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Steel castings — Magnetic particle inspection

Pièces moulées en acier — Contrôle par magnétoscopie

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Foreword

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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.

International Standard ISO 4986 was prepared by Technical Committee ISO/TC 17, *Steel*, Sub-Committee SC 11, *Steel castings*.

Annexes A, B, C, D, E and F of this International Standard are for information only.

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Steel castings — Magnetic particle inspection

1 Scope

This International Standard specifies a test method for determining the acceptance limits of surface discontinuities[1] detected by magnetic particle inspection, when such an inspection procedure has been contractually agreed upon at the request of the purchaser. It applies to all magnetic steel castings, whatever casting process is used.

A steel shall be considered to be magnetic if the magnetic induction is greater than 1 T for a magnetic field strength equal to 2,4 kA/m.

NOTE 1 It should be remembered that magnetic particle inspection, like all methods of non-destructive inspection, forms part of an overall or special assessment, which is defined in the contract.

2 Conditions of magnetic particle inspection

This International Standard only applies to the parts of castings and the percentage of castings to be inspected. The conditions shall be clearly indicated on the enquiry, in the request for prices and, more particularly, in the order sent to the supplier and accepted by him.

The manufacturing stage(s) at which the inspection is to be carried out shall be clearly defined by agreement between the parties.

For each part of the castings to be inspected, the following shall be indicated:

— the severity level (see table 1);

— the type of discontinuity indication (linear or non-linear) (see annex A).

The severity level and the type of discontinuity indication could differ according to the part of the casting to be inspected. (For surface condition, see 3.3.)

Unless otherwise specified, the severity level applies both to linear or aligned indications and to non-linear indications (clusters).

The test is considered to be satisfactory if the discontinuity indications obtained are of levels below or equal to those selected from table 1 and in accordance with clause 5.

If not, it shall be the responsibility of the founder to bring the casting into conformity with the specification defined above, by a method approved by the purchaser.

In general, there is no limit to the extent of discontinuities acceptable in a casting, provided that in the casting as a whole no area of 105 mm × 148 mm[2] contains discontinuities which exceed the severity level specified.

3 Method of inspection

3.1 Operating mode

The general principles of magnetic particle inspection are described in annex F.

3.2 Qualification of the operators

The tests shall be carried out and interpreted by technically competent operators whose qualifications shall be agreed upon at the time of the enquiry or order.

1) "Surface discontinuities" means discontinuities located in the metal which are open to the surface or come very close to it, so that the magnetic bridge is narrow.

2) Format ISO A6.

Table 1 — Severity levels for magnetic particle inspection

This table fixes the maximum surface area, in square millimetres, and/or the length, in millimetres, within the frame ISO A6 — 105 mm × 148 mm.

Severity levels		001	01	1		2		3		4		5	
Means of observing indications		Magnifying glass or eye[1]		Eye		Eye		Eye		Eye		Eye	
Magnification		⩽ 3		1		1		1		1		1	
Length (L) of the smallest indication considered (mm)		0,3		1,5		2		3		5		10	
Non-linear clusters (SM)[2]	Total area (mm²)	—	—	10		35		70		200		500	
	Length of individual indication (mm)	1	1	2[3]		4[3]		6[3]		10[3]		16[3]	
Linear indications (LM)[4] or aligned (AM)[5]	Indication type	Isolated or cumulative	Isolated or cumulative	Isolated	Cumulative	Isolated	Cumulative	Isolated	Cumulative	Isolated	Cumulative	Isolated	Cumulative
	Wall thickness $\delta \leqslant 16$ mm	0	1	2	4	4	6	6	10	10	18	18	25
	Wall thickness 16 mm $< \delta \leqslant 50$ mm	0	1	3	6	6	12	9	18	18	27	27	40
	Wall thickness $\delta > 50$ mm	0	2	5	10	10	20	15	30	30	45	45	70
Examples of applications		Fabrication for aircraft or space craft: — lost wax casting — special applications		Other casting, according to surface and application									

1) The use of a magnifying instrument with a measuring graticule is permitted.
2) Non-linear indications (SM): $L < 3b$ where L is the length and b the larger indication.
3) At the most, two indications of the designated length are permitted.
4) Linear indication (LM): $L \geqslant 3b$
5) Aligned indications (AM): linear, or non-linear, separated by a maximum of 2 mm and comprising at least three indications.

3.3 Surface condition

The surface to be examined shall be clean, free from oil, grease, sand or scale or any other condition which could interfere with the correct interpretation of magnetic particle indications. It shall be sand or shot blasted (round or angular shot), ground or machined in line with the severity level demanded.

When a non-fluorescent inspection medium is used this shall be of a colour that will provide adequate contrast with the background of the surface being inspected. This can be obtained by the use of a coloured pigment inspection medium or the surface may be covered with a contrast paint.

The required surface condition of the areas of the casting to be inspected shall be subject to agreement at the time of enquiry or order (see annex B).

3.4 Conditions of examination

The inspection shall be carried out with the naked eye or at a maximum magnification of 3 × (see table 1).

4 Acceptance test

4.1 Discontinuity indications

Magnetic particle inspection is a means of non-destructive inspection which allows the detection of surface discontinuities which cannot normally be observed by visual examination. The discontinuity indications are linear[3] or aligned[4] or non-linear (clusters). The discontinuities listed in annex A may correspond to the different types of magnetic particle inspection.

Detection of the discontinuities is connected with the direction of the magnetic flux in the casting. It is therefore essential to carry out a control in two directions which are essentially perpendicular, unless otherwise specified in the order, to make sure that the discontinuity runs counter to the flux in at least one direction.

4.2 Severity levels

Seven severity levels are recognized in accordance with table 1. Depending on the severity level required, it is necessary to carry out the test on a surface corresponding to a given degree of finish (see annex B):

— precision;

— smooth;

— rough.

The maximum permissible length for linear or aligned indications varies with the casting section thickness δ. Three thickness categories are specified:

— $\delta \leqslant 16$ mm

— 16 mm $< \delta \leqslant 50$ mm

— $\delta > 50$ mm

Table 1 shows the minimum length below which the indications are not to be taken into consideration in the respective category.

Examples of linear and non-linear indications, given to a scale of 1, are shown in annex C. These have been established in accordance with table 1 and in compliance with the procedure given in annex F.

