TESCO METERING

Accuracy, Precision, Uncertainty

TESCO's Meter School

TESCOOL

July 20-23, 2025

July 22nd 2025

Carson Scaccetti

OVERVIEW

- VIM
- Accuracy, Precision, Uncertainty
- Uncertainty Budget
- Traceability
- Where can I find information:
  - Uncertainty on calibration certificate
  - Laboratories' accredited uncertainties and measurement fields
  - Guides for Uncertainty, and uncertainty budgets

VIM

- The International Vocabulary of Metrology
- Developed by the 8 member orgs of the Joint Committee for Guides In Metrology (JCGM)
- Purpose to harmonize worldwide the fundamental terminology of Metrology
- VIM4 2CD (second committee draft) – 7/31/2023

ACCURACY

3.15 [VIM3: 2.13; VIM2: 3.5; VIM1: 3.05]
measurement accuracy

accuracy

closeness of agreement between a **measured value** and a **reference value** of a **measurand**

NOTE 1 Accuracy is customarily thought of as pertaining to

1) a **measurement procedure**: in this case closeness of agreement is often reported quantitatively in terms of **bias** and standard deviation, which are evaluated through **validation** or **verification**, where known reference values are provided by **measurement standards**, **certified reference materials** or **reference measurement procedures**. Algorithms for evaluation are given in ISO 5725 [13]);

2) a **measuring instrument** or a **measuring system**: in this case closeness of agreement is often reported quantitatively in terms of an **accuracy class** or **maximum permissible error,** which are evaluated through verification or calibration, where known reference values are provided by measurement standards, certified reference materials or reference measurement procedures;

3) a **measurement** whose outcome is a single measured value or a set of measured values: in either of these cases the reference value is a **true value**, which is not known, and is estimated using all available information including information about the accuracy of the measurement procedure and of the measuring instrument used in the measurement. Sometimes measurement accuracy is reported quantitatively in terms of **measurement uncertainty**.

NOTE 2 Accuracy can be interpreted as the combination of **measurement trueness** and **measurement precision**. However, the term “measurement accuracy” should not be used to refer to measurement trueness and the term “measurement precision” should not be used to refer to measurement accuracy.

NOTE 3 A measurement is said to be more accurate when it offers a smaller **measurement error**.

ACCURACY

- Consistency of results under same or similar conditions
- Truly only reflects closeness of a measurement(s) and a set /reference value
- Older Mil-spec
- TAR
- Think closeness of a thrown dart to bullseye

PRECISION

3.17 [VIM3: 2.15]
measurement precision

precision

closeness of agreement among **indications** or **measured values** obtained by replicate **measurements** on the same or similar objects under specified conditions

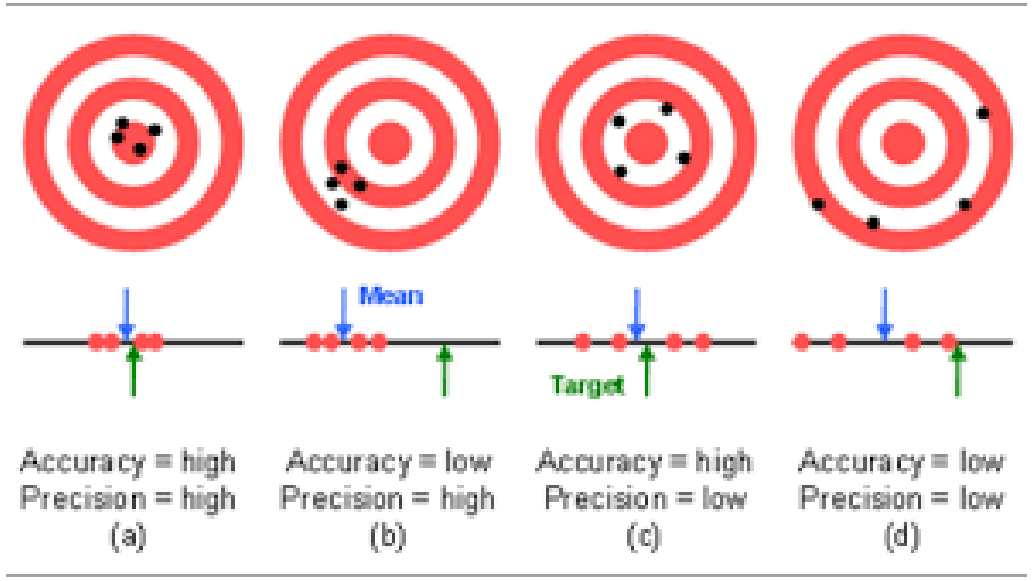
NOTE 1 Measurement precision is sometimes interpreted as closeness of a **random measurement error** to zero. In this case, closeness is often reported quantitatively in terms of standard deviation, variance, coefficient of variation or precision limits under the specified conditions of measurement.

NOTE 2 Measurement precision is customarily thought of as pertaining to either 1) a **measurement procedure**, 2) a **measuring instrument** or a **measuring system**, or 3) a set of indications or measured values.

NOTE 3 The specified conditions mentioned in the definition can be, for example, **repeatability conditions of measurement**, **intermediate precision conditions of measurement**, or **reproducibility conditions of measurement**. The specified conditions typically relate to, but are not necessarily limited to, **measurement method**, measurement procedure, measuring system, measuring system operator, operating conditions, period of time and measurement location. The specification of the conditions should include what the changes are, to the extent practical.

NOTE 4 Measurement precision may be evaluated by replicate measurements on similar objects, provided that variability among the objects is negligible.

PRECISION



- Accuracy is more of an outdated terminology still utilized
- Typically this is quantified through repeatability, and expressed as standard deviation, variance
- Contributor of variability and uncertainty
- Can be random or systematic
- Think of spread or clustering of thrown darts to bullseye

UNCERTAINTY

3.1 [VIM3: 2.26; VIM2: 3.9; VIM1: 3.09]

measurement uncertainty

uncertainty of measurement

uncertainty

parameter characterizing the dispersion of the **values** being attributed to a **measurand**, based on the information used

NOTE 1 Measurement uncertainty is generally part of a **measurement result**.

NOTE 2 Measurement uncertainty can be interpreted as doubt about a **true value** of the measurand that remains after making a **measurement**.

NOTE 3 The parameter characterizing dispersion can be, for example, a **standard uncertainty** (or a specified multiple of it), or the half-width of an interval, having a stated **coverage probability**.

