A metrological traceability chain prevents circular reasoning in measurement design

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In previous Editorials [1, 2], we described how the establishment of ‘metrological traceability’ [3] of a ‘measurement result’ [4], enables to walk back to the ‘reference’ [5] along the “trace” through which a measurement result did come to us: the ‘metrological traceability chain’ [6].

A characteristic of a chain is that it is one-dimensional. Does that also apply to a metrological traceability chain? In principle, yes. It may have “side chains” visualizing various secondary input quantities and their values (with associated uncertainties), which may influence the measurement result (and its associated uncertainty), but we will not here be looking at these secondary effects.

We choose the simplest case of a metrological traceability chain: the chain consisting of one link [1], which runs from the value of the measurand to the value embodied in the working calibrator used to calibrate the measuring system used. In fact, there are two “sub-links” involved: the first from the value embodied in the working calibrator to establishing the calibration curve of the measuring system to be used in the measurement and the second associated with the measurement, result for the unknown value of the measurand obtained by using the calibrated measuring system. Walking backwards along the “trace” from the result to the chosen ‘reference’ enables to see which steps have been taken to obtain the measurement result and see how the link was established from an unknown ‘quantity value’ [7] of the ‘measurand’ [8] to a known value of the same quantity embodied in the working ‘calibrator’ [9] chosen by the analyst to calibrate his/her ‘measuring system’ [10]. The calibration

of the analyst’s measuring system by means of the calibrator enables to operate that system and obtain a meaningful, i.e. calibrated, measurement result. The whole operation “realizes” a link between the unknown value of the measurand and the known quantity value embodied in the calibrator.

We also showed that the metrological traceability chain is established in the office *prior* to the measurement in the laboratory: it is a *decision* on the choice of the calibrator. This decision must be taken, of necessity, *before* the measurement is carried out: it is needed to know which calibrator must be purchased or obtained otherwise and then used.

Clearly, there is a natural sequence of decisions involved: the definition of the measurand by the analyst (possibly in consultation with the requestor of the measurement result) and the choice of the reference, i.e. the choice of a suitable working calibrator, to which metrological traceability of the measurement result will be established.

The combination of these (definition of measurand and choice of working calibrator) enables to perform:

1. the calibration of the analyst’s chosen measuring system and
2. the actual measurement of the measurand, using that calibrated measuring system.

[Note: a logical consequence of the “realization” of a metrological traceability chain consisting of one “link” is two measurement uncertainties: one associated with a calibration and one associated with a measurement (the two “sub-links” referred to above).]

The decision process by which the metrological traceability chain, laid out during the planning of the measurement, is *unidirectional* along the chain because

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of the metrological sequence—one could even say the metro-logical sequence—of the two steps above. It is constituted by sequential steps logically following each other in time. Hence, one could even call it a chrono-logical sequence.

Let us now look at the case of a metrological traceability chain, which consists of more than one link: if the chosen calibrator of the first link was connected, i.e. “traceable”, to a more suitable or a more refined calibrator (i.e. one carrying a value having a smaller uncertainty), a similar link as described above can be construed between both calibrators. It is established between the value of the analyst’s working calibrator and the value embodied in the more refined calibrator. The total metrological traceability chain just becomes longer: it now consists of two links. Additional links may be necessary or wanted, and these can be construed in a similar way. If pursued to the ultimate possible, this process leads to the definition of the chosen measurement unit *where it automatically ends because the value of a unit is not measured*. It is defined. In any case, “walking backwards” along the metrological traceability chain is *unidirectional*: we can only do it in one direction.

It follows that we cannot use the ‘measured quantity value’ [11] embodied in the working calibrator of the analyst to calibrate the more refined calibrator from which the working calibrator is dependent. At the time we use the working calibrator, the more refined calibrator had been employed already: we needed it to calibrate the measuring system, which was used to obtain the value of the working calibrator.

Once a metrological traceability chain is established (*before* the measurement was started), one cannot inverse the interpretation of the sequence of operations *after* the measurement. If this were done, it would mean that a result obtained by means of a working calibrator (obtained later on) is reused in the assigning of a value to the more refined calibrator (performed earlier): a “circular reasoning” in the design—and subsequently in the performance—of a measurement. And circular reasoning is non-scientific, and not even meaningful.

A metrological traceability chain is indeed very useful in any measurement design because it is *unidirectional* and helps to avoid the trap of circular reasoning by making such reasoning visible.

It is a clarifying thought.

As the introduction of metrological principles in chemical measurement always should be.

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Editor-in-Chief

By the way, looking for justification of Metrology in Chemistry? *Chilean export of marine and agricultural products (about USD 10 000 000 000 p.a.) is vulnerable due to lack of sufficiently credible and traceable measurement results*. [Fundacion Chile and WTO/OECD statistics over 2008 and before, at SIM Policy meeting in Rio de Janeiro, 2009, quoted by R Kaarls at the 5th Brazilian Congress of Metrology, 2009-11-09 in Salvador, Bahia, Brasil]

This order of magnitude demonstrates the responsibility of all commercial parties involved, for demonstrating metrological comparability of their measurement results and, to achieve that, for the metrological traceability of their measurement results.

Both are basic requirement for preventing unfair trade.

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