NATIONAL LABORATORIES
ACCREDITAION BUREAU
NLAB
Borg Riad El –Maadi (2) , Kornish El – Maadi ,
Cairo – Egypt.

NLAB

STGP 003

Calibration of weighing Machines

Issued by	Chief Executive
Type/Code No	Specialized Technical Guidance Publications /STGP 003
Issued to	NLAB Assessors & Laboratories
Issue No	1
Date of Issue	January 2008
No. of Pages	18 Pages

LAB14

EDITION 4 November 2006

Calibration of Weighing Machines

CONTENTS

CHANGES SINCE LAST EDITION

Changes from previous edition are indicated by a marginal line.

United Kingdom Accreditation Service, 21-47 High Street, Feltham, Middlesex, TW13 4UN
Website: www.ukas.com Publication requests Tel: 020 8917 8421 (9am – 1pm) Fax: 020 8917 8500

1 INTRODUCTION

1.1 Laboratories that have been assessed by UKAS as meeting the requirements of ISO/IEC 17025 *General Requirements for the Competence of Testing and Calibration Laboratories* may be granted UKAS accreditation. Several guidance publications on the application of these requirements, providing extra information, detail and limitations are listed in *UKAS Publications, M4.*

1.2 This publication (LAB 14) provides guidance on the application of specific requirements for laboratories carrying out weighing operations as part of their testing activities, and that may wish either to calibrate their weighing equipment in-house, or to use an external calibration body. It does not cover all the requirements of ISO/IEC 17025, which remains the authoritative document. By following the guidance given laboratories will be able to demonstrate at assessment that they meet the requirements. Alternative methods may be used provided they are shown to give an equivalent outcome.

2 CALIBRATION OF WEIGHTS

2.1 As a convenience, weights can be classified in accordance with the recommendations of the International Organisation of Legal Metrology (OIML), as set out in their current document R111-1 (see Bibliography). Each class specifies maximum permissible errors from a range of nominal conventional mass values, but the classification that can be given to a weight also depends upon its material, density, corrosion resistance, hardness, wear resistance, brittleness, magnetic properties, construction and surface finish.

Class E1 These weights are the highest accuracy class, and are intended to be used for traceability between national mass standards and OIML class E2 weights and lower. The maximum permissible error from nominal value at 1 kg is ± 0.5 mg.

Class E2 Suitable for use for traceability of OIML class F1 weights and lower; also with OIML accuracy class I weighing instruments. The maximum permissible error from nominal value at 1 kg is ± 1.6 mg.

Class F1 Suitable for use for traceability of OIML class F2 weights and lower; also with OIML accuracy class I weighing instruments. The maximum permissible error from nominal value at 1 kg is ± 5 mg.

Class F2 Suitable for use for traceability of OIML class M1 weights and lower; also with OIML accuracy class II weighing instruments. Intended for use in high value commercial transactions such as gold and precious stones. The maximum permissible error from nominal value at 1 kg is ± 16 mg.

Class M1 Suitable for use for traceability of OIML class M2 weights and lower; also with OIML accuracy class II weighing instruments. The maximum permissible error from nominal value at 1 kg is ± 50 mg.

Class M2 Suitable for use for traceability of OIML class M3 weights; also with OIML accuracy class III weighing instruments. Intended for use in normal commercial transactions where goods are sold by weight. The maximum permissible error from nominal value at 1 kg is ± 160 mg.

Class M3 Suitable for use with OIML accuracy class III or IIII weighing instruments. The maximum permissible error from nominal value at 1 kg is ± 500 mg.

It is not necessary for the purposes of accreditation to use weights that are certified as meeting one of the OIML classification specifications, but most major weight manufacturers make their weights to conform, though weights designed to meet other or older national specifications are also sometimes available. Any type of weights may be used as long as its characteristics are appropriate to the stability and accuracy required in the environment and application in which it is to be used.

Note
Many weights have cavities that can be filled with loose material in order to adjust the overall mass of the weight. The material should ideally be of a non-powdering metallic material that will not corrode in contact with air or with the metal of the weight. It should also be of a similar density to (or the same material as) the material of the weight. It is has a different density, the volume used should be small enough not to significantly change (10% or less) the overall density of the weight.

2.2 Weights should be calibrated regularly. The appropriate calibration period will depend upon the amount of drift between successive calibration values that is acceptable for the application, compared with the drift that the weights have historically shown under their conditions of storage and use. One easily interpreted way of monitoring this is to plot a graph for each weight, showing its successive calibration values against time. Bars can be drawn for each calibration point that show the values to which the previous calibration could have drifted and still be acceptable. The way each weight is drifting can then be seen at a glance, and weights in a set can be compared to see if there are common effects that could indicate handling or environmental problems. For all weights, the change in measured mass between successive calibrations should be no more than the acceptable drift limits that are used in the uncertainty budget for the use of the weight. If monitoring shows that weight values drift unacceptably between calibrations, then some action is needed. Generally, a desire for control of quality and cost-effectiveness would lead to a review of handling techniques and storage, the suitability of the weight type and environment for the application. However, in the short term and where weights are in constant use or unavoidably in a hostile environment, increasing the frequency of re-calibration may be necessary.

