Discussion.

Sir FREDERICK BRAMWELL, President, proposed a vote of thanks to Mr. Hamilton-Smythe. All should thank him—those who agreed with his views for advocating them, and those who did not, for the opportunity of stating their objections. He would beg the Author to be good enough to explain the tabular comparison given in the Appendix to the Paper. Sir Frederick Bramwell.

Mr. HAMILTON-SMYTHE said he had put forward a mode of calculation, almost at random, with which engineers were familiar. He had taken British measures to find the weight of water in a tank 10 feet 6 inches by 6 feet 2 inches by 1 foot 1 inch, and also the nearest equivalent metric measures—3·20 metres by 1·88 metre by 0·33 metre. He had done this in British measures approximately. He had not converted the cubic feet into the exact number of lbs., but had assumed 1,000 oz. to the cubic foot, the more exact weight being 998·2 oz., or thereabouts. Taking 1,000 oz. produced an error but shortened the process. To effect the calculation with British measures by the shortest way required ninety-four figures. It was done accurately in metric measures with thirty-five figures. Mr. Hamilton-Smythe.

Mr. HENRY MAUDSLAY said the Author had not done himself or his subject justice in putting that calculation in such a form, because British measures of feet and inches would have to be reduced first of all to the lowest denomination before calculations were begun, or else it would be necessary to have a book of decimals, or to work it out in some other form, before arriving at the results which had been obtained. The "5" in 10·5 meant "6" inches. There was thus a mental calculation as to the half of a foot put in decimal terms, and to put measurements of feet and inches and different proportions—eighths and sixteenths—in such a way into figures that the calculation could be commenced, would represent an extra number of figures. Thus, instead of the calculation being as was shown in the tabular comparison, there ought to have been many more figures. He understood that the terms under which the Paper had been brought before the Institution had reference only to engineering purposes, and he remembered, as a result of the International Exhibition of 1851, that Sir Joseph Whitworth and others, including Mr. (now Sir William) Armstrong, prepared scales to metric measure, and to decimals of feet, carefully and elaborately Mr. Maudslay.

Mr. Maudslay. made. At the same time they were rendered easy of comprehension. One remark in the Paper with reference to money opened another question. He supposed it would make very little difference to the British commercially, or as engineers, whether Russia or Turkey ever adopted the metric system or not. He had travelled considerably in countries where the metric system was in operation, and he found that the ordinary people of those countries were enabled to conduct the affairs of every-day life with greater facility, rapidity, and accuracy, than English people could with their own peculiar system. After the first International Exhibition in 1851, so much was said and done about the metric system, that it was almost impossible to elicit a new idea upon the subject. He did not think the arguments that could now be brought forward would enable any one to form a more sound judgment on the matter, than could be arrived at from what had been already exhibited by those who had carefully examined the metric system. If it came to be a question of adopting a form of metric system, he thought that a large majority of engineers would carry the day for it. They were dissatisfied with the present English measures. The difficulties to be encountered, in changing the figures in calculations, represented possible fallacies and inaccuracies, and the greater the number of figures, the greater the number of calculations to be made, thereby increasing the chances of error. He would distinctly express himself in favour of the metric system, or some system which adopted an easy form for calculation, and that the different terms should be called by names that might be readily learned. The thirty-five millions of people in this country, and the Americans, required that names should be given to the different measures, weights, and numbers, and values of money, which they could easily understand and remember, rather than terms and names which would be difficult to learn, and if learned would be soon forgotten.

Mr. Owen. Mr. G. WELLS OWEN observed that it was one of the drawbacks incident to the lot of suffering humanity, a heritage from the days of the Tower of Babel, that people of different nationalities were hampered in their intercourse with each other by differences of language, and, although perhaps not coming so directly from that historical event, by differences of measures, moneys, and weights. Many of those difficulties and differences had been considerably modified of late years, and, perhaps he was not over sanguine in thinking that they would be still more so. The Paper, which tended to a discussion upon one mode of modifying some of those difficulties, was one which he thought the Institution

Mr. Owen.

might very well discuss, because it was more than thirty years since a discussion on a similar subject took place. On the 28th of February, 1854, a Paper by Mr. James Yates was read before the Institution "On the French System of Measures, Weights, and Coins."[1] The discussion upon that Paper related more especially to the matter of the decimal coinage, and, although the consensus of opinion seemed to be in favour of a decimal system, the discussion turned to a great extent upon what was the best standard of value as the basis for that decimal coinage. The part that more particularly interested engineers was that concerning weights and measures, and therefore he would allude no further to the coinage, beyond saying that he hoped that if England ever did adopt a decimal coinage she would disregard all questions as to what the present coins were, and effect a radical change by assimilating it to that of the other countries which were members of the Latin Monetary Union. Those who were accustomed to travel where that league prevailed knew how easy it was to pass backward and forward from one country to another without changing their money, and they also knew what difficulties arose the moment they passed from one of those countries into some neighbouring State unconnected with the Union. No doubt there would be great inconveniences in adopting an entirely different standard of value, but, although that might be so, it was only necessary to consider what had been done, for instance, in Germany, where, at the time of the formation of the German Empire, the numerous coinages that prevailed in the various States were abolished. Former travellers in Germany would probably remember the difficulties they experienced there. He hoped that if England did adopt a new coinage it would be assimilated to the French franc. The more immediate question before the Institution, however, was that of weights and measures, and perhaps it would be interesting in connection with that if he mentioned the dates at which different countries had adopted the metric system of weights and measures, in order to show how it had spread in recent years. In France, metric weights and measures were enacted in 1795, but were not made compulsory till 1840. The metric system, with Dutch names, was introduced into Holland in 1820, but from the 1st of January, 1870, the metric names came in, with facultative use of the old Dutch names. The next country which took the matter up was a very small one at a considerable distance from France—the kingdom of

[1] Minutes of Proceedings Inst. C.E. vol. xiii., p. 272.

Mr. Owen. Greece—where metric weights and measures, but with Greek names, were introduced by an ordinance dated the 26th of October, 1836. In 1852, Portugal decreed that the metric basis should be used, and a period of ten years was fixed for its introduction and adoption. The metric measures of length came into use in January 1860, weights in July 1861, surface measures in July 1862, and measures of capacity in January 1863. In Spain the metric system was adopted on the 1st of January, 1859, and became compulsory on the 1st of July, 1868. It was also the legal system of all the Spanish Colonies. In Italy the system was adopted in 1859, when most of the Italian States were united to form the Kingdom of Italy. In the German Empire it came into use in 1872, and in the Austro-Hungarian Empire it was made permissive on the 1st of January, 1873, and compulsory on the 1st of January, 1876. In Switzerland it became the legal system on the 1st of January, 1873; it was adopted in Sweden by an Act of the 19th of May, 1875; and in Norway by an Act of the 22nd of May, 1875, to come into force at the expiration of three years after the passing of the law. In the United States it became permissive by an Act of the 28th of July, 1866. He did not know the date when the system was introduced into Belgium, but it was in use there, and also in the Ionian Islands, Algeria, the United States of Colombia, Peru, Chili, the Argentine Republic, and Uruguay; and it was also permissive in British North America under an Act of 1873. Of course, if the metric system of measures were adopted in England the old systems must be discarded. As the Author had stated, the minds of engineers in America and England were saturated, especially with regard to ironwork, with dimensions expressed in English inches and fractions of inches. That would be a great trouble to English engineers at first, but he thought they must not look so much to what would be a trouble to themselves as to what would be a benefit to the world at large, and no doubt in a short time they would get so familiarized with the new measures, as to use them as readily and freely as they now did the old ones. When the German Empire adopted the metric system of measures, sixteen States fused into that Empire had no less than sixteen different lengths for the foot, varying from 9·84 inches to 12·35 inches. Their other measures varied in a similar manner, but the metric system had been adopted throughout Germany without entailing much inconvenience. All specifications in Germany and Austro-Hungary were now prepared on the metric system, and therefore he thought there would not be much difficulty in getting used to it in England, where he hoped it would one day or other, perhaps by degrees, be adopted. Mr. Owen.