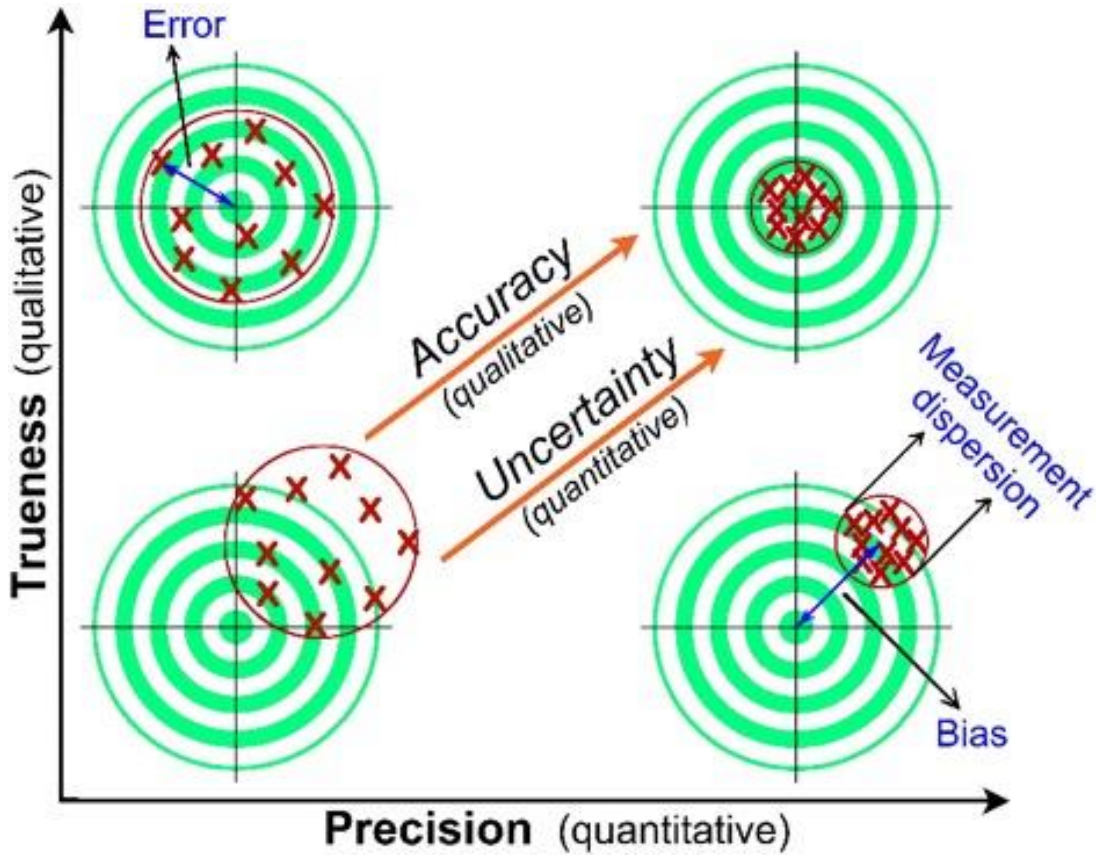
NOTE 4 Measurement uncertainty includes components arising from several sources, as listed in the GUM [30], including both **random** and **systematic errors**, caused by **measurement precision** and **measurement trueness** accordingly.

NOTE 5 Components of measurement uncertainty arising from systematic errors include components associated with **corrections**. Sometimes estimated systematic errors are not corrected for but, instead, associated measurement uncertainty components are incorporated.

NOTE 6 In general, it is understood that the measurement uncertainty is associated with a stated value attributed to the measurand. The choice of a different value results in a modification of the associated uncertainty.

NOTE 7 Guidance about the evaluation and expression of measurement uncertainty is provided by the GUM [30].

UNCERTAINTY



- A quantification of the doubt about a measurement
- “Margin of Error”
- Includes not just the dispersion of repeated measured values, but all contributors, known and estimated unknown, systematic and random
- Often expressed as an Expanded Uncertainty with a coverage factor
- Think of the radius of a circle drawn the cluster of thrown darts to bullseye

UNCERTAINTY BUDGET

3.10 [VIM3: 2.33]
uncertainty budget

statement of a **measurement uncertainty**, of the components of that measurement uncertainty, and of their calculation and combination

NOTE An uncertainty budget specifies the **measurement model**, estimates and measurement uncertainties associated with the **quantities** in the measurement model, covariances, type of applied probability distributions, degrees of freedom, type of evaluation of measurement uncertainty, and any **coverage factor** if **expanded uncertainty** is considered, where relevant.

3.11 [VIM3: 2.35]
expanded measurement uncertainty

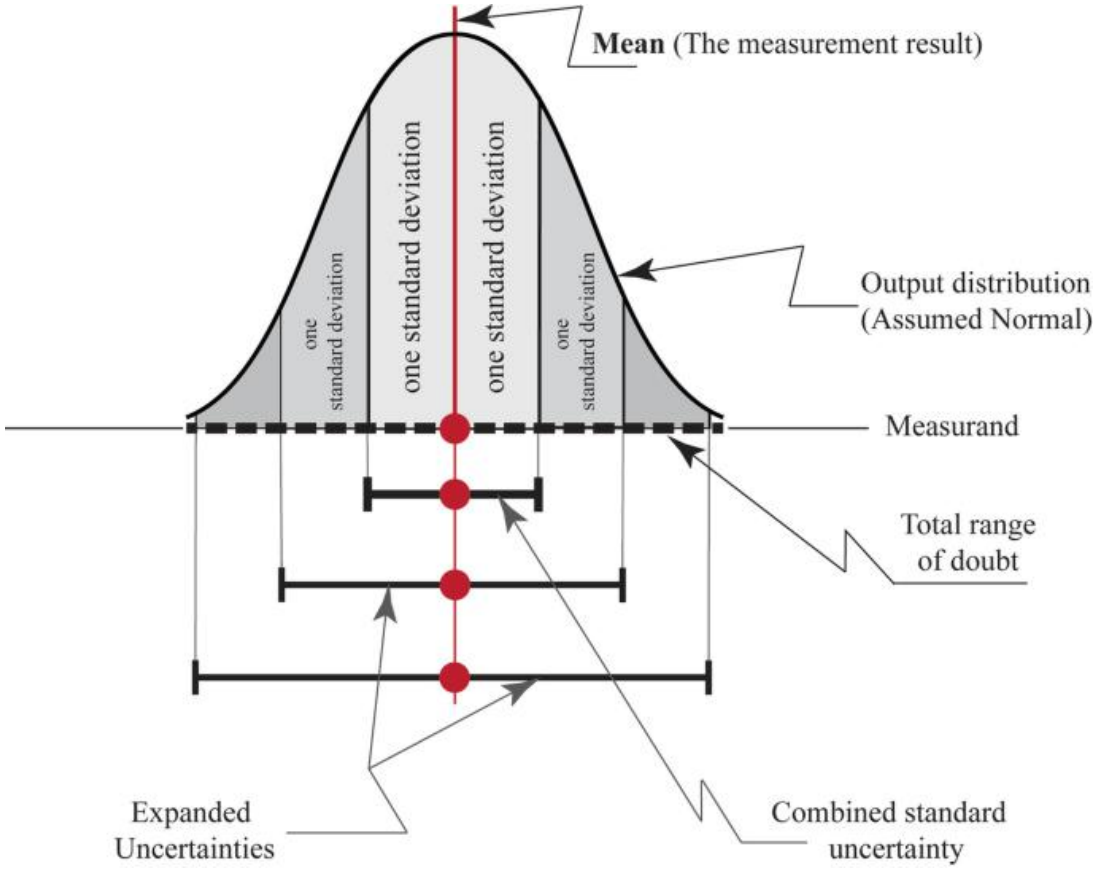
expanded uncertainty

product of a **standard measurement uncertainty** and a factor greater than one

NOTE 1 The factor mentioned in the definition is a **coverage factor** and depends upon the type of probability distribution attributed to the **quantity** in a **measurement model** and the selected **coverage probability**. Expanded uncertainties are meaningful only for symmetric distributions.

