A Study of Measurement

Measurement Systems

A **system of measurement** is a set of units which can be used to specify anything which can be measured and were historically important, regulated and defined because of trade and internal commerce[1].

History

Although we might suggest that the Egyptians had discovered the art of measurement, it is only with the Greeks that the science of measurement begins to appear. The Greek's knowledge of geometry, and their early experimentation with weights and measures, soon began to place their measurement system on a more scientific basis. By comparison, Roman science, which came later, was not as advanced...

The French Revolution (1789-1799) gave rise to the metric system, and this has spread around the world, replacing most customary units of measure. In most systems, length (distance), weight, and time are *fundamental quantities*; or has been now accepted as better in science and engineering. Some systems have changed to recognize the improved relationship, notably the 1824 legal changes to the imperial system[2].

Historically, a wide range of units was used for the same quantity, in several cultural settings, length was measured in inches, feet, yards, fathoms, rods, chains, furlongs, miles, nautical miles, stadia, leagues, with conversion factors which were not simple powers of ten or even simple fractions within a given customary system. Nor were they necessarily the same units (or equal units) between different members of similar cultural backgrounds. It must be understood by the modern reader that historically, measurement systems were perfectly adequate within their own cultural milieu[3]. Moreover, changing a measurement system has real fiscal and cultural costs as well as the advantages that accrue from replacing one measuring system with a better one.

In antiquity[4], *systems of measurement* were defined locally, the different units were defined independently according to the length of a king's thumb or the size of his foot, the length of stride, the length of arm, or per custom like the weight of water in a keg of specific size, perhaps itself defined in *hands* and *knuckles*. The unifying characteristic is that there was *some definition* based on *some standard*, however egocentric[5] or amusing it may now seem viewed with eyes used to modern precision.

In the metric system and other recent systems, a single basic unit is used for each fundamental quantity. Often secondary units (multiples and submultiples) are used which convert to the basic units by multiplying by powers of ten.

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[1] an interchange of goods
[2] system of units defined in the British Weights & Measures Act of 1824
[3] surroundings
[4] the period of history before the Middle Ages
[5] regarding the self or individual as the center of all things

Current Practices

The Metric System is complete or nearly complete in almost all countries of the world. US customary units are heavily used in the United States and to some degree Liberia. U.S. units are used in limited contexts in Canada due to a high degree of trade.

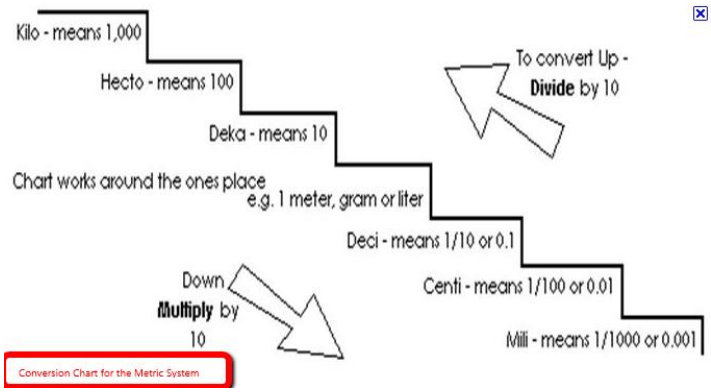
A number of other jurisdictions have laws mandating or permitting other systems of measurement in some or all contexts, such as the United Kingdom – where for example its road signage legislation only allows distance signs displaying imperial units (miles or yards) – or Hong Kong.

In the United States, metric units are widely used in science, military, and partially in industry, but customary units predominate in household use. At retail stores, the liter is a commonly used unit for volume, especially on bottles of beverages, and milligrams are used to denominate the amounts of medications, rather than grains. Also, other standardized measuring systems other than metric are still in universal international use, such as nautical miles and knots in international aviation.

Metric System

Metric systems of units have evolved since the adoption of the first well-defined system in France in 1795. During this evolution[6] the use of these systems has spread throughout the world, first to non-English-speaking countries, and then to English speaking countries.

Multiples and submultiples of metric units are related by powers of ten and their names are formed with **prefixes**. This relationship is compatible with the decimal system of numbers and it contributes greatly to the convenience of metric units.



In the early metric system there were two fundamental or base units, the meter for length and the gram for mass.
Additionally, the liter is used to measure capacity.

Imperial & U.S. Customary Systems

Both imperial units and U.S. customary units derive from earlier English units. Imperial units were mostly used in the British Commonwealth and the former British Empire but in most Commonwealth countries they have been largely supplanted by the metric system. They are still used for some applications in the United Kingdom but have been mostly replaced by the metric system in commercial, scientific, and industrial applications.

US customary units, however, are still the main system of measurement in the United States. While some steps towards metrication have been made (mainly in the late 1960s and early 1970s), the

[6] any process of growth

customary units have a strong hold due to the vast industrial infrastructure and commercial development. The effort is proceeding slowly due to the overwhelming financial cost of converting the existing infrastructure. US companies which trade internationally are more likely to use the metric system due to international. The metric system is preferred in certain fields such as science, medicine, technology and the military. The building profession uses US customary units, though architects working internationally are increasingly adapting to the metric system.

Precision & Accuracy

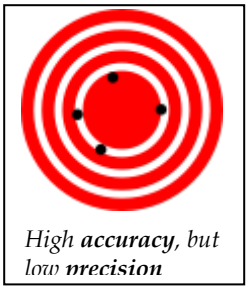
In the fields of science, engineering, industry and statistics, the **accuracy** of a measurement system is the degree of closeness of measurements of a quantity to that quantity's actual (true) value. The **precision** of a measurement system, also called reproducibility[7] or repeatability, is the degree to which repeated measurements under unchanged conditions show the same results.

Accuracy indicates proximity of measurement results to the true value, and precision indicates the repeatability or reproducibility of the measurement.

A measurement system can be accurate but not precise, precise but not accurate, neither, or both. For example, if an experiment contains a systematic error, then increasing the sample size generally increases precision but does not improve accuracy. The end result would be a consistent yet inaccurate string of results from the flawed experiment. Eliminating the systematic error improves accuracy but does not change precision.

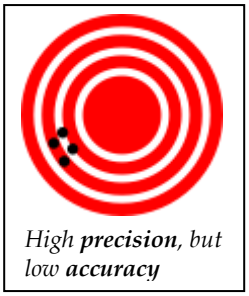
A measurement system is designated *valid*[8] if it is both *accurate* and *precise*. Accuracy is the degree of veracity while in some contexts precision may mean the degree of reproducibility.

The **analogy** used here to explain the difference between accuracy and precision is the target comparison. In this analogy, repeated measurements are compared to arrows that are shot at a target. Accuracy describes the closeness of arrows to the bullseye at the target center. Arrows that strike closer to the bullseye are considered more accurate. The closer a system's measurements to the accepted value, the more accurate the system is considered to be.



*High **accuracy**, but low **precision***

To continue the analogy, if a large number of arrows are shot, precision would be the size of the arrow cluster. When all arrows are grouped tightly together, the cluster is considered precise since they all struck close to the same spot, even if not necessarily near the bullseye. The measurements are precise, though not necessarily accurate.



*High **precision**, but low **accuracy***

However, it is *not* possible to reliably achieve accuracy in individual measurements without precision—if the arrows are not grouped close to one another, they cannot all be close to the bullseye. (Their *average* position might be an accurate estimation of the bullseye, but the individual arrows are inaccurate.)

[7] the ability to make a copy
[8] well-founded