Mr. Fowler. Mr. PERCIVAL FOWLER said he had been abroad for some years, and had known many engineers well acquainted with the two systems, but he had never met one who, after a month's practice, did not prefer the decimal metric system. He considered that, with the increasing international communication of the present day, it was of the highest importance that weights, measures, &c., should be uniform in all countries. Scientists had long since recognized the convenience of an international technical language, and in biology, botany, and many other sciences, Latin or Greek names had been chosen which were intelligible to all the civilized world; in electricity the new nomenclature had been adopted by an International Commission. Considering that a uniform decimal system had been adopted in nearly all civilized countries, it was necessary that England should seriously consider the question. English machinery went all over the world, and had to be mounted in other countries by workmen who were not acquainted with eighths, sixteenths, full thirty-seconds, and other like measures. In England the decimal system had been used in many ways. Barometers were graduated in inches and tenths of an inch, level-staffs to feet and tenths of a foot; and in spite of ourselves the decimal system was being introduced into this country. The difficulty of learning the metric system had been immensely overrated. He could speak from practical experience that in Spain, in a week, the workmen became thoroughly conversant with metres, centimetres, and millimetres, and he was certain that the difficulty of changing the English system of weights and measures to the decimal system had been greatly over-estimated. He had heard it said that English weights and measures were more convenient, but he did not see how that could be. He believed that one Ordnance scale was $\frac{1}{25,344}$, and besides the poles, yards, feet and inches, the land measure was 7·92 inches in a link, 100 links in a chain, and 80 chains to a mile. Silver and lead ores were reckoned by so many ounces troy to 1 ton avoirdupois, so that in order to arrive at the proportion of silver in lead it was necessary to take two separate measures, and calculate them. With regard to the question of calculations for water, since a litre of water weighed a kilogram, the calculation was of the simplest sort. In England the measurement was effected in cubic feet or gallons, and he always had to refer to a book of tables, for he could never remember the equivalent figures. A most inconvenient scale was three-sixteenths of

Mr. Fowler. an inch to a foot, and a calculation had to be made as to what proportion that was. He did not understand why it was that Englishmen had not yet adopted the decimal system. The French proverb might be true, "Les Français inventent, mais les Anglais perfectionnent," but as regarded the decimal system, Englishmen had neither invented nor improved it, and he thought they ought to adopt what had been found practicable in nearly all civilized countries. It would be of the greatest convenience, as he did not believe that a single member of the Institution had not constantly to refer to a table of that extraordinary medley English weights and measures.

Mr. De Salis. Mr. RODOLPH DE SALIS desired to mention a few facts which he thought told in favour of the present systems. It could not be denied that starting with a clean slate a universal system of weights, measures, and coinage would be desirable; but it might be fairly questioned whether a decimal system would be the best, and if a decimal system were adopted, whether it should be based on the metre; and as different systems were in existence, it might also be questioned whether the advantages of a change would counterbalance the disadvantages. In considering such a change, the advantages should be gauged not by the preferences of scientific persons, but by the convenience of the bulk of the people; and he certainly thought, for general purposes, a system admitting of binary and ternary subdivisions was more convenient than a system based on decimal subdivisions. All knew the convenience of dividing anything into halves, quarters, or thirds, or their subdivisions. It was not so clear how conveniently to divide things into fifths, tenths, and hundredths in the ordinary practical affairs of life. Of course, for all purposes of calculation a decimal system had immense advantages; but, practically, that system was in use in all calculations. Everything was decimalized, or was worked by logarithms. Even actuarial computations were always made in sovereigns and decimals of sovereigns; indeed, under the present system, computers had the advantage of using decimals when they liked, and fractions when they were most convenient. The present measures, he thought, were very convenient. A yard, for example, was the $\frac{1}{1,760}$th of a mile, and the $\frac{1}{4,840}$th of an acre. Then there was the ternary division of the yard, the foot. He had always considered the foot to be a particularly handy measure for hydraulic and other calculations. It correlated very well with the gallon and the pound, 25 quarter gallons or 50 pints making a cubic foot—near enough for all practical purposes—and

10 lbs. of water a gallon. With regard to the practical uses of the foot, the only instance he would give was that of building, and the cognate trade of brickmaking. A brick was $\frac{3}{4}$ by $\frac{1}{4}$ of a foot, and its breadth was its length divided binarily. Those were convenient fractions, and from them quantities could be estimated. The thickness of a wall was one brick, a brick and a half or two bricks, and it contained so many courses of brickwork, all in terms of the foot. If the metric system were adopted instead, it would be found that a brick was equal to 0·2286 by 0·0762 by 0·1143 of a metre, which he did not think would be very convenient. But if the brick were to be changed to suit the new system, the inconvenience would be very great; all contracts for the sale of brick earth would have to be revised, and brickmaking machinery would become antiquated. Again, it would be a great disadvantage that new work could not be conveniently joined to old work. The old bricks could not be used with the bricks of the new standard. How could old work be bonded on to new? It would be almost sure to result in failure. With regard to the theoretical basis, he agreed with the Author that the accuracy or otherwise of its relation to the meridian was not material; but according to Sir John Herschel,[1] the inch was as scientific a basis as the metre. Again, the yard was an extremely convenient step, and on that account a good basis. It was a better step than the metre. It was a natural step for a tall man, and a very long step for a short man; but adding 3·37 inches for each step would probably put it beyond the compass of a short man, and he could state personally that it was a longish step for a tall man. That was a practical consideration which ought not to be disregarded. What were the advantages to be gained by the adoption of a change which would certainly affect nearly every transaction in life? A map (Plate 1) had been exhibited showing the size of the countries using metric measures as compared with the British islands, and on the theory that the smaller must yield to the greater, it was urged that the metric system should be adopted in England. That argument, if worth anything, operated entirely the other way. The British sway extended over one-fifth of the habitable globe, while the area of metric countries was only about one-thirty-fifth. The British empire included a population of 310 millions, the United States 50 millions, and the metric countries about 200 millions. The British imports

Mr. De Salis

[1] "The yard, the pendulum, and the metre, considered in reference to the choice of a standard of length." 1863.

Mr. De Salis. and exports for 1883 to the British possessions amounted to £188,000,000, to the United States to £135,000,000, to various other places to £142,000,000, making a total of £465,000,000; the amount to the metric countries was £266,000,000. Therefore, as far as size went, the balance was entirely on the side of the present measures. The coinage would certainly be more conveniently affected by a change than weights and measures; but he thought the commercial classes were not in favour of change. In 1849 the florin, the decimal subdivision of a pound, was introduced, and the coinage of half-crowns was stopped. In 1874, a circular was addressed to bankers and others interested, asking whether half-crowns should be discontinued or florins, or whether both should be coined. In official phraseology the answer to the circular showed an "overwhelming preponderance" in favour of the continuance of both coins, while out of six letters to "The Times" on the subject, not one advocated the dropping of the half-crown. He did not regard with the Author's equanimity the depreciation in the value of their library which would result from a change in notation. No doubt a certain number of text-books would be translated, but the bulk of the works, all the Parliamentary papers, books of reference, and, he should imagine, nineteen-twentieths of the library would become antiquated and practically unusable; whereas under the present system it was found that any good book published in French or German was promptly translated into English with English measures, and took its place beside English literature. It had been urged that the metric or decimal system was much easier to learn. No doubt it was, but surely that was not altogether an advantage. He would put it in the form of a proportion sum: As Greek is to French so is the English complicated system to the metric system in point of mental training. He dissented altogether from the idea that the professional classes should be the first to advocate a change of that sort. Such a change ought to come from the bottom and not from the top, and ought to be the product of necessity. That the bulk of the people did not feel the need of the change was, he thought, shown by the fact stated by the Author, that the general public in both countries, England and the United States of America, appeared indifferent on the subject. As professed mathematicians, or at least arithmeticians, he thought engineers ought to be ready to adapt themselves to any system that appeared to commend itself to their clients, and not expect them to give up convenient binary divisions in order to facilitate professional calculations. He classed a universal system of measures, weights, and money in the same category with a universal language. Both were theoretically very advisable, but he thought they were not practicable. No doubt they would be much less anomalous than the present system, but he doubted whether they would be so useful. Mr. De Salis.

Mr. R. C. RAPIER said that ten years ago he should have made much the same speech as that which had just been delivered. In 1868, when the great discussion on the subject took place, he was strongly in favour of retaining things as they were; he then thought there was no measure of length so convenient as the English foot, and no unit of capacity so useful as the English gallon. But circumstances altered cases. During the last fifteen years he had been obliged to have recourse to metres, kilometres, and such like measures, and he found that they were not so objectionable after all; in fact, he had compiled some useful and handy rules for himself on the subject. Mr. De Salis had spoken of the importance of conserving the English system. Mr. Rapier ventured to say that the English weights and measures were not a system, they were an accident; they were never created upon any systematic principle or plan. In one part of the country 14 lbs. were a stone, and in another 16 lbs., and similar diversities were well known. Whether the standard of length was a pendulum vibrating seconds, or the common yard or foot, he did not care; but he maintained that a decimal system was the right one, and he inclined strongly to the metric system, because it was already established over the rest of Europe. The metric system had the advantage of an intelligible and definite connection between units of length, units of capacity, and units of weight. The metre was referable to the vibration of a pendulum; so would any other unit be, but it so happened that the cubic metre coincided very nearly with the English ton, the French tonne. He thought encouragement might be taken from the fact of that connection. With regard to money, the present system on the plan shadowed forth by the Author, and previously mentioned by Sir John Herschel, admitted readily of an adaptation to a decimal system, and it had a tolerably near affinity to the system on the Continent, bearing in mind that twenty English shillings were as good as twenty-five francs. The convenience of the relationship of the measures on the metric system was very great. For instance, a cubic metre of water was a ton. The number of cubic metres of any other material multiplied by its specific gravity gave the number of tons. Again, to take a familiar illustration, that of a railway to be laid with rails 35 kilo- Mr. Rapier.

