
**Metallic powders — Determination
of oxygen content by reduction
methods —**

Part 2:
**Loss of mass on hydrogen reduction
(hydrogen loss)**

*Poudres métalliques — Dosage de l'oxygène par les méthodes de
réduction —*

*Partie 2: Perte de masse par réduction dans l'hydrogène (perte dans
l'hydrogène)*

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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 documents 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).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

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 119 *Powder metallurgy*, Subcommittee SC 2, *Sampling and testing methods for sintered metal materials (excluding hardmetals)*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/SS M11, *Powder metallurgy*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This third edition cancels and replaces the second edition (ISO 4491-2:1997), which has been technically revised.

The main changes compared to the previous edition are as follows:

- adding of precision statement.

A list of all parts in the ISO 4491 series can be found on the ISO website.

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.

Metallic powders — Determination of oxygen content by reduction methods —

Part 2: Loss of mass on hydrogen reduction (hydrogen loss)

1 Scope

This document specifies a method for the determination of the relative loss of mass which a metallic powder undergoes when heated in a stream of pure dry hydrogen under specified conditions.

The purpose of this test is to evaluate a chemical powder characteristic which is of importance to the powder metallurgical industry. The test is not intended as a means for the determination of the content of specific elements (see [Annex A](#) and ISO 4491-1).

The test method is applicable to unalloyed, partially alloyed and completely alloyed powders of the metals listed in [Table 1](#) (see [7.2.1](#)). It is not applicable to lubricated powders or to mixtures of metal powders.

2 Normative references

There are no normative references in this document.

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 Reagents and materials

Hydrogen, with a maximum oxygen content of 0,005 % mass fraction and a dew point not higher than -45 °C.

Nitrogen or argon, with a maximum oxygen content of 0,005 % mass fraction and a dew point not higher than -45 °C (see also [7.2.3](#), third paragraph).

5 Apparatus

5.1 General

An example of suitable test arrangement is shown schematically in [Figure 1](#).

5.2 Balance

Laboratory balance, of sufficient capacity, and capable of weighing to $\pm 0,1$ mg.

5.3 Furnace

Electrically heated tubular furnace, that can be continuously operated at the appropriate temperatures given in [Table 1](#) and that has a control system capable of maintaining the temperature in that part of the tube containing the boat ([5.6](#)) to within the temperature tolerance stated in [Table 1](#).

When testing magnetic powders, it is recommended that wire-wound furnaces are wound non-inductively.

5.4 Gas-tight tube

Gas-tight tube, of quartz or refractory material (for example dense alumina). The inside diameter of the tube shall be between 25 mm and 40 mm and its length such that it extends about 200 mm beyond each end of the furnace.

When a large number of hydrogen loss determinations is to be carried out, a larger furnace than that described in this document, and one which permits several test portions to be tested simultaneously, may be used, provided that the temperature and time conditions shown in [Table 1](#) are fulfilled and the results obtained are in agreement with those obtained when the test is carried out with the preferred apparatus.

5.5 Thermocouple

Totally enclosed thermocouple, for example platinum/platinum-rhodium, and an indicating or recording instrument, permitting the measurement of temperature with maximum permissible error of 5 °C.

If for some reason it is desirable to place the thermocouple outside the reduction tube, this is acceptable. But in this case, a preliminary calibration shall be made with a second thermocouple placed inside the tube to ascertain that the temperature of the test sample is in accordance with the values and tolerances specified in [Table 1](#).

