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ISO 8249

Second edition
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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

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Contents

Page

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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

International Standard ISO 8249 was prepared in collaboration with the International Institute of Welding which has been approved by the ISO Council as an international standardizing body in the field of welding.

This second edition cancels and replaces the first edition (ISO 8249:1985), which has been technically revised.

Annexes A and B of this International Standard are for information only.

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 International Standard. 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 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, laid down in this International 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 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.

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

1 Scope

This International 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 steel[1)] 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 International 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 International Standard. For dated references, subsequent amendments to, or revisions of, this publication do not apply. However, parties to agreements based on this International 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 curve[2].

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.

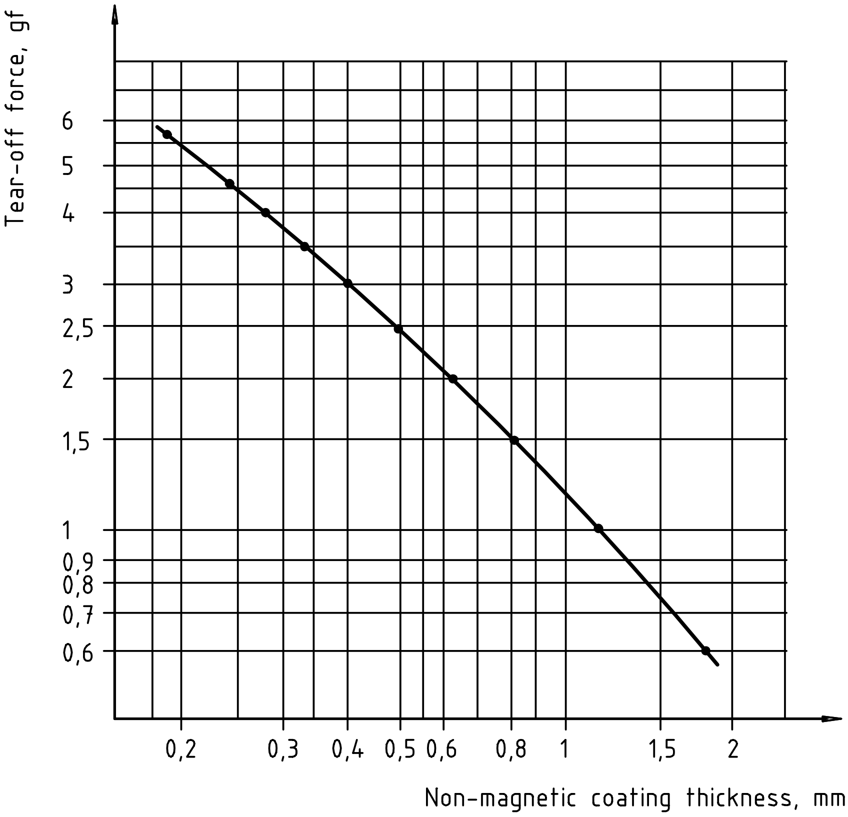


Figure 1 — Relationship between the tear-off forces of the standard magnet defined in 4.2 and the coating thickness standards defined in 4.1

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:

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

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

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 recommended.[3)] 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.

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	0,134	35,3	0,3	19,1
0,021	108	0,05	67,5	0,079	50,6	0,136	34,9	0,32	18,1
0,022	105,7	0,051	66,7	0,08	50,2	0,138	34,5	0,34	17,2
0,023	103,4	0,052	56,9	0,082	49,3	0,14	34,2	0,36	16,4
0,024	101,3	0,053	65,1	0,084	48,6	0,142	33,8	0,38	15,7
0,025	99,2	0,054	64,4	0,086	47,8	0,144	33,5	0,4	15
0,026	97,3	0,055	63,7	0,088	47,1	0,146	33,2	0,42	14,4
0,027	95,4	0,056	63	0,09	46,4	0,148	32,8	0,44	13,8
0,028	93,6	0,057	62,3	0,092	45,7	0,15	32,5	0,46	13,2
0,029	91,9	0,058	61,6	0,094	45,1	0,155	31,7	0,48	12,7
0,03	90,3	0,059	60,9	0,096	44,4	0,16	31	0,5	12,3
0,031	88,7	0,06	60,3	0,098	43,8	0,165	30,3	0,55	11,2
0,032	87,2	0,061	59,7	0,1	43,2	0,17	29,7	0,6	10,3
0,033	85,8	0,062	59,1	0,102	42,6	0,175	29	0,65	9,6
0,034	84,4	0,063	58,5	0,104	42,1	0,18	28,4	0,7	8,9
0,035	83	0,064	57,9	0,106	41,5	0,185	27,9	0,75	8,3
0,036	81,7	0,065	57,3	0,108	41	0,19	27,3	0,8	7,7
0,037	80,5	0,066	56,8	0,11	40,5	0,195	26,8	0,9	6,8
0,038	79,3	0,067	56,2	0,112	40	0,2	26,3	1	6,1
0,039	78,1	0,068	55,7	0,114	39,5	0,205	25,8	1,2	4,93
0,04	77	0,069	55,2	0,116	39	0,21	25,3	1,4	4,09
0,041	75,9	0,07	54,7	0,118	38,6	0,22	24,4	1,6	3,45
0,042	74,8	0,071	54,2	0,12	38,1	0,23	23,6	1,8	2,94
0,043	73,8	0,072	53,7	0,122	37,7	0,24	22,8	2	2,54
0,044	72,8	0,073	53,2	0,124	37,2	0,25	22,1	2,2	2,21
0,045	71,8	0,074	52,8	0,126	36,8	0,26	21,4	2,4	1,94
0,046	70,9	0,075	52,3	0,128	36,4	0,27	20,8	2,6	1,72
0,047	70	0,076	51,9	0,13	36	0,28	20,2	2,8	1,53
0,048	69,1	0,077	51,4	0,132	35,6	0,29	19,6	3	1,36