NOTE 2 Expanded measurement uncertainty is termed “overall uncertainty” in paragraph 5 of Recommendation INC-1 (1980) (see the GUM [30]).

UNCERTAINTY BUDGET



- Specifies the contributors of uncertainty of a measurement model or process
- Type A – components derived from statistical analysis
- Type B – components by means other than Type A
- Convert into standard uncertainties (u) through divisors based on probability
- Combined through statistical method, typically RSS
- Multiplied by coverage factor

UNCERTAINTY BUDGET

- Unc Budget for the measure the length of a steel rod using a digital caliper.

🔧 **Equipment Used:**

- Digital caliper (resolution: 0.01 mm)
- Steel rod (nominal length: ~100 mm)
- Measurement environment: controlled room at 20°C

Source of Uncertainty	Type	Distribution	Value (±)	Divisor	Standard Uncertainty (u)
Caliper resolution	B	Rectangular	0.01 mm	√3	0.0058 mm
Calibration uncertainty	B	Normal	0.02 mm	1	0.02 mm
Repeatability (operator error)	A	Normal	0.015 mm	1	0.015 mm
Temperature variation effect	B	Rectangular	0.01 mm	√3	0.0058 mm
Thermal expansion correction	B	Rectangular	0.005 mm	√3	0.0029 mm

UNCERTAINTY BUDGET

📊 **Combined Standard Uncertainty:**

$$U_c = \sqrt{0.0058^2 + 0.02^2 + 0.015^2 + 0.0058^2}$$
$$= \sqrt{0.000034 + 0.0004 + 0.000225 + 0.000034} \approx 0.027\ mm$$

📈 **Expanded Uncertainty (with coverage factor k = 2 for ~95% confidence):**

$$U = k \cdot u_c = 2 \cdot 0.027 \approx 0.054\ mm$$

📌 **Final Reported Result:**

Measured length = 100.00 mm ± 0.05 mm (k = 2, 95% confidence level)

UNCERTAINTY TO TRACEABILITY

- Uncertainty budgets are a requirement of ISO17025
- ISO17025 REQUIRES traceability
- How does a tech/user/customer know this or is ensured of this?
- Lets pivot to Quality Infrastructure

6.5 Metrological traceability

6.5.1 The laboratory shall establish and maintain metrological traceability of its measurement results by means of a documented unbroken chain of calibrations, each contributing to the measurement uncertainty, linking them to an appropriate reference.

NOTE 1 In ISO/IEC Guide 99, metrological traceability is defined as the "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".

NOTE 2 See Annex A for additional information on metrological traceability.

6.5.2 The laboratory shall ensure that measurement results are traceable to the International System of Units (SI) through:

a) calibration provided by a competent laboratory; or

NOTE 1 Laboratories fulfilling the requirements of this document are considered to be competent.

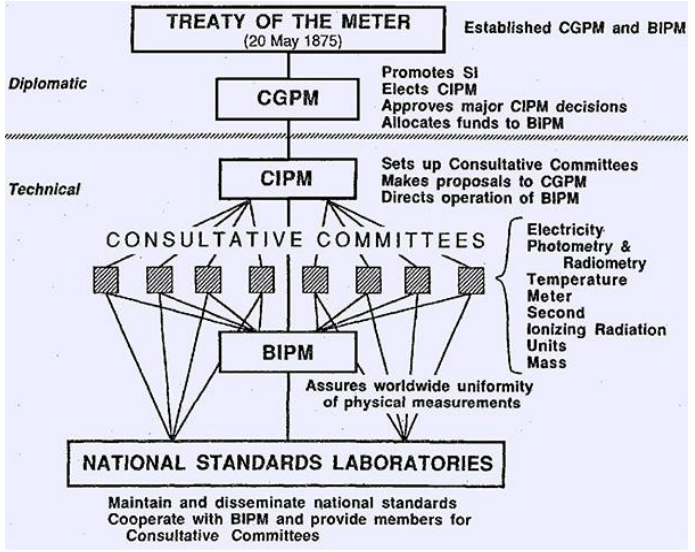
b) certified values of certified reference materials provided by a competent producer with stated metrological traceability to the SI; or

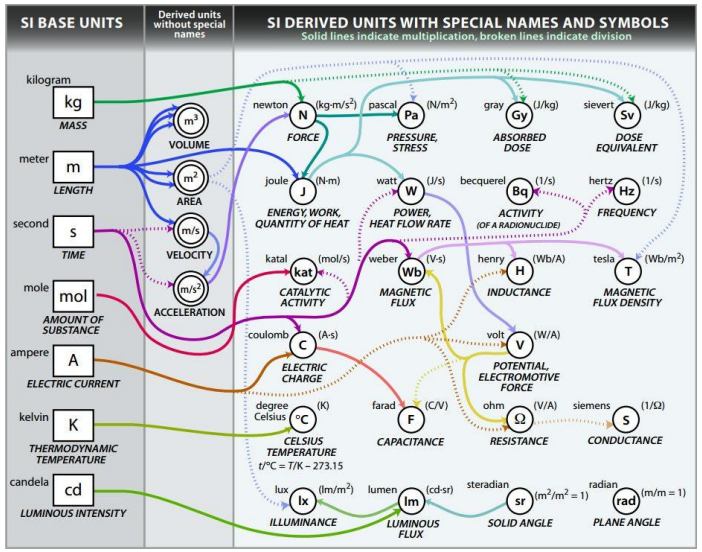
NOTE 2 Reference material producers fulfilling the requirements of ISO 17034 are considered to be competent.

c) direct realization of the SI units ensured by comparison, directly or indirectly, with national or international standards.

METRE CONVENTION

- SI – The International System of Units
  - International Bureau of Weights and Measures (BIPM)
  - General Conference on Weights of Measures (CGPM)
  - International Committee for Weights and Measures (CIPM)
- Recently just celebrated the 150th anniversary on world metrology day May 20th





