
Steel castings — Magnetic particle inspection

Pièces moulées en acier — Contrôle par magnétoscopie

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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 2.

The main task of technical committees is to prepare International Standards. 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 document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 4986 was prepared by Technical Committee ISO/TC 17, *Steel*, Subcommittee SC 11, *Steel castings*.

This second edition cancels and replaces the first edition (ISO 4986:1992), which has been technically revised.

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Introduction

This International Standard complements the general principles of magnetic particle inspection described in ISO 9934-1 for the additional requirements of the foundry industry.

Magnetic particle inspection, as well as any other non-destructive examination, is part of a general or specific assessment of the quality of the casting to be agreed between the purchaser and the manufacturer at the time of acceptance of the order.

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Steel castings — Magnetic particle inspection

1 Scope

This International Standard specifies a method for the magnetic particle inspection of ferro-magnetic steel castings.

It also gives acceptance criteria through severity levels defined by the nature, the area and the dimensions of the discontinuities present.

This International Standard applies to all ferro-magnetic castings, independent of the moulding method.

A steel casting is considered to be ferro-magnetic if the magnetic induction is greater than 1 T (Tesla) for a magnetic field strength of 2,4 kA/m.

This International Standard only applies to those areas of the castings specified for inspection, as well as the percentage of castings to be inspected.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 3059, *Non-destructive testing — Penetrant testing and magnetic particle testing — Viewing conditions*

ISO 4990, *Steel castings — General technical delivery requirements*

ISO 9712, *Non-destructive testing — Qualification and certification of personnel*

ISO 9934-1, *Non-destructive testing — Magnetic particle testing — Part 1: General principles*

3 Ordering information

Subject to agreement between the manufacturer and the purchaser, enquiries and purchase orders for castings requiring magnetic particle inspection should include the following information.

The areas of the castings and the percentage of the castings to be inspected shall be indicated in the enquiry.

The manufacturing stage(s), when magnetic particle inspection(s) is (are) to be performed, shall be defined by agreement between the manufacturer and the purchaser.

The sensitivity can differ depending on the method of magnetic particle inspection selected. Hence the required severity levels and the method shall be agreed between the manufacturer and the purchaser.

The order shall be subject to an agreement between the manufacturer and the purchaser and shall specify at least the following points:

- the qualification or certification of the operators who will carry out the inspection (see 4.2);
- the required surface finish of the areas to be inspected (see 4.3);

It is recommended that the assessment of surface finish be carried out using a visual cast surface roughness comparator rather than an instrumental method (see Annex A).

- if inspection is to be performed in only one direction (see 4.1);
- the method to be used (type of detection media);
- whether or not the casting is to be demagnetized after inspection has been performed (viz. maximum residual field strength values).

For each area of the casting to be inspected (see Clauses 5 and 6):

- the type of discontinuity;
- the severity level.

NOTE The type of discontinuity and the severity level can vary depending on the area of the casting inspected.

For the classification, reference shall be made to the severity levels defined in Tables 1 and 2 (see 6.1).

The indications resulting from an inspection can be compared to the reference figures. The reference figures are included for convenience only. In the event of a dispute, reference shall be made to the tables.

4 Method of inspection

4.1 Operating mode

The operating mode shall be agreed between the purchaser and the supplier. Unless otherwise specified (see Clause 3), it is necessary to carry out an inspection by magnetizing sequentially in two directions perpendicular to each other (see ISO 9934-1).

When the direction of stress is known, the inspection may be performed in one direction only, in order to take into account the most detrimental discontinuity.

NOTE The magnetic images need not necessarily correspond to discontinuities as pseudo-defects can appear.

4.2 Qualification of the operators

Inspection shall be performed by personnel qualified in accordance with ISO 9712 or by a certification scheme which is considered to be equivalent. The qualification level of the personnel shall be agreed between the manufacturer and the purchaser by the time of acceptance of the order.

4.3 Surface preparation

The surface to be inspected shall be clean and free from oil, grease, sand, scale, moulding and coating residues, or any other contaminant which can interfere with the correct implementation and interpretation of the magnetic-inspection test results. For small indications, it may be necessary to improve the surface; some guidance for the surface is given in Annex A.

