

AWS A4.2M:2006 (ISO 8249:2000 MOD)
An American National Standard

**Standard Procedures
for Calibrating
Magnetic Instruments
to Measure the Delta
Ferrite Content of
Austenitic and Duplex
Ferritic-Austenitic
Stainless Steel
Weld Metal**



American Welding Society



Key Words— Instrument calibration, delta ferrite, stainless steel weld metal, austenitic stainless steel weld metal, duplex stainless steel weld metal

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Approved by the
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Standard Procedures for Calibrating Magnetic Instruments to Measure the Delta Ferrite Content of Austenitic and Duplex Ferritic-Austenitic Stainless Steel Weld Metal

Supersedes ANSI/AWS A4.2M/A4.2:1997

Prepared by the
American Welding Society (AWS) A5 Committee on Filler Metals and Allied Materials

Under the Direction of the
AWS Technical Activities Committee

Approved by the
AWS Board of Directors

Abstract

Calibration procedures are specified for a number of commercial instruments that can then provide reproducible measurements of the ferrite content of austenitic stainless steel weld metals. Certain of these instruments can be further calibrated for measurements of the ferrite content of duplex ferritic-austenitic stainless steel weld metals. Calibration with primary standards (nonmagnetic coating thickness standards from the U.S. National Institute of Standards and Technology) is the preferred method for appropriate instruments. Alternatively, these and other instruments can be calibrated with weld-metal-like secondary standards.

Reproducibility of measurement after calibration is specified. Problems associated with accurate determination of ferrite content are described.



American Welding Society

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Foreword

This foreword is not a part of AWS A4.2M:2006 (ISO 8249:2000 MOD), *Standard Procedures for Calibrating Magnetic Instruments to Measure the Delta Ferrite Content of Austenitic and Duplex Ferritic-Austenitic Stainless Steel Weld Metal*, but is included for informational purposes only.

This document is an adoption of ISO 8249:2000, *Welding — Determination of Ferrite Number (FN) in austenitic and duplex ferritic-austenitic Cr-Ni stainless steel weld metals*, with additional normative and informative annexes, to replace AWS A4.2M/A4.2:1997, *Standard Procedures for Calibrating Magnetic Instruments to Measure the Delta Ferrite Content of Austenitic and Duplex Ferritic-Austenitic Stainless Steel Weld Metal*, first published in 1974 and revised in 1986 and again in 1991. These specifications were prepared by the Subcommittee on Welding Stainless Steel of the Welding Research Council and by the AWS Committee on Filler Metals. Then it was revised again in 1997 by AWS A5 Committee on Filler Metals and Allied Materials. The current revision is the second to use the SI system of measurement as the primary system, and updates the standard in the light of new information.

The current revision is a modified adoption of ISO 8249:2000 due to the inclusion of Annex C (normative). While everything acceptable to ISO 8249:2000 is acceptable to AWS A4.2M:2006, calibration of instruments according to Annex C is not acceptable according to ISO 8249:2000. A listing of changes from ISO 8249:2000 is shown in Annex F. Also note that ISO uses commas (,) and AWS uses periods (.) for decimals. The ISO decimal commas have been replaced by periods in this document for consistency.

A certain minimum ferrite content in most austenitic stainless steel weld metals is useful in assuring freedom from microfissures and hot cracks. Upper limits on ferrite content in austenitic stainless steel weld metals can be imposed to limit corrosion in certain media or to limit embrittlement due to transformation of ferrite to sigma phase during heat treatment or elevated temperature service. Upper limits on ferrite content in duplex ferritic-austenitic stainless steel weld metals can be imposed to help assure ductility, toughness, and corrosion resistance in the as-welded condition.

Reproducible quantitative ferrite measurements in stainless steel weld metals are therefore of interest to filler metal producers, fabricators of weldments, weldment end users, regulatory authorities, and insurance companies.

Attention is drawn to the possibility that some of the elements of this standard may be the subject of patent rights. AWS and ISO shall not be held responsible for identifying any or all such patent rights.

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 described in this standard. The Ferrite Number of a weld metal has been considered approximately equivalent to the percent ferrite content, particularly at low FN values. More recent information suggests that the FN may 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 upon the actual composition of the alloy in question.

Although other methods are available for determining the Ferrite Number, the standardized measuring procedure, described in this standard, 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) shall be used instead of “ferrite percent” 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.

Comments and suggestions for the improvement of this standard are welcome. They should be sent to the Secretary, AWS A5 Committee on Filler Metals and Allied Materials, American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

Official interpretations of any of the technical requirements of this standard may only be obtained by sending a request, in writing, to the Managing Director, Technical Services Division, American Welding Society. A formal reply will be issued after it has been reviewed by the appropriate personnel following established procedures.

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

1 Scope

This standard 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 steel¹⁾ weld metal through the attractive force between a weld metal sample and a standard permanent magnet;
- the preparation and measurement of standard pads for shielded 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 described in this standard 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 will 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 reference

The following normative document contains provisions which, through reference in this text, constitute provisions of this standard. For dated references, subsequent amendments to, or revisions of, this publication do not apply. However, parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent edition of the normative document indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO/TR 15510:1997, *Stainless steels — Chemical composition*.

3 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 upon 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”.

4 Calibration

4.1 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 following limits:

Element	Limit %
C	0.08 to 0.13
Si	0.10 max.
Mn	0.30 to 0.60
P	0.040 max.
S	0.050 max.

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.

NOTE 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.

4.2 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.

4.3 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 curve²⁾.

4.4 Calibration curve

In order to generate a calibration curve, determine the force needed to tear off the standard magnet defined in 4.2 from several coating thickness standards defined in 4.1. Then convert the thickness of non-magnetic coating of the coating thickness standards into FN according to Table 1, or according to the equivalent equation (1), as follows:

$$FN = \exp\{1.8059 - 1.11886 [\ln(t)] - 0.17740 [\ln(t)]^2 - 0.03502 [\ln(t)]^3 - 0.00367 [\ln(t)]^4\} \quad (1)$$

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

2) 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.

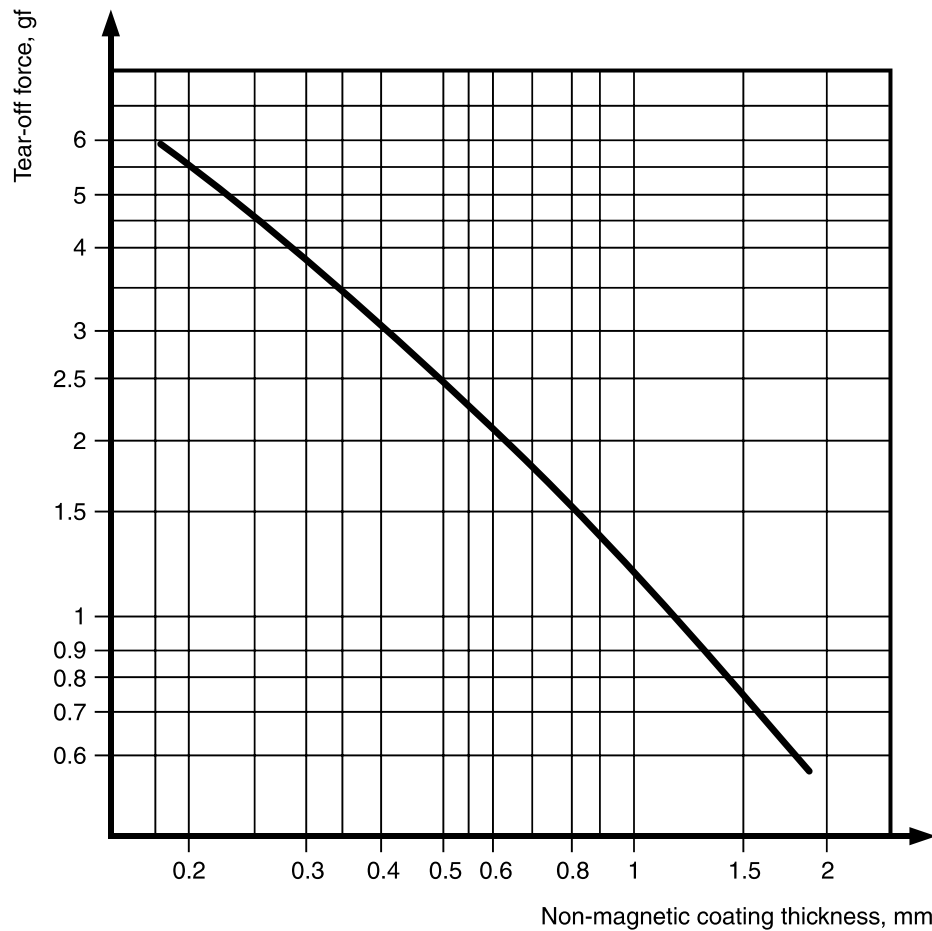


Figure 1 — Relationship between the tear-off forces of the standard magnet defined in 4.2 and the coating thickness standards defined in 4.1

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 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 recommended³⁾. 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.

4.5 Calibration of other instruments with primary standards

In principle, instruments with other than a standard magnet, and instruments using an approach to magnetic property measurement other than magnetic attractive force, can be calibrated with primary standards providing that sufficient statistical data is collected. This has been done only with two older “legacy” instruments — see Annex C.

3) This calibration procedure may 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 4.2. Instruments which cannot be calibrated by the coating thickness standards and by the procedure specified in 4.2 to 4.4 may be calibrated as described in clause 7.

Table 1 — Relationship between Ferrite Number and thickness of non-magnetic coating of coating thickness standards (specified in 4.1) for calibration of instruments for measurement of ferrite content through attractive force (specified in 4.3) using the standard magnet (specified in 4.2)

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
0.020	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	66.0	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
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

5 Standard method for shielded metal arc covered electrode test pads

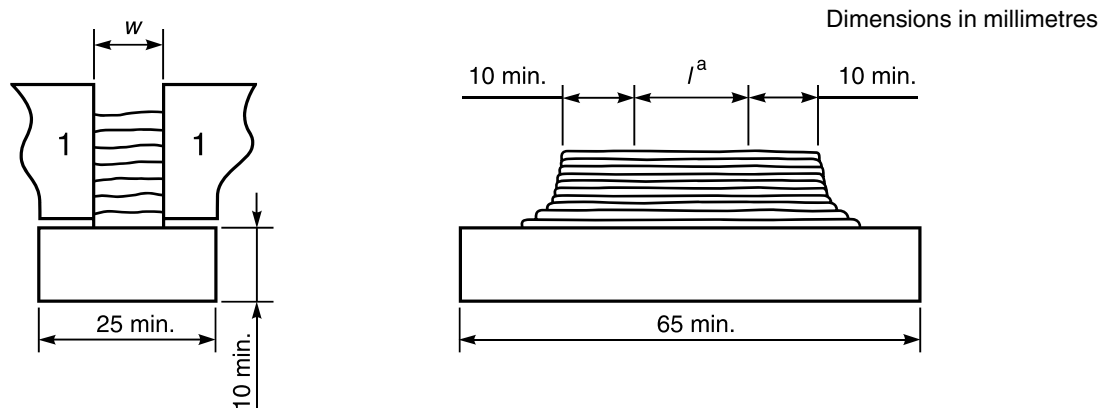
5.1 Dimensions of weld metal test specimens

Standard weld metal test specimens for shielded metal arc covered 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 4.2 and 4.3, a larger specimen may be necessary. In such cases, the size and way of producing the pad shall be clearly and carefully defined.

5.2 Depositing weld metal test specimens

- a) 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 2.

- b) 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 ≥ 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 $70 \times 25 \times 25$

NOTE The base metal should preferably be austenitic Cr-Ni steel type X2CrNi18-9 [304L] or X5CrNi18-9 [304] (see ISO/TR 15510) and in this case the minimum pad height is 13 mm. Mild steel (C-Mn steel) may also be used and in this case the minimum pad height is 18 mm.

^a Ferrite content shall be measured in this area.

Figure 2 — Weld metal specimen for ferrite determination

- c) The arc length shall be as short as practicable.
- d) The welding currents shall comply with the values given in Table 2. The weld stops and starts shall be located at the ends of the weld build-up. The welding direction shall be changed after each pass.
- e) The weld pad may be cooled between passes by water quenching no sooner than 20 s after the completion of each pass. The maximum temperature between passes shall be 100 °C. Each pass of the last layer shall be air cooled to a temperature below 425 °C before water quenching.
- f) Each weld pass shall be cleaned before the next is deposited.
- g) In all cases, the topmost layer, at least, shall consist of a single bead deposited with a maximum weave of $3 \times$ the core wire diameter.

