Correspondence.

Mr. A. Barclay remarked that there was a convenient mode of graduating and figuring a rule which was applicable to any arbitrary unit and subdivision. In the ordinary fitters' and joiners' English two-foot rule, folded in the middle on a compass-joint, the inches, figured on each face from left to right, 1 to 24, were usually divided into $\frac{1}{2}$, $\frac{1}{4}$, $\frac{1}{8}$, and $\frac{1}{16}$. If any work had to be centered, the unit end of the rule was made to correspond with one limit, and the reading was taken at the other limit (say $21\frac{3}{4}\frac{1}{16}$ inches bare); it was then necessary, mentally, to halve this quantity, represented by two numerals, two fractions, and the difference to the nearest division; and having by this process obtained the new half quantity ($10\,\frac{7}{8}\,\frac{1}{32}$ inches scant, which had also two numerals, two fractions, and a difference), to note the corresponding reading on the rule, and against it make a trial centre mark, which was very likely to require adjustment. Next the accuracy of its position must be checked by an equal half measurement to the other limit. The rule which he preferred had the usual divisions and figures, and also on one face next the outer edge were two scales of half-inches figured 1 to 24 from the joint to each end, the half-inches having the same number of sub-divisions as the scale of inches. With this rule, having ascertained the cross measure (say, as before, $21\,\frac{3}{4}\,\frac{1}{16}$ inches bare), and found the corresponding figures and divisions on the two half-inch scales, they would, when laid on the work, exactly coincide with the two opposite limits, and the centre would be marked off with confidence at the joint zero. It was only necessary to remember the first measurement as a comparative length, calculation was unnecessary, and halving a measurement by this method of substituting the appropriate scales was accomplished with accuracy and dispatch. The Japanese artizans, now at work at the Exhibition at South Kensington, used a bamboo rule of native make, like a drawing-scale, the unit being the English foot divided into 10, 100, and $\frac{100}{2}$. Mr. Barclay.

Mr. H. Bauerman, as the result of long experience in the use of various metrological systems in different countries, was unable to agree with the Author's conclusions as to the desirability of internationalizing the metrical system to the exclusion of all others. He thought that the weights and measures used at any particular time by any people fairly corresponded to their local and temporary necessities, and as new necessities arose, they would be met by the adoption of new, or by the modification of old, units. Take, for instance, the progress in the use of the ton as a business unit. For Mr. Bauerman.

Mr. Bauerman. many centuries commercial requirements were satisfied by the hundredweight or quintal, and indeed the latter, until lately, if not now, did survive in the Newfoundland and Labrador cod fisheries. Increase in the scale of operations, however, led to the adoption of the twenty-fold larger unit, first in England, and at longer intervals in foreign countries. Strangely enough in Germany, where the cwt.-unit lingered longest, the ton had been supplemented by a ten-fold larger unit, the wagon, corresponding to the contents of a ten-ton railway-wagon, which was now commonly used in the coal and iron districts of the Rhineland. These were examples of change of use due to commercial necessities, and which had been effected without inconvenience; but it would be very different to attempt to impose an entirely new metrological system upon a people without regard to local usages. Those who advocated the universality of the metric system seemed to consider arithmetical convenience as synonymous with convenience of every kind, which was not necessarily true. For instance, when a large number of similar articles had to be divided into small packages, there was a distinct saving of packing materials by making them up in twelves rather than in tens. Here the convenience of the packer was in sharp contrast to that of the computer, so that while the latter might prefer to consider twelve as 1·2 decade, the former would regard ten as five-sixths of a dozen, and it would only depend upon the relative strength of the two parties which view should prevail, if one were to be used to the exclusion of the other. The Author's arithmetical illustration did not appear to have much bearing upon the question, for although he had used a large number of figures to arrive at an incorrect result in determining the contents of the English tank, as contrasted with a smaller number required for the determination of the equivalent metrical volume, the former was due to the use of incorrect factors and an inappropriate arithmetical method, which again was conditioned by the assumption that civilized arithmetic must necessarily be decimal. In other words, he preferred multiplying by 0·167, which was inexact, to dividing by 6, which was right. The Author's suggestion that English engineers would be precluded from using foreign technical literature, because in the latter, dimensions were, as a rule, expressed in millimetres, did not seem to accord with the experience of the Institution, which for some years past had supplied abstracts of the more important Papers in foreign journals, in English, but in many cases with the original dimensions. These had been so far appreciated as to be largely reproduced in English and American journals when of special interest, which would scarcely have been done had the editors considered them as a matter unintelligible to their subscribers; and in the case of one contributor at any rate, such abstracts had led to correspondence sometimes of an enquiring and sometimes of a mildly controversial character, but in neither case had there been any misapprehension as to dimensions. The Author's views as to decimalizing English money were also contrary to experience. The physical decimalization of the sovereign had been attempted in England by the issue of double shillings, which were intended to supersede half-crowns, and the coinage of the latter was discontinued for many years; but when they became scarce the public asked for a further supply, and got them, whereby the decimal system pure and simple was tacitly abandoned, but at the same time public convenience was enhanced by having the two kinds of coin instead of only one kind. The Latin Monetary Convention in its present form was rather intended to reduce the circulation of a token coin, the franc of $\frac{835}{1000}$ fine, than to facilitate its international currency. Mr. Bauerman.

