The metric system of weights and measures / by J. Pickering Putnam.

THE METRIC SYSTEM

PUTNAM

THE

METRIC SYSTEM

OF

WEIGHTS AND MEASURES.

BY

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Second Edition, Revised and Enlarged.

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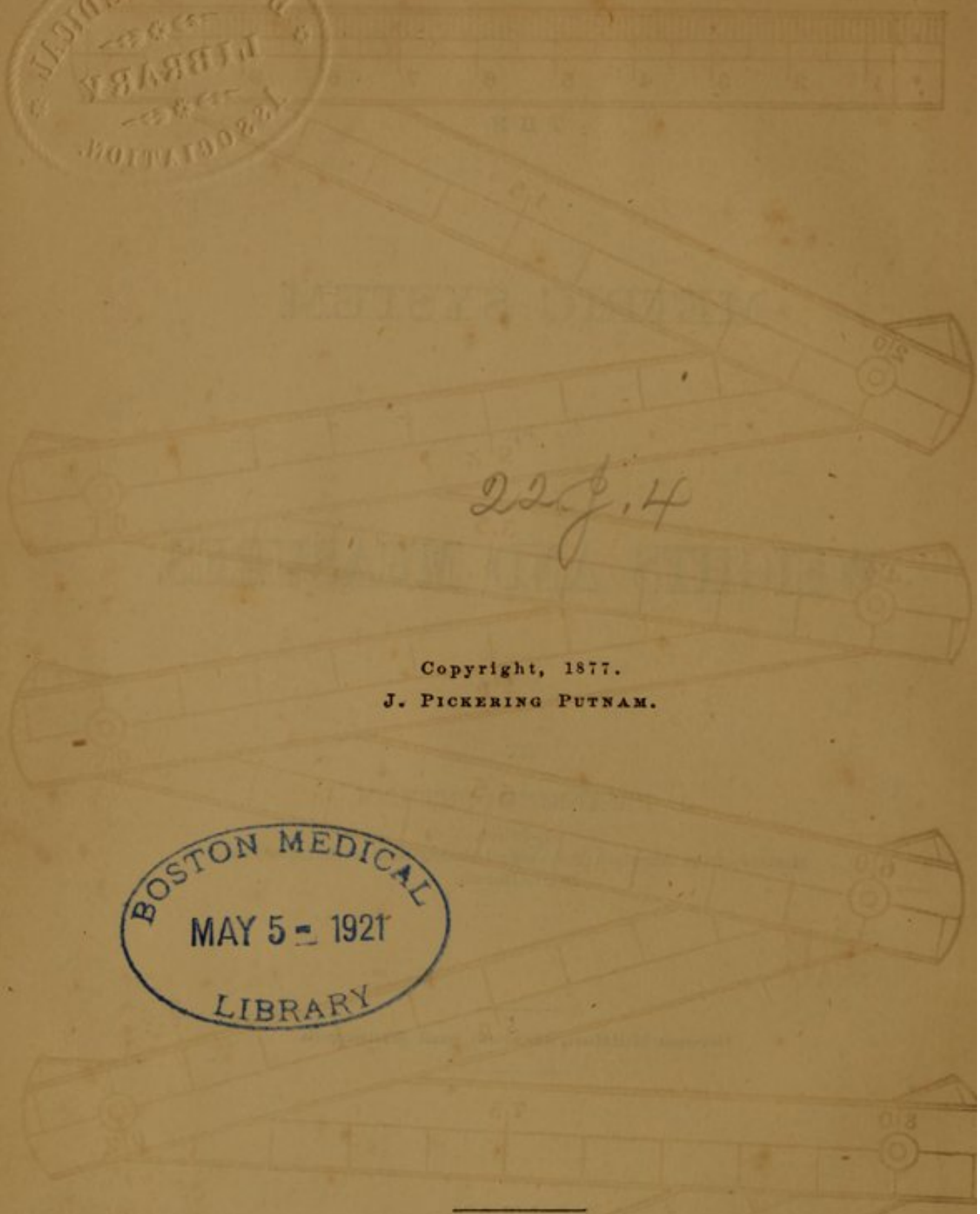

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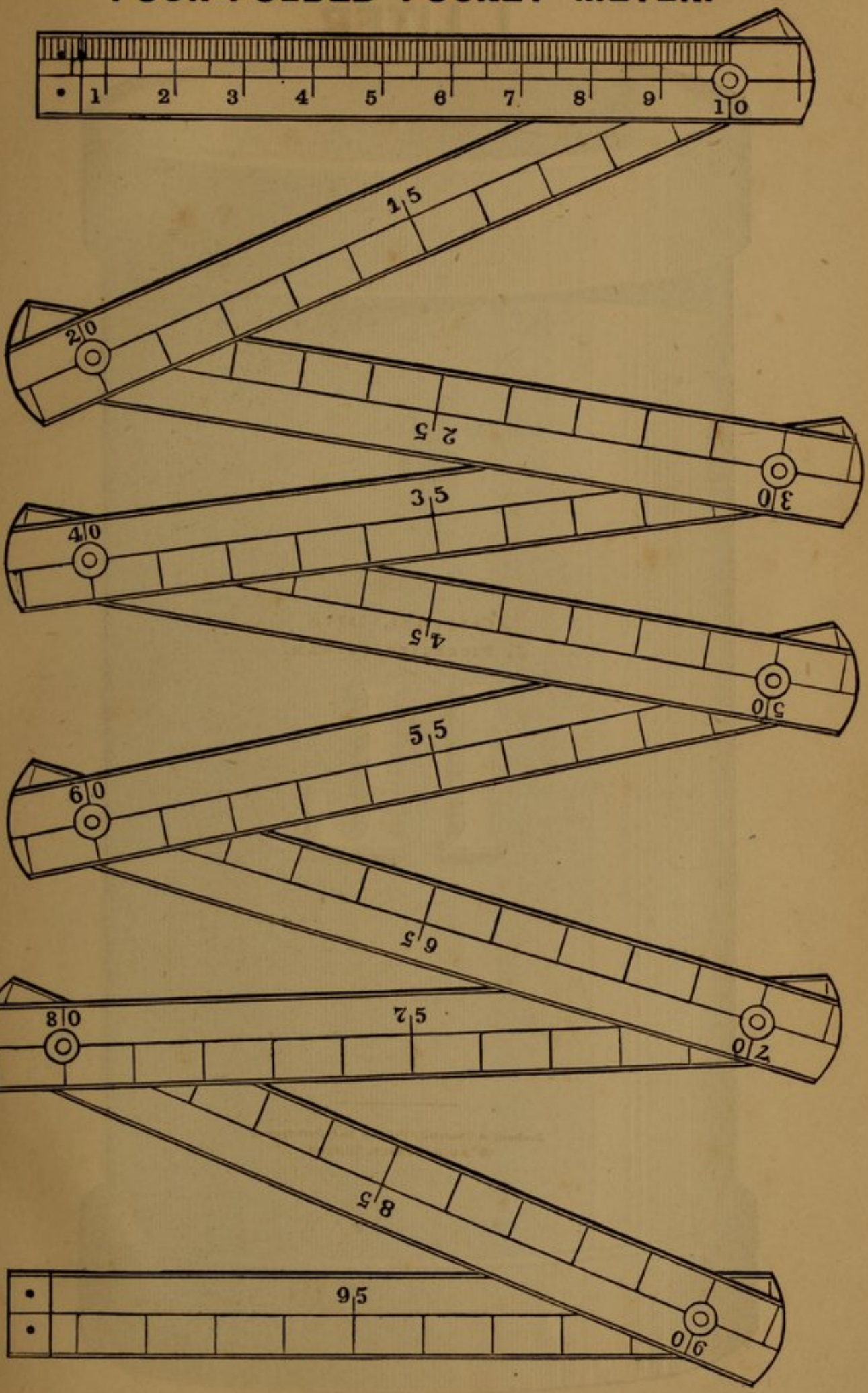

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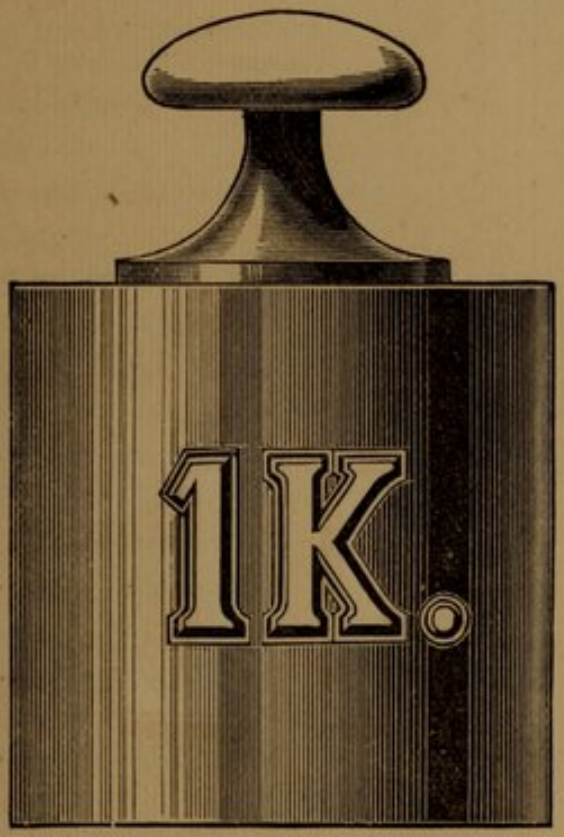

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THE METRIC* OR DECIMAL SYSTEM OF WEIGHTS AND MEASURES.

PREFACE.

"THE great utility of a standard, *fixed in its nature*, and founded on the easy rule of decimal proportions, is sufficiently obvious. It led the government, at an early stage, to preparatory steps for introducing it; and a completion of the work will be a just title to the public gratitude."—*Madison, Annual Message of* 1816.

Washington felt the great importance of a "standard at once invariable and universal," and earnestly recommended it to the attention of the first Congress of the United States.

Jefferson desired to reduce "every branch to the same decimal ratio already established in coins, and thus bring the calculation of the principal affairs of life within the arithmetic of every man who can multiply and divide plain numbers."

John Quincy Adams says of the Metric System: "Considered merely as a labor-saving machine, it is a new power offered to man incomparably greater than that which he has acquired by the new agency which he has given to steam. It is in design the greatest *invention* of human ingenuity since that of printing."

It is not proposed here to *defend* the Metric System. It needs no defence. Since these great statesmen lived, and many others might be quoted, it has been adopted by the majority of nations, and seems destined very soon to become universal. If, however, like everything else that is useful, it has its enemies, these will be found to be principally composed of men who professedly do not know what it is. We hear it said, "I do not like these innovations;

* Metric and meter (the linear unit of measure = about 3.28 feet, or 3 ft. 3⅜ in.) are derived from the Greek word "*metron*," which signifies "*measure*."

I prefer old institutions;" or, "I cannot advocate what I do not understand;" or, "I have no doubt it is a very good thing, and certainly a very important thing, but, at my time of life, and using the weights and measures as little as I do, it will be of no advantage to me to attempt to reform the world;" or, again, "We get along well enough with our present system; why trouble ourselves to change?" So, before the invention of printing, men thought they got along well enough with pens. They did not trouble themselves about electricity as a means of communication until the electric telegraph was invented. Indifference is the greatest enemy to progress, for every man knows that it is his duty to promote the general welfare as far as lies in his power. And, in regard to the personal advantages to individuals to be derived from the use of the new system, we hope to show that there is no man, whatever be his age or position, who will not be more or less benefited by the change. There is, however, another class of opponents, much smaller than the first, though no less formidable. It is composed of those who admit the advantages of the new system to be immense, and who believe that it must sooner or later supplant the old, but who dread the practical difficulties of the transition, and, fearing individual inconveniences, oppose the reform through short-sighted selfishness. For these, therefore, as well as for those who have not as yet given the subject the attention it has so eminently the right to claim, the following pages are written.

The reform, which the United States has already begun, has just been successfully accomplished (in 1872) by Germany. Let us profit by her experience. By observing what difficulties she had to encounter, and how they were met by the public, we may judge of what we must ourselves expect. If the immediate introduction of the new system was attended with results disastrous to commerce and manufacture, we may look for similar troubles at home, and be on our guard against them. But if, on the contrary, the transition was effected easily and rapidly, and without interruption to business, or great personal inconvenience on the part of the public, we may take courage, and, by acting vigorously and simultaneously, render success in our case also certain.

For our information on this subject, we must look to those who have made careful observation, on the spot, of the manner in which the new system was received in Germany at the time of its general introduction to the exclusion of all others, especially by the mechanics, manufacturers and builders, and all who make immediate practical use of the weights and measures.

In view of what has already been so ably written on the Metric System of Weights and Measures for use in the United States, especially by Dr. F. A. P. Barnard, LL.D., of Columbia College, President of the American Metrological Society, whose very interesting work, published in 1872, may be considered the most complete and exhaustive treatise ever written on the subject, we should not have ventured to add anything had we not felt that professional interest in a subject so intimately connected with the practice of architecture, and our experience in Germany, at the time of its introduction there, when the observations above referred to, in regard to its reception by the people, were made on the spot, might perhaps be turned to some account in throwing light upon the subject at home.

All we pretend, therefore, is to present, in a form compact enough to be within the reach of everybody, some of those facts, a knowledge of which cannot fail to make every thinking man an admirer of the system and an advocate for the important reform; a knowledge which has already led a majority of the civilized inhabitants of the globe to join hands by adopting it in common.

For those who desire to become more thoroughly familiar with the subject of the Metric System in all its bearings, and who are interested in the equally important subject of a universal coinage, we refer to the above-mentioned book of Dr. Barnard, whom we have frequently quoted in the following pages, and whose earnest and untiring labors with those of his eminent co-operators in the American Metrological Society, in behalf of the reform, seem destined soon to be rewarded by the sight of the American people in full enjoyment of the new system, and learning to appreciate, in a measure, the extent and value of their endeavors.

Many thanks are also returned to Mr. J. E. Hilgard, of the United States Coast Survey, for information in regard to the latest operations of the International Metric Commission, to which he is delegate from the United States, and for assistance in the preparation of the Illustrated Chart. Also to Professors Benjamin Pierce, E. C. Pickering, J. P. Cooke, Jr., and E. P. Seaver.

J. PICKERING PUTNAM.

4 PEMBERTON SQ., APRIL 9, 1874.

INTRODUCTION TO THE SECOND EDITION.

Since the publication of the first edition of this book important progress has been made in advancing the practical introduction of the Metric System in the United States.

For this progress we are indebted partly to the zeal of individuals working independently, partly to business enterprise, many firms having found the use of the system profitable, either on account of its own merits, or on account of the excellent opportunity for advertisement which its rapidly increasing popularity afforded; and partly to the practical interest taken in the movement by scientific and professional bodies, especially engineering, medical, and pharmaceutical associations, and above all by the *American Metric Bureau*.

Organized and concerted action was necessary. It was seen that the work to be done was sufficient to employ the entire energy of a society devoted solely to metric work. Such a society was therefore organized by active friends of the system, and their concentrated efforts have during the short period of their corporate existence accomplished tenfold what the members could have done acting independently.

This Bureau, incorporated in the summer of 1876, under the laws of Massachusetts, already includes among its members many of the most prominent educators and influential citizens of the United States.

A short account of the Bureau and its method will be found in the Appendix.

Under the heading of "Metric Nomenclature," on pages 59–61. we have substituted for the few paragraphs on this subject in the first edition, a digest of the report of the Bureau on the spelling, pronunciation and abbreviation of the Metric Nomenclature.

Several woodcuts have been added to the text and a new chart, designed with great care and printed in colors, has been substituted for the old lithograph.

The Appendix is intended to give the latest information and other matter of interest connected with the introduction of the Metric System. The whole work has been carefully revised, corrected, and enlarged. This has been done with the aid of members of the Metric Bureau and of the Metrological Society, whose services are hereby gratefully acknowledged.

4 PEMBERTON SQ., March, 1877.

METRIC TABLES.

The following simple tables give all that there is in the Metric or Decimal System of Weights and Measures:—

MONEY.

10 mills	make a cent.
10 cents	make a dime.
10 dimes	make a dollar.
10 dollars	make an eagle.

LENGTH.

