Definitions Handout

What is METROLOGY?

Metrology is the science of measurement, embracing both experimental and theoretical determinations at any level of uncertainty in any field of science and technology.

What is a MEASUREMENT?

Process of experimentally obtaining one or more quantity values that can reasonably be attributed to a quantity.

What is a MEASURAND?

Quantity intended to be measured

What is a CALIBRATION?

Operation that, under specified conditions, in a first step, establishes a relation between the quantity values with measurement uncertainties provided by measurement standards and corresponding indications with associated measurement uncertainties and, in a second step, uses this information to establish a relation for obtaining a measurement result from an indication

Measurement Result + Uncertainty

Do not confuse calibration with 'adjustment'

What is TRACEABILITY? (Answer is in 3 parts)

Metrological traceability: Property of a measurement result whereby the result can be related to a reference through a documented unbroken chain of calibrations, each contributing to the measurement uncertainty

Metrological traceability chain: traceability chain sequence of measurement standards and calibrations that is used to relate a measurement result to a reference

Metrological traceability to a measurement unit: metrological traceability where the reference is the definition of a measurement unit through its practice realization

Note: The expression "traceability to the SI" means 'metrological traceability to a measurement unit of the International System of Units.'

What is OBJECTIV EVIDENCE?

Proof in the form of records

What is a DOCUMENT?

To maintain. A collection of instructions. How to. Procedure

What is a RECORD?

To retain. Your completed document. History. Evidence

What is a lab's SCOPE?

Measuring capabilities.

Metrology Acronyms

Acronym	**Name**
NIST	National Institute of Weights & Measures
AB	Accrediting Body
CMC	Calibration and Measurement Capability (scope)
GLP	Good Laboratory Practices
GMP	Good Measurement Practices
GUM	Guide to the Expression of Uncertainty in Measurement
RMO	Regional Metrology Organization
SDO	Standards Development Organization
SI	International System of Units
SOP	Standard Operating Procedure
SAP	Standard Administrative Procedure
VIM	International Vocabulary of Measurement
RMAP	Regional Measurement Assurance Program
SWAP	Southwestern Measurement Assurance Program (our region of RMAP)
BIPM	International Bureau of Weights and Measures
ILAC	International Laboratory Accreditation Cooperation
OIML	International Organization for Legal Metrology
ASTM	American Society for Test and Materials
NCSLI	National Conference of Standards Laboratories, International
ISO	International Organization for Standardization

Symbol	Description
S	Standard reference weight
X	Weight to be calibrated (unknown)
S_c	Check standard
t	Small calibrated tare weight, A subscript to s or x is used to indicate the larger weight with which it is associated
sw	Small calibrated weight used to evaluate the sensitivity of the balance
M	The mass (true mass) of a specific weight. Subscripts s, x, t, sw are used to identify the weight (equals Nominal plus Correction)
N	The nominal value of a specific weight. Subscripts s, x are used to identify the weight
C	The correction for a specific weight. Subscripts s, x are used to identify the weight.
CM	The conventional mass of a specific weight. Subscripts s, x, t, sw are used to identify the weight.
ρ_a	Density of air at time of calibration
ρ_n	Density of normal air (1.2 kg/m^3)
ρ	Density of masses; subscripts s, x, t_s, t^x, sw are used to identify the weight
dof	Degrees of freedom
k	k value; coverage factor
O	Observation; subscripts 1 - ∞ are used to identify the observation
d	bias
u	uncertainty
u_s	Uncertainty of the Standard mass(es)
s_p	Accepted standard deviation of the process
u_{drift}	Uncertainty of the allowable drift
u_{sw}	Uncertainty of the allowable sensitivity error
u_b	Uncertainty of the maximum magnitude of the buoyancy correction
u_d	Uncertainty associated with bias
u_o	Uncertainty due to other factors
U	Expanded uncertainty (u * k)
$MABC$	Magnitude of the Air Buoyancy Correction
E_n	Normalized Error Test
P_n	Normalize Precision Test

Symbol	Description
V_{x60}	Volume of the unknown vessel at 60°F
V_{s60}	Volume of the standard vessel at 60°F
$NSCV$	Neck Scale Correction Value
sr_f	Scale reading, final
sr_i	Scale reading, initial
$\rho_1, \rho_2, \ldots \rho_N$	Density of the water in the standard prover where ρ_1 is the density of the water for the first delivery, ρ_2 is the density of the water for the second delivery, and so on until all N deliveries are completed
$\Delta_1, \Delta_2, \ldots, \Delta_N$	Volume difference between water level and the reference mark on the standard where the subscripts *1,2,…N,* represent each delivery as above. If the water level is below the reference line, Δ is negative. If the water level is above the reference line, Δ is positive. If the water level is at the reference line, Δ is zero for slicker-plate type standards.
$t_1, t_2, \ldots t_N$	Temperature of water for each delivery with the subscripts as above
α	Coefficient of cubical expansion for the standard in units /°F
β	Coefficient of cubical expansion for the prover in units /°F
t_x	Temperature of the water in the filled unknown vessel in units °F
ρ_x	Density of the water in the unknown vessel in g/cm^3
u_m	Ability to read the meniscus in both S and X

What are the differences between mass, true mass and conventional mass values?

