[COMMITTEE PRINT]

NOTES ON CONVERSION TO THE METRIC SYSTEM

REPORT

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LETTER OF TRANSMITTAL

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND ASTRONAUTICS,
Washington, D.C., July 19, 1965.

Hon. GEORGE P. MILLER,
Chairman, Committee on Science and Astronautics.

DEAR MR. CHAIRMAN: It is a pleasure to transmit this draft report, "Notes on Conversion to the Metric System," prepared in response to your request of May 19, 1965. An attempt has been made in this report to bring together representative information concerning the historical, technical, international, financial, industrial, and legislative aspects of the metric system and the types of problems involved in converting to it. It is hoped that this material will be useful as background information to members of the committee in preparing for the forthcoming hearings on H.R. 2626.

In planning the scope of this study, care has been taken to include, wherever possible, information you had requested in your letter of May 19, 1965, concerning the advantages and disadvantages of the metric system, the extent of its current use in the United States, and the experience and cost factors in those countries that have recently converted to the metric system. It is unfortunate that the last item is not well represented in the existing literature. Estimates of the costs to convert vary over a wide range, differ from industry to industry, and even from company to company within an industry. Definitive studies, either in the United States or in the United Kingdom, where the decision to convert was recently made, have not been available.

The draft report was prepared by Mr. H. E. Weihmiller, a private consultant on contract with the Library of Congress. The work was conducted under the guidance of Dr. Lawton M. Hartman, senior specialist in science and technology, Science Policy Research Division. Special acknowledgment should be made of the important assistance that was rendered by Mr. Alvin G. McNish, Chief of the Metrology Division and Mr. Lawrence J. Chisholm, technical writer in the Office of Weights and Measures, National Bureau of Standards, Department of Commerce; Mrs. Ellen C. Collier, analyst in the Foreign Affairs Division, Legislative Reference Service; and Mr. Charles Missar, referral specialist in the National Referral Center for Science and Technology, Library of Congress.

Sincerely yours,

HUGH L. ELSBREE, *Director.*

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NOTES ON CONVERSION TO THE METRIC SYSTEM

Part I

INTRODUCTION

The original metric system was the outgrowth of a proposal made by the French Abbé Gabriel Mouton in 1670 that a new, universal unit of measure be established and that the larger and smaller units be in multiples or submultiples of 10. For the basic unit, Mouton suggested the length subtended by 1 minute of arc of a great circle measured at the surface of the earth. In 1790, the French National Assembly called on the French Academy of Sciences to work out a suitable system of units for both measure and weight.

While Mouton's unit of measure did not prevail, the decimalization system he proposed became the heart of the resulting metric system. The French Academy decided that the basic unit of measure should be equal to one ten-millionth of the earth's quarter meridian (from the North Pole to the equator) which passed through Paris. This unit, called the "meter," is approximately equal to 39.37 inches. The basic unit of weight was tied to this meter in that the mass (weight) of 1 cubic centimeter of water, under specified conditions, was established as 1 gram.

The new system was formally adopted by France on April 7, 1795, and the first platinum meter bar was made and marked in 1799. Due to the confusion caused by the introduction of such a completely new system of weights and measures and the general opposition of the people to this innovation at that time, Napoleon relaxed the mandatory provision for its use in 1799 and in 1812 permitted the return to the old standards. However, a new and more stringent act was passed, effective January 1, 1840, making the use of the metric system mandatory and forbidding the use of any other system of weights and measures.

Belgium, the Netherlands, and Luxembourg had earlier adopted the metric system, and each successive decade saw more and more nations of the world joining the list until, by 1960, practically all nations had accepted the metric system, in varying degrees from mandatory and exclusive use to permissive use. Exceptions were the United Kingdom, the Commonwealth nations, and the United States. However, on May 24, 1965, the United Kingdom announced that it was the Government's policy to adopt the metric system in the United Kingdom sector by sector, except for a few specified industries, over the ensuing 10 years.

In the United States, efforts to standardize and simplify the common usage English inch-pound system began with the birth of the Nation. The Articles of Confederation granted to the Continental Congress the "* * * sole and exclusive right and power of * * * fixing the standard of weights and measures throughout the united

states * * *". When the Constitution became effective in 1789, it too stated that "The Congress shall have Power * * * To regulate Commerce * * * *among the several States * * * To * * * * fix the Standard of Weights and Measures."

In 1790, upon request, Thomas Jefferson submitted to the House a report embodying two alternate plans, one for retaining the basic English system then current, but making the measures invariant, and a second for adopting the metric system then being strongly advocated in France as the new universal system for the world. Neither proposal was acted upon, and many studies and reports followed, including one by John Quincy Adams in 1821, but without definitive congressional action till 1866. In that year, Congress passed a law making the metric system the official basis for determining weights and measures standardization in the United States. On May 20, 1875, 16 countries and the United States signed a document known as the "Treaty of the Meter," establishing and providing for the maintenance of a permanent International Bureau of Weights and Measures to be located near Paris. In 1878, the United States ratified the Metric Convention of 1875 and received officially meter No. 27 and kilogram No. 20 in 1890.

While the early metric system was confined to defining the standards for length, mass, and time, subsequent actions added standards for electrical current, temperature, and light intensity. The expanded system has become the international system (SI), but it is still commonly called the metric system.

In the past 6 years there has been a revival of interest in having the metric system adopted in the United States as the common system of weights and measures to gradually replace the more cumbersome English foot-pound system. In 1959, bills were introduced in the House and in the Senate of the 86th Congress to authorize studies by the U.S. Department of Commerce (National Bureau of Standards) of the practicability and desirability of the adoption by the United States of the metric system of weights and measures, and a House concurrent resolution was introduced favoring such adoption by the United States. Starting June 28, 1961, the House Committee on Science and Astronautics held hearings on H.R. 269 and H.R. 2049, and on January 7, 1964, the Senate Committee on Commerce held a hearing on S. 1278—all of which would have authorized such studies. None of these bills was enacted. However the printed hearings contain a wealth of information and opinion on the entire subject.

There also exists a large number of books, reports, articles, pamphlets, addresses, etc., covering the history of weights and measures generally, of the development of the metric system particularly, and the reasons why it should or should not be adopted in the United States. The arguments pro and con are numerous, and the most general have been summarized as a part of this report.

There does not appear to be, however, very much readily available information, at least translated into English, on the pertinent experiences and the detailed costs and benefits attending the adoption of the metric system in the countries which have done so recently. Information and data that does exist on these aspects could not, of course, be translated directly to U.S. conditions, but the information may help to provide perspective.

Similarly, an attempt has been made to collect and include information on the extent of present usage of the metric system within the United States. Science generally is probably the most widespread and continuous user of the metric system; ball bearings and spark plugs have been dimensioned metrically since their early import and this practice has continued for manufacture in the United States. Certain Government activities, such as geodesy, and certain portions of the military, particularly in the use by the Army of the metric system for linear distances of weapon fire-control and by the Navy in its Medical Corps, make use of this system. As far back as 1873, the Treasury Department directed that the weights of certain of our coins be designated in grams.

Throughout industry there are many large companies which make dual use of both the English and metric measurements in the manufacture of certain products, and in particular use the metric system when so requested by foreign customers. The pharmaceutical industry is often cited as an example of a whole industry which recently and voluntarily converted its product manufacturing measurements to the metric system, profitably in at least the case of one large company. No modern survey of the full extent of usage of the metric system in the United States is known to exist, so that there are probably many other cases beyond those noted in this report.

For possible interest as an analog to the adoption of the metric system, a note has been added on the origin of our present calendar and some of the complications that attended changes that have been made.

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PART II

THE METRIC SYSTEM

1. Ancient Systems of Measures

The origin of measures of length is to be found in parts of the human body. Their values, roughly estimated, as well as their names, establish this beyond doubt. The foot, the digit, the palm, the span, the cubit, the nail, the arm, etc., are in all languages derived from the same source; and, in the popular view of measurement, they do not considerably differ in length. It is also unquestionable that in former times, when authenticated measures were not so easily obtained, the hands, arms, and feet were much more frequently used than they are at present when every workman, however humble, is in possession of a measure.

"Taking a well-proportioned man, a fathom is reckoned to equal his height or stature; the girth or the pace, one-half his stature; the cubit, or measurement from the elbow to the ends of the extended fingers, one-quarter; the foot, one-sixth; the span, one-eighth; and the breadth of the palm, one-fourteenth." [1]

The ancient cubit, prominent as a basic unit of measurement in the building of the pyramids and often referred to in the Bible,[2] was later carried from Egypt to Greece and Rome. The fathom (also the length to which a man can extend his arms—6 feet) is still a basic unit in the United States, being a common marine measurement and the unit of our hydrographic charts.

Equally early was the adoption in China of a standard of length. The origin is unknown and appears to date from the second or third millennium B.C. "The standard was quite as scientific as it was convenient for the public usage. The distance between two knots of a certain cylinder of bamboo when taken as a whistle, producing a certain tune, was chosen as a standard of length." [3] As a matter of fact the same Chinese character denotes this standard of length or "foot" and also the musical note G of the *diatonic* scale. It is interesting to observe that the procedure has come full circle in the present-day method of relating the length of the meter to a natural wavelength. (See p. 7.) The Chinese system too was "metric" in the sense that subdivisions (the "foot" contained 10 "inches") and multiples of the standard unit were based on powers of 10.

As the civilized world and its population grew and spread, different regions borrowed, revised, or invented many varying systems of weights and measures to fit their particular needs. A listing of usual and unusual names of units of weights and measures used in the various countries before (and often after) the introduction of the metric

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[1] Woolhouse, W. S. B., F.R.A.S. "Weights and Measures of All Nations", 1859, p. 2.

[2] "The Metric System of Weights and Measures," The National Council of Teachers of Mathematics, 20th Yearbook, Bureau of Publications, Teachers College, Columbia University, p. 81.

[3] Wu, C. C., Director, Ministry of Industries, Bureau of Standard Weights and Measures, China, "Unification of Weights and Measures in China," 1934, p. 1.

system, with their equivalents in the United States customary or in metric units, requires 4½ pages (double columned) of fine print in the Encyclopedia Britannica,[4] so numerous were they.

In Europe, the use of Roman numerals (using letters) prevailed for many centuries following the fall of that empire, and it was not until about 1500 A.D. that they were superseded by the Hindu-Arabic system of numerals that we use today.[5] It was not very long thereafter that the decimal system was invented, followed closely by proposals that resulted in the metric system, and eventually in the international system as we know it today.

2. Origin of the Metric System

Nearly 300 years ago, in 1670, the French Abbé Gabriel Mouton proposed a new, simplified and coordinated system of measurements incorporating the decimal system. At that time, the various European kingdoms had many different types of measuring systems growing out of the Roman Empire metrology which was inherited but also embellished by many new units appropriated or conceived from a variety of sources. Often the same-named units varied and trade between countries was at least difficult.

For his system, Mouton chose the length of 1 minute of arc of a great circle on the earth's surface as the basic unit, which he called the "milliare," and larger or smaller units were named, being multiples or divisions of the standard by decimalization. Only 85 years earlier, in 1585, the Flemish mathematician Simon Stevin had invented the decimal system itself—a feat which some rank among the world's greatest advances. Using the dot (.) as the tool, he placed it at the right-hand end of any figure as the normal position; moving it one digit to the left divided the number by 10, or one digit to the right multiplied it by 10, and so on for any number of multiples of 10. By this method, the cumbersome fractions in common use could be replaced by decimals which were easily handled. That is, if one measure of anything contained 15¼ units, it could be expressed as 15.25 units, and 10 measures contained a total of 152.5 units.

While Mouton's basic unit of length did not prevail, his proposal of decimalizing the measurement system became the heart of the later metric system. Soon after Mouton's original suggestion, Jean Picard, in 1671, and Christian Huygens, in 1673, proposed other natural unit standards, one being based on the length of a pendulum with a specified period of swing. These attempts were based on finding some natural, common, and reproducible basic standard of length to replace the varying measures based on parts of the human body which were the early bases for most systems in vogue. It was not until 1790 that search for an acceptable basic unit of length was successful.