Mr. F. Briffault pointed out two instances that had come under his notice in connection with two foreign waterworks where the decimal and metric systems alone were used. The Brazilian Government had been supplied with 95,000 tons of pipes and connections from this country for the waterworks of Rio de Janeiro, this quantity being divided between four manufactories. The castings were all weighed in kilograms, the weighing-machines having been made expressly for the purpose. At first the men did not take kindly to the innovation; but at the end of a fortnight, after finding out the great saving of trouble thereby effected, they much preferred this system to the British. Having only to deal with one unit of weight, the kilogram, the numbers were at once read off the weighing-machine; and at the conclusion of the day's work the columns were added up, and three figures pointed off to the left gave of course the total in metric tons. Only simple addition being necessary, the class of men entrusted with these operations could do their work without error, whereas had the weight been of several denominations, a hopeless muddle would have arisen. At the termination of the contract, there was only a discrepancy in weight between the Government authorities and the contractors of under 3 tons. Considering the magnitude of the undertaking, such a result would scarcely have been attained had British measures been used. There had also been a great saving of time and money in clerks' salaries by the adoption of this system, in the two and a half years occupied on the work. In the Mr. Briffault.

Mr. Briffault. case of the Constantinople waterworks, similar satisfactory results had been obtained by the use of the decimal system; but in Turkey the advantage of it over the British system was even more marked. The number of pipes arriving damaged and cracked in transport up country was very great; they had consequently to be cut on the spot in order to be utilized; and there was thus a great variety of lengths to deal with. To weigh the pipes after cutting was impossible for many reasons; so the reduced lengths were measured in metres and centimetres, and the maximum weight allowed per lineal metre being fixed, the two had but to be multiplied together, and the result was metric tons and decimal parts of the same. With feet, and inches, and tons, cwts., qrs., and lbs., a vast amount of tedious work would have been necessary, and with a doubtful result as to its correctness.

Mr. Chapman. Mr. W. D. Chapman remarked that in the "Standard" of the 16th of December, 1884, there appeared a leading article to the effect that a Dutch company could sell Dutch milk in London "at the price of $2\frac{3}{4}d.$ per litre—or, in other words, at a little over $2d.$ per quart." On proceeding to check this calculation, he found that $2\frac{3}{4}d.$ per litre was $3\frac{1}{8}d.$ per quart—a difference which completely disposed of the arguments in the "Standard." He thought that many practical English farmers, interested, as he was, in English dairy-farming, had been misled by having to assume the accuracy of the erroneous conversion of measures, and had needlessly admitted the hopelessness of competing with the Dutch company, simply because the want of an international language of measurement deceived them as to the facts of an enterprise affecting their business. This was merely one recent example of many cases where English business had been fettered, and English business men deceived, in questions of international competition where measures were concerned.

Mr. J. Craig. Mr. John Craig observed that most of the advantages and disadvantages of substituting the metric system of weights and measures for the British system had, no doubt, been fully entered upon and discussed. He wished only briefly to add his experience of the working of both the above systems, and also of other systems in various countries. Great weight must be attached to the remark in the Paper as to the position held by England and the United States of America in the manufacture of engineering machinery. It was generally admitted by engineers that any violent change of the measures now in use would be practically impossible, as far as this branch of mechanical engineering was concerned; besides, a strong feeling existed amongst many mechanical engineers against any change; they even asserted that British measures

Mr. J. Craig.

were, for their purposes, better than any others in use. No such feeling existed amongst civil engineers; nor would interests be affected in anything like the same degree if the metric system were at once generally adopted in connection with all field- and office-work undertaken by them, for which the consent of Parliament had to be obtained. He had never met a civil engineer who had used the metric system in field and office, on railway or other public work, who did not admit its great superiority to the British. If his experience agreed with that of the majority of the civil branch of the profession, he submitted that steps should be taken to have the metric system allowed, or enforced, on all public works; its use would thus become known, and gradually extend, and the way prepared for the time when the metric system, or other system based on somewhat similar principles, should be adopted by all English-speaking peoples. Literature, in connection with all branches of the profession, would soon adapt itself to a new order of things. It had been said, "To acquire a new language is to enter upon a new world." The advantages a British engineer would gain by a literature written in terms of an almost universal measure with which he was familiar, would be great indeed. The advantages derived from the nomenclature of the metric system, although great, were, he thought, of secondary importance; that was, if the nomenclature should in any way prove a bar to the system coming into general use. He would prove a benefactor to his country who would suggest some good plan whereby he could retain many familiar names for certain of the metric dimensions. The adoption of the metric system in India, on the Government and public works, so far as might be required for engineering purposes, would not cause much inconvenience, especially if time were given. In most, if not in all the Colonies, the change would be hailed with joy, and would form a not unimportant link in the chain which was gradually being forged, to bind them in one mighty federation with the mother-country. In some of the colonies its adoption would do away with the difficulty of introducing British measures amongst peoples under our rule, whose system of weights and measures might be as good as ours, and whose likes and dislikes were quite as strong. At the Cape, for example, all railways and public works were carried out by the use of British measures. Land was, however, surveyed, bought, and sold by Dutch measurement. The colonial ton, of 2,000 lbs., and cwt. 100 lbs., could not, he thought, with advantage be replaced by the British ton and cwt. In the markets of the country the measures were most confusing, and there was certainly great

Mr. J. Craig. need for reform. To have a decimal system of coinage would no doubt facilitate the use and introduction generally of the metric system. The great convenience of a decimal system of coinage could only fully be realized by those who had resided for a time in a country where such a system was in use. He feared, however, the opposition to change would be very great. Time could not be given for it to come gradually into use, and a change when made must be compulsory on all. He did not think accounts would ever be kept in pounds sterling and mils. The pound sterling must always remain, but florins and cents could easily be substituted for shillings and pence, and the British penny might still remain a force in the land, in name and appearance. Accounts kept in the above way would effect a saving of 20 per cent. in the number of figures required on a page of a written-up ledger, to say nothing of the advantages in other ways.