The surface may be either shot blasted with round or angular shot, or sand blasted, or ground or machined so that the smallest relevant indication required can be evaluated.

The surface to be inspected may be painted to provide a contrast before inspection (see ISO 9934-1).

4.4 Conditions of inspection

The inspection shall be carried out with the naked eye or at a maximum magnification of 3× and under viewing conditions in accordance with ISO 3059.

5 Acceptance criteria

5.1 Definition of magnetic-inspection indications

5.1.1 General

The discontinuity indications revealed by the magnetic particle inspection can have different shapes and sizes. The distinction between the discontinuity indications is made depending on the ratio of the length L of the indication to its width W , in the manner described in 5.1.2 and 5.1.3.

5.1.2 Non-linear indications (SM)

The indications are considered to be non-linear when the length L is smaller than three times the width W . Indications are considered to be aligned when the distance between non-linear indications is less than 2 mm and at least three indications are aligned. An alignment of indications is considered to be a unique indication and its length is equal to the overall length L of the alignment.

The symbol for non-linear indications is SM (S for surface and M for magnetic particle).

5.1.3 Linear indications (LM)

The indications are considered to be linear when the length L is greater than or equal to three times the width W .

The symbol for linear indications is LM (L for linear and M for magnetic particle).

Indications are considered to be aligned when the distance between two linear indications is smaller than the length L of the longest indication. An alignment of indications is considered to be a unique indication and its length is equal to the overall length L of the alignment.

5.2 Severity levels

5.2.1 General

The severity levels are designed as a reference scale and are defined depending on the types of indications.

5.2.2 Non-linear indications

For the non-linear indications, the severity levels (see Table 1) are defined by

- the length (largest dimension) L_1 of the smallest indication to be taken into account, and
- the maximum length L_2 of the indications.

5.2.3 Linear and aligned indications

5.2.3.1 General

For the linear and aligned indications, the severity levels (see Table 2) are defined by

- the length (largest dimension) L_1 of the smallest indication to be taken into account,
- the maximum length L_2 of the linear and aligned indications, and
- the sum of the lengths of the linear and aligned indications exceeding the length L_1 in the frame measuring 105 mm × 148 mm.

5.2.3.2 Section thickness type

Three section thickness types are specified (see Table 2):

- a: $t \leq 16$ mm;
- b: $16 \text{ mm} < t \leq 50$ mm;
- c: $t > 50$ mm;

where t is the section thickness.

5.2.4 Selection of the severity level

The severity levels shall be selected from Tables 1 and/or 2 in conjunction with, if necessary, the reference figures given in Annexes B and C. The reference figures are drawn to a scale of 1:1 and are given as examples. The largest non-relevant indication is shown in a 26 mm × 37 mm frame corresponding to the ISO format A10.

Table 1 and Annex B correspond to non-linear (SM) indications (isolated).

Table 2 and Annex C correspond to linear (LM) indications and aligned (AM) indications¹⁾.

The severity levels cannot be considered in the same progression from Table 1 to Table 2. They should not be considered equivalent as regards inspection severity. The severity criteria and the severity levels can differ from one part of a casting to another.

The choice of the reference figure depends on the section thickness type.

5.2.5 Designation of severity levels

The requirements in the order or in the specifications shall conform to the terminology used in this International Standard.

Examples of correct terminology are given below:

- non-linear indications, level 2: SM 2 (see 5.1.2);
- linear and aligned indications, level 5: LM 5 (see 5.1.3).

1) It should be noted that several equivalent severity levels defined in Table 2 are represented by the same reference figure. In certain cases, the equivalence of the figure is only approximate because of slight differences in the parameters in Table 2.

6 Classification of the indications and interpretation of results

6.1 Classification of the indications using Tables 1 and 2

6.1.1 General

In order to classify a discontinuity indication, it is necessary to place a 105 mm × 148 mm frame in the most unfavourable location, i.e. showing the greatest severity for discontinuities.

Demagnetization can be necessary for special applications and before carrying out a retest.

6.1.2 Non-linear indications

Only those indications with a length greater than L_1 shall be taken into account (see Table 1).

The length of these indications shall be measured.

