



British Standard

Magnetic materials

Part 5. Methods of measurement of the
magnetic properties of magnetically hard
(permanent magnet) materials

Matériaux magnétiques

Partie 5. Méthodes de mesure des propriétés magnétiques des matériaux durs (aimants permanents)

Magnetische Werkstoffe

Teil 5. Verfahren zur Messung der magnetischen Eigenschaften dauermagnetischer Werkstoffe

National foreword

This Part of BS 6404 has been prepared under the direction of the Iron and Steel and Non-ferrous Metals Standards Committees. It is identical with IEC 404-5 : 1982 'Magnetic materials, Part 5 : Methods of measurement of the magnetic properties of magnetically hard (permanent magnet) materials', published by the International Electrotechnical Commission (IEC).

The methods described in this Part of BS 6404, apart from some minor differences in detail, are included in the current edition of BS 5884. The current edition of BS 5884 also describes methods of test for the measurement of the d.c. magnetic properties of solid steels and a method of measurement of the coercivity of magnetic materials in an open magnetic circuit. These additional methods of test are now the subjects of BS 6404 : Parts 4 and 7 respectively which are identical with IEC Publications 404-4 : 1982 and 404-7 : 1982 respectively.

BS 5884 is being revised to include only the remaining methods described in the current edition, namely test methods for the determination of the relative magnetic permeability of feebly magnetic materials.

This Part of BS 6404 is the fifth part of a series of British Standards based on the IEC series 'Magnetic materials'. The Part numbers of the British Standard follow the Parts of the IEC publication. The following Parts of the British Standard have been published.

Part 1 Classification

Part 2 Methods of measurement of magnetic, electrical and physical properties of magnetic sheet and strip

Part 3 Methods of measurement of specific total losses of magnetic sheet and strip by means of a single sheet tester

Part 4 Methods of measurement of the d.c. magnetic properties of solid steels

Part 7 Method of measurement of the coercivity of magnetic materials in an open magnetic circuit

Part 8 Individual materials

Section 8.2 Specification for cold-rolled magnetic, non-oriented, alloyed steel strip delivered in the semi-processed state

Section 8.3 Specification for cold-rolled magnetic, non-oriented, non-alloyed steel strip delivered in the semi-processed state

Section 8.4 Specification for cold-rolled, non-oriented magnetic steel sheet and strip delivered in the finally annealed state

Additional Parts of IEC 404 will be published and are expected to provide the basis for additional Parts of BS 6404.

Terminology and conventions. The text of the international standard has been approved as suitable for publication as a British Standard without deviation. Some terminology and certain conventions are not identical with those used in British Standards; attention is drawn especially to the following.

Wherever page numbers are quoted, they are IEC page numbers.

Cross-reference. The Technical Committee has reviewed the provisions of IEC 50(901), to which reference is made in the text, and has decided that they are acceptable for use in conjunction with this standard.

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

CONTENTS

	Page
National foreword	Inside front cover
Committees responsible	Back cover

INTRODUCTION

Clause	
1. Scope	2
2. Accuracy and reproducibility	2
3. Definitions	2

CHAPTER I: MATERIALS HAVING AN INTRINSIC COERCIVITY H_{cJ}
LESS THAN OR EQUAL TO 600 kA/m

4. Object	3
5. Electromagnet	3
6. Test specimen	4
7. Determination of the magnetic flux density	4
8. Measurement of the magnetic field strength	5
9. Determination of the demagnetization curve	5
10. Determination of the $(BH)_{max}$ product	7
11. Determination of the recoil line	7
12. Test report	7

CHAPTER II: MATERIALS HAVING AN INTRINSIC COERCIVITY H_{cJ}
GREATER THAN 600 kA/m

13. Object	8
14. Method of measurement	8
15. Test report	9

FIGURES	10
-------------------	----

APPENDIX A – Influence of the air-gap between the test specimen and the pole pieces	14
---	----

British Standard

Magnetic materials

Part 5. Methods of measurement of the magnetic properties of magnetically hard (permanent magnet) materials

INTRODUCTION

1. Scope

This standard is applicable only to magnetically hard materials, the properties of which are presumed homogeneous throughout their volume. Its object is to specify standard methods of measurement of the magnetic properties of magnetically hard materials in a closed magnetic circuit.

The performance of a magnetic system is not only dependent on the properties of the magnetically hard material but also on the dimensions of the system, the air-gap and other elements of the magnetic circuit.

The measuring method, in principle, makes use of a closed loop simulating a ring. As the magnetic characteristics may substantially depend on the value of the applied magnetic field, two methods have been included for two coercivity ranges of magnetically hard materials:

- one for magnetically hard materials having an intrinsic coercivity less than or equal to 600 kA/m (Chapter I);
- the other for magnetically hard materials having an intrinsic coercivity greater than 600 kA/m (e.g. rare earth cobalt alloys) (Chapter II).

