

---

---

**Welding — Determination of Ferrite  
Number (FN) in austenitic and duplex  
ferritic-austenitic Cr-Ni stainless steel  
weld metals**

*Soudage — Détermination de l'indice de ferrite (FN) dans le  
métal fondu en acier inoxydable austénitique et duplex ferritique-  
austénitique au chrome-nickel*

<https://standards.iteh.ai>  
Document Preview

[ISO 8249:2018](https://standards.iteh.ai/catalog/standards/iso/9ea71146-3aac-4852-a56c-40ff18d4e781/iso-8249-2018)

<https://standards.iteh.ai/catalog/standards/iso/9ea71146-3aac-4852-a56c-40ff18d4e781/iso-8249-2018>



**iTeh Standards**  
**(<https://standards.iteh.ai>)**  
**Document Preview**

[ISO 8249:2018](https://standards.iteh.ai/catalog/standards/iso/9ea71146-3aac-4852-a56c-40ff18d4e781/iso-8249-2018)

<https://standards.iteh.ai/catalog/standards/iso/9ea71146-3aac-4852-a56c-40ff18d4e781/iso-8249-2018>



**COPYRIGHT PROTECTED DOCUMENT**

© ISO 2018

All rights reserved. Unless otherwise specified, or required in the context of its implementation, no part of this publication may be reproduced or utilized otherwise in any form or by any means, electronic or mechanical, including photocopying, or posting on the internet or an intranet, without prior written permission. Permission can be requested from either ISO at the address below or ISO's member body in the country of the requester.

ISO copyright office  
CP 401 • Ch. de Blandonnet 8  
CH-1214 Vernier, Geneva  
Phone: +41 22 749 01 11  
Fax: +41 22 749 09 47  
Email: [copyright@iso.org](mailto:copyright@iso.org)  
Website: [www.iso.org](http://www.iso.org)

Published in Switzerland

# Contents

Page

<b>Foreword</b> .....	<b>iv</b>
<b>Introduction</b> .....	<b>v</b>
<b>1 Scope</b> .....	<b>1</b>
<b>2 Normative references</b> .....	<b>1</b>
<b>3 Terms and definitions</b> .....	<b>1</b>
<b>4 Principle</b> .....	<b>1</b>
<b>5 Calibration</b> .....	<b>2</b>
5.1 Coating thickness standards.....	2
5.2 Magnet.....	2
5.3 Instruments.....	2
5.4 Calibration curve.....	3
<b>6 Standard method for covered electrode test pads</b> .....	<b>5</b>
6.1 Dimensions of weld metal test specimens.....	5
6.2 Depositing weld metal test specimens.....	5
6.3 Measuring.....	6
6.3.1 Surface finishing.....	6
6.3.2 Individual measurements.....	6
6.3.3 Reporting.....	7
<b>7 Standard methods for test pads of other processes and for production welds</b> .....	<b>7</b>
7.1 Standard method for test pads for other weld metals.....	7
7.2 Production welds.....	7
<b>8 Other methods</b> .....	<b>7</b>
8.1 Methods.....	7
8.2 Maintaining calibration.....	8
<b>9 Procedures used to prepare secondary standards for delta ferrite in austenitic stainless steel weld metal</b> .....	<b>8</b>
<b>Annex A (informative) Manufacture of secondary standards by strip cladding</b> .....	<b>9</b>
<b>Annex B (informative) Manufacture of secondary standards by centrifugal chill casting</b> .....	<b>19</b>
<b>Bibliography</b> .....	<b>27</b>

## 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](http://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](http://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](http://www.iso.org/iso/foreword.html).

This document was prepared by IIW, the International Institute of Welding, Commission II.

Any feedback, question or request for official interpretation related to any aspect of this document should be directed to IIW via your national standards body. A complete listing of these bodies can be found at [www.iso.org/members.html](http://www.iso.org/members.html).