2.3 Weights should always be kept clean. Except for cast iron weights, they should not be handled with bare hands, but be used either with tweezers, lifters or using non-abrasive gloves. (Where tweezers and lifters are used, they should be designed with a suitable surface to avoid metal-to-metal contact.) It is best to make sure that weights do not get dirty, because any cleaning (except light dusting with a soft brush) will tend to alter the mass of the weight, leading to a need for recalibration. If cleaning is essential, try to avoid over-vigorous rubbing or the use of abrasives and polishes. If it is necessary to use pure water or some organic solvent, a period of stabilisation ranging from hours to weeks may be necessary, depending upon the accuracy class and material of the weight.

2.4 To avoid excessive wear, it is good practice to avoid metal-to-metal contact with the weights. Other than for the smallest (milligram series), it is advisable that acid-free tissue be used between the load receptor and the weight or weights applied to it.

United Kingdom Accreditation Service, 21-47 High Street, Feltham, Middlesex, TW13 4UN
Website: www.ukas.com Publication requests Tel: 020 8917 8421 (9am – 1pm) Fax: 020 8917 8500

2.5 Weights used either for weighing operations or for the calibration of weighing machines should have calibrations traceable to national standards, and should have the accuracy or uncertainty of measurement required for the weighing operation being performed.

2.6 Calibrations recognised by UKAS as traceable to national standards should be evidenced by appropriate calibration certificates, and can be provided:

(a) by the National Physical Laboratory or the National Standards Laboratory of another country that is covered by a mutual recognition agreement with the UK or,

(b) by a UKAS accredited calibration laboratory or,

(c) by an accredited calibration laboratory accredited by an overseas body that is party to the international multilateral agreements for accreditation bodies or,

(d) in-house using documented procedures that have been assessed as appropriate by UKAS. This might be through the use of reference standard weights owned by the laboratory, or through the use of a suitable calibrated weighing machine. The reference standard weights should be in a current state of calibration in accordance with (a), (b) or (c) above and paragraph 2.2. The weighing machine should be in a current state of calibration in accordance with paragraphs 3.3 and 3.5.

2.7 Where weights are used as part of testing equipment, for example in a pressure or force measuring machine, they should be calibrated and used in a manner similar to normal weights. Their values may be expressed in units other than mass, provided that the method of conversion is clearly indicated and understood.

3 CONSIDERATIONS IN THE USE OF WEIGHING MACHINES

3.1 Before a weighing machine enters service, it should be checked at the site of use to make sure it functions adequately for the application. These checks will need to be repeated whenever it is re-positioned.

3.2 All weighing machines will be affected to a greater or lesser extent by draughts, vibration, inadequate support surfaces and temperature changes, whether across the machine or with time. Electronic weighing machines can also be affected by other influences, or cause measurement errors in the way they interact with weights. Influences to consider include electrical and electromagnetic interference, and magnetic effects.

3.3 Some influences will show themselves as instability in the weighing indications, but some will be less obvious as they can cause consistent indication errors. It should not be assumed because a machine has been in service for some time that it is making correct measurements.

3.4 AIR MOVEMENTS AND HEAT SOURCES

3.4.1 The environment should be assessed for obvious influences. If there is any discernible draught or possibility of air movement, its significance can be assessed by turning off the source of the draught where possible, or by arranging a crude draught shield such as a cardboard box, and looking to see how the loaded indication changes. If there is a discernible change in the indicated value or its stability, then consideration should be given to suitable precautions during use. If a permanent shield is used, care should be taken that the materials used are not prone to holding static electrical charges, which can affect measurements.

3.4.2 If it is absolutely necessary to site a weighing machine near a window, screening should be considered to avoid heating the machine by direct sunlight, and to reduce the possibility of air movements when the outside and inside temperatures are different. Care should also be taken to avoid locating weighing machines over or close to sources of heat, such as radiators and ovens, as these are likely to cause measurement problems due to direct heating and the presence of convection currents in the air.

3.5 SUPPORT SURFACES AND VIBRATION

3.5.1 Where significant vibration is present, it can often be detected by touching the support surface with the fingers. If vibration can be felt, and if it is possible to switch the source of it off, changes in the loaded indication can be looked for. In general, a better solution is to find a location that is unaffected by vibration or flexing. The adequacy of the supporting surface can be checked by tapping and loading the surface next to the machine whilst it is indicating a small load value, and seeing if the indication changes in any way. If it does, consideration should be given to using a firmer support. Care should always be taken to ensure that the weighing machine is levelled, where appropriate using the bubble level that is usually attached to the frame.