Table 2 — Welding parameters and deposit dimensions

Electrode diameter mm	Welding current ^a A	Approximate dimensions	
		width (<i>w</i>) mm	length (<i>l</i>) mm
1.6	35 to 45	12.5	30
2	45 to 55	12.5	30
2.5	65 to 75	12.5	40
3.2	90 to 100	12.5	40
4	120 to 140	12.5	40
5	165 to 185	15	40
6.3	240 to 250	18	40

^a Or 90 % of the maximum value recommended by the electrode manufacturer.

5.3 Measuring

5.3.1 Surface finishing

After welding, the weld build-up of nominally austenitic stainless steel weld metals (< 30 FN) shall be prepared smooth and flat, taking care to avoid heavy cold working⁴⁾ of the surface; this aim can be achieved by draw filing with a sharp clean 350 mm flat mill bastard file held on both sides of the weld and with the long axis of the file perpendicular to the long axis of the weld. Draw filing shall be accomplished by smooth forward strokes along the length of the weld with a firm downward pressure being applied. The weld shall not be cross-filed.

After welding, the weld build-up of duplex ferritic-austenitic stainless steel weld metals (> 30 FN) shall be ground with successively finer abrasives to a finish of 600 grit or finer. Care shall be taken during grinding to avoid excessive pressure that leads to burnishing or overheating of the surface.

The finished surface shall be smooth with all traces of weld ripple removed. The prepared surface shall be continuous over the length to be measured and not less than 5 mm in width.

5.3.2 Individual measurements

A minimum of six ferrite readings shall be taken at different locations on the finished surface along the longitudinal axis of the weld bead. Care shall be taken to isolate the weldment under test from vibrations which can cause premature magnet detachment during measuring.

For weld metals of 20 FN or less, only a single reading need be taken at each location. For weld metals above 20 FN, five readings shall be taken at any single location, and only the reading corresponding to the highest FN amongst those five readings shall be accepted as the FN for that location. A minimum of six locations shall be so measured as to obtain the required values for averaging.

5.3.3 Reporting

The six or more accepted readings obtained shall be averaged to a single value for conversion to the Ferrite Number reported for the weld metal under test.

6 Standard methods for test pads of other processes and for production welds

6.1 Standard method for test pads for other weld metals

The standard method for producing covered electrode test pads may be almost directly applicable to other weld metals, e.g. flux cored arc weld deposits. In preparing such test pads, the pad length may need to be increased so that the area of ferrite measurements does not include the weld crater. For submerged arc weld metal, the test pad width and length may both need to be increased. For all test pads, the pad shall consist of a minimum of six layers, with at least the top layer consisting of a single bead. In general, preparation and measurement shall follow the instructions of clause 5 as far as possible.

6.2 Production welds

The method of depositing the weld test specimen has a considerable influence upon the result of ferrite content measurement. Consequently, the results of ferrite content measurement obtained on specimens deposited in a way differing from that specified in 5.1 and 5.2, or 6.1, and on production welds are likely to differ from the results obtained on specimens deposited according to 5.1 and 5.2, or 6.1. In all cases, however, ferrite content measurement shall be made along the approximate centreline of a given weld bead.

4) Cold working may produce martensite, which is also ferromagnetic and gives a false ferrite indication.

It is necessary to ensure that the measurement is not disturbed by the incidental presence of strongly ferromagnetic materials, such as mild steel or cast iron. During measurement, such materials shall be kept at a distance of at least 18 mm from permanent magnets of the size and strength of the standard magnet. Other magnets and/or instruments may require larger or smaller distances to be free from the effect of nearby strongly ferromagnetic materials.

Caution is necessary when measuring the ferrite in cladding deposited on ferromagnetic materials, and when measuring the ferrite in thin stainless steel welds (e.g. less than 5 mm thick). The first case may lead to false high values, and the second may lead to false low values. The required minimum stainless steel weld thickness for correct ferrite measurement depends upon the depth of material sensed by the particular instrument in use.

7 Other methods

7.1 Methods

Methods for determining ferrite content other than through the evaluation of attractive force or methods differing from that described in this standard may be used, such as volumetric determination by magnetic saturation, provided that they have been calibrated by secondary standards in which the ferrite content has been determined by the method described in this standard. Secondary standards can be prepared using the method specified in 5.1 and 5.2, by assigning to them FN values by the method specified in 5.3. See Annex D for a description of several instruments which have proven suitable.

NOTE These secondary standards, prepared as shown in annexes A and B, are available from the International Institute of Welding (IIW) via TWI (The Welding Institute) in the United Kingdom or the National Institute of Standards and Technology (NIST) in the USA.

7.2 Results

The results obtained by methods other than the method described in this standard, even if calibrated in accordance with 7.1, may, under certain circumstances, differ from those obtained by the method described in this standard. Hence, in cases of dispute, the method described in this standard shall be used.

On a given specimen, the average FN as determined by other methods and compared with measurements obtained with the method described in this standard, shall be within a tolerance band of ± 1 FN in the FN range up to 10 FN and this may be proportionally higher as the FN increases beyond 10 FN.

7.3 Maintaining calibration

Instruments shall be checked periodically against secondary standards or primary standards. It is therefore recommended that the organization which uses the instrument ensure that a set of standards be available. It is the responsibility of the user to see that the frequency of checking is adequate to maintain calibration. One standard shall be used for each of the ranges (see Table 3) for which the instrument is to be used. The average value of five measurements at individual positions on the standard shall be within the maximum deviations specified in Table 3.

Table 3 — Maximum allowable deviation in the periodic FN check

FN range	Maximum deviation from the FN value assigned to the standard
$0 < \text{FN} \leq 4$	± 0.5
$4 < \text{FN} \leq 10$	± 0.5
$10 < \text{FN} \leq 16$	± 0.6
$16 < \text{FN} \leq 25$	± 0.8
$25 < \text{FN} \leq 50$	$\pm 5\%$ of assigned FN
$50 < \text{FN} \leq 110$	$\pm 8\%$ of assigned FN

8 Procedures used to prepare secondary standards for delta ferrite in austenitic stainless steel weld metal

Coating thickness standards are not suitable for use as primary standards with all types of ferrite measuring instruments. A need therefore exists for secondary standards for both calibration and cross-reference of instruments in the laboratory and under shop and field conditions. The first set of secondary standards was made by Teledyne McKay in the late 1960s. These were a build up of SMAW much like the pad shown in 5.2. They were used to develop the FN system of measuring ferrite as we know it today, replacing the % ferrite system previously used. Teledyne McKay subsequently produced and sold sets of these secondary standards, but ceased doing so in the late 1970s. Therefore in about 1980, the International Institute of Welding (IIW) requested some organizations, in particular TWI (The Welding Institute, UK) to prepare sets of secondary standards, each consisting of eight blocks of austenitic stainless steel weld metal with Ferrite Numbers in the approximate range 3 FN to 27 FN. An original manufacturing run of 100 sets was prepared by strip cladding. When the original 100 sets had been distributed internationally, a new procedure for producing secondary standards was developed (CNIITMASH, Russia) using centrifugal chill casting to produce large rings in which most of the wall thickness contained a weld-metal-like microstructure. Blocks of dimensions approximately 10 mm × 12 mm × 20 mm were machined from the portion of the ring wall containing the weld-metal-like microstructure. This new procedure was shown, by round robin testing in IIW Commission II, to produce materials suitable for secondary standards over the whole range from near zero to over 100 FN. FN measurements and assignment of the certified FN for each block were carried out at TWI or NIST. The procedures used to prepare the last two types of secondary standards are described in annexes A and B.

Annex A (informative)

Manufacture of secondary standards by strip cladding

A.1 Materials

A.1.1 Base metal

The base metal on which the nominally austenitic weld metal was deposited was unalloyed steel type B1 (see ISO 4954) in the form of bars with dimensions 100 mm × 100 mm × 800 mm. The surfaces to be clad were cleaned by free-hand grinding.

A.1.2 Welding consumables

The submerged arc strip cladding process was used. Suitable combinations of strips and fluxes were used so that it was possible to obtain eight FN levels in the range 3 FN to 27 FN in undiluted weld metal. Welding strips consisting of unstabilized, extra-low-carbon austenitic stainless Cr-Ni steel were used, with a cross-sectional area of 60 mm × 0.5 mm. The welding fluxes were agglomerated and contained varying metal powder additions. Before use, the fluxes were rebaked at 300 °C for 1 h.

A.2 Welding procedures

The weld metal in each case consisted of a seven-layer strip clad deposit on the base material, as illustrated in Figure A.1. After each layer, the welding direction was changed. The power supply used had a drooping characteristic. Welding parameters used are given in Table A.1.

The bead deposition sequence is shown in Figure A.2. To minimize the distortion of the base metal, one side of the bar was first clad with three layers. After turning the bar, three layers were welded on the opposite side.

This procedure was continued with two pass sequences until the last bead.

Table A.1 — Welding parameters

Current	650 A
Voltage	29 V
Speed of travel	100 mm/min
Stick out	25 mm
Polarity of the strip	d.c./electrode positive
Preheating	None
Interpass temperature	200 °C max.
Cooling after welding the last layer	Still air

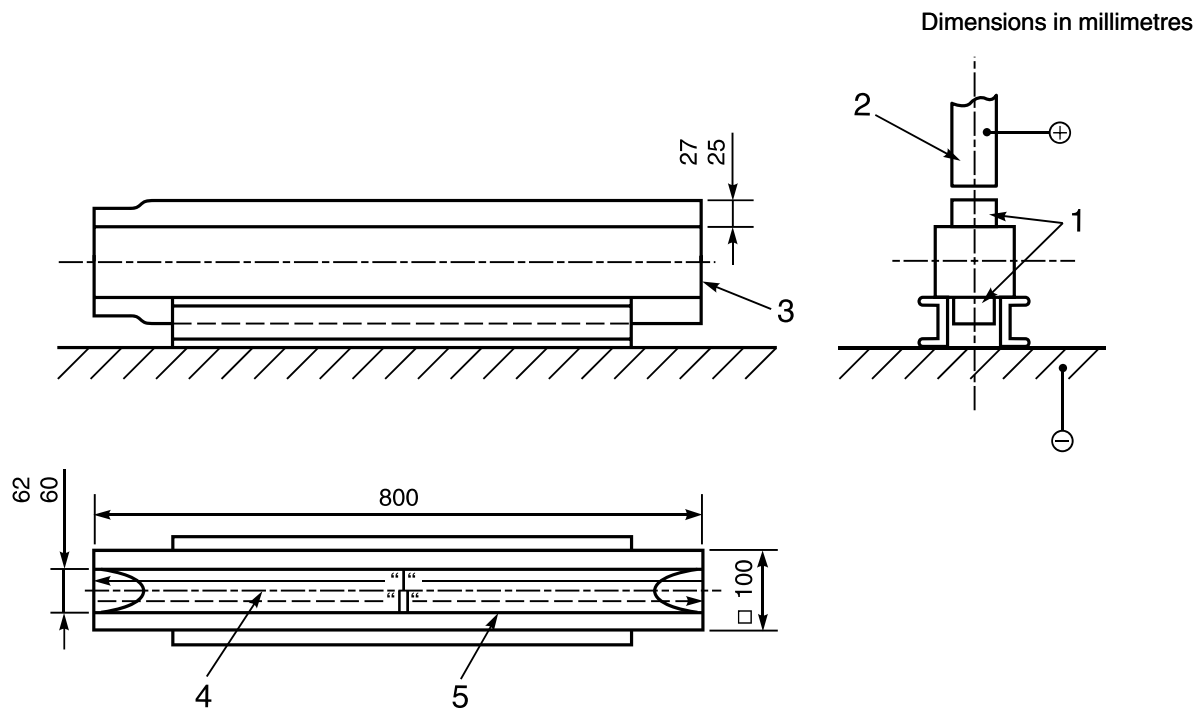
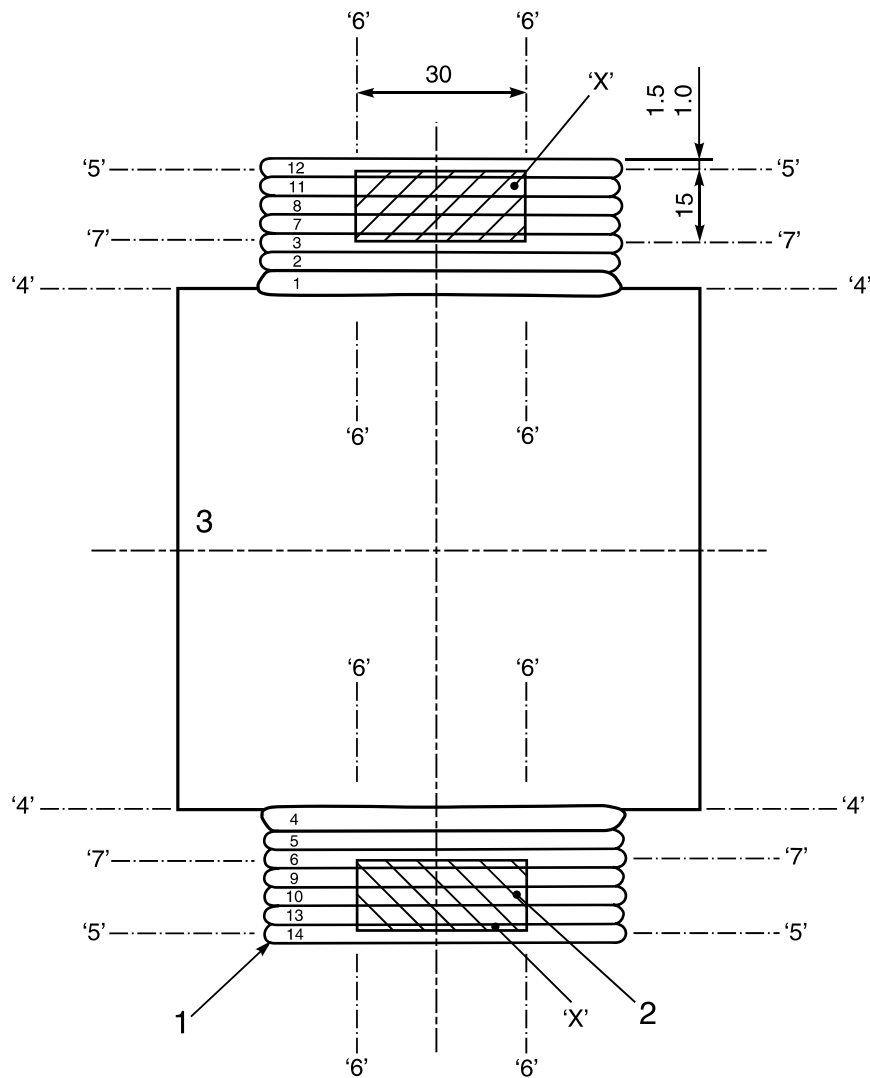