5 Interpretation of results

In order to classify discontinuity indications obtained by magnetic particle inspection of the casting, it is necessary to place a frame measuring 105 mm × 148 mm positioned in the most unfavourable location relative to the indications being evaluated. The test is considered satisfactory if the indications being evaluated are less severe or equal to those specified in the order.

Indications are equivalent when they show the same clusters of non-linear indications or the same length of linear indications of similar appearance.

The types of indications are given only as a guide and the classification by severity level is based on the length of the discontinuities, in accordance with table 1.

Aligned and non-aligned indications shall be taken into account for the calculation of the cumulative length.

6 Order

The enquiry and/or order shall specify the following points:

a) the parts of castings and percentage of castings to be inspected (see clause 2);

b) the manufacturing stage(s) at which the inspection is to be carried out, as agreed between the parties concerned (see clause 2);

3) The largest dimension L (length) is at least three times the smallest b (width) ($L \geqslant 3b$). (See table 1.)

4) See note 5 of table 1.

c) the surface condition for the areas to be inspected (see 3.3);

d) the type of discontinuity indication and the severity level for each part of casting to be inspected (see clause 2 and 4.2);

e) the qualification of the operators carrying out the inspection (see 3.2);

f) if the inspection is not to be carried out in two perpendicular directions (see 4.1);

g) whether or not the casting should be demagnetized after the inspection has been carried out (see F.6.7).

Annex A
(informative)

Nature of discontinuities — Types of indication

Nature of discontinuities	Nomenclature	Indications obtained by passage of the magnetic flux in the optimum direction	Type	Definition
Blow-holes Pitting	A	Non-linear clusters Aligned	SM AM	$L < 3b$ $d < 2$
Sand spots Inclusions	B	Non-linear clusters Aligned	SM AM	$L < 3b$ $d < 2$
Shrinkage	C	Linear Non-linear clusters Aligned	LM SM AM	$L \geqslant 3b$ $L < 3b$ $d < 2$
Tears	D	Linear Aligned	LM AM	$L \geqslant 3b$ $d < 2$
Cracks	E	Linear Aligned	LM AM	$L \geqslant 3b$ $d < 2$
Core supports	F	Linear Non-linear clusters Aligned	LM SM AM	$L \geqslant 3b$ $L < 3b$ $d < 2$
Chills	G	Linear Non-linear clusters Aligned	LM SM AM	$L \geqslant 3b$ $L < 3b$ $d < 2$
Cold shuts	H	Linear Aligned	LM AM	$L \geqslant 3b$ $d < 2$

L = length of indication
b = width of indication
d = distance, in millimetres, between two indications, edge-to-edge

Annex B
(informative)

Equivalence of surface conditions (as a guide)

Surface condition	Precision						Smooth				Rough	
Roughness R_a (µm) [1]	1,6		3,2		6,3		12,5		25		> 25	
Surface preparation	Very smooth grinding Smooth precision	Very smooth shot blasting	Very smooth grinding Very smooth machining Precision	Smooth shot blasting Investment cast	Smooth grinding	Smooth shot blasting Precision cast (ceramic)	Grinding Smooth machining	Smooth shot blasting Precision cast (shell moulded, ceramic)	Grinding Rough machining	Medium shot blasting Careful moulding	Rough preparation	Sand cast
BNIF 341-02	—	—	—	—	1S2	—	2S2 3S2	1S1	4S2 5S2	2S1 3S1	1S3 2S3 5S3 6S3	4S1 5S1 6S1
ACI	—	—	—	—	—	SIS1	—	SIS3	—	SIS4	—	—
CSC (Cast Surface Comparator)	—	—	—	C30	—	C40	—	C70	—	C90	—	—
SCRATA		—	—	—	—	—	—	A1	H1 H2	A2 A3	G2 G3	A4 C3 D3
LCA 2 Grinding	15	—	16	—	17	—	18	—	19	—	—	—
LCA 3 Shot blasting	—	N7 (15)	—	N8 (16)	—	N9 (17)	—	N10 (18)	—	N11 (19)	—	—

1) The roughness values R_a indicated in this table are those given by the manufacturers of small plates.

S1: As cast or shot blasted

S2: Ground

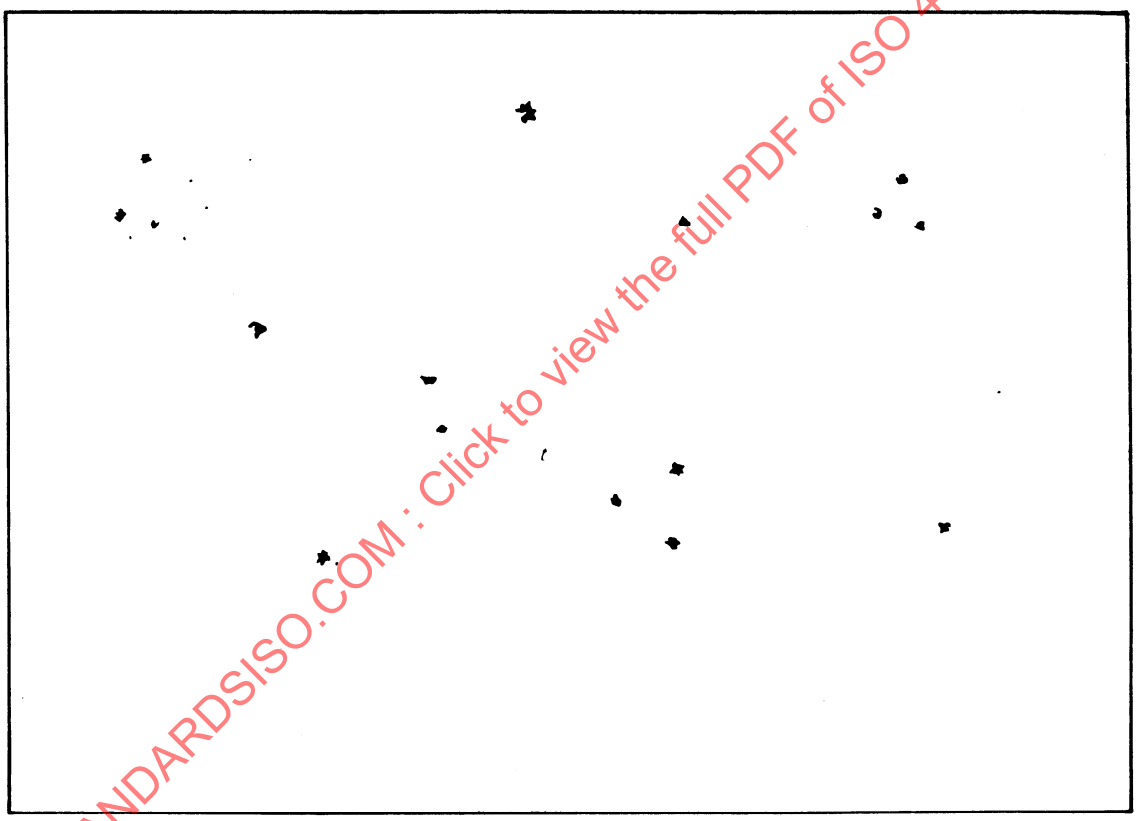
Annex C
(informative)

