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Method for

Magnetic particle flaw detection

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Cooperating organizations

The Mechanical Engineering Standards Committee, under whose direction this British Standard was prepared, consists of representatives from the following:

Association Offices Technical Committee*
Association of Consulting Engineers
Association of Hydraulic Equipment Manufacturers
Association of Mining Electrical and Mechanical Engineers
British Compressed Air Society
British Electrical and Allied Manufacturers' Association (BEAMA)*
British Gas Corporation
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The organizations marked with an asterisk in the above list, together with the following, were directly represented on the Technical Committee entrusted with the preparation of this British Standard:

BNF Metals Technology Centre
British Airways
British Chemical Engineering Contractors' Association
British Institute of Non-destructive Testing
British Non-ferrous Metals Federation
Institute of Quality Assurance
Non-destructive Testing Centre
Society of British Aerospace Companies Limited
Steel Casting Research and Trade Association
United Kingdom Atomic Energy Authority
Water-tube Boilermakers' Association
Welding Institute
Coopted expert

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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Contents

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.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

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

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.

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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 chart[1] 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, Colombus, 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 (± 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 (± 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 nm[2] 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 T[3].

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/m[4] 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**).

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.

[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.

9.1.5 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.

10 Current flow technique

10.1 General. In the technique of magnetization known as "current flow", current from an external source, such as a low voltage transformer winding, is passed between two contact areas established on the surface of the component.

In fixed installations, the component is firmly clamped between contact heads. With portable equipment, electrical contact is generally effected by means of hand-held prods pressed on to the surface of the component (see clause **17**).

If the contact areas are at the ends of a long, uniform section, as in Figure 1, the current becomes evenly distributed over the surface. The current required is proportional to the peripheral dimension.

This technique favours the detection of a flaw having its major axis parallel to, or within 45° of, the direction of current flow.

NOTE Flaws in the bore of a hollow component will not be revealed.

10.2 Precautions during testing. These precautions apply to fixed installations. Where a current flow (prods) technique is used, reference shall be made to clause **17.**

Every precaution shall be taken to prevent excessive heating, burning or arcing. Certain metals, including copper and zinc, may, if used as electrical contacts, contaminate and cause metallurgical damage to the component if arcing occurs.

The cleanness of both contact heads and the component shall be such as to ensure good electrical contact. Contact heads shall have a contact area that is as large as possible, compatible with the component being tested. Contact heads are generally made of steel to which copper braid or composite copper mesh/gauze pads are fitted. Pads shall be inspected before each application of current. Where there is any evidence of fraying, burning or other damage that could diminish contact or conductivity, the pads shall be renewed before any further testing. Pads shall be constructed from mesh, gauze or braid selected for the purpose. The material shall be woven or fashioned in such a manner that it is even and uniform in thickness throughout. The arrangement used for attaching the pads to contact heads shall ensure that they are held firmly in position without distortion. Zinc contact pads shall not be used.

NOTE Lead contact pads may be used, but only in well-ventilated conditions, because they may generate harmful vapour which may cause headaches and/or dizziness.

Contact heads used without pads shall be made of steel or aluminium. Copper or copper-faced heads shall be used only if metallurgically acceptable, or the contact surfaces and clamping arrangement are such as to preclude any possibility of overheating, burning or arcing.

The current shall not be switched on until the clamping arrangement has been checked and contact pressure confirmed. The contact pressure shall not be released until the current has been switched off.

With parts of slender cross section, the clamping arrangement shall be checked to ensure that distortion is not caused by excessive pressure during testing.

The current application time during any test shall not be unduly sustained, and any rise in temperature shall be less than that which would cause damage or distortion.

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.

10.3 Current values to be used. The current values to be used for common waveform and ammeter combinations are given in Table 2 and Table 3. In other cases, the current values may be calculated from Table 1.

Table 2 gives values for the detection of surface-breaking flaws only, and it is based on the magnetic properties of the constructional and engineering steels referred to in **9.1.1**. If other materials are to be tested, the current values shall be modified accordingly.

Where fixed installations are used for the testing of high-tensile or highly-stressed components in the aerospace industry, the values in Table 3 shall apply.

In Table 2 and Table 3, the current values for non-round components are based on the perimeter of the largest cross section of the part to be examined, through which current has to flow.

10.4 Varying cross section. With items of varying cross section, a single value of current shall be used only when the current values required to magnetize the larger and smaller sections are in a ratio of less than 1.5 : 1. When a single value of current is used, the larger section shall govern the current value.

10.5 Technique sheet. The technique sheet (see **7.2**) shall include:

a) the position of the two contact areas;

b) the waveform and magnitude of the current.

11 Threading bar or cable technique

11.1 General. Magnetization by the threading bar technique is performed by passing current through a conductor placed within a bore or aperture in the component (see Figure 2). This technique favours the detection of flaws where the major axes lie parallel to, or within 45° of, the direction of current flow. The technique can also be applied by using one or more heavy flexible cables through the bore of the aperture (see Figure 3 and Figure 4).

11.2 Precautions during testing. When using a threading bar on a component with a closed end, precautions shall be taken to ensure good contact on the blind face. Threading bars and flexible cables shall be insulated to prevent contact with the component and between individual windings.

11.3 Current values and coverage. The surface under test shall lie completely within a circle centred on the conductor, the radius R (in mm) of which is given by $R = I/15$, or $R = I/56$ in the case of aerospace applications, where I is the peak value of current (in A).

Alternatively, the current values given in either Table 2 or Table 3 can be used.

Where several bars or cables are passed through the component, the current value shall be reduced in proportion to the number of windings. In this case, the same current shall be flowing in each winding in the same direction, and the measured current shall be that flowing in each individual winding.

The surface to be inspected may be covered in one or more operations. Where the component does not constitute a closed and continuous path for magnetic flux, the test shall satisfy the conditions specified in clause **14**.

11.4 Technique sheet. The technique sheet (see **7.2**) shall include the following:

a) the form and dimensions of the threading bar or cable;

b) the number of threading bars or cables;

c) the waveform and magnitude of the current.

12 Rigid coil technique

12.1 General. In the standard coil technique of magnetization, the component is placed within a current-carrying coil and is thus magnetized in a direction parallel to the axis of the coil itself (see Figure 5), favouring the detection of flaws basically in a direction transverse to the axis of the coil.

12.2 Current values to be used. In all instances, the magnetizing coil shall produce a minimum level of flux below saturation level for the material at the relevant section, but not less than one-third of the saturation level. Higher values may be used but they shall not exceed those that produce "furring" at the relevant section.

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

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.

$$NI = \frac{K}{L/D}$$

where

N		is the number of effective coil turns
I		is the current (in A)
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/π)
K	=	32 000 for the mean value of a d.c. source and for the peak value of any waveform
K	=	22 000 for an a.c. source (r.m.s. 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 minimize the current, extenders shall be used to improve the effective length of the component.

12.3 Technique sheet. The technique sheet (see **7.2**) shall include:

a) the form and dimensions of the coil;

b) the number of turns;

c) the waveform and magnitude of the current;

d) the position, or repeat positions, of the coil relative to the component.

Table 2 — Current values for general engineering applications

Current waveforms	D.C. source	A.C. source	Single-phase full-wave rectified	Single-phase half-wave rectified	Three-phase full-wave rectified	Three-phase half-wave rectified	All waveforms
Type of ammeter	A	B	A	A	A	A	Peak
Current (A) for basically round components per millimetre of diameter	7.5	5.3	4.8	2.4	7.2	6.2	7.5
Current (A) for non-round components per millimetre of perimeter	2.4	1.7	1.5	0.75	2.3	2.0	2.4

NOTE The types of ammeter denoted by "A" and "B" in Table 2 are defined in Table 1, viz.
"A": permanent magnet, moving coil, or other types measuring mean values.
"B": moving iron, induction, electrodynamic, or other types measuring r.m.s. values.

