International Standard ISO 8249

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Welding — Determination of ferrite number in austenitic weld metal deposited by covered Cr-Ni steel electrodes

Soudage — Détermination de l'indice de ferrite des dépôts en acier inoxydable austénitique au chrome-nickel obtenus avec des électrodes enrobées

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Foreword

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Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council. They are approved in accordance with ISO procedures requiring at least 75 % approval by the member bodies voting.

International Standard ISO 8249 was prepared by Technical Committee ISO/TC 44, *Welding and allied processes*, in collaboration with the International Institute of Welding.

Users should note that all International Standards undergo revision from time to time and that any reference made herein to any other International Standard implies its latest edition, unless otherwise stated.

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Welding — Determination of ferrite number in austenitic weld metal deposited by covered Cr-Ni steel electrodes

0 Introduction

At present, experimental methods are not available that give 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 and AWS Standard A4.2-74, these being essentially equivalent. The ferrite number of a weld metal is approximately equivalent to the percentage ferrite content, particularly at low FN values.

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.

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1 Scope

This International Standard specifies the method and apparatus for

— the measurement of the delta ferrite content in largely austenitic stainless steel 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 TIG, MIG and submerged arc (in these cases, the way of producing the pad should be defined);

— the calibration of other instruments to measure FN.

2 Field of application

The method laid down in this International Standard is intended for use on weld metals in the as welded state. It is also applicable to 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 steel samples.

3 References

ISO 525, *Bonded abrasive products — General features — Designation, marking, ranges of outside diameters and tolerances.*

ISO 683/13, *Heat-treated steels, alloy steels and free-cutting steels — Part 13: Wrought stainless steels.*[1)]

ISO 4954, *Steels for cold heading and cold extruding.*

4 Principle

The measurement of the ferrite content of largely austenitic stainless steel weld metal through the attractive force between a weld metal sample and a permanent magnet is based 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 stainless steel weld metal, ferrite is magnetic, whereas austenite, carbides, sigma phase and inclusions are non-ferromagnetic.

1) At present at the stage of draft. (Revision of ISO 683/13-1974.)

5 Calibration

5.1 Coating thickness standards

The coating thickness standards shall consist of non-magnetic copper coating 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 Bureau of Standards (NBS) may be used.]

5.2 Magnet

The standard magnet shall be a permanent magnet of cylindrical shape, 2 mm in diameter and about 50 mm in length. One end of the magnet shall be hemispherical, with a 1 mm radius and polished. As an example, such a magnet can be made of 36 % cobalt magnet steel, 48,45 ± 0,05 mm long, magnetically saturated and then desaturated 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).

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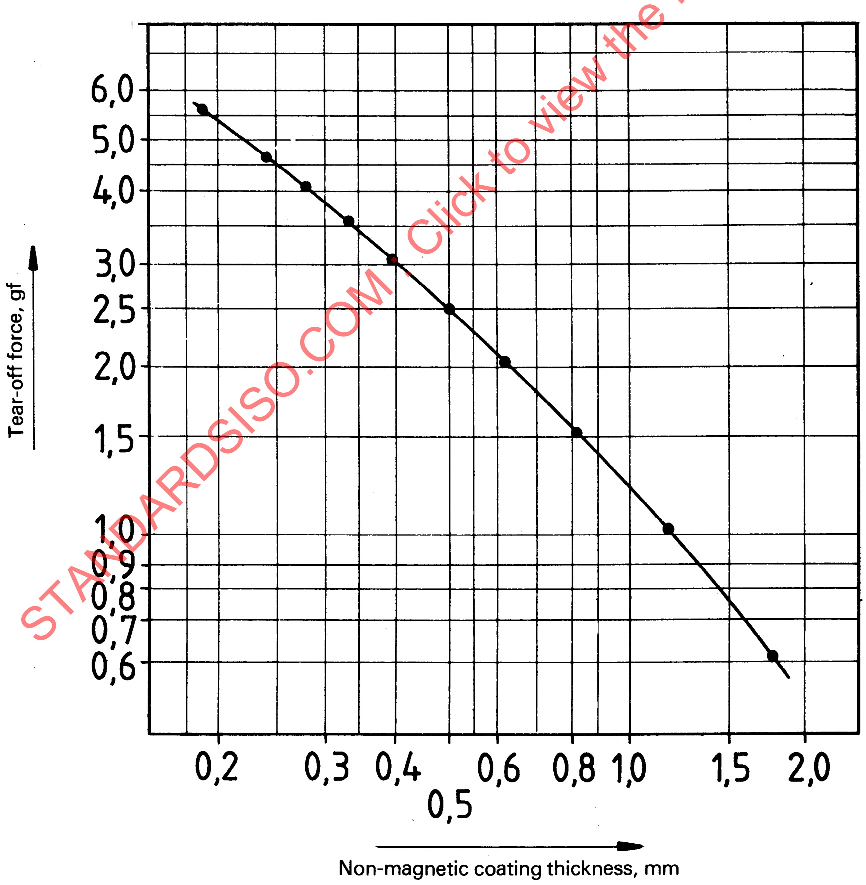