Figure A.1 — Method of depositing weld metal for secondary standard by strip cladding

Dimensions in millimetres

**Key**

- 1 Weld deposit
- 2 Secondary standard
- 3 Base metal

Figure A.2 — Bead deposition and machining sequences for secondary standards by strip cladding

A.3 Machining and marking

A.3.1 Cutting programme

Initially, the end section was cut off, corresponding to lines '1' – '1' in Figure A.3. Chips for the chemical analysis of the seventh layer were taken at the locations marked by 'a' in Figure A.3. Cutting of the other end section followed along lines '2' – '2'.

The rest of the bar was divided along lines '3' – '3', and the deposits separated from the base metal along lines '4' – '4' (see Figure A.3).

The rough preparation of the test surface followed, along lines '5' – '5' (see X in Figure A.2).

Subsequently, lateral machining along lines '6' – '6' and machining of the bottom surface along lines '7' – '7' was performed (see Figure A.2).

The division of the rough machined weld bars, following the lines '8' – '8', is shown in Figures A.3 and A.4. Subsequently, the single specimens were finished. Thirty specimens could be produced from each bar clad on both sides.

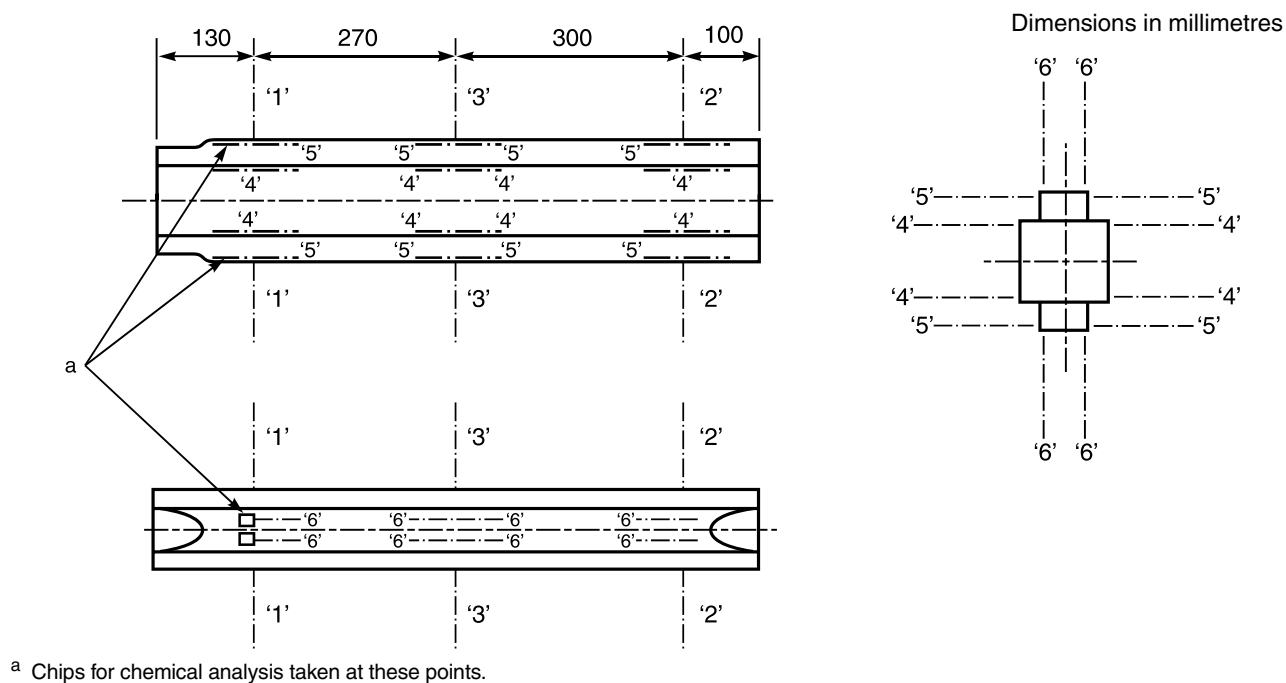
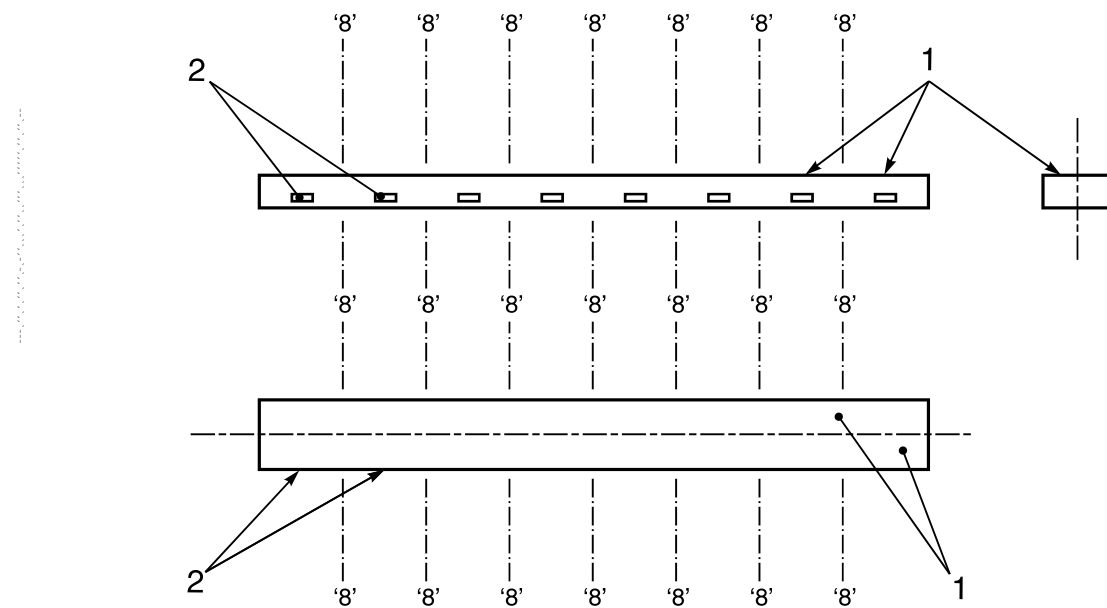


Figure A.3 — Cutting sequences for secondary standard by strip cladding



Key

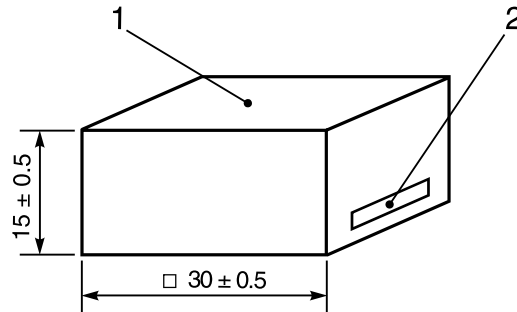
- 1 Test surfaces
- 2 Marking regions

Figure A.4 — Extraction of individual strip cladding secondary standards

A.3.2 Dimensions, tolerances, surface finish

The dimensions and tolerances of the finished “ferrite secondary standards” are shown in Figure A.5. The test surface was ground with an 8A-80-G-9-V39 grinding disc (see ISO 525). All the other surfaces were rough finished.

Dimensions in millimetres



Key

- 1 Test surface
- 2 Marking region

Figure A.5 — Marking of each strip cladding ferrite secondary standard

A.3.3 Marking for standard identification

The marking of the standards took place on a side face as shown in Figures A.4 and A.5. The marks produced with figure stamps were arranged so that the distance from the test surface was as great as possible.

The reading direction of the marking indicates the welding direction in the seventh layer. The designation of the standards consists of letters and numbers. The letters (A to H) indicate increasing FN values, with the number following indicating the set number.

A.4 Chemical composition

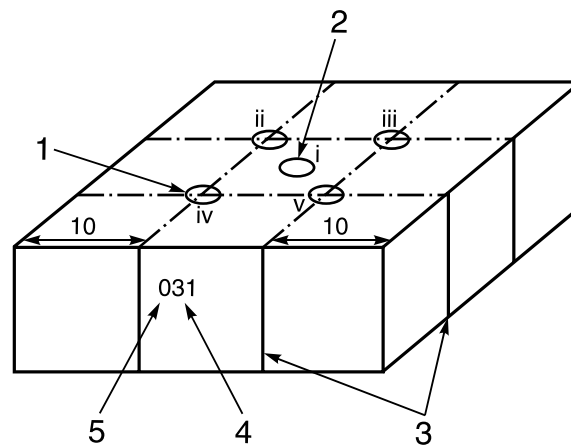
An example of the full chemical analysis of the seventh layer of the deposit (for all the standards) is shown in Table A.2.

Table A.2 — Example of the chemical composition of seventh layer of strip clad deposits

Seventh layer of deposited metal	Element mass fraction (%)								
	C	Si	Mn	P	S	Cr	Mo	Ni	Nb
A1-A15	0.020	1.00	0.78	0.021	0.019	19.62	0.13	11.79	< 0.05

A.5 Marking for FN measuring point location

The standards were received at TWI in the conditions described in Clause A3. FN measurements were to be made at five locations on each standard. The individual samples were thus marked by scribing on the sides as indicated in Figure A.6. The intersections of the imaginary lines joining these marks defined four measuring points. The fifth measuring point was in the centre of the measuring face. The points were identified by (i) to (v) as shown in Figure A.6, but these characters were not marked on the block itself.



Key

- 1 Points identified by intersection of imaginary lines
- 2 Central point
- 3 Scribed lines
- 4 Standard set number
- 5 Individual standard

Figure A.6 — Marking on each strip cladding secondary standard sample and identification of the five measuring points

A.6 FN measuring instruments and calibration

A.6.1 Introduction

The instruments and procedures used were in conformity with the requirements of this standard. Before commencing production and measurement of sets of FN standards for general issue, TWI carried out trials on a prototype set of standards. These demonstrated that FN values ascribed to standards by TWI were consistent with results obtained by other organizations, and also that the strip cladding samples could be used for a range of commercial ferrite measuring instruments.

