RESEARCH COMMITTEE ON RIVETED JOINTS.

REPORT UPON EXPERIMENTS ON DOUBLE-RIVETED LAP AND BUTT JOINTS MADE WITH THICKER PLATES AND LARGER RIVETS CLOSED UNDER HEAVIER PRESSURES, SERIES XIV.

By PROFESSOR ALEXANDER B. W. KENNEDY, F.R.S., *Honorary Life Member.*

The Research Committee on Riveted Joints, having made thirteen series of experiments, of which the three last were reported to the Institution in April 1885, placed also before the Members on the same date an Abstract of the whole results, so far as they had gone, drawn up by the Reporter.* This Abstract was read and discussed at that meeting of the Institution. The Committee subsequently decided that it was advisable to make further experiments on Double-Riveted Lap and Butt Joints, to a small extent in duplication of the former tests, but mainly with the use of heavier hydraulic pressures in riveting, thicker plates, and larger rivets. These experiments, which constitute Series XIV of those made by the Committee, form the subject of the present Report. In one respect at any rate, namely the size of the rivets used in the larger joints, they are probably unique. Their principal results are given in the subjoined Tables XXXIX and XL, pages 566-569.

The plate used in the joints was kindly supplied, as on former occasions, by the Landore Siemens-Steel Co. The preparation and riveting up were done by Messrs. Fielding and Platt, of Gloucester, the machines used for riveting being those of Mr. Tweddell. The actual testing of the joints themselves was carried out by the Reporter on the 300-ton machine at Lloyd's Proving House at Netherton, the use of which was kindly granted on very liberal terms. The very numerous tensile tests of plate strips, etc.,

* For complete list of previous Series I to XIII see Proceedings April 1885, Table XXXVI, page 263.

and the shearing tests, were made in the Engineering Laboratory at University College, London.

Series XIV consist of thirty-three riveted joints in all. Of these nine are in $\frac{3}{8}$ -inch plate, fifteen in $\frac{1}{2}$ -inch plate, and nine in 1-inch plate. The thirty-three joints are divided (see Tables XXXIX and XL, pages 566-569) into eleven sets of three each, each set receiving a different distinguishing letter. The sets marked A, B, and C were all taken from one plate; D, E, and H from another; F and G from a third; and K, L, and M from a fourth plate. In all cases the metal was cut so that the direction of pull in the joint was in the direction of the length of the plate. Detailed drawings of the joints are given in Plates 105 to 109, and the dimensions marked thereon need not be here recapitulated; the drawings also give details of the dimensions of the rivets used, from which it will be seen that ample length was provided to make good ends.

The results of the first eighteen experiments are given in Table XXXIX, pages 566-567. These are all on $\frac{3}{8}$ and $\frac{1}{2}$ -inch plate with the diameters of rivets formerly used, but with much heavier pressures used in riveting than those formerly employed, these heavier pressures being fixed by Mr. Tweddell. For comparison's sake three lap-joints in each thickness of plate were also riveted up by hand. Out of the nine joints in each thickness of plate there are thus three (A and D) hand-riveted lap, three (B and E) machine-riveted lap, and three (C and F) machine-riveted butt. In form they differ from most of those of Series XII and XIII in that each joint contains an even number of rivets, and not an odd number. In this respect they were the same as the former $\frac{1}{2}$ -inch double-riveted butt-joints (Table XXXII, Proceedings 1885, page 224, and Fig. 4, Plate 27). This point was discussed in the last Report of this Committee (Proceedings 1885, page 213), and will be further referred to. It was thought at the time that it would be better to make this alteration in future experiments, but the result leaves it doubtful whether or not the change was advisable.

In Table XL, pages 568-569, are given the results of experiments on double-riveted lap and butt joints in $\frac{1}{2}$ and 1-inch plate, with extra large rivets, and with specially heavy riveting pressures, fixed

by Mr. Tweddell. All these joints are of course machine-riveted. In the $\frac{3}{4}$ -inch lap-joints (G) the rivets were 1.6 inch diameter; in the 1-inch lap-joints rivets of 1.3 inch diameter were used in three joints (K), and rivets of 1.75 inch diameter in three joints (L). The $\frac{3}{4}$ -inch butt-joints (H) were made with 1.6 inch rivets, and the 1-inch butt-joints (M) with 1.3 inch rivets.