10 milli-meters	make a centimeter.
10 centi-meters	make a decimeter.
10 deci-meters	make a meter.
10 meters	make a dekameter.
10 deka-meters	make a hektometer.
10 hekto-meters	make a kilometer.
10 kilo-meters	make a myriameter.

WEIGHTS.

10 milli-grams	make a centigram.
10 centi-grams	make a decigram.
10 deci-grams	make a gram.
10 grams	make a dekagram.
10 deka-grams	make a hektogram.
10 hekto-grams	make a kilogram.
10 kilo-grams	make a myriagram.

CAPACITY.

10 milli-liters	make a centiliter.
10 centi-liters	make a deciliter.
10 deci-liters	make a liter.
10 liters	make a dekaliter.
10 deka-liters	make a hektoliter.

THE SQUARE AND CUBIC MEASURES

are nothing more than the squares and cubes of the measures of length. (Thus a square and a cubic milli-meter are the square and the cube of which one side is a milli-meter in length.) The *ar* and *ster* are other names for the square dekameter and the cubic meter.

"In this brief space you behold the whole Metric System of Weights and Measures. What a contrast to the anterior confusion! A boy at school can master the Metric System in an afternoon. Months, if not years, are required to store away the perplexities, incongruities and inconsistences of the existing weights and measures, and then memory must often fail in reproducing them. The mystery of compound arithmetic is essential in the calculations which they require. All this is done away by the decimal progression, so that the first four rules of arithmetic are ample for the pupil."

CHARLES SUMNER

THE METRIC SYSTEM
OF
WEIGHTS AND MEASURES.

ITS FINAL ESTABLISHMENT IN GERMANY TO THE EXCLUSION OF ALL OTHER SYSTEMS.

The Metric System has now received the sanction of law among more than half the inhabitants of the civilized and Christian world. In 1864 it was legalized in Great Britain; in Germany, in 1868. After four years of preparation, on the 1st of January, 1872, it was made compulsory in the latter country, and no other system was any longer legal. In 1866 it was legalized in the United States. We have now had eleven years for preparation, more than twice as long as was considered sufficient for the German nation.

The difficulty of making this unavoidable change must necessarily continue to increase the longer it is deferred; and, whenever a destiny becomes manifestly inevitable, it is the part of wisdom to advance to meet it, rather than to await the lingering process by which it must otherwise accomplish itself.

No more fruitful source of fraud and embarrassment in business transactions, and of waste in time and money, in all the various works of civilization, can be found than the endless diversity and complexity of standards of measurement in use throughout the world.

The only remedy for this evil is the universal adoption of some common system of weights and measures.

Such a common system is offered us in the metric, a system, according to which the weight and dimensions

of every material thing, whether solid, liquid or gaseous, whether on land or on water, whether in the earth or in the heavens, and whether determined by the scale, plummet, balance, barometer or thermometer, are ascertained by a method absolutely uniform, entirely simple, and equally suitable to the use of all mankind, resting upon a single invariable standard of linear measure, with multiples and sub-multiples, like those of our monetary system, exclusively decimal, with appropriate names, similar in all languages; and itself secure against the possibility of change or loss through carelessness, or accident or design, by being constructed on scientific principles and copied for distribution among the different nations of the world.

When, in 1872, the German Empire joined ranks with the ever-increasing majority of nations using the Metric System, several excellent pamphlets were there published for the purpose of enlightening the general public as to its advantages, and giving some ingenious devices for familiarizing them rapidly with the metric values.

Now that a vigorous movement is being made simultaneously throughout the United States for promoting its practical introduction here, the need is more than ever felt for some such popular treatise to facilitate the work and to help remove an opposition to it like that which the first introduction of any valuable institution or discovery is sure to encounter whenever any change for the better is required in the existing order of things.

The new system is, however, rapidly gaining ground, and each year finds new adherents to the cause, as one after another the most enlightened nations awake to the full appreciation of its immense advantages.

"The rising generation will embrace it, and ever afterwards number it among the choicest possessions of an advanced civilization." — *Charles Sumner.*

Before the reform, the system used by Germany was similar to ours, so that from her experience we may fairly judge of what we must expect. It is true the Germans are a well-educated and thinking people, and, as might be expected, learned to appreciate at once the advantages of a system based on purely scientific principles; but the Americans are also an intelligent people, and we feel convinced that, when the subject shall have been fairly brought up before their minds, they will be no less active than the Germans in possessing themselves of a machine so saving of time, trouble and money. Congress has already (in 1866) legalized the use of the Metric System, and is now distributing the standard metric weights and measures among the several States, but this body is not likely to go further in the matter by rendering its use obligatory until called upon to do so by the people themselves. Situated as we are, so distant from the majority of those countries which use the Metric System, the public at large does not feel directly the loss it actually sustains, especially in commerce, on account of this difference of systems. It falls, in the first instance, upon the Custom House and the wholesale dealers in foreign goods and upon our exports, but is ultimately divided, of course, among the public, or actual consumers of these goods, without their knowing anything about it.

This partly accounts for our being so much behind the rest of the world in our delay to complete the process of metric reform we began in 1866.*

* "In addition to the law authorizing the use of the Metric System, the Secretary of the Treasury has been directed to furnish to the Governor of each State one set of the standard weights and measures of the Metric System for the use of the States respectively, and, further, the Postmaster General has been directed to furnish to the post-offices exchanging mails with foreign countries, and to such other offices as he shall think expedient, postal balances denominated in grams, of the Metric System; and, un-

Of the imports and exports of the United States for 1860, which amounted in all to 762,000,000 dollars, the amount of nearly 700,000,000 dollars was with nations and their dependencies which had authorized, or taken the preliminary steps to authorize, the Metric System. This was before Germany had adopted it.

The new system was at first received by the public in Germany, as was to be expected, in very different ways. Some were indifferent; others considered it as an altogether unnecessary innovation, from which only a thousand inconveniences and disadvantages to trade and manufacture would result; others, however, and by far the greatest number, composed of the most intelligent and enlightened of the people, looked upon the reform as a necessary result of the general advance of civilization, from which the greatest blessings were to be derived in the end, and applied themselves with corresponding zeal to secure this good, in order to realize from it as early as possible the numerous advantages they anticipated.

In a very short time, however, as the beauty and simplicity of the new system began to be generally understood, those belonging to the first two classes rapidly diminished in numbers, until finally few grumblers were to be found left. The sturdiest antagonist to innovation, prompted at first by what seemed to be a kind of patriotic feeling of allegiance to what is established, handed down from their fathers, and inculcated by education, began to

til otherwise provided by law, one half ounce Avoirdupois is to be deemed and taken for postal purposes as the equivalent of fifteen grams of the metric weights; and so adopted in progression, and the rates of postage are to be applied accordingly." Thus the first step was taken toward the final establishment of the Metric System in the United States. The President was also authorized to appoint a special commissioner to facilitate the adoption of one uniform coinage between the United States and foreign countries. See Appendix, page 8.

yield finally to the general advance of the times, and to see that to reject the new system solely on the ground of its novelty, was to attempt to arrest the progress of civilization itself, and to maintain that no man should add anything to his present stock of knowledge that involved the abandonment of old ideas and exploded theories.

The immediate practical difficulties to making the change were represented as far more formidable than they actually proved to be in execution, where a simultaneous effort was made throughout the country. Thus it was objected that the lumbermen, the hardware, brick, and other manufacturers, who worked to feet and inches, would greatly suffer. Experience shows us, however, that this fear was greatly exaggerated. Every man had only his small share of the reform to sustain, and each was aided by his neighbor, so that everything went with astonishing smoothness and ease, and the manufacturers soon began to appreciate the advantages of a system which so greatly facilitated all their calculations, and advanced the interests of commerce, both foreign and domestic. In some cases the gauges were slightly altered to suit the new measures, and in others the old forms were retained, where the new metric values could be applied to them without the inconvenience of retaining too small fractions. In many cases it was found that instead of the expected inconvenience, a great convenience was experienced from the change at the very outset. In the case of the brick manufacture, for example, great annoyance was expected here, because the three dimensions were intended to measure even inches. The result, however, proved to be exactly the reverse; to architects and builders, the importance of which can scarcely be overestimated. It was this. Previous to the reform in the different German States, the dimensions of bricks varied as much as the different systems of measures

themselves. The result was an inconvenience, the extent of which only the practical architect and builder can realize. Immediately upon the introduction of the Metric System, every brick-yard in Germany was obliged to shape its bricks after a uniform pattern, to the immense relief of the consumers. 6.5 cm. (centimeters) × 12 cm. × 25 cm. is now the measure of bricks in Germany. The same difficulty overcome by the Germans still holds us in bondage. No two brick-yards turn out the same sized bricks, and accuracy in the estimate of cost and artistic effect is only possible at the expense of infinite labor. Good fortune permitting, we shall be relieved of this inconvenience, and adopt, it is to be hoped, for the sake of uniformity, the same figures for our bricks just adopted by the Germans.

What difficulty will be encountered at first in our home manufactures will be offset by convenience in our imports and exports, where we deal with countries using the Metric System.

EARLY HISTORY, CAUSES WHICH LED TO THE FINAL ADOPTION OF THE METRIC SYSTEM.

In the earliest stages of civilization and among savages commerce is conducted in the form of barter, or, if some conventional standard of weights and measures is adopted, it has no scientific method, but is the result of accident or caprice. Such is the system now used in the United States. The accurate calculation of relative values being thus rendered exceedingly laborious, when not actually impossible, commerce is immensely injured, though often without the knowledge of the majority of those concerned, and an incredible amount of time and money is lost. But where

these clumsy tables differ from each other in every State, or where even for the same place several different tables are used for the same purpose, as with our Avoirdupois, Troy and Apothecary's tables, for weighing solid bodies, the confusion and difficulty become so great, that in most cases the attempt at accurate calculation is given up in practice altogether.

Apothecaries compound their medicines by one table, and sell them by another; bread is sold by a third table, or Troy weight; butter by Avoirdupois. Our gallon could confuse the clearest head. There are thirty-two gallons in a barrel of cider, thirty-one and one-half or thirty-six in a barrel of ale or milk, thirty in a barrel of fish, forty-two in a tierce of wine, oil, etc., sixty-three in a hogshead of wine, fifty-four in a hogshead of beer, eighty-four in a puncheon of wine, two in a peck of grain, etc.

The dry gallon contains the convenient number of *two hundred and sixty-eight and four-fifths* cubic inches; the wine gallon *two hundred and thirty-one* inches; and the beer gallon *two hundred and eighty-two* cubic inches.

"The ounce, the drachm and the grain are specific names," says John Quincy Adams, "indefinitely applied as indefinite parts of an indefinite whole. The English pound Avoirdupois is heavier than the pound Troy, but the ounce avoirdupois is lighter than the ounce Troy. The weights and measures of all the old systems present the perpetual paradox of a whole not equal to all its parts. Even numbers lose the definite character which is essential to their nature. A dozen become sixteen, twenty-eight signify twenty-five, one hundred and twelve mean a hundred. The indiscriminate application of the same generic term to different specific things, and the misapplication of one specific term to another specific thing, universally

pervade all the old systems, and are the inexhaustible fountains of diversity, confusion and fraud."

It might have been expected that when America threw off the yoke of British pounds, shillings and pence, she would overturn all the rest of the ridiculous tables as she did those of the money-changers; but instead of so doing she retained them all, only adding to the general confusion by introducing a few vagaries of her own. Thus our liquid and dry measures differ widely from the British, and, until 1855 the two standards of length varied by about one part in 17,230, which made our mile about 3,677 inches more than the English mile. Our measures of capacity vary in the different States of the Union. There are four different sizes of the gallon-measure in use, and the standard gallon varies from the English Imperial gallon by forty-six inches, and two hundred and seventy-four one thousandths of an inch, and so on with the weights and measures. These, however, are "mere trifles," and we are above caring anything about them. We are satisfied to know that we have *about* the worth of our money, and are not at all particular to have the measurements perfect or the scales exactly balanced. Indeed, for some of us this is quite a convenience, for it enables us to treat our neighbors as the early settlers of the Nieuw Netherlands treated the Indians when every Dutchman's hand weighed a pound and every Dutchman's foot weighed two pounds.

Most of us would open our eyes in astonishment if told that to make and keep a mathematically accurate standard of any weight or any measure is next to a mathematical impossibility; yet such is the case, and the Egyptians of four thousand years back were far ahead of us Americans to-day, for when Piazzi Smith announced that the porphyry sarcophagus, discovered in the Great Pyramid of Egypt, was in every dimension a convenient fraction of some

great unerring distance, like the earth's orbit or meridian, the scientific world stood in wondering admiration at the ingenuity of the ancient priests who had succeeded in recording the only perfect standard of measurement in a material which heat would not lengthen nor cold contract, and which was alike defiant of worms and rust.

When, in 1871, a bill was introduced in the English Parliament to render the use of the Metric System obligatory, and was lost only on a very slight minority, Sir Rowland Hill stated that England was losing *six per cent.* on her postage alone, with France, and *seventeen per cent.* on her postage with Prussia, in consequence of a want of identity in weights and measures.

It is a disagreeable thing to make a change in so important an institution as a system of weights and measures; but, for this very reason, if for no other, an end should be put to all possibility of change in future by adopting, once and for all, a system which is unalterable.

It has been the world's experience, since the birth of civilization, that wherever systems of weights and measures are founded upon mere accident or caprice, they have undergone perpetual change both by chance and by legislation; and this change can only be arrested by the adoption of a system rendered permanent as well by universal adoption among nations as by the scientific principles upon which it is constructed. As an example of this perpetual change, to take a single case out of a hundred similar ones, I have before me the accounts of four important changes made in the liquid gallon in England, and of a half-a-dozen changes in the bushel.

ORIGIN OF THE METRIC SYSTEM IN FRANCE.

The same great confusion, in this respect, existed in France before her revolution as exists with us now. Feeling the evil, she set vigorously to work to overcome it, and succeeded. It was the intention of France from the beginning to choose such a system that, in the end, every other nation would adopt it. This was no small undertaking; for a measure must be deduced from some unalterable magnitude in nature, which should be equally exact for every part of the globe, in order to be equally suitable for the use of all nations.

According to John Quincy Adams, "It is one of those attempts to improve the condition of human kind, which, should it even be destined ultimately to fail, would, in its failure, deserve little less admiration than in its success."

Several methods of obtaining a fixed natural length were considered: —

1. Length of the pendulum beating seconds.
2. Distance through which a body falls in the first second of its descent.
3. The one ten millionth part of a quadrant of the earth's meridian.

The length of the pendulum beating seconds could never give satisfactory results, because it varied according to its distance from the equator.

For the same reason, and also on account of the difficulty of measuring accurately the distance through which a body falls during the first second, this method was also abandoned.

The third was therefore adopted as being the one supposed to be best fitted to satisfy the requirements of

the problem. A trigonometrical measurement of an arc of the earth's meridian (extending through France from Dunkirk to Barcelona) was instituted, under the direction of the most eminent mathematicians of Europe. The length of the meridian, thus found in *toises*, was divided into forty million equal parts, and each part called a meter. Hence the length of the meter was declared to be a certain determinate part of the toise, and the prototype meter was caused to be constructed in platinum by the International Commission which met at Paris in 1799, and declared to be the definitive base of the Metric System of Weights and Measures forever. This base has never been altered. The subdivision and multiples of this length were made on the decimal system, and the weight of a cubic centimeter of water at 4° Centigrade, or the condition of its greatest density, was adopted as the unit of weight, and called a "*gram.*"

The determining of the unit of weight, which was entrusted by the members of the French Academy of Sciences to Lefevre Gineau and Fabbroni, led to the important discovery that water was densest, not at the freezing point, but at 4° Centigrade above it. Hence the gram is equal to the weight of a cubic centimeter of water at 4° Centigrade, and not at the freezing point.