Table 3 — Current values for aerospace applications

Current waveforms	D.C. source	A.C. source	Single-phase full-wave rectified	Single-phase half-wave rectified	Three-phase full-wave rectified	Three-phase half-wave rectified	All waveforms
Type of ammeter	A	B	A	A	A	A	Peak
Current (A) for basically round components per millimetre of diameter	28	20	18	9	27	23	28
Current (A) for non-round components per millimetre of perimeter	9	6.4	5.7	2.9	8.6	7.4	9

NOTE The types of ammeter denoted by "A" and "B" in Table 3 are defined in Table 1, viz.
"A": permanent magnet, moving coil, or other types measuring mean values.
"B": moving iron, induction, electrodynamic, or other types measuring r.m.s. values.

13 Flexible cable technique (coil technique using a flexible cable)

13.1 General. This is a technique of magnetization in which a current-carrying cable is tightly wound around the component (see Figure 6). It favours the detection of flaws lying parallel to the cable.

The area to be inspected shall lie between the turns of the coil thus formed. The coil shall be moved over the component at coil-length intervals, to ensure that the specified coverage is achieved.

13.2 Current values to be used with direct current. To achieve the required magnetization using direct or rectified current, the peak value of the current flowing in the cable shall have a minimum value of:

$$I = 7.5(T + (Y^2/4T))$$

where

I is the peak value of the current (in A)

T is the wall thickness (in mm) of the component, or its radius if it is in the form of a solid bar of circular section

Y is the spacing (in mm) between adjacent windings in the coil.

13.3 Current values to be used with alternating current. To achieve the required magnetization using alternating current, the peak value of the current flowing in the cable shall have a minimum value of:

$$I = 7.5(10 + (Y^2/40))$$

where

I is the peak current (in A)

Y is the spacing (in mm) between adjacent windings in the coil.

13.4 Technique sheet. The technique sheet (see **7.2**) shall include:

a) the number and spacing of the turns in the coil;

b) the waveform and magnitude of the current;

c) the repeat positions of the cable or coil.

14 Flexible cable technique (using a flexible cable adjacent to the test surface)

14.1 General. This is a technique of magnetization in which an insulated, current-carrying cable is laid parallel to the surface of the component, adjacent to the area to be tested. It favours the detection of flaws lying parallel to the cable, or within 45° of this direction.

14.2 Precautions during testing. The adjacent cable 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 inspection zone as possible and, in all cases, this distance shall be greater than 10*d*, where *d* is the width of the inspected area, expressed in millimetres.

The cable shall be moved over the component at intervals of less than 2*d* to ensure that the specified coverage is achieved.

Flexible cables shall be insulated to prevent contact with the component and between individual windings.

14.3 Magnetizing conditions. To achieve the required magnetization, the cable shall be so mounted that its centreline is at a perpendicular distance, *d*, from the inspection surface.

The width of the effective inspection area on each side of the cable centreline is then *d*, and it is related to the peak current flowing in the cable by:

$$I = 30d$$

where

I is the peak current (in A)

d is the width of the inspected area (in mm).

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. In this case, the surface inspected shall lie within a distance *d* of the cable or the coil windings, where $d = NI/30$, and NI are the ampere-turns.

14.4 Technique sheet. The technique sheet (see **7.2**) shall include:

a) the waveform and magnitude of the current;

b) the position, or repeat positions, of the cable relative to the component, including the perpendicular distance of the cable from the surface;

c) the instructions to ensure that the return cable does not interfere with the inspection;

d) the width, *d*, of the inspected area on each side of the cable.

15 Magnetic flow technique

15.1 General. The component, or portion of it, shall close the magnetic circuit of an electromagnet or a permanent magnet. The technique favours the detection of flaws where the major axes lie transverse to the line joining the pole pieces of the magnet, as shown in Figure 7.

15.2 Level of magnetization. The pole pieces of the magnet shall abut intimately against the component. When using bench-type electromagnets, the magnetic field strength shall lie between the value which is just sufficient to cause saturation of the material at the relevant section and not less than one-third of that value.

15.3 Permanent magnets and d.c. electromagnets. Permanent magnets and d.c. electromagnets (d.c. yokes) shall have a maximum pole spacing of 150 mm. If the pole spacing is less than or equal to 75 mm, the magnets shall be capable of lifting not less than 0.24 kg per millimetre of pole spacing. If the pole spacing is greater than 75 mm, the lifting power shall be at least 18 kg.

The lifting power is the ability of the magnet to lift a piece of ferritic steel by magnetic attraction alone.

The pull-off force is the force that has to be applied to one pole piece to break its adhesion to a surface, leaving the other one attached. The pull-off force shall have a value equivalent to at least 9 kg.

On structures where the geometry or the surface finish affects the contact with the magnet, the strength of the magnet and the adequacy of the surface contact shall be verified by measuring the pull-off force on the structure itself.

The specified test values provide a level of magnetization lower than 0.72 T. Permanent magnets and d.c. electromagnets shall, therefore, be used only where other techniques of magnetization are impracticable.

15.4 A.C. electromagnets. When using a.c. electromagnets (a.c. yokes), the strength of the magnet shall be assessed by measuring the lifting power or the pull-off force.

The lifting power shall be equivalent to not less than 4.5 kg for a pole spacing of 300 mm or less, and the pull-off force shall have a value equivalent to not less than 2.25 kg for the same pole spacing.

15.5 Field strength meters and flaw indicators. Magnetic field strength meters and portable flaw indicators shall not be used in conjunction with permanent magnets or with d.c. electromagnets.

15.6 Area inspected. When using permanent magnets and d.c. or a.c. electromagnets, the inspected area shall be considered to be not greater than the area of the circle inscribed between the pole pieces.

15.7 Technique sheet. The technique sheet (see **7.2**) shall include the following:

a) the form and dimensions of the magnet;

b) the position of the two contact areas;

c) the method by which the strength of the magnet and the adequacy of the surface contact are to be established and the frequency with which the checks are to be made.

16 Induced current flow technique

16.1 General. The expression "induced current flow technique" is given to a technique of setting up circumferential current flow in a large ring specimen by making it, in effect, the secondary of a mains transformer. The optimum flaw direction is basically circumferential (see Figure 8) and the current induced in the component shall be in accordance with Table 2 or Table 3.

16.2 Technique sheet. The technique sheet (see **7.2**) shall include the following:

a) the waveform and magnitude of the current and the transfer characteristics;

b) the method by which the magnitude of the current induced in the component is to be measured.

17 Current flow (prods) technique

17.1 General. The technique of magnetization known as "current flow (prods)" is a variation of the current flow technique (see clause **10**).

In the current flow (prods) technique, a current from an external source, such as a low voltage transformer winding, is passed between two contact areas established on the surface of the component by means of two hand-held prods, as shown in Figure 9. The technique favours the detection of flaws where the major axes lie parallel to, or within 45° of, the direction of current flow.

17.2 Precautions. Every precaution shall be taken to prevent excessive heating, burning or arcing. Certain metals, including copper and zinc, may, if used as the prod material, contaminate and cause metallurgical damage to the component if arcing occurs. For this reason and the fact that perfect contact is difficult to achieve with prods, they shall be made of steel or aluminium. Zinc shall not be used and copper or copper-tipped prods shall be used only in applications where complete assurance can be given that metallurgical damage will not occur. The cleanness of both prod contact faces and the component shall be such as to ensure good electrical contact. Prods shall have a minimum dimension of 10 mm and shall have as large a contact area as possible.

For some applications, contact pads may be used between prods and the component where it can be demonstrated that better contact is achieved and the danger of arcing reduced. Zinc contact pads shall not be used.

NOTE Lead contact pads may be used, but only in well-ventilated conditions, because they may generate harmful vapour which may cause headaches and/or dizziness.