The experiments will probably be most easily followed if taken up in order, comparing each set with the one which it most resembles of those formerly tested. For this purpose we may begin with the joints A and B in Table XXXIX, pages 566-567, double-riveted lap-joints in $\frac{3}{4}$ -inch plate, comparing them with those of Table XXIX (Proceedings 1885, pages 201 and 218. Compare also Fig. 1, Plate 105, with Fig. 1, Plate 27, of 1885.) Here, although it was intended that the plates should be precisely of the quality formerly used, it was unfortunately found out only too late that the plates sent for Series XIV had a tenacity of only about 25 to 26 tons per square inch, instead of 29 to 30 tons. Besides being deficient in tenacity, the plate was distinctly laminated in appearance, and was wanting in ductility, as is shown in the tests in Table XXXVII, pages 550-551, where the results of tensile tests on three pieces cut from each joint are given. In the hand-riveted joints slip became visible at 32.5 per cent. of the breaking load, in the machine-riveted at 43.2 per cent., as against 25.2 per cent. and 50 per cent. formerly. The pressure used in riveting these first joints was fixed by Mr. Tweddell at 35 tons,* or nearly the same as before, although he was disposed at first to think this pressure somewhat too high for the small rivets. There was no other sensible difference between the results of the hand and the machine riveting, except that

* An accumulator having 6 inches diameter and 10 feet stroke was used in all cases, and was connected to the machine by small pipes, which did away with any sudden drop. The distance the ram lowered in closing a rivet was as follows:—

Pressure 100 tons,	...	drop 31 inches.
" 70 "	...	" 23 "
" 35 "	...	" 10 "

the latter gave slightly the higher efficiency. The efficiency of the joints was 74 per cent., against 80 per cent. formerly reached in the joints which gave way in the plate. This reduced value is owing entirely to the absence of any considerable excess of strength in the plate due to perforation. In the former joints this excess amounted to 10·5 per cent. (given as "exactly 10 per cent." in 1885, page 203); here it was only 2·7 per cent. All the joints gave way in the plate, the shearing stress in the rivets reaching about 21 tons per square inch. Table XXXVIII, page 560, shows that the average shearing resistance of the rivet steel was 24·6 tons per square inch. It must be noted however that one set of the former joints (Series XIII, Table XXIX) gave way by shearing the rivets at about 21·5 tons per square inch, reaching only 67 per cent. efficiency. If these joints be taken into account, the mean efficiency of the seven former joints is 76·4 per cent., against 74·0 in the present ones; but this is probably not so satisfactory a method of comparison as the other.

The double-riveted butt-joints in $\frac{3}{4}$ -inch plate (C in Table XXXIX, pages 566-567) compare with the joints of Series XII and XIII in Table XXX. The dimensions are the same, with the exception of the breadth and number of rivets; the pressure used in riveting was 35 tons, or practically the same as before, the rivets being 0·7 inch diameter in both cases. Slip became visible only at 71·5 per cent. of the final load, as against 66·8 per cent. formerly. Fracture occurred in the plates in all cases, the stress in the rivets being inevitably very small in this type of joint unless the bearing pressure be excessive, and this was kept under 40 tons per square inch. The efficiency of the joints was 75 per cent., as against 79·2 per cent. formerly reached, this difference being again due to the very small excess of strength consequent upon perforation, which was only 1 per cent. against 6 per cent. formerly.

Going on now to the $\frac{3}{4}$ -inch plates (which Table XXXVII, pages 552-555, shows to have been of much more satisfactory quality than the thinner plates), we can compare first the sets D and E of Table XXXIX, pages 566-567, with the joints given

in Table XXXI. These are all double-riveted lap-joints, and the old and new sets are identical except for the differences formerly specified, and for the pressure used in riveting, which was 70 tons* in Series XIV against 35 tons in Series XII and XIII, the rivets being 1.1 inch diameter in all cases. In the hand-riveted joints slip began at 29.8 per cent. of the maximum load, as against 21.2 per cent. formerly, while the joints riveted under heavy pressure show no corresponding gain, slip beginning now at 31.8 per cent. against 33.7 per cent. before, or practically at the same point. The rivet bar used in these joints had a shearing resistance of 24 to 26 tons per square inch, while rivets made from that bar had a resistance below 20 tons per square inch; the particulars are given in Table XXXVIII, page 561. Three out of the six joints tested broke in the rivets, the average shearing stress being 17.9 tons per square inch. (In these joints the rivets were of course only in single shear, and exposed to some tension owing to the bending of the plates; while all the shear experiments were on double shear, where no bending could occur.) In four of the earlier experiments with this type of joint fracture also occurred in the rivets, but at a much higher load, namely 21.0 tons per square inch, the mean efficiency of those joints being 61.8 per cent. The mean efficiency of the three joints of Series XIV which sheared the rivets was only 52.4 per cent., on account of the much smaller resistance of the rivets. In the former experiments five joints broke in the plate, with a mean efficiency of 70.2 per cent., the plate having an excess strength of 7.8 per cent. In the present series three joints broke in the plate with 65.2 per cent. efficiency, the excess strength being only 1.4 per cent.

