INSTITUTE OF MARINE ENGINEERS

INCORPORATED.

SESSION 1901-2.

President—JOHN CORRY, ESQ.

NINETY-FIFTH PAPER

(OF TRANSACTIONS)

THE VALUE OF ACCURACY OF MEASUREMENT, STANDARDS, AND GRADATIONS OF SIZE.

BY

MR. FRANK COOPER (MEMBER).

READ AT

58 ROMFORD ROAD, STRATFORD,

On MONDAY, MARCH 11th, 1901.

DISCUSSION CONTINUED

MONDAY, MARCH 25th, 1901.

PREFACE.

58 Romford Road,
Stratford, Essex.
Monday, March 11th, 1901.

A meeting of the Institute of Marine Engineers was held here this evening, presided over by Mr. J. G. Elmslie (Member of Council), when a Paper on "The Value of Accuracy of Measurement, Standards, and Gradations of Size," was read by the author, Mr. Frank Cooper (Member).

The Paper was illustrated by the exhibition of several interesting machines and samples of bolts and nuts, showing the divergence from standards of threads and sizes. The discussion was adjourned until next meeting.

JAS. ADAMSON,
Hon. Secretary.

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THE VALUE OF ACCURACY OF MEASUREMENT, STANDARDS, AND GRADATIONS OF SIZE.

BY MR. FRANK COOPER, R.N.R. (MEMBER).

READ AT

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MONDAY, MARCH 11th, 1901.

CHAIRMAN:

MR. J. G. ELMSLIE (MEMBER OF COUNCIL).

MUCH has been written during the past few years, and principally in the pessimistic mood, regarding the increase of competition Great Britain is meeting with in the manufacture of machinery and in the iron trade generally, in which up to the present she has held the premier position. We have been told in so many words that the old country is effete, and that she must very soon give way to those who are adopting methods of manufacture and commercial business generally on a less conservative and more "up-to-date" method.

Without giving way to this extreme view, but recognising that competition is good for nations, as it is for individuals, it might be well to turn to their best possible use any lessons to be learnt from the increase of competition which undoubtedly has taken place and adopt the methods which have been employed by competing countries in so far as they can be shown to be advantageous.

Great Britain suffers to an extent from an excess of conservatism—the result partly of her age and partly of her success. An elderly man is, as a rule, less radical than conservative, and a successful man is, as a rule, less pushing than the man who has yet to make his name. This explains to an extent the very rapid strides that have been made both by Germany and the United States in iron and steel manufactures. Great Britain was so far ahead of them when they started that nothing less than supreme efforts were wanted on their part to make any headway at all in the race. However much we may assert that we are still ahead in many branches of engineering, and in none perhaps more than in marine engineering, there is no use blinking the fact that in workshop practice generally we can learn much from our American cousins. It is not meant to be implied here that the American workman is a better workman than the British workman. Far from it. The British workman can still hold his own with any body of men in the world, either in skill or in resource. But the most magnificent workmen cannot hold their own long against workmen who are provided with better tools or methods, just as the bravest and noblest soldiers must in the end give way to the better equipped or more up-to-date armies. It may be true, in a sense, that "he is a bad workman who blames his tools," but it is quite as true that a good workman will do better work with good tools than with bad ones. Given then the best workmen, why should they not be provided with the best tools and with the best methods? That our tools and methods might be improved must be admitted by all except those who believe we have come to that most undesirable end, viz., "perfection." When a man has reached that summit he is of little more use in this world.

The fact that some American practice is ahead of some of ours is due partly to the other fact that "Necessity is the mother of invention." Labour in the United States has never been so plentiful as it has been with us, and this particularly applies to skilled labour. Labour-saving devices were therefore things of necessity and were soon forthcoming. With us labour has been more plentiful and cheap and the necessity for labour-saving devices consequently less. It is also true that in the United States every skilled workman is recognised to have brains and is encouraged to use them—to the profit, be it hoped, of both his employer and himself. Where this is the case, as it is in a number of shops in this country, the very best results for all must follow. Many of you, however, could no doubt name shops where no brains are recognised, excepting those of the master and the foreman. In such shops it seems extremely doubtful if the full capacity of the manufactory is being attained. Is it not a fact that when men are put on piece-work they very soon devise means of more expeditiously accomplishing the end than when they are merely working by the hour under the regular shop methods? Making full allowance for the fact that "the end" is to make more money for themselves, it is nevertheless true that on piece-work men use their brains more, as well as their hands better probably, and are less under strict surveillance as far as the method of doing the work is concerned. Men on piece-work do also at times use their brains for ulterior purposes, and it is not the object of this paper to applaud all the practices of piece-work. The matter has only been referred to for the purpose of suggesting that it might be well in many cases to allow men a little more latitude and freedom in methods of carrying out work.

In accuracy of measurement and in standardising machines and parts we are not in this country as far ahead as the United States. This may be due to the fact that we have not yet adopted automatic machinery to the same extent as they have.

The advantage of the adoption of automatic labour-saving machinery is twofold: it saves labour (and the expense of labour) and it results in greater accuracy. It saves labour, because one man can look after more than one machine, and the accuracy of the work depends on the machine and not on the experience or expertness of the workman. This does not mean, however, that you will be able to turn out your work with a poorer class of men. On the contrary, the more automatic your machinery becomes, the better must the brains and the hands be to look after them. This may appear to be a paradox, but an illustration in connection with marine engineering will make it patent to you all. In the early days of marine engineering, marine engineers were probably as good handicraftsmen as any that are sailing now, but they certainly did not require to have the wide scope of knowledge and resource which marine engineers now have. Electric lighting, hydraulic lifting and refrigeration were then in their infancy, if not quite unknown to the average marine engineer, whereas now the majority of marine engineers must know and be able to handle these machines. Engines and boilers are better made than in the old days, and require much less attention to keep them working, but this is more than made up for by the augmentation of other machinery. It would therefore be just as correct to say that you now require a poorer class of marine engineers to look after marine engines and boilers, because they are so much better made and better equipped, as it would be to say that by adopting automatic labour-saving machinery a poorer class of workmen will be competent to attend to it. The best paid men have always been, and always will be, the most valuable to their employers.

The adoption of automatic labour-saving machinery has still a further advantage, viz., it leads to the production of duplicate and interchangeable parts. The construction of a bicycle is not by some considered a great engineering feat. But the cycle manufacturers of this country deserve the thanks of the engineering community for having been the means of extending greatly the system of duplication and working to standards. It is hardly too much to say that had our cycle makers proceeded upon the old-fashioned lines of making each piece fit its own place—and its own place only—all our bicycles would have been "made in Germany," or the United States of America. Whether that would financially have really been a matter for regret or congratulation raises a point which does not come within the scope of this paper, but the fact remains that by adopting "up-to-date" methods and machinery our cycle makers were able to hold their own against all comers as far as perfection of product and price were concerned. This was only done by the introduction of labour-saving machinery and the interchangeable system. The question arises whether this system is being adopted to as great an extent as it merits.

The object of this paper is to bring to your notice a few suggestions regarding (1) the value of accuracy of measurement, (2) the great advantage of standardising parts and having proper gradations of size, and (3) the advisability of abolishing some of our present methods of measurement by gauges such as wire gauges, etc. The adoption of the first would lead to the second and would assuredly abolish the third.

So long as we continue to measure by eighths, sixteenths, thirty-seconds, sixty-fourths, etc., the expressions $\frac{1}{4}$ in. *full* or $\frac{1}{4}$ in. *bare* will continue to be used, because it is impossible to describe by a vulgar or any other fraction a measurement which is just *apparently* over or under a particular line on a rule. And it is just as impossible for any man to say what is *full* or what is *bare* as it is to tell how many *fulls* or how many *bares* make one inch.

The adoption of the system of describing measurements by decimal fractions would, however, alter all this. With vulgar fractions on our rules it is only possible to go so far by lines on a straight surface. Some rules are marked with hundredths of an inch, but it is practically impossible to measure to them, and even if it were any turner or fitter knows that the 100th part of an inch is not a fine measurement. For the purpose of illustrating this point I have here an external cylindrical gauge which is 1 in. exactly (to the 1/10,000th part of an inch). I have also here an internal cylindrical gauge which has four steps on it, the largest one being exactly the same size (to a ten thousandth part of an inch) as the external gauge. The next step is 1/10,000th of an inch less than 1 in., the third is 1/1,000th of an inch less than 1 in., the fourth is 1/100th of an inch less than 1 in. People sometimes smile when one speaks of measuring to the 1,000th part of an inch, but these gauges will show you that you are measuring with that amount of accuracy every day of your lives without knowing it if you do not have an instrument for gauging these measurements. It is, of course, quite impossible to see such measurements on a rule, and it is almost as difficult to describe them by the regular vulgar fractions, but the adoption of the decimal system of measurement would remove all difficulties in that way.

The decimal system of measurement has not found the favour it deserves in this country, because a great many people are under the impression that the decimal system can only be introduced and used if we alter our standards of measurement. Our standard of measurement is the standard yard of 36 in., and there is no reason at all why the fractions of an inch should not be described in decimal fractions, leaving inches, feet, and yards as they are at present. When a man describes a size as an eighth *full*, no man living can possibly tell accurately how much another man's *full* is, if indeed the man himself can say how much it is. By the very expression of such a size he simply says, "it is something more than $\frac{1}{8}$ in., but how much I cannot describe." Now with the decimal system this is all changed and a man can say, according to what instrument he measures by, whether the size is 1,000th or 1/10,000th part of an inch greater than $\frac{1}{8}$ in. The vulgar fraction $\frac{1}{8}$ in. is by decimals 0·125 in. Now if you have an instrument which measures to the 1/1,000th of an inch you can immediately describe by how many thousandths of an inch the size is larger than $\frac{1}{8}$ in. If it is 1/1,000th you say ·126 in., and if 2/1,000ths you say ·127 in. instead of $\frac{1}{8}$ *in. full*, and now everybody knows that the size which you designate is that size within the 1/1,000th part of an inch. This is another advantage of the decimal system of measurement, viz., that those who read your figures know to what degree of accuracy you are measuring. Because, if you are measuring to the 10,000th part of an inch you use four places of decimals, and if to the 1,000th part of an inch you use three only. If, for instance, you describe $\frac{1}{8}$th full as 0·1265 in. anyone will know that the size is 15/10,000ths of an inch over $\frac{1}{8}$ in., because 1,250/10,000ths is $\frac{1}{8}$ in., and you write ·1265 in. which is ·0015 or 15/10,000ths more.

It is of course impossible to measure to such accuracy with an ordinary rule, but with micrometer calipers these sizes can be measured with ease and with accuracy. They are so simple that any man or boy with average intelligence can learn to read them in a few minutes. One even who is not accustomed to decimal fractions can very quickly become used to them as the decimal equivalents of the regular vulgar fractions are, as a rule, stamped on the bar. To make matters easier even than with the ordinary micrometer caliper, Mr. J. Ciceri Smith devised a micrometer, on which he read a paper before the Royal Scottish Society of Arts in Edinburgh in 1895. On this micrometer, one of which I have here (see Fig. 2), the decimal sizes of the inch appear before you in figures as you turn it, and Mr. Smith prepared a special table for the reading of this micrometer, a copy of which is by his courtesy shown. In this table, as you will see, you have all the decimal equivalents of the fractions of an inch by 64ths, so that it is an extremely simple matter to say at once what vulgar fraction and how many 1,000ths more or less any size is.