5 Standard method for covered electrode test pads

5.1 Dimensions of weld metal test specimens

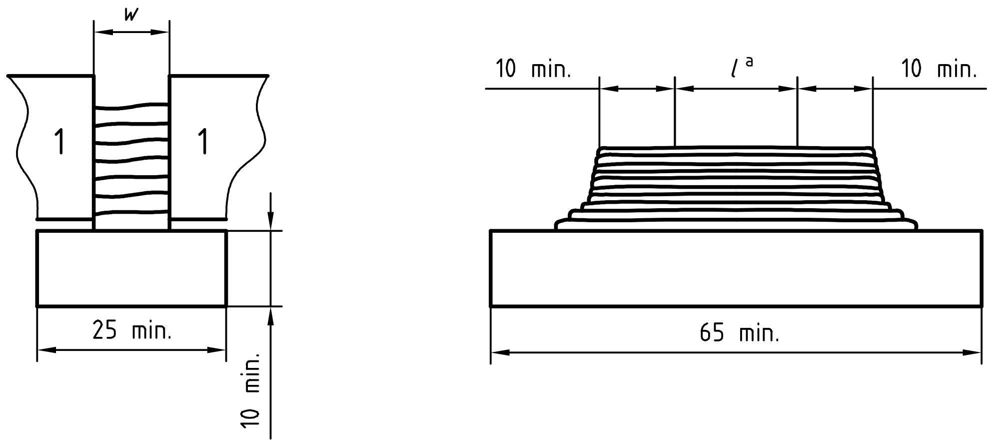
Standard weld metal test specimens for manual electrodes shall be of the size and shape indicated in Figure 2. For the measurement of ferrite content by instruments/magnets or processes other than those specified in 4.2 and 4.3, a larger specimen may be necessary. In such cases, the size and way of producing 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 × the core wire diameter. The arc shall not be allowed to come into contact with the copper bar.

Dimension in millimetres



Key

1 Copper bar of dimensions 70 × 25 × 25

NOTE The base metal should be preferably be austenitic Cr-Ni steel type X2CrNi18-9 or X5CrNi18-9 (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 over 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 laid.

g) In all cases, the topmost layer, at least, shall consist of a single bead deposited with a maximum weave of 3 × the core wire diameter.

Table 2 — Welding parameters and deposit dimensions

Electrode diameter	**Welding current** [a]	**Approximate dimensions**	
		width (w)	length (l)
mm	A	mm	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 working[4)] 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.

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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 laid down in this International 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 laid down in this International 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.

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 laid down in this International Standard, even if calibrated in accordance with 7.1, may, under certain circumstances, differ from those obtained by the method laid down in this International Standard. Hence, in cases of dispute, the method laid down in this International Standard shall be used.

On a given specimen, the average FN as determined by other methods and compared with measurements obtained with the method laid down in this International 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 to hand. 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
$0 < FN \leqslant 4$	± 0,5
$4 < FN \leqslant 10$	± 0,5
$10 < FN \leqslant 16$	± 0,6
$16 < FN \leqslant 25$	± 0,8
$25 < FN \leqslant 50$	± 5 % of assigned FN
$50 < FN \leqslant 110$	± 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. Therefore in about 1980, the International Institute of Welding (IIW) requested some organisations, 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 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.

