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Steel and iron castings — Magnetic particle testing

Pièces moulées en acier et en fer — 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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

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

This third edition cancels and replaces the second edition (ISO 4986:2010), which has been technically revised. The main changes compared to the previous edition are as follows:

- addition of definition of a cluster of non-linear (SM) in [6.1.2](#);
- addition of “aligned (AM) indications” in [6.1.3](#), [6.2.3](#), [6.2.4](#), [7.1.3](#) and [Annex C](#)

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document complements the general principles of magnetic particle testing described in ISO 9934-1 with additional requirements of the steel foundry industry.

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

Steel and iron castings — Magnetic particle testing

1 Scope

This document specifies a method for the magnetic particle testing of ferro-magnetic steel and iron castings.

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

This document is applicable to all ferro-magnetic castings, independent of the moulding method.

A steel and iron 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 document only applies to those areas of the castings specified for testing, as well as the percentage of castings to be tested.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 NDT personnel*

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

3 Terms and definitions

No terms and definitions are listed in this document.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

4 Ordering information

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

- a) the area of the casting to be tested;
- b) the qualification of the operators who will carry out the testing (see 5.2) or interpretation (see 7.2);
- c) the frequency/number of castings to be tested;
- d) the manufacturing stage, when magnetic particle testing is to be performed;
- e) the required surface finish of the areas to be tested (see 5.3):

- f) if testing is to be performed in only one direction (see [5.1](#));
- g) the method to be used (type of detection media);
- h) whether or not the casting is to be demagnetized after testing has been performed (viz. maximum residual field strength values);
- i) that test is to be carried out in accordance with ISO 9934-1;
- j) the type of discontinuity;
- k) the severity level.

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

The severity level can vary depending on the method of magnetic particle testing selected and the area of the casting tested (see [Tables 1](#) and [2](#)).

The indications produced by magnetic particle testing can be compared to reference figures. The reference figures are included for convenience only. In the event of a dispute, reference shall be made to the tables.

5 Testing

5.1 Operating mode

The operating mode shall be agreed between the purchaser and the supplier. Unless otherwise specified (see [Clause 4](#)), it is necessary to carry out the test by magnetizing sequentially in two directions perpendicular to each other (see ISO 9934-1).

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

NOTE The magnetic images are not necessarily corresponding to discontinuities as pseudo-defects can appear.

5.2 Qualification of the operators

Testing shall be performed by personnel qualified in accordance with ISO 9712 or equivalent recognised standards. The qualification level of the personnel shall be agreed between the manufacturer and the purchaser by the time of acceptance of the order.

5.3 Surface preparation

The surface to be tested 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 testing results. For small indications, it may be necessary to improve the surface condition. [Annex A](#) provides guidance on recommended surface finish for testing based on indication allowed.

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 tested may be painted to provide a contrast before the test.

5.4 Conditions of testing

The testing shall be carried out unaided or at a maximum magnification of 3× under viewing conditions in accordance with ISO 3059.

6 Acceptance criteria

6.1 Definition of magnetic particle testing indications

6.1.1 General

Indications revealed by the magnetic particle testing can have different shapes and sizes. An overview of types of indications is given in EN 1369. The distinction between linear and non-linear indications is made depending on the ratio of the length L of the indication to its width W , in the manner described in 6.1.2 and 6.1.3.

6.1.2 Non-linear indications (SM)

Indications are considered to be non-linear when the length L is smaller than three times the width W . Indications are considered to be clustered when the distance between non-linear indications is less than 2 mm and at least three indications are clustered. A cluster of indications is considered to be a single non-linear indication when its length is equal to the overall length L of the cluster specified in Table 1.

NOTE The symbol for nonlinear indications is SM (S for surface and M for magnetic particle).

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

Characteristic	Severity levels						
	SM 001	SM 01	SM 1	SM 2	SM 3	SM 4	SM 5
Testing 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 nonlinear 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.							

6.1.3 Linear indications (LM) and aligned indications (AM)

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

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

The lengths of linear indications greater than the length of smallest indication to be considered shall be added together and the result shall be compared to the total (T) length specified in Table 2.

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 single linear indication and its length is equal to the overall length L of the alignment.

NOTE The symbol for aligned indications is AM (A for aligned and M for magnetic particle).

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

Characteristic		Severity levels											
		LM 001	LM 01	LM 1		LM 2		LM 3		LM 4		LM 5	
Testing 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 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 ^a	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 testing selected.													
^a 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.													

6.2 Severity levels

6.2.1 General

The severity levels are a reference scale, each level depends on the type of indications.

6.2.2 Non-linear indications

The severity levels for non-linear indications ([Table 1](#)) are defined by:

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

6.2.3 Linear and aligned indications

6.2.3.1 General

The severity levels for linear indications ([Table 2](#)) are defined by:

- the length (largest dimension) L_1 of the smallest indication to be considered,
- the maximum length L_2 of the individual (I) linear indications, and
- the total (T) of the lengths of the linear indications exceeding the length L_1 in a frame measuring 105 mm × 148 mm.

6.2.3.2 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.

6.2.4 Selection of the severity level

The severity levels shall be selected from [Tables 1](#) and/or [2](#). The reference figures in [Annexes B](#) and [C](#) 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) and aligned (AM) indications.

NOTE Note 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](#).

The severity levels cannot be considered in the same progression from [Table 1](#) to [Table 2](#). They should not be considered equivalent as regards 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.

6.2.5 Designation of severity levels

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

Examples of correct terminology are given below:

- non-linear indications, level 2: SM 2 for non-linear indications with a maximum of 8 non-linear indications, L1 of 2 mm and L2 of 6 mm (see [6.1.2](#) and [Table 1](#));
- linear indications, level 5: LM 5c for linear indications and $t > 50$ mm with L1 of 5 mm and L2 of 45 mm for individual indications or 70 mm for total indications (see [6.1.3](#) and [Table 2](#)).

7 Classification of the indications and interpretation of results

7.1 Classification of the indications using [Tables 1](#) and [2](#)

7.1.1 General

In order to classify an 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.

7.1.2 Non-linear indications

Only 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 severity level of the SM indications shall be established using [Table 1](#).

7.1.3 Linear and aligned indications

The length L of the isolated indications greater than the smallest length to be considered, 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 testing location shall be measured.

The severity level of the LM indications shall be established using [Table 2](#).