A.6.2 Instruments used

Two “Magne-Gages[®]”⁵⁾, manufactured by the American Instrument Company (USA)⁶⁾, were used to make measurements on each set of standards. To ensure that the differences between the two instruments were within acceptable limits, at the commencement of the programme both “Magne-Gages”, after calibration as described in A.6.4, were used to make measurements on all samples comprising one complete set of standards. The two sets of data were well within the range of variation in measurements expected for 95 % of “Magne-Gages”.

A.6.3 Magnet strength checks

Before the commencement of measurements, the magnets associated with each of the “Magne-Gages” were checked to ensure they corresponded to the requirements of this standard. This was done by using a laboratory balance to measure tear-off forces from a set of eight USA National Institute of Standards and Technology (NIST)⁷⁾ coating thickness standards. The standards employed (see Table A.3) were the seven supplied with each individual instrument, together with an eighth one (SRM 1312, nominal thickness 0.2 mm) acquired directly from NIST.

5) Magne-Gage is a registered trademark of Magne-Gage Sales & Service Co., Inc.

6) Now Magne-Gage Sales & Service Co., Inc.

7) NIST was formerly named National Bureau of Standards (NBS).

Table A.3 — NIST standards employed for “Magne-Gage” calibration for strip cladding secondary standards

NIST SRM No.	Nominal coating thickness mm
1312	0.2
1313	0.25
1314	0.38
1315	0.5
1316	0.64
1317	0.76
1318	1.01
1319	1.52

After measurements on every 10 sets of secondary standards, the magnet strengths for each instrument were rechecked to ensure that they still conformed to the requirements.

Magnets were cleaned according to the manufacturer’s instructions before each calibration.

A.6.4 Ferrite number calibration

The Ferrite Number (FN) versus the white dial reading calibration for each “Magne-Gage” instrument was derived according to the procedure described in this standard. The eight NIST coating thickness standards used were those shown in Table A.3 and a zero point was also determined using a completely non-magnetic material.

Both “Magne-Gages” displayed a bend in the calibration at about 13 FN, and thus separate best-fit straight lines (least-squares method) were drawn through the calibration points above and below this level. The equations of these lines were used to derive FN values from white dial readings during subsequent measurement work on the secondary standards.

The maximum tolerances on the positions of individual calibration points were taken as those specified in AWS A4.2. In fact, much better tolerances were achieved in all cases.

A calibration was carried out on each “Magne-Gage”:

- at the start of each day’s work, and
- after the measurement of 4 sets of secondary standards.

A.7 Measuring procedure on secondary standards

A.7.1 Instruments and operators

Four complete sets of readings were taken on each set of eight ferrite secondary standards, by two operators each using both “Magne-Gages”. Although only two operators were employed on any given set of secondary standards, several operators were employed during the entire measurement programme.

A.7.2 Demagnetization

No attempt was made to demagnetize the standards, as the “Magne-Gage” has been reported to be insensitive to premagnetization.

A.7.3 Measurements on each ferrite standard

On each individual ferrite standard, three readings were taken at each of the five measurement points, for each operator and “Magne-Gage”. Non-magnetic jigs were fitted over the standards to aid rapid and accurate location of the measurement points, these consisting of recessed blocks of plastic with suitably sized and positioned holes. The standard was not repositioned between the three individual measurements on any one point.

Each standard thus had a total of 60 “Magne-Gage” white dial readings taken from it, twelve for each individual measurement session.

Readings for each operator and “Magne-Gage” were completed within one measurement session.

A.7.4 Data recording and analysis

Data from the readings by each “Magne-Gage” operator were recorded together with the “Magne-Gage” number, FN calibration reference, date and operator’s name.

Each set of three white dial readings per individual measurement point was averaged and an FN value produced from the appropriate calibration equation for each point. An average FN value for each standard was produced from the FN values for the five measurement points.

A.7.5 Presentation of results

The presentation of the results on the card to accompany each set of standards was as illustrated in the example in Table A.4.

In addition, a label adjacent to each standard in the box showed the overall average FN value for all measurements on that standard. All values were quoted to 0.1 FN.

Each boxed set of eight standards was also provided with a short booklet, briefly describing the preparation of the set.

Table A.4 — Example of the tabular presentation of results on the card accompanying each box of standards (Secondary weld metal standards, Set 68 — May 1980)

Standard number	Measure- ment point	“Magne-Gage” 1				“Magne-Gage” 2				Mean FN for each point	FN overall average
		Operator No. 1		Operator No. 2		Operator No. 1		Operator No. 2			
		FN each point	Mean FN all five points	FN each point	Mean FN all five points	FN each point	Mean FN all five points	FN each point	Mean FN all five points		
A68	1	2.8	2.7	2.8	2.7	2.7	2.6	2.6	2.6	2.7	2.7
	2	2.5		2.8		2.6		2.5		2.5	
	3	2.8		2.8		2.6		2.6		2.7	
	4	2.7		2.6		2.5		2.5		2.6	
	5	2.8		2.7		2.6		2.6		2.7	
B68	1	4.6	4.7	4.6	4.7	4.5	4.5	4.6	4.6	4.6	4.6
	2	4.6		4.6		4.5		4.4		4.5	
	3	4.8		4.8		4.5		4.6		4.7	
	4	4.8		4.8		4.5		4.6		4.7	
	5	4.6		4.6		4.4		4.6		4.5	
C68	1	8.9	8.9	8.8	8.9	8.8	8.7	8.7	8.6	8.8	8.8
	2	8.9		8.9		8.7		8.6		8.8	
	3	8.9		8.8		8.6		8.5		8.7	
	4	9.2		9.1		8.8		8.8		8.9	
	5	8.9		8.9		8.6		8.6		8.7	
D68	1	11.0	11.0	11.0	11.1	10.6	10.5	10.8	10.7	10.9	10.8
	2	10.8		10.9		10.5		10.8		10.7	
	3	11.1		11.2		10.4		10.8		10.9	
	4	10.8		10.8		10.3		10.4		10.6	
	5	11.3		11.6		10.7		10.9		11.1	

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Annex B (informative)

Manufacture of secondary standards by centrifugal chill casting

B.1 Materials

As a result of tests carried out by the Russian delegation to IIW Commission II, it was found that centrifugally chill cast rings with a diameter of approximately 500 mm and wall thickness of approximately 20 mm, of nominally austenitic and duplex ferritic-austenitic chromium-nickel steels, exhibited a weld-metal-like microstructure through most of the wall thickness. In round robin tests among nine laboratories in six countries, it was established that the homogeneity of small blocks machined from rings of ferrite contents from near zero FN to about 100 FN was excellent over the whole range of interest. Such blocks could thus serve as secondary standards for calibration of various instruments. Due to the homogeneity of the blocks, they could be suitable, in particular, for calibrating instruments utilising magnetic saturation methods for determining a volumetric percentage of ferrite: thus, in principle, it would be possible to establish a relationship between FN and volumetric percent ferrite (FP) over a specific alloy range. Also, due to the homogeneity of the centrifugally cast metal, the preparation of samples having rectangular or cylindrical form and suitable to be certified in both FN and FP (the latter by utilising the magnetic saturation method) is possible. Such samples might then be used for calibrating volumetric and local devices.

Figure B.1 shows a sketch of a centrifugally chill cast ring from which the small blocks were machined. FN was measured at each of five points on each of the six surfaces of the blocks, measuring 10 mm × 12 mm × 20 mm, as shown in Figure B.2, during the round robin evaluations. Figure B.3 shows the overall average measurements for several samples, while Figure B.4 shows the averaged face centre results only. No significant difference can be noted between the face centre results and the overall results, attesting to the homogeneity of the blocks. Thus, one could, in principle, assign both an FN based upon surface measurements, and an FP based on volumetric measurement by magnetic saturation, to a given block or cylinder of this material.

As a result of the homogeneity of these samples as demonstrated in the round robin testing, IIW Commission II, by Resolution No. 4 taken during the 1993 Glasgow Annual Assembly, asked the Russian delegation (the company MLADIS) to proceed with production of rings to provide sets of eight blocks well distributed over the range of near zero FN to about 30 FN, and sets of eight blocks well distributed over the range of over 30 FN to

Dimensions in millimetres

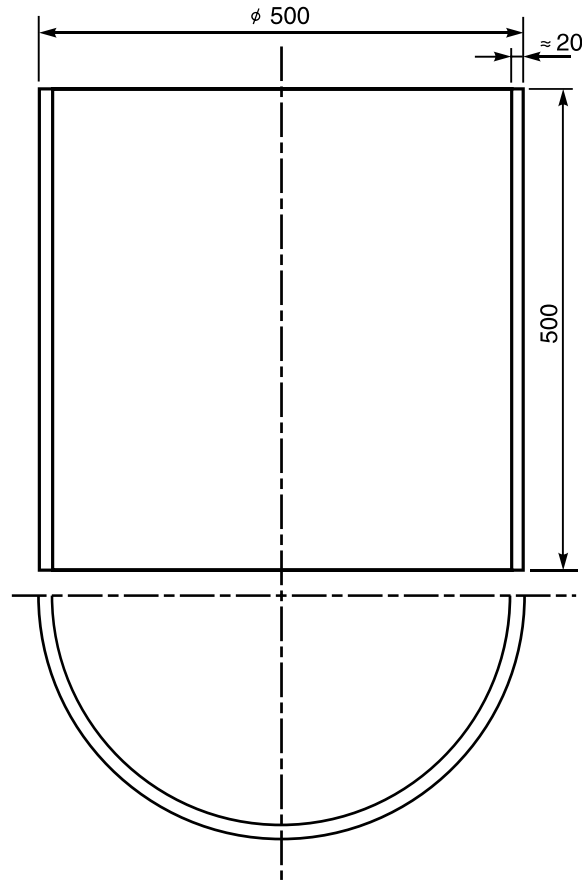


Figure B.1 — Centrifugally chill cast ring for secondary standards

Dimensions in millimetres

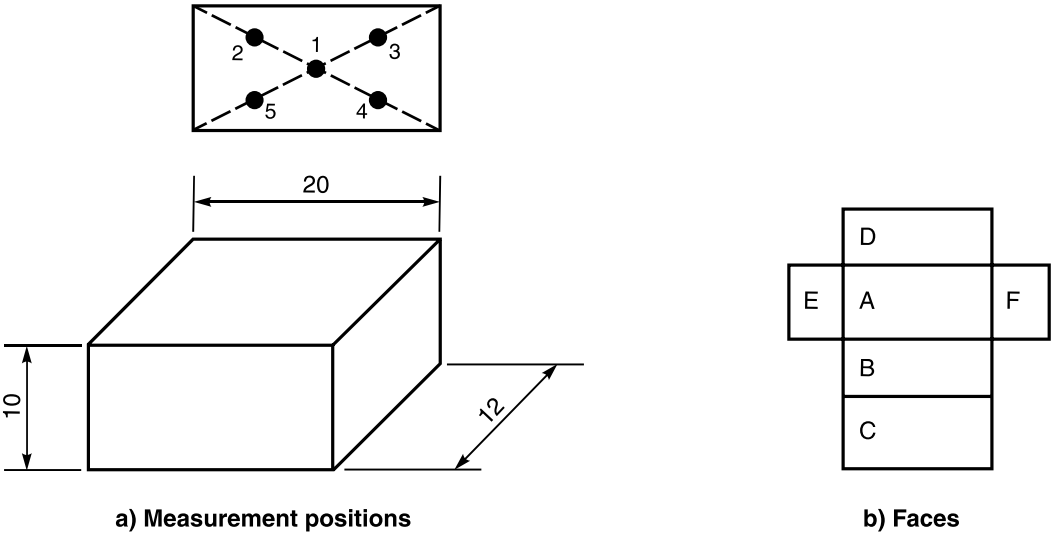


Figure B.2 — Dimensions and FN measurement positions on six faces of blocks machined from centrifugally chill cast rings