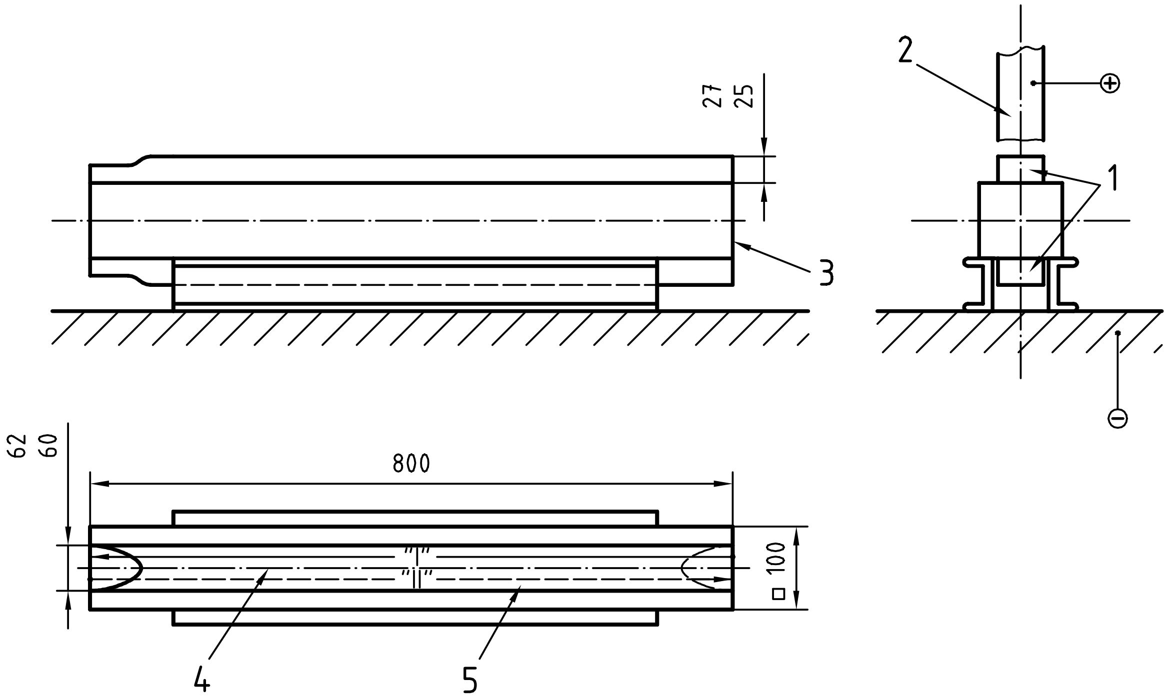
The bead deposition sequence is shown in Figure A.2. To minimize the distortion of the base metal, one side of the bar was first clad with three layers. After turning the bar, three layers were welded on the opposite side.