Figure 1 — Relationship between the tear-off forces of the standard magnet defined in 5.2 and the coating thickness standards defined in 5.1

5.3 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[1].

5.4 Calibration curve

In order to generate a calibration curve, determine the force needed to tear off the standard magnet defined in 5.2 from several coating thickness standards defined in 5.1. Then convert the thickness of non-magnetic coating of the coating thickness standards into FN according to table 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 3 to approximately 27 FN ferrite, a set consisting of a minimum of eight standards with copper coating thickness graduated between approximately 0,178 and approximately 1,778 mm is recommended[2].

Table 1 — Relationship between ferrite number and thickness of non-magnetic coating of coating thickness standards (specified in 5.1) for calibration of instruments for measurement of ferrite content through attractive force (specified in 5.3) using the standard magnet (specified in 5.2)

Thickness mm	FN	Thickness mm	FN	Thickness mm	FN
0,178	28,3	0,546	11,2	1,067	5,7
0,190	27,1	0,559	11,0	1,092	5,5
0,203	25,9	0,572	10,8	1,118	5,4
0,216	24,8	0,584	10,5	1,143	5,2
0,229	23,8	0,597	10,3	1,168	5,1
0,241	22,9	0,610	10,1	1,194	5,0
0,254	22,0	0,622	9,9	1,219	4,8
0,266	21,1	0,635	9,7	1,245	4,7
0,279	20,3	0,648	9,5	1,270	4,6
0,292	19,6	0,660	9,4	1,295	4,5
0,305	18,9	0,673	9,2	1,321	4,4
0,318	18,3	0,686	9,0	1,346	4,3
0,330	17,7	0,699	8,9	1,372	4,2
0,347	17,1	0,711	8,7	1,397	4,1
0,356	16,6	0,724	8,6	1,422	4,0
0,368	16,1	0,737	8,4	1,448	3,9
0,381	15,6	0,749	8,3	1,473	3,8
0,394	15,2	0,762	8,1	1,499	3,75
0,406	14,8	0,787	7,9	1,524	3,68
0,419	14,4	0,813	7,6	1,549	3,60
0,432	14,0	0,838	7,3	1,575	3,52
0,445	13,6	0,864	7,1	1,600	3,45
0,457	13,3	0,889	6,9	1,626	3,37
0,470	12,9	0,914	6,7	1,651	3,30
0,483	12,6	0,940	6,5	1,676	3,24
0,495	12,3	0,965	6,3	1,702	3,18
0,508	12,0	0,991	6,1	1,727	3,12
0,521	11,7	1,016	6,0	1,753	3,06
0,533	11,5	1,041	5,8	1,778	3,00

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1) 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 USSR origin). In addition, after suitable in-house alterations, some laboratory balances can be used.

2) 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 5.2. Instruments which cannot be calibrated by the coating thickness standards and by the procedure specified in 5.2 to 5.4 may be calibrated as described in clause 8.

6 Standard method for manual electrodes

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

6.2 The weld metal specimens shall be deposited as follows :

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 below figure 2). Each layer shall be made in a single pass for electrode diameters greater than or equal to 4 mm.

For small diameters, each 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.

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.

