kind of still for use in that type of country. As a general rule two of these tanks are coupled together, as shown in the illustration, and about 1,000 pounds of leaves and terminal branchlets are placed into each tank and 80 to 100 gallons of water added. The lids are suitably sealed with clay and fastened to the tank by means of iron clips or stirrups. A fire is placed beneath the tank and as the water boils it carries the oil over with the steam. Both steam and oil are condensed in long lengths of 2-inch piping (which are connected to the tanks and are carried for a distance of about 50 feet beneath running water in a creek) and collected in a suitable receptacle, usually a 4-gallon petrol tin. The oil is skimmed off the surface of the water and placed in a convenient container such as a 40-gallon petrol drum for transport to a rail or boat head.

Although the stills are crude they are, nevertheless, very efficient if handled in an intelligent manner. They are portable, easily dismantled, and can be moved about from district to district as required.

(An article by the same author, on the chemistry of Eucalyptus Oils, will appear in the following number of this magazine.)

EARLY MEASUREMENTS AND UNITS OF MEASUREMENT, AND HOW WE OBTAINED THE SYSTEMS WE USE TO-DAY.

Part III. The C.G.S. System.

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THIS is the third, and presumably the last article in this series.* It introduces the system of standards and of units universally employed by scientists, and one which is adopted internationally (with few exceptions) for general usage. It is not now a Continental or a

*I plead guilty to having written the two preceding ones also—this Magazine, Vol. I, No. 1, pp. 23-35, and Vol. I, No. 2, pp. 39-43.

French system, though it originated there and still has its headquarters in the French capital; it is an international system, controlled by "Le Bureau International des Poids et Mesures", the committee of which is representative of the people of the world; it is subsidised by practically all nations. Great Britain has been a member since 1884.

France was responsible for its initiation. As in all countries, systems of units were many and confused in France in the 18th Century, there being many recognised but variable units for measuring the same quantity, values varying in different parts of the country. Attempts had been made to rectify this, but no definite or successful measures had been taken to bring order out of confusion. The French indulged, as we do to-day, in "pintes", "boisseau" (bushels), "onces", "grain", "mille", "perch" and such units. Then came the Revolution, and with it a burning desire to reform everything whether it needed it or not; fortunately the reorganisation of the nation's standards and systems of units was entrusted to skilled and meticulous scientists, so that the precision of their observations is still a matter of admiration, and the system of units they established has remained, and has been adopted by the world.

The period 1789 to 1799, ten very disturbed years in France, saw this work begun and completed. By a decree of the 8th May, 1790, from the French National Assembly, an attempt was made to introduce and make compulsory a metric system, and to establish a decimal system based on the "metre", itself intended to represent one ten-millionth part of the quadrant of the meridian through Paris. It was necessary to have standards; the preparation of these standards was entrusted to the National Institute of Science, and appears to have been made in 1795, though they were presented to the legislative body and deposited in the Palais des Archives in Paris in 1799. The scientists primarily concerned with these original national standards ("des Archives") were Borda, Lefevre-Gineau, and Fabbroni. Their standard metre was based on measurements of the meridian made in terms of the old French measure, the "toise", and it was found that the theoretical length of the new metre should be 0·513074 toise. The standard "Mètre des Archives" they produced was a flat bar of platinum, 25 millimetres wide and 4 millimetres thick, and the metre length was defined as the distance between the centres of *the end faces* of this bar, at the temperature of melting ice. Already, you will observe, the definition of the legal standard of length made no reference to the earth's quadrant. To produce the "Kilogramme des Archives" a bronze cylinder of length equal to its diameter (243·5 millimetres) was made, by careful measurement and weighing in water, to have a mass equal to that of a cubic decimetre of pure water at 4° C. From this bronze copy the platinum standard (des Archives) was made; the discrepancy between what it was supposed to be, the mass of a cubic decimetre of water at the temperature of maximum density, and what it was made to be was only 2·7 parts in 100,000—a much more accurate result than could have been expected with the means available 140 years ago.