Mr. Rapier. grams per metre, there were 70 metric tons in a kilometer; it was easy to reckon how many English tons there would be according to the English system, but in the other case it was obvious. If the members would regard the matter practically for about six months, they would begin to think in the new measures, and then the whole would become perfectly easy. To facilitate thinking in metric measures he had adopted the following ready rules: To convert metres into feet divide by 3, and move the decimal point one place to the right. To convert feet into metres, multiply by 3, and move the decimal point one place to the left. To convert millimetres into inches, multiply by 4, and move the decimal point one place to the right. To convert inches into millimetres, divide by 4, and move the decimal point one place to the left. To change hectares into acres, divide by 4, and move the decimal point one place to the right. To convert square metres into square yards, add one-fifth. To change cubic metres into cubic yards, add one-third. To convert kilometres into miles, divide by 2, and add one-fourth. All the above examples were worked by the use of the elementary numbers 3, 4 and 5, and gave results correct within $1\frac{1}{2}$ per cent., and the rules were therefore sufficiently near for the purpose of mental calculation to facilitate a familiarity with the metric equivalents.

Mr. Young. Mr. E. W. Young, to show the comparison between decimals and duodecimals, exhibited a calculation in compound addition by both methods, in which there was one column more in the decimal sum than in the duodecimal. Again, to illustrate the ordinary transactions in commerce, millions of which took place every day in London alone, suppose a shopman wished to ascertain the cost of 17 yards at $5\frac{3}{4}d.$, he did not reduce $5\frac{3}{4}d.$ to farthings, multiply by 17, and reduce back to pence and shillings, but he applied a process of mental arithmetic, thus: he said, Why, that is 17 sixpences less 17 farthings, or 8*s.* 6*d.* less $4\frac{1}{4}d.$, that is 8*s.* $1\frac{3}{4}d.$ It was done in an instant. Now if the decimal system were in force, and there were 25 farthings to the sixpence, the shopman would have to multiply yards by farthings, which would be far less convenient than the present system. Indeed for every little purchase made, the shopman would have to pull out pencil and paper to make a calculation. The duodecimal system had the advantage over the decimal system in admitting the use of fractions to a much greater extent, so that sums could be more easily done mentally. It was not the convenience of the scientific or professional man in his office that ought to be considered, but the general convenience of the multitude in the millions of transactions going on throughout

Mr. Young.

the country. The introduction of the metre would necessarily mean the introduction of the decimal system generally, and he thought that an alteration to the decimal system would occasion very great inconvenience, and it was exceedingly doubtful whether there would be any economy of labour in it. For the purpose of contrasting the metre with the present British standards of measurement, the following example afforded a fair comparison between the two systems. The sum was: required the contents in cubic yards of a block of masonry 88 feet by 3 feet 9 inches by 2 feet 3 inches. The usual way of doing this was by fractions, thus, $\frac{88^y}{3} \times 1\frac{1}{4}^y \times \frac{3}{4}^y$. The threes cancelled one another, and the result was at once $\frac{110}{4}$ cubic yards $= 27 \cdot 5$ cubic yards. Using the decimal system, it would be necessary first to multiply 88 by $3 \cdot 75$, and the product by $2 \cdot 25$, involving a large number of figures. Even then the result would only be in cubic feet, and though it would be unfair to the decimal system to debit it with the figures that would be needed to reduce cubic feet to cubic yards, the sum so done would be a better comparison of the two systems than the example given by the Author, which he thought ingeniously unfair. With regard to the suggestion that twenty-five farthings would equal sixpence; that, he thought, would be a great disaster, because 24 could be divided by 2, 4, 8, 12, 6, and 3, and those numbers were again divisible by others. Altogether there were eighteen divisions and subdivisions, but 25 could only be divided once by 5. He did not know how it was that the present duodecimal system was first hit upon. Evidently those who made 12 inches to the foot had some idea of utility. The same system was constantly used. There were twenty-four hours to the day; the arc was divided into 360°, a multiple of twelve. He had heard, however, that an agitation was going on for a division of the circle into decimals, which he should very much regret. If that were accomplished he supposed there would be a demand for twenty hours to the day instead of twenty-four. There was a disadvantage in the decimal system in consequence of the similarity of some of the terms, such as decimetre and decametre, decilitre and decalitre, deciare and decare, decistere and decastere. He believed that working men would be confused with words so much alike, and a great many mistakes would be made through bad writing. If a man forgot to dot the "i" that might make all the difference between a decimetre and a decametre. He thought it would be a good thing to get rid of the 66-feet chain.

Mr. Young. There were many anomalies in the present system, and a great many things that it might be desirable to change; but it was a serious matter to propose to change the whole of the system adopted in England, in the Colonies, and in the United States. He considered it a mistake to lay so much stress upon foreign commerce. No doubt it was large, but it was small in comparison with the internal commerce of the country. Foreign commerce, too, was wholesale, while internal commerce was chiefly retail; so that there might be ten thousand or one hundred thousand transactions taking place in this country with the present system of coinage and measures for one negotiation in metres. When Englishmen went abroad they took French money with them, and knew how to deal with it, and on returning home they had no difficulty in reverting to their own system. It might be necessary for German duchies about the size of an English county, placed between two large states like France and Germany, to adopt the metric system, but not a country like England.

Mr. Cowper. Mr. C. E. COWPER wished to call attention to three points. With reference to the calculation submitted by the Author, some of the advocates of the British system had computed it in different ways, some by duodecimals and some by vulgar fractions. The Author had brought it forward as a sample calculation to show the superior advantage of the metric system, but he did not think he had done his best; because, though the tank might have been marked on the drawing 10 feet 6 inches, its dimensions would be, perhaps, when made, $\frac{3}{8}$ inch more or less than that length. What was a tank to be measured for? If he had to measure the tank to find the weight of the water, in order to ascertain what sized injector to put in, or what size of feed-pump to use for a boiler, he would be content to take it approximately—say, 2 tons, which would be near enough. Suppose, on the other hand, great accuracy were needed—if, for example, the tank were used for gauging water in a pumping-engine trial, measuring the feed-water into the boiler, (and the contract price might depend upon the economy,) the case would be very different. In that case the dimensions of the tank might be 10 feet $6\frac{3}{8}$ inches by 6 feet $2\frac{5}{8}$ inches; and the depth of the water, perhaps, 1 foot $\frac{3}{16}$ inch. He thought the duodecimal system, or the vulgar-fraction system, would not then work out so neatly; but by the metric system it did not matter whether the measurement was 0·33, 0·34, or 0·35; the calculation was not any longer. Again, the Author might, he thought, have made more of the smallness of the unit. Regarding the question as a matter of abstract principle, suppose it were

Mr. Cowper.

necessary to make an arrangement for a new world, where no difficulties would arise on account of established customs or international intercourse, a small unit of measurement, convenient to work to, and one that could be easily divided on boxwood or steel, would certainly be looked for. Such a unit existed in the millimetre, but not in the inch, or any decimal division of the inch or foot; the tenth of an inch was too large and the one-hundredth too small. The millimetre was as small as required for any practical purposes, and it could be subdivided microscopically to any extent. Reference had been made to the use of logarithms; but he wished now to direct attention to the mechanical use of logarithms, to which, he contended, the metric system lent itself. He might raise a smile if he referred to the slide-rule, because people generally thought of the dirty, black, greasy thing which the fitter carried in his pocket and did not know how to use; the slide-rule there was in the wrong place; the fitter did not want it, and the proper place for it was in the office. It was little used in England, and one of the reasons for that was the complicated English system, or combination of systems, of weights and measures. In France, one of the improved forms of the slide-rule was found, he had been informed, on almost every engineer's desk; in electrical engineering it was very largely employed. Two of the largest electrical establishments in England used one or other form of the slide-rule, or the logarithm-slide, to a great extent. He therefore claimed that the metric system being a decimal system, which allowed every calculation to be checked readily by the slide-rule, possessed a substantial advantage. Many persons thought this instrument a trivial affair; but only a practical acquaintance with it would enable them to form a sound judgment as to its merits.

Mr. Chaney.

Mr. H. J. Chaney thought it was desirable, in order to facilitate discussion, to separate the question of weights and measures from that of money. The money aspect was no doubt very interesting, but experience had shown that the question of the introduction of a new system of weights and measures could be best considered by itself. The subject under discussion was not that of decimalizing weights and measures, or introducing a decimal system of money, but the desirability of introducing the metric system which was not only decimal, but binary. He supposed that few persons who had much acquaintance with the present system of weights and measures could admit it to be the best that could be provided. The metric system, *per se*, was by far the most convenient; but then the inconvenience of making a

Mr. Chaney. change which would so largely affect the daily transactions of life had to be considered. The discussion, he thought, should deal with the difficulties in the way of such a change. The question of the comparative advantages of the metric and British Imperial systems had been well thrashed out. Reference had been made to the Standing Orders requiring that all scales should be according to Imperial measure, as 4 inches to the mile, and he would suggest for consideration the nearest form of metric equivalent. Besides 4 inches to the mile, the Standing Orders might also permit a scale of 65 millimetres to the kilometre. Buildings, also, were to be drawn to an enlarged scale, of not less than $\frac{1}{4}$ inch to every 100 feet; for that scale there might also be permitted a scale of 7 millimetres to every 30 metres. Sections might be given to a scale of 1 millimetre in every 1,200 millimetres, or in every 12 decimetres, as well as to a scale of 1 inch to every 100 feet. Quantities might be allowed to be given in metres and parts of a metre, as well as in yards, feet, decimal parts of a foot, and inches. Distances might be permitted to be expressed in kilometres and metres, as well as in miles, furlongs, chains, poles, yards, and feet.