Although the length of the meter, fixed as a certain determinate part of the toise, was based on a careful meridian survey occupying seven years, and represented the ten-millionth part of the quadrant, it was nevertheless clear that no absolutely accurate measurement of the earth's meridian, or of its diameter or polar axis, or of any other supposedly unalterable dimension, could ever be made, and that, moreover, if the standard meter at Paris were lost at any time, no second standard exactly like it could ever be made to replace it. Accordingly, in 1872,

on the 24th of September, the International Metric Commission, composed of scientific men from all countries (the United States included), met at Paris for the purpose of providing against this danger, in case the standard meter at Paris were destroyed, and of assuring in the future absolute accuracy and unalterability in the standards by providing each of the different countries using the Metric System an authentic standard to be kept at home, which should be exact copies of the prototype meter bar at Paris, by being all cast from the same ingot of metal. The Convention therefore decided to make a new bar to replace the prototype, out of better material and with a better cross section or shape; and furthermore, that, beside this new prototype bar, there should be kept always at the International Bureau, or in depositories selected by the permanent Commission in charge of the bureau, four other similar bars, kept in a temperature as little variable as possible, for the purpose of studying the effects of time by comparison at intervals, and that still another similar bar should be kept at invariable temperature and in a vacuum. They even recommended that, for further security, samples be made in quartz and in beryl. Each meter bar is to have a cross section which combines the figures of the letter X and the letter H, the division lines being engraved upon the upper surface of the cross division. (For full-size drawing of this section, see chart.) The Convention resolved also that bars of similar form, cast from the same ingot of platinum and iridium, in order that the expansion, contraction and other modifying influences should be the same for all the bars, verified with similar care, should be constructed for all nations that contributed to the maintenance of the bureau. Thus in the future the metric standards of every country will have the same legal authenticity as the prototype standard itself.

But as no two bars have ever been made, or ever will be made, of exactly the same length, every one of these authentic copies of the prototype will be accompanied by its certified equation, to be always used when derivative bars are compared with the standard. The Commission resolved that all the meter bars constructed by their order should be made from an ingot formed from a single casting, and that this ingot should consist of ninety per cent. of platinum and ten per cent. of iridium, to give it greater hardness. To give any idea of the wonderful care and delicacy with which all these operations are now being conducted would carry us beyond the limits and intent of this treatise. Enough to say that all the care and caution that modern science can afford is employed to render these standards as unalterable and indestructible as any natural base itself could be.

The Commission of Oct. 4th, 1873, decided to melt 250 kilogs (about 670 lbs. Troy) of platinum and iridium, and cast it at one time, in order to secure an ingot of metal large enough to make all the standards required.

They expect to make at least forty-five standard meters *à trait*. Up to October, 1873, twenty-seven had already been ordered by different countries, including the United States. Thirty-one countries are represented in the Commission. Besides the meters *à trait*, as many standard kilograms, made in the same manner, and about as many metres *à bout*, have been ordered by the same countries. The meter *à trait* is the standard meter in which the length of the unit is represented by two lines engraved upon the surface of the rod, one at each end, the rod itself being longer than a meter by two centimeters.

The meter *à bout* is one in which the rod itself is exactly one meter long from end to end.

The construction of these standards is being executed

as rapidly as the nature of the work will allow. The casting was expected to take place in April, 1874, and the whole work will probably be completed by next October; and, soon after, a set of these monuments of scientific skill and ingenuity will be deposited in the office of weights and measures at Washington. It is calculated that one hundred and eighty kilograms of metal will make about forty meters. Cost of platinum per meter, about 4,000 francs.

The length of the meter is determined from the rods when encased in ice.

RAPID PROGRESS OF THE SYSTEM AFTER ITS ADOPTION IN FRANCE IN 1840, TO THE EXCLUSION OF ALL OTHER SYSTEMS.

The use of the Metric System was enforced in France, to the exclusion of any other system, in 1840 (date of legislation, 1837).

After this date other countries followed the example of France in rapid succession, until to-day it is used by the majority of the civilized and Christian world. "At the Universal Exposition of 1867, in Paris," says Dr. Barnard, "thirteen measures of length from different countries were exhibited under the name of foot, or its equivalent, but among these there were only eight values essentially different; and two of these were metric. Yet after giving some attention to this subject without pretending to exhaust it, I have found more than one hundred foot measures, each differing more or less from all the rest in value, which have been in use at one time or another at one part or another of Europe. Similar remarks might be made of the units of weight and capacity. There has, therefore, been large progress made toward uniformity, and the

most important steps and the most significant steps are those which have been taken in our century. We cannot suppose that this progress is going to be arrested at the point which it has now reached." Alexander, in his dictionary of weights and measures, gives about two thousand different names, representing at least five thousand different units of weights and measures, which have been in use.

PROGRESS OF THE REFORM IN ENGLAND.

The system was legalized in Great Britain in 1864; and judging from the numerous bills brought up since then in Parliament, to render it obligatory, success in this direction seems very near at hand. Some of the India State Railways have been made with the gauge of one meter, and the use of the meter in British India is said to be rapidly increasing. The growing weakness of the opposition may be judged of by reading some of the objections raised to one of the last bills for the compulsory adoption of the system in England. Dr. Barnard quotes from the London "Guardian" a report of the debate in the House of Commons on the bill of 1871: —

"Mr. Beresford Hope, in moving the rejection of the bill, said that, while he was in favor of uniformity, he desired to have English weights and measures, and not French ones. The changes proposed by Mr. Smith would overthrow all our long-established habits and customs, — nay, our very proverbs; for no one would be able hereafter to talk about 'giving an inch and taking an ell.' — (A laugh.)"

To which Dr. Barnard remarks, "This latter argument of Mr. Beresford Hope is rather more witty than weighty, but it is less true than either; for though the ell (which

after all is a French measure) has ceased to be used in England for a century or two, the proverb seems to be still as lively as ever. As for stigmatizing the Metric System as *French*, it was never quite just to do so, and it is at present altogether absurd; since this system has become the system of more than half the civilized world."

The report continues: —

"The rejection of the bill was seconded by Mr. Stevenson, and was supported by Mr. Scourfield, by Alderman Lawrence, who pointed out that the adoption of the *litre* would diminish the poor man's pint of beer without any proportionate diminution of price [a surprisingly knowing alderman this must have been], and by Mr. Fothergill. Mr. Healey pointed out the inconvenience of having to go to a foreign capital for standards, which might at any moment be melted down in a general conflagration of the city. If agriculturists want a uniform measure, why on earth did they not adopt the Imperial bushel?"

This last argument, however weighty it might have seemed at the time, has lost its force since the International Conference of 1872 met at Paris and caused the various standard meters to be made for distribution, as above described.

"The bill was supported by forty-three associated Chambers of Commerce and Agriculture, by Farmers' Clubs, Workingmen's Associations, and many scientific bodies. It was supported by the representatives of the largest constituencies in the kingdom — Manchester, Liverpool, Glasgow, Leeds, Birmingham, North Staffordshire, South Leicestershire, and South Norfolk. It was opposed, by the member for Cambridge University, on the ground that the French unit was not a proper unit; by the astronomer Royal and Sir J. Herschel." [Since 1872, again, these objections are, of course, all rendered harmless]. "For the

Metric System, however, they had the authority of three gentlemen who possessed the most extensive scientific knowledge, combined with the greatest business knowledge of this or any other age, — Sir William Armstrong, Sir Joseph Whitworth, and Sir William Fairbairn."

LATE GREAT PROGRESS IN THE UNITED STATES.

Few realize the extent to which the Metric System has already been adopted in the United States. Already made legal by Congress in 1866, its use among scientific men and in scientific works is very general. It is used extensively by the United States Coast Survey, the greatest of our public works. It is used in the most important laboratories of our colleges. It is used altogether by our analytic chemists, and largely by physicians, and all those who have dealings with foreign countries, and, further than this, it is the ardent desire of every man who fully understands it to see its use among us universal. The decimal subdivision of the foot is used by our engineers.

SIMULTANEOUS ACTION ON THE PART OF THE PUBLIC MEMORIALS TO CONGRESS. CIRCULAR.

The following circular, endorsed by the literary, scientific, and otherwise influential public men throughout the country, has received the signatures of many hundreds of our leading architects and engineers.

THE METRIC OR DECIMAL SYSTEM OF WEIGHTS AND MEASURES.

The Metric System of Weights and Measures has now received the sanction of law among more than half the inhabitants of the civil-

ized and Christian world. It has, up to this date, been adopted by the French, Germans, Spaniards, Italians, Portuguese, Dutch, Belgians, Mexicans, Swiss, Austrians, Danes, Grecians, British in India, Brazilians, and the majority of the civilized inhabitants of South America; in all about four hundred and twenty millions of souls.

In 1864 the system was legalized in Great Britain; in Germany, in 1868. After four years of preparation, on the 1st of January, 1872, it was made compulsory in that empire, and no other system was any longer legal. In 1866 it was legalized in the United States. It is now 1874, and we have had eight years for preparation, — twice as long as was allowed to the people of Germany. Its general adoption among us should no longer be delayed.

"No cause," says an eminent writer on the subject, "since the earliest organization of civilized society, has contributed more largely to embarrass business transactions among men, especially by interfering with the facility of commercial exchanges between different countries, or between different provinces, cities, or even individual citizens of the same country, than the endless diversity of instrumentalities employed for the purpose of determining the quantities of exchangeable commodities. For the inconvenience and confusion resulting from this cause, but one effectual remedy can possibly be suggested, and that is the general adoption throughout the world of a common system of weights and measures."

Such a common system is offered us in the Metric — a system, according to which the weight and dimensions of every material thing, whether solid, liquid or gaseous, whether on land or on water, whether in the earth or in the heavens, and whether determined by the scale, plummet, balance, barometer or thermometer, are ascertained by a method absolutely uniform, entirely simple, and equally suitable to the use of all mankind, resting upon a single invariable standard of linear measure, with multiples and sub-multiples, like those of our monetary system, exclusively decimal, with appropriate names, similar in all languages; and itself secure against the possibility of change or loss through carelessness, or accident or design, by being constructed on scientific principles and copied for distribution among the different nations of the world.

It is clear that England, owing to the progress she has already made in this direction, and to her position in Europe, must very soon complete the process she has already begun, of adopting this system.

The United States should not *wait* for England. The German, French, and other foreign element here already exerts a great pressure in the direction of its general adoption. Moreover, having al-

ready, in our dollars, dimes, cents, and mills the principle of the Metric System in actual use before us, it will be only an extension of a method already familiar, to carry out the same system in all other measures of quantity. There being, therefore, with us nothing to learn, no serious difficulty will be encountered, even with the most uneducated classes, for they make use of the principle already. How many of the best educated understand and are masters of our present senseless and complicated system of weights and measures?

The Metric System, moreover, is already in use in the most important of our great public works, — the United States Coast Survey.

Under our republican form of government, it is not to be expected that our national legislature will, in a matter so nearly touching the daily business and habits of every citizen, be in advance of the people themselves. Congress has made the Metric System legal, and has power to make it compulsory; but this is a power which that body is not likely to exercise until a call for such action shall come up to its members from their constituents at home.

For further progress in this direction, therefore, we must now look to the people themselves. The work must be done practically, not by the literary and scientific, who, however deeply they feel the importance of the subject, and however earnestly they may desire an immediate change for the better, are not in a condition to secure its general adoption. Nor can it be done by the laboring and less educated classes, who no more feel the want of it than the world in general felt the want of steamboats and railroads before the invention of steam power. It must be done by those whose professions require them to make constant use of weights and measures, and for whom the imperfections of the present system are a continual source of annoyance and loss in time and power, and whose position is such in relation to the other classes, that their example must be followed both by those on the one hand whom they employ, and by those on the other who employ them.

The work of introducing the Metric System of measures of length or distance should be undertaken by the architects, engineers and builders. By agreeing to use the metric measures of length in all their professional transactions, commencing on a certain day fixed several months in advance, they will necessitate the gradual and harmonious introduction of those measures as well among the workmen employed by them, as by their clients for whom their plans are made; for, in order to understand the measurements figured upon these plans by the architects, such workmen must familiarize them

selves with the principles of the system from which the numbers are derived.

Vigorous efforts will be necessary, and many difficulties must be overcome, before we can hope to succeed. But so large a portion of the civilized world has already accomplished what we are proposing, country after country in so rapid succession has ranged itself in the metric ranks, that the necessity of things must soon drive us into completing what we have already begun; and no reflecting man will deny that the difficulty of making this unavoidable change must necessarily continue to increase the longer it is deferred, and that, whenever a destiny becomes manifestly inevitable, it is the part of wisdom to advance to meet it, rather than to await the lingering process by which it must otherwise accomplish itself.

The following simple tables give all that there is in the Metric or Decimal System of weights and measures: —

MONEY.

10 mills	make	a cent.
10 cents	"	" dime.
10 dimes	"	" dollar.
10 dollars	"	an eagle.

LENGTH.

10 milli-meters	make	a centimeter.
10 centi-meters	"	" decimeter.
10 deci-meters	"	" meter.
10 meters	"	" dekameter.
10 deka-meters	"	" hektometer.
10 hekto-meters	"	" kilometer.
10 kilo-meters	"	" myriameter.

WEIGHTS.

10 milli-grams	make	a centigram.
10 centi-grams	"	" decigram.
10 deci-grams	"	" gram.
10 grams	"	" dekagram.
10 deka-grams	"	" hektogram.
10 hektograms	"	" kilogram.
10 kilo-grams	"	" myriagram.

CAPACITY.

10 milli-liters	make a	centiliter.
10 centi-liters	"	" deciliter.
10 deci-liters	"	" liter.
10 liters	"	" dekaliter.
10 deka-liters	"	" hektoliter.

THE SQUARE AND CUBIC MEASURES

are nothing more than the squares and cubes of the measures of length. (Thus a square and a cubic milli-meter are the square and the cube of which one side is a milli-meter in length.)

The *ar* and *ster* are other names for the square dekameter and the cubic meter.

The undersigned, therefore, venture to recommend to the members of the several professions employing weights and measures, that they, or as many of them as, after due consideration, may be disposed to co-operate for the furtherance of this desirable object, should enter into some formal written compact with each other, binding themselves, after some definitely fixed time in the future, to act on the plan above suggested, from employing in their professional transactions only the metric weights acd measures. On their own part, the undersigned engage to do all that may be in their power, by their advocacy, by their influence, or, if possible, by means of a more practical nature, to promote this important reform.

[Signatures of literary, scientific and otherwise influential public men.]

We, the undersigned, ...
.....do hereby agree to use the Metric System of.....
..... on and after (before if desired) the 1st day of.....
.....in all our professional transactions, provided that a majority of our profession in the .....largest cities of the United States agree to do the same.

[Signatures of professional men and of the public generally.]

MEMORIALS.

Two memorials, printed by the American Metrological Society, a few weeks ago, at the same time with the circular, and petitioning Congress to do some of those things which it may do to advance the cause, have received the signatures of influential men from all parts of the country.

Of the first of these memorials the following is the last paragraph, which explains the object of the whole: —

"The prayer of your memorialists therefore is, that your honorable body may see fit to enact, during your present session, such laws as may be necessary to effect the objects set forth in this memorial as desirable, viz.: laws which shall make practicable, as well as legal, the use of the Metric System of weights and measures, in the estimation and computation of customs-duties in the custom-houses of the United States; which shall make it obligatory upon the post-office department of the United States to assess postages on matters transmitted through the mails in accordance with the provisions of the metric postal act of 1866; which shall require, in the reports of all the great public works conducted under the authority of the federal government, numerical statements involving dimensions, or quantities of any kind, to be made in metric denominations, as well as in those of the metrology in common use in the country; and which shall extend this requisition to statistical and other documents involving statements of quantities, which may be issued under authority of any of the departments of the executive governments."

The second memorial relates to coinage, and is as follows: —

"MEMORIAL

"*To the Hon. the Senate and House of Representatives of the United States, in Congress assembled:* —

"The Memorial of the Undersigned, members of the Metrological Society of the United States, and others, respectfully showeth: —

"That the coinage of the United States, in both the metals, gold

and silver, is, at this time, in weight, almost in strict accordance with the denominations of the Metric System. By the coinage act of 1873, the silver coinage is, by the explicit terms of the law, made entirely so.

The legal weights of the gold coins are Metric within so small a fraction that, for the smaller coins, the tolerance remedy allowed by law for error of weight, in the mechanical process of coinage, more than covers the difference. The weight of standard gold in the dollar is twenty-five grains and eight-tenths of a grain; and that of pure gold twenty-three grains and twenty-two one hundredths. This last weight exceeds one gram and a half by just seven one-hundredths of a grain; an excess having the value of about three-tenths of a cent; while the legal tolerance on the gold dollar is one quarter of a grain of standard gold, of the value of one cent. The gold coins of the United States, when in circulation, lose in weight shortly, by abrasion, more than sufficient to bring them to the Metric standard. There seems, therefore, to be no valid objection to such a modification of the law which declares what shall be the weights of the gold coins of the United States, as to make the amount of pure gold contained in the dollar exactly one gram and a half; the weights of the other gold coins being modified accordingly. Should this change be made, all the coins of the United States, except the base metal tokens, will be made conformable to the same system of weights, and will be consistent with each other.