All micrometer calipers do not of course indicate the measurements in this way, but the reading of any micrometer caliper is such a simple matter that it would be a calumny on the intelligence of any workman to say that the reason he did not use it was because he could not read it. The principle of the micrometer caliper is a screw free to move in a nut. An opening to receive the work to be measured is afforded by the backward movement of the screw and the size of opening is indicated by the graduations. An illustration of the micrometer in its simplest form is shown on Fig. 1, and may be described as follows :

MICROMETER CALIPER.

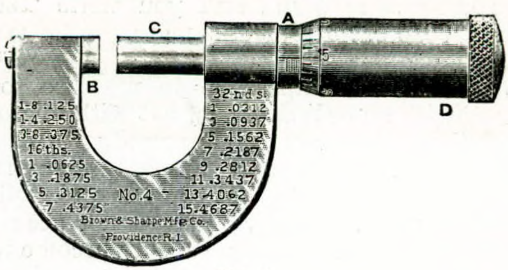


FIG. 1.

The pitch of the screw C is forty to the inch. The graduations on the barrel A, in a line parallel to the axis of the screw, are forty to the inch, and figured 0, 1, 2, etc., every fourth division. As these graduations conform to the pitch of the screw, each division equals the longitudinal distance traversed by the screw in one complete revolution; and shows that the caliper has been opened 1/40th or 25/1000th of an inch.

The bevelled edge of the thimble D is graduated into twenty-five parts, and figured every fifth division, 0, 5, 10, 15, 20. Each division, when coincident with the line of graduations on the barrel A, indicates that the gauge screw has made 1/25 of a revolution, and the opening of the caliper increased 1/25 of 25/1,000 = 1/1,000th of an inch.

Hence, to read the caliper, multiply the number of divisions visible on the scale of the barrel by 25, and add the number of divisions on the scale of the thimble, from zero to the line coincident with the line of graduations on the hub. For example: As the caliper is set in the illustration, there are three whole divisions visible on the barrel. Multiplying this number by 25 and adding 5, the number of divisions registered on the scale of the thimble, the result is 80/1,000ths of an inch. $(3 \times 25 = 75 + 5 = 80.)$ These calculations are readily made mentally.

CICERI SMITH'S PATENT MICROMETER.

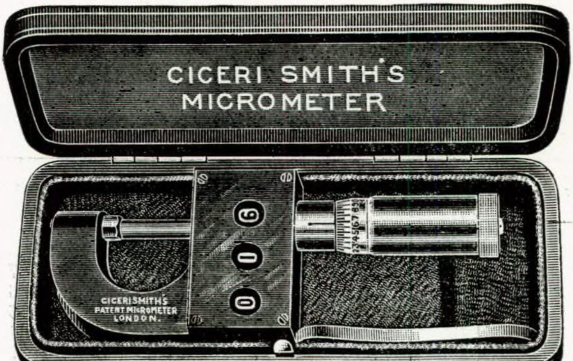


FIG. 2.

This direct-reading micrometer caliper is constructed to measure, in decimal parts of an inch, in accordance with the British Board of Trade Standard, the thicknesses of all kinds of wire, sheet metal, rods, tubes, shafting, spindles, printers' type, balls for bearings, paper card-board, glass, and mica sheets, etc. It will be found invaluable to those engaged in the manufacture of wire cables, steel needles, rifles, cartridges, machinery parts and fittings; to electricians for the measuring of their wires, etc.; to printers and publishers for measuring paper when estimating the probable thicknesses of books; to wire drawers for measuring their jewels; to mechanical and consulting engineers, etc., etc.

As in the ordinary decimal gauge the wire or other article to be measured is placed between the "anvil" (or hexagonal nut) and the steel face of the spindle, the thimble being rotated in either direction until the required adjustment is obtained; the exact measurement in decimal parts (or 1,000ths) of an inch is at the same time automatically and accurately recorded in clear figures on the index, these readings responding in either direction with the most delicate movements of the screw.

Its advantages over the micrometer in ordinary use are immediately obvious, as—(1) the measurements are automatically recorded and are seen at a glance, (2) there are no fine graduations on the hub to be counted, and the figures coincident with these are consequently dispensed with, (3) there are absolutely no calculations to be made, and hence no risk of error, (4) there is no undue and injurious strain on the eyesight, the figures being clearly marked in black on a white ground, which gives no glare, and (5) the readings of any number of measurements are taken with the grand combination of ease, rapidity, and accuracy.

SPECIAL TABLE OF EQUIVALENTS.

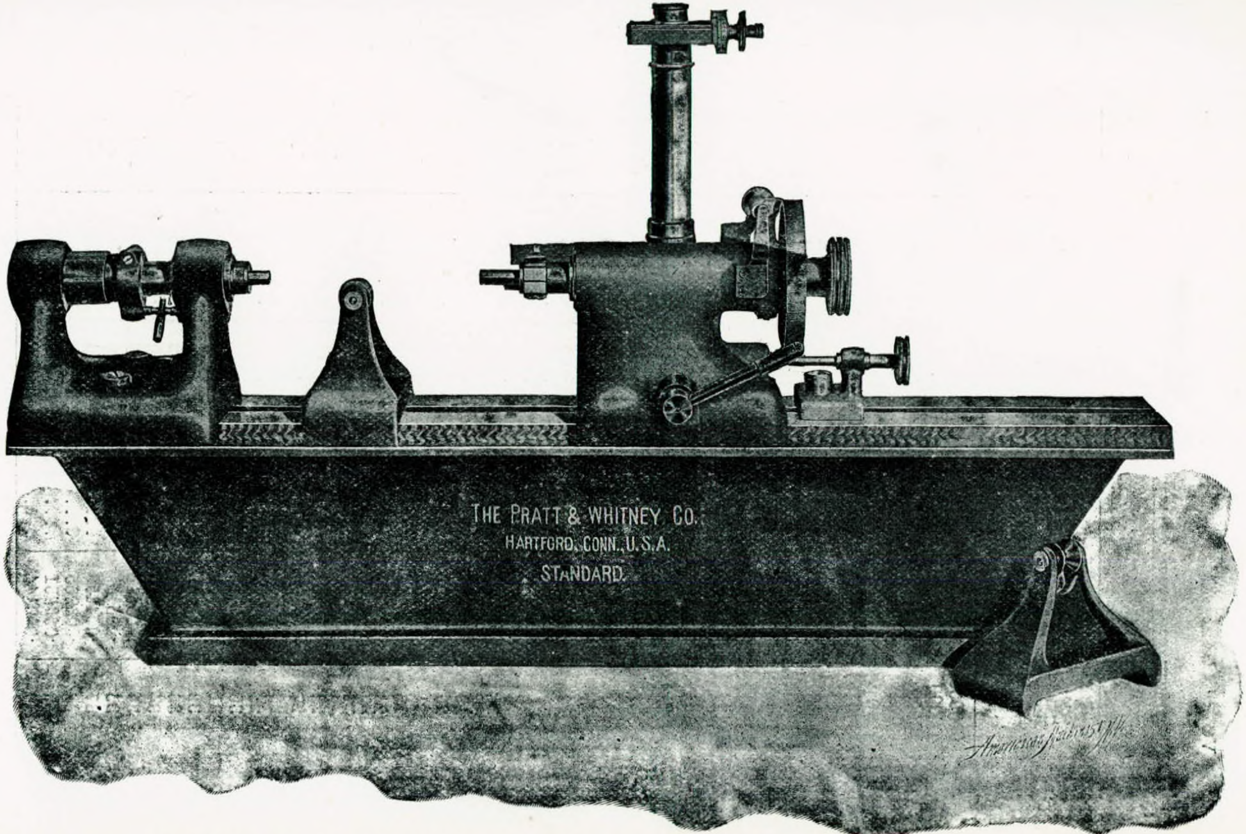
For use with Ciceri Smith's Patent Micrometer.

4ths	8ths	16ths	32nds	64ths	Inches	Millimetres
				1	·0156	0·3969
			1	2	·0312	0·7937
				3	·0468	1·1906
		1	2	4	·0625	1·5875
				5	·0781	1·9844
			3	6	·0937	2·3812
				7	·1093	2·7781
	1	2	4	8	·125	3·175
				9	·1406	3·5719
			5	10	·1562	3·9687
				11	·1718	4·3656
		3	6	12	·1875	4·7625
				13	·2031	5·1594

4ths	8ths	16ths	32nds	64ths	Inches	Millimetres
			7	14	·2187	5·5562
				15	·2343	5·9531
1	2	4	8	16	·250	6·350
				17	·2656	6·7469
			9	18	·2812	7·1437
				19	·2968	7·5406
		5	10	20	·3125	7·9375
				21	·3281	8·3344
			11	22	·3437	8·7312
				23	·3593	9·1281
	3	6	12	24	·375	9·525
				25	·3906	9·9219
			13	26	·4062	10·3187
				27	·4218	10·7156
		7	14	28	·4375	11·1125
				29	·4531	11·5094
			15	30	·4687	11·9062
				31	·4843	12·3031
2	4	8	16	32	·500	12·700
				33	·5156	13·0966
			17	34	·5312	13·4935
				35	·5468	13·8904
		9	18	36	·5625	14·2872
				37	·5781	14·6841
			19	38	·5937	15·0810
				39	·6093	15·4778
	5	10	20	40	·625	15·875
				41	·6406	16·2716
			21	42	·6562	16·6684
				43	·6718	17·0653
		11	22	44	·6875	17·4622
				45	·7031	17·8591
			23	46	·7187	18·2559
				47	·7343	18·6528
3	6	12	24	48	·750	19·050
				49	·7656	19·4465
			25	50	·7812	19·8434
				51	·7968	20·2403
		13	26	52	·8125	20·6371
				53	·8281	21·0340
			27	54	·8437	21·4309
				55	·8593	21·8277
	7	14	28	56	·875	22·225
				57	·8906	22·6215
			29	58	·9062	23·0183
				59	·9218	23·4152
		15	30	60	·9375	23·8121
				61	·9531	24·2089
			31	62	·9687	24·6058
				63	·9843	25·0027

The fine measurements which can be made by micrometer and vernier calipers are as accurate as are commercially necessary and practical in every day work. When finer or more accurate measurements are required, such as in making standard gauges, etc., an expensive measuring machine is then necessary. Sir Joseph Whitworth constructed one by which differences of the one-millionth part of an inch could be detected. The Pratt & Whitney Co., of Hartford, Conn., U.S.A., make measuring machines regularly for the market which will measure accurately to the one twenty-thousandth part of an inch, and will indicate to the forty-thousandth part of an inch or less. One of these machines you will have the opportunity of inspecting at the close of the Paper.

Even the fine measurements that can be made by these accurate instruments pale into absolute insignificance, however, when we come to read the decimal equivalents of some of our every-day steel and wire gauges. On page 18 is printed a table showing a few of the wire and plate gauges in common use in this country and in the United States of America. This Table does not give them all by any means, as "their name is legion"; but the few that are listed will show the want of uniformity and the utter absence in most of them of any system of arithmetical progression. The American Standard Wire Gauge is one of the few which make any attempt at uniformity of variation, and as it has been designed on the principle of geometrical progression, it lands us in decimal equivalents which run us into six places of decimals (the one-millionth part of an inch), although this is asking little of us when we compare the figures with the numbers designating the sizes of the United States standards for plate.



STANDARD MEASURING MACHINE.—Made by PRATT & WHITNEY Co., Hartford, Conn., U.S.A.

DIFFERENT STANDARDS FOR WIRE GAUGES IN USE.

Dimensions of Sizes in Decimal Parts of an Inch.