The contact faces of the prods, or pads, if fitted, shall be inspected before each application of current. Where there is evidence of burning or other damage, the prods shall be refaced, or the pads renewed. Pads shall be constructed from mesh, gauze or braid selected for the purpose. The material shall be woven or fashioned in such a manner that it is of even and uniform thickness throughout. The arrangement used for attaching pads to prod ends shall ensure that they are held firmly in position without distortion.

The current shall not be switched on until adequate contact pressure has been achieved. The contact pressure shall not be released until the current is switched off.

The current application time during any test shall not be unduly sustained and any rise in temperature shall be less than that which would cause damage or distortion.

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.

17.3 Practical procedures. The current spread and relative intensity is complex when using prods, especially if the component has changes of form. When inspecting flat surfaces and those with radii of curvature greater than half the prod spacing, the inspected area shall be a circle inscribed between the prods when the peak current value is not less than 7 500 amps per metre of prod spacing.

Factors by which indicated current values shall be multiplied to obtain peak values are given in Table 1.

Alternatively, with the same restriction on the radii of curvature of the surface, the inspected area shall be an ellipse inscribed between the prods, with the minor axis equal to half the prod spacing. In this case, the peak current shall be not less than 4 700 amps per metre of prod spacing.

Where the requirement is for the inspection of a narrow region approximating to the prod width, the peak current shall be not less than 3 750 amps per metre of prod spacing.

Figure 10 and Figure 11 show examples of search patterns that shall be used with the above test values for inspecting flat surfaces, or those with radii of curvature between the prods greater than half the prod spacing, as measured around the periphery.

When inspecting surfaces with radii of curvature between the prods less than half the prod spacing, as measured along the surface, the above methods of assessment no longer apply in which case the effective area shall be determined by one of the methods described in appendix B and an appropriate search pattern following the general principles illustrated in Figure 11 shall be utilized.

17.4 Technique sheet. The technique sheet (see **7.2**) shall include the following:

a) the separation between the two contact areas (prod spacing);

b) the waveform and magnitude of the current, expressed in terms of the indicated meter reading and not the peak value;

c) the test pattern and its orientation with respect to the surface under examination;

d) the composition of the contact material.

18 Application of the detecting medium

18.1 General. Unless residual magnetization techniques are used (see **9.2.2**), the detecting medium shall be applied immediately prior to and during magnetization. The application shall cease before magnetization is terminated. Sufficient time shall be allowed for the indications to build up before moving or examining the component or structure under test.

Means for preserving the indications are described in appendix E.

18.2 Dry powder. Dry powder, when used, shall be applied in a manner that will guard against disturbance of the indications.

18.3 Immersion procedure. Where an immersion procedure is used, precautions shall be taken to avoid disturbance of the indications upon removal of the component from the ink bath.

18.4 Other applications. During any surface application of magnetic ink, it shall be allowed to flow on to the component with very little pressure, so that the particles are allowed to adhere to a flaw indication without being washed off.

18.5 Draining. After inking, the component shall be allowed to drain so as to improve the contrast of any flaw indications.

19 Viewing

19.1 General. The entire surface under test shall be viewed before proceeding to the next stage in the testing procedure. Viewing shall be carried out after each excitation. Where viewing is obstructed, the component shall be removed from the machine to permit adequate viewing of all areas. Care shall be taken to ensure that magnetic indications are not disturbed after magnetization has stopped and before the indications have been inspected and recorded. More detail can be revealed by the use of a low-power magnifier (see BS 5165).

19.2 Non-fluorescent inks and powders. When using non-fluorescent inks and powders:

a) there shall be good contrast between the detecting medium and the component being inspected;

b) the area under inspection shall be evenly illuminated at a level of not less than 500 lx (lux)[5)] daylight or artificial light.

19.3 Fluorescent inks and powders. When using fluorescent inks and powders:

a) the inspection area shall be darkened and the ambient white light level shall be not greater than 10 lx;

b) the UV-A irradiance level at the surface being inspected shall be not less than 0.8 mW/cm^2 or 800 µW/cm^2 (see BS 4489);

c) unnecessary reflections of ultraviolet radiation from the test surface shall be avoided and, in some instances, it may be advantageous to view the test surface through a bandpass filter designed to pass light wavelengths between 500 nm and 600 nm.

[5)] As a guide, this would be achieved by using either a fluorescent tube of 80 W at a distance of about 1 m, or a tungsten filament pearl lamp of 100 W at a distance of about 0.2 m.

NOTE 1 Photochromic spectacles should not be worn when working with UV-A as exposure to it, like exposure to bright sunlight, may cause darkening and therefore lower the ability of the wearer to detect flaws.

NOTE 2 For checking the performance of UV-A lamps and irradiance at the working surface, see BS 4489.

19.4 Marking of flaws. Where necessary, the positions of flaws shall be marked on the tested component by a method that will not affect the use of the component or prejudice any subsequent testing.

19.5 Polished plated cylindrical components. Polished, plated components of cylindrical form shall be viewed during magnetization.

20 Recording of indications

20.1 General. For the purpose of interpreting and classifying indications, the values of current or applied field shall be standardized to within 10 % of the values agreed in the technique sheet.

Areas giving indications shall be assessed as tested and shall not be demagnetized prior to assessment.

20.2 Classification of indications

20.2.1 *Introduction.* Magnetic particle flaw detection is capable of revealing and classifying flaws in the following categories: crack-like flaws, inclusions and rounded indications, linear indications, non-relevant indications.

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 than three times the width.

20.2.2 *Cracks and crack-like flaws.* Where cracks or crack-like flaws are revealed, their position, size, orientation and type shall be recorded.

20.2.3 *Inclusions and rounded indications.* Inclusions and rounded indications shall be reported.

20.2.4 *Linear indications.* Linear indications that cannot be further classified shall be treated as crack-like flaws and recorded as in **20.2.2**. Intermittent and aligned indications shall be treated as linear indications.

20.3 Non-relevant indications. The indications obtained in magnetic particle flaw detection may be due to spurious effects, such as magnetic writing, changes in section, or the boundary between materials of different magnetic properties.

The operator shall carry out any necessary testing and observations to eliminate non-relevant indications.

Where there is doubt about the interpretation of indications, they shall be classified in accordance with **20.2**.

21 Reporting

21.1 All tests carried out in accordance with this British Standard shall be the subject of a written test report.

21.2 In addition to the results, the report shall include at least the following information:

a) work location;

b) description and identity of the component tested;

c) date of test;

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) name of the company;

g) name and signature of the person performing the tests.

21.3 In some cases, it may not be necessary to have prepared procedure and technique sheets and, in all cases where these are absent, the report shall include as a minimum:

a) description of equiment used;

b) technique of flux generation;

c) indicated current values and waveform for each technique used;

d) distance between contact areas or dimensional details of coils, etc.;

e) detection medium used and background;

f) surface preparation;

g) viewing conditions;

h) method of recording or marking of indications.

Suggested report, technique and procedure sheets are given in appendix D.

Where magnetic particle tests are performed on plant or components in service, reference shall be made to the reason for testing and to the previous history, if known.

22 Demagnetization

22.1 General. Demagnetization requires the use of a field equal to, or greater than, that used for magnetization, and the various ways in which it can be achieved are specified in **22.2**. It shall be carried out only if specifically requested.

22.1.1 *Pretest demagnetization.* Where, before testing, the component or structure may have a level of residual magnetization such that adherent swarf, opposing flux or the possibility of spurious indications could limit the efficacy of the test, prior demagnetization shall be implemented.

22.1.2 *Post-test demagnetization.* After applying a magnetic test, the component concerned may remain quite strongly magnetized and, although this will not have any effect on its mechanical properties, it may be undesirable for other reasons. In this event, post-test demagnetization shall be implemented.

22.1.3 *Precautions.* During demagnetization, if components are demagnetized in a group, the container shall not be magnetic and the components shall not be in contact with one another in such a way as to form a magnetic circuit.

After demagnetization, the component shall be removed from the vicinity of the demagnetizing coil or machine, as it may be remagnetized if allowed to stay within the magnetic field around the demagnetizer. To guard against this possibility, the component shall be removed to a distance of at least 1.5 m.