Mr. Walton Williams. Mr. W. WALTON WILLIAMS said he did not think it was necessary to choose immediately between the two systems. Engineers, before tying themselves down to the metric system, ought to consider whether it could be in any way improved. According to French engineers the metric system was absolute perfection, and Englishmen were a set of idiots for not adopting it. He had been obliged to use the metric system for many years abroad, and he desired to point out two or three disadvantages connected with it, in the hope that they might be remedied. No man could step a long distance in metres. He had seen French engineers try to do so; they could step 100 metres, but, if the distance was 400 or 500 metres, they would reckon every step to be 90 centimetres, equivalent to the English yard. The Author had stated that the metre was the right length for a measure, but Mr. Williams contended that no man could measure with it easily. The eye subtended an angle of 60°, so that a man's arms ought to be a metre long to be able to see both ends of the metre rule. The Author had stated that a workman could measure with a metre rule in two-thirds of the time required with a two-foot rule. That he denied from his experience of foreign workmen, who with a metre measure were generally longer and less accurate measuring than Englishmen with a two-foot rule; besides which the foreigner generally called in another workman to put a mark at the end.

The French themselves did not admit that the metre was absolutely the best unit of length, for any one going into a draper's shop would find that a half-metre and not a metre measure was generally used; the demi-kilo was frequently used for weight, and the customer might be heard asking for "Le quart d'un demi-kilo." With reference to levelling, it did not make much difference theoretically whether engineers divided a foot or a metre by the decimal system, except that they could frequently see the foot mark on a staff, when they could not see the metre mark. He had known instances in which a mistake had been made of a whole metre, because a man would not, or did not, lift up the staff the required distance. If a French staff with a disk were used it would be different, but where the staffman moved the disk up and down it had to be brought each time to be verified, so that the time was doubled. With regard to drawings, if they were made to a scale of $\frac{1}{10,000}$, $\frac{1}{5,000}$, or even $\frac{1}{1,000}$, it did not matter whether feet or metres were used. In drawing to a larger scale, 1 inch to the foot, the English $\frac{1}{12}$ corresponded to the French $\frac{1}{10}$; but to vary it the Englishman could go from 1 inch to $1\frac{1}{2}$ inch, or to $\frac{3}{4}$ of an inch, while the Frenchman would have to go up to $\frac{1}{5}$ or down to $\frac{1}{20}$. It had been said that $\frac{3}{16}$ of an inch was an absurd scale. Possibly; but it was $\frac{1}{64}$ of a foot; and 64 was 2 multiplied by itself five times. To put $\frac{1}{64}$ of a metre into decimals, six places of decimals would be required. He did not say that engineers ought not to adopt the metric system, but they should not be absolutely tied down to it as it at present existed. It was their duty to improve it if possible according to the saying already quoted: "Les Français inventent, mais les Anglais perfectionnent." He wished to address a few words to those who were in the habit of preparing drawings for foreign works. He had had many such drawings sent out from England, and they had been usually drawn to an English scale, and the dimensions inserted in metres. When a Spanish stonemason, or an Italian carpenter saw such drawings he was puzzled, and fresh ones had to be prepared for his use. To those who were in the habit of using the 1-inch or $1\frac{1}{2}$-inch scale $\frac{1}{10}$ was not convenient, but he thought that, considering the immense number of drawings going abroad for foreign work, a little sacrifice ought to be made in order to adapt them to the metric system, even if that system were not generally adopted in this country. Mr. Walton Williams.

Mr. W. H. THELWALL remarked that he had used both the metric and the English systems for nearly twenty years, and although he was not frightened at the metric system, he was Mr. Thelwall.

Mr. Thelwall. decidedly of opinion that the English was much more convenient in all matters of civil engineering. The Author had not given any statement of the relative times taken to do various works. He had said that a French workman could measure planks in two-thirds of the time occupied by an English workman, but if that statement was to be of any value, it ought to be supported by actual experiment. He fully agreed with what had been urged by Mr. Walton Williams that the metre was inconveniently long for accurate measurement. The Author's statement with regard to levelling was much too vague to be of any practical value, since it contained no account of the time saved. According to his own experience, French engineers were not satisfied with working to centimetres, but, even in trial sections over rough ground, worked to millimetres. In the case of sections of railways the ground and formation-levels, and the heights and depths of cuttings and banks, had been all worked out to millimetres, requiring three places of decimals instead of two, which was a serious matter. Referring all measures to the metre involved the use of a much larger number of figures than the English system. He had copied some dimensions, that he had recently met with in a French publication, of a tramway locomotive. The diameter of the cylinder was 0·220 m.; in English measure it would be 9 inches: the stroke of the piston was 0·350 m.; in English it would be 14 inches: the weight, empty, was 11,000 kilograms; in English, 11 tons: the weight, running, 13,000 kilograms; in English, 13 tons: the heating surface 18·90 square metres; in English, 203 square feet. Thus there were twenty-two figures in French, and only ten in English, measure. Take another instance, that of the strains and weight of a wrought-iron pillar, having a load of 25 square metres of flooring weighing 6,600 kilograms per square metre. $25 \times 6,600 = 165,000$ kilograms. The area of the pillar was

Web	450×12	=	5,400	square millimetres.
4 plates . . .	500×12	=	24,000	" "
4 angles . . .	$\frac{100 \times 100}{12}$	=	9,000	" "
4 " . . .	$\frac{80 \times 80}{10}$	=	6,000	" "
Total			44,000	" "

$$\text{Load per square millimetre } \frac{165,000}{44,000} = 3 \cdot 7 \text{ kilograms.}$$

In English measures the above would be, load of 270 square feet of flooring weighing 0·6 ton per square foot = 270 × 0·6 = 162 tons. The area of the pillar would be Mr. Thelwall.

	Inches.		Inches.		Inch.		Square Inches.
Web	18	×	$\frac{1}{2}$			=	9
4 plates	19	×	$\frac{1}{2}$			=	38
4 angles	4	×	4	×	$\frac{1}{2}$	=	15
4 ,, ...	3	×	3	×	$\frac{3}{8}$	=	8
			Total				70

$$\text{Load per square inch } \frac{162}{70} = 2 \cdot 32 \text{ tons.}$$

Such examples might be multiplied indefinitely. They had not been made up for the purpose of showing comparisons unfavourable to the metric system, but were fair samples taken at random from actual French practice, and converted into the corresponding English figures. Again, such things as diameters of pipes were measured by 200 millimetres, 150 millimetres, and so on, the English equivalent for which would be 8 inches and 6 inches. It frequently happened that, in the French system, three figures were used instead of one; and when in taking out quantities the figures had to be multiplied, the difference was very serious. If the Author really considered that there was a saving of time by the metric system, he ought to have given an example such as an estimate of work, or the calculations and quantities in a large iron bridge properly worked out by both the metric and the English systems, and not the long sum in the Appendix, which could be computed with less than half the number of figures given. He was convinced that the more acquaintance English engineers had with the practical working of the metric system, the less disposed they would be to exchange their own for it.

Mr. Airy. Mr. W. Airy thought that the Author had somewhat mixed up two very different matters, the metrical unit and the decimal system, which ought to be kept distinct. It appeared to him that the best unit was that which the experience of people had decided to be the best for the greatest number of measurements. For the great bulk of measurements—those relating to building, construction, and manufactures generally—the metre could not be used without subdivision, and it was therefore, in his opinion, wholly unfit for the unit for such measurements. That was proved by the fact that, in England, where the people had the choice both of the yard and the foot—and the yard for that purpose might be considered as comparable with the metre—for the great bulk of their measurements they used the foot, and not the yard. He thought it would hardly be denied that the foot was the real unit

Mr. Airy. of the English people. The metre was much too long a unit for the ordinary affairs of life; and even in France, the head-quarters of the metre, there were cases in which the French still used the foot. In Sweden and Norway also, as well as in other countries professing to use the metric system, the foot was employed for a variety of purposes. He thought there could be no doubt that the decimal subdivision of the unit, whatever it might be, afforded great facilities for calculation; and therefore for all those measures, or classes of measures, which involved frequent or complex calculations, great advantages would be derived from the adoption of that method. It would, for example, be a great advantage to subdivide the foot into 10 inches, and the inches into tenths, and he thought that such a change would be acceptable to the country at large; but for all measures referring to articles of consumption, he believed the binary system, which was much more simple to uneducated people than the decimal system, had a firm hold upon the people, which it would be impossible to shake. The Author would have done well to have made some mention of the case of Russia, which, long after the metric system was fairly established in central Europe, had occasion to set her standards in order, and after due consideration had adopted the English foot as the unit, altering the national measures so as to form exact multiples of it.

