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3.1 COMPATIBILITY OF MODULES

Background
An EC type approval document will often allow the use of alternative loadcells and weighing platforms provided that certain conditions are met. A typical example of the wording from a type approval document is given below;

Any compatible loadcell(s) may be used providing the following conditions are met:

- There is a respective OIML Certificate of Conformity (R60) or a test certificate (EN45501) issued for the loadcell by a Notified Body responsible for type examination under Directive 2009/23/EC.

- The certificate contains the loadcell types and the necessary loadcell data required for the manufacturer's declaration of compatibility of modules (WELMEC 2, Issue 5, 2005) and any particular installation requirements. A loadcell marked NH is allowed only if humidity testing to EN45501 has been conducted on this loadcell.

- The compatibility of the loadcells and indicator is established by the manufacturer by means of the compatibility of modules calculation, contained in the above WELMEC 2 document, at the time of verification or declaration of EC conformity of type.

- The loadcell transmission must conform to one of the examples shown in the WELMEC Guide 2.4, "Guide for Loadcells", or as shown in the drawing 'Module load cell', Annex 3.

It can be seen from the above that the key to establishing whether or not a particular indicator and loadcell is to carry out the compatibility of modules calculation. When the compatibility calculations show that the complete instrument will meet the essential requirements it can be submitted for verification. The compatibility of modules calculations should be submitted with the rest of the documentation to the notified body carrying out the initial verification.

Where a type approval certificate is not available, a combination of modules, each having its own test certificate, may be connected together to form a complete weighing instrument. In this case, the compatibility of modules calculation should be submitted with the application for EC type examination or EC unit verification.

The WELMEC 2 document gives guidance on the completion of this calculation.

The WELMEC guidelines may seem to be daunting at first but they are based on sound engineering principles and on ensuring that the configuration of the assembled instrument is within the specifications given for the components. A basic summary of these is given in the following.

Summary of requirements

Criteria	Considerations	WELMEC condition
Resolution		
Accuracy class of the instrument is within that specified for indicator and load cells	Specified accuracy classes for indicator and load cells (e.g. indicator class III and load cells class C3)	1
Number of intervals for the instrument is within limits for the indicator	Specified number of intervals for the indicator	4
Number of intervals for the instrument is within limits for the load cell	Specified number of intervals for the load cells	6a
The interval of the instrument is not below the minimum for the load cell	Minimum interval for the load cell	7
The interval is compatible with the minimum output dead load return value for the load cells	Minimum dead load output return for the load cells (multi-range or multi-interval instruments only)	6b / 6c
Capacity		
The load on a load cell is within the maximum specified	Scale capacity, dead load, no. of load cells, lever works, initial zero, non-uniform distribution (NUD)	5
Electrical		
The signal per interval is greater than the minimum required for the indicator	Minimum signal for the indicator, mV/V for the load cell, cell capacity, scale capacity, no. of cells	8
The load cell resistance is within range specified for the indicator	Specified range for the indicator, load cell input resistance, no. of cells	9
The resistance of any connecting cable is within that specified for the indicator	Maximum specified for the indicator, cable length, cable cross section	10
Temperature		
The temperature range of the instrument is within the limits for both indicator and load cells	Temperature ranges for the indicator and load cell	2
Errors		
Combined effect of errors of components	Fractions of the permissible errors for each component	3

WELMEC 2 Requirements

The WELMEC 2 document lists 10 requirements, each of which need to be checked to establish if a particular combination of modules is acceptable. The requirements from WELMEC 2 are listed below with explanatory comments in italics:

1. Accuracy class of weighing instrument, compatible to class of indicator and load cell(s).

   This is to ensure that the classes of the individual components are compatible, it would not be acceptable to attempt to verify an instrument as a Class II machine if it used an indicator which was only suitable for Class III or IIII.

2. Temperature limits of the weighing instrument compared with the temperature limits of the load cell(s) and the electronic indicator.

   Some modules may have a restricted temperature range and not cover the full range of -10ºC to +40ºC. This can be important when considering Class III machines using modules intended for Class I and II instruments, these often have a restricted temperature range.

3. Sum of the squares of the fractions p_i of the maximum permissible errors of load cell(s), connecting elements and indicator (EN 45501, No. 3.5.4) must not exceed 1.

   Each module of a weighing instrument is allowed a fraction (p_i) of the total maximum permissible error. A loadcell may be given a p_i of 0.7, an indicator may have a p_i of 0.5 and other parts have a p_i of 0.5. These values should be stated in the approval documentation. The compatibility assessment will check that the squares of the individual errors does not exceed 1.

   $p_1^2 + p_2^2 + p_3^2 \leq 1$

4. Number of verification scale intervals of the weighing instrument must not exceed maximum number of verification scale intervals of the electronic indicator

   If an indicator is certified for a maximum of 3000 scale intervals it would not be acceptable to use it on a system with a resolution of 4000 scale intervals.

5. Maximum capacity of load cell(s) must be compatible with the Max of the weighing instrument (EN 45501, No 4.12.1). (Explanation of "NUD" and suggested equation for Q are given in Section 3.1.6.6.).

   This calculation is used to ensure that the loadcells will not be overloaded during use. The capacity of the loadcell(s) will need be take the maximum load, the deadload of the weighing platform, any additive tare, the initial zero setting range plus any expected overload. In general, where the loadcell capacity is twice the maximum plus any deadload this factor can be disregarded and Q = 1.

6. **a)** Compatibility of the maximum number of verification scale intervals of load cell(s) to the number of verification scale intervals of the weighing instrument (EN 45501, No 4.12.2).

   The maximum number of intervals given in the loadcell approval must not be less that the maximum number of verification intervals for the complete system. Loadcells are often given codes to show the maximum number of verification scale intervals, for example C3 = 3000 intervals. A 5000 division instrument could not be verified with C3 loadcells.

6. **b)** Compatibility of minimum dead load output return of the load cell to the verification scale interval of a **multi interval instrument** (Condition corresponding to EN45501, No4.12.2, as agreed by WELMEC WG2 Decision 8 dated 23 November 1994).

In the case of a loadcell used in a multi interval equipment the deadload return figure after the maximum load has been applied for 30 minutes shall be less than half of the smallest verification scale interval (e_1) of the equipment after the reduction ratio and the number of loadcells has been taken into account.

$DR \leq 0.5\ e_1\ R/N$

This condition does not need to be checked for a single range instrument.

6. **c)** Compatibility of minimum dead load output return of the load cell to the verification scale interval of a **multiple range instrument** (Condition corresponding to EN45501, No4.12.2, as agreed by WELMEC WG2 Decision 8 dated 23 November 1994).

   In the case of a loadcell used in a multiple range equipment the deadload return figure after the maximum load has been applied for 30 minutes shall be less than the smallest verification scale interval (e_1) of the equipment after the reduction ratio and the number of loadcells has been taken into account.

   $DR \leq e_1\ R/N$

   This condition does not need top be checked for a single range instrument.

6. **d)** Compatibility of minimum dead load of the load cells to the actual dead load of the load receptor.

   Where the loadcell approval document specifies a minimum load this must be less than the actual deadload of the weighing platform. This is often specified as zero or not given on the loadcell approval and can be disregarded in most cases.

7. Minimum load cell scale interval (EN 45501 No 4.12.3) must be compatible to verification scale interval of the weighing instrument.

   The minimum loadcell interval must not be greater than the scale verification interval after the number lo loadcells and the reduction ratio have been taken into account.

   $Vmin \leq e\ R / \sqrt{N}$

   The minimum loadcell scale interval is usually not given directly, the loadcell certificate will have a figure which must be divided by the maximum capacity on order to calculate the minimum interval;

   $Vmin = E_{max} / Y$

8. Actual input voltage per verification scale interval must not be less than the minimum input voltage per verification scale interval for the electronic indicator.