The level of the SM indications shall be established using Table 1.

6.1.3 Linear and aligned indications

The length L of the isolated indications greater than the minimum length taken into account, defined by the required severity level, shall be measured. The sum of the indications included in the 105 mm × 148 mm frame shall be calculated.

The section thickness t at the inspection location shall be measured.

The level of the LM and AM indications shall be established using Table 2.

The lengths of the linear and aligned indications greater than the minimum length shall be summated and the result shall be compared to the "cumulative" length specified in Table 2.

6.2 Interpretation of results

The casting shall be considered to conform with this International Standard when the observed severity level is equal to or better than that specified in the order. If, for any indication type, the observed severity level is worse than that specified in the order, the casting shall be considered not to conform with this International Standard.

NOTE Non-linear indications, as well as linear and aligned indications, can appear simultaneously on the same part of the casting.

7 Cleaning after examination and demagnetization

Parts shall be cleaned after examination.

8 Inspection documents

When an inspection document is specified in the enquiry and the order, it shall contain at least the following information:

- information on the manufacturer;
- information on the purchaser (including the order number);

- the casting designation;
- the date and place of inspection;
- the traceability identification;

and also, as applicable, any of the following:

- a reference to this International Standard for the acceptance criteria;
- the position of the inspection stage in the manufacturing process;
- the surface finish;
- the inspection method;
- the equipment used;
- the magnetization used;
- the testing materials used;
- the criteria required in accordance with this International Standard;
- the reference to the specification;
- the results (description and location);
- the cartography of the significant indications;
- the decision taken after the interpretation of results;
- the elements required in ISO 4990 [type of document, signature(s) of the authorized persons according to the type of document];
- the name and the signature of the non-destructive testing operator and his certification or qualification.

A model of a bilingual inspection document is shown in Annex D.

Table 1 — Severity levels for magnetic particle inspection — Non-linear (SM) indications (isolated)

Characteristic	Severity levels						
	SM 001	SM 01	SM 1	SM 2	SM 3	SM 4	SM 5
Inspection means	magnifying glass or eye		eye				
Magnification for observation of penetrant indication	≤ 3		1				
Length L_1 of the smallest indication to be considered, in millimetres	0,3		1,5	2	3	5	5
Maximum number of non-linear indications allowed	—	—	8	8	12	20	32
Maximum individual length L_2 allowed, in millimetres	0	1	3 ^a	6 ^a	9 ^a	14 ^a	21 ^a
^a A maximum number of two indications of the designated dimension are permitted.							

Table 2 — Severity levels for magnetic particle inspection — Linear (LM) and aligned (AM) indications

Characteristic		Severity levels											
		LM 001 AM 001	LM 01 AM 01	LM 1 AM 1	LM 2 AM 2	LM 3 AM 3	LM 4 AM 4	LM 5 AM 5					
Inspection means		magnifying glass or eye		eye									
Magnification for observation of magnetic particle indication		≤ 3		1									
Length L_1 of the smallest indication to be considered, in millimetres		0,3		1,5		2		3		5		5	
Acceptable indications ^a Individual (I) or total (T) length		I or T		I	T	I	T	I	T	I	T	I	T
Maximum length L_2 of linear (LM) and aligned (AM) indications allowed depending on the section thickness t , in millimetres ^b	section thickness type a $t \leq 16$ mm	0	1	2	4	4	6	6	10	10	18	18	25
	section thickness type b $16 \text{ mm} < t \leq 50$ mm	0	1	3	6	6	12	9	18	18	27	27	40
	section thickness type c $t > 50$ mm	0	2	5	10	10	20	15	30	30	45	45	70
NOTE 1 Only values expressed in this table are valid. Reference figures are for information only (see Annex C).													
NOTE 2 The sensitivity can differ depending on the method of magnetic particle inspection selected.													
^a A maximum number of two indications of the designated maximum dimension are permitted.													
^b No functional relationship exists between each type of section thickness and maximum crack length, relative to a fracture-mechanics study. However, this table is a useful guide where no relevant fracture-mechanics parameters currently exist.													