3. Summary of the International System of Units

Referred to as the international system or SI (expanded from the original metric system), this system contained in Resolution No. 6 of the 10th General Conference on Weights and Measures, Paris,

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[4] "Encyclopedia Britannica," 1962 edition, William Benton, publisher, Chicago, vol. 23, pp. 488E–488H.
[5] "The Metric System of Weights and Measures," op. cit., p. 8.

1955, adopted the six units intended to serve as a practical basis for purposes of international relations: [6]

Length	meter	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Temperature	degree Kelvin	°K
Luminous intensity	candela	cd

"Definitions of the most important SI units are given in the following paragraphs. These definitions have been extracted from the records of the International Committee and the General Conference." [7]

The *meter* (unit of length) is the length of exactly 1,650,763.73 wavelengths of the radiation in vacuum corresponding to the unperturbed transition between the levels $2p_{10}$ and $5d_5$ of the atom of Krypton 86, the orange-red line.

The *kilogram* (unit of mass) is the mass of a particular cylinder of platinum-iridium alloy, called the International Prototype Kilogram, which is preserved in a vault at Sèvres, France, by the International Bureau of Weights and Measures.

The ephemeris *second* (unit of time) is exactly 1/31,556,925.974,7 of the tropical year of 1900, January, 0 days, and 12 hours ephemeris time.

The *ampere* (unit of electric current) is the constant current which, if maintained in two straight parallel conductors of infinite length, of negligible circular sections, and placed 1 meter apart in a vacuum, will produce between these conductors a force equal to 2×10^{-7} newton per meter of length.

The thermodynamic *Kelvin degree* (unit of temperature) is the unit of temperature determined by the Carnot cycle with the triple-point temperature of water defined as exactly 273.16° K.

The *candela* (unit of luminous intensity) is of such a value that the luminous intensity of a full radiator at the freezing temperature of platinum is 60 candela per centimeter squared.

The basic relations between units of the U.S. customary and the metric system is:

1 U.S. yard=0.9144 meter [8]

and, an avoirdupois pound:

1 lb. avdp.=0.453,592,37 kilogram

or an avoirdupois ounce:

1 oz. avdp.=28.349,523,125 grams.

"Inasmuch as a major characteristic of the metric system is the use of decimal multiples and submultiples for describing magnitudes larger or smaller than the primary units, terms to be used as prefixes have been promulgated by the international organization responsible for the metric system. These are as follows:

Multiples	Prefixes	Symbols	Pronunciation
10	deka	da	dĕk′ȧ
10^2 (100)	hecto	h	hĕk′tō
10^3 (1000)	kilo	k	kĭl′ō
10^6	mega	M	mĕg′ȧ
10^9	giga	G	jĭ′gȧ
10^{12}	tera	T	tĕr′ȧ

[6] Mechtly, E. A., George C. Marshall Space Flight Center, National Aeronautics and Space Administration, "The International System of Units—Physical Constants and Conversion Factors," NASA SP 7012, 1964, p. 2.

[7] Ibid., p. 3.

[8] "Units of Weight and Measure (U.S. Customary and Metric), Definitions and Tables of Equivalents," U.S. Department of Commerce, National Bureau of Standards, Miscellaneous Publication 233, Dec. 20, 1960, pp. 2., 6., 11.

Submultiples	Prefixes	Symbols	Pronunciation
10^{-1} (0.1)----	deci	d	dĕs′ĭ
10^{-2} (0.01)---	centi	c	sĕnt′ĭ
10^{-3} (0.001)--	milli	m	mĭl′ĭ
10^{-6}---------	micro	μ	mī′krō
10^{-9}---------	nano	n	năn′ō
10^{-12}--------	pico	p	pe′cō
10^{-15}--------	femto	f	fĕm′tō
10^{-18}--------	atto	a	ăt′tō

"The official French spelling for the prefix representing the multiple 10 is deca. This prefix has long been spelled 'deka' in the United States, Great Britain, Germany, and a few other countries."[9]

4. Standardization

Questions concerning the metric system and its possible adoption should be viewed within the total context of standards generally, since these form the basis for orderly technical and commercial activity.

"If peoples and governments are to work together successfully for some common goal, one of the first requirements is a mutually agreed upon medium of communication. This does not mean that they must all speak the same language, but that the scientific and technical terms they use, the measurements, the symbols, the specifications ought to be given in a form which means exactly the same thing to them all. * * * One of the most obvious is the system of weights and measures, and participants in the Conference repeatedly expressed the desire for a universal adoption of the metric system, as being the most widely used already and the easiest with which to calculate. * * *

"A bewildering variety of electrical equipment, for example, is on the world market: a simple light bulb bought in one country will not fit into a socket bought in another, nor will it operate on the same voltage; and similar incompatibilities are found in almost everything to do with electricity, from the transformers and high tension wires to the winding of an armature, the variations occurring not only from one country to another but from manufacturer to manufacturer."[10]

"Standards are often complex to prepare and use. They may classify materials, define a range of qualities or grades, lay down how to test materials and assess the results, or specify the dimensions, performance, and ratings of components and machines, and the maintenance and operation of equipment. Their value depends largely on their wide acceptance and, while they themselves are a disciplining factor, their use requires industrial and, indeed, national discipline.

"The importance of standardization has long been recognized by the industrialized countries, both on a national and on an international level. In these countries, a vast amount of scientific knowledge and industrial operating experience has been embodied in agreed and published standards. Altogether, 60,000 to 70,000 national standards have been published. * * *

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[9] Astin, Dr. Allen V., Director, National Bureau of Standards, Department of Commerce, Washington, D.C., "The Metric System and the International System of Units," contained in "Conversion to Metric System," hearings on S. 1278 before the Committee on Commerce, U.S. Senate, 88th Cong., 2d sess., Jan. 7, 1964, p. 9.

[10] "Science and Technology for Development" (report on the United Nations Conference on the Application of Science and Technology for the Benefit of the Less Developed Areas), vols. I to VIII, United Nations, Geneva, Switzerland, 1963, vol. 2, p. 195.

"The present moment, when many new countries are embarking on industrial development programs, is particularly favorable for a major standardization effort. In these countries there is so far only a limited amount of established production procedure and connected vested interest; consequently, the inconvenience that adoption of new procedures might entail, or the resistance that might be raised to change, is less than it might otherwise be. * * *

"During the early stages of a standardization effort, measures should be taken to promote public awareness, expecially in the ranks of industry, of the workings and value of standardization. For instance, in the Soviet Union, and in India, a major publicity campaign was launched (to carry through standardization and conversion to the metric system) with the aid of books, booklets, posters, films, etc., to explain standardization and so increase understanding of its importance. * * *

"Developing countries need not start from scratch in adopting standardization; they can rely on the comprehensive experience of the developed countries which is available to them through the international organizations working in this field. The principal one is the International Standardization Organization (ISO), which is a nongovernmental organization with headquarters in Geneva. Its objective is to promote the development of standards in the world with a view to facilitating international exchange of goods and services and to develop cooperation in the sphere of scientific, technological, and economic activity." [11]

"In some countries, standards are compulsory and penalties are imposed for nonobservance; they are regarded as an instrument for full-scale economic planning. This is the attitude in the Soviet Union and most of the Socialist countries." [12]

In the United States, the Government has a continuing responsibility for standards for both military and civil goods and usages; however, industrial organizations and especially trade associations have been extremely active and successful in setting up respected and widely adopted standards in nearly every field of commercial activity. In addition, they have large staffs constantly working on these standards and on the necessary consultations with foreign organizations over matters which vary from those as basic as screw threads to attempt to resolve questions over the entire range of commercial products and practices.

In the recent "LaQue Report," a comprehensive study of standardization and standards, the panel's letter of transmittal to the Assistant Secretary of Commerce for Science and Technology states: "* * * The most important finding was the need for a more effective organization using improved procedures for voluntary coordination and promulgation of standards that would meet the requirements for recognition as 'U.S.A. Standards' both nationally and in international standardization activities. * * * The development of standards should be left to the several private organizations already active in this field. These were found to be competent, effective, and aware of the continuing need for a dynamic standards activity responsive to the requirements of our freedom oriented society. * * *" [13]

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[11] Ibid., vol. VII, pp. 119–120.
[12] Ibid., vol. IV, p. 56.
[13] "Report of the Panel on Engineering and Commodity Standards of the Commerce Technical Advisory Board, Feb. 2, 1965, Clearinghouse for Federal Scientific and Technical Information, U.S. Department of Commerce, PB 166811 (with separate Appendix PB 166812).

PART III

THE EXPERIENCE OF ADOPTING NATIONS

1. Chronological Listing of Adopting Nations

While the adoption of the metric system by France occurred in 1795, the requirements for use were relaxed in 1812, and a more stringent act was finally passed in 1837 making the use of the metric system compulsory and exclusive, effective in 1840. The following chronological listing shows the effective dates on which other adopting countries also made the use of the metric system a legal requirement. Many other countries have also adopted the metric system to some extent. Thus, in the United States the metric system is legal but not compulsory; in others it is compulsory in certain areas and not in others, etc. These countries have not been shown in the following list. It should also be noted that probably in no country has conversion been complete in the sense of having eliminated the use of all traditional and popular units, while other countries (e.g., India) are currently in transition with target dates in the future.

Countries in which the use of the metric system is required by law [1]

Year		*Year*		*Year*	
1816	Belgium	1852	Portugal	1868	Bolivia
1816	Netherlands	1854	Colombia	1869	Peru
1820	Luxembourg	1854	Monaco	1871	Ecuador
1840	France	1863	Italy	1871	Spain
1872	Brazil	1896	Mexico	1927	U.S.S.R.
1872	Germany	1907	Iceland	1933	Iran
1872	Saar	1907	San Marino	1933	Turkey
1876	Antilles	1910	Congo	1935	Lebanon
1876	Austria	1912	Costa Rica	1935	Syria
1876	Czechoslovakia	1912	Denmark	1936	Thailand
1876	Hungary	1912	Guatemala	1938	Indonesia
1876	Liechtenstein	1912	Honduras	1938	Iraq
1877	Switzerland	1912	Nicaragua	1949	China (mainland)
1878	Mauritius	1912	Salvador	1949	Korea
1880	Seychelles	1914	Cambodia	1951	Albania
1882	Cuba	1914	Venezuela	1954	China (Taiwan)
1882	Norway	1916	Panama	1954	Israel
1883	Yugoslavia	1917	Philippines	1954	Jordan
1884	Rumania	1917	Surinam	1955	Dominican Republic
1887	Argentina	1919	Poland		
1889	Sweden	1921	Malta	1955	Sudan
1892	Bulgaria	1922	Haiti	1958	India
1892	Finland	1923	Morocco	1959	Greece
1894	Uruguay	1926	Afghanistan	1959	Japan
1895	Tunisia	1927	Libya	?	Paraguay
1843	Algeria	1865	Chile		

[1] Principal sources: "Recent Progress of the Metric System," appendix to the "Report of the 10th General Conference on Weights and Measures," International Bureau of Weights and Measures, Paris, 1955, pp. 59–72; "The Metric System," hearings on H.R. 269 and H.R. 2049 before Subcommittee No. 1 of the Committee on Science and Astronautics, U.S. House of Representatives, 87th Cong., 1st sess., June 28, 29, and July 21, 1961, p. 15; and supplemental data from National Bureau of Standards file records.

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2. France

An effective drive to develop the metric system began under the revolutionary government of France in 1789. "On May 8, 1790, the National Assembly officially requested the French Academy of Sciences to work out a system of units suitable for adoption by the entire world. At this time, there was a great confusion and jumble of units of weights and measures, not only in France, but everywhere. Units in use were poorly defined and varied from one place to the next, and from one guild to another." [1]

The French Academy decided on a standard unit of length equaling one ten-millionth of the earth's quarter meridian (from the North pole to the equator) passing through Paris. This unit was called the "meter." It is nearly 10 percent longer than our current yard; i.e., 1 meter equals 39.37 inches. The corresponding unit of mass (or weight) was called the "gram" and is the mass (or weight) of 1 cubic centimeter of pure water (under specified conditions of temperature, etc.). One gram is equal to roughly 0.0353 ounce, or 1 ounce equals approximately 28.35 grams.