"The prayer of your memorialists therefore is, that your honorable body may see fit, during your present session, to pass an act supplementary to the coinage act of 1873, adjusting the weight of the gold coins of the United States, so as to make them expressible in Metric denominations.

"And your memorialists, as in duty bound, will ever pray, etc."

OTHER INFLUENCES NOW AT WORK TO RENDER THE EARLY INTRODUCTION OF THE SYSTEM IN THE UNITED STATES INEVITABLE.

Thus, throughout the world scientific men, associations and journals are beginning to use the Metric System exclusively in their experiments, calculations and writings. The International Statistical Congress, composed of dele-

gates from all nations, publishing their scientific reports containing a vast mass of valuable and interesting information in regard to the actual wealth, productions, natural and artificial, and general condition of industry, and commerce of all countries, systematically collected, and philosophically arranged, with a view to promoting the general welfare, have adopted the Metric System, as otherwise the quantities collected would be incomparable and unintelligible, and, therefore, unavailable. Speaking of the rise of this Congress, Dr. Barnard says: "From this epoch dates a new era in the history of the world's legislation. For the enlarged views of the reciprocal duties, as well as of the true interests of nations, in which this great general movement originated, are destined, through its instrumentality, to impress themselves more and more completely upon human institutions; until statutes shall at last cease to be monuments of ignorance, prejudice, or ignoble jealousies, and the aim of all laws shall be the greatest good of the greatest number. One most important result has already been secured by the action of these congresses; in that so far as the science of statistics is concerned, so far, we may even say, as the successful conduct of governmental administration is concerned, it has made the Metric System of Weights and Measures a system of universal necessity, and rendered a familiar acquaintance with it absolutely indispensable to every statesman, every publicist, every teacher or student of political economy, and every enlightened lawgiver throughout the world."

The International Social Science Association, having adopted the system, exerts its great influence throughout every corner of the civilized world, to bring about its universal adoption.

Other international conferences have been often called together for the special purpose of establishing this system in every land.

AMERICAN METRIC BUREAU.

Established in the summer of 1876 by advocates of the Metric System, this society has by its vigorous work and well-chosen plan of action already advanced the cause more than its most enthusiastic friends could have expected.*

AMERICAN METROLOGICAL SOCIETY.

Finally another powerful arm has been raised in our midst, to help on the general good. A body of learned and public-spirited men has lately been formed under the name of the American Metrological Society, for the sole purpose of promoting the public welfare in this important particular. Their influence has begun to be widely felt, as we have already seen.

PREDICTION OF JOHN QUINCY ADAMS.

No words could be found better fitted to conclude this part of the subject than these eloquent ones of John Quincy Adams: —

"If man upon earth be an improvable being, if that universal peace which was the object of a Saviour's mission, which is the desire of the philosopher, the longing of the philanthropist, the trembling hope of the Christian, is a blessing to which the futurity of mortal man has a claim of more than mortal promise; if the Spirit of Evil is, before the final consummation of things, to be cast down from his dominion over men, and bound in the chains of a thousand years, — the foretaste here of man's eternal felicity; then this system of common instruments to accomplish all the changes of social and friendly commerce will furnish the links of sympathy between the inhabitants of the most distant regions; the meter will surround the world in use as well as in multiplied extension; and one language of weights and measures will be spoken from the equator to the poles."

* See Appendix, page 1.

SOME OF THE ADVANTAGES OF THE METRIC SYSTEM.

I. Uniformity. It is the International System.

II. Simplicity.

III. Its base inalterable.

IV. Its multiples and subdivisions decimal.

V. Its units of weight, length, volume and capacity mutually related upon scientific principles.

VI. Nomenclature expressive of values.

Let us examine each of these advantages in detail.

I.

THE ADVANTAGES OF HAVING A COMMON SYSTEM OF WEIGHTS AND MEASURES THROUGHOUT THE WORLD

are manifold.

1st. It renders intelligible to us all foreign literature containing statements of values in weights or measures, which would otherwise be useless; and, reciprocally, it renders our books, magazines and journals intelligible to foreigners, and facilitates their circulation abroad; in short, it opens between nations, channels of communication which would otherwise be closed.

2d. It removes that impediment to the propagation of knowledge among the people, which now exists in our country where our scientific books employ, as is generally the case, the Metric System, or to the progress of science itself, when the Metric System cannot be adopted in the books.

3d. It facilitates commerce by removing the possibility of delays, inaccuracies and difficulties in reducing values from one system to another, and the liability to imposition which would otherwise result from a diversity of systems.

4th. It facilitates travel in foreign countries, and diminishes the danger of imposition.

THE METRIC THE ONLY SYSTEM THAT CAN BECOME A COMMON SYSTEM.

That the Metric System is the only one that can ever become universal is now no longer a matter of doubt. It has already taken too deep root and its superiority over all other systems is too widely appreciated, to allow of its ever being torn up and supplanted by another. Even had it become less universal, it is clear that, had we refused to adopt this the most perfect of systems, for the sake of uniformity, we should have been still less willing to accept any other. On the other hand, it would, for the same reasons, have been doubly impossible for us to persuade other nations to adopt ours, especially as no two systems were commensurable with each other. Charles Sumner says, "A system of weights and measures born of philosophy rather than of chance, is what we now seek. To this end old systems must be abandoned. A chance system cannot be universal. Science is universal. Therefore, what is produced by science may find a home everywhere."

II.

THE ADVANTAGE OF SIMPLICITY.

Twelve words are all that are necessary to designate the various units of weights and measures, and all their decimal multiples and subdivisions in this system. The Metric System is composed of twelve words. Surely this cannot be very difficult to master. Our present system is composed of about fifty words.

In order to ensure these twelve words against all possibility of change, and to facilitate their acceptation by all nations, they were not taken from any modern language,

but are derived from the Greek and Latin, the two principal languages of the ancient world.

These words are, —

Units.	1 Meter,	from the	Greek	Metron,	signifying	a Measure.
	2 Liter,	" "	"	Litra,	"	a Pound.
	3 Gram,	" "	"	Gramma,	"	a small Weight.
	4 Ar,	" "	Latin	Area,	"	a Surface.
	5 Ster,	" "	Greek	Stereos,	"	a Solid.
Sub-divisions.	6 Milli,	" "	Latin	"Mille,"	"	Thousand.
	7 Centi,	" "	"	"Centum,"	"	Hundred.
	8 Deci,	" "	"	"Decem,"	"	Ten.
Multiples.	9 Deka,	" "	Greek	Deka,	"	Ten.
	10 Hekto,	" "	"	Hecaton,	"	Hundred.
	11 Kilo,	" "	"	Chilioi,	"	Thousand.
	12 Myria,	" "	"	Myrioi,	"	Ten thousand.

These words are already in use in the English language. Thus, Meter in *thermometer*, *metrology*, etc.; Liter in *litrameter;* Gram in *gram* (See Webster's Dic.) Ar in *area;* Ster in *stereoscope;* Mille in *millenium* or *mill;* Centi in *century* or *cent.;* Deci in *decimal;* Deka in *decade;* Hekto in *hecatomb;* Kilo in *chiliad;* Myria in *myriad.*

In addition to the tables already given these two are used: —

SQUARE MEASURE.

100 cent-ars make an ar (= 100sq. m.)
100 ars make a hektar (= 10000 sq. m.)

Being accustomed to the words mill, cent and dime, we shall find the words "milligram," "centigram" and "decigram" quite as simple and easy to pronounce as our words "pennyweight-troy," "hundredweight-avoirdupois," "scruple-apothecaries," etc., notwithstanding the assertion to

the contrary of those who grieve to give up the "*short and sharp Anglo-Saxon* words used in our present *familiar* old tables" of weights and measures.

Finally, the Metric has all the advantage in point of simplicity over all other systems of weights and measures that our Federal system of money can claim over the monetary systems of other countries where the denominations are not decimal.

In England, a body called "The International Decimal Association" sent a circular to schoolmasters, asking how much would be saved in that country in education, were the Metric to supplant the old system.

After a very careful calculation, the answer returned was, that there would be a saving of money of about £350,000 (1,750,000 dollars) a year, and in time an amount equally astonishing. The reason of this is the difficulty in elementary education of committing our tables to memory, and learning to manipulate them, and the absolute hopelessness of being able to remember them. A vast amount of valuable time and energy which is needed for useful study is lost in attempting to master these tables.

III.

THE ADVANTAGE OF UNALTERABILITY.

The base of the system has been rendered unalterable by reproducing, on scientific principles, and with mathematical accuracy, the standard previously obtained and preserved at Paris, and distributing the copies for use and safe-keeping among the several nations of the civilized world. Thus the unit of length becomes as indestructible and unalterable a standard as the meridian itself, or any other natural, unalterable magnitude, and, guarded by all nations, no one can alter it by legislation.

IV.

ADVANTAGES OF DECIMAL DENOMINATIONS.

Our Federal currency shows us the advantages of the decimal system, in the facility and rapidity with which we make reductions and calculate values. We should consider our burden intolerable if, instead of this simple table, we were obliged to use three or four complicated ones, all different from each other, like our three different tables for measuring weight; one, for instance, like the English pounds, shillings and pence, for buying medicine; another, different from the first, for buying our groceries; and a third, different from either, and perhaps containing vulgar fractions for greater variety, for buying our jewelry and other ornaments.

As before mentioned, our engineers feel so deeply the importance of the decimal subdivision, that, notwithstanding the inconvenience of complicating our system, they have adopted the decimal subdivision of the foot.

There are other advantages under this head, especially important to architects, engineers, mechanics, and contractors. Such as the greater convenience in measuring off the full size from small drawings which vary now between the inconvenient quantities of $\frac{1}{32}$ in., $\frac{1}{30}$ in., $\frac{1}{16}$ in., $\frac{1}{8}$ in., $\frac{1}{2}$ in., $\frac{3}{4}$ in., 1 in., $1\frac{1}{2}$ in., 3 in., etc., to the foot; so that in measuring off the full size a considerable diversity of multiples must be used. With the decimal system nothing would be easier than the reading off of the full size from the scale drawings, 1.50 representing either the full size of 1m. 50 c. or 1 decim. 50 mm., or 1 c. 5 mm., according to the scale of the drawing expressed upon it, the mere alteration of the position of the decimal point giving the desired full size on the scale dimensions.

Then the decimal subdivision leaves less chance of error from the misreading of figures. Every architect has, for example, experienced the liability to mistake in reading 1′ 5″ as 15″ instead of 17″.

Problems to show the relative facilities of reduction by the old and new systems.

EXAMPLE, METRIC SYSTEM.

Problem. — Reduce 1543514 centimeters to Kilometers, and meters.

OPERATION:

There is no operation except to write the decimal point and read the result, Thus

15 Km. 435.14 m. *Ans.*

EXAMPLE, OLD SYSTEM.

Problem. — Reduce 1543514 inches to miles, furlongs, etc.

OPERATION.

12) 1543514 in.

3) 128626 ft. + 2 in.

$5\frac{1}{2} = \frac{11}{2}$) 42875 yds. + 1 ft.

2

11) 85750 halves of yd.

40) 7795 r. + $\frac{5}{2}$ yds. = 2 yds., 1 ft., 6 in.

8) 194 f. + 35 r.

24 m. + 2 f.

24 m., 2 f., 35 r., 2 yds., 1 ft., 2 in.
1 ft., 6 in.

24 m., 2 f., 35 r., 2 yds., 2 ft., 8 in. *Ans.*

V.

MEASURES OF LENGTH, VOLUME, WEIGHT AND CAPACITY COMMENSURABLE.

This is an enormous advantage, for if the weight of a body is given we can know easily its volume and reciprocally.

In our present system there exists no such relation between the weights and measures.

As a result of this relationship in the Metric System, the unit of weight is easily obtained and becomes as unalterable as the unit of length, the gram or unit of weight being the weight of a cubic centimeter of distilled water at 4° Centigrade.

A cubic meter of water weighs a ton or 1,000 kilogs. In ship-building it is a special advantage to have a unit which bears an exact proportion to a ton of water; a ton now contains 35.955 cubic feet, and the only way to get rid of the long decimal fraction is *to add salt to the water until thirty-five cubic feet weigh exactly a ton*, an operation sufficiently difficult to perform successfully when the ocean is the object to be operated upon.

Problems to show the relative facilities of calculation by the old and new systems.

EXAMPLE, METRIC SYSTEM.

Problem. — What is the weight of 257 cubic meters, 200 cubic decimeters, 100 cubic centimeters, and 700 cubic millimeters of cannel coal? Given, specific gravity of cannel coal 1.27. 1 cu. cm. of water weighs 1 g. 1 cu. cm. of cannel coal weighs 1.27 g.

OPERATION.

257200100.7
1.27

17990140119
5140040034
2570020017

Ans. 326392542.159

326 Metric Tons, 392 Kg., 542.159 g.

EXAMPLE, OLD SYSTEM.

Problem. — What is the weight of 2 cubic rods, 3 cubic yards, 18 cubic feet, and 40 cubic inches of cannel coal? Given, specific gravity of cannel coal 1.27, and supposed weight of 1 cubic inch of water about 252.7453+ grains.

By the old system it is impossible to solve the problem accurately.

OPERATION.

2 cu. rods, 3 cu. yds., 18 cu. ft., 40 cu. in.

$166\frac{3}{8}$
2
2 cu. rods = $332\frac{3}{4}$ cu. yds.
3
$335\frac{3}{4}$
27
2345
670
$20\frac{1}{4}$
$335\frac{3}{4}$ cu. yds. = $9065\frac{1}{4}$ cu. ft.
18
$9083\frac{1}{4}$
1728
72664
18166
63581
9083
432
$9083\frac{1}{4}$ cu. ft. = 15695856 cu. in.
40
15695856 cu. in. = 2 cu. rods, 3 cu. yds., 18 cu. ft., 40 cu in.

$5\frac{1}{2} = \frac{11}{2} \times \frac{11}{2} \times \frac{11}{2} = \frac{1331}{8} = 166\frac{3}{8}$.

The U. S. Bureau of Weights and Measures have accepted (though it is incorrect) the weight of 1 cu. inch of water

= 252.7453 grs.
1.27
17692171
5054906
2527453
320.986531 = grs. weight of 1 cu. in. cannel coal.

320.986
94175376
125567168
141263064
31391792
47087688
7000) 5038162373.457 grs.
25) 719737 lbs., 3873.457 grs.
4) 28789 qrs., 12 lbs.
20) 7197 cwt., 1 qr.
359 T., 17 cwt.

7000 grs. Troy = 1 lb. Avoirdupois.

3873.457 grs. Troy = $\frac{3873.457}{7000}$ lbs. Avoirdupois.

$\frac{3873.457}{7000} \times 16 = \frac{7746.914}{875}$ oz.

875) 7746.914 (8.853+ oz.
7000
7469
7000
4691
4375
3164

16
5118
853
13.648+ drams.

Ans. 359 T., 17 cwt., 1 qr., 12 lbs., 8 oz., 13.648 drs.

In the second operation 380 figures are required, in the first only 68.

In the second *fifteen* different mathematical operations have to be performed.

In the first only *two*.

This is but a fair comparison of the two systems.

VI.

THE NAMES EXPRESS VALUES.

The nomenclature is thus easy to learn, and once learned can never be forgotten.

The names are often abbreviated in speaking. Thus, "Kilogram" is called "Kilo." In writing they are almost always abbreviated.

The following seems to be the best method of abbreviation: —

The abbreviations are written after the figures, as 24 mm., 27.3 g., 72 Kg.

The Greek names, or names of the higher orders of units, are written in capitals, as Kg. (Kilogram), Mm. (Myriameter).

The Latin names, or names of the lower orders of units, are written in small letters, as cg. (centigram), mm. (millemeter). In square measure the word square is abbreviated sq.; thus, 3 sq. m. = 3 square meters.

In solid measure the word cubic is abbreviated *cu.*; thus, 4 cu. Hm. = 4 cubic Hektometers.*

The system possesses other advantages, such as its great value as an intellectual and educational machine, but these I pass by, as I think enough has been said to explain its principles.