Mass and True Mass

The *mass* of a body relates to the amount of material it contains (see full definition) and there is no difference between *mass* and *true mass*. The prefix *true* is sometimes added to the word *mass* where it is important to make it clear that a particular value of mass being considered is not a *conventional mass* value and it is particularly important to avoid this potential ambiguity when, for example, specifying the value of weights (see below).

The international prototype kilogram, on which the mass scale throughout the world is realized, is defined as *a true mass of exactly 1 kilogram*. Most high accuracy comparisons are performed on a true mass basis but the values are usually converted to conventional mass values when quoted on a certificate.

Conventional Mass

When a weight is calibrated the mass value quoted on its certificate of calibration is normally a *conventional mass value* - appropriate where the value is determined by weighing the item in air in accordance with International Recommendation OIML R 33. This Recommendation says formally: *For a weight at 20 °C, the conventional mass is the mass of a reference weight of a density of 8 000 kg/m*^{3} *that it balances in air of density 1.2 kg/m*^{3}.

Some background to conventional mass

Air is a fluid and, as such, exerts a buoyancy force on all objects weighed in it. The value of buoyancy will depend on the volume of the object being weighed and the density of the air surrounding it - which itself changes with temperature, humidity, composition and pressure (see air density change with altitude). The buoyancy effect cancels out if a weight is calibrated on a two-pan balance by comparison with a reference weight of identical density. In practice though, the weight being calibrated will undoubtedly have a density value that is different to that of the reference weight (even if only slightly) and a correction for the differential buoyancy effect will need to be applied.

Every day hundreds of thousands of weighings are performed where the accuracies required make buoyancy effects very significant. It is not realistic to perform such measurements in vacuum - where there is no buoyancy effect - but, even if this were possible, most weights are used in air and the mass values attributed to them must reflect the conditions under which they will be used.

International Recommendation OIML R 33 essentially provides an in-air 'datum', or set of reference conditions, which defines the conventional mass of a weight, at 20 °C, as the (true) mass of a reference weight of a density of 8 000 kg/m^3 that just 'balances' it when in air of density 1.2 kg/m^3 (see above for exact wording). In practice these conditions will not be realized exactly and small corrections for temperature, material density and air density have to be applied to allow for this.

Completely unofficial text for conveying the spirit of what is meant by conventional mass might therefore be *a value, slightly different from the true mass value, which an object appears to have when it is used in normal-ish ambient conditions* - but please don't quote us on this one!

Last Updated: 25 Mar 2010
Created: 9 Aug 2007

Source:

http://www.npl.co.uk/

http://www.npl.co.uk/reference/faqs/what-are-the-differences-between-mass,-true-mass-and-conventional-mass-values-(faq-mass-and-density)

Mass calibration (metrology) terms explained in plain English.

Air Buoyancy

The buoyant effect of air on an object, acting against the attraction of gravity.

The air is always exerting a lifting effect on an object – on all objects. The magnitude of that lifting effect is a direct function of the density of the air relative to the volume of the object under consideration.

"Normal" air under "perfect" conditions, that is, 20.00 degrees Celsius, atmospheric pressure of 760.5 mm of mercury, and humidity of 50%, has a density of 1.200 mg/cm^3.

From a practical standpoint, everything we weigh is surrounded by air, so the convention for expressing the weight, or the mass, of an object, has evolved to express that perceived weight as "mass in air", or Conventional Mass.

Conventional Mass (Mass in air versus reference density of 8.0 g/cm^3)

A hypothetical weighing of a mass in "perfect" air, that is, air of typical composition, at exactly 20.00 degrees C, atmospheric pressure of 760.5 mm of mercury, and a relative humidity of 50%. Under these "perfect" conditions, the density of the air would be 1.2000 mg/cm^3.

Since realization of these parameters is a practical impossibility, in a calibration lab the ambient conditions are stabilized to the greatest extent possible, and the temperature, pressure and humidity are carefully measured. From these values the density of the air is calculated, and the results of the calibration are adjusted mathematically to present the result as though the calibration had been conducted in "perfect" conditions.

No discussion of Conventional Mass would be complete without a mention of the 8.0 g/cm^3 standard. Stainless steel is the "standard" material from which most high quality laboratory weights are fabricated. Stainless steel has a density of approximately 8 g/cm^3, hence the reference. Years ago, brass was the most common material for laboratory weights, and 8.4 g/cm^3 was the reference density.

In the real world, the ideal density of 8.0 g/cm^3 is seldom realized. Most stainless steel weights have densities of from 7.84 to 7.95 g/cm^3, although some of the new weights on the market come very, very close to the ideal density of 8.0 g/cm^3.