Professor J. D. Everett. Professor J. D. EVERETT agreed with the Author in thinking that the adoption of the metric system of measures and weights would be a great benefit, by effecting a saving of a vast amount of useless labour. The case had, he thought, been fairly and clearly stated in the Paper. He was glad to find one point insisted on which had often been overlooked, namely, the facility which a decimal system afforded for logarithmic calculation. The remark must be extended not only to the use of tables of logarithms, but to the use of logarithmic scales, such as the slide-rule in its ordinary form, or in the circular form, or in the parallel-column form employed in his "Proportion Table," or in the helical form which, in Professor Fuller's "Spiral Slide Rule," admitted of working to five places of figures. He concurred in the importance of speedily decimalizing the British money reckoning and coinage. Any partial decimalization of the coinage, not carried far enough to admit of keeping accounts decimally, was of no advantage. In his opinion the arrangement that would least disturb existing prices would be to decimalize upwards from the farthing, because every sum of money, according to present reckoning, would have an exact equivalent in the new reckoning, whereas the present penny and halfpenny would have no exact equivalents in a system decimalized downwards from the pound sterling. But a minimum of disturbance was not the only consideration. He was in favour of neither of the systems above compared, but had for many years held the opinion that the best system to adopt would be the American system of dollars and cents. When travelling in America many years ago, he was greatly struck, not only with the facility afforded for calculation, but with the extreme convenience of the coinage. An abundance of change for all sorts of purchases could be carried without burdening the pocket, and though a stranger, he could count his change with as much ease as in his own country, and with much more ease than in France, notwithstanding that the coinage there was likewise decimal. He claimed that the American system was more economical of space in account books than either the French system or a decimalized system founded on the pound sterling. It started from the cent (about a halfpenny) as the unit in the right-hand column. A decimalized system, founded on the pound, must start from the mil as the unit in the right-hand column; for the hundredth of a pound ($2\frac{1}{2}d.$, nearly) was too large for less sums to be ignored. The pound would therefore be the unit in the fourth column from the right hand, and space must be left for three columns to the right of it. In the American system only two columns were wanted to the right hand of the dollar column, so that the unit in the fourth column from the right hand was ten dollars. This was rather more than two pounds sterling, and thus with a given number of columns twice as large a sum could be expressed in the American system as in the pound and mil system. The disturbance of prices would be much less than in the pound and mil system, for 100 cents were $4s.\ 1\frac{1}{2}d.$, and 100 halfpence were $4s.\ 2d.$ The difference between a cent and a halfpenny was therefore 1 part in 100, whereas the difference between a mil and a farthing was 4 parts in 100. He thought the importance of adhering to the pound sterling in its exactitude had been greatly exaggerated, and he believed that no confusion would be introduced in foreign relations by making payments in five-dollar gold pieces, each worth £1 $0s.\ 7\frac{1}{2}d.$, instead of in sovereigns as hitherto. Professor J. D. Everett.

Professor H. Hennessy observed that the utility of a complete international system of weights and measures, based on the existing international system of counting and calculation, seemed to be clearly established, and the Author of the Paper had shown that no profession would profit more by such a system than the profession of civil engineering. If the whole question were open to revision, probably a decimal metric system, founded upon a standard of length common to all nations, such as a fraction of the earth's polar axis, would be most acceptable. This had been proposed by Professor Hennessy long since, and a complete series of measures and weights derived from it had been exhibited at South Kensington in 1876. It fulfilled all requirements of a complete system, and on account of the close approach of one of its fractions to the existing British inch,[1] it was strongly supported by some eminent Professor Hennessy.

[1] The polar inch differed from the British inch by the thousandth part or less.—H. H.

Professor Hennessy. persons including the late Sir John Herschel. But when he reflected on the fact that the majority of the civilized part of mankind had already adopted the French metrical system, and that every day this system was becoming more familiar to British students of engineering through their observation of foreign works, or perusal of foreign scientific and technical publications, he could not hesitate to express his concurrence in the views of those who advocated its adoption for all nations. Some inconveniences would have to be endured for a short time before workmen and calculators were familiar with the new system, but these inconveniences had been cheerfully encountered by great nations already, and their experience might be fairly appealed to in answer to this difficulty. Men of science and engineers, whose minds were accustomed to accurate estimates of number and magnitude, would in general have no difficulty in employing more than one system. Thus, while he had found it advantageous to use the decimal metrical system in applied mechanics, thermo-dynamics, and mathematical physics, he had been often obliged also to employ the British system, on account of its use in ordinary applications. But this very circumstance had only made the superiority of the metrical system more distinctly felt, and made him more than ever desire that it alone should be employed throughout the world.