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

Dimensions in millimetres



Key

1 Weld deposit, 7 layers

2 Strip consumable

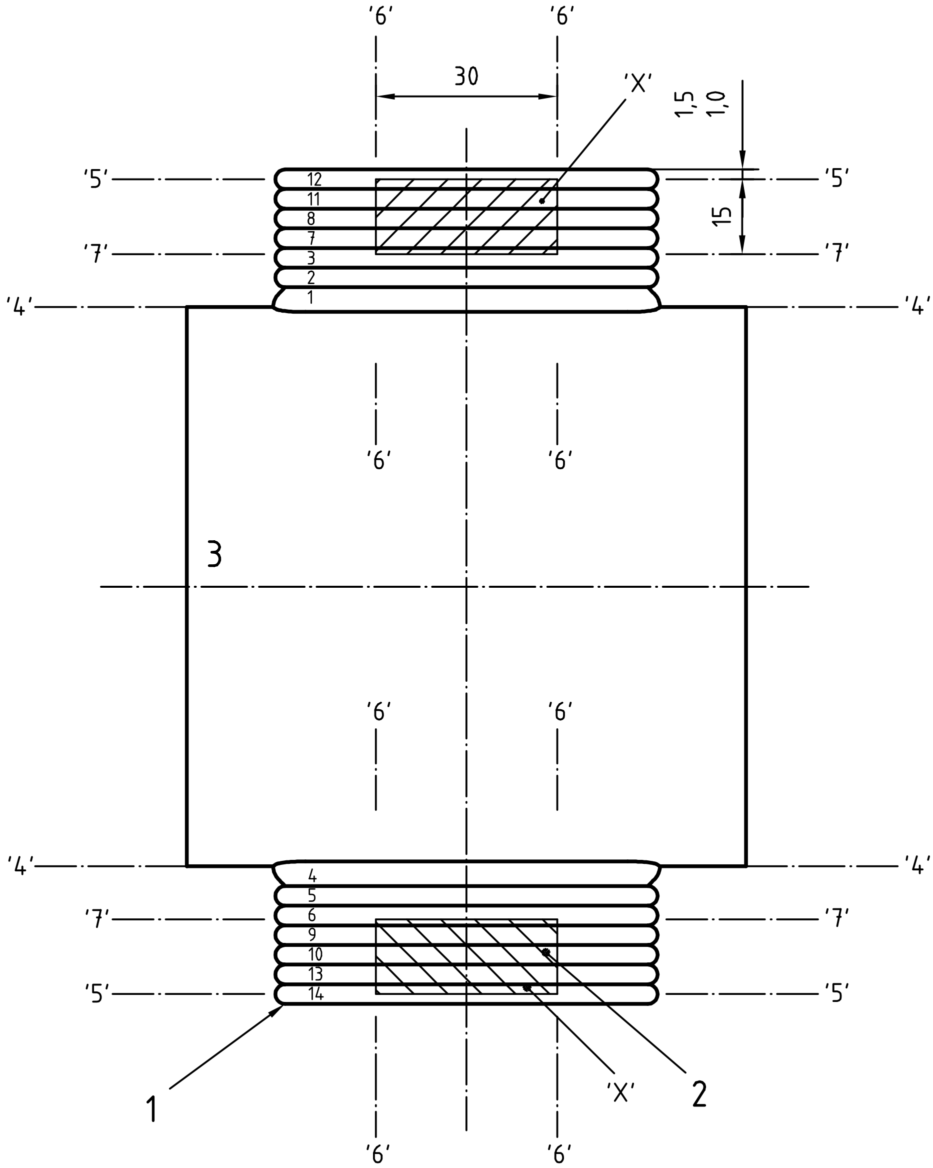
3 Base metal

4 Passes 1, 3, 5, 7 on each side

5 Passes 2, 4, 6 on each side

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'.

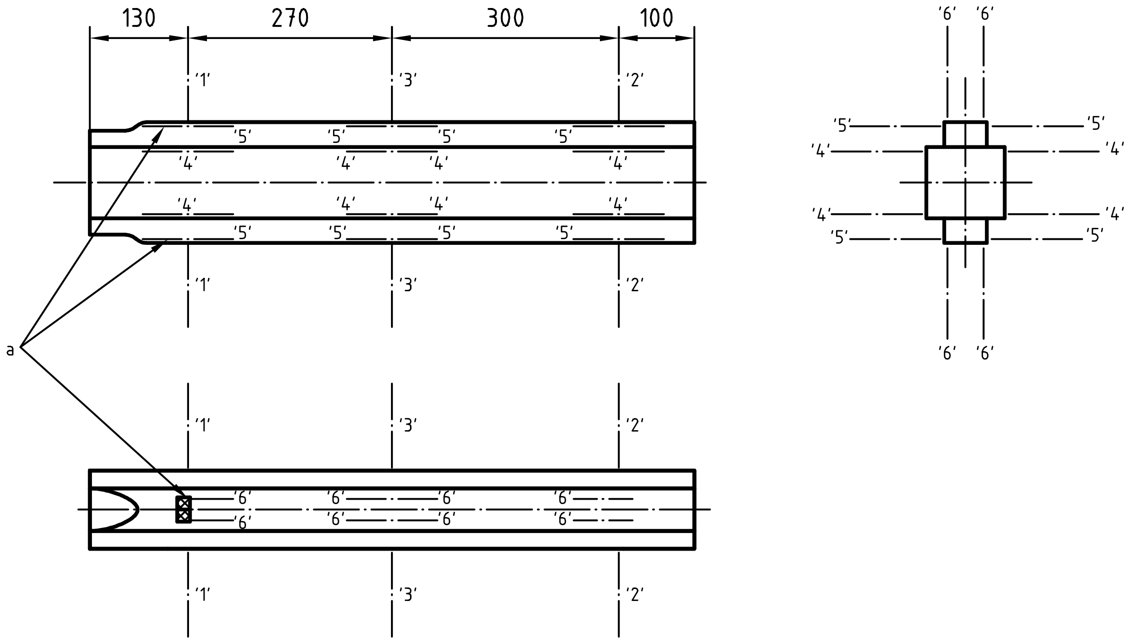
The rest of the bar was divided along lines '3' — '3', and the deposits separated from the base metal along lines '4' — '4'. See Figure A.3.

The rough preparation of the test surfaces 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).

