FACULTY OF ENGINEERING

UNIVERSITI PUTRA MALAYSIA

CALIBRATION OF BALANCE

UPM/FK/MML/CMD2

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1.0 OBJECTIVE

To calibrate balance Non-Automatic Weighing Instrument (NAWI) with capacity as follows:

Capacity: , up to 100 g, up to 1 kg, up to 10 kg.

2.0 SCOPE

The scope of this procedure covers the process of calibrating balance according to OIML R76-1. Standard weights used for the calibration of an instrument shall meet the metrological requirements of OIML R-111.

The calibration work is carried out on-site.

The selection of weight (minimum class) used to calibrate balance is shown in Table 1.

As guidance, the selection of the class of standard weight for calibrating weighing machine is based on the class of standard weight that has the best accuracy for the given resolution of balance at the maximum balance capacity. For example, weighing machine with capacity of up to 50 g with resolution of 0.1 mg should be calibrated with E_2 class (or higher class), because for 50 g of E_2 class has a Maximum Permissible Error of less than the balance resolution of 0.1 mg.

Table 1: A possible selection of weights (minimum class) for calibration of weighing machines

Capacity	Resolution						
	100 g	10 g	1 g	100 mg	10 mg	1 mg	0.1 mg
Up to 50 g		F_1	F_1	F_1	F_1	F_1	E_2
Up to100g	F_1	F_1	F_1	F_1	F_1	F_1	
Up to 500 g	F_1	F_1	F_1	F_1	F_1	E_2	
Up to 1 kg	F_1	F_1	F_1	F_1	F_1		
Up to 5 kg	F_1	F_1	F_1	F_1	E_2		
Up to 10 kg	F_1	F_1	F_1	F_1			

REFERENCES

REFERENCE DOCUMENT	DOCUMENT TITLE
R - 64	OIML R111-1:2004(E) Weights of classes E1, E2, F1, F2, M1, M1–2, M2, M2–3 and M3 Part 1 - Metrological and Technical Requirements
R - 66	JCGM 200: 2012 International vocabulary of metrology – Basic and general concepts and associated terms (VIM) 3rd edition 2008 version with minor corrections
R - 67	JCGM 100:2008 GUM 1995 with minor corrections Evaluation of measurement data — Guide to the expression of uncertainty in measurement
R - 68	M3003 : 2012 The Expression of Uncertainty and Confidence in Measurement
R - 70	OIML R76-1:2006(E) Non-automatic weighing instrument Part 1 - Metrological and technical requirements - Tests
R - 72	LAB 14 Calibration of Weighing Machines, UKAS, Edition 4, 4 November 2006
R – 78	EURAMET/cg-18/v.02 Guidelines on the Calibration of Non-Automatic Weighing Instruments

3.0 GLOSSARY AND TERMINOLOGY

3.1 GLOSSARY

QM	:	Quality manager
DCO	:	Document Control Officer
TM	:	Technical Manager
UJK	:	Unit Jaminan Kualiti/Quality Assurance Unit
MML	:	Mass Metrology Laboratory

3.2 TERMINOLOGY

a) Calibration

The set of operations that establish, under specified conditions, the relationship between values of quantities indicated by a measuring instrument or measuring system, or values represented by a material measure or a reference material, and the corresponding values realized by standards.

b) Accuracy Class

Class designation of a weight or weight set which meets certain metrological requirements intended to maintain the mass values within specified limits.

c) Calibration Certificate

Certificate issued only by authorized or accredited laboratory that record the results of a calibration.

d) Set of weights or weight set

Series or group of weights, usually presented in a case so arranged to make possible any weighing of all loads between the mass of the weight with the smallest nominal value and the sum of the masses of all weights of the series with a progression in which the mass of the smallest nominal value weight constitutes the smallest step series.

e) Nominal Value

Rounded or approximate value of a characterizing quantity of a measuring instrument or measuring system that provides guidance for its appropriate use.

f) Conventional Mass

Conventional value of the result of weighing in air, for a weight taken at a reference temperature of 20 °C, the conventional mass is the mass of a reference weight of a density of 8 000 kg m^{-3} which it balances in air of a reference density of 1.2 kg m^{-3}.