3.6 ELECTRICAL AND ELECTROMAGNETIC INTERFERENCE

3.6.1 Areas where electronic weighing machines are in use (including as appropriate adjacent areas outside the room) should be assessed for potential sources of electrical, electromagnetic and magnetic interference. Equipment such as induction furnaces can be very 'noisy' in all three. Switching on machinery, ovens and other heating equipment may generate line-borne interference through the power supply, as may spark-inducing equipment. Mobile telephones, 'walkie-talkie' radios, radio communication centres, emergency services' radio transmitters and spark-inducing equipment can all create interference that is capable of changing the indication of some machines while the radio field is present. In all cases where the source of the interference can be put at least temporarily under the laboratory's control, the source can be turned on or off to establish whether the loaded indication of the machine is in any way affected. If problems are found, then consideration should be given to isolating the machine from the source of the interference, re-locating it, or acquiring a machine that is less susceptible to the interference. Where available, equipment CE marked for compliance with the Electromagnetic Compatibility (EMC) Directive for the appropriate environment should be less affected.

3.7 MAGNETIC EFFECTS

3.7.1 Many modern weighing machines make use of strong magnets in their principle of operation. As a result, there is often a magnetic field present above and around the load receptor. This makes possible an interaction between what is loaded on the pan and the magnet inside the machine, and can therefore change the value indicated during a weighing. As the effect is likely to increase with the magnetic relative permeability of the material weighed, if 'magnetic' materials are ever used on the load receptor during the weighing it is important that the effect of their presence is assessed. Such materials would include stainless steels, irons (including crucibles used for holding materials for weighing), cast irons, tungsten carbide and various cobalt materials and rare earths. A simple experiment will show if there is any effect on the indicated weighing value (see paragraph 3.7.3).

3.7.2 In general, there will not be a significant effect if no magnetic field is detectable on the unloaded load receptor. Moving a simple hand-held compass through the volume around and above the load receptor will show by movements of the compass needle if the machine is producing a magnetic field.

Note

Steel reinforcing bars in concrete, electrical cables, motors and other structures may also produce magnetic fields that the compass will detect, and these could also affect the measurement accuracy of the weighing machine. If a field is detected, the magnitude of the effect should be assessed to see if it is significant.

3.7.3 To check whether the weighing machine indications are affected by magnetic influences, the following tests can be applied. Select items that have been or will be weighed, and by moving the compass slowly around, across and up/down them, pick out the item that gives the greatest deflection of the compass needle.

(a) Place the item chosen on the load receptor with a non-magnetic spacer on top of it. (A suitable non-magnetic spacer might be an empty cardboard 3½ inch floppy disk box or similar, providing that it is strong enough to support the selected load.) Note the loaded indication of the weighing machine. Now place the non-magnetic spacer on the load receptor with the test load on top of it. Note the loaded indication. The two indications should, of course, be the same. Repeat the loadings to be sure that any difference found is not due to drift or the repeatability of the machine.

(b) Now place the test load on the load receptor without the non-magnetic spacer, and note the loaded indication. Invert the test load, replace it on the load receptor and note the loaded indication again. Repeat the two loadings if necessary to be sure any variation is not due to drift or the repeatability of the machine.

3.7.4 If there is no difference in the indications at either (a) or (b), the machine can be assumed not to have measurement problems associated with magnetism for the application. If there is a difference in the results for (a) but not for (b), the test load was effectively not permanently magnetised, but the machine does give indication errors when used to weigh items of sufficiently high magnetic relative permeability. If there is a difference in the results for both (a) and (b), then the test load was effectively permanently magnetised. The results for (a) will therefore not necessarily be consistently reproducible, but the machine does give indication errors when used to weigh items of sufficiently high magnetic relative permeability.

3.7.5 If consideration of paragraph 3.7.4 above leads to the conclusion that a mass measurement problem exists as a result of magnetic influences, a number of corrective approaches are possible. These include changing the materials loaded on to the load receptor to those with a lower magnetic relative permeability or introducing a non-magnetic spacer to the pan to position the load far enough from the machine not to cause an effect. The necessary separation distance can be found by experiment. A suitably large diameter aluminium tube with aluminium end-plates welded top and bottom often proves suitable as a spacer. Where neither of these two solutions is possible, replacing the equipment may be necessary.

3.8 BUOYANCY EFFECT

3.8.1 Weighing machines are calibrated by accredited laboratories on a conventional mass basis. If the true mass of an object is to be found, or if conventional mass is required but the air density is not 1.2 kg m^{-3}, then an air buoyancy correction must be made. This correction will vary depending on the density of the object weighed and of the air at the time of weighing. In air of density 1.2 kg m^{-3}, no corrections would be required to give conventional mass. However, the correction for true mass would be zero for stainless steel (density 8 000 kg m^{-3}), -7 ppm for brass (density 8 400 kg m^{-3}),

+ 1 050 ppm for water (density 1 000 kg m^{-3}) and + 1350 ppm for organic solvents (density 800 kg m^{-3}). For a 1 kg load these corrections would be 0 mg, -7 mg, +1.05 g and +1.35 g, respectively. If the air density is different from 1.2 kg m^{-3}, then other correction values will be needed for both true and conventional mass.