"It seems clear that the original intent of the founders was to establish a system primarily for the exchange of goods on both a national and international basis and that engineering and scientific use of the system was a secondary development. In its original form, units for only two quantities were defined in the system—the meter for the unit of length and the gram for the unit of mass. * * * As it it exists today, the international system (SI) is a complete and consistent system of units suitable for all measurements in physical science and engineering.

"The great advantage of SI is that there is only 1 unit for each physical quantity—the meter for length (L), kilogram (instead of gram) for mass (M), second for time (T), etc. From these elemental units, units for all other mechanical quantities are derived (such as speed, acceleration, force, work or energy, and power). The SI units for force, energy, and power are the same regardless of whether we are dealing with mechanical, electrical, chemical, or nuclear processes." [2]

Reverting to the time of the original adoption of the metric system, "I think you would further be interested to know a few of the immediate popular reactions that occurred in France when, on May 8, 1790, the decimal metric system was imposed upon the French people by law of the Republican Convention. The Convention went all out for the decimal system in every aspect of measurement and adopted a system which was based upon a rather inaccurate measurement of the quarter meridian running through Paris.

"The measures were vastly inconvenient, bore no resemblance to anything in the old system, caused untold confusion, and actually had to be enforced by spies and police.

"Months were divided into three periods of 10 days each, plus a 5-day year-end period called 'Joure Sensculottidies.' Days were divided into 10 hours of 100 minutes of 100 seconds. It was a crime to sell eggs, buns, or anything else by the dozen. You had to buy 10 or 20 of what you wanted.

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[1] "The International System of Units," American Society for Quality Control, Annual Technical Conference Transactions, 1965, p. 431.

[2] Ibid., p. 431.

"On August 1, 1793, the Weights and Measures Committee was thanked for its work, all scientific academies were closed, and Lavoisier (the great scientist and principal member of the Metric Committee) was sent to the guillotine. The citizens didn't like the metric system."[3] (See also annex B.)

However, the new system was formally adopted by France on April 7, 1795, although the surveying necessary to accurately fix the length of the meter bar was not finished until 1798. The first official platinum meter bar was made and marked in 1799.

"Napoleon won the popular acclaim of all Frenchmen when he relaxed the metric law in 1799, returned to the Gregorian Calendar in 1805, and permitted the old standards to be used in 1812. He did standardize the old system, however."[4]

On July 4, 1837, the French Chambers passed a more stringent act making the use of the metric system compulsory after January 1, 1840, and forbidding the use of any other system.[5] Belgium, Luxembourg, and Holland had earlier adopted the metric system, and in each decade following, more nations joined these ranks.

In 1875, the International Bureau of Weights and Measures was officially formed at a convention of 19 countries, and 17 nations joined the organization. The headquarters were established just outside of Paris.

At the International Conference of Weights and Measures held in Paris in September 1889, the U.S. representative accepted official Meter No. 27 and Kilogram No. 20 (in addition to several earlier official copies). These were carefully transported to the United States, accepted at a ceremony in the White House, and then deposited in a subterranean vault at the National Bureau of Standards in Washington.

3. India

The following available information concerning conversion to the metric system by India is quoted from the article "Change-Over in Industries" contained in the issue of the bimonthly publication of the Indian Government, Journal of Weights and Measures, entitled "Metric Measures," March, 1964.

"Shri T. Swaminathan, Secretary to the Government of India, Department of Supplies and Technical Development, New Delhi, presided over the session.

"Speaking about the introduction of metric system in India, the chairman stated that the move was initiated by India long back and it was welcomed by all. Since people are accustomed to a particular way of working and as different standards of weights and measures had been in vogue, the problem was quite difficult. In spite of it, standard specifications have been laid down for a variety of products and definite progress made toward achieving the goal of changeover to the metric measurements.

"He pointed out that the adoption of the metric system in the country was an opportunity as well as a challenge. It was an opportunity as it helped in national integration through the adoption of uniform weights and measures and trading practices all over the

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[3] Davis, Representative John W. (Democrat, of Georgia), "Congress and the Metric System," an address before the annual meeting of the Metric Association, Inc., Philadelphia, Dec. 28, 1962, p. 7.

[4] "The Metric System of Weights and Measures," The National Council of Teachers of Mathematics 20th Yearbook (compiled by the Committee on the Metric System, J. T. Johnson, chairman), Bureau of Publications, Teachers College, Columbia University, New York, 1948, p. 7.

[5] "The International System of Units," ASQC, op. cit., p. 431.

country and also enabled us to step up our export trade with other countries, as 80 percent of the countries use the metric system. It was a challenge to engineers and others because the industries had now to solve a large number of problems of a fundamental nature in a rather limited period of time. He referred to the considerable rethinking undertaken in countries using the FPS (foot-pound-second) system where production for export was required to be made both in the foot-pound and the metric system.

"In the context of the European Common Market, the chairman observed that if India was to trade with these Common Market countries, she would naturally have to change over as early as possible, so as to be able to walk side by side with other countries who were becoming more and more unified. He mentioned the statement issued by the British Standards Institution (BSI) on the adoption of the metric system in the United Kingdom. He said that it is a matter of pride to all of us that the BSI was now looking to India and the ISI (Indian Standards Institution) for guidance and advice because India had already gone ahead with the adoption of the metric system. Even then, if we have to catch up with the other 80 percent countries who use the metric system, we had to do a lot of work which remained to be done. Much of it has to be achieved by 1966, the target date for the full adoption of the metric system.

"* * * It is necessary for financial as well as technical reasons that we should work out a realistic program for phasing the program. The Indian Standards Institution had now provided almost all the specifications for raw materials and equipment and production to the metric system. It was now necessary that the industries should take steps to order raw materials to metric specifications and plan a program for changing their production to the metric system. If these steps are not taken it is likely that many industries may create difficulties for themselves. * * *

"The chairman and many others pointed out that both the United Kingdom and the United States were willing to supply equipment in the metric system, provided the partner country asked for it. They were already giving such equipment not only to the West European countries but also to India whenever asked for specifically.

"* * * A determined effort was now necessary if the industry was not to be caught on the wrong foot as far as raw materials and end products were concerned. The expenditure, it was pointed out again and again during the discussion, was not at all heavy." [6]

Considering that India adopted the metric system officially only in 1958, the reported speed of the transition, in certain sectors at least, appears interesting. In the previously quoted issue of the Journal of Weights and Measures [7] there is also a condensation of "Brochure on the Introduction of Metric System in the Highways Department," Highways and Rural Works Department, Government of Madras, September 1963, which includes, in part:

"After considering in detail the various steps to be taken, the Highways Department changed over to the metric system from November 14, 1962, on the following lines:

"(1) All works under execution were to be continued till completion in the F.P.S. system with the same conditions and contract to avoid complications which would arise.

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[6] "Metric Measures" (Journal of Weights and Measures), Ministry of International Trade, India Government, New Delhi, vol. 7, No. 2, March 1964, pp. 20–23.

[7] Ibid., vol. 7, No. 2 (March 1964), p. 30.

"(2) The works for which estimates were sanctioned in F.P.S. system prior to November 14, 1962, and tenders not settled, tendering was to be called for in metric units by converting the quantities but the work was to be executed in the F.P.S. system. Payment was expected to be in the C.G.S. (metric) system.

"(3) All estimates sanctioned after November 14, 1962, should be in the C.G.S. system."

In a subsequent issue of this journal:

"* * * Almost the entire production of steel sections in the country is now in standard millimeter sizes. Manufacturers of fasteners have agreed to all demands for fasteners conforming to Indian standards. * * * In all licenses for setting up new industrial enterprises to start production on or after January 4, 1966, a condition will be imposed that both the product and, to the extent possible, the machinery installed, should be of metric system design." [8]

A. COST ESTIMATES OF CONVERSION

There are few reports, papers, or articles available on the cost experiences of nations that have adopted the metric system and experienced the transition problems. This is also evident in the lack of references to such foreign costs in the large number of papers concerning the possible adoption of the metric system in the United States. The following information is one of the exceptions:

Since India is a large, populous, and industrially expanding nation and also one of those most recently adopting the metric system, the following information, taken from "Cost of Adoption of Metric System" in the Indian Journal of Weights and Measures, volume 7, No. 6 (November 1964), is especially important:

"The Standards of Weights and Measures Act received the President's assent in December 1956. The act enjoined Government to enforce the metric system of weights and measures in commercial transactions throughout the country by December 1966. In 1958, the metric weights were introduced in trade on a small scale. Later, metric weights and measures were introduced by stages in the whole country. By the end of 1963, the metric system had come into effective use in all commercial transactions.

"An attempt has been made to estimate the cost to the nation in changing its weights and measures. The cost was shared by the Government both at the center and in the States, trade, industry, transport, communications, and by the public at large. The cost can be broadly classified under the following heads:

"(1) Replacement of old weights and measures by metric weights and measures.

"(2) Conversion of weighing machines.

"(3) Cost of State governments, in enforcing weights and measures, and in adopting the new system in Government departments.

"(4) Cost to Central Government departments and undertakings.

"(5) Cost to industry.

"(6) Miscellaneous costs in sectors such as road transport, shipping, etc.

[8] Ibid., vol. 7, No. 4 (July 1964), p. 20.

"(1) REPLACEMENT OF WEIGHTS AND MEASURES

"The use of old weights and measures became illegal in certain parts of the country in October 1960. By March 1963, old weights and measures had been almost completely replaced by metric weights and measures throughout the country. Total replacement thus took place during a period of 3 years. * * * According to statistics supplied by them (State government inspectors), the estimated cost of metric weights and measures which went into circulation during this period was Rs72 million ($15.1 million). A part of this represented normal replacement of old and wornout weights and measures which in any case would have taken place. The normal lifespan of a commercial weight or measure is about 5 years. Every year about 20 percent of the weights and measures in circulation are, therefore, replaced. In a period of 3 years, 60 percent would be replaced in the normal course. Of the new weights and measures which came into circulation during the period April 1960 to March 1963, only about 40 percent represented accelerated replacement due to the introduction of the new system. The expenditure to the nation on this account was Rs28.8 million ($6.04 million).[9]

"(2) CONVERSION OF WEIGHING MACHINES

"The estimated value of conversion carried out by recognized manufacturers of weighing machines is Rs6.2 million ($1.3 million). Of this, Rs3.7 million represents work done for major industries like iron and steel, cotton textiles, etc., and the balance of Rs2.5 million for other industries including small scale industry, road transport, wholesale trade, etc.

"(3) COST TO STATE GOVERNMENT

"Between 1958–59 and 1963–64, the State governments spent about Rs47 million ($9.86 million) on the enforcement of weights and measures, publicity, training of staff, replacement of weights and measures, conversion of weighing machines in government departments, etc.

"(4) COST TO CENTRAL GOVERNMENT

"The estimated expenditure of Central Government departments and undertakings is as follows:

	Rs. in millions
"(1) Railways	10.2
"(2) Posts and telegraph	3.0
"(3) Publicity	6.9
"(4) Transport and communications	1.0
"(5) Other departments and undertakings	3.5
"Total ($5.16 million)	24.6

"(5) COST TO INDUSTRY

"According to the Oil Industry Metric Committee, which represents all the oil companies, the oil industry spent Rs2.5 million on the conversion of petrol dispensing pumps and other measuring equipment, publicity, training of staff, etc.

[9] As of Dec. 31, 1963, 1 Indian rupee Rs.=$0.2098.

"The expenditure for other major industries was estimated through sample surveys conducted by the Directorate of Weights and Measures, Ministry of Commerce, Government of India. It was not possible to make such surveys for small industries or for small-scale and cottage industries. The cost to industry including small-scale industry was as follows:

	Rs. in millions
"(1) Cotton textiles	2.0
"(2) Jute textiles	.8
"(3) Sugar	3.6
"(4) Cement	.3
"(5) Iron and steel	.5
"(6) Petroleum	2.5
"(7) Tea	2.4
"(8) Miscellaneous industries, including small-scale industry	5.0
"Total ($3.59 million)	17.1

"(6) OTHER SECTORS (INCLUDING ROAD TRANSPORT)

"The cost in these sectors was mainly for conversion of weighing machines and replacement of weights and measures which have been counted under other heads. Expenditures on other items would be relatively small and is estimated at Rs2 million.