This third edition cancels and replaces the second edition (ISO 8249:2000), which has been technically revised. The main changes compared to the previous edition are as follows:

- corrections have been made to [Table 2](#) (previously Table 1);
- minor editorial changes in [Clause 9](#) (previously Clause 8) and throughout the document have been made.

## Introduction

At present, there is no universal opinion concerning the best experimental method that gives an absolute measurement of the amount of ferrite in a weld metal, either destructively or non-destructively. This situation has led to the development and use, internationally, of the concept of a "Ferrite Number" or FN. A Ferrite Number is a description of the ferrite content of a weld metal determined using a standardized procedure. Such procedures are laid down in this document. The Ferrite Number of a weld metal has been considered approximately equivalent to the percentage ferrite content, particularly at low FN values. More recent information suggests that the FN can overstate the volume percent ferrite at higher FN by a factor in the order of 1,3 to 1,5, which depends to a certain extent on the actual composition of the alloy in question.

Although other methods are available for determining the Ferrite Number, the standardized measuring procedure, laid down in this document, is based on assessing the tear-off force needed to pull the weld metal sample from a magnet of defined strength and size. The relationship between tear-off force and FN is obtained using primary standards consisting of a non-magnetic coating of specified thickness on a magnetic base. Each non-magnetic coating thickness is assigned an FN value.

The ferrite content determined by this method is arbitrary and is not necessarily the true or absolute ferrite content. In recognition of this fact, the term "Ferrite Number" (FN) is used instead of "ferrite per cent" when quoting a ferrite content determined by this method. To help convey the message that this standardized calibration procedure has been used, the terms "Ferrite Number" and "FN" are capitalized as proper nouns.

**iTeh Standards**  
**(<https://standards.iteh.ai>)**  
**Document Preview**

[ISO 8249:2018](https://standards.iteh.ai/catalog/standards/iso/9ea71146-3aac-4852-a56c-40ff18d4e781/iso-8249-2018)

<https://standards.iteh.ai/catalog/standards/iso/9ea71146-3aac-4852-a56c-40ff18d4e781/iso-8249-2018>



# Welding — Determination of Ferrite Number (FN) in austenitic and duplex ferritic-austenitic Cr-Ni stainless steel weld metals

## 1 Scope

This document specifies the method and apparatus for:

- the measurement of the delta ferrite content, expressed as Ferrite Number (FN), in largely austenitic and duplex ferritic-austenitic stainless steel<sup>1)</sup> weld metal through the attractive force between a weld metal sample and a standard permanent magnet;
- the preparation and measurement of standard pads for manual metal arc covered electrodes. The general method is also recommended for the ferrite measurement of production welds and for weld metal from other processes, such as gas tungsten arc welding, gas shielded metal arc welding and submerged arc welding (in these cases, the way of producing the pad should be defined);
- the calibration of other instruments to measure FN.

The method laid down in this document is intended for use on weld metals in the as-welded state and on weld metals after thermal treatments causing complete or partial transformation of ferrite to any non-magnetic phase. Austenitizing thermal treatments which alter the size and shape of the ferrite change the magnetic response of the ferrite.

The method is not intended for measurement of the ferrite content of cast, forged or wrought austenitic or duplex ferritic-austenitic steel samples.

## 2 Normative references

[ISO 8249:2018](https://standards.iteh.ai/catalog/standards/iso/9ea71146-3aac-4852-a56c-40ff18d4e781/iso-8249-2018)

<https://standards.iteh.ai/catalog/standards/iso/9ea71146-3aac-4852-a56c-40ff18d4e781/iso-8249-2018>

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 terminological databases for use in standardization at the following addresses:

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

## 4 Principle

The measurement of the ferrite content of largely austenitic stainless steel weld metal through the attractive force between a weld metal sample and a permanent magnet is based on the fact that the attractive force between a two-phase (or multiphase) sample containing one ferromagnetic phase and one (or more) non-ferromagnetic phase(s) increases as the content of the ferromagnetic phase increases. In largely austenitic and duplex ferritic-austenitic stainless steel weld metal, ferrite is magnetic, whereas austenite, carbides, sigma phase and inclusions are non-ferromagnetic.

