**Palestine Polytechnic University**

**Graduation Project**

# Effect of Uncertainty in Non-Automatic Scales in Standard and Non-Standard Conditions

Student Name

Muhannad Azmouti

Supervisor

Dr.

Husein Amro

**Submitted to the College of Engineering**
**in partial fulfillment of the requirements for the**
**Bachelor degree in mechanical Engineering**

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Palestine Polytechnic University

College of Engineering

Mechanical Engineering Department

Hebron – Palestine

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Chair of the Department Signature

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# Abstract

The main purpose of this research is to determine the effect of the three variables (temperature, humidity and barometric pressure) on the measurement process. Moreover, do these variables affect the uncertainty rate? Moreover, how can we avoid the large proportion of uncertainty, if any.

It is very important for the quality officer to take into account the uncertainty value to improve the production situation.

And, the measurement process must take skepticism into account, no matter how much the error, so in order to avoid production errors and obtain a high-quality product.

At the end of the research, the quality officer will understand where the uncertainty value came from and how he can employ it in the measurement process. Therefore, in the measurement process, the uncertainty value must be taken into account, whatever the error is, in order to avoid production errors and obtain a high-quality product.

In order to obtain a good result in the measurement, the uncertainty value must be added to the production processes, but provided that the appropriate standard conditions are maintained, and that the scale used is proportional to the nature of the work based on the decision

# الملخص

الغرض الاساسي من هذا البحث هو توضيع تأثير المتغيرات الثلاث (الحرارة، الرطوبة والضغط) على عملية القياس وهل لهذه المتغيرات أن تؤثر على نسبة الارتياب؟ وكيف يمكننا تفادي نسبة الارتياب الكبيرة اذا وجدت. ومن المهم جدا على مسؤول الجودة الاخذ بعين الاعتبار في قيمة الارتياب لتحسين الوضع الانتاجي.

وفي نهاية البحث سوف يفهم مسؤول الجودة من أين أتت قيمة الارتياب وكيف يمكنه أن يوظفها في عملية القياس لذلك في عملية القياس يجب أن تأخذ قيمة الشك في الاعتبار، مهما كان الخطأ، وذلك لتجنب أخطاء الإنتاج والحصول على منتج عالي الجودة.

وللحصول على نتيجة جيدة في القياس، يجب إضافة قيمة الارتياب في عمليات الإنتاج، ولكن بشرط الحفاظ على الشروط المعيارية المناسبة، وأن يكون المقياس المستخدم متناسبًا مع طبيعة العمل بناءً على القرار.

# الإهــــــداء

إلى من هم أشرف منا جميعا ... الشهداء والأسرى

إلى التي علمتني درساً بالعقيدة ودرساً أخر في حب الوطن بضربة يد عندما رأتني أَرسم بالنقل واجبي البيتي رسم خارطة فلسطين وأنا بالسادسة من عمري ... إلى أمي.

إلى نبع العطاء الذي لا ينضب... أبي.

إلى كلية الهندسة.

إلى دائرة الهندسة الميكانيكية ...بطاقمها الإداري والتدريسي.

إلى المشرف على البحث الدكتور الفاضل: حسين عمرو.

والى الأستاذ الفاضل المهندس: جلال السلايمة

الذي أتاح لنا هذه الفرصة للتقدم واكتساب العلم والمهارة في نهضة الوطن

إلى أهلي وأحبائي

إلى الوطن الجريح – فلسطين.

إليكم جميع

أهدي عملي المتواضع هذا

# الشكر

في البداية، أود أن أشكر أسرتي على كل دعمهم ووقوفهم بجانبي طوال حياتي، وخاصة السنوات الأربع التي انقضت. كما أود أن أعبر عن امتناننا وتقديرنا وشكرنا العميق لمشرفي الدكتور حسين عمرو لدعمه وتوجيهي في كل خطوة خلال الفصل، ولكل دكتور وأستاذ نهض في يوم عطلته لتزويدنا والاستفادة من بحر المعرفة

وأخيرًا، نود أن نشكر جامعتنا على المساعدة والدعم المقدمين في مرافقها على مدار السنوات الأربع الماضية، وقسم الهندسة الميكانيكية لدينا على الجهد الكبير الذي بذله خلال دراستنا لتعزيزنا بكل المعرفة المطلوبة.

# Abbreviations

| Symbol | Definition | Unit |
|---|---|---|
| C | correction | |
| $D$ | drift, variation of a value with time | |
| $E$ | error (of an indication) | g, kg, t |
| $I$ | indication of an instrument | g, kg, t |
| $L$ | load on an instrument | g, kg, t |
| $Max$ | maximum weighing capacity | g, kg, t |
| $Max_1$ | upper limit of specified ‘weighing range, Max□ □ Max | g, kg, t |
| $Min$ | value of the load below which the weighing result may be subject to an excessive relative error | g, kg, t |
| $Min'$ | lower limit of specified weighing range, Min□ □ Min | g, kg, t |
| $R$ | indication (reading) of an instrument not related to a test load | g, kg, t |
| $T$ | temperature | °C, K |
| $Tol$ | specified tolerance value | |
| $U$ | expanded uncertainty | g, kg, t |
| $W$ | weighing result, weight in air | g, kg, t |
| $d$ | scale interval, the difference in mass between two consecutive indications of the indicating device | g, kg, t |
| $d_T$ | effective scale interval < d , used in calibration tests | g, kg, t |
| $k$ | number of items x, as indicated in each case | |
| $k$ | coverage factor | |
| $m$ | mass of an object | g, kg, t |
| $m_c$ | conventional value of mass, preferably of a standard weight | g, kg, t |
| $m_N$ | nominal conventional value of mass of a standard weight | g, kg, t |
| $m_{ref}$ | reference weight (“true value“) of a test load | g, kg, t |
| mpe | maximum permissible error (of an indication, a standard weight etc.) in a given context | g, kg |
| n | number of items, as indicated in each case | |
| s | standard deviation | |
| t | time | h, min |
| u | standard uncertainty | |
| $\rho$ | density | kg/m³ |
| $\rho_0$ | reference density of air, $\rho_0$ =1,2 kg/m³ | kg/m³ |
| $\rho_a$ | air density | kg/m³ |
| $\rho_c$ | reference density of a standard weight, □c = 8 000 kg/m³ | kg/m³ |

# Suffix

| Suffix | Related to |
|---|---|
| B | air buoyancy |
| *D* | drift |
| N | nominal value |
| T | test |
| adj | adjustment |
| cal | calibration |
| conv | convection |
| dig | digitalisation |
| ecc | eccentric loading |
| *i*, *j* | numbering |
| intr | weighing instrument |
| max | maximum value from a given population |
| min | minimum value from a given population |
| proc | weighing procedure |
| ref | reference |
| rep | repeatability |
| s | standard (mass); actual at time of adjustment |
| tare | tare balancing operation |
| temp | temperature |
| time | time |
| 0 | zero, no-load |

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# Chapter 1 : Introduction

## 1.1 Introduction

In this research, we decided to delve into the problem of measuring non-automated measurements in non-standard conditions affected by ambient temperature and environmental conditions, for example. Is there an effect of these conditions? Moreover, how can we deal with it?

If we look at those around us, for non-automatic scales in particular, we notice that they have a great role in regulating aspects of life, as they have a major role in maintaining the balance and life of society. The process of buying and selling deals commodities that has weight or volume.

This field is considered one of the areas of metrology that has a special role in industry and scientific experiments; as it is not possible to construct a building without taking into account the engineering dimensions and the required quantities. Metrology is one of the most important pillars of the pharmaceutical industry, and this field is very sensitive in dealing with accurate measurements. Measurement is one of the most important elements required to obtain product quality and reduce risks and costs as well.

We know that every measuring instrument needs to be calibrated and therefore the uncertainty value must be calculated. Therefore, we will perform several experiments on 5 non-automatic measures, as we will calibrate these measures under both standard and non-standard conditions.

Therefore, in this paper, we will deal with methods to calibrate and find the uncertainty generated by the calibration process, and whether there is an actual effect of the conditions surrounding the measurement process.

## 1.2 Research Problem

The idea of this research came from my observations of the abnormal conditions through which the measurement processes are carried out in some factories and laboratories, without taking into account the standard conditions surrounding the measuring device and their direct impact on the quality of the product. In this research, I will explain the effect of measurement in non-standard conditions and compare it with standard conditions that take into account quality and measurement to come up with the highest possible measurement accuracy in the laboratory or factory.

## 1.3 Research Objective

Most production plants and engineering testing laboratories tend to implement the quality system for several reasons as follows:

- Raising the efficiency and quality of the product.
- Obtaining (ISO 17025) certificate or the Palestinian Quality Certificate (PS)
- For internal or external audits to obtain the approval of the Palestinian Accreditation Unit with regard to engineering testing laboratories.
- Exporting abroad, which is sometimes required for calibration certificates by the foreign importer.

Therefore, we will make comparisons in the calibration process on samples of non-automatic scales in standard and non-standard conditions; there will be an explanation for the difference in this research between measurement in different conditions and the effect of uncertainty in measuring devices, and its impact on the production process.

## 1.4 Importance Of Research

Importance and value of research:

1) Raising the quality of manufactured products based on the uncertainty created by packaging measuring devices or even measuring devices used in production lines.
2) Extracting high quality information by metrology in regarding of product delivery and labor.

3) Instructing the owners of factories and engineering test laboratories of the importance of calibrating measuring devices, regardless of the reason for their desire to obtain a calibration certificate, or just an external requirement, whether for auditing or accreditation.
4) Using this research as a reference guide for factories interested in calibrating measuring devices and the procedures followed in the calibration process.
5) Employing the uncertainty value and the error rate in the measurement equipment.

## 1.5 Basic Research Elements

By presenting the hypotheses of the problem, it is necessary to define the basic concepts that we will address in this research in order to determine the three basic concepts that we have:

**a) Metrology**

Metrology is one of the basic sciences that is included in all aspects of life from research and studies to daily work - such as filling fuel in your car - and other life activities that include the measurement. In the past, some countries were forced to adopt some of their own units of measurement to facilitate their activities.

Several units of measurement for the same quantity were established. In some countries, weight is measured in pounds, ounces, and pounds. The different units of measurement became an obstacle to intra-regional trade until the heads of 17 countries agreed on May 20, 1875 in Paris to establish the International Bureau of Weights and Measures (BIPM) under an agreement known today as the Meter Convention.

**b) Pillars of the calibration process**

From the above definitions, we conclude that the calibration process is based on the following pillars:

**1)** Measuring device: the equipment for which the calibration process is used.

**2)** Standard reference: the reference with which we compare the equipment or quantity to be calibrated, one of its conditions is that it must be traceable, meaning that it is linked to a series of calibrations that support each other, and this series is connected to one of the units of the International System of Units (SI).

**3)** Meteorologist: the person who conducts the calibration process.

**4)** Laboratory: the place where the appropriate environmental conditions are available to conduct the calibration process (temperatures / dust-free), humidity / distance from vibrations and mechanical shocks / distance from electric and magnetic fields and their sources and distance from heat sources such as sunlight and others.

**5)** The process of calibration: by which the measurement specialist or the calibration technician receives the steps of conducting the calibration process.

**6)** Calibration records: the data of the calibration process are recorded in these documents.

**7)** Calibration certificate: the document includes the final judgment on the efficiency of the equipment and a statement of the value of the measured quantity; the uncertainty (percentage of doubt) in the process is included.

### c) The Uncertainty Value

The word "uncertainty" means doubt, and thus in its broadest sense "uncertainty of measurement" means doubt about the validity of the result of a measurement. Because of the lack of different words for this general concept of uncertainty and the specific quantities that provide quantitative measures of the concept, for example, the standard deviation. [3]

The uncertainty value in the measurement process is a value that is calculated by using mathematical equations. The value comes after the calibration process calculated from the values taken from the calibration process, and depends mainly on the iterative error of the measuring instrument, and the uncertainty value in the reference device.

## 1.6 Time Table

Table1  Project time table

| WEEK / SUBJECT | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| Selecting project idea | | | | | | | | | |
| State of art review | | | | | | | | | |
| Selecting reading device | | | | | | | | | |
| collect information's | | | | | | | | | |
| Making report | | | | | | | | | |
| Making presentation | | | | | | | | | |

# Chapter 2 : Calibration Of Non-Automatic Scales

## 2.1 Elements Of The Calibration

1. Applying test loads to the instrument under specified conditions.
2. Determining the error or variation of the indication.
3. Evaluating the uncertainty of measurement to be attributed to the results [1] .

## 2.2 Place Of Calibration

Calibration is normally performed in the location where the instrument is being used. If an instrument is moved to another location after the calibration, possible effects from

1. difference in local gravity acceleration,
2. variation in environmental conditions,
3. Mechanical and thermal conditions during transportation are likely to alter the performance of the instrument and may invalidate the calibration. moving the instrument after calibration should therefore be avoided, unless immunity to these effects of a particular instrument, or type of instrument has been clearly demonstrated. Where this has not been demonstrated, the calibration certificate should not be accepted as evidence of traceability [1].

## 2.3 Test Loads

Test loads should preferably consist of standard weights that are traceable to the SI unit of mass. However, other test loads may be used for tests of a comparative nature – e.g. test with eccentric loading, repeatability test – or for the mere loading of an instrument e.g., preloading, tare load that is to be balanced, substitution load [1].

## 2.4 Standard Weights

The traceability of weights to be used as standards shall be demonstrated by calibration consisting of:

1. determination of the conventional value of mass $m_c$ and/or the correction $\delta m_c$ to its nominal value $m_N$: $\delta m_c = m_c - m_N$ ,together with the expanded uncertainty of the calibration $U_{95}$or;

confirmation that $m_c$ is within specified maximum permissible errors mpe :

$$m_N - (mpe - U_{95}) \leq m_c \leq m_N + (mpe - U_{95})$$

The standards should further satisfy the following requirements to an extent appropriate to their accuracy:

3. density $\rho_s$sufficiently close to $\rho_s$ = 8 000 kg/m$^3$,
4. surface finish suitable to prevent a change in mass through contamination by dirt or adhesion layers,
5. magnetic properties such that interaction with the instrument to be calibrated is minimized. [2]

Weights that comply with the relevant specifications of the International Recommendation OIML R 111 should satisfy all these requirements.

The maximum permissible errors, or the uncertainties of calibration of the standard weights, shall be compatible with the scale interval (d) of the instrument and/or the needs of the client with regard to the uncertainty of the calibration of the instrument.

## 2.5 Measurement Methods

Tests are normally performed to determine

- the repeatability of indications,
- the errors of indications,
- the effect of eccentric application of a load on the indication.

A Calibration Laboratory deciding on the number of measurements for its routine calibration procedure should consider that, in general, a larger number of measurements tends to reduce the uncertainty of measurement but increase the cost. Details of the tests performed for an individual calibration may be fixed by agreement of the client and the Calibration Laboratory, in view of the normal use of the. instrument the parties may also agree on further tests or checks which may assist in evaluating the performance of the instrument under special conditions of use. Any such agreement should be consistent with the minimum numbers of tests sections [1].

## 2.6 Repeatability Test

The test consists of the repeated deposition of the same load on the load receptor, under identical conditions of handling the load and the instrument, and under constant test conditions. The test load(s) need not be calibrated nor verified, unless the results serve for the determination of errors of indication as per 2.7. The test load should, as far as possible, consist of one single body.

The test is performed with at least one test load $L_L$which should be selected in a reasonable relation to Max and the resolution of the instrument, to allow an appraisal of the instrument performance. For instruments with a constant scale interval d a load of about 0.5 $Max \leq L_T \leq Max$ is quite common; this is often reduced for instruments where $L_L$ would amount to several 1000 kg. For multi-interval instruments a load below and close to $Max_1$ may be preferred. For multiple range instruments, a 00load below and close to the capacity of the range with the smallest scale interval may be.

Sufficient A special value of $L_L$may be agreed between the parties where this is justified in view of a specific application of the instrument. The test may be performed at more than one test point, with test loads $L_T, 1 \leq j \leq k_L$ with $k_L$= number of test points. Prior to the test, the indication is set to zero. The load is to be applied at least 5 times, or at least 3 times where $L_T \geq 100$ kg. Indications $I_{Li}$ are recorded for each deposition of the load. After each removal of the load, the indication should be checked, and may be reset to zero if it does not show zero; recording of the no-load indications $I_{0i}$ may be advisable. In addition,

the status of the zero-setting or zero-tracking device if fitted should be recorded. [2]

## 2.7 Test For Errors Of Indication

This test is performed with L k ≥ 5 different test loads $L_T, 1 \leq j \leq k_L$ , distributed fairly evenly over the normal weighing range or at individual test points agreed upon.

As Examples for target values $K_L$ = 5: zero or Min; 0,25 Max; 0,5 Max; 0,75 Max; Max. Actual test loads may deviate from the target value up to 0,1 Max, provided the difference between consecutive test loads is at least 0,2 Max, $K_L$ = 11: zero or Min, 10 steps of 0,1 Max up to Max. Actual test loads may deviate from the target value up to 0,05 Max, provided the difference between consecutive test loads is at least 0,08 Max.

The purpose of this test is an appraisal of the accuracy of the instrument over the whole weighing range [2] . Where a significantly smaller range of calibration has been agreed, the number of test loads may be reduced accordingly, provided there are at least 3 test points including $Min'$ and $Max'$, and the difference between two consecutive test loads is not greater than 0,15Max. It is necessary that test loads consist of appropriate standard weights or of substitution loads. Prior to the test, the indication is set to zero. The test loads $l_{Tj}$are normally applied once in one of these manners

1. increasing by steps with unloading between the separate steps – corresponding to the majority of uses of the instruments for weighing single loads,
2. continuously increasing by steps without unloading between the separate steps; this may include creep effects in the results but reduces the amount of loads to be moved on and off the load receptor as compared to 1,
3. continuously increasing and decreasing by steps – procedure prescribed for verification tests in [2] (or [3]), same comments as for 2,
4. continuously decreasing by steps starting from Max - simulates the use of an instrument as hopper weigher for subtractive weighing, same comments as for 2.

