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Measurement and calibration: considerations based on the International Vocabulary of Metrology (VIM, 3rd Ed.) and related standards

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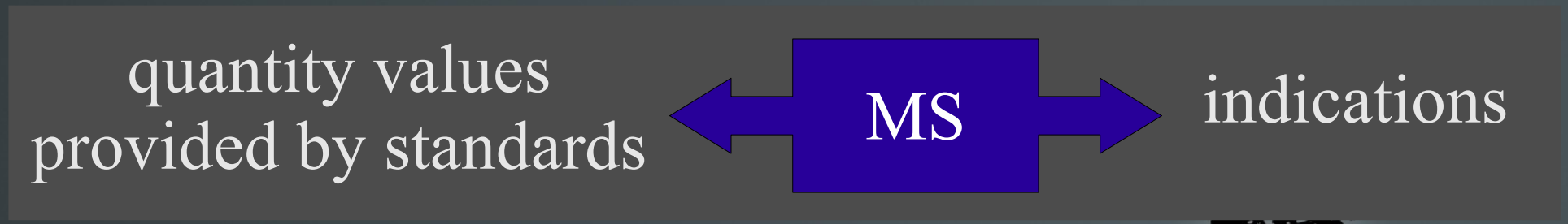
Some research questions

- What is the correct use of the information provided by calibration when implementing a measurement procedure?
- What are the relations between calibration and metrological confirmation? and between calibration data, instrumental uncertainty and measurement uncertainty?
- What is the proper interpretation of the term “accuracy” that sometimes is applied to address the metrological characteristics of a measuring instrument?

Before the VIM 3

Calibration according to the VIM 2

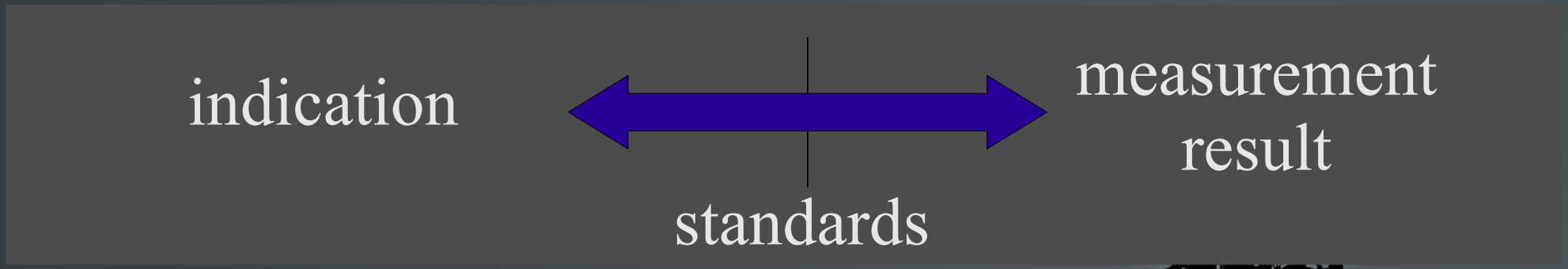
"set of operations that establish, under specified conditions, the relationship between values of quantities indicated by a measuring instrument or measuring system, or values represented by a material measure or a reference material, and the corresponding values realized by standards"



Before the VIM 3

Calibration according to the IEV

"set of operations which establishes, by reference to standards, the relationship which exists, under specified conditions, between an indication and a result of a measurement"
[see also http://www.electropedia.com]



Calibration according to the VIM3

"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"

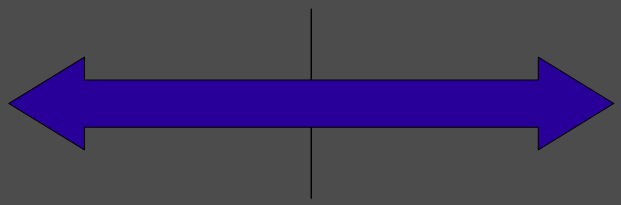
1st step

quantity values and measurement uncertainties provided by standards

indications and measurement uncertainties

2nd step

indication



measurement result

What is a measurement result?