---

1) The term "austenitic-ferritic (duplex) stainless steel" is sometimes applied in place of "duplex ferritic-austenitic stainless steel".

## 5 Calibration

### 5.1 Coating thickness standards

The coating thickness standards shall consist of non-magnetic copper applied to an unalloyed steel base of size 30 mm × 30 mm. The thickness of the unalloyed steel base shall be equal to or greater than the experimentally determined minimum thickness at which a further increase of the thickness does not cause an increase of the attractive force between the standard permanent magnet and the coating thickness standard. The thickness of the non-magnetic copper coating shall be known to an accuracy of ±5 % or better. The chemical composition of unalloyed steel shall be within the limits given in [Table 1](#).

**Table 1 — Chemical composition limits - unalloyed steel**

Element	Limit % (by mass)
C	0,08 to 0,13
Si	0,10 maximum
Mn	0,30 to 0,60
P	0,040 maximum
S	0,050 maximum

The copper coating may be covered by a chromium flash. The force required to tear off a given permanent magnet from the copper coating side of such a standard increases as the thickness of the copper coating decreases.

To ensure adequate reproducibility of the calibration, the coating thickness standards defined above should be used. In particular, coating thickness standards produced by the US National Institute of Standards and Technology (NIST, formerly National Bureau of Standards or NBS) may be used.

### 5.2 Magnet

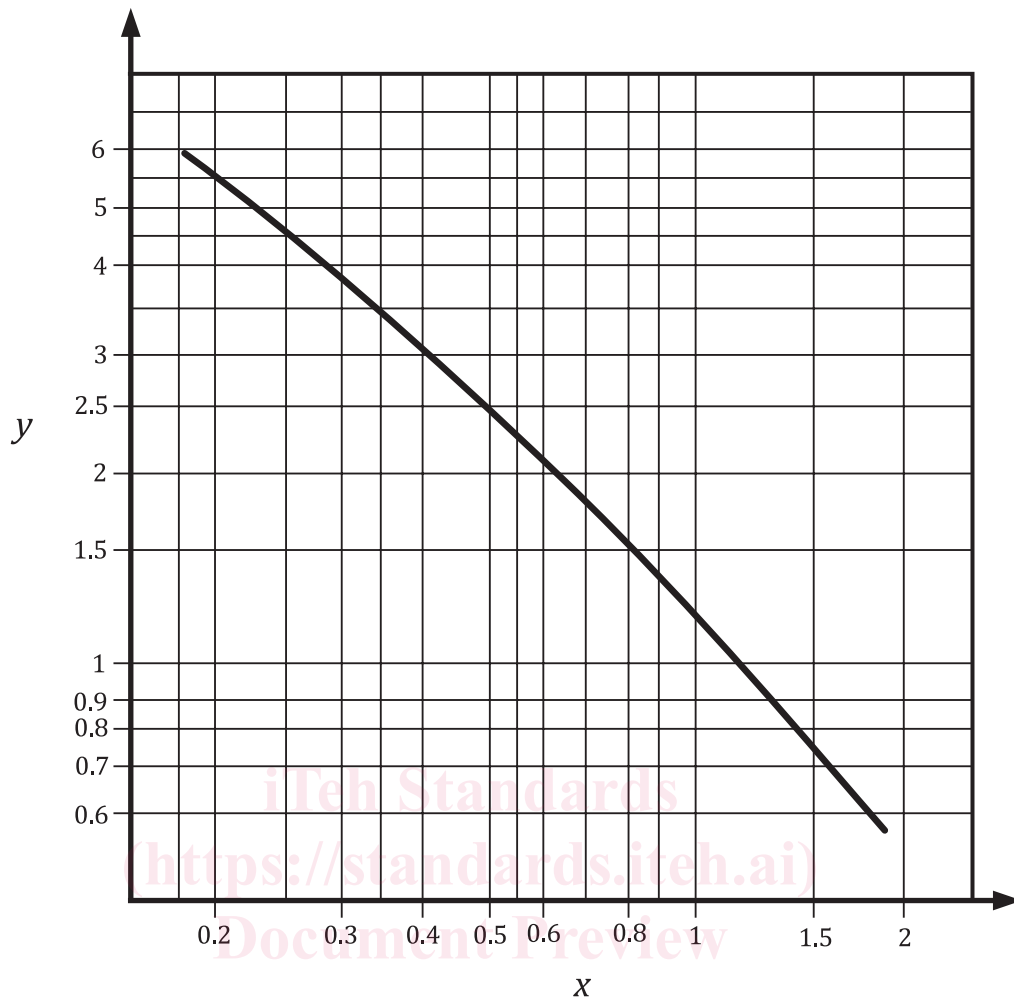
The standard magnet shall be a permanent magnet of cylindrical shape, 2 mm in diameter and about 50 mm in length. One end of the magnet shall be hemispherical, with a 1 mm radius and polished. As an example, such a magnet can be made of 36 % cobalt magnet steel, 48,45 mm ± 0,05 mm long, magnetically saturated and then diluted to 85 %. The magnetic strength of the magnet shall be such that the force needed to tear off the standard magnet from the different coating thickness standards is within ±10 % of the relationship shown in [Figure 1](#) (the weight of the magnet excluded). This is equivalent to a relationship between tear-off force and Ferrite Number of 5,0 FN/g ± 0,5 FN/g.