Mr. Hett. Mr. C. L. Hett remarked that in 1870 the Butterley Company obtained the contract for the Dordrecht Railway Bridge, and he had prepared the drawings for the steam cranes, scaffolding, &c., required in its erection. As the piling and superstructure of the staging had to be erected by a Continental contractor, the drawings were made to metric measures. Drawing-scales were ordered having the most generally used English graduations on one edge, and corresponding metric divisions on the other. By the use of these scales all difficulty was overcome, and rapid progress made. The drawings of the bridge itself were prepared in Holland, under the supervision of the Dutch Government engineers, and were dimensioned in metric figures throughout. But in the works there was an outcry. The men at first said they could not, and would not work to such outlandish dimensions. The purchase of a few metric rules, however, settled the difficulty; and after a fortnight's practice, one of the old hands who had been most opposed to them, admitted that the metric measures were much the easiest to use; especially where an even pitch could not be employed, but a given number of equidistant rivets had to occupy a certain space, the pitch being an odd dimension. It should be mentioned that no member of the Butterley staff nor any of the workmen had had any previous experience of metric measures. The absurdity of the present system of measurement was well exemplified in the case of railway-bridges and of drainage pumping-works. In each case a plan of the site was supplied drawn to a scale of chains and links, the heights being given in feet and decimals of a foot, while the drawings for the ironwork were made in feet and inches. The standing arguments used against the metric measures were the Whitworth screw-threads, the 1-inch and 6-inch ordnance maps, and the loss that would accrue from the depreciation of patterns and templates. The former difficulty was not felt abroad when the metric system was established, any more than inconvenience was experienced at home from the odd diameters of the standard gas-threads. The second objection could be removed by engraving metric scales on the plates from which the maps were printed. At present, owing to the variable contraction of the paper, accurate measurements could only be taken with the scale printed on the maps. Even now the ordnance maps on the larger scales were made without regard to the time-honoured yard and inch, being plotted to scales of $\frac{1}{2,500}$, $\frac{1}{500}$, &c., of the actual size. On such maps, metrical scales could be used with great convenience, but a rule divided into inches was valueless. The last objection appeared at first to be a very important one, yet it was more so in appearance than in reality. A thoroughly good set of patterns or templates would retain their value, while obsolete ones would probably be destroyed rather sooner than if there had been no change in the measures. Mr. Hett.

With regard to the British system, or rather want of system, of weights, little need be said. In trying to improve them, matters had only been made worse. The cental of 100 lbs. originated with the Liverpool corn-merchants, who, after using it illegally for years, obtained Government sanction for its adoption in 1879. It was expected to effect a reform in the sale of corn; but nothing of the kind had occurred. A Bill had been laid before the House of Commons to render the use of the cental compulsory in the corn-trade of England. The scheme of decimalization of the coinage mentioned by the Author, and which had been so frequently advocated, might be easily introduced. The poor would approve of it, as they would get $12\frac{1}{2}d.$ for $1s.$; but the difficulty would be in the temporary loss to the revenue of 4 per cent. in postage and receipt stamps. Although this subject had been thoroughly discussed years ago, it was under very different conditions to those which now prevailed. At that time there was hardly a competitor with England in the foreign trade. The British were virtually in a position to dictate to countries employing the metric system, and

Mr. Hett. to say, "There is our machinery made to our measurements, and without the slightest consideration of your convenience." But now it was different; there were makers from countries employing the metric system ready to supply any order for machinery, and year by year the excellence of their goods would be improved until their workmanship was equal to our own, and our last advantage over them would be gone. It was sometimes urged that if the United States did not adopt the metric system, why should England? The Americans were agitating for its adoption; and the first country to change would have a great advantage in trading with those other nations who had already adopted it. At the same time America did not purchase machinery from the British, and therefore their case need not be considered. Now that education was compulsory, the extra work involved on the rising generation and their instructors by the clumsy system of English weights and measures should be carefully considered. As so much was being spent in education, and cases of "over-pressure" were so frequently reported, should not an effort be made to abolish a system which was admitted on all hands to involve an enormous amount of unnecessary labour? The feeling that the metric system must sooner or later be adopted was not confined to engineers and scientific men; it was shown by the action of the Leicestershire Chamber of Agriculture in 1878, which opposed the legalization of the cental on the ground that it might impede the adoption of metric weights and measures. Few persons attempted to defend the present system, yet there was a general hopelessness of any change. Improvement had been advocated; but any alteration would involve greater confusion than a total change, while the international character of the metric system would not be attained. The importance of the subject was so great that Government might be asked to aid the change by adopting the metric system throughout their departments. If adopted exclusively in the customs, metric weights would immediately be made the basis of railway charges, much to the relief of goods' clerks and accountants. Wholesale houses would follow, and gradually the system would be accepted by the small retailers.