Number of Wire Gauge	American or Brown & Sharpe	Birmingham or Stubs' Wire	Imperial Wire Gauge	Stubs' Steel Wire	U.S. Stand. for Plate	Number of Wire Gauge
000000	....	....	.464	....	·46875	000000
00000	....	....	·432	....	·4375	00000
0000	·46	·454	.400	....	·40625	0000
000	·40964	·425	·372	....	·375	000
00	·3648	·38	·348	....	·34375	00
0	·32486	·34	·324	....	·3125	0
1	·2893	·3	·300	·227	·28125	1
2	·25763	·284	·276	·219	·265625	2
3	·22942	·259	·252	·212	·25	3
4	·20431	·238	·232	·207	·234375	4
5	·18194	·22	·212	·204	·21875	5
6	·16202	·203	·192	·201	·203125	6
7	·14428	·18	·176	·199	·1875	7
8	·12849	·165	·160	·197	·171875	8
9	·11443	·148	·144	·194	·15625	9
10	·10189	·134	·128	·191	·140625	10
11	·090742	·12	·116	·188	·125	11
12	·080808	·109	·104	·185	·109375	12
13	·071961	·095	·092	·182	·09375	13
14	·064084	·083	·080	·180	·078125	14
15	·057068	·072	·072	·178	·0703125	15
16	·05082	·065	·064	·175	·0625	16
17	·045257	·058	·056	·172	·05625	17
18	·040303	·049	·048	·168	·05	18
19	·03589	·042	·040	·164	·04375	19
20	·031961	·035	·036	·161	·0375	20
21	·028462	·032	·032	·157	·034375	21
22	·025347	·028	·028	·155	·03125	22
23	·022571	·025	·024	·153	·028125	23
24	·0201	·022	·022	·151	·025	24
25	·0179	·02	·020	·148	·021875	25
26	·01594	·018	·018	·146	·01875	26
27	.014195	·016	.0164	·143	·0171875	27
28	·012641	·014	·0149	·139	·015625	28
29	·011257	·013	·0136	·134	·0140625	29
30	·010025	·012	·0124	·127	·0125	30
31	·008928	.01	·0116	·120	·0109375	31
32	·00795	·009	·0108	·115	·01015625	32
33	·00708	·008	·0100	·112	·009375	33
34	·006304	·007	·0092	·110	·00859375	34
35	·005614	·005	·0084	·108	·0078125	35
36	·005	·004	·0076	·106	·00703125	36
37	·004453	....	·0068	·103	·006640625	37
38	·003965	....	·0060	·101	·00625	38
39	·003531	....	·0052	·099	....	39
40	·003144	....	·0048	·097	....	40

By an Act of Congress for the purpose of securing uniformity, a table was established as the only gauge for sheet and plate iron and steel in the United States of America, as shown below.

SIZES OF NUMBERS OF THE
UNITED STATES STANDARD GAUGE
FOR SHEET AND PLATE IRON AND STEEL.

An Act establishing a Standard Gauge for Sheet and Plate-Iron and Steel.—Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled: That for the purpose of securing uniformity the following is established as the only gauge for sheet and plate iron and steel in the United States of America, namely:

Number of Gauge	Approximate thickness in fractions of an in.	Approximate thickness in decimal parts of an in.	Weight per square ft. in oz. Avoirdupois	Weight per square ft. in lb. Avoirdupois
0000000	$\frac{1}{2}$	·5	320	20·00
000000	$\frac{15}{32}$	·46875	300	18·75
00000	$\frac{7}{16}$	·4375	280	17·50
0000	$\frac{13}{32}$	·40625	260	16·25
000	$\frac{3}{8}$	·375	240	15·
00	$\frac{11}{32}$	·34375	220	13·75
0	$\frac{5}{16}$	·3125	200	12·50
1	$\frac{9}{32}$	·28125	180	11·25
2	$\frac{17}{64}$	·265625	170	10·625
3	$\frac{1}{4}$	·25	160	10·
4	$\frac{15}{64}$	·234375	150	9·375
5	$\frac{7}{32}$	·21875	140	8·75
6	$\frac{13}{64}$	·203125	130	8·125
7	$\frac{3}{16}$	·1875	120	7·5
8	$\frac{11}{64}$	·171875	110	6·875
9	$\frac{5}{32}$	·15625	100	6·25
10	$\frac{9}{64}$	·140625	90	5·625
11	$\frac{1}{8}$	·125	80	5·
12	$\frac{7}{64}$	·109375	70	4·375
13	$\frac{3}{32}$	·09375	60	3·75
14	$\frac{5}{64}$	·078125	50	3·125
15	$\frac{9}{128}$	·0703125	45	2·8125
16	$\frac{1}{16}$	·0625	40	2·5
17	$\frac{9}{160}$	·05625	36	2·25
18	$\frac{1}{20}$	·05	32	2·
19	$\frac{7}{160}$	·04375	28	1·75
20	$\frac{3}{80}$	·0375	24	1·50
21	$\frac{11}{320}$	·034375	22	1·375
22	$\frac{1}{32}$	·03125	20	1·25
23	$\frac{9}{320}$	·028125	18	1·125

Number of Gauge	Approximate thickness in fractions of an in.	Approximate thickness in decimal parts of an in.	Weight per square ft. in oz. Avoirdupois	Weight per square ft. in lb. Avoirdupois
24	1/40	·025	16	1·
25	7/320	·021875	14	·875
26	3/160	·01875	12	·75
27	11/640	·0171875	11	·6875
28	1/64	·015625	10	·625
29	9/640	·0140625	9	·5625
30	1/80	·0125	8	·5
31	7/640	·0109375	7	·4375
32	13/1280	·01015625	6½	·40625
33	3/320	·009375	6	·375
34	11/1280	·00859375	5½	·34375
35	5/640	·0078125	5	·3125
36	9/1280	·00703125	4½	·28125
37	17/2560	·006640625	4¼	·265625
38	1/160	·00625	4	·25

And on and after July first, eighteen hundred and ninety-three, the same and no other shall be used in determining duties and taxes levied by the United States of America on sheet and plate iron and steel. But this Act shall not be construed to increase duties upon any articles which may be imported.

Section 3.—That in the practical use and application of the Standard Gauge hereby established, a variation of two and one-half per cent. either way may be allowed.

Approved March 3, 1893.

You will note that it is the approximate thickness which is given in vulgar fractions of an inch, and also that it is the *approximate* thickness which is given by, in some cases, *eight and nine places of decimals* of one inch! Nine places of decimals—the one-billionth part of an inch! Surely this is accuracy with a vengeance if it is not irony! These figures are surely not intended for practical purposes. No human hand or eye could measure with any known instrument to such a degree of accuracy, and even if they could, the price of attaining that standard would be absolutely prohibitive for all practical purposes—the more so, as probably the first time the gauge was used the pushing of a piece of plate tightly into the recess would alter the size of the gauge by the one-billionth part of an inch! Standard wire and plate gauges all cost money, and one wants quite a little fortune to purchase one of each and then has no guarantee how long they will remain accurate nor any means of adjusting them when they wear. The only safe method of keeping them accurate is not to use them at all. People, however, do not purchase these gauges for the purpose of keeping them in their pockets, but for the purpose of using them, and the result is, that even if these Standard Gauges are correct when they are made—which a great many of them are not—they very soon wear, each one wears in proportion to the number of times it is used, and the actual fact is, that hardly any two gauges that have been used are correct or are out by the same amount.

In this connection it may not be out of place to read here the following circular which was issued by Messrs. Miller, Metcalf & Parkin, a firm of steel manufacturers in the United States, on the difficulties experienced in using wire gauges of the usual forms, viz.:

MEMORANDUM ON GAUGES.

Referring to the annexed tables, we would call attention to some of the absurdities and anomalies of the present system of gauges, denoted by numbers.

A perusal of these tables should satisfy us that we have a sufficient variety to choose from, and ample refinement, when we get down to 1/1,000,000th of an inch, which is the final figure in some cases.

In some cases the difference between two numbers falls as low as two 1/1,000th of an inch, in others it is only one 1/1000th, etc.

It may be possible to make one gauge to any of these standards, which shall be so accurate as to defy the detection of an error, and with the same care it may be possible to make a thousand such gauges, but every mechanic, and every person accustomed to making accurate measurements of the best work, knows that it is simply impossible to obtain absolute accuracy in such pieces of work, when produced in large quantities.

It is impossible commercially, on account of the cost, and that settles the question.

Everyone knows of the wonderful accuracy of the Whitworth gauges, and also their enormous price, which makes them almost unsaleable.

In regard to ordinary wire gauges, they are notoriously inaccurate, because they cannot be made accurate and be at all saleable.

We have two new gauges in our possession, which were kept in our offices for purposes of comparison, and to prevent their wearing they were not allowed to go into the mills.

In a recent case, a sample under discussion, measured on one gauge tight 23, and on the other, light 24, and our customer said it was neither by his gauge, and did not suit him, anyhow.

One of our new gauges has its No. 23 so much larger than its No. 22, that the difference can be easily detected by the naked eye; yet No. 23 ought to be 2 to 4/1,000th smaller than No. 22.

If we were to roll No. 23 by that gauge, how would our customer get what he wanted, unless his gauge accidently contained the same blunder? Yet our gauge is a new one, stamped with the maker's name, and cost about 6 dollars.

Another trouble is with the wearing of the gauges, for which there is no remedy; and we imagine that no man ever throws away a gauge because it is worn out. On the contrary, it represents an outlay of 6 dollars; he is used to it; he measures everything by it; and he is mad when anything does not measure to suit it. A still more serious difficulty arises from a very common mode of ordering. We frequently have orders for such a gauge, "light" or "tight," "full" or "scant," "heavy" or "easy"; or such a number and one-half, for instance 15½.

This latter is terribly confusing to a roller; he almost always takes it to mean that it is to be thicker than the whole number, and is pretty certain to make 14½ for 15½, if he is not warned beforehand.

How is it possible for a roller to know how many millionths of an inch another man, whom he never saw, means when he says No. 28 "full," or No. 27 "easy"? and how is he to guess how many thousandths of an inch the other man's gauge is wrong in its make, or how many hundredths it has worn in years of steady use? This is no fancy sketch; the above are every-day difficulties in this age, when every man knows just what he wants and will have nothing else, and yet has no better way of telling his wants than to say I want such a gauge "tight," when probably his gauge differs from every other gauge that was ever made.

There is a very easy and simple way out of the whole snarl, and that is to abandon fixed gauges and numbers altogether.

The micrometer Sheet Metal Gauges, made by Brown & Sharpe Manufacturing Company, cost less than a common gauge, or no more. They measure thousandths of an inch very accurately, and even a quarter of a thousandth may be neatly measured.

They are very simple, so that any boy of ordinary intelligence can be taught to use one in a very few minutes. They have very easy arrangements for re-adjustment, when worn; and even when worn considerably, they can be used accurately, without adjustment, by making allowance for the error in reading at the zero line.

We find that mechanics like to work to them, and that there is very little trouble to get sheet rolling done to within a thousandth of an inch on fine sizes.

Our works are fully supplied with these instruments, and we urge all parties in ordering to give us dimensions and not numbers.

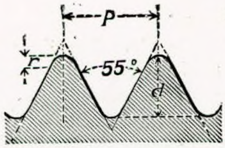
We cannot now recall a single case of serious complaint having arisen where we have had dimensions expressed in decimals to work to.

