BRITISH STANDARD

BS EN ISO 9934-1:2001
*Incorporating Amendment No. 1*

CONFIRMED
DECEMBER 2007

# Non-destructive testing — Magnetic particle testing —

## Part 1: General principles

The European Standard EN ISO 9934-1:2001, with the incorporation of amendment A1:2003, has the status of a British Standard

ICS 19.100

# National foreword

This British Standard is the official English language version of EN ISO 9934-1:2001, including amendment A1:2003. It is identical with ISO 9934-1:2000. It supersedes BS 6072:1981, which will remain current as an obsolescent standard. BS 6072:1981 will be fully withdrawn on publication of BS EN 2857-1 and BS EN 2857-2.

The UK participation in its preparation was entrusted to Technical Committee WEE/46, Non-destructive testing, which has the responsibility to:

— aid enquirers to understand the text;

— present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;

— monitor related international and European developments and promulgate them in the UK.

A list of organizations represented on this committee can be obtained on request to its secretary.

**Cross-references**

The British Standards which implement international or European publications referred to in this document may be found in the *BSI Catalogue* under the section entitled “International Standards Correspondence Index”, or by using the “Search” facility of the *BSI Electronic Catalogue* or of British Standards Online.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

**Compliance with a British Standard does not of itself confer immunity from legal obligations.**

This British Standard, having been prepared under the direction of the Engineering Sector Policy and Strategy Committee, was published under the authority of the Standards Policy and Strategy Committee on 21 December 2001

**Summary of pages**

This document comprises a front cover, an inside front cover, the EN ISO title page, pages 2 to 17 and a back cover.

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# EUROPEAN STANDARD
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December 2001

**+ A1**

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English version

## Non-destructive testing - Magnetic particles testing - Part 1: General principles (ISO 9934-1:2001)
(includes amendment A1:2003)

Essais non destructifs - Magnétoscopie -
Partie 1: Principes généraux du contrôle (ISO 9934-1:2001)
(inclut l'amendement A1:2003)

Zerstörungsfreie Prüfung - Magnetpulverprüfung -
Teil 1: Allgemeine Grundlagen (ISO 9934-1:2001)
(enthält Änderung A1:2003)

This European Standard was approved by CEN on 29 December 2000; amendment A1 was approved by CEN on 20 November 2003.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Management Centre or to any CEN member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the Management Centre has the same status as the official versions.

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Ref. No. EN ISO 9934-1:2001 + A1:2003 E

# Contents

# Foreword

The text of EN ISO 9934-1:2001 has been prepared by Technical Committee CEN/TC 138 "Non-destructive testing", the secretariat of which is held by AFNOR, in collaboration with Technical Committee ISO/TC 135 "Non-destructive testing".

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by June 2002, and conflicting national standards shall be withdrawn at the latest by June 2002.

This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

# Foreword to amendment A1

This document EN ISO 9934-1:2001/A1:2003 has been prepared by Technical Committee CEN/TC 138 "Non-destructive testing", the secretariat of which is held by AFNOR.

This Amendment to the European Standard EN ISO 9934-1:2001 shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by June 2004, and conflicting national standards shall be withdrawn at the latest by June 2004.

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## 1 Scope

This European standard specifies general principles for the magnetic particle testing of ferromagnetic materials. Magnetic particle testing is primarily applicable to the detection of surface-breaking discontinuities, particularly cracks. It can also detect discontinuities just below the surface but its sensitivity diminishes rapidly with depth.

The standard specifies the surface preparation of the part to be tested, magnetization techniques, requirements and application of the detection media and the recording and interpretation of results. Acceptance criteria are not defined. Additional requirements for the magnetic particle testing of particular items are defined in product standards (see the relevant EN Standard).

This standard does not apply to the residual magnetization method.

## 2 Normative references

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

EN 473, *Non-destructive testing - Qualification and certification of NDT personnel - General principles*.

EN 1330-1, *Non-destructive testing - Terminology - Part 1 : General terms*.

EN 1330-2, *Non-destructive testing - Terminology - Part 2 : Terms common to non-destructive testing methods*.

EN ISO 3059, *Non-destructive testing - Penetrant testing and magnetic particle testing - Viewing conditions (ISO 3059:2001)*.

prEN ISO 9934-2, *Non-destructive testing - Magnetic particle testing - Part 2 : Characterisation of products (ISO/DIS 9934-2:1999)*.

prEN ISO 9934-3, *Non-destructive testing - Magnetic particle testing - Part 3 : Equipment (ISO/DIS 9934-3:1998)*.

prEN ISO 12707, *Non-destructive testing - Terminology - Terms used in magnetic particle testing*.