6.3 Measuring shall carried out as follows:

a) After welding, the weld build-up shall be draw filed to provide sufficient finished surface to make the required ferrite readings. Draw filing shall be done with a 35 cm 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 and backward strokes along the length of the weld with a firm downward pressure being applied. The weld shall not be cross-filed.

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

b) A total of six ferrite readings shall be taken on the filed surface along the longitudinal axis of the weld bead.

c) The six readings obtained shall be averaged to a single value for conversion to the ferrite number.

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Dimensions in millimetres

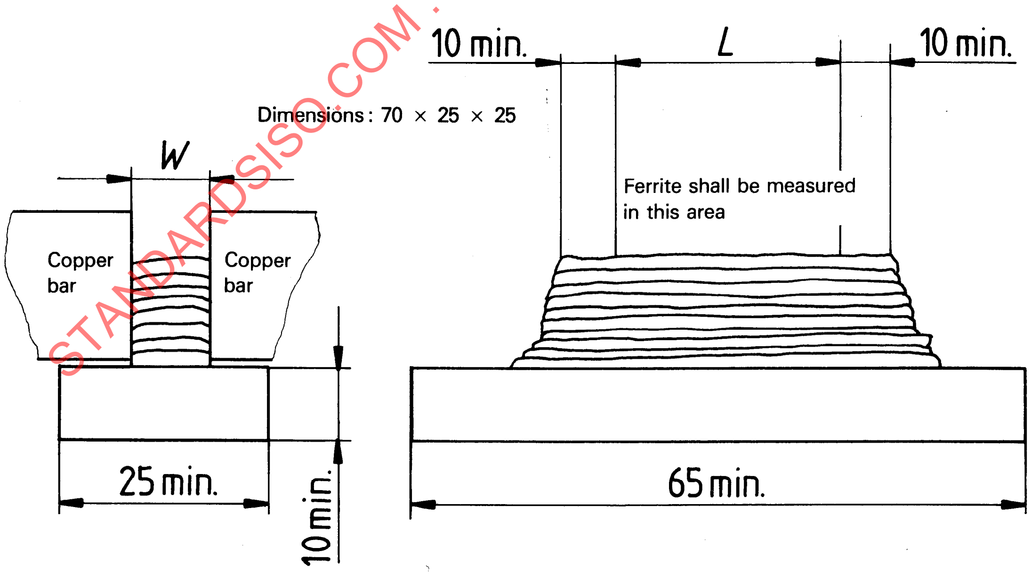

Figure 2 — Weld metal test specimen for ferrite determination

NOTE — The base metal should preferably be austenitic Cr-Ni steel type 10 or 11 (see ISO 683/13) 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.

Table 2 — Welding parameters and deposit dimensions

Electrode diameter mm	Welding current[1] A	Approximate dimensions	
		width W mm	length L mm
1,6	35 to 45	12,5	30
2,0	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 260	18	40

1) Or 90 % of the maximum value recommended by the electrode manufacturer.

7 Production welds and other measuring techniques

7.1 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 6.1 and 6.2 and on production welds are likely to differ from the results obtained on specimens deposited according to 6.1 and 6.2.

7.2 Other measuring techniques

See 6.1 for other instruments, magnet sizes and processes.

7.3 Nearby ferromagnetic materials

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.

8 Other methods

8.1 Methods

Methods for determining the ferrite content other than through the attractive force or methods differing from the method laid down in this International Standard in respect of the standard magnet may be used, provided that they have been calibrated by secondary weld metal standards in which the ferrite content has been determined by the method laid down in this International Standard. These secondary weld metal standards, prepared as shown in the annex, are available from the International Institute of Welding (IIW) via the Welding Institute in the United Kingdom. Alternatively, secondary standards can be prepared using the method specified in 6.1 and 6.2, by assigning to them FN values by the method specified in 7.2 and 7.3.

Volumetric devices using magnetic saturation cannot be directly calibrated in this way, but if a correlation of 1 : 1 (± 0,005) with the method laid down in this International Standard can be proved, such methods and devices may be used.

8.2 Results

The results obtained by methods other than the method laid down in this International Standard, even if calibrated in accordance with 8.1, may, under certain circumstances, differ from those obtained by the the method laid down in this International Standard. Hence, in case 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 ± 1,0 FN in the FN range up to 10 FN and may be proportionally higher as the FN increases beyond 10 FN.