   When a scale is loaded each scale interval will result in a certain signal from the loadcell, usually in the order of microvolts. This requirement establishes that the indicator can resolve the loadcell signal with sufficient accuracy. The output from the loadcell is calculated using the sensitivity of the loadcell (mV/V), the excitation voltage from the indicator, the maximum capacity of the loadcell, the scale interval, the number of loadcells used and the reduction ratio of the weighing system. This must be equal to or greater then the minimum figure given in the type approval or test certificate for the indicator.

9. Actual load cell impedance must be within the allowed range of load cell impedance for the electronic indicator.

The number of loadcells any particular indicator can drive will depend on the excitation power available from the indicator and the resistance of the loadcell(s) used. As additional loadcells are added the equivalent impedance is reduced and more power is required from the indicator to maintain the excitation voltage.

10. Cable length per wire cross section of the connection cable between the junction box for the load cell(s) and the indicator must not exceed the value specified for the indicator.

    Using an excessive length of cable between the indicator and the loadcells can result in errors due to the resistance of the cable. This is less important in cases where a six wire connection system is in use, here a separate pair of wires is used to sense the excitation voltage at the loadcell. If it is mentioned the connecting cable will be specified in terms of its length and cross sectional area, the figure will be given as m/mm^2. For example with a cable specified as 50 m/mm^2 a length of 100m could be used if it had a cross sectional area of 2mm^2.

For each of the applicable conditions shown above a pass/fail is awarded. Any single failure means that the combination of modules does not meet the conformity requirement and the system must be redesigned.

The calculation can be done manually and recorded on the sample forms which are given in WELMEC 2 or a spreadsheet can be used to perform the calculations.

References

WELMEC 2 Directive 90/384/EEC: Common Application - Non-automatic weighing instruments

OIML R60 Metrological regulations for loadcells

EN45501 Metrological aspects of non-automatic weighing instruments

3.2 NOTES ON THE CORRECT USAGE OF WEIGHING EQUIPMENT

However accurate the weighing instrument may be, incorrect use will prejudice the weighing result.

Firstly, the correct equipment must be specified for the intended use. In particular, the division size should be appropriate, noting the fact that for equipment of similar technology, the higher the capacity the coarser the weighing resolution.

The equipment must be installed properly to ensure that the effects of any external influences are minimised. This is the responsibility of the person or organization carrying out the installation.

In use, note should be taken of the following:

General weighing applications

- Ensure that the scales are balanced, or display zero before weighing
- If a container or protective covering is used, ensure that this is allowed for by pressing the appropriate 'tare' or 'zero' key.
- Ensure that the load is not in contact with anything other than the weighing platform.
- Ensure that no part of the weighing platform or load receptor is touching an external object such as a wall or cable.
- Minimise the effects of external influences such as air currents (small devices), wind (large devices), vibration, etc.
- If the weighing instrument is portable and moved from one location to another, ensure that it is maintained in a level position and located on a firm and even surface.

Medical weighing

- Ensure the patient's clothing is not touching any fixed part of the scales or surroundings.
- When using chair scales ensure the patient's feet are not touching the ground, nor arms brushing against an adjacent fixture.
- When monitoring periodical weight change, ensure that the patient always wears clothing of similar weight.
- Do not weigh young children on scales of high capacity designed for adults. The weighing interval may be too coarse resulting in a higher than acceptable percentage error.

Crane scales or hanging scales

- Safety is more of an issue with scales with a suspended load because of the potential damage or injury that could be caused in the event of mechanical failure. Users must ensure that the equipment is rated for its intended purpose and inspected regularly.
- Moving loads may cause the displayed weight to vary. Some scales may be equipped with a hold function to assist with determining the actual weight.

3.3 CALIBRATION

All members of the UKWF that offer calibration services are obliged under conditions of membership to comply with the calibration codes of practice. There is one code of practice for NAWIs and another for cementitious product batching equipment.

Compliance with the codes will be monitored by the UKWF. In general, those members registered to ISO 9001:2008 will be required to incorporate the codes of practice into their quality control system and declare their compliance by questionnaire. Those members not registered will be required to undergo a regular audit. The codes themselves will also be subject to regular review by the UKWF. Any companies registered to ISO 9001:2008 or accredited by UKAS are likely to have additional requirements defined by their quality systems.

For any equipment used for controlled purposes the Weights and Measures Act 1985 and associated regulations will apply. The legislative requirements will always take precedence; members are required to act in accordance with the legislation and if equipment is found to be in breach, whether through calibration or any other considerations, members are required to inform the customer and notify them of their legal obligations or to seek advice from a Trading Standards Officer.

The tolerances of the test weights to be used will depend on the instrument to be calibrated. Both codes of practice give requirements and recommendations and section 3.2 of the Technical Articles on weights reproduces a table from UKAS guide LAB 14 giving recommendations of test weight tolerances.

The acceptable tolerances for the instrument being calibrated are subject to agreement with the customer. Again, legislative requirements take precedence and the codes of practice give recommended tolerances otherwise.

The scope of the calibration tests and procedures is similarly subject to agreement with the customer. The NAWI code of practice defines a series of tests and classifies them as “mandatory”, “recommended” and “optional” depending on whether it is an initial or a routine calibration. The following table is reproduced from the UKWF NAWI calibration code of practice, edition 4:

Test	**Initial Calibration**	**Routine Calibration**
Repeatability	Recommended	Recommended
Eccentric Loading	Mandatory	Mandatory
Linearity / Hysteresis	Mandatory	Mandatory
Weighing with Tare	Recommended	Optional
Sensitivity	Recommended	Optional

Please refer to the codes of practice for more detailed information.

3.4 WEIGHTS

Introduction
It normally starts with a phone call from a potential customer, "I need some weights …".
As with any enquiry for any piece of weighing equipment, the first and most important point to establish is to what purpose the requested item is going to be put. With weights it can be very broadly broken down into, is the weight in "use for trade" and does it therefore need to be stamped or is it to be used for calibration or test purposes?

3.4.1 STAMPED WEIGHTS OR THOSE IN "USE FOR TRADE"

Key questions to be answered here should be:

a) When does a weight need to be stamped?
b) What weights can be stamped?
c) Who can stamp a weight and what does that involve?

a) According to the Weights & Measures Act 1985, part II, section 7, "use for trade" means being used in connection with a transaction which itself "is by reference to quantity or is a transaction for the purposes of which there is made or implied a statement of the quantity of goods to which the transaction relates and the use is for the purpose of the determination or statement of that quantity".

In possibly plainer English and for practical purposes, a weight must be stamped if it is being used as part of a transaction wherein its known value is being directly used to determine the quantity of the product being measured and that determined quantity is then being used as a basis for a value which will be charged for the product.

With the prevalence now of electronic weighing equipment in our country, these instances are obviously far fewer than before the advent of load cell technology. A typical example these days could be the use of stamped weights with a mechanical counter scale in an environment such as an outdoor market where electronic scales may not be suitable.

Another example of where a stamped weight can be used is as part of an average weight system as defined in the code of practical guidance for packers and importers, chapter 1, section 28, where non-automatic weighing machines for that use "may be stamped or not" providing that "the accuracy of the equipment is to be verified every working day by applying stamped weights…"

b) As imperial units were removed from the Schedules by the Metrication Order 1999, the only unit of measurement of mass or weight legal for use in the UK in a stamped application is metric, that being the kilogram, the gram and the milligram. Any weight marked with any other unit cannot be stamped and cannot therefore be used in an "in use for trade" application.

As per The Weights Regulations 1985, schedule 3, part V, section 3, the following metric weights are lawful for use for trade:-

25kg 20kg 10kg 5kg 2kg 1kg 500g 200g 100g 50g 20g 15g 10g 5g 4g 3g 2g 1g 500mg 400mg 300mg 200mg 150mg 100mg 50mg 20mg 10mg 5mg 2mg 1mg

Obviously, all the above weights are offered as standard with the exception of the 4g, 3g, 400mg, 300mg and 150mg. These, for whatever reason, have fallen by the wayside as the 5, 2, 1 sequence has become the accepted industry standard.

