MSL Technical Guide 6

Magnetic Effects in Weighing

Introduction

MSL has established a capability to measure magnetic properties of weights because of concerns about magnetic effects in weighing.

Magnetic Effects in Weighing

Modern electronic balances generate magnetic fields. This is because the force-balance weighing cell in these balances contains one or more permanent magnets. Near the pan, the vertical component of these fields can be similar in magnitude to the Earth's magnetic field (~50 μT).

If the sample being weighed is magnetic, the balance reading may be incorrect because of the magnetic force between the sample and the combined magnetic field due to the Earth and the balance.

The most common magnetic effects in weighing arise from the standard weights that are used with balances because these weights are usually magnetic to some extent. Magnetic effects in weighing occur mostly with samples that include iron. The vast majority of other materials that are weighed on balances are essentially non-magnetic.

The magnetic effect on weighings can be large. For example, a client complained to their balance supplier that the reading of the balance varied by more than 20 times the balance resolution when they checked the balance for pan position error. The supplier checked the balance and found no significant pan position error. It turned out that the weight used by the client to check pan position error was magnetised.

Magnetic effects in weighing can occur at all accuracy levels because of the materials allowed for standard weights (see below).

Magnetism

What do we mean by magnetic? Materials exhibit two forms of magnetism simultaneously – magnetic susceptibility and permanent magnetism. With magnetic susceptibility, the weight appears to be magnetised only when it is in a magnetic field (e.g., near a magnet). This induced magnetism disappears when the magnetic field is removed and reverses when the field is reversed. Usually weights are diamagnetic – that is, the induced magnetism generates an attractive force towards the magnet generating the field. With permanent magnetism, as the name suggests, the weight behaves like a permanent magnet.

Requirements for Standard Weights

The OIML (International Organisation of Legal Metrology) International Recommendation R 111 gives specifications for the material of standard weights:

- weights must resist wear, oxidation and corrosion;
- the weight surface must be sufficiently smooth;
- the density of the weight must be within given limits of 8000 kg/m^{-3}; and
- the magnetic susceptibility and permanent magnetism of the weight must not exceed specified values.

A revision of OIML R 111 (now in final draft form) includes revised and expanded recommendations for permanent magnetism and magnetic susceptibility. These values, which are based on recent studies on many different electronic balances of various capacities, are given in Table 1 and Table 2 at the end of this Technical Guide.

Meeting the Magnetism Requirements

Materials that may meet the R 111 specifications are austenitic stainless steel for the highest accuracy weights, plated brass for intermediate accuracy, and coated cast iron for the lowest accuracy. However, there is no guarantee that the specifications for magnetism will be met – cast iron is readily magnetised, some industrial brass contains magnetic impurities, and cold working of austenitic stainless steel can give it relatively high values of magnetic susceptibility and permanent magnetism.

Given the current awareness of magnetic effects, new weights from commercial providers should meet the new R 111 requirements, but the only way to be sure is by measuring the magnetic properties of the weights.

Measuring Magnetic Properties

MSL has recently established a susceptometer facility for measuring the magnetic properties of weights. This is shown in Figure 1. The current version is suitable for weights from about 2 g to 10 kg. An extension to larger weights is planned.

The susceptometer works by measuring the force on the weight under test when it is subjected to a magnetic field of no more than 2.5 mT (millitesla). To achieve this, a small permanent magnet is placed on the top of a tall pedestal on the balance pan at a well-defined distance below the weight under test. This measurement is repeated with the field reversed (magnet inverted) and the permanent magnetism and magnetic susceptibility of the weight are calculated from the two forces. A reference standard for magnetic susceptibility, traceable to the BIPM (*Bureau International des Poids et Mesures*), is used to establish the distance from the centre of the permanent magnet to the base of the weight under test. A check standard is used to confirm that the facility is giving valid results.

