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MEASUREMENT UNITS OF LENGTH, MASS AND TIME IN INDIA THROUGH THE AGES

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ABSTRACT

Measurement has been an essential in human life since the dawn of civilization. Before the introduction of metric system in India there were various measurements units for length, mass and time. A standard of measurement had to be developed which is acceptable to everybody. In this article, an attempt has been made to highlights the measurement units in India during different periods.

Keywords: legal metrology, weights and measure, metric system

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I. INTRODUCTION

Measurements are made to increase knowledge and understanding of the world we live in. Measurement science is the basis of modern science and technology and consequently of modern civilization. Length is the most necessary measurement in every walk of life. Early measuring methods for length were based on the use of human body parts. Lengths and width of fingers, thumbs, hands, hand spans, cubits and body spans seems to have been popular choices. But there will be considerable variation in the length of the body parts of different person so the use of a piece of stick of wooden or other material as unit of length was one of the bright ideas for length measurement. The unit of length used in ancient India included dhanus (bow), the krosha and the yojana. During the period of Mughal emperor, Akbar, the gaz was used as the unit of measuring length. Each gaz was divided into 24 equal parts and each part was called tassuj. The gaz was wildly used as a unit of length till the metric system was introduced in 1956. During British period the inch, foot and yard were used to measure length whereas grains, ounce, pound etc were used to measure mass. The essential unit of mass used in India included ratti, masha, tola, chattank, seer and maund. Ratti is a red seed whose mass is approximately 120 mg. It was widely used by goldsmiths and by practitioner of traditional medicine system in India. In ancient India, the length of the shadow of trees or other objects was used to know the approx time of the day. Long time durations were expressed in terms of the lunar cycle. During Vedic period in India various units of measurement are used for calculations of tithi, naksatra etc for social and religious events. Many civilization and emperors produced their own measurement standards that were accepted throughout their nation.

II. LENGTH MEASUREMENTS

In Mohen jodaro era (3000B.C.), the size of the bricks all over the region was same. The length, breadth and width of bricks are always in the ratio of 4:2:1 and taken as standard. During Maurya Empire (400 BC), Chanakya (Kautilya) in his famous book 'Arthashashtra' laid down the units of weights and measures and principles of enforcement i.e., legal metrology. In Arthashastra, Chanakya mentions two types of dhanushas as units for measuring lengths and distances. One is the ordinary dhanusha, consisting of 96 angulas, and the other dhanusha is mentioned as garhpatya dhanusha and consists of 108 angulas, used for measurement of roads and distances. Chanakya also mentions that a dhanurgraha consists of 4 angulas and a yojana consists of 8000 dhanushas. The smallest unit of length was parmanu.The elements of measurement system and definition of some of the units of length and their conversion may be written as

8 parmanu =1 rajahkan (dust particle coming from the wheel of a chariot)

8 rajahkan = 1 liksha (egg of lice)

8 liksha = 1 yookamadhya

8 yookamadhya = 1 yavamadhya

8 yuvamadhya = 1angul (approximate width of a finger) = 2 cm =0.787402 inch

8 angul = 1 dhanurmushti = 16 cm = 6.299 inch

4 angul = 1 dhanugraha = 8 cm = 3.14961 inch

12 angul = 1 vitasti = 24 cm = 9.44882 inch

2 vitasti =1 aratni or hast (or haath) = 48 cm = 18.8976 inch

4 aratni (haath) = 1 dand or dhanush = 192 cm = 6.299 feet

10 dand = 1 rajju = 19.2 meter =62.9921 sq.ft

2 rajju = 1 paridesh = 125.98 feet

2000 dhanush = 1 krosh = 4199.475 yard = 3840 meter (approx) = 3.84 km

4 krosh (goruta) = 1 yojan ≈ 9 miles ≈15 km (approx)

The Mughal measurement system measured length and land in terms of gaz and beegha with the following relationship.