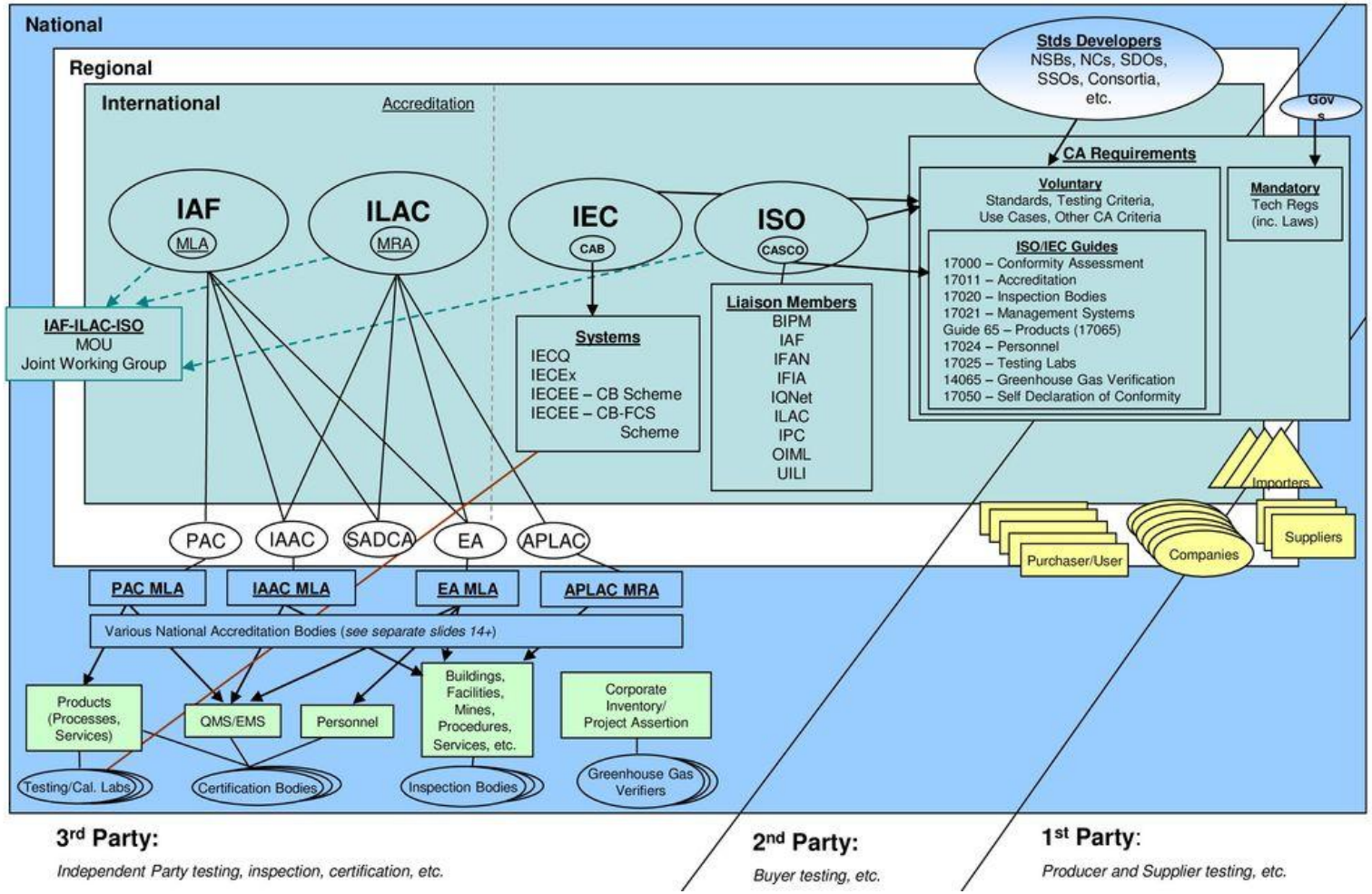
INTERNATIONAL QUALITY INFRASTRUCTURE

- 1955, The International Organization of Legal Metrology founded (OIML)
- International Accreditation Forum (IAF)
- International Laboratory Accreditation Cooperation (ILAC)
- International Organization for Standardization (ISO)
- Mutual Recognition Agreement(MRA)
- Multilateral Recognition Agreement (MLA)

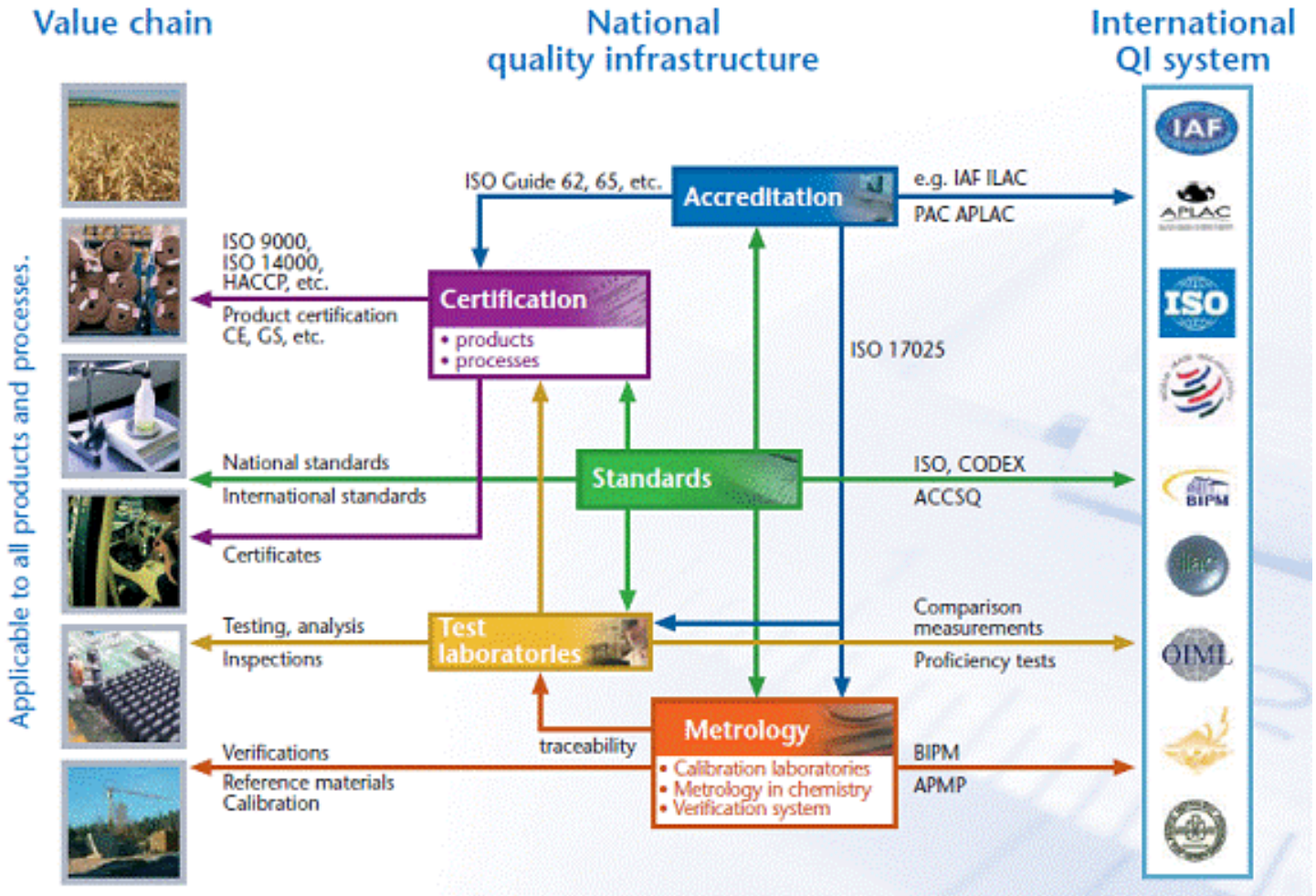
INTERNATIONAL CONFORMITY ASSESSMENT SYSTEM