Mr. Hurter. Mr. Ferdinand Hurter, Ph.D., held that the only important reason for a change from the English to the metric system was that many nations had adopted the latter. Perfect internationality was, however, impossible, since Germany had not adopted the coinage of other continental countries. The metric system did not save so much time as was usually claimed for it. Where a decimal system was obligatory, the English people used it. True, it required

Mr. Hurter.

more time to attain a knowledge of the English system and its special arithmetic at school; but that time was not lost, and the pupil who mastered the greater difficulties became the better man in the end. The examples of saving of time which the Author had given were not very well chosen. If the French carpenter had a folding metre-rule, he would not measure more quickly than the English carpenter; if the rule were not jointed, give the carpenter a five-foot staff or a measuring tape. The multiplication, which the Author supposed the carpenter to make, was never made to his knowledge. The carpenter said 2, 4, 6, &c., as he turned the rule over. He was certain that a man well acquainted with his business could accomplish as much work, on an average, by the English system as he would by the metric system, and in considering so important a question as a change from one system to another, the difficulties which the system presented to the uninitiated must not be left out of sight. The calculation of the weight of water in a tank could have been much shortened by abandoning the decimals of feet, and by remembering that 1 ton of water was 36 cubic feet (error 0·2 per cent., or 5 lbs. to the ton). One point had been overlooked by the Author, namely, that the one-foot rule was as often used as an instrument for subdividing as it was to obtain data for a calculation. In this respect the one-foot rule, with its binary and ternary subdivisions, was as much superior to the metric rule as a circle divided into 360° was superior to one divided into 100°. Suppose it was required to subdivide 1 metre, this could be done by means of one thousand divisions in fifteen different ways. Take the same length, $39\frac{3}{8}$ inches, and use an English two-foot rule, divided into sixteenths of an inch, and there were twenty-three ways of subdividing it into equal parts, though the eye had only six hundred and thirty divisions to examine, instead of one thousand. But compare the yard in this way; it could be subdivided by means of an English rule, obtainable for 3*s*., in forty-two different ways. It was in the workshop that the English system was superior to the French; and the English inch was the standard for screw-cutting, not only in England, but throughout the world. It must not be forgotten that the British public was not prepared, nor preparing for such a change. Decimal calculation was unknown to the mass of the people. Boys were allowed to leave school, having passed the fifth standard, void of all knowledge of decimal arithmetic. Surely it would be unfair to take the masses by surprise! But if the metric system must be, let it be the metric system pure, the metric system compulsory; not a metric system at the option of any engineer. Let

Mr. Hurter. there be no mixture, particularly in plans to be submitted to, and discussed by, parliamentary committees.

Mr. Jackson. Mr. L. D'A. JACKSON observed, with regard to the choice between British and French metric measures, that British engineers dealt more with persons of their own nation, with colonial English, with citizens of the United States of America, and with semi-civilized and barbarous nations, than they did with nations that had adopted the French metric measures. Hence British measures were preferable for the English engineer. It was also important to notice that Russia used British measures in part. This first guide to choice should certainly settle the matter. Next, the British measures were good, useful, suitable, and convenient measures, while the French metric measures were mostly mere nominal units, among which there were only three or four useful measures. Lastly, there was no excuse for adopting the bad measures of the French in England, where a single, though incongruous, system already existed. When the French, the Italians, and the Germans adopted them, they had booksful of various measures of their own, and their internal jealousies prevented them from selecting among the best of those well known to themselves. Moreover, the installation of the metre was effected by fine and by imprisonment, the leading men having been previously won over by flattery. Engineers found that the British measures were inconvenient for purposes of calculation. If, then, they wished to decimalize, let them decimalize on their own existing units, thus keeping themselves in accord generally with the measures of their own nation. The selection of British units for decimalization should be left to committees of experts. In the interim engineers should be allowed, by Act of Parliament, or by Order in Council, to decimalize without restraint on any or all of the existing British measures, with the sole restriction of adherence to some one unit and its decimal multiples, and sub-multiples, in each class of measure. The difficulties would be few, as any one complete decimal system was easily comparable with any other complete decimal system within the separate classes of length, surface, cubic and weight units.

Professor Jenkin. Professor FLEEMING JENKIN said he should like to record his opinion that if any change were made by engineers in their standards of measurement, they should adapt the C. G. S. system, as it was called, with absolute derived units for force, &c. This change must, in his opinion, be made sooner or later, whether engineers liked it or not; and any half measure, such as taking a kilogram as a unit of force, or a kilogrammetre as a unit of work, would only entail additional inconvenience; but dynes and ergs had a clear practical advantage to recommend them. The C. G. S. system (centimetre, gram, second) had been already sanctioned as regarded electrical measurements by the International Conference of 1883 and 1884, held in Paris under the presidency of Mr. Cochery. This was the thin edge of the wedge, and since the wedge was a good strong one, and the motive for driving it home was of overwhelming importance to physicists, driven home it would be. Those who wished to know what the C. G. S. system was might consult Everett on "Units and Physical Constants." If this system had been in practical use, Professor Jenkin would have been saved one-half the labour in preparing his lecture on Gas Engines, which he had delivered before the members of the Institution. Professor Jenkin.

Mr. S. W. Johnson remarked that for the last twelve years the decimal system of measurement on the Midland Railway, referred to by Mr. Fernie in 1863,[1] had been employed only for the tire-boring, for contraction, and for the purpose of measuring test-bars, while Whitworth's templates and gauges were in use for all other workshop details. Mr. Johnson.

Mr. T. J. Nicolls observed that the incongruities and anomalies which were of daily experience under the accepted methods of weighing, measuring, and valuing, might be illustrated by reference to "Portland cement." The evil was first apparent in the specification, drawn more or less in the following general terms: "The cement shall . . . and weigh . . . pounds per bushel (striked); . . . per cent. must be retained on a sieve of . . . meshes per square inch; and bricks of the neat cement must be equal to a strain of . . . pounds per square inch. The tests will be applied to . . . bricks in each lot of . . . tons, &c." But this did not exhaust the weights and measures connected with cement. It was sold "by" the ton (never by the bushel), and "in" either bags or casks of indefinite, varying, bulk and weight. It was commonly used by the cubic yard (concrete), or square yard (plastering, flooring, &c.). The annexed table presented a transaction in Portland cement, in terms which were hardly credible as being those of actual experience; cement was Mr. Nicolls.