22.2 Demagnetization techniques

22.2.1 *Aperture type coil.* The component is passed through an aperture type coil carrying an alternating current. The component is then removed to an axial distance of not less than 1.5 m or to some other position where the flux is not detectable, and the current is switched off.

22.2.2 *Aperture type coil (with variable current).* With suitable switching gear, a coil is used to apply a continuously diminishing alternating field to the component, which remains stationary. The component is not removed until the sequence has been completed.

22.2.3 *Reversing d.c. magnetization.* The component is placed between the poles of an electromagnet and a field strong enough to saturate it magnetically is applied. The field is then reduced to zero in small steps and its direction is reversed at each step, until zero current is reached. Each step should be 50 % of the preceding one, down to the minimum possible.

22.2.4 *A.C. yokes.* The a.c. yoke technique is normally used on components in situ in a structure that cannot be easily removed from the parent structure. The energizing yoke is passed over the surface of the component and removed to a distance of at least 450 mm from it. The stroking action is repeated as many times as necessary to cover the whole test area. Stroking is always in the same direction, the yoke being moved away in a circle before being returned to the component.

22.2.5 *Diminishing a.c. flow.* Where a diminishing a.c. flow is used, successive excitations at current values diminishing in steps not exceeding 50 % of the previous value, down to the minimum possible, will leave the component effectively demagnetized.

22.3 Heat treatment. Where a partly finished component that has been tested is subsequently subjected to a temperature above its Curie point (normally 700 °C or above), this heat treatment automatically demagnetizes it.

22.4 Remanent magnetization tests. One of the tests in **22.4.1** to **22.4.3** shall be used for checking the degree of demagnetization of a component and the choice of the particular test shall be agreed between the interested parties.

22.4.1 *Compass test.* A suitable compass (see BS MA 2-7) is placed in a position well clear of all magnetizing and demagnetizing equipment or any ferromagnetic material. The component under test is then positioned at the agreed distance on the east-west axis and slowly rotated through 360°. During this operation, the compass needle shall not be deflected through more than 1°. If this limit is exceeded, the component shall be demagnetized again and the compass test repeated.

22.4.2 *Tests with flux and field strength meters.* The measuring device is placed on the surface of the component and it is rotated and moved over the component to measure the largest value of magnetic field adjacent to the surface. This field strength shall not exceed the agreed value. If the limits is exceeded, the component shall be demagnetized again and the test repeated.

22.4.3 *Non-quantitative test.* Where quantitative data are not required, a non-magnetized ferritic steel paper clip on the end of a length of thread shall not be attracted by the surface, when placed in close proximity to it.

23 Cleaning

After testing and acceptance, unless otherwise agreed between the interested parties, all components shall be cleaned to remove all traces of detecting media.

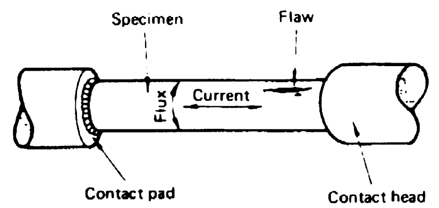


Figure 1 — Current flow technique

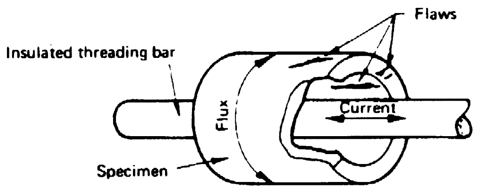


Figure 2 — Threading bar or cable technique

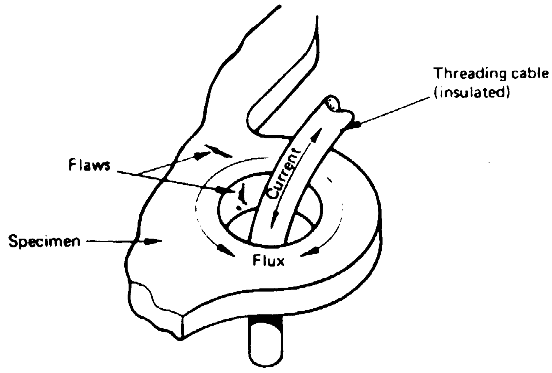


Figure 3 — Flexible threading bar technique

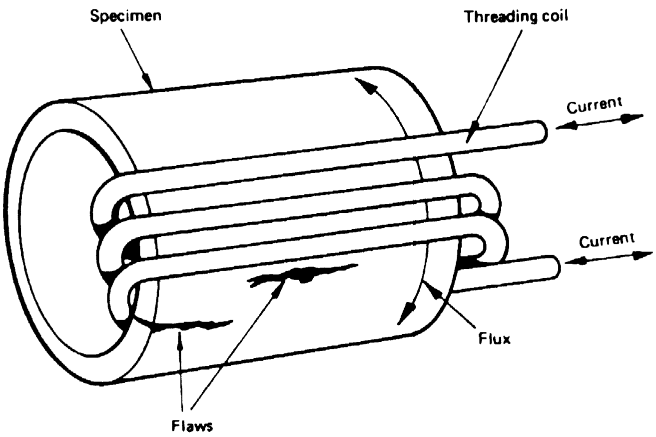


Figure 4 — Flexible cable technique (using cable wound through the specimen)

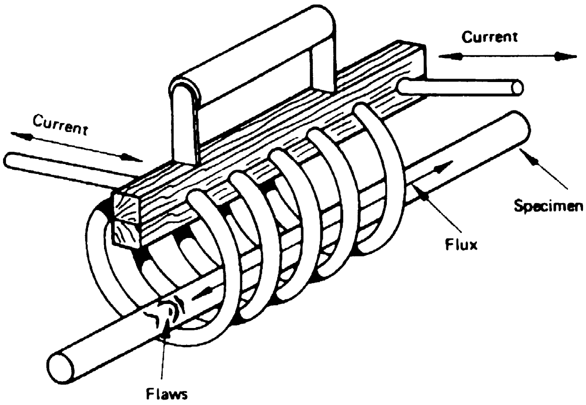


Figure 5 — Coil technique

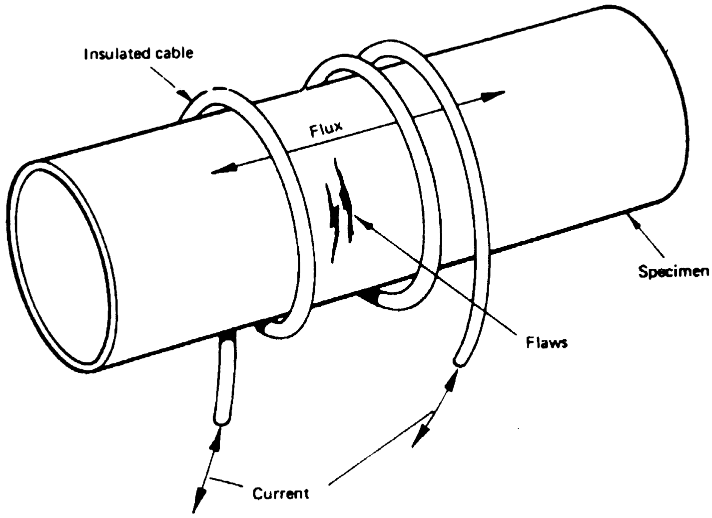


Figure 6 — Flexible cable technique (using cable wound round the specimen)