3.3 Minimum Accuracy Class of weights

Weights are classified into tolerance limit classes. The International Regulation R111, issued by OIML classifies weights from 1 mg to 50 kg. It classes E_1, E_2, F_1, F_2, M_1, M_2 and M_3. For the calibration of weights of the particulars accuracy class, reference standard weights of the next higher class should be used; i.e. reference standard weights of class E_2 are used for calibration of weights of class F1.

Table 2 : Application and Requisite of Standard Weight

Accuracy OIML Class	Application and Requisite
E_1	Traceable to national mass standards and guarantees traceability of weights of class E_2
E_2	Used for initial verification/calibration of weights of class F_1
F_1	Used for initial verification/calibration weights of class F_2
F_2	Used for initial verification/calibration weights of class M_1 and M_2
M_2	Used for initial verification/calibration of weights of class M_3

4.0 EQUIPMENT USED

4.1 Standard weights (Table 3)

Table 3 : List of Standard Weights

No.	Set of Standard Weight	Standard Weight
1.	Stainless steel weight standard set (1 mg to 10 kg) Id No.: 158850 [1 mg, 2 mg (.), 2 mg, 5 mg, 10 mg, 20 mg (.),20 g, 50 mg, 100 mg, 200 mg (.), 200 mg, 500 mg, 1 g, 2 g (.), 2 g, 5 g, 10 g, 20 g (.), 20 g, 50 g, 100 g, 200 g (.), 200 g, 500 g, 1 kg] Id No.: 158830 (1 kg (.), 2 kg (.), 2 kg, 5 kg) Id No.: 30000174 (2 kg (..)) Id No.: 158510 (10 kg)	E_2 (Working)
2.	Stainless steel weight standard set (1mg to 10kg) Id No.: 158916 (1 mg, 2 mg (.), 2 mg, 5 mg, 10 mg, 20 mg (.), 20 mg, 50 mg, 100 mg, 200 mg (.), 200 mg, 500 mg, 1 g, 2 g (.), 2 g, 5 g, 10 g, 20 g (.), 20 g, 50 g, 100 g, 200 g (.), 200 g, 500 g, 1 kg) Id No.: 11125907 (1 kg, 2 kg (.), 2 kg, 5 kg) Id No.: 158726 (10 kg)	F_1 (Swiss)
3.	Stainless steel weight standard set (1 g – 5 kg) Id No.: 11119517 (1 g, 2 g (.), 2 g, 5 g, 10 g, 20 g (.), 20 g, 50 g, 100 g, 200 g (.), 200 g, 500 g) Id No.: CX 3944 – 11119464 (1 kg) Id No.: CX 3945 – 11119464 (1 kg) Id No.: CX 3945 – 11119465 (2 kg) Id No.: 11119465 (2 kg) Id No.: 11119465 (2 kg) Id No.: CX 3945 – 11119466 (5 kg)	F_1 (China)

4.2 Temperature and Humidity recorder (Table 4)

Table 4: Specification of temperature and humidity recorder

Type of Equipment	Manufacturer	Model	Range
Portable Digital Thermohygrometer	Airforce Asset code: SOO575133	JB913	0 to 50 °C 15 to 95 %
Portable Digital Thermohygrometer	Airforce Asset code: SOO575134	JB913	0 to 50 °C 15 to 95 %

5.0 PROCEDURE

5.1 Standard Weights Selection

Set of standard weights used for the calibration of balance are determined. Selection of standard weight used for the calibration of the balance are from classes E2 and F1 as defined in OIML R111-1 as mentioned in LAB 14 is shown in Table 1.