As per The Weights Regulations 1986, part II, the following shapes must be adhered to in the manufacture of weights suitable for use for trade:

25kg must be of the irregular octahedronal form
20 to 5kg can be of the rectangular form
10kg to 1g can be of the cylindrical form
2kg to 100g can be of the hexagonal form
500 to 1mg can be of the flat or wire type

Taken in conjunction with the additional criteria laid down in the same regulations for the density and hardness of the materials which these weights can be manufactured from, the following types are those offered as standard:

25 to 5kg iron bar
2kg to 100g iron hexagonal
10kg to 1g brass cylindrical
500 to 1mg flat or wire type alloy or nickel

Other criteria covered in this section include the finish of the weights, stating that they may "be painted, coated or otherwise treated to inhibit corrosion", their adjusting holes, "no metric weight less than 20g shall have an adjusting hole" and "an adjusting hole shall be in the form of a cavity in a plane surface of the weight", and their marking, "all weights other than wire weights shall be marked with a durable and legible indication of their purported mass".

Lastly, the weights must be adjusted as per the Prescribed Limits of Error laid down in Table 1 of schedule 4 of the 1986 Regulations. These limits are always a positive value above the purported mass of the weights, in other words a weight which is tested and found to be below this mass or above the prescribed limit cannot be stamped fit for use for trade. Please see section 3.4.3 where this table is reproduced.

The actual testing and stamping of these weights falls with the local weights & measures authorities to perform. Section 4 of part I of the 1985 Weights & Measures Act calls upon each authority to maintain "local standards", as per Schedule 3 "being proper and sufficient for the purposes of this Act". Paragraph 4 goes on to state that "no article shall be used as a local standard unless there is for the time being in force a certificate of its fitness for the purpose issued by the Secretary of State".

The local or working standard which an inspector uses to test a weight submitted for stamping must be itself traceable through the tertiary and secondary standards back to the primary standard itself. The stamping itself consists of exactly that. On establishing that the weight satisfies all the requirements of the legislation, the inspector will mark either the material (normally lead) which has been used to adjust the weight or, in the case of a solid weight with no adjusting chamber, the bottom of the weight itself with the crown symbol, the year of stamping and the unique identifying mark of the set of weights which were used for the purpose of testing by comparison.

The inspectors are also empowered to "retest" a weight which has already been stamped and to obliterate the original stamp with a six-pointed star if the weight is found "to be heavier or lighter than its purported mass by more than the prescribed limit of error", or if it does no longer satisfy any of the other laid down criteria. For example, the finish of the weight may have deteriorated to such an extent that the marking of the purported mass is no longer visible.

If a weight is not required for a trade application then it is probably to be used for the calibration of weighing equipment or for the periodic checking of weighing equipment. Weights for either of these purposes could be described as "test weights".

3.4.2 TEST WEIGHTS

These weights, in terms of their construction, accuracy and suitability for the designated purpose, are governed primarily by specifications laid down in the OIML (Organisation Internationale De

Metrologie Legale) R111 (2004). Although not a legally binding document in its own right, most of the recommendations laid down in it have been incorporated in EC member states' subsequent own legislation.

R111 recognises seven different classes of weight in terms of their accuracy, the coarsest being M3 which is referred to as "domestic" and the finest being E1 which could be a "primary standard". The range of weights is the same as with those legal for trade with the exception of the 25kg not being recognized, it being a throwback to the old imperial 56lb weight, and the range is further extended through 50kg and on upwards to 5000kg.

The maximum permissible errors for weights up to 50kg in size are shown in section 3.3 of OIML R111 under the heading of Table 1. This is reproduced here in section 3.4.4.

Irrespective of whether a test weight is being used to calibrate or check the accuracy of a weighing machine, the type and accuracy of the weight suitable for either purpose will be determined by the displayed resolution of the weighing machine itself. This resolution being the ratio between the weighing machine's capacity and it's displayed weighing increment or division.

The United Kingdom Accreditation Service (UKAS), from their "Calibration of weighing machines", edition 4, November 2006, section 4 offer a "possible selection table of weights for calibration of weighing machines". This can be used as a guideline for determining which standard of weight should be used to calibrate or test a weighing machine according to its capacity and division. Please see section 3.4.5 for this table.

Weights being used for either of these purposes may also very well have to be "certified" or "calibrated". Whether they have to be or not will be determined by any relevant quality standards which are in place either, for example, in terms of the service which the calibrating agent might be offering or operating under, or in terms of the quality system which the user or operator might adhere to. The certification itself should be able to provide proof in the form of traceability to a national standard that the test weights being used to perform the task were themselves accurate to a stated tolerance when last tested and/or certified or calibrated.

A service or calibration engineer should therefore be testing or calibrating the weighing machine with weights which can be proved to be sufficiently accurate for the displayed resolution of the machine taking into account any uncertainty in the actual accuracy of those weights. For example, a weight adjusted to the M1 tolerance may be in theory sufficiently accurate to calibrate the weighing machine as per the UKAS guidelines in Table 1, but the possible uncertainty of its actual weight might be so great that it is in fact not suitable.

Using a 1kg weight for example, the testing authority might have issued a certificate of calibration for it stating that the measured value found was 1000.05g (within the specified tolerance for M1) but that there was an uncertainty of measurement of +/- 10mg giving it an actual possible weight of 1000.06g (outside the specified tolerance for M1).

The condition or material from which the test weight is made should also be taken into consideration. For instance, an iron weight with a painted finish, even though it might be of sufficient accuracy for the purpose, might not be acceptable in a particularly clean environment such as a laboratory.

Although there is no legislation which specifies how regularly test weights should themselves be recalibrated, the accepted industry norm for weights of F2 class or below is once every 12 months. However, if the weights are being used with such a frequency that their accuracy cannot be guaranteed for this length of period, or they are being used in an environment where again their accuracy might be questionable after this amount of time, then a shorter time interval would be recommended.

As a general rule, and as per UKAS recommendations in sections 2.3 of Lab14 (edition 4, November 2006), weights other than cast iron should not be handled with bare hands and contact between the weights should be avoided. Both of these measures combined will prolong the accuracy of the weights.

3.4.3 THE WEIGHTS REGULATION 1986
REGULATION 10, SCHEDULE 4, PRESCRIBED LIMITS OF ERROR

Table 1

1. Purported mass of the weight	2. Prescribed limits or error passing as fit for use for trade (+ only)	3. Prescribed limits of error in relation to the obliteration of the stamp (±)
25 kg	4000 mg	4000 mg
20 kg	3200 mg	3200 mg
10 kg	1600 mg	1600 mg
5 kg	800 mg	800 mg
2 kg	400 mg	400 mg
1 kg	200 mg	200 mg
500 g	100 mg	100 mg
200 g	50 mg	50 mg
100 g	30 mg	30 mg
50 g	30 mg	30 mg
20 g	20 mg	20 mg
15 g	20 mg	20 mg
10 g	20 mg	20 mg
5 g	10 mg	10 mg
4 g	10 mg	10 mg
3 g	5 mg	5 mg
2 g	5 mg	5 mg
1 g	5 mg	5 mg
500 mg	2.5 mg	2.5 mg
400 mg	2.5 mg	2.5 mg
300 mg	2 mg	2 mg
200 mg	2 mg	2 mg
150 mg	2 mg	2 mg
100 mg	1.5 mg	1.5 mg
50 mg	1.2 mg	1.2 mg

