

CONFIRMED
OCTOBER 1986

Method for

Magnetic particle flaw detection

UDC 620.179.141:621.317.4

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Non-destructive Testing Centre	

This British Standard, having been prepared under the direction of the Mechanical Engineering Standards Committee, was published under the authority of the Executive Board and comes into effect on 27 February 1981

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The following BSI references relate to the work on this standard:
Committee reference MEE/169
Draft for comment 79/72952 DC

ISBN 0 580 11832 0

Amendments issued since publication

Amd. No.	Date of issue	Comments
3960	September 1982	Indicated by a sideline in the margin
4542	June 1984	Indicated by a sideline in the margin
4843	April 1986	Indicated by a sideline in the margin

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Foreword

Over the past years, several British Standards have been issued describing the application of magnetic particle flaw detection techniques to specific products. It was accordingly considered that it would now be opportune to prepare a comprehensive basic standard for this particular method of non-destructive testing. This British Standard has accordingly been prepared under the direction of the Mechanical Engineering Standards Committee and due account has been taken of the corresponding aerospace standard, BS M 35:1970 “Method for magnetic particle flaw detection of materials and components”, which provide the basis for this work.

This British Standard has been prepared to provide detailed information on magnetic particle flaw detection to which other BSI committees responsible for the application of appropriate techniques to specific products and establishing acceptance criteria can make reference. It is, however, recognized that some variation in basic techniques may be required for particular applications. For example, in the derivation of the formulae covering the flexible cable technique described in clause 13, certain assumptions are involved and, in some circumstances, there may be practical limitations in the application of this technique. Consideration is therefore being given to the preparation of a further BSI publication (a Published Document (PD)) in which the background considerations which have been taken into account in the preparation of this standard will be explained.

It is emphasized that the effectiveness of magnetic particle inspection rests on the technical competence of the personnel employed on such work and their ability to interpret the indications given by the techniques. In interpreting results from magnetic particle inspection, it is necessary to distinguish between relevant indications from flaws and non-relevant indications arising from other causes.

Magnetic particle flaw detection is often used in conjunction with other testing methods. The use of any non-destructive testing methods should always be considered in relation to testing and inspection as a whole. When such methods are specified, the most suitable and economic method of inspection compatible with the ultimate application for the product should always be employed.

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Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 28, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

0 Introduction

0.1 Basic principles. Magnetic particle flaw detection depends basically on sensing the discontinuous change between the permeability of the ferromagnetic material and the permeability of the flaw. When the test piece is suitably magnetized, favourably orientated flaws, at or near the magnetized surface, distort the magnetic field, causing local flux-leakage fields. If finely divided, ferromagnetic particles are applied to the surface of the magnetized test piece, they are attracted by the flux-leakage field and accumulate at the site of the flaw, thus enabling it to be detected.

0.2 Optimum flaw direction. Maximum sensitivity is achieved when the flaw lies at right angles to the magnetic flux, but the sensitivity is not reduced below the effective level if the flaw is orientated at an angle of up to 45° from the optimum direction. Beyond 45°, the sensitivity is diminished appreciably. For this reason, the complete examination of any surface requires the flux to be passed in two directions at right angles to each other, in separate operations.

0.3 Advantages

0.3.1 Magnetic particle flaw detection can detect cracks, non-metallic inclusions and other discontinuities in or near the surface of ferromagnetic materials.

0.3.2 The sensitivity of the inspection is not greatly impaired by the presence of foreign matter within the flaws, unless the contaminant has magnetic properties similar to those of the test piece.

0.3.3 It is possible to inspect components that have been treated with a non-magnetic coating (e.g. cadmium plate or paint) not greater than 50 µm thick, with only slight loss of sensitivity.

0.4 Limitations

0.4.1 The method cannot be used on non-magnetic materials.

0.4.2 Post-cleaning may be necessary in circumstances where the characteristics of the magnetic particles may be deleterious to the subsequent operation of the component.

0.4.3 The presence of surface coatings may reduce the sensitivity obtainable.

0.4.4 Flaws that do not break the surface give diffuse indications, and these indications become increasingly diffused with increase in the distance of the flaw below the surface.

