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Guidance notes for use with NPL low permeability reference materials

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ABSTRACT

These guidelines have been prepared to assist users of low permeability measuring equipment who wish to calibrate their instruments using NPL reference materials.

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Approved on behalf of Chief Executive, NPL
by Dr T G Blaney, Head, Division of Electrical Science.

CONTENTS

	Page
1 INTRODUCTION	1
2 NPL REFERENCE MATERIALS - AVAILABILITY	1
3 INSTRUMENTS	1
3.1 MAGNETIC BALANCE TYPE	2
3.2 STRAIN GAUGE TYPE	3
3.3 FLUXGATE TYPE	4
4 NPL REFERENCE MATERIALS - USE	5
5 LIMITATIONS	6
6 REFERENCES	7
7 APPENDIX 1	8

1 INTRODUCTION

Reference materials for the calibration of magnetic permeability measuring equipment have been developed at the National Physical Laboratory¹. The relative magnetic permeability of these materials has been measured in accordance with BS 5884:1987². These guidance notes have been prepared to assist the operator with the calibration of permeability measuring equipment when using NPL reference materials.

2 NPL REFERENCE MATERIALS - AVAILABILITY

The reference materials are available in the form of bars of approximately 300 mm long and 25 mm x 25 mm section. They have a good surface finish which has been carefully machined to avoid altering the surface magnetic properties. The dimensions of the reference materials were selected to facilitate both the absolute measurement method and the various shaped commercial instrument probes which need to be carefully positioned on their surface³.

The reference materials have a good uniformity and stability with time and are supplied with a certificate of measurement which states the uncertainty of measurement for that particular bar.

The current range of reference materials covers three different values of relative magnetic permeability measured at a field strength of 10 kA/m;

Stainless steel AISI Type 316	at approx 1.0030
Naval brass Type CZ114	at approx 1.060
Ni/Al bronze Type DGS 1043	at approx 1.40

The above values of relative magnetic permeability are dependent on the magnetic field strength at which they are measured - see Sections 4 and 5.

Reference materials are available from:-

Magnetics Section
Division of Electrical Science
National Physical Laboratory
Teddington
Middlesex
TW11 0LW
United Kingdom.

3 INSTRUMENTS

There are three main types of commercial instruments which could be calibrated using the NPL reference materials. The magnetic balance type, which compares the attraction of a magnet to a series of reference inserts and its attraction to the specimen under test. This instrument indicates the range of permeability in which the test sample lies. The two other types of instrument, which give a continuous scale reading, utilise a permanent magnet and either strain gauge or fluxgate elements to measure the effect of test materials in contact with their probes. The last two types usually have a number of ranges and their linearity over these ranges is not good. The instruments, therefore, need to be calibrated using a material of permeability close in value to that which is under test.

The magnetic field strength at the tip of the probe of each type of instrument has been found to be significantly different. The magnetic field strength at the tip of a particular probe can be conveniently measured using a Hall effect probe and gaussmeter.

3.1 MAGNETIC BALANCE TYPE

The general arrangement of magnetic balance instruments for measuring relative magnetic permeability is shown in figure 1. This type of instrument is essentially a permeability indicator since a counterbalanced magnet is attracted either to the test specimen or one of a range of reference inserts. The permeability value then lies between the value of that insert and the one of next lower value to which the magnet is not attracted.

The advantages of this type of instrument are:

- i) it is quick and easy to use
- ii) low cost
- iii) useful for examining shaped samples

The main disadvantage is that calibration is very difficult. The problem is to generate reference materials which have exactly the same permeability as each insert at the magnetic field strength prevailing at the tip of the magnet in the indicator. This would be a formidable task.

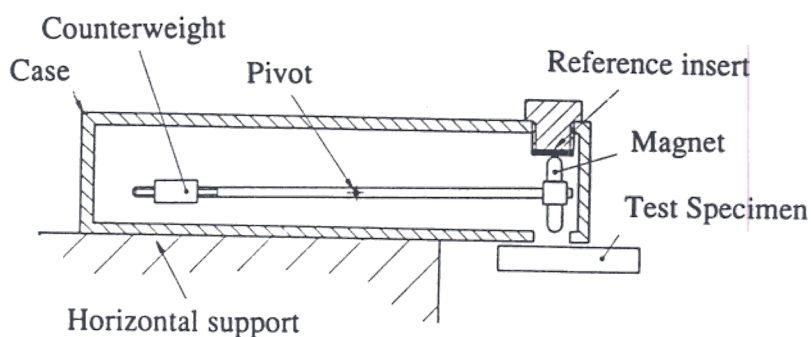


Figure 1 Magnetic balance instrument.

This instrument is easier to use if placed in a fixed position whilst bringing the standard bar or material under test up to the tip of the magnet.

