocks and baked in situ during the start-up of the pot by the process heat. The quality of the paste is of primary importance as to ensure long operation without disturbance.

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Carbonaceous materials used in the production of aluminium — Cold and tepid ramming pastes — Determination of rammability of unbaked pastes

1 Scope

This document describes a method of producing a compaction curve indicating the rammability of carbonaceous ramming pastes used to line cathodes utilized in the production of aluminium.

Determination of the rammability enables a ramming paste with the optimum density to be selected.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 5725-2, *Accuracy (trueness and precision) of measurement methods and results — Part 2: Basic method for the determination of repeatability and reproducibility of a standard measurement method*

ISO 14422, *Carbonaceous materials used in the production of aluminium — Cold-ramming pastes — Methods of sampling*

3 Terms and definitions

No terms and definitions are listed in this document.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://www.electropedia.org/>

4 Symbols

h	measured height of test specimen, in cm
m	mass of paste placed in cylinder, in g
N	number of impacts
N_2	minimum value of second derivative of $\rho(N)$
r	inner radius of rammer cylinder, in cm
α	scaling or normalization parameter describing the steepness of the compaction curve (which decreases as α increases)
γ	location parameter which shifts the origin of the distribution
ρ_{\max}	maximum value of density, in $\text{g}\cdot\text{cm}^{-3}$

ρ_0 initial value of density, representative of loose compaction of the paste under its own weight in $\text{g}\cdot\text{cm}^{-3}$,

$\rho(N)$ density after N impacts, in $\text{g}\cdot\text{cm}^{-3}$

5 Principle

Ramming paste is compacted in a laboratory rammer. The paste is subjected to a total of 350 impacts. The density of the paste is measured as a function of the number of impacts. The data is fitted to a three-parameter cumulative Weibull distribution function given by [Formula 1](#):

$$\rho(N) = \rho_{\max} - \Delta\rho \times \exp\left[-\left(\frac{\log_{10} N - \gamma}{\alpha}\right)^6\right] \quad (1)$$

A ramming parameter N_2 , corresponding to the number of impacts for which the second derivative of the Weibull function has a minimum value, is then calculated.

An alternative method of evaluation is to determine the ratio of the density after 50 impacts to the density after 100 impacts, as shown by [Formula 2](#).

$$\frac{\rho(50)}{\rho(100)} \quad (2)$$

6 Apparatus

6.1 General. An example of a rammer mould is shown in [Figure 1](#).

6.2 Rammer cylinder. The rammer cylinder is made of steel, with an inner diameter of 50 mm.

6.3 Ram base. The ram base is made of steel. The ram base shall fit into the rammer cylinder and act as the bottom of the cylinder.

6.4 Rammer. The rammer consisting of a steel piston, a falling weight mounted so that it can be dropped onto the top of the piston, and a height-measuring device accurate to 0,1 mm. The mass of the falling weight shall be 6,7 kg and the weight shall travel a constant distance to impact of $(50 \pm 0,1)$ mm.

6.5 Box (with lid). The box is capable of containing the amount of ramming paste needed to produce one test specimen. The free space over the paste shall not be more than 50 % of the volume of the paste.

6.6 Heating/cooling cabinet. The Heating/cooling cabinet is capable of being maintained at a constant temperature $\pm 0,5$ °C in the range 5 °C to 100 °C.

6.7 Insulation layer. The insulation layer (for example, 1-cm-thick polystyrene), for insulation of the rammer cylinder, or thermostatically controlled surround (see [Figure 1](#)).

6.8 Balance. The balance shall have an accuracy of 0,1 g.

7 Sampling

Sample the paste in accordance with ISO 14422.

NOTE Experience has shown that 150 g to 200 g of ramming paste is necessary for each test specimen.

8 Procedure

Ensure the cylinder, the ram base and the piston are clean.

Weigh the necessary amount of ramming paste (to the nearest 0,1 g) into a suitable box (6.4). If the amount of ramming paste to be used is not known, determine the required mass by preliminary tests [the height of the test specimen after compaction shall be (50 ± 5) mm (see below)]. Seal the box. Heat or cool the box together with the rammer cylinder (6.1), the ram base (6.2) and the insulation/surround (6.6) to the test temperature (agreed between the interested parties) in the heating/cooling cabinet (6.5) for 2 h to 3 h.

Transfer the paste to the cylinder. Protect the cylinder with the insulation or surround (6.6). Place the cylinder in the rammer (6.3) and lower the piston until it is resting on the paste. Compact the ramming paste with a total of 350 impacts, reading the height h of the test specimen (to the nearest 0,1 mm) from the scale on the ramming apparatus, with the piston head resting on the specimen, after 1, 2, 3, 4, 5, 7, 10, 15, 20, 25, 30, 35, 40, 50, 60, 80, 100, 120, 150, 180, 230, 280 and 350 impacts. Where several impacts are made between height measurements, compact the test specimen at a rate of about 1 impact per second.

If the final height of the compacted test specimen is not equal to (50 ± 5) mm, discard the results and repeat the test with another sample mass.

Remove the test specimen. Clean the cylinder, the ram base, and the piston carefully after each test.