That there is a deal of practical truth and good common sense in the circular will be admitted, although it is hard to make a departure from usage. It seems to the writer, however, that the days for such fixed and arbitrary gauges have gone. They were devised to meet a want which could not at the time be otherwise met. Wire was required of sizes and accuracy which could not be defined by an ordinary line rule, and so standard sizes of holes were bored to which to measure the wire. Now that micrometer calipers which will measure the 1/1000th or the 1/10,000th part of an inch are within the reach of all, it is reasonable to ask that wire gauges be abolished and that measurements be made in accordance with our standards and with some definite relation the one to the other. Sir Joseph Whitworth formulated a system of measurements over forty years ago and read a paper on the subject before the Institution of Mechanical Engineers at Manchester, on 25th of June, 1857. In this paper he expressed his conviction that "great and rapid progress would be made in many branches of the mechanical arts, if the decimal system of measure could be generally introduced." In this paper he set out a new wire gauge, the numbers of which had some meaning—a thing which no other wire gauge ever had. He proposed that the gauge should be numbered from 1 to 500, and that the number of the gauge should designate the number of 1,000ths of an inch which it represented. That is to say, gauge No. 1 represents 1/1,000th of an inch, or ·001 in.; gauge No. 16, 16/1,000 or ·016 in.; gauge No. 32 = 32/1,000 or ·032 in., and so on. This gauge, strange to say, has never been adopted, although it seems to combine all the elements of a good gauge and gives a range of sizes from ·001 up to ½ in. The gauges at present in use appear to the writer to be not only senseless but useless. If anyone speaks of No. 16 he cannot be understood until he explains what No. 16 he refers to, as No. 16 Stubs Wire or B.W.G. is ·065 in., whereas

No. 16 Stubs steel wire is something quite different, viz., ·175 in., and No. 16 Imperial wire is again different, viz., ·064. It appears, therefore, that as a man must know what size he wants before he can describe it by a gauge number he had better by far describe it in decimal parts of an inch, and then there is no "possible probable shadow of doubt," in fact "no possible doubt whatever" as to what he wants. The micrometer caliper places this possibility within the reach of all.

Although we have not adopted Sir Joseph Whitworth's proposed standard wire gauge his standard of screw threads was adopted, and no one will deny the tremendous advantage which has accrued from that seemingly small matter. Before the Whitworth standard was adopted each one had his own ideas of what pitch, angle and form of thread should belong to each diameter of bolt. The formation of a standard in one country, however, sometimes leads other countries to formulate a standard of their own, instead of adopting one which has been standardised by their neighbours, and this has taken place with screw threads. The Whitworth standard of screw thread was established in 1841, although not fully developed until 1861, and has been since then largely used, not only in this country but on the Continent of Europe and in the United States of America. The Whitworth thread is not, however, at the present moment the universal standard thread, and it is very doubtful whether it ever will be. There are at the present time four standard threads which are largely used by the various manufacturing countries, viz., the Whitworth almost exclusively in Great Britain and to a large extent in Germany, the sharp V and the Sellers or United States standard in the United States of America, and the international standard thread (Metric System) in France, Switzerland, etc. Illustrations of the forms of these threads and their formulæ are given on page 25.

WHITWORTH STANDARD THREAD.



FORMULA:

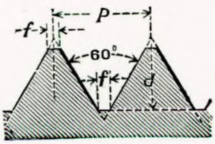
$p = \text{pitch} = \dfrac{1}{\text{No. Threads per in.}}$

$d = \text{depth} = p \times .64033.$

$r = \text{radius} = p. \times .1373.$

Diameter	1/4	5/16	3/8	7/16	1/2	9/16	5/8	11/16	3/4	13/16	7/8	15/16	1
No. Threads per in.	20	18	16	14	12	12	11	11	10	10	9	9	8
Diameter	1 1/8	1 1/4	1 3/8	1 1/2	1 5/8	1 3/4	1 7/8	2	2 1/8	2 1/4	2 3/8	2 1/2	2 5/8
No. Threads per in.	7	7	6	6	5	5	4 1/2	4 1/2	4 1/2	4	4	4	4
Diameter	2 3/4	2 7/8	3	3 1/8	3 1/4	3 3/8	3 1/2	3 5/8	3 3/4	3 7/8	4		
No. Threads per in.	3 1/2	3 1/2	3 1/2	3 1/2	3 1/4	3 1/4	3 1/4	3 1/4	3	3	3		

UNITED STATES STANDARD THREAD.



FORMULA:

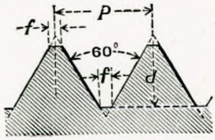
$p = \text{pitch} = \dfrac{1}{\text{No. Threads per in.}}$

$d = \text{depth} = p \times .6495.$

$f = \text{flat} = \dfrac{p}{8}$

Diameter	1/4	5/16	3/8	7/16	1/2	9/16	5/8	3/4	7/8	1	1 1/8	1 1/4
No. Threads per in.	20	18	16	14	13	12	11	10	9	8	7	7
Diameter	1 3/8	1 1/2	1 5/8	1 3/4	1 7/8	2	2 1/8	2 1/4	2 3/8	2 1/2	2 5/8	2 3/4
No. Threads per in.	6	6	5 1/2	5	5	4 1/2	4 1/2	4 1/2	4	4	4	
Diameter	2 7/8	3	3 1/8	3 1/4	3 3/8	3 1/2	3 5/8	3 3/4	3 7/8	4		
No. Threads per in.	3 1/2	3 1/2	3 1/2	3 1/2	3 1/4	3 1/4	3 1/4	3	3	3		

INTERNATIONAL STANDARD THREAD (METRIC SYSTEM).



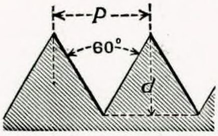
FORMULA:

$p = \text{pitch} = \dfrac{1}{\text{No. Threads.}}$

$d = \text{depth} = p \times .6495.$

$f = \text{flat} = \dfrac{p}{8}$

SHARP "V" THREAD.



FORMULA:

$p = \text{pitch} = \dfrac{1}{\text{No. Threads per in.}}$

$d = \text{depth} = p \times .8660.$

Diameter	1/4	5/16	3/8	7/16	1/2	9/16	5/8	11/16	3/4	13/16	7/8	15/16	1
No. Threads per in.	20	18	16	14	12	12	11	11	10	10	9	9	8
Diameter	1 1/8	1 1/4	1 3/8	1 1/2	1 5/8	1 3/4	1 7/8	2	2 1/8	2 1/4	2 3/8	2 1/2	2 5/8
No. Threads per in.	7	7	6	6	5	5	4 1/2	4 1/2	4 1/2	4 1/2	4 1/2	4	4
Diameter	2 3/4	2 7/8	3	3 1/8	3 1/4	3 3/8	3 1/2	3 5/8	3 3/4	3 7/8	4		
No. Threads per in.	4	4	3 1/2	3 1/2	3 1/2	3 1/4	3 1/4	3 1/4	3	3	3		

INTERNATIONAL STANDARD.

TAPS AND DIES.

The table of Standard for screw threads adopted by the "Congrès International pour l'Unification des Filetages," held in Zurich, October 2–4, 1898, is printed herewith.

Below will be found extracts from the proceedings of the Zurich Congress that will be of interest to manufacturers and all who are interested in the adoption of an International System of Screw Threads.

RESOLUTIONS OF THE CONGRESS.

The Congress has undertaken the task of unifying the threads of machine screws. It recommends to all those who wish to adopt the Metric system of threads to make use of the proposed system. This system is the one which has been established by the "Society for the Encouragement of National Industries," with the following modifications adopted by this Congress:

1. The clearance at the bottom of thread shall not exceed $\frac{1}{16}$ part of the height of the original triangle. The shape of the bottom of the thread resulting from said clearance is left to the judgment of the manufacturers. However, the Congress recommends rounded profile for said bottom.

3. The Table for Standard Diameters accepted is the one which has been proposed by the Swiss Committee of Action. (This table is given below.) It is to be noticed especially that 1·25 mm. pitch is adopted for 8 mm. diameter, and 1·75 mm. pitch for 12 mm. diameter. The pitches of sizes between standard diameters indicated in the table are to be the same as for the next smaller standard diameter.

The rules adopted unanimously by the members of the Congress will be formulated by the Swiss Union of Manufacturers, the German Association of Engineers, and the "Society for the Encouragement of National Industries." The system will be known under the name of International System (Système Internationale.—S.I.).

Angle of Thread, 60°; Flat on the Top and Bottom $\frac{1}{8}$ of Pitch.

Diam. Millimeters.	Pitch Millimeters	Diam. Millimeters.	Pitch. Millimeters.	Diam. Millimeters.	Pitch. Millimeters.
6	1·0	20	2·5	48	5·0
7	,,	22	,,	52	,,
8	1·25	24	3·0	56	5·5
9	,,	27	,,	60	,,
10	1·5	30	3·5	64	6·0
11	,,	33	,,	68	,,
12	1·75	36	4·0	72	6·5
14	2·0	39	,,	76	,,
16	,,	42	4·5	80	7·0
18	2·5	45	,,		

It will be seen that the system of threads adopted unanimously by the International Congress is the same as the one of the Society of Encouragement, with very slight modifications.

The "International Standard" is the same, with the modifications noted, as that now in very general use in France. The clearance of $\frac{1}{16}$, the depth of the thread, permits the use of either flat or rounded threads in the taps, as the angle diameter is the same in both cases.

It seems very desirable indeed that an international standard should in some manner be arrived at, but there seems little room for hope in the meantime. If it were only a case of agreeing among ourselves whether the angle should be 55° or 60°, whether the top and bottom of the threads should be rounded or flatted or whether a $\frac{1}{2}$ in. bolt should have twelve or thirteen threads, there would be good room for hoping that some compromise could be effected and a universal or international standard screw thread established. But there is a much greater difficulty than any or all of these. The Whitworth and the Sellers systems are based on the British unit of measurement and this can probably never be adopted by the countries employing the metric unit. It is indeed quite clear that if ever a universal system of screw threads is adopted it must be on the metric system, and Great Britain and the United States of America will be obliged to give up the system of measurement by feet and inches in favour of the more convenient metre and its subdivisions. Before stating how long it will be before this comes to pass it may be well to reflect on the saying that "it is not safe to prophesy" and apparently "the time is not yet." For they have not yet settled among themselves what shall be their metric standard thread. To Sir Joseph Whitworth, whatever may be the ultimate result of standardisation, belongs the glory of having evolved order out of chaos as far as screw threads are concerned.

But Sir Joseph Whitworth did not work "for glory" but for accuracy. When he communicated his paper "On an Uniform System of Screw Threads" to the Institution of Civil Engineers in 1841, he wrote, speaking of the choice of a standard of screw threads, "the nature of the case is such that *mere approxima-*

tion would be unimportant, absolute identity of thread being indispensable. . . . It is mainly for want of accuracy that screw bolts so frequently fail. Unless the threads of the screw and nut exactly correspond in every part and coalesce throughout their whole length and depth, their mutual action is completely deranged, power and strength are both sacrificed, and friction is proportionally increased. . . . To maintain uniformity, provision must be made for multiplying standards of the diameters and threads. . . . This part of the case is connected with a subject of great extent which, under every aspect, lays claim to the attention of practical engineers. We allude to the general use of standard gauges, graduated to a fixed scale, as constant measures of size. It is quite practicable by such means to work to a common measure with a degree of accuracy sufficient for all ordinary purposes. Corresponding parts instead of being got up one to another might be prepared separately. The indefinite multiplication of sizes would thus be prevented and the economy of the workshop simplified to an extent beyond calculation."