The lengths of the linear indications greater than the minimum length shall be summated and the result shall be compared to the total (T) length specified in [Table 2](#).

7.2 Interpretation of results

The casting shall be considered to conform with this document when the observed severity level is equal to or less 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 document.

NOTE Non-linear indications and linear indications can appear on the same part of the casting.

8 Cleaning after examination and demagnetization

Parts shall be cleaned after examination.

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

9 Test report

When a test report is specified in the enquiry and the order, it shall contain at least the following information:

- a) information on the manufacturer;
- b) information on the purchaser (including the order number);
- c) the casting designation;
- d) the date and place of testing;
- e) the traceability identification;

and, as applicable, any of the following:

- a reference to this document for the acceptance criteria;
- the position of the testing stage in the manufacturing process;
- the surface finish;
- the test method;
- the equipment used;
- the magnetization used;
- the testing materials used;

- the criteria required in accordance with this document;
- 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 certification/qualification, name and the signature of the non-destructive testing operator.

A model of a bilingual test report is shown in [Annex D](#).

Annex A

(informative)

Recommended surface finish for magnetic particle testing

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

Length L_1 of smallest indication to be considered mm	Visual/tactile comparators ^a	
	BNIF	SCRATA
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):

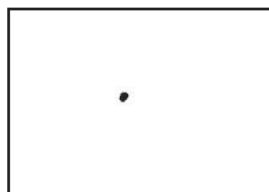
- *SCRATA comparators for the definition of surface quality of castings*, available from Castings Technology International, Advanced Manufacturing Park, Brunel Way, Rotherham, S60 5WG, United Kingdom; info@castingstechnology.com
- BNIF 359 - Recommandation technique du Bureau de Normalisation des Industries de la Fonderie - Caractérisation d'états de surface des pièces moulées - Utilisation des échantillons types de 110 × 160 mm, available from CTIF, 44 avenue de la Division Leclerc, 92310 Sèvres, France, www.ctif-editions.com.

NOTE These products are examples of a suitable products available commercially. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO of these products.

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.

