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NATIONAL STANDARDS (ETALONS): METHODS OF MEASURING

and

INTRODUCTION AND APPLICATION OF METRIC SYSTEM AND SI UNITS [1]

by

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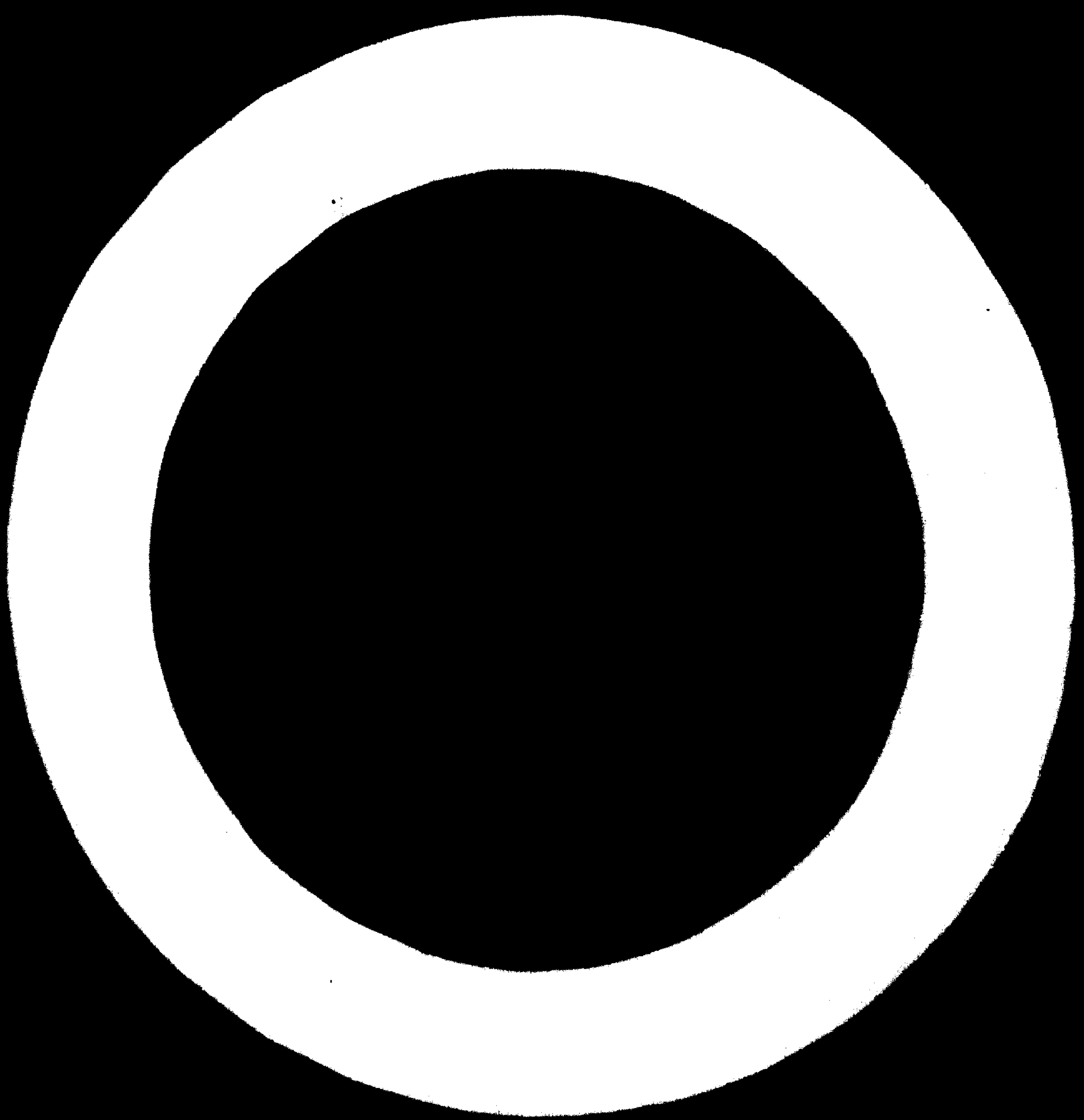