Snapshot of the International Conformity Assessment System

with relationships to regional and national systems



NATIONAL QUALITY INFRASTRUCTURE

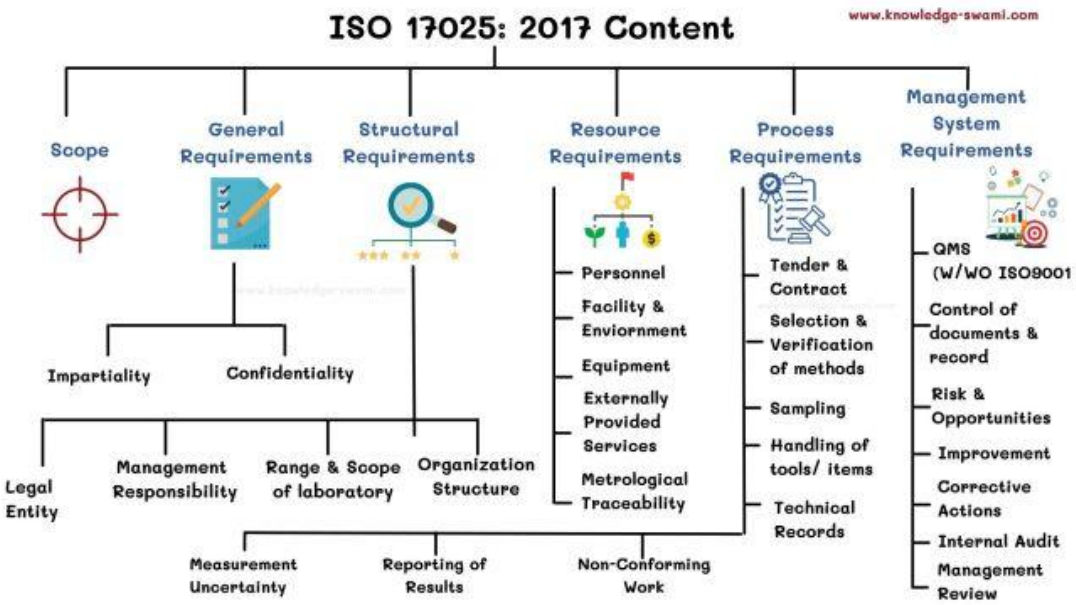


How Does TESCO Fit?

- TESCO is ISO 9001:2015 certified
  - DEKRA – Conformity Assurance Body (CAB)
    - ANSI National Accreditation Board (ANAB)
      - Inter-American Accreditation Cooperation MLA (IAAC)
        - IAF
- TESCO's Laboratory is ISO/IEC 17025: 2017 Accredited
  - PJLA – Accreditation Body
    - ILAC MRA

ISO/IEC 17025

- ISO/IEC 17025:2017 – General requirements for the competence of testing and calibration laboratories
- Repeatable, verifiable, impartial, assured, recognizable results
- Hallmarks of 17025
  - Evaluation of Measurement Uncertainty
  - Selection, verification, and validation of methods
  - Reporting of Results
  - Metrological Traceability



2.41 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**

NOTE 1 For this definition, a 'reference' can be a definition of a **measurement unit** through its practical realization, or a **measurement procedure** including the measurement unit for a non-**ordinal quantity**, or a **measurement standard**.

NOTE 2 Metrological traceability requires an established **calibration hierarchy**.

NOTE 3 Specification of the reference must include the time at which this reference was used in establishing the calibration hierarchy, along with any other relevant metrological information about the reference, such as when the first calibration in the calibration hierarchy was performed.

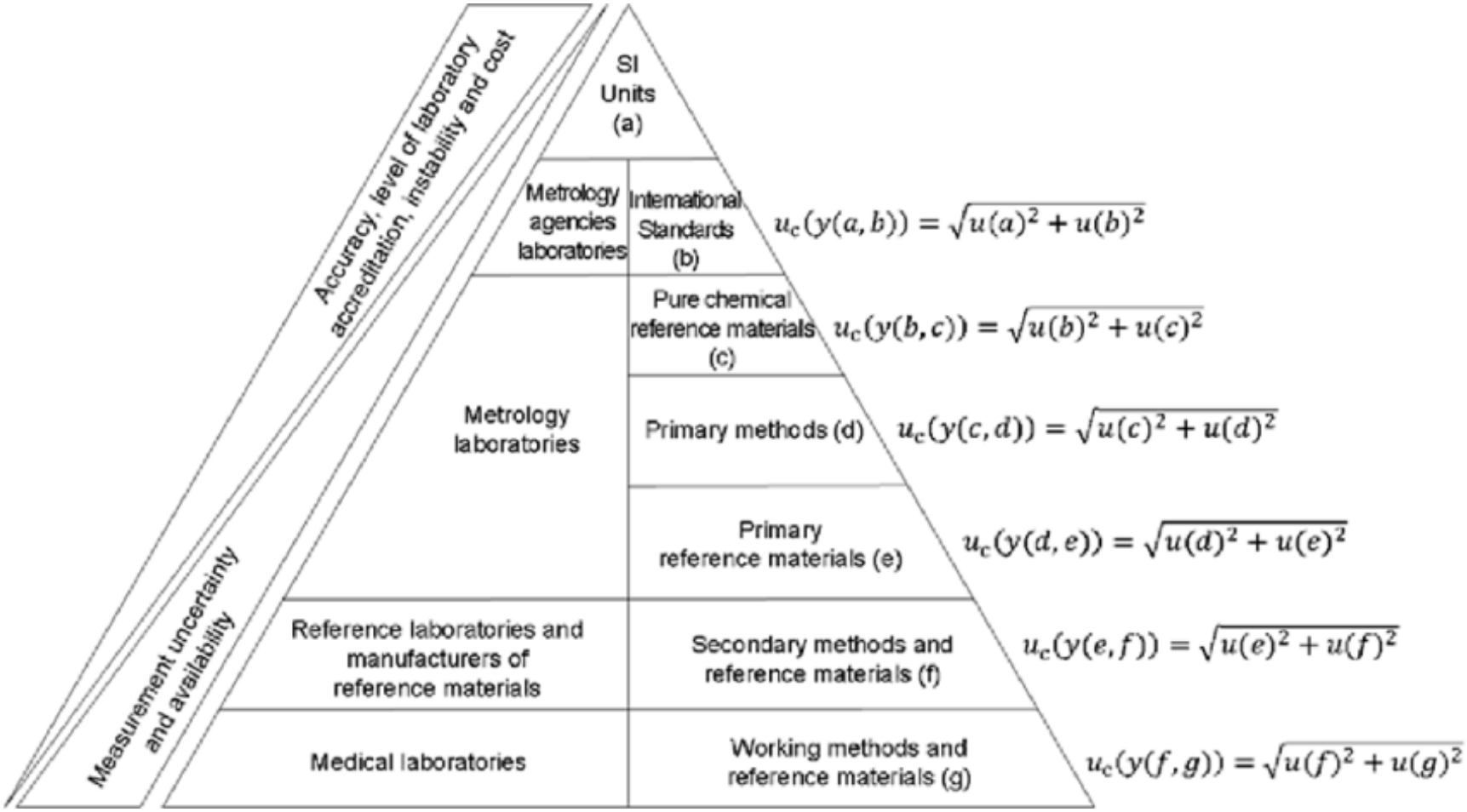
NOTE 4 For **measurements** with more than one **input quantity in the measurement model**, each of the input **quantity values** should itself be metrologically traceable and the calibration hierarchy involved may form a branched structure or a network. The effort involved in establishing metrological traceability for each input quantity value should be commensurate with its relative contribution to the measurement result.