Examples of severity levels

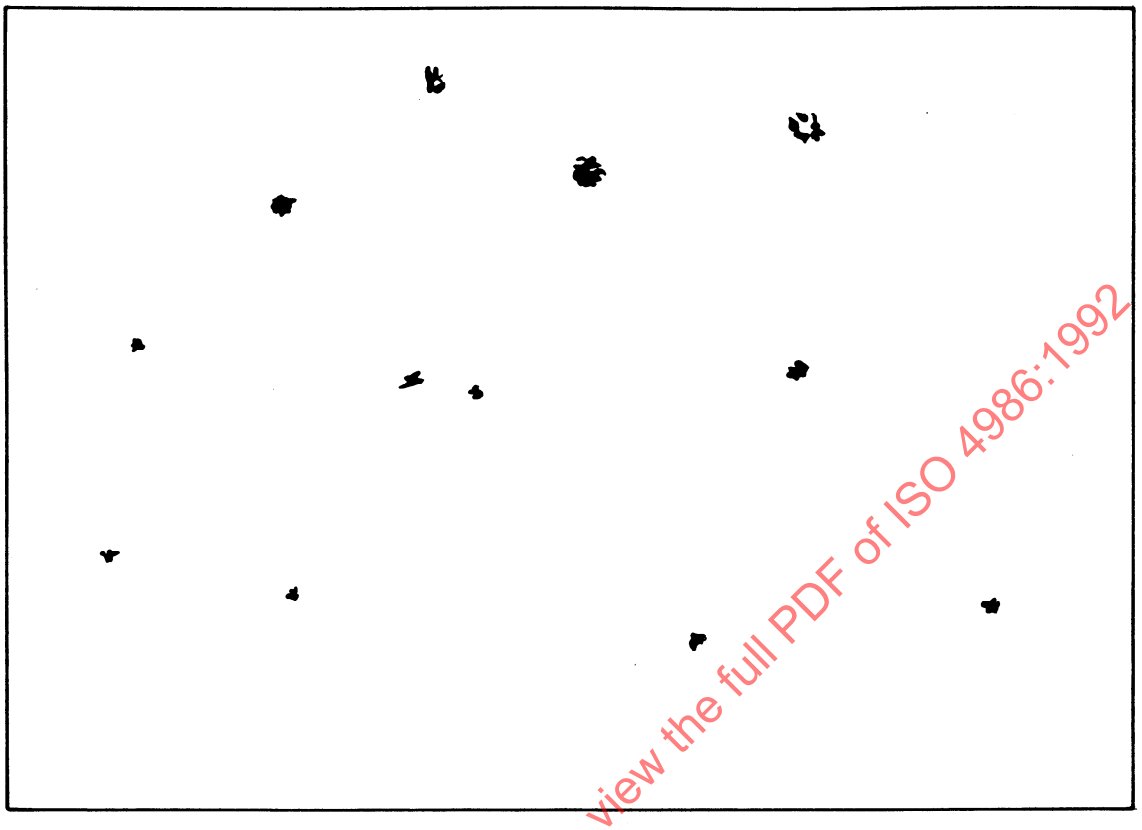
C.1 Non-linear indications

Sketches of non-linear indications (SM 1 to SM 5) are given in C.1.1 to C.1.5.