"TOTAL COST

"The total expenditure incurred so far on the reform of weights and measures is roughly as follows:

	Rs. in millions
"(1) Replacement of weights and measures	28.8
"(2) Recalibration of weighing machines, except in major industries (the cost for major industries is counted in item (5) below)	2.5
"(3) Cost to State governments	47.0
"(4) Cost to Central Government	24.6
"(5) Cost to industry	17.1
"(6) Other sectors	2.0
"Total ($25.6 million)	122.0

"The total cost of Rs122 million (Rs12.2 crores) ($25.6 million) is modest in relation to the magnitude of the reform and its significance to the country's economy. The reform is, however, not complete since the metric system has yet to be fully adopted in engineering and technology. This is bound to be a slow process and would take considerable time. Further, engineers and technologists throughout the world would have to be equally familiar with both systems. It is, therefore, not possible to anticipate a time when the foot-pound system would be completely eliminated from these fields."

As stated above, the recorded costs to the Indian economy to date is only a part of the expected total cost, the amount of which cannot now be estimated without further study. However, the degree of conversion already achieved nationwide is surprising. The comparability of the Indian experience and the costs to be expected in any other nation must also take into account many factors of conditions, timing, extent, public and industrial attitudes, etc., of the particular nations involved.

It may be noted that in 1962, the Indian nation had a population of 449,381,000, an area of 1,176,153 square miles, and a GNP of

$36.9 billion (translating the rupee value at the prevailing exchange rate).[10 11]

4. Japan

Summarizing a paper by Mitsuo Tamano, Director, National Research Laboratory of Metrology, Tokyo, Japan, "Japan's Transition to the Metric System," which appeared in a paper presented to the 47th National Conference on Weights and Measures, Washington, D.C., June 5, 1962, Kiproff condenses Japan's experience as follows:

"The measurement law establishes, in Japan, the legal measuring units. The metric system became the unique measuring system authorized in Japan since January 1, 1959. Before this adoption of the metric system, Japan had as many as three measuring systems simultaneously. The traditional units dating back before 1891 were the 'Shaku' and 'kan.' In 1891, the metric system was approved and conversion factors between the two systems were fixed. In 1909, the foot-pound system was also adopted as legal. In 1919 it was decided that a single system should be adopted. Following a study by a committee for weights and measures, it was decided to adopt the metric system exclusively. A bill was passed in 1921 providing for compulsory changeover in two phases to start in 1924. During the first 10 years, all Government offices, public services, and leading industries were to change. During the second 10 years, all other activities were to change. As the deadline approached, opposition increased and the conversion dates were postponed. During all this time (since 1926), the textbooks of the primary schools had been adopting the metric system so that most people knew the system.

"After Japan's defeat in 1945 and occupation by the U.S. forces, the movement was set back. Japan again came to use three systems. Because of the resulting confusion, Japan adopted the metric system in 1951 allowing a transition period to end December 31, 1958.

"An intensive campaign was initiated for promotion. Pamphlets, posters, newspapers, radio, and TV were used effectively. Cooperation of the mass media helped to keep expenses low. In some cases, the force of law was necessary but was used only to a minor degree.

"Although complete conversion was not achieved on the deadline date, January 1, 1959, a survey taken at the time indicated 85 percent compliance. Some exceptions are permitted in the import and export business. The system can never be complete in Japan until there is one system throughout the world. This depends largely on the adoption of the metric system in the United States and Great Britain. The author (of the original article) expresses hope that this adoption will be realized as soon as possible." [12]

5. China (Mainland)

In mainland China, during the period of preparation for the change to the metric system, which it formally adopted in 1949, the Director of the Ministry of Industries, Bureau of Standard Weights and Measures, reported in 1934: "It was found impossible to secure the adoption

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[10] "Statistical Abstract of the United States," 85th (1964) annual edition, Government Printing Office, Washington, D.C.

[11] "Estimates of National Income, 1963, 1964," Central Statistical Organization, Department of Statistics, Cabinet Secretariat, Government of India.

[12] Kiproff, Peter, Temple University, "Standardization—Inches vs. Meters—The Big Dilemma," January 1965, summarizing a series of current papers, pro and con.

of the new weights and measures by a change direct from the old, and it was therefore arranged that the old measures be retained but with such adjustments of their values as to establish a direct relationship to metric values.

"The capacity of the gallon is to reduce to the exact equivalent of 4 liters, thus the quart would be 1 liter and the pint half a liter. The pound, which would be made equal to exactly half a kilogram, and the British ton should be reduced to make it equal to the metric ton, and divided into 2,000 new pounds. The measure of length, which should probably be last to be changed, would be revised by making the 'yard' equal to the meter." [13] Between that report and the later adoption noted above, the Government of mainland China changed hands completely.

6. U.S.S.R.

In an article translated from Russian,[14] note is made that Standartizatsiya is the only scientific and technical journal in the Soviet Union devoted to problems of state standardization. It also includes information on "the single system of measuring units, the International System (SI)."

In another Russian paper, stressing the close affinity between standards and the uniform systems of measurements, it is stated:

"The inculcation of standards leads to considerable economy in social labour, as provision is made by the standards for the most advantageous form, weight, size of products, the manufacturing of which takes less time, materials, resources, etc.

"Standardization exerts a substantial influence on the development of technical progress, as standards establish rational series of technical characteristics of machines, equipment, and instruments as well as their assemblies and details, such standards determine progressive assortment of goods and raw materials.

"Standardization and normalization are the means of speeding up the development and mastering the production of new goods and reduction of the preparatory cycle for their production, since standards introduce the necessary uniformity, regulate the characteristics of the components used, thus considerably simplifying the process of preparing for production. * * *

"In the Soviet Union the work on standardization is considered to be an important government measure and a part of the general plan for the national economy development.

"The Soviet state standards are obligatory for application throughout the territory of the USSR and are a State law in production * * *

"At present more than 8,000 State standards are functioning in the Soviet Union * * *.

"The whole system of standardization in the Soviet Union is based on the application of international metric system of measures. The successful introduction of this system in our country in the course of a short period of time has been accomplished as a result of a number of organizational and technical measures taken * * *." [15]

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[13] Wu, C. C., Director, Ministry of Industries, Bureau of Standard Weights and Measures, China, "Unification of Weights and Measures in China," July 1934, p. 1.

[14] Instrument Society of America, "Russian Translations," 1964, p. 850.

[15] Vjatkin, A. E., chairman of the Committee of Standards, Measures and Measuring Instruments, under the Council of Ministers of the U.S.S.R., president of the International Standards Organization, in agenda item: D:3:3 U.S.S.R., "Standardization as a Means of Achievement of Scientific, Technical and Economic Progress and the Application of Advanced Experience in Underdeveloped Countries," United Nations Conference on the Application of Science and Technology for the Benefit of the Less Developed Areas, Geneva, Switzerland, Feb. 4–20, 1963, Summary, pp. 1–2.

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7. United Kingdom

In Britain, prior to 1960, "The last examination of the case for decimal coinage in the United Kingdom was undertaken by a Royal Commission in 1918. The Board of Trade Committee on Weights and Measures in 1951 included in their report a chapter on adoption of the metric system in the United Kingdom, and in 1957, the Federation of British Industries conducted a brief survey of the attitude of British industry toward a further enquiry into decimal coinage and the metric system. So far as we are aware no detailed investigation into the implications of the changeover to the metric system has hitherto been carried out in this country.[16]

"Summary: Our information as to the costs of a general adoption of the metric system by United Kingdom is unsatisfactory. Out of 523 respondents to our questionnaires from individual companies in industry and commerce, less than one-half gave any figures or cost factors. * * * Such figures as were obtained showed wide variation between firms even for a specific changeover period in a particular industry.

"There is no unique answer to the question as to the cost of the changeover. It would require a detailed investigation in each individual industry. Even this assessment would not complete the picture. One industry uses the products of another and a change in one would have to be considered in conjunction with a change in each related industry in order to arrive at the most economic phasing of a general changeover.

"All that can be said in summing up on the cost question is that transitional costs would undoubtedly be very heavy in some spheres, particularly in engineering. As regards the financial benefits to be gained, these appear to be small and, indeed, of such a different order of magnitude as to provide an inadequate return on a purely financial basis in relation to the associated transitional costs. It can, of course, be argued that a perpetual small benefit will in the long run outweigh a high transitional cost, yet we feel the case for the general adoption of the metric system must be argued on other than financial grounds." [17]

The effects of these British studies and support for studies and analysis in the United States have also been reported in a recent issue of Science.[18]

Like the United States, the United Kingdom has also been periodically reviewing the relative merits of changing to the metric system as compared with alternate proposals. "In 1960, a survey covering 87 percent of industry (in United Kingdom) showed 84 percent of respondents in favor of Britain's adopting metric weights and measures, but 65 percent wanted no action unless the Commonwealth and the United States follow." [19]

In a statement by the British Standards Institution in May 1962, there is included: "From the point of view of the United Kingdom's export trade as a whole, the use of the metric system and of metric standards will be increasingly demanded by our trade not only with Europe—whether we are members of the Common Market or not—

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[16] "Decimal Coinage and the Metric System—Should Britain Change?" a joint report of committees appointed by the British Association for the Advancement of Science and the Association of British Chambers of Commerce, London, 1960, Preface.

[17] Ibid., p. 46.

[18] "Adoption of the Metric System," editorial by Dael Wolfle, Science, July 9, 1965, p. 139.

[19] "Should the U.S. Go Metric?" Product Engineering, Oct. 2, 1961, p. 69.

but also, and perhaps even more significantly, with markets in the developing countries in Asia, South America, and elsewhere, which are of major importance as providing growing outlets for our future trade. * * *" [20]

Then, in discussing the manner of effecting the change at home, it further states: "Clearly, the time required for a change would vary from industry to industry and would have to be planned and phased according to their needs, but it is only on the basis of a firm assumption of a general move, *which nothing less than a Government directive could induce*, that most individual industries could or would take any decisive action, or even discuss the problem realistically with their customers and suppliers."

The referenced statement then sets forth the step-by-step actions which would be logical to accomplish the transition in a suggested 20-year period, starting with "consultations and cooperative efforts (following the recommended Government pronouncement with leading industrial bodies, consultive councils, educational authorities, professional societies and institutions, trade unions, trade associations, chambers of commerce, and many others. * * *"

That statement was circulated to the 50 principal industry standards committees of the BSI for comments which were then summarized by its executive committee as, in part: "Though recognizing the size and complexity of the task, the great majority of industries accept that a change is inevitable." [21]

"* * * Since then (1962), committees in BSI (British Standards Institution) representative of manufacturers and other interested bodies in a wide range of industries have considered this review and the main questions which emerged from it—whether particular industries wished to change to the metric system, how long it would take, and whether it should be dependent on a parallel move by the United States or the Commonwealth, as well as detailed questions on the metric standards to be used.

"The positive view now reported is, with only a few exceptions, not conditional on similar action by the United States or the Commonwealth.

"Export advantages: The BSI's high-level Export Panel favors a change to metric because of the increasing use of the metric system in the more rapidly expanding world markets, and in view of Britain's growing trade with Europe.

"The report recognizes that the time to make a change will vary from industry to industry and that certain of them—notably petroleum equipment, aircraft, and automobiles—must remain basically on the inch-pound system of standards until a change is made in parallel industries in the United States. In some other parts of the engineering industry the move would inevitably be protracted with dual production, to inch and metric standards, to cater for special customers and for spares and replacements over a considerable period. * * *"

"Changes made to standards (which in the main are voluntary in Britain) could be quickly reflected—even without Government action—in trade and commerce and in daily life. Use of the metric system is permitted by law in this country, except for sale of a limited number of goods of specific weights. Clearly, however, a Government

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[20] A statement by the British Standards Institution, PD 4555, May 1962: "Change to the Metric System?" pp. 1, 4.

[21] A report by the British Standards Institution following consultations with industry. PD 5069, Oct. 1963: "British Industry and the Metric system," p. 3.

pronouncement would decisively influence the pace of any change and the effectiveness of action throughout the economy. * * *" [22]

The culmination occurred on May 24, 1965, when the British Board of Trade made a declaration to the House of Commons that the United Kingdom would adopt the metric system sector by sector until it became the primary system of weights and measures for the country as a whole, and set a target date for its accomplishment at 10 years hence. Canada followed that move by recently calling for a full study of the effects of a similar adoption in that country.