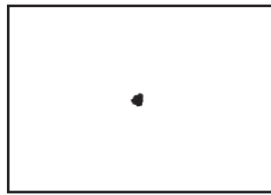


a) Maximum size allowed for a non-relevant indication for severity level SM 1

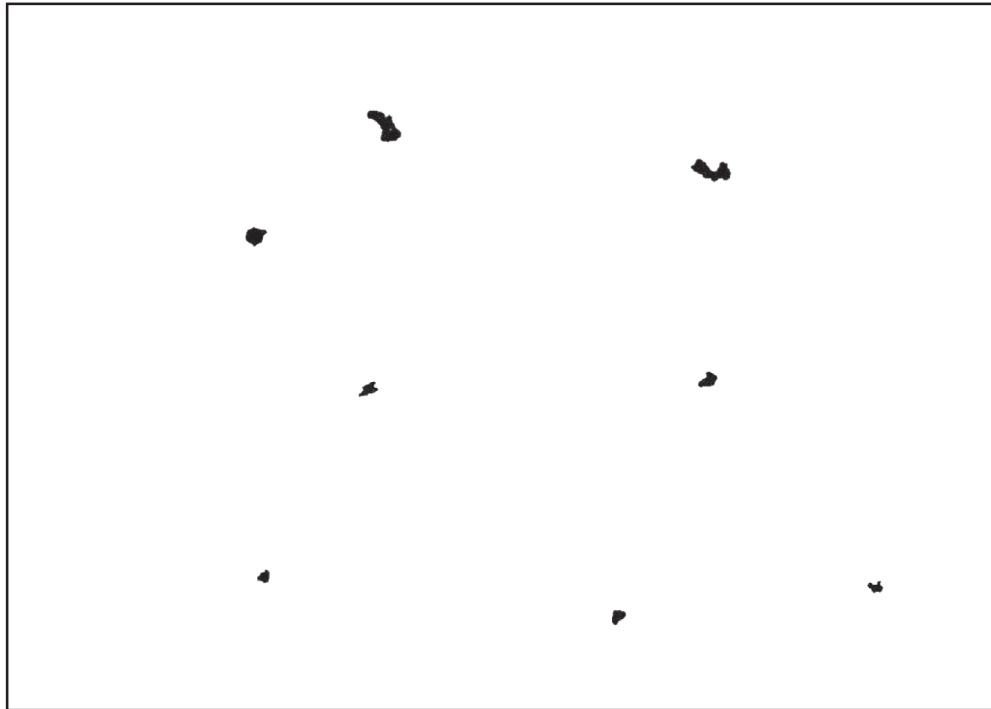


b) Severity level SM 1

Figure B.1 — Severity level SM 1

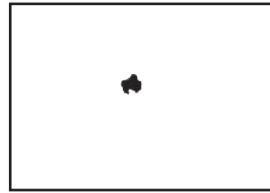


a) Maximum size allowed for a non-relevant indication for severity level SM 2



b) Severity level SM 2

Figure B.2 — Severity level SM 2

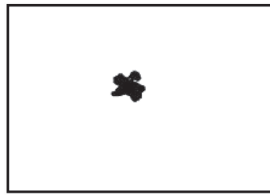


a) Maximum size allowed for a non-relevant indication for severity level SM 3



b) Severity level SM 3

Figure B.3 — Severity level SM 3

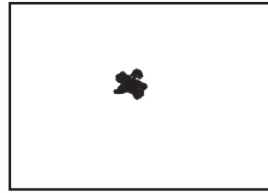


a) Maximum size allowed for a non-relevant indication for severity level SM 4

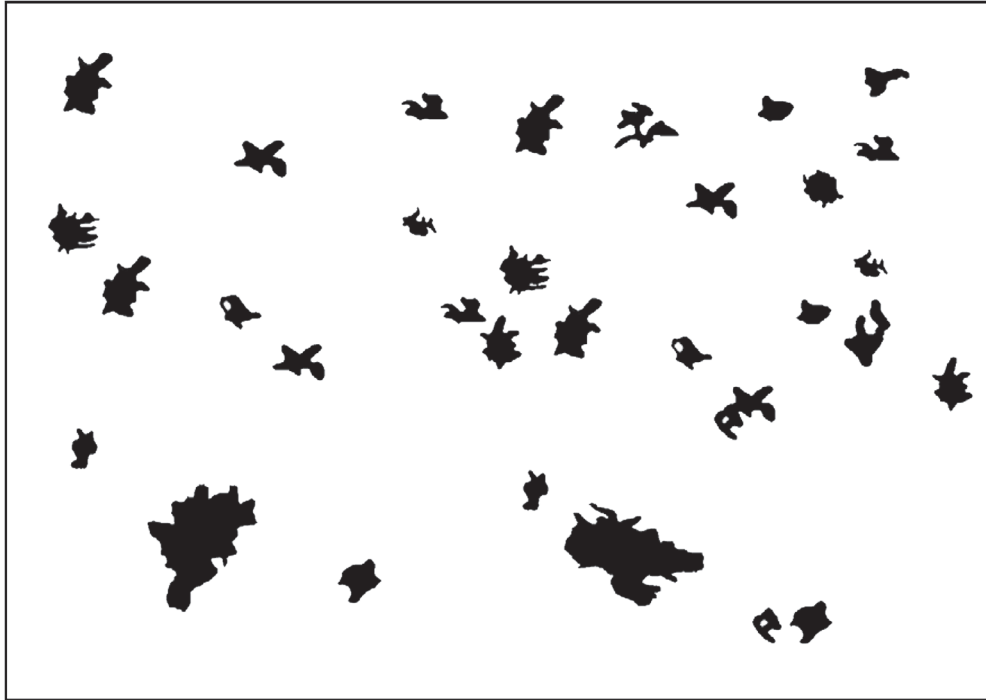


b) Severity level SM 4

Figure B.4 — Severity level SM 4



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



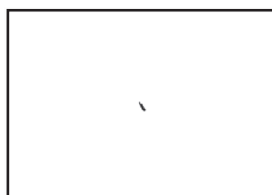
b) Severity level SM 5

Figure B.5 — Severity level SM 5

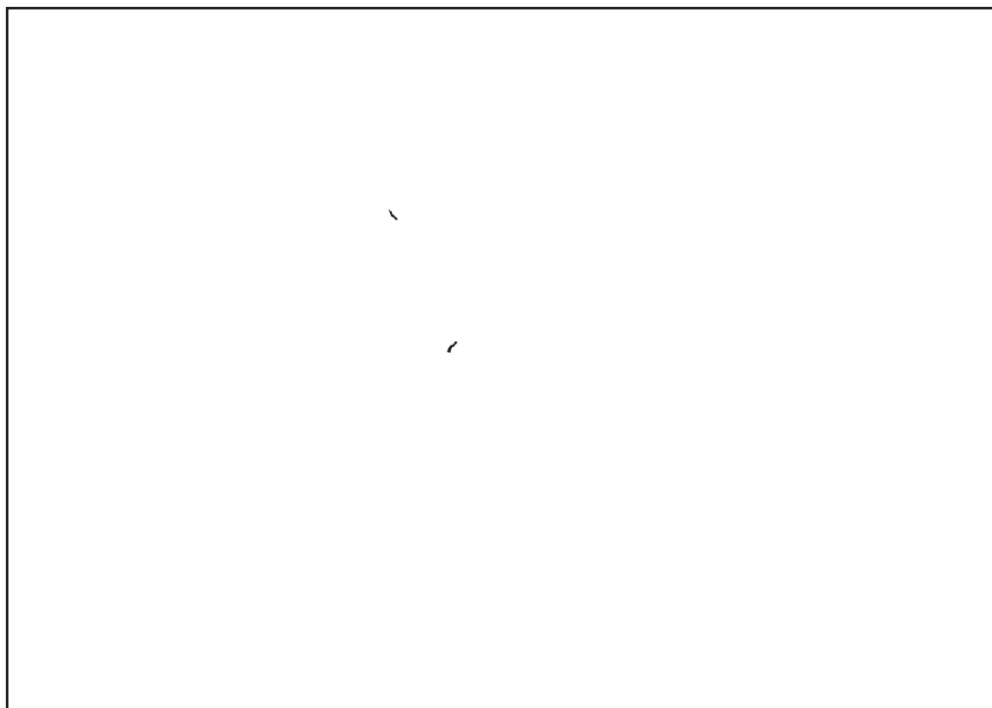
Annex C (informative)

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.

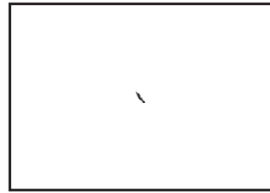


a) Maximum size allowed for a non-relevant indication for severity level LM 1a or AM 1a