1 girah= width of 3 fingers (Anguli)

1 hath = 8 girah

1 gaz = 2 hath

1 kathi = 55/6 hath

1 pand = 20 kathi

1 beegha = 20 pand

1 beegha = 20 vishwa

1 viswah = 20 viswansah.

The gaz was widely used till the introduction of the metric system in India in 1956.

In June 1864, the government of India recommended inch, foot, yard and mile for linear measurement and acre for area measurement with their conversion are given as

1 mile = 8 furlongs = 1760 yards = 1.61 km

1 furlong = 220 yards

1 acre = 4840 sq. yards = 1/10(furlong) ^{2}

1 sq.yard = 9 sq. ft.

1 sq. mile = 640 acres

1 hectare ≈ 2.47 acres = 10000 sq. m. (approx)

The adoption of these linear measures makes the Indian system completely dependent upon the British system. A committee appointed on 10th Oct.1913 again recommended a system based on the combination of Indian & British systems.

In 1950, mile and furlong were common markers on road in India. The minimum unit of length is one inch. Other linear and land measures and their conversion may be given as

1 inch=2.54 cm

1 foot = 12 inch=30.48 cm

1 yard = 3 feet = 0.0914metre

1 furlong = 660 feet =220 yard

1 mile = 1760 yards or 5280 feet =1.61 km

1 chain = 22 yard

1 acre = 43560 sq.feet = 4840 sq. yards

1 sq.yard = 9 sq. ft.

1 sq. meter = 1.196 square gaz

1 sq.gaz = 0.836126 sq. meter

1 kaththa ≈ 2.5 decimal = 1361.25 sq.ft. ≈ 100 sq.meter

1 beegha = 2304.576036 sq.meter

1 sq. mile ≈ 2.5 sq. km = 640acre

After independence, it was realized that for fast industrial growth of the country, it would be necessary to establish a modern measurement system in the country. The Lok Sabha in April 1955 resolved: ‘This house is of the opinion that the Government of India should take necessary steps to introduce uniform weights and measures throughout the country based on metric system’. The Central Act of 1956 called weights and measure Act 1956 enabled Government of India to establish standards of weight and measures system to introduce metric system. The metric system is an internationally agreed decimal system of measurement. In metric system multiples and submultiples of unit follow a decimal pattern. Length is now defined in terms of the speed of light, assumed to be an exact value (299,792,458 m/s) The standard unit of length in metric system is the meter.

To introduce the metric system in India the government established National Physical Laboratory (NPL) as the measurement standards laboratory. The standards maintained at NPL are periodically compared with standards maintained at other National Metrological Institutes in the world as well as the BIPM in Paris. This exercise ensures that Indian national standards are equivalent to those of the rest of the world. The standard unit of length, meter, is realized by employing stabilized Helium -Neon laser as a source of light. Its frequency is measured experimentally. From this value of frequency and the internationally accepted value of the speed of light (299,792,458 metres/second), the wavelength is determined using the relation: Wavelength = Velocity of light / frequency. The nominal value of wavelength, employed at NPL is 633 nanometer. By a sophisticated instrument, known as an optical interferometer, any length can be measured in terms of the wavelength of laser light. The present level of uncertainty attained at NPL in length measurements is $\pm 3 \times 10^{-9}$. However in most measurements, an uncertainty of $\pm 1 \times 10^{-6}$ is adequate.

III MASS MEASUREMENTS

During pre-Akbar period, weights system varied from region to region, commodity to commodity, and rural to urban areas. The weights were based on the weight of various seeds. Weights were made of iron or of stone. Balance (tula) with two pans of different sizes were used for weighing different quantities. The early unit was a grain of wheat or barleycorn used to weigh the precious metals silver and gold. Larger units preserved in stone standards were developed that was used as units of mass. Akbar standardized weights using a barley corn (Jau).