Mr. Hanson. Mr. E. B. Hanson said he thought that the sum, given in the duodecimal system, ought to have been worked by duodecimals and not by decimals. In answer to Mr. Airy, it would be sufficient to say that the standard yard was divided into feet, of which 1 foot was divided into 12 inches, and so the foot formed part of the standard. The Author had found fault with engineers for measuring with a two-foot rule, and afterwards asked them to measure with a 20-metre chain, which was hardly consistent. He then spoke of "five-sixteenths full," or "bare three-eighths," as if they were the same thing. Mr. Hanson had always understood that if there was a hole of exactly three-eighths diameter, the cylinder which would fit into it would be a "bare three-eighths," and *vice versâ*. He did not think that any brickwork or any engineering work was measured in rods now: he believed it was always measured in cubic yards. A scale $\frac{3}{16}$ inch to a foot was, he believed, one of the best. It came near to 5 feet to the inch, and it had the advantage that it was a fractional part of $1\frac{1}{2}$ inch to the foot, which was so useful a scale to the carpenter, inasmuch as $\frac{1}{8}$ inch on his rule represented an inch. Ordinary working plans for railways and so on were plotted

Mr. Hanson.

with the horizontal scale 2 chains, and the vertical scale 20 feet to an inch respectively. There was not the slightest difficulty in passing from one to the other. The same scale did for both, whereas with the metric system two scales would be necessary to measure by, and there would be a constant changing. If parliamentary deposited plans were plotted in metres, farmers and others would be wanting to know how many square metres there were in an acre. They did not reckon by metres, and it would take years to make them do so. When he was in Paris during the Exhibition of 1878, he went with a brother engineer to visit some shops where several young artizans were being taught under the French Government, and he was much astonished to find that they were using the two-foot rule, and also using English names for the various tools. On asking the reason he was told that it was found to be so much more convenient. In some shops in England, where a large number of Germans were employed, machines had been constructed partly in millimetres and partly in inches. Pulleys and things of that sort were generally measured in inches, and the smaller parts in millimetres. Considering that the metre was introduced into France forty-five years before it was properly legalized, before railways were made, and before engineering works assumed their present importance, the time it would take to introduce it into England now could hardly be estimated. There were certain standards in England which might be considered as hard and fast. The railway gauge was one of them, and it could never be altered. The measurement of 4 feet $8\frac{1}{2}$ inches looked well enough as it was, but in the new system it would be 1·435 m. There was also a standard measurement of bricks. If the metric system were introduced, he supposed that bricks would be made $\frac{1}{4}$ metre long. A trial had been made of bricks 10 inches by 5 inches by 3 inches, but they had not succeeded, and he believed the use of them had ceased.

Mr. Vernon-Harcourt.

Mr. L. F. Vernon-Harcourt said there could be no doubt that scientifically the metric system, in which the weights and measures were connected, and arranged according to a definite plan, was better than the English; but there were some disadvantages in it which ought not to be over-looked. The metre, being a larger unit than a foot, required more subdivision to measure small dimensions, and was less well adapted for levelling than feet and decimals of a foot. The constant use of decimals, moreover, in the metric system, led to the abandonment of fractions and proportions, which had a distinct value of their own in certain cases. Errors, for instance, were more liable to occur when gradients were

Mr. Vernon-Harcourt. expressed in decimals, such as 0·00125 and 0·000333, instead of as 1 in 800 and 1 in 3,000; and $\frac{3}{16}$ and $\frac{1}{60,000}$, were simpler modes of expressing these proportions than 0·1875 and 0·000016̇. In a string of noughts after the decimal point, one of them was very liable to be omitted, or the decimal point itself might be readily misplaced, causing in either case a tenfold error. Also fractions were expressed more shortly in words, and were consequently more easily remembered and repeated than decimals, where each digit had to be separately named; and the use of commas for marking off the thousands, which greatly facilitated the reading of figures, could not be employed for decimals. The Author had stated that scales for drawings were much better represented by the French than by the English system, and Mr. Vernon-Harcourt had therefore taken the trouble of looking out a few scales given in some French engineering works, of which the following were instances of those occasionally adopted; namely, 0·06667 m. per kilometre, 0·00143 m. per metre, 0·004165 m. per 100 metres, 0·0104 m. per metre, and 0·0278 m. per kilometre. Those figures, he thought, would be sufficient to show that the French scales were not always so simple as some persons imagined. No doubt a reform might be introduced, and it would be a great advantage in all engineering literature to have scales that would be comparable. He had himself tried to introduce such scales in the form of definite simple fractions of the natural size. In the illustrations for a book very shortly to be published[1] he had managed to make two hundred and twenty-five figures to nine scales, all of these scales being multiples, or parts of one another, ranging between one-thirty-thousandth and one-hundredth of the full size; so that it was possible to compare the various plans together. As to the statement with reference to calculations, he felt sure that any one who had worked with Bidder's tables for getting out earthwork could do so more quickly that way than by any other method. The Author had stated that in the case of English measurements, bushels, and cubic yards were used. When inspecting works in France he had frequently asked for the proportions of cement or lime employed in concrete or mortar, and he was always told that there were so many kilos to the cubic metre; so that in that respect there was not much advantage in the French system over the English. If the new system were adopted in parliamentary plans, especially if some plans were figured in metres and others in the ordinary English dimensions, both witnesses and the legal

[1] "Harbours and Docks," by L. F. Vernon-Harcourt, vol. ii., plates.

profession would be much puzzled. It was questionable whether the advantage in consulting foreign books, that would accrue from the adoption of the metric system, would for a long time counterbalance the loss resulting from the different notation of the whole existing British and American engineering literature. Much of this literature, including the eighty volumes of Minutes of Proceedings of the Institution, could not be reproduced with metric measures; and the necessary alterations in the Ordnance survey and the Admiralty charts would involve a large expenditure. If the metric system were introduced it would simplify calculations; but, in making the change, it would be necessary to take into account all the English-speaking communities, and a conference would be required in order to arrive at a consensus of opinion. A common system of weights and measures would be of very great value. The discussion, however, had indicated that much could be urged on both sides of the question; and unless the balance of advantage proved greatly in favour of the change, the present generation could hardly be forced to incur great inconvenience for the possible benefit of posterity. The change, if made, should be gradual, with the concurrent use for some time of both systems, and aided by elaborate conversion tables. Moreover, in such a matter, Great Britain could not be regarded merely as a European power, and the metric system would have to be adopted also simultaneously by the Colonies and the United States if any real benefit was to be gained. Mr. Vernon-Harcourt.

Mr. J. W. Barry agreed with Mr. Airy that the metre was far too large a unit for practical work. Some portion of his early life having been passed in measuring up work with quantity-surveyors, he could bear out the statement that in no case was the yard used as the unit of measurement, and in the case even of large dimensions, the foot was universally employed. He could by no means adopt the recommendation of Mr. Airy that the foot should be divided into ten parts. It was a very great advantage that it was divided into twelve parts. Any one who had had much practical work would know the advantage of being able to divide the foot by two, three, four, and six. The decimal system was comparatively useless to a man who had to work with his hands, or for mental calculations, and, moreover, absolute correctness could not in many cases be obtained by it. By the duodecimal system absolute correctness could always be obtained. Very often a measurement was required which had, perhaps, to be afterwards multiplied many hundreds of times, and if there was a small Mr Barry.

Mr. Barry. fraction wrong in the original measurement it might result in a serious error. The change from the duodecimal to a decimal system would, in his opinion, be a retrograde movement. He thought nothing was to be gained by discarding duodecimals, and would say, in the words of Lord Melbourne, "Why cannot you let it alone?"

Mr. Preece. Mr. W. H. Preece said he happened to be a member of the Committee of the British Association which had succeeded in establishing a system of electrical units based on the metrical system, and that system was now in use by every nation throughout the world, so that electricians in every country could speak amongst themselves in a language understood by all. There was not a labourer in any electrical engineering establishment who did not speak in accordance with a metric system which was completely understood. The advantages of the metric system were not to be met by ridicule. It would be an easy thing to turn the British system into ridicule. It might be said, for example, that Englishmen were so consistent that they measured the depth of the ocean by fathoms, and the height of mountains by feet; they measured their own height by feet, and the height of their horses by hands; they measured the surface of the land in miles of 1,760 yards, and the surface of the sea in miles of 2,025 yards; ale and beer were measured by barrels, kilderkins, hogsheads, pipes, and the like; they weighed their fuel in chaldrons, tons, or loads, according, as they used coke, coal, or wood; then there was Troy weight, avoirdupois, and apothecaries weight, with scruples, ounces, pounds, and so on. But ridicule would not convert any one. The only valid objection raised to the decimal system was that it could not be divided by one-third. For two years he had been trying to find out any circumstances that had necessitated his dividing by one-third, and the only thing that had come under his notice was the bill of his lawyer, who divided the pound by one-third, and charged 6*s.* 8*d.* It had been stated that the metric system was invented by the French; but with reference to the decimal system, it was worth knowing that on the 14th of November, 1783, before the system was proposed in France, James Watt wrote a letter to Mr. Kirwan, in which he fully developed a decimal system based upon the pound.[1] He agreed with previous speakers that the decimal system and the metric system should be kept separate. The metric system was a system of measurements

[1] "The Origin and Progress of the Mechanical Inventions of James Watt," by J. P. Muirhead, vol. ii., p. 179.

based on uniformity and simplicity, a system that would bring the whole civilized world together under one roof, and enable men to speak to each other in one language. He did not like to prophecy, but he thought the time was not far distant when the engineering profession would, like one of its branches, the electrical, seize upon the decimal and metric system as a labour-saving machine. It was a mistake to say that the metric system was not a binary system; it was essentially a binary system. Reference had been made by other speakers to the use in France of half a kilogram and half a millimetre. All men reasoned by experience. The man who had been accustomed all his life to the one-foot rule could not understand the metre, just as the man who had been used to the metre could not understand the one-foot rule. The English system had the merit of being ancient. It was established in 1266 by Henry III., who ordered that for the future 1 dwt. should be thirty-two grains of wheat, and that 20 dwt. should be 1 oz., and 12 oz. 1 lb. Edward II., in 1324, ordered that three barleycorns should be 1 inch, and 12 inches 1 foot. The British system, therefore, rested upon the scientific basis of the weight of a grain of wheat and the dimensions of a barleycorn. Mr. Preece.