True Mass (Mass in vacuum)

Contrary to what the name implies, “Mass in Vacuum” is **NOT** what a weight would weigh in a perfect vacuum, with no air buoyancy effect. The term ‘Mass in Vacuum’ is a misnomer, and causes confusion.

To illustrate the concept of True Mass, consider the following hypothetical example: We have two perfect kilogram weights, each having a Conventional Mass value of exactly 1000.000000 g. The first mass is a calibrated reference mass, made from stainless steel, with an ideal density of 8.0 g/cm^3. The second weight is a calibrated mass is also made from stainless steel, but has a commonly seen density of 7.95 g/cm^3.

Now let’s consider effect of the air buoyancy on each of the masses:

From basic physics we know that Volume = Mass / Density, so:

The first stainless steel mass has a claimed density (from the manufacturer) of 8.0 g/cm^3, accordingly, the volume of this mass is:

1000.000000 divided by 8 = 125.00000000 cm^3

The second stainless steel mass has a density from the manufacturer of 7.95 g/cm^3, so its volume is:

1000.000000 divided by 7.95 = 125.78616352 cm^3

Now – if we could compare these two masses inside a perfect vacuum, there would be NO air buoyancy effect, so we can calculate how much MORE each mass would weigh in a vacuum by multiplying the volume of the mass by the density of “perfect” air:

The 8.0 g/cm^3 mass: 125 x 1.200 = 150.00000000 mg

The 7.95 g/cm^3 mass: 125.78616352 x 1.200= 150.943396224 mg

We can see that the 7.95 mass weighs more (in a vacuum) than the 8.0 mass by .943396 mg:

$$\begin{array}{r} 150.943396224 \\ -150.000000000 \\ \hline 0.943396224 \end{array}$$

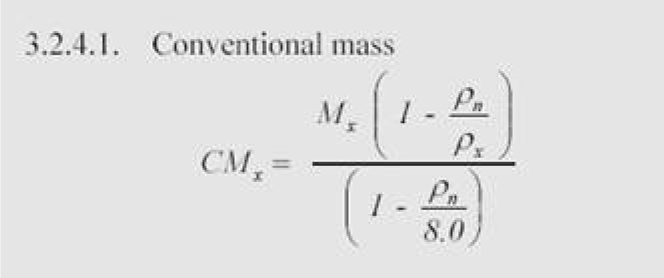
Accordingly, the True Mass of the 7.95 mass is 1000.000944 (rounding to 6 decimal places).

True Mass, therefore, is **not** what a weight would weigh in a vacuum, but rather, what it would weigh *compared against a reference standard mass (with a known value) on a “perfect” equal arm balance inside a “perfect” vacuum chamber.’*

The magnitude of the difference between the Conventional Mass and True Mass is the effect of the air buoyancy *__on the difference between the volumes__* of the two masses.

Now we can turn it around and convert back to Conventional Mass:

The formula (from NIST mass calibration procedures) to convert True Mass to Conventional Mass is as follows:



3.2.4.1. Conventional mass

$$CM_x = \frac{M_x\left(1 - \frac{\rho_n}{\rho_x}\right)}{\left(1 - \frac{\rho_n}{8.0}\right)}$$

Where:

CMx = Conventional Mass of weight X

Mx = True Mass of weight X

Pn = ‘Normal Air’ density of 1.2 mg/cm^3

Px = Density of weight X (7.95)

Work the calculation (1000.000944(1-0.0012/7.95))/(1-0.0012/8) and the result is 1000.000000 (rounded to 6 decimal places).

A well equipped calibration laboratory seeking to undertake high precision measurements of this type, approaches the calibration of mass by creating an environment where the ambient variables are stabilized to the greatest extent possible; then precisely measuring temperature, atmospheric pressure and humidity, calculating the air density from these parameters, and then conducting a matrix of intercomparisons (weighings) between a standard, the weight being tested, and a check standard (a second calibrated mass), using approved procedures and mathematical equations. In the course of the calibration the buoyant effects of the air on the standard, the test weight and the check standard are calculated and compensated for. The laboratory then reports Conventional Mass and True Mass with an appropriate measurement uncertainty attributable to each result.

Think about it:

- If the density of the mass is less than 8.0 g/cm^3, its True Mass will be greater than its Conventional Mass.
- The inverse is also true – a mass with a density greater than 8.0 g/cm^3 will have a True Mass value smaller than its Conventional Mass value.
- A mass with a density of 8.0 g/cm^3 will have exactly the same value for its True Mass and Conventional Mass.

Bottom line: use the Conventional Mass values for standard weight uses – i.e., balance calibration and verification. The True Mass values are typically used only by calibration laboratories, or for reference information.

Source:

https://icllabs.com/

https://icllabs.com/mass-calibration-metrology-terms-explained-in-plain-english/