3.2 STRAIN GAUGE TYPE

The manufacturer's instructions should be followed during the setting up procedure of the instrument. There is a continuous scale readout and three different range settings. It is not easy to reset the calibration of this instrument, but by using an NPL reference material close in value to the material under test it would be possible to assess the value of the test sample by interpolation. The general arrangement of this type of instrument is shown in figure 2.

$$P_2 = P_1 \frac{S_2}{S_1}$$

where

S_1 = Scale reading of instrument probe on NPL reference bar

S_2 = Scale reading of instrument on sample

P_1 = Relative magnetic permeability of NPL reference bar

P_2 = Relative magnetic permeability of sample

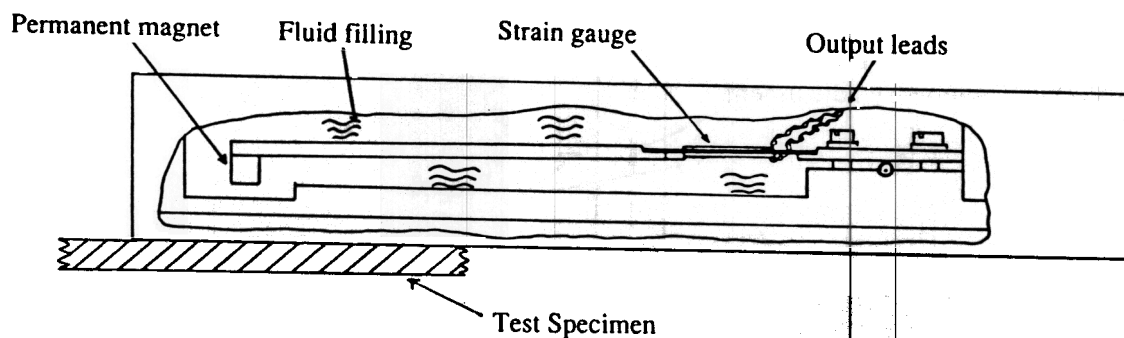


Figure 2 Strain Gauge type instrument.

3.3 FLUXGATE TYPE

This instrument is sometimes supplied with a calibration disc whose value of magnetic permeability is stated. There are four ranges and an option of a probe designed for fixed installation only with a $\times 10$ sensitivity for measuring materials with a permeability of less than 1.01. Experience has shown that it is difficult to calibrate these instruments on all ranges using the one insert. NPL reference bars can be used directly to calibrate the instrument, but it is advisable to only use a bar with a magnetic permeability close to that of the sample under test.

It has been found that by using a non-magnetic jig to hold the probe on this instrument measurements are easier to make and problems with tilting the probe can be reduced, particularly at low values of magnetic permeability (Appendix 1).

When using the most sensitive probe with this instrument problems of variations in the earth's magnetic field can occur, and zeroing can prove difficult.

It has been found that the carrying handle on these instruments can be strongly magnetic and therefore should not be used close to the measuring probe or the standard bars.

The general arrangement of a fluxgate type instrument is shown in figure 3

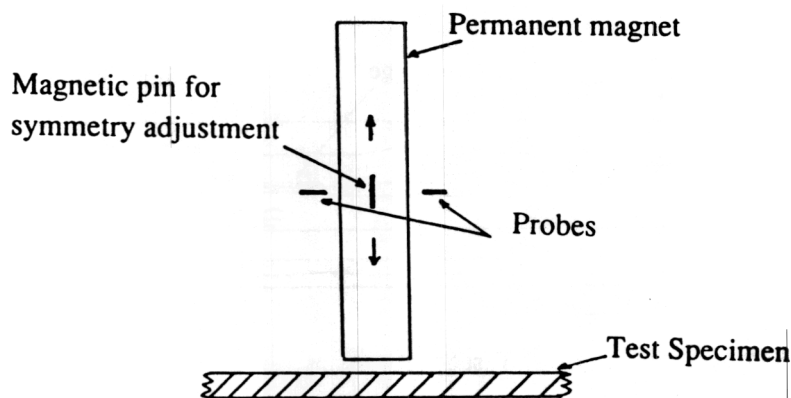


Figure 3 Fluxgate type instrument.

4 NPL REFERENCE MATERIALS - USE

The NPL reference materials all have a small ferromagnetic content in order to achieve the permeability required, consequently their permeability will be different at different field strengths. Typical variations are shown in figures 4a, 4b, and 4c.