8.3 Maintaining calibration

Instruments shall be checked periodically against secondary weld metal standards or primary standards. It is therefore recommended that the organization which uses the instrument ensures that a set of standards is 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

Ferrite number range	Maximum deviation from the FN value assigned to the standard
0 < FN < 4	± 0,50
4 < FN < 10	± 0,50
10 < FN < 16	± 0,60
FN > 16	± 0,80

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Annex

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 instrument.

A need, therefore, exists for secondary standards based on weld metal, for both calibration and cross-reference of instruments in the laboratory and under shop and field conditions.

The IIW thus requested some organizations, and particularly the Welding Institute, 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 to 27 FN.

Welding and machining of the standards were carried out, with FN measurements being performed at the Welding Institute. The procedures used are described below.

A.1 Materials

A.1.1 Base metal

The base metal on which the 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 freehand 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 to 27 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 3. After each layer, the welding direction was changed. The power supply used had a drooping characteristic. Welding parameters used are given in table 4.

Table 4 — 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

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Dimensions in millimetres

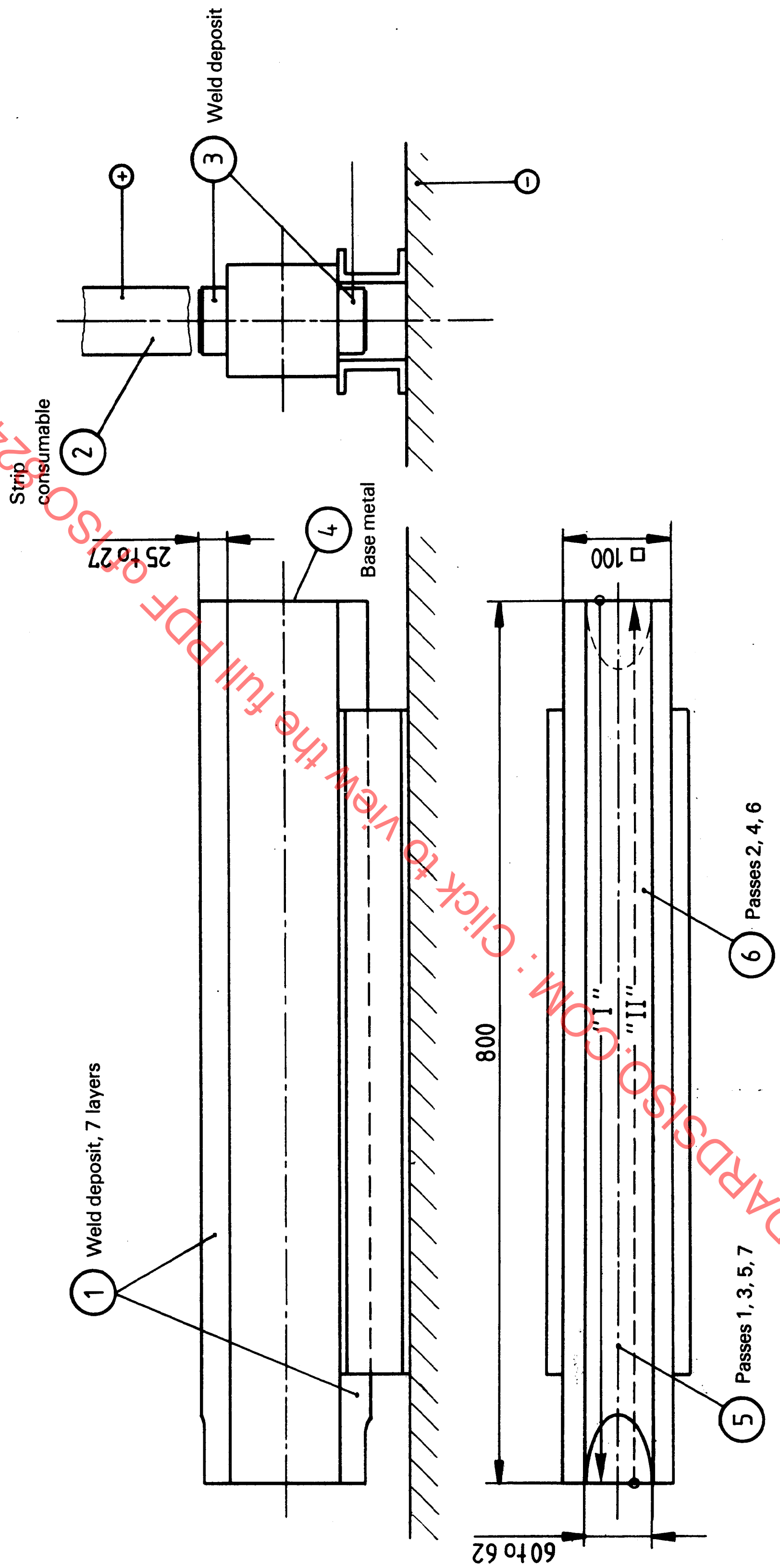

Figure 3 — Method of depositing weld metal

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The bead deposition sequence is shown in figure 4. 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.

A.3 Machining and marking

A.3.1 Cutting programme

Initially, the end section was cut off, corresponding to lines '1' – '1' in figure 5. Chips for the chemical analysis of the seventh layer were taken at the locations marked (4).

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'.

The rough preparation of the test surfaces followed, along lines '5' – '5' (see (5) on figure 4).

Subsequently, lateral machining along lines '6' – '6' and machining of the bottom surface along lines '7' – '7' was performed (see figure 4).