On multi-interval instruments, the methods above may be modified for load steps smaller than Max, by applying increasing and/or decreasing tare loads, tearing the instrument, and applying a test load close to but not larger than Max1 to obtain indications with$d_1$.

On a multiple range instrument [2] (or [3]), the client should identify which range(s) shall be calibrated. [2]

Further tests may be performed to evaluate the performance of the instrument under special conditions of use, e.g., the indication after a tare balancing operation, the variation of the indication under a constant load over a certain time, etc. The test, or individual loadings, may be repeated to combine the test with the repeatability test under 5.1.
Indications $I_{Lj}$ are recorded for each load. In the case that the loads are removed, the zero indication should be checked, and may be reset to zero if it does not show zero; recording of the no-load indications $I_{0j}$[2].

## 2.8 Eccentricity Test

The test comprises placing a test load $L_{ecc}$in different positions on the load receptor in such a manner that the center of gravity of the applied load takes the positions as indicated in Figure 1 or equivalent positions, as closely as possible.

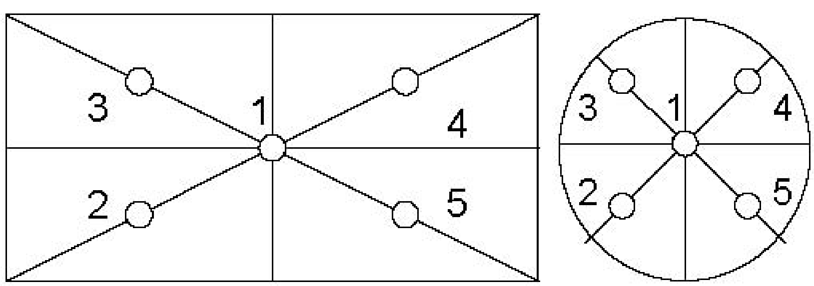


Figure 1 Positions of load for test of eccentricity

Where:

1. Centre
2. Front left
3. Back left

4. Back right
5. Front right

There may be applications where the test load cannot be placed in or close to the center of the load receptor. In this case, it is sufficient to place the test load at the remaining positions as indicated in Figure 1. Depending on the platter shape, the number of the off-center positions might deviate from Figure 1.

The test load $L_{ecc}$ should be about Max / 3 or higher, or $Min' + (Max' - Min')/3 \cdot \cdot$ or higher for a reduced weighing range.

Advice of the manufacturer, if available, and limitations that are obvious from the design of the instrument should be considered – e.g., see OIML R76 [1] (or EN 45501) for special load receptors.

For a multiple range instrument [1](or [2]) the test should only be performed in the range with the largest capacity identified by the client (see 4.1.1, 2nd paragraph).

The test load need not be calibrated or verified, unless the results serve to determine the errors of indication [1].

The test can be carried out in different manners:

1. Prior to the test, the indication is set to zero. The test load is first put on position 1, is then moved to the other 4 positions in arbitrary order. Indications Li I are recorded for each position of the load.
2. The test load is first put on position 1, then the instrument is taxed. The test load is then moved to the other 4 positions in arbitrary order. Indications Li I are recorded for each position of the load.
3. Prior to the test, the indication is set to zero. The test load is first put on position 1, removed, and then put to the next position, removed, etc. until it is removed from the last position. Indications $I_{Li}$ are recorded for each position of the load. After each removal of the load, the indication should be checked, and may be reset to zero if it does not show zero; recording of the no-load indications $I_{0i}$.

4. The test load is first put on position 1, then the instrument is taxed. The test loads is then moved to the next position and moved back to position 1, etc. until it is removed from the last position. The center indication $I_{Li}$ is recorded individually for all off-center indications $I_{Li}$.

Method 3 and 4 are suggested for instruments that show a substantial drift during the time of the eccentricity test.

For methods 2 and 4 zero-setting or zero-tracking devices must be switched off during the complete eccentricity test [1].

## 2.9 Resolution

Indications are normally obtained as integer multiples of the scale interval d.

At the discretion of the calibration laboratory and with the consent of the client, means to obtain indications in higher resolution than in d may be applied, e.g., where compliance to a specification is checked and smallest uncertainty is desired. Such means may be.

1. switching the indicating device to a smaller scale interval $d_T < d$ ("service mode").In this case, the indications are obtained as integer multiple of $d_T$.

2. applying small extra test weights in steps of $d_T = \frac{d}{5}\ or\ \ d/10$ to determine more precisely the load at which an indication changes unambiguously from $I'$ ・ to $I'$ + d ("changeover point method"). In this case, the indication I' is recorded

together with the amount ・L of the n additional small test weights necessary to increase $I'$ by one d.

where the changeover point method is applied, it is advised to apply it for the indications at zero as well as for the indications at load. [2]

## 2.10 Coverage Factor (K) For Expanded Uncertainty Of Measurement

The coverage factor k shall in all cases be chosen such that the expanded uncertainty of measurement has a coverage probability of 95, 45%.

**Normal distribution and sufficient reliability**

The value $k \neq 2$, corresponding to a 95, 45% probability, applies where

a) A normal (Gaussian) distribution can be attributed to the error of indication.
b) The standard uncertainty u (E) is of sufficient reliability (i.e. it has a sufficient number of degrees of freedom), see JCGM 100 [3].

Normal distribution may be assumed where several (i.e., $N \geq 3$) uncertainty, components each derived from “well-behaved” distributions (normal, rectangular or the like), contribute to u(E) in comparable amounts. Sufficient reliability is depending on the degrees of freedom. This criterion is met where no Type A contribution to u (E) is based on less than 10 observations.

A typical Type A contribution stems from repeatability. Consequently, if during a repeatability test a load is applied not less than 10 times, sufficient reliability can be assumed [1].

# Chapter 3 : Uncertainty Calculation

## 3.1 Standard Uncertainty Of The Indication

Contributions by instrument resolution

The contribution by includes rounding for the no-load indication and for the loaded indication. A rectangular distribution with limits is assumed and the following mathematical model is applied:

**3.1.1** $\delta I_{dig0}$ Accounts for the rounding error of no-load indication. Limits are $\pm\ d_0/2$ or $\pm d_T/2$ as applicable; rectangular distribution is assumed, therefore [1].

$$\left(\boldsymbol{\delta I_{dig0}}\right) = \frac{\mathbf{d_0}}{\mathbf{2\sqrt{3}}} \qquad \textbf{(3.1-1)}$$

**3.1.2** $\delta I_{digL}$ Accounts for the rounding error of indication at load. Limits are $\pm$ d or

2 T $\pm$ d as applicable; rectangular distribution to be assumed, therefore [1].

$$\mathbf{u}(\boldsymbol{\delta I_{digL}}) = \frac{\mathbf{d_I}}{\mathbf{2\sqrt{3}}} \qquad \textbf{(3.1-2)}$$

From the above equations (1.3 & 2.3) we can find the value of $\delta I_{dig}$ [1]

$$\mathbf{u}(\boldsymbol{\delta I_{dig}}) = \frac{\boldsymbol{d^2}}{\mathbf{12}} \qquad \textbf{(3.1-3)}$$

**3.1.3** $\delta I_{rep}$ Accounts for the error due to imperfect repeatability; normal distribution is assumed, estimated [1] , We can say that the equation used to find the value of the frequency is the standard deviation equation

$$\mathbf{u}\left(\boldsymbol{\delta I_{rep}}\right) = \mathbf{s}(\mathbf{I}) \qquad \textbf{(3.1-4)}$$

**3.1.4** $\delta I_{ecc}$ accounts for the error due to off-centre position of the centre of gravity of a test load. This effect may occur where a test load is made up of more than one body. Where this effect cannot be neglected, an estimate of its magnitude may be based on these assumptions [1]:

$$\mathbf{u}(\boldsymbol{\delta}\mathbf{I}_{\mathbf{ecc}}) = \frac{|\Delta \mathbf{I}_{\mathbf{ecc,i}}|_{\mathbf{max}}}{(2\mathbf{L}_{\mathbf{ecc}}\sqrt{3})} \qquad \textbf{(3.1-5)}$$

## 3.2 Standard Uncertainty Of The Reference Mass

The rightmost term stands for further corrections that may in special conditions be necessary to apply, it is not further considered hereafter. The corrections and their standard uncertainties are:

**3.2.1** $\delta m_c$ is the correction to $\boldsymbol{m_N}$ to obtain the actual conventional value of mass $m_c$; given in the calibration certificate for the standard weights, together with the uncertainty of calibration U and the coverage factor k. The standard uncertainty is [1].

$$\mathbf{u}(\boldsymbol{\delta}\mathbf{m}_{\boldsymbol{c}}) = \frac{\boldsymbol{U}}{\boldsymbol{k}} \qquad \textbf{(3.2-1)}$$

Where the standard weight has been calibrated to specified tolerances Tol, e.g., to the $mpe$ given in R 111[3], and where it is used its nominal value $m_N$, then $\delta m_c$= 0, and rectangular distribution is assumed, therefore [1].

$$\boldsymbol{u}(\boldsymbol{\delta m_c}) = \frac{\boldsymbol{mpe}}{\sqrt{\mathbf{3}}} \qquad \textbf{(3.2-2)}$$

**3.2.2** $\delta m_B$ is the correction for air buoyancy. The value depends on the density $\rho$ of the calibration weight, on the assumed range of air density a, and on the adjustment of the instrument [1].

$$\mathbf{u}(\boldsymbol{\delta}\mathbf{m}_{\mathbf{B}}) = \frac{-\mathbf{m}_{\mathbf{N}}(\boldsymbol{\rho}_{\mathbf{a}} - \boldsymbol{\rho}_{\mathbf{0}})}{\boldsymbol{\rho}} \qquad \textbf{(3.2-3)}$$

From above formula we must find air density $(\boldsymbol{\rho_a})$ by CIPM-formula [4].

Where:

$$\boldsymbol{p_a} = \frac{\mathbf{0.34848}*\boldsymbol{p}-\mathbf{0.009024}*\boldsymbol{h}*\boldsymbol{exp}^{\mathbf{0.0612}*\boldsymbol{t}}}{\mathbf{273.15}+\boldsymbol{t}} \qquad \textbf{(1)}$$

$\rho_a$: air density in kg/$m^3$

$p$ : barometric pressure in hPa

$h$ : relative humidity of air in %

$t$ : air temperature in °C.

**3.2.3** $\delta m_D$ is a correction for a possible drift of c m since the last calibration. A limiting value D is best assumed, based on the difference in $\boldsymbol{m_c}$ evident from consecutive calibration certificates of the standard weights. In the absence of such information, D may be estimated in view of the quality of the weights, and frequency and care of their use, to a multiple of their expanded uncertainty U ($\boldsymbol{\delta m_c}$ ) [1] *:*

$$\boldsymbol{D = k_D U(\delta m_c)} \quad \textbf{(3.2-5)}$$

Where:

$\boldsymbol{k_D}$ : may be chosen from 1 to 3.

It is not advised to apply a correction but to assume even distribution within ± D (Rectangular distribution). The standard uncertainty is then [1].

$$\mathbf{u(\delta m_D) = \frac{\boldsymbol{D}}{\sqrt{3}}} \quad \textbf{(3.2-6)}$$

After the Find the standard uncertainty for discrete values;

The basic formula for the calibration is:

$$\boldsymbol{u^2(E) = u^2(I) + u^2(m_{ref})} \quad \textbf{(3.2-7)}$$

The expanded uncertainty of the error is:

$$\mathbf{U(E) = ku(E)} \quad \textbf{(3.2-8)}$$

## 3.3 Standard uncertainty of reading in use

To account for sources of variability of the reading, (3.1) applies, with I replaced by R:

**3.3.1** $\delta R_{dig\ 0}$ Accounts for the rounding error at zero reading [1].

$$\boldsymbol{u(\delta R_{dig\ 0}) = \frac{d_0}{\sqrt{12}}} \quad \textbf{(3.3-1)}$$

**3.3.2** $\delta R_{dig\ L}$accounts for the rounding error at load reading [1].

$$\mathbf{u(\delta R_{digL}) = \frac{d_L}{\sqrt{12}}} \quad \textbf{(3.3-2)}$$

**3.3.3** $\delta R_{rep}$ Accounts for the error due to imperfect repeatability [1].

$$\mathbf{u(\delta R_{rep}) = s(R)} \qquad \textbf{(3.3-3)}$$

**3.3.4** $\delta R_{ecc}$ accounts for the error due to off-center position of the center of gravity of a loud [1].

$$\mathbf{u(\delta R_{ecc}) = \frac{|\Delta I_{ecc,i}|_{max}}{(2L_{ecc}\sqrt{3})}} \qquad \textbf{(3.3-4)}$$

## 3.4 Uncertainty From Environmental Influences

The correction term $\delta R_{instr}$accounts for at least 3 effects. The corresponding uncertainties are estimated, based on the user's knowledge of the properties of the instrument.

The term temp $\delta R_{temp}$accounts for a change in the characteristic (or adjustment) of the instrument caused by a change in ambient temperature $K_T$is the sensitivity of the instrument to temperature variation.

When the balance is controlled by a temperature triggered adjustment by means of the built-in weights then ΔT can be reduced to the trigger threshold. [1].

$$\boldsymbol{u(\delta R_{temp}) = \frac{k\Delta T}{\sqrt{12}}} \qquad \textbf{(3.4.1)}$$

**3.4.1** The term $\delta R_{buoy}$accounts for a change in the adjustment of the instrument due to the variation of the air density [1].

$$\boldsymbol{u(\delta R_{bouy}) = \frac{\Delta\, p_a}{p_c^{2}}\, u\, (p_s)} \qquad \textbf{(3.4.2)}$$

**3.4.2** The term $\delta R_{adj}$ accounts for a change in the adjustment of the instrument since the time of calibration due to ageing, or wear and tear [1].

$$\boldsymbol{u(\delta R_{adj}) = \frac{\Delta E(Max)}{Max}\sqrt{3}} \qquad \textbf{(3.4.3)}$$

## 3.5 Uncertainty From The Operation Of The Instrument

The correction term $\delta R_{proc}$ accounts for additional errors which may occur where the weighing procedure is different from the one(s) at calibration. No corrections are actually, being applied but the corresponding uncertainties are estimated, based on the user's knowledge of the properties of the instrument [1].

**3.5.1** The term $\delta R_{Tare}$ accounts for a net weighing result after a tare balancing operation [1].

$$\mathbf{u(\delta R_{Tare}) = \frac{q_{E\,max} - q_{E\,min}}{\sqrt{12}}} \qquad \textbf{(3.5-1)}$$

**3.5.2** The term $\delta R_{time}$ accounts for possible effects of creep and hysteresis [1].

$$\mathbf{u(\delta R_{time}) = \frac{\Delta E_{jmax}}{(m_j\sqrt{12})}} \qquad \textbf{(3.5-2)}$$

**3.5.3** $\delta R_{ecc}$ accounts for the error due to off-centre position of the center of gravity of a load [1].

$$\boldsymbol{u}\mathbf{(\delta R_{ecc}) = \frac{|\Delta I_{ecc,i}|_{max}}{(L_{ecc}\sqrt{3})}} \qquad \textbf{(3.5-3)}$$

The relative standard uncertainty related to errors resulting from environmental effects is calculated by

$$\boldsymbol{u^2(R)} = [\,\mathbf{u^2(\delta R_{dig\,0}) + u^2(\delta R_{dig\,L}) + u^2(\delta R_{rep}) + u^2(\delta R_{ecc})}] + [\,\mathbf{u^2(\delta R_{temp}) + u^2(\delta R_{bouy}) + u^2(\delta R_{Tare}) + u^2(\delta R_{time})}] \qquad \textbf{(3.5-4)}$$

$$\boldsymbol{u^2}\mathbf{(W^*) = u^2(R) + u^2(E)} \qquad \textbf{(3.5-5)}$$

$$\mathbf{u^2(W) = u^2\,(W^*) + u^2(\delta R_{inster}) + u^2(\delta R_{proc})} \qquad \textbf{(3.5-6)}$$

The expanded uncertainty of a weighing result is:

$$\mathbf{U(W) = ku(w)} \qquad \textbf{(3.5-7)}$$

Now we can find expanded uncertainty by (Indication for discrete test load) And (standard uncertainty of a weighing result)

The final equation is:

$$\boldsymbol{Uncertainty\ of\ Measurement} \mp= \sqrt{\boldsymbol{ku^2(E) + ku^2(w)}} \qquad \textbf{(3.5-8)}$$

## 3.6 In another context, we can use the equation (Propagation of uncertainties) [6].

$$\boldsymbol{Uncertainty\ of\ Measurment} \mp= \boldsymbol{\delta O}$$

$$\sqrt{\left[\left(\frac{\partial O}{\partial K} w_K\right)^2 + \left(\frac{\partial O}{\partial I} w_I\right)^2 + \left(\frac{\partial O}{\partial a} w_a\right)^2 + \left(\frac{\partial O}{\partial (N) I} w_{(N)I}\right)^2 + \left(\frac{\partial O}{\partial K_M I_M} w_{K_M I_M}\right)^2 + \left(\frac{\partial O}{\partial H} w_H\right)^2 + \left(\frac{\partial O}{\partial R} w_R\right)^2 + \left(\frac{\partial O}{\partial U_{mass}} w_{mass}\right)^2\right]}$$

**Where- :**

*$\delta O$: is the uncertainty in O (overall error)*

*$w_i$: the uncertainty in the individual measurement*

*K: sensitivity*

*I: Input*

*a : ideal straight-line intercept*

$N(I)$: *Non-linearity*

*KM and KI: - ambient temperature, atmospheric pressure, relative humidity, supply voltage.*

*H: Hysteresis*

*R: Resolution*

$U_{mass}$: $\boldsymbol{Uncertanity\ of\ Mass\ Referance}$

### 3.6.1 Sensitivity

This is the change ΔO in output O for unit change ΔI in input I.

$$Sensitivity = \frac{\Delta O}{\Delta I} \quad \equiv \text{Slop} \qquad \qquad 3.6.1$$

### 3.6.2 Ideal straight line ($a$)

An element is said to be linear if corresponding values of I and O lie on a straight

line. The ideal straight line connects the minimum point A ($I_{min}$, $O_{max}$) to maximum

point B ($I_{min}$, $O_{max}$) (Figure 4).