3.4.4. OIML R 111
TABLE 1: MAXIMUM PERMISSIBLE ERRORS

Nominal Weight	±δ*m* in mg						
	Class E_1	Class E_2	Class F_1	Class F_2	Class M_1	Class M_2	Class M_3
5000 kg			25,000	80,000	250,000	800,000	2,500,000
2000 kg			10,000	30,000	100,000	300,000	1,000,000
1000 kg		1,600	5,000	16,000	50,000	160,000	500,000
500 kg		800	2,500	8,000	25,000	80,000	250,000
200 kg		300	1,000	3,000	10,000	30,000	100,000
100 kg		160	500	1,600	5,000	16,000	50,000
50 kg	25	80	250	800	2,500	8,000	25,000
20 kg	10	30	100	300	1,000	3,000	10,000
10 kg	5	16	50	160	500	1,600	5,000
5 kg	2.5	8.0	25	80	250	800	2,500
2 kg	1.0	3.0	10	30	100	300	1,000
1 kg	0.5	1.6	5	16	50	160	500
500 g	0.25	0.80	2.5	8.0	25	80	250
200 g	0.10	0.30	1.0	3.0	10	30	100
100 g	0.05	0.16	0.5	1.6	5	16	50
50 g	0.030	0.10	0.30	1.0	3.0	10	30
20 g	0.025	0.080	0.25	0.8	2.5	8	25
10 g	0.020	0.060	0.20	0.6	2.0	6	20
5 g	0.016	0.050	0.16	0.5	1.6	5	16
2 g	0.012	0.040	0.12	0.4	1.2	4	12
1 g	0.010	0.030	0.10	0.30	1.0	3	10
500 mg	0.008	0.025	0.08	0.25	0.8	2.5	
200 mg	0.006	0.020	0.06	0.20	0.6	2.0	
100 mg	0.005	0.016	0.05	0.16	0.5	1.6	
50 mg	0.004	0.012	0.04	0.12	0.4		
20 mg	0.003	0.010	0.03	0.10	0.3		
10 mg	0.003	0.008	0.025	0.08	0.25		
5 mg	0.003	0.006	0.020	0.06	0.20		
2 mg	0.003	0.006	0.020	0.06	0.20		
1 mg	0.003	0.006	0.020	0.06	0.20		

3.4.5 A POSSIBLE SELECTION TABLE OF WEIGHTS FOR CALIBRATION OF WEIGHING MACHINES

Taken from UKAS guide LAB 14 Calibration of Weighing Machines, edition 3, October 2004, table 1

Capacity	**Resolution**							
	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 to 100 g	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	M2	F2	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 paragraphs 4.2.2 and 4.2.4 of the text								

The cited paragraphs are as follows:

"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."

"4.2.4. 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."

3.5 ERRORS OF UNCERTAINTY

General

The principle of determining the uncertainty of any type of scientific or engineering based measurement follows similar guidelines. There are a number of guidelines available but because these have to cater for any type of measurement, they tend to be all-encompassing and it is not always quite so obvious how to adapt it to a particular requirement.

The response of many people in the Weighing Industry when faced with tackling measurement uncertainty is "why bother, I already use calibrated weights"?

As a purely hypothetical illustration consider the following; You were caught speeding in your car by a policeman with a hand-held speed gun and then prosecuted for travelling at 49mph in a 40mph limited area. Following this prosecution, you enquire of the accuracy of the hand held speed gun and are told ±10%. You assume fair play as you were accused of travelling well over 44mph.

However on making further enquires, you discover the following:

- The gun was calibrated in a test laboratory strapped to a bench and hand operation can add a further ±4mph uncertainty to the readings;
- The specification of the hand gun quotes a possible error of ±1% per °C. As the calibration was performed at 20 °C and the temperature at the time of the offence was measured at 10°C, the measurement has a further uncertainty of ±10%.

Are you still satisfied the prosecution was fair?

What Constitutes an Uncertainty?

The obvious answer has to be anything that can influence the measurement process. However, what you actually need to include in the uncertainty calculation will depend upon the significance of the effect upon the measurement.

There are some uncertainties less obvious than others. For instance, if you use calibrated weights the drift between calibrations can be significant. In order to account for this drift, the actual value of the weight needs to be recorded at the time of calibration and a record kept. From this record the drift can be calculated.

A fairly comprehensive list of the types of uncertainty associated with the weighing process can be found in Measurement Good Practice Guide No. 71, 2004, 'The Measurement of Mass and Weight' published by The Institute of Measurement and Control and available as a download from the NPL website:

http://publications.npl.co.uk/npl_web/pdf/mgpg71.pdf.

Make a list of all the possible effects that can influence the measurement, including the value of the effect. This is often expressed in parts per million (ppm).

Rank the uncertainty types in their order of influence.

Some effects will be more dominant than others. So there will be major influences and minor ones.

There is a school of opinion that because of the summation process used in the uncertainty calculation, anything less than one tenth of the most major influence will have an insignificant effect on the final result. Some people will of course disagree and include everything.

As a practical example: If you are vessel weighing, the influence of both connecting pipes and wind speed could be greater than 1,000ppm. So you probably need not consider the effect of gravity variation due to the Lunar phase changes which will be in the order of 0.1ppm if the weighing system is measuring force (e.g. load cells). However, if you have a force generating machine in a National Standards Laboratory and were trying to achieve an uncertainty of better than 1ppm, the Lunar gravity change would become significant.

Different types of uncertainty

The collection and summation of these uncertainties use statistically-based processes. There are some quite comprehensive guidelines published that describe the decision making and statistical processes in detail. Two are listed below:

"EA-4/02, 1999, Expressions of the Uncertainty of Measurements in Calibration" published by the European co-operation for Accreditation and available on their website:

"M3003 The Expression of Uncertainty and Confidence in Measurement" published by UKAS and available on their website:

There are two additional guides by UKAS that discuss the subject: LAB 12 The Expression of Uncertainty in Testing and LAB 14 Calibration of Weighing Machines, both also available from the UKAS website above.

Although the above publications give a comprehensive guide, a brief overview of the process is given below.

The uncertainties can be banded into two types:-

The ones that follow a normal type distribution and the ones that don't. These are known as type A and type B. A simplified descriptive example, showing the different types of measurement uncertainty, is shown below.

Standard Uncertainty

1) Standard Uncertainty of the **resolution** of the indicator $\mathbf{u_{res}}$

This is a rectangular distribution and therefore a type B.

$$u_{res} = \frac{a}{2\sqrt{3}}$$

Where a is the resolution of the indicator

2) Standard Uncertainty of the **repeatability** of the indicator $\mathbf{u_{rep}}$

This is a normal distribution and therefore a type A

$$u_{rep} = \frac{1}{\sqrt{n}} \left(\frac{100}{d_m} \sqrt{\frac{1}{(n-1)} \sum_{j=1}^{j=n} (d_J - d_m)^2} \right)$$

Where

n = N° of readings

d_J = value for each test

d_m = mean of value

This part of the above equation:-

$$\sum_{j=1}^{j=n} (d_J - d_m)^2$$

may look complicated but it is only the mean of all the load readings at this particular point (say 2kg on the way up), subtracted from each individual reading at this load value. This is then squared. This process is repeated for all the individual readings at this point. All these squared readings are then added together.

If you don't want the answer in percent leave out the100. If you want the answer in ppm, replace the 100 by 10^6.

3) Standard Uncertainty of the **applied force u_{std}**

This is often a normal distribution and therefore a type A. Sum the uncertainties quoted on the calibration certificate(s) for all the weights used.

4) Uncorrected **drift of the standard** weight(s) since their last calibration u_{drift}

This is a rectangular distribution and therefore a type B. Usually at least 1x the uncertainty of calibration for each weight used; but the actual drift can be estimated from the trends of the calibration histories.

5) Air buoyancy correction u_{AB}

This is a rectangular distribution and therefore a type B. If the span of the weighing instrument is adjusted before calibration then uncertainty limits of 1ppm for stainlesssteel weights or 3ppm for cast iron weights could be used. Note: the ppm values are derived from the instrument's range under test (often the capacity of the instrument).