## 3 Terms and definitions

For the purposes of this standard, the terms and definitions given in EN 1330-1, EN 1330-2 and prEN ISO 12707 apply.

## 4 Qualification and certification of personnel

It is assumed that magnetic particle testing is performed by qualified and capable personnel. In order to provide this qualification, it is recommended to certify the personnel in accordance with EN 473 or equivalent.

## 5 Safety and environmental requirements

Magnetic particle testing may require the use of toxic, flammable and/or volatile materials. In such cases, working areas shall therefore be adequately ventilated and far from sources of heat or flames. Extended or repeated contact of detecting media and contrast paints with the skin or mucous membranes shall be avoided.

Testing materials shall be used in accordance with the manufacturer's instructions. National accident prevention, electrical safety, handling of dangerous substances and personal and environmental protection regulations shall be observed at all times.

When using UV-A sources, care shall be taken to ensure that unfiltered radiation from the UV-A source does not directly reach the eyes of the operator. UV-A filters, whether forming an integral part of the lamp or a separate component, shall always be maintained in a safe condition.

NOTE Magnetic particle testing often creates high magnetic fields close to the object under test and the magnetizing equipment. Items sensitive to these fields should be excluded from such areas.

## 6 Testing procedure

When required at the time of enquiry and order, magnetic particle testing shall be performed in accordance with a written procedure.

NOTE The procedure may take the form of a brief technique sheet, containing a reference to this and other appropriate standards. The procedure should specify testing parameters in sufficient detail for the test to be repeatable.

## 7 Surface preparation

Areas to be tested shall be free from dirt, scale, loose rust, weld spatter, grease, oil and any other foreign matter that may affect the test sensitivity.

The surface quality requirements are dependent upon the size and orientation of the discontinuity to be detected. The surface shall be prepared so that relevant indications can be clearly distinguished from false indications.

Non-ferromagnetic coatings up to approximately 50 µm thick, such as unbroken tightly adherent paint layers, do not normally impair detection sensitivity. Thicker coatings reduce sensitivity. Under these conditions, the sensitivity shall be verified.

There shall be a sufficient visual contrast between the indications and the test surface. For the non-fluorescent technique, it may be necessary to apply a uniform, thin, adherent layer of an approved contrast aid paint.

## 8 Magnetization

### 8.1 General requirements

The minimum flux density in the component surface shall be 1 T. This flux density is achieved in low alloy and low carbon steels with high relative permeability with a tangential field strength of 2 kA/m.

NOTE 1 For other steels, with lower permeability, a higher tangential field strength may be necessary. If magnetization is too high, spurious background indications may appear, which could mask relevant indications.

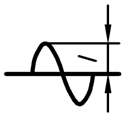
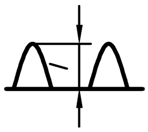
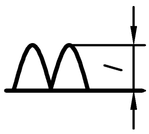
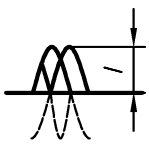
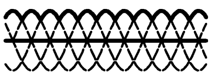
When magnetization is generated from time-varying currents, the rms. value is the required quantity. If the current meter on the magnetizing equipment records the mean current, the corresponding rms. value is given in Table 1, for various common waveforms. The use of pulsed or phase-cut currents requires specific measurements.

If cracks or other linear discontinuities are likely to be aligned in a particular direction, the magnetic flux shall be aligned perpendicular to this direction where possible.

NOTE 2 The flux may be regarded as effective in detecting discontinuities aligned up to 60º from the optimum direction. Full coverage may then be achieved by magnetizing the surface in two perpendicular directions.

When there is need to find sub-surface discontinuities, d.c. or rectified waveforms shall be used.

**Table 1 - Relationship between peak mean and rms values for various sinusoidal waveforms**

| Wave form | Peak | Mean | rms | rms/means |
|---|---|---|---|---|
| Alternating current  | $I$ | 0 | 0.707 $I$ $(=\frac{I}{\sqrt{2}})$ | - |
| Alternating current half-wave rectified  | $I$ | 0.318 $I$ $(=\frac{I}{\pi})$ | 0.5 $I$ | 1.57 |
| Alternating full-wave rectified  | $I$ | 0.637 $I$ $(=\frac{2}{\pi}I)$ | 0.707 $I$ $(=\frac{I}{\sqrt{2}})$ | 1.11 |
| Three phase half-wave rectified  | $I$ | 0.826 $I$ | 0.840 $I$ | 1.02 |
| Three phase sinusoidal full wave rectified  | I | 0.955 $I$ $(=\frac{3}{\pi}I)$ | | |

## 8.2 Verification of magnetization

The adequacy of the surface flux density shall be established by one or more of the following methods :

a) by testing a component containing fine natural or artificial discontinuities in the least favourable locations ;

b) by measuring the tangential field strength as close as possible to the surface Information on this is given in prEN ISO 9934-3 ;

c) by calculating the tangential field strength for current flow methods. Simple calculations are possible in many cases, and they form the basis for current values specified in the informative annex ;

d) by the use of other methods based on established principles.