There was no intention at the time that these should be International Standards, and that a metric and decimal system should prevail throughout all nations. The invitation extended to citizens was "de donner une preuve de leur attachement à l'unité et à l'indivisibilité de la République, en se servant dès à présent des nouvelles mesures". An official publication, issued by the Director of the Bureau International on the occasion of the 50th anniversary of its foundation, informs me that the original standards were accepted and deposited in the Archives "le 4 Messidor an VII" (22nd June, 1799). (An earlier English publication states that they were deposited in the Archives on the 9th December, 1799.) The system of which they were the Standards of length and mass was a decimal one, as it is now; but the education of the majority of the people is not effected by a revolution, and the decimal system was coldly received. So much so that in 1812, France again being an Empire, the people were pleased to receive an Imperial decree "pour faciliter et accélérer l'établissement de l'uniformité des Poids et Mesures dans notre Empire" which reintroduced some of the old pre-revolutionary units, and subdivisions based not on the decimal but on the duodecimal system. The decimal system was politically tinted, and not appreciated. This prepared the way for a ministerial edict in February, 1816, which abolished the decimal fractions and commanded the exclusive employment of the system of weights and measures "usuel" (that of 1812) for commercial purposes. This edict remained in force for 25 years, the populace apparently being happy in their restoration to a binary and duodecimal system, whilst the decimal system was only taught in schools and used by public departments.

Little by little, however, the decimal system became popularised, so that in 1837, on the 4th July, a law was passed prohibiting the use of any weights and measures other than those of the metric system, based on the Standards in the Archives. So that we find ourselves with the standards prepared during the time of the French Revolution, the basis of the Metric System, again approved with that system by the law of 1837, which took effect as from the 1st January, 1840 so as to give people time to become accustomed to the complete and sole use of the metric system and decimal divisions. It had taken over 40 years to establish the system in France after the depositing of the standards in the Archives; and this was in the land of its origin. It is now the compulsory system in most countries, but has not taken so long to introduce in such subsequent cases.

Having established the system in France, the Government of that country was next concerned with efforts to have it adopted as a legal system in other countries, and with that end in view prepared and distributed copies of its standards to other nations. The adoption abroad of this as a legal system was rapid. International Exhibitions showed the necessity of utilising some common world standard of mass and length, as well as of time (the second), and comments were made in England after the International Exhibition of 1851, which led to influence being brought to bear to have the metric system legalised in that country.

By an Act of 29th July, 1864, the use of the "weights and measures" of the metric system was legalised in England.

At the "Exposition de Paris" in 1867, scientists and manufacturers felt and urged strongly that the metric system should be adopted internationally, and that the Standards should be in the charge of an International Committee; and a committee, mainly of delegates from countries represented at that Exhibition, was formed as a "Committee of Weights and Measures and Money" to discuss the possibility of uniformity. This led to the usual epidemic of committees and commissions, with the rapid growth of which we are familiar even to-day. The fact that 22 years of activity elapsed before the scheme reached fruition causes no surprise.

The Academy of Science at St. Petersburg presented a report which was adopted in June, 1867. In October of the same year, the Geodedic Association, meeting in conference in Berlin (most European States being represented) adopted a series of resolutions dealing with the subject; to which the "Bureau des Longitudes" drew the attention of the French Government, who formed a new Commission composed of members of the Bureau and of the Academy of Science to consider them. In the meantime (two years) the Academy at St. Petersburg drew up its own recommendations as to the Standards, as a result of a commission they had appointed in April, 1869; this also was considered by the Academies of Science, and approved in August, 1869.

An unanimous wish to call together an International Conference on the matter, expressed by the Academies of Science both of Paris and of St. Petersburg, and by the conference of the Geodedic Association, required to be treated seriously; and the French Government issued, on the 16th November, 1869, an invitation to Foreign Governments to send their representatives to Paris to an International Conference. Twenty-four countries sent delegates (38 men in all), to which were added ten French representatives.

The Commission was called to meet at Paris on the 8th August, 1870; it met—some members being absent because they were at war with France, and were then occupied in destroying portions of it—and held five sessions. It was not exactly the right time to ensure the unanimous recommendation of the resolution that it was advisable to create *in Paris* an International Bureau of Weights and Measures; moreover, most of the French delegates liked their Standards of Borda, "des Archives", and did not take kindly to the suggestion that new standards should be made for International purposes, and that national copies of these new standards should be compared and sent to subscribing countries. At any rate, before breaking up, this Commission formed a "committee for preparatory investigation", composed of the French members of the Commission, and nine strangers. This committee met in Paris in 1872; the full Commission was called together again later that same year, and actually held eleven meetings in September and October. The Commission decided to make a new Standard, not to be based on fresh measurements of the quadrant, but on the Mètre des Archives "dans l'état où il se trouve". This was to be of platinum-iridium, of the composition recommended for its permanency by H. Sainte-Claire Deville; and was to be of the X-section recommended by H. Tresca.