### 5.3 Instruments

The measurement by this method shall be made by an instrument enabling an increasing tear-off force to be applied to the magnet perpendicularly to the surface of the test specimen. The tear-off force shall be increased until the permanent magnet is detached from the test specimen. The instrument shall accurately measure the tear-off force which is required for detachment. The reading of the instrument may be directly in FN or in grams-force or in other units. If the reading of the instrument is in units other than FN, the relationship between the FN and the instrument reading shall be defined by a calibration curve.

NOTE Many instruments used to measure the thickness of a non-magnetic coating over a ferromagnetic base are suitable (e.g. MAGNE-GAGE of USA origin) and some commercially available instruments are designed directly for measurement of ferrite content (e.g. ALPHA-PHASE-METER of former USSR origin). In addition, after suitable in-house alterations, some laboratory balances can be used.



**Key**

x non-magnetic coating thickness, millimetres (mm)

y tear-off force, gram force (gf)

**Figure 1 — Relationship between the tear-off forces of the standard magnet defined in 5.2 and the coating thickness standards defined in 5.1**

#### 5.4 Calibration curve

In order to generate a calibration curve, determine the force needed to tear off the standard magnet defined in 5.2 from several coating thickness standards defined in 5.1. Then, convert the thickness of non-magnetic coating of the coating thickness standards into FN in accordance with Table 2, or in accordance with Formula (1)<sup>[4]</sup>:

$$FN = \exp\{1,805\ 9 - 1,118\ 86 [\ln(t)] - 0,177\ 40 [\ln(t)]^2 - 0,035\ 02 [\ln(t)]^3 - 0,003\ 67 [\ln(t)]^4\} \quad (1)$$

where  $t$  is the non-magnetic coating thickness, expressed in millimetres.

Finally, plot the calibration curve as the relationship between the tear-off force in the units of the instrument reading and the corresponding FN.

To calibrate the instrument for measurement of ferrite content within the range from 0 FN to approximately 30 FN, which is appropriate for nominally austenitic stainless steel weld metals, a set

consisting of a minimum of eight standards with copper coating thicknesses between approximately 0,17 mm and approximately 2 mm is recommended.

NOTE This calibration procedure can give misleading results if used on instruments measuring the ferrite content in ways other than through the attractive force or on instruments measuring ferrite through the attractive force but employing other than the standard magnet defined in 5.2. Instruments which cannot be calibrated by the coating thickness standards and by the procedure specified in 5.2 to 5.4 can be calibrated as described in Clause 8.