Combining Uncertainties

The **combined standard uncertainty** (u_c) is calculated from the square root of the sum of the squares of the individual standard uncertainties.

$$u_c = \sqrt{u_{res}^2 + u_{rep}^2 + u_{std}^2 + u_{drift}^2 + u_{AB}^2}$$

Expanded Uncertainty (u_{exp})

The calculation of the expanded uncertainty is simply the coverage factor (k) multiplied by the combined uncertainty (u_c)

$u_{exp} = k \times u_c$

The generally accepted practice is to use a coverage factor of k = 2 and use this to calculate the expanded uncertainty. Normally this will give a confidence level of approximately 95%.

Note: The value for the coverage factor (k) may have to be modified, if the random contributions (usually repeatability) are relatively large compared with the other contributions. Modification of the coverage factor (k) is dealt with in UKAS document M3003.

The above notes are for guidance only. Each measurement process is likely to be unique and will therefore require its own tailor made uncertainty contributions.

3.7 PROTECTION SPECIFICATIONS

Although our industries have in-depth standards and test procedures to define load cell and weighing system performance, no standards have been developed to cover product suitability for specific environmental conditions.

In the absence of such standards, most manufacturers have adopted the international Index of Protection (IP rating) system (IP/IEC 529 or EN 60529) or National Electrical Manufacturers Association Standards (NEMA publication 250) to define the level of sealing for their products. Both standards provide good test procedures for environmental sealing when applied to the products for which they were intended - those being electrical enclosures, but they are not very well suited to weighing equipment.

IP Ratings
The IP standard describes a system for classifying the degree of protection provided by the enclosures of electrical equipment:

- Protection of persons against access to hazardous parts inside the enclosure.
- Protection of the equipment inside the enclosure against the ingress of solid foreign objects.
- Protection of equipment inside the enclosure against harmful effects due to the ingress of water.

Unfortunately, no definition is given for the term "harmful effects". Presumably, for enclosures, the main problem with water could be one of electrical shock to persons in contact with the enclosure, rather than malfunctioning of the unit. Furthermore, the standard only relates to water ingress and ignores moisture, chemicals, corrosion, etc.

The IP rating code is based on a two digit number. The first digit is the rating for solids and dusts, the second digit is the rating for liquids.

The commonly used categories to describe load cell and weighing equipment sealing are:

IP65	Protected against low pressure jets of water from all directions, limited entrance allowed
IP66	Protected against strong jets of water e.g. for use on ship decks, limited entrance allowed
IP67	Protected against the effects of immersion between 15cm and 1m
IP68	Protected against long periods of immersion under pressure

When a 7 or 8 designation is specified for a product, it is important to note that the standard clearly states that “an enclosure designated with a second characteristic numeral 7 or 8 is considered unsuitable for exposure to water jets (designated by second characteristic 5 or 6) and need not comply with requirements for numeral 5 or 6 unless it is dual coded, e.g. IP66 / IP68”. In other words, under certain conditions and for certain product designs, a product that has passed a half hour immersion test may not necessarily pass one which involves the use of high pressure water jets from all angles.

NEMA Standards

Classifications in the NEMA system run from NEMA 1 to NEMA 12, but load cell manufacturers concern themselves with NEMA 4 and NEMA 6. Unlike the IP system, NEMA does concern itself with environmental conditions such as corrosion, rust, freezing, oil and coolants.

NEMA 4 enclosures are intended for indoor and outdoor use, providing a degree of protection against windblown dust, rain, splashing water, and hose directed water. However, no consideration is given for the effects of internal condensation. NEMA 4X enclosures meet the same standards as NEMA 4 and are constructed of 304 stainless steel or other material offering equal corrosion resistance.

NEMA 6 enclosures are used where there is a chance of temporary immersion. This standard calls for the highest part of the enclosure to remain submerged in water, with its highest point 1.83 metres below the surface for 30 minutes. NEMA 6P enclosures are used where prolonged immersion may occur and resistance to corrosion is needed.

While it may seem that NEMA standards offer some advantages over the IP system for corrosion resistance, they only relate to external corrosion of enclosures. This is very limited when applied to the more complex load cell construction and the different effects of corrosion or water ingress.

References

British and EN standards can be obtained from the British Standards Institute (BSi) website. See the bibliography for full references.

NEMA standards can be obtained from the NEMA website:

http://www.nema.org/stds/
Search for publication number 250.

The NEMA website also provides a comparison between the NEMA standards and the IP ratings:

http://www.nema.org/stds/briefcomparison.cfm

3.8 RISK ASSESSMENTS

Risk Assessment – Health and Safety Law

General Duty on Employer
The Management of Health and Safety at Work Regulations 1999 place a general duty on employers to assess all risks to employees and 'others' that arise as a result of work activity.

'Others' includes the employees of another employer where, for example, work is being undertaken on a customer's premises. It also includes members of the public where work could put members of the public at risk.

Specific Risks
Requirements to assess specific risks are covered in other Regulations. The Approved Codes of Practice and/or Guidance Notes that accompany the Regulations give help on when and how this needs to be done. Examples of specific Regulations include:

- Control of Substances Hazardous to Health Regulations
- The Control of Noise at Work Regulations (Introduced April 2006)
- Display Screen Equipment Regulations
- Manual Handling Operations Regulations
- Fire Precaution Workplace Regulations
- Confined Spaces Regulations

General Requirement of a Risk Assessment

- It must be 'suitable and sufficient'
- Carried out by / under the supervision of a competent person
- Significant findings documented where employer has 5 or more employees
- Assessments should be reviewed periodically

HSE Guidance on Risk Assessment
Useful guidance on risk assessment has been published by the Health and Safety Executive (HSE) in a free publication entitled 'Five Steps to Risk Assessment'. This is available from the HSE website or from HSE Books.

It is suggested readers obtain a copy of the publication and read it in conjunction with this paper.

HSE Terminology – 'Hazard' and 'Risk'
The HSE define a 'hazard' as 'something that has the potential to cause harm'. A 'risk' is defined as' the likelihood that the potential for harm is realised'.

A hazard can be something that could give rise to danger – for example electricity. The risk is how likely it is that a person might get an electric shock whilst carrying out work on a particular task involving electricity.

A hazard can also be a particular work activity in itself such as:
- Installing a machine
- Operating a machine
- Working at height

If we consider working at height as a hazard one associated risk is how likely it is that a person might fall from a ladder whilst painting a house.
Carrying out a Risk Assessment – the Basics

Conducting a risk assessment starts with asking 3 simple questions in relation to a hazard – remember the hazard could well be the work activity itself.

1. What could go wrong or how might harm occur whilst we are doing this job?
2. How likely is it to go wrong – given the circumstances?
3. How bad would the injury be if it did go wrong?
   (Estimating likelihood and extent of the injury will be dealt with later.)

Consideration can then be given as to whether the risk is acceptable. Ideally risks should be eliminated. For example, if there is a risk of electric shock whilst servicing a machine, the risk of shock can be eliminated through effective electrical isolation. If the risk cannot be eliminated then it should be reduced to an acceptable level by introducing suitable risk controls.

<u>Risk Controls</u>
The Approved Codes of Practice that accompany Regulations suggest risk controls in an order of preference – a hierarchy. This is shown below.

- Elimination
- Substitution – a mobile tower is safer than a ladder
- Barriers, guards
- Use of rules, procedures – permit to work prior to starting job
- Warning signs
- Use of Personal Protective Equipment

Risk Assessment – Through Task Analysis
In order to explain the general principles of risk assessment we shall use an example of work which most people will be familiar with.

Let's suppose that you and your partner have recently purchased a large Victorian semi-detached house. You wish to restore some of the rooms to the Victorian style and plan to start with the hall, stairs and landing.

Tasks will include:
- Lifting existing carpets.
- Stripping paint from woodwork for re-varnishing.
- Removal of wallpaper / re-papering.
- Washing ceilings re-painting with emulsion.
- Sanding floor for re-staining.

Tools, equipment, materials:
- Assorted hand tools – brushes, scraper, wire wool
- Power tools – hot air paint stripper, industrial sander (hired in) portable sander, electric wall paper steamer (stripping paper)
- Ladders
- Paint /varnish stripper, various paints, wood stain and varnish.