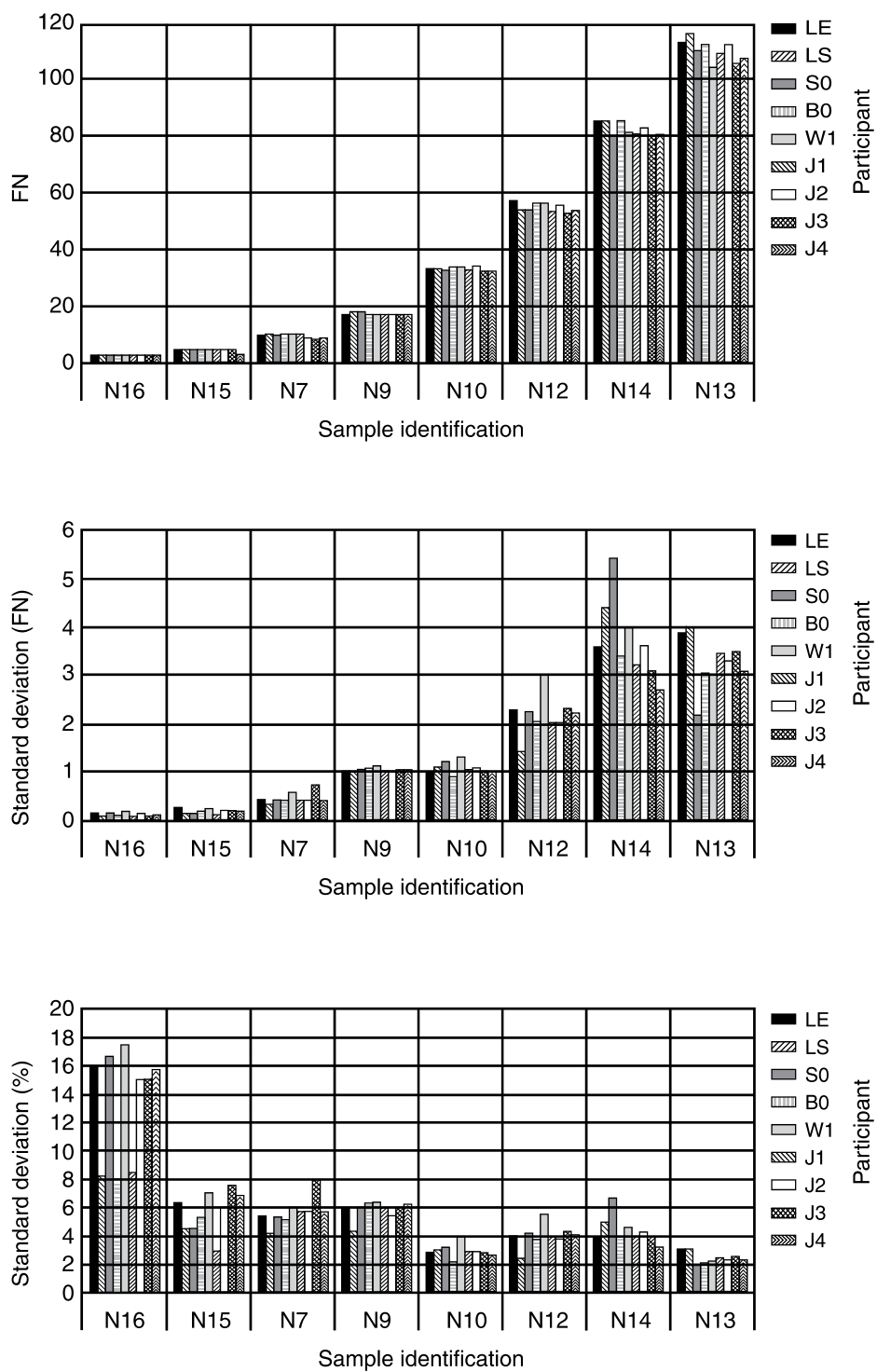


Figure B.3 — IIW Commission II, 6th round robin measurement results — Overall results

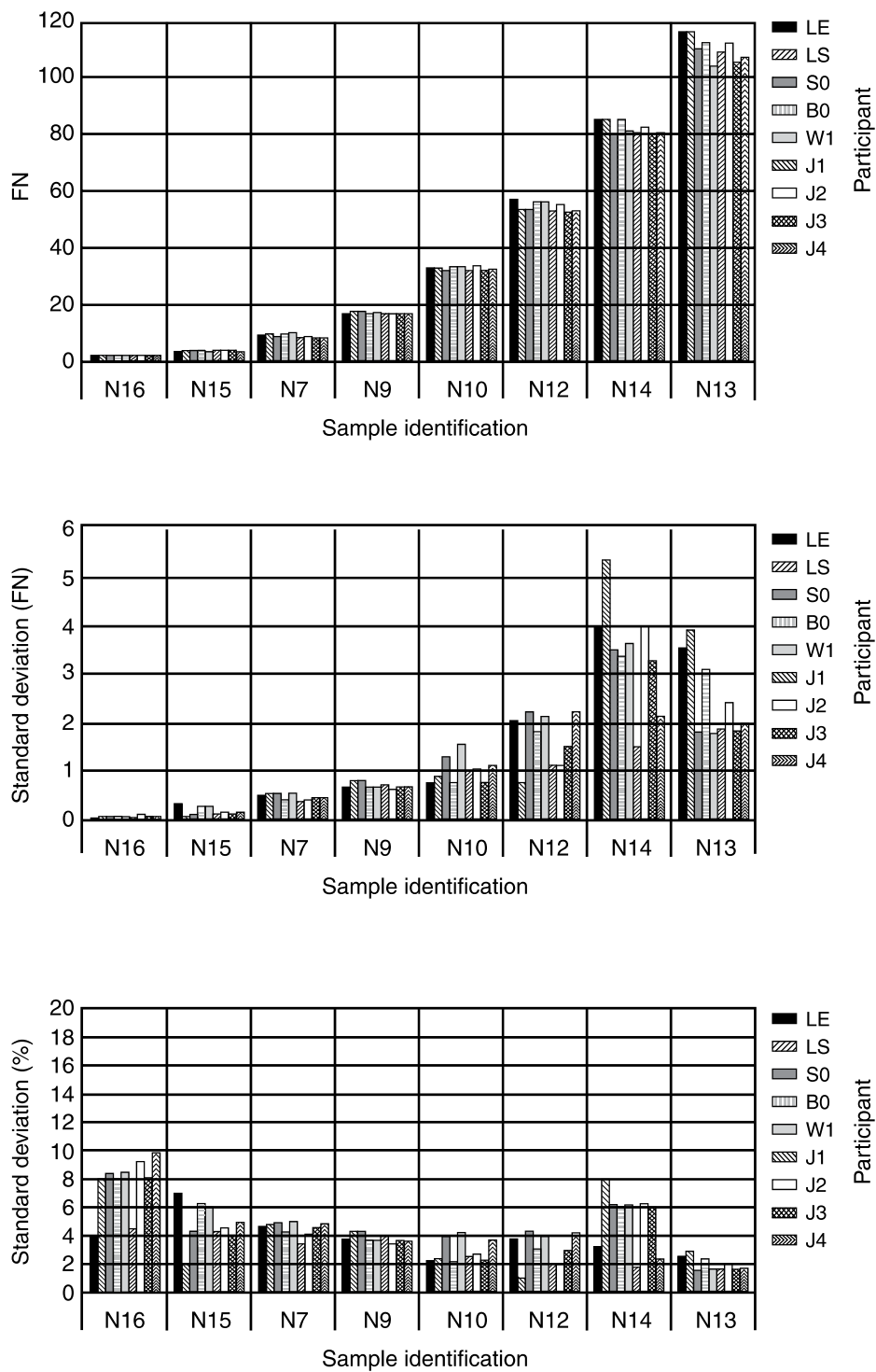


Figure B.4 — IIW Commission II, 6th round robin measurement results — Face centre results

about 110 FN. After machining, the individual blocks were provided to TWI for assignment of FN, packaging, and distribution to purchasers.

B.2 Machining and marking

The secondary samples were cut from the centrifugal cast rings by cold sawing. They were then machined to 10 mm × 12 mm × 20 mm and finished by machine grinding. The identification number of each sample was engraved on a 12 mm × 20 mm face, opposite to the test face; the latter face was left unmarked.

B.3 FN measuring instruments and calibration

Two “Magne-Gage” instruments, manufactured by the American Instrument Company (USA), were used to make FN measurements on each sample. The instruments and magnets used were as described in A.6.1, A.6.2 and A.6.3.

Calibration of the instruments for measurements up to 30 FN was carried out as in A.6.4. For measurements above 30 FN, the instruments were calibrated using the NIST coating thickness standards shown in Table B.1, with the counterweights indicated.

Table B.1 — NIST standard used for “Magne-Gage” calibration for centrifugally cast secondary standard samples

SRM No.	Standard reference No.	Nominal coating thickness mm	Counterbalance nominal weight g
1323	—	0.098	8
1323	—	0.111	8
1323	—	0.133	8
1323	—	0.173	8
1321	—	0.0344	16
1321	—	0.0377	16
1321	—	0.042	16
1321	—	0.048	16

B.4 Measuring procedure on secondary standards

B.4.1 Instruments and operators

Four complete sets of readings were taken on each set of eight ferrite secondary standards, by two operators each using both “Magne-Gages”.

A check calibration, using the appropriate primary standards, was carried out at the start of each day's work and after the measurement of a maximum of 4 sets (32 specimens) of secondary standards. These check measurements fell within the ranges of maximum deviation given in ANSI/AWS A4.2 and listed in Table B.2.

Table B.2 — Tolerance on the position of calibration points using primary standards

Ferrite number range	Maximum allowable deviation
$0 < \text{FN} \leq 5$	± 0.4
$5 < \text{FN} \leq 10$	± 0.5
$10 < \text{FN} \leq 15$	± 0.7
$15 < \text{FN} \leq 20$	± 0.9
$20 < \text{FN} \leq 30$	± 1.0
$30 < \text{FN} \leq 90$	$\pm 5 \% \text{ of assigned FN}$

B.4.2 Demagnetization

No attempt was made to demagnetize the standards, as the “Magne-Gage” has been reported to be insensitive to premagnetization.

B.4.3 Measurements on each ferrite standard

Each sample was positioned under the magnet so that the contact point was at the centre of the test face, i.e. at the intersection of imaginary lines drawn from opposite corners.

On each individual ferrite standard, five readings were taken at the measurement point, for each operator and “Magne-Gage”. A non-magnetic jig was fitted over the sample to aid rapid and accurate location of the measurement point. This jig consisted of a recessed block of plastic with a suitably sized and positioned hole. The standard was not repositioned between the individual measurements on any one point.

Each standard thus had a total of 20 “Magne-Gage” white dial readings taken from it. Readings by one operator using one “Magne-Gage” were completed within one measurement session.

B.4.4 Data recording and analysis

Data from the readings by each “Magne-Gage” operator were recorded together with the “Magne-Gage” number, FN calibration reference, date and operator’s name.

For ferrite levels up to 20 FN, each set of five white dial readings was averaged and an FN value produced from the appropriate calibration equation. For ferrite levels above 20 FN, the highest FN value was taken from the five white dial readings.

An average FN value for each standard was produced from the FN values for the measurements of the four operator/“Magne-Gage” combinations.

B.4.5 Presentation of results

The presentation of the results on the card accompanying each set of standards was as illustrated in the example in Table B.3. In addition, a label adjacent to each standard in the box showed the overall average FN value for all measurements on that standard. Values were quoted to 0.1 FN for samples up to 30 FN, and to 0.5 FN for samples covering the range 30 FN to about 100 FN.

Each boxed set of eight standards was also provided with a short booklet, briefly describing the preparation of the set.

Table B.3 — Examples of the tabular presentation of results of the card accompanying each box of centrifugally cast standards

(Secondary weld metal standards. Set No. 10 — February 1995)

Standard number	FN at test face centre				FN overall average
	Magne-Gage No. 1		Magne-Gage No. 2		
	Operator No. 1	Operator No. 2	Operator No. 1	Operator No. 2	
482	1	1.1	0.9	1.1	1
191	2	2.1	2.1	2	2.1
79	4.9	4.8	4.7	4.8	4.8
1331	8.3	8.5	8.2	7.9	8.2
1709	12	12	11.7	11.6	11.8
669	15.5	15.6	15.1	15.2	15.4
605	23.1	23	22.3	22.4	22.7
584	29.5	29	28.6	29.5	29.2

(Secondary weld metal standards. Set No. 30 — March 1995)

Standard number	FN at test face centre				FN overall average
	Magne-Gage No. 1		Magne-Gage No. 2		
	Operator No. 1	Operator No. 2	Operator No. 1	Operator No. 2	
733	32.5	33.5	32	31	32.5
1625	38.5	38.5	37.5	37	38
1845	41.5	39.5	41	41.5	41
913	48	49.5	51.5	50	50
240	58.5	58	59	58	58.5
1578	72.5	73	68	69	70.5
1203	83.5	82	79	82	82
1222	86.5	90.5	86.5	86.5	87.5

Bibliography

- [1] ISO 525:1999, *Bonded abrasive products — General requirements*.
- [2] ISO 4954:1993, *Steels for cold heading and cold extruding*.