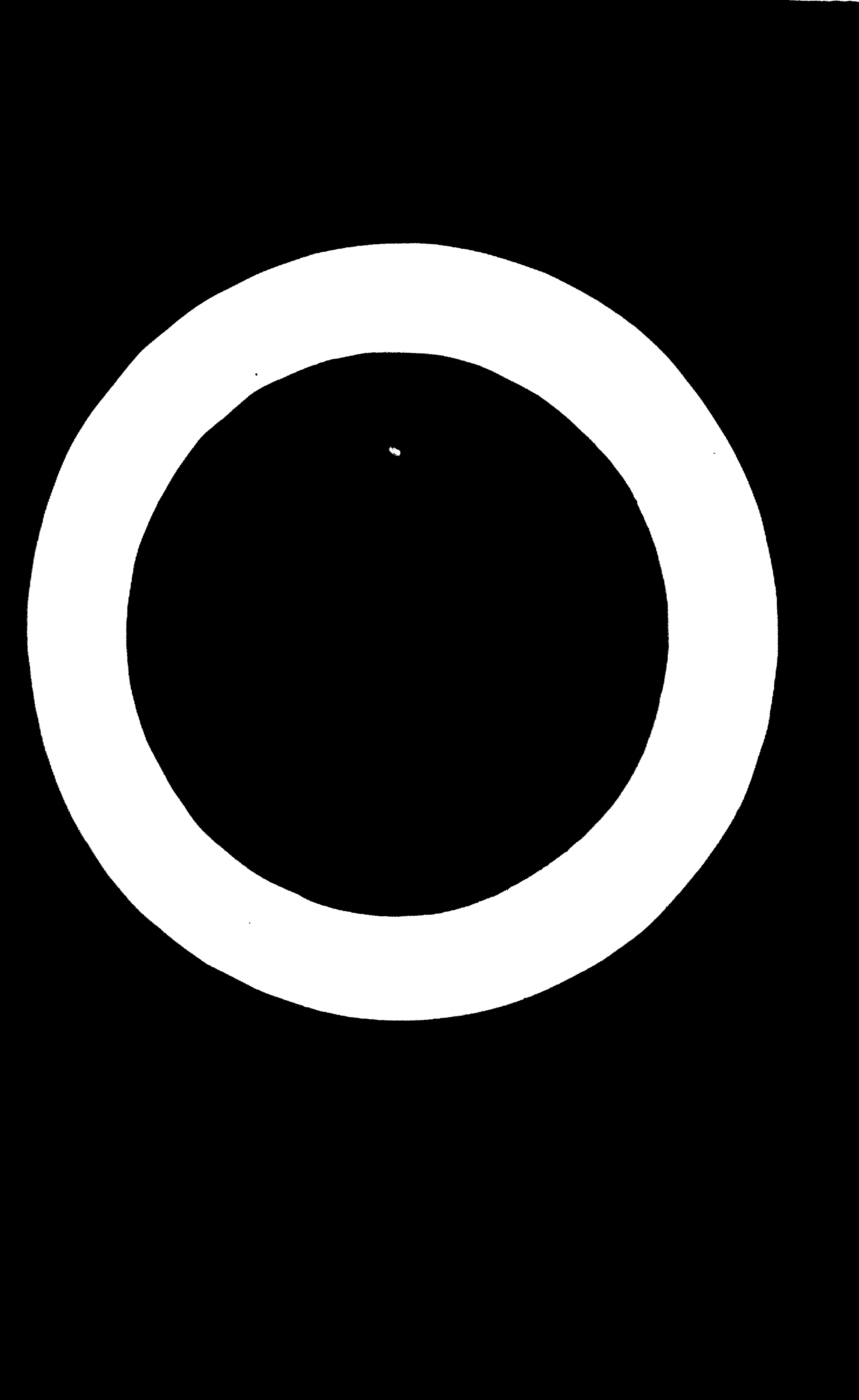

I. NATIONAL STANDARDS (ETALONS): METHODS OF MEASURING

1. Problems of establishment and maintenance of national standards system

The national standards system in Japan has long been established and maintained by two laboratories, the National Research Laboratory of Metrology (NRLM) and the Electrotechnical Laboratory (ETL), both belonging to the Agency of Industrial Science and Technology (AIST), Ministry of International Trade and Industry (MITI). Briefly speaking, the ETL contains activities in the fields of electric, photometric, acoustic and radioactive standards, while all the other mechanical and thermal standards are taken charge of by the NRLM. The organizations of these laboratories are described below.