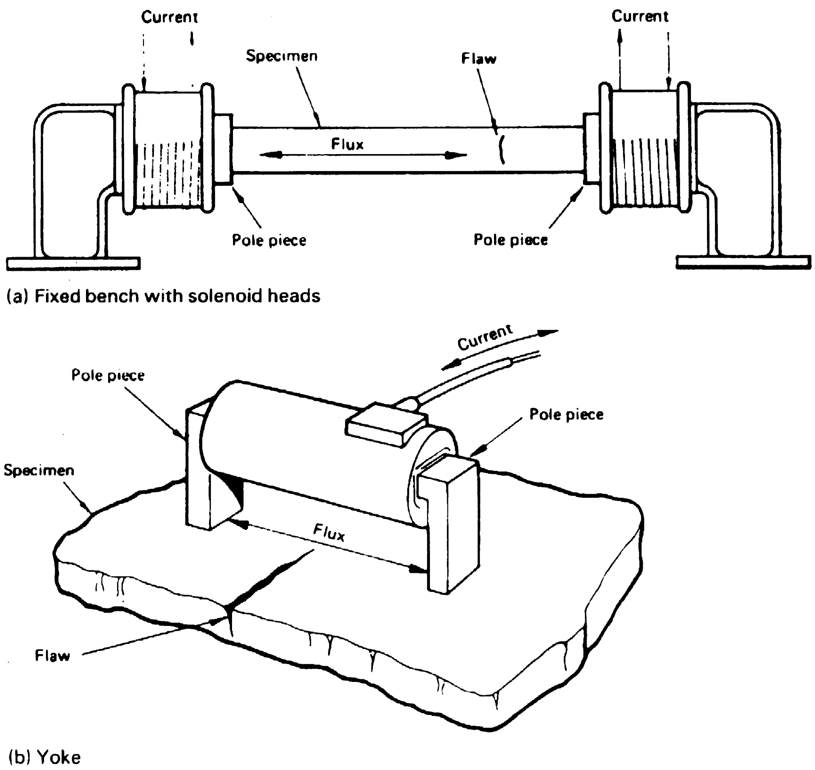


Figure 7 — Magnetic flow technique

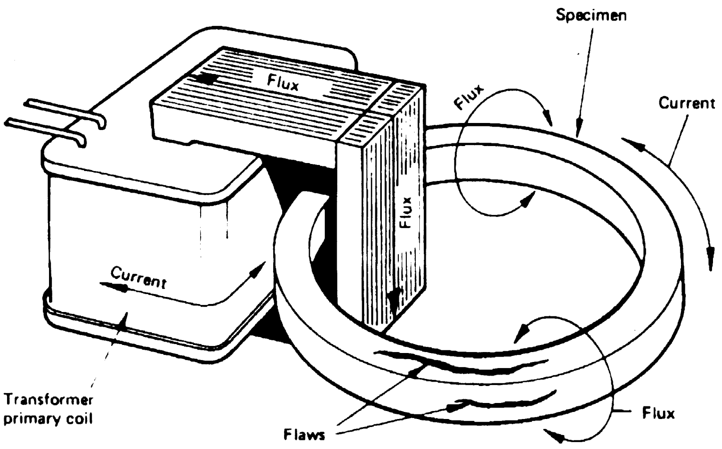


Figure 8 — Induced current flow technique

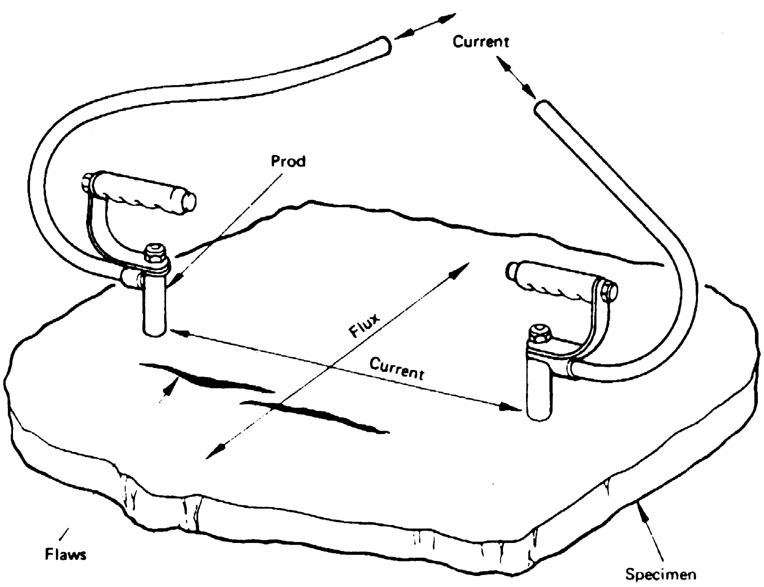
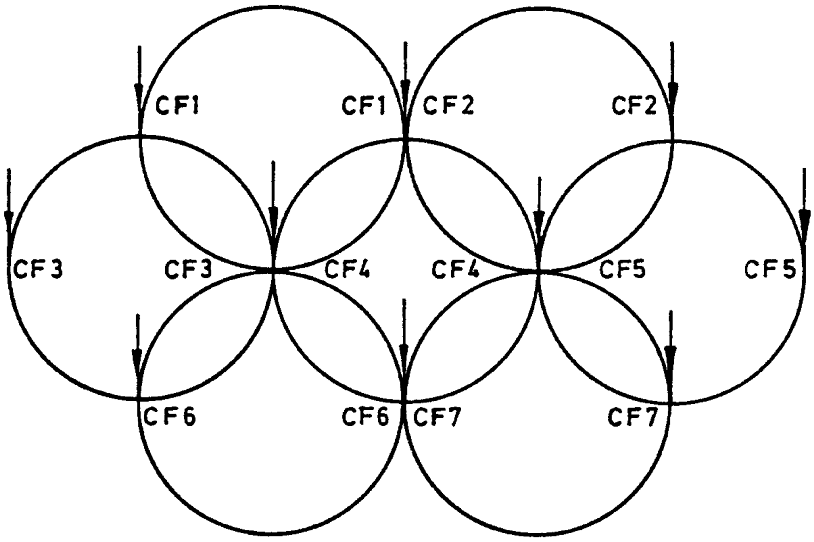
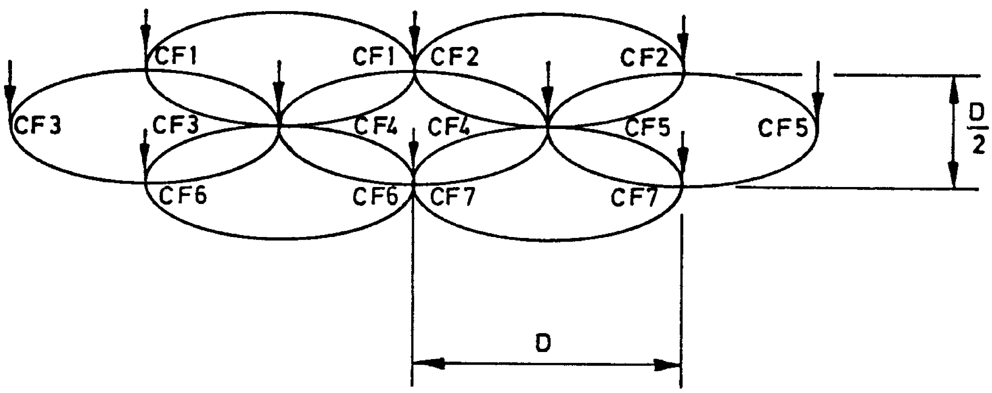


Figure 9 — Current flow technique (prods)



NOTE. Successive prod positions are designated CF1-CF1, etc. The inspected area is considered to be a circle inscribed between the prods. To detect flaws in all orientations, the test is repeated with the whole pattern rotated through 90°.

Figure 10 — Search pattern which is acceptable when using current flow (prods) technique to inspect flat surfaces and those with radii of curvature greater than half the prod spacing (peak current value not less than 7 500 amps per metre of prod spacing)



NOTE. The pattern is similar to that in figure 10, except that the inspected area is an ellipse inscribed between the prods with a minor axis equal to half the prod spacing.