The double-riveted butt-joints in $\frac{3}{4}$ -inch plate, set F in Series XIV, compare with those of Series XII and XIII in Table XXXII, but were riveted up with 70 tons pressure instead of 35 tons. In both cases fracture occurred in the plate. Slip began at 34 per cent. of the maximum load in the earlier experiments, but this proportion is increased to 49 per cent. in Series XIV. The efficiency of the

* The riveting of Series E and F was done in a plate-closing machine, 30 tons coming on the plate first, then 40 tons on the rivet, and finally the whole 70 tons on the rivet.

joints is practically the same in both sets of experiments, being about 67 per cent. In both sets of experiments the plate showed defect instead of excess of strength; this amounted to 9.5 per cent. in Series XII and XIII, and 10.5 per cent. in Series XIV. The same type of joint however had reached 71.3 per cent. efficiency when hand-riveted in Series XI (Table XXXII), the defect of strength in that case being only 4.8 per cent.

In Table XL, pages 568-569, are given results of experiments on fifteen joints, in five sets of three each, in which larger rivets as well as higher pressures have been used. The double-riveted lap-joints in $\frac{3}{4}$ -inch plate, set G, can be compared with those in Table XXXI, as well as with sets D and E of Table XXXIX, the particulars of which have just been given. These new joints G had rivets 1.6 inch diameter, and were riveted up with a pressure of 100 tons. They were of exactly uniform strength in plates and in rivets, for the weakest broke at 240.4 tons by shearing the rivets, and the strongest at 242.4 tons by tearing the plate; the mean efficiency of the three was 69.4 per cent., as against 65.2 per cent. with the smaller rivets, being a gain of 6.4 per cent. This is in spite of the fact that there is now a loss of strength in the plate amounting to 1.8 per cent., instead of a gain of 1.4 per cent. It will be noticed also that the joints which broke in the rivets had precisely the same strength as those which broke in the plate, instead of being far weaker. The rivets sheared only at 20.1 tons per square inch, instead of 17.9 tons per square inch. It will be seen from Table XXXVIII, page 561, that the 1.1 inch rivets were much weaker in shear than the bar from which they were made (26 tons per square inch falling to 19.87); while the 1.6 inch rivets, page 563, were actually a little stronger than the bar from which they were made (23 tons per square inch against 22.85). As regards the point about which there was reason to expect the most striking improvement, it was singular to find that none occurred. Slip began at 29.2 per cent. of the maximum load, a lower percentage than before, instead of a higher one.

For double-riveted butt-joints in $\frac{3}{4}$ -inch plate the set H of Series XIV, Table XL, pages 568-569, compares with set F of

Table XXXIX, and with the joints of Series XII and XIII given in Table XXXII. The new joints had 1.6 inch rivets closed under 100 tons pressure, instead of 1.1 inch rivets closed under 70 tons in set F, or under 35 tons in Series XII and XIII. All the joints broke in the plate, and showed a loss of strength of about 9 per cent., or a little less than with the same type of joint formerly. The efficiency of the joints was 67.9 per cent.; practically therefore it was unchanged. Slip became visible at 46.5 per cent. of the maximum load, a much higher percentage than in Series XII and XIII, but a little lower than for the 1.1 inch rivets in set F, in which it began at 49 per cent.

The remaining nine joints of Series XIV, Table XL, pages 568-569, were in plate 1 inch thick, so they do not compare directly with any former joints tested by the Committee, but must be considered principally by themselves. They consisted of three sets, all riveted with 100 tons closing pressure. Set K were lap-joints with 1.3 inch rivets; set L lap-joints with 1.75 inch rivets; and set M butt-joints with 1.3 inch rivets. All the joints broke by tearing the plate. The set K gave the highest plate stress at fracture of any joints in Series XIV, namely 30.9 tons per square inch, although the tensile strength of the original plates was higher in several other sets than in set K. The plate stress at fracture of the joints in set K showed an excess strength of 11.6 per cent. With this help the joints reached an efficiency of 65.4 per cent. Slip began very low, at 28 per cent. of the maximum load. The rivets stood nearly 21 tons per square inch, but did not give way. Their shearing resistance, as given in Table XXXVIII, page 562, is 23.92 tons per square inch.

In set L, although made from plate of very nearly identical quality, the excess strength practically disappeared, the joints breaking at 27.59 tons per square inch as against a plate tenacity of 27.49 tons per square inch. In spite of this, which means a loss of 11 per cent. as compared with set K, the efficiency of the joints with the large rivets rose to 66.8 per cent. The point at which slip began also rose to 34.4 per cent. of the maximum load. It

is worth mentioning that in one of the three joints of this set, L 3, both plates of the joint tore simultaneously at the maximum load.

The butt-joints, set M, reached a higher efficiency (69·3 per cent.) than any other of the 1 inch joints, although, as in the former cases, the plate showed defect instead of excess of strength, the defect here amounting to 6·8 per cent. Slip began at 44·3 per cent. of the maximum load. It was possible to proportion these large joints so as to get a greater stress on the rivets than in any other of the butt-joints, and here that stress reaches 18·5 tons per square inch, a stress above that at which the rivets had given way (in single shear) in sets D and E, Table XXXIX. The $1\frac{3}{4}$ -inch rivet-bar and rivets both gave a shearing resistance of over 23 tons per square inch in the testing machine, Table XXXVIII, page 564.