0.4.5 Structural variations and certain types of segregation may give rise to misleading indications.

0.5 Personnel. All persons associated with magnetic particle flaw detection shall have been adequately trained to the agreed levels appropriate to their responsibilities and be able to read the Jaeger J.2 chart¹⁾ at a distance of 0.5 m. It is necessary for all operators and supervisors to observe the requirements of the Health and Safety at Work etc. Act 1974.

1 Scope

This British Standard specifies techniques and procedures for magnetic particle flaw detection of ferromagnetic materials. Magnetic particle flaw detection is primarily used for the detection of surface-breaking flaws, particularly cracks. It can also detect flaws just below the surface, but its sensitivity diminishes rapidly with depth.

2 References

The titles of the standards publications referred to in this standard are listed on the inside back cover.

3 Definitions

For the purposes of this British Standard, the terms and definitions given in BS 3683-2 apply.

4 Magnetizing apparatus and associated equipment

4.1 Fixed installations

4.1.1 The installation shall be capable of enabling the component or material to be tested in accordance with the individual techniques specified.

4.1.2 The installation shall be equipped with controls for adjusting the excitation current, either continuously from zero to the maximum value, and/or in steps, such that any required current values can be obtained within ± 10 % of the nominal.

4.1.3 The apparatus shall be equipped with an ammeter for measuring the current used in any test. The ammeter shall have a scale length of 60 mm or greater, and shall comply with accuracy class 5 (± 5 %) of BS 89. The nominal waveform of the energizing current shall be shown on the apparatus, together with the manner in which the current is indicated by the meter of the apparatus, e.g. peak, r.m.s., mean.

¹⁾ Obtainable from the American Society for Non-destructive Testing, 3200 Riverside Drive, Columbus, Ohio 43221, USA.

4.1.4 The installation shall have a reservoir tank to contain the magnetic flaw detection ink. Suitable means shall be provided for agitation of the ink prior to its application. If the tank is not fitted with a powered agitator, it shall be so designed that adequate agitation by a manually-operated paddle can be carried out frequently during the operation of the magnetizing equipment.

Air agitation of the ink shall not be used for kerosene or other mineral-oil based inks.

4.1.5 Means shall be provided for applying the detecting medium to the component under test, in such a manner that the flow complies with the requirements of clause 18.

4.1.6 The possible effect of magnetic constructional materials in a magnetic ink supply system shall be carefully considered, since their magnetization may affect the functioning of the equipment.

4.2 Mobile and portable apparatus

4.2.1 The installation shall be capable of enabling the component or material to be tested in accordance with the individual techniques specified. Mobile and portable apparatus consisting of high current, low voltage supplies, shall be equipped with an ammeter for measuring the current used in any test. The ammeter shall have a scale length of 60 mm or greater, and shall comply with accuracy class 5 ($\pm 5\%$) of BS 89. The nominal waveform of the energizing current shall be shown on the apparatus, together with the manner in which the current is indicated by the meter of the apparatus, e.g. peak, r.m.s., mean.

4.2.2 Where the technique requires provision for the adjustment of current, the equipment shall comply with the requirements for fixed installations.

4.2.3 Portable electromagnets (yokes) may be used without ammeters, provided the test requirements given in clause 15 are satisfied.

4.2.4 Auxiliary apparatus, such as contact prods, shall be provided in accordance with the techniques listed.

4.3 Control tests on equipment

4.3.1 General. The apparatus and ancillary equipment shall be checked at least every three months by a competent person to ensure its continuing efficacy. A record of the check shall be kept.

4.3.2 Ammeter. A check ammeter shall be used which shall apply to the same form factor and operate over approximately the same range of current as the machine ammeter. It shall comply with accuracy class 5 ($\pm 5\%$) of BS 89 for industrial, portable instruments and have a scale length of 80 mm or greater. The difference between the machine ammeter and the check ammeter shall not exceed 10 % of the scale reading of the machine ammeter at any reading within its effective range.

4.3.3 Functional test. A functional test shall be carried out by the operator before commencing work. The test shall be designed to ensure the proper functioning of both the equipment and the magnetic medium.

Suitable test pieces and procedures are given in appendix C but, for certain types of fixed installation, the functional test described in appendix C is impracticable. Where this is the case, an alternative functional test shall be agreed between the interested parties.