***Linearity error:*** *It is the difference between the true value and the reading value when linear relationship is assumed*

$$O_{ideal} = KI + a \qquad \qquad 3.6.2$$

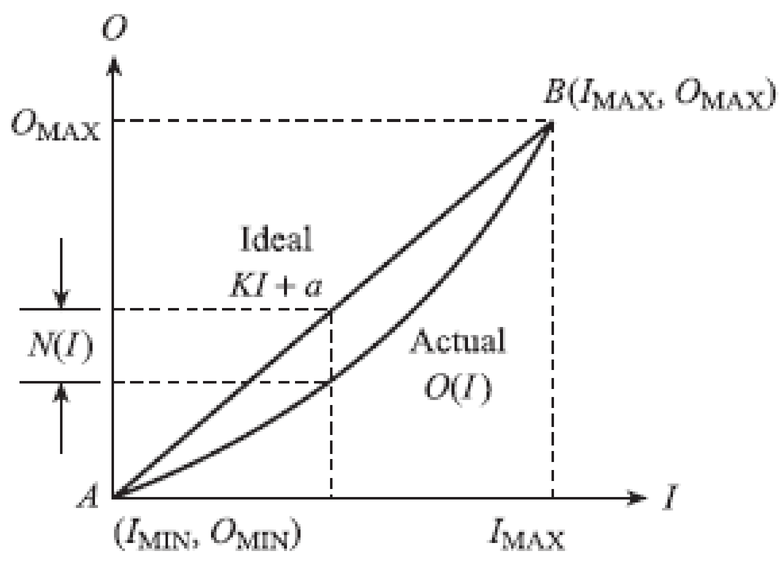


**Figure 4** Definition of non-linearity.

- **Non-linearity N(I)**

In many cases the straight-line relationship defined by eqn [3.6.2] is not obeyed and the element is said to be non-linear. Non-linearity can be defined (Figure 4) in terms of a function N (I) which is the difference between actual and ideal straight-line behavior.

$$\boldsymbol{N}(\boldsymbol{I}) = \boldsymbol{KI} + \boldsymbol{a} + \boldsymbol{O}(\boldsymbol{I}) \qquad \textit{3.6.2}$$

## 3.6.3 Environmental effects:

In general, the output O depends not only on the signal input I but on environmental inputs such as ambient temperature, atmospheric pressure, relative humidity, supply voltage, etc. Thus, if equ [3.6.3] adequately represents the behavior of the element under 'standard' environmental conditions.

$$\mathbf{O} = \mathbf{KI} + \mathbf{a} + \mathbf{N}(\mathbf{I}) + \mathbf{K_M I_M I} + \mathbf{K_I I_I} \qquad \mathbf{3.6.3}$$

***$K_M$ is the changing sensitivity for unit change in $I_M$.***

***KM and KI are referred to as environmental coupling constants or sensitivities***

## 3.6.4 Hysteresis

An instrument is said to exhibit hysteresis when there is a deference in readings depending on whether the value of the measured quantity is approached from above or below. Hysteresis may be the result of mechanical friction, magnetic effect, elastic deformation, or thermal effect.

$$\boldsymbol{H(I) = O(I)_{I\uparrow} - O(I)_{I\downarrow}} \quad 3.6.4$$

### 3.6.5 Resolution

The resolution of an instrument is the smallest change in the quantity being measured that will produce an observable change in the reading of the instrument.

The value of the resolution is added based on the rectangular distribution and divided by $\sqrt{3}$.

### 3.6.6 Uncertainty of mass reference

The uncertainty value is taken from the certificate of calibrated masses and divided according to the rectangular distribution divided by $\sqrt{3}$.

The rightmost term stands for further corrections that may in special conditions be necessary to apply, it is not further considered hereafter. The corrections and their standard uncertainties.

The search was done based on the reported expanded uncertainty of measurement is in accordance with a Guidelines on the Calibration of non-Automatic Weighing Instruments - Version 4.0 (11/2011).

Then I verified the equations through one general equation that includes all the variables from the reference (Bentley, J. P. (2005). Principles of measurement systems. Pearson education.)

- **The first Reference is a Guidelines on the Calibration of non-Automatic Weighing Instruments - Version 4.0 (11/2011):**

مؤسسة المواصفات والمقاييس الفلسطينية- مديرية القياس الوطني

**Palestine Standards Institution – Metrology Directorate**

**CERTIFICATE OF CALIBRATION**

| Certificate No. | B001 |
|---|---|

| | | | |
|---|---|---|---|
| Date of calibration | 06.06.2021 | | |
| Date of issue | 12.06.2021 | | |
| Client | PSI | Address | Ramallah |

**Instrumunt Information**

| | | | | | |
|---|---|---|---|---|---|
| Instrument | Digital Balance | | | Units of Measure | g |
| Model | STB6202C | | | Scale Class | II |
| Manufacturing | ADAM | | | Resolution | 0.01 g |
| serial No. | AEAA039 | | | Location | Pressuer Lab. |
| Range | 0.00 | 6200 | g | Condition | Non- Standard |

**The Ambient Condition**

| | Star | End |
|---|---|---|
| Temperature ( °C ) | 19.8 | 20.2 |
| Humidity ( % ) | 54.3 | 49.9 |
| Barometric Pressure (mbar) | 918.0 | 918.6 |

**Referance Instrument**

| Instrument | Serial No. | Cert. No. |
|---|---|---|
| Set of weights Class F1 | 254145 | M 214560 |

**Summery Of Calibration Method**

Calibrated measuring device by reference mass based on the classification of the balance

**Calibration Standerd**

Calibration process performed acording to OIML R 76-1

The reported expanded uncertainty of measurement is in accordance with a Guidelines on the Calibration of non-Automatic Weighing Instruments - Version 4.0 (11/2015)

Uncertinity of measuerment multiplied by the coverage factor k=2 for rectangulare disribuation it corresponds coverage probability of approximtily 95 %

| Calibrated By | Muhannad Azmouti |
|---|---|

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Ramallah–Almasyoun–AL Quds Build.P O Box 2258 رام الله، الماصيون، مبنى القدس ص ب
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CERTIFICATE OF CALIBRATION

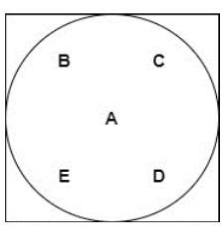
## Linerity Test

| Applied Load (g) | Indicated Reading (g) | Error (g) |
|---|---|---|
| 0 | 0.00 | 0.00 |
| 10.00 | 10.00 | 0.00 |
| 50.00 | 50.00 | 0.00 |
| 200.00 | 200.00 | 0.00 |
| 500.00 | 499.99 | 0.01 |
| 1000.00 | 1000.00 | 0.01 |
| 1500.00 | 1500.01 | 0.00 |
| 2000.00 | 2000.05 | -0.03 |
| 4000.00 | 4000.15 | -0.15 |
| 4500.00 | 4500.18 | -0.19 |
| 5000.00 | 5000.21 | -0.21 |
| 6200.00 | 6200.29 | -0.31 |

## Repetability Test

| Applied Load g | Unloaded Reading g | Loaded Reading g |
|---|---|---|
| 3000 | 0.0 | 2999.95 |
| | 0.0 | 2999.95 |
| | 0.0 | 2999.94 |
| | 0.0 | 2999.95 |
| | 0.0 | 2999.95 |

## Eccentricity Test




| Position | g | Loaded Reading |
|---|---|---|
| A | 2000 | 1999.93 |
| B | | 1999.90 |
| C | | 1999.90 |
| D | | 1999.90 |
| E | | 1999.92 |
| A | | 1999.93 |

| Uncertinity Of Measurement | ± | 0.03 g |
|---|---|---|



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- **The Second Reference is a (Principles of Measurement Systems. (n.d.), John P. Bentley):**

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**Palestine Standards Institution – Metrology Directorate**

**CERTIFICATE OF CALIBRATION**

| Certificate No. | B001 |
|---|---|

| | | | |
|---|---|---|---|
| Date of calibration | 06.06.2021 | | |
| Date of issue | 12.06.2021 | | |
| Client | PSI | Address | Ramallah |

**Instrumunt Information**

| | | | |
|---|---|---|---|
| Instrument | Digital Balance | Units of Measure | g |
| Model | STB6202C | Scale Class | II |
| Manufacturing | ADAM | Resiluation | 0.01 g |
| serial No. | AEAA039 | Location | Pressuer Lab. |
| Range | 0.00 – 6200 g | Condition | Non- Standard |

**The Ambient Condition**

| | Star | End |
|---|---|---|
| Temperature ( °C ) | 19.8 | 20.2 |
| Humidity ( % ) | 54.3 | 49.9 |
| Barometric Pressure (mbar) | 915.7 | 915.5 |

**Referance Instrument**

| Instrument | Serial No. | Cert. No. |
|---|---|---|
| Set of weights Class F1 | 254145 | M 214560 |

**Summery Of Calibration Method**

Calibrated measuring device by reference mass based on the classification of the balance

**Calibration Standerd**

Calibration process performed acording to OIML R 76-1

The reported expanded uncertainty of measurement is in accordance with a Guidelines on the Calibration of non-Automatic Weighing Instruments - Version 4.0 (11/2015)

Uncertinity of measuerment multiplied by the coverage factor k=2 for rectangulare disribuation it corresponds coverage probability of approximtily 95 %

| Calibrated By | Muhannad Azmouti |
|---|---|

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**CERTIFICATE OF CALIBRATION**

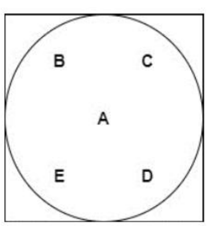
## Linerity Test

| Applied Load (g) | Indicated Reading (g) | Error (g) |
|---|---|---|
| 0 | 0.00 | 0.00 |
| 10.00 | 10.00 | 0.00 |
| 50.00 | 50.00 | 0.00 |
| 200.00 | 200.00 | 0.00 |
| 500.00 | 499.99 | 0.01 |
| 1000.00 | 1000.00 | 0.01 |
| 1500.00 | 1500.01 | 0.00 |
| 2000.00 | 2000.05 | -0.03 |
| 4000.00 | 4000.15 | -0.15 |
| 4500.00 | 4500.18 | -0.19 |
| 5000.00 | 5000.21 | -0.21 |
| 6200.00 | 6200.29 | -0.31 |

## Repetability Test

| Applied Load g | Unloaded Reading g | Loaded Reading g |
|---|---|---|
| 3000 | 0.0 | 2999.95 |
| | 0.0 | 2999.95 |
| | 0.0 | 2999.94 |
| | 0.0 | 2999.95 |
| | 0.0 | 2999.95 |

## Eccentricity Test




| Position | g | Loaded Reading |
|---|---|---|
| A | 2000 | 1999.93 |
| B | | 1999.90 |
| C | | 1999.90 |
| D | | 1999.90 |
| E | | 1999.92 |
| A | | 1999.93 |

| Uncertinity Of Measurement | ± | 0.04 g |
|---|---|---|

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Tel: +970-(0)2-2984144\2965191 Fax:(0)2-2964433 info@psi.pna.ps www.psi.pna.ps

# Chapter 4: The Experiments

## 4.1 Introduction

To produce high quality, we need to adjust the ambient conditions of the scale. The ambient conditions depend on three basic variables: temperature, atmospheric pressure, and humidity. In addition, the scale should be placed on a stable surface away from air fluctuations that affect the reading of the scale.

In these experiments, we will explain how these conditions affect the non-automatic balance reading devices, how the temperature change during the calibration process can significantly affect and how these conditions have a decisive influence on the measurement results and on the uncertainty value.

## 4.2 Ambient Condition

I made standard conditions according to 17025, where the ambient conditions were as follows:

1) Temperature approx.: - 20°
2) Humidity approx.: - 50 %
3) Barometric Pressure approx.: - 915 m bar

And I created non-standard conditions, where the ambient conditions were as follows:

1) Temperature approx.: - 30°
2) Humidity approx.: - 40 %
3) Barometric Pressure approx.: - 918 m bar

It is worth noting that the relationship between the three environmental conditions is the density of air, as in the equation (3.2-4)

### 4.3 Classification Of Instruments [4]

The verification scale interval, number of verification scale intervals and the minimum capacity, in relation to the accuracy class of an instrument, are given in Table

Table 2 Accuaracy instrument

| **Accuracy class** | **Verification scale interval, e** | **Number of verificationscale intervals, *n* = Max/*e*** | | **Minimum capacity, Min (Lower limit)** |
|---|---|---|---|---|
| | | minimum | maximum | |
| Special (I) | 0.001 g ≤ e* | 50 000** | – | 100 *e* |
| High (II) | 0.001 g ≤ **e** ≤ 0.05 g<br>0.1 g ≤ **e** | 100<br>5 000 | 100 000<br>100 000 | 20 *e*<br>50 *e* |
| Medium (III) | 0.l g ≤ **e** ≤ 2 g<br>5 g ≤ **e** | 100<br>500 | 10 000<br>10 000 | 20 *e*<br>20 *e* |
| Ordinary (III) | 5 g ≤ **e** | 100 | 1 000 | 10 *e* |

## 4.4 Chose set of weights to calibration scales [4]

Recommendation for the selection of weight classes -It is recommended selecting the weights in order to minimize their uncertainty contribution to the balance uncertainty as far reasonably possible so that user tolerance requirements are met.

The following selection criteria for weight classes could be considered:

1. 1 000 000 < $\frac{Max}{d}$ : selection an OIML $E_2$ or ASTM Class 1 weight, or a a weight with uncertanity not wors than the permitted OIML $E_2$ or ASTM Class 1 uncertainty, which is one- third or less of the maximum permissible error; it is recommended to always use the conventional mass value as the referance value.

2. 150 000 < $\frac{Max}{d}$ ≤ 1 000 000 for aweight where the nominal value is used as the referance value select an OIML $F_1$ or ASTM Class 2 weight or better for a weight where the conventional mass value is useas the reference value select an OIML $F_2$ or ASTM Class 4 weight or better.

3. 15 000 < $\frac{Max}{d}$ ≤ 150 000 for aweight where the nominal value is used as the referance value select an OIML $F_2$ or ASTM Class 4 weight or better for a weight where the conventional mass value is use as the reference value select an OIML $M_1$ or ASTM Class 5 weight or better .

4. $\frac{Max}{d}$ ≤ 15 000 for aweight where the nominal value is used as the referance value select an OIML $M_1$ or ASTM Class 5 weight or better for a weight where the conventional mass value is use as the reference value select an OIML $M_2$ or ASTM Class 6 weight or better.

5. For multi-interval and multi range balance, Max and (d) refer to the interval/range with the smallest scale interval, abbreviated as $Max_1$ and$d_1$, respectively.

## 4.5 Balance Setting

It is very important, before commencing the measurement or calibration process, that the scale is positioned appropriately to the conditions of the room in which it is located.

The balancing site must be stable and free from vibration. In the event of such disturbances, the scale should be placed on a table with legs that are anti-vibration and not affected by movement around the table, preferably made of marble.

Some non-automatic scales are affected by the magnetic field, so it is worth noting that it should be kept away from the fluctuations of the magnetic field, as the effect of the magnetic field is shown by reading the scale index in terms of the measured quantity increase or decrease.

It should be noted that one of the most important things that must be taken into account is the air current, as the exposure of the scale to the air current makes it not give a correct reading.

It is very important that when performing the scale calibration process at the work site, knowing that if the scale is moved from the work site after the calibration process, the calibration is considered invalid for several reasons, including:

1. The probability of the difference in the acceleration due to gravity.
2. Variation in environmental conditions.
3. Mechanical and balanced conditions and the possibility of scale damage due to transportation.

Therefore, it is better not to move the scale from its position after the calibration process

## 4.6 Create Standard Conditions

It is known that each factory has a laboratory dedicated to tests and experiments. Therefore, there are standard conditions for these laboratories. One of the most important international standards they rely on is ISO 17025, which is specialized in everything related to testing laboratories.

The laboratory supervising the production or construction process must take into account the standard and operating conditions on the production line to produce a defect-free product. Therefore, it is recommended to adjust the scale at the beginning of production and monitor the products during the day, because the scale is affected by ambient conditions of temperature, pressure and humidity due to the operational conditions of the factory.

## 4.7 Variations Of Parameters Constituting The Air Density [1]

### 4.7.1 Barometric Pressure:

The average barometric pressure $P(h_{SL})$ may be estimated from the altitude $h_{SL}$ in metre above sea level of the location, using the relation

$$P(h_{SL}) = P(h_0) - h_{SL} * \left(0.12 \frac{hPa}{m}\right)$$

With $P(h_0) = 1013.12\ hPa$

At any given location, the variations at most $\Delta$ p = ± 40 hPa about the average Within these limits, the distribution is not rectangular as extreme values do occur only once in several years. It is more realistic to assume a normal distribution, with $\Delta$ p being the "$2\sigma$" or even the "$3\sigma$ ". Hence

u( $\Delta$ p) = 20 hPa (for k = 2) or u( $\Delta$ p) = 13,3 hPa (for k = 3)

### 4.7.2 Temperature

The possible variation max min $\Delta T = T_{max} - T_{min}$ of the temperature at the place of use of the instrument may be estimated from information which is easy to obtain:

limits stated by the client from his experience, reading from suitable recording means, setting of the control instrument, where the room is acclimatized or temperature stabilized; in case of default sound judgement should be applied, leading to –e.g.