Mr. HAMILTON-SMYTHE, in reply upon the discussion, said he regretted that criticisms of the particular calculation in metric, and in decimalized British measures which he had, perhaps somewhat unadvisedly, selected, appeared to have diverted a good deal of attention from the broader question of the general comparative merits of British and metric measures for engineering purposes. By ingenious sleights of mind, when calculating British measures by vulgar fractions, and by great proficiency in mental arithmetic, some English engineers were able to evolve results in engineering calculations which excited the admiration of simpler arithmeticians. The capacity for such feats had no doubt been fostered, as was suggested by Mr. De Salis, by long practice and experience in battling with the complexities of British measures; and the difficulties which English boys had to contend with in learning British arithmetic and mensuration had, in many cases, developed mathematical capacities similar to those literary capacities which were supposed to have been developed by long and arduous studies of ancient Greek literature. Literary men, however, were able to escape from the Greek particles and irregular verbs after leaving a school or college; whereas, British engineers could never evade the wholesome discipline of those rather irksome educators, the com- Mr. Hamilton-Smythe.

Mr. Hamilton-Smythe. pound rules of arithmetic and the British tables of weights and measures. It had once been urged that the introduction of machinery would destroy the individual capacity of the handicraftsman. Possibly this had been the case, yet the general result of the introduction of labour-saving machinery could hardly be alleged to have been unsatisfactory, and it might be asked whether the time now devoted to mastering the complexities of British arithmetic and mensuration might not be more usefully employed in overcoming technical difficulties, the study of which might develop equal mental capacities with more directly remunerative results. As time went on, and England became more fully equipped with engineering works, British engineers would probably find themselves more dependent on foreign work, and brought more into competition with foreign engineers in securing it. A considerable portion of this work would lie in countries using the metric system, so that familiarity with the system which, to quote Mr. De Salis, "appeared to commend itself to their clients," would probably be of ever-increasing importance to British engineers; while, if they were always to be burdening their memories with a double set of standard engineering dimensions and quantities, for use alternately at home and abroad, they would carry a load that would handicap the brains of most in the race for foreign work. If engineers wanted to get the full advantage out of a system of measures, they must accustom themselves to think in it. Mr. De Salis had deprecated any alteration in the size of the brick generally used in England; but bricks measuring 22 centimetres by 11 centimetres by 7·5 centimetres, would probably bond in sufficiently well with standard English brickwork. At any rate, the quality of the compound brickwork would depend most likely more upon other considerations than on the minute difference in size between the two kinds of bricks. He agreed with Mr. Walton Williams that a levelling-staff divided into separate metres was most inconvenient, and productive of error when read through a level at short distances; but if Mr. Williams would try the levelling-staff mentioned in the Paper, divided throughout into decimetres and centimetres only, omitting metre marks, his difficulty would disappear. Such levelling-staves had long been in common use, and he had used one in Austria for several years. The metric system afforded an ample supply of drawing scales to suit the convenience of the draughtsman and the sizes of his drawing paper; but it was hardly to be expected that conveniently finite metric scales would coincide exactly with the various existing British scales, which had been

Mr. Hamilton-Smythe.

adopted on account of their finite relation to the various British measures. If such had happened to be the case, one of the reasons for discarding British measures in favour of metric measures for the sake of facility for international comparison of maps and drawings would not exist. He thought no practical disadvantage would arise, as regarded the convenient size of drawings, if scales of $\frac{1}{50}$ and $\frac{1}{100}$ were used with metric measures instead of scales of $\frac{1}{48}$ and $\frac{1}{96}$ with British measures. It should be remembered that metric scales were not meant to be used to represent feet and inches, and conversely that British scales were not suited to represent metres and their decimal submultiples. As Mr. Thelwall had objected to the waste of figures involved by writing 200 millimetres and 13,000 kilograms, he might economize in them by writing the synonyms 2 decimetres and 13 tonnes. Mr. Airy seemed to have implied that the feet sometimes used in France and Norway were of the same length as the British foot; whereas he understood these feet differed about 1 per cent. and 3 per cent. respectively from the British foot, and if so would be of little value for international purposes. The adoption by Russia of the British foot was an argument, though of limited value, in favour of British measures which had been overlooked in the Paper; but it was probably merely the correction of the length of a foot that had been used in Russia ever since Peter the Great carried home an English carpenters' foot-rule, and imposed it on his subjects as a standard measure. Mr. Hanson had joined Mr. Walton Williams in a defence of the $\frac{3}{16}$-inch to a foot scale; but the advantage claimed for it of suiting the existing divisions on a carpenters' rule would disappear if the carpenters' rule became metric, and the carpenter would then find that the natural scales of $\frac{1}{50}$ and $\frac{1}{100}$ would suit the metric rule quite as well. So far as he was aware, there had never been any question of the metric system affecting the British standard railway gauge, which was practically the same as the standard railway gauges of most countries using the metric system; and he thought Mr. Hanson was hardly justified in assuming that if the metric system were introduced into England, bricks would necessarily be made $\frac{1}{4}$ metre long. He regretted that Mr. Hanson had not stated what the young artisans in France happened to be measuring with a two-foot rule. If, for instance, they were measuring British-made machinery, it might be more convenient to use a two-foot rule for that purpose, on account of the various dimensions of what they were measuring having been constructed to finite British measurements. Many of the incon-

Mr. Hamilton-Smythe. veniences attributed to the metric system would be found to vanish on investigation. If computers preferred expressing metric measures in vulgar, instead of in decimal, fractions, they were at liberty to do so, nor was there anything to prevent a man speaking of $\frac{1}{4}$ metre instead of 25 centimetres. It had been urged by Mr. Vernon-Harcourt that if metric measures were allowed to be used in Parliament, both witnesses and the legal profession would be much puzzled. He doubted, however, whether the average witness could be as easily puzzled with metric measures after a short experience of them, as he could always be with British measures, while the members of the Parliamentary Bar had certainly sufficient intelligence to enable them to master the metric system in addition to their briefs. He was struck with Mr. Barry's quotation from Lord Melbourne. Lord Melbourne, having attained to great eminence in his own line of life, apparently became disposed to think that changes must necessarily be for the worse. But there were many things, including the methods of measuring used in England, which had not yet been brought to perfection, and it appeared, from the remarks of Mr. Preece and others, there were some eminent members of the Institution of Civil Engineers who thought our time-honoured British measures for engineering purposes might be improved upon with advantage. Almost every large general question resolved itself into a choice between evils, or into a balance of advantages, and the question between British and metric measures was no exception. He contended that, on the whole, the net balance of advantages was so much in favour of the metric system, that all impediments to its use in England should be removed as far as possible; and that it would be to the ultimate interest of English engineers to begin to make use of it for professional purposes. He believed continental experience, as he had pointed out in the Paper, had proved this to be much more easy than many members would have been disposed to think, and the temporary translating of the comparatively few measurements which specially concerned the outside public in the plans of engineering schemes, had not been found so laborious as might have been supposed. In Ireland, land purchased for engineering works had to be computed in Irish land measures, the conversions into which were at least as troublesome as the conversion of hectares into statute acres. Sub-contracts for fencing, walling, and even some other kinds of masonry, were in Ireland set in Irish lineal perches, and various local measures had to be used there for purchasing lime, roadmetalling, and some other engineering materials. Any one taking the trouble to investigate the approximate relations existing between metric and British measures, would find rules for approximate and rapid interconversion, which were at least as easily remembered and applied as the many ingenious mnemonics so freely used for abridging British fractional arithmetic and mensuration. Take for instances of the former— Mr. Hamilton-Smythe.

10 lineal	metres	approximately	equal to	11 lineal	yards.
10 square	,,	,,	,,	12 square	,,
10 cubic	,,	,,	,,	13 cubic	,,

When once, however, metric measures had supplanted British standard and local measures, all such approximate and other converters would be discarded and give place to more remunerative engineering knowledge.

Sir Frederick Bramwell.