To extend the calibration from approximately 30 FN to 100 FN, which is appropriate for duplex ferritic-austenitic stainless steel weld metals, a set consisting of a minimum of five standards with coating thicknesses between 0,03 mm and 0,17 mm is recommended.

**Table 2 — Relationship between Ferrite Number and thickness of non-magnetic coating of coating thickness standards (specified in 5.1) for calibration of instruments for measurement of ferrite content through attractive force (specified in 5.3) using the standard magnet (specified in 5.2)**

Coating thickness <i>t</i> mm	FN	Coating thickness <i>t</i> mm	FN	Coating thickness <i>t</i> mm	FN	Coating thickness <i>t</i> mm	FN	Coating thickness <i>t</i> mm	FN
0,020	110,5	0,049	68,3	0,078	51,0	0,134	35,3	0,300	19,1
0,021	108,0	0,050	67,5	0,079	50,6	0,136	34,9	0,320	18,1
0,022	105,7	0,051	66,7	0,080	50,2	0,138	34,5	0,340	17,2
0,023	103,4	0,052	65,9	0,082	49,3	0,140	34,2	0,360	16,4
0,024	101,3	0,053	65,1	0,084	48,6	0,142	33,8	0,380	15,7
0,025	99,2	0,054	64,4	0,086	47,8	0,144	33,5	0,400	15,0
0,026	97,3	0,055	63,7	0,088	47,1	0,146	33,2	0,420	14,4
0,027	95,4	0,056	63,0	0,090	46,4	0,148	32,8	0,440	13,8
0,028	93,6	0,057	62,3	0,092	45,7	0,150	32,5	0,460	13,2
0,029	91,9	0,058	61,6	0,094	45,1	0,155	31,7	0,480	12,7
0,030	90,3	0,059	60,9	0,096	44,4	0,160	31,0	0,500	12,3
0,031	88,7	0,060	60,3	0,098	43,8	0,165	30,3	0,550	11,2
0,032	87,2	0,061	59,7	0,100	43,2	0,170	29,7	0,600	10,3
0,033	85,8	0,062	59,1	0,102	42,6	0,175	29,0	0,650	9,6
0,034	84,4	0,063	58,5	0,104	42,1	0,180	28,4	0,700	8,9
0,035	83,0	0,064	57,9	0,106	41,5	0,185	27,9	0,750	8,3
0,036	81,7	0,065	57,3	0,108	41,0	0,190	27,3	0,800	7,7
0,037	80,5	0,066	56,8	0,110	40,5	0,195	26,8	0,900	6,8
0,038	79,3	0,067	56,2	0,112	40,0	0,200	26,3	1,000	6,1
0,039	78,1	0,068	55,7	0,114	39,5	0,205	25,8	1,200	4,93
0,040	77,0	0,069	55,2	0,116	39,0	0,210	25,3	1,400	4,09
0,041	75,9	0,070	54,7	0,118	38,6	0,220	24,4	1,600	3,45
0,042	74,8	0,071	54,2	0,120	38,1	0,230	23,6	1,800	2,94
0,043	73,8	0,072	53,7	0,122	37,7	0,240	22,8	2,000	2,54
0,044	72,8	0,073	53,2	0,124	37,2	0,250	22,1	2,200	2,21
0,045	71,8	0,074	52,8	0,126	36,8	0,260	21,4	2,400	1,94

Table 2 (continued)

Coating thickness $t$ mm	FN	Coating thickness $t$ mm	FN	Coating thickness $t$ mm	FN	Coating thickness $t$ mm	FN	Coating thickness $t$ mm	FN
0,046	70,9	0,075	52,3	0,128	36,4	0,270	20,8	2,600	1,72
0,047	70,0	0,076	51,9	0,130	36,0	0,280	20,2	2,800	1,53
0,048	69,1	0,077	51,4	0,132	35,6	0,290	19,6	3,000	1,36