NOTE Flux indicators (e.g. shim-type), placed in contact with the surface under test, provide a guide to the magnitude and direction of the tangential field strength, but should not be used to verify that the tangential field strength is acceptable.

## 8.3 Magnetizing techniques

This section describes a range of magnetization techniques. Multi-directional magnetization can be used to find discontinuities in any direction. In the case of simple-shaped objects, formulae are given in the annex for achieving approximate tangential field strengths. Magnetizing equipment shall meet the requirements of and be used in accordance with prEN 9934-3.

Magnetizing techniques are described in the following Clauses.

NOTE More than one technique may be necessary to find discontinuities on all test surfaces and in all orientations. Demagnetization may be required where the residual field from the first magnetization cannot be overcome. Techniques other than those listed may be used provided they give adequate magnetization, in accordance with 8.1.

### 8.3.1 Current flow techniques

#### 8.3.1.1 Axial current flow

Current flow offers high sensitivity for detection of discontinuities parallel to the direction of the current.

Current passes through the component, which shall be in good electrical contact with the pads. A typical arrangement is shown in Figure 1. The current is assumed to be distributed evenly over the surface and shall be derived from the peripheral dimensions. An example of approximate formula for the current required to achieve a specified tangential field strength is given in annex A.

Care shall be taken to avoid damage to the component at the point of electrical contacts. Possible hazards include excessive heat, burning and arcing.

NOTE Certain contact materials such as copper or zinc may cause metallurgical damage to the component if arcing occurs. Lead contact pads may be used, but only in well ventilated conditions, because they may generate harmful vapours. Contact areas should be as clean and as large as practicable and of a material compatible with the component under test.

#### 8.3.1.2 Prods; Current flow

Current is passed between hand-held or clamped contact prods as shown in Figure 2, providing an inspection of a small area of a larger surface. The prods are then moved in a prescribed pattern to cover the required total area. Examples of testing patterns are shown in Figure 2 and Figure 3. Approximate formulae for the current required to achieve a specified tangential field strength are given in annex A.

This technique offers the highest sensitivity for discontinuities elongated parallel to the direction of the current.

Particular care shall be taken to avoid surface damage due to burning or contamination of the component by the prods, as for 8.3.1.1. The warning in this subclause concerning the use of lead prods should also be noted. Zinc plated or galvanised prods shall not be used. Arcing or excessive heating shall be regarded as a defect requiring a verdict on acceptability. If further testing is required on such affected areas, it shall be carried out using a different technique.

#### 8.3.1.3 Induced current flow

Current is induced in a ring shaped component by making it, in effect, the secondary of a transformer, as shown in Figure 4. An example of an approximate formula for the induced current required to achieve a specified tangential field strength is given in annex A.

### 8.3.2 Magnetic flow techniques

#### 8.3.2.1 Threading conductor

Current is passed through an insulated bar or flexible cable, placed within the bore of a component or through an aperture, as shown in Figure 5.

This method offers the highest sensitivity for discontinuities parallel to the direction of current flow. The example of approximate formula given in annex A for a central conductor is also applicable in this case. For a non-central conductor, the tangential field strength shall be verified by measurement.

#### 8.3.2.2 Adjacent conductor(s)

One or more insulated current-carrying cables or bars are laid parallel to the surface of the component, adjacent to the area to be tested and supported a distance $d$ above it, as shown in Figure 6 and Figure 7.

The adjacent conductor technique of magnetization requires the material being tested to be in close proximity to a current flowing in one direction. The return cable for the electric current shall be arranged to be as far removed from the testing zone as possible and, in all cases, this distance shall be greater than 10 $d$, where 2 $d$ is the width of the tested area

The cable shall be moved over the component at intervals of less than 2 $d$ to ensure that the inspection areas overlap. An example of an approximate formula for the current required to achieve a specified tangential field strength in the test zone is given in annex A.

#### 8.3.2.3 Fixed installation

The component, or a portion of it, is placed in contact with the poles of an electromagnet, as shown in Figure 8.