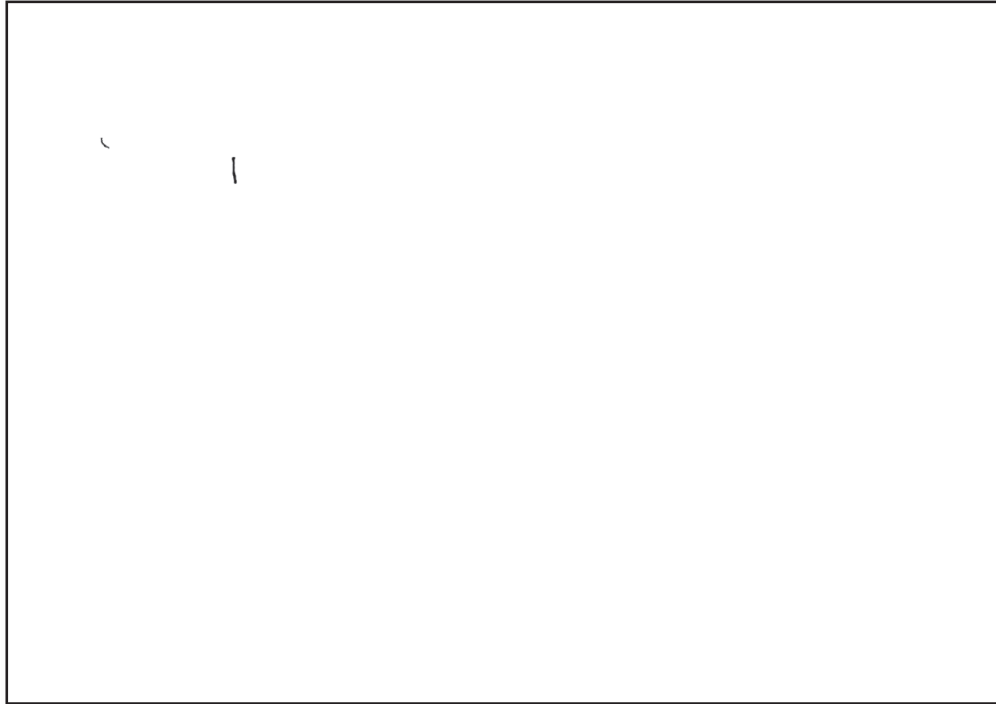


b) Severity level LM 1a or AM 1a

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

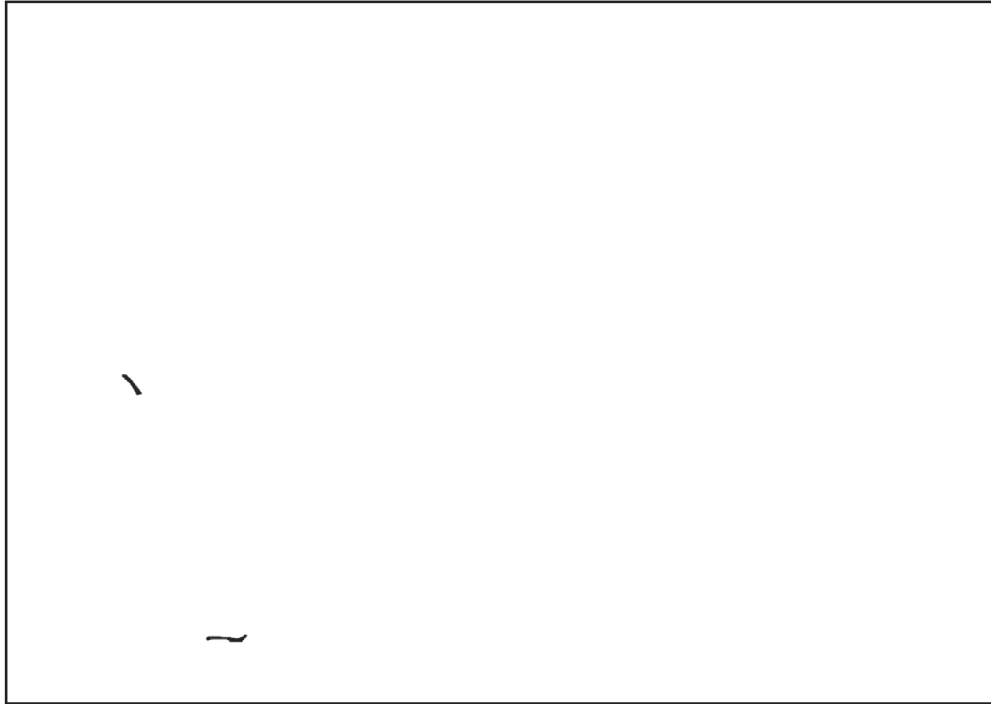


b) Severity level LM 2a or AM 2a

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

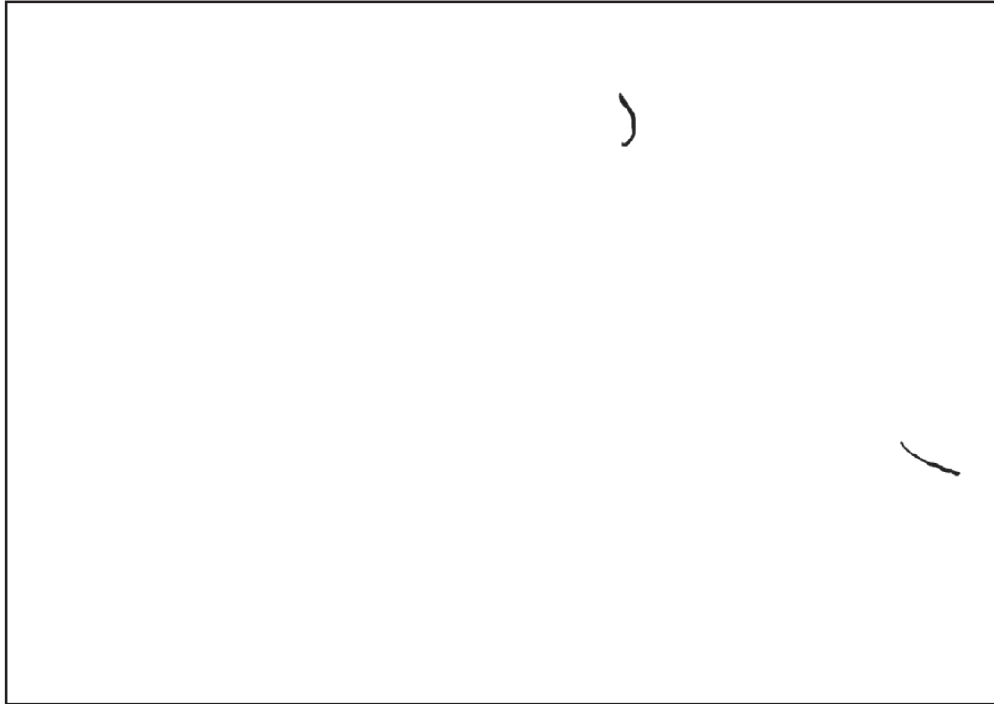


b) Severity level LM 3a or AM 3a

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

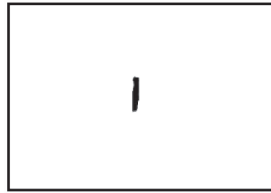


a) Maximum size allowed for a non-relevant indication for severity level LM 4a or AM 4a