Dimensions in millimetres

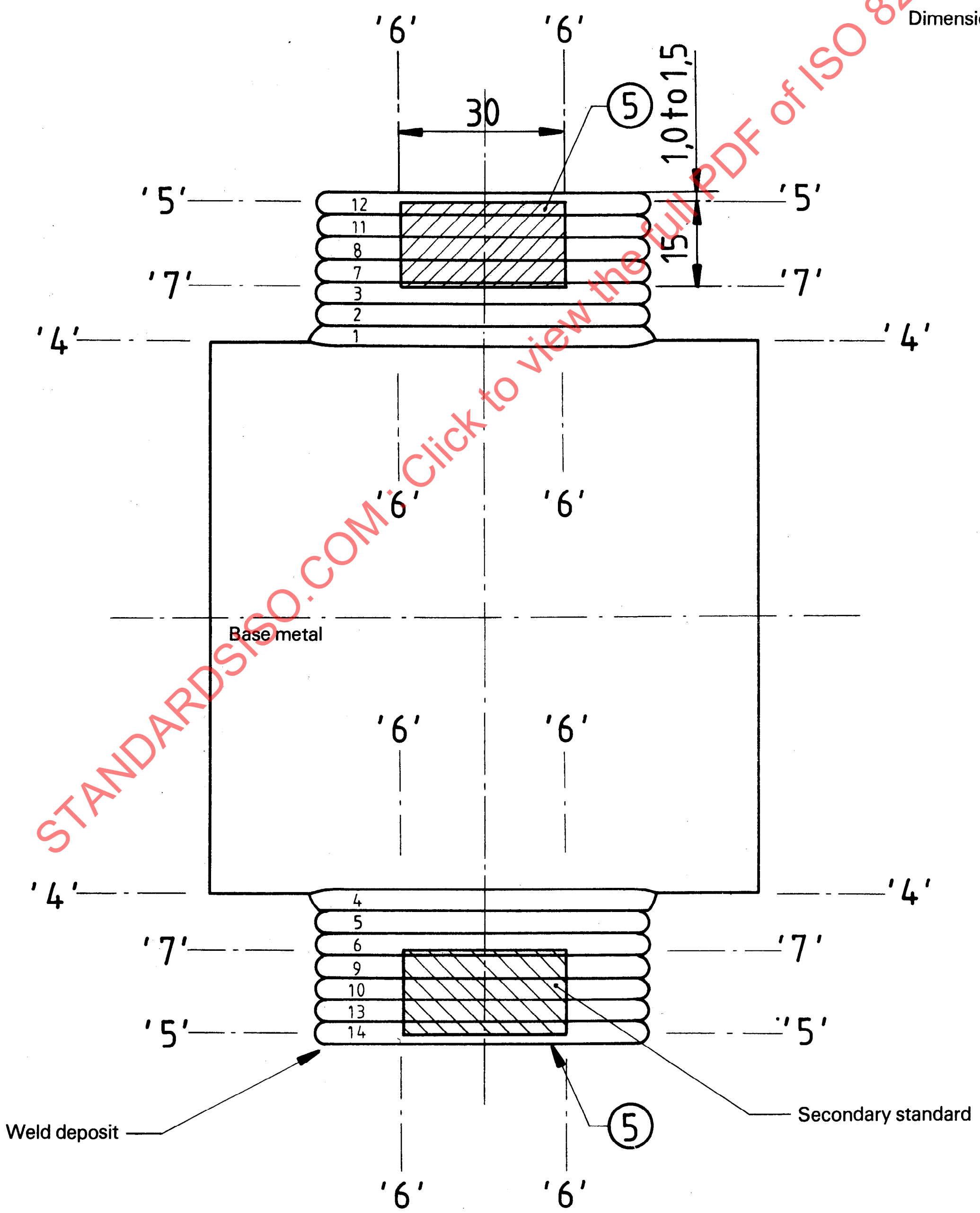

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Figure 4 — Bead deposition and machining sequences