#### 8.3.2.4 Portable electromagnet (Yoke)

The poles of an a.c. electromagnet (yoke) are placed in contact with the component surface as shown in Figure 9. The testing area shall not be greater than that defined by a circle inscribed between the pole pieces and shall exclude the zone immediately adjacent to the poles. An example of a suitable testing area is shown in Figure 9.

NOTE The magnetization requirements defined in 8.1, can only be met with a.c. electromagnets. D.c. electromagnets and permanent magnets may only be used by agreement at the time of enquiry and order.

#### 8.3.2.5 Rigid coil

The component is placed within a current-carrying coil so that it is magnetized in the direction parallel to the axis of the coil, as shown in Figure 10. Highest sensitivity is achieved for discontinuities elongated perpendicular to the coil axis.

When using rigid coils of a helical form, the pitch of the helix shall be less than 25 % of the coil diameter.

NOTE For short components, where the length to diameter ratio is less than 5, it is recommended that magnetic extenders be used. The current required to achieve the necessary magnetization is thus reduced.

An example of an approximate formula is given in annex A for the current required to achieve a specified tangential field strength.

#### 8.3.2.6 Flexible coil

A coil is formed by winding a current-carrying cable tightly around the component. The area to be tested shall lie between the turns of the coil, as shown in Figure 11.

The annex A gives approximate formulae for the current required to achieve a specified tangential field strength.

## 9 Detection media

### 9.1 Properties and selection of media

The characterisation of detection media shall be in accordance with prEN ISO 9934-2.

Various types of detection media exist in magnetic particle testing. Usually the detection media is a suspension of coloured (including black) or fluorescent particles in a carrier fluid. Water-based carriers shall contain wetting agents and usually a corrosion inhibitor.

Dry powders are also available. They are generally less able to reveal fine surface discontinuities.

Fluorescent media usually gives the highest sensitivity provided there is an appropriate surface finish, good drainage to maximise indication contrast, and well controlled viewing conditions, in accordance with Clause 10.

Coloured media can also offer high sensitivity. Black and other colours are available.

NOTE To achieve good colour contrast between discontinuities and the test surface it may be necessary to apply a thin layer of contrast aid paint in accordance with Clauses 7 and 10.

### 9.2 Testing of detection media

prEN ISO 9944-2:1999 defines mandatory and recommended tests that are to be carried out before or periodically during inspection.

A sensitivity check shall be carried out before and periodically during testing, in accordance with prEN ISO 9934-2 using a suitable reference piece.

If a magnetic ink is re-used or re-circulated, particular care shall be taken to maintain its performance.

### 9.3 Application of detection media

For the continuous method, the detecting media shall be applied immediately prior to and during the magnetization. The application shall cease before magnetization is terminated. Sufficient time shall be allowed for indications to develop before moving or examining the component or structure under test.

Dry powder, when used, shall be applied in a manner that minimises disturbance of the indications.

During application of a magnetic ink, it shall be allowed to flow onto the surface with very little pressure so that the particles are allowed to form an indication without being washed off.

After applying a suspension, the component shall be allowed to drain so as to improve the contrast of any indications.

## 10 Viewing conditions

The viewing conditions shall meet the requirements of EN ISO 3059.

The entire surface under test shall be viewed before proceeding to the next stage in the testing procedure. Where viewing is obstructed, the component or equipment shall be moved to permit adequate viewing of all areas. Care shall be taken to ensure that indications are not disturbed after magnetization has stopped and before the component has been inspected and indications recorded.

### 10.1 Coloured media

When using coloured detection media :

a) there shall be good contrast between the detection media and the test surface ,

b) the area under test shall be evenly illuminated at a level of not less than 500 Ix (lux) daylight or artificial light.

NOTE Strong reflections from the surface should be avoided.

### 10.2 Fluorescent media

When using fluorescent detection media, the room or area where the testing is to be made shall be darkened, to a maximum ambient white light level of 20 lx. The testing area shall be illuminated with UV-A radiation. The UV-A radiation shall be measured in accordance with EN ISO 3059 and shall have an intensity at the test surface greater than 10 $W/m^2$ (1000 $\mu W/cm^2$). A higher UV-A radiation allows a proportionally higher ambient white light level to be accepted, provided it can be shown that contrast between indications and their surroundings is maintained.

Prior to examination, sufficient time shall be allowed for the eyes to become adapted to the reduced ambient lighting.

The ultraviolet lamp shall be turned on a few minutes (normally at least 5 minutes) prior to use in order to guarantee the correct radiation level.

NOTE The operator should avoid looking directly into the UV-A radiation or areas that act as mirrors for the radiation.

Photochromic spectacles shall not be worn when working with UV-A as exposure to it may cause darkening and therefore lower the ability of the wearer to detect discontinuities.