Annex A

(informative)

Recommended surface finish for magnetic particle inspection

Table A.1 — Recommended surface finish for magnetic particle inspection

Dimension of smallest indication mm	Visual/tactile comparators ^a	
	BNIF ^b	SCRATA ^b
0,3	2/0S2	—
0,3	3/0S1 - 2/0S1 1/0S2	—
0,3	2/0S1 - 1/0S1 1 S2 - 2 S2	—
1,5	1 S1 - 2 S1 3 S2 - 4 S2	—
2	2 S1 - 3 S1 4 S2 - 5 S2	A 2 H 2
3	unspecified (rough surface)	A 3 - A 4 H 3

^a Two visual/tactile comparators are currently used (see ISO 11971):

— *SCRATA comparators for the definition of surface quality of steel castings*, available from Castings Technology International, Advanced Manufacturing Park, Brunel Way, Rotherham, S60 5WG, United Kingdom;

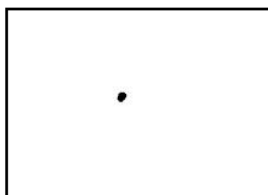
— *BNIF 359, Recommandation technique du Bureau de Normalisation des Industries de la Fonderie. Caractérisation d'états de surface des pièces moulées — Utilisation des échantillons types de 110 mm × 160 mm*, available from Éditions Techniques des Industries de la Fonderie, 44 avenue de la Division Leclerc, 92310 Sèvres, France.

^b See Annex B.

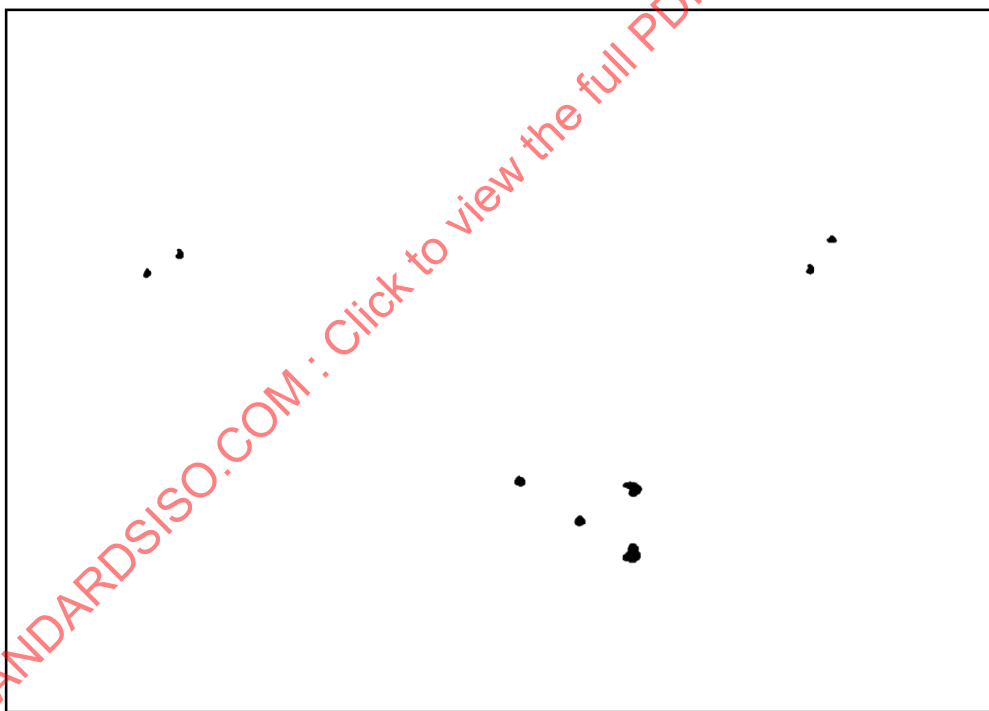
Annex B (informative)

Reference figures — Non-linear indications (SM)

All reference figures shown in this annex are for guidance only. They are drawn and shall be used at a scale of 1:1.