If each task, listed above, is considered to be a hazard then a complete risk assessment can be conducted by brainstorming what could go wrong at each stage.

Lifting the carpets – what could go wrong, how might harm occur?
- Manual handling injury
- Accidentally kneeling on carpet grippers

Stripping paint from woodwork for re-varnishing – what could go wrong?
- Chemical burn from stripper
- Burns from hot-air stripper…and so on.

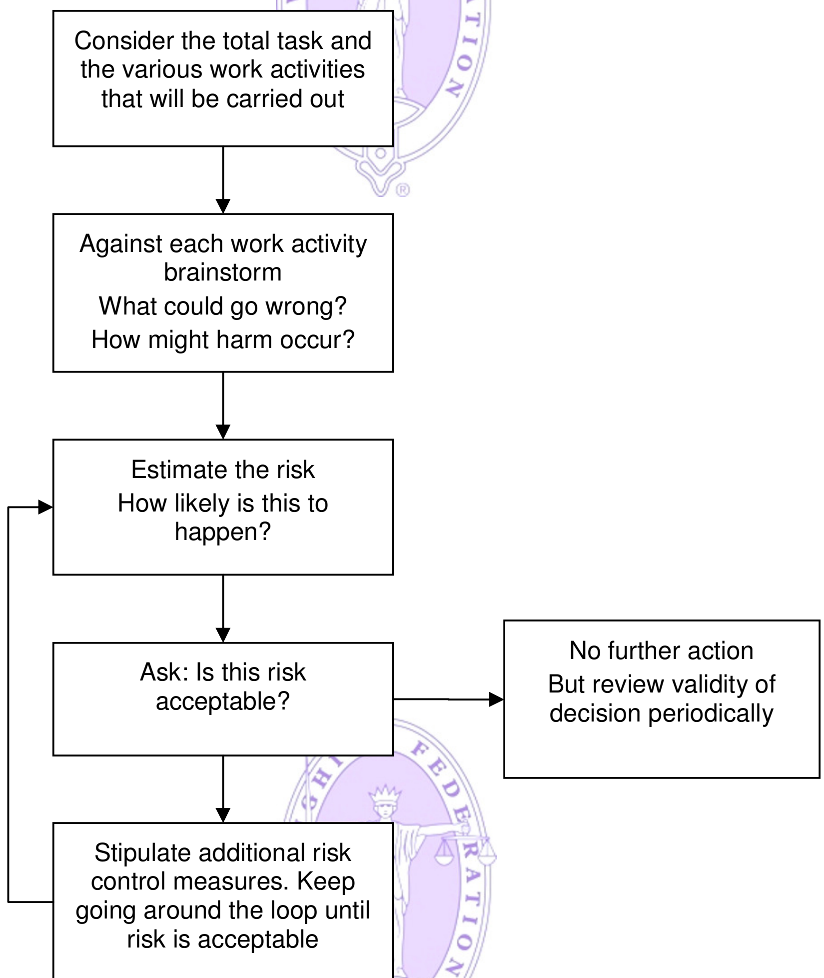
The process involves going through each operation in a systematic way so we can identify what could go wrong.

Consideration then needs to be given as to how likely it is to go wrong as well as how serious the injury, or other outcome, might be.

Thought then needs to be given as to whether the risk is acceptable – is it as low as we can get it?

If the risk is not acceptable then thought needs to be given to the additional risk controls that can be introduced to get the risk down to an acceptable level.

The flow chart below may be helpful.



The risk assessment in the flow chart is often a two-stage process; if the risk is not acceptable and additional risk controls are specified. A record is made of the 'initial risk' – before additional controls were specified. An assessment is then made with the specified controls in place – this is the 'residual risk'. (See Risk Assessment Form)

Estimating Likelihood and Severity

Various systems have been devised. Some organisations put numerical values on likelihood and severity. The overall risk is Likelihood Factor multiplied by the Severity Factor. Some organisations prefer to rank likelihood and severity in terms of high, medium and low. Example of a numerical scheme is given below.

Likelihood – some organisations use a 1 – 5 rating. Guidance may be given on how to apply these.

1. Very unlikely to occur – might occur once
2. Unlikely to occur
3. Likely to occur
4. Very likely to occur
5. Certain to occur

Severity – when estimating severity it is important to base the estimate on the extent of an injury that will typically occur from a given event. The worst possible case scenario should not be used.

1. Minor injury with no lost time
2. Injury up to 3 days off work
3. Reportable injury under RIDDOR
4. Major injury/long term absence
5. Fatality

Under this system the lowest risk (Likelihood x Severity) has a factor of 1. The highest risk has a factor of 25. This would represent an unacceptable risk rating.

Quantitative Assessment

NUMERICAL VALUE	LIKELIHOOD	SEVERITY
1	Very Unlikely	Minor Injury with no time off
2	Unlikely	Injury and/or up to 3 days off
3	Likely	Reportable event - RIDDOR
4	Very Likely	Major injury/long term absence
5	Certain	Death

Likelihood	Risk rating: Likelihood x Severity				
5	5	10	15	20	25
4	4	8	12	16	20
3	3	6	9	12	15
2	2	4	6	8	10
1	1	2	3	4	5
Severity	1	2	3	4	5

Health

Severity - do not overlook the impact some work activity can have on health.

Some problems will have a rapid effect others may take years to develop.

GSS GROUP

4

The chart above has been adapted from practices in the offshore oil and gas industry. The Safety Management System of a company may stipulate. Tasks in the red area must not proceed. Tasks in the brown area can only proceed when the method has been thoroughly reviewed by a Senior Manager. Jobs in the green area can go ahead.

Risk Assessment Form

Below is an alternative form to the one suggested by the HSE in ‘Five Steps to risk assessment:

Task Analysis Risk Assessment Form

Assessed by:
Assessment Date:
Review Date:

Detail of task:

HAZARD Activity Equipment Substance	**RISK** What could go wrong? How could harm occur?	Initial Risk L x	S =	R	CONTROL MEASURES	Residual Risk L x	S =	R

3.9 MARKET SURVEILLANCE

Introduction
If you import into or manufacture equipment in the EU, it must comply with all of the requirements of all of the directives that apply to it. It is your job to ensure that this is the case. Simply relying on the CE mark being present is not a sufficient defence to prevent possible investigation or prosecution. You will have to undertake some of your own tests and back them up with all of the technical information relating to the equipment.

What is market surveillance?
It is the responsibility of all governments to ensure that instruments that are placed on the on the market comply with all aspects of the Directives that apply to them.

If you take responsibility for manufacturing or importing weighing instruments it will be up to you to ensure that you comply with the requirements of all directives by carrying out checks on the instruments that you supply. A failure to carry out any checks may leave you open to action, and potential prosecution, by market surveillance authorities.

What is the difference between market surveillance and inspections?
Market Surveillance takes place when the instrument is first verified and put into use. This may be at the place that it is manufactured or imported, but if the accuracy is dependent upon where the instrument is used, such as weighbridges, the market surveillance will be carried out there.

Market surveillance will examine all of the technical aspects of the weighing instrument. In practice this will involve checking that the instrument complies with all aspects of the type approval certificates. It may involve a relatively cursory check, but could involve the market surveillance authorities examining all of the technical files relating to the instrument and may involve the testing of all aspects of the machine to ensure compliance. This can be very time consuming and the manufacturer or importer can be responsible for the any failure to comply with any of the requirements.

Inspection takes place after the instrument has been put into use, and will invariably be carried out by a local Weights and Measures Inspector. Inspection usually involves checking the accuracy of the instrument although some of the checks carried out when doing an inspection can be considered market surveillance.

Is the difference between market surveillance and inspection important?
The main difference between market surveillance and inspection is the powers available to the authorities if a manufacturer or importer does not comply with the requirements. If non-compliance is revealed during an inspection, the instrument can be rejected, a notice can be left or advice can be given. The effect of the enforcement invariably will only relate to that instrument.