## 11 Overall performance test

Before testing begins, an overall performance test is recommended. It shall be used to reveal discrepancies in either the procedure or the magnetization technique or the detection media.

The most reliable test is to inspect a representative part containing natural or artificial discontinuities of a known type, location, size and size distribution. Test parts shall be demagnetized and free from indications resulting from previous tests.

In the absence of actual production parts with known discontinuities, fabricated test pieces with artificial discontinuities, e.g. flux shunting indicators of the cross or shim-type may be used.

## 12 Interpretation and recording of indications.

Care should be taken to differentiate between true indications and spurious or false indications, such as scratches, changes of section, boundary between regions of different magnetic properties, or magnetic writing. The operator shall carry out any necessary testing and observations to identify and, if possible, to eliminate the reason for such false indications.

NOTE Light surface dressing may be of value where permitted.

All indications which cannot be confidently discounted as false shall be classified as linear or rounded, in accordance with the following definition, and shall be recorded as required by the product standard.

Linear indications are those indications in which the length is more than three times the width. Rounded indications are indications that are circular or elliptical and where the length is less or equal to three times the width.

## 13 Demagnetization

When required at the time of enquiry and order, post-test demagnetization shall be carried out by an appropriate technique, in order to achieve maximum residual field strength value.

NOTE 1 Demagnetization requires the use of an alternating field which is reducing from an initial field strength equal to, or greater than, that used for magnetization.

NOTE 2 A complete demagnetization is often very difficult to achieve, especially when the test object has been magnetized using d.c. Components initially magnetized using d.c. techniques, low frequency or reversing d.c. demagnetization are used.

NOTE 3 There are occasional circumstances when demagnetization is necessary before testing is carried out. This is when the initial level of residual magnetism is such that adherent swarf, opposing flux or spurious indications could limit the effectiveness of the test.

## 14 Cleaning

After testing and acceptance, if required, all components shall be cleaned to remove detecting media.

NOTE In addition, it may be necessary to protect the component against corrosion.

## 15 Test report

If a test report is required it shall include as a minimum the following information :

a) name of the company ;

b) work location ;

c) description and identity of the part tested ;

d) stage of test (e.g. before or after heat treatment, before or after final machining) ;

e) reference to the written test procedure and the technique sheets used ;

f) description of equipment used ;

g) magnetization technique, including (as appropriate) indicated current values, tangential field strengths, waveform, contact or pole spacing, coil dimensions, etc. ;

h) detection media used, and contrast aid paint if used ;

i) surface preparation ;

j) viewing conditions ;

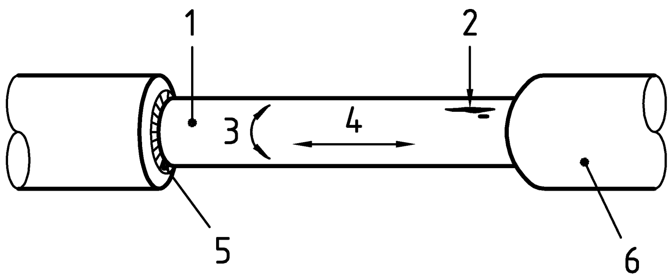
k) maximum residual field strength after test, if appropriate ;

l) method of recording or marking of indications ;

m) date of test ;

n) name, qualification and signature of the person performing the tests.

The test report shall then contain the test results, including a detailed description of the indications and a statement as to whether they meet the acceptance criteria.