There was a lot of discussion about the Kilogram Standard, some members declaring it was 200 to 300 milligrams "out" from the mass of 1000 c.c. of pure water at 4° C.; but finally it was decided not to make any reference to water, but to base the new Standard on the old Kilogramme des Archives "dans son état actuel". Platinum-iridium was to be used, and it was to be a cylinder of length equal to its diameter, with rounded edges. Copies were simultaneously to be made and compared, and distributed to the subscribing countries. The Commission elected, to operate between periods when it was called together, a "Permanent Committee"; it then expressed the wish that an International Bureau of Weights and Measures might be formed, and dissolved. The labour of making the Standards and copies was then proceeded with in Paris—all metre "national standards," for instance, were to be made from a single ingot, formed in one melting. This meant melting and flowing in one operation 250 Kilograms of a very refractory mixture. The metals were collected, and several preliminary experiments made after they were purified—then on the 13th May, 1874, in the presence of the President of the French Republic, the big ingot was prepared. Sixty-nine metre substandards might have been made from the 250 Kilograms; but, owing to fissures and other flaws, all these were not obtained. The "Permanent Committee" gave these X-standards their approval, discussed technical matters, and withdrew.

These Commissions and Committees had not been able to commit their Governments. To make the matter definitely one between the Governments of the world, the French Government issued the necessary invitations, and the "Conférence diplomatique du Mètre" was called for the 1st March, 1875. Twenty Governments sent their official representatives, supported by large numbers of scientific and technical advisers. Great Britain was represented by H. W. Chisholm. The delegates fell naturally into three groups: (1) Those who supported the establishment of a permanent International Bureau, (2) those who opposed that proposal, and (3) those who reserved their judgments. On the 12th April, 1875, the matter was decided; fourteen voted for the permanent Bureau, two supported the establishment of a Bureau the life of which would be limited to the time necessary for the creation and adoption of the new "prototypes", and four reserved their decisions.

This Convention then created an International Bureau of Weights and Measures, located in Paris, and acting under the supervision of an International Committee, which was itself under the control of the General Conference. It was provided that 100,000 francs should be subscribed for the first year's activities, to allow for the making and comparing of the new International and National Standards; whilst 75,000 francs should be available for subsequent years, with the hope that the second year might be cut to 50,000 francs to preserve the average of 75,000 francs. This was found to be quite insufficient, and the Governments subscribing were regularly asked for increased votes. A total of a few thousand pounds, divided amongst all the subscribing nations, was not really a heavy cost.

The French Government gave to the Bureau International the old "Pavillon de Breteuil", in the Parc de Saint-Cloud, at Sèvres, near Paris, and by the Seine. Some twenty-five thousand square metres of land around it were also presented—this had been the site of the older Trianon de Saint-Cloud. Great Britain did not ratify the Convention in 1875, and Mr. Chisholm withdrew. Britain decided to play in 1884, and the Astronomer Royal (W. H. Christie) became a member of the Convention in 1885.

The General Conference still instructs the International Committee, and meets every six years.

You will remember that the French Section had produced a large ingot of the platinum-iridium alloy (90 parts of platinum, 10 parts of iridium); the mean density of this was found to be 21·115 grammes cm.$^{-3}$, whilst for smaller specimens of a similar alloy of pure materials a density of 21·455 grammes cm.$^{-3}$ was found. This upset Sainte-Claire Deville, and he asked that the work be done all over again—that the materials be repurified and recast. His advice was disregarded, and the work went ahead. In 1877 the International Committee refused to accept this alloy of wrong density, and called upon the French Government to "stop the manufacture of metres commenced by the French Section, and to prepare prototypes in conformance with the conditions approved by The Convention of the Metre"; which was certainly disturbing. The French Section had given up five years to the construction of these "lengths", and now concentrated on the construction of three of them in this alloy, ordering the remainder from the London firm of Johnson, Matthey and Co., who had supplied much of the platinum and iridium for the previous ingot. This firm had not previously cast an ingot of this material of greater mass than 50 Kilograms; but the French had had even less experience, their earlier work having been with much smaller quantities; their big ingot had been produced after thirty preliminary fusings and flowings. After research work on the two alloys, in 1880 the Committee came to the conclusion that either alloy might be employed, and that the subscribing nations might make their choice.

Thus the various national prototypes were not ready till 1886 in the case of the Kilogram, nor till 1887 in the case of the metre.