Thus wrote Sir Joseph Whitworth nearly sixty years ago. The result has been so far satisfactory, but only so far. If the simple system proposed had been acted upon it would certainly be possible for us to purchase our bolts from one manufacturer and our nuts from another, in the assurance that the one would fit the other. But what do we find as a matter of practice? As a rule we find that most manufacturers, although professing to supply Whitworth standard bolts and nuts, work to their own standard, and that differs from some other standard just sufficiently to prevent A's nuts fitting B's bolts. This no doubt is a matter of common knowledge, but as it is always safer when making such statements to have one's proof handy, I have here three bolts and nuts made by three different manufacturers of bolts and nuts—all first-class makers. You will see that much time and skill have been spent in finishing the bolts and nuts, and one would be justified in looking for as much care in the preparation of the sizes of the bolts and the fit of the thread. These three bolts are professedly one inch standard Whitworth, and for convenience of reference I had them marked A, B and C, immediately on receipt from the makers. The nuts are a fairly good fit on their own respective bolts, but they are *not interchangeable.* "A" nut is too slack for "B" bolt, so slack in fact that it fairly rattles on it, and is too tight for "C" bolt. "B" nut, of course, is too tight for "A" bolt and will not go on at all on "C" bolt, while "C" nut runs on quite freely on both "A" and "B" bolts.

Comparing the diameters with a one inch Whitworth standard external gauge we find bolt "A" too small in external diameter, but "B" and "C" bolt up to standard over the top of the threads. Comparing the threads with Whitworth standard one inch thread gauges, a pair of which I have here, we find that the standard external gauge will not go on at all as far as "A" bolt is concerned, although, as we found, the diameter of "A" bolt over the top of the threads was less than one inch. "B" bolt is correct, but on "C" bolt the gauge will not enter at all.

This emphasises what Sir Joseph Whitworth meant when he said that "mere approximation is unimportant, absolute identity of thread being indispensable." It may be said that absolute identity of thread is not required and cannot be commercially obtained. But the bolt and nut marked "B" show that identity is obtainable and necessary. If all bolt and nut manufacturers worked to standard Whitworth gauges and threw out all taps that did not tap nuts that would accurately fit the standard gauge, we should have all our nuts standard size. And as bolts are, or should be, threaded to fit the nuts we should also consequently have all our bolts standard size. Taps of course will wear and so will dies, but an occasional reference to the standard gauge would show at once when a tap should be discarded. A tap will cut the threads of thousands of nuts (100,000 is within the limit) before it wears sufficiently to have to be thrown out, so that it is not a waste of taps which is the cause of the present inaccuracies. The fault is in the scarcity of standard gauges, or in the want of reference to them. There should be no difficulty whatever in obtaining taps which are accurate in dimensions and form of thread and it would be a simple matter for each bolt and nut manufacturer to refuse to accept taps that were not in accordance with Whitworth standard thread gauges.

Accuracy of measurement, however, to be of the best value, must be combined with standards of measurement and proper gradations of size. There is great room for advance in this way and the standardising of parts of machinery would be of very great value to marine engineers especially. Take, for instance, the flanges of steam and other pipes. Suppose a standard were established for the diameter and thickness of flanges, the diameter of bolt circle and the size and number of bolts. At present each maker has practically his own standard and this is not beneficial in any way to either the makers or the users. This matter has recently been considered by a Committee of the Society of Mechanical Engineers of the United States, together with the leading valve and fitting makers of that country, and a schedule of standard pipe flanges was adopted by them and is recommended for general adoption. This table is given herewith and should be worthy of consideration by the Institute of Marine Engineers.

SCHEDULE OF STANDARD PIPE FLANGES.

Adopted July 18, 1894, by a Committee of the Master Steam and Hot Water Fitters' Association, a Committee of the Society of Mechanical Engineers of the United States, and the leading valve and fitting manufacturers of the United States.

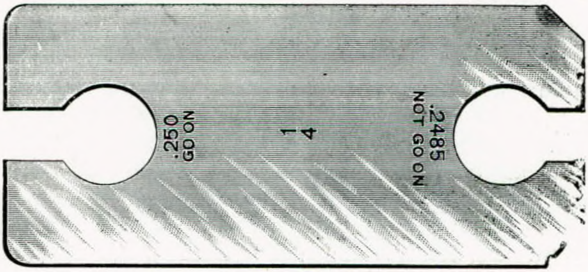
Pipe size, inches	Pipe thickness, $\frac{P+100}{\cdot 4S}d+\cdot 333\left(1-\frac{d}{100}\right)$ S-18,000 lb.	Thickness, nearest fraction, inches	Stress on pipe per square inch at 200 lb.	Radius of fillet, inches	Flange diameter inches	Flange thickness at hub for iron pipe, inches	Flange thickness at edge, inches	Width flange face, inches	Bolt circle diameter, inches	Number of bolts	Bolt size diameters, inches	Bolt length, inches	Stress on each bolt, per square inch at bottom of thread at 200 lb.
2	·409	$\frac{7}{16}$	460	$\frac{1}{8}$	6	1	$\frac{5}{8}$	2	$4\frac{3}{4}$	4	$\frac{1}{2}$ $\frac{5}{8}$	2	825
$2\frac{1}{2}$	·429	$\frac{7}{16}$	550	$\frac{1}{8}$	7	$1\frac{1}{8}$	$\frac{11}{16}$	$2\frac{1}{4}$	$5\frac{1}{2}$	4	$\frac{1}{2}$ $\frac{5}{8}$	$2\frac{1}{4}$	1,050
3	·448	$\frac{7}{16}$	690	$\frac{1}{8}$	$7\frac{1}{2}$	$1\frac{1}{4}$	$\frac{3}{4}$	$2\frac{1}{4}$	6	4	$\frac{1}{2}$ $\frac{5}{8}$	$2\frac{1}{2}$	1,330
$3\frac{1}{2}$	·466	$\frac{1}{2}$	700	$\frac{1}{8}$	$8\frac{1}{2}$	$1\frac{1}{4}$	$\frac{13}{16}$	$2\frac{1}{2}$	7	4	$\frac{1}{2}$ $\frac{5}{8}$	$2\frac{1}{2}$	2,530
4	·486	$\frac{1}{2}$	800	$\frac{1}{8}$	9	$1\frac{3}{8}$	$\frac{15}{16}$	$2\frac{1}{2}$	$7\frac{1}{2}$	4	$\frac{5}{8}$ $\frac{3}{4}$	$2\frac{3}{4}$	2,100
$4\frac{1}{2}$	·498	$\frac{1}{2}$	900	$\frac{1}{8}$	$9\frac{1}{4}$	$1\frac{3}{8}$	$\frac{15}{16}$	$2\frac{3}{8}$	$7\frac{3}{4}$	8	$\frac{5}{8}$ $\frac{3}{4}$	3	1,430
5	·525	$\frac{1}{2}$	1,000	$\frac{1}{8}$	10	$1\frac{1}{2}$	$\frac{15}{16}$	$2\frac{1}{2}$	$8\frac{1}{2}$	8	$\frac{5}{8}$ $\frac{3}{4}$	3	1,630
6	·563	$\frac{9}{16}$	1,060	$\frac{1}{8}$	11	$1\frac{1}{2}$	1	$2\frac{1}{2}$	$9\frac{1}{2}$	8	$\frac{5}{8}$ $\frac{3}{4}$	3	2,360
7	·60	$\frac{5}{8}$	1,120	$\frac{1}{8}$	$12\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{16}$	$2\frac{3}{4}$	$10\frac{3}{4}$	8	$\frac{5}{8}$ $\frac{3}{4}$	$3\frac{1}{4}$	3,200
8	·639	$\frac{5}{8}$	1,280	$\frac{1}{8}$	$13\frac{1}{2}$	$1\frac{3}{4}$	$1\frac{1}{8}$	$2\frac{3}{4}$	$11\frac{3}{4}$	8	$\frac{5}{8}$ $\frac{3}{4}$	$3\frac{1}{2}$	4,190
9	·678	$\frac{11}{16}$	1,310	$\frac{3}{16}$	15	$1\frac{3}{4}$	$1\frac{1}{8}$	3	$13\frac{1}{4}$	12	$\frac{5}{8}$ $\frac{3}{4}$	$3\frac{1}{2}$	3,610
10	·713	$\frac{3}{4}$	1,330	$\frac{3}{16}$	16	2	$1\frac{3}{16}$	3	$14\frac{1}{4}$	12	$\frac{3}{4}$ $\frac{7}{8}$	$3\frac{5}{8}$	2,970
12	·79	$\frac{13}{16}$	1,470	$\frac{3}{16}$	19	2	$1\frac{1}{4}$	$3\frac{1}{2}$	17	12	$\frac{3}{4}$ $\frac{7}{8}$	$3\frac{3}{4}$	4,280
14	·864	$\frac{7}{8}$	1,600	$\frac{3}{16}$	21	2	$1\frac{3}{8}$	$3\frac{1}{2}$	$18\frac{3}{4}$	12	$\frac{7}{8}$ 1	$4\frac{1}{4}$	4,280
15	·904	$\frac{15}{16}$	1,600	$\frac{3}{16}$	$22\frac{1}{4}$	2	$1\frac{3}{8}$	$3\frac{5}{8}$	20	16	$\frac{7}{8}$ 1	$4\frac{1}{4}$	3,660
16	·946	1	1,600	$\frac{3}{16}$	$23\frac{1}{2}$	$2\frac{1}{4}$	$1\frac{7}{16}$	$3\frac{3}{4}$	$21\frac{1}{4}$	16	$\frac{7}{8}$ 1	$4\frac{1}{4}$	4,210
18	1·02	$1\frac{1}{16}$	1,690	$\frac{3}{16}$	25	..	$1\frac{9}{16}$	$3\frac{1}{2}$	$22\frac{3}{4}$	16	1 $1\frac{1}{8}$	$4\frac{3}{4}$	4,540
20	1·09	$1\frac{1}{8}$	1,780	$\frac{3}{16}$	$27\frac{1}{2}$	..	$1\frac{11}{16}$	$3\frac{3}{4}$	25	20	1 $1\frac{1}{8}$	5	4,490
22	1·18	$1\frac{3}{16}$	1,850	$\frac{1}{4}$	$29\frac{1}{2}$	..	$1\frac{13}{16}$	$3\frac{3}{4}$	$27\frac{1}{4}$	20	1 $1\frac{1}{4}$	$5\frac{1}{2}$	4,320
24	1·25	$1\frac{1}{4}$	1,920	$\frac{1}{4}$	$31\frac{1}{2}$ 32	..	$1\frac{1}{4}$ $1\frac{7}{8}$	$3\frac{3}{4}$ 4	$29\frac{1}{4}$ $29\frac{1}{2}$	20	1 $1\frac{1}{4}$	$5\frac{1}{2}$	5,130
26	1·30	$1\frac{5}{16}$	1,980	$\frac{1}{4}$	$33\frac{3}{4}$ $34\frac{1}{4}$	..	$1\frac{3}{8}$ 2	$3\frac{7}{8}$ $4\frac{1}{8}$	$31\frac{1}{4}$ $31\frac{3}{4}$	24	1 $1\frac{1}{4}$	$5\frac{3}{4}$	5,030
28	1·38	$1\frac{3}{8}$	2,040	$\frac{1}{4}$	36 $36\frac{1}{2}$	..	$1\frac{7}{16}$ $2\frac{1}{16}$	4 $4\frac{1}{4}$	$33\frac{1}{2}$ 34	28	1 $1\frac{1}{4}$	6	5,000
30	1·48	$1\frac{1}{2}$	2,000	$\frac{1}{4}$	38 $38\frac{3}{4}$	..	$1\frac{1}{2}$ $2\frac{1}{8}$	4 $4\frac{3}{8}$	$35\frac{1}{2}$ 36	28	$1\frac{1}{8}$ $1\frac{3}{8}$	$6\frac{1}{4}$	4,590
36	1·71	$1\frac{3}{4}$	1,920	$\frac{1}{4}$	$44\frac{1}{2}$ $45\frac{3}{4}$	..	$1\frac{3}{4}$ $2\frac{3}{8}$	$4\frac{1}{4}$ $4\frac{7}{8}$	42 $42\frac{3}{4}$	32	$1\frac{1}{8}$ $1\frac{3}{8}$	$6\frac{1}{2}$	5,790
42	1·87	2	2,100	$\frac{1}{4}$	51 $52\frac{3}{4}$	..	$1\frac{7}{8}$ $2\frac{5}{8}$	$4\frac{1}{2}$ $5\frac{3}{8}$	$48\frac{1}{2}$ $49\frac{1}{2}$	36	$1\frac{1}{4}$ $1\frac{1}{2}$	$7\frac{1}{4}$	5,700
48	2·17	$2\frac{1}{4}$	2,130	$\frac{1}{4}$	$57\frac{1}{2}$ $59\frac{1}{2}$	..	2 $2\frac{3}{4}$	$4\frac{3}{4}$ $5\frac{3}{4}$	$54\frac{3}{4}$ 56	44	$1\frac{3}{8}$ $1\frac{1}{2}$	$7\frac{3}{4}$	6,090

The formula for thickness which heads the second column is intended for cast-iron pipe, and the figures for thickness in the second and third columns are for that material under 200 lb. pressure or less. The double sets of figures for flanges of pipe sizes above 24 in. are intended one for pressures of 200 lb. and the other for less, and the same observation applies to the two sizes of bolts.