Specified for density	per bushel.
The full of the bushel to weigh so many . . .	pounds.
Bought "by" the	ton.
Delivered "in"	bags or casks.
Tested for fineness	per cent.
,, over so many meshes per inch depending on.	S. W. G.
,, for strength in lbs. per	square inch.
And used by the	cub. yd. or sq. yard.

[1] Minutes of Proceedings Inst. C.E. Vol. xxii. p. 606.

Mr. Nicolls. Surely the fittest parallel to such application of figures as Portland cement evidently required, was to be found in the old farmer's clock which, to those who knew its ways, told half-past four in the day by striking twelve and pointing to five minutes to nine. A similar juggling had to be performed in dealing with iron. It was generally held to

Weigh . . . . a decimal of a pound per cubic inch	or pounds per square foot 1 inch thick.
Was measured in	feet and inches.
Priced and bought per	ton.
Tested for tensile strength in pounds per	square inch.
„ for elongation decimally.	per cent.
„ for deflection by a binary subdivision of the	lineal inch, or by per cent. of span.

To give an additional example: take the apparently simple case of estimating the weight of rails per mile of railway—

Rails, say	80 pounds per yard.
The multiplier for pounds per mile was . .	1,760 !
And the divisor for tons per mile was . .	2,240 !

Compare the arithmetical process involved by these figures with the methods of arriving at the number of units of gross weight under the decimal (metric) system, which was, so to speak, automatic.

Rails, say	40 kilograms per metre.
Both { multiplier for weight (kilog.) per mile (kilometre) and divisor for tons (milliers), though little used }	= 1,000.

Thus the arithmetical process was effected immediately, and the required result obtained by simply changing the names of the multiplicand from kilograms to milliers.

To revert to the units in the case of Portland cement. It would be observed that only "pounds" and "tons," and "square inch" and "square" or "cubic yard" had any fixed relationship, according to any tables in existence; and for purposes of calculation, these relationships were represented by the numerical expressions $\frac{1}{2,240}$, and $\frac{1}{36 \times 36} = \frac{1}{1,296}$, and $\frac{1}{36 \times 36 \times 36} = \frac{1}{46,656}$; while under a decimal (such as the metric) system, the representative fraction would be $\frac{1}{1,000}$ or $0 \cdot 000$, and sub-multiples or multiples of it. The bushel was said to be of a capacity which, stated in terms of

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British units, simply could not be measured. On the authority of "Molesworth" it might be taken as equal to $2{,}218\frac{16}{100}$ cubic *inches* = $1\frac{28}{100}$ *cubic foot.* The inch and the foot (which were much too small and too large as units of minimum dimension), were defined, or at least, their sizes were accepted, conventionally. Not so the pound weight. The British "system" boasted two distinct pound weights; and while those who knew what was meant, professed to find things easy, it could not be quite so clear to foreigners who might wish or require to refer to English calculations.

A popular magazine had lately informed its readers that a "grain" of gold might be beaten out to cover 56 square inches with leaves only $\frac{1}{22{,}800}$ of an inch in thickness. What did the statement convey to the general reader as to the relationship of the "grain" to the "inch" square or lineal? None; there was no such relationship. Casual readers might forget that there was any use for the word "grain" so applied, other than as a rough indication of minute bulk; but ancient history traced connection between it and the grain of wheat as a measure of weight; yet it might be that the "grain" of gold referred to would but ill compare with the grain of wheat either as to size or weight. Hence the particulars in the statement, though not detracting from the wonderful ductility of gold, were wholly worthless as a comparison of actual facts. Any one having more or less intimate knowledge of workshop practice, or intercourse with the foremen of departments, would realize the contortions of memory, and the evolutionary processes necessary to enable the mind to comprehend the rough cube of a piece of stick which was announced to be 2 feet $1\frac{3}{4}$ inch long, $4\frac{5}{8}$ inches broad, and $\frac{7}{8}$ and $\frac{1}{16}$ inch thick. Such an experience might be compared with the equally systematic measurement of a timber log by a farm hand: "Five times the length of my stick, twice the length of my foot, then this straw, then half a brick, and a bit over." He had heard a University Professor and a Fellow of his College boast to his pupils, that he had never mastered and did not "know" the English tables of weights and measures. The professor always had his sympathy.

It was to be hoped that the Paper would lead to useful results. The advantages of the alteration it advocated were far from being overrated; they were such as seemed to afford an occasion for the origination of a movement having in view the final substitution of a simple and attractive system of numbers, already well tested, for the present anomalies, and the illogical jumble of terms and quantities. It would not be enough to decimalize the British tables of weights and measures; that was

Mr. Nicolls. impossible, however practicable to deal in that manner with the coinage. Sooner or later there must be a complete decimal system for all purposes of calculation and measurement. It was to be hoped that it might not remain to be secured for the English, as it had been for the French, among the results of a sanguinary revolution.