9 Expression of results

9.1 Calculation of the density

Calculate the density of the paste $\rho(N)$ corresponding to each specimen height measured (i.e. to each number of impacts N at which a height measurement was made) from Formula 3:

$$\rho(N) = \frac{m}{\pi r^2 h} \quad (3)$$

where

m is the mass, in g, of the ramming paste placed in the cylinder, accurate to 0,1 g;

r is the inner radius of the ramming cylinder, in cm, accurate to 0,01 cm;

h is the height of the unbaked test specimen as read from the rammer scale, in cm, accurate to 0,01 cm.

Round the results to the nearest $0,001 \text{ g}\cdot\text{cm}^{-3}$.

Plot $\rho(N)$ against N to give a compaction curve.

9.2 Interpretation of the curve

A paste showing a slow asymptotic approach towards its maximum density is said to be a dry paste, whereas a paste showing a rapid asymptotic approach towards its maximum density is said to be a wet paste.

9.3 Determination of N_2

9.3.1 Fitting the data to a Weibull function

The data fit is based on the similarities between compaction curves presented with a logarithmic abscissa and statistical cumulative distribution functions. A general three-parameter cumulative Weibull distribution function is chosen.

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Determine the parameters ρ_{\max} , $\Delta\rho$, α and γ by fitting the values of $\rho(N)$ calculated in 9.1 to the Weibull function given in Formula 4:

$$\rho(N) = \rho_{\max} - \Delta\rho \times \exp\left[-\left(\frac{\log_{10} N - \gamma}{\alpha}\right)^6\right] \quad (4)$$

The fitting can be done by the least-squares method, for which various commercial computer programmes are available. Normally, a set of starting values for the four parameters is needed. The starting values in Table 1 can be used.

Table 1 — Starting values for Formula (5)

ρ_{\max}	1,500
$\Delta\rho$	0,500
α	3
γ	-2

9.3.2 Calculation of N_2

Putting the third derivative of $\rho(N)$ equal to zero [i.e. $\rho(N)''' = 0$] enables the turning point of the density distribution curve to be determined. The minimum value of the second derivative $\rho(N)''$ is used as the evaluation criterion for the rammability.

The number of impacts (N_2) which gives the minimum value of the second derivative of $\rho(N)$ (with respect to $\log_{10} N$), when the third derivative is equal to zero, is given by:

$$\rho(N)''' = \frac{12\Delta\rho}{\alpha^3} \times e^{-\left(\frac{\log_{10} N - \gamma}{\alpha}\right)} \times \left[18 \left(\frac{\log_{10} N - \gamma}{\alpha}\right)^{15} - 45 \left(\frac{\log_{10} N - \gamma}{\alpha}\right)^9 + 10 \left(\frac{\log_{10} N - \gamma}{\alpha}\right)^3 \right] = 0 \quad (5)$$

It is possible to solve Formula (5) exactly:

$$N_2 = 10^{(1,145\alpha + \gamma)} \quad (6)$$

Calculate the number of impacts N_2 which gives the minimum value of the second derivative of $\rho(N)$ (third derivative = 0) using Formula (6) and the parameters from the curve-fitting operation carried out in 9.3.1. Round the value calculated for N_2 to the nearest whole number.

NOTE Typically, values lie in the range $65 < N_2 < 130$. Such values were found to give good rammability when compared with practical work at one smelter. The range can, however, depend on the ramming technology used.

9.4 Determination of $\rho(50)/\rho(100)$

Alternatively, calculate the density after 50 impacts divided by the density after 100 impacts, $\rho(50)/\rho(100)$, using the values of $\rho(50)$ and $\rho(100)$ determined in 9.1.

NOTE Typically, values lie in the range $0,960 < \rho(50)/\rho(100) < 0,975$. Such values were found to give good rammability when compared with practical work at one smelter. The range can, however, depend on the ramming technology used.

10 Precision

10.1 Precision shall be determined in accordance with ISO 5725-2

10.2 N_2

Repeatability (r) = 0,18 × material average – 3,71

Reproducibility (R) = $0,34 \times$ material average + 2,65

The number of degrees of freedom, ν , is the number of laboratories (5) \times number of samples (4) \times analysed in duplicate (2) was 40.

10.3 $\rho(50)/\rho(100)$

Repeatability (r) = 0,004 9

Reproducibility (R) = $0,496 \times$ material average – 0,473 1

The number of degrees of freedom is the number of laboratories (6) \times number of samples (4) \times analysed in duplicate (2), which is 48.

11 Test report

The test report shall include the following information:

- a) the document version used, i.e. ISO 17544:2024;
- b) all details necessary for identification of the sample tested;
- c) the temperature used for the test;
- d) the results of the test:
 - 1) the curve of density versus number of impacts,
 - 2) the values of the parameters ρ_{\max} , $\Delta\rho$, α and γ determined by fitting the curve to the Weibull function,
 - 3) the value obtained for N_2 or $\rho(50)/\rho(100)$;
- e) the date of the test;
- f) details of any unusual features noted during the determination;
- g) details of any operation not included in this document or regarded as optional.