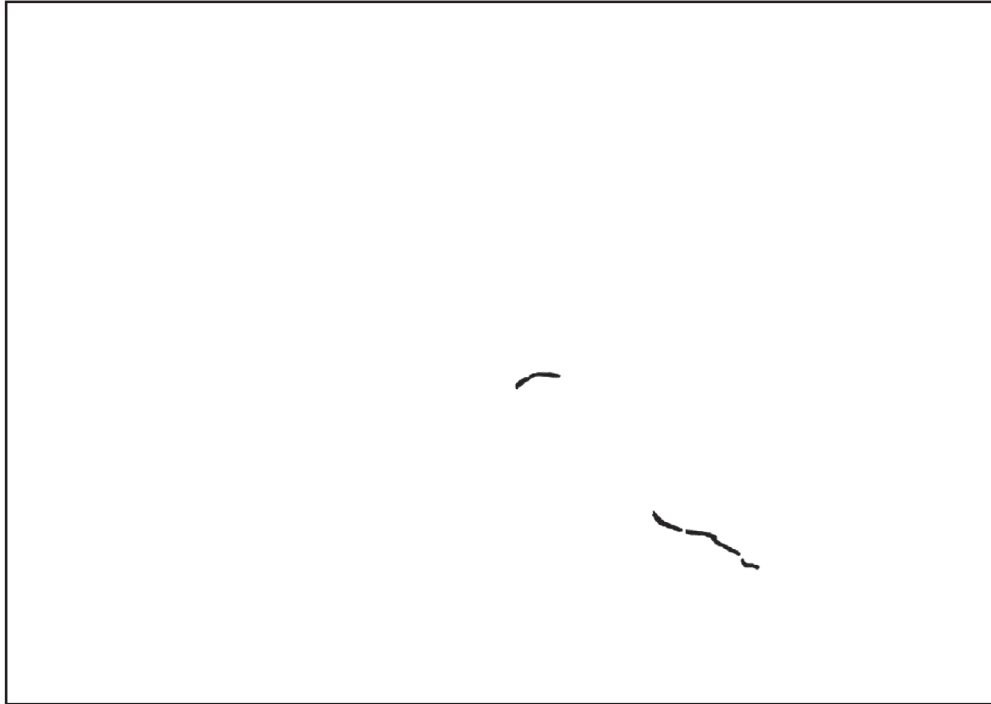


b) Severity level LM 4a or AM 4a

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

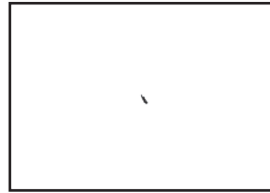


a) Maximum size allowed for a non-relevant indication for severity level LM 5a or AM 5a

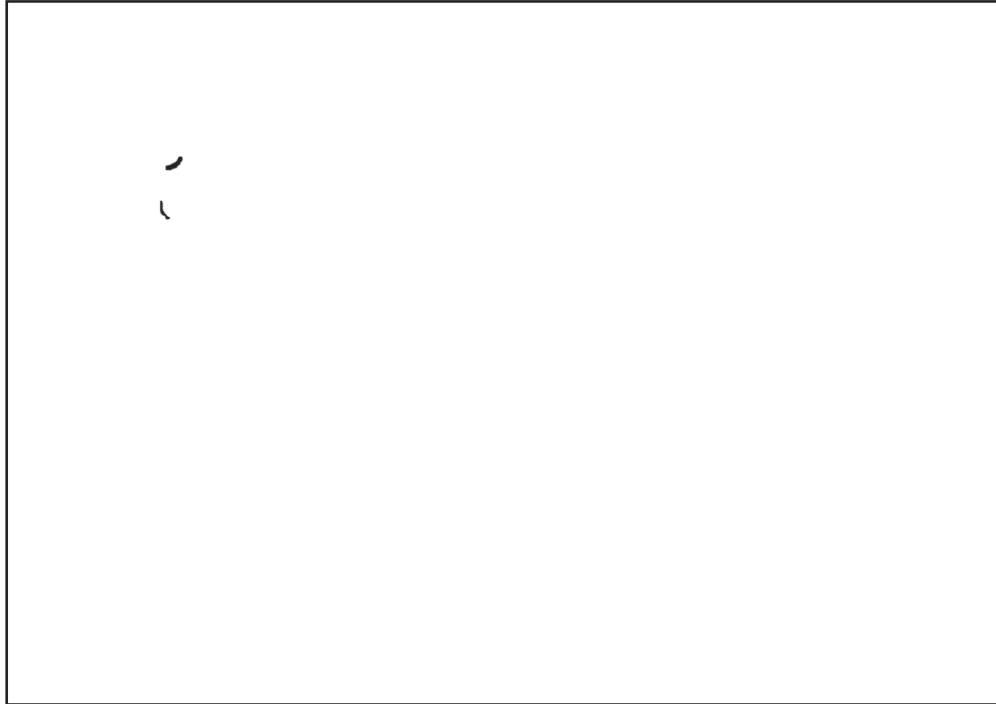


b) Severity level LM 5a or AM 5a

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

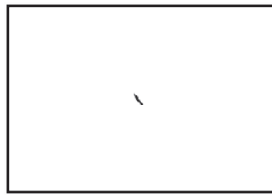


a) Maximum size allowed for a non-relevant indication for severity level LM 1b or AM 1b