NOTE 5 Metrological traceability of a measurement result does not ensure that the measurement uncertainty is adequate for a given purpose or that there is an absence of mistakes.

NOTE 6 A comparison between two measurement standards may be viewed as a calibration if the comparison is used to check and, if necessary, correct the quantity value and measurement uncertainty attributed to one of the measurement standards.

NOTE 7 The ILAC considers the elements for confirming metrological traceability to be an unbroken **metrological traceability chain** to an **international measurement standard** or a **national measurement standard**, a documented measurement uncertainty, a documented measurement procedure, accredited technical competence, metrological traceability to the SI, and calibration intervals (see ILAC P-10:2002).

NOTE 8 The abbreviated term "traceability" is sometimes used to mean 'metrological traceability' as well as other concepts, such as 'sample traceability' or 'document traceability' or 'instrument traceability' or 'material traceability', where the history ("trace") of an item is meant. Therefore, the full term of "metrological traceability" is preferred if there is any risk of confusion.


Accuracy, level of laboratory accreditation, instability and cost
Measurement uncertainty and availability
SI Units (a)
Metrology agencies laboratories
International Standards (b)
Pure chemical reference materials (c)
Metrology laboratories
Primary methods (d)
Primary reference materials (e)
Reference laboratories and manufacturers of reference materials
Secondary methods and reference materials (f)
Medical laboratories
Working methods and reference materials (g)
$u_c(y(a,b)) = \sqrt{u(a)^2 + u(b)^2}$
$u_c(y(b,c)) = \sqrt{u(b)^2 + u(c)^2}$
$u_c(y(c,d)) = \sqrt{u(c)^2 + u(d)^2}$
$u_c(y(d,e)) = \sqrt{u(d)^2 + u(e)^2}$
$u_c(y(e,f)) = \sqrt{u(e)^2 + u(f)^2}$
$u_c(y(f,g)) = \sqrt{u(f)^2 + u(g)^2}$

2.42 METROLOGICAL TRACEABILITY CHAIN

metrological traceability where the reference is the definition of a **measurement unit** through its practical realization

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

sequence of **measurement standards** and **calibrations** that is used to relate a **measurement result** to a reference

NOTE 1 A metrological traceability chain is defined through a **calibration hierarchy**.

NOTE 2 A metrological traceability chain is used to establish **metrological traceability** of a measurement result.

NOTE 3 A comparison between two measurement standards may be viewed as a calibration if the comparison is used to check and, if necessary, correct the **quantity value** and **measurement uncertainty** attributed to one of the measurement standards.

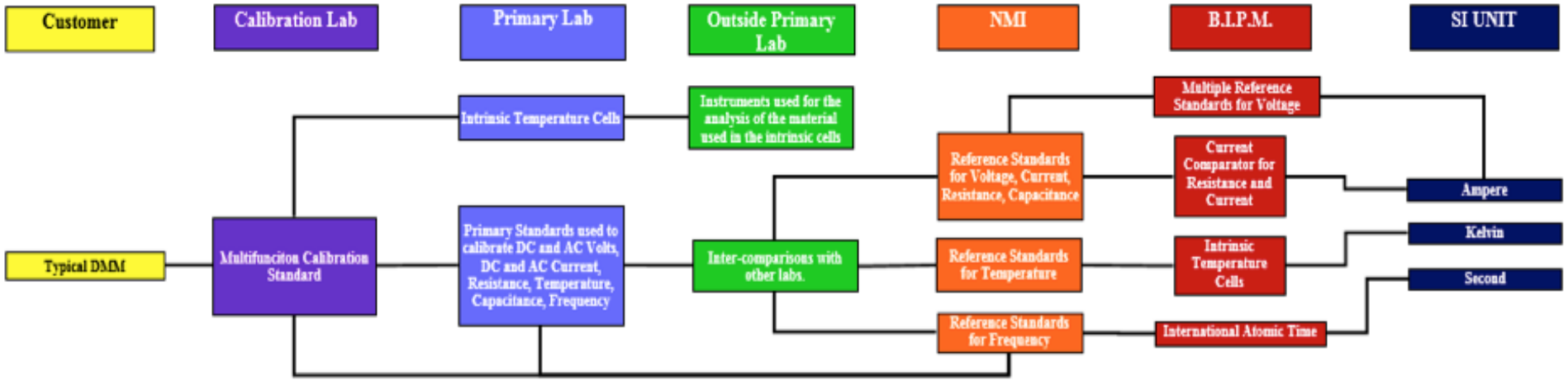
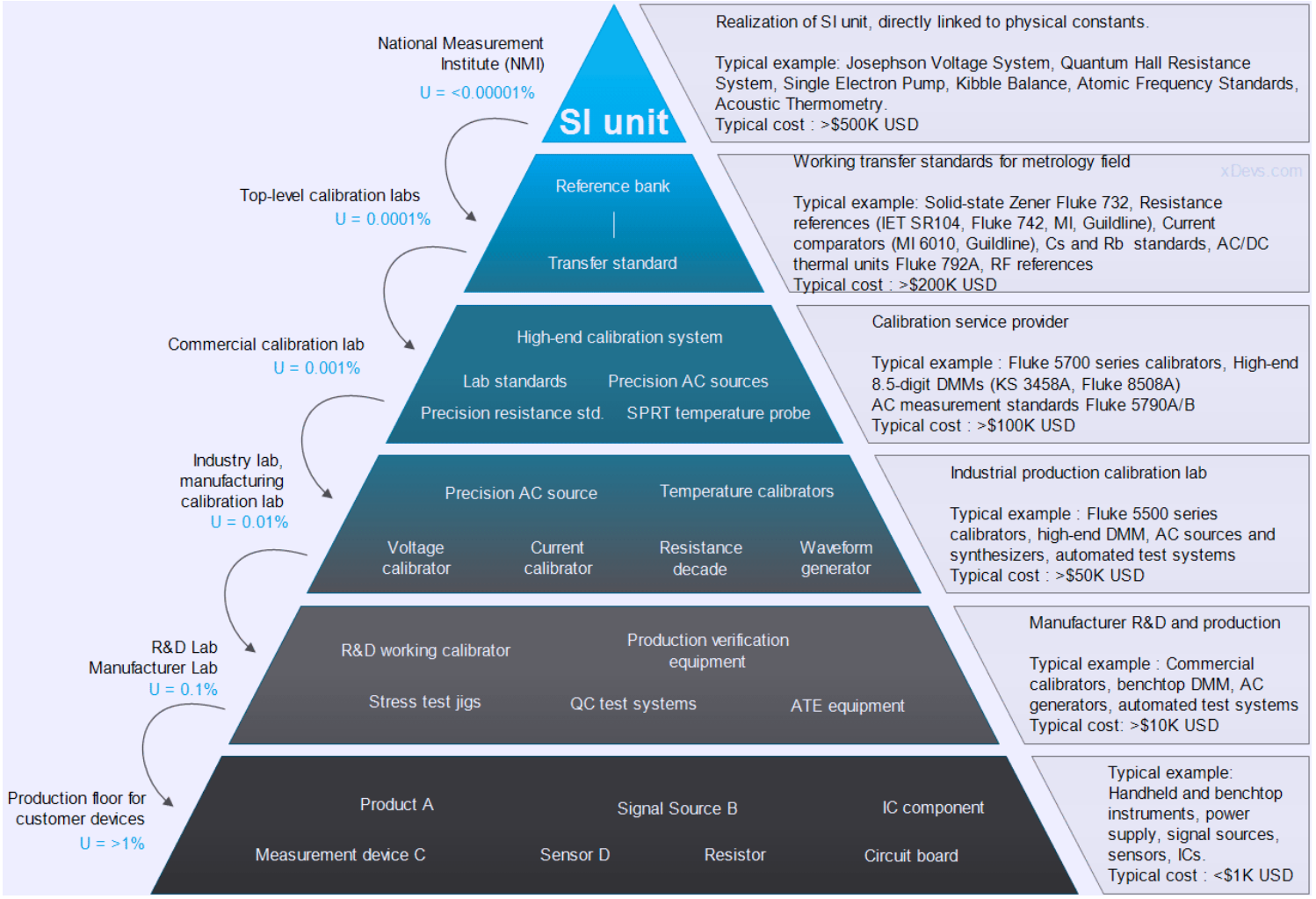