It is obvious from the figures given above that all the differences between the strength of the joints in Series XIV and of those in Series XI to XIII lie within the limits covered by what has been called the "excess strength due to perforation." This matter has been dealt with at some length in former Reports, and especially in the "Abstract of Results" (Proceedings 1885, page 249) under clause (i) of the general conclusions. This clause may perhaps be here repeated with advantage:—"The metal between the rivet holes has a considerably greater tensile resistance per square inch than the unperforated metal. This excess tenacity amounted to more than 20 per cent., both in $\frac{3}{8}$ -inch and $\frac{1}{2}$ -inch plates, when the pitch of the rivets was about 1·9 diameters. In other cases $\frac{3}{8}$ -inch plate gave an excess of 15 per cent. at fracture with a pitch of 2 diameters, of 10 per cent. with a pitch of 3·6 diameters, and of 6·6 per cent. with a pitch of 3·9 diameters; and $\frac{1}{2}$ -inch plate gave 7·8 per cent. excess with a pitch of 2·8 diameters." As variation of this excess strength may thus account for variations in the strength of joints considerably greater than those which have occurred between the joints now under consideration, the proper interpretation of the experiments seems really to depend on the method of dealing with this point. An examination was therefore made, with special reference to this matter, of all the experiments carried out by the Committee; and it

shows that—without any exceptions save those of two small joints made with $\frac{1}{2}$ -inch rivets in $\frac{3}{8}$ -inch plate in Series VI—they point to the following conclusions:—

(i) The “excess strength due to perforation” is *increased* by anything which tends to make the stress in the plate uniform, and to diminish the effect of the narrow strip of metal at the edge of the specimen, and especially (a) by an increase in the number of rivets, and (b) by the use of an odd instead of an even number of rivets in a double-riveted specimen, so as to get the narrow strip symmetrically on both sides instead of only on one side of the specimen.

(ii) It is *diminished* by increase in the ratio $\frac{p}{d}$ of pitch to diameter of hole: so that in this respect it becomes less as the efficiency of the joint increases.

(iii) It is *diminished* by any increase in hardness of the plate.

(iv) For a given ratio $\frac{p}{d}$ of pitch to diameter of hole it is also apparently *diminished* as the thickness of the plate is increased. The ratio of pitch to thickness of plate does not seem to affect this matter directly, at least within the limits of the experiments.

It is sufficient here to cite one or two instances in illustration of these points. The maximum excess strength found was in Series VIII, Tables XXII, XXIV, and XXXIV, where with seven rivets in breadth and ratio $\frac{p}{d} = 1.95$ it was 15 per cent., and with $\frac{p}{d} = 1.91$ it was 24.8 per cent., taking into account those joints only which broke in the plate. Table XXIX gives 10.5 per cent. with $\frac{p}{d} = 3.62$, and Table XXX 6 per cent. with $\frac{p}{d} = 3.93$, both with $\frac{3}{8}$ -inch plate. With $\frac{3}{4}$ -inch plate, on the other hand, Table XXXI gives only 8 per cent. with $\frac{p}{d} = 2.82$; and in Table XXXII, where $\frac{p}{d}$ is increased to 4.0, and where the joint is made one-sided (that is, with a whole number of pitches in breadth), the want of symmetry in the stress appears to more than counterbalance the small effect of the perforation, and in Series XII and XIII the excess is changed into a *defect* of 9.8 per cent. In Series XIV *all* the joints were made with a breadth equal to a whole number of pitches, which is the primary cause of the generally

lower value of the excess strength in this series than in former ones. The hardness of the $\frac{3}{8}$ -inch plates in sets A, B, and C has no doubt further diminished the excess in these sets; and all the other experiments fall in with the general conclusions just stated. The large excess of 11.6 per cent. in set K, even with 1-inch plates, corresponds to the small value $\frac{p}{d} = 2.42$ and the large number of rivets (eight). This excess diminishes at once to zero when $\frac{p}{d} = 3.0$ and only four rivets are used, in set L; and further becomes a defect of 6.8 per cent. when, with the same smaller number of rivets, $\frac{p}{d}$ is increased to 3.92 in set M.