The following nomenclature was prevalent in North India before 1833 till the metric system came in:-

4 chawal (grain of rice) = 1 dhan (weight of one wheat berry)

4 dhan = 1 ratti = 1.75 grains = 0.11339825 gram

8 ratti = 1 masha = 0.9071856 gram

12 masha = 96 ratti = 1 tola =180 grains = 11.66375 gram

80 tolas = 1 seer = 870.89816 gram

40 seers = 1 maund = 8 pasri = 37.32422 kilogram

1 chattank = 4 kancha = 5 tola

1 pav = 2 adh-pav = 4 chattank = ¼ seer

1 seer = 4 pav = 16 chattank = 80 tola = 933.1 grams

1 paseri = 5 seer

British used weight of wheat berries as a standard. British chose Barley corn to weigh gold same as Akbar. The British made an effort to achieve uniformity in weights and measures. British rulers want to relate the Indian weights to those existing in Great Britain. In May 1833, the Government of India passed Regulation VII of 1833, according to which the Farrukkabad rupee was altered to 180 grains in consonance with the Madras and Bombay rupee. The weight of this rupee was taken to be one 'tola' which was a well known native denomination and the tola was defined to be equal to 180 grains. The adoption of these mass measures makes the Indian system completely dependent upon the British system. A committee appointed on 10th Oct.1913 again recommended a system based on the combination of Indian & British systems. For weight it suggested 'tola' as one unit equal to 180 grains of British weight. Eventually, British introduced their own system for weighing gold (troy ounce), commodities (pound/cwt/ton).

One troy ounce = 480 barley corn

1 troy ounce = 120 carat = 31.1034768 gram

1 troy pound = 12 troy ounce.

3.75 troy ounce = 10 tola

Weight of 1 Barley corn = 64.79891 milligram

Weight of 1 Wheat berry = 45.561732 milligram

Weight of 64 dhan (wheat Berries) = weight of 45 jau (Barley Corns)

In 1878, the troy Pound was abolished.

In the mean time, 'Government of India Act 1935' came into existence. In 1939 central legislature passed the standards of Weight act (Act IX of 1939) applicable to whole of British India. Once again it laid down a standard tola of 180 grains, 1 seer of 80 tolas, a maund of 40 seers, a pound of 7000 grains, an ounce equal to one sixteenth part of a pound , a half hundred-weight of 112 pounds and a ton of 2240 pounds. The act was brought into force from July 1,

1942. This allows tola /seer/maund system to coexist with pound /ton system. In 1956, for metric conversion, the Government of India defined the Standards of Weights and Measures Act (No. 89 of 1956, amended 1960, 1964) as follows:

1 seer = 0.99910 kilogram

1 maund = 40 seer = 37.324 kg

1 seer = 80 tola = 933.10 g

1 tola= 11.66375 gram =12 masha

1 masha = 8 ratti = 0.97gram

In 1887, the unit of mass kilogram is defined as the mass of a specific platinum- iridium alloy cylinder kept at the international Bureau of Weights and Measures at Sevres, France and since then the definition has not been changed since that time because Platinum-iridium is an unusually stable alloy. The Indian national standard of mass, kilogram, is copy number 57 of the international prototype kilogram supplied by the International Bureau of Weights and Measures (BIPM: French-Bureau International des Poids et Mesures), Paris. This is a Platinum Iridium cylinder whose mass is measured against the international prototype at BIPM. The NPL also maintains a group of transfer standard kilograms made of non-magnetic stainless steel and nickel - chromium alloy. The uncertainty in mass measurements at NPL is $\pm 4.6 \times 10^{-9}$.

IV. TIME MEASUREMENTS

Indian time measurement system is considered to be the oldest time measurement systems. Indian scriptures give us a wealth of information about the different methods and techniques used in ancient India for time measurement. This measurement system is not only complete but also very precise and accurate. The time measurement system in ancient India was excellent and it covered a range from micro seconds to trillions of years including the cycles of the universe. A time-based activity involves a time scale based on some system of measurement. All systems of time measurement are based on the time of revolution or rotation of various celestial bodies including the moon and the sun. People of pre Aryan days were keenly interested in knowing the motion of heavenly bodies to predict solar and lunar eclipses and lunar month etc. There are 12 months each consisting of two paksh (14 days) according to the orbiting of the moon around the earth. The actual number of days in a month may vary by a day according to the position of the moon and the sun.