If the non-compliance relates to a matter of meeting the requirements of the directives, the market surveillance authority can ask for all instruments in the market place with that non-compliance to be withdrawn, can issue a warning to all other European states informing them of the problem. In certain circumstance can withdraw the right of the manufacturer to make EC Declarations of Conformity for up to a month.

If manufacturers or importers are to avoid the draconian powers that can be used they must takes positive steps to ensure compliance

What should I do?
If you are a manufacturer, authorised representative or importer into the EU of equipment you must take positive steps to ensure that you are meeting the obligations of the directive. To do nothing will leave you open to actions in the event of a non-compliance being discovered by the authorities.

These checks do not have to be a repeat of the type approval test, but will be at a lower level to ensure that you have taken steps to ensure compliance. You would only need to keep the paper work records suggested in 1) below for each type of instrument that you manufacture or import, The number of instruments that you should carry out checks on will be dependant upon the type and number of instruments and whether you operate as a manufacturer or importer. If you are an importer it should include a small number of instruments in each batch that you import.

1) Checking and keeping a copy of all aspects of the technical assessments that have taken place ensure compliance of the instrument. This would include not only those certificates or reports that relate to the weighing aspects, but any documentation that relates to electrical safety or electromagnetic immunity.

2) To ensure that all of the appropriate markings are on the instrument and that the markings relate to the instrument to which they are applied: Is the maximum capacity of the instrument and the range of the tare the same as the one marked?

3) To ensure the correct edition of the software is on the instrument.

4) Correct sealing of the instrument to ensure that the security of the instrument is maintained. This should include the security of any software.

5) If you are not verifying the instrument you may carry out some basic metrological tests. This should include the application of known loads to the instrument and may include such things as a checking the instrument when the instrument is very hot or very cold or leaving a load on the instrument to check it does not creep.

This list is not exhaustive, but is intended to give examples of the type of checks that could be done.

It may not be necessary to carry out the suggested checks on each instrument. Depending upon the nature of your business they could be done on a sample of each consignment.

A checklist is attached to this document which may be of use in designing the type of checks that you carry out on the instruments. You should always keep records of the checks so that any inspection or market surveillance authority can see what you have done.

Checklist for Market Surveillance

	Yes	No	Comments
The first two headings should be completed for each model of instrument			
Do you have a copy of the TAC and other Test Certificates on file?			
Do you have a copy of any test results associated with the machine on file?			
The following checks should be carried out on a reasonable number of instruments			
Correct application of CE Mark			
Correct application of M mark			
Correct application and location of other markings- (Information on these markings)			
Does the data marked on the machine relate to the instrument to which it is applied?			
Is the software edition number the correct one?			
Do you have the Declarations of Conformity for all relevant directives?			
Is the instrument and the software appropriately secured?			
If completing as second stage verification, do you have the appropriate certificates for the 1st stage?			
Have you carried out metrological tests on the instrument			
Tested in extreme heat or cold			
Tested for creep			

3.10 WEIGHING INSTRUMENTS USED FOR BUYING AND SELLING GOLD, OTHER PRECIOUS METALS, PRECIOUS STONES AND PEARLS

Members will be aware that there has recently been an upsurge in the number of people wishing to sell gold and jewellery and consequently, an upsurge in the number of jewellers and other organisations offering to buy. Many jewellers are now placing advertisements offering to buy gold based on weight. (For instance, this morning a number of jewellers in Birmingham had signs outside their shops offering to buy gold at £12.20 per gram.) To do this, they obviously need to be using Type Approved and Verified weighing instruments as this falls under both the definition of “use of trade” in the Weights and Measures Act 1985 and “Commercial Transaction” in the Non-Automatic Weighing Instruments (NAWI) Directive.

More and more jewellers are therefore looking to buy suitable weighing instruments. The following notes are therefore intended as a reminder to members of the special conditions which apply to non-automatic weighing instruments used for the jewellery trade.

Use of Class II instruments

Regulation 28 (30 of the Non-Automatic Weighing Instruments Regulations 2000 (S.I. 2000 No. 3236)) states:

> *A person shall not use for trade any instrument other than an instrument of accuracy classification Class I or Class II in any transaction*
>
> *(a) to, or to articles made from gold, silver or other precious metals, including gold or silver thread of fringe;*
>
> *(b) to precious stones or pearls.*

Quite clearly, therefore, any jeweller seeking to buy a non-automatic weighing instrument must be advised that he must purchase a Class I or Class II instrument; a normal Class III retail scales is not suitable.

Use of auxiliary indication

The normal Class III retail weighing instrument the indicators that are displayed are unambiguous, e.g. a 15kg x 5g weighing instrument displays in intervals of 5g. This is known as the verification scale interval (*e*) and this is marked on the instrument in the format e = 5g. However, many Type Approved and Verified Class I and Class II instruments are equipped with auxiliary indicated devices; that is, they are verified to be accurate to one level, but for guidance purposes they indicate to a higher level. For example, a balance may be verified to 2kg x 0.1g, but will have an additional display that enables it to be read to 0.01g (often the extra digit is of a different colour or is distinguished in some way). This additional digit is known as the actual scale interval (*d*), as opposed to the verification scale interval. In such cases, the instrument will be marked with an additional marking showing that the verification scale interval *e* is equal to 10*d*.

Whilst this auxiliary indication is a useful facility for many applications it is considered that an auxiliary indication would be confusing to the general public and consequently, auxiliary indications are not permitted on instruments used for selling jewellery in the presence of the customer. Schedule 2, Article 14 of the NAWI regulations states that on “instruments used for direct sales to the public… auxiliary indicating devices and extended indicating devices are not permitted”. A TSO/authorised officer would be acting within his powers if he rejected/disqualified any instrument with an auxiliary device being used for that purpose. The TSO could also reject or disqualify such instrument used for buying jewellery on the basis that it was unsuitable for its purpose, using his powers under regulation 27. If an instrument is used away from the customer, then this restriction does not apply.

Weighing below "Min"

Generally speaking, a NAWI may be used for weighing below its marked "Min" value provided that such use is occasional rather than normal. For example, a supermarket could use its 15kg x 5kg retail instrument with its marked "Min" value of 100g to weigh the occasional sale goods below 100g (often used when a customer wishes to purchase, say, 1 slice of ham at a deli counter), but if a TSO found that the supermarket was selling this quantity 50 times a day, every day, he could justifiably argue that the instrument was not suitable for the purpose for which it was being used and he could require it to be replaced with a more suitable instrument.

However, under Regular 28(2) of the regulations mentioned above, this concession of allowing occasional use of an instrument below its marked "Min" value is specifically prohibited when determining the weight of gold, silver, precious metals, precious stones, pearls, drugs and other pharmaceutical products.

Summary

When advising/supplying weighing instruments for use in the buying or selling of gold to and from the public, jewellers must be advised that:

1. the instrument must be Type Approved and Verified
2. the instrument must be Class I or Class II
3. the instrument for direct sales can not have any auxiliary indication
4. the instrument can not be used for weighing below its marked "Min" value.

3.11 IN-HOUSE CALIBRATION OF TEST WEIGHTS

In general, in-house calibration of test weights can be an acceptable solution providing it is in accordance with the quality system of a company and fully traceable weights are used. However, this does require that the reference weights are of an appropriate tolerance class.

OIML Recommendation R111-1: 2004 (E) defines 9 classes or categories of weights. These are E1, E2, F1, F2, M1, M1-2, M2, M2-3, and M3. E1 is the most accurate and M3 being the least accurate.

Of these, we are concerned with Classes M1 and higher. M1 is the class that a Trading Standards Officers Working Standard weights would fall into and it is the class which members would normally have their test weights calibrated to for normal testing, calibration and verification of Class III and IIII non-automatic weighing instruments. The maximum tolerance on a 1kg M1 weight is 50mg.