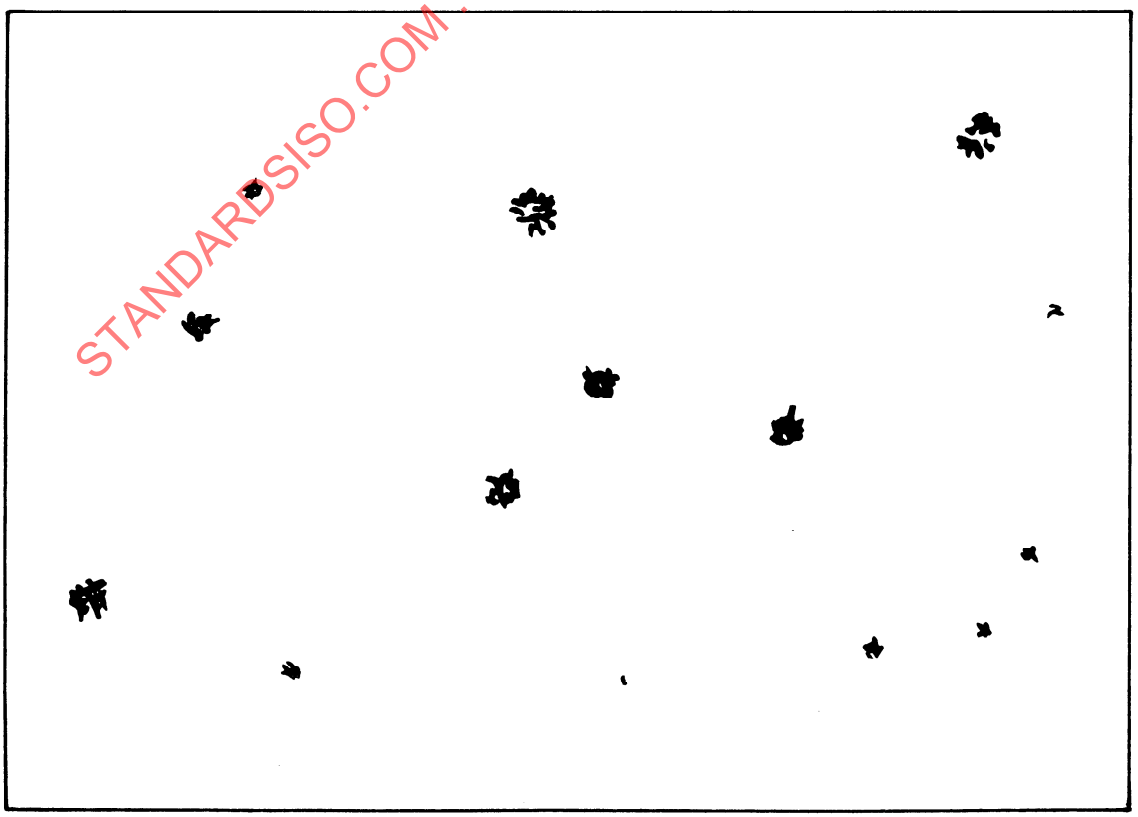
C.1.1 Severity level SM 1



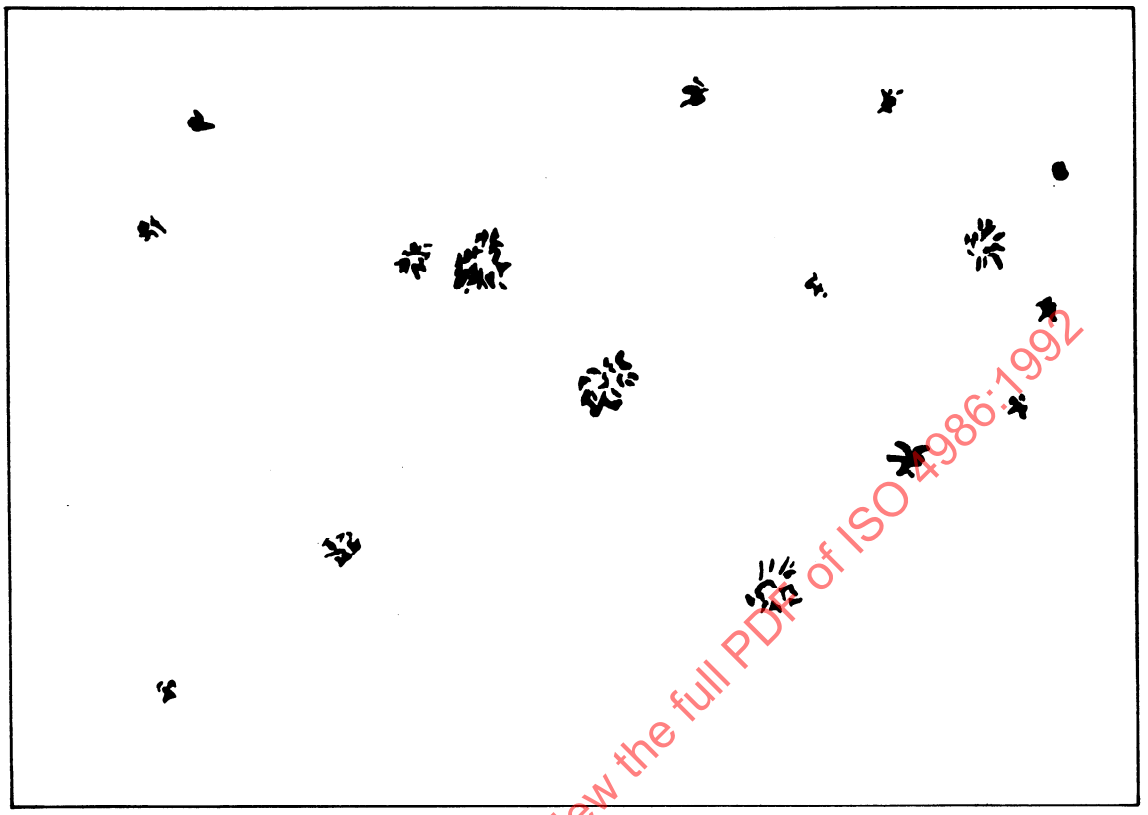
C.1.2 Severity level SM 2



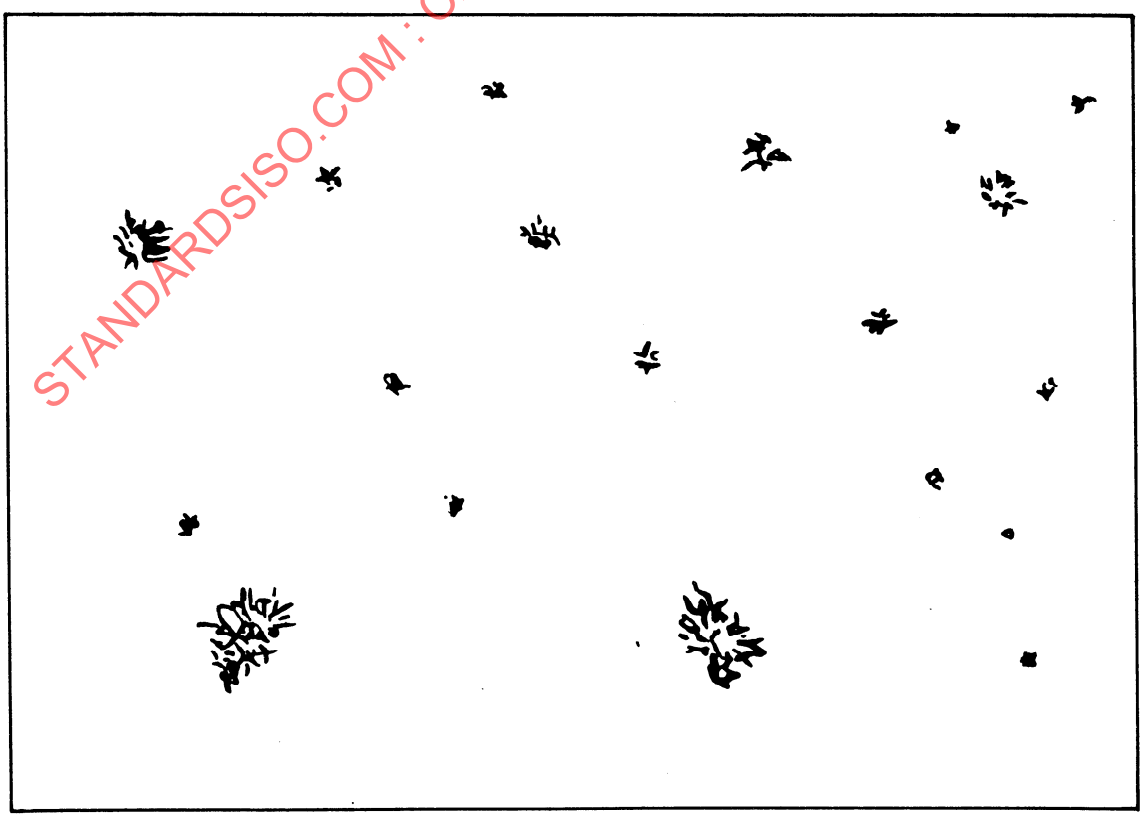
C.1.3 Severity level SM 3



C.1.4 Severity level SM 4



C.1.5 Severity level SM 5



C.2 Linear and aligned indications (symbolized AM)