3.8.2 To make buoyancy corrections, the measured values may be multiplied by the factors given in the following formulae:

To obtain conventional mass:

$$\text{Factor} = 1 + \frac{D_{a-1.2}}{D_u} - \frac{D_{a-1.2}}{D_s}$$

To obtain true mass:

$$\text{Factor} = \left(\frac{\left(1 - \frac{1.2}{8000}\right)}{\left(1 - \frac{1.2}{D_s}\right)} \right) \times \left(\frac{\left(1 - \frac{D_a}{D_s}\right)}{\left(1 - \frac{D_a}{D_u}\right)} \right)$$

where: D_a = density of air during the weighing in kg m^{-3}
D_s = density of the reference weight (usually 8000 kg m^{-3})
D_u = density of the material being weighed in kg m^{-3}

A reasonable approximation of the air density (uncertainty ± 5000 ppm of the calculated air density) may be obtained from the following formula:

$$D_a = \frac{0.348444\,p - h(0.002\,52t - 0.020\,582)}{(273.15 + t)}$$

Where: D_a = air density in kg m^{-3}
p = air pressure in mbar
h = relative humidity of the air in %
t = air temperature in °C

For best results, the weighings to which these corrections should be applied should generally be either by comparison with a calibrated standard weight, or (where the facility is available) by direct weighing after the weighing machine has been 'spanned' by use of a calibrated weight (see paragraph 4.3.2).

3.9 CALIBRATION - GENERAL CONSIDERATIONS

3.9.1 Weighing machines should be calibrated regularly throughout their range. Where a machine is only used over a part of its capacity, calibration may be restricted to this range. In this case, a notice stating the range that has been calibrated should be prominently displayed on the machine. Note that (although this will vary with the application and the weighing machine) measurements made in the lowest 5% or 10% of a weighing machine's capacity may not be sufficiently accurate to use. In general, a different weighing machine with a smaller capacity will make better measurements in that range.

3.9.2 Calibrations may be performed in-house in accordance with documented procedures that have been assessed as appropriate by UKAS, using weights that have been traceably calibrated. Details of what would be considered appropriate for in-house

United Kingdom Accreditation Service, 21-47 High Street, Feltham, Middlesex, TW13 4UN
Website: www.ukas.com Publication requests Tel: 020 8917 8421 (9am – 1pm) Fax: 020 8917 8500

calibrations are in Section 4. Alternatively, the calibration of weighing machines may be undertaken by a suitable accredited calibration laboratory, as evidenced by an appropriate calibration certificate. If a non-accredited external calibrator is used, it will be necessary to ensure that the requirement of ISO/IEC 17025 that the calibrating laboratory can demonstrate competence, measurement capability and traceability is met. The uncertainty of measurement should also be determined.

3.9.3 Weights used for the calibration of weighing machines should be appropriate to the accuracy of the machine being calibrated. In any case, wherever possible they should have 95% confidence level uncertainty of calibration less than half the smallest digit size or recorded scale interval of the weighing machine to be calibrated. If groups of weights are to be used together, then this criterion should be applied to the arithmetic sum of the uncertainties. This will ensure that the uncertainty of the weight(s) used will not give rise to an undetected error in the calibration of the weighing machine.

3.10 ZERO-TRACKING

3.10.1 Some electronic weighing machines have a ‘zero-tracking’ facility. When a machine has been either ‘zeroed’ when unloaded, or tared to show zero when a load has been applied, zero-tracking will keep its indication locked to zero, provided that any incremental load change is not greater than a pre-set amount - often half a digit. This means that if a slow load change may occur at zero indication and would be significant to the measurement, it is important that the zero-tracking facility is disabled, either by changing the software setting or by adding a small weight that is present throughout the weighing.

3.11 EXERCISING

3.11.1 Weighing machines of all types should be ‘exercised’ by loading to near maximum capacity or service load several times before being calibrated or used.

3.12 CALIBRATION AND CHECK INTERVALS

3.12.1 The frequency of calibration will depend on the type of machine and its use. The machine should be calibrated fully (see paragraph 4.3.3) at least once a year, unless sufficient evidence has been obtained to show that the machine has remained well within acceptance limits and that the interval can be extended.

3.12.2 Daily or before-use checks should be made on weighing machines (see section 6) and the results recorded. This applies whether the machine has been calibrated in-house or by an external organisation.

3.12.3 Other regular checks (intermediate checks) may be required between full calibrations, dependent upon use and intervals between full calibrations. In particular, regular eccentric-load indication tests can be helpful in the early detection of faults developing in the weighing machine (see paragraph 5.3.2). Results of intermediate checks should be recorded.