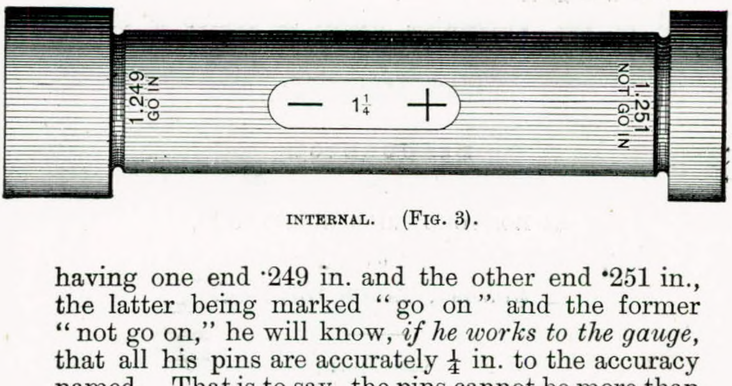
Too much cannot be done in this way, for the fewer sizes we have to deal with the more expeditious must be our work and the chances of having a duplicate part consequently greater. Even engines themselves should be standardised, as indeed they would be to a much greater extent if our engine builders had a more free hand. The result of standardising must always be cheaper and better work, because it must be cheaper in proportion to make a great number of any one thing than to make each one different. Another result of standardising is the subdivision of labour and the setting up of factories for the making of special parts instead of every engine builder making everything for his own engine. The statement that this specialising results in a deterioration of workmen is not borne out by facts, for it takes just as intelligent a workman to become part of a system and carry out his part of the scheme as to fit one piece of mechanism to its own place only.

This subject might be continued *ad infinitum*, but probably enough has been said to open up the matter for discussion, and out of discussion no doubt some good will come. There is no doubt whatever that great advantages are to be gained both in cost and quality of production by the adoption of uniformity of sizes and interchangeability of parts if at the same time proper gradations of size are attended to. Absolute perfection is, of course, unattainable, but each manufacturer has the means at hand to dictate how much error one way and the other shall be passed. This is very conveniently done by the use of "difference" or "limit" gauges. Let us say a turner is turning out pins which have to be finished accurately to $\frac{1}{4}$ in., say, to 1/1,000th part of an inch, plus or minus. If he works with an external limit gauge such as is shown (Fig. 3)

LIMIT GAUGES.



EXTERNAL.



INTERNAL. (FIG. 3).

having one end ·249 in. and the other end ·251 in., the latter being marked "go on" and the former "not go on," he will know, *if he works to the gauge*, that all his pins are accurately $\frac{1}{4}$ in. to the accuracy named. That is to say, the pins cannot be more than 1/1,000th inch larger than $\frac{1}{4}$ in., otherwise they would not go on the gauge end which is ·251 in., and they cannot be more than 1/1,000th inch less than $\frac{1}{4}$ in., otherwise they would go on the gauge end marked ·249 in. In the same way holes can be bored to the internal limit gauges and gauged with the same amount of accuracy. By the use of these gauges it will be seen that much less time is required to make sure of a size than if only one gauge were used, and to save the workman from making mistakes, and to save his time in constantly consulting the figures, it is best to make each end of the gauge of a different shape, as shown in the illustration.

The want of uniformity and the lack of proper gradations of size is common whether it be parts of a steam engine or the engine itself; and it will be an advance in the right direction when our marine engine builders have certain gradations of sizes of steam engines and offer these standards and stick to them. The makers of auxiliary machinery are ahead in this way and the standard sizes of pumps, feed pumps, electric engines, dynamos, donkeys, etc., find ready sale. There seems no reason why main engines should not follow the same lines, and the result would be a benefit both to the manufacturer and to the purchaser, which of course is to the national good.

DISCUSSION

AT

58 ROMFORD ROAD, STRATFORD,

ON

MONDAY, MARCH 11th, 1901.

CHAIRMAN:

MR. J. E. ELMSLIE (MEMBER OF COUNCIL).

THE CHAIRMAN: You have now heard this paper read, and it ought to lead to a very good discussion. The question of standardisation is a very large one, and it has an important bearing on the cost of machinery. If we are to hold our own we must make the same advances in this respect as Germany and the United States. The advantages of the metric system have been found very great, but in this country we do not seem inclined to take it up. The subject of piecework and its effect in reducing the cost of work is perhaps hardly within the scope of the paper, but Mr. Cooper has referred to that matter. In the United States piecework has been found to answer, but here it does not answer equally well, because it appears to be the general rule that when a man working on piecework is found to be making too much money the price is at once cut down. I have seen it over and over again. In one of the shops of one of the great railway companies it was found that the links for the locomotives cost a certain price, and one of the people in the shop asked that they might be given out at that price on piecework. They were given out at that price, which was given upon the assumption that the men would be able to make time and a half. However, the men made considerably more than time and a half, and the cost of the links to the company came down to less than half what it was before. But the men made 10s. a day. The directors said that the men could not be allowed to make 10s. a day, so they returned to the old system. There is a book written by Joshua Rhodes which tells the whole story and which company it was. The paper is now open for discussion.

Mr. J. R. RUTHVEN (Member of Council) said that Mr. Cooper had brought a very important subject before them, but it seemed to him that if they used the decimal system in connection with the inch as a standard they would then get all the accuracy they desired, and there would be no such mistake as "three feet nine" being taken for 39 inches. He would be sorry to lose the inch measurement, and thought it would answer for all practical purposes up to, say, about 10 ft., while three places of decimals would give them thousandths of an inch.

Mr. G. W. NEWALL (Member) said he was afraid that many turners of the old school might find trouble in reading a caliper of this description, although he had noticed that when they were given dimensions in certain fractions they sometimes spent some minutes in ascertaining what size those dimensions represented, and they often arrived at the conclusion that it was something "full." That was the trouble with the vulgar fraction system. With the decimal system that would be removed, and it would be a very good thing. There was a reference in the paper to brains in the workshop. He was afraid that in the bulk of establishments brains were not recognised so much as they should be. Any fitter or turner in the employ of engineers who got out a special device whereby work was improved or cheapened should receive from his employers some recognition of his ingenuity; this was often not done. He believed that some time ago Messrs. Denny, of Dumbarton, gave some inducements in the way of prizes or special remuneration for the exercise of brains among their workmen, and if that were done more than at present in the workshops in this country we should get the better men to come to the front. Workmen should be encouraged to make use of any mechanical genius they might possess. If a workman, especially a trades union workman, got his pay whether he was a good man or not, such was very disheartening to a man who had mechanical genius in him. This was a point that should be more fully recognised between master and men, and we should then be more in the way in which the Americans carried on their work. He could not agree with Mr. Ruthven about measuring in inches up to a size of 10 ft., and thought it would be no improvement. As Mr. Cooper had apparently gone into this question more than most of them, he could perhaps tell them how these standard gauges were first brought about. Somebody must have started them. They were not the result of accident; but they were so various in their sizes that it would be interesting to know how they were introduced in the first place, and about when? The author had been talking in the paper of millionths of an inch, but he (Mr. Newall) remembered having a little to do with some measurements that were difficult to get at owing to their fineness. Experiments were made by Professor Boyd in connection with the manufacture of filaments for supporting the ends of galvanometers, and the object of those experiments was to obtain the finest and strongest material that could be found. For the purposes of his experiments Professor Boyd used molten wax. The head of an arrow having been dipped in the wax the arrow was fired across the room or apartment, when a very fine thread or filament of the material followed the arrow. This thread or filament was so fine that the eye could not follow it, but they were nevertheless able to lift it up and store it. When he (Mr. Newall) inquired how they ascertained the thickness of this filament he was told that a powerful electric light having been thrown upon a screen the thread or filament was brought in front of the light, and it was only by measuring the shadow that they could tell the thickness of the filament. With regard to the remarks of the author towards the end of the paper, he would like to ask what parts of a marine engine Mr. Cooper would standardise? To standardise much of the marine engine was rather a big order.

Mr. G. HALLIDAY (Member) said the author had shown them three bolts with nuts which, although nominally of the same standard size, were not interchangeable. He should like to ask whether these bolts and nuts were manufactured in this country, if there was any explanation of the difference of fitting, and what was the cause from a mechanical point of view.