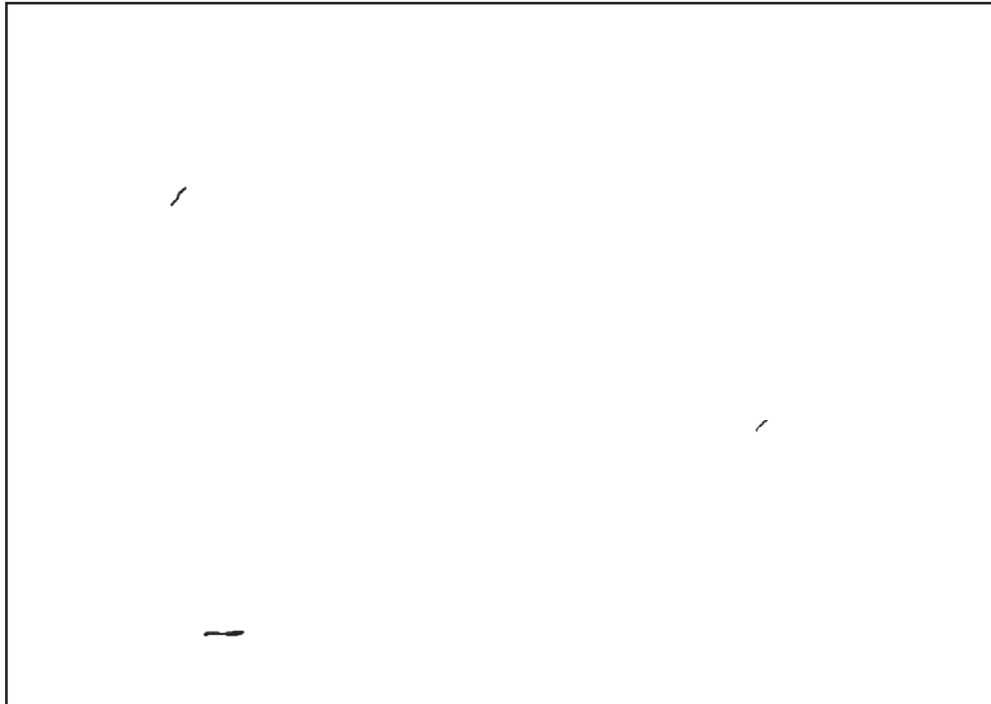


b) Severity level LM 1b or AM 1b

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

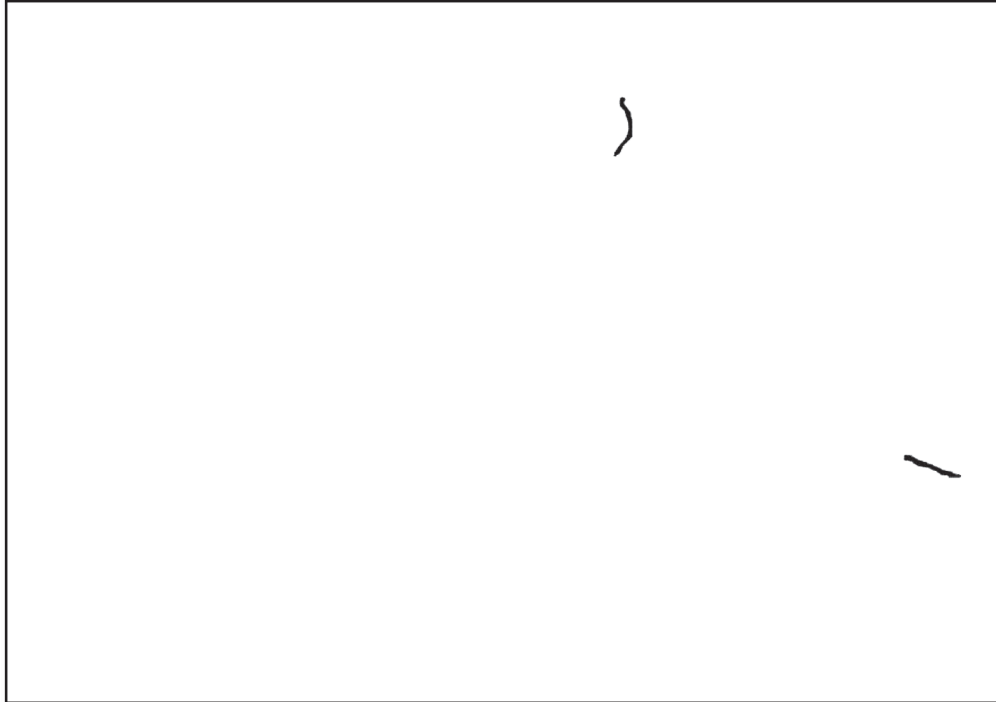


b) Severity level LM 2b or AM 2b

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

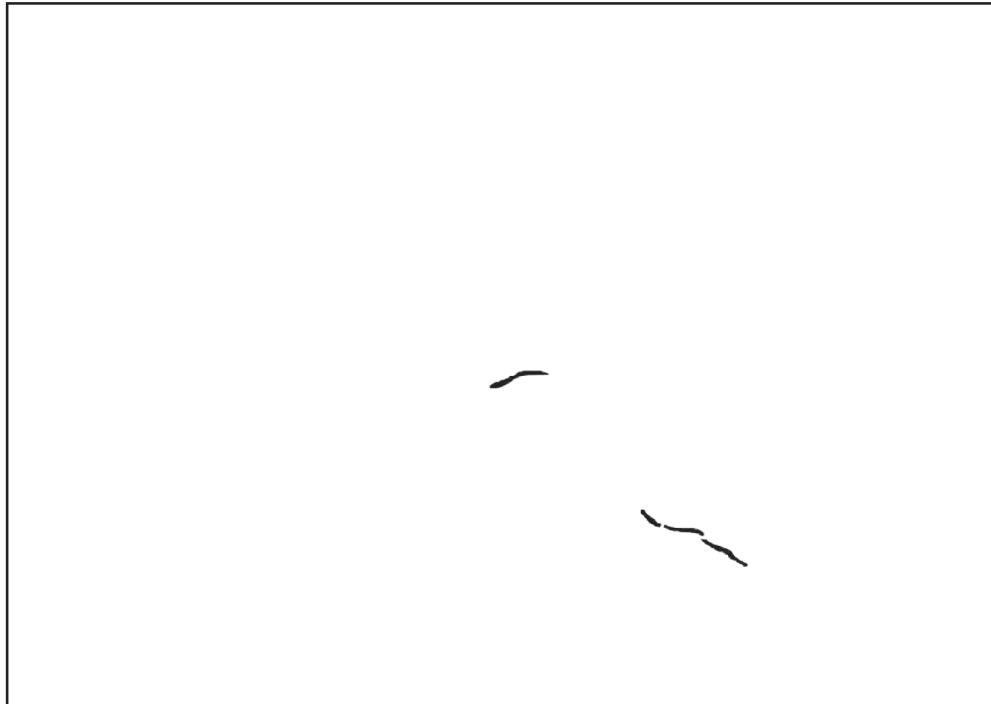


b) Severity level LM 3b or AM 3b

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

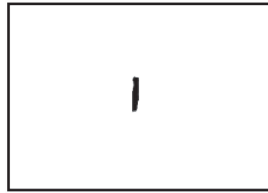


a) Maximum size allowed for a non-relevant indication for severity level LM 4b or AM 4b



