What is legal metrology about ?

Pavel Klenovsky, Marc Wouters, Wilfried de Waal, WELMEC e.V.

Abstract: The basic principles of measurements in protection of public interests having a history as long as mankind are explained by authors from European legal metrology organization WELMEC e.V.

Let us start with the story of the Egyptian cubit. It is believed that about 3,000 years B.C. the Egyptian unit of length was established. The Royal Egyptian Cubit was decreed to be equal to the length of the forearm from the bent elbow to the tip of the extended middle finger plus the width of the palm of the hand of the Pharaoh ruling at the time. The Royal Cubit Master was carved from the block of black granite to endure for all time. Workers building tombs, temples and pyramids were supplied with cubit sticks made of wood or granite. The Royal Architect or foreman of each construction site was responsible for maintaining and transferring the unit of length to the workers´ cubit sticks. It was required that the cubit sticks to be brought at each full moon to be compared to the Royal Cubit Master. Failure to do so was punished by death. Though the punishment prescribed was severe, the ancient Egyptians had anticipated the spirit of the present-day system of legal metrology, standards, traceability and calibration recall. With this standardization and uniformity of length, they achieved amazing accuracy. The Great Pyramid of Giza was constructed to stand roughly 230.3 meters. Using cubit sticks, the builders were within 11.5 centimetres - an accuracy of 0.05 % !

It is therefore clear that metrology belongs to the oldest human activities and its essential elements are present to this day (together with some controversies), naturally in much more sophisticated form. Today, the scope of legal metrology is not given by a decision of a sovereign, but usually by an act of parliament and usually it consists of the following elements:

- definitions of the units of measurement;
- national (physical) standards (there is only one term “standard” in English for physical and paper standards);
- the reliability of measuring instruments and the trustworthiness of measurements in economical transactions;
- the establishment and role of national bodies associated with metrology, international relations.

Definitions of official units of measurements have developed in a close relation to trade – from local markets to international trade. The fragmentation of definitions of units was a big obstacle to trade – the attempts to overcome it finally led to the foundation of the Metre Convention in 1875 (May 20 – Day of Metrology). Today the most widely used in practice is the SI system of units launched in 1960 Systéme International d´Unités - SI). The adaptation to the SI is a long-term process complicated by the fact that citizens are reluctant to get rid of units with which they are in contact in everyday life. It is especially the case of the so called imperial (English) units used in the USA, the UK and some other countries. In both countries a process called metrication has been running for many years, the most difficulties are in areas where directly citizens would buy goods by quantities. Sometimes the change is a bit overdue – see e.g. the rather exotic unit of temperature, the Fahrenheit – it is now only used in the USA and 3 small economies: Liberia, Belize and the Cayman Islands. Confusions between SI and imperial units do occasionally happen and they might be expensive: e.g. in 1999 NASA launched a spacecraft called Mars Climate Orbiter at the cost of 125 mil. USD. 99% of the voyage went smoothly, at the end a rocket was put in operation to control its entrance into the atmosphere of Mars. In the manual NASA gave the values of the required thrust in SI units – however, the mission navigation operator mistakenly thought that the values are in imperial units – and the Orbiter was lost forever. As given by trade conventions, with some non-SI units we will have to live forever: the mass of precious metals in troy ounce (31.1034768 g), the volume of crude oil in (U.S.) barrels (158.987294928 L), the altitude, resp. speed in air traffic (U.S. feet, resp. miles per hour).

Technical implementations of those definitions - their physical realizations – are closely connected with each other. What we need in trade and manufacture are comparisons between measurements made at different times and locations – we need so called (metrological) traceability. This is achieved by creating traceability chains of consecutively calibrated standards of increasing metrological parameters – on top “sits” a national standard. Even at present those national standards are officially commissioned by a state authority in a way given by law. Their metrological parameters need not necessarily be the best available in a given quantity of measurement (these are called primary standards), they are derived from the needs of local economy. In the last 100 years the approach to construct physical standards is to employ the last achievements of physics, especially macroscopic quantum phenomena, and to relate the base units to universal physical constants. For non-metrologists it might be surprising that a number of the Nobel Prizes in Physics were awarded for discoveries leading to a better realization of a unit of measurement (last time in 2012: David J. Wineland from the US national metrology institute NIST – his improved optical “clock” was for a couple of months the most accurate measuring instrument in the world).

From the view of general public legal metrology is most associated with regulatory measures taken to protect public interests in transactions using measuring instruments – trade, utility measurements, collection of taxes and sanctions, healthcare etc. The depth of the regulation in general should follow the principle Caveat emptor (Buyer beware), i.e. regulation should be applied only when the customer cannot protect himself/herself. This is surely the case of measuring instruments when any customer alone cannot find out whether the measuring instrument measures accurately or not. As in ancient Egypt, historically under major spotlight here are measuring instruments to charge fees directly to citizens in trade by mass and volume, the so called classical Weights & Measures (W&M). In the last century fuel dispensers and taximeters were added. These measuring instruments are verified/inspected by official bodies authorized by state.

Recent developments are bringing bring new challenges. Due to the physical separation of the measured values from the measuring instrument (e.g. by the use of apps and smart meters) customers tend to be less aware of the importance of the quality and integrity of the measured value itself. This poses a serious risk from the point of metrology as it is known from the past that eventually this will trigger situations of data manipulation by a party to gain financial advantage over the other party in the transaction. Especially, because the corresponding sanctions to violators are now not that tough as in ancient Egypt. Therefore, the public even today should keep carefully an eye on politicians whether measures are not excessively compromised by business lobbying.

There is another not well understood matter in legal metrology: in the deployment of measuring instruments a trade-off between the associated costs (installation, repairs, re-verifications) and their metrological parameters has to be achieved – all those costs are going to be paid by customers, either directly or indirectly, so that most accurate and therefore most costly measuring instruments cannot be used.

In summary, at the first glance it might appear that working in legal metrology should be a good job for lawyers by education but without expertise in the underlying technical and metrological concepts it would be difficult to achieve effective results.