5 Detecting media

5.1 Magnetic flaw detection inks and powders shall comply with the requirements of BS 4069.

5.2 If magnetic ink is reused or recirculated, a check on the total solids content shall be made immediately before use, or at intervals of two days during continuous use. Since magnetic ink will rapidly settle, thorough mixing of fluid and solid shall be maintained at all times. All checks shall be in accordance with BS 4069 and the solids content shall conform to the limits defined in that standard.

5.3 Magnetic ink shall be discarded and replaced when it becomes discoloured or contaminated by any foreign substance to the extent that proper distribution and concentration of the suspension, or definition of the magnetic particle indication, is affected.

5.4 Magnetic inks shall not be mixed unless they are of the same type and specification and are supplied by the same manufacturer.

5.5 The performance of fluorescent magnetic ink used in a system where it is recirculated (i.e. pumped) shall be assessed weekly by comparing its performance in revealing known flaws with the performance of a fresh sample of ink.

6 Safety precautions

6.1 General. It is necessary for all operators and supervisors to observe the requirements of the Health and Safety at Work etc. Act 1974.

The following are guidelines and do not absolve from contractual obligations or responsibilities under the Health and Safety at Work etc. Act 1974.

6.2 Fire hazard. Before any electrical equipment is used, all parties having obligations under the Health and Safety at Work etc. Act 1974 shall satisfy themselves that there will be no danger as a result of any overheating or sparking.

NOTE Attention is drawn to the British Standard codes of practice, e.g. BS 5345 concerning the use of electrical apparatus and associated equipment for use in explosive atmospheres of gas or vapour and in mining applications.

Attention is also drawn to the dangers of vapour ignition as a result of prods overheating and/or arcing when using the current flow technique and the possibility of igniting accumulations of flammable materials in the vicinity of the test. This technique should not be used in confined spaces unless adequate ventilation is provided. It is recommended that all electrical equipment has attached to it, or is accompanied by, a fire extinguisher suitable for petrol, gas and electrical fires. Attention is drawn to BS 5423.

6.3 Electrical safety. All equipment involving the use of mains electricity shall comply with the relevant regulations in the latest version of the Health and Safety at Work etc. Act 1974.

Where equipment has a mains supply of 110 V and above, it shall be fitted with an earth-leakage current circuit-breaker. The circuit shall trip with a leakage current to earth of not more than 30 mA. For portable equipment, and particularly if reaction injuries are possible, consideration shall be given to more stringent electrical safeguards by reducing the leakage current for trip to 12 mA and incorporating a concomitant earth continuity monitor.

6.4 Toxic materials. Some of the materials used in magnetic particle flaw detection may be toxic, e.g. lead contact pads may give off toxic vapour when overheated. Suitable precautions to avoid these hazards shall be taken and all materials shall always be used in accordance with the supplier's instructions.

Two types of hazard exist as a result of spraying aerosols of non-destructive testing products in confined spaces. The first is due to the creation of a mist which, at low concentrations, is a nuisance particulate (see "Threshold Limit Values, 1976": Guidance Note EH 15/76, from the Health and Safety Executive). The second is the result of evaporation of propellant and contents to form a gaseous contamination.

The mist hazard is prevented by the use of face masks capable of absorbing the mist while working in confined spaces. The vapour/gas contamination requires fan circulation within a confined space and a knowledge of the threshold limit value (T.L.V.) of the aerosol contents. The minimum volume of a confined space into which an aerosol can be discharged without exceeding the T.L.V. can be estimated by methods that are detailed in "Threshold Limit Values, 1976".

6.5 Safe use of UV-A. It is essential that personnel using black-light sources avoid looking directly at the sources, as this may cause fluorescence of the eyeball.

Filters shall be checked for evidence of cracking, as ultraviolet radiation at wavelengths below 320 nm²⁾ can be very dangerous.

NOTE For guidance on the safe use of UV-A, see "Protection against ultraviolet radiation at the workplace" by the National Radiological Protection Board and published by HMSO.

7 Testing procedures

7.1 General. All tests shall consist of the processes specified in the procedure sheet (see 7.2). The required tests shall be carried out in the order indicated in a) to l) below.