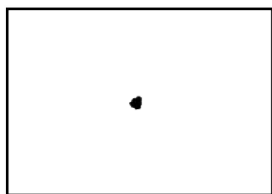


a) Maximum size allowed for a non-relevant indication for severity level SM 1



b) Severity level SM 1

Figure B.1 — Severity level SM 1

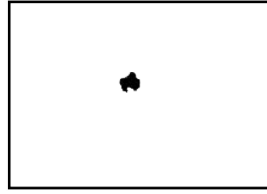


a) Maximum size allowed for a non-relevant indication for severity level SM 2



b) Severity level SM 2

Figure B.2 — Severity level SM 2

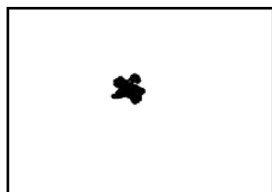


a) Maximum size allowed for a non-relevant indication for severity level SM 3



b) Severity level SM 3

Figure B.3 — Severity level SM 3

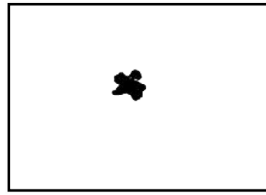


a) Maximum size allowed for a non-relevant indication for severity level SM 4

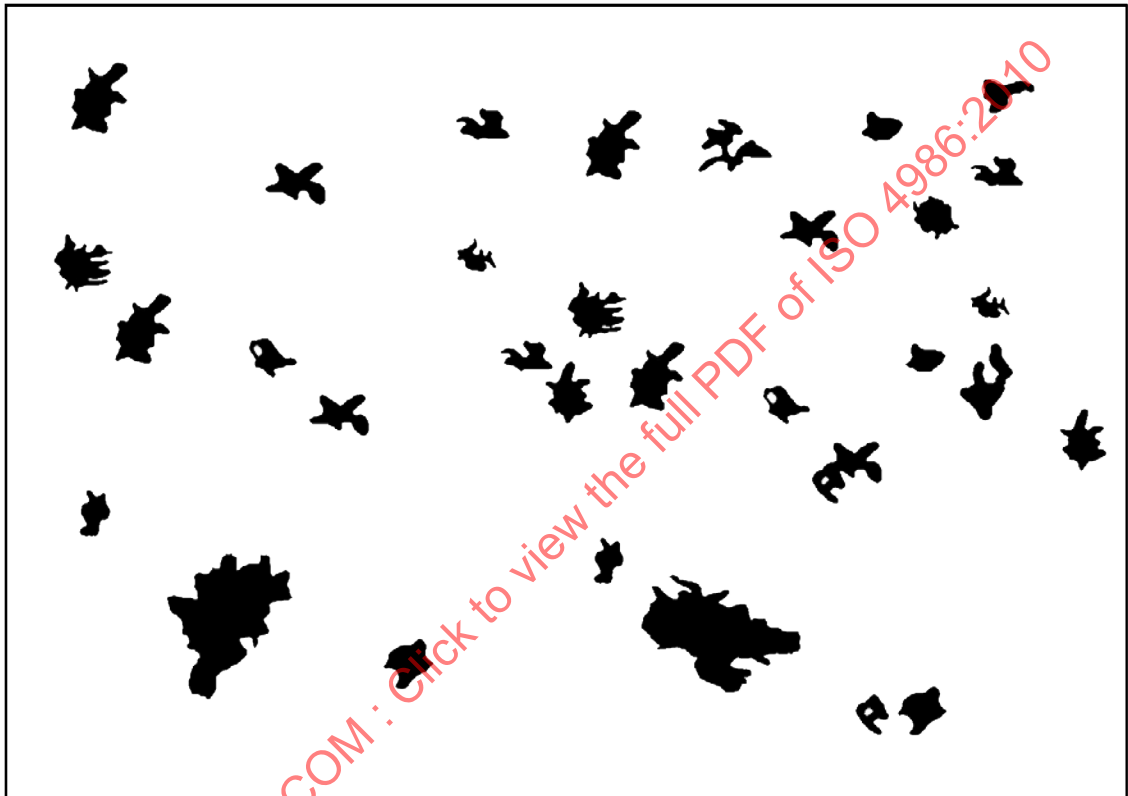


b) Severity level SM 4

Figure B.4 — Severity level SM 4



a) Maximum size allowed for a non-relevant indication for severity level SM 5



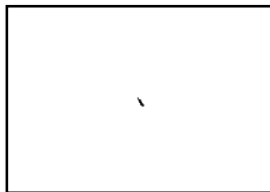
b) Severity level SM 5

Figure B.5 — Severity level SM 5

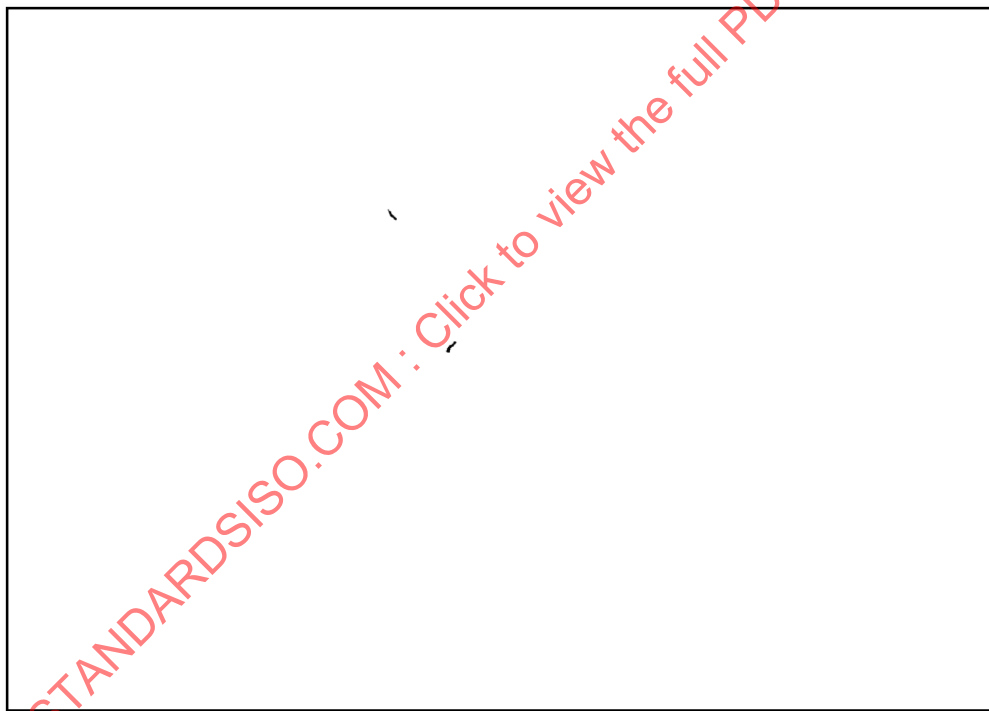
Annex C (informative)

Reference figures — Linear (LM) and aligned (AM) indications

All reference figures shown in this annex are for guidance only. They are drawn and shall be used at a scale of 1:1.

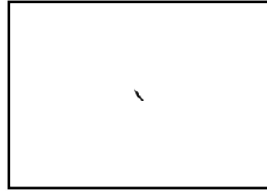


a) Maximum size allowed for a non-relevant indication for severity level LM 1a or AM 1a