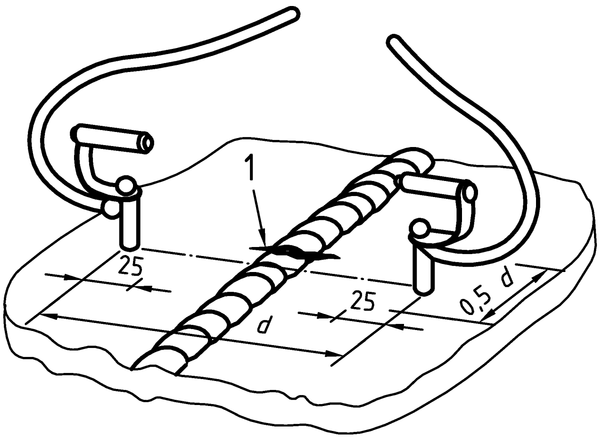



**Key**

1 Specimen
2 Flaw
3 Flux
4 Current
5 Contact pad
6 Contact head

**Figure 1 - Axial current flow**

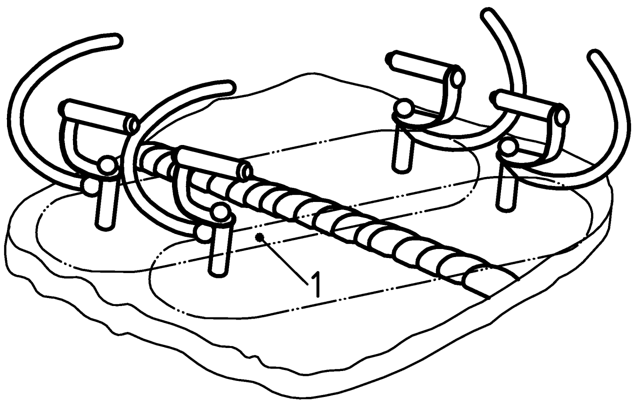
Dimensions in millimetres




**Key**

1 Flaw

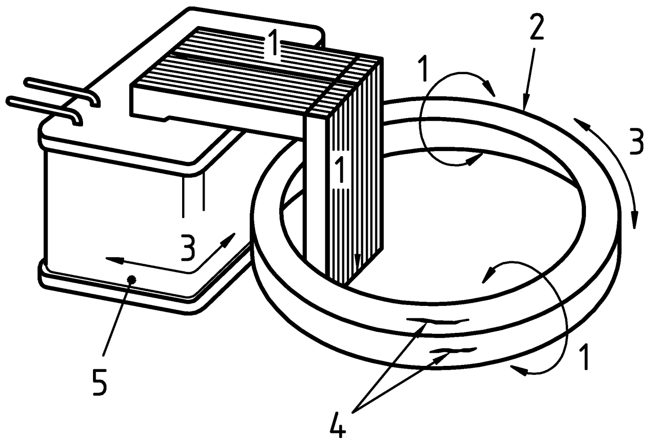
**Figure 2 - Prods; Current flow**




**Key**

1 Overlap

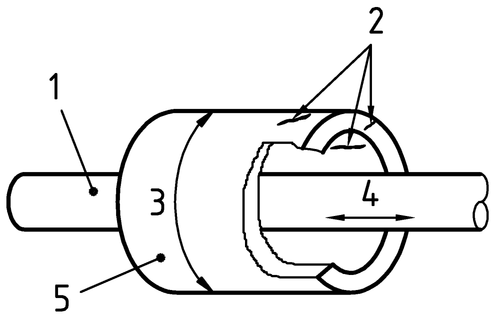
**Figure 3 - Prods; Current flow**




**Key**

1 Flux
2 Specimen
3 Current
4 Flaw
5 Transformer primary coil

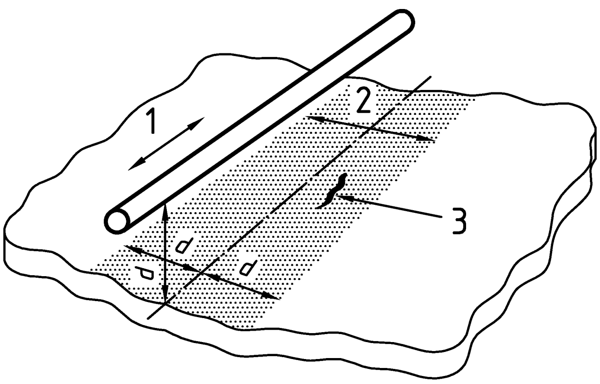
**Figure 4 - Induced current flow**




**Key**

1 Insulated threading bar
2 Flaws
3 Flux
4 Current
5 Specimen

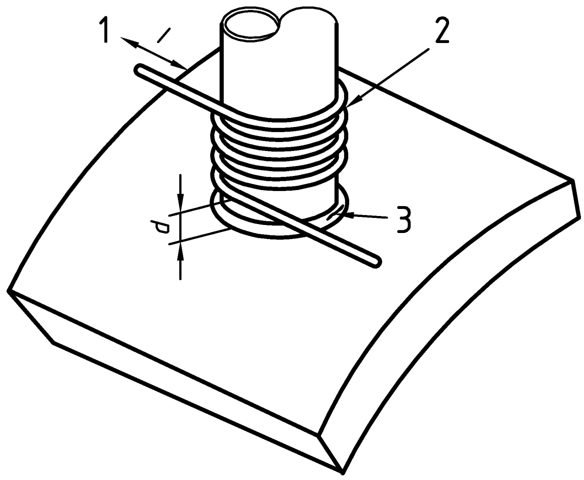
**Figure 5 - Threading conductor**




**Key**

1 Current
2 Flux
3 Flaw

**Figure 6 - Adjacent conductor**

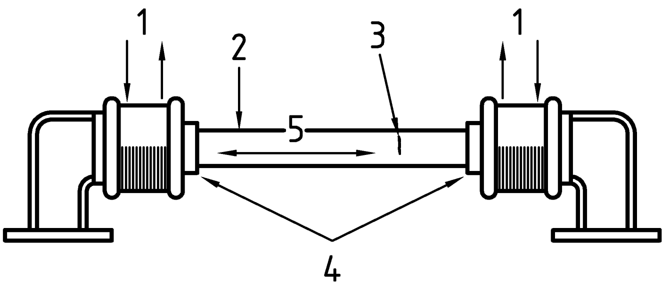



**Key**

1 Current
2 N turns
3 Flaw direction

**Figure 7 - Adjacent cable (coiled)**

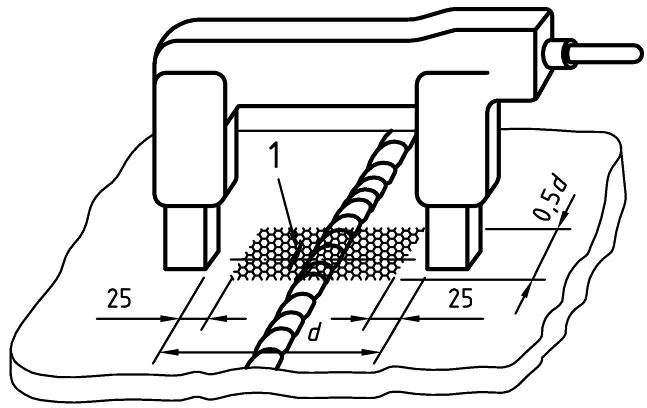
Dimensions in millimetres




**Key**

1 Current
2 Specimen
3 Flaw
4 Pole piece
5 Flux