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[22] "Metric Measures," Journal of Weights and Measures, Ministry of International Trade, India Government, New Dehli, vol. 7, No. 2 (1964), quoting BSI News (British Standards Institution), November 1963, p. 13.

PART IV

CONSIDERATION OF THE METRIC SYSTEM IN THE UNITED STATES

1. Historical Proposals

The varied nationalities of our early immigrants, who brought with them and used the familiar weights and measures of their homelands, caused a polyglot of measuring systems between regions, and often within regions. For the same-named measures often varied appreciably due to local customs, varied between colonies, and even from those of the originating country. One had to be wary of what basis was being used in any transaction.

Gradually, however, the English foot-pound system predominated, but even with this, variances persisted internally and externally. With the Declaration of Independence in 1776, and the ratification by the colonies in 1781 of the Articles of Confederation, a new effort to resolve the problem of uniform weights and measures began. In the latter document, one of the powers granted to the Continental Congress was that of the "sole and exclusive right and power of * * * fixing the standard of weights and measures throughout the united states" (art. 9, par. 4). Note that, unlike the power to regulate commerce, which was limited to that between States, this authority to determine and regulate weights and measures was all-encompassing. Later, when the Constitution became effective in 1789, article I, section 8, paragraphs 3 and 5 stated: "The Congress shall have Power * * * To regulate Commerce * * * among the several States * * * To * * * fix the Standard of Weights and Measures."[1][2]

On request, Thomas Jefferson made a report to the House on this subject in 1790 containing two plans. The first was based on retaining the current English system of weights and measures but providing means to make them invariant. A part of it provided, for example, that it "be established that an ounce is of the weight of a cube of rainwater, of one-tenth of a foot, or rather, that it is the thousandth part of the weight of a cubic foot of rainwater, weighed in the standard temperature; that the series of weights of the United States shall consist of pounds, ounces, pennyweights, and grains, whereas 24 grains shall be 1 pennyweight, 18 pennyweights 1 ounce, 16 ounces 1 pound." [3]

The second Jefferson plan was, briefly, based on adoption of the metric system which was then being proposed and nearing adoption in France particularly. His second plan proposed "reducing every branch to the same decimal ratio already established in their coins,

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[1] "The Federal Basis for Weights and Measures," U.S. Department of Commerce, National Bureau of Standards, NBS Circular 593, June 5, 1958, p. 2.

[2] "Units of Weight and Measure," U.S. Customary and Metric, U.S. Department of Commerce, National Bureau of Standards, NBS Miscellaneous Publications 214, p. 60.

[3] "The Federal Basis for Weights and Measures," op. cit., p. 4.

and thus bringing the calculation of the principal affairs of life within the arithmetic of every man who can multiply and divide plain numbers." [4] Much consideration by the House and Senate followed, but no legislation resulted.

"'The period between 1799 and 1828 was marked, as had been the two preceding decades, by requests for the adoption of standards, appointment of select committees of the Congress to consider standardization, the preparation and presentation of numerous committee reports, and extended discussions; but no legislation resulted. The period was highlighted, however, by the report of 1821 of John Quincy Adams, prepared at the request of the Senate." [5] That report compared and analyzed the English and French systems, the weights and measures legislation of each State, etc., and proposed to "render uniform and stable the weights and measures which we at present possess." [6]

Note that in rejecting any proposal to change to the metric system, "In 1821, Congress concluded that it was impractical to make the change because of the cost and complexity, and this was in a relatively simple and primitive economy; compared to our complex economy (1959) it would have been an easy job. * * *" [7]

"On May 29, 1830, the Senate, having been reminded by one of its members of the report, 2 years earlier, to the effect that differences in the standards in use at various customhouses were causing loss of revenue, adopted the following resolution:

'*Resolved*, That the Secretary of the Treasury be directed to cause a comparison to be made of the standards of weights and measures now used at the principal customhouses in the United States, and report to the Senate at the next session of Congress.' * * *

"The investigation of the standards in use at the customhouses disclosed that serious differences existed in the values of the standards used at various ports, but it appeared that average values for the standards were in fairly good agreement with the values of corresponding British standards at the time of the American Revolution. * * *

"As a prerequisite to the construction of the weights and measures for the customs service, certain fundamental units were adopted by the Treasury Department, as follows:

"1. The yard of 36 inches.

"2. The avoirdupois pound of 7,000 grains, being 7,000/5,760 pounds troy.

"3. The gallon of 231 cubic inches.

"4. The bushel of 2,150.42 cubic inches." [8]

On June 14, 1836, the Congress adopted a joint resolution directing the Secretary of the Treasury to have made and be sent to the Governor of each State a complete set of all weights and measures adopted as standard, and followed this in 1838 by also sending each State one standard balance. To fulfill these directives, the Office of Weights and Measures was established.[9]

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[4] Ibid., pp. 5–6.
[5] Ibid., pp. 5–6.
[6] Ibid., p. 7
[7] Raviolo, Victor, executive director, Ford Motor Co., Detroit, "Conversion in Terms of Cost and Utility," 1959, p. 1.
[8] "The Federal Basis for Weights and Measures," NBS Circular 593, June 5, 1958, National Bureau of Standards, U.S. Department of Commerce, Washington, D.C., p. 8.
[9] "The Federal Basis for Weights and Measures," op. cit., pp. 10–11.

"The joint resolution of July 27, 1866 (not that of 1836), reads as follows: 'That the Secretary of the Treasury be, and is hereby, authorized and directed to furnish to each State, to be delivered to the governor thereof, one set of standard weights and measures of the metric system for the use of the States, respectively.'

"* * * Directly related to the joint resolution of July 27, 1866, is the law of July 28, 1866, which made legal throughout the United States the employment of weights and measures of the metric system. As enacted, the text of this law was as follows:

"'It shall be lawful throughout the United States of America to employ the weights and measures of the metric system: and no contract or dealing, or pleading in any court, shall be deemed invalid or liable to objection because the weights and measures expressed or referred to therein are weights or measures of the metric system.

"'The tables in the schedule hereto annexed shall be recognized in the construction of contracts and in all legal proceedings as establishing, in terms of the weights and measures now in use in the United States, the equivalents of the weights and measures expressed therein in terms of the metric system; and said tables may be lawfully used for computing, determining, and expressing in customary weights and measures the weights and measures of the metric system.'" [10]

"A series of events and actions that occurred during the period 1870–93, although not, strictly speaking, legislation, had a profound and lasting effect upon the weights and measures situation in the United States. These occurrences involved primarily the standards of the metric system of weights and measures. By a combination of adherence to a treaty and administrative action within the Treasury Department, the United States succeeded in correlating its system of weights and measures with those of other nations and in resolving the issue of its own fundamental standards." [11] This period included the receipt of and acceptance by the United States of official meters and kilograms from the International Bureau, and culminated with the Treasury Department's approval of the Mendenhall Order on April 5, 1893, which stated that henceforth, the yard and the pound within the United States would be based upon the meter and the kilogram. The ratios between the related units were given, but these were slightly adjusted in 1959 by the National Bureau of Standards in conjunction with its counterparts of Australia, Canada, New Zealand, South Africa, and the United Kingdom to define:

An international yard equals 0.9144 meter;

An international pound equals 0.45359237 kilogram.[12]

The Treasury had also earlier tied some of our coinage to the metric system, "'* * * the weight of the half-dollar shall be twelve grams and one-half a gram; the quarter-dollar and the dime shall be, respectively, one-half and one-fifth of the weight of said half-dollar.' (Revised Statutes of the United States, sec. 3513)." [13]

In 1894, it was enacted by Congress that the international electrical units should be the legal units of electrical measurement in the United States. In 1950, Public Law 617 repealed the act of 1894 (Public Law 105) and redefined the units in the metric system and similarly

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[10] "The Federal Basis for Weights and Measures," op. cit., pp. 11–12.
[11] Ibid., pp. 13–14.
[12] Senate hearings, 1964, op. cit., p. 12.
[13] NBS Miscellaneous Publication 214, op. cit., p. 60.

defined the photometric units, candle and lumen, in the metric measures. Also, in 1913, the metric carat was adopted as the unit of weight for diamonds and other precious stones.[14]

Particularly during the first half of this century, there was also increasing activity in organizations outside the Government. In line with the vital relation between all standards and the systems of measurements used for industrial purposes, the American Standards Association in 1913 adopted and issued (ASA B48.1–1913) a simple relationship (also adopted by similar organizations in 15 other countries) of:

1 inch equals 25.4 millimeters (exactly)

from which,

1 yard equals 0.9144 meter (exactly).[15]

In 1921, the National Industrial Conference Board made a comprehensive study and report [16] of the whole problem, but conditions have, of course, changed appreciably in the intervening 44 years. In the recent "LaQue Report," [17] there are included pertinent comments and recommendations of the appropriate panel although this group was concerned primarily with standards. Also, a relatively small number of surveys of particular industrial groups have been published, but no modern comprehensive survey or study in the light of current conditions exists.

2. Summary of Legislative Action

Nearly 175 years have elapsed since the first serious consideration was given to adoption of the metric system within the United States. For reasons related to both internal and external events, the metric system has been gradually creeping more and more into our way of life, especially in its official aspects. Some of the more prominent actions are the following: [18]

1791—Jefferson submitted two plans to the Congress, one better fixing the uniformity of the common usage English (inch-pound) system of weights and measures, the other to adopt the metric system as then known. Congress rejected both.

1821—John Quincy Adams attempted, without success, to promote a uniform system of weights and measures throughout the young nation.

1866—On July 28 Congress passed a law making the metric system the official basis for weights and measures standardization in the United States.

1875—On May 20, the United States entered into a treaty with 16 powers establishing the International Bureau of Weights and Measures, and providing for its administration.[19]

1878—In May, the United States ratified the Metric Convention of 1875, and received officially Meter No. 27 and Kilogram No. 20 in 1890.

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[14] Ibid., p. 61.
[15] Ibid., p. 61.
[16] National Industrial Conference Board, "The Metric vs. the English System of Weights and Measures,' Research Report No. 42, October 1921.
[17] "Report of the Panel on Engineering and Commodity Standards of the Commerce Technical Advisory Board," secs. A and B, Feb. 2, 1965, Clearing House for Federal Scientific and Technical Information, Department of Commerce, PB–166, 811, and PB–166, 812.
[18] The material in this section has been taken in part from the thesis by Roth contained in the Senate hearings, 1964, op. cit.
[19] Collingwood, Harris, Economics Sections, Legislative Reference Service, Library of Congress, Washington, D.C., "The Metric System as Applied in the United States," Feb. 25, 1952, p. 6.

1893—The Secretary of the Treasury provided that henceforth the international prototype meter and kilogram would be regarded as fundamental standards by the Office of Weights and Measures (which later became the present National Bureau of Standards). This ruling was known as "The Mendenhall Order."

1902 and 1906—Bills brought before the Congress to make the metric system mandatory were narrowly defeated.

1938—Bills to make the metric system compulsory were introduced in both the House and the Senate of the 75th Congress, but were not passed.

1947—The U.S. Army adopted metric units as basic to its design of the Universal Polar Stereographic and Universal Transverse Mercator Grid Systems "in view of the necessity for simplification and speed."

1957—A U.S. Army regulation was published establishing that the meter would be the measurement of linear distances to which weapons and related equipment would be converted.

1957—In September, a committee of the Organization of American States proposed that the metric system be adopted throughout the Western Hemisphere.

1958—In December, Australia, Canada, New Zealand, South Africa, the United Kingdom, and the United States adopted common standards for the inch-pound system in metric terms. One inch was made equivalent to 2.54 centimeters and 1 pound equivalent to 0.45359237 kilograms. (The Coast and Geodetic Survey, which had used a slightly different conversion factor previously, retained their established relationship of 1 inch equaling 2.540005 centimeters because of the extensive revisions which would be necessary to their charts and measurement records. The resulting foot based on this retained conversion is known as the American Survey foot.)