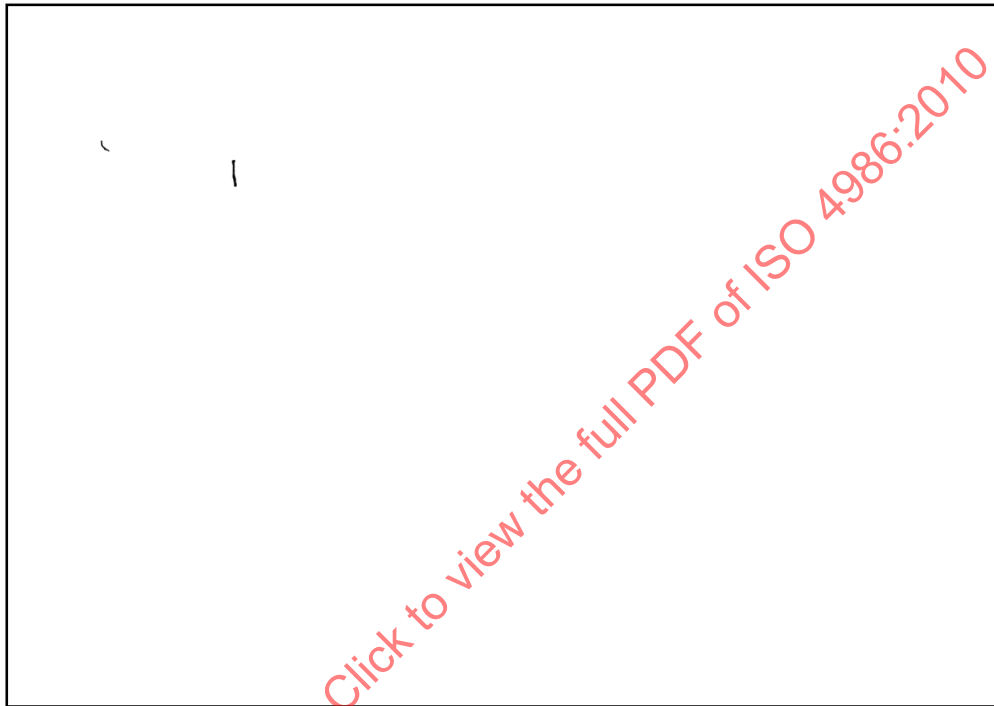


b) Severity level LM 1a or AM 1a

Figure C.1 — Severity level LM 1a or AM 1a

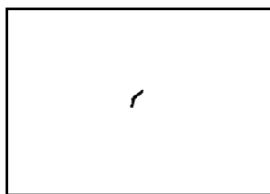


a) Maximum size allowed for a non-relevant indication for severity level LM 2a or AM 2a



b) Severity level LM 2a or AM 2a

Figure C.2 — Severity level LM 2a or AM 2a

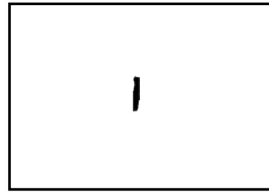


a) Maximum size allowed for a non-relevant indication for severity level LM 3a or AM 3a



b) Severity level LM 3a or AM 3a

Figure C.3 — Severity level LM 3a or AM 3a



a) Maximum size allowed for a non-relevant indication for severity level LM 4a or AM 4a



b) Severity level LM 4a or AM 4a

Figure C.4 — Severity level LM 4a or AM 4a



a) Maximum size allowed for a non-relevant indication for severity level LM 5a or AM 5a



b) Severity level LM 5a or AM 5a

Figure C.5 — Severity level LM 5a or AM 5a

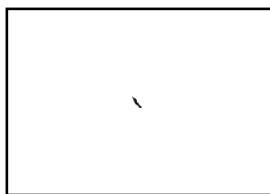


a) Maximum size allowed for a non-relevant indication for severity level LM 1b or AM 1b



b) Severity level LM 1b or AM 1b

Figure C.6 — Severity level LM 1b or AM 1b



a) Maximum size allowed for a non-relevant indication for severity level LM 2b or AM 2b



b) Severity level LM 2b or AM 2b

Figure C.7 — Severity level LM 2b or AM 2b

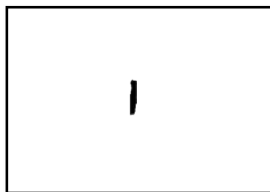


a) Maximum size allowed for a non-relevant indication for severity level LM 3b or AM 3b



b) Severity level LM 3b or AM 3b

Figure C.8 — Severity level LM 3b or AM 3b



a) Maximum size allowed for a non-relevant indication for severity level LM 4b or AM 4b



b) Severity level LM 4b or AM 4b

Figure C.9 — Severity level LM 4b or AM 4b

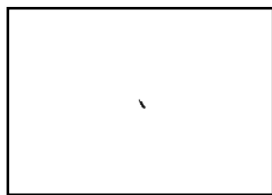


a) Maximum size allowed for a non-relevant indication for severity level LM 5b or AM 5b



b) Severity level LM 5b or AM 5b

Figure C.10 — Severity level LM 5b or AM 5b



a) Maximum size allowed for a non-relevant indication for severity level LM 1c or AM 1c



b) Severity level LM 1c or AM 1c

Figure C.11 — Severity level LM 1c or AM 1c