Figure 11 — Search pattern for the current flow (prods) technique when the peak current value is 4 700 amps per metre of prod spacing

Appendix A Selection of test techniques for magnetizing material or components of specific geometric shape

The techniques selected from Table 4 or Table 5 shall include tests to cover flaws in all required directions. The complementary techniques given in Table 5 allow for these requirements.

Table 4 — List of testing techniques

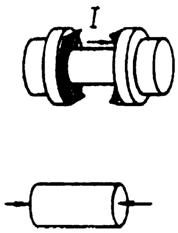
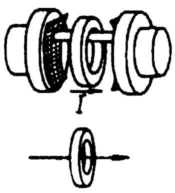
Excitation technique, geometry and drawing symbol	Direction applied	Sensitive to flaws in the main surfaces in direction of:			Descriptive abbreviation in Table 5[a]
		Major axis	Transverse	Short transverse	
Current flow (CF) 	Major axis	Yes[b]	No	No	CF/L/current value
	Transverse to major axis	No	Yes	Yes	CF/T/current value
	Short transverse to major axis (on round object at 90° to CF/T)	No	Yes	Yes	CF/ST/current value
	At the quoted degrees angle to CF/T on a round object	No	Yes	Yes	CF/T60/current value
	Special direction as detailed	In line with direction of test			CF/X/current and directional detail
Threading bar (TB) (includes threading cable techniques) 	Through main bore	Yes (including bore faults)	No	No	TB/L/current value
	Through transverse subsidiary bore	No	Yes	Yes	TB/T/current value
	Through short transverse subsidiary bore	No	Yes	Yes	TB/ST/current value
	Through nominated subsidiary hole	In line with direction of test			TB/X/current value and details

Table 4 — List of testing techniques

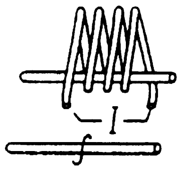
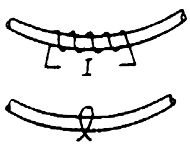
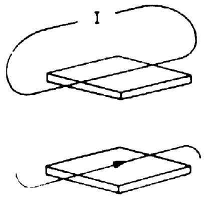
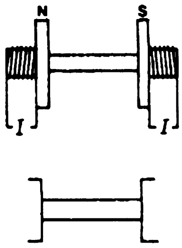
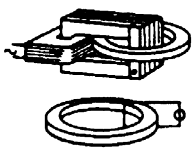
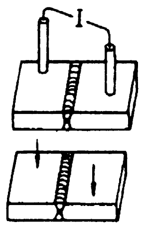
Excitation technique, geometry and drawing symbol	**Direction applied**	**Sensitive to flaws in the main surfaces in direction of:**			**Descriptive abbreviation in Table 5**[a]
		Major axis	**Transverse**	**Short transverse**	
Coil (C) 	Major axis along coil bore	No	Yes	Yes	Coil/L/current value and coil details
	Transverse to coil bore (applicable only where extenders are used)	Yes	No	Yes	Coil/T/current value and coil details
Flexible cable (FC) 	Wound around the section	In a direction parallel to conducting cable			FC/current value/turns or cable arrangement[c]
Adjacent flexible cable (AFC) 	Adjacent to the section	In a direction parallel to conducting cable			AFC/current value/cable height above test piece[c]

Table 4 — List of testing techniques

Excitation technique, geometry and drawing symbol	Direction applied	Sensitive to flaws in the main surfaces in direction of:			Descriptive abbreviation in Table 5[a]
		Major axis	Transverse	Short transverse	
Magnetic flow (MF) 	Major axis	No	Yes	Yes	MF/L/current value
	Transverse to major axis	Yes	No	No	MF/T/current value
	Short transverse to major axis on non-round objects (on round objects at 90° to MF/T)	Yes	Yes	No	MF/ST/current value
	At the quoted degrees angle to MF/T	At 90° to direction of test			MF/T60/current value
	Special directions as nominated	At 90° to direction of test			MF/X/current value
Induced current (IC) 	Major axis (yoke through bore)	Circumferential but not radial			IC/—/current value
Current flow with prods (CFP) 	As test CF/L				CFP/L/current value and detail
	As test CF/T				CFP/T/current value and detail
	As test CF/ST				CFP/ST/current value and detail
	Special nominated direction	In line with the test direction			CFP/X/current value and detail

[a] See also note 3 at the end of appendix A. Current values shall be in accordance with clauses **9** to **17**, as appropriate.
[b] Also radial on end faces, where visible.
[c] For repeated tests, e.g. on long bars, test spacing positions shall be quoted.

Table 5 — Test techniques for material or components of specific geometric shape

Shape	[a]Basic test techniques in Table 4 giving commonly specified degree of coverage	[a]Complementary test techniques required when full coverage of ends of minor faces is essential
Long bar	CF/L and MF/L, or CF/L and coil/L	CF/T and CF/ST, or MF/T and MF/ST, or CF/T and MF/T
Short bar	CF/L and MF/L, or CF/L, CF/T and CF/ST, or MF/L, MF/T and MF/ST, or CF/L and coil/L	As long bar
Helix (spaced winding), e.g. spring	CF/L and TB/L, or CF/L, MF/T and MF/ST	As long bar (if practicable)
Long tube (see note 6)	TB/L and MF/L, or TB/L and coil/L	CF/T and CF/ST
Short tube (see note 6)	TB/L and MF/L, or TB/L, CF/T and CF/ST, or MF/L, MF/T and MF/ST, or TB/L and coil/L	As long tube
Long closed end tube	As long tube	*Closed end:* As long bar *Open end:* CF/T and CF/ST
Short closed end tube	As short tube	*Closed end:* As long bar *Open end:* CF/T and CF/ST
Large tube	FC/— and CFP/T, or CFP/L and CFP/T, or TB/L and CFP/T	FC/—, CFP/T and CFP/ST
Small ring	TB/L, CF/T and CF/ST, or CF/T, CF/ST, MF/T and MF/ST, or CF/L and IC/—, or TB/L and IC/—	None
Large ring	FC,CFP/T or TB/L (repeat at stated intervals with TB close to inner surface) and CFP/T, or IC/— and FC	None
Large plate	CFP/L and CFP/T or AFC (two directions)	On all minor faces as column 2
Small plate	CF/L and CF/T, or MF/L and MF/T, or CF/L and MF/L, or CF/L and coil/L	By performing any two alternatives, the minor faces will be covered
Large disc	CFP/L and CFP/T or AFC (two directions)	On all minor faces as column 2
Small disc	CF/T and CF/ST, or MF/T and MF/ST, or MF/T and CF/T	By performing any two alternatives, the minor faces will be covered

[a] Descriptive symbols are in accordance with column 6 of Table 4.

Table 5 — Test techniques for material or components of specific geometric shape

Shape	[a]Basic test techniques in Table 4 giving commonly specified degree of coverage	[a]Complementary test techniques required when full coverage of ends of minor faces is essential
Large sphere	CFP/L and CFP/T or AFC (two directions)	None
Small sphere	CF/L, CF/T and CF/ST, or MF/L and MF/T, or coil/L and coil/T (using extenders, for both techniques)	None

[a] Descriptive symbols are in accordance with column 6 of Table 4.

NOTE 1 In Table 5, the term “long” refers to shapes in which the ratio of length to maximum sectional dimension is greater than 5 : 1. The term “short” is applied to shapes having a ratio less than 5 : 1.

NOTE 2 The term “large” refers to specimens of such dimension that they cannot be adequately tested in the desired direction in one basic operation with the equipment available.

NOTE 3 The following abbreviations are used in the descriptive symbol to define the direction of test:

- L denotes that the test is applied through the longitudinal (major) axis of the component. To avoid confusion, the bore axis on a tube, or a ring, is always considered as the longitudinal direction. On a disc, the longitudinal direction is considered to be at right angles to the flat faces.
- T denotes that the test is applied transversely (at right angles to the major-axis direction).
  On non-round components, the long transverse direction is implied.
  On round components, a diametrical test is implied.
- ST denotes that the test is applied in the *short transverse* direction on non-round objects. On round components, a diametrical test is implied at 90° to the T test.
- T 60°(120°, etc.) denotes a further transverse test on a round component spaced at the quoted angular position from the first transverse test.
- X denotes an unusual direction for which descriptive details are added.