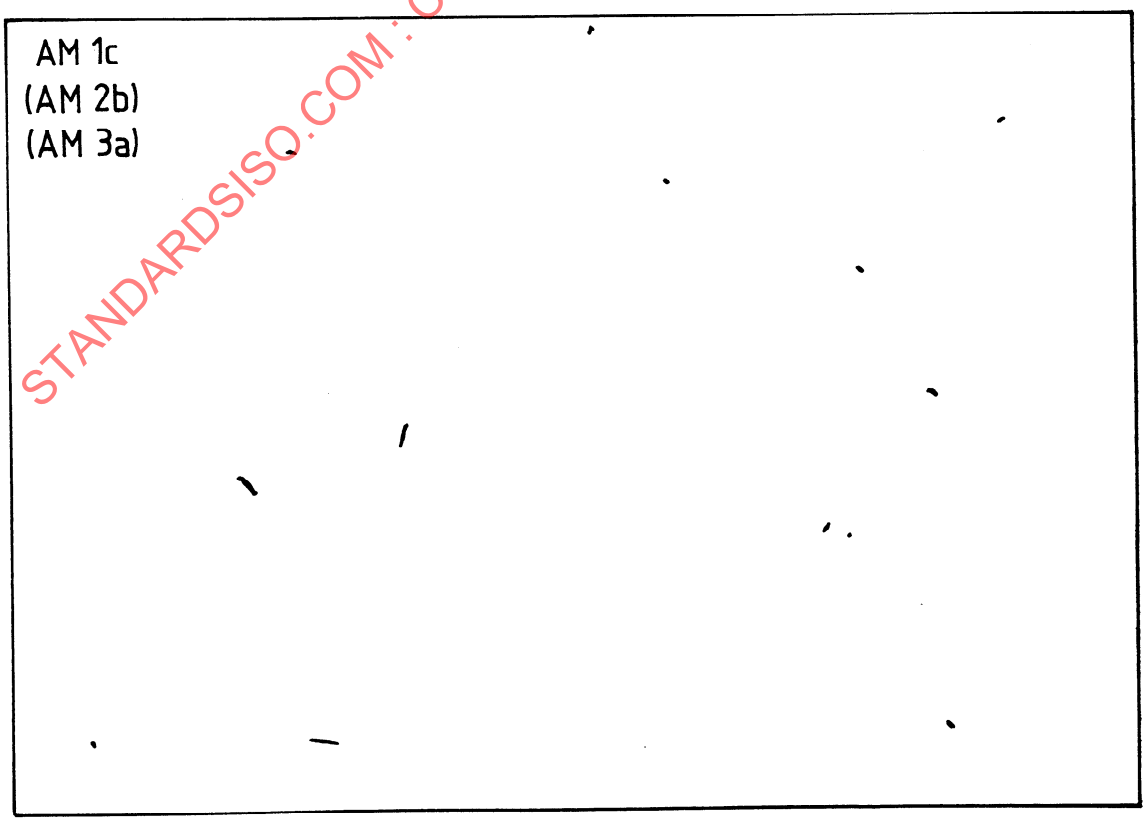
Sketches of linear and aligned indications (types A to H) are given in C.2.1 to C.2.7.

The severity levels in parentheses correspond approximately.