Figure 1: Very simple illustration of a traceability chain.

CALIBRATION HIERARCHY



"NIST TRACEABILITY"

- Why is it that the Industry requires "NIST traceability"?
  - NAVY
  - MIL-SPEC
  - ANSI Z540.1
- Risk Mitigation
- Measurement veracity
- Where do I find this information?
  - Calibration Certificate – Traceability statement
  - Guaranteed on a 17025 Cal report/certificate
    - Look for the Logo/stamp
- Traceable to the International System of Units (SI), through National Metrology Institutes e.g. NIST, NRC, NPL, etc.), via ratiometric techniques, or natural physical constants.
  - "Traceable to SI"

WHERE/HOW CAN I FIND TRACEABILITY?

- Look for the stamps
  - Provided by accreditation bodies
  - Will have specific accreditation number
  - NVLAP, A2LA, PJLA
- Find the traceability statement
  - They all more or less say the same thing: Traceable to SI

7.8.4 Specific requirements for calibration certificates

7.8.4.1 In addition to the requirements listed in 7.8.2, calibration certificates shall include the following:

a) the measurement uncertainty of the measurement result presented in the same unit as that of the measurand or in a term relative to the measurand (e.g. percent);

NOTE According to ISO/IEC Guide 99, a measurement result is generally expressed as a single measured quantity value including unit of measurement and a measurement uncertainty.

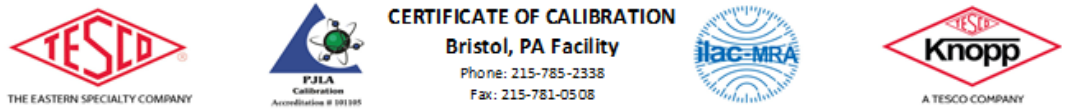
b) the conditions (e.g. environmental) under which the calibrations were made that have an influence on the measurement results;

c) a statement identifying how the measurements are metrologically traceable (see Annex A);

d) the results before and after any adjustment or repair, if available;

e) where relevant, a statement of conformity with requirements or specifications (see 7.8.6);

f) where appropriate, opinions and interpretations (see 7.8.7).



This calibration is traceable to the International System of Units (SI), through National Metrology Institutes (e.g. NIST, NRC, NPL, etc.), via ratiometric techniques, or natural physical constants. The results contained within this certificate relate only to the items calibrated and shall not be reproduced other than in full, and only with prior written approval from the TESCO Calibration & Testing Laboratory. Calibration Certificates are valid only with an authorized signature. The above instrument was tested and calibrated in accordance with TESCO ISO/ IEC 17025:2017 Quality Manual, Rev 4, dated 3-May-22.

WHERE CAN I FIND UNCERTAINTIES?

- On your calibration certificate if of an “ISO17025 Level” or with “ISO17025 accredited uncertainties”
- Look for “Uncertainty”, “Exp Unc”, “Expanded Uncertainty”, “Measurement Uncertainty”
  - These are the expanded uncertainties, or total uncertainty associated with that measure and multiplied by coverage factor
  - Do not confuse with standard uncertainty or calibration process uncertainty (CPU)
    - These uncertainties are only parts of the combined and expanded uncertainties

TESCO METERING

WHERE CAN I FIND UNCERTAINTIES?

THE EASTERN SPECIALTY COMPANY

PJLA Calibration Accreditation # 101105

CERTIFICATE OF CALIBRATION

Bristol, PA Facility

Phone: 215-785-2338

Fax: 215-781-0508

A TESCO COMPANY

Certificate #: TESCO060225-01

CCS1 - DCV

Voltage (V)	Current (A)	Seconds (s)	Energy (W·h)	Ref measure (V)	DUT Measure (V)	DUT Err (µV/V)	SMU (µV/V)	CPU (µV/V)	EUc (µV/V)
200	20	10	11.11111	200.0700	200.0709	4.3	4	85	85
400	20	10	22.22222	400.0790	400.0805	3.8	2	70	70
600	20	10	33.33333	600.0663	600.0660	-0.6	2	65	65
800	20	10	44.44444	800.0801	800.0814	1.7	1	62	63
1000	20	10	55.55556	1000.098	1000.099	1.1	1	61	61
200	50	10	27.77778	200.0722	200.0726	2.1	4	85	85
400	50	10	55.55556	400.0818	400.0827	2.1	1	70	70
600	50	10	83.33333	600.0691	600.0697	1.1	0	65	65
800	50	10	111.1111	800.0847	800.0851	0.5	1	62	63
1000	50	10	138.8889	1000.105	1000.106	1.0	1	61	61
200	100	10	55.5556	200.0769	200.0767	-1.1	1	85	85
400	100	10	111.1111	400.0882	400.0884	0.6	1	70	70
600	100	10	166.6667	600.0774	600.0785	1.9	1	65	65
800	100	10	222.2222	800.0953	800.0982	3.6	1	62	63
1000	100	10	277.7778	1000.117	1000.119	1.2	1	61	61
200	200	10	111.1111	200.0850	200.0843	-3.7	1	85	85
400	200	10	222.2222	400.1002	400.1000	-0.5	3	70	70
600	200	10	333.3333	600.0925	600.0930	0.8	0	65	65
800	200	10	444.4444	800.1143	800.1140	-0.3	1	62	63
1000	200	10	555.5556	1000.143	1000.141	-1.6	1	61	61

TESCO METERING

WHERE CAN I FIND UNCERTAINTIES?