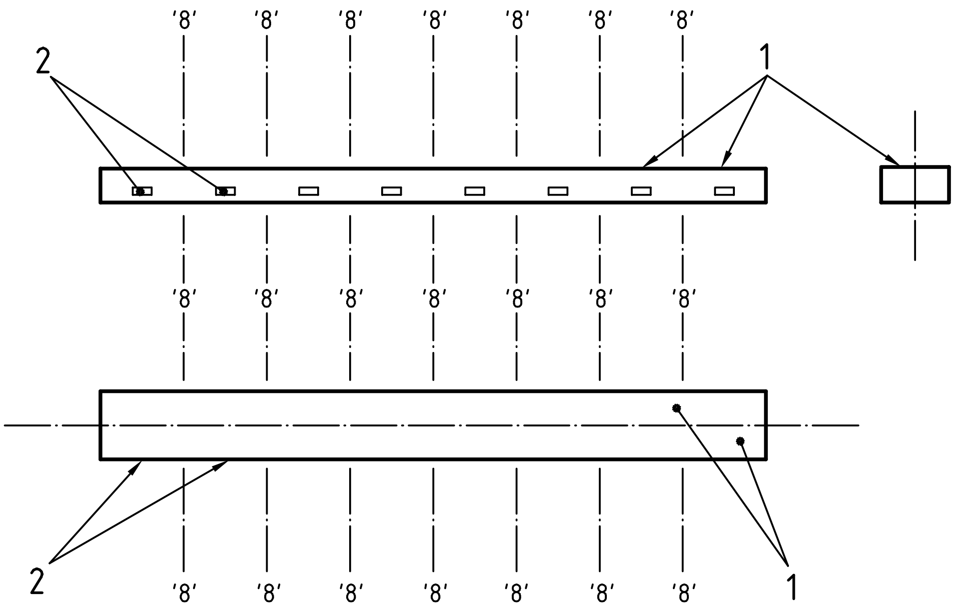
The division of the rough machined weld bars, following the lines '8' — '8', is shown in Figures A.3 and A.4. Subsequently, the single specimens were finished. Thirty specimens could be produced from each bar clad on both sides.

Dimensions in millimetres



[a] Chips for chemical analysis taken at these points.

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



Key

1 Test surfaces

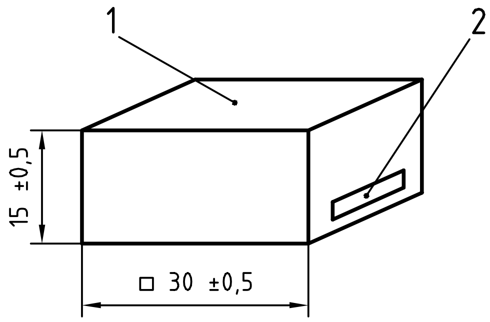
2 Marking regions

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.

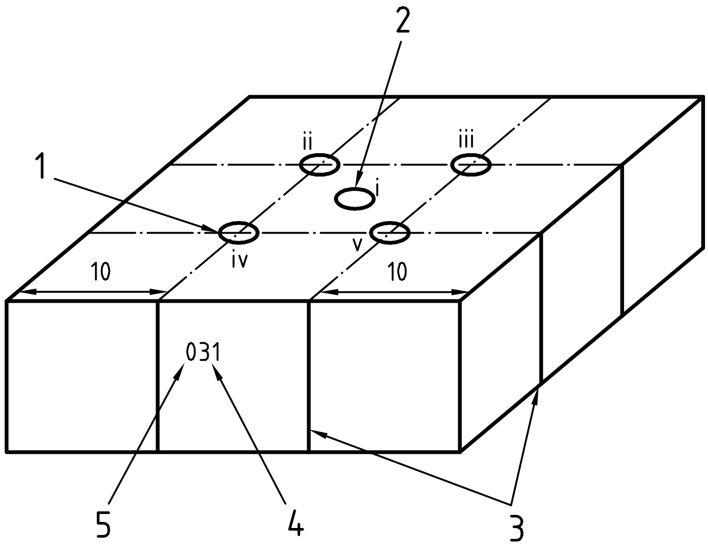
Table A.2 — Example of the chemical composition of seventh layer of strip clad deposits

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 A.3. 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.

Dimensions in millimetres



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 International 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", manufactured by the American Instrument Company (USA), 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 International Standard. This was done by using a laboratory balance to measure tear-off forces from a set of eight USA National Bureau of Standards (NBS) 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 NBS.

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.

Table A.3 — NBS standards employed for "Magne-gage" calibration for strip cladding secondary standards

NBS 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

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 laid down in this International Standard. The eight NBS 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 by one operator "Magne-gage" were completed within one measurement session.