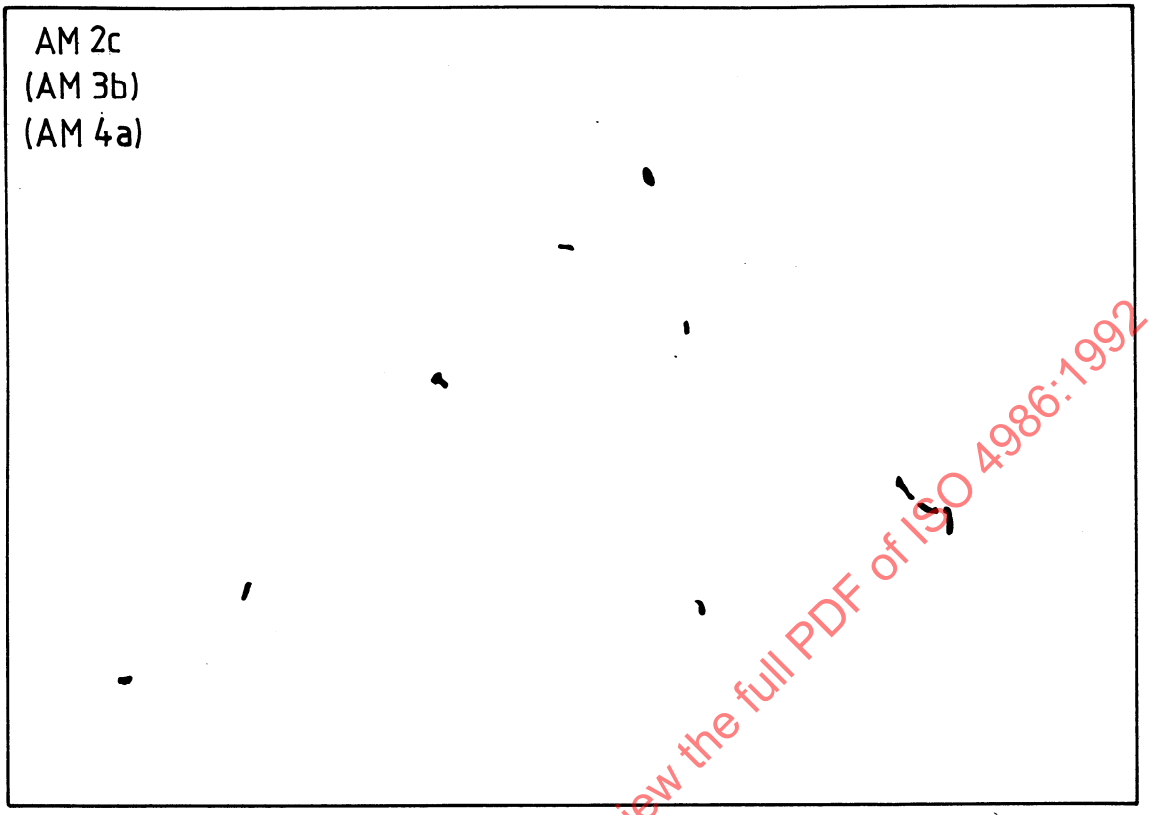
C.2.1 Severity level AM 1a

C.2.2 Severity level AM 1b

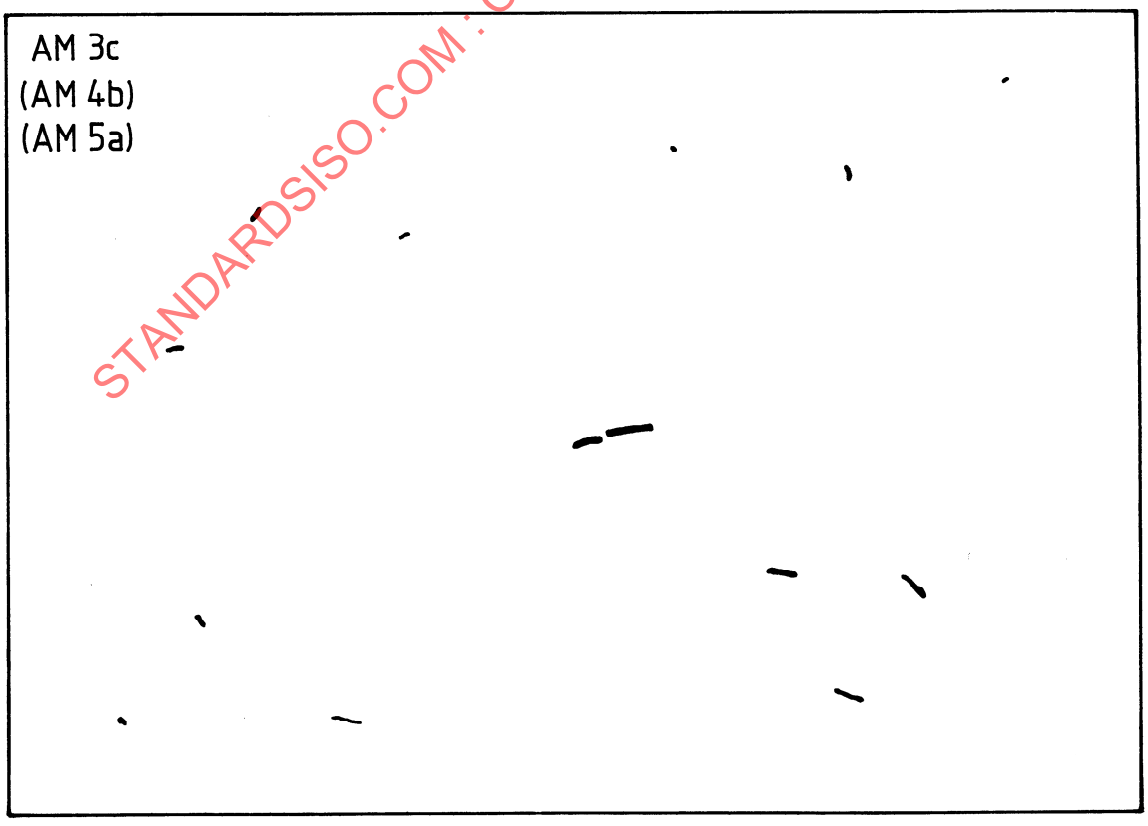
C.2.3 Severity level AM 1c



C.2.4 Severity level AM 2c

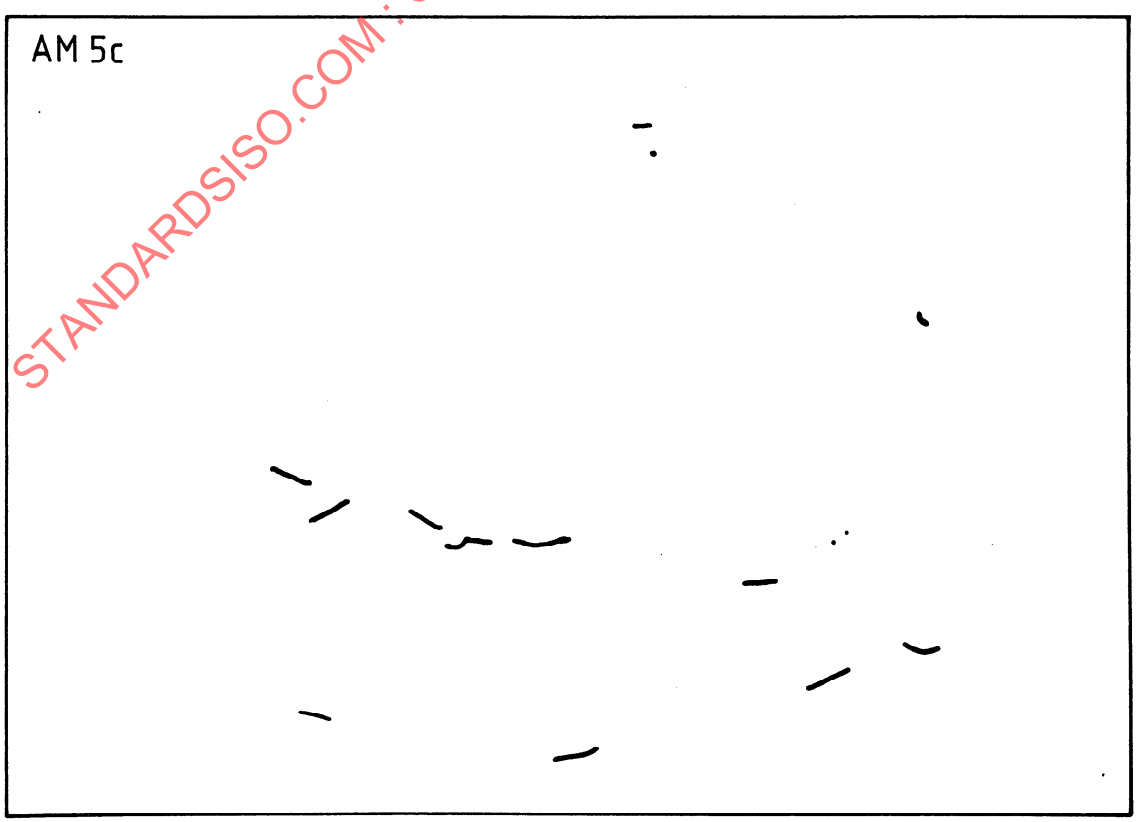


C.2.5 Severity level AM 3c



C.2.6 Severity level AM 4c

C.2.7 Severity level AM 5c



Annex D
(informative)