3.12.4 Full calibrations should be performed after a significant change In the laboratory’s environmental conditions, a change in position of the weighing machine, or following service or repairs carried out on the weighing machine (whether carried out by the user or by a service agent). Intermediate checks, or full calibrations, should also be performed when there is any reason to believe that any other change has occurred which may affect the accuracy of the weighing machine, or where servicing is planned that can be expected to adjust its characteristics.

3.12.5 If any intermediate check reveals a significant change in the accuracy of a weighing machine a full calibration should be carried out. As a result, it may be necessary to review the validity of measurements made on the machine since the previous calibration. Consideration should also be given to repair and/or adjustment of the machine, and modification of any external factor that may have caused the change in accuracy. As in paragraph 3.12.4, where servicing work is carried out it should be followed by a further full calibration.

4 IN-HOUSE CALIBRATION OF WEIGHING MACHINES

4.1 INTRODUCTION

4.1.1 This section describes general procedures that would be assessed as appropriate if adopted for calibrations performed in-house.

4.1.2 For the purpose of this section weighing machines include balances and electronic and mechanical industrial weighing equipment (see Appendix A).

4.2 WEIGHTS REQUIRED FOR IN-HOUSE CALIBRATIONS

4.2.1 The series of weights held should cover the range of the weighing machine. Where a particular weighing machine is used only over a very limited range it is possible to reduce the number of weights held. If the design of a weighing machine requires a specific value of weight to be provided to set the weighing range, then this should also be provided, even if it is outside the limited weighing range as defined above.

4.2.2 The design and accuracy of weights used for in-house calibrations should be appropriate to the weighing machine being calibrated, and where possible should have a 95% confidence level uncertainty of calibration less than half the smallest digit size or recorded scale interval of the weighing machine to be calibrated. Where groups of weights are to be used to make up a single load, this criterion should be applied to the arithmetic sum of the weight's individual calibration uncertainties.

4.2.3 The apparent mass of weights used will be affected by their buoyancy in the air in which they are used, and this will change with the air density. The calibration value of the weights will have been certified for air density 1.2 kg m^{-3}. If the buoyancy effect caused by a different air density at the time of use leads to an error in the applied load that is greater than one half of the resolution of the weighing machine being calibrated, a correction should be made.

4.2.4 Weighing machines as described in Table 1 can usually be calibrated using calibrated weights in the pattern of the designated OIML class. The table assumes that the uncertainty of calibration of the weights used will be 1/3 of its specified maximum permissible error. In most cases it will be possible to obtain smaller calibration uncertainties than this, and it may therefore be possible to use a weight of a lower class. However, when selecting suitable weights, attention should still be given to properties of the weights other than accuracy, such as magnetism, corrosion and wear resistance. In most laboratory applications, it would not be appropriate to select a class lower than M1.

Table 1 A possible selection table of weights for calibration of weighing machines

	Resolution							
Capacity	**100 g**	**10 g**	**1 g**	**100 mg**	**10 mg**	**1 mg**	**0.1 mg**	**<0.1 mg**
Up to 50 g		M3	M3	M3	M2	F2	E2	E1
Up to100g	M3	M3	M3	M3	M1	F1	E1	E1
Up to 500 g	M3	M3	M3	M2	F2	E2		
Up to 1 kg	M3	M3	M3	M1	F1	E1		
Up to 5 kg	M3	M3	M2	F2	E2			
Up to 10 kg	M3	M3	M1	F1	E1			
Up to 50 kg	M3	M2	F2	E2				
Up to 100 kg	M3	M1	F1					
Up to 500 kg	M2	F2	E2					

Note: This table should be interpreted in conjunction with 4.2.2 and 4.2.4 of the text.

4.3 GENERAL CALIBRATION PROCEDURE

4.3.1 The documented procedure for in-house calibration of a weighing machine should involve sufficient measurements to define the performance of that machine.

4.3.2 Where the machine to be calibrated is electronic, and has a so-called 'calibration' facility that allows the output of the machine to be adjusted between zero and an internally or externally applied weight, it is advisable for this facility to be operated prior to the calibration, and also for it to be operated regularly before the weighing machine is used.

4.3.3 The procedure should include tests for the following parameters, except where the construction or use of the machine renders a particular test inappropriate:

(a) *Repeatability* (using a minimum of ten repeated measurements when calibrating a range up to 50 kg, and a minimum of five repeated measurements when calibrating a range exceeding 50 kg). This test should be done at or near the nominal maximum capacity of the machine or at the largest load generally weighed, returning to zero after each reading. For machines having more than one range, this test should be carried out for each range used. It is not necessary for the weight used for a repeatability test to be traceably calibrated.