Sir FREDERICK BRAMWELL, President, said he wished, before the close of the meeting, to ask the indulgence of the members for $0 \cdot 083\dot{3}$, or it might be $0 \cdot 166\dot{6}$ of an hour. What was the object of a system of arithmetic? He supposed that it was to be able to make calculations in the easiest manner, and to arrive at sufficiently accurate results. The question, therefore, was whether the system in use in England, or that in use on the Continent, was the more likely to satisfy these conditions. He felt inclined to say, from many years' consideration and experience, that the English system was the more likely to give this satisfaction. Of course a mere statement of opinion, if unsupported by facts, was of no value, and he therefore desired to give one or two reasons for the faith that was in him. He wished to be allowed to use the decimal system with English weights and measures when he liked, and to use vulgar fractions when he liked. At the present time the metric system was permissive in England, so that any one could use it when he pleased; but he presumed that the object of the Author was to have an Act—a compulsory Act—which should forbid the use of the present English weights and measures. What would be thought by the advocates of the metric system, if those who preferred English weights and measures were to introduce a Bill for the purpose of prohibiting the metric and the decimal method. They would, no doubt, look upon such a measure as being very wrong and improper, and he must be permitted, on the other hand, to regard the introduction of a Bill to compel the use of the metric system as being equally wrong

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and improper. His hearers must not suppose that the advocates of the metric system were not amenable to the charge of seeking to make the continued use of the existing system a crime. The Bill brought in by Messrs. Ewart, Bazley, Baines, Smith and Graves on the 24th of February, 1868, contained the following penal clauses:—

"10. From and after the expiration of years from the passing of this Act, the Imperial and all local or customary weights and measures shall be abolished, and every person who shall sell by any denomination of weights and measures other than those of the standard metric weights and measures, or such decimal multiples or decimal parts thereof as are authorized by this Act, shall on conviction be liable to a penalty not exceeding the sum of forty shillings for every such sale.

"11. From and after the expiration of years after the passing of this Act, if any person or persons shall print, or if the clerk of any market or other person shall make any return, price list, price current, or any journal or other paper containing price list or price current, in which the denomination of weights and measures quoted or referred to shall denote or imply a greater or less weight or measure than is denoted or implied by the same denomination of the metric weights and measures under and according to the provisions of this Act, such person or persons or clerk of the market shall forfeit and pay any sum not exceeding ten shillings for every copy of every such return, price list, price current, journal, or other paper which he or they shall publish."

There must indeed be an extreme superiority of one system over the other, to justify an enactment that would cause a man to be considered a breaker of the law and liable to penalty simply because he chose to make his calculations by the old method instead of by the new one. All that he asked was, that liberty should be left to people to make their own selection, and he thought if that liberty were continued it would be easy to foretell the result. The permission to use the metric system as a legal measure had existed in England for some years, and in the United States for a still greater number of years, but it had not been adopted; whereupon the advocates of the metric system, not content with leaving it to the selection of the people to use that which was most convenient, wanted to force their particular mode upon them by means of penalties. To come now to a consideration of the relative advantages and disadvantages of the two systems. What were the facts? The Author had spoken of "stones," "drams," "scruples," and so on; but such measures were not used by engineers. He had ridiculed the scale of three-sixteenths of an inch, but, as had already been pointed out, that was one sixty-fourth of a foot, and he believed that his mind was as capable of grasping the idea of one thing being sixty-four times the size of another as it was of being impressed by the notion that the relative dimensions of two objects were 1 and 100. The Author had brought forward a pair of calculations to illustrate the general superiority of the decimal-metric system above the existing English system; but in one sense, and in one sense only, was this calculation that had been placed before them typical of the metrical and decimal system—in the enlarged copy on the wall the decimal point appeared in the wrong place, as it always did. Some years ago he went into the workshops of the Paris and Lyons railway, where he was shown a drawing of a locomotive, with a variable blast-pipe, and he asked what was the maximum and what the minimum area. One of the engineers took a sheet of foolscap, covered it with figures from top to bottom, and then gave him a dimension rather bigger than that of the cylinder. Sir Frederick Bramwell had a two-foot rule in his pocket, and, finding that the drawing was made on the scale of one-tenth, he applied the English inch tenth, and so got out the area and translated it into French measures, which he did in one-fifth part of the time occupied by the man figuring on the paper. He did not displace the decimal point, because he had not got one. Reverting to the calculations on the wall, he wished to show how utterly misleading they were. The Author had placed before the members two comparative calculations, employed to ascertain the weight in tons and decimals of tons of the water contained in a given sized vessel. In consequence of the bulk of water representing the weight in French measures he was enabled to stop in his calculation on arriving at the cubic contents, and to say, "The whole thing is done; there is the weight of the water; but if you do it in English measurements you will have all these additional figures to use before you can get the weight of the water." Assume for the moment the difference in the length of the two calculations existed, what did it prove as regarded the general question? Nothing whatever. To what did it apply? To fresh water at a particular temperature, and to nothing else. There was no other liquid on the face of the earth, from ether to mercury, for which it would be true. It was not true for salt water, nor would it even do for fresh water at a different temperature. In any other case a multiplier must be used to get the weight, which would make the metric calculation as complex as the Author's English example. But who but one whose mind was warped by the metric system would have thought of turning inches into decimals of feet prior to

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calculation? Would not any one else have worked the sum thus?—

10	6	
6	2	
63	0	
1	9	
64	9	
1	1	
64	9	
5	4	9
70	1	9

The annexed sum showed how any one not saturated with decimals dealing with 10 feet 6 inches by 6 feet 2 inches by 1 foot 1 inch would have treated it. There in twenty-five figures was the answer, as regarded the cubic contents, while the metric system, to reach the same point, had needed thirty-five figures. Mr. Percy Fowler had spoken, to his great astonishment, of the way in which workmen in Spain used the metric system, and made calculations which persons of the same class could not make in England with the ordinary English measures. He had never travelled in Spain, but he had travelled in France, Italy, and Germany, and had made it his business to ascertain what the facts were with regard to the powers of the people to do anything in the way of mental arithmetic, and he said unhesitatingly that in those three countries it was the rarest possible thing to meet a person who could make a mental calculation, not because they were wanting in intelligence or ability, for they were quite equal to the English in those respects, but because they dealt with a system so cumbrous that it absolutely precluded mental calculation. Let any one go to a French railway station, and ask for three tickets from A to B, and it would generally be found that the man (or, as was commonly the case, a woman, with a man to look after her) could not tell the amount without taking a piece of chalk or a pencil and making a calculation. The clerk would have no more idea of what three times the single fare was than a child would have. Compare such a person's power of calculation with that of an English butcher's wife or daughter who was in the habit of dealing with pounds and ounces and pence. Let him test the question nearer home. Could many of those present mentally square $3 \cdot 25$? He believed very few. But there was no difficulty in squaring $3\frac{1}{4} = 10\frac{9}{16}$. $10\frac{9}{16}$ was a sum easily appreciated and easily expressed, while in $10 \cdot 5625$, the decimal equivalent of the vulgar fraction was much more cumbrous, and he ventured to think did not form any impression on the mind, except that it was a little more than one half. Again, which of them could square $4 \cdot 125$? That to the majority would be almost impossible, but with $4\frac{1}{8}$ there was no difficulty. $17\frac{1}{64}$ compared with $17 \cdot 015625$. It appeared to him that a system like the present one, which enabled mental calculations to be made rapidly and accurately, was enough for all practical purposes. It did not lie in the mouth of decimalists to insist upon absolute accuracy, because they were content with approximation, and must of necessity be so

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in many cases. With regard to the statement as to the metre being the ten-millionth part of a quadrant of the meridian, Mr. Hawksley had fully exposed this in his presidential address, to which he would refer the members.[1] The whole thing had been a failure, and Frenchmen themselves did not use the notation, nor did they use the unit of weight. It had been intended, if it were desired to express the thousandth part of a metre, it should be done by writing the word metre, and putting below it a decimal point followed by two 0's and a 1, thus $\overset{\text{Metre}}{0\cdot001}$; but what was the fact? A millimetre was expressed by m/m. So with the kilogram. It was intended that should be the unit, and the lesser divisions were to be indicated by a decimal point and the regular number of ciphers, but the fact was the unit was too large, and accordingly the French bought and sold by the half-kilogram, and they called it the $\frac{1}{2}$ kilo, and not 0·500 kilo, or even 500 grams, these modes were too roundabout as compared with "half a kilogram," and humanity would say half a kilogram in spite of penalties. Centimes, again, were often replaced by sous. The "tonne," also, was not a part of the metric system, but was an invention to cure a failure in the system. People did not and would not deal with thousands of figures when they could adopt another mode of expressing the number compendiously by a single figure. As regards the facilities afforded by English weights and measures, he desired to be permitted to refer to the numberless short cuts in mental calculations given by the present system. How much they would have to forego if they were forbidden to say that plate-iron was 5 lbs. to the foot super, and cast-iron 4 inches to the pound, adding $\frac{1}{20}$ to make the necessary correction. Round-iron, by the present system, could have its weight calculated in a moment, squaring the diameter in eighths and dividing by twenty-five, or multiplying by four, gave the weight in lbs. per foot at once; for example, $1\frac{3}{8} = 11$, $11^2 = 121$, $121 \times 4 = 484$ lbs. per foot. Water had been referred to as an instance of the wonderful use of the metric system. He would take a water illustration of a simple calculation by the English system. If engineers wanted to know how much a pump would lift, what did they do? They squared the diameter and multiplied by the stroke of the piston in yards, and at once obtained the amount in lbs., as every yard upon the circular inch was a pound. Taking an 8-inch pump, the square was 64; it was making 10 yards a minute—

[1] Minutes of Proceedings Inst. C.E. vol. xxxiii., p. 342.