1.1. NRLM

The NRLM consists of six divisions and three regional branches. The annual budget is approximately two million US dollars and the number of personnel is 270. Two of the six divisions are of administrative character and the three branches are much smaller in scope than the head office. We therefore explain in detail the activities of the four divisions alone in which are dealt with the national metrological standards.

The First Division consists of the Applied Optics, Engineering Metrology and Measurement System Sections.

The research works of the Applied Optics Section includes (1) interferometric measurement of standard scales, gage blocks and wavelengths, (2) development of wavelength measurement technique in the infrared region, (3) angle and angular velocity measurement by means of ring lasers and (4) development of small stabilised lases for practical use.

Engineering Metrology Section: (1) high precision measuring machine for length, shape and surface roughness, (2) elements of measuring instruments and (3) measurement and isolation of vibration.

Measurement System Section: (1) mass standards including the national prototype of the kilogram, (2) various kinds of hardness standards and (3) reliability of man-machine systems.

Second Division: Thermometry, Thermal Measurements and Quantum Metrology Sections.

Thermometry Section: temperature standards below the gold point down to the liquid helium region.

Thermal Measurements Section: (1) pyrometry, (2) evaluation of temperature in the plasma region and (3) determination of lattice constants by means of X-ray diffraction.

Quantum Metrology Section: (1) cesium frequency standards, (2) laser physics, (3) methane-absorption-line stabilized laser and (4) fluctuation analysis.

Third Division: Fluid Metrology and Mechanical Metrology Sections.

Fluid Metrology Section: (1) various flow measurement techniques, (2) viscometry and rheometry and (3) density, concentration and humidity measurement.

Mechanical Metrology Section: (1) dead weight force standards up to 50 tf, (2) high pressure standards upto 20 kbar and (3) material testing.

Fourth Division: First and Second Sections for Measuring equipments.

First Section: (1) researches, examinations, verifications and pattern approvals for measures, taximeters, balances, weights and load cellsand (2) development of load testing devices.

Second Section: researches, examinations, verifications and pattern approvals for themometers, densitometers, gas and water-supply meters and pressure gages.

1.2. ETL

The ETL consists of fourteen divisions and a regional branch.

Only two of the fourteen divisions are engaged in metrological researches. Since the present writer is not a specialist in the fields covered by this laboratory, only a brief outline of these two divisions is described here.

Division of Quantum Technology: (1) primary standard of luminous intensity, (2) researches on photometry, radiometry and colorimetry, (3) researches on the standards and the measuring techniques of ionizing radiations and disintegrations, (4) research on material properties by means of ionising radiations and (5) examinations, verifications and pattern approvals of illumination meters, dosimeters and disintegration meters.

Division of Standards and Metrology: (1) researches on the standards and the measuring techniques of electromagnetic quantities, (2) establishment of electromagnetic standards by means of fundamental physical constants, (3) researches on noise-level standards and electronically composed soundsand (4) examinations, verifications and pattern approvals of watt-hour meters and noise meters.

2. Methods and means of high accuracy measuring

A survey of the methods and means of high accuracy measurements carried out at the NRLM is given below, under classification by physical quantities.

2.1. Length

A krypton 86 primary standard lamp, combined with a manostat to maintain the triple point of nitrogen, is in use whenever it is necessary to determine wavelengths for metrological purposes.

Four interferometers are in daily use: (1) Möbius-band interferometer for intercomparison of wavelengths, (2) fringe- counting interferometer for standard scales up to 2 m, (3) multipath interferometer for gage blocks up to 1 m and (4) interferometer capable of measuring fifteen shorter gage blocks successively.

Anumber of measuring machines and optical devices permit calibration of scales and gages by comparative measurement.

Pattern approval for taximeters was started at the beginning of this year.

2.2. Mass

A newly developed balance, for use exclusively in comparison of primary standard weights with the national prototype of the kilogram, proved a reproducibility of 10^{-9}. The contact between the knife edges and their supports is kept unchanged during the interchange of position of weights.

Standard balances of capacities up to 1 t and down to 1 g permit calibration of various weights for practical use.

Pattern approval for weighing scales in commercial use has been in force for several years.

2.3. Time.

A cesium frequency standard will come into operation within a few months. Another cesium standard will be installed two years later. For the moment, we are obliged to make use of the time signal "JJY" for precise chronometry, which is emitted by the Radio Research Laboratories, Ministry of Posts and Telecommunications.

Calibration of chronometers can be accepted in exceptionally emergent cases, such as the Tokyo Olympic Games in 1964.