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

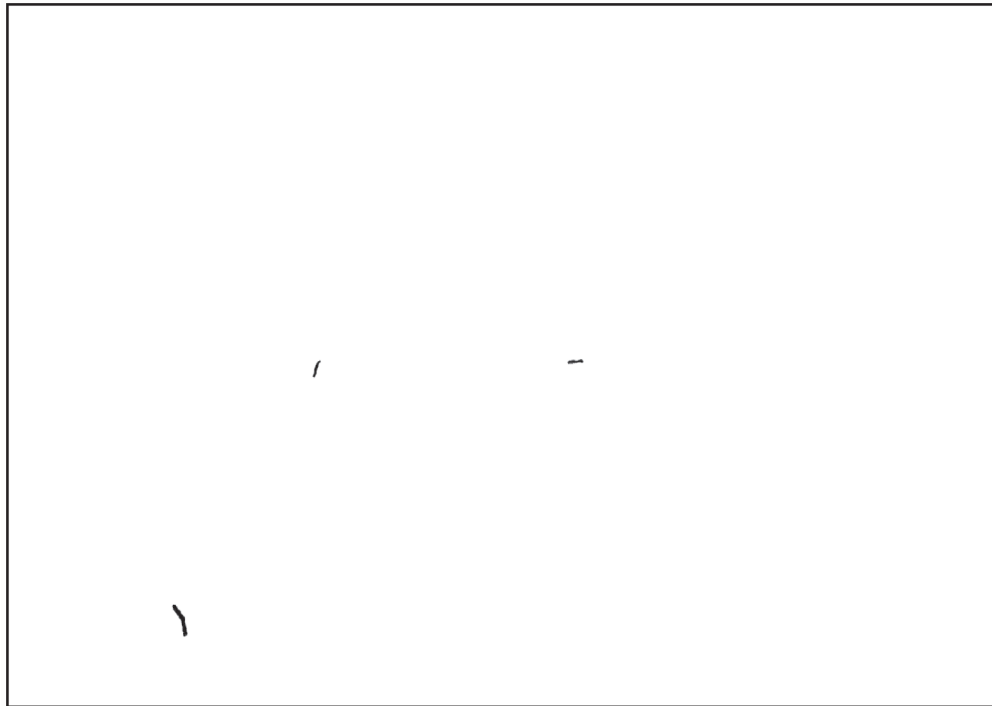


b) Severity level LM 5b or AM 5b

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

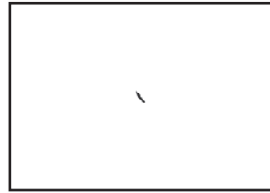


a) Maximum size allowed for a non-relevant indication for severity level LM 1c or AM 1c