S.O. WO-00787855 SERIAL No. 2823A11732 CAL DATE 14 May 2024

FINAL INTERNAL TEMPERATURE AFTER AC CAL 34.2°C

3458A AC VOLTS & CURRENT DATA (AS RECEIVED)

CAL POINT	LOW LIMIT	MEASURED	HIGH LIMIT	UNCERTAINTY	STATUS
.01V 1kHz	.00999690	.01000014	.01000310	.00000010	
.01V 20kHz	.00999590	.00999939	.01000410	.00000016	
.01V 100kHz	.00994890	.00997910	.01005110	.00000022	
.01V 300kHz	.00959800	.00983437	.01040200	.00000042	
.01V 1MHz	.00987500	.00996615	.01012500	.00000180	
.1V 1kHz	.0999910	.1000030	.1000090	.0000023	
.1V 20kHz	.0999840	.1000024	.1000160	.0000022	
.1V 100kHz	.0999180	.0999627	.1000820	.0000022	
.1V 300kHz	.0996900	.0998056	.1003100	.0000024	
.1V 1MHz	.0989900	.0997930	.1010100	.0000065	
1V 1kHz	.999910	1.000038	1.000090	.000012	
1V 20kHz	.999840	.999975	1.000160	.000014	
1V 50kHz	.999680	1.000038	1.000320	.000017	
1V 100kHz	.999130	1.000108	1.000870	.000019	
1V 300kHz	.996900	1.001037	1.003100	.000032	
1V 500kHz	.989900	1.002405	1.010100	.000070	
1V 1MHz	.989900	1.006257	1.010100	.000252	
3V 100kHz	2.99739	2.99882	3.00261	.000065	
10V 10Hz	9.99890	10.00019	10.00110	.00029	
10V 20Hz	9.99890	10.00030	10.00110	.00021	
10V 40Hz	9.99910	10.00028	10.00090	.00020	
10V 1kHz	9.99910	10.00040	10.00090	.00014	
10V 4kHz	9.99840	10.00026	10.00160	.00014	
10V 8kHz	9.99840	9.99985	10.00160	.00014	
10V 10kHz	9.99840	9.99980	10.00160	.00014	
10V 20kHz	9.99840	9.99972	10.00160	.00014	
10V 50kHz	9.99680	9.99954	10.00320	.00020	
10V 100kHz	9.99180	9.99619	10.00820	.00022	
10V 300kHz	9.96900	9.97968	10.03100	.00045	
10V 500kHz	9.89900	9.98278	10.10100	.00083	
10V 1MHz	9.89900	10.03839	10.10100	.00293	
100V 1kHz	99.9780	100.0018	100.0220	.0014	
100V 20kHz	99.9780	99.9964	100.0220	.0016	
100V 50kHz	99.9630	99.9959	100.0370	.0021	
100V 100kHz	99.8780	99.9718	100.1220	.0029	
700V 1kHz	699.699	700.003	700.301	.0114	
700V 20kHz	699.559	699.963	700.441	.0144	
.01V 4MHz	.0092930	.0097098	.0107070	.0000102	
.1V 4MHz	.095930	.099612	.104070	.000102	
.1V 8MHz	.095920	.099660	.104080	.000160	

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WHERE CAN I FIND UNCERTAINTIES?

Test Description	APPLIED	Lower Limit	TEST RESULT	Upper Limit	Status	Exp Unc
-100.00000 mV	-100.000000 mV	-100.00080 mV	-99.99994 mV	-99.99920 mV	Pass	5.1e-007 V
1 V Range						
0.00000000 V	0.000000000 V	-0.00000106 V	-0.00000027 V	0.00000106 V	Pass	7.4e-008 V
1.00000000 V	1.000000000 V	0.99999570 V	0.99999942 V	1.00000430 V	Pass	2.5e-006 V
-1.00000000 V	-1.000000000 V	-1.00000430 V	-0.99999813 V	-0.99999570 V	Pass	2.5e-006 V
10 V Range						
0.0000000 V	0.00000000 V	-0.0000023 V	0.0000000 V	0.0000023 V	Pass	2.4e-007 V
10.0000000 V	9.99999534 V	9.9999548 V	10.0000057 V	10.0000358 V	Pass	3.1e-006 V
1.0000000 V	1.00000000 V	0.9999955 V	0.9999996 V	1.0000045 V	Pass	2.5e-006 V
-1.0000000 V	-1.00000000 V	-1.0000045 V	-0.9999979 V	-0.9999955 V	Pass	2.5e-006 V
-10.0000000 V	-9.99999534 V	-10.0000358 V	-10.0000050 V	-9.9999548 V	Pass	4.2e-006 V
100 V Range						
100.000000 V	100.0000000 V	99.999370 V	100.000016 V	100.000630 V	Pass	3.2e-004 V
-100.000000 V	-100.0000000 V	-100.000630 V	-100.000007 V	-99.999370 V	Pass	3.2e-004 V
1000 V Range						
1000.00000 V	1000.000000 V	999.98190 V	999.99941 V	1000.01810 V	Pass	3.3e-003 V
-1000.00000 V	-1000.000000 V	-1000.01810 V	-999.99894 V	-999.98190 V	Pass	3.3e-003 V

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CERTIFICATE OF CALIBRATION

Certificate No
EVL973984

Everett Service Center 1420 75th St. SW Everett Washington 98203 USA
TELEPHONE: 888-993-5853 FAX: 425-446-6390

Accredited Calibration Laboratory No 2166.01

Range	Fund	Harmonic Number	Set Phase	Set Amplitude	Measured Value	Phase Difference	Expanded Uncertainty	% of Spec	Compliance With Spec
23 V	57 Hz	1	0 °	16.00 V	0.000 0 °	0.000 0 °	0.001 2 °	2 %	
		99	0 °	4.50 V	-0.112 7 °	-0.059 7 °	0.057 °	-13 %	
	57 Hz	7	0 °	5.00 V	-0.002 1 °	-0.003 0 °	0.004 9 °	-6 %	
		15	-25 °	5.00 V	-25.000 6 °	-0.001 1 °	0.014 °	-1 %	
		33	0 °	5.00 V	0.017 2 °	0.042 1 °	0.026 °	21 %	
		55	-20 °	5.00 V	-20.038 5 °	-0.024 9 °	0.038 °	-6 %	
		84	0 °	5.00 V	-0.205 9 °	-0.190 6 °	0.050 °	-42 %	
	50 Hz	1	0 °	16.00 V	0.000 0 °	0.000 1 °	0.001 2 °	6 %	
	60 Hz	1	0 °	16.00 V	0.000 1 °	0.000 1 °	0.001 2 °	6 %	

Where Can I Find Accredited Laboratories Unc?

- A2LA
  - https://customer.a2la.org/index.cfm?event=directory.index
- PJLA
  - https://www.pjlabs.com/search-accredited-organizations
- NVLAP
  - https://www-s.nist.gov/niws/index.cfm?event=directory.search
- NMIs
  - https://www.bipm.org/kcdb/cmc/advanced-search

Where Can I Find Guides to Uncertianty?

- https://www.bipm.org/en/committees/jc/jcgm/publications
- https://www.isobudgets.com/
- https://www.nist.gov/itl/sed/topic-areas/measurement-uncertainty
- https://www.fluke.com/en-us/learn/blog/metrology
- https://www.pjlabs.com/resources

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COMMENTS, QUESTIONS, DISCUSSION

Carson Scaccetti
TESCO – The Eastern Specialty Company
Laboratory Manager
Carson.Scaccetti@tescometering.com
215-228-0500 EXT 272

COURSE FEEDBACK

Please Take a Few Minutes To Provide Feeback About The Course & Instructor