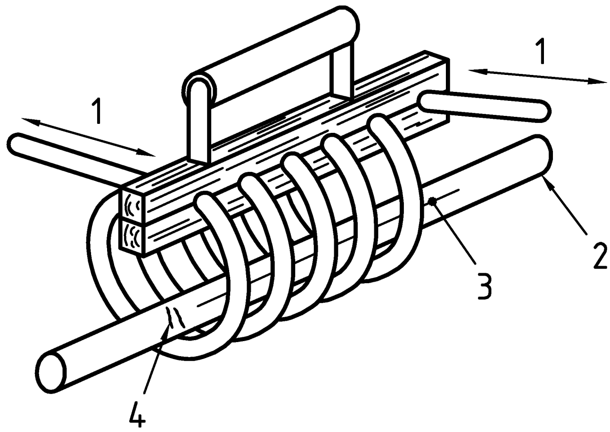
**Figure 8 - Magnetic flow**




**Key**

1 Flaw

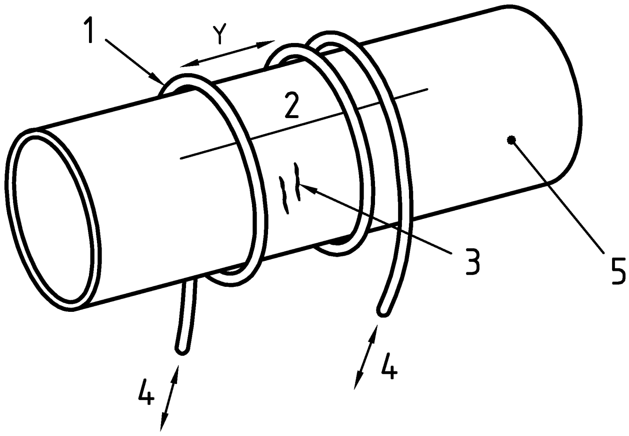
**Figure 9 - Portable electromagnet (yoke)**




**Key**

1 Current
2 Specimen
3 Flux
4 Flaws

**Figure 10 - Rigid coil**




**Key**

1 Insulated cable
2 Flux
3 Flaws
4 Current
5 Specimen

**Figure 11 - Flexible coil**

# Annex A
(informative)

# Example for determination of currents required to achieve specified tangential field strengths for various magnetization techniques

All formulas may be used they give the approximate current required to provide adequate magnetization for simple-shaped components or parts of larger components. When magnetization is generated from time varying currents, the rms. value is the required quantity. The current is expressed in terms of the tangential field strength, $H$, on the perimeter of the test zone, as required by 8.1. Examples of determination of currents required to achieve specified tangential field strengths for various magnetization techniques are given hereafter.