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National Annexes

Annex C (Normative)

Calibration of Legacy Instruments with Primary Standards

This annex is a part of AWS A4.2M:2006 (ISO 8249:2000 MOD), *Standard Procedures for Calibrating Magnetic Instruments to Measure the Delta Ferrite Content of Austenitic and Duplex Ferritic-Austenitic Stainless Steel Weld Metal*, and includes mandatory elements for use with this standard.

C1. Introduction

Since each type of ferrite measuring instrument responds differently to the primary standards, it is not possible to use the same table of coating thickness versus Ferrite Number for all instruments. Depending primarily upon the volume sensed by the instrument probe, the calibration table is different for different instruments. It is a laborious process to develop a calibration table, such as Table 1 which is specific to one particular instrument (the Magne-Gage) with one particular magnet (the Number 3 magnet) as described in 4.2. To develop an appropriate calibration table, it is necessary to use secondary standards to find which instrument reading corresponds to which FN, with several instruments of the same design to take into account instrument variability, then determine the coating thickness of a primary standard which corresponds to a given instrument reading. This has been done only with two specific instruments other than a Magne-Gage.

C2. Scope

This Annex provides for calibration of a pre-1980 Fischer Feritscope Model FE8-KF with analog readout and dual-contact “normalized” probe, using primary standards. No tables for calibration with primary standards are available for post-1980 Feritscope instruments (those with digital readouts or single-pole probes). A separate calibration is provided for an Inspector Gage Model Number 111 with either a 6F (“% ferrite”) or a 7F (FN) scale.

C3. Calibration of a Fischer Feritscope⁸ Model FE8-KF with Primary Standards

C3.1 This instrument, with analog readout and dual-contact “normalized” probe, may have a scale reading in FN, but the scale shall be calibrated against the FN values given in Table C.1 for primary standards before using the instrument to determine Ferrite Number of weld samples. Alternately, the instrument may be calibrated with secondary standards as given in Clause 7.

C3.2 The manufacturer’s instructions with regard to the use of the instrument and the adjustments of the scale shall be followed.

C3.3 The FNs shall be assigned from Table C.1 to each of the available primary standards. For thicknesses between those given in Table C.1, the FNs shall be interpolated as closely as possible. Eight or more thickness standards shall be used, with nominal thickness corresponding to Ferrite Numbers well distributed in the range 0 to 25 FN. The instrument reading for each of the available primary standards shall then be determined.

C3.4 The instrument readings shall be plotted on Cartesian coordinates paper versus the FN assigned from Table C.1 for each primary standard. A “best fit” line shall be drawn through the data. Alternately, a regression

⁸ Both “Feritscope” and “Ferritescope” are used interchangeably and are trademarks of Helmut Fischer GmbH and Company.

Table C.1
Ferrite Numbers (FN) for Primary Standards for Feritscope Model FE8-KF Calibration

Coating Thickness mm	FN	Coating Thickness mm	FN	Coating Thickness mm	FN
2.00	1.9	0.72	7.3	0.38	13.1
1.90	2.1	0.70	7.5	0.37	13.4
1.80	2.3	0.68	7.7	0.36	13.8
1.70	2.6	0.66	8.0	0.35	14.1
1.60	2.8	0.64	8.2	0.34	14.5
1.50	3.1	0.62	8.4	0.33	14.9
1.45	3.3	0.60	8.7	0.32	15.3
1.40	3.5	0.58	9.0	0.31	15.7
1.35	3.7	0.56	9.3	0.30	16.2
1.30	3.8	0.54	9.6	0.29	16.7
1.25	4.0	0.52	9.9	0.28	17.2
1.20	4.3	0.50	10.3	0.27	17.8
1.15	4.5	0.49	10.4	0.26	18.4
1.10	4.7	0.48	10.6	0.25	19.1
1.05	5.0	0.47	10.8	0.24	19.8
1.00	5.3	0.46	11.1	0.23	20.5
0.95	5.6	0.45	11.3	0.22	21.4
0.90	5.9	0.44	11.5	0.21	22.3
0.85	6.2	0.43	11.7	0.20	23.3
0.80	6.6	0.42	12.0	0.19	24.4
0.78	6.8	0.41	12.3	0.18	25.6
0.76	7.0	0.40	12.5	—	—
0.74	7.1	0.39	12.8	—	—

equation shall be fit to the data collected as described in C3.3.

C3.5 For approved calibration, all readings shall fall within the maximum allowable deviations shown in Table C.2 from the “best fit” line. If any calibration readings fall outside of these allowed variations, the data shall be restudied, or the manufacturer of the instrument shall be consulted, or both.

Table C.2
Maximum Allowable Deviation
of the Periodic Ferrite Number (FN)
Check for Feritscopes/Ferritescopes

Ferrite Number Range	Maximum Allowable Deviation of the Periodic FN Check from the FN Assigned to the Primary Standard in Table C.1
0 to 5	±0.40
Over 5 to 10	±0.40
Over 10 to 15	±0.70
Over 15	±1.0

C3.6 The graph plotted as in C3.4, or a regression equation fit to it, may now be used to determine the FNs of stainless steel weld metals from the instrument reading.

C4. Calibration of Inspector Gages⁹

C4.1 This instrument is the Inspector Gage Model Number 111 with either a 6F (“% ferrite”) or a 7F (FN) scale. The latter is preferable because it has smaller divisions.

C4.2 The manufacturer’s instructions with regard to the use of the instrument and adjustments of the scale shall be followed.

C4.3 The FNs shall be assigned from Table C.3 to each of the available primary thickness standards. For thicknesses between those given in the table, the FNs shall be interpolated as closely as possible. Seven or more thickness standards shall be used, with nominal thicknesses corresponding to Ferrite Numbers well distributed in the range 0 to 30 FN. The instrument reading for each of the available primary standards shall then be determined.

⁹ Trademark of Elcometer Instruments Ltd.

Table C.3
Ferrite Numbers (FN) for Primary Standards for Inspector Gage Calibration

Coating Thickness mm	FN	Coating Thickness mm	FN	Coating Thickness mm	FN
2.00	3.9	0.88	11.2	0.53	18.1
1.95	4.1	0.86	11.5	0.52	18.4
1.90	4.3	0.84	11.7	0.51	18.7
1.85	4.5	0.82	12.0	0.50	19.0
1.80	4.7	0.80	12.3	0.49	19.3
1.75	4.9	0.78	12.6	0.48	19.7
1.70	5.2	0.76	13.0	0.47	20.0
1.65	5.4	0.74	13.3	0.46	20.4
1.60	5.6	0.72	13.7	0.45	20.8
1.55	5.9	0.70	14.0	0.44	21.2
1.50	6.1	0.69	14.2	0.43	21.6
1.45	6.4	0.68	14.4	0.42	22.0
1.40	6.7	0.67	14.6	0.41	22.4
1.35	7.0	0.66	14.8	0.40	22.9
1.30	7.3	0.65	15.0	0.39	23.3
1.25	7.7	0.64	15.3	0.38	23.8
1.20	8.0	0.63	15.5	0.37	24.3
1.15	8.4	0.62	15.7	0.36	24.8
1.10	8.9	0.61	15.9	0.35	25.4
1.05	9.3	0.60	16.2	0.34	25.9
1.00	9.8	0.59	16.4	0.33	26.5
0.98	10.0	0.58	16.7	0.32	27.1
0.96	10.3	0.57	16.9	0.31	27.8
0.94	10.5	0.56	17.2	0.30	28.4
0.92	10.7	0.55	17.5	0.29	29.1
0.90	11.0	0.54	17.8	0.28	29.9

C4.4 The instrument readings shall be plotted on Cartesian coordinates paper versus the FN assigned from Table C.3 for each primary standard. A “best fit” line shall be drawn through the data. Alternately, a regression equation shall be fit to the data collected as described in C4.3.

C4.5 For approved calibration, all readings shall fall within the maximum allowable deviations shown in Table C.4 from the “best fit” line. If any calibration readings fall outside of these allowed variations, the data shall be restudied, or the manufacturer of the instrument shall be consulted, or both.

Table C.4
Maximum Allowable Deviation
of the Periodic Ferrite Number (FN)
Check for Inspector Gages

Ferrite Number Range	Maximum Allowable Deviation of the Periodic FN Check from the FN Assigned to the Primary Standard in Table C.3
0 to 5	±0.40
Over 5 to 10	±0.40
Over 10 to 15	±0.70
Over 15	±1.0

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Annex D (Informative)

Instruments

This annex is not a part of AWS A4.2M:2006 (ISO 8249:2000 MOD), *Standard Procedures for Calibrating Magnetic Instruments to Measure the Delta Ferrite Content of Austenitic and Duplex Ferritic-Austenitic Stainless Steel Weld Metal*, but is included for informational purposes only.

D.1 Acknowledgment

These standard procedures are based upon studies and recommendations made by the Subcommittee on Welding Stainless Steel of the High Alloys Committee of the Welding Research Council (WRC)¹⁰ and work within International Institute of Welding Subcommittee II-C. The document on which much of this standard is based is the *Calibration Procedure for Instruments to Measure the Delta Ferrite Content of Austenitic Stainless Steel Weld Metal*, published by the WRC on July 1, 1972. Expansion of the measurement system beyond 28 FN is based upon *Extension of the WRC Ferrite Number System*, D. J. Kotecki, *Welding Journal*, November, 1982, and International Institute of Welding Documents II-C-730-84, II-C-821-88, II-C-835-88 and II-C-836-88.

D.2 Magne-Gage and Magne-Gage-Type Instruments

D2.1 The Magne-Gage¹¹ (Figure D.1) is usable only in the flat position on relatively small specimens. The probe is a long, thin magnet hung from one end of a balance beam, with a counterweight fixed to the other end of the balance beam. A spiral spring allows the force applied to the magnet to be varied. The spring is wound by means of turning a knob with a corresponding reading on a dial. When the magnet is pulled free of a specimen, the white dial reading used in conjunction with the calibration curve establishes the FN of the specimen.

¹⁰ Welding Research Council, P.O. Box 201547, Shaker Heights, OH 44120.

¹¹ Manufactured by Magne-Gage Sales & Service, 629 Packer Street, Avoca, PA 18641.

D2.2 Returning the Magne-Gage periodically to the factory for maintenance is desirable. With frequent use, one year is a reasonable time; with occasional use, two years.

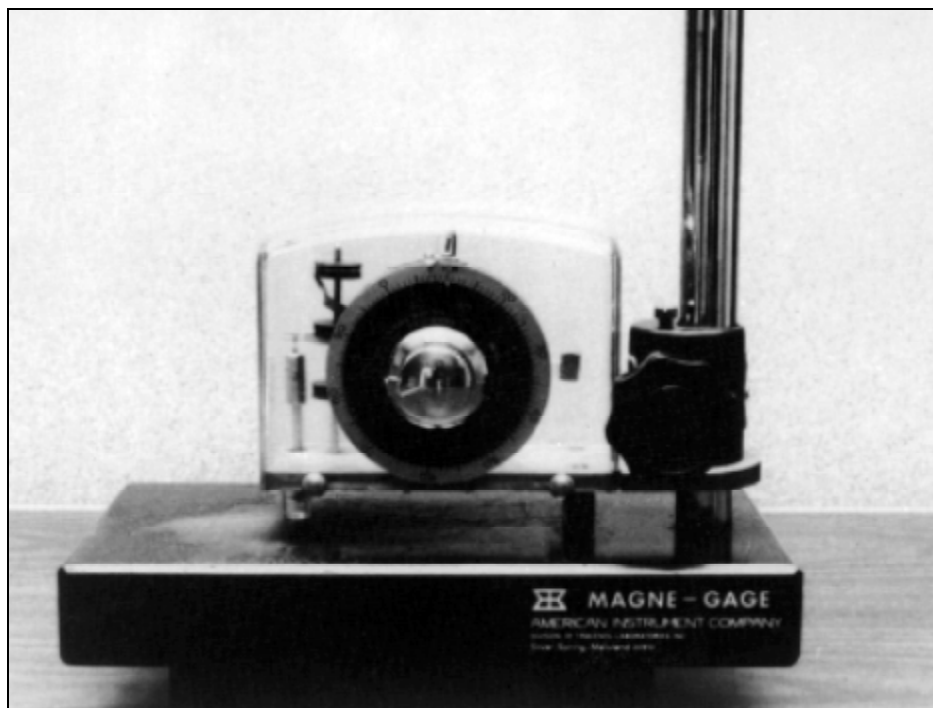
D2.3 A Magne-Gage No. 3 Magnet or equivalent can be used with a variety of torsion balances to obtain the same results as are obtained with a Magne-Gage. A complete example of such a Magne-Gage-type instrument is given in *Extension of the WRC Ferrite Number System*, referenced in E1. Numerous other configurations could also be conceived. This is outside the scope of this standard.