In actual practice we may consider that all the ordinary boiler joints are of sufficiently great length and have a sufficiently fair pull to entitle them to full allowance under point (i). The excess strength, as affected by ratio of pitch to diameter, may be taken as diminishing to zero when this ratio is 4.5 or more, and as being about 12 per cent. when it is 2: so that for any value of the ratio r between these numbers the percentage of excess strength may be taken as $12 \left(\frac{4.5 - r}{2.5} \right)$ for $\frac{3}{8}$ -inch plate. The experiments do not give information sufficient for enabling the thickness of the plate to be taken accurately into account; but probably 9 may be substituted for 12 per cent. in $\frac{3}{4}$ -inch and 1-inch plate. If we take the figures on this basis and assume (in respect to point iii) that the plate is uniformly soft in all cases, we can bring the various experiments into comparison on a uniform basis, with the results given in Table XLI, page 570, which may probably be taken as containing the figures most nearly applicable to practice that can be deduced from the experiments so far as they have gone.

In addition to the above assumption that the plate is uniformly soft, it has been assumed in computing the results in Table XLI that all the joints are proportioned so as to break in the plate, or, if in the rivets, not until the full strength of the plate is reached; and only those joints which broke in this fashion have been taken into account in this connection. The question of the irregularity in the shearing resistance of steel, emphasised in a former report, is still further brought to the front by these experiments, Table

XXXVIII, pages 560-564, and becomes of special practical importance in view of the strong wish which has recently been expressed to raise the allowable working pressure in marine boilers.

Besides Tables XXXIX and XL, which give the result of tests of the riveted joints themselves, this Report is accompanied by two other Tables, which have been already referred to. In Table XXXVII, pages 550-559, are given the results of tensile tests of three strips cut out of the uninjured part of each of the joint plates which actually broke in the joint tests. Tests had previously been made of pieces cut from the scrap of the plates from which the joints were made; but the results of these tests were not sufficiently regular to be of much use, and the tests in Table XXXVII were therefore made. The reference numbers and letters are sufficient to identify the pieces cut from each particular joint. A summary of all these eighty-four tensile tests is given at the end of the Table, pages 558-559.

Table XXXVIII, pages 560-564, gives the results of sixty-nine shearing tests of the rivets and the rivet-steel used. All these tests were made in double shear, on test pieces of the form shown in Fig. 10, Plate 29, of the Committee's last Report (Proceedings 1885). The two "lots" of rivet bars mentioned in the Report were received by Messrs. Fielding and Platt at different times from Landore, but were supposed to be of the same quality. Both lots were used in the making of the joints. The smaller sized rivets were not tested as rivets; the bar has a fairly uniform shearing resistance of 23 to 24 tons per square inch. The 1.1 inch bar, page 561, differs a good deal in the two lots, and the rivets are very greatly weaker than the bar from which they were made. There is also a good deal of difference between the rivets made from the two lots of 1.3 inch bar, page 562, but their average agrees fairly with that of the bar; and the same is true of the larger sizes. It is clear that it is perfectly possible to make the bar into rivets without in the smallest degree reducing its shearing resistance. The rivets used in the experiments were all made by hand for Messrs. Fielding and Platt at the Gloucester Wagon Works.

The final Table XLI, page 570, has already been referred to. It contains a summarised statement of the type and leading dimensions of the joints of the four series XI to XIV, with the efficiencies worked out on the basis already discussed, so as to eliminate accidental variation, as far as possible, and to obtain figures which will be as closely as possible comparative for joints of similar materials. With joints of iron plate, or of harder steel, no doubt other figures may be obtained; but it is believed that the figures here given are not far from being the maximum likely to be obtained with double-riveted lap and butt joints made in material such as that used by the Committee. The general conclusions to be drawn from this Table appear to be that for $\frac{3}{8}$ -inch plate, with ordinary diameter of rivet, the lap-joint is very nearly as strong as the butt, and an efficiency of 75 to 76 per cent. can be reached. For $\frac{1}{2}$ -inch plate the butt-joint is considerably stronger than the lap, with the same size rivets; an increase of size of rivets considerably increases the efficiency of the joints. The figures are, roughly, 72 and 68 per cent. for 1.1 inch rivets, and 76 and 74 per cent. for 1.6 inch rivets. The butt-joints made with 1.1 inch rivets however, but with 70 tons closing pressure, reach an efficiency of 76 per cent.—as high as the similar joints with larger rivets. With 1-inch plate the butt-joint has an enormous advantage over the lap with the same sized rivets, and even over the much stronger lap with larger sized rivets. It will be remembered that the comparison here made is one of *strength* only, and not one of suitability for use in boilers on other grounds.