(b) *Sensitivity*, or the value of a scale division (should be omitted for machines with digital displays). The sensitivity of mechanical weighing machines will generally change with load, and it is therefore necessary to measure the sensitivity at a load similar to that for which the machine is used. For a machine used across its range, it would be appropriate to measure the sensitivity with no load, loaded at half its capacity and loaded at or near its full capacity.

(c) *Departure of indication from nominal value*, covering at least 10 points, evenly spread over the range; extra points may be required to make the even spread convenient, or to cover specific loadings used in the normal application. For machines that have internal weights (eg dial-up weights) each weight setting

United Kingdom Accreditation Service, 21-47 High Street, Feltham, Middlesex, TW13 4UN
Website: www.ukas.com Publication requests Tel: 020 8917 8421 (9am – 1pm) Fax: 020 8917 8500

should be tested. For machines having more than one range, this test should be carried out for each range used.

(d) *Eccentric or off-centre loading*, using a load of between 1/4 and 1/3 of the maximum capacity, typically placed between 1/2 to 3/4 of the distance from the centre of the load receptor to the edge, in a sequence of centre, front, left, back, right, centre, or equivalent. It is not necessary for the weight used for the eccentric-load indication test to be traceably calibrated.

(e) *Effect of tare and/or balancing mechanism* (only for graduated balance/tare mechanisms).

4.3.4 The error allowed for a particular machine, for a particular test, should be set by the laboratory after considering the use to which the machine is put. Manufacturer's specifications for weighing machines will often be inappropriate for the application.

4.3.5 In order to comply with the requirements of ISO/IEC 17025, the laboratory needs to ensure that a suitable uncertainty of measurement is calculated for the weighing machine calibration. A worked example that is consistent with the ISO *Guide to the Expression of Uncertainty in Measurement* is available in UKAS publication M3003.

5 USE OF CALIBRATION RESULTS

5.1 A typical set of certified calibration results will consist of a repeatability figure, a set of eccentric load measurement data, a set of indication error measurements across the range of interest, and a 95% confidence level uncertainty of measurement. This uncertainty figure applies only to the measured values obtained during the calibration, and should not be used as an estimate of the maximum indication error that the machine will give in use.

5.2 Repeatability is generally expressed as a standard deviation figure for each measuring range calibrated, based on a sample of 10 repeat readings up to and including 50 kg, and on a sample of 5 repeat readings above 50 kg. To estimate the range that will include 95% of all the indications that the weighing machine might produce for a given load under the same conditions, multiply the repeatability standard deviation by the appropriate value for Student's '*t*' (see Table 2 - reprinted from UKAS publication M3003). For machines up to 50 kg this is typically 2.325, and for machines with a capacity greater than 50 kg it is typically 2.87. The resulting figure is then plus or minus about a mean value. (This means that the total range of values in which 95% of the indicated values for a given load will fall is twice the certified standard deviation times Student's *'t'*). Note that this figure will include the effects of normal eccentric loading in use, providing that users are trained to load reasonably precisely at the centre of the receptor.

Table 2	**Student *'t'* values**											
ν_{eff}	1	2	3	4	5	6	7	8	10	12	14	16
k_{95}	13.97	4.53	3.31	2.87	2.65	2.52	2.43	2.37	2.28	2.23	2.20	2.17
ν_{eff}	18	20	25	30	35	40	50	60	80	100	∞	
k_{95}	2.15	2.13	2.11	2.09	2.07	2.06	2.05	2.04	2.03	2.02	2.00	

Note: a coverage factor of k=2 actually relates to a level of confidence of 95.45% for a normal distribution. For convenience this is approximated to 95% which relates to a coverage factor of 1.96. However, the difference is not generally significant since, in practice, the level of confidence is based on conservative assumptions and approximations to the *true* probability distributions. The values given in Table 2 are for a level of confidence of 95.45%.

5.3 Although the 'eccentricity' test gives a numerical value of the indication error when the load is applied off-centre, the result should not be taken as a limit on the range of eccentric load indication errors that the machine could produce. A particular load used in certain defined positions on the load receptor may not be typical of use, and will generally not be extreme. The eccentric load indication error is some function of the load applied, its distance from the centre of the load receptor, and its angular position on the receptor. The calibration does not produce enough information to define this function, and so no predictions of the indication error in use can be derived. If the machine is used properly, with loads positioned near the centre of the receptor, the indication errors in use are likely to be smaller than those found during the calibration. Conversely, a heavier load nearer the edge of the receptor could produce a larger indication error than that found by the calibration.

Note:
The main benefit of the eccentric loading test is to monitor the condition of the weighing machine. Records should be maintained of the results, and each test carried out at the same loading and positions. It will then be possible to detect deterioration in the condition of the machine, and to monitor if it performs below acceptable limits. Repair of the machine can then be arranged before it leads to poor measurement results.

5.4 The measurements of indication error across the range of the machine can be used to either plot the error curve of the machine and hence make corrections for particular loadings, or to estimate the maximum indication error that is likely to affect the weighing result if no correction is made to a weighing result.