NOTE 4 Unless otherwise stated, every operation is to be repeated, as required, to ensure full coverage of the inspected areas.

NOTE 5 Where applicable, the complete coverage of any specific shape can be obtained by combining any one of the alternative techniques shown in column 2 of Table 4 with any one set of supplementary operations shown in column 3. In some cases, the same operation is common to both the basic and supplementary techniques.

NOTE 6 On tubular components, the threading bar tests can be replaced by longitudinal current flow, if the detection of flaws in the bore or on end faces is not required.

NOTE 7 When specifying a technique for components with a non-conducting surface (such as a proprietary phosphate treatment or paint) it is essential to avoid current flow tests, unless the removal of the surface locally at the contact areas can be tolerated.

NOTE 8 For certain parts, there are other special techniques that may be used, e.g. flat washers, which may be tested whilst in contact with a flat steel bar carrying current appropriate to its dimensions. In such instances, the precise test conditions shall be specified.

NOTE 9 Portable electromagnets can be used to test components of all shapes.

Appendix B Methods for determining the inspected areas when using the current flow (prods) technique

B.1 Use a part with a known natural or artificial flaw and determine the maximum distance from a line joining the (two) prod positions at which the flaw can be satisfactorily delineated when equidistant from the prods, using the proposed separation and current value. A portable magnetic flux indicator may be used for this purpose, provided it indicates a peak magnetic field value of 2 400 A/m in the appropriate orientation.

B.2 Using a flux meter operating on the Hall effect principle, measure the magnetic field strength close to the surface in a direction tangential to the surface and perpendicular to the line between the prods. Use the meter range that gives the largest deflection and calibrate the zero and one other point on this range with a standard zero-field chamber and a standard magnet. Convert the readings to peak field values using a multiplication factor appropriate to the instrument and waveform chosen. The inspected area shall be considered as that within which the peak field component exceeds 2 400 A/m, or as an ellipse where the major axis lies between the two prods and the minor axis joins the points to the centreline, transverse to the prod axis, and the peak field component is 2 400 A/m.

B.3 Increase the current to three times the current envisaged for the test and determine the limits of the area over which saturation occurs. With the normal test current, this area will then be magnetized to an overall level of not less than one-third saturation.

Appendix C Test pieces and test procedure

C.1 Current flow test piece. The standard test piece for checking current flow equipment should be in accordance with the details given in Figure 12 and Table 6. It should be maintained free from corrosion and oxidization.

C.2 Procedure

a) Thoroughly degrease and magnetize the test piece.

b) Clamp it within head and tailstock of the test bench.

c) Apply magnetic ink while the current is being increased.

d) Establish the current required to make the hole nearest to the outer surface of the ring visible on the outer surface.

e) Further increase the current to establish indications from the other two holes on the outer surface of the ring.

f) Note the current value required to establish each hole indication. (If the magnetizing system is functioning correctly, each hole should be visible at each subsequent check with the test piece.)

Repeat the test for each current waveform with which the magnetizing unit is equipped, bearing in mind that the 22.5 mm pitch circle (p.c.) radius hole is unlikely to show positively on an alternating current waveform below 900 A (r.m.s.).

C.3 Magnetic flow/coil test piece. The standard test piece for checking magnetic flow equipment and coils should be in accordance with the details given in Figure 13. It should be maintained free from corrosion and oxidization.

C.4 Procedure

a) Thoroughly degrease and demagnetize the test piece.

b) Clamp it between the poles of the test bench (magnetic flow) or, alternatively, place it centrally in the coil parallel to the coil axis.

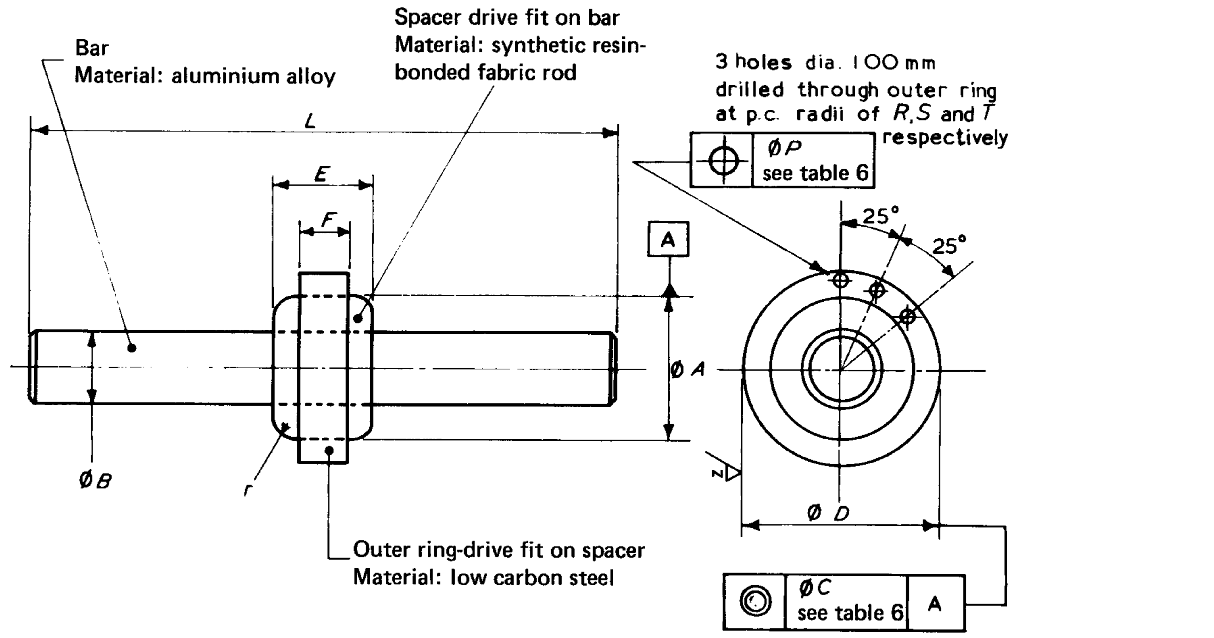
c) Energize the equipment and establish that the transverse hole in the middle of the test piece shows a strong indication.

Table 6 — Dimensions of standard test piece for current flow checking

	Outer ring bore	Bar diameter	Outer ring concentricity tolerance	Outer ring diameter	Spacer length	Outer ring length	Bar length[a]	Hole positional tolerance	Hole pitch circle radii			Spacer	Surface texture R_a[b]
Dimension	*A*	*B*	*C*	*D*	*E*	*F*	*L*	*P*	*R*	*S*	*T*	*r*	*Z*
mm	nominal 38.00	± 0.05 19.00	diameter 0.05	± 0.025 50.00	± 0.4 25.00	± 0.24 12.50	nominal 150.0	diameter 0.05	true position 23.50	true position 23.00	true position 22.50	nominal 5.0	1.6 µm to 3.2 µm

[a] Length of bar may be varied to suit individual circumstances.