Mr. Parker-Rhodes. Mr. C. E. PARKER-RHODES, late of H.M. Consular Service, was in favour of the metric-decimal system in substitution for the present British weights, measures, and coinage. In the adoption thereof for all purposes no difficulty would arise, even in ordinary commercial and trade transactions, particularly in the measurement of land. As to advantages, he need only state that a case of survey had recently been submitted to arbitration at the Surveyors' Institution, in which an error of 1 acre in excess existed where the correct quantity was a little over 2 acres. Saving of time in calculation was likewise in favour of the system now acknowledged by numerous states; and by the diminution of operations and figures the memory was less taxed. The liability to error was also reduced to a minimum. The conversion of British weights, measures, and currency in foreign countries would always be to the disadvantage of British interests, at the same time resulting in considerable fluctuations. International uniformity was greatly needed, as might be proved by the importations of all commodities under the British flag in foreign countries.

Professor R. H. Smith. Professor R. H. SMITH thought experience proved that there was no great difficulty in introducing new measures into the practical life of a nation; certainly not as regarded engineering practice. Putting the case of France aside, Germany, Russia, Italy, and Austria, had adopted the French metric system throughout practically the whole of their engineering work, and had become familiar with it within a comparatively short period. Again Sir Joseph Whitworth's workmen used a system different from any other, namely $\frac{1}{10}$ inch, and this without difficulty or liability to error. In the workshop, liability to error was, under existing circumstances, more often due to the workmen having a variety of conflicting scales marked on their rules than to any other cause. The theoretic objection most commonly made to the metric system was that the duodecimal division was more advantageous than the decimal. As a matter of theory he thought this argument mistaken. There was a real necessity for representing the fraction $\frac{1}{2}$ in the simplest possible fashion, whatever system might be adopted, because of the great physical importance of binary symmetry for the sake of balancing weights, &c. The great majority of dimensions was for such reasons marked off in halves, Professor R. H. Smith.

but beyond the fraction $\frac{1}{2}$ he thought no fraction had any more importance than another. Physically the dimension of 0·88 inch would suit every purpose just as well as $\frac{7}{8}$ inch. Physically it was just as convenient to buy in 0·765 ton of iron as 15 cwt. If the 0·75 was preferred, it was only because the notation made 0·75 a little more easy to calculate than 0·765. If the notation adopted made it easier to reckon 0·765 than 0·75, then the commonly used fraction would be 0·765 and not 0·75. Therefore so long as the system of notation represented $\frac{1}{2}$ simply, *i.e.*, so long as its base was an even number, he thought it of little theoretical importance what base was taken. Obviously 2 or 4 was clumsily small because with these, large numbers would be represented by great arrays of figures. Practically it was of the utmost importance to adhere to 10, because, although he believed it would be easy to introduce new physical quantitative units, he knew from repeated attempts that it was extremely difficult to change the fundamental idea of numerical notation; and also because the decimal system was not only deeply ingrained in our minds, but was wide-spread over the world, there being no nations having any notation at all, who did not count by it. No one who had lived and worked on the Continent, and who recollected at the same time what was the usage of scientific men all over the world, could for a moment contemplate the possibility of converting the continental peoples to the use of British measures. It followed that if an international system of measurement was to be attained, it could only be accomplished by the approximation of British to the best metric system that would be generally acceptable. Men devoted to pure science used now almost exclusively the centimetre and its derivatives. He believed the centimetre was commonly used in France by engineers also. In Germany, however, the millimetre was almost universally employed by engineers as the unit of length. The reason evidently was that the centimetre was too long to make it possible even commonly to avoid fractions in dimensioning drawings, &c. In calculating the diameter of a shaft, for instance, it would be most improper to round off the result to a whole number of centimetres, unless the size were an unusually large one. The thicknesses of plates could never be expressed without fractions. But in practice it was found that a fraction of a millimetre need never be used except occasionally in fitting dimensions together, or for sheet-metal, or for wire. The committee of the British Association recommended the adoption of the centimetre and the gram because the system so based made the specific gravity coincide with the specific weight (weight per unit volume) of each substance. He submitted that

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this was no good reason. Specific gravities were of no use to engineers or any other class of practical men. Tables of specific gravity he had always looked upon as nuisances. Weights should be calculated from experiments on the heaviness of the material dealt with, and from linear measurements. For this purpose specific weights were wanted, not specific gravities. With tables of specific gravities only to go by, a double multiplication must be made where only one was needed according to any rational method. To realize the excessive uselessness of specific gravities it should be remembered that the comparison only referred to water at one particular temperature and pressure. It so happened that in the one instance, where it appeared at first sight that specific gravities might be of direct practical use, namely in the calculation of the buoyancy of ships, the specific gravity of the water to be dealt with, namely sea-water, was so far from unity that the difference could not be neglected. Specific weight was what was always practically dealt with, and the specific weight of water was certainly not the most important specific weight entering into the calculations of engineers. It was hardly used except in hydraulic engineering. In steam-engineering that of steam was of vastly more importance than that of water. He thought, therefore, that for practical purposes there need be no definite relation between the units of length and of weight or mass; and the most convenient units he had used in his own calculations were the millimetre and the kilogram.

Mr. Thursfield.