5.5 If no corrections are applied to indications on the weighing machine in use, then an approximate uncertainty of the indications can be used. This is the arithmetic sum of the greatest measured indication error across the range and the certified uncertainty of measurement. Note that this is not rigorously true, being only at 95% confidence at the point of the greatest calibrated indication error and an over-estimate of uncertainty elsewhere in the range. Note also that it is only valid if the in-use weighings are made over a similar range of eccentricity to that during the repeatability calibration, and that no allowance is made for any change of behaviour of the machine after the calibrations. With many electronic weighing machines, the effects of changes in behaviour can be minimised by using the 'calibration' function and built-in spanning weight, where is it available.

6 DAILY OR BEFORE-USE CHECKS ON WEIGHING MACHINES

6.1 Checks should be carried out between full calibrations on a daily or before use basis. Where the weighing machine is electronic and has a so-called 'calibration' facility that allows the output of the machine to be adjusted between zero and an internally or externally applied weight, it is advisable for this facility to be operated prior to the daily check, and also for it to be operated regularly before the weighing machine is used, to permit compensation for changing environmental factors such as temperature and air density.

6.2 The checks should include checking or adjusting the zero of the weighing machine, followed by the placement of a single weight (usually of a size appropriate to the normal range or load of use for the weighing machine) on the load receptor. This may be either a calibrated weight, or a weight kept for the purpose and which has been weighed immediately following the last full calibration of the machine. The machine's indication should be recorded.

6.3 The procedure for the daily, or before-use, check should define an action limit or error allowance that is appropriate for the use of the machine.

6.4 If the action limit is exceeded, a full calibration (with or without adjustment) should be carried out before further use of the weighing machine.

7 GLOSSARY OF TERMS

Capacity The greatest load a weighing machine is designed to weigh. Sometimes marked on it as 'Max'.

Calibration Specific types of measurement performed on measuring instruments to establish the relationship between the indicated values and known values of a measured quantity.

NB: The term 'calibration' as defined internationally does not include adjustment of the instrument.

Conventional mass For a weight taken at 20°C, the conventional mass is the mass of a reference weight of a density of 8000 kg m^{-3} which it balances in air of a density of 1.2 kg m^{-3}.

Discrimination The smallest change in mass that can be detected by the weighing machine.

Range The least and greatest load for which a machine is or can be used, and for which continuous mass values will be displayed with the same resolution.

Repeatability A measure of a weighing machine's ability to display the same result when repeated measurements are made under the same weighing conditions.

Resolution	The mass value of the smallest scale or digital interval displayed by the weighing machine. Sometimes marked on it as ‘d’.
Span	The mass value of the difference between the greatest and least load for which continuous mass values will be displayed with the same resolution.
Sensitivity	The number of divisions change in reading per unit mass.
Tare	Facility which enables the weighing machine reading to be adjusted to read zero with an object on the load receptor.
Turning point	The reading at the extremity of the swing of the pointer, ie, where it changes its direction of motion.
Uncertainty	The amount by which a true value may differ from a measured value, at a given confidence level.

8 BIBLIOGRAPHY

8.1 International Organisation of Legal Metrology (OIML), R111-1, Edition 2004 (E), *Weights of classes* E_1, E_2, F_1, F_2, M_1, $M_{1\text{-}2}$, M_2, $M_{2\text{-}3}$ *and* M_3.

8.2 International Standards Organisation (ISO), *Guide to the Expression of Uncertainty in Measurement.*

8.3 United Kingdom Accreditation Service (UKAS), M3003, *The Expression of Uncertainty and Confidence in Measurement.*

United Kingdom Accreditation Service, 21-47 High Street, Feltham, Middlesex, TW13 4UN
Website: www.ukas.com Publication requests Tel: 020 8917 8421 (9am – 1pm) Fax: 020 8917 8500

APPENDIX A EXAMPLES OF TYPES OF WEIGHING MACHINES

A1 SINGLE PAN - ELECTRONIC

A1.1 Most of these machines measure the total net downwards force or weight, rather than compare forces. A common type is the electromagnetic force compensation machine, described in paragraph A1.2. Other machines may use load cells as the transducer.

A1.2 An electromagnetic force compensation machine has a coil, rigidly attached to the pan, placed in the field of a magnet. When a weight is placed on the machine, the load receptor lowers, moving a position sensor and resulting in an increase in the coil current. This causes a magnetic counter force to be generated which returns the pan to its original position, and the resultant compensation current is measured as a voltage change. The weight on the pan is in direct proportion to the measured voltage, and thus the value of the weight may be obtained. Since the main operation of the weighing machine is electrical/electronic rather than opto-mechanical, it is generally referred to as an 'electronic weighing machine'.