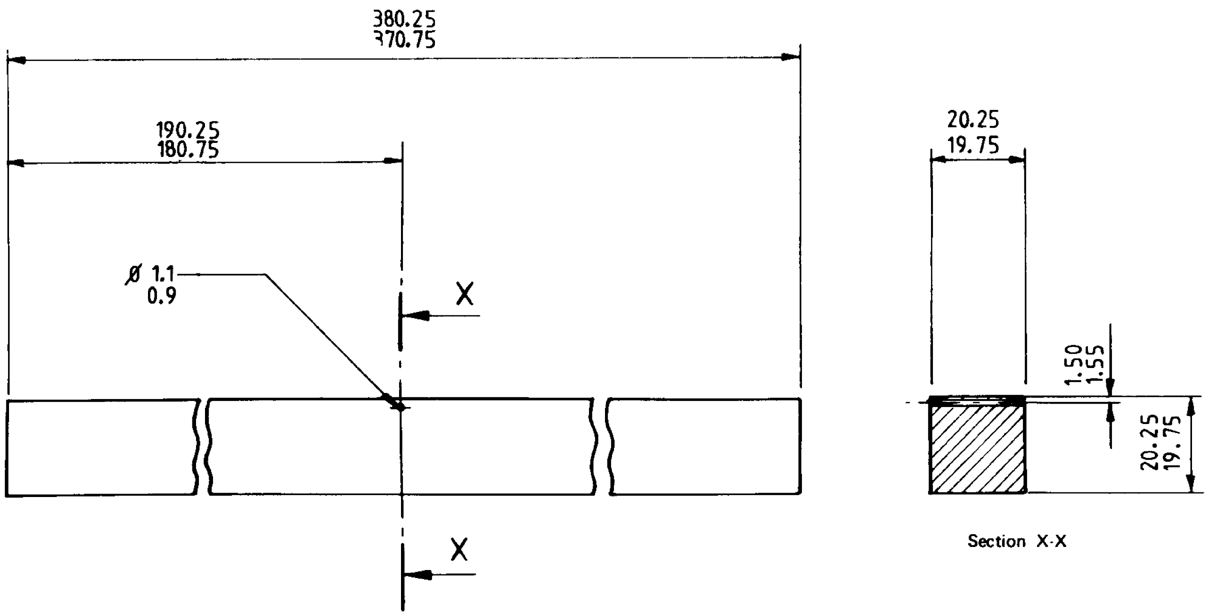
[b] In accordance with BS 1134.



NOTE 1. All components to be centrally disposed on bar.

NOTE 2. Circumference of ∅ *D* to be vapour-blasted with grit in the range G12 to G24 in accordance with BS 2451 to produce the surface finish specified.

Figure 12 — Details of standard test piece for current flow checking



NOTE 1. All dimensions are in millimetres.

NOTE 2. Roughness grade limits N7/N6.

NOTE 3. ∀ All over.

NOTE 4. Material: low carbon steel complying with the requirements of BS 970.

Figure 13 — Test piece for checking magnetic flow and coil magnetization

Appendix D Report, technique and procedure sheets

D.1 Introduction. Appendix D illustrates the form that typical report, technique and procedure sheets should take.

D.2 Report sheet: magnetic particle flaw detection

Name and address of company

Location

Description and identity of component/part tested

Date of test

Stage of test

Description of equipment used

Detecting medium, background and viewing conditions

Method of flux generation

Distance between contact areas

A.C./D.C./half-wave/full-wave rectified

Maximum/minimum A

Surface preparation

Method of recording/marking indications

Reason for test

Previous history

Results of tests

Name and signature of person conducting test

D.3 Technique sheet: magnetic particle flaw detection

Name and address of company

Description and identity of component/part

Sketch or workpiece (with main dimensions)

Test technique	*Current*	*Flaws sought*
(Indicate on above sketch)	(Values and waveforms used)	
A	A	A
B	B	B
C	C	C
D	D	D
E	E	E

Equipment used (state distance between contact areas, coil dimensions, etc.)

A

B

C

D

E

Detecting medium — Background

Viewing conditions

Method of recording/marking indications

Approved by

Date

D.4 Procedure sheet: magnetic particle flaw detection

Name and address of company
Description and identity of component/part
Main dimensions
Material and specification
Area to be tested
Purpose of test

Stage at which test conducted	(a)
	(b)
	(c)
	(d)
Surface condition at time of test	(a)
	(b)
	(c)
	(d)

Associated technique sheet nos.
Associated documents (code or standard)
Acceptance/rejection criteria (code or standard)

Date of test	Prepared by
	Approved by
	Performed by

Appendix E Preservation of indications

E.1 General. It is sometimes necessary for flaw evaluation or record purposes to preserve the flaw indications on the workpiece, or to retain them as a separate permanent record. Prior to such action, it is essential to ensure that the test conditions, and in particular the magnetizing levels, are as near as possible to the level recommended in the technique. The methods listed below have been found suitable for this purpose.

E.2 Preparation for preservation. If dry powder is used, no preparation is necessary.

If any oil-based carrier fluid is used, the surface should be drained and adequately dried.

Another possibility is to retest the workpiece using a magnetic ink made with a volatile carrier fluid.

E.3 Preservation of indications on the workpiece. To obtain a permanent record, either photography or one of the methods given in a) to f) should be used. It is essential that a common datum be established on both the workpiece and the record and that care be taken not to disturb the indications.

a) Cover the indications with a transparent adhesive film. Carefully peel off the film and the adhering indications and reapply to either paper or card of contrasting colour.

b) Degrease the test surface, cover with a white matt adhesive film and retest. After drying, if necessary, cover the indications with a clear film in the manner described in a) and transfer together the pair of films to the record card.

c) Spray the tested area with a quick-drying, strippable coating. Strip off this coating and view the face previously in contact with the workpiece, to which the indications will be transferred.

d) Heat the workpiece to an approved temperature and, without delay, slowly immerse in a powdered plastics material and slowly withdraw. Allow it to drain and cure in accordance with the manufacturer's instructions. Strip off the coating complete with indications from the workpiece and view the face previously in contact with it.

e) Degrease the test surface and coat with a proprietary, strippable, magnetic-oxide paint. Magnetize the part to saturation and peel off the coating. If it is dipped in agitated magnetic ink, it will reveal the flaw indications on the oxide film.

f) Degrease the test area and coat with a proprietary, self-curing, magnetic, silicone-rubber compound. Magnetize to saturation and allow the compound to cure. The oxide in the compound will migrate to the position of any flaw and, when removed from the workpiece, the rubber previously in contact with the surface will show the flaw.

NOTE Method f) is more suitable when strong permanent magnets or sustained magnetic flow is used. It can be applied very successfully to small holes and to internal threads in components.

E.4 Photographic records. When a photographic record is made, the resulting photograph of the tested surface should, if possible, be actual size. If the surface of the workpiece is highly polished, care should be taken to avoid highlights. The use of a matt-contrast medium applied prior to testing may be desirable.

E.5 Limitations of preservation methods. Methods a) to c) of **E.3** are generally restricted to surfaces of simple geometric form because of the difficulties involved in removing the films. Method d) does not generally produce satisfactory results from fluorescent magnetic inks as compared with black magnetic inks.

blank

Publications referred to

BS 89, *Specification for direct acting indicating electrical measuring instruments and their accessories.*

BS 970, *Wrought steels in the form of blooms, billets, bars and forgings.*

BS 1134, *Method for the assessment of surface texture.*

BS 2451, *Chilled iron shot and grit.*

BS 3683, *Glossary of terms used in non-destructive testing.*

BS 3683-2, *Magnetic particle flaw detection.*

BS 4069, *Magnetic flaw detection inks and powders.*

BS 4360, *Specification for weldable structural steels.*

BS 4489, *Method for measurement of UV-A radiation (black light) used in non-destructive testing.*

BS 5044, *Contrast aid paints used in magnetic particle flaw detection.*

BS 5165, *Guide to the selection of low-power magnifiers used for visual inspection.*

BS 5345, *Code of practice for the selection, installation and maintenance of electrical apparatus for use in potentially explosive atmospheres (other than mining applications or explosive processing and manufacture).*

BS 5423, *Specification for portable fire extinguishers.*

BS MA 2, *Magnetic compasses and binnacles.*

BS MA2-7, *Individual testing of magnetic compasses and accessories: Classes A and B.*

BS M 35, *Method for magnetic particle flaw detection of materials and components*[6].

National Radiological Protection Board. Protection against ultraviolet radiation in the workplace. Published by HMSO.

[6] Referred to in foreword only. Subsequently withdrawn in November 1984 and superseded by BS 6072.

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