Mr. W. E. Thursfield observed that there could be no question as to the desirability of an international standard of weights and measures for engineering purposes; and, as England and America were the only two countries which still retained their old fashioned and complicated methods of arriving at arithmetical conclusions, nothing more than their common assent was necessary to give an international character to the metric and decimal systems employed by engineers on the Continent. Having had some twenty years' practical experience of the immense saving in time and labour, of the simplicity of manipulation, and of the greater accuracy obtainable by the use of the metre as the standard of all dimensions in every branch of technical work, he had great pleasure in bearing testimony to the undoubted advantages, in the several instances adduced by the Author, of the metric and decimal systems, and in supporting his arguments in favour of their adoption in place of any other. With regard to the depreciation of existing English technical literature, and of machinery, compiled and constructed in accordance with the present systems

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of calculation and measurement, the rapid improvements in detail, and the wear and tear of material, necessitated renewal from time to time; and the advantages to be derived by the student, as well as by the manufacturer, from the means afforded them, by an international standard of comparison, of judging the theoretical and practical results of their professional brethren in other countries, must be of more value than the loss of waste paper, and of old metal left on their hands at the end of the period of the transition. In drawing a comparison between the descent, in integral fractions, of the subdivisions of a metre, and of an inch (as quoted by the Author), Mr. Sellers appeared to have lost sight of the fact that the metre was divided into 1,000 parts, not 100; and that it was consequently capable of fourteen integral subdivisions $\frac{1}{2}$, $\frac{1}{4}$, $\frac{1}{5}$, $\frac{1}{8}$, $\frac{1}{10}$, $\frac{1}{20}$, $\frac{1}{25}$, $\frac{1}{40}$, $\frac{1}{50}$, $\frac{1}{100}$, $\frac{1}{125}$, $\frac{1}{250}$, $\frac{1}{500}$, $\frac{1}{1000}$, all of which could be contained on one scale; whereas, to obtain the full benefit of the inch scale, three separate forms of subdivision, or three scales were necessary, namely, the inch divided in terms of $\frac{1}{8}$, $\frac{1}{10}$, and $\frac{1}{12}$. That sizes of machinery advancing by $\frac{1}{16}$ inch were more useful and saleable, than those advancing by millimetres, was rather a matter of local prejudice, than of universal opinion. It must be immaterial to a purchaser whether the cylinders of several engines submitted for his choice had advancing diameters of $9\frac{7}{16}$ inches, $9\frac{1}{2}$ inches, and $9\frac{9}{16}$ inches, or 239 millimetres, 241 millimetres, and 243 millimetres, as the respective differences, between the latter dimensions in millimetres and the former in sixteenths of an inch, were only 0·25, 0·08 and 0·07 per cent. It would be equally correct to surmise that a fourteen-hand cob, and a sixteen-hand hunter, would be less useful and saleable if advertised at 147·5 centimetres, and 168·5 centimetres, supposing the purchaser to be intimate with the metric system. If anything, he thought the Author undervalued the saving in time by the use of the metric and decimal system in calculation; the surveyor, most expert at quantities, with the handiest of ready reckoners, would scarcely be able to work out the same number of items expressed in tons, cwts, qrs. and lbs., at x shillings per ton in one hour, as could be calculated by any one, with only a short practice in the decimal system, in three-quarters of an hour, if the weights were expressed in kilograms, and price in shillings per metre-ton; to say nothing of the increasing chance of error in proportion to the greater number of operations, and of the longer time necessary to check the results, without which the calculations were useless. With regard to the extension of the metric and decimal system to the purposes of general commerce, Mr. Thursfield. he agreed with the Author, that the full benefit of such a step could only be reaped in conjunction with a compulsory system of decimal coinage; but, in the face of the competition of over one hundred and eighty millions of European producers, of whom one hundred and twenty millions either held, or were hungering after Colonial possession as outlets for their produce, or as standpoints from which to assail the mercantile supremacy of England, all using one standard of measure, differing from, and simpler, than the British; he thought it would be wiser, if also the mercantile world, or so much of it as would have to withstand the attack of foreign competition, were to place itself on an equal footing with its competitors, by adopting, as early as possible, their standard of mensuration.

The course of dissemination, before its adoption became compulsory, was sketched by the Author, in his reference to the method by which the change was effected in Austro-Hungary. He thought, however, his suggestions might have gone further, and that part of the burden laid on engineers might have been transferred to the shoulders of the schoolmaster. It was of no use to familiarize the workmen with a new and simpler system of measurement and calculation, if their children, who, in all human probability, were destined to take their place, were brought up in an old and complicated one. In conclusion, he agreed with the Author that practically the decimalization of the coinage was as simple, if not easier, than the conversion of weights and measures for commerce. This had been aptly illustrated in Germany, where one universal standard of monetary value had been introduced in place of the heterogeneous coinages of her numerous petty States; and in Austria, where the florin, formerly composed of 60 kreuzers, now contained 100. Yet in both countries no other change than that of nomenclature had taken place in measuring many articles of daily use. For instance, the old Krügel (0·531 litre) had become the modern $\frac{1}{2}$ litre; the old Seitel (0·353 litre) $\frac{1}{3}$ litre; the Pfiff (0·177 litre) $\frac{1}{6}$ litre. Meat and other commodities, formerly sold by the pound, were now computed by the $\frac{1}{2}$ kilogram, and so on, with, however, be it remarked, almost invariably a slight loss to the public, and a corresponding advantage to the tradesman.

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27 January, 1885.

Sir FREDERICK J. BRAMWELL, F.R.S., President, in the Chair.

The Discussion upon the Paper by Mr. Hamilton-Smythe on "A Comparison of British and Metric Measures for Engineering Purposes," occupied the evening.