A.7.4 Data recording and analysis

Data from the readings by one "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		
	1	2,8		2,8		2,7		2,6		2,7	
	2	2,5		2,8		2,6		2,5		2,5	
A68	3	2,8	2,7	2,8	2,7	2,6	2,6	2,6	2,6	2,7	2,7
	4	2,7		2,6		2,5		2,5		2,6	
	5	2,8		2,7		2,6		2,6		2,7	
	1	4,6		4,6		4,5		4,6		4,6	
	2	4,6		4,6		4,5		4,4		4,5	
B68	3	4,8	4,7	4,8	4,7	4,5	4,5	4,6	4,6	4,7	4,6
	4	4,8		4,8		4,5		4,6		4,7	
	5	4,6		4,6		4,4		4,6		4,5	
	1	8,9		8,8		8,8		8,7		8,8	
	2	8,9		8,9		8,7		8,6		8,8	
C68	3	8,9	8,9	8,8	8,9	8,6	8,7	8,5	8,6	8,7	8,8
	4	9,2		9,1		8,8		8,8		8,9	
	5	8,9		8,9		8,6		8,6		8,7	
	1	11,0		11,0		10,6		10,8		10,9	
	2	10,8		10,9		10,5		10,8		10,7	
D68	3	11,1	11,0	11,2	11,1	10,4	10,5	10,8	10,7	10,9	10,8
	4	10,8		10,8		10,3		10,4		10,6	
	5	11,3		11,6		10,7		10,9		11,1	