TABLE XXXVII. (continued to page 559)

SERIES XIV. Elasticity and

Test number, and Mark on piece.	Dimensions of Strips of 6 and 10 inches length.			Limit of Elasticity per square inch.		Breaking Load per square inch.	
	Breadth. Inch.	Thickness. Inch.	Area. Sq. Inch.	Lbs.	Tons.	Lbs.	Tons.
13037 A 1	0·967	0·406	0·392	36,750	16·41	56,260	25·12
	0·967	0·406	0·392	37,360	16·68	58,320	26·04
	0·966	0·411	0·397	37,120	16·57	58,130	25·95
			Means	37,080	16·55	57,570	25·70
13038 A 2	0·940	0·410	0·385	36,390	16·25	56,740	25·34
	0·940	0·411	0·386	38,080	17·00	56,280	25·13
	0·940	0·410	0·385	38,190	17·05	56,350	25·17
			Means	37,550	16·77	56,460	25·21
13039 A 3	0·965	0·408	0·394	37,580	16·78	57,180	25·52
	0·966	0·408	0·394	37,760	16·86	57,870	25·84
	0·966	0·408	0·394	38,920	17·37	58,330	26·03
			Means	38,090	17·00	57,790	25·80
13040 B 1	0·987	0·401	0·396	36,900	16·47	53,880	24·05
	0·987	0·405	0·400	35,840	16·00	52,050	23·24
	0·966	0·403	0·389	37,100	16·56	53,060	23·69
			Means	36,610	16·34	53,000	23·66
13041 B 2	0·988	0·405	0·400	38,980	17·40	57,120	25·50
	0·988	0·408	0·403	39,520	17·64	56,930	25·42
	0·988	0·405	0·400	38,230	17·07	58,090	25·94
			Means	38,910	17·37	57,380	25·62
13042 B 3	0·987	0·410	0·405	38,560	17·22	56,760	25·34
	0·966	0·412	0·398	39,050	17·43	57,670	25·74
	0·987	0·412	0·407	39,220	17·51	57,200	25·54
			Means	38,940	17·39	57,210	25·54

(see continuation on opposite page)

(continued from opposite page) TABLE XXXVII.

Tenacity of Steel Plates used.

Ratio of Limit to Break.	Extension in length tested. Per cent.	Reduction of Area at fracture. Per cent.	Calculated Work of fracture per cubic inch. Inch-Tons.	Nature of Fracture.
0.653 0.640 0.639	18.7 25.0 23.3	43.0 48.1 50.1	4.15 5.73 5.71	Silky; slightly laminated. Do. do. Do. do.
0.644	22.3	47.1	5.20	
0.641 0.677 0.678	25.3 26.3 25.0	48.7 49.7 47.1	5.64 5.89 5.62	Slightly laminated throughout. Do., very irregular. Do. do.
0.665	25.5	48.5	5.72	
0.657 0.652 0.667	22.8 21.8 22.0	54.9 54.1 50.9	5.15 4.98 5.09	Silky. Do. Do.
0.659	22.2	53.3	5.07	
0.685 0.688 0.699	19.1 19.7 20.1	47.9 50.4 42.2	4.11 4.10 4.28	Silky; slightly laminated. Do. do. Do. do.
0.691	19.6	46.8	4.16	
0.682 0.694 0.658	17.2 16.4 20.3	47.8 46.8 46.7	3.92 3.74 4.66	Silky; somewhat laminated. Do. do. Do. do.
0.678	18.0	47.1	4.11	
0.679 0.677 0.686	21.6 20.8 18.2	52.7 52.4 44.1	4.89 4.77 4.16	Silky; slightly laminated. Do. do. Do. do.
0.681	20.2	49.7	4.61	

(continued from opposite page)

TABLE XXXVII. (continued from preceding page)

SERIES XIV. Elasticity and

Test number, and Mark on piece.	Dimensions of Strips of 10 and 8 inches length.			Limit of Elasticity per square inch.		Breaking Load per square inch.	
	Breadth.	Thickness.	Area.	Lbs.	Tons.	Lbs.	Tons.
	Inch.	Inch.	Sq. Inch.				
13043 C 1	0·963	0·375	0·361	41,970	18·74	62,080	27·71
	0·987	0·372	0·367	41,770	18·65	61,960	27·67
	0·989	0·372	0·368	42,150	18·82	61,800	27·59
			Means	41,960	18·74	61,950	27·66
13044 C 2	0·988	0·379	0·374	36,040	16·09	60,070	26·82
	0·988	0·379	0·374	39,260	17·53	59,440	26·54
	0·988	0·379	0·374	41,650	18·60	60,150	26·86
			Means	38,980	17·41	59,890	26·74
13045 C 3	0·985	0·408	0·402	38,800	17·32	54,780	24·46
	0·985	0·408	0·402	36,000	16·07	53,140	23·73
	0·985	0·408	0·402	38,440	17·16	56,950	25·43
			Means	37,750	16·85	54,960	24·54
13047 D 2	0·987	0·750	0·740	48,640	21·71	63,060	28·15
	0·986	0·752	0·741	38,040	16·98	63,130	28·18
	0·984	0·753	0·741	43,730	19·53	63,650	28·42
			Means	43,470	19·41	63,280	28·25
13048 D 3	0·967	0·743	0·718	41,760	18·64	60,720	27·11
	0·986	0·740	0·730	42,770	19·10	62,100	27·72
	0·968	0·745	0·721	39,110	17·46	61,250	27·34
			Means	41,210	18·40	61,360	27·40
13051 E 3	0·980	0·748	0·733	43,390	19·37	63,860	28·51
	0·985	0·750	0·739	44,270	19·77	63,360	28·29
	0·955	0·749	0·715	41,100	18·35	63,420	28·32
			Means	42,920	19·16	63,550	28·37

(see continuation on opposite page)

(continued from opposite page) TABLE XXXVII.