A1.3.1 Because the machine displays its output in units of mass directly related to the net down-force it experiences at the load receptor, it is susceptible to mass measurement errors as the density of the air that is displaced by the load varies from the reference value of 1.2 kg m^{-3}. Even with temperature compensation built into the design, there is also likely to be a change in the indicated mass value for any given load as the instrument's temperature changes.

A1.3.2 To overcome these and other problems, manufacturers often include a facility that applies one or more accurately adjusted weights to the load mechanism, enabling the controlling electronics to 'span' the change in electrical output of the transducer between zero and load to indicate the adjusted value of the applied weight. This means that weighings carried out on the machine while conditions are the same as during the 'spanning' are effectively comparisons against the 'spanning' weight. This arrangement reduces the magnitude of a number of measurement errors. In general, a better weighing result can be expected if the facility is operated before the machine is used.

A1.3.3 This spanning facility is sometimes initiated automatically, and sometimes manually, depending on the machine. It is usually referred to by manufacturers as the 'Calibration' or 'Cal' function. In most designs the 'spanning' weight(s) are contained inside the machine housing and are applied by the machine itself, but in some cases the weights have to be applied externally by the operator.

A1.4.1 Because of the magnetic fields used by electromagnetic force compensation machines, and which are often detectable through the load receptor, it is not uncommon for there to be significant measurement errors when magnetically susceptible materials such as irons and tungsten carbide are applied to the load receptor. Even stainless steels can cause an effect, and these should always be austenitic, not martensitic.

A1.4.2 It is not necessary for the applied load to be permanently magnetised for there to be an effect, though this is likely to make the effect more pronounced and less predictable. Simply to be significantly magnetically susceptible (to be attracted to magnets) will often be sufficient to cause a measurement error.

A1.4.3 For these reasons it is appropriate to consider whether any potentially magnetically susceptible materials are used with the weighing machine, either for weighing or, as in the case of crucibles, for holding material being weighed. If there is any possibility of this happening, the machine should be evaluated to see if it is significantly affected by magnetic influences; if it is, possible preventative measures can then be assessed. If no preventative measures are possible, consideration should be given to whether the machine is fit for purpose.

A2 SINGLE PAN - TWO KNIFE EDGE

A2.1 These machines are either termed top-loading or analytical, and are usually critically damped.

A2.2 In a top-loading machine, the pan is supported above the balance beam by a linkage system and there is usually no arresting mechanism.

A2.3 An analytical machine has the pan suspended below the balance beam and the beam is arrested during loading and unloading of weights on the pan.

A2.4 These machines have built in weights so that when a weight is placed on the pan an equivalent weight is removed from the pan assembly, thus ensuring that the weight to be supported by the knife edges in the machine is approximately constant. Machines of this type are referred to as constant load machines. An optical or digital display indicates the value of the weight on the pan.

A3 TWO PAN - THREE KNIFE EDGE

A3.1 These weighing machines have three knife edges that lie in a plane. Two of the knife edges support the pans and are nominally equi-distant from the central knife edge. This type of weighing machine is known as an 'equal arm machine' and may be damped or undamped.

A3.2 When two nominally equal weights are placed one on each pan, the beam comes to rest at an angle to the horizontal. This position is known as the rest-point and is indicated by means of a pointer attached to the beam.

A3.3 Damped weighing machines usually have a light and optical projection system to image a scale or graticule onto a screen and damping is usually arranged to be critical, that is the pointer crosses the rest-point once and then comes to rest. The damping medium may be oil or a magnetic field, but is usually air.

A3.4 Undamped weighing machines, although subject to a small amount of natural damping, are operated in a dynamic mode, that is, readings are taken without waiting for the pointer to come to rest. Readings are taken of the pointer turning points and the centre of the swing or rest-point is obtained from a standard formula, $[(t_1 + t_3)/2 + t_2]/2$, where t_1, t_2 and t_3 are successive values of the turning point. It is usual for at least the first swing after release of the beam to be ignored, as it may be unrepresentative of the decay of subsequent swings.

A4 OTHER INDUSTRIAL MACHINES

A4.1 Other weighing machines generally used for industrial weighing include platform machines, counter machines and weighbridges. Most of these have flat plate load receptors and use mechanical or electronic (load cell) measurement systems.

A4.2 These fall into three main groups:

(a) Platform machines using load-cell sensors, usually having no lever mechanism for amplification (or reduction) of the applied force.

(b) Platform machines employing mechanical levers for reduction of the applied force using a mechanical indicator such as a steelyard, or pointer and dial; the latter principle is also used for the smaller counter machines.

(c) Some counter machines are essentially two-pan mechanical devices, but do not use a simple beam. These require the use of weights to counterbalance the major part of the force. An analogue scale indicates the difference in the two weights.

United Kingdom Accreditation Service, 21-47 High Street, Feltham, Middlesex, TW13 4UN
Website: www.ukas.com Publication requests Tel: 020 8917 8421 (9am – 1pm) Fax: 020 8917 8500