All these prototypes were compared with one another and with the corresponding new "International prototype" in each case. The Conference was called again in 1889, to distribute the thirty-one "metres" and forty-three "Kilograms" of pure alloy, and four "metres" of the French alloy.

The International Prototype Kilogram and the International Prototype Metre remain at the "Bureau International des Poids et Mesures", at the "Pavillon de Breteuil", Sèvres, near Paris. They are the World Standards. The national prototype standards were distributed amongst the subscribing nations, and act as the legal basis of the metric systems in those countries. *Reference to a metre, or to a Kilogram, is, however, always fundamentally to the International Prototypes at Sèvres.*

The iridium-platinum Standards were made in London, under the control of George Matthey, F.R.S.; they were completed in Paris by Messrs. Brunner, Collot and Laurent, the lines on the metre (very fine, and scarcely visible to the naked eye) being traced by M. G. Tresca, at the Conservatoire des Arts et Mètiers; you will remember that the section of the metre, subsequently called the "Tresca Section", was designed by him. The chemical tests of the alloys were made by Professor Stas, and by Messrs. Sainte-Claire Deville, Debray, and Tornoë. The "verifications" were effected by Dr. Broch and Dr. Benoit, assisted by Drs. Pernet, Choppins, Guillaume, and Messrs. Marek and Thresin.

The two prototypes received by Great Britain in 1889 are a "line" standard (un étalon à traits), and a Kilogram mass. In 1894 we received also a metre "end" Standard (un étalon à bouts). The lines on the "étalon à traits" are very fine, being just visible without magnification.

With each prototype metre sent to subscribing nations went two mercury thermometers, which enable the temperature of the national Standard to be read to 0·01 centigrade degree; the construction, calibration, and comparison of these thermometers was the work of the Bureau.

The British (national prototype) metre, No. 16, is actually of length 1 metre — $0{\cdot}6\mu \pm 0{\cdot}2\mu$ at 0° C. (μ stands for a "micron", which is one-thousandth of a millimetre. So that our copy is *not* precisely a metre but somewhere from 4×10^{-4} to 8×10^{-4} of a millimetre out. We thus know its length to within one part in five million.)

The British (national prototype) Kilogram, No. 18, is a highly polished cylinder, bearing a faint distinguishing mark. Its volume at 0° C. has been found to be 46·414 millilitres. Its actual mass is 1 Kilogram $+0{\cdot}070 \pm 0{\cdot}002$ milligrammes. So that we know its true mass to one part in five hundred million.

As you know, the unit of mass, the gramme, is one-thousandth of the mass of the International Prototype Kilogram. The unit of length, the centimetre, is one-hundredth of the Standard metre length, as measured on the International Prototype Metre at 0° C. The unit of time being the mean solar second, previously defined (Vol. I, No. 1, p. 34), the abbreviations of the names of units give the system its name—C.G.S.

These three articles are not on the subject of metrology as such, but are essentially what they purport to be in their titles. So the discussion goes no further, although it could be expanded greatly even within its legitimate field; nor will I discuss the much argued question as to whether we should cease to be one of the nations for which the metric system is only "facultatif", and join the majority for which it is "obligatoire". Britishers do not like being *compelled* to do things—but I am sure that we will eventually all use the standards of the C.G.S. system, and employ its units exclusively, before your generation passes. It has been in use now some 135 years. It has been an International System, with national standards distributed, for but 45 years; yet to-day there are 31 countries members of the Convention, representing populations of 750 million people, of whom nearly 600 millions employ the C.G.S. Standards as those of their national system. Many of the remaining millions make more use of the C.G.S. system than of any other; that applies particularly to scientists throughout the world.

Later, I will arrange for an article, by an authority on such matters, on the Comparison of Measures.

CARBOHYDRATES AND THEIR CHEMISTRY.

By Professor J. C. Earl, D.Sc., Ph.D.
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We eat them, we wear them, we sit and stand on them, we write on them and even make some of our most popular drinks from them. Wheat and other cereals contain starch, a carbohydrate; sugar is also a carbohydrate; cotton, linen and other textiles of vegetable origin contain large proportions of the carbohydrate cellulose; cellulose is also found in wood.

The isolation of cellulose from wood in a more or less uncontaminated condition is the first stage in the manufacture of much of our paper, and cellulose so obtained often forms the raw material from which, by chemical processes, artificial silk, lacquers, films and other common commodities are made. The carbohydrates are also the basis of the fermentation industries, leading not only to alcoholic beverages but also to a variety of useful solvents, such as butanol, butyl acetate, acetone, and so on.