In ancient India, Vedic and Puranic texts describe a system of time measurement starting with the time taken for twinkling of an eye and going up to the age of the creator Brahma, based on the solar/human year. During Vedic period (5000B.C.), Indians had separate names for much smaller time intervals. The terms for smallest time interval and its multiples are as follows.

1 permanu = 26.3μs

2 permanu = 1anu = 52.67 μs

3 anu = 1 trisrenu =158 μs

3 trisrenu = 1 truti = 474 μs

100 truti = 1 vedh = 47.4 ms

3 vedh =1 love = 0.1s

3 love = 1 nimesh = 0.43s

3 nimesh = 1 kshan = 1.28 s

5 kshan = 1 kashta = 6.4s

15 kashta = 1 laghu = 1.6min.

15 laghu = 1 nadika (danda) = 1 ghadi = 60 Pal= 24 minute.

2 nadika = 1 mahurat=2 ghadi =30 kala = 48 min.

30 mahurat = 1 day and 1 night = 24hrs = 24 hora

7 day and seven night = 1 saptah

2 saptah = 1 paksh

2 paksh= 1 lunar month

2 month = 1 ritu

3 ritu = 1 ayan= 6 months

2 ayan = 1 human year = 12 month = 365 days = 1 varsh

100 varsh = 1 shatabdi = 1 century

10 shatabdi = 1 sahasrabda

432 sahasrabda= 1 yug (kaliyug)

For larger unit of time, the year is taken as the unit and has the following multiples:

1 kaliyuga = 4, 32,000 human years

2 kali yugas = 1 dwapar yuga=864000 human years

3 kali yugas = 1 treta yuga =1296000 human years

4 kali yugas = 1 satya yuga = 728000 human years

10 kaliyugas =1 mahayuga = 4,320, 000, human years

1000 mahayuga= 1 kalpa = 4,320, 000,000 human years = 1 day of Brahma

The time interval second was originally defined in terms of the time of rotation of earth about its own axis. The time of rotation is divided into 24 equal parts, each part is called an hour. An hour is divided into 60 minutes and each minute is subdivided into 60 seconds. Thus one second is equal to $1/86400^{th}$ part of the solar day. But it is known that the rotation of the earth varies substantially with time and therefore, the length of a day is a variable quantity may be very slowly varying. In 1967, the second was redefined to take advantage of high precision attainable in a device known as an atomic clock, which uses the characteristic frequency of the cesium -133 atoms as the reference clock. The second is now defined as the duration of 9192631770 periods of the radiation corresponding to transition between two hyperfine levels of the ground state of cesium-133 atom. The cesium atomic clocks maintained at NPL are linked to the world through a set of global positioning satellites.

V. SYSTEM OF UNITS

In the course of development of units a number of systems were adopted. Two systems which were extensively used were the cgs and mks system. The cgs system was based on centimeter, gram and second as the unit of length, mass and time while mks system used meter, kilogram and second for the same. The International System of units (SI) was adopted by the 11th General Conference on Weights and Measures (CGPM) in 1960. In the International System there is only one SI unit for each physical quantity. The metre is the length of path travelled by light in vacuum during a time interval of 1/299 792 458 of a second (17th CGPM, 1983). The kilogram is the unit of mass; it is equal to the mass of the international prototype of the kilogram (3rd CGPM, 1901). The second is the duration of 9 192 631 770 periods of the radiation corresponding to the transition between the two hyperfine levels of the round state of the cesium-133 atom (13th CGPM, 1967). It is recommended that only SI units be used in science and technology.

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