If we use an M1 weight to calibrate an M1 weight we can very quickly get well outside the maximum tolerance. Assume our M1 reference standard is 40 mg below the nominal value of 1kg. If we then use this to calibrate our test weight which we find is 45mg below the nominal value, we would assume that our test weight is within the tolerance, because its error is less than 50mg, but the error on our reference weight of -40mg means in reality that the overall error on our test weight is -95mg, well outside the tolerance.

For that reason OIML R 111-1: 2004 (E) requires that weights are calibrated against a higher class of weight, and as a rule of thumb it recommends that the uncertainty of the error of the reference weight should not exceed 1/3 of the tolerance on the weight being calibrated. As the tolerances between weight classes are generally in the ratio 3:1, (i.e. the tolerance on an F2 weight is approximately one third of the tolerance on an M1 weight) it is fairly obvious that F2 should be the lowest class of weight used when calibrating an M1 weight, preferably the reference standard should be F1 to reduce the margin of error as far as possible.

Copies of R111-1:2004(E) can be downloaded free of charge from the OIML website at www.oiml.org/publications

3.12 AUDITORS NOTES ON CALIBRATION

The UK Weighing Federation (UKWF) has compiled the following notes to assist Management Systems Auditors when considering the calibration of weighing instruments. These notes have been updated to reflect the requirements of ISO 9001:2008.

There is confusion and often misunderstanding about whether calibration should be carried out by UKAS Accredited Laboratories. Whilst there are odd occasions where this is necessary, in the vast majority of cases, particularly for weighing instruments that fall within the category of Class III or Class IIII instruments as defined in OIML (Organisation Internationale de Metrologie Legale) Recommendation R76, calibration to UKAS accreditation level is far more than necessary and the additional cost would not add any value to the veracity of the calibration certificate.

Non-Automatic Weighing Instruments are those that require the intervention of an operator at some stage during the weighing process.

The appropriate Clause of ISO 9001:2008 is 7.6 which, for ease of reference is reproduced here:

> *7.6 Control of monitoring and measuring equipment*
>
> *The organization shall determine the monitoring and measurement to be undertaken and the monitoring and measuring equipment needed to provide evidence of conformity of product to determined requirements.*
>
> *The organization shall establish processes to ensure that monitoring and measurement can be carried out and are carried out in a manner that is consistent with the monitoring and measurement requirements.*
>
> *Where necessary to ensure valid results, measuring equipment shall:*
> *a) be calibrated or verified, or both, at specified intervals, or prior to use, against measurement standards traceable to international or national measurement standards; where no such standards exist, the basis used for calibration or verification shall be recorded (see 4.2.4);*
> *b) be adjusted or re-adjusted as necessary;*
> *c) have identification in order to determine its calibration status;*
> *d) be safeguarded from adjustments that would invalidate the measurement result;*
> *e) be protected from damage and deterioration during handling, maintenance and storage.*
>
> *In addition, the organization shall assess and record the validity of the previous measuring results when the equipment is found not to conform to requirements. The organization shall take appropriate action on the equipment and any product affected.*
> *Records of the results of calibration and verification shall be maintained (see 4.2.4).*

In 1999, recognising the need for a consistent approach to the calibration of non-automatic weighing equipment, the UKWF in consultation with the Trading Standards Institute, LACORS (Local Authorities Co-ordinating body on Regulatory Services) and the Institute of Measurement and Control drafted a practical guide to calibration of weighing instruments. The guide was issued in the form of a Code of Practice and UKWF members providing calibration services to their customers are required to adopt and follow the Code. Those members who are themselves ISO 9001:2008 certified are required to reference the Code in their QMS documentation so that compliance will be covered by both the internal audit system, and by the Certification Body; those UKWF members who are not ISO 9001:2008 certified are audited by the Federation itself for compliance. In the following table we compare ISO 9001:2008 requirements against the UKWF Code of Practice.

ISO 9001:2008; Clause 7.6 Requirement	**UKWF Calibration Code of Practice Summary of Requirement**
The organization shall establish processes to ensure that monitoring and measurement can be carried out and are carried out in a manner that is consistent with the monitoring and measurement requirements.	The UKWF Code requires that specific tests designed to reliably and consistently measure the weighing instruments performance are carried out and recorded during the calibration exercise. The tests are designed around those laid down by the OIML in Recommendation R76.
Where necessary to ensure valid results, measuring equipment shall *a) be calibrated or verified, or both, at specified intervals, or prior to use, against measurement standards traceable to international or national measurement standards; where no such standards exist, the basis used for calibration or verification shall be recorded.*	UKWF Members are required to carry out calibration using test weights that have been calibrated in a manner traceable to national standards. Members may either use the services of UKAS accredited Laboratories for the calibration of their weights, or have them calibrated by a Local Authority Trading Standards Department operating under section 74 of the Weights and Measures Act. In either case the calibration is directly traceable to the UK Primary Standards. Members are required to identify the calibration status of their test weights on the calibration certificate that they issue .
Where necessary to ensure valid results, measuring equipment shall….. *b) be adjusted or re-adjusted as necessary;*	UKWF Members are required to carry out both “As Found” and - if adjustment or repair has been necessary - “Definitive” tests on the weighing instruments that they calibrate.
Where necessary to ensure valid results, measuring equipment shall …. *c) have identification in order to determine its calibration status;*	The Code requires UKWF members to record serial numbers or other identification on the test records and on the calibration certificate that they issue.
Where necessary to ensure valid results, measuring equipment shall …. *d) be safeguarded from adjustments that would invalidate the measurement result;*	UKWF Members are required to affix a calibration label to the weighing instrument, identifying the calibration date. The label should be impossible to remove without destruction, and should, whenever possible be placed so that access to any adjustment facility is not possible without the label being broken.
Where necessary to ensure valid results, measuring equipment shall …. *e) be protected from damage and deterioration during handling, maintenance and storage.*	UKWF Members are trained in the handling and maintenance of weighing instruments and will provide advice and guidance to customers who may wish to store equipment during periods when it is not in use.
In addition, the organization shall assess and record the validity of the previous measuring results when the equipment is found not to conform to requirements. The organization shall take appropriate action on the equipment and any product affected.	The Code requires UKWF members to provide details of any errors found during the calibration. In normal circumstances weighing instruments are deemed to be satisfactory if they are performing within the tolerances laid down in Weights and Measures legislation, but where a customer wishes he may specify his own tolerances if the equipment is not legally controlled by the Weights and Measures legislation. In either instance the tolerances applicable are required to be recorded on the calibration certificate.

Records of the results of calibration and verification shall be maintained (see 4.2.4).	UKWF Members are required to provide their customers with a calibration certificate which must include details of the instrument calibrated, the date and place of calibration, the tests carried out and the results of those tests, as well as the information detailed above. In addition the Certificate is required to identify the calibrating organization, membership of the UKWF and the fact that the calibration has been carried out in accordance with the Code .

In addition to the above, the UKWF also requires Members to ensure that the personnel they use to carry out calibrations are adequately trained and that the training is recorded in their files. Compliance with the code is mandatory on Members offering calibration service.

Some users of weighing instruments have endeavoured to carry out calibration themselves. In such instances, it is unlikely that they are aware of the need to maintain traceability between the weights they use and national standards; they are unlikely to have been trained in correct calibration procedures; they are often unaware of what tolerances are acceptable; they are unlikely to be able to distinguish between those errors caused by malfunction and those caused by incorrect usage, and in the event of a problem they will still need to use a specialist to carry out any necessary corrective actions.

Copies of the UKWF Calibration Code of Practice for non-automatic weighing instruments can be obtained from the UK Weighing Federation; please contact the Federation Secretariat via our web-site www.ukwf.org.uk.

If you have any queries or questions relating to the Code or this note please contact the Federation's Technical Officer at technical2@ukwf.org.uk.

The Federation has also produced a Code of Practice for weighing instruments used for weighing cementitious products; the requirements are broadly similar to those for non-automatic weighing instruments and the same high standards of training, traceability, record keeping, certificate content and sealing are included. Copies are available from the UKWF Secretariat, if required.