Tenacity of Steel Plates used.

Ratio of Limit to Break.	Extension in length tested. Per cent.	Reduction of Area at fracture. Per cent.	Calculated Work of fracture per cubic inch. Inch-Tons.	Nature of Fracture.
0·676 0·674 0·682	21·0 17·0 17·5	51·5 48·1 50·6	5·19 4·19 4·32	Silky. Do. Do., slight trace of lamination.
0·677	18·5	50·1	4·57	
0·600 0·660 0·692	14·4 16·7 15·5	48·3 45·1 44·1	3·35 3·93 3·73	Silky laminated in centre, with a few crystalline spots. Silky, somewhat laminated. Do. do.
0·651	15·5	45·8	3·67	
0·708 0·677 0·675	20·3 19·5 22·0	48·5 50·5 48·1	4·48 4·13 4·99	Silky, somewhat laminated. Do. do. Do. do.; drew down in two places.
0·687	20·6	49·0	4·53	
0·771 0·603 0·687	23·1 20·5 24·4	58·8 58·5 57·5	6·01 5·01 6·21	Silky. Do. Do.
0·687	22·7	58·3	5·74	
0·688 0·689 0·639	19·9 21·5 20·8	62·0 59·4 61·0	4·83 5·34 5·00	Silky. Do. Do.
0·672	20·7	60·8	5·06	
0·680 0·699 0·648	21·9 21·9 22·1	57·2 56·0 56·9	5·57 5·57 5·52	Silky, very faint lamination. Do. do. Do. do.
0·676	22·0	56·7	5·55	

(continued from opposite page)

In length of 10 inches.

In length of 8 inches.

TABLE XXXVII. (continued from preceding page)

SERIES XIV. Elasticity and

Test number, and Mark on piece.	Dimensions of Strips of 8 and 10 inches length.			Limit of Elasticity per square inch.		Breaking Load per square inch.	
	Breadth.	Thickness.	Area.	Lbs.	Tons.	Lbs.	Tons.
	Inch.	Inch.	Sq. Inch.				
13052 F 1	0·991	0·738	0·731	49,230	21·98	64,650	28·86
	0·991	0·734	0·727	46,200	20·63	64,260	28·69
	0·989	0·735	0·727	44,580	19·90	64,140	28·64
			Means	46,670	20·84	64,350	28·73
13053 F 2	1·000	0·740	0·740	43,710	19·52	65,680	29·32
	0·945	0·748	0·707	49,670	22·17	64,960	29·00
	0·945	0·749	0·708	49,180	21·96	64,610	28·84
			Means	47,520	21·22	65,080	29·05
13054 F 3	0·940	0·745	0·700	48,010	21·44	63,510	28·36
	0·940	0·745	0·700	47,140	21·05	64,280	28·70
	0·940	0·745	0·700	46,270	20·66	63,250	28·24
			Means	47,140	21·05	63,680	28·43
13057 G 3	0·970	0·717	0·695	53,930	24·08	64,720	28·89
	0·975	0·723	0·705	49,390	22·05	64,540	28·81
	0·975	0·722	0·704	50,290	22·45	63,930	28·55
			Means	51,200	22·86	64,400	28·75
13058 H 1	1·000	0·748	0·748	45,730	20·42	62,730	28·01
	1·000	0·748	0·748	44,120	19·70	62,170	27·75
	1·000	0·750	0·750	49,360	22·04	64,330	28·72
			Means	46,400	20·72	63,080	28·16
13059 H 2	0·985	0·750	0·739	49,550	22·12	65,210	29·12
	0·983	0·747	0·734	46,580	20·80	64,560	28·82
	0·979	0·747	0·731	45,960	20·52	64,920	28·98
			Means	47,360	21·15	64,900	28·97
13060 H 3	0·990	0·746	0·739	49,560	22·13	65,320	29·16
	0·990	0·746	0·739	47,530	21·22	64,270	28·69
	0·988	0·746	0·737	46,410	20·72	64,160	28·65
			Means	47,830	21·36	64,580	28·83

(see continuation on opposite page)

(continued from opposite page) TABLE XXXVII.

Tenacity of Steel Plates used.