17 °C ≤ t ≤ 27 °C for closed office or laboratory rooms with windows,

$\Delta t$ ≤ 5 K for closed rooms without windows in the centre of a building,

- 10 °C ≤ t ≤ + 30 °C or t ≤ + 40 °C for open workshops or factory halls.

As has been said for the barometric pressure, a rectangular distribution is unlikely to occur for open workshops or factory halls where the atmospheric temperature prevails. However, to avoid different assumptions for different room situations, the assumption of rectangular distribution is recommended, leading to

$$u(\Delta T) = \Delta T/12$$

### 4.7.3 Relative Humidity

The possible variation max min $\Delta h = h_{max} - h_{min}$ of the relative humidity at the place of use of the instrument may be estimated from information which is easy to obtain: limits stated by the client from his experience, reading from suitable recording means, setting of the control instrument, where the room is acclimatized; in case of default, sound judgement should be applied, leading, for example, to 30 % ≤ h ≤ 80 % for closed office or laboratory rooms with windows, $\Delta h$ ≤ 30 % for closed rooms without windows in the centre of a building, 20 % ≤ h ≤ 80 % for open workshops or factory halls.

It should be kept in mind that at h < 40 % electrostatic effects may already influence the weighing result on high resolution instruments, at h > 60 % corrosion may begin to occur.

As has been said for the barometric pressure, a rectangular distribution is unlikely to occur for open workshops or factory halls where the atmospheric relative humidity prevails. However, to avoid different assumptions for different room situations, the assumption of rectangular distribution is recommended, leading to

$$u(\Delta h) = \Delta h/12$$

We also defined at the beginning of the research the value of uncertainty, namely:

The uncertainty or doubt value in the measurement process is a value that is calculated using mathematical equations, because it comes after the calibration process, it is calculated from the values taken from the calibration process, and depends mainly on the frequency error of the measuring instrument and the uncertainty value of the reference device.

Nevertheless, it should be clear to quality supervisor or the production line officer that the uncertainty value is not related to the error value; the uncertainty value actually depends on the repeatability test, and depends on the scale analysis and calibration reference mass, while the error is caused by several reasons.

It is known that the measurements are made in standard conditions defined by international specifications to read the best measured value with the least error.

There may be some errors during the measurement process and these errors can be categorized into three main errors:

I. Systematic errors: these errors can be expected and determined, but it is not necessary to know these errors with high accuracy, among these systemic errors are:
   1) Errors caused by a measuring device or instrument.
   2) Errors caused by the measuring technician.
   3) Errors caused by the conditions surrounding the measuring device.
   4) Errors caused by the measurement mechanism.

II. Random errors: these are errors that cannot be expected or eliminated. The measurement value spins around the true value, and the total error consists of several sources, including:
   1) Variations in the position of the scale.
   2) Variables in the environmental conditions surrounding the device.
   3) The displacement ratio of the measuring instrument.
   4) Errors caused by the measuring technician.
   5) Errors caused by vibrations that can be associated with the measuring instrument.

III. Compound errors: these are errors that consist of systematic and random errors.

## 3.6 Non-Scale Specifications

In this section, we will discuss how the experiments were done and entered into the uncertainty calculation program (Adam scale 6 kg for example) :-

First of all, you must know the capacity of the non-automatic scale and the Resolution to test the set of weight mass suitable for the calibration process.

Capacity = 6000 g

Resolution = 0.01 g

I. Since we have the capacity of the scale and the value of the resolution, according to the following equation, we can choose the appropriate set of weight mass.

$$\frac{Max}{d} = \frac{6000}{0.01} = 600\ 000$$

600 000 as per ASTM E898 located between 150 000 < $\frac{Max}{d}$ ≤ 1 000 000 So here we choose the set of weight mass (F1)

## 3.7 Enter The Data Into The Uncertainty Value Calculation Program

We enter client data and calibration date, then we start with the next steps to calculate the uncertainty value using Excel: -

1. Enter the instrument information on the data cover sheet

| 1. Instrumunt Information | | | | | |
|---|---|---|---|---|---|
| Instrumen | Digital Balance | | | Units of Measure | g |
| Model | STB6202C | | | Scale Class | II |
| Manufactu | ADAM | | | Resiluation | 0.01 g |
| serial No. | AEAA039 | | | Location | Pressuer Lab. |
| Range | 0.00 | 6200 | g | Condition | Standard |

2.Enter The Ambient Condition

| 2. The Ambient Condition | | | |
|---|---|---|---|
| | | Star | End |
| Temperature | (°C ) | 19.8 | 20.2 |
| Humidity | ( % ) | 54.3 | 49.9 |
| Pressure | (mbar) | 915.7 | 915.5 |

2. As the next step, we go to the data entry sheet and choose the appropriate set of weight mass.

| Nominal Load | Msss | Set of weights Class F1 | | | |
|---|---|---|---|---|---|
| | Mass 1 | Mass 2 | Mass 3 | Mass 4 | Mass 5 |
| g | | | | | |
| 0 | 0.000 | 0.00 | 0.00 | | |
| 10 | 10.00 | | | | |
| 50 | 50.00 | | | | |
| 200 | 200.00 | | | | |
| 500 | 500.00 | | | | |
| 1000 | 1000.00 | | | | |
| 1500 | 1000.00 | 500.00 | | | |
| 2000 | 2000.00 | | | | |
| 4000 | 2000.00 | * 2000 | | | |
| 4500 | * 2000 | 2000.00 | 500.00 | | |
| 5000 | 2000.00 | * 2000 | 1000.00 | | |
| 6200 | 5000.00 | 1000.00 | 200.00 | | |

| Nominal Load | Indicated Reading | | Avg. Reading | Error |
|---|---|---|---|---|
| | UP | Down | | |
| g | | | | |
| 0.0 | 0.00 | 0.00 | 0.0 | 0.0 |
| 10.0 | 10.00 | 10.01 | 10.01 | -0.01 |
| 50.0 | 50.01 | 50.01 | 50.01 | -0.01 |
| 200.0 | 200.02 | 200.01 | 200.02 | -0.01 |
| 500.0 | 500.03 | 500.02 | 500.03 | -0.03 |
| 1000.0 | 1000.07 | 1000.00 | 1000.04 | -0.03 |
| 1500.0 | 1500.10 | 1500.09 | 1500.10 | -0.09 |
| 2000.0 | 2000.15 | 2000.13 | 2000.14 | -0.13 |
| 4000.0 | 4000.29 | 4000.27 | 4000.28 | -0.29 |
| 4500.0 | 4500.29 | 4500.27 | 4500.28 | -0.29 |
| 5000.0 | 5000.34 | 5000.31 | 5000.33 | -0.33 |
| 6200.0 | 6200.37 | 6200.33 | 6200.35 | -0.38 |

3. Then we start calibrating the scale using the reference mass so that it includes the capacity of the scale .Where the data is entered into the indicator reading list, and the linear examination process is carried out, ascending (UP) and descending (Down).

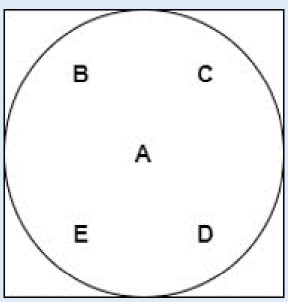
   - Note: - the resulting error is the difference between average reading and conventional mass from mass reference.

| Data cover | Data Entry | Equations | Mass Reference | Certificate Cover | Certificate Results | Chart |
|---|---|---|---|---|---|---|

4. Then we perform a repeatability test, as the mass used in the repeatability test is half the maximum load or more and the test is repeated 5 times for the same mass.

| Nominal Load | Unloaded Reading | Indicated Reading |
| --- | --- | --- |
| g | | g |
| | 0.00 | 3000.15 |
| | 0.00 | 3000.11 |
| 3000 | 0.00 | 3000.13 |
| | 0.00 | 3000.14 |
| | 0.00 | 3000.12 |

5. Then we conduct an Eccentricity test, where the centers, and the load is one third of the scale capacity As per the picture shown below.




| Position | Load | Reading |
| --- | --- | --- |
| | g | g |
| A | | 2000.09 |
| B | | 2000.06 |
| C | 2000 | 2000.07 |
| D | | 2000.10 |
| E | | 2000.06 |
| A | | 2000.09 |

**Then the** results will appear on the certificate results sheet

Where the certificate shows the results:

I. Linearity Test.

II. Repeatability Test

III. Eccentricity Test

IV. Uncertainty of measurement

| | | | |
| --- | --- | --- | --- |
| Uncertinity Of Measurement | ± | 0.08 | g |

## 3.8 The Result

### ADAM Balance 6000 g

- **Linearly Test**

  A number of measurements to test the error of the scale

Table2 Linearty Test

| Standard Condition | | |
|---|---|---|
| **Applied Load (g)** | **Indicated Reading (g)** | **Error (g)** |
| 0 | 0.00 | 0.00 |
| 10.00 | 10.01 | -0.01 |
| 50.00 | 50.01 | -0.01 |
| 200.00 | 200.02 | -0.01 |
| 500.00 | 500.03 | -0.03 |
| 1000.00 | 1000.04 | -0.03 |
| 1500.00 | 1500.10 | -0.09 |
| 2000.00 | 2000.14 | -0.13 |
| 4000.00 | 4000.28 | -0.29 |
| 4500.00 | 4500.27 | -0.29 |
| 5000.00 | 5000.33 | -0.33 |
| 6200.00 | 6200.35 | -0.38 |

| Non -Standard Condition | | |
|---|---|---|
| **Applied Load (g)** | **Indicated Reading (g)** | **Error (g)** |
| 0 | 0.00 | 0.00 |
| 10.00 | 10.00 | 0.00 |
| 50.00 | 50.00 | 0.00 |
| 200.00 | 200.00 | 0.00 |
| 500.00 | 499.99 | 0.01 |
| 1000.00 | 1000.00 | 0.01 |
| 1500.00 | 1500.01 | 0.00 |
| 2000.00 | 2000.05 | -0.03 |
| 4000.00 | 4000.15 | -0.15 |
| 4500.00 | 4500.18 | -0.19 |
| 5000.00 | 5000.21 | -0.21 |
| 6200.00 | 6200.29 | -0.31 |

- ## Reputability Test

The test consists of the repeated deposition of the same load on the load receptor, under identical conditions of handling the load and the instrument, and under constant test conditions.

Table 3 Repatability Test

| Standard Condition | | |
|---|---|---|
| **Applied Load (g)** | **Unloaded Reading g** | **Loaded Reading g** |
| **3000** | **0.0** | **3000.15** |
| | **0.0** | **3000.11** |
| | **0.0** | **3000.13** |
| | **0.0** | **3000.14** |
| | **0.0** | **3000.12** |

| Non -Standard Condition | | |
|---|---|---|
| **Applied Load (g)** | **Unloaded Reading g** | **Loaded Reading g** |
| **3000** | **0.0** | **2999.95** |
| | **0.0** | **2999.95** |
| | **0.0** | **2999.94** |
| | **0.0** | **2999.95** |
| | **0.0** | **2999.95** |

- ## Eccentricity Test

The test comprises placing a test load $L_{ecc}$ in different positions on the load receptor in such a manner that the center of gravity of the applied load takes the positions as indicated in Figure 1 or equivalent positions, as closely as possible.

Table 4 Eccentricity Test

| Standard Condition | | |
|---|---|---|
| **Position** | **g** | **Loaded Reading** |
| **A** | **2000** | **2000.09** |
| **B** | | **2000.06** |
| **C** | | **2000.07** |
| **D** | | **2000.10** |
| **E** | | **2000.06** |
| **A** | | **2000.09** |

| Non -Standard Condition | | |
|---|---|---|
| **Position** | **g** | **Loaded Reading** |
| **A** | **2000** | **1999.93** |
| **B** | | **1999.90** |
| **C** | | **1999.90** |
| **D** | | **1999.90** |
| **E** | | **1999.92** |
| **A** | | **1999.93** |

- **Uncertainty Of Measurement**

Uncertainty here is the value of the doubt resulting from the calibration process

Table 5 Uncertinity Of Measurment

| Standard Condition | | |
|---|---|---|
| **Uncertainty Of Measurement** | ± | **0.08 g** |

| Non -Standard Condition | | |
|---|---|---|
| **Uncertainty Of Measurement** | ± | **0.02 g** |

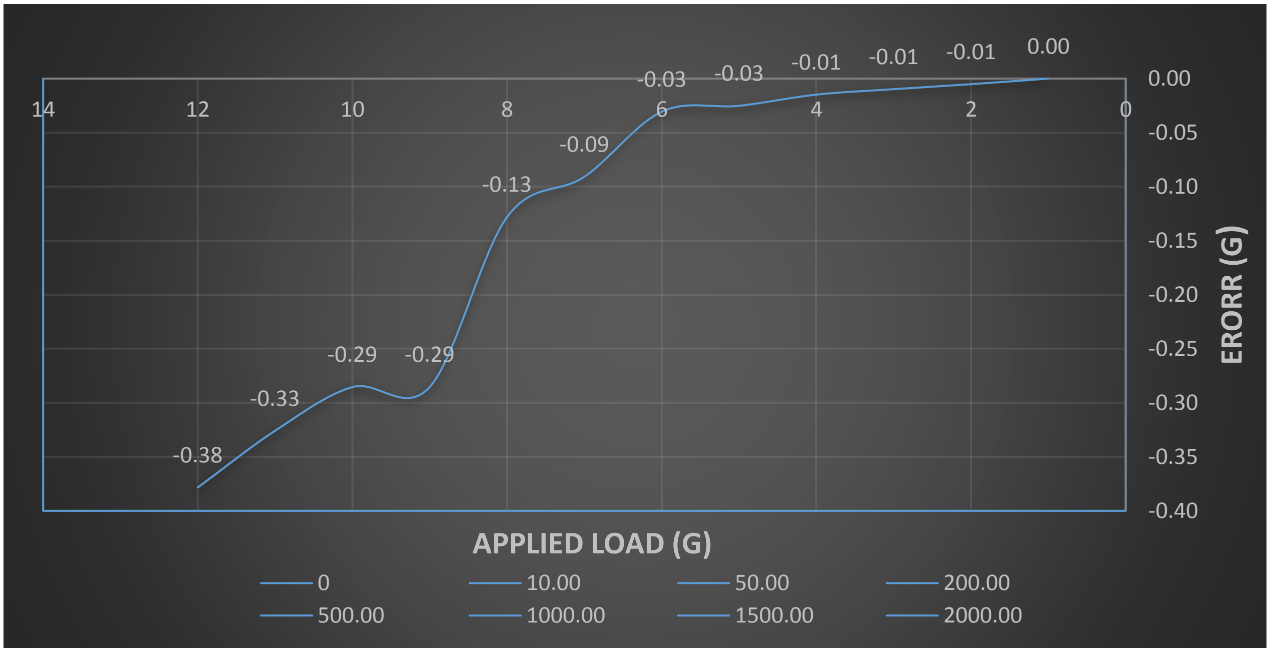



Figure 2 ADAM Balance 6000 g (Standard Condition)

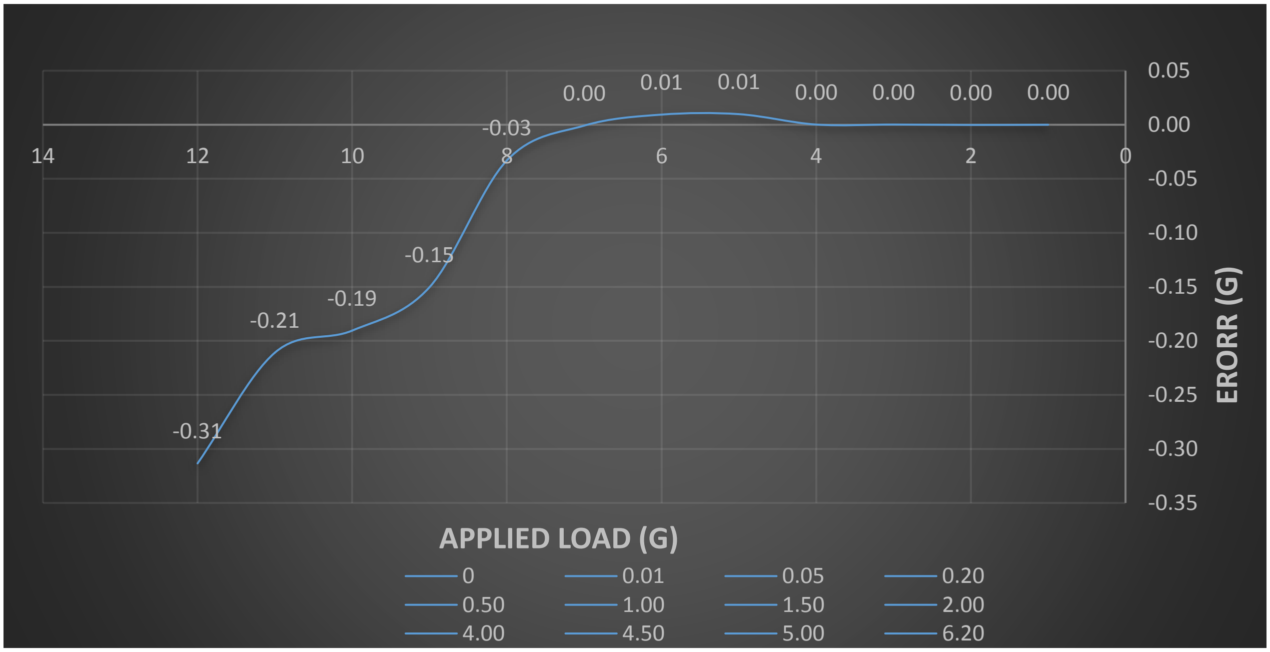



Figure 3 ADAM Balance 6000 g (Non -Standard Condition)

As we note in the two figures 2 & 3, there is no significant difference in the error and this confirms that the operational conditions of the scale do not differ still under the operational conditions.