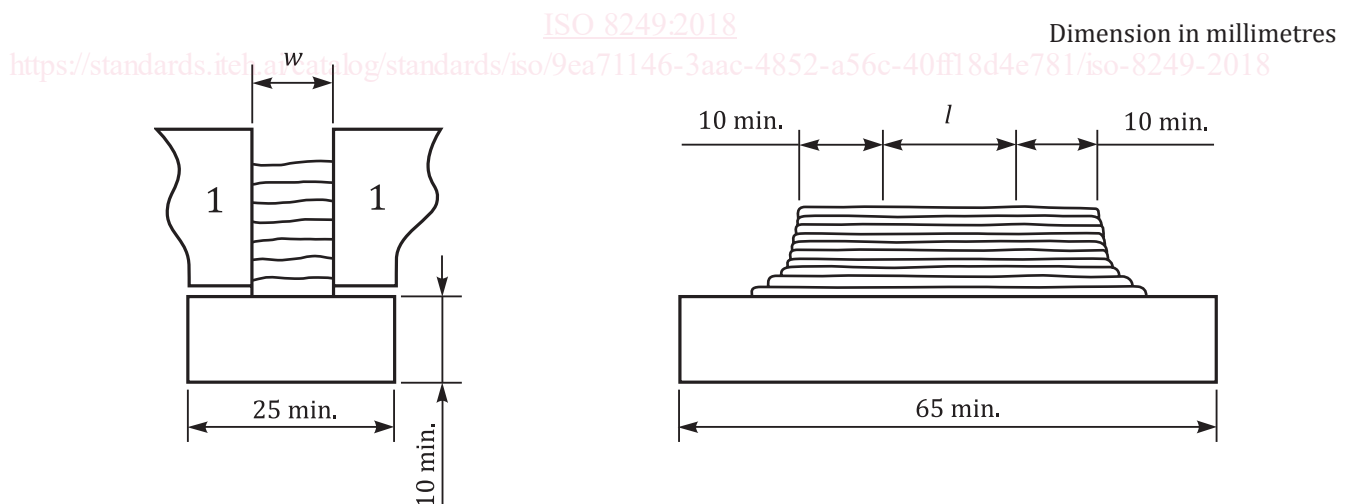
## 6 Standard method for covered electrode test pads

### 6.1 Dimensions of weld metal test specimens

Standard weld metal test specimens for manual electrodes shall be of the size and shape indicated in [Figure 2](#). For the measurement of ferrite content by instruments/magnets or processes other than those specified in [5.2](#) and [5.3](#), a larger specimen can be necessary. In such cases, the size and way of producing the pad shall be clearly and carefully defined.

### 6.2 Depositing weld metal test specimens

- The weld pad shall be built up between two copper bars laid parallel on the base plate. Spacing shall be adjusted to accommodate the electrode size to be used as specified in [Table 3](#).
- The weld pad shall be built up by depositing layers one on top of the other to a minimum height of 12,5 mm (see the Note on [Figure 2](#)). Each layer shall be made in a single pass for electrode diameters  $\geq 4$  mm. For small diameters, each layer except the top layer shall be constituted by two or more beads deposited with a maximum weave of 3 times the core wire diameter. The arc shall not be allowed to come into contact with the copper bar.



#### Key

- 1 copper bar of dimensions 70 × 25 × 25  
 $l$  length of the area where ferrite content is measured (see [Table 3](#))  
 $w$  width of the area where ferrite content is measured (see [Table 3](#))

NOTE The base metal is preferably austenitic Cr-Ni steel type X2CrNi18-9 or X5CrNi18-9 (see [ISO 15510](#)) and, in this case, the minimum pad height is 13 mm. Mild steel (C-Mn steel) can also be used and, in this case, the minimum pad height is 18 mm.

Figure 2 — Weld metal specimen for ferrite determination