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

Dimensions in millimetres

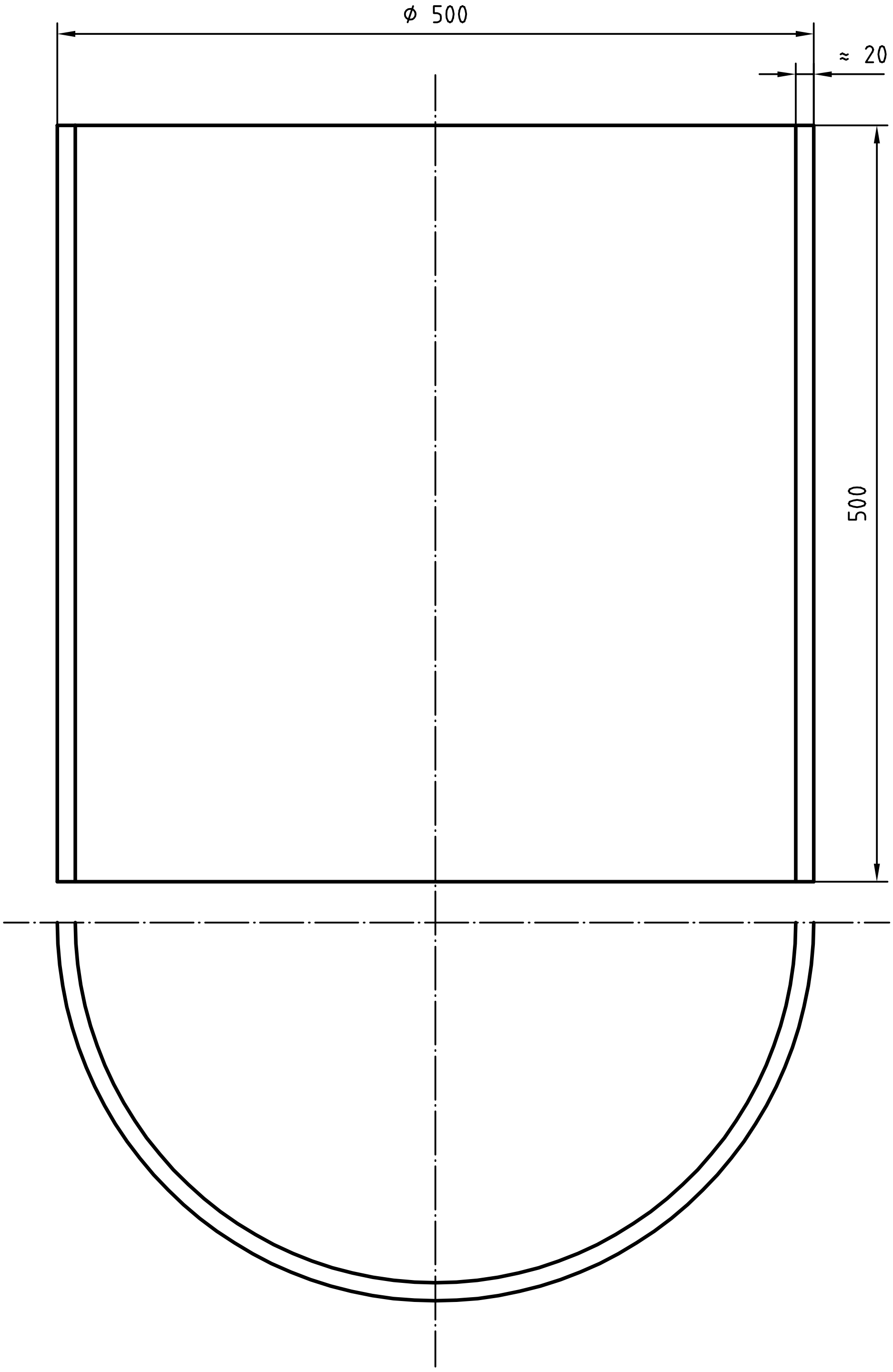


Figure B.1 — Centrifugally chill cast ring for secondary standards

Dimensions in millimetres

a) Measurement positions

b) Faces

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

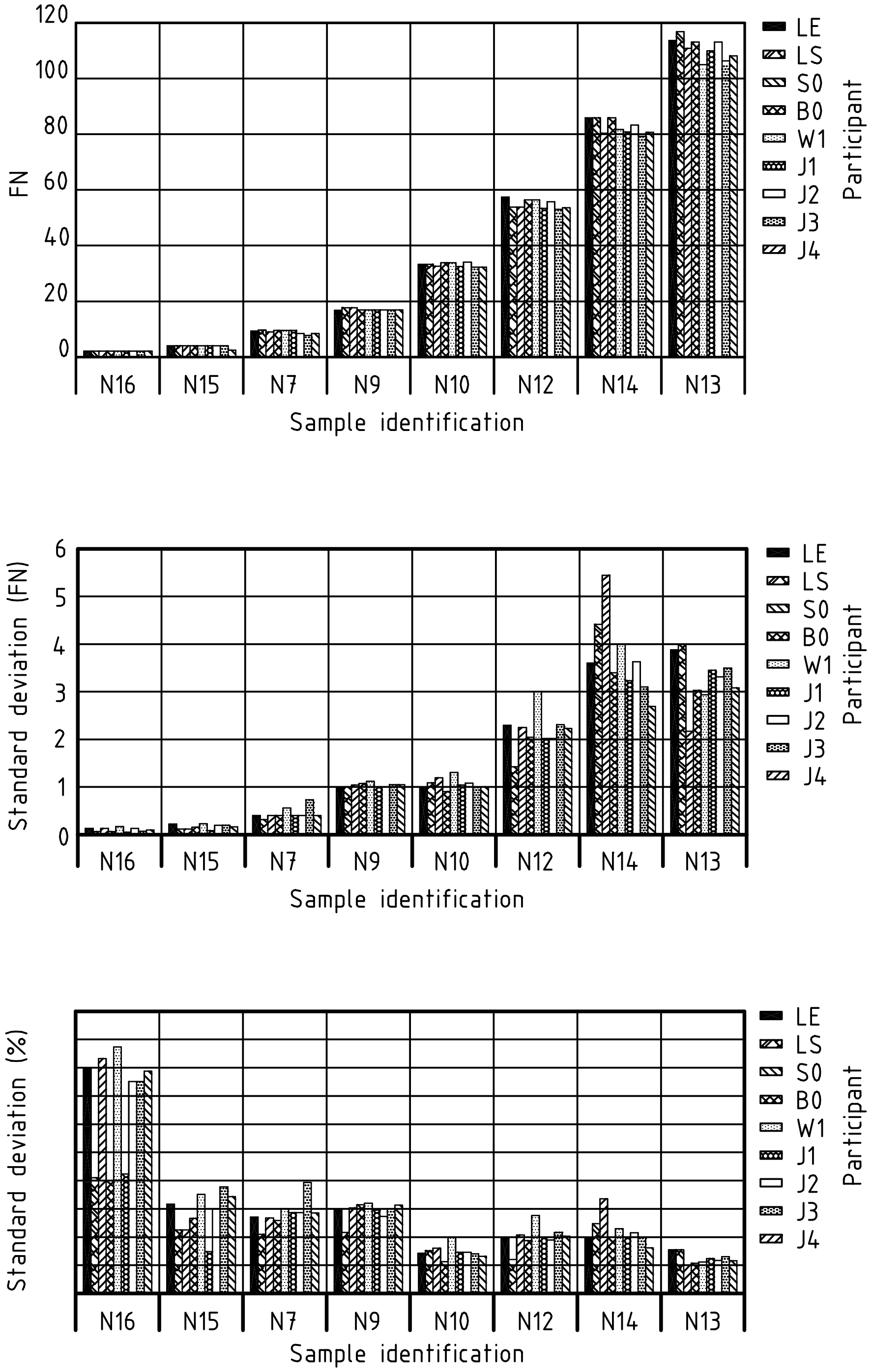


Figure B.3 — IIW Commission II, 6th round robin measurement results – Overall results