- a) Surface preparation, in accordance with clause 8.
- b) Pretest demagnetization, in accordance with clause 22.
- c) Degreasing and cleaning, in accordance with clause 8.
- d) Magnetization, in accordance with clause 9.
- e) Application of the detecting medium, in accordance with clause 18.
- f) Viewing, in accordance with clause 19.
- g) Marking the position of the indications, in accordance with clause 19.
- h) Recording of the indications, in accordance with clause 20.
- i) Demagnetization, in accordance with clause 22.
- j) Cleaning, in accordance with clause 23.
- k) Repetition of d) to j) as necessary, to cover tests specified in the approved technique.
- l) Protection against corrosion, as required.

7.2 Documentation of procedure. All tests shall be documented by a written test procedure, or shall be detailed in a comprehensive report (see clause 21.)

The written test procedure shall specify the processes that are to be performed on a particular component or test piece and shall include the information specified in subsequent clauses of this British Standard. In addition, any special pretreatment, such as weld dressing, shall be stated.

Where appropriate, the written test procedure may consist of a procedure sheet of the form shown in appendix D. The procedure sheet shall be accompanied by one or more techniques sheets of the form shown in appendix D.

²⁾ 1 nm = 10⁻⁹ m.

The technique sheet is a document specifying the magnetizing operations that are to be performed on a particular component or test piece in the order in which the operations are carried out. When accompanied by instructions stipulating the procedures common to all mandatory magnetic particle flaw detection tests, the procedure sheet and its accompanying technique sheets become a detailed specification of the required inspection.

8 Surface preparation

8.1 General. All areas to be tested shall be prepared and cleaned in accordance with the requirements stated in the written procedure.

8.2 Painted parts. Painted parts shall be tested only if the paint forms a thin, coherent coating, tightly adhering to the surface and normally not thicker than 50 µm. Thicker coatings reduce sensitivity, and tests under these conditions shall be made only where the specification calls for the detection of gross defects.

For current flow tests on painted parts, the paint shall be removed from the agreed areas of contact using an approved method. Other painted parts will require only degreasing, unless the colour of the paint is the same as that of the particles in the ink to be used and is likely, therefore, to provide poor contrast to it. In this case, an approved contrast aid shall be applied, but the total thickness of the paint shall not exceed 50 µm.

A contrast aid is normally a thin, white, adherent coating which is compatible with the ink and removable after use. Paint for this purpose shall comply with the requirements of BS 5044.

8.3 Loose rust and loose scale. Loose rust and thick or loose scale shall be removed from the component by an approved method.

9 Magnetization

9.1 General requirements

9.1.1 Magnetic particle flaw detection shall be carried out at levels of magnetic flux density equal to, or greater than, 0.72 T³⁾.

For most engineering steels with ferritic or tempered martensitic structures, the permeability exceeds 240 at relevant field intensity levels and the above criterion can, therefore, be satisfied at ambient temperatures, with an applied field of 2 400 A/m⁴⁾ tangential to the surface under inspection and in close proximity to it, provided that the geometry of the component does not lead to significant self-demagnetization (see 22.2).

³⁾ T (the tesla) is the SI unit of magnetic flux density and is equal to 10 kilogauss.

⁴⁾ 1 A/m = 0.01256 oersted or 1 oersted = 79.58 A/m.

9.1.2 The peak current value is the relevant quantity used for the calculation of magnetic field intensity.

Since it is normally impracticable to use ammeters that respond to peak current, r.m.s. or mean current meters may also be used, from which peak current shall be established. For conversion, such instruments shall be calibrated against an instrument that responds to peak current value, using current of the same waveform as that generated by the magnetic equipment. Alternatively, when the waveform is known and is undistorted, the peak value shall be assessed using the relevant conversion factor of Table 1.

NOTE Before applying the data in Table 1, it is necessary to establish that a conversion factor has not already been incorporated in the metering system.

Table 1 — Factor by which indicated current values are multiplied to obtain peak values

Waveform	Type of ammeter	
	A Permanent magnet, moving coil or others measuring mean values	B Moving iron, induction, electrodynamic or others measuring r.m.s. values
Direct current	1.00	1.00
Alternating current	Not applicable	1.41
Full-wave rectified, single-phase current	1.57	1.41
Half-wave rectified, single-phase current	3.14	2.00
Full-wave rectified, three-phase current	1.05	1.05
Half-wave rectified, three-phase current	1.21	1.19

9.1.3 For optimum flaw detection, the major axis of the discontinuity shall be perpendicular to the direction of the magnetic flux (i.e. in the same direction as the current flow), but it shall be regarded as effective up to 45° from this direction (see 0.2).