1959—Two bills, H.R. 7401 and S. 2420, and one resolution, House Concurrent Resolution 364, were introduced in the 86th Congress, 1st session, providing for studies of conversion to the metric system to be made by the Department of Commerce, but none was acted upon.

1960—On October 14, the 11th General Conference on Weights and Measures defined the new international meter as 1,650,763.73 wavelengths of the orange-red line of krypton 86. The inch thus became equal to 41,929.399 wavelengths of this krypton line.

1965—On May 24, the British Board of Trade announced that, and without waiting for a concurrent policy statement by the United States, it was the United Kingdom Government's policy to adopt the metric system, sector by sector, and set a target date for conversion at 10 years.

3. Recent Congressional Interest

Of the many bills introduced in the House of Representatives and the Senate since 1959, calling for a study by the Department of Commerce of the adoption of the metric system in the United States or for its adoption, none reached the floor of either Chamber. Hearings

were held on H.R. 269 and H.R. 2049, beginning June 28, 1961, before a House committee and on S. 1278, on January 7, 1964, before a Senate committee, as noted below.

1959—House of Representatives, 86th Congress, 1st session: *H.R. 7401* (Mr. Overton Brooks). A bill to provide that the National Bureau of Standards shall conduct a program of investigation, research, and survey to determine the practicability of the adoption by the United States of the metric system of weights and measures.

House, 86th Congress, 1st session: *House Concurrent Resolution 364* (Mr. James G. Fulton). Concurrent resolution favoring the adoption in the United States of the metric system of weights and measures.

Senate, 86th Congress, 1st session: *S. 2420* (Mr. Richard Neuberger). A bill to provide that the Secretary of Commerce shall conduct a study to determine the practicability and desirability of the adoption by the United States of the metric system of weights and measures.

1961—House, 87th Congress, 1st session: *H.R. 269* (Mr. James Roosevelt). A bill to provide that the Secretary of Commerce shall conduct a study to determine the practicability and desirability of the adoption by the United States of the metric system of weights and measures.

House, 87th Congress, 1st session: *H.R. 2049* (Mr. George P. Miller). A bill to provide that the National Bureau of Standards shall conduct a program of investigation, research, and survey to determine the practicability of the adoption by the United States of the metric system of weights and measures. (Hearings were held on H.R. 269 and H.R. 2049 before Subcommittee No. 1 of the Committee on Science and Astronautics, U.S. House of Representatives, starting June 28, 1961. Reported out of committee, but not enacted. Printed hearings: "The Metric System.")

House, 87th Congress, 1st session: *Concurrent Resolution 44* (Mr. James G. Fulton). Concurrent resolution expressing the sense of the Congress with respect to the adoption in the United States of the metric system of weights and measures.

Senate, 87th Congress, 1st session: *S. 2030* (Mrs. Maurine B. Neuberger). A bill to provide that the Secretary of Commerce shall conduct a study to determine the desirability and practicability of the adoption by the United States of the metric system of weights and measures.

1963—House, 88th Congress, 1st session: *H.R. 18* (Mr. George P. Miller). A bill to provide that the National Bureau of Standards shall conduct a program of investigation, research, and survey to determine the practicability of the adoption by the United States of the metric system of weights and measures.

House, 88th Congress, 1st session: *H.R. 403* (Mr. James Roosevelt). A bill to provide that the Secretary of Commerce shall conduct a study to determine the practicability and desirability of the adoption by the United States of the metric system of weights and measures.

House, 88th Congress, 1st session: *House Concurrent Resolution 145* (Mr. James G. Fulton). Concurrent resolution ex-

pressing the sense of the Congress with respect to the adoption in the United States of the metric system of weights and measures.

Senate, 88th Congress, 1st session: *S. 1278* (Mr. Claiborne Pell). A bill to provide that the National Bureau of Standards shall conduct a program of investigation, research, and survey to determine the practicability of the adoption by the United States of the metric system of weights and measures. (Hearings were held before the Senate Committee on Commerce on S. 1278 on January 7, 1964. Printed hearings: "Conversion to the Metric System.")

1964—House, 88th Congress, 2d session: *H.R. 10089* (Mr. Robert McClory). A bill to provide that the National Bureau of Standards shall conduct a program of investigation, research, and survey to determine the practicability of the adoption in the United States of the metric system of weights and measures.

1965—House, 89th Congress, 1st session: *H.R. 38* (Mr. Robert McClory). A bill to provide that the National Bureau of Standards shall conduct a program of investigation, research, and survey to determine the practicability of the adoption by the United States of the metric system of weights and measures.

House, 89th Congress, 1st session: *H.R. 1154* (Mr. James Roosevelt). A bill to provide that the Secretary of Commerce shall conduct a study to determine the practicability and desirability of the adoption by the United States of the metric system of weights and measures.

House, 89th Congress, 1st session: *H.R. 2626* (Mr. George P. Miller). A bill to provide that the National Bureau of Standards shall conduct a program of investigation, research, and survey to determine the practicability of the adoption by the United States of the metric system of weights and measures.

Senate, 89th Congress, 1st session: *S. 774* (Mr. Claiborne Pell). A bill to provide that the Department of Commerce shall conduct a program of investigation, research, and survey to determine the practicability of the adoption by the United States of the metric system of weights and measures.

PART V

ASPECTS OF THE METRIC SYSTEM IN THE UNITED STATES

1. Extent of Current Usage

In the early years of this country, the world's centers of science and research were located chiefly in the countries of Western Europe where the metric system was in vogue (except for the United Kingdom). American scientists became used to that system through their use of foreign scientific reports, studies and contacts abroad, equipments and terminologies common in this field, and they retained it as the United States expanded rapidly in its scientific endeavors and accomplishments. This common mode of scientific measurement and expression has facilitated rapport of scientists throughout the world. This has been demonstrated repeatedly, particularly in large international projects such as the recent International Geophysical Year.

In somewhat similar vein, the finest ball bearings and spark plugs were originally made abroad in metric dimensions and imported by the United States for use in machines and equipment otherwise using inches. When manufacture of these components began in the United States, the metric system of dimensions was retained and prevails today.

As noted elsewhere herein, some agencies of the Federal Government were early advocates and users of the metric system, particularly the Treasury Department, which originally had supervision of weights and measures. In 1873 following legalization of the new system in 1866, it decreed that the weights of certain coins should be made and expressed in the grams of the metric system. Following closely, in 1878, the Medical Corps of the Navy Department adopted the metric system exclusively.

Certain other parts of the Military Establishment have also made partial use of the metric system. For example, Col. G. P. Grant, the Army representative appearing in hearings on "The Metric System" (H.R. 269 and H.R. 2049) before the House Committee on Science and Astronautics in 1961 related: "In an effort to simplify procedures and develop a better capability of working with the armies of friendly nations, the meter was selected as a common unit for linear distance measure. This policy was expressed in Army Regulations 700–75, * * *.

"The target date of January 1, 1966, was selected to reach the objective of this common unit in Army weapons and associated fire-control equipment.

"Again, I would like to emphasize, the drawings, machine tools, and gages from which the equipment is, or will be, produced will be in the English or inch system.

"* * * I have been asked to say that the U.S. Marine Corps is joining us in the same date and time frame." [1]

The U.S. pharmaceutical industry is often cited as an example of a major sector of our economy converting to the metric system voluntarily. This occurred around 1957 after considerable advance study and planning. One reason this case is so prominent is that, after conversion, one large company found that the actual conversion costs which could be counted approximated about one-tenth their prior estimates; further, it is estimated that the resulting savings each year thereafter would equal or exceed the total cost of conversion.[2] How applicable that experience or the financial results are to other and differing industries or organizations cannot be readily determined without further studies in depth, taking into account the unique characteristics of each firm or industry, the timing, conditions at home and abroad, and many other pertinent factors.

The electric power industry conventionally measures electrical service in kilowatt-hours, as is done in the metric countries.[3] [4]

Fifty years ago, in a report prepared by Dr. S. W. Stratton, National Bureau of Standards, for the International High Commissioner on Uniformity of Pan-American Laws, he cites examples of large, successful manufacturers who were even then using the metric system, in some cases for both domestic and world trade. "The list, which he truly says might be extended almost indefinitely included:

American Locomotive Co.
Baldwin Locomotive Works.
Brown & Sharpe (measuring tools and gages).
Pratt & Whitney (metric gages and standards.)
Waltham Watch Co.
The Standard Tool Co.
Morse Twist Drill Co.
Bausch & Lomb Optical Co.
Eastman Kodak Co.
Lufkin Rule Co. (measuring tapes and rules).
International Exporting & Importing Corp.
Keuffel & Esser Co. (drafting instruments).
Powers-Weightman-Rosegarten (drugs and chemicals).
Library Bureau.
DeLaval Cream Separator Co.
L. S. Starrett Co. (fine mechanical tools).
Greenfield (Mass.) Tap, Die & Machine Tool Co." [5]

A more modern listing (not known to be available) would, without doubt, expand this list substantially, not alone in the increased numbers of long-established companies but also in the great numbers of newly established firms in science, research, drugs, plastics, aeronautics and astronautics, atomic energy, etc. "There are many industries which are partially on the metric system; the chemical industry,

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[1] "The Metric System," hearings before Subcommittee No. 1 of the Committee on Science and Astronautics, U.S. House of Representatives, 87th Cong., 1st sess., on H.R. 269 and H.R. 2049, June 28 and 29 and July 21, 1961, p. 29.

[2] "Conversion to Metric System," hearing before the Committee on Commerce, U.S. Senate, 88th Cong., 2d sess., on S. 1278, June 7, 1964, p. 19.

[3] Davis, Representative John W., op. cit., p. 4.

[4] McNish, A. G., Chief, Metrology Division, Institute for Basic Standards, National Bureau of Standards, Washington, D.C., "The International System of Units," ASQC Annual Technical Conference Transactions, 1965, p. 434.

[5] Drury, Aubrey, "World Metric Standardization: An Urgent Issue," 1922, pp. 26–27.

electric power, photography, optometry, electronics, and many others." [6]

Many shoppers have undoubtedly noticed the increasing numbers of packaged grocery items, of food products particularly, which are now showing on their covers the weights in both ounces and grams, the latter generally being in parentheses following the former. This is probably caused, in part, at least, by the needs of their export trade. India, for example, requires that all incoming imports be labeled in metric units.

Finally, the Olympic games, and, as a matter of fact, nearly all other amateur sports events of an international character are conducted by the metric system of measurement, which is used officially by most of the great international amateur sport federations. This of course, is logical enough since the great majority of the countries, of the world use the metric system exclusively. This means that most of the official world's records are tabulated in meters, although it is true that for comparison records are also listed in English units.[7]

2. Relation to Education

Except for the most emphatic opponents of general conversion to the metric system, the consensus appears to favor the earliest introduction of the teaching of this new system in our educational programs. In the preparatory and transition periods, both the English and the metric system would be taught, eventually phasing out the inch-pound instruction if and when it became obsolete. In response to an industry-oriented questionnaire in the 1961 Timken Roller Bearing Co. survey, most respondents favored commencing the teaching of the metric system in the sixth, seventh, or eighth grades of school. Citing one reply therein: "If there is the remotest chance that we are going to be faced with this situation (metric conversion), we will be well advised to teach it to our youngsters now, so that their generation will be prepared for it, and so that there will be an adequate number of people available to industry who are trained in it." [8]

Another observer goes so far as to state: " * * * Leading educators feel that the confusion of our system makes learning it an arithmetic ordeal for schoolchildren—whereas the metric system can be learned in an hour." [9]

Floyd W. Hough, chairman of the AGU study of the metric system in the United States, reports the view of the American Geophysical Union:

"In the educational field lies perhaps one of the greatest benefits which would accrue from our eventual abandonment of the English units in favor of the metric. Teachers of mathematics will agree that fully 25 percent of a child's time, and the teacher's as well, could be saved in arithmetic courses if the simple interrelated metric decimal units were substituted for the English. Such monstrosities as proper fractions, improper fractions, numerators, least common