Mr. R. D. KEAY (Member) said that Americans had gone ahead more than we had, especially in standardising, but he believed there were a few places in this country where that was done even more perfectly than in America. He recently had an opportunity of seeing the system of gauging as carried out at the works of Messrs. Willans and Robinson, of Rugby. This firm made engines used for electric lighting. The engines were of standard sizes, which were indicated on shop books by the letters A to V, and the parts having been made were sent into stores. The standard designs were strictly adhered to in every respect, and all parts of the engines were made to gauges and jigs, so that all similar portions of engines of a given size were strictly interchangeable. The firm endeavoured to keep the different parts of all the sizes of engines in store, so that when an engine was ordered it was simply a case of getting the various portions from the store and putting them together. Before being put into the store, any parts found to be not to gauge were returned to the workshop for adjustment. To give an idea of the accuracy of the work, a cylinder that had been bored and faced up was taken at random. It was put on a face plate—one faced end of the cylinder being on the face plate—and the plug gauge for this particular size of cylinder was put into it. The plug gauge simply floated, just sinking so far as was necessary to compress the air in the cylinder sufficiently to support its weight. The plug could then be spun round, and apparently its motion in the cylinder was almost frictionless. If pushed down into the cylinder it rebounded, the air underneath it acting as a spring. The next experiment was to slide the cylinder slightly over the face plate so as to let out a little of the air from underneath the plug, and to allow the plug to go deeper down into the cylinder. By means of a crane the plug was then lifted up. It rose a certain distance, and then the cylinder itself, together with the face plate, came with it. While the plug remained suspended from the crane the cylinder and face plate could be easily moved up and down on the plug. Perhaps the most interesting feature of this experiment was the fact that the makers said that the boring of the cylinder and the facing of the flanges were done at one operation, so that this exactness of work was apparently procured without undue expense in the workshop, although the careful checking of the work must be paid for. The importance of working to gauges could not be over-estimated where the article manufactured was produced in such numbers as to warrant it. In the case of an engine it was evidently a great convenience to be able to get replace parts at once in the event of a breakdown. He believed the Americans admitted that they had not carried out the standardising of parts to such perfection as we in England had done, but there was need in England for standardising to be more generally adopted than at present. There were only a few shops where it had been adopted systematically. We had recently read a good deal in the Press about American locomotives, and this was a point that also bore on the subject. He believed that the reason why the Americans had the order for these locomotives over us was that the engines were wanted in a hurry and the Americans made them to standards. The reason, in his opinion, why the Americans had come out on top was that they had adopted the system of working to standards. On the question of screw threads he supposed that in the course of their practical experience they had all come across the difficulty of making the nuts fit the bolts, and he was rather surprised to learn recently that one American firm had adopted a thread of its own, the idea being to bring back the repairs to their own yard. He thought, however, they had got beyond that. With regard to the metric system he thought it would be a pity if there was any misunderstanding as to their opinion on that point. He did not think there could be any question whatever that the metric system was the best system to adopt, particularly if they wanted to go in for scientific accuracy. The metric system was generally adopted on the Continent and in America, and he thought the British manufacturer would have to adopt the metric system, at least in his tables and catalogues if he did not work to it. Foreigners could not understand our system; it was so clumsy. Something had been said about piecework. It had a certain bearing on the subject of this paper, and he agreed with the last speaker in thinking that the workman should have some encouragement to do his best. The effect of trade unionism was to take away from the workmen all interest in their work, and several firms had in the past few years adopted the American system of paying their workmen according to results. They made a sort of contract with the workmen to do the work in a given time, and if they did the work in less time then they shared with the employer a portion of the profit that was derived by the employer owing to the saving of time. Messrs. Weir, of Glasgow, said that this system had increased their output by 30 per cent., and that the employés had benefited to the extent of 15 per cent. Under this system immediately anything went wrong with a machine the workmen went at once to the foreman and had the machine put right. In addition to that, if a workman hit upon a method of doing his work expeditiously he was allowed to reap the benefit of his ingenuity. He thought we should have to come to some system of that kind in this country to counteract the effects of trade unionism.

Mr. BALES: The author has dealt with the subject of screw threads. To any thoughtful turner or mechanic very little consideration is necessary to convince himself that the difficulties in producing a correct Whitworth or rounded top and bottom V thread are infinitely greater than in the flat top and bottom V thread adopted by the Franklin Institute, and known as the U.S. standard thread. Any thread cut in the lathe on the Whitworth standard principle cannot be finished with the single point tool, but requires to be rounded by means of a chaser, and in this process of chasing very considerable deformation is possible, not usually by any want of manual dexterity but by the chaser itself being incorrect. It is common knowledge that cast steel is considerably affected by the process of hardening, and presuming that the hob from which the thread of chasing tool is cut has its thread cut in the lathe absolutely correct, that is of a true and uniform pitch, then after hardening the pitch may no longer be correct. The chaser cut from this hob will contain the error of pitch existing in the hob, and upon it in its turn being hardened may have added to it errors of its own. Again, if this chaser were used to finish a new hob, the latter will contain the errors in the chaser added to whatever error it may itself obtain in the hardening. It is true that all these errors may not exist in one direction, and those of one hardening may correct those caused by another hardening, but it is not necessarily the case. I think therefore that there can be little doubt that it is preferable to employ a form of thread that can be cut by a single point tool and finished with that tool, as that form of tool can be ground to a correct shape after hardening.

Mr. W. McLaren (Member of Council) said he certainly thought that their thanks were due to Mr. Cooper for this valuable contribution. But in the first place it must not be forgotten that if our foreign competitors had gone ahead of us in some respects they had had the advantage of all our experience. Then, again, employers must be considered. The plant of former years cost more than it did to-day, and an employer could not always afford to throw out tools that were still good and answered his purpose and replace them by more up-to-date appliances. Then they came to the side issue that had been raised about the British workman and piecework, and he was very sorry that this point had been raised, because it brought in the subject of trade unionism. In his view the trade unionist was not to be run down altogether. In the course of his paper the author referred to the cycle industry, and there was perhaps no industry that had gone ahead more in the matter of improved tools and machinery, but he (Mr. McLaren) did not think that all these improved tools and machinery were of American origin and manufacture. Many of them were, he believed, first brought forward in this country.

The discussion was then adjourned until Monday, March 25th.

Mr. J. T. SMITH proposed and Mr. NEWALL seconded a vote of thanks to Mr. Cooper for his paper.

Mr. COOPER in acknowledging the vote said he hoped to reply to the criticisms of the several speakers at the next meeting.

A vote of thanks to the Chairman, proposed by Mr. AUKLAND and seconded by Mr. KEAY, concluded the meeting.

DISCUSSION CONTINUED

AT

58 ROMFORD ROAD, STRATFORD,

ON

MONDAY, MARCH 25th, 1901.

CHAIRMAN:

MR. JAS. ADAMSON (HON. SECRETARY).

THE CHAIRMAN stated that Mr. Cooper would reopen the subject by replying to some of the remarks that followed the reading of the paper at the last meeting, and at the conclusion of this reply on the discussion that had already taken place it would be open to the members present to continue the discussion on the subject.

Mr. Frank Cooper: Several speakers referred to the remarks regarding piecework in the paper. The paper was, I think, quite distinct as to the reason of this subject being referred to, viz., that piecework showed that men could, if left a little more to themselves, improve at times upon the methods existing in the shop under timework conditions. A discussion as to the merits or demerits of piecework as a system would, of course, be foreign to the subject matter of the paper. Mr. Halliday asked the reason why two bolts out of the three shown were not standard size. This also was, I think, quite clearly stated in the paper, viz., that the taps used in tapping the nuts were not standard size. In both cases the taps appear to have been larger than standard, as was shown by the fact that both nuts were too slack upon the Whitworth standard internal thread gauge, resulting in the bolts, which were threaded to suit the nuts, being turned out too large, and consequently being too tight for the Whitworth standard external thread gauge. Mr. Newall drew attention to the discrepancy between the figures on the micrometer caliper and the figures describing the reading of it. There is an error in the proof sheets here, but this will be rectified before the paper is finally printed. As the micrometer is set in the illustration it reads 75/1000 and not 80/1000 as printed. I hope to be able to obtain for addition to the paper, as suggested by Mr. Newall, some information as to the history of the adoption of the wire gauges now in use. It would no doubt be interesting reading if any reliable information is extant. In reply to the question as to what parts of a marine engine could be standardised, I should say that all parts that are turned, bored, or fitted should be standardised. Sir Joseph Whitworth, writing on this subject in 1882, said: "In every machine which combines the working of many similar parts for the attainment of a common result, absolute identity of size in the corresponding parts and absolute identity of difference of size between parts which are required to fit one another are matters of paramount importance. The latter requirement applies especially to the difference in diameter which should exist between any revolving part and that within or around which it revolves, and the amount of this difference must be determined by experience for each particular machine, and should then be strictly adhered to." Mr. Keay in his remarks amplified this statement by showing that Messrs. Willans and Robinson adopt the standard and gauge system in the building of their largest engines—the cylinders, etc., being bored to fit standard plugs. In reply to Mr. J. Ciceri Smith *re* wire gauges, I think the system proposed by Sir Joseph Whitworth (see page 23 of paper) would answer all requirements, for it gives a range of sizes from 0·001 in. up to 0·5 in., 500 sizes in half an inch; the great advantage of this system of gauges being that each number showed its own size, and a larger number means a larger size than a smaller one—the reverse of the system at present in use. Mr. McLaren, if I understood him correctly, said that a proprietor could not always afford to throw out tools that were still good and replace them by more up-to-date ones. This, of course, is a matter for the master himself to settle, but too much weight is sometimes laid upon the fact that tools are still good, overlooking the fact that since that particular tool was built a better paying one may have been devised. Sometimes the question, "Can I afford to throw out my old tools and buy new ones?" should be put, "Can I afford to be without the new tools?" Mr. McLaren quite misinterpreted my meaning when he said that I credited the United States with supplying the cycle manufacturers with all the tools which led to their success. A reference to the second paragraph on page 9 of the paper will show that what was said was that "by adopting up-to-date methods and machinery our cycle makers were able to hold their own against all comers." No reference was made in this connection to American-built machinery, although at the same time I believe that most of the machinery introduced during the cycle boom *was* American machinery.

Mr. J. T. SMITH (Member of Council) said he was sorry that he had not been able to give this paper the attention that it undoubtedly deserved, but there could be no questioning the fact that standardising was the proper thing. There was obviously great advantage in having the parts of machinery interchangeable, and standardising being so very beneficial he had no doubt that it would be carried out much more in the future than in the past.

Mr. W. LAWRIE (Member of Council) said that Mr. Cooper's paper dealt with one part of a very wide and important subject. The position that we in this country occupied in the industrial and commercial world was one that affected nearly every section of the community, and any suggestion or idea that could be brought forward for the improvement of that position deserved their very best consideration. Accuracy of measurement, the proper grading of dimensions, and standardising machines, or parts, were matters that had not yet received the attention they deserved in this country. In fact, speaking generally, our workshop practice had followed behind that of some of our Continental rivals, and it ought to be our duty to make up the leeway as soon as possible. The question of the sizes of the threads in bolts and nuts appeared to be one that ought to be very easily settled, and yet it remained unsettled. Mr. Cooper had shown them clearly that they could not rely upon the nuts of one maker fitting the bolts of another manufacturer. In his (Mr. Lawrie's) own experience he required not long ago a nut for the stud in the flange of a cylinder. He sent ashore for the required nut, giving, of course, the proper dimensions, but when the nut was supplied it would not fit the stud at all. It was subsequently found that the pitch of the thread in the nut was nearly double the pitch of the thread on the bolt. Surely such a state of things was hardly creditable to us as a practical people. It seemed to him that the standardising of the threads of bolts and nuts could be very simply brought about by agreement among the manufacturers without any interference by the Government. Of course, in describing measurements "a full 1-16th" or "a full 1-32nd" were terms or expressions that ought to have passed away long ago, but from what appeared in the paper it seemed that even if we adopted micrometer calipers we were not rid of the entire difficulty. Mr. Cooper had spoken of the progress in America in the way of standardising and automatic machinery as being due to the fact that skilled labour was not so plentiful in the States, and necessity thus became the mother of invention, but that explanation did not, he thought, entirely cover the case. He (Mr. Lawrie) had met a good many Americans, and it had always impressed him that they were strongly averse to manual labour if they could possibly avoid it, and this feeling, he thought, had more to do with the development of machinery than anything else. Mr. Cooper had told them that brains in the workshop were at a discount, but that had hardly been his (Mr. Lawrie's) experience. As a rule when they got a smart man in a workshop he usually obtained some recognition, and if in this country labour-saving appliances had not been employed so largely as in America, it was owing in a great degree to the fact that our labour people did not want labour-saving appliances. He remembered one occasion when they were proposing to introduce some labour-saving machinery on board a steamer, that the machinery was very strongly objected to on the ground that it would be the means of taking the bread out of the men's mouths. Mr. Cooper had suggested standardising in relation to steam and other pipes used on board ship, but the standardising of steam pipes would be a rather difficult matter, because in one ship they might have a 4-inch pipe for a pressure of 150 lb., while in another steamer they might want a 4-in. pipe for a pressure of 200 or 250 lb. It would be equally difficult, he believed, to standardise the main parts of a marine engine, because engines were designed and built to develop certain powers under certain conditions, and each maker had his own idea how those powers should be developed. Where parts could be standardised it was, he thought, their business to carry out the idea as far as practicable. When they came to consider foreign competition it was not only a question of the machinery on board ship. There were other points which it was not quite their province to go into. We had lost the blue ribbon of the Atlantic, but, as Colonel Denny pointed out in his presidential address, it was not the engineers who had lost it, but the shipowners. Colonel Denny also said that, knowing something about the Germans, he did not believe that they would continue running these large vessels unless they made them pay. A meeting was held recently at the Chamber of Commerce, when a large shipbuilder was in the chair, and as he was one of those who contended that these fast steamers did not pay it was expected that he would have something to say on the point, but he did not refer to it. From the last annual report of the North German Lloyd it appeared that on her best voyage the *Deutschland* received in freight £28,600, while the cost of running the vessel for that voyage was £10,000, leaving a profit of £18,600. As against that was taken the case of the *Ivernia*, which on her best voyage earned £10,000 in freight, while the cost of the voyage was £4,000, leaving a profit of £6,000, or about one-third of the profit in the case of the *Deutschland*. It would not do to argue that the *Deutschland* did as well on the average of every voyage during the year, but the figures showed that Colonel Denny was fairly near the mark when he said that the Germans would not take up anything if it did not pay them. With all our drawbacks, however, we were not behind other nations so far as marine engineering was concerned. At the same time we should get behind them if we simply marked time.