Recommended indicators

D.1 The indicators which are recommended for use are given in figures D.1, D.2 and D.3. However, indicators other than A1, A2 and A3 may be used, for example the Berthold indicator.

Dimensions in millimetres

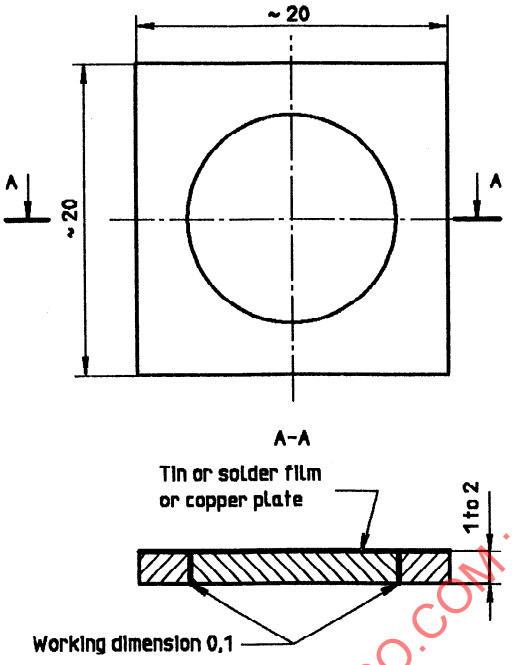


Figure D.1 — Indicator A1 (defined in the French Standard NF A 09-125) [1]

Dimensions in millimetres

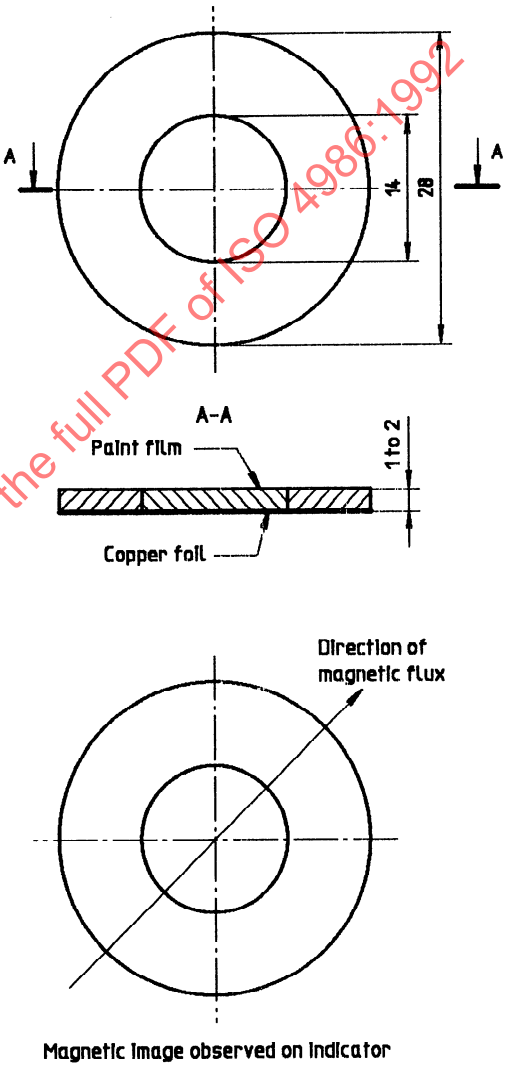


Figure D.2 — Indicator A2 (defined in the French Standard NF A 09-125) [1]