* The German Institute of Architects and Engineers have, at Berlin, lately adopted the sign □ for the abbreviation of square, as 3 □ m.; but this is difficult to write quickly and too liable to be mistaken for ○. Some writers prefer the forms m^2 and m^3.

OBJECTIONS TO THE METRIC SYSTEM CONSIDERED.

Some objections have been made to the Metric System. Of these the majority are too evidently groundless to justify their consideration, where amusement is not the principal object sought after. The rest deserve notice on account of the weight, not of the arguments themselves, but of the names of their authors, who, however, seem scarcely to have been serious in offering them. Moreover, since these objections were made, public opinion on this subject has undergone material change, and it is probable that many of those who once criticised are now among the most earnest advocates for what the majority of the world has made its international system of weights and measures.

FIRST OBJECTION.

"THE UNIT BASE TOO LONG." *

We learn by experience that a *foot measure* is too short for common use. Carpenters and builders, for instance, are found never to use the single foot measure. Either the folded two-foot or the three-foot measure is adopted. Now the use of these measures involves, on the part of the mechanic, complicated or annoying calculations for every measure taken, because, first, the measure used is not the unit in which the distance to be measured must be expressed, but a multiple of that unit; and secondly, because the odd inches, if over twelve, must be reduced to feet and inches by dividing by twelve, and the quotient

* The objections considered are principally those given in the report of the committee appointed by the Convocation of the University of the State of New York, for the purpose of considering the subject of a uniform system of weights and measures. First committee appointed in 1866. Report published in 1870.

then added to the even feet already calculated, unless while performing the second part of the problem the first has been forgotten. With the metric system, however, no calculation is necessary, because the measure used is the unit itself; so that the distance to be measured is read off directly, without any calculation.

As for folding, it is found that the meter is capable of folding into a greater number of even parts than any other measure now in use, as an examination of the large collection exhibited in the rooms of the Metric Bureau will prove. The four-folded meter is only 25 centimeters, or 10 inches long, while the two-folded two-foot rule is 12 inches long, or too long for convenient pocket use.

TRIANGULAR SCALE.

The metric system does away with the need of using the triangular scale, whose six bevelled edges are required by the present system to contain the various scales used by architects and engineers in making drawings of convenient sizes. Only two bevelled edges are required by the metric system, yet they represent a greater variety of useful scales than the six under the old system.

SECOND OBJECTION.

"BY ADOPTING THE METER WE SHOULD SEVER OUR CONNECTION WITH GREAT BRITAIN."

Supposing the weights and measures used by the United States and Great Britain were the same, which they are not, and that such a breach were therefore possible, it is evident that this very rupture would necessitate its own speedy cure.

English conservatism is already vibrating in the balance between the pound and the kilogram. Old fogyism, with its *foot* in the scale, has long enabled the pound to stand against the greater actual weight of the kilogram, but it now shows signs of succumbing.

The law of 1864, legalizing the new system in England, and later, that of 1870, authorizing its enforcement in British India, sufficiently show this. The weight of America thrown on the metric side would quickly put an end to all further trouble, and the meter would once more measure the meridian, in uniting by a single tie all the nations of the world.

It would be mortifying for America, with her boasted enterprise, to allow herself to be dragged into the metric ranks by the slow coach of old England, who, we are told,* was about four hundred years behind the continental nations in the introduction of our present Arabic digits.

Mr. Nystrom presents an interesting picture of the difficulties encountered by giving some of the objections then raised in England to the introduction of the Arabic notation, in language substantially, he says, as follows: —

"It would be ridiculous to introduce these curious-looking Arabic characters into our beautiful language and letters, and our people could never learn to understand or appreciate them. They have a character looking something like this, ३, which is said to represent three. Look at our III. Any man, without learning, can see that that means three. Another character, like this, ५, they say, represents five. What is the use of adopting such a sign for our beautiful V., which impresses the mind at once that it means five? And then they put several of these signs together, like this, ३५, which, they say, means

* See pamphlet on the Metric System, by John W. Nystrom, C. E., published in Philadelphia, in 1876.

thirty-five. Who can understand that? Our XXXV. is clear, and can be understood without any education, namely, that three tens and a five means thirty-five. Such characters may answer very well for scientific men who understand Arabic, but they are not practical for the people."

THIRD OBJECTION.

"THE DECIMAL DIVISION TOO DIFFICULT."

"Another serious difficulty is started of an educational character. Ten, it seems, is a difficult number to grasp; and one-tenth part is a still more difficult fraction. We can never know anything about one-tenth 'until we have divided the unit into two equal parts, into three, into four, and so on up to ten.' Since this is the case, it is melancholy to reflect how much more objectionable is our actual system of weights and measures than the Metric; since it will be necessary to divide the foot into three, into four, and so on all the way up even to twelve, before the faintest conception of an inch can begin to dawn upon our minds; and when we turn our attention to the pound and the ounce avoirdupois, the formidably protracted extent of this unavoidable operation becomes quite disheartening. Still, however grave this business of ten may be, I suppose that our children must some time or other know something about decimal arithmetic; and they will have to know something about it whether they learn the Metric System or not. If they know it, they know the system, all but its nomenclature; if they don't know it, then I can conceive of no educational machinery better suited to make them know it than the visible magnitude of the Metric measures placed before their eyes. The question is not whether we shall teach the Metric System to babes, but

whether we shall teach it along with the arithmetic, and as a part of the arithmetic, which boys must learn at any rate. The objector does not, apparently, discover that his argument is no less damnatory to our Federal Currency than to the Metric System; yet my observation in the streets of New York satisfies me that *gamins* of very tender years, without having enjoyed the advantages of scholastic culture, or having been carefully and systematically carried through the operation of dividing the unit into two parts, into three parts, into four parts, and so on up to ten, acquire an acute appreciation of the relative value of a dime stamp and a nickel."

The committee itself admits that "To consume the time of the young, at school, in teaching old systems long superseded by better ones, is little short of a crime."

FOURTH OBJECTION.

"THE DECIMAL DIVISION OFTEN UNSUITABLE FOR PRACTICAL PURPOSES."

In the words of the committee, "Because the binary subdivision is better in many cases than the decimal." For this very reaason those countries using the metric system use also the binary subdivisions. Thus, in Germany, according to a law passed on the 26th of January, 1870, Art. 5, the following denominations of the liter-pieces were ordered to be constructed: 20, 10, 5, 2, 1, 0.2, 0.1, $\frac{1}{2}$, $\frac{1}{4}$, $\frac{1}{8}$, $\frac{1}{16}$, $\frac{1}{32}$, 0.05, 0.02 liter pieces.

Convenient as the division of substances into halves and quarters may be in ordinary dealings, it is far less so in figuring drawings for practical work of all kinds. $3\frac{7}{8}$, for example, is a clumsy fraction of an inch to write out on small drawings; much more so $3\frac{7}{16}$, or $3\frac{7}{32}$; but where any arithmetical operation is to be performed with these

vulgar fractions, a vulgar error on the part of the workman is but too common an occurrence.

To allow room, for instance, for a $\frac{7}{8}''$ board, armed with a $1\frac{3}{16}''$ iron, a carpenter must first reduce $\frac{7}{8}$ to sixteenths. $\frac{7}{8} = \frac{14}{16}$. Then $1\frac{3}{16}$ to 16ths; $1 = \frac{16}{16}$; $16 + 3 = 19$. $1\frac{3}{16} = \frac{19}{16}$. Then $\frac{14}{16} + \frac{19}{16} = \frac{33}{16}$. Divide 33 by $16 = 2\frac{1}{16}$, which, if correctly done, is the correct answer.

All this calculation and figuring is avoided by the use of decimals, as it is in our calculations with dollars and cents. Thus, with a board 3.7 cm. thick, and an iron 2.5 cm., the calculation is performed by simply adding the two decimals together, giving us 6.2 cm. for our answer. Instead of the awkward and vulgar expressions "$\frac{3}{8}$ scant," or "$\frac{3}{8}$ full," or, which is very common among mechanics, "$\frac{3}{8}$ and a 16th," or even, as I have sometimes heard, "$\frac{3}{8}$ and a 16th and a 32d," we have in the metric system simply another decimal added, in the form of millimeters.

The only defect of the metric system is the defect of our arithmetic itself, and as long as our decimal arithmetic is maintained, the metric is the best of all the systems that have ever been devised. Those, therefore, who decry the metric system, because its units cannot be halved and quartered, must, to be consistent, also decry our table of money and our whole decimal system of arithmetic itself.

FIFTH OBJECTION.

THE PRACTICAL DIFFICULTIES IN THE WAY OF ITS INTRODUCTION.

An objection is made on the ground of the difficulties to be encountered in securing its practical introduction.

There is the difficulty, first, of learning the metric nomenclature and its principles of decimal division; second,

of familiarizing one's self with the actual Metric values; and, third, of reducing values from the old to the new system; and, fourth, of accommodating the gauges of machinery to the new measures.

In regard to the first difficulty, as the Metric vocabulary contains but twelve words, and of these the majority already in common use in the English language, probably no American will allow that the mastery of these twelve words is more than his intelligence can accomplish. This is certain, that if there be one man in a thousand who can repeat one half of the names in our present tables and give their values, he will have acquired the feat only at the expense of an extraordinary amount of patience and perseverance.

As for the decimal denominations, they are used already in that most popular of all our tables, — the table of Federal money.

In regard to the second difficulty, that of learning the Metric values, thanks to the beauty and simplicity of the law upon which the system is founded, it will vanish as soon as approached, and a glance at the chart at the end of this pamphlet, giving full-sized drawings of the Metric Weights and Measures, will show that after all they are not so formidable as is generally supposed.

The third difficulty is one which will, it is true, for a time at least, render necessary the use of tables of reduction, like those accompanying this pamphlet. But the relief experienced in escaping from the bondage of the old system, and entering into the full enjoyment of one which renders calculation tenfold easier, will more than compensate us for the temporary annoyance of making an occasional *reduction*. The fourth difficulty has already been considered.

SIXTH OBJECTION.

"WE CANNOT CONVENIENTLY DEAL IN ONE SYSTEM AND THINK IN ANOTHER."

To this objection Dr. Barnard says, "It is an undeniable truth that, *if we give up our present measures we shall cease to have them any longer*. 'What follows?' say your committee with anxiety; 'we have blotted from the mind of the nation the foot, and a knowledge of every measure into which it enters as a unit.' This is evidently a serious business. It reminds of the sad case of the lad, who, having eaten his cake, desired to have it again. The committee go on to explain that, instead of twenty-five feet, we shall have to say something else; and instead of one hundred and forty-five miles we shall have to say something else still. And, exploring the extent of the calamity, the committee become gloomily figurative; and, speaking with deep emotion of "the cubic foot, known wherever the English language is spoken," they tell us that this cherished object "is also gone, and in the twilight of its existence we grope about for a substitute." I do not deny that this is eloquence; but I respectfully submit that it is not argument. There cannot but be some of us who will consider that this tenderly lamented cubic foot, with its inconvenient numerical relation to the cubic inch of 1728 to 1, and its more inconvenient relation to the common unit of liquid capacity of 1728 to 231; and its even still more inconvenient relation to the unit of dry capacity of 1728 to 2,150.42 is very well out of the way.

"I will not attempt to follow the committee further in their lament. But I cannot omit to notice, in passing, the perplexing embarrassment of the honest man who, setting out to purchase the convenient quantity of fourteen

rounds of beef for his dinner, after there have ceased to be any pounds, is astounded at finding that he will be compelled to pay for the amazing number of grammes expressed by the figures six thousand three hundred and fifty-six; or in case that he is bankrupted by this huge demand, will be permitted to compromise the matter only on condition of buying six Kilogrammes, three hectogrammes, five decagrammes, and six grammes. I wish to present a parallel to this. I go to my tailor for a coat, and he states to me the price, in a sum expressed by the four digits named above, in the same order, viz., six, three, five, six. The committee has given the general rule for reading concrete decimal numbers as follows: 'All the readings are made in the lowest unit.' Hence, the cent being the lowest money unit involved in the price named, my tailor is under the necessity of informing me that I can have the coat for six thousand three hundred and fifty-six cents; and it will not be lawful for him to vary the form of expression in any manner unless to say, by way of alternative, that he will give me the coat for six eagles, three dollars, five dimes, and six cents.

"I would, however, advise the unfortunate man who finds so much trouble with his marketing, not to buy his meat by the pound, after pounds have gone out of date; but to content himself with a round six Kilogrammes, or, in case he is very hungry, say six and a half."

SEVENTH OBJECTION.

"THE NOMENCLATURE TOO DIFFICULT, AND DERIVED FROM A FOREIGN LANGUAGE."

Prof. Davies, of West Point, in his eloquent lecture, delivered three years ago in New York, on the fearful and

disastrous consequences which are to be expected upon the introduction of a strange system of weights and measures into the United States, asks, "Can we abandon our short, sharp Saxon words, for their equivalents expressed in a foreign language?" I fear this bitter sacrifice must be made. The short and sharp Saxon *yard* must be given up for the clumsy *meter*, and the familiar *dram* must yield to the *gram*, — mysterious word derived from an unknown tongue! — though here, indeed, the difference will not be so keenly felt, as but one letter is altered, and we shall find some consolation for the loss of our dram in reflecting that it is no less of Greek origin than gram.

Then, again, it is exceedingly gloomy to reflect that our short and simple *Kilderkins*, *barleycorns*, *pennyweights and hundredweights*, must make way for the unpronounceable and incomprehensible *liters*, *centimeters*, *centigrams and Kilograms*. Nay, even our dearly beloved and graceful *hogsheads* and *puncheons*, to say nothing of our delicate *pipes* and *butts*, must all be swept away to make room for the clumsy foreigner. It is true the new names are no more foreign than such words as *dime*, *cent*, *mill*, *telegram*, *stereotype*, *photograph*, and a hundred others, which, like decigram, centigram and milligram, are derived from the Greek and Latin. Yet we should be sorry to be obliged to give up the use of all the valuable articles above enumerated, simply because their names were, for the convenience of scholars, of foreign origin. Avoirdupois and Troy (from the Ville de Troyes) are both French words.

Moreover, it must be borne in mind that the metric nomenclature is compounded of but twelve very short words, no one of the compounds containing over five letters. If, however, any one finds these twelve words too much for him, after having struggled for a lifetime in the vain attempt to master the endless old ones, he may still use the short and

sharp Saxon names in his private affairs, even after the rest of the world has long accommodated itself to the new system, just as many people among us still use the old words shillings and pence, though the majority of the public have accustomed themselves to the use of those inconvenient Latin words *dime*, *cent* and *mill*.

Charles Sumner, in his address to the Senate in 1865, advocating the Metric System, says, "A system intended for universal adoption must discard all local or national terms. The prefixes employed are equally intelligible in all countries. They are no more French than English or German. They are in their nature common or cosmopolitan, and in all countries they are equally suggestive in disclosing the denomination of the measure. They combine the peculiar advantages of a universal name and a definition. The name instantly suggests the measure with exquisite precision."

EIGHTH OBJECTION.

"THE DECIMAL DIVISION HAS FAILED WHEN APPLIED TO THE CIRCLE."

In answer to this objection we quote the words of Delambre, who will certainly be admitted as good authority on the subject. In his description of the operation of measuring the great French meridian arc, he says, "Three of our four circles were divided into decimal grades or degrees, each having the value of $360° \div 400 = 0.9° = 540' = 3240''$. This division is much the most convenient for the uses of the repeating circle, and would be equally so for the verniers of all instruments whatever. Many persons hold to the old system by habit, and because they have made no use of the new; but no one of those who have practised both

will willingly return to the old." Some engineers of the present day have the verniers of their theodolites divided decimally, on account of the great convenience of the decimal division in laying out railroad curves.

NINTH OBJECTION.

"THE UNIT OF LENGTH SHOULD BE SOME DIMENSION OF THE HUMAN PERSON."