# Chapter 5: Summary and Discussion

## 5.1 Common Sources of Uncertainty:

- **Source from under Test**

**I. Repeatability**

Repeatability or test–retest reliability is the closeness of the agreement between the results of successive measurements of the same measure, when carried out under the same conditions of measurement. In other words, the measurements are taken by a single person or instrument on the same item, under the same conditions, and in a short period of time. A less-than-perfect test–retest reliability causes test–retest variability. Such variability can be caused by, for example, intra-individual variability and inter-observer variability. A measurement may be said to be repeatable when this variation is smaller than a pre-determined acceptance criterion.

**II. Hysteresis**

It is the dispersion in the value of the error that we have as a result of the tests that have been done, where you can see the error in negative and positive

**III. Resolution**

Resolution: The smallest increment an instrument can detect and display—hundredths, thousandths, millionths. Range: The upper and lower limits an instrument can measure a value or signal.

As we have noted the presence of the value of Resolution m in many equations, as it has an impact on the value of uncertainty, where the greater the Resolution, the greater the result of the uncertainty.

Resolution is one of the most important things that must be taken into account when choosing a balance for the factory or laboratory, according to the product that is manufactured.

As for the calibration, it is what determines the set of weights that is suitable for the calibration process

- **Source from Standard**

**I. Standard**

Specifications are one of the most important things involved in finding the uncertainty value. When calibrating the process, the following must be determined:

1. Classification of Instruments
2. Non-Scale Resolution
3. Non-Scale Capacity

**II. Uncorrected error**

It is the unintended error that can happen, for example, during the installation or transportation process, or the scale may be affected by a high temperature that led to a malfunction in one of the sensors.

**III. Drift of Standard**

Drift is a measurement error caused by the gradual shift in a gauge's measured values over time. Although incorrect handling can accelerate it, nearly all measuring instruments will experience drift during their lifetime. If left unchecked, this shift can cause extensive measuring errors, safety hazards, and quality issues.

The changes over the time period can be found through an equation The relative adjustment.

## 4.8 Future Work

In fact, many different adaptations, tests, and experiments have been left for the future due to lack of time, There are some ideas that I would have liked to try during the description, This research focused mainly on the effect of the conditions surrounding the non-automatic scale (temperature, humidity and atmospheric pressure), but there are some things that can affect the uncertainty value, such as the vibration surrounding the non-automatic scale, especially in concrete factories and construction factories, due to the lack of a reference instrument with a calibration certificate that measures the percentage of Vibration and oscillations in place.

In addition, I need to search and delve deeper into the derivation of the equations of vibrations to obtain an equation used to find the uncertainty value.

## 4.9 Conclusion

Experiments have been conducted on five different non-automatic scales with standard and non-standard conditions, and through the experiments, it was found that since the environmental conditions are proportional to the operational conditions of the scale according to (Oiml R-76) according to the clause (3.9.2.1), which states:

“If a particular working temperature is not specified in the descriptive tags of an apparatus, that apparatus shall maintain its metrological properties within the following temperature limits” [5]:

- 10°C / +40°C

In reality, the temperatures should not change as stipulated in Clause (3.9.2.3), which states:

“The indication at zero or near zero shall not vary by more than one verification scale interval for a difference in ambient temperature of 1 °C for instruments of class.” I and 5 °C for other classes”.

For multi-interval instruments and for multiple range instruments this applies to the smallest verification scale interval of the instrument [5]“.

It is noticeable in my experiments that I found the error is almost constant in both cases, while the uncertainty value changes if the temperature and humidity change during the measurement process; it is very important to keep close intervals to check the temperature during the production process.

Therefore, we conclude from this research that a constant temperature must be maintained on the production line in order not to deviate in the production process and to maintain product quality.

In the end, the measurement process must take skepticism into account, no matter how much the error, so in order to avoid production errors and obtain a high-quality product.

And, to obtain a good result in the measurement, the uncertainty value must be added in the production processes, but on condition that the appropriate standard conditions are maintained, and that the scale used is commensurate with the nature of the work based on the resolution

The search was done based on the reported expanded uncertainty of measurement is in accordance with a Guidelines on the Calibration of non-Automatic Weighing Instruments - Version 4.0 (11/2011).

Then I verified the equations through one general equation that includes all the variables from the reference (Bentley, J. P. (2005). Principles of measurement systems. Pearson education.)

## <u>The Final Result: -</u>

We note that the equations used in both references can be used to calculate the uncertainty of non-automatic scales, we also note that we can use the second equation (3.6) to find the uncertainty of any measurement process (such as thermometers, dimensional measuring tools, pressure gauges, etc.).

# Reference

[1] EURAMENT, "Guidelines on the calibration of non-Automatic Weighing Instruments," cg-18/ Version 3.0 , (03/2011).

[2] OIML. R111, ", Weights of Classes E1, E2, F1, F2, M1, M1-2, M2, M2-3, M3,," Edition , 2004.

[3] J. JCGM, " Evaluation of measurement data—Guide to the expression of uncertainty in measurement.," ISBN 50 (): 134., Int. Organ. Stand. Geneva , 2008.

[4] ASTM E898.

[5] " "OIML R 76-1."," *Internationale, Organisation, and OF LEGAL METROLOGY*.

[6] Bentley, J. P. (2005). Principles of measurement systems. Pearson education.)

# Appendix A: Experiments

## A.1 ADAM 6 kg (non-Standard)

مؤسسة المواصفات والمقاييس الفلسطينية- مديرية القياس الوطني

**Palestine Standards Institution – Metrology Directorate**

CERTIFICATE OF CALIBRATION

| Certificate No. | B002 |
|---|---|

| | | | |
|---|---|---|---|
| Date of calibration | 13.06.2021 | | |
| Date of issue | 19.06.2021 | | |
| Client | PSI | Address | Ramallah |

**Instrumunt Information**

| | | | | | |
|---|---|---|---|---|---|
| Instrument | Digital Balance | | | Units of Measure | g |
| Model | STB6202C | | | Scale Class | II |
| Manufacturing | ADAM | | | Resiluation | 0.01 g |
| serial No. | AEAA039 | | | Location | Pressuer Lab. |
| Range | 0.00 | 6200 | g | Condition | Non-Standard |

**The Ambient Condition**

| | Star | End |
|---|---|---|
| Temperature ( °C ) | 30.0 | 30.3 |
| Humidity ( % ) | 32.2 | 36.0 |
| Barometric Pressure (mbar) | 918.0 | 918.6 |

**Referance Instrument**

| Instrument | Serial No. | Cert. No. |
|---|---|---|
| Set of weights Class F1 | 254145 | M 214560 |

**Summery Of Calibration Method**

Calibrated measuring device by reference mass based on the classification of the balance

**Calibration Standerd**

Calibration process performed acording to OIML R 76-1

The reported expanded uncertainty of measurement is in accordance with a Guidelines on the Calibration of non-Automatic Weighing Instruments - Version 4.0 (11/2015)

Uncertinity of measuerment multiplied by the coverage factor k=2 for rectangulare disribuation it corresponds coverage probability of approximtily 95 %

| Calibrated By | Muhannad Azmouti |
|---|---|

PAGE 1 OF 2 PAGES

Ramallah–Almasyoun–AL Quds Build.P O Box 2258 رام الله، الماصيون، مبنى القدس ص ب
Tel: +970-(0)2-2984144\2965191 Fax:(0)2-2964433 info@psi.pna.ps www.psi.pna.ps

CERTIFICATE OF CALIBRATION

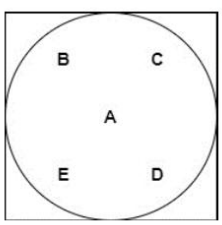
## Linerity Test

| Nominal Load (g) | Indicated Reading (g) | Error (g) |
|---|---|---|
| 0 | 0.00 | 0.00 |
| 10.00 | 10.01 | -0.01 |
| 50.00 | 50.01 | -0.01 |
| 200.00 | 200.02 | -0.01 |
| 500.00 | 500.03 | -0.03 |
| 1000.00 | 1000.04 | -0.03 |
| 1500.00 | 1500.10 | -0.09 |
| 2000.00 | 2000.14 | -0.13 |
| 4000.00 | 4000.28 | -0.29 |
| 4500.00 | 4500.27 | -0.29 |
| 5000.00 | 5000.33 | -0.33 |
| 6200.00 | 6200.35 | -0.38 |

## Repetability Test

| Nominal Load g | Unloaded Reading g | Loaded Reading g |
|---|---|---|
| 3000 | 0.0 | 3000.15 |
| | 0.0 | 3000.11 |
| | 0.0 | 3000.13 |
| | 0.0 | 3000.14 |
| | 0.0 | 3000.12 |

## Eccentricity Test




| Position | g | Loaded Reading |
|---|---|---|
| A | 2000 | 2000.09 |
| B | | 2000.06 |
| C | | 2000.07 |
| D | | 2000.10 |
| E | | 2000.06 |
| A | | 2000.09 |

| Uncertinity Of Measurement | ± | 0.08 g |
|---|---|---|

PAGE 2 OF 2 PAGES

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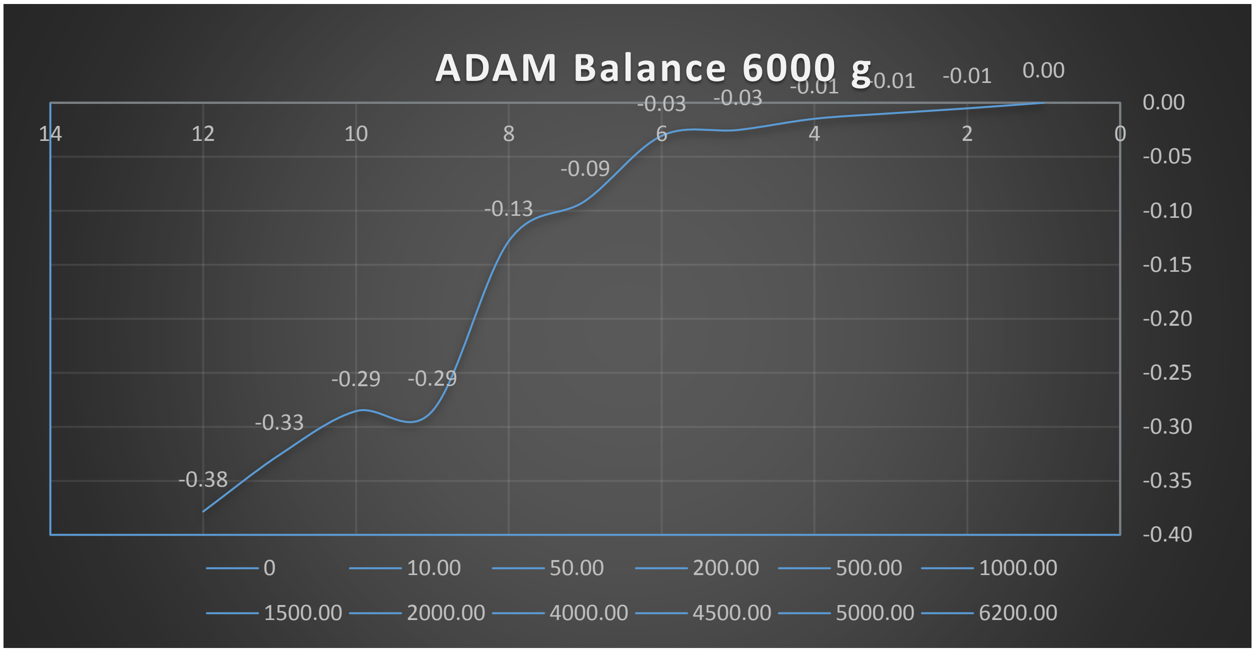
ADAM Balance 6000 g
-0.38
-0.33
-0.29
-0.29
-0.13
-0.09
-0.03
-0.03
-0.01
-0.01
-0.01
0.00
14
12
10
8
6
4
2
0
0.00
-0.05
-0.10
-0.15
-0.20
-0.25
-0.30
-0.35
-0.40
0
10.00
50.00
200.00
500.00
1000.00
1500.00
2000.00
4000.00
4500.00
5000.00
6200.00

## A.2 ADAM 6 kg (Standard)

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**Palestine Standards Institution – Metrology Directorate**

CERTIFICATE OF CALIBRATION

| Certificate No. | B001 |
|---|---|

| | | | |
|---|---|---|---|
| Date of calibration | 06.06.2021 | | |
| Date of issue | 12.06.2021 | | |
| Client | PSI | Address | Ramallah |

**Instrumunt Information**

| | | | | | |
|---|---|---|---|---|---|
| Instrument | Digital Balance | | | Units of Measure | g |
| Model | STB6202C | | | Scale Class | II |
| Manufacturing | ADAM | | | Resiluation | 0.01 g |
| serial No. | AEAA039 | | | Location | Pressuer Lab. |
| Range | 0.00 | 6200 | g | Condition | Standard |

**The Ambient Condition**

| | Star | End |
|---|---|---|
| Temperature ( °C ) | 19.8 | 20.2 |
| Humidity ( % ) | 54.3 | 49.9 |
| Barometric Pressure (mbar) | 915.7 | 915.5 |

**Referance Instrument**

| Instrument | Serial No. | Cert. No. |
|---|---|---|
| Set of weights Class F1 | 254145 | M 214560 |

**Summery Of Calibration Method**

Calibrated measuring device by reference mass based on the classification of the balance

**Calibration Standerd**

Calibration process performed acording to OIML R 76-1

The reported expanded uncertainty of measurement is in accordance with a Guidelines on the Calibration of non-Automatic Weighing Instruments - Version 4.0 (11/2015)

Uncertinity of measuerment multiplied by the coverage factor k=2 for rectangulare disribuation it corresponds coverage probability of approximtily 95 %

| Calibrated By | Muhannad Azmouti |
|---|---|

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# CERTIFICATE OF CALIBRATION

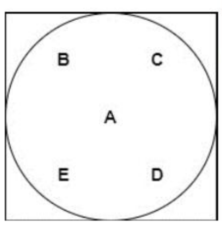
## Linerity Test

| Applied Load (g) | Indicated Reading (g) | Error (g) |
|---|---|---|
| 0 | 0.00 | 0.00 |
| 10.00 | 10.00 | 0.00 |
| 50.00 | 50.00 | 0.00 |
| 200.00 | 200.00 | 0.00 |
| 500.00 | 499.99 | 0.01 |
| 1000.00 | 1000.00 | 0.01 |
| 1500.00 | 1500.01 | 0.00 |
| 2000.00 | 2000.05 | -0.03 |
| 4000.00 | 4000.15 | -0.15 |
| 4500.00 | 4500.18 | -0.19 |
| 5000.00 | 5000.21 | -0.21 |
| 6200.00 | 6200.29 | -0.31 |

## Repetability Test

| Applied Load g | Unloaded Reading g | Loaded Reading g |
|---|---|---|
| 3000 | 0.0 | 2999.95 |
| | 0.0 | 2999.95 |
| | 0.0 | 2999.94 |
| | 0.0 | 2999.95 |
| | 0.0 | 2999.95 |

## Eccentricity Test




| Position | g | Loaded Reading |
|---|---|---|
| A | 2000 | 1999.93 |
| B | | 1999.90 |
| C | | 1999.90 |
| D | | 1999.90 |
| E | | 1999.92 |
| A | | 1999.93 |

| Uncertinity Of Measurement | ± | 0.02 g |
|---|---|---|

PAGE 2 OF 2 PAGES

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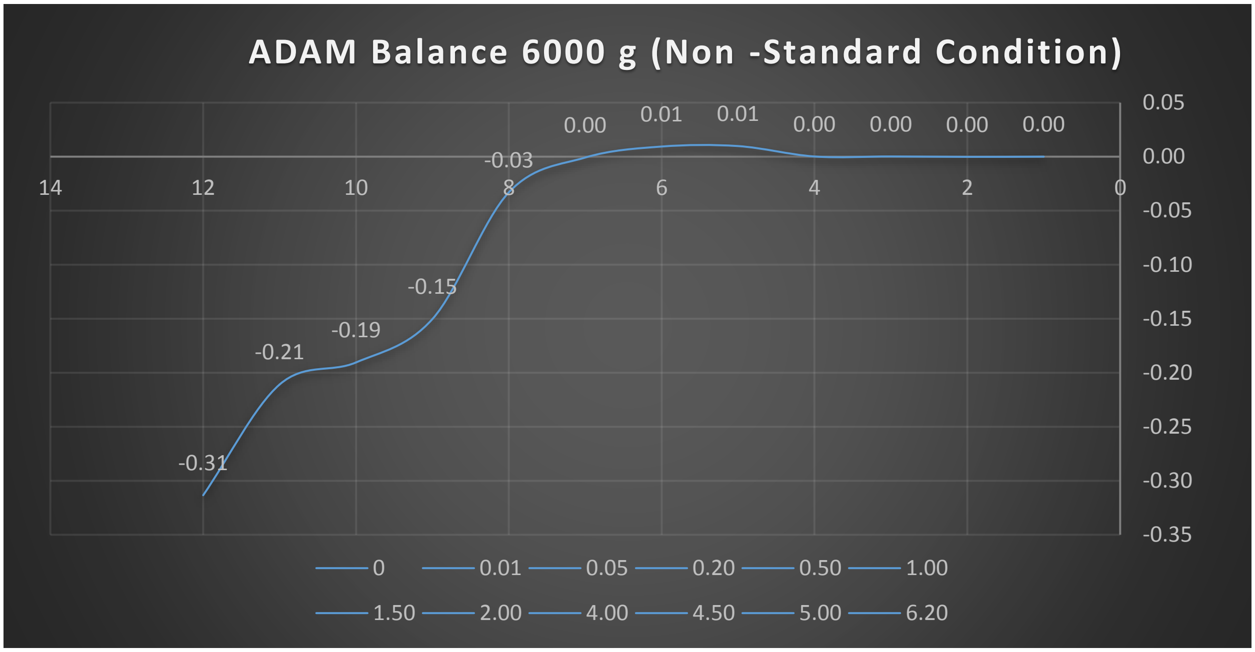
ADAM Balance 6000 g (Non -Standard Condition)
0.00
0.01
0.01
0.00
0.00
0.00
0.00
-0.03
-0.15
-0.19
-0.21
-0.31
14
12
10
8
6
4
2
0
0.05
0.00
-0.05
-0.10
-0.15
-0.20
-0.25
-0.30
-0.35
0
0.01
0.05
0.20
0.50
1.00
1.50
2.00
4.00
4.50
5.00
6.20