2.4. Temperature

Researches covering all the region of the International Practical Temperature Scale are in ceaseless progress.

An argon plasma stabilised by means of a water jacket has been realized for the purpose of thermometry in 10^4 K region.

Below the triple point of hydrogen, where the Temperature Scale rest undefined, researches are under way by using gas thermometers, semi-conductors or magnetism.

Calibration of glass thermometers, thermocouples, platinum resistance thermometers and various other thermoelements can be accepted on request.

2.5. Volume

The most important among the daily business in volumetry is the pattern approval for gas and water-supply meters.

Owing to development of flow meters compensating automatically the pressure loss, an important improvement in precision has been achieved on calibration of various flow meters for industrial use.

Research on large-scale flowmetry of the order of 10^4 m^3/h will start from the next year.

Research on flowmtry by means of laser scattering is being promoted.

2.6. Density

Calibration of hydrostatic balances is accepted on request.

A new determination of the relation between the concentration and the specific gravity of a mixture of ethanol and water has been accomplished several years ago.

A standard-humidity chamber has been developed in order to improve the precision of calibration of hygrometers.

2.7. Force

Force standards up to 50 tf have been maintained by a deadweight machine, and up to 500 tf by an oil-pressure load-testing machine. 5000 tf load-testing machine will be installed several years later.

2000 tf load cells are now being manufactured for trial.

Examination of loops, load cells, other load-detecting devices and load-testing machines can be accepted on request.

2.8. Pressure

Pressure standards are supplied through calibration of liquid column manometers and piston-cylinder pressure generating machines.

Trial manufacture of a 20 kbar pressure generating machine has been accomplished. Researches on fixed points for pressure of mercury, water and various other substances and on strain gages are being promoted.

2.9. Others

In addition to the most important activities enumerated above, are also carried out the researches and examinations for various other quantities, say, viscosity, hardness, surface roughness, etc.

3. Standardization of methods and means of testing and calibration of measuring instruments and devices

The legal control in our country of measuring instruments is separated from our industrial standards "JIS". There are four ordinances which provide in detail the methods and means of testing and calibration, as well as the structure and tolerance of measuring instruments.

One of the ordinances of the government provides (1) classification of measuring instruments for which the verification is obligatory, (2) executing organizations of verifications, say, MITI, regional governments and Japan Electric Meters Inspection Corporation, (3) the interval after which the verification becomes invalid and (4) tolerances for verifications.

One of the ordinance of MITI provides (1) difference between the first and subsequent verifications, (2) structure of instruments and (3) method of verifications.

The scope of the standard instruments which serve for determining the error of the instruments under verification are provided by two other ordinances.

The structures and the tolerances provided by the recommendations of the OIML are introduced into these ordinances as far as possible.

II. INTRODUCTION AND APPLICATION OF METRIC SYSTEM AND SI UNITS

1. Historical remarks

Instead of discussing directly the need for unification of unit systems, the present writer would like to present first the history of introduction in Japan of the metric system and the SI. This history, he believes, is indeed a witness for the need for unification, including also the problems of international cooperation, advantages and drawbacks of unit systems and expenditures for changing unit systems.

1.1. Epoch of a new government

When the old feudalistic government collapsed in 1868 and a new form of government was established, this government was obliged to reform its weights and measures system. Both the yard-pound and the metric systems had been known in this country, and the governmental officials were more attracted by the simplicity of the metric system.

A plan was contrived to modify the Japan's original scale "shaku" as one third of a meter, but this idea was not realised for the reason that a revision of units might have created a great confusion, since the original units "shaku" and "kan" were the measuring base of cereals and agricultural fields which were still current as a matter of tax collection.

In 1875, a new system was created which used the new shaku and kan based on certain conversion factors from meter and kilogram. Use of other unit systems, however, remained optional.

1.2. Unit systems in 1891

Japan joined the Convention of the Meter in 1886, and the national prototypes were obtained in 1890. A new Weights and Measures Act passed the National Diet in 1891. This Act was based on the shaku-kan system, where shaku was defined as 10/33 meter and kan as 3.75 kilograms. The metric system was also included in the Act. No provision, however, was found in the Act prohibiting other unit systems including the yard-pound.

As the industry and foreign trade of Japan expanded, the relative weight ofthe yard-pound countries in Japan's economy also increased. Thus, in spite of the policy of the government to unify unit systems into a single metric in future, it became unavoidable to give approval to the use of the yard-pound system as well. This system was also included in the Act in 1909.