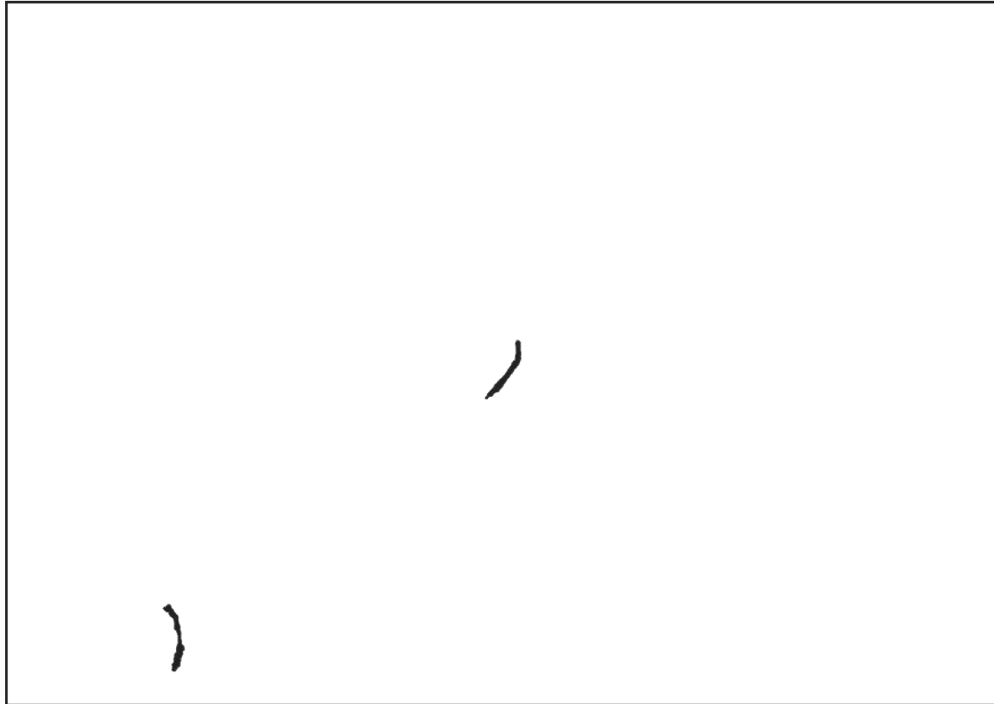


b) Severity level LM 1c or AM 1c

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



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

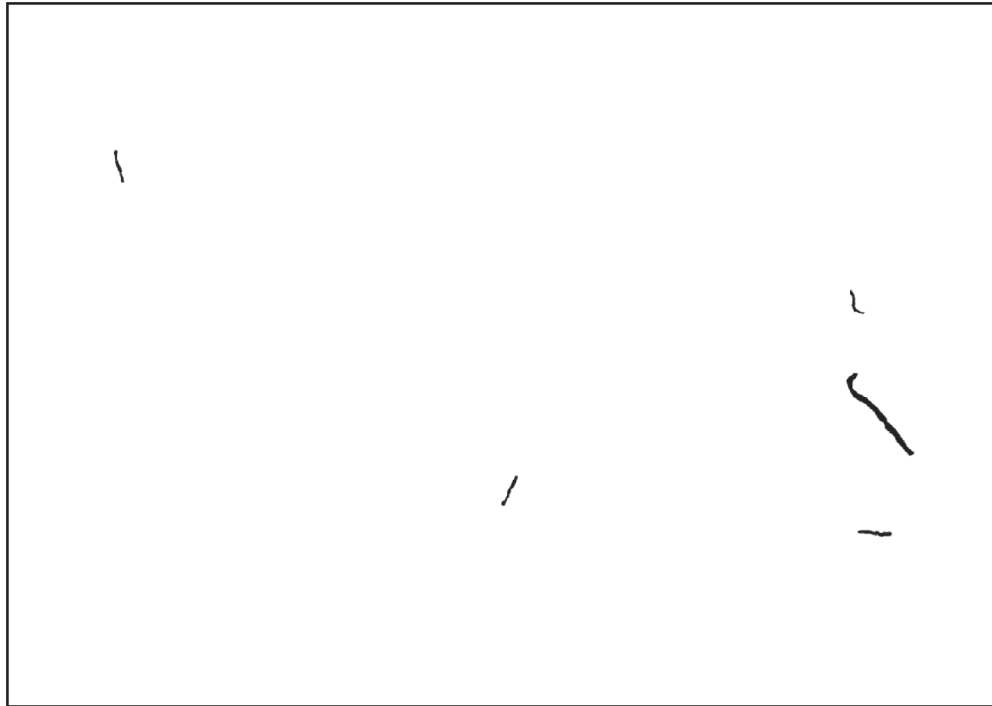


b) Severity level LM 2c or AM 2c

Figure C.12 — Severity level LM 2c or AM 2c



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

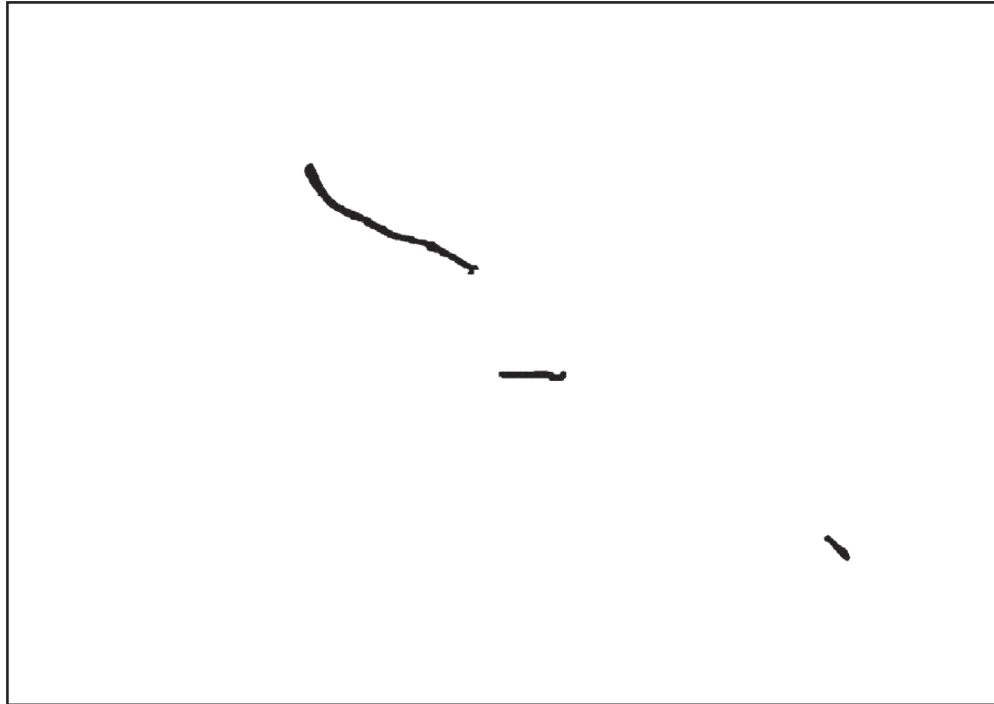


b) Severity level LM 3c or AM 3c

Figure C.13 — Severity level LM 3c or AM 3c



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



b) Severity level LM 4c or AM 4c

Figure C.14 — Severity level LM 4c or AM 4c



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



b) Severity level LM 5c or AM 5c

Figure C.15 — Severity level LM 5c or AM 5c

Annex D (informative)

Model of a magnetic particle test report

Company <i>Société</i>	Magnetic particle test report <i>Contrôle par magnétoscopie – Rapport d'essais</i>		No. <i>N°</i>	
			Sheet <i>Page</i>	
			According to <i>Conforme à</i>	
Customer <i>Client</i>		Order No. <i>Commande n°</i>		
Specification <i>Spécification</i>		Material <i>Nuance</i>	Heat No. <i>Coulée n°</i>	
Identification <i>Marquage</i>	Quantity <i>Quantité</i>	Casting designation <i>Désignation des pièces</i>	Lot No. <i>N° du lot</i>	Drawing No. <i>Plan n°</i>
Area examined – <i>Zone contrôlée</i> <input type="checkbox"/> 100 % <input type="checkbox"/> testing scheme – <i>plan de contrôle</i> <input type="checkbox"/> cavity root – <i>fonds affouillements</i>				
Stage – <i>Stade</i> <input type="checkbox"/> after heat treatment – <i>après traitement thermique</i> <input type="checkbox"/> before stress relieving – <i>avant détensionnement</i>				
Testing conditions – <i>Conditions d'examen</i>				
Apparatus – <i>Appareil</i>				
Magnetic particle reference – <i>Référence du produit indicateur</i>				
Surface condition – <i>État de surface</i> <input type="checkbox"/> shot-blasted – <i>grenailé</i> <input type="checkbox"/> ground – <i>meulé</i> <input type="checkbox"/> machined – <i>usiné</i>				

Casting temperature – <i>Température de la pièce moulée</i> <input type="checkbox"/> 16 °C up to/jusqu'à 60 °C <input type="checkbox"/> 61 °C up to/jusqu'à 320 °C <input type="checkbox"/> °C
Magnetization method – <i>Type d'aimantation</i>
Test material – <i>Produit indicateur</i> <input type="checkbox"/> dry – <i>sec</i> <input type="checkbox"/> wet – <i>humide</i> <input type="checkbox"/> fluorescent – <i>fluorescent</i>
Rod spacing – <i>Distance entre touches</i> mm Magnetizing current – <i>Courant d'aimantation</i> A
Type of current – <i>Type de courant</i> <input type="checkbox"/> alternating – <i>alternatif</i> <input type="checkbox"/> direct – <i>continu</i> <input type="checkbox"/> pulsatory – <i>pulsé</i>
Tangential field strength – <i>Valeur du champ tangentiel</i> ... A/m Field indicator – <i>Témoin d'aimantation</i>
Test results – <i>Résultats de l'examen</i>
According to – <i>Conforme à</i>
Accepted – <i>Accepté</i> <input type="checkbox"/> yes – <i>oui</i> <input type="checkbox"/> no – <i>non</i>
Non-conformance note – <i>Fiche d'anomalie</i>
Continuation sheet – <i>Annexe</i> <input type="checkbox"/> yes – <i>oui</i> <input type="checkbox"/> no – <i>non</i>
Inspection authority – <i>Organisme de contrôle</i>
Quality assurance section – <i>Service assurance qualité</i>
Date/place – <i>Date/lieu</i>
Signature of inspector/operator – <i>Signature de l'inspecteur/opérateur</i>

If applicable, tick the relevant box.

Cocher la case correspondante, suivant le cas.

Bibliography

- [1] ISO 9934-1, *Non-destructive testing — Magnetic particle testing — Part 1: General principles*
- [2] EN 1369, *Founding — Magnetic particle testing*
- [3] ISO 11971, *Steel and iron castings — Visual testing of surface quality*