[6] "Metric Units of Measure," 5th edition, Metric Association, Washington, D.C., 1964, p. 7.
[7] "The Metric System of Weights and Measures," The National Council of Teachers of Mathematics: 20th Year (compiled by the Committee on the Metric System, J. T. Johnson, chairman), Bureau of Publications, Teachers College, Columbia University, New York, 1948, p. 123.
[8] Baker, John B., chief engineer, International Division, Timken Roller Bearing Co., Canton, Ohio: "A Sampling of the Attitudes of American Industry Toward the Proposed Conversion of the Inch-System to the Metric System," September 1961 (contained in Senate hearing, 1964, op. cit., p. 59).
[9] Porter, Sylvia, Washington Evening Star, Dec. 26, 1963 (contained in Senate hearings, 1964, op. cit., p. 15).

denominators, greatest common divisors, and mixed numbers could be laid to rest with the celluloid collar and the oxcart. There can be no doubt among those familiar with both systems that the change from English units to metric would appreciably relieve the teaching load in our grade schools and high schools in all curriculums that involve both mathematics and the sciences." [10]

"American youngsters at an early age take quickly to our monetary system. They find that the decimal concept used in money enables them to readily grasp existing interrelations between the values of one denomination when measured against another. With understanding comes self-assurance, and the U.S. youngster is ready and anxious to engage in finance." [11]

"When this same American youth is introduced to our English system of measurements, he finds himself faced with an apparent arbitrary arrangement of unrelated units such as length in miles, area in acres, and volume in gallons. * * * Our shortage of scientific and engineering manpower, it would appear, can only be aggravated rather than alleviated by this problem of comprehension." [12]

"From an educational point of view, it appears that the metric system is preferable to the English system because (1) the memory burden of numbers is substantially less so that it is an easier system to learn and comprehend; (2) the decimal expressions are used instead of fractions making possible greater speed and accuracy in calculating; and (3) it embodies a simple and direct relationship between length, area, and volume making it a better mental tool for visualizing scientific and engineering problems." [13]

"* * * the earlier teaching of decimals * * * might well go a long way toward making our younger pupils less prejudiced against 'mathematics' and science." [14]

Dr. J. T. Johnson, chairman of the Mathematics Department of Chicago Teachers College and for 25 years president of the Metric Association, has said that 2 years of elementary arithmetic could be eliminated from the grade school program if the United States drops the inch-pound system in favor of the metric." [15]

The potential need for adequate, advance, and continuing education in the new system is not confined to our schools alone. Those out of school and working in industry, business, finance, government, the military, and many other activities require familiarization, instruction, retraining, and indoctrination according to their individual and collective needs. As other nations have found and as repeatedly reported in the literature, the public especially must be effectively educated not only in the numerical and technical aspects of the new system, but also in the usefulness and benefits of the change. The manner of accomplishing this through government, industry, universities, the press and other media, with releases, examples, conver-

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[10] Hugh, Floyd W., "Why Adopt the Metric System?" Civil Engineering, vol. 30, November 1960, contained in Senate hearings, 1964, op. cit., p. 33.

[11] Roth, Norman H., Department of the Navy (Thesis No. 137), "The Desirability and Practicability of Adoption of the Metric System," Mar. 13, 1964 (contained in Senate hearings, 1964, op. cit., pp. 32 and 33).

[12] Roth, op. cit., pp. 32 and 33.

[13] Hough, op. cit., p. 33.

[14] Kayan, Prof. Carl, Department of Mechanical Engineering, Columbia University, New York, in "Evolution Versus Revolution," 1961 SAE International Congress and Exposition of Automotive Engineering (contained in Senate hearings, 1964, op. cit. p. 64).

[15] Ladd, Dr. Arthur, and Katherine, in "Toward a Universal Language of Measurement," from the May 1963 issue of Washington (State) Education magazine (contained in Senate hearings, 1964, op. cit. p. 52, referring to Dr. Johnson).

sion tables, charts, feature articles, pamphlets, etc., is clear. If and when the new system is adopted, a concerted and coordinated campaign, nationwide and continuous, is necessary to make the change as palatable, painless, and beneficial as possible.

Technically, an important prerequisite is that both government and industry prepare well in advance of any actual transition the full range of specifications, regulations, and instructions in the new units. The wisdom of also including the replaced inch-pound units in parentheses as well will be dictated by the circumstances. The problem in many technical and similar specifications is that directly converted numbers cannot always be merely substituted for the older; many partial or complete recalculations will be required and must be resolved to preclude absurdities, incompatibilities, etc. It is in such areas that a comprehensive study and plan, benefiting from the detailed experiences of other nations already converted or currently converting, and modified to our own needs, can be of vital assistance.

3. Cost Considerations

The wide range of published cost estimates for conversion to the metric system nationwide in the United States—variously put from $4 to $5 billion up to $100 billion [16]—reflects the current lack of a factual, detailed study or other basis on which realistic costs can be computed. The very magnitude of the problem plus the many alternatives to be considered leave the door open for large variations which are influenced, in addition, by varying attitudes toward the basic theme.

"These differences arise in no small measure because different persons are basing their views and estimates on different assumptions as to the nature and scope of conversion and on the very limited information as to the changes that would be involved and the cost and manpower that these changes would entail. * * *

"The only reliable method of estimating the overall cost of nationwide conversion would be to determine the cost of individual operations as a function of the time of conversion, and to sum up these individual functions in order to obtain the minimum cost at an optimum time of conversion. The data for this operation would have to be obtained by setting teams of engineers and accountants to work in a number of firms and businesses taken as samples. For each firm and business an equation would be developed relating the cost of making the change to the time in months or years. These equations would then be summed by a computer to give the overall cost as a function of time. This information would then be available to serve as a basis for action at the national level." [17]

Many local estimates have been made. Characteristic are the following:

"Estimates vary from $100 million to $200 billion.

"Mr. Trowbridge (General Motors) names $26 billion (nationwide).

"Harold Sizer, director of design, Machine Tool Division, Browne & Sharpe Manufacturing Co., Providence, R.I., estimates his company's cost of changeover of dimensional drawings alone at $900,000.

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[16] Senate hearings, 1964, ibid., p. 13.

[17] McPherson, Archibald T., Associate Director for International Standards, Office of Technical Services, National Bureau of Standards, U.S. Department of Commerce, Washington, D.C., "Problems Involved in Determining the Cost and the Optimum Time of Conversion to the Metric System," Metric Association annual meeting, AAAS Conference, Philadelphia, Pa., Dec. 28, 1962, pp. 1–2.

"C. Edgar Hogan, manager, general engineering, Heald Machine Co., Worcester, Mass., estimates changeover costs for his company at $9.76 million.

"General Electric Co. estimates $200 million for its changeover, including $80 million for the modification or replacement of equipment, $44 million for redocumentation, $23 million for modification or replacement of testing and measuring equipment, $21 million for training personnel, and $19 million for the operation of dual production facilities." [18]

The foregoing is only a sketch of the ramifications involved in such a study for this highly industrialized nation in which such a change involves considerations of political, technical, and industrial aspects—decisions as to whether an item should be converted at all, partially modified, or obsoleted and replaced, depend greatly on who is making such decision, who is to pay the cost, and what effect it will have on others. The need to gather and analyze the facts, provide alternate estimates, and prepare plans based on different optimizations, out of which will grow a set of ground rules, is clear. International and military aspects are also an important ingredient in the policy, timing, and financial considerations. Further, the cost experiences of other converted or converting nations are, at best, only general aids not easily transferable when the conditions unique to the huge, complex, and dynamic American economy and way of life are necessarily included.

4. Summary of Advantages

The many reports, books, articles, addresses, hearings, etc., concerning the metric system contain a wealth of opinions and comment on the advantages and disadvantages of the metric system per se, comparisons of its virtues with those of such alternate systems as the decimalized inch, and especially the reasons for and against its adoption by the United States. Clearly some of these arguments can be debated on the basis of fact, the assumptions made, or their degree of relevance. Characteristic of the positions taken are the summary statements listed below, in favor of the metric system and its adoption, and those listed in the next section, as disadvantages.

(1) Since metric units are related by multiples or submultiples of 10, problems of designation and calculation would be simplified. "If American industry went to the metric system we could stop wasting time looking up decimal equivalents, trying to multiply fractions, et cetera. * * *" [19]

(2) Conversion is simple and easy between units of weight, length, area, volume, and energy.

(3) The metric system can be learned more easily since its terminology is simple and uniform. "It's easier to teach in school." [20] Significant time saving in school could result.

(4) "Savings—both tangible and intangible—would come from faster calculations by engineers and scientists, better understanding among businessmen and scientists everywhere, reduction of expensive

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[18] "Meter vs. Inch: Cold War Continues," Steel, Nov. 2, 1964, pp. 96–97.
[19] Schmid, Walter, manager of manufacturing engineering, Stewart-Warner Corp., Chicago, Ill., in "Should Industry in America Switch to the Metric System," Factory, April 1965, p. 93.
[20] "Meter vs. Inch: Cold War Continues," Steel, Nov. 2, 1964, pp. 94–99.

errors during conversions from one system to another." [21] "It removes the communications barrier between scientists and engineers." [22]

(5) "In addition to the advantages of precision, efficiency, and simplicity at home, the metric system would enhance our position in world trade markets, for nations on the metric system understandably prefer to shop in nations offering goods in metric measurements." [23] "Our use of the inch system is a definite deterrent to world marketing." [24] "These new nations are going metric, and Africa represents a huge market for American industry. * * * If we are not to miss out on foreign trade, we have to give these customers what they want, what they need. Our products must be things they can use and repair." [25]

(6) There is a widespread opinion, even among many opponents to the change now, that change to the metric system in the United States is inevitable and might as well begin sooner than later when the cost will be still higher. "The solution is foregone—we'll go metric. We'd better quit stalling and start planning." [26]

(7) The benefits of conversion to the metric system in the United States would greatly offset the costs of conversion, in the opinion of proponents, and in some cases could result in a net profit. "* * * perhaps the biggest savings by going metric would be 'the ability to purchase parts and equipment at lower cost because they would be made for both the U.S. and foreign markets. The greater the number of units per setup, the lower the cost per machine.'" [27] "It removes double stockage of parts by industries now selling parts and equipment here and abroad." [28]

(8) The detrimental aspects of conversion are believed by proponents to be greatly exaggerated, especially for a changeover that would be spread over years, possibly decades.[29]

(9) The new factor, namely, the decision in the United Kingdom to convert to the metric system sector by sector, now leaves the United States practically alone, of the nations of the world, unconverted. "If everybody else communicates and trades in the simple metric system, and we cling to our antique pounds, inches, etc., we've had it eventually—and our children, too." [30]

(10) Certain sectors, such as science, have long been on the metric system; others, notably the pharmaceutical industry and geodesy, have already converted.

5. Summary of Disadvantages

The principal objections to the metric system are centered on the cost of the conversion process and the inconvenience of breaking old habit patterns. Another class of argument indicates that conversion is occurring now, industry by industry, as dictated by circumstances.

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[21] Porter, Sylvia, op. cit., p. 16.
[22] "Meter vs. Inch: Cold War Continues," Steel, op. cit., p. 97.
[23] Porter, Sylvia, op. cit., p. 16.
[24] Staples, Elton E., vice president, Metallurgical Group, Basic Products Corp., Steel, op. cit., p. 96.
[25] Schmid, Walter, op. cit., p. 93.
[26] Muschamp, George M., vice president, engineering, Industrial Products Group, Honeywell, Inc., Steel, op. cit., p. 96.
[27] Staples, Elton E., op. cit., p. 96.
[28] "Meter vs. Inch: Cold War Continues," op. cit., p. 97.
[29] Porter, Sylvia, op. cit., p. 15.
[30] Editorial, "The Metric System Is Coming to the U.S.A.: What It Will Do to Us, and How," Air Conditioning, Heating & Refrigeration News, June 22, 1964.

The following items are characteristic.

(1) There is a natural reluctance to abandon something (the English foot-pound system) which has become deeply rooted through hundreds of years of usage. "The worst part of going metric will be just getting used to the sound and sight of unfamiliar units." [31]

(2) Additional work, time, and cost would be necessary to re-educate people, to learn, and to apply a new system which would affect practically every aspect of daily life.

(3) Misunderstandings and confusion would attend the transition period while two different systems—the English and the metric—would be in use.