VIM2

value attributed to a measurand, obtained by measurement

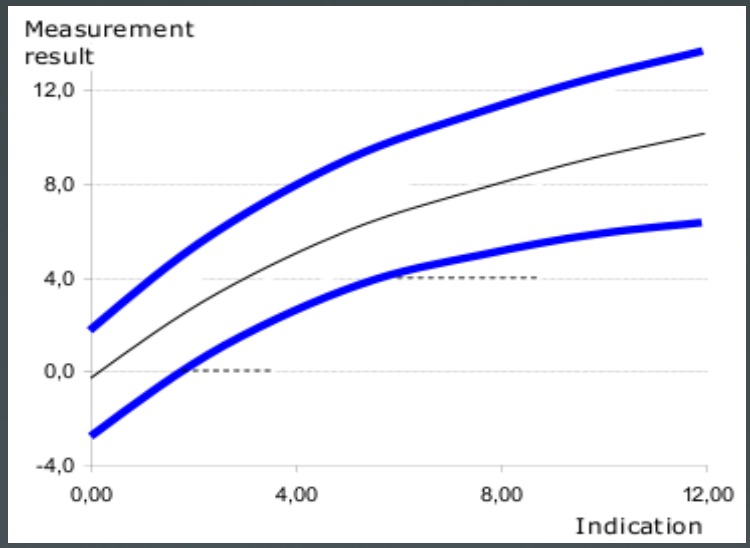
VIM3

set of quantity values being attributed to a measurand together with any other available relevant information

and the term “measured quantity value” has been introduced, defined as “quantity value representing a measurement result”, also noting that in the GUM the term “result of measurement” is used for 'measured quantity value'...

The underlying logic...

… as typically applied by means of a calibration diagram (“graphical expression of the relation between indication and corresponding measurement result”)



- An indication is a “quantity value provided by a measuring system” that “can be used to provide a corresponding measured quantity value”
- “a measurement result is generally expressed as a single measured quantity value and a measurement uncertainty”

so that calibration is mandatory for any MS and is a matter of interest to both manufacturers and users

On calibration diagrams

They have the double function of formalizing:

- the metrological performance of the MS
- the relation for deriving measurement results from indications

so that these diagrams fulfill both calibration steps, by making available to users what is needed to:

1. interpret any indication in terms of the corresponding quantity value
2. attain additional information to produce a measurement result

that is, to develop an uncertainty budget, by interpreting the strip width in terms of an instrumental measurement uncertainty and thus obtaining a measurement uncertainty

From instrumental measurement uncertainty to measurement uncertainty

MS manufacturers should specify how calibration diagrams are firstly generated and therefore the hypotheses to be assumed for the conversion (shape of the distribution, coverage factor, ...), including the considered influence quantities and their limiting values

Two alternative strategies can be adopted to acquire, and then communicate, this calibration data:

1. Reference conditions
2. Widened conditions

Two strategies

1. Reference conditions

The limiting values for influence quantities are chosen

only for reference, or "best performance", conditions

As a consequence the calibration strip is (relatively)

narrow

but

it does not keep into account all operative conditions

It is a common situation, e.g., for

simple mechanical measuring instruments

2. Widened conditions

The limiting values for influence quantities are chosen

so to identify the predictable conditions users might face

As a consequence the calibration strip is (relatively)

wide

but

it keeps into account all operative conditions

It is a common situation, e.g., for

ordinary electrical measuring instruments

Two strategies: consequences for users

1. Reference conditions	2. Widened conditions
This strategy is	
elegant: instrumental uncertainty is kept as a separate component of measurement uncertainty in the uncertainty budget	rough: instrumental uncertainty is taken into account as an approximation of measurement uncertainty
but the measurement model	
must be explicitly defined	can remain implicit
and influence quantities	
must be measured	are not required to be measured
If calibration data are misunderstood, measurement uncertainty will be in general	
underestimated	overestimated

On the use of the term “accuracy”

Sometimes MS manufacturers use the term “**accuracy**” to denote MS metrological performance, as documented by the calibration diagram

This has to be interpreted as a complex statement such as:

any measurement process which employs the MS and complies with the conditions stated by the given calibration data, with no further influence quantities of any type, produces results within the given calibration strip

Hence this usage is much more adequate when applied to MSs with calibration data generated through strategy 2

For the discussion

Provided that this analysis is correct (in the paper it is also applied to metrological confirmation, verification, and adjustment),

should the VIM maintain a general characterization of the concepts,
at the price of having possible ambiguities in them,

or should it instead refine the concepts,
at the price of becoming longer and plausibly more complex?