5.2 Pre Weighing Check at MML

Comparison of standard weights before and after calibration works.

a) Select a piece of suitable standard weight as reference standard with its accuracy must be at least one step higher than the test weight (weights used for the calibration of the balance) by following Table 5. Use forceps or glove during handling the standard weights. Only the mass stated in Table 5 will be compared.

Table 5 : Standard Weights for Pre Weighing Check and Post Weighing Check

No.	Nominal Value (g)	Standard Weights	Test Weight
1.	1 mg, 2 mg, 5 mg, 10 mg, 20 mg, 50 mg, 100 mg, 200 mg, 500 mg, 1 g, 2 g, 5 g, 10 g, 20 g, 50 g, 100 g, 200 g, 500 g, 1 kg, 2 kg, 5 kg, 2 kg, 10 kg	E_2 Master	E_2 Working
2.		E_2 Working	F_1 (Swiss)
3.		E_2 Working	F_1 (China)

b) Select the suitable weighing machines as a comparator following Table 5.

Table 5: Balance or Comparator

Type of Equipment	Manufacturer	Model	Capacity	Resolution
Balance/ comparator	Mettler Toledo Serial No.: B047089728	XP56C	1 mg to 50 g	1 µg
Balance/ comparator	Mettler Toledo Serial No.: B049095302	AX2005	100 g to 2 kg	0.01 mg
Balance/ comparator	Mettler Toledo Serial No.: B049093709	AX10003S	1 kg to 10 kg	1 mg

c) Switch on the comparator until the indicator shows that the comparator is ready to operate.

d) The test weight and standard weight must be cleaned up from any dust or other unwanted particles attached to it using devices such as air blower or lint-free tissues.

e) Record the temperature and relative humidity for the weighing cycles in Pre and Post Calibration Log Book LB9 (UPM/FK/LB9)

f) Weighing cycles

XP56C and XP10003S

i. Open the comparator chamber.
ii. Place the reference weight on the pan of the mass comparator.
iii. Close the comparator chamber.
iv. Wait until indicated value is stable.
v. Tare and record the value as A1.
vi. Open the comparator chamber.
vii. Replace the reference weight with the test weight.
viii. Close the comparator chamber.
ix. Wait until indicated value is stable.
x. Record the value as B1.
xi. Open the comparator chamber.

xii. Replace the test weight with the reference weight.
xiii. Close the comparator chamber.
xiv. Wait until indicated value is stable.
xv. Record the value as A2.

AX2005

i. Determine the individual test weight to be calibrated.
ii. Set the total pan weight to be 2 kg inclusive of the test weight by adjusting the dial weights (manually switchable and keypad operated).
iii. Open the comparator chamber.
iv. Place the reference weight on the pan of mass comparator,
v. Close the comparator chamber.
vi. Wait until indicated value is stable.
vii. Tare and record the value as A1.
viii. Open the comparator chamber.
ix. Replace the reference weight with the test weight.
x. Close the comparator chamber.
xi. Wait until indicated value is stable.
xii. Record the value as B1.
xiii. Open the comparator chamber.
xiv. Replace the test weight with the reference weight
xv. Wait until indicated value is stable.
xvi. Record the value as A2.

g) The standard error calculated from the pre weighing check activity shall not exceed the maximum permissible error (MPE) – refer Table 1 of document OIML R111-1:2004(E).

5.3 Calibration on site

a) Place the maximum weight according to the capacity of the balance. If the balance give a presice reading, record the reading in UPM/FK/MML/W2 and competent personnel are able to continue the job.

b) Record maximum and minimum environmental condition.