5.6 Boat

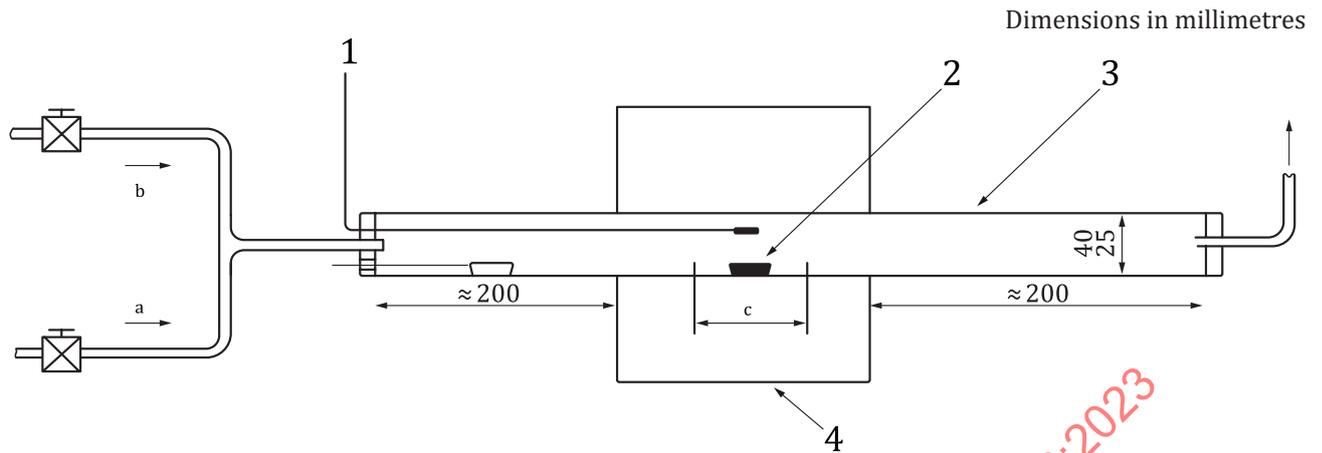
Boat, preferably of high-alumina ceramic with a polished surface. Other materials, for example quartz and nickel, may be used when test conditions allow. The boat shall be of such dimensions, for example 75 mm long and 12 mm wide, that the thickness of the powder, when uniformly distributed, does not exceed 3 mm.

New boats shall be pre-treated in a stream of hydrogen at the test temperature and stored in a desiccator.

A boat may be used more than once, provided that it is always used for testing the same metal powder or type thereof and provided that it is carefully cleaned by mechanical means between determinations and stored in a desiccator.

5.7 Supply unit

Supply unit for hydrogen and either nitrogen or argon, with pressure gauges and flow meters to control the flow of gas.

**Key**

- 1 thermocouple (5.5)
 2 boat (5.6)
 3 quartz tube (5.4)
 4 furnace (5.3)

- a Nitrogen or argon inlet.
 b Hydrogen inlet.
 c Heating zone.

Figure 1 — Diagram of suitable test arrangement

6 Sampling

The powder shall be tested in as-received condition.

The loss in mass shall be determined on two test portions.

The mass of the test portion shall be approximately 5 g, except for powders of low apparent density it may be reduced to comply with the requirements of 5.6 and 7.2.2.

7 Procedure

7.1 General

Carry out two determinations on each test sample.

7.2 Test procedure

7.2.1 Heat the furnace (5.3), with the tube (5.4) inserted, to the temperature indicated in Table 1 for the metal powder being tested.

Table 1 — Reduction temperatures and times

Metal powder	Reduction temperature	Reduction time ^a
	°C	min
Tin bronze ^b	750 ± 15	30
Tin	425 ± 10	30

a) These reduction times are given for guidance purposes only. Shorter times may be applied provided that for each apparatus and for each type of powder experience has shown them to be sufficient to guarantee the completion of the hydrogen loss reactions.

b) Results should be interpreted with care. See A.6.

Table 1 (continued)

Metal powder	Reduction temperature	Reduction time ^a
	° C	min
Silver	550 ± 10	30
Copper	850 ± 15	30
Copper lead ^b	600 ± 10	10
Leaded bronze ^b	600 ± 10	10
Iron and steel	1 100 ± 20	60
Cobalt	1 000 ± 20	60
Nickel	1 000 ± 20	60
Tungsten	1 000 ± 20	60
Molybdenum	1 100 ± 20	60
Rhenium	1 150 ± 20	60

a) These reduction times are given for guidance purposes only. Shorter times may be applied provided that for each apparatus and for each type of powder experience has shown them to be sufficient to guarantee the completion of the hydrogen loss reactions.

b) Results should be interpreted with care. See A.6.