(4) It would be necessary for industry, governments, households, etc., to maintain double inventories of products, parts, specifications, etc., in both systems, possibly for decades. "Conversion doesn't mean erasing the dimensions in inches on your engineering drawings and replacing them with metric equivalents. * * * When (metric proponents) talk of conversion to metric, they mean the development of one interchangeable stock of parts throughout the whole world. This means that all of our size modules must be replaced by the size modules of a system which at the present time * * * is foreign to us." [32]

(5) The enforced obsolescence of many machines, parts, equipments, appliances, etc., because of the growing lack of replacement or repair parts, and a steady increase of nonfits, nonuniformity, and oddness of such parts.

(6) It would be necessary to convert and adapt many books, charts, tables, specifications, standards, signs, markings, etc., to conform to the new metric system.

(7) Common industrial standards in inch sizes have been established by all English-speaking countries. For example, the American Unified Thread is used for almost all engineering purposes except in heavy industry. In this connection: "Two standards for screw thread dimensions are now recognized internationally—one based on the inch and the other based on the metric system. The final step toward agreement among the metric countries was only taken last November at the meeting of the International Organization for Standardization at New Delhi. This move brings these nations almost up to the stage that those using the inch system reached in the early fifties, when the United States, Britain, and the Commonwealth adopted 'unified' dimensions, not only for screw threads, but also for bolts, nuts, and other simple fasteners to make their products more interchangeable." [33] In anticipation of this meeting: "The ISO meeting in New Delhi, India, later this year, could adopt fastener standards that would hamper U.S. industry's ability to sell its products abroad." [34]

(8) The percentage of engineering and manufacturing being conducted in the inch system may be a better measure than the percentage of the nations or the people of the world who use the inch or metric system.

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[31] Versagi, Frank J., "The Metric System: Let Us Begin," Air Conditioning, Heating & Refrigeration News, June 22, 1964.

[32] Belford, R., Steel, op. cit.

[33] "Standardization in Engineering: Discordant Harmony," Economist, Dec. 26, 1964, p. 1452.

[34] Masterson, Frank, president, Industrial Fastener Institute, in "Fastener Makers Debate Inch vs. Metric Systems," Steel, July 27, 1964, pp. 44–45.

(9) Adoption of the metric system might give foreign metric countries undue competitive advantage in exporting to the United States.

(10) Surveys made by the American Standards Association in 1945 and 1947 of industry generally, by the Automobile Manufacturers Association in 1948 of the automotive chief engineers, and by General Motors Corp. of its 37 divisions returned replies overwhelmingly stating that those polled were not experiencing appreciable difficulty in living with the two systems, and that use of the decimalized English units of measure sufficed their practical needs well.[35]

(11) Since the U.S. export trade amounts to only 5 percent of technical goods produced, some opponents object to a disruption of the other 95 percent.[36]

(12) Some proponents of the decimalized inch system go so far as to suggest that if a strong stand is taken on such a decision, and worldwide standards in that system are pressed, particularly with the dominant position of the United States in output, the metric system may eventually wither.[37] On the other hand, some see both the English and metric systems persisting, expecially for screw thread standards, with sizes in each system being used. These persons do not think that either system will ever be wholly abandoned.[38]

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[35] Trowbridge, Roy P., director, General Motors engineering standards section, General Motors Corp. "An Automotive Viewpoint on Measurement Systems," an address before the AAAS, Washington, D.C. Dec. 30, 1958, p. 3.

[36] Kiproff, Peter, Temple University, Philadelphia, "Standardization—Inch vs. Meters," p.

[37] Kiproff, op. cit., p. 6.

[38] "Everybody Happy After ISO Meeting," Steel, Mar. 8, 1965, p. 28.

ANNEX A

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ANNEX B

THE ANALOGY OF CALENDAR REVISIONS

Similar to the long and tortuous efforts to devise a simple and world-wide accepted system of weights and measures is the history of the evolution of our present-day calendar.

"Word about the calendar used by the Egyptians and the Babylonians was carried from one country to another by travelers and businessmen and soldiers. In this way, information about (such) calendars was carried to Europe * * *," and of special interest, to early Greece and Rome, but not until the latter's calendar had gone through a continuous series of drastic adjustments (below).

As early as the rule of Ptolemy III (247–221 B.C.), Egypt recognized the need for an additional day every 4 years to rectify its then common calendar of 365 days every year. This was found necessary in order to keep the calendar better mated to the seasons, and so it was decreed in 238 B.C. in an edict preserved on the famous Canopus Stone (discovered in 1886). "Notwithstanding Ptolemy's staunch support, the plan was defeated. Old custom was too firmly entrenched. The influential priest-astronomers opposed it as an encroachment on their prerogatives and the public through apathy and indifference let them have their way. Thus progress was thwarted and an illogical and unscientific pattern was perpetuated." [1] After Ptolemy's death, the leap-year innovation was gradually ignored in favor of the earlier and more familiar uniform years, and was not revived until 200 years later.

Rome, in the meantime, had been carrying on its own experiments and alterations to its calendar. The original 10-lunar-month year of approximately 300 days (the 60 days of deep winter were simply ignored) accepted by Romulus when he founded Rome in 753 B.C. soon turned out to be hopeless. His successor, Numa Pompilius, added January and February to the calendar and brought it up to 355 days, but it was still out of step with the seasons. To overcome this, he inserted an additional 13th month of 22 or 23 days every 2 years, calling it Mercedonius and placing it after the 23d of February.

"Realizing that the awkward 13th month needed some authoritative supervision, Numa assigned it to the Pontifex Maximus, head of the newly created College of Pontiffs. He failed to realize this would lead to all kinds of abuse—that the occasional 13th month would become a 'political plum' which clever and unscrupulous officials could manipulate for their own purposes. By lengthening or shortening the intervals between the intercalations, friends could be kept in power, enemies removed, dates advanced or postponed, and all kinds of schemes promoted. The original intent to keep the cal-

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[1] Achelis, Elisabeth, "Of Time and the Calendar," Hermitage House, 1955, p. 43.

endar in line with the seasons was lost, so that in the first century B.C. the spring equinox had strayed from its place by about 3 months."[2]

In this interval, "* * * to increase the troubles, the calendar was not only jealously guarded by the priests, aided and abetted by the magistrates, but was kept out of reach of the public as well. * * * The calendar emancipator, Flavius, resented the custom of paying tithes in order to learn on what calendar date such and such a legal act was permitted. Through ways and means unknown to us, he succeeded in obtaining a copy of this precious calendar with its prohibited days and dates, and publicly listed them on tablets hung around the Forum. This unprecedented but highly courageous act, about 304 B.C., aroused immediate public attention and approval. * * * Flavius received rich rewards from the people. * * * The Flavian act paved the way for the later Julian reform."[3]

In passing, it is noteworthy that our current calendar still shows vestiges of that earlier Roman 10-month calendar, above, in that September, October, November, and December were so named as the 7th, 8th, 9th, and 10th months therein.[4]

It was not until 200 years after Ptolemy III, above, that the leap year was again revived. Then, Julius Caesar, who had lived in Egypt for some time after its conquest by Rome, listened to the mathematician, Sosigenes, that the true year was really 365¼ days long, so that every fourth year one day had to be added to the calendar to make it "perfect." This arrangement was again decreed, effective in 44 B.C., and the "Julian calendar" was born. He also reaffirmed changing the starting month of the year from Martius (March) to Januarius (January).[5]

In A.D. 325, 369 years after the adoption of the Julian calendar, the Council of Nicaea recognized that a small error still remained since the seasons were starting progressively earlier. The vernal equinox which had occurred on March 25 in the original period, was now already occurring 4 days earlier, on March 21, by the Julian calendar, but no corrective steps were taken at that time. In the succeeding centuries, the error progressively increased.

In the Calendar Room in the Vatican, the relation of the sun's apparent movements and the calendar had long been under study when, in 1581, a demonstration by Italian scientists convinced Pope Gregory XIII that the calendar was by then running 10 days too fast according to the sun. Sosigenes' earlier error of figuring each year a little more than 11 minutes longer than actual was gradually causing progressively earlier appearance of the starts of the seasons.

By Papal decree in 1581, it was directed that the day following October 4, 1582, would become October 15, 1582, thus dropping 10 days from the calendar so that the critical day of the beginning of spring was also restored to March 21 where it had stood at the Council of Nicaea 1,257 years before. Since the year had since been figured at 365 days 5 hours 49 minutes and 12 seconds[6] (so that 1 mean tropical year in the Gregorian system equaled 365.2425 days), another small adjustment had to be made. The resulting Gregorian rule stated: "Hereafter a year whose number in the Christian Era is

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[2] Achelis, Elisabeth, op. cit., p. 46.
[3] Achelis, Elisabeth, "The Calendar for Everybody," G. P. Putnam's Sons, New York, 1943, p. 23.
[4] Black, P. A., T.D., F.R.S.E., "The Calendar and Its Reform," Gall & Inglis, London, 1932, p. 1.
[5] Brindze, Ruth, "The Story of Our Calendar," Vanguard Press, 1949, pp. 35 and 38.
[6] This has since been corrected to 365.2422 days for the tropical or ordinary year, equaling 365 days 5 hours 48 minutes and 46 seconds.

exactly divisible by four shall be a leap year (366 days); but a century year shall be a common year (365 days), unless it is an exact multiple of 400." [7] A still finer adjustment was also required later for the longer ranges, and this was taken care of by making the years 4,000, 8,000, 12,000, etc., common years also.[8] The Gregorian reform also changed the start of the year from March 25, which the Church had adopted in the ninth century A.D., to January 1 again.

It took a long time in some areas to win the adoption of the Gregorian calendar. The English Government, for example, did not adopt it until 170 years later, in 1752. By that time, the accruing error had increased to 11 days by the old Julian calendar. Accordingly, in 1752, it was decreed that the day following September 2 would become September 14, dropping the intervening 11 days forever. In addition, Britain changed the starting day of the year from March 25 to January 1, and her then American colonies followed suit in both changes. George Washington's birthday, February 11 by the old calendar, became February 22 by the Gregorian.[9]

"Of course some people got mixed up, and others were angry about the change. People complained just as they had in ancient Babylonia when extra months had been added. Families who rented houses by the month or men who had borrowed money on which they paid interest, grumbled that they had been cheated. They would have to pay the full rate for a month that had been cut short by 11 days." [10]

"That month of September 1752—when the calendar was converted from the Julian to the Gregorian—was the shortest in English or any other history; shorter even than the ancient Aztec month of 20 days, for it contained only 19.

"True, the Act had provided that 'nothing is intended to extend, to accelerate or anticipate the time of payment of any rent, annuity or sum of money * * *,' and had gone into great detail about putting forward dates of 'markets, fairs and marts, and courts thereon depending * * *,' and the 'opening, inclosing or shutting up any lands or common pastures according to diverse customs, privileges and usages * * *,' but there were those who believed that not only were they losing 11 days' wages but that their lives were being shortened. Partly this problem was solved by the printing, in all newspapers of the period, of tables showing the deduction which could be made from monthly and annual wages or payments to adjust them to shorter terms; but that did not satisfy those who objected on religious grounds as is shown by the following note published in Felix Farley's Journal, the contemporary British newspaper, on January 6, 1753:

" 'Yesterday, being Old Christmas Day, the same was obstinately observed by our country people in general, so that yesterday (which was Market Day by order of our Magistrates) there were but few at

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[7] Archer, Peter, S.J., Canisius College, Buffalo, N.Y., "The Christian Calendar and the Gregorian Reform," Fordham University Press, 1941.
[8] Ibid., p. 59.
[9] Brindze, Ruth, op. cit., pp. 48 and 49.
[10] Ibid., p. 48.

Market, who embraced the opportunity of raising their butter to 9d. or 10d. a pound.' Which was about double the usual price. In some market towns, says one authority, the farmers were wholly absent; and to gratify the feelings of their parishoners many rural clergy preached 'Nativity sermons' on the following Sunday." [11]

[11] Davis, Representative John W. (Georgia), House of Representatives, U.S. Congress, in "Congress and the Metric System," an address before the annual meeting of the Metric Association, Philadelphia, Pa., Dec. 28, 1962, pp. 6 and 7.

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