The environmental condition for performing balance calibration on-site should be as follows:

Control Condition

Temperature	25 ± 10 °C
Relative Humidity	Shall not exceed 85 % at the upper limit of the temperature range

c) Precaution during calibration

a. Always keep operator's hands and face at a reasonable distance away from weighing chamber. This is to avoid the effect of temperature by operator's body.
b. The operator should not place his/her hands in the weighing chamber more than absolutely necessary while loading and unloading weight.
c. Avoid using standard weight that are electrified due to friction or magnetized.

d) Clean any dirt or unwanted particle on the balance.

e) Make sure the balance is well aligned by checking the air bubble is in the center of the level indicator. Use the leveling feet to make adjustments.

f) Open the box cover and place the mass on special surface and let it acclimatize with the surrounding so that thermal equilibrium can be stabilized.

g) The procedure should include tests for the following parameters.

h) The calibration process

Repeatability Test

i. Determine the half and full capacity of the balance.
ii. Tare the balance and record the balance reading (T1) in the Worksheet for Balance Calibration (UPM/FK/MML/W2).
iii. Place the standard weight with nominal value for half capacity of the balance on the pan of the balance
iv. Record the balance reading (A1) in the Worksheet for Balance Calibration (UPM/FK/MML/W2).
v. Remove the standard weight from the pan.
vi. Repeat step ii to v 10 times.
vii. Repeat step ii to viii with standard weight with nominal value of full capacity of the balance.

Off-center Loading Test

i. Select standard weight with nominal value that is in the range of 1/3 to 1/4 of the balance full capacity.
ii. Place the standard weight at the Center (A) part of the balance pan.
iii. Tare and record the value in Worksheet for Balance Calibration (UPM/FK/MML/W2).
iv. Remove the standard weight and place it back at the Left (B) part of the balance pan.
v. Record the value.
vi. Repeat step iv to v at Back (C), Right (D), Front (E), and Center (A) part of the balance pan.
vii. Repeat step ii to v for two times. Refer to Figure 1 for the suggested location on the pan.

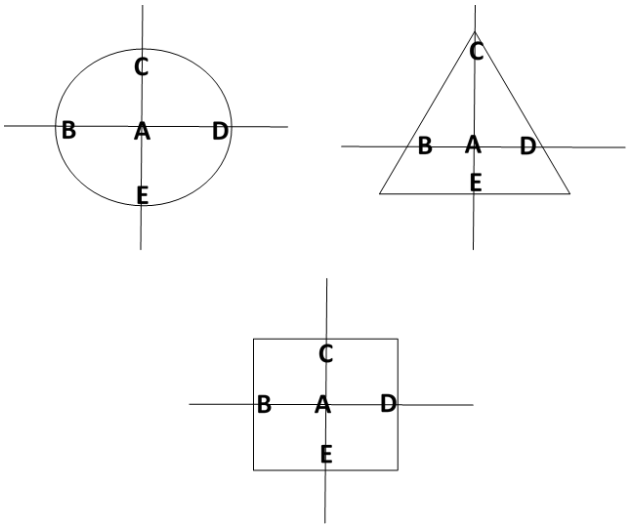

Figure 1: Suggested location on the pan for Off-center Loading test.

Weighing Performance Test

i. Determine the nominal load required to be applied on the balance with 10% increment within its range.
ii. Tare and record the value (T1) in the Worksheet for Balance Calibration (UPM/FK/MML/W2).
iii. Place standard weight according to the previously determined nominal value with 10% increment.
iv. Record the value (A1) in Worksheet for Balance Calibration (UPM/FK/MML/W2).
v. Remove the standard weight from the weighing pan.
vi. Repeat step ii to v for the other predetermined 10% weight increments.

vii. Repeat step ii to vi for 3 times.

Hysteresis

i. Determine the half and full capacity of the balance
ii. Select two pieces of standard weights, each has a value of half capacity of the balance.
iii. Tare the balance and record the value in Worksheet for Balance Calibration (UPM/FK/MML/W2).
iv. Place the first piece (M1) of standard weight on the balance pan. Record the value in Worksheet for Balance Calibration (UPM/FK/MML/W2).
v. Add the second piece (M2) on the balance pan and record the value.
vi. Remove M1 and record the value.
vii. Remove M2 and record the value.