## A.1 Axial current flow (8.3.1.1 and Figure 1)

The required current, $I$, is given by :

$$I = H \times p$$

Where

$I$ is the current in amperes ;

$p$ is the component perimeter, in millimetres ;

$H$ is the tangential field strength, in kiloamperes per metre.

With items of varying cross section, a single value of current shall be used only when the current values required to magnetize the largest and smallest sections are in a ratio of less than 1,5:1. When a single value of current is used the largest section shall govern the current value.

## A.2 Prods Current flow (8.3.1.2 and Figures 2 and 3)

To inspect a rectangular test zone as shown in Figures 2 and 3, the rms. Current, $I$, is given by :

$$I = 2,5\ H \times d$$

Where

$I$ is the intensity of current, in amperes ;

$d$ is the prod spacing, in millimetres ;

$H$ is the tangential field strength, in kiloamperes per metre.

This formula applies for $d$ up to 200 mm.

Alternatively the test zone may be a circle inscribed between the prods but excluding the area within 25 mm of each prod. In this case :

$$I = 3\ H \times d$$

In both above cases, formulae are only reliable when the radius of curvature of the inspection surface exceeds half the prod spacing.

## A.3 Induced current flow (8.3.1.3 and Figure 4)

The required current, $I_{ind}$, is given by :

$$I_{ind} = H \times p$$

Where

$I_{ind}$ is the current, in amperes ;

$p$ is the component perimeter, in millimetres ;

$H$ is the tangential field strength, in kiloamperes per metre.

With items of varying cross section, a single value of current shall be used only when the current values required to magnetize the largest and smallest sections are in a ratio of less than 1,5:1. When a single value of current is used the largest section shall govern the current value.

NOTE The induced current cannot be easily calculated from the primary current.

## A.4 Threading conductor (8.3.2.1 and Figure 5)

For a central conductor the current is given by A.1 of this informative annex.

If the test part is a hollow pipe or similar item the current shall be calculated according to the outside diameter when testing the outside surface, and according to the inside diameter when testing the inner surface.

## A.5 Adjacent conductor (8.3.2.2 and Figures 6 and 7)

To achieve the required magnetization, the cable shall be mounted so that its centreline is at a perpendicular distance, $d$, from the test surface.

The width of the effective test area on each side of the cable centreline is then d, and the rms. current flowing in the cable is required to be :

$$I = 4\ \pi \times d \times H$$

where

$I$ is the rms current, in amperes ;

$d$ is the distance of cable above the surface, in millimetres ;

$H$ is the tangential field strength, in kiloamperes per metre.

When testing radiused corners on cylindrical components or branch joints (e.g. stub-to-header welds), the cable may be wrapped around the surface of the component or the branch and several turns may be bunched in the form of a closely wrapped coil as shown in Figure 7. In this case, the surface inspected shall lie within a distance $d$ of the cable or the coil windings, where $d = NI/4\pi H$ and $NI$ are the ampere-turns.

## A.6 Rigid coil (8.3.2.5 and Figure 10)

Where the component occupies less than 10% of the coil cross-sectional area and the component is placed along the axis at the bottom of the coil, the following formula shall apply and the test shall be repeated at coil-length intervals.

$$NI = \frac{0{,}4H \times K}{L/D}$$

Where

$N$ is the number of effective coil turns ;

$I$ is the current, in amperes ;

$H$ is the tangential field strength, in kiloamperes per metre ;

$L/D$ is the ratio of the length of a component to its diameter for components of circular section (in the case of components of non-circular section, $D$ = perimeter/$\pi$ ) ;

K = 22 000 for an a.c. source (rms. value) and for full-wave rectified current (mean value) ;

K = 11 000 for half-wave rectified current (mean value).

NOTE Where components have a ratio of $L/D$ greater than 20, the ratio is considered to be 20.

With short components (i.e. $L/D$ smaller than 5), the formula given above results in large values of current. To minimise the current, extenders shall be used to increase the effective length of the part.

## A.7 Coil formed by flexible cable (8.3.2.6 and Figure 11)

To achieve the required magnetization using direct or rectified current, the rms. value of the current flowing in the cable shall have a minimum value of :

$$I = 3H\,[T + (Y^2/4T)]$$

where

$I$ is the rms. value of the current, in amperes;

$H$ is the tangential field strength, in kiloamperes per metre;

$T$ is the wall thickness of the component, in millimetres, or its radius if it is in the form of a solid bar of circular section ;

$Y$ is the spacing between adjacent windings in the coil, in millimetres.

To achieve the required magnetization using alternating current, the rms. value of the current flowing in the cable shall have a minimum value of :

$$I = 3H\,[10 + (Y^2/40)]$$

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