The foot is our unit of length, and they say it is taken from the human foot. The average length of the human foot is, however, 10.058 inches, and not 12 inches. Therefore, whatever may have been the origin of any of the other 100 feet before mentioned, the unit, at least, of *our* present system is *not* taken from the human foot, though this scarcely needs demonstration, for if any one possessing a foot of his own believes it to be twelve inches long, he has only to measure it and see that he gives himself credit for more than he possesses. It is derived from the yard, or original English unit, which was taken from the arm of Henry I. in 1101. In the Metric System, however, the unit of measure is the length from the ends of the fingers of the right arm stretched out to the left ear. The breadth of the palm is a decimeter, and of the end of the little finger a centimeter. A pace is $\frac{9}{10}$ (nine-tenths) of a meter. Hence 50 paces are 45 meters; 100 paces, 90 meters, etc.

TENTH OBJECTION.

"THE EXPENSE OF MAKING THE CHANGE TOO GREAT."

In answer to the objection, so often urged, that the adoption of the international weights and measures would be a source of great inconvenience and expense at first to machinists and manufacturers, we add the following:

That the advocates of the system have made diligent and ample inquiries of machinists and manufacturers in various countries of Europe, and find that the objection is one of theory, and not of fact, as those who have actually tried the experiment testify. The machinery was required to be replaced by new only after the old was worn out, and special provision was made by law for all cases where the expenses of the transition would otherwise fall too heavily. German legislation shows that the government took good care that none of its subjects should be bankrupted by this change. Every precaution was taken, and every difficulty foreseen and provided for, so that, when the change was actually made, the public found no such trouble as had been predicted, but the cost was so distributed that the burden was felt by none. The American Watch Company, at Waltham, turns out an average of 360 watches a day, or about 108,000 a year. Eight years ago this enterprising company, chiefly for the purpose of increasing the accuracy and perfection of their work, adopted exclusively the metric system; and now every machine in that great workshop is gauged to the meter and its subdivisions. Nevertheless, they are still in a flourishing condition! Inasmuch as the old machinery was largely worn out when replaced by the new, it has been estimated that the actual loss sustained in altering the gauges and tools of all kinds was little or nothing.

When an extensive factory like the above finds it economical, alone and unaided, to accomplish with success a complete revolution in its system of weights and measures, adopting one which places it at variance with all its immediate neighbors, of what avail is it to theorize on the impracticability of our adopting, without great expense, one which not only will be used in common by all our countrymen, but which will place us at once in harmony with the majority of the civilized nations of the globe?

ELEVENTH OBJECTION.

"THE BASE NOT WELL CHOSEN NOR CORRECTLY DETERMINED."

If the system was once open to this criticism, scientific men having, in some cases, objected to it on account of inaccuracy in the determination of its base, the objection has evidently now ceased to be valid. Since the method proposed in 1872, for rendering the unit of length no longer dependent upon accurate measurement of the earth's meridian, has been adopted, the meter, though an artificial standard, has nevertheless become invariable. Whether or not it would have been better in the beginning to have chosen the ten-millionth part of something else, say the diameter of the earth or that of the sun, rather than of the quadrant of the earth's meridian, is no longer a matter of the least practical importance, since, once chosen and reproduced, as above described, it can hereafter never again be altered.

Having thus briefly considered the most reasonable of the objections made against the system, we will conclude by giving what we believe to be the best method of familiarizing the public with the Metric values.

SYSTEM OF INSTRUCTION ADOPTED IN GERMANY.

Nothing can give so lasting and correct a conception of a thing as the direct view of it in its actual proportions. With this principle in view, the present advanced system of instruction in German schools aims at combining as far as possible with verbal explanation the actual exhibition, either by drawings or by models, of the object to be taught. In this way much time and trouble is saved.

Just before the Metric System was enforced in Germany, a committee of teachers was called together for the purpose of determining the best method of familiarizing the public with the Metric values. The following was one of the most excellent methods largely adopted in the schools.

By this method no comparison between the old and new systems is necessary to explain the Metric values, and no geometrical knowledge is presupposed. The work is done by bringing models of the new weights and measures directly before the eyes of the student and explaining their relations to each other.

In order to accomplish this, a certain amount of apparatus is necessary. There is required, *first*, what the Germans call a "Schulmeter;" *second*, a large chart giving a full-size drawing of the square meter, with its various subdivisions; *third*, a chart like that which accompanies this book; *fourth*, a decimeter cube, which can be taken apart and resolved into its component centimeter cubes; and, *fifth*, a hollow cubical box made of tin, and

large enough to contain exactly the above-mentioned decimeter cube, to illustrate the measures of capacity, both dry and liquid, and the relations of the same to the measures of length and volume. Being made to contain exactly a cubic decimeter, this box represents the *liter*, and, when filled with water at 4° Centigrade, its weight represents the Kilogram. Thus the mutual relations of the weights and measures is seen at a glance, and the impression produced is positive and permanent.

The Metric values and the whole principle of the system may be well taught in an hour with this apparatus.

Without it, to attempt to convey a clear idea of the new values, by numerical comparison with the old, is a tedious and unsatisfactory task, expensive of time, and productive of no permanent results. It gives us numbers, but no ideas.

We should have also at hand a hollow tin deciliter, which, filled with water, will give us the hectogram; a hollow centiliter, to illustrate the dekagram; and a hollow milliliter or hollow centimeter cube to illustrate, filled with water, the gram or unit of weight. (See Chart.)

The "School Meter" is a square piece of wood, one meter long, three centimeters wide, and three centimeters thick. One side is left clear, without division marks, and represents the meter length. The second side is subdivided into ten equal parts or decimeters, painted in colors alternating light and dark. (See chart.)

The third side shows, in addition to the decimeters, the further decimal subdivisions of centimeters, the first light-colored decimeter being divided up into centimeters alternating black and white; and finally the first white centimeter is again subdivided into alternating black and white millimeters.

The fourth and last side is divided like the regular meter used in actual measurements.

By means of this device a large class may be instructed at once, as the colors and peculiar arrangement of the subdivisions allow even the smallest of them to be distinctly seen from a great distance.

The various sides of the meter may be explained in succession, beginning with that without divisions, and stating that it represents the unit of length a distance equal to about one ten-millionth part of the quadrant of a meridian, explaining the principles of its subdivision, its relation to the measures of weight, volume and capacity, and comparing it with various linear magnitudes in the room, as, for instance, the height of the table, the breadth of the door and windows, etc.

In the same way the remaining three sides may be explained in succession, and afterwards the rest of the apparatus may be similarly treated.

The multiples of the meter may be represented by cords, with divisions a meter apart, indicated by knots painted black for greater distinctness.

METRIC NOMENCLATURE.

Most approved Spelling, Pronunciation, and Abbreviation, as adopted by the American Metric Bureau, and by the American Metrological Society.

Spelling.	Pronunciation.	Abbreviation.
meter,	(meeter) like gas-meter . . .	m.
liter,	(leeter) " pique	l.
gram,	(grăm) " dram	g.
ar,	(ar) " are	a.
deci,	(dĕsĭ) " decimal . . .	d.
centi,	(sĕntĭ) " cent	c.
milli,	(mĭlĭ) " mill	m.
deka,	(dĕka) " decade	D.
hekto,	(hĕktō) " hecatomb . . .	H.
kilo,	(kĭlō) " chiliad	K.
myria,	(mĭrĭa) " myriad	M.

ABBREVIATION.

To abbreviate the pronunciation of the compound words, the whole of the first component part or prefix is pronounced, together with the first letter of the second component part or unit, as kīlōg., millīm, centīm, Hectōg., etc., the letters in this case, of course, retain their regular

pronunciation. These words are words already largely used, and, consisting of only six letters and two syllables, are no longer than the boasted short Saxon words *inches* and *ounces*. In some cases the superiority of the metric nomenclature is at once apparent, as in the case of "millim," instead of *sixteenth of an inch*.

SPELLING.

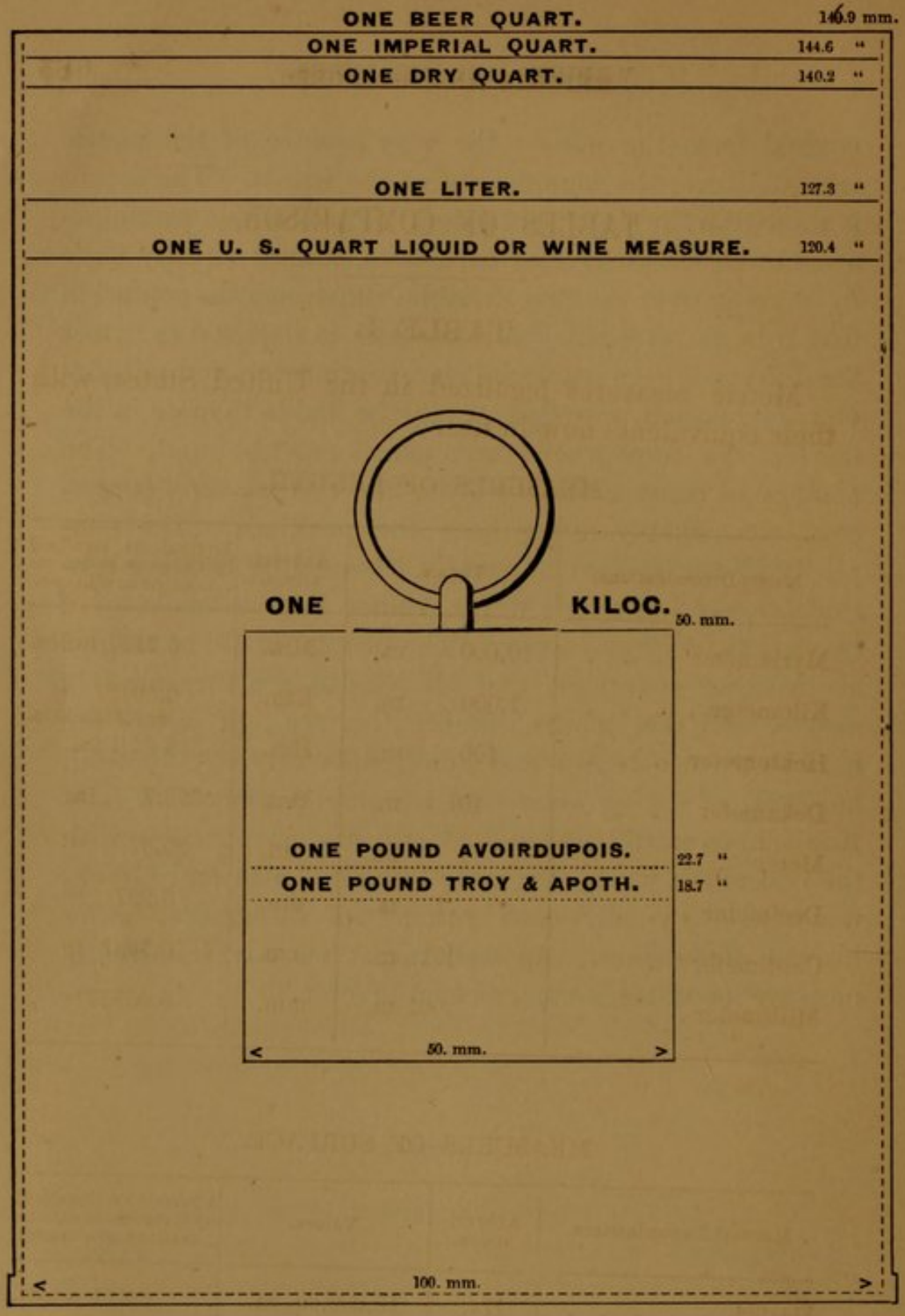
The spelling of the above words is in conformity with the German spelling, and with their pronunciation.

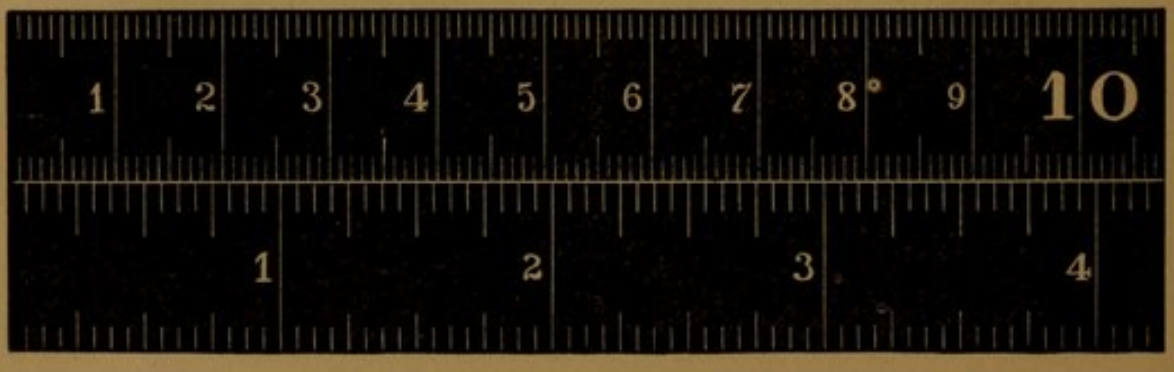
Meter, moreover, is already spelled with the termination *er*, not *re*, both in the original word, signifying "measure," i. e., *gas-meter*, and in the compounds *thermometer*, *barometer*, *diameter*, etc. The final *me* is omitted from "gram" also, for brevity (a practical reason of great importance in this case). *Gramme* is sometimes mispronounced *grammy*. The *k* is used in *deka* to distinguish the word from *deci*. The advantages in pronunciation and etymology for this spelling are important. It is also in conformity with the government reports of Germany, England, and the United States. Consistency with *deka* requires *hekto*. *Ar* omits the final *e*, both to insure its correct pronunciation and to distinguish it from the verb *are*. Consistency with *ar* requires *ster*.

ACCENT.

The accent of every prefix, and every unit, is on the first syllable in the simple words as well as in their compounds. "The pronunciation," says the report of the American Metric Bureau on this subject, "centim′-eter, decim′-eter, kilom′-eter, etc., should never be used. It is out of harmony with the rest of the world, and serves to

conceal from the masses the very essence of the metric nomenclature, the significance of the words. The accent is wanted in the significant place. The common pronunciation of *thermometer* and *barometer*, almost exactly alike by slurring over the first syllable, illustrates the confusion that is to be avoided. A close ear is required to detect the difference between decim′eter, centim′eter, and millim′-eter, and serious mistakes would be liable to arise in the noise of the shops where these names must be used. The analogy of many English words, like *thermometer*, *barom-eter*, etc., simply strengthens the positions. The simplicity of the system is greatly lessened by treating centim′eter, etc., as single words, rather than as made up of two words, *centi* and *meter*. The people should be taught, as in other countries, that all lengths are measured in *meters*, and that tenths, hundredths, etc., of *meters* are used as we use tenths and hundredths of *feet*. Instead, however, of saying *hundredth measure*, a name that only Englishmen would understand, we say, in common with the rest of the world, the same thing in Latin and Greek, understood by all, *centi* instead of *hundredth*, *meter* instead of *measure*. As well might we say hundredth′ measure′ or waterm′-eter, as centim′-eter."


ONE BEER QUART.
146.9 mm.
ONE IMPERIAL QUART.
144.6 "
ONE DRY QUART.
140.2 "
ONE LITER.
127.3 "
ONE U. S. QUART LIQUID OR WINE MEASURE.
120.4 "
ONE KILOG.
50. mm.
ONE POUND AVOIRDUPOIS.
22.7 "
ONE POUND TROY & APOTH.
18.7 "
50. mm.
100. mm.


1 2 3 4 5 6 7 8 9 10
1 2 3 4

TABLES OF COMPARISON.

TABLE I.

Metric measures legalized in the United States, with their equivalents now in use.

MEASURES OF LENGTH.

Metric Denominations.	Values.	Abbreviations.	Equivalents legalized by Congress in denominations now in use.
Myriameter . . .	10,000 m.	Mm.	6.2137 miles.
Kilometer	1,000 m.	Km.	0.62137 " or 3280 ft. 10 in.
Hektometer . . .	100 m.	Hm.	328 ft. 1 in.
Dekameter . . .	10 m.	Dm.	393.7 in.
Meter	1 m.	m.	39.37 "
Decimeter	.1 m.	dm.	3.937 "
Centimeter . . .	.01 m.	cm.	0.3937 "
Millimeter	.001 m.	mm.	0.03937 "

MEASURES OF SURFACE.

Metrical Denominations.	Abbreviations.	Values.	Equivalents legalized by Congress in denominations now in use.
Hectar	Ha.	10,000 sq. m.	2.471 acres.
Ar	a.	100 sq. m.	119.6 sq. yds.
Centar	ca.	1 sq. m.	1550 sq. in.