5.4 Measurement Uncertainty is calculated with referring to the following consideration

a) Uncertainty from reference, U_{ref}

$$U_{ref} = \frac{U_{cert}}{k}, \qquad \text{(Equation 1)}$$

Where U_{cert} is the worst measurement uncertainty of the standard weights (r) used in the calibration from the calibration certificate.

b) Uncertainty from drift, U_{drift}

$$U_{drift} = \frac{MPE}{3\sqrt{3}} \qquad \text{(Equation 2)}$$

where MPE is the maximum permissible error of the standard weight

c) Uncertainty from equipment resolution, U_{res}

$$U_{res} = \frac{d}{2\sqrt{3}} \qquad \text{(Equation 3)}$$

Where *d* is resolution of the balance or comparator

d) Uncertainty from air boyancy, U_{ab}

$$U_{ab} = \frac{MPE}{4\sqrt{3}} \qquad \text{(Equation 4)}$$

e) Uncertainty from calibration, U_{rep} (for all three tests, repeatability, weighing performance, and off-center loading)

$$U_{rep} = \frac{t(\sigma)}{\sqrt{n}}, \qquad \text{(Equation 5)}$$

where $\sigma = \sqrt{\frac{\sum(\bar{r}-r_i)^2}{n-1}}$, t is 1 for repeatability test, and t is 2.3 for weighing performance and off-center loading. Choose the highest U_{rep} among the three tests.

f) Combined uncertainty, U_{comb}:

$$U_{comb} = \sqrt{{U_{rep}}^2 + {U_{ref}}^2 + {U_{drift}}^2 + {U_{res}}^2 + {U_{ab}}^2} \qquad \text{(Equation 6)}$$

g) Expanded uncertainty, U_{exp}:

$U_{exp} = k(U_{comb})$, k = coverage factor = 2 (Equation 7)

The calibration certificate for the standard mass gives an uncertainty at a coverage probability of approximately 95% (k= 2).

5.5 Post weighing check at MML

Upon return from on-site calibration, repeat step 5.2 prior to placing back the weight to its original storage.

5.6 Reporting

a. Transfer all result to Excel Worksheet as JOB NUMBER-CP NAME-CAPACITY .xls
b. Prepare calibration report according to SAMM Policy 7 Calibration Certificate which also consists of
    i. Report No. (on header)
    ii. Page (on header)
    iii. Issued to
    iv. Report No.
    v. Job No.
    vi. Date of Calibration
    vii. Environmental Condition

1. Ambient Temperature
2. Relative Humidity

viii. Calibrated instrument
1. Brand
2. Model
3. Capacity
4. ID No.
5. Resolution

ix. Calibration Procedure

x. Statement of level of confidence with a coverage factor *k*=2

xi. Equipment Used
1. Description
2. Certificate No.
3. Calibration Due Date
4. Traceability

xii. Result of Calibration consist of
1. Unit in g
2. Weighting Performance Test consist of
   a. Nominal Load
   b. Error
3. Repeatability Test consist of
   a. Load for half and full capacity
   b. Standard Deviation for half and full capacity
4. Off Centre Test
   a. Load
   b. Position
   c. Error
5. Hysteresis
   a. M1-M2
   b. Z1-Z2

c. Measurement Uncertainty
   a. The estimated uncertainty of the calibration result with 95% confidence level with a coverage factor of K=2 is
   b. U value

xiii. Calibrated by

xiv. Checked by

5.7 Calibration Certificate will be issued according to Appendix A: Calibration Certificate Template.

6.0 RECORDS

No.	File/Document	Location and Duration	Responsibility	Authority and Method of Disposal
1.	UPM/FK/TR/FL-18 **Calibration Certificate** • Application for Calibration Services Form (UPM/FK/F 3 - F) • Calibration Certificate • Amendment to Test/Calibration Report (UPM/FK/F 10) • Worksheet for Balance Calibration (UPM/FK/MML/W 2)	Laboratory 6 years	TM/DTM	QM/DCO Shred