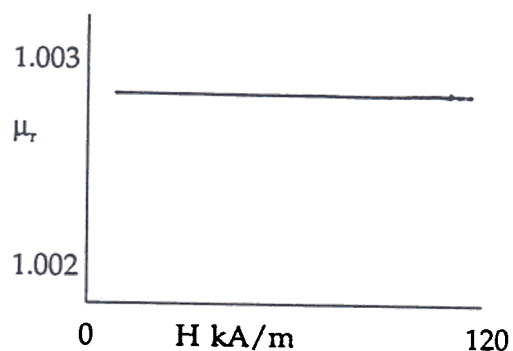


Figure 4a
Stainless steel

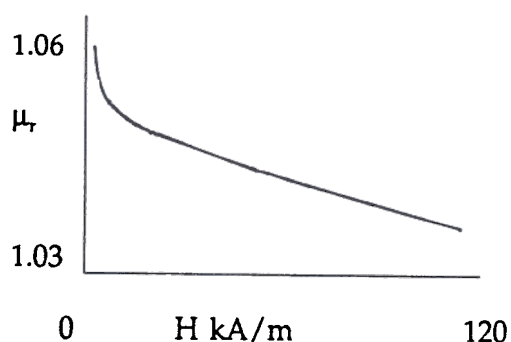


Figure 4b
Brass

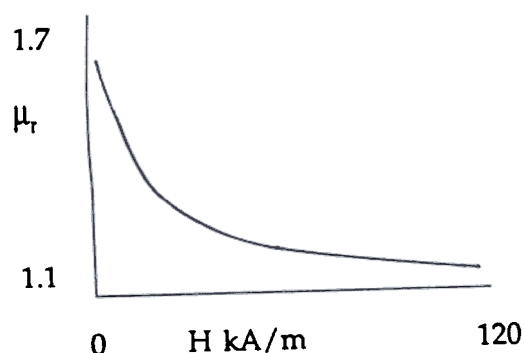


Figure 4c
NI/Al/Bronze

It is important, therefore, to recognise that different types of commercial instrument produce different field strengths at the tip of their probes. Ideally, the magnetic field strength at the tip of each individual probe should be determined as indicated in Section 3. The permeability of the NPL reference material should then be determined at that particular magnetic field strength.

At NPL, the relative magnetic permeability of the reference bars can be measured over the range of magnetic field strength from 5 kA/m to 120 kA/m using the method described in clause 3 of BS5884:1987².

When using the NPL reference materials to calibrate commercial instruments the probes must be placed at the centre of the bar and not near the edges or at the ends. It has been found that when measuring curved surfaces and thin (less than 8 mm thick) samples with commercial instruments a direct comparison cannot be made with the NPL reference materials.

The reference bars should be stored in a dry, clean and non-magnetic area and should be suitably protected from accidental damage to their surface.

It is essential when using the NPL reference materials, or when testing samples, to keep their surface and the surface of the probe clean and free from any ferromagnetic contamination. The area in which the calibration of the instrument is carried out should also be checked to ensure no magnetic material is present which would interfere with the measurement. (Ferromagnetic items such as steel screws in workbenches, magnetic door-catches and contents of drawers under the calibration area should be removed or avoided. A survey of the area using a small hand magnet is a simple but effective means of detecting ferromagnetic objects).

5 LIMITATIONS

When using NPL reference materials for calibrating magnetic permeability measuring equipment the following limitations must be considered:

- i) The instrument probes operate at different field strengths to that at which the reference bar may have been measured.
- ii) The ferromagnetic content of the test piece may be different to that of the reference bar. Thus although their relative magnetic permeability may be the same at one particular field strength it may be different at other magnetic field strengths.

This problem occurs with all types of permeability measuring instruments using a permanent magnet in the sensing probe. Due to this magnet the material under test is being measured at a magnetic field strength much higher than the earth's magnetic field whereas materials of low magnetic permeability normally operate in the earth's magnetic field. From measurements made on materials so far, the relative magnetic permeability is *higher* in the earth's field than at fields prevailing at the detection point of sensors (see figures 4a, 4b and 4c). Correlation between permeabilities measured at these high magnetic field strengths and the values for the earth's field is extremely difficult since the variation in magnetic permeability with field strength varies from material to material and even from one batch to another.

In cases where it is required to determine the change in the earth's magnetic field due to the presence of a low permeability magnetic material, consideration should be given to methods of measuring such small changes directly (for example by using a fluxgate magnetometer).

- iii) It is important to follow manufacturers guidelines on the recommended dimensions of the test piece.
- iv) Most of the measuring instruments may be used successfully for magnetic sorting and for looking at differences in permeability over a test piece rather than precisely

determining the value of relative magnetic permeability.

6 REFERENCES

- 1 *Reference materials for calibrating magnetic permeability measuring equipment, Drake, A.E. and Ager C.I., IEEE Trans on Magnetism, Vol 26, No 5, Sept 1990.*
- 2 *British Standard 5884:1987. Determination of relative magnetic permeability of feebly magnetic material.*
- 3 *DES Report No 119, Report on the development of low magnetic permeability reference materials, Ager C.I. and Drake A.E., August 1993.*

APPENDIX 1

Example of jigs suitable for holding the fluxgate probe.