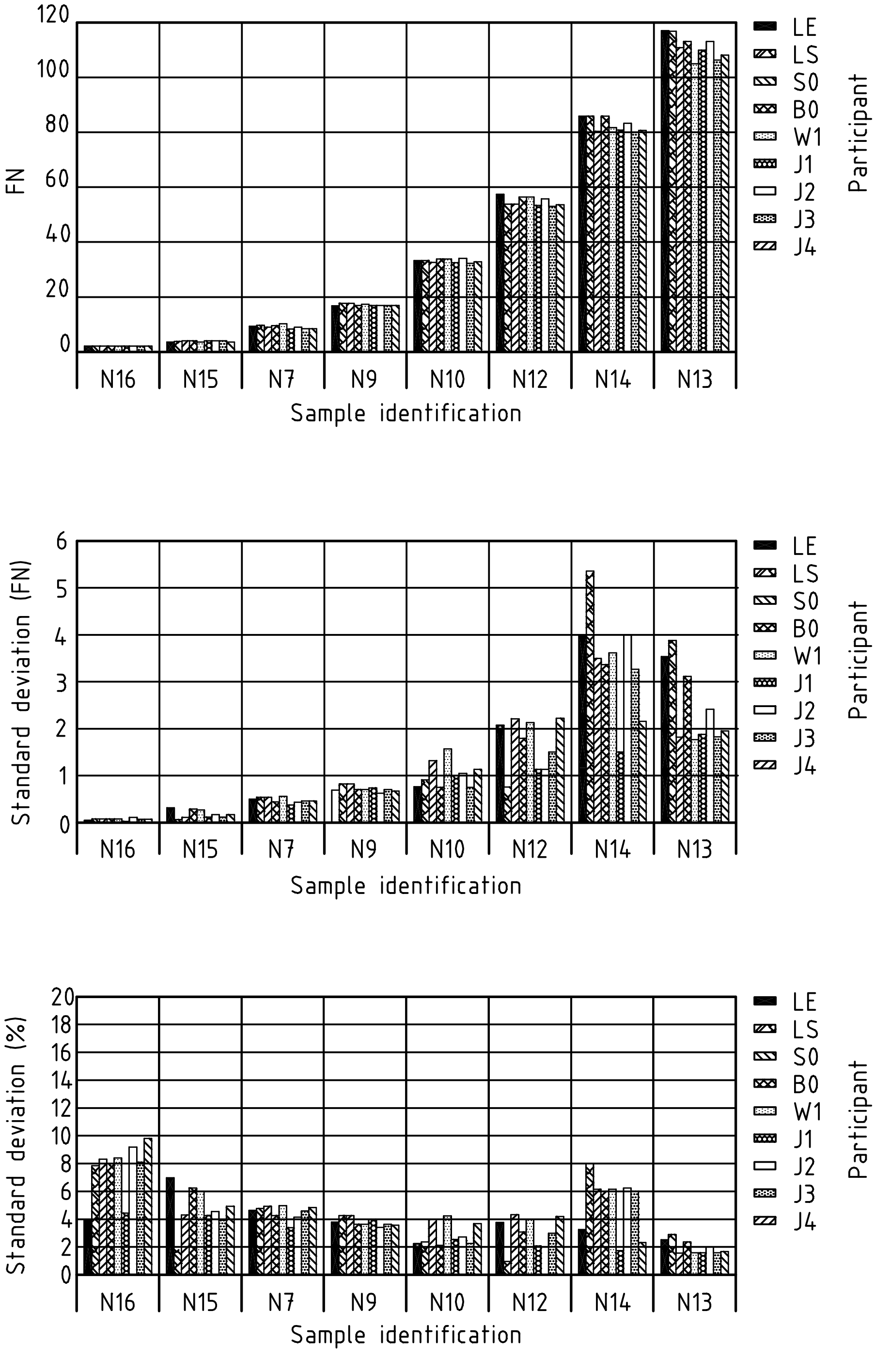


Figure B.4 — IIW Commission II, 6th round robin measurement results – Face centre results

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	–	0,034 4	16
1321	–	0,037 7	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
$0 < FN \leqslant 5$	± 0,4
$5 < FN \leqslant 10$	± 0,5
$10 < FN \leqslant 15$	± 0,7
$15 < FN \leqslant 20$	± 0,9
$20 < FN \leqslant 30$	± 1,0
$30 < FN \leqslant 90$	± 5 % 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 operator and "Magne-gage" 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

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[1] ISO 525:1999, *Bonded abrasive products — General requirements.*

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