## A.3 ADAM 30 (non-Standard)

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**Palestine Standards Institution – Metrology Directorate**

CERTIFICATE OF CALIBRATION

| Certificate No. | B004 |
|---|---|

| | | | |
|---|---|---|---|
| Date of calibration | 10.06.2021 | | |
| Date of issue | 19.06.2021 | | |
| Client | PSI | Address | Ramallah |

**Instrumunt Information**

| | | | | | |
|---|---|---|---|---|---|
| Instrument | Digital Balance | | | Units of Measure | g |
| Model | STB30002C | | | Scale Class | III |
| Manufacturing | ADAM | | | Resiluation | 0.1 g |
| serial No. | AEAA041 | | | Location | Pressuer Lab. |
| Range | 0.00 | 30000 | g | Condition | Non-Standard |

**The Ambient Condition**

| | Star | End |
|---|---|---|
| Temperature ( °C ) | 30.5 | 30.3 |
| Humidity ( % ) | 35.1 | 42.0 |
| Barometric Pressure (mbar) | 918.6 | 918.0 |

**Referance Instrument**

| Instrument | Serial No. | Cert. No. |
|---|---|---|
| Set of weights Class M1 | 1831012 | W0140417 |

**Summery Of Calibration Method**

Calibrated measuring device by reference mass based on the classification of the balance

**Calibration Standerd**

Calibration process performed acording to OIML R 76-1

The reported expanded uncertainty of measurement is in accordance with a Guidelines on the Calibration of non-Automatic Weighing Instruments - Version 4.0 (11/2015)

Uncertinity of measuerment multiplied by the coverage factor k=2 for rectangulare disribuation it corresponds coverage probability of approximtily 95 %

| Calibrated By | Muhannad Azmouti |
|---|---|

PAGE 1 OF 2 PAGES

Ramallah–Almasyoun–AL Quds Build.P O Box 2258 رام الله، الماصيون، مبنى القدس ص ب
Tel: +970-(0)2-2984144\2965191 Fax:(0)2-2964433 info@psi.pna.ps www.psi.pna.ps

CERTIFICATE OF CALIBRATION

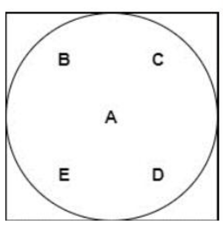
## Linerity Test

| Nominal Load (g) | Indicated Reading (g) | Error (g) |
|---|---|---|
| 0 | 0.00 | 0.00 |
| 500.00 | 500.00 | 0.01 |
| 1000.00 | 999.95 | 0.06 |
| 1500.00 | 1499.95 | 0.07 |
| 2000.00 | 1999.85 | 0.17 |
| 2500.00 | 2499.85 | 0.18 |
| 3000.00 | 3000.05 | -0.02 |
| 5000.00 | 4999.90 | 0.12 |
| 10000.00 | 9999.75 | 0.41 |
| 15000.00 | 14999.20 | 0.98 |
| 20000.00 | 19999.20 | 1.07 |
| 29000.00 | 28998.10 | 2.22 |

## Repetability Test

| Nominal Load g | Unloaded Reading g | Loaded Reading g |
|---|---|---|
| 15000 | 0.0 | 14999.40 |
| | 0.0 | 14999.40 |
| | 0.0 | 14999.40 |
| | 0.0 | 14999.20 |
| | 0.0 | 14999.30 |

## Eccentricity Test




| Position | g | Loaded Reading |
|---|---|---|
| A | 10000 | 9999.80 |
| B | | 9999.20 |
| C | | 10000.40 |
| D | | 10000.00 |
| E | | 10000.10 |
| A | | 9999.90 |

| Uncertinity Of Measurement | ± | 0.45 g |
|---|---|---|

PAGE 2 OF 2 PAGES

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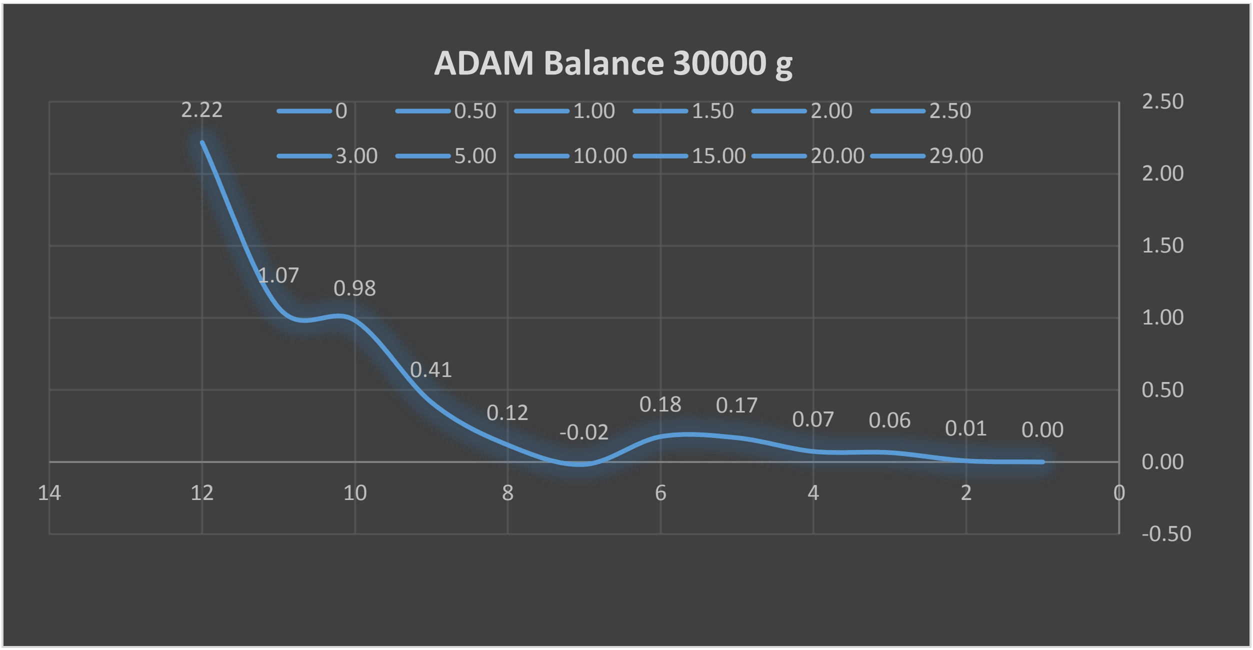

ADAM Balance 30000 g
0
0.50
1.00
1.50
2.00
2.50
3.00
5.00
10.00
15.00
20.00
29.00
2.22
1.07
0.98
0.41
0.12
-0.02
0.18
0.17
0.07
0.06
0.01
0.00
14
12
10
8
6
4
2
0
2.50
2.00
1.50
1.00
0.50
0.00
-0.50

## A.4 ADAM 30 kg (Standard)

مؤسسة المواصفات والمقاييس الفلسطينية- مديرية القياس الوطني

**Palestine Standards Institution – Metrology Directorate**

**CERTIFICATE OF CALIBRATION**

| Certificate No. | B003 |
|---|---|

| | | | |
|---|---|---|---|
| Date of calibration | 06.06.2021 | | |
| Date of issue | 17.06.2021 | | |
| Client | PSI | Address | Ramallah |

**Instrumunt Information**

| | | | | | |
|---|---|---|---|---|---|
| Instrument | Digital Balance | | | Units of Measure | g |
| Model | STB30002C | | | Scale Class | II |
| Manufacturing | ADAM | | | Resiluation | 0.01 g |
| serial No. | AEAA041 | | | Location | Pressuer Lab. |
| Range | 0.00 | 30000 | g | Condition | Standard |

**The Ambient Condition**

| | Star | End |
|---|---|---|
| Temperature ( °C ) | 20.3 | 19.2 |
| Humidity ( % ) | 41.7 | 55.1 |
| Barometric Pressure (mbar) | 915.5 | 915.4 |

**Referance Instrument**

| Instrument | Serial No. | Cert. No. |
|---|---|---|
| Set of weights Class M1 | 1831012 | W0140417 |

**Summery Of Calibration Method**

Calibrated measuring device by reference mass based on the classification of the balance

**Calibration Standerd**

Calibration process performed acording to OIML R 76-1

The reported expanded uncertainty of measurement is in accordance with a Guidelines on the Calibration of non-Automatic Weighing Instruments - Version 4.0 (11/2015)

Uncertinity of measuerment multiplied by the coverage factor k=2 for rectangulare disribuation it corresponds coverage probability of approximtily 95 %

| Calibrated By | Muhannad Azmouti |
|---|---|

PAGE 1 OF 2 PAGES

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CERTIFICATE OF CALIBRATION

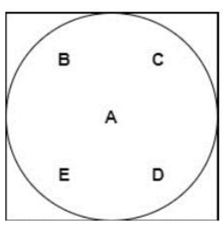
## Linerity Test

| Nominal Load (g) | Indicated Reading (g) | Error (g) |
|---|---|---|
| 0 | 0.00 | 0.00 |
| 500.00 | 500.00 | 0.01 |
| 1000.00 | 1000.10 | -0.09 |
| 1500.00 | 1500.10 | -0.08 |
| 2000.00 | 2000.15 | -0.13 |
| 2500.00 | 2500.15 | -0.12 |
| 3000.00 | 3000.10 | -0.07 |
| 5000.00 | 5000.15 | -0.13 |
| 10000.00 | 9999.90 | 0.26 |
| 15000.00 | 14999.50 | 0.68 |
| 20000.00 | 19999.45 | 0.82 |
| 29000.00 | 28998.50 | 1.82 |

## Repetability Test

| Nominal Load g | Unloaded Reading g | Loaded Reading g |
|---|---|---|
| 15000 | 0.0 | 15000.00 |
| | 0.0 | 15000.10 |
| | 0.0 | 15000.10 |
| | 0.0 | 15000.10 |
| | 0.0 | 15000.10 |

## Eccentricity Test




| Position | g | Loaded Reading |
|---|---|---|
| A | 10000 | 9999.90 |
| B | | 10000.80 |
| C | | 10000.00 |
| D | | 9999.80 |
| E | | 10000.30 |
| A | | 10000.00 |

| Uncertinity Of Measurement | ± | 0.22 g |
|---|---|---|

PAGE 2 OF 2 PAGES

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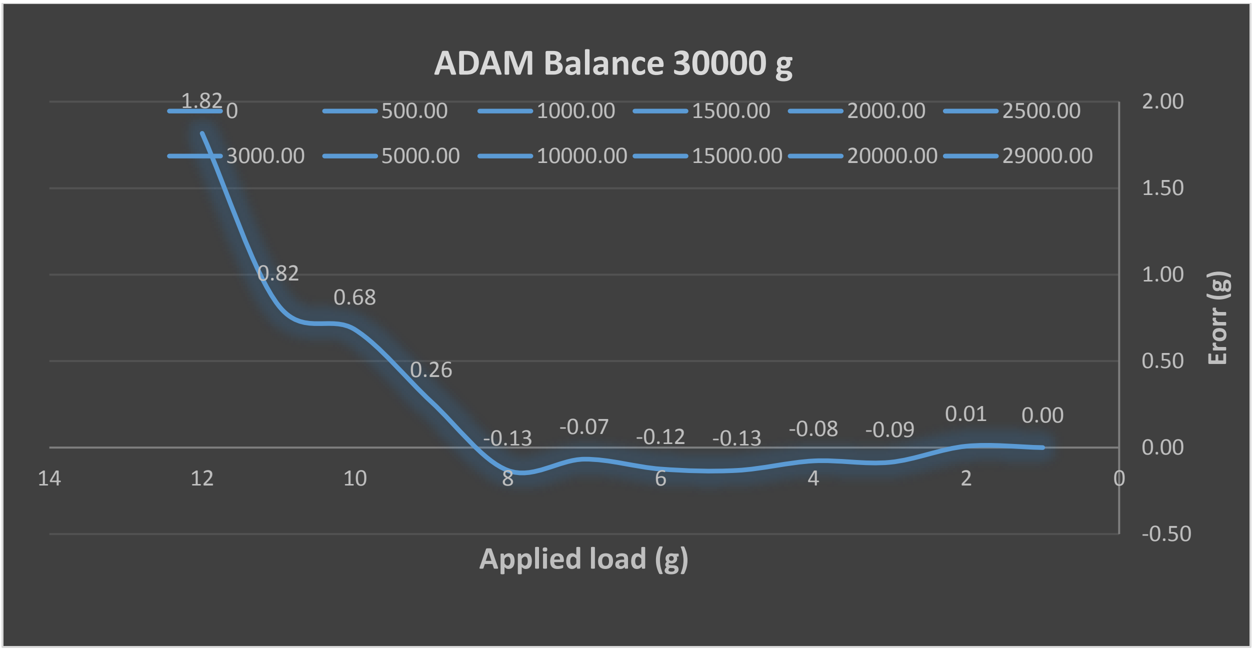
ADAM Balance 30000 g
0
500.00
1000.00
1500.00
2000.00
2500.00
3000.00
5000.00
10000.00
15000.00
20000.00
29000.00
1.82
0.82
0.68
0.26
-0.13
-0.07
-0.12
-0.13
-0.08
-0.09
0.01
0.00
2.00
1.50
1.00
0.50
0.00
-0.50
Erorr (g)
14
12
10
8
6
4
2
0
Applied load (g)

# A.5 Presica 6 kg (Non-standards)

مؤســـسة المواصفـات والمقاييـس الفلسـطينية- مديرية القياس الوطني

**Palestine Standards Institution – Metrology Directorate**

CERTIFICATE OF CALIBRATION

| Certificate No. | B005 |
|---|---|

| | | | |
|---|---|---|---|
| Date of calibration | 10.06.2021 | | |
| Date of issue | 20.06.2021 | | |
| Client | PSI | Address | Ramallah |

**Instrumunt Information**

| | | | | | |
|---|---|---|---|---|---|
| Instrument | Digital Balance | | | Units of Measure | g |
| Model | LS6200C | | | Scale Class | II |
| Manufacturing | Presica | | | Resiluation | 0.01 g |
| serial No. | 7201349 | | | Location | Pressuer Lab. |
| Range | 0.00 | 6200 | g | Condition | Non-Standard |

**The Ambient Condition**

| | Star | End |
|---|---|---|
| Temperature ( °C ) | 30.9 | 31.4 |
| Humidity ( % ) | 43.0 | 41.6 |
| Barometric Pressure (mbar) | 918.5 | 918.4 |

**Referance Instrument**

| Instrument | Serial No. | Cert. No. |
|---|---|---|
| Set of weights Class E2 | PSI-R-PM012 | W0180517 |

**Summery Of Calibration Method**

Calibrated measuring device by reference mass based on the classification of the balance

**Calibration Standerd**

Calibration process performed acording to OIML R 76-1

The reported expanded uncertainty of measurement is in accordance with a Guidelines on the Calibration of non-Automatic Weighing Instruments - Version 4.0 (11/2015)

Uncertinity of measuerment multiplied by the coverage factor k=2 for rectangulare disribuation it corresponds coverage probability of approximtily 95 %

| Calibrated By | Muhannad Azmouti |
|---|---|

PAGE 1 OF 2 PAGES

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# CERTIFICATE OF CALIBRATION

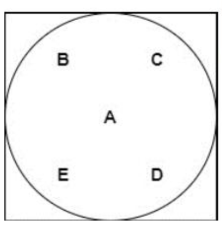
## Linerity Test

| Nominal Load (g) | Indicated Reading (g) | Error (g) |
|---|---|---|
| 0 | 0.00 | 0.00 |
| 1.00 | 1.01 | 0.00 |
| 5.00 | 5.01 | -0.01 |
| 10.00 | 10.01 | -0.01 |
| 20.00 | 20.01 | -0.01 |
| 100.00 | 100.02 | -0.02 |
| 200.00 | 200.02 | -0.02 |
| 500.00 | 500.06 | -0.06 |
| 1000.00 | 1000.10 | -0.10 |
| 1500.00 | 1500.14 | -0.14 |
| 3000.00 | 3000.27 | -0.27 |
| 6000.00 | 6000.56 | -0.56 |

## Repetability Test

| Nominal Load g | Unloaded Reading g | Loaded Reading g |
|---|---|---|
| 3000 | 0.0 | 3000.29 |
| | 0.0 | 3000.28 |
| | 0.0 | 3000.28 |
| | 0.0 | 3000.27 |
| | 0.0 | 3000.26 |