2. Accuracy and reproducibility

In the case of the test methods described in this standard it is not always possible to refer to fundamental principles. The final accuracy of the test apparatus is a complex function dependent on the measuring instruments and other features of the measuring environment and equipment components; therefore it is not always possible to state the absolute accuracy which can be attained. However, experience in the use of a given method indicates the reproducibility which can be expected.

3. Definitions

The definitions relating to the various terms used in this standard are defined in IEC Publication 50(901): International Electrotechnical Vocabulary (I.E.V.), Chapter 901: Magnetism.

For magnetically hard materials this standard deals with both the coercivity H_{CB} and the intrinsic coercivity H_{CJ} which is a fundamental quantity and of increasing importance particularly in dynamic applications.

The measurements specified in this standard are of the magnetic flux density B against the magnetic field strength H and the magnetic polarization J is related to these quantities by the following equation:

$$B = \mu_0 H + J$$

Using this relationship H_{CJ} values can be obtained from the BH hysteresis loop.

CHAPTER 1: MATERIALS HAVING AN INTRINSIC COERCIVITY H_{cJ} LESS THAN OR EQUAL TO 600 kA/m

4. Object

The object of this chapter is to define the method of measurement of the magnetic flux density and the magnetic field strength and also the determination of the demagnetization curve and recoil line of magnetically hard materials having an intrinsic coercivity H_{cJ} of less than or equal to 600 kA/m.

5. Electromagnet

The test is carried out in a closed ferromagnetic circuit consisting of an electromagnet made of soft magnetic material and the test specimen. The construction of the yokes should be symmetrical; at least one of the poles should be movable to minimize the air-gap between the specimen and the pole pieces.

For certain measurements, the yoke and the poles are laminated to decrease eddy currents. The coercivity of the pole material should normally be not more than 100 A/m.

To obtain sufficiently uniform magnetization in the space occupied by the test specimen, the following conditions shall be fulfilled simultaneously:

Geometrical conditions (Figure 1, page 22)

$$d_1 \geq d_2 + 1.2 l \quad (1)$$

$$d_1 \geq 2.0 l \quad (2)$$

where:

d_1 = diameter of a circular pole piece or the shortest dimension of a rectangular pole piece, in metres

l = distance between the pole pieces, in metres

d_2 = maximum diameter of the cylindrical volume with a homogeneous field, in metres

Electromagnetic conditions

The flux density in the pole pieces shall be maintained very low compared with the saturation flux density so that the pole faces shall be brought as near as possible to be equipotential. In practice, the flux density shall be less than 1 T in iron and less than 1.2 T in iron alloy containing 35% to 50% cobalt.

The error due to an inhomogeneous magnetic field in the test specimen is particularly significant in the first quadrant at high magnetic field strengths.

Under the above conditions, the field in the specified volume gives variations in homogeneity less than:

2% radially

2% axially

The yoke is excited by magnetizing coils which are arranged symmetrically as near as possible to the test specimen. The axis of the test specimen shall be congruent with the axis of the magnetizing coils. For magnetizing the test specimen in the electromagnet, the minimum necessary value of magnetic field strength shall be provided. This value of magnetic field strength varies according to the nature of the magnetically hard materials and depends parti-

cularly on its degree of anisotropy. An approximate relationship exists between the value of the maximum field strength ($H_{\max}$) and the intrinsic coercivity (H_{cJ}). This approximate relationship is as follows:

$$H_{\max} = k H_{cJ} \quad (3)$$

The coefficient k varies according to the nature of the magnetically hard material and is generally between 3 and 5.

At high field strengths, a mechanical force may compress the test specimen. It is therefore necessary to lock the poles.

6. Test specimen

The test specimen shall have a simple shape (for example cylinder or parallelepiped) and its dimensions shall be chosen in accordance with equations 1 and 2. The length l of the test specimen shall be greater than 5 mm.

The end faces of the test specimen shall be ground parallel to each other and as nearly as possible perpendicular to the test specimen axis to reduce the air-gap (see Appendix A).

The cross-sectional area of the test specimen shall be as uniform as possible throughout its length, any variation shall be less than 1% of its minimum cross-sectional area.

In the case of anisotropic material the direction of magnetization should be marked on the test specimens.

7. Determination of the magnetic flux density

The changes in flux density in the specimen are determined by integrating the voltages induced in a search coil.

The search coil shall be wound as closely as possible to the specimen and symmetrical with respect to the pole faces. The leads shall be tightly twisted to avoid errors caused by voltages induced in loops in the leads.

The total error of measuring the magnetic flux density shall be not greater than $\pm 2\%$.

The variation of flux density ΔB in the test specimen between the two instants t_1 and t_2 is given by:

$$\Delta B = B_2 - B_1 = \frac{1}{AN} \int_{t_1}^{t_2} U dt \quad (4)$$

where:

B_2 = flux density at the instant t_2 , in teslas

B_1 = flux density at the instant t_1 , in teslas

A = cross-sectional area of the test specimen, in square metres

N = number of turns on the search coil

$\int_{t_1}^{t_2} U dt$ = integrated induced voltage, in webers