MEASURES OF CAPACITY.

Metric Names.	Abbreviations.	No. of Liters.	Dry Measure.	Liquid or Wine Measure.
Kiloliter or Ster	Kl. st.	1000	1.308 cu. yds.	264.17 gals.
Hektoliter . . .	Hl.	100	2 bu. 3.35 pks.	26.417 "
Dekaliter . . .	Dl.	10	9.08 qts.	2.6417 "
Liter	l.	1	0.908 qt.	1.0567 qts.
Deciliter . . .	dl.	.1	6.1022 cu. in.	0.845 gill.
Centiliter . . .	cl.	.01	0.6102 " "	0.338 fld. oz.
Milliliter . . .	ml.	.001	0.061 " "	0.27 fld. dr.

WEIGHTS.

Metric Denominations and Values.			Weight of what quantity of Water at maximum.	Equivalent in denominations now in use. Avoirdupois weight.
Names.	Abbreviations.	No. of Grams.		
Metric Ton . . .	M. T.	1,000,000	1 cu. meter.	2204.6 lbs.
Quintal	Q.	100,000	1 hektoliter.	220.46 "
Myriagram . . .	Mg.	10,000	10 liters.	22.046 "
Kilogram or Kilo .	Kg.	1,000	1 liter.	2.2046 "
Hektogram . . .	Hg.	100	1 deciliter.	3.5274 oz.
Dekagram . . .	Dg.	10	10 cu. centim.	0.3527 "
Gram	g.	1	1 " "	15.432 grs.
Decigram . . .	dg.	.1	.1 " "	1.5432 "
Centigram . . .	cg.	01	10 cu. millim.	0.1543 "
Milligram . . .	mg.	.001	1 " "	0.0154 "

TABLE II.

ENGLISH AND METRIC EQUIVALENTS ARRANGED ALPHABETICALLY.

The following table is based on these two equations given by the best British authorities:—

1 meter = 39.3707904 inches.
1 gram = 15.43234874 grains.

NOTE.—For all practical purposes the ratios need be carried out to three or four decimal places only. Indeed it is doubtful whether more than this is ever to be recommended, except in special cases where the utmost accuracy is required for scientific purposes, and then only when the special history of each standard and its comparisons is taken into account, since a variation of two or three degrees in the temperature of the standards would generally produce in them a change of value greater than any difference in figures beyond the third decimal place. Moreover, authorities disagree in these small figures. The value of the pound in Kilograms, according to Rankine, differs from that of Alexander by about one part in 19,000,—a difference which would exceed that produced by a variation of figures beyond the third or fourth decimal place.

Trantwine gives the U. S. yard as longer than the British by about one part in 17,230, but the following extract from a letter dated March 21st, 1877, just received from our best authority on the subject, J. E. Hilgard, Inspector of the U. S. Standard Weights and Measures, shows how a general misunderstanding on the subject has arisen, and states that, as nearly as they can be measured, the U. S. and British standards are now the same.

"The American Yard and Pound are precisely the same as the British Imperial Standards of the same names. . . . . .

"We possessed no verified copy of the British Yard until 1855, when the new British Standards were completed and distributed. We had used 36 inches of a scale made by Houghton and Simms for the Coast Survey which was supposed to be exact at 62° Fahrenheit, but on comparison with a copy of the British Standard in 1855, it was found slightly too long at that temperature, and proves to be standard at 59°.4 Fahrenheit. Hence have arisen some statements giving for the meter a different value in American inches from that expressed in British inches. There is in fact no such difference."

TABLE II.

			Logarithms.
ACRE	= 40.46710	Ares	1.607102
ANKER	= 4.54346	Dekaliters	0.6573867
AR	= 0.09885	Rood	—2.9949767
"	= 0.02471	Acre	—2.3928727
"	= 3.95383	Square Rods	0.5960180
BARREL (U. S. Wine)	= 1.19259	Hectoliters	0.0764911
" (Imp. Wine)	= 1.63564	"	0.2136877
" (Beer)	= 1.66232	"	0.2207146
BUSHEL (U. S. Dry)	= 0.35243	"	—1.54708
" " "	=35.243	Liters	1.54708
" (Imp.)	=36.3233	"	1.5601853
BUTT OR PIPE (U. S. Wine)	=477.036	Liters	2.6785511
" " " (Imp. Wine)	=490.693	"	2.6908098
CENTAR	=(1 sq. meter) = 10.76430	Square Feet	1.03198579
"	" " = 1.19603	Square Yards	0.0777420
CENTIGRADE 1°	=1.8°	Fahrenheit	
CENTIGRAM	= 0.15432	Grain Troy	—1.1884222
"	= 0.00564	Dram Avoirdupois	—3.7512791
CENTILITER	= 0.08452	Gill (U. S.)	—2.9269595
CENTIMETER	= 0.39371	Inch	—1.5951764
"	= 3.93708	Lines	0.5951742
" (sq.)	= 0.15500	Square Inch	—1.1903317
" (cu.)	= 0.06103	Cubic Inch	—2.7855434
" "	= 16.22821	Minims	1.2102703
" "	= 0.27047	Fluid Drachm	—1.4321191
" "	= 0.03381	" Ounce	—2.5290452
CENT	= 5.18	Centimes	0.7143298
CHALDRON	= 1.12778	Kiloliters	0.0512252
CORD	= 3.62436	Cubic Meters	0.5592315
CORD FOOT	= 0.45304	" "	—1.6561365
DECIMETER	= 0.32809	Foot	—1.5159930
"	= 3.9371	Inches	—1.5951764
" (sq.)	= 15.50059	Square Inches	1.1903485
" "	= 0.10764	Square Foot	—1.0319737
" (cu.)	= 61.02705	Cubic Inches	1.7855225
" "	= 0.03532	" Foot	—2.5480207
DECILITER	= 0.84522	Gill (U. S.)	—1.9269698
"	= 0.21130	Pint (U. S.)	—1.3248995
"	= 0.10565	Quart (U. S.)	—1.0238695
"	= 0.17325	Beer Pint	—1.2386732
"	= 0.18160	Dry "	—1.9251158

TABLE II. — *Continued.*

			Logarithms.
DECIGRAM	= 0.05643	Dram Avoirdupois	—2.7515101
"	= 1.54323	Grains Troy	0.1884278
"	= 0.06430	Pennyweight Troy	—2.8082110
DEKALITER	= 1.13497	Pecks	0.0549844
"	= 0.24063	Firkin	—1.3813498
"	= 0.12228	Runlet	—1.0873554
"	= 0.22010	Anker	—1.34262
DEKAMETER	= 1.98842	Rods	0.2985081
"	= 32.80899	Feet	1.5159930
"	= 10.93633	Yards	1.0388716
" (sq.)	= 119.60332	Square Yards	2.077432
" "	= 0.02471	Acre =(1 Ar)	—2.3928727
" "	= 3.95383	Square Rods "	0.5960180
" (cu.)	=1308.0215	Cubic Yards	3.1166143
DIME	= 0.51780	Franc	—1.7141620
DOLLAR	= 5.1826	Francs	0.7145477
DRACHM (Apoth.)	=3.88794	Grams	0.5897195
" (Fluid)	=3.69727	Cubic Centimeters	0.5677811
" (Avoirdupois)	= 1.77185	Grams	0.2484269
EAGLE	= 51.826	Francs	1.7145477
FAHRENHEIT 1°	= 0.555°	Centigrade	
FATHOM	= 1.82877	Meters	0.2611852
FIRKIN	= 4.15579	Dekaliters	0.6186546
"	= 0.41557	Hectoliter	—1.6186546
FLUID DRACHM	= 3.69727	Cubic Centimeters	0.5678810
" OUNCE	= 29.57812	" "	1.4709702
FOOT	= 0.30479	Meter	—1.4830007
"	= 3.04794	Decimeters	0.4830063
"	= 30.47944	Centimeters	1.483006
" (sq.)	= 0.09290	Square Meter	—2.9680157
" "	= 9.28996	" Decimeters	0.9670137
" (cu.)	= 0.02832	Cubic Meter or Stere	—2.4520932
" "	= 28.31531	Cubic Decimeters	1.4510212
" (cord)	= 0.45304	Cubic Meter or Stere	—1.6561365
FRANC	= 0.19295	Dollar	—1.2854448
FURLONG	= 2.01164	Hectometers	0.3035502
"	= 0.20116	Kilometer	—1.3035416
GALLON (U. S. Wine)	= 3.7859	Liters	0.57815
" (Imp. Wine)	= 4.54346	"	0.6573867
" (Beer)	= 4.61754	"	0.6644106
GILL (U. S. Wine)	= 0.11831	"	—1.0720215
" (Imp. Wine)	= 0.14198	"	—1.1512272
GRAIN (Troy)	=64.79895	Milligrams	1.8115683

TABLE II. — *Continued.*

			Logarithms.
GRAIN (Troy) =	6.47989	Centigrams	0.8115683
" =	0.64798	Decigram	—1.8115683
" =	0.06480	Gram	—2.8115683
GRAM =	15.43235	Grains Troy	1.1884334
" =	0.64301	Pennyweight	—1.8082177
" =	0.56438	Dram	—1.7515716
" =	0.77162	Scruple	—1.8874035
" =	0.03527	Ounce Avoirdupois	—2.5474055
HAND =	0.10160	Meter	—1.0068937
" =	1.01598	Decimeters	0.0068937
" =	10.15981	Centimeters	1.0068937
HEKTOGRAM =	3.21507	Ounces Troy	0.5071904
HEKTOLITER =	0.83851	Barrel (U. S.)	—1.9235082
" =	0.62888	Tierce "	—1.7985678
" =	0.41926	Hogshead "	—1.6224834
" =	0.20963	Pipe "	—1.3214534
" =	1.04814	Tuns "	0.02041930
" =	0.61138	Imperial Barrel	—1.7863112
" =	0.40759	" Hogshead	—1.6102235
" =	0.26202	" Puncheon	—1.4183344
" =	0.20379	" Pipe	—1.3081829
" =	0.10190	" Tun	—1.0081742
" =	1.20314	Kilderkins	0.0803161
" =	0.60157	Beer Barrel	—1.7792862
" =	0.38672	" Hogshead	—1.5873966
" =	2.83742	Bushels	0.4529236
" =	0.35468	Dry Quarter	—1.5498367
HEKTOMETER =	0.49711	Furlong	—1.6964525
" =	19.88440	Rods	2.2985124
" =	109.36420	Yards	2.0388743
" =	328.09260	Feet	2.5159969
" (sq.) =	2.47114	Acre	—0.3928903
HEKTAR =	0.00386	Square Mile	—3.5865873
" =	2.47114	Acres	0.3928903
HEWN TON =	1.41577	Cubic Meters	0.1509928
HOGSHEAD (U. S. Wine) =	238.518	Liters	2.3775229
" (Imp. Wine) =	245.34673	"	2.3896037
" (Beer) =	258.58236	"	2.4125989
HUNDRED WEIGHT (100 lbs.) =	45.35926	Kilogs	1.6566663
" " (112 lbs.) =	50.80238	"	1.7058842
INCH =	2.53995	Centimeters	0.4048251
" (sq.) =	6.45136	Square Centimeters	0.8096512
" (cu.) =	16.38617	Cubic "	1.2144809

TABLE II. — *Continued.*

			Logarithms.
KILDERKIN	=	0.83116 Hectoliter	—1.9196846
KILOGRAM	=	2.20462 Pounds Avoirdupois	0.3433337
"	=	0.08818 Quarter (25 lbs.)	—2.9453701
"	=	0.07874 " (28 lbs.)	—2.8961954
"	=	0.022046 Hundred Weight (100 lbs.).	—2.3433298
"	=	0.019684 " " (112 lbs.).	—2.2941134
"	=	2.67923 Pounds Troy	0.4270099
KILOLITER	=	0.88670 Chaldron	—1.9477767
KILOMETER	=	0.62138 Mile	—1.7933573
"	=	0.20713 League	—1.3162430
LEAGUE	=	4.82794 Kilometers	0.6837619
LINE	=	0.25400 Centimeter	—1.4048337
LITER	=	8.451219 Gills	0.9269693
"	=	2.11305 Pints	0.3249098
"	=	1.05652 Quarts	0.0238775
"	=	0.26413 Gallon	—1.4218177
"	=	7.04309 Imperial Gills	0.8477639
"	=	1.76077 " Pints	0.2457026
"	=	0.88039 " Quart	—1.9446751
"	=	0.22010 " Gallon	—1.3426200
"	=	0.02838 Bushel (U. S. Dry)	—2.4530124
METER	=	3.28090 Feet	0.5159930
"	=	9.84270 Hands	0.9931142
"	=	1.09363 Yards	0.0388703
"	=	0.54681 Fathom	—1.7378364
" (sq.)	=	1.19603 Square Yards	0.0777423
" "	=	10.76440 Square Feet	1.0319857
" (cu.)	=	35.31658 Cubic Feet	1.5479788
" "	=	2.20729 Cord "	0.3438614
" "	=	1.30802 Cubic Yards	0.1166177
" "	=	0.88291 Round Ton	—1.9459164
" "	=	0.84087 Shipping Ton	—1.9247289
" "	=	0.70633 Hewn Ton	—1.8480077
" "	=	0.27591 Cord	—1.4407674
MILE	=	1.60931 Kilometers	0.2066397
" (sq.)	=	258.98944 Hectares	2.4132822
MILL	=	0.518 Centime	—1.7143298
MILLIGRAM	=	0.015432 Grain	—2.1884222
MILLIMETER	=	0.039370 Inch	—2.5950551
" (sq.)	=	0.00155 Square Inch	—3.1903317
" (cu.)	=	0.00061 Cubic "	—4.7853298
MILLILITER	=	0.00845 Gill	—3.9268567
MINIM	=	0.06162 Cubic Centimeter	—2.7897217
MYRIAGRAM	=	26.79227 Pounds Troy	1.4270096

TABLE II. — *Continued.*

	Logarithms.
MYRIAMETER = 6.21382 Miles	0.7933587
OUNCE (Avoirdupois) = 28.34954 Grams	1.4525457
" (Troy) = 31.10349 "	1.4928093
" (Fluid) = 29.57812 "	1.4709704
PECK = 0.88108 Dekaliter	—1.9440153
PENNYWEIGHTS = 1.55517 Grams	0.1917779
PERCH = 0.50291 Dekameter	—1.7014903
PINT (U. S.) = 0.47325 Liter	—1.6750906
" (Imp.) = 0.56793 "	—1.7542948
" (Beer) = 0.57719 "	—1.7613188
" (Dry) = 0.55067 "	—1.7408914
PIPE (U. S.) = 4.77036 Hectoliters	0.6789151
" (Imp.) = 4.90693 "	0.6908098
POUNDS (Avoirdupois) = 0.45359 Kilogram	—1.6566635
" (Troy and Apoth.) = 0.37324 "	—1.5719882
PUNCHEON = 3.81650 Hectoliters	0.5816653
QUART (U. S.) = 0.9465 Liter	—1.9761206
" (Imp.) = 1.13586 "	0.0543113
" (Beer) = 1.15438 "	0.0623489
" (Dry) = 1.10135 "	0.0419253
QUARTER (25 lbs.) = 11.33981 Kilograms	1.0546068
" (28 lbs.) = 12.70059 "	1.1038243
" (Dry) = 2.81946 "	0.4501660
QUINTAL (100 Kilog.) = 267.92273 Pounds Troy	2.4270095
ROD = 0.50291 Dekameter	—1.7014903
ROD SQ. = 0.25292 Ar	—1.4029832
ROOD = 10.11677 "	1.00504187
ROUND TON = 1.13261 Cu. Meters	0.0530804
RUNLET = 8.17822 Dekaliters	0.9126587
SCRUPLE = 1.29598 Grams	0.1125987
SHIPPING TON = 1.18924 Cu. Meters	0.0752697
STER (1 Cu. Meter) = 35.31658 Cu. Feet	1.5479785
TIERCE = 1.59012 Hectoliters	0.2014271
TON (2,000 lbs.) = 0.90719 Ton	—1.9576983
" (2,240 lbs.) = 1.01605 "	0.00681508
" (1,000 Kilogs.) = 1.10231 " (2,000 lbs.)	0.0423037
" " ") = 0.9844 " (2,240 lbs.)	—1.9930878
" (Shipping) = 1.18924 Cu. Meters	0.0752697
" (Round) = 1.13261 "	0.0530804
TUN (U. S. Wine) = 9.54072 Hectoliters	0.9795811
" (Imp.) = 9.81387 "	0.9918403
YARD = 0.91438 Meter	—1.9611267
" (Sq.) = 0.83610 Sq. Meter	—1.9222582
" (Cu.) = 0.76451 Cu. Meter	—1.8833832

APPENDIX.