## Eccentricity Test




| Position | g | Loaded Reading |
|---|---|---|
| A | 2000 | 2000.20 |
| B | | 2000.23 |
| C | | 2000.24 |
| D | | 2000.23 |
| E | | 2000.21 |
| A | | 2000.20 |

| Uncertinity Of Measurement | ± | 0.06 g |
|---|---|---|



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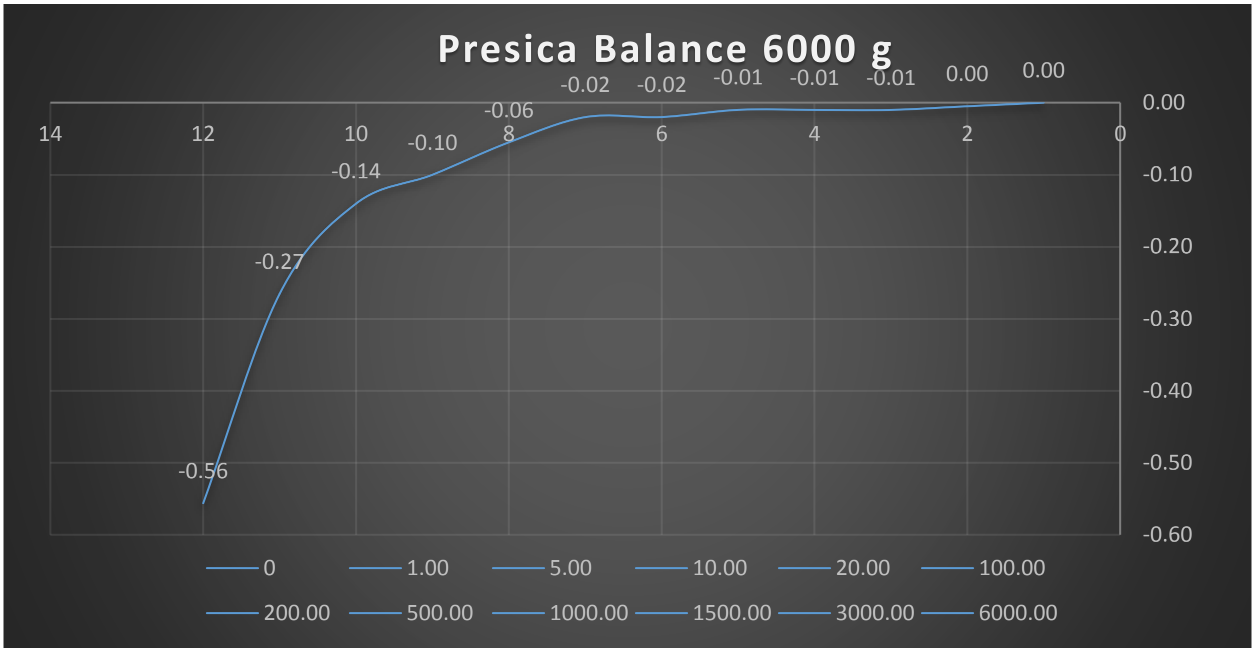
Presica Balance 6000 g
-0.56
-0.27
-0.14
-0.10
-0.06
-0.02
-0.02
-0.01
-0.01
-0.01
0.00
0.00
14
12
10
8
6
4
2
0
0.00
-0.10
-0.20
-0.30
-0.40
-0.50
-0.60
0
1.00
5.00
10.00
20.00
100.00
200.00
500.00
1000.00
1500.00
3000.00
6000.00

## A.6 Presica 6 kg (Standards)

مؤسسة المواصفات والمقاييس الفلسطينية- مديرية القياس الوطني

**Palestine Standards Institution – Metrology Directorate**

**CERTIFICATE OF CALIBRATION**

| Certificate No. | B006 |
|---|---|

| | |
|---|---|
| Date of calibration | 10.06.2021 |
| Date of issue | 20.06.2021 |

| | | | |
|---|---|---|---|
| Client | PSI | Address | Ramallah |

**Instrumunt Information**

| | | | | | |
|---|---|---|---|---|---|
| Instrument | Digital Balance | | | Units of Measure | g |
| Model | LS6200C | | | Scale Class | II |
| Manufacturing | Presica | | | Resiluation | 0.01 g |
| serial No. | 7201349 | | | Location | Pressuer Lab. |
| Range | 0.00 | 6200 | g | Condition | Non-Standard |

**The Ambient Condition**

| | Star | End |
|---|---|---|
| Temperature ( °C ) | 20.7 | 21.4 |
| Humidity ( % ) | 47.7 | 46.7 |
| Barometric Pressure (mbar) | 915.6 | 915.4 |

**Referance Instrument**

| Instrument | Serial No. | Cert. No. |
|---|---|---|
| Set of weights Class E2 | PSI-R-PM012 | W0180517 |

**Summery Of Calibration Method**

Calibrated measuring device by reference mass based on the classification of the balance

**Calibration Standerd**

Calibration process performed acording to OIML R 76-1

The reported expanded uncertainty of measurement is in accordance with a Guidelines on the Calibration of non-Automatic Weighing Instruments - Version 4.0 (11/2015)

Uncertinity of measuerment multiplied by the coverage factor k=2 for rectangulare disribuation it corresponds coverage probability of approximtily 95 %

| Calibrated By | Muhannad Azmouti |
|---|---|

PAGE 1 OF 2 PAGES

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CERTIFICATE OF CALIBRATION

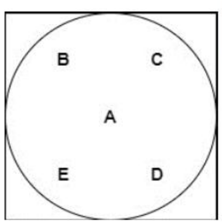
## Linerity Test

| Nominal Load (g) | Indicated Reading (g) | Error (g) |
|---|---|---|
| 0 | 0.00 | 0.00 |
| 1.00 | 1.00 | 0.00 |
| 5.00 | 5.00 | 0.00 |
| 10.00 | 10.00 | 0.00 |
| 20.00 | 20.00 | 0.00 |
| 100.00 | 99.99 | 0.02 |
| 200.00 | 200.05 | -0.05 |
| 500.00 | 500.05 | -0.05 |
| 1000.00 | 1000.10 | -0.10 |
| 1500.00 | 1500.13 | -0.14 |
| 3000.00 | 3000.21 | -0.21 |
| 6000.00 | 6000.37 | -0.37 |

## Repetability Test

| Nominal Load g | Unloaded Reading g | Loaded Reading g |
|---|---|---|
| 3000 | 0.0 | 3000.27 |
| | 0.0 | 3000.26 |
| | 0.0 | 3000.26 |
| | 0.0 | 3000.26 |
| | 0.0 | 3000.27 |

## Eccentricity Test




| Position | g | Loaded Reading |
|---|---|---|
| A | 2000 | 2000.19 |
| B | | 2000.22 |
| C | | 2000.23 |
| D | | 2000.22 |
| E | | 2000.19 |
| A | | 2000.20 |

| Uncertinity Of Measurement | ± | 0.03 g |
|---|---|---|



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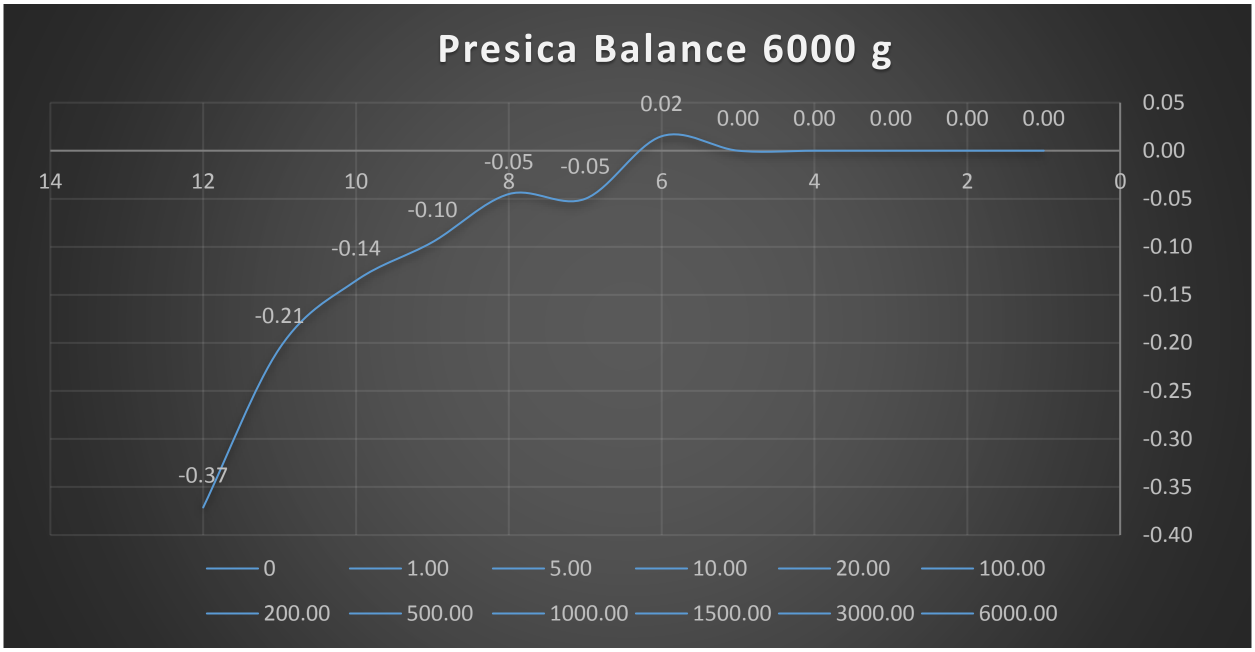
Presica Balance 6000 g
0.02
0.00
0.00
0.00
0.00
0.00
-0.05
-0.05
-0.10
-0.14
-0.21
-0.37
14
12
10
8
6
4
2
0
0.05
0.00
-0.05
-0.10
-0.15
-0.20
-0.25
-0.30
-0.35
-0.40
0
1.00
5.00
10.00
20.00
100.00
200.00
500.00
1000.00
1500.00
3000.00
6000.00

## A.7 Sartorius 2 kg (Non-Standards)

مؤسسة المواصفات والمقاييس الفلسطينية- مديرية القياس الوطني

**Palestine Standards Institution – Metrology Directorate**

CERTIFICATE OF CALIBRATION

| Certificate No. | B007 |
|---|---|

| | | | |
|---|---|---|---|
| Date of calibration | 06.06.2021 | | |
| Date of issue | 19.06.2021 | | |
| Client | PSI | Address | Ramallah |

**Instrumunt Information**

| | | | | | |
|---|---|---|---|---|---|
| Instrument | Digital Balance | | | Units of Measure | g |
| Model | MSE2203S | | | Scale Class | II |
| Manufacturing | Sartorius | | | Resiluation | 0.001 g |
| serial No. | 33001392 | | | Location | Pressuer Lab. |
| Range | 0.00 | 2200 | g | Condition | Standard |

**The Ambient Condition**

| | Star | End |
|---|---|---|
| Temperature ( °C ) | 30.3 | 30.9 |
| Humidity ( % ) | 42.0 | 41.0 |
| Barometric Pressure (mbar) | 918.5 | 918.3 |

**Referance Instrument**

| Instrument | Serial No. | Cert. No. |
|---|---|---|
| Set of weights Class E2 | PSI-PM-012 | W0120517 |

**Summery Of Calibration Method**

Calibrated measuring device by reference mass based on the classification of the balance

**Calibration Standerd**

Calibration process performed acording to OIML R 76-1

The reported expanded uncertainty of measurement is in accordance with a Guidelines on the Calibration of non-Automatic Weighing Instruments - Version 4.0 (11/2015)

Uncertinity of measuerment multiplied by the coverage factor k=2 for rectangulare disribuation it corresponds coverage probability of approximtily 95 %

| Calibrated By | Muhannad Azmouti |
|---|---|

PAGE 1 OF 2 PAGES

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CERTIFICATE OF CALIBRATION

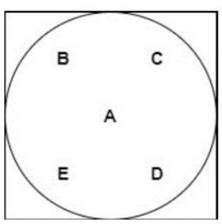
## Linerity Test

| Nominal Load (g) | Indicated Reading (g) | Error (g) |
|---|---|---|
| 0 | 0.000 | 0.000 |
| 0.50 | 0.500 | 0.000 |
| 1.00 | 1.001 | 0.000 |
| 5.00 | 5.001 | -0.001 |
| 10.00 | 9.999 | 0.001 |
| 20.00 | 20.001 | -0.001 |
| 50.00 | 50.001 | -0.001 |
| 200.00 | 200.001 | -0.001 |
| 400.00 | 400.001 | -0.001 |
| 1000.00 | 1000.002 | -0.002 |
| 1500.00 | 1500.001 | -0.001 |
| 2200.00 | 2200.002 | -0.002 |

## Repetability Test

| Nominal Load g | Unloaded Reading g | Loaded Reading g |
|---|---|---|
| 1200 | 0.0 | 1200.002 |
| | 0.0 | 1199.999 |
| | 0.0 | 1199.999 |
| | 0.0 | 1199.998 |
| | 0.0 | 1200.001 |

## Eccentricity Test




| Position | g | Loaded Reading |
|---|---|---|
| A | 750 | 750.000 |
| B | | 749.997 |
| C | | 750.001 |
| D | | 750.003 |
| E | | 750.001 |
| A | | 750.000 |

| Uncertinity Of Measurement | ± | 0.004 | g |
|---|---|---|---|



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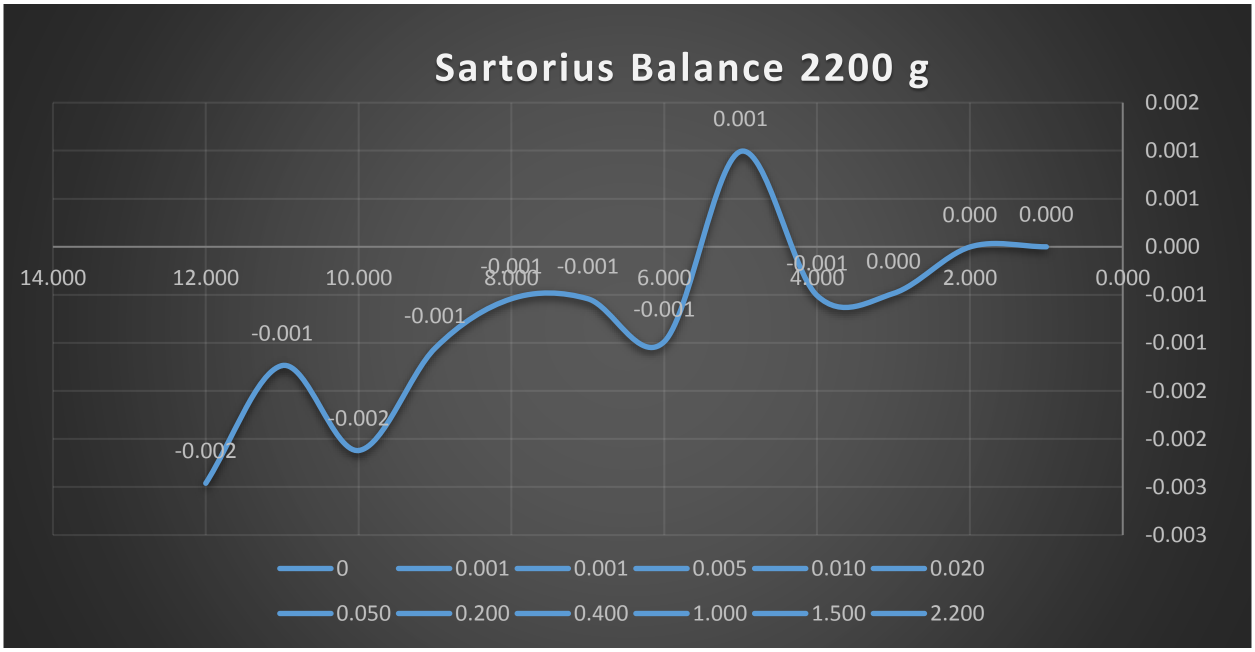
Sartorius Balance 2200 g
0.002
0.001
0.001
0.000
-0.001
-0.001
-0.002
-0.002
-0.003
-0.003
14.000
12.000
10.000
8.000
6.000
4.000
2.000
0.000
-0.002
-0.001
-0.002
-0.001
-0.001
-0.001
-0.001
0.001
-0.001
0.000
0.000
0.000
0
0.001
0.001
0.005
0.010
0.020
0.050
0.200
0.400
1.000
1.500
2.200

## A.8 Sartorius 2 kg (Standards)

مؤسسة المواصفات والمقاييس الفلسطينية- مديرية القياس الوطني

**Palestine Standards Institution – Metrology Directorate**

**CERTIFICATE OF CALIBRATION**

| Certificate No. | B008 |
|---|---|

| | | | |
|---|---|---|---|
| Date of calibration | 10.06.2021 | | |
| Date of issue | 20.06.2021 | | |
| Client | PSI | Address | Ramallah |

**Instrumunt Information**

| | | | | | |
|---|---|---|---|---|---|
| Instrument | Digital Balance | | | Units of Measure | g |
| Model | MSE2203S | | | Scale Class | II |
| Manufacturing | Sartorius | | | Resiluation | 0.001 g |
| serial No. | 33001392 | | | Location | Pressuer Lab. |
| Range | 0.00 | 2200 | g | Condition | Standard |

**The Ambient Condition**

| | Star | End |
|---|---|---|
| Temperature ( °C ) | 21.1 | 21.8 |
| Humidity ( % ) | 45.4 | 45.7 |
| Barometric Pressure (mbar) | 915.6 | 915.5 |

**Referance Instrument**

| Instrument | Serial No. | Cert. No. |
|---|---|---|
| Set of weights Class E2 | PSI-PM-012 | W0120517 |

**Summery Of Calibration Method**

Calibrated measuring device by reference mass based on the classification of the balance

**Calibration Standerd**

Calibration process performed acording to OIML R 76-1

The reported expanded uncertainty of measurement is in accordance with a Guidelines on the Calibration of non-Automatic Weighing Instruments - Version 4.0 (11/2015)