1.3. Unit systems in 1920

In the 1891 Act, the provided units were limited to the classical "weights and measures" use. In 1910's, Japan's development in science and industry necessitated the establishment of units for use in the field of physics. The Act was revised in 1920 to include units of density, force, pressure, work, power, temperature, and so on.

The revision in 1920 contained another important item that the shaku-kan and the yard-pound systems would be recognised only for a limited period; ten years for governmental affairs and thirty-four important industries, and twenty years for all the other fields.

On the other hand, an Act named the Electricity Measurements Act was promulgated in 1910, which provided units of various electro-magnetic quantities.

1.4. Diffusion of and Resistance against the metric system

Dissemination of the metric system was commenced immediately after the 1920 revision. Japan was beginning to grow into a modern industrial nation at that epoch, and this turned out to be a very convenient situation for diffusion of the metric system. New investments in facilities, domestic manufacture of modern industrial products and establishment of various industrial standards were simultaneously commenced, and a majority of them employed the metric system. Thus, 74 percent of the whole industry had shifted over to the metric system by 1933.

In the field of commerce, however, things did not go so smoothly. During the same period, the metric system covered only 40 percent of commerce.

Resistance against unification to the metric system was raised in early 1930's partly from the ultranationalistic conception to exclude unit systems of foreign origin, and partly from the economic burden lying heavily upon the governmental budget. The government was obliged to promulgate in 1933 an Ordinance providing the recognition of the general use of the two non-metric systems until 1958 and the unlimited use of shaku-kan for lands, buildings and historical commodities.

1.5. Unit systems in 1951

Occupation of Japan by the Allied Forces raised a revival of the yard-pound system, and the shaku-kan system also revived in the markets of the Japanese public. This was, nevertheless, a merely temporary phenomenon.

In order to cope with the post war situation, the Weights and Measures Act was abolished and a new Measurements Law was promulgated in 1951. The time limit provided by the 1933 Ordinance was maintained, and the metric system was accepted as a single unit system available since 1959 for general use. Only one exception was the measurement of the area of lands and buildings, but this measurement was also unified in 1966.

The Electricity Measurements Act continued to be a separate law from the 1951 Measurements Law.

1.6. Unit system in 1966

The unit system provided by the Measurements Law was completely amended in 1966 to conform with the Resolution 12, designating SI, of the General Conference of Weights and Measures in 1960. The Electricity Measurements Act was of course abolished and the SI units of all the quantities listed in this Resolution were included.

1.7 Future problems

Actually in force is the 1966 amendment. The General Conference in 1967 and 1971 adopted and will adopt several new definitions, names and symbols of units and prefixes, for instance, second, kelvin, candela, mole, pascal, siemens, peta, exa etc. These items will also be included in the Measurements Law within a shortest delay.

2. Need for unification of units for the improvement of international cooperation and trade.

It is needless to say that the metric domain in the world has ceaselessly been expanding for these two centuries. The present writer understands that the obligation of the metric system and the abolishment of the yard-pound are under investigation in a number of yard-pound nations of economical importance, for instance, Australia, United Kingdom, United States and Canada.

We desire, and probably all the metric nations are desiring, that the yard-pound nations would turn to adopt the metric system as their single unit system, and thus a world-wide unification of the unit system would be accomplished in a nearest future.

3. Systems of units, their advantages and drawbacks

For the present, there is a lot of confusion even in the units covered under the name of the metric system; MKS and CGS, absolute and gravitational, esu, emu and gaussian, calorie, torr, curie, röntgen, etc. We, not only the public but also the specialists in metrology, are in ceaseless needs of conversion tables between these units and SI.

The most desirable way to solve this confusion is a gradual transition to a coherent unit system. Neither unit systems, the present writer is sure, surpass the SI, coherent system composed of as many basic units, supplementary units and prefixes as possible.

4. Expenditures for changing unit systems

During the epoch when Japan was in conflict in 1930's and 1940's, it was quite unable to unify the unit systems because of the heavy economical burden of the government.

After the restoration of peace, however, the government reconfirmed the policy of unification in 1951 and this unification was indeed accomplished in 1958.

This fact seems to endorse that the accomplishment of unification depends more on the will and the efforts of the promoting bodies than the economical situation of the government.

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