7.2.2 Weigh the boat (5.6) to the nearest 0,1 mg. Distribute the test portion throughout the boat to a uniform depth not exceeding 3 mm. Weigh the boat with the test portion to the nearest 0,1 mg.

7.2.3 Pass nitrogen (see Clause 4) through the tube at a flow rate corresponding to a gas speed of at least 25 mm/s, as measured in the cooling zone of the tube, for a period of at least 1 min. Insert the boat containing the test portion in the tube and move it until it is at the centre of the uniform-temperature zone of the furnace. The boat shall be moved sufficiently slowly to prevent ejection of powder as a result of a high rate of gas evolution. Continue the flow of nitrogen for 1 min.

If difficulties are experienced in preventing ejection of powder from the boat, the powder may be pressed (without addition of lubricant) to form a low density compact, or, if such a compact has a very low green strength, it may be wrapped in oxide-free copper foil. The copper foil can only be used when the test temperature exceeds the melting temperature of copper.

When testing powders that are susceptible to combination with nitrogen (for example chromium-containing alloy steel powder), the purging operations shall be carried out with argon instead of nitrogen (see 7.2.5 and 7.2.6).

7.2.4 Start up the flow of hydrogen (see Clause 4) and discontinue the flow of nitrogen. Establish an even flow of hydrogen through the tube, corresponding to a gas speed of at least 25 mm/s in the cold zone of the tube. This is equivalent to approximately 50 l/h for a tube of 25 mm diameter and approximately 110 l/h for a tube of 40 mm diameter. Maintain the flow of hydrogen for the period of time indicated in Table 1. During this time, maintain the temperature of the furnace within the prescribed range.

7.2.5 At the end of the prescribed time, start up the flow of nitrogen again and discontinue the flow of hydrogen. Withdraw the boat after 2 min to 3 min to the cool part of the tube beyond the end of the furnace.

7.2.6 Allow the boat with the reduced test portion to cool in the nitrogen atmosphere to below 35 °C, remove it from the tube and permit it to cool to ambient temperature in a desiccator.

7.2.7 Weigh the boat with the reduced test portion to the nearest 0,1 mg.

8 Calculation and expression of test results

The hydrogen loss f_{HL} , expressed as a mass fraction in percent, is given by [Formula \(1\)](#):

$$f_{HL} = \frac{m_2 - m_3}{m_2 - m_1} \times 100 \quad (1)$$

where

f_{HL} is the hydrogen loss expressed as a mass fraction in percent;

m_1 is the mass, in grams, of the empty pre-treated boat ([5.6](#));

m_2 is the mass, in grams, of the boat with the test portion before the test;

m_3 is the mass, in grams, of the boat with the reduced test portion after test.

The mean of the two determinations is calculated. This calculation and the expression of the test results are carried out according to the rules shown in [Table 2](#).

Table 2 — Calculation of mean value

Hydrogen loss % (mass fraction)	Calculation of test results to the nearest %	Maximum permissible differ- ence between two determina- tions	Expression of results to the nearest %
≤ 0,2	0,01	max. 0,01 % (absolute value)	0,01
> 0,2 ≤ 0,5	0,01	max. 5 % of mean	0,02
> 0,5 ≤ 1,0	0,01	max. 5 % of mean	0,05
> 1,0	0,01	max. 5 % of mean	0,1

9 Precision

Four different types of metal powders, see [Table 3](#), were included in the inter-laboratory study to develop this precision statement.

Table 3 — Type of powders included in the inter-laboratory study

Powder type
Pure atomized iron powder
Sponge iron powder
Water atomized copper powder
Tungsten powder

In [Table 4](#), the repeatability and reproducibility are presented as one standard deviation.