Uncertinity of measuerment multiplied by the coverage factor k=2 for rectangulare disribuation it corresponds coverage probability of approximtily 95 %

| Calibrated By | Muhannad Azmouti |
|---|---|

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Ramallah–Almasyoun–AL Quds Build.P O Box 2258 رام الله، الماصيون، مبنى القدس ص ب
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# CERTIFICATE OF CALIBRATION

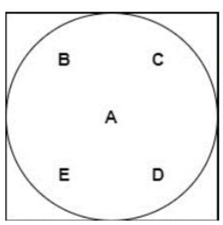
## Linerity Test

| Nominal Load (g) | Indicated Reading (g) | Error (g) |
|---|---|---|
| 0 | 0.000 | 0.000 |
| 0.50 | 0.500 | 0.000 |
| 1.00 | 1.000 | 0.000 |
| 5.00 | 5.004 | -0.004 |
| 10.00 | 9.999 | 0.001 |
| 20.00 | 20.002 | -0.001 |
| 50.00 | 50.000 | 0.000 |
| 200.00 | 200.000 | 0.000 |
| 400.00 | 400.001 | -0.001 |
| 1000.00 | 1000.001 | -0.002 |
| 1500.00 | 1500.003 | -0.003 |
| 2200.00 | 2200.007 | -0.007 |

## Repetability Test

| Nominal Load g | Unloaded Reading g | Loaded Reading g |
|---|---|---|
| 1200 | 0.0 | 1200.002 |
| | 0.0 | 1200.003 |
| | 0.0 | 1200.003 |
| | 0.0 | 1200.003 |
| | 0.0 | 1200.002 |

## Eccentricity Test




| Position | g | Loaded Reading |
|---|---|---|
| A | 750 | 749.999 |
| B | | 750.000 |
| C | | 750.002 |
| D | | 750.003 |
| E | | 750.001 |
| A | | 749.999 |

| Uncertinity Of Measurement | ± | 0.005 | g |
|---|---|---|---|



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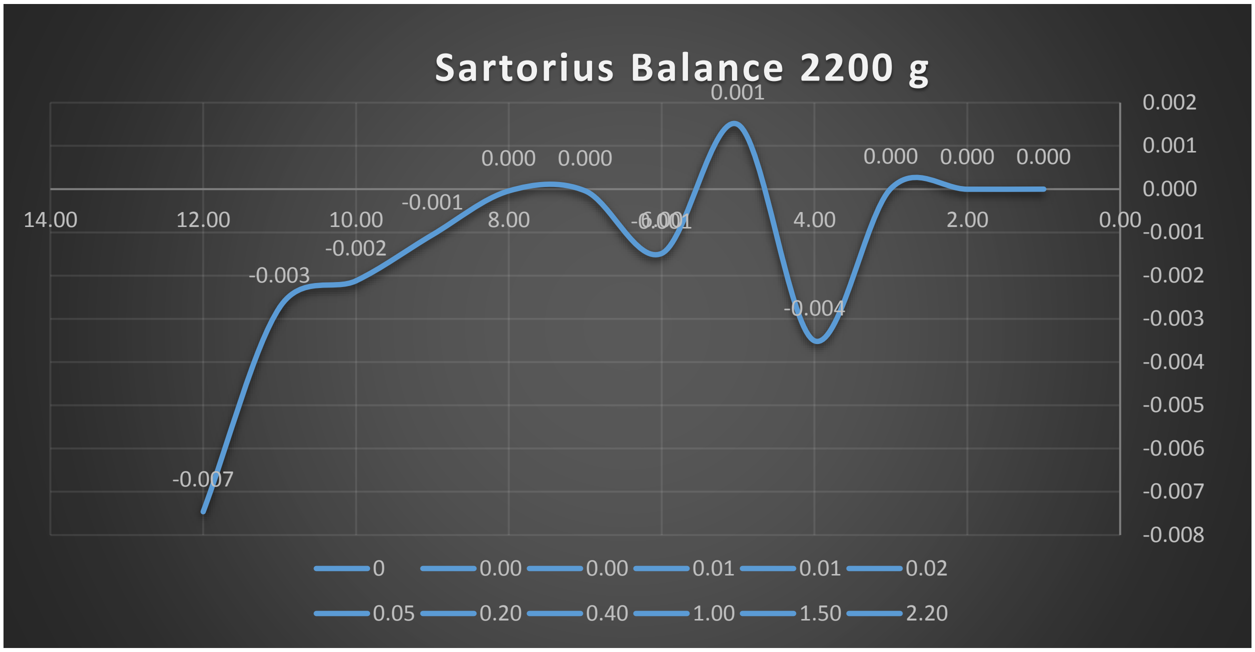
Sartorius Balance 2200 g
0.001
0.000 0.000
0.000 0.000 0.000
-0.001
-0.002
-0.003
-0.001
-0.004
-0.007
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
0.002
0.001
0.000
-0.001
-0.002
-0.003
-0.004
-0.005
-0.006
-0.007
-0.008
0
0.00
0.00
0.01
0.01
0.02
0.05
0.20
0.40
1.00
1.50
2.20

## A.9 Sartorius 10 kg (Non -Standard)

مؤسســة المواصفـات والمقاييـس الفلسـطينية- مديرية القياس الوطني

**Palestine Standards Institution – Metrology Directorate**

CERTIFICATE OF CALIBRATION

| Certificate No. | B009 |
|---|---|

| | | | |
|---|---|---|---|
| Date of calibration | 06.06.2021 | | |
| Date of issue | 19.06.2021 | | |
| Client | PSI | Address | Ramallah |

**Instrumunt Information**

| | | | | | |
|---|---|---|---|---|---|
| Instrument | Digital Balance | | | Units of Measure | g |
| Model | MSE10202S | | | Scale Class | II |
| Manufacturing | Sartorius | | | Resiluation | 0.01 g |
| serial No. | 33001393 | | | Location | Pressuer Lab. |
| Range | 0.00 | 10200 | g | Condition | Non-Standard |

**The Ambient Condition**

| | Star | End |
|---|---|---|
| Temperature ( °C ) | 30.6 | 30.9 |
| Humidity ( % ) | 41.0 | 43.0 |
| Barometric Pressure (mbar) | 918.3 | 918.5 |

**Referance Instrument**

| Instrument | Serial No. | Cert. No. |
|---|---|---|
| Set of weights Class F1 | 254145 | M 214560 |

**Summery Of Calibration Method**

Calibrated measuring device by reference mass based on the classification of the balance

**Calibration Standerd**

Calibration process performed acording to OIML R 76-1

The reported expanded uncertainty of measurement is in accordance with a Guidelines on the Calibration of non-Automatic Weighing Instruments - Version 4.0 (11/2015)

Uncertinity of measuerment multiplied by the coverage factor k=2 for rectangulare disribuation it corresponds coverage probability of approximtily 95 %

| Calibrated By | Muhannad Azmouti |
|---|---|

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**CERTIFICATE OF CALIBRATION**

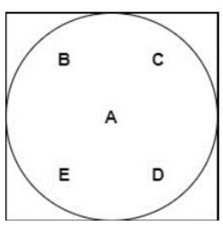
## Linerity Test

| Nominal Load (g) | Indicated Reading (g) | Error (g) |
|---|---|---|
| 0 | 0.00 | 0.00 |
| 5.00 | 5.00 | 0.00 |
| 20.00 | 20.00 | 0.00 |
| 100.00 | 100.00 | 0.01 |
| 500.00 | 499.98 | 0.02 |
| 1000.00 | 999.95 | 0.05 |
| 2000.00 | 1999.89 | 0.12 |
| 4000.00 | 3999.75 | 0.25 |
| 5000.00 | 4999.64 | 0.36 |
| 7000.00 | 6999.52 | 0.42 |
| 9000.00 | 8999.45 | 0.51 |
| 10000.00 | 9999.26 | 0.78 |

## Repetability Test

| Nominal Load g | Unloaded Reading g | Loaded Reading g |
|---|---|---|
| 5200 | 0.0 | 5199.67 |
| | 0.0 | 5199.67 |
| | 0.0 | 5199.66 |
| | 0.0 | 5199.66 |
| | 0.0 | 5199.66 |

## Eccentricity Test




| Position | g | Loaded Reading |
|---|---|---|
| A | 3500 | 3499.80 |
| B | | 3499.76 |
| C | | 3499.73 |
| D | | 3499.77 |
| E | | 3499.76 |
| A | | 3499.79 |

| Uncertinity Of Measurement | ± | 0.03 g |
|---|---|---|



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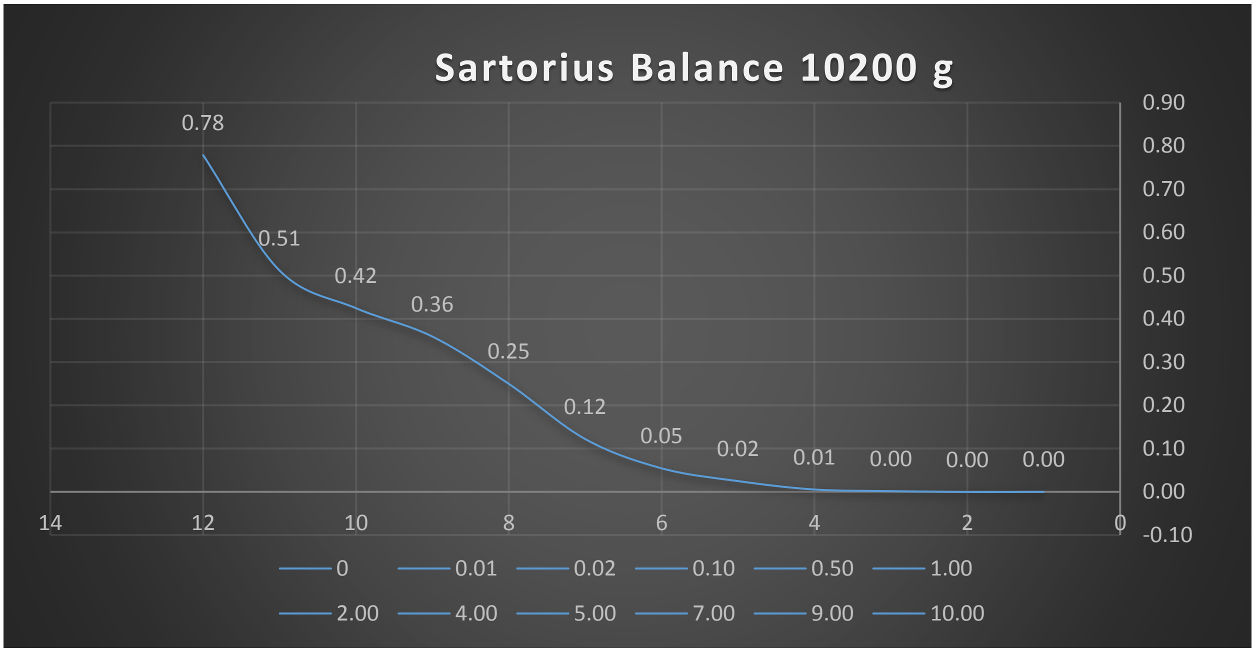
Sartorius Balance 10200 g
0.78
0.51
0.42
0.36
0.25
0.12
0.05
0.02
0.01
0.00
0.00
0.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
-0.10
14
12
10
8
6
4
2
0
0
0.01
0.02
0.10
0.50
1.00
2.00
4.00
5.00
7.00
9.00
10.00

## A.10 Sartorius 10 kg (Standard)

مؤسسة المواصفات والمقاييس الفلسطينية- مديرية القياس الوطني

**Palestine Standards Institution – Metrology Directorate**

**CERTIFICATE OF CALIBRATION**

| Certificate No. | B010 |
|---|---|

| | | | |
|---|---|---|---|
| Date of calibration | 10.06.2021 | | |
| Date of issue | 20.06.2021 | | |
| Client | PSI | Address | Ramallah |

**Instrumunt Information**

| | | | | | |
|---|---|---|---|---|---|
| Instrument | Digital Balance | | | Units of Measure | g |
| Model | MSE10202S | | | Scale Class | II |
| Manufacturing | Sartorius | | | Resiluation | 0.01 g |
| serial No. | 33001393 | | | Location | Pressuer Lab. |
| Range | 0.00 | 10200 | g | Condition | Standard |

**The Ambient Condition**

| | Star | End |
|---|---|---|
| Temperature ( °C ) | 20.9 | 21.1 |
| Humidity ( % ) | 43.2 | 43.0 |
| Barometric Pressure (mbar) | 915.7 | 915.7 |

**Referance Instrument**

| Instrument | Serial No. | Cert. No. |
|---|---|---|
| Set of weights Class F1 | 254145 | M 214560 |

**Summery Of Calibration Method**

Calibrated measuring device by reference mass based on the classification of the balance

**Calibration Standerd**

Calibration process performed acording to OIML R 76-1

The reported expanded uncertainty of measurement is in accordance with a Guidelines on the Calibration of non-Automatic Weighing Instruments - Version 4.0 (11/2015)

Uncertinity of measuerment multiplied by the coverage factor k=2 for rectangulare disribuation it corresponds coverage probability of approximtily 95 %

| Calibrated By | Muhannad Azmouti |
|---|---|

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# CERTIFICATE OF CALIBRATION

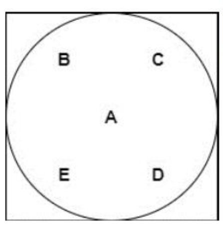
**Linerity Test**

| Nominal Load (g) | Indicated Reading (g) | Error (g) |
|---|---|---|
| 0 | 0.00 | 0.00 |
| 5.00 | 5.00 | 0.00 |
| 20.00 | 20.01 | 0.00 |
| 100.00 | 100.01 | 0.00 |
| 500.00 | 499.99 | 0.01 |
| 1000.00 | 999.97 | 0.03 |
| 2000.00 | 1999.94 | 0.07 |
| 4000.00 | 3999.87 | 0.13 |
| 5000.00 | 4999.80 | 0.20 |
| 7000.00 | 6999.71 | 0.23 |
| 9000.00 | 8999.61 | 0.36 |
| 10000.00 | 10199.57 | 0.47 |

**Repetability Test**

| Nominal Load g | Unloaded Reading g | Loaded Reading g |
|---|---|---|
| 5200 | 0.0 | 5199.80 |
| | 0.0 | 5199.79 |
| | 0.0 | 5199.79 |
| | 0.0 | 5199.79 |
| | 0.0 | 5199.78 |

**Eccentricity Test**




| Position | g | Loaded Reading |
|---|---|---|
| A | 3500 | 3499.87 |
| B | | 3499.85 |
| C | | 3499.85 |
| D | | 3499.87 |
| E | | 3499.85 |
| A | | 3499.81 |

| Uncertinity Of Measurement | ± | 0.04 g |
|---|---|---|



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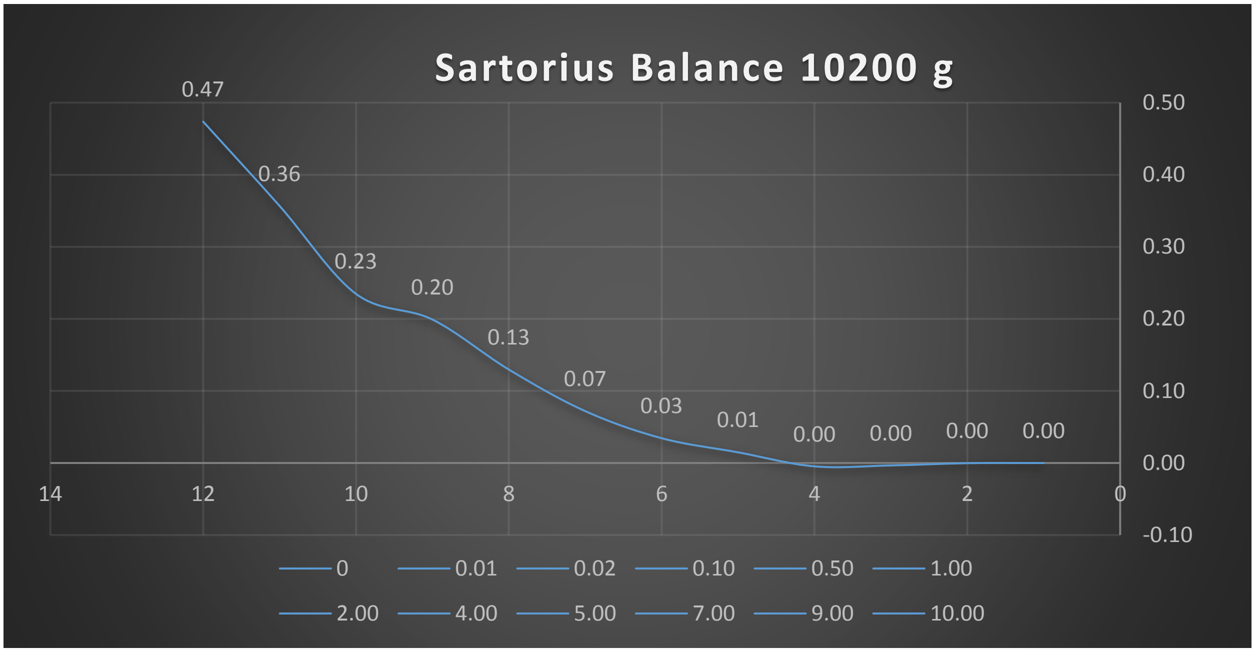
Sartorius Balance 10200 g
0.47
0.36
0.23
0.20
0.13
0.07
0.03
0.01
0.00
0.00
0.00
0.00
0.50
0.40
0.30
0.20
0.10
0.00
-0.10
14
12
10
8
6
4
2
0
0
0.01
0.02
0.10
0.50
1.00
2.00
4.00
5.00
7.00
9.00
10.00