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64 gallons a minute—there they had it in a moment. Another instance, 1 inch of rain to the acre was 100 tons, or, to be more accurate, 101 tons. In the United States, where, as here, they had the option to use legally the metric system, they had not used it. Mr. Sellers, one of the best authorities, had said that the thing was not fit to be used. He would refer the members to one who was not a bad engineering authority, Rankine. He would read to them the last verse of Rankine's song in praise of the three-foot rule:—

> "Here's a health to every learned man that goes by common sense;
> And would not plague the workman on any vain pretence;
> But as for those philanthropists who'd send us back to school,
> Oh, bless their eyes, if ever they tries to put down the three-foot rule."

He would also read an extract from a speech of Mr. Beresford Hope on the same subject, made in the debate on Mr. Ewart's Bill:—

"Decimalization is a process of calculation for the benefit of the calculator. Metricalization is not a process, but a system of measures, so called from its unit or base, which happens accidentally to be facilitated by the ease with which its details may be worked out through means of the decimal notation. The metrical system in itself is an abstruse and philosophic one, founded upon the fancy of some French men of science at the time of the Revolution, who adopted as the starting-point of the system the measurement of the earth's circumference, and by way of a unit, measured the 10,000,000th part of a quadrant of a meridian through Paris (about $39\frac{5}{13}$ inches) which they termed a 'metre.' No doubt those multiples and aliquot parts of the metre which form the French measures of length are adjusted to meet the decimal system, as are also the measures of area, capacity, and weight, which are by a further process built upon the metre. But decimal notation is equally applicable for the man who finds that it helps his calculations whenever he has to work out his sum in our old weights and measures; for decimals are really not a system, but, as I said, a process for easily reaching a certain practical result, like logarithms or algebraical symbols. I grant all the advantages which their friends urge in behalf of decimals for the purpose of calculation; but it requires no Act of Parliament to enable those who appreciate them to make their own calculations by way of decimals. Least of all, is legislation needed for the merchant princes—the men of enormous means and gigantic transactions—whose advocate my hon. friend the Member for Liverpool (Mr. Graves) has made himself. They have but to keep a calculating clerk—an employé whose one duty is to manipulate the decimals—and they have got what they want. The sufferers will be the little people—the small buyers and sellers, the hucksters and the marketers—who will be compelled under the penalties of a compulsory Act of Parliament, to learn and to use a system which is, in its outward type, as non-natural as it is novel. I will, in order to prove my point, take the most familiar instance, and show that although a great deal has been said about the advantages of the French subdivisions, yet, after all, our subdivisions are more natural for the ordinary purposes of life. If a boy has to divide an apple, does he ever think anything

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about the circumference of the earth and its aliquot parts, or about the decimal system and its unrivalled facilities for calculation? No; but he takes his apple, and cuts it into two parts if he wants to halve it, and those halves into quarters if he wants to make four parts of it. In the same way, if a housewife has to cut up the loaf for her family, she divides it into two, into four, into eight, or into sixteen parts, and the sixteen people share their bread naturally. Supposing the loaf to weigh originally a pound, each of these sixteen divisions comes out an ounce. Such is the *rationale* of our system of measuring—the binary system so-called—founded on continual halving, and proved, by the common sense of mankind, before the great era of enlightenment inaugurated in 1789, to be the most convenient and natural one. But I may be told—Halve away, but then express your halvings in decimals. This is very easy for the merchant prince to do when he is totting up his large transactions in 'centals,' or for the Chancellor of the Exchequer when dealing with a nation's finances; but how will it suit the little transactions of daily life? I come back to my loaf. How are ordinary people to represent halves and quarters by decimal points? The symbol of a half is the figure 'five,' with a dot to its left hand; the symbol of half that quantity, that is of a quarter, is the sum twenty-five, also with a dot to its left hand. Arithmeticians understand how this can come about, and the symbols have grown natural in their eyes; but in what—even the most infinitesimal—degree do they tell their own story to the unlearned? What palpable relations towards each other can be disentangled out of these most frequently recurring symbols? What is there in the nature of things to show that the dotted five means a half, and the dotted twenty-five a half of that half, and a quarter of the 'one,' with no dot on either side, which stands for unity? Decimal notation is then, after all, as I have been arguing, a process, and not a system. It is a process good for the schools, and good for the bustling counting-house and the large sum, but the poor man would be completely thrown out if he had to employ—under penal legislation, too—decimal points for the purpose of measuring his little purchases by halves and quarters. With permissive means, such as now exist, the system will come in where it is wanted, and be kept out where it is not wanted; but under a compulsory enactment it will intrude itself everywhere, and show itself in its real colours as nothing less than a public nuisance. But the more we examine the Bill of the hon. Member for Dumfries, the more inapplicable do its provisions seem for the purposes of practical life. I have touched upon the principles of the metric system, let me now call the attention of the House to the language in which (after the French model) it is proposed to clothe that system. The new unit of weight is to be the 'gram' or 'gramme,' which is attained by providing a square vessel, whose capacity is the cube of the hundredth part of a metre ('centimetre,' to wit), and then weighing the amount of water which it will hold at a certain temperature. One-tenth part of this gram is to be a de*ci*gram, and ten times a gram is to be a de*ka*gram, for the reformers decreed that aliquot parts were to be named after the Latin, and multiples after the Greek numerals. How in the name of common sense can we make poor people understand that because there are the letters 'ci' in the one word it means the tenth of a gram, and that because there are the letters 'ka' in the other it means 10 grams, or 100 decigrams? My hon. friends the Member for Dumfries and the Member for Liverpool come to this House representing great commercial transactions; but I stand up for the poor man. Only imagine an honest housewife going into a shop and asking for a decigram of pepper, and a dekagram of tea; imagine, too, the milkmaid selling her fluid by the litre. The Member for Liverpool is a kind-hearted man; is he then prepared, with all the stringent force of a penal statute, to enact that,

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when one of his youthful constituents may desire to effect a commercial transaction in a manufacture for which one portion of that great borough is famous; he should be bound to go to the shop and tender his 'dime' for three decigrams of Everton toffee? Fancy the farmer who has been accustomed ever since he entered on his farm to cultivate the 'ten' or the 'twelve-acre field,' having to consult the steward about liming the seventeen *are* field, or be a criminal and a contemner of the laws of his country. Fancy the bumpkin who was prepared to boast that he was within a decimetre of catching the fox as he crept through a gap about a dekametre from the white gate. If the theorists and the men of wealth—men of brains, it may be, but as certainly men of self-assurance—have worked out this system for themselves, there are poor men, who form the majority of mankind, for whom it will never answer, and there are men of brains at least equal who are decidedly opposed to its adoption. Is it not possible that our present system is not only quite as convenient and useful as the metric system, but a little more philosophical also? Why should a standard founded on the quadrant of the earth's circumference passing through the meridian of Paris be a better one than ours? No doubt it looks very solemn, from the grand nomenclature with which it is propped, but all those odd names for the French weights and measures were adopted at the first heat of the great Revolution, when the pedantic aping after ancient Greek and Latin terms led to their being applied to everything novel and French—from the scanty proportions of a lady's dress to the most intricate principles of jurisprudence and moral philosophy. Moreover, they have taken root in nations whose vernacular languages are themselves derived from the old classical tongues. May it not, I repeat, be just possible that our unit is as good as that of the French, even upon the most abstract grounds?" [1]

Mr. Beresford Hope, having spoken in that commonsense way, had quoted a letter from Sir John Herschel, which was very well worth reading, but he would not detain the members with it. He would only refer to one other matter, and that was the coinage. It had been said, you may decimalize the pound without difficulty. This was one part of the case which had not been considered. Once let the pound be decimalized, and there would be an end of the guinea. He did not know whether there were any physicians or barristers present, but if there were he would remind them that by the new system they would lose $0 \cdot 047619$ of their incomes—in other words $\frac{1}{21}$. When the pound was decimalized no one would be prepared to pay the next division, which would be $\frac{1}{10}$ instead of $\frac{1}{20}$. In conclusion, he would tell them of a ready way which he always used for mental calculation when turning millimetres into inches. Mr. Rapier had said, multiply by 4, but this needed a correction, which was, deduct $\frac{1}{64}$ of the product; this would give an answer as near the truth as the 3 .. $3\frac{3}{8}$ commonly taken; for example, 16 millimetres $\times\ 4 = 64 - \frac{1}{64} = 63 = 6 \cdot 3$ inches.

[1] Hansard's Parliamentary Debates, vol. cxcii., May 13th, 1868.