Table 4 — Repeatability and reproducibility as standard deviations

Tested powder	Level Average H ₂ -loss %	Repeatability (S_r) Standard deviation %	Reproducibility (S_R) Standard deviation %
Pure atomized iron powder	0,09	0,006	0,019
Sponge iron powder	0,15	0,019	0,035
Water atomized copper powder	0,18	0,020	0,037
Tungsten powder	0,08	0,012	0,014

The difference between two test results found on identical test material by one operator using the same apparatus within the shortest feasible time interval will exceed the repeatability limit (r), see [Table 5](#), on average not more than once in 20 cases in the normal and correct operation of the method.

Test results on identical test material reported by two laboratories will differ by more than the reproducibility limit (R), see [Table 5](#), on average not more than once in 20 cases in the normal and correct operation of the method

Table 5 — Repeatability and Reproducibility, difference between two tests at 95 % probability level

Tested powder	Level	Repeatability	Reproducibility
	Average H ₂ -loss %	Limit (r) %	Limit (R) %
Pure atomized iron powder	0,09	0,017	0,053
Sponge iron powder	0,15	0,052	0,097
Water atomized copper powder	0,18	0,057	0,103
Tungsten powder	0,08	0,033	0,039

The precision data were determined from an experiment organized and analysed in accordance with ISO 5725-2 in year 2020 where each of the powders included in the investigation was analysed two times by 7 laboratories.

The laboratories participating in the study were following the test procedure described in ISO 4491-2. All participating laboratories used their own test equipment (furnace, scale and boats) for the study.

10 Test report

The test report shall include the following information:

- a) a reference to this document, i.e. ISO 4491-2:2023;
- b) all details necessary for the identification of the test sample;
- c) the test results obtained;
- d) details of any operations not specified in this document, or regarded as optional;
- e) details of any occurrence which may have affected the results
- f) the date of the test.

Annex A (informative)

Interpretation of results

A.1 The loss of mass of a powder on hydrogen reduction, commonly called hydrogen loss, is a powder characteristic that has proved useful in the processing of powder metallurgical materials. It was originally considered to be an estimate of the oxygen content of hydrogen-reducible oxides but, with the advent of more complex and alloyed powders, it is now thought that other chemical changes can contribute, positively or negatively, to the measured loss in mass. Thus, the following factors should be considered when interpreting experimental results.

A.2 The measured loss of mass does not include oxygen present in the form of oxides such as SiO_2 , Al_2O_3 , MgO , CaO , BeO and TiO_2 , which are not reducible under the test conditions.

A.3 The loss of mass includes any water vapour and/or hydrocarbons present in the powder.

A.4 The loss of mass includes gases which, owing to either adsorption or occlusion, can be present in the powder and which are liberated during heating. The amount of such gases is normally negligible.

A.5 The loss of mass includes elements other than oxygen which are present in the powder and which under the specified test conditions are partially or completely removed, either because they are volatile or because they react with the hydrogen or with oxides present in the powder to form volatile compounds. Examples are carbon, nitrogen, phosphorus and sulfur.

A.6 The loss of mass includes metals which are present in the powder and which under the specified test conditions are volatile and therefore partially or completely removed during the test. Lead, zinc and cadmium are examples of such metals.

A.7 If carbon is present in the powder, the loss of mass during the hydrogen loss test can include oxygen from oxides which under the specified test conditions are reduced by the carbon. Examples of such oxides are Cr_2O_3 and MnO which, when present in carbon-containing steel powders, can be reduced by carbon under the specified test conditions

A.8 Powders containing manganese and/or chromium, or other elements with a high affinity for oxygen, can be oxidized during the test by the atmosphere or through reduction of less refractory oxides. In extreme cases this can result in a negative figure for hydrogen loss (i.e. an increase of mass during the test).

A.9 The results can be influenced by the presence of reducible, oxidizable or volatile metals, metalloids or compounds. The results obtained on such powders should be used with caution and their interpretation should be subject to agreement between supplier and user.