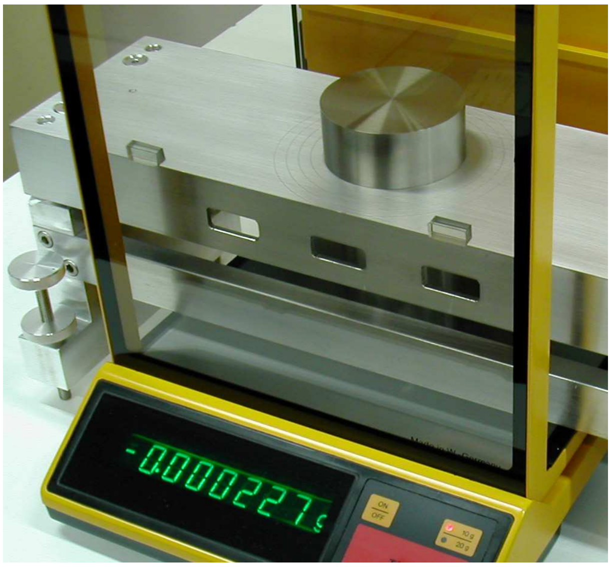

Figure 1. The MSL susceptometer.

Magnetic susceptibility values down to below 0.01 can be measured with an expanded uncertainty of about 10 %. Values for permanent magnetism can be measured down to below 0.1 A/m. The expanded uncertainty associated with the measurement of permanent magnetism is 10 % at best.

Typical Values

The MSL susceptometer has only recently been commissioned but it is already giving us an insight into likely values for magnetic susceptibility χ and permanent magnetism *M*.

- High quality (class E_1 or E_2) weights:
  $\chi \sim 0.003$ to 0.004 and $M \le 0.1$ A/m.
- NIST Class P weights (similar to ANSI/ASTM Class 4 and OIML Class F2):
  $\chi \le 0.06$ and $M \le 10$ A/m.
- Special non-magnetic tungsten weights:
  $\chi \sim 0.02$ and $M \sim 0.7$ A/m.
- Type 316 austenitic stainless steel purchased commercially:
  χ varied from 0.004 to 0.4 for different batches.

Do's and Don'ts!

Here is a list of "do's and don'ts" associated with magnetism and weighing:

- **Do** get the magnetic properties of some of your weights checked next time they are calibrated. If your weights are submitted to MSL for calibration, several of these weights will normally be checked for magnetism as part of the calibration service. Older weights are more likely to have poor magnetic properties. If you have any concerns about a weight, contact MSL for advice.
- **Do** keep magnets well away from standard weights. Remember that the lower the quality of weight, the more easily it is magnetised! Hence …
- **Don't** test your weights for magnetism by bringing a magnet near them. This may cause the weight to become permanently magnetised.
- **Don't** make your own weights. If you need special weights, contact us for advice. It is hard to make weights that have stable mass values and acceptably low magnetic susceptibility and permanent magnetism.
- **Don't** weigh permanent magnets on your balance pan – you may permanently magnetise parts of your balance. If you have to weigh a magnet, make sure that it is 50 mm or more above the pan on an aluminium support (aluminium is non-magnetic) and average the two readings with the magnet one way up and inverted.

Further Information

If you want to know more about weighing, contact MSL and book in for a Balances and Weighing Training Workshop. See the MSL website: http://msl.irl.cri.nz.

Prepared by C M Sutton, April 2004.

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Table 1. Maximum permanent magnetisation, $\mu_0 M$ /µT, by OIML R 111 Class.

Weight Class	E_1	E_2	F_1	F_2	M_1	$M_{1\text{-}2}$	M_2	$M_{2\text{-}3}$	M_3
$\mu_0 M$ /µT	2.5	8	25	80	250	500	800	1,600	2,500
M A/m	2.0	6.4	20	64	199	398	637	1,273	1,989

Table 2. Maximum magnetic susceptibility, χ, by OIML R 111 Class and nominal mass value *m*.

Weight Class	E_1	E_2	F_1	F_2
$m \le 1$ g	0.25	0.9	10	-
$2\text{ g} \le m \le 10\text{ g}$	0.06	0.18	0.7	4
$20\text{ g} \le m$	0.02	0.07	0.2	0.8

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