Mr. H. C. WILSON (Member) said this was a very interesting paper, and one worthy of every consideration. From a cursory glance at the paper, it appeared to him that the question of standardising could be divided under two separate and distinct heads: firstly, standardising from a commercial point of view; and secondly, standardising from a workshop practice point of view. There could be no doubt that standardising from a commercial point of view was very desirable so far as it could be carried out. If a man could at a moment's notice, comparatively speaking, supply, either from stock or from patterns, a duplicate part of any machine, that man had a great advantage over another man who did not standardise commercially; and a man who stocked these parts commercially was likely to command a much larger business than the man who simply made them from hand to mouth. But when they came to the actual practice of standardising in the workshop, with the ordinary workshop workers, the whole matter reduced itself down almost to the level of the ordinary practice. His impression was that the whole result would depend then, as now, upon the skill of the actual operator himself in the workshop. He agreed that it was extremely desirable to have more accuracy of measurement, but accuracy still depended in a very great measure upon the man who worked the tools. The touch of the workman had a great deal to do with it. Then the question would arise, how far standardising could be adopted in the workshop with advantage? Supposing they had two propellers made to the same gauge for a certain taper of cone, and they required to substitute the second propeller for the one first fitted. Would that second propeller go on the shaft and fit exactly the same as the first? Certainly not. Then take the ordinary connecting rods. They were made with certain distances from centre to centre, but would there be any absolute advantage in having them made exactly similar, dead correct to the same gauge all the way? Supposing a connecting rod broke down, and another one made absolutely the same in every way was sent to take its place. Did any man suppose that that second connecting rod would go up in its place and away to sea without any trouble? Some amount of adjustment would be absolutely essential in the nature of things.

Mr. J. R. RUTHVEN (Member of Council) said he quite appreciated the importance of standardising, but the three bolts with nuts that Mr. Cooper had brought before them furnished a somewhat unfortunate example, because standard threads had been in the market longer than any other form of standards. The idea had occurred to him, however, whether, if they hampered themselves with restrictions as to sizes, they would not hamper their designing faculties. If they hampered themselves too much they would become more like the Chinese. As Mr. Wilson had pointed out, the commercial aspect and the workshop aspect of the question seemed to clash to some extent, and he thought it would be a pity if automatic machinery came in too quickly to starve out the workmen.

Mr. WILSON said that from what he could gather he was afraid he had been somewhat misunderstood. Take, for example, the case of fitting a propeller on the cone of a propeller shaft. The fitting of one cone on to another was rather a delicate piece of work, and if a propeller, after being taken off the shaft for any purpose, was put back on the same cone, they would probably find, in nine cases out of ten, that the propeller went further up on the cone than it did before. If a propeller on being replaced on the same cone went further on to the cone than before it was taken off, what was likely to happen in fitting an entirely new propeller? A certain amount of fitting or adjustment was absolutely necessary.

Mr. CICERI SMITH (Visitor) said he thought they were all pretty well agreed that standardising would be a very great advantage, but there was one point which seemed to him to have been very lightly touched upon, and that was the international value of standardising from a commercial point of view. From the commercial point of view it would, he thought, be of very great value indeed, especially to the British merchant and manufacturer, because we seemed to be behind our Continental competitors in regard to foreign competition where an international standard was required. When goods were required for foreign countries, where the metric system was more or less universally adopted, the British merchant was at a great disadvantage, and he thought that something might be done to advance in the workshop the adoption of the metric system to a greater extent than at present. In one part of his paper Mr. Cooper said that if the parts or fractions of an inch, instead of being described as at present, were always described in decimal fractions we should have a decimal system, but he could not quite agree with the author on this point, because we should still retain the inch, the foot, and the yard, and the system introduced would really be a combination of the decimal system with the inch, foot and yard standards of measurement.

Mr. WALKER (Member) said he agreed with the last speaker that the more general adoption of the metric system for international purposes would be greatly to our advantage.

Mr. PETER SMITH (Member) said that in reading over this paper he found that the author had not left himself open to much criticism, and he quite agreed with him when he wrote that Great Britain was suffering from an excess of conservatism. Compared with the United States we were somewhat behindhand, although Mr. Cooper made it clear that he did not intend to imply that the American workman was a better workman than the British workman. He (Mr. Smith) was very much impressed by a conversation that he had a few years ago with a gentleman—a manufacturer—from Australia, who had travelled all over America and the Continent, and wherever he saw an improved tool or appliance worth adopting he sent it to Australia. This gentleman told him that after his experiences during his travels he was never so much disgusted in his life, as had he made his voyages ten years earlier he would by that time have been able to retire. He (Mr. Smith) asked him what country struck him most, and the gentleman replied: "America, by a long way." This gentleman also told him of one instance in America where he found an apprentice boy attending to four machines and turning out work for which four men had previously been paid 10s. a day in the same shop. He (Mr. Smith) recently had the pleasure of going over Messrs. Weir's workshops, and he ventured to say that those shops were as well up-to-date as any in the country. Special accommodation was provided where the men could hang up their clothes and wash themselves at the end of the day's work, and if he pleased a man could leave the workshop as clean and respectable as a clerk would leave an office. Messrs. Weir deserved great credit for the system that they had adopted in this respect. It was a system that went a long way to improve the British workman, while the firm probably got the best class of men. They always paid the standard rate of wages. It ought to be possible, however, with regard to such appliances as Weir's pumps, for example, to send to Messrs. Weir for a duplicate of any part that had given out or needed replacing. Reference had been made to the fitting of propellers on propeller shaft cones. He had an experience with a new vessel which had been running for four years, and the propeller shaft was taken in for lining up. When the propeller boss was put on to the cone again he found, much to his surprise, that it would not go on up to the old mark, and the fact of the matter, as it afterwards proved, was, that a film of oil had prevented that boss going up to its original mark.

The CHAIRMAN said he thought they were all pretty well agreed that the object indicated in the title of the paper ought to be carried out to its fullest extent. It would be a substantial gain if each maker would even standardise his own work. It was very aggravating when they ordered two or three dozen nuts of a certain size to find that the nuts would not fit the bolts, although this often arose possibly through the wearing of the dies. Great advantage would result to those engaged in engineering if every maker followed the same system as that followed by several engine builders, and adopted a definite standard for everything that they made. In illustration of the value of so making parts of machinery that they were interchangeable in an emergency, he mentioned that on one occasion, some fifteen years ago, a steamer broke down off Dover, having broken piston rods. There happened at that moment to be a sister ship in dock in London, with similar engines; so, after checking the dimensions, a wire was sent to London for her piston rods to be sent to the disabled vessel at Dover. The pistol rods were sent and fitted. The steamer thus got away probably a week earlier than if the duplicate piston rods had not been available. In locomotive work the system of standardising was carried on to a much greater extent than in marine engineering; and speaking of locomotives one was reminded that it would also be a great advantage if there could be some system of standardising in railway rates. He had read Mr. Cooper's paper with a great deal of pleasure, and he hoped that this discussion might be the means of bringing about some improvement among some of the makers who were amenable to the reasonable advantages to be derived from such a system.

Mr. F. COOPER, who was then called upon by the Chairman to reply, said that generally speaking there was not very much to reply to. The fact of the matter appeared to be that standardising was a good thing and that accuracy of measurement was a good thing. There appeared, however, to be a slight difference of opinion as to how far accuracy should go. Mr. Wilson said that standardising could be divided into two sections—standardising from a commercial point of view, and standardising from a workshop practice point of view. He (Mr. Cooper) did not see, however, that they could make any difference between the two. Every works was in a way a commercial undertaking. People did not establish and carry on workshops for the mere sake of workshop practice. Usually workshops were carried on for the purpose of making something that the owner was going to sell, which was a commercial undertaking; and if standardising was a good thing commercially, it ought to be a good thing for the workshop. The sewing machine was one of the best examples of the results of standardising. Owing to the system of standardising that was adopted, sewing machines could now be made at such a price that almost everybody could afford to have one in his own house. Another good example of the effects of standardising was the introduction of automatic machinery for making hats, and there were now about twenty times more people employed in the making of hats than ever there were before the automatic machinery was introduced. Although the immediate effect of the introduction of automatic machinery was to throw some men out of employment for a time, the ultimate result was to increase the number employed very largely. He was very pleased to hear Mr. Peter Smith mention the conveniences provided by Mr. Weir for the workmen at his Glasgow works, and this kind of accommodation was quite common in the workshops of America. In fact in some workshops in America bath-rooms were provided, and the men were allowed to have a bath once or twice a week in their master's time. The argument in the paper for adopting the decimal system was only meant to induce people in this country to use the decimal system more than they did with the idea that it would result in the adoption of the metric system. When they were dealing with feet and yards they did not perhaps require to be so particular as to be accurate to the 10,000th part of an inch, but in measuring the smaller sizes the gauges and micrometers referred to in the paper showed very clearly that even the 10,000th part of an inch was a very appreciable quantity. If members knew the number of workmen in this country who were working to the decimal system and who were working to micrometer calipers they would be very much surprised. There were to his own knowledge firms in London alone who were selling from 50 to 100 micrometer calipers every week, which showed that this idea of measuring more accurately and measuring by thousandths, instead of by "bares" and "fulls," was on the increase. One gentlemen said that even when measuring with micrometer calipers it was a matter of touch. So it was, to an extent, but not to an extent that would make any appreciable difference in a size. With regard to the metric system, they did not usually look upon Russia as a particularly go-ahead nation, but since this paper was read he had had a paper handed to him from which it appeared that Russia had now decided to adopt the metric system of weights and measures.

The discussion was then closed.

The CHAIRMAN announced that as the second Monday in April would be Easter Monday the next meeting of the Institute would be held on the fourth Monday in April, the 22nd, and in deference to a desire expressed by certain members that meeting would probably be held in the City, provided suitable arrangements could be made. The paper to be read on that occasion would be on "Marine Salvage Work," by Mr. M. W. Aisbitt, with special reference to the salving of the *Paris*.

A vote of thanks to the Chairman concluded the meeting.