Dimensions in millimetres

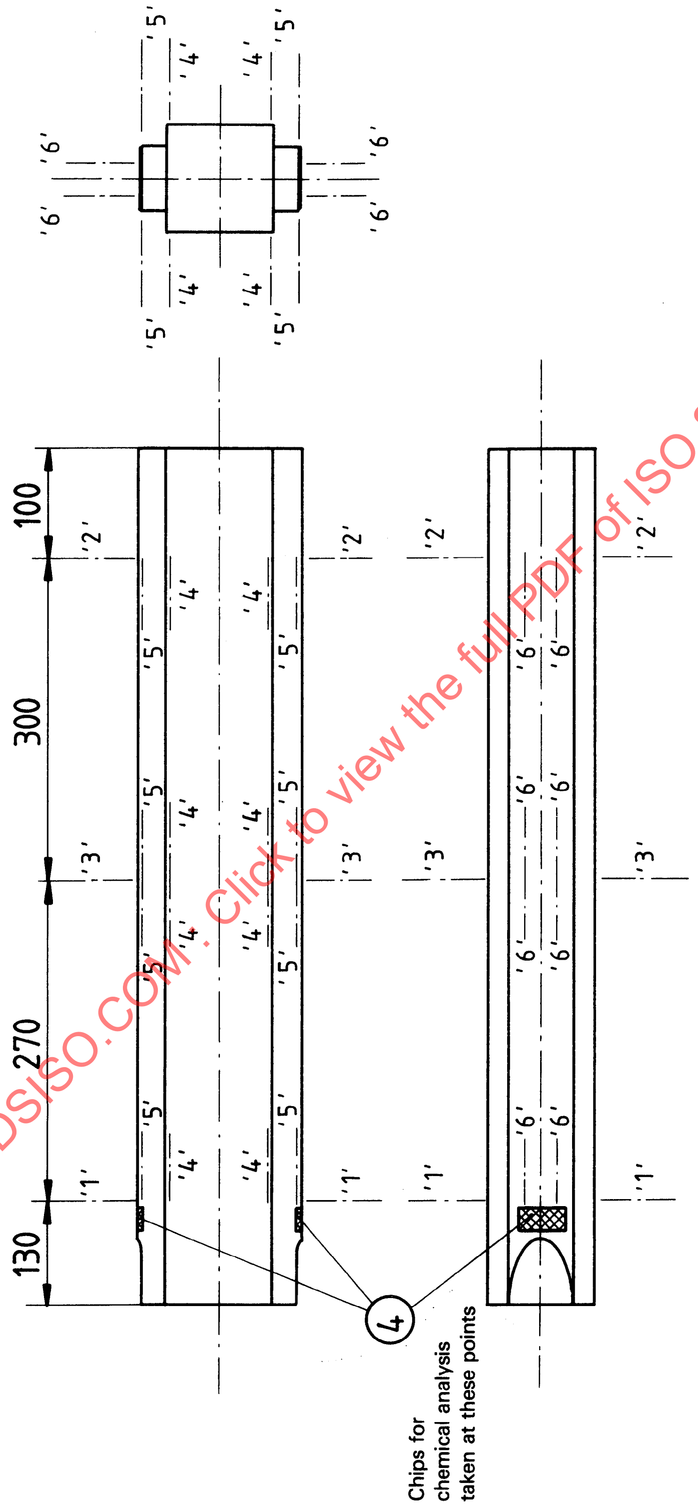

Figure 5 — Cutting sequences

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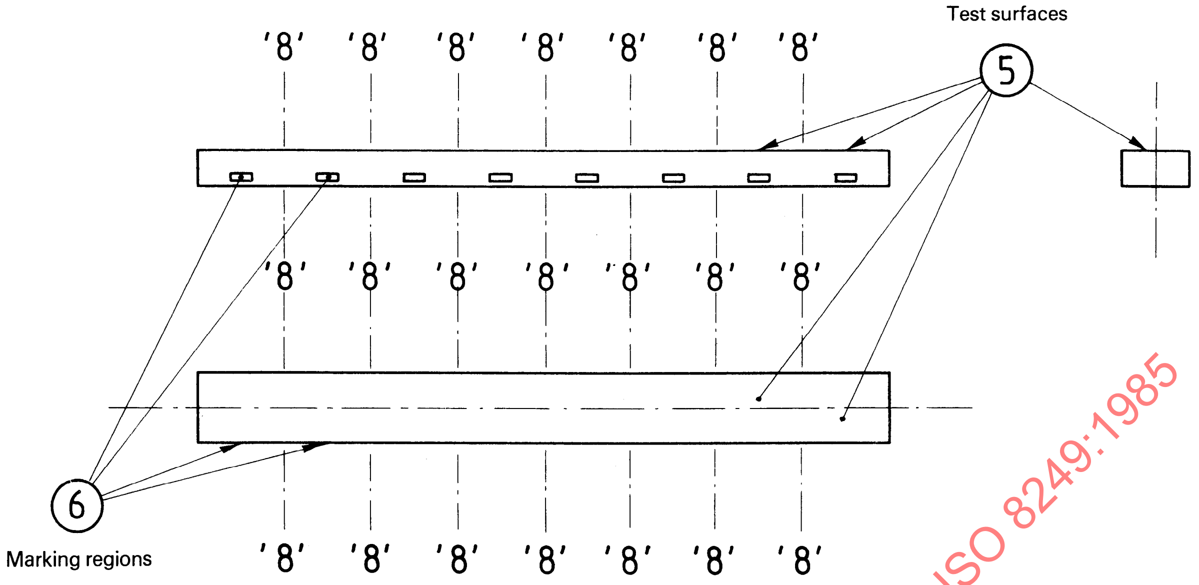

Figure 6 — Extraction of individual standards

The division of the rough machined weld bars, following the lines '8' – '8', is shown in figures 5 and 6. Subsequently, the single specimens were finished. Thirty specimens could be produced from each bar clad on both sides.

A.3.2 Dimensions, tolerances, surface finish

The dimensions and tolerances of the finished "ferrite-secondary-standards" are shown in figure 7. The test surface was ground with a grinding disc 8A-80-G-9-V39 (see ISO 525). All the other surfaces were rough finished.

Dimensions in millimetres

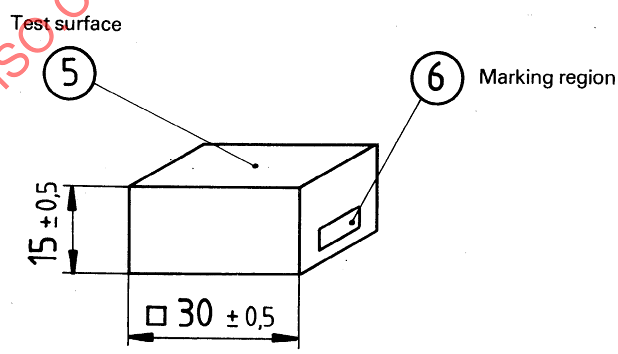

Figure 7 — Marking of each ferrite secondary standards

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