9.1.4 Magnetization by a.c. gives improved sensitivity to surface flaws. Where the technique is required to respond to subcutaneous discontinuities, d.c. magnetization is preferable.

9.1.5 There is an upper limit to the effective range of magnetic flux density. This is appreciably below saturation and corresponds to a flux level beyond which the magnetic particles begin to develop a background effect ("furring"). This reduces the definition of true flaw indications and hence reduces sensitivity, especially for small indications. If such conditions should arise, the technique shall be revised. The action necessary may require the improvement of surface condition or the reduction of magnetic field intensity within the limits of **9.1.1**, until an acceptable definition of indications is achieved.

9.1.6 The magnetic field strength values specified shall apply to all tests, and the magnetic ink or powder shall be applied immediately prior to and during magnetization (see **18.1**), with the possible exceptions mentioned in **9.2**, which shall be agreed in writing before application.

9.2 Exceptional requirements

9.2.1 A magnetic flux density in excess of 0.72 T may be achieved at a lower magnetic field intensity than that specified in the case of materials of high permeability. A reduced field intensity level shall be applied only where there is adequate confirmatory information to establish that the specified level of magnetic flux density has thereby been attained.

9.2.2 Where, by agreement, the magnetic ink or powder is applied after magnetization (i.e. using only residual magnetization), increased values of magnetic field intensity shall be used with d.c. magnetization.

9.2.3 The requirements for the aerospace industry are exceptional and are specified in **10.3** and **11.3**.

9.3 Magnetic field intensity indicators. Where it is necessary to confirm the magnetizing field intensity and direction, a tangential field strength meter shall be used. Portable flux indicators shall be used only to confirm the field direction or to provide a rough guide to field and flux levels (see **15.5**).

9.4 Specifying a technique

9.4.1 Technique sheet. A technique sheet is a document specifying the magnetizing operations to be performed on a particular component or test piece. This is supplemented by a procedure sheet and instructions stipulating the procedure common to all mandatory magnetic particle flaw detection; the technique sheet then becomes a detailed specification of the required inspection.

9.4.2 Coverage. The technique sheet shall stipulate the amount of coverage and the direction of magnetization of the component being examined.

9.4.3 Component shape. When magnetizing operations are to be repeated at intervals (e.g. along the length or circumference of a component), the separation between the test stations shall be specified.

Appendix A summarizes a number of techniques which provide acceptable coverage for components of specific basic shapes. Each of these permits the use of several different combinations of magnetizing techniques (see clauses **10** to **17**). In addition, appendix A gives alternative selections of supplementary magnetizing operations which shall be applied when full coverage is essential.

The techniques described in appendix A shall be modified as necessary to admit a large number of components which essentially conform to the basic shapes but are non-uniform in section. Thus, if the ratio of the maximum diameter to the minimum diameter of a multidiameter, bar-shaped component is very nearly 1 : 1, the appropriate basic technique may be applied directly, using an average current value. For ratios up to 1.5 : 1, the current flow and threading bar tests shall be made at a current value corresponding to the maximum diameter. In this instance, however, any flaw found shall be assessed at the current value appropriate to the diameter of the portion in which it occurs. Finally, when the value of the maximum diameter of the specimen exceeds 1.5 : 1 on smaller diameters, separate tests shall be carried out as necessary, at different current values, to avoid background effects. A similar procedure shall be applied with components that are derivatives of other basic shapes.

More complex components shall be considered as consisting of two or more basic shapes joined together. Thus a pipe with a large diameter flange at each end represents a combination of two rings and a tube. Each of these portions shall be magnetized in accordance with the appropriate individual techniques described in appendix A.

Unusual components and components with non-magnetic attachments require special operations and these operations shall be recorded.

9.4.4 Procedure. The technique sheet shall include the information specified under each technique heading. In addition, any special pretreatment, such as weld dressing, shall be stated.

9.4.5 Preferred form of technique sheet. The preferred form of technique sheet is shown in appendix D. The symbols used in drawings to indicate operations, together with symbols for the various techniques of magnetization, are given in appendix A.