D2.4 A Magne-Gage No. 3 Magnet normally complies with the requirements of 4.2. Once this is verified, the Magne-Gage No. 3 Magnet can be used, after calibration with primary standards, for Ferrite Number measurement either with a Magne-Gage instrument, or with a suitably modified beam balance.

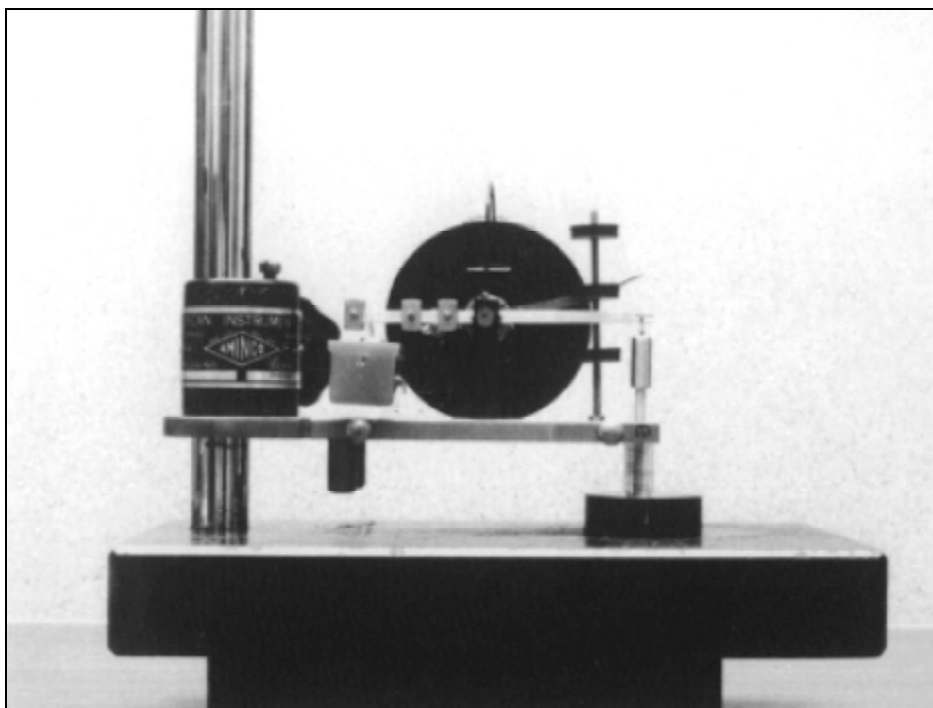
D3. Feritscope/Ferritescope¹²

These instruments, which consist of a probe connected by a cable to an electronics package (Figure D.2), are usable in any position. Several models and a variety of probes are available. Only one model and probe (FE8-KF) has been shown to be able to be calibrated with primary standards, as given in Table C.1. All other models must be calibrated with weld-metal-like secondary standards as no standard tables have been developed for calibration with primary standards. Models are available in either battery-powered or alternating current versions. At least one model (the MP30) can be calibrated with secondary standards up to 80 FN or more.

¹² Manufactured by Fischer Technology, 750 Marshall Phelps Road, Windsor, CT 06095.

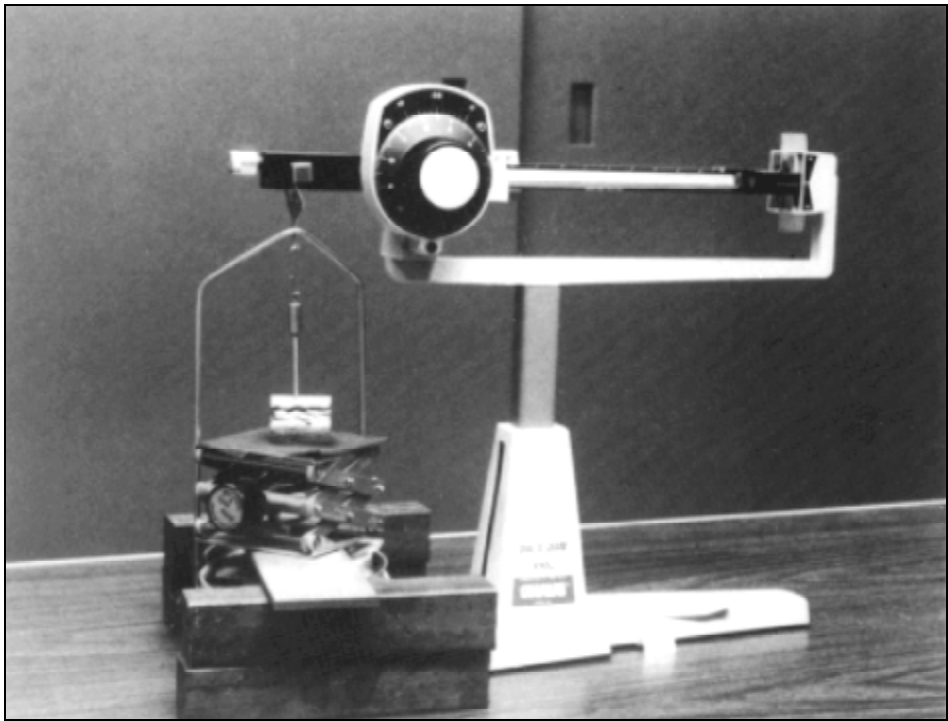


(A) STANDARD MAGNE-GAGE



(B) MAGNE-GAGE FROM REAR, COUNTERWEIGHT ADDED TO LEFT SIDE OF BALANCE BEAM

Figure D.1—Magne-Gage-Type Instruments



(C) TORSION BALANCE WITH MAGNE-GAGE NO. 3 MAGNET

Figure D.1 (Continued)—Magne-Gage-Type Instruments

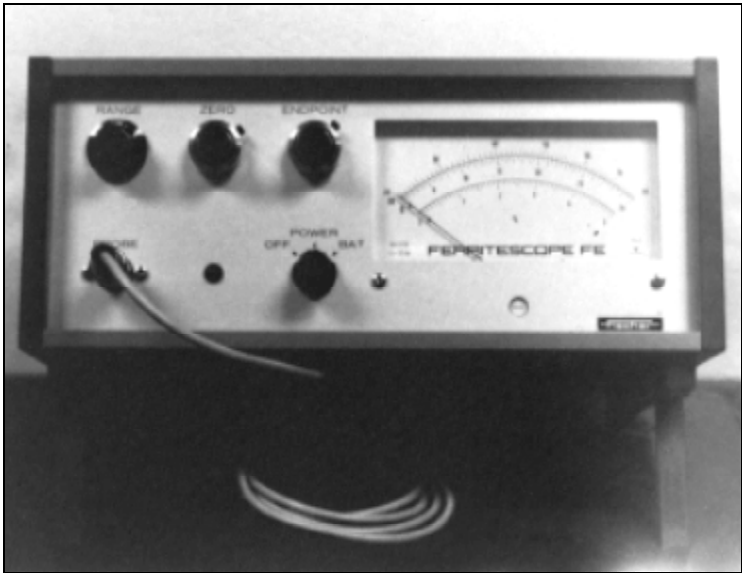


Figure D.2—Ferritescope Model FE8-KF

D4. Inspector Gage¹³

This instrument (Figure D.3) is usable in any position. It is a hand-held magnetic instrument with thumb-actuated spring tension. The instrument gives direct readings in FN if it is a new model designed to do so. Older models can be rebuilt by the manufacturer to give acceptable readings on weld metal in terms of FN. At the time of this printing, the ability of Inspector Gages to determine ferrite above 30 FN is unknown. The Inspector Gage Model Number 111 with either a 6F (“% ferrite”) or a 7F (FN) scale can be calibrated with primary standards according to D4. Other models can only be calibrated with secondary standards.

D5. Other Instruments

The following instruments at the time of the writing of this revision are not capable of being calibrated to primary standards. They can, however, be calibrated with weld-metal-like secondary standards and produce acceptable consistent results. Again, it is the responsibility of the user to ensure that instrument calibration is maintained and to have the instrument repaired by the manufacturer if consistent readings on the weld-metal-like secondary standards cannot be obtained. At the time

¹³ Manufactured by Elcometer, Inc., 1893 Rochester Industrial Drive, Rochester Hills, MI 48309.

of this printing, the ability of these instruments to determine ferrite above 30 FN is unknown.

D5.1 Ferrite Indicator.¹⁴ This instrument (Figure D.4) is commonly called a Severn Gage. It is usable in any position. It is a go-no-go type gage which determines whether the ferrite content of the weld under test is above or below that of each of a number of inserts of various magnetic strengths which come with the instrument. At least one unthreaded test insert must be available for use in conjunction with one of the threaded inserts with specified FN values. The purpose of the unthreaded inserts is to assure that the magnet has not lost strength. Details may be obtained from the manufacturer for conversion of percent-ferrite values on earlier model Severn gages to FN. Severn gages calibrated directly in terms of FN are now available. Older model gages can be converted to the FN scale by the manufacturer. Calibration of a Severn gage with secondary standards can only be approximate because the Severn gage does not provide a discrete FN test value, only a range of possible FN values for the sample under test.

D5.2 Foerster Ferrite Content Meter.¹⁵ This is a light battery-powered instrument (Figure D.5) usable in any position. It closely resembles the Feritscope in its operation

¹⁴ Manufactured by Severn Engineering Co., Inc., 98 Edgewood Street, Annapolis, MD 21401.

¹⁵ Marketed by Foerster Instrument, Inc., 140 Industry Drive, RIDC Park West, Pittsburgh, PA 15275.



Figure D.3—Inspector Gage



Figure D.4—Ferrite Indicator (Severn Gage)

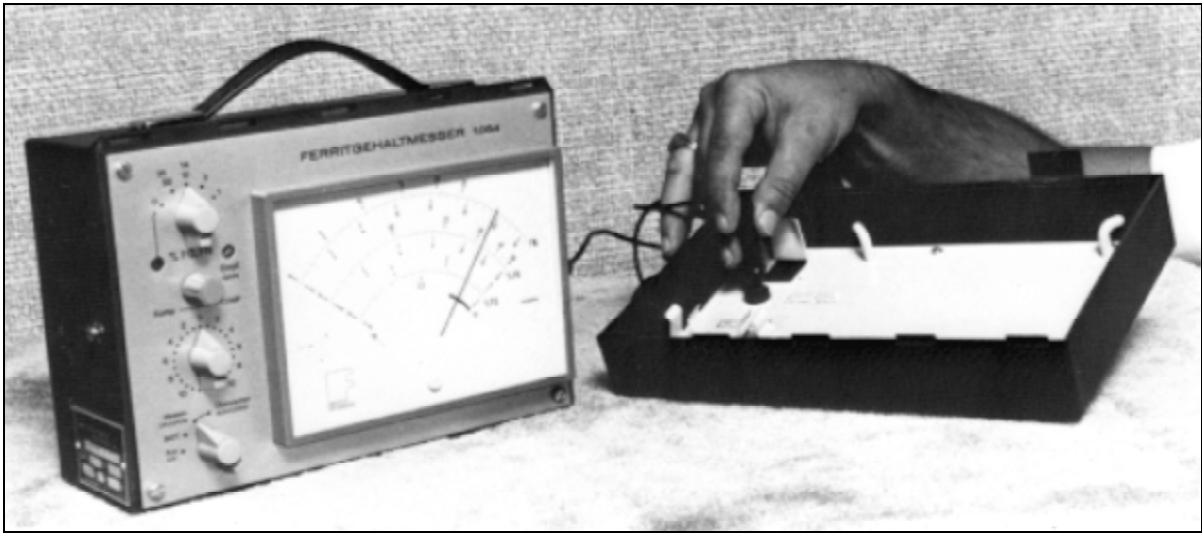


Figure D.5—Foerster Ferrite Content Meter

except that it has a single contact-point probe which allows ferrite determination in very localized regions. On older models, the meter output indicates ferrite content as a percentage, which can be effectively converted to FN values by use of suitable weld-metal-like secondary standards to produce a satisfactory calibration curve. Newer models are now available on which the meter reads directly in FN values.