Dimensions in millimetres

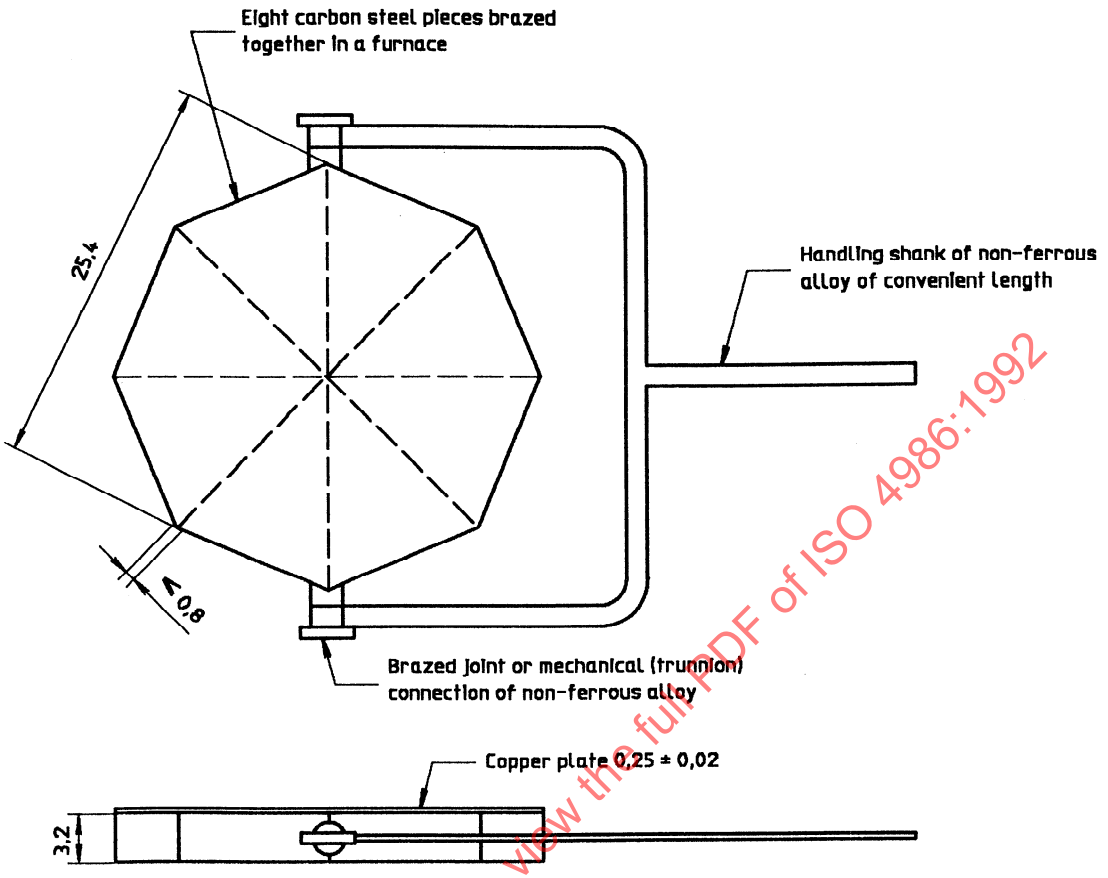


Figure D.3 — Indicator A3 (defined in the American Standard ASTM E 709) [2]

D.2 Bibliography

[1] AFNOR, NF A 09-125:1982, *Essais non destructifs des produits métallurgiques — Principes généraux de l'examen magnétoscopique.*

[2] ASTM, E 709-80 (Reapproved 1985), *Standard practice for magnetic particle examination.*

Annex E
(informative)

Method of squares for illustrations

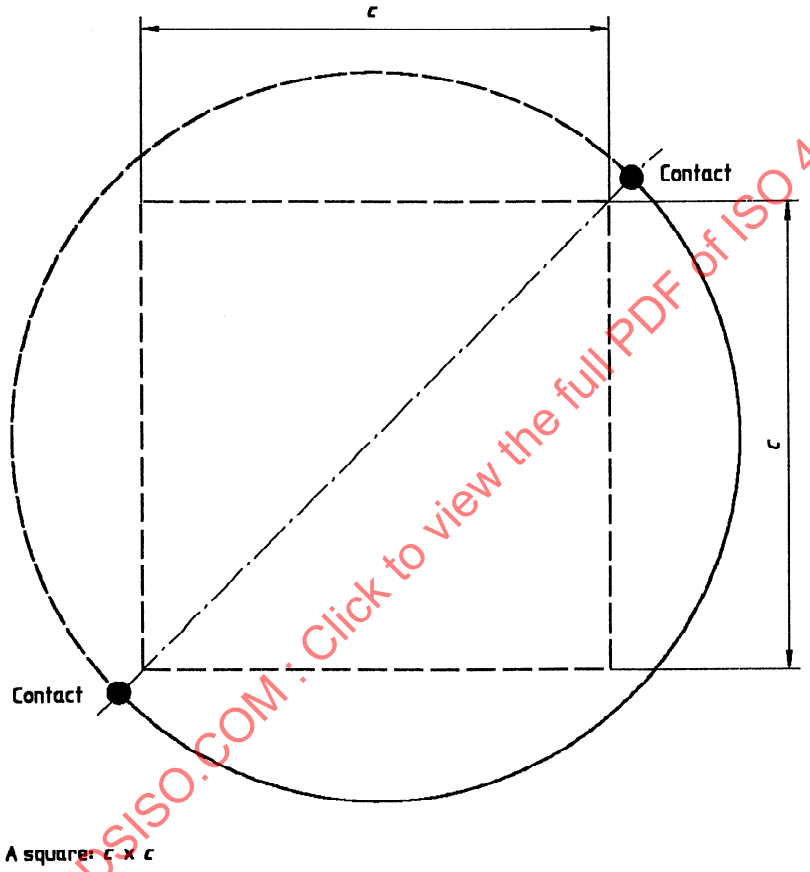


Figure E.1 — Diagonal method

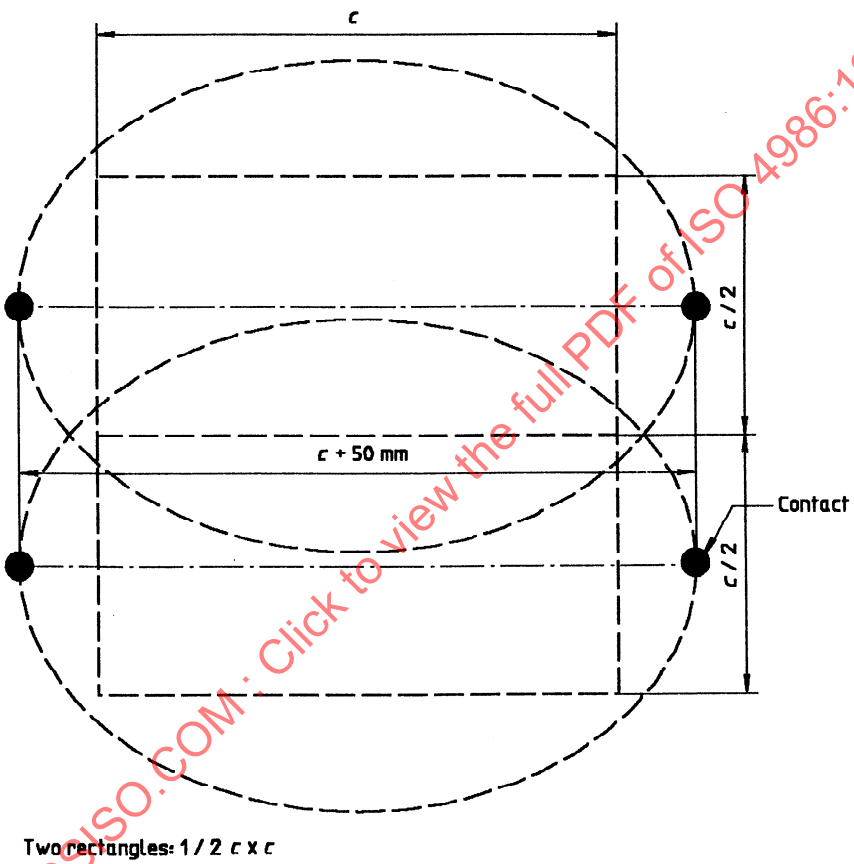


Figure E.2 — Double rectangle method