AMERICAN METRIC BUREAU.

General Office, Tremont Place, cor. Beacon street, Boston.

For the great progress made by the metric system, within the last year, we are indebted largely to the establishment, in 1876, of the American Metric Bureau.

The nature of this organization is best explained by Art. 2 of its Constitution, which reads: —

"The object of this Bureau shall be to disseminate information concerning the metric system; to urge its early adoption; and to bring about actual introductions wherever practicable. To this end it will secure the delivery of addresses; publish articles; circulate books, pamphlets, and charts; distribute scales and measures; introduce the practical teaching of the system in schools; and in all proper ways, as far as the means at its disposal will allow, the Bureau will urge the matter upon the attention of the American people till they shall join the rest of the world in the exclusive use of the International Decimal Weights and Measures."

While all discussions on the theory of the system, its merits and its application to the various requirements of science, and the whole question of international coinage, are referred to the American Metrological Society, the Bureau devotes itself to the actual introduction of the system into schools and into general public use.

The influence of this Bureau has already begun to be widely felt. It publishes an official monthly journal (the "Metric Bulletin"), which is widely circulated, and the "New England Journal of Education," the leading educational paper of the country, has a special metric department, edited by the Secretary of the Bureau.

The Metrological Society and the Metric Bureau have made strenuous efforts to render a thorough knowledge of the metric system obligatory for admission to the colleges of the United States, to have it taught in all the schools, and to have the terms of the system employed, as far as practicable, in the daily instruction of the class-room. To accomplish this, circulars have been sent to the various schools and colleges throughout the country, with the most satisfactory results, a large number having already returned favorable answers, and reported that the steps recommended had been taken.

AMHERST COLLEGE LIBRARY.

To illustrate what has been done by enterprising advocates of the system to spread a practical knowledge of the metric units, the following is quoted from the "Metric Bulletin": —

"For the last four years all measurements have been made in metric denominations. Everything has been included, and not simply the designation of size in the catalogues. The carpenter's work on shelves, counters, tables, check-lists, etc., is from metric specification. All blanks, cards, binding lists, etc., are made in metric sizes. . . . The prices for binding are fixed according to the height of the books in cms., and so on throughout the library."

PROGRESS.

From the many encouraging instances of progress cited by the "Metric Bulletin" as made within the last year, we have room only to mention a few.

THE AMERICAN SOCIETY OF CIVIL ENGINEERS

have recently passed a vote (the largest ever made by the society) to further, by all legitimate means, the adoption of the metric standards as the only authorized standards of weight and measure in the United States, and to memorialize Congress in furtherance of this object.

THE AMERICAN INSTITUTE OF MINING ENGINEERS

voted unanimously, according to the "Engineering and Mining Journal" of March 3, 1877, to adopt the metric measures and weights in all papers read before the Institute.

MASSACHUSETTS LEGISLATURE.

The Massachusetts Legislature passed a resolve instructing the State delegation in Congress to forward, by all legitimate means, the adoption of the metric system. This was carried in the Senate by a vote of 25 to 7, and in the House of Representatives by a vote of 73 to 40. Violent opposition was made by a learned clergyman of the House, on account of its alleged atheistical tendency, he himself accepting the pyramid inch of Captain Piazzi Smith as coming directly from the Almighty, and deeming any departure from its use as sacrilegious. (The long list

of 252 different feet that have been used and abandoned by nations now employing the meter seems to us a sorry commentary on the divinity of the foot.) The same opponent, however, explained that the base of the metric system was incorrect, and that, in short, the whole machine was an upstart of despotism, with falsehood for its corner-stone.

ADOPTION OF THE METRIC SYSTEM IN THE MANUFACTURES AND TRADES.

The "Bulletin" gives the names of a large number of manufacturing firms, including furniture-makers, paper manufacturers, philosophical instrument makers, stationers, opticians, watchmakers, tailors and others, who make an extensive, and some, like the Am. Watch Co., at Waltham, *exclusive*, use of the metric measures, and they state that they are doing all that is in their power to hasten its universal adoption.

PHYSICIANS AND DRUGGISTS.

The physicians and druggists are well known to be eager for a reform, for now they are obliged to use both systems, and this trouble will continue until the metric is made the only legal system. The leading medical journal of New York says in a recent editorial: "We have little doubt of a very general adoption of the metric system in this city, and of its early extension to other parts of the country."

METRIC STANDARDS DISTRIBUTED AMONG THE STATES.

Twenty-seven of the United States have already been furnished by the Government with a complete set of metric standards. Each set comprises: —

1 "end" (á bout) measure of cast-steel.
1 "line" (á trait) measure of brass.
1 kilogram of brass.
1 demikilog of brass.
1 gram, with subdivisions down to 1 milligram.
1 ten-kilogram weight.
1 liter of brass.
1 dekaliter.

THE METRIC SYSTEM IN THE POSTAL SERVICE.

Revised Statutes of the United States, title Postal Service, Section 3,880, now reads: "The Postmaster-General shall furnish the post-offices exchanging mails with foreign countries, and to such other offices as he may deem expedient, postal balances denoted in grams of the metric system, fifteen grams of which shall be the equivalent, for postal purposes, of one half ounce avoirdupois, and so on in progression."

Thus it is intended that fifteen grams shall be accepted as a legal letter-weight, where heretofore one-half ounce has been the limit. Fifteen grams is about six per cent. more than one-half ounce. So that by the new law, six per cent. of the bills for postage is saved by those who use the metric balances. This, when generally known, will greatly advance the progress of the new system, since those having heavy correspondence will save a considerable sum annually.

Metric postal balances have already been delivered to post-offices in the following places: Chicago, Boston, Washington, Philadelphia, Baltimore, Cleveland, Buffalo, Annapolis, Corpus Christi, Waltham, Petersburg, San Francisco, St. Louis, Pottsville, Georgetown, and New York.

METRIC COINAGE.

It will be a matter of surprise to most people to learn that our twenty-cent silver pieces and our five-cent nickel pieces weigh just five grams each, so that three of either of these pieces of money weigh fifteen grams, or one letter-weight. The convenience of this will at once be seen. Each man carries his own letter-weights in his pocket. The silver ten-cent piece, moreover, weighs just two and one-half grams, and the fifty-cent piece weighs twelve and one-half grams. Two fifty-cent pieces weigh twenty-five grams. Hence forty dollars' worth of silver weighs just one kilogram, and any silver coin is worth four cents per gram. Sixty cents in silver is therefore one letter rate.

EXTENT TO WHICH THE METRIC SYSTEM HAS BEEN ADOPTED ABROAD.

To render the information given below as reliable as possible, the consuls and others having official or commercial relations with many of the countries cited have been visited, and the latest and best authorities consulted. Especial reference is made to the most thorough work of A. Guislain Lemale, published in Havre, in 1875.

The metric has been made the only legal system in the following countries. (The dates following the names give the years after which the use of the system has been rendered by law obligatory.)

France (1840), *Germany* (1872), *Spain* (1859), *Italy* (1863), *Portugal* (1863), *Holland* (1821), *Belgium* (1836), *Mexico* (1862), *Austria* (1876), *Sweden* (1889), *Brazil* (1872), *Turkey* (1870), *Roumania* (1866), *Moldavia* (1866), *Wallachia* (1866), and the *French*, *Dutch* and *Spanish Colonies* (1866 and 1868).

The system has been adopted in whole by the majority of the *South American States;* and in part by *Switzerland*, *Greece* and *Denmark;* legalized by *Great Britain* in 1864, and in *British India* the Governor-General was authorized, in 1870, to render its use obligatory.

Russia has taken the preliminary steps towards its final adoption. A law of 1870 prescribes the use of the system in all the operations of the Custom House.

COMPULSORY LEGISLATION IN THE UNITED STATES.

Objection has been made to any further legislation by the United States Congress in favor of the metric system, on the ground that it would be contrary to the spirit of our institutions. Every one is at liberty to use it now, it is said, and its advantages ought to bring it into general use without any more legal enactments. So they probably would, after an unnecessarily long period of confusion. But it is now the policy of our law to enforce the use of specified standards in commercial transactions, as a protection to the interests of the buyer. Using weights and measures other than the ones prescribed is forbidden under penalty. This is not because the legal standard is necessarily a good one, but it insures uniformity. Unless men live like Robinson Crusoe, on a desert island, they must submit to many such arbitrary rules for the convenience of society, even though they may not immediately understand their full value. Ultimately the metric will probably be declared the only legal standards, and that enactment will be accepted, just as we accept the rule of the road, and "turn to the right, as the law directs." There is nothing in the nature of things immoral in turning to the left, but *some* law must be established. By fixing in advance the date after which our common measures shall be abandoned, simultaneous action may be secured, and a great deal of the usual annoyance of changing standards may thus be avoided.

Every ordinance of civilized society is in a greater or less degree an act of tyranny by which men have been

deprived, by the intelligence of the few, of their natural inheritance of ignorance and barbarism; and most of them in a greater degree than that bringing order out of chaos by enforcing the use of the metric system.

MEMORIALS TO CONGRESS.

It is not necessary for those who petition Congress to render the use of the metric system obligatory after some date, to be fixed in advance by that body, to enter into a detailed explanation as to how the Government is to legislate for this reform. It is to be presumed that our Legislature will give the matter the full consideration it needs, and appoint a committee of experts sufficiently wise to make the proper laws. The experience of other countries will give ample matter for study and reflection on the part of such a committee. Nor need the advocates of the system refuse to add their petitions to Congress to the rest, on the ground that it is premature. The people have only to let Congress know when *they* are ready, and leave it to that body to decide when the proper time shall arrive for action. They may rest quite sure that Congress will be the last likely to precipitate matters.

DUODENARY OR DUODECIMAL ARITHMETIC.

There are some learned men who oppose the metric system on the ground that the decimal law of progression is not the best than can be devised, and refuse to change our system except for one based on a more perfect law. Others, less learned, claim that our tables are already duodecimal, and oppose a change which would deprive us of the advantages thereof. They do not wish to "decimate," they say, but to "halve and quarter things."

Examining first the position of the latter class we fail to see in what respect our tables are duodecimal, as these latter claim. The duodecimal system of notation is that in which the figure 1 (or the first figure used in numeration, whatever sign may be chosen therefor) followed by 0 has the value of twelve units, and not of ten, as in the decimal system. In this sense the duodecimal does not exist at all, much less could it exist alone in our tables of weights and measures.

Let us now see if our tables are duodecimal in *any* sense. In the only other sense of the word, a duodecimal is a number belonging to a series, all of which are multiples of 12, or the scale of which is 12. A table of weights and measures is in this sense duodecimal when the units therein progress by 12's. We will examine our tables (we can do it with the aid of an arithmetic or cyclopædia), and see if they progress by 12's.

I find the first table usually given in our school books to be that of Federal Currency. In this we have four 10's. There are no duodecimals, but decimals, in *every* sense of the word.

The next table is that of liquid measure. Here we find two 4's, three 2's, one 63, and one $31\frac{1}{2}$. Again no 12's, but instead a 63 and a $31\frac{1}{2}$, neither of which can be "halved or quartered."

Next comes the table of avoirdupois weight. This contains two 16's, one 28, one 4, and one 20. Still no 12's, but, instead, one multiple of 10.

In this way, if we go through all the tables, we shall find every variety of number, with a good share of fractions thrown in for ornament. But how many 12's are there? We will count them.

I have before me fifteen different arithmetics, taken at random from a much larger collection.

In no two of these are the tables exactly alike in form and number. I find them most complete in Walkingame's Arithmetic, an old work. Not including the four 10's in the table of money, nor the numbers in that of English money, these tables contain one hundred and fourteen numbers. Among these appear nine 3's, four 5's, two 7's, five 8's, one 10, three 20's, six 30's, three 40's, one 50, three 60's, two 100's, one 640, one 1,120, six 31's, one 1,728, one $1\frac{1}{2}$, one $5\frac{1}{2}$, one $7\frac{1}{2}$, one $13\frac{1}{2}$, one $31\frac{1}{2}$, one $272\frac{1}{4}$, nine 2's, and eleven 4's.

And how many 12's? Only four! And two of these used for the same thing, namely, to express the relation between the ounce and the pound in *two different tables*.

Only four 12's, with one hundred and fourteen numbers which are not 12's. Adding to the numbers given in these tables those in other arithmetics, but not included in this, we have one hundred and twenty-eight, of which, by the way, six are 10's, and twenty-six are integral multiples of 10. Six contain vulgar fractions, forty-four cannot be evenly quartered, and twenty-seven cannot even be *evenly halved!*

Such are the tables which we so often hear called *duodecimal*.

But it may be objected that these four 12's are oftener used than many of the other numbers; one, for instance, in the table of long measure, where it expresses the relation between feet and inches. It is true that it occupies here a peculiarly important place, and it is for this very reason that our engineers have given it up, — given up the only 12 in this table, and divided the foot into 10. This, too, they have done, knowing that they thereby subjected themselves to the inconvenience of being at variance with their neighbors. Such is the importance which practical men have laid upon having the base of our system of metrology the same as that of our arithmetic.

"THE DECIMAL LAW OF PROGRESSION AN IMPERFECT ONE."

It seems to us that to reject the metric system because the base of our arithmetic is not the most perfect that can be devised is to reject the very first and surest step by which that ideal arithmetic may be obtained.

To render possible so radical a change as that of the base of our system of notation, it is likely that a far higher degree of civilization than the present will have to be attained. At present the public mind would be incapable of foreseeing and appreciating the advantages to result from a revolution of this kind. What better means of paving the way for such an appreciation could be devised than the accomplishment of some kindred reform? The universal adoption of an international system of weights and measures would act as nothing in strengthening the firm foothold already acquired by the decimal in the minds of men, and it could make no appreciable addition

to the difficulty of eradicating it, should the attempt be made at some future time to substitute for the decimal some more perfect base.

Once in the enjoyment of a universal and simple system of metrology, the world will be in a proper condition to look back upon the confusion of the past, and judge from analogy of the advantages which will be likely to come from an improvement of still greater importance. Should the system ultimately adopted happen to be the duodecimal, the *meter*, *liter* and *gram* need not necessarily be altered, but simply duodecimated, or divided duodecimally. Or if such a subdivision were found to render the sub-units too small, one of these sub-units themselves (as the *decimeter*,* for instance, which would preserve the *liter* and *kilogram* without change) might be retained unaltered, and the multiples increased in proportion.

The additional work of changing the values of a few of our units of weight and measure, or even of adopting an entirely new system, would, in the enormous undertaking of altering the base of an arithmetic used for centuries by the entire civilized world, be scarcely more perceptible than an additional grain of sand in the labor of moving a mountain.

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* This length would correspond nearly with that of the "*meton*" given in Mr. Nystrom's very ingenious Duodecimal Tables.

METRIC SYSTEM OF WEIGHTS AND MEASURES.

CHART No. 3, TO ACCOMPANY PUTNAM'S "METRIC SYSTEM."

HALF METER = 5 DECIMETERS = 50 CENTIMETERS = 500 MILLIMETERS.

FIGURES COPIED FROM GOVERNMENT STANDARDS AT WASHINGTON.

PLATINUM WEIGHTS.

BRASS WEIGHTS.

DEMI KILOGRAM. 1 KILOGRAM.

DOUBLE DECIMETER.

1 CUBIC CENTIMETER OR **1000** CUBIC MILLIMETERS = **1** MILLILITER.

10 CUBIC CENTIMETERS = **10** MILLILITERS AND OF WATER WEIGHS **1** DEKAGRAM.

SECTION OF THE INTERNATIONAL STANDARD PLATINUM METER BARS MADE AT PARIS FOR ALL NATIONS.

(Terminal lines or gradua-tions engraved at x.)

American Metric Bureau, Tremont Place, cor. Beacon Street, Boston.

The expansion and contraction of the paper will alter the sketches, but not the relative sizes.