D5.3 Unspecified Instruments. A number of other magnetic measuring instruments are available for various

purposes. Many are regarded as not suitable in their present form because of limitations such as range, problems in calibration, or varying response due to the position of use or to their relation to the north-to-south magnetic field lines of the earth. Instruments which are suitable in other respects must still be calibrated to the FN scale in a manner traceable to this standard. This can be accomplished by the use of a set of weld-metal-like secondary standards, as specified in Clause 7. The establishment of an adequate correlation is the responsibility of the user.

Annex E (Informative)

Guidelines for the Preparation of Technical Inquiries

This annex is not a part of AWS A4.2M:2006 (ISO 8249:2000 MOD), *Standard Procedures for Calibrating Magnetic Instruments to Measure the Delta Ferrite Content of Austenitic and Duplex Ferritic-Austenitic Stainless Steel Weld Metal*, but is included for informational purposes only.

E1. Introduction

The American Welding Society (AWS) Board of Directors has adopted a policy whereby all official interpretations of AWS standards are handled in a formal manner. Under this policy, all interpretations are made by the committee that is responsible for the standard. Official communication concerning an interpretation is directed through the AWS staff member who works with that committee. The policy requires that all requests for an interpretation be submitted in writing. Such requests will be handled as expeditiously as possible, but due to the complexity of the work and the procedures that must be followed, some interpretations may require considerable time.

E2. Procedure

All inquiries shall be directed to:

Managing Director
Technical Services Division
American Welding Society
550 N.W. LeJeune Road
Miami, FL 33126

All inquiries shall contain the name, address, and affiliation of the inquirer, and they shall provide enough information for the committee to understand the point of concern in the inquiry. When the point is not clearly defined, the inquiry will be returned for clarification. For efficient handling, all inquiries should be typewritten and in the format specified below.

E2.1 Scope. Each inquiry shall address one single provision of the standard unless the point of the inquiry involves two or more interrelated provisions. The provi-

sion(s) shall be identified in the scope of the inquiry along with the edition of the standard that contains the provision(s) the inquirer is addressing.

E2.2 Purpose of the Inquiry. The purpose of the inquiry shall be stated in this portion of the inquiry. The purpose can be to obtain an interpretation of a standard's requirement or to request the revision of a particular provision in the standard.

E2.3 Content of the Inquiry. The inquiry should be concise, yet complete, to enable the committee to understand the point of the inquiry. Sketches should be used whenever appropriate, and all paragraphs, figures, and tables (or annex) that bear on the inquiry shall be cited. If the point of the inquiry is to obtain a revision of the standard, the inquiry shall provide technical justification for that revision.

E2.4 Proposed Reply. The inquirer should, as a proposed reply, state an interpretation of the provision that is the point of the inquiry or provide the wording for a proposed revision, if this is what the inquirer seeks.

E3. Interpretation of Provisions of the Standard

Interpretations of provisions of the standard are made by the relevant AWS technical committee. The secretary of the committee refers all inquiries to the chair of the particular subcommittee that has jurisdiction over the portion of the standard addressed by the inquiry. The subcommittee reviews the inquiry and the proposed reply to determine what the response to the inquiry should be. Following the subcommittee's development of the response, the inquiry and the response are presented to

the entire committee for review and approval. Upon approval by the committee, the interpretation is an official interpretation of the Society, and the secretary transmits the response to the inquirer and to the *Welding Journal* for publication.

E4. Publication of Interpretations

All official interpretations will appear in the *Welding Journal* and will be posted on the AWS web site.

E5. Telephone Inquiries

Telephone inquiries to AWS Headquarters concerning AWS standards should be limited to questions of a general nature or to matters directly related to the use of the standard. The AWS Board of Directors' policy requires that all AWS staff members respond to a telephone request for an official interpretation of any AWS stan-

dard with the information that such an interpretation can be obtained only through a written request. Headquarters staff cannot provide consulting services. However, the staff can refer a caller to any of those consultants whose names are on file at AWS Headquarters.

E6. AWS Technical Committees

The activities of AWS technical committees regarding interpretations are limited strictly to the interpretation of provisions of standards prepared by the committees or to consideration of revisions to existing provisions on the basis of new data or technology. Neither AWS staff nor the committees are in a position to offer interpretive or consulting services on (1) specific engineering problems, (2) requirements of standards applied to fabrications outside the scope of the document, or (3) points not specifically covered by the standard. In such cases, the inquirer should seek assistance from a competent engineer experienced in the particular field of interest.

Annex F (Informative)

List of Deviations from ISO 8249:2000

This annex is not a part of AWS A4.2M:2006 (ISO 8249:2000 MOD), *Standard Procedures for Calibrating Magnetic Instruments to Measure the Delta Ferrite Content of Austenitic and Duplex Ferritic-Austenitic Stainless Steel Weld Metal*, but is included for informational purposes only.

Additional Normative Annex:

Annex C, *Calibration of Legacy Instruments with Primary Standards*

Additional Informative Annexes:

Annex D, *Instruments*

Annex E, *Guidelines for the Preparation of Technical Inquiries*

Editorial Changes:

The title has been changed from *Welding — Determination of Ferrite Number (FN) in austenitic and duplex ferritic-austenitic Cr-Ni stainless steel weld metals* to *Standard Procedures for Calibrating Magnetic Instruments to Measure the Delta Ferrite Content of Austenitic and Duplex Ferritic-Austenitic Stainless Steel Weld Metal*.

In all cases changed “This International standard” to “This standard.”

In the Scope changed “manual metal arc” to “shielded metal arc.”

Added new subclause 4.5.

Added zeroes in Table 1 after decimal to make these figures consistent.

Added “Shielded Metal Arc” in title of Clause 5.

Changed “manual” to “shielded metal arc covered” in 5.1.

Deleted “be” after “should” in the Note of Figure 2.

Changed “laid” to “deposited” in 5.2 item f.

Changed “over” to “of” in 5.2, item e.

Added reference to Annex D in 7.1.

Deleted “to hand” from the end of second sentence of 7.3.

Added after first two sentences in Clause 8, “The first set of secondary standards was made by Teledyne McKay in the late 1960s. These were a build up of SMAW much like the pad shown in 5.2. They were used to develop the FN system of measuring ferrite as we know it today, replacing the % ferrite system previously used. Teledyne McKay subsequently produced and sold sets of these secondary standards, but ceased doing so in the late 1970s.”

Added “last” in Clause 8, last sentence.

Added apostrophe to third line of A.3.1 to read ‘2’ – ‘2’.

Changed “National Bureau of Standards (NBS)” to “National Institute of Standards and Technology (NIST)” in A.6.3.

Added footnote 7 “NIST was formerly named National Bureau of Standards (NBS).”

Changed “NBS” to “NIST” in A.6.3, Table A.3, and A.6.4.

Changed “by one operator” to “for each operator and” in the last sentence of A.7.3.

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AWS Filler Metal Specifications by Material and Welding Process

	OFW	SMAW	GTAW GMAW PAW	FCAW	SAW	ESW	EGW	Brazing
Carbon Steel	A5.2	A5.1	A5.18	A5.20	A5.17	A5.25	A5.26	A5.8, A5.31
Low-Alloy Steel	A5.2	A5.5	A5.28	A5.29	A5.23	A5.25	A5.26	A5.8, A5.31
Stainless Steel		A5.4	A5.9, A5.22	A5.22	A5.9	A5.9	A5.9	A5.8, A5.31
Cast Iron	A5.15	A5.15	A5.15	A5.15				A5.8, A5.31
Nickel Alloys		A5.11	A5.14		A5.14			A5.8, A5.31
Aluminum Alloys		A5.3	A5.10					A5.8, A5.31
Copper Alloys		A5.6	A5.7					A5.8, A5.31
Titanium Alloys			A5.16					A5.8, A5.31
Zirconium Alloys			A5.24					A5.8, A5.31
Magnesium Alloys			A5.19					A5.8, A5.31
Tungsten Electrodes			A5.12					
Brazing Alloys and Fluxes								A5.8, A5.31
Surfacing Alloys	A5.21	A5.13	A5.21	A5.21	A5.21			
Consumable Inserts			A5.30					
Shielding Gases			A5.32	A5.32			A5.32	

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AWS Filler Metal Specifications and Related Documents

Designation	Title
FMC	<i>Filler Metal Comparison Charts</i>
IFS	<i>International Index of Welding Filler Metal Classifications</i>
UGFM	<i>User's Guide to Filler Metals</i>
A4.2M (ISO 8249 MOD)	<i>Standard Procedures for Calibrating Magnetic Instruments to Measure the Delta Ferrite Content Austenitic and Duplex Ferritic-Austenitic Stainless Steel Weld Metal</i>
A4.3	<i>Standard Methods for Determination of the Diffusible Hydrogen Content of Martensitic, Bainitic, and Ferritic Steel Weld Metal Produced by Arc Welding</i>
A4.4M	<i>Standard Procedures for Determination of Moisture Content of Welding Fluxes and Welding Electrode Flux Coverings</i>
A5.01	<i>Filler Metal Procurement Guidelines</i>
A5.1/A5.1M	<i>Specification for Carbon Steel Electrodes for Shielded Metal Arc Welding</i>
A5.2	<i>Specification for Carbon and Low Alloy Steel Rods for Oxyfuel Gas Welding</i>
A5.3/A5.3M	<i>Specification for Aluminum and Aluminum-Alloy Electrodes for Shielded Metal Arc Welding</i>
A5.4/A5.4M	<i>Specification for Stainless Steel Electrodes for Shielded Metal Arc Welding</i>
A5.5/A5.5M	<i>Specification for Low-Alloy Steel Electrodes for Shielded Metal Arc Welding</i>
A5.6	<i>Specification for Covered Copper and Copper Alloy Arc Welding Electrodes</i>
A5.7	<i>Specification for Copper and Copper Alloy Bare Welding Rods and Electrodes</i>
A5.8/A5.8M	<i>Specification for Filler Metals for Brazing and Braze Welding</i>
A5.9/A5.9M	<i>Specification for Bare Stainless Steel Welding Electrodes and Rods</i>
A5.10/A5.10M	<i>Specification for Bare Aluminum and Aluminum-Alloy Welding Electrodes and Rods</i>
A5.11/A5.11M	<i>Specification for Nickel and Nickel-Alloy Welding Electrodes for Shielded Metal Arc Welding</i>
A5.12/A5.12M	<i>Specification for Tungsten and Tungsten-Alloy Electrodes for Arc Welding and Cutting</i>
A5.13	<i>Specification for Surfacing Electrodes for Shielded Metal Arc Welding</i>
A5.14/A5.14M	<i>Specification for Nickel and Nickel-Alloy Bare Welding Electrodes and Rods</i>
A5.15	<i>Specification for Welding Electrodes and Rods for Cast Iron</i>
A5.16/A5.16M	<i>Specification for Titanium and Titanium Alloy Welding Electrodes and Rods</i>
A5.17/A5.17M	<i>Specification for Carbon Steel Electrodes and Fluxes for Submerged Arc Welding</i>
A5.18/A5.18M	<i>Specification for Carbon Steel Electrodes and Rods for Gas Shielded Arc Welding</i>
A5.19	<i>Specification for Magnesium Alloy Welding Electrodes and Rods</i>
A5.20/A5.20M	<i>Specification for Carbon Steel Electrodes for Flux Cored Arc Welding</i>
A5.21	<i>Specification for Bare Electrodes and Rods for Surfacing</i>
A5.22	<i>Specification for Stainless Steel Electrodes for Flux Cored Arc Welding and Stainless Steel Flux Cored Rods for Gas Tungsten Arc Welding</i>
A5.23/A5.23M	<i>Specification for Low-Alloy Steel Electrodes and Fluxes for Submerged Arc Welding</i>
A5.24/A5.24M	<i>Specification for Zirconium and Zirconium Alloy Welding Electrodes and Rods</i>
A5.25/A5.25M	<i>Specification for Carbon and Low-Alloy Steel Electrodes and Fluxes for Electroslag Welding</i>
A5.26/A5.26M	<i>Specification for Carbon and Low-Alloy Steel Electrodes for Electrode Gas Welding</i>
A5.28/A5.28M	<i>Specification for Low-Alloy Steel Electrodes and Rods for Gas Shielded Arc Welding</i>
A5.29/A5.29M	<i>Specification for Low-Alloy Steel Electrodes for Flux Cored Arc Welding</i>
A5.30	<i>Specification for Consumable Inserts</i>
A5.31	<i>Specification for Fluxes for Brazing and Braze Welding</i>
A5.32/A5.32M	<i>Specification for Welding Shielding Gases</i>

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