Ratio of Limit to Break.	Extension in length tested.		Reduction of Area at fracture.	Calculated Work of fracture per cubic inch.	Nature of Fracture.
	Per cent.		Per cent.	Inch-Tons.	
0.762	In length of 8 inches.	20.4	56.7	5.42	Silky. Do. Do.
0.719		21.5	55.4	5.59	
0.695		23.0	56.2	5.91	
0.725		21.6	56.1	5.64	Silky. Do. Do.
0.666		22.1	58.5	6.03	
0.765		23.8	59.9	6.36	
0.762		23.0	59.7	6.11	
0.731		23.0	59.4	6.17	Silky. Do. Do.
0.756		21.1	59.0	5.50	
0.733		21.8	61.1	5.70	
0.732		21.9	58.6	5.63	Silky. Do. Do.
0.740		21.6	59.6	5.61	
0.834	In length of 10 inches.	19.5	55.2	5.32	Silky. Do. Do.
0.765		18.9	55.8	5.02	
0.786		18.2	55.9	4.83	
0.795		18.9	55.6	5.06	Silky. Do; a few hard spots. Do. do.; a roll flaw on surface.
0.729		17.3	58.6	4.51	
0.710		20.2	60.3	5.06	
0.768		14.6	56.9	3.87	Silky. Do. ; a few hard spots; very slight Do. do. ; somewhat irregular.
0.736		17.4	58.6	4.48	
0.760		20.8	55.7	5.57	
0.722		20.2	57.2	5.28	Silky. Do. ; a few hard spots; very slight Do. do. ; somewhat irregular.
0.708		20.1	58.3	5.26	
0.730		20.4	57.1	5.37	
0.759		19.5	56.8	5.23	Silky. Do. ; a few hard spots. Do. do.
0.740		20.5	55.1	5.37	
0.723		19.3	59.1	5.02	
0.741		19.8	57.0	5.21	

TABLE XXXVII. (continued from preceding page)

SERIES XIV. Elasticity and

Test number, and Mark on piece.	Dimensions of Strips of 10 inches length.			Limit of Elasticity per square inch.		Breaking Load per square inch.	
	Breadth.	Thickness.	Area.	Lbs.	Tons.	Lbs.	Tons.
	Inch.	Inch.	Sq. Inch.				
13061 K 1	1.003	0.987	0.990	44,550	19.88	62,230	27.78
	0.977	0.988	0.985	42,640	19.03	62,170	27.75
	1.005	0.985	0.990	44,560	19.89	62,230	27.78
			Means	43,920	19.60	62,210	27.77
13062 K 2	0.986	0.969	0.955	40,300	18.00	62,280	27.80
	0.990	0.969	0.959	39,410	17.60	62,620	27.96
	0.989	0.969	0.958	40,170	17.94	62,530	27.92
			Means	39,960	17.85	62,480	27.89
13063 K 3	0.996	0.990	0.986	44,030	19.66	61,220	27.33
	0.993	0.988	0.981	39,250	17.52	61,520	27.46
	1.003	0.988	0.991	39,560	17.66	61,040	27.25
			Means	40,950	18.28	61,260	27.35
13064 L 1	0.936	1.004	0.940	42,460	18.96	59,080	26.38
	0.936	1.004	0.940	44,700	19.96	60,340	26.94
	1.000	1.004	1.004	39,040	17.43	59,480	26.55
			Means	42,070	18.78	59,630	26.62
13065 L 2	1.009	0.960	0.969	44,090	19.69	62,460	27.88
	1.016	0.963	0.978	46,510	20.76	62,960	28.11
	1.013	0.960	0.973	45,000	20.09	62,990	28.12
			Means	45,200	20.18	62,800	28.04
13066 L 3	1.005	1.004	1.009	43,710	19.52	62,100	27.72
	0.983	1.001	0.984	45,190	20.17	62,620	27.96
	1.003	1.004	1.007	43,090	19.24	62,220	27.78
			Means	44,000	19.64	62,310	27.82

(see continuation on opposite page)

(continued from opposite page) TABLE XXXVII.

Tenacity of Steel Plates used.

(continued from opposite page)

Ratio of Limit to Break.	Extension in length of 10 inches. Per cent.	Reduction of Area at fracture. Per cent.	Calculated Work of fracture per cubic inch. Inch-Tons.	Nature of Fracture.
0.716 0.686 0.716	18.7 21.5 24.0	58.5 59.6 59.1	4.70 5.34 6.03	Silky. Do. Do.; a few hard spots.
0.706	21.4	59.1	5.36	
0.648 0.630 0.643	19.2 20.9 20.0	59.8 60.1 59.6	4.71 5.12 4.92	Silky; a few hard spots. Do. Silky.
0.640	20.0	59.8	4.92	
0.719 0.638 0.648	20.0 23.7 23.7	59.1 58.9 58.3	4.98 5.72 5.70	Silky. Do. Do.
0.668	22.5	58.8	5.47	
0.719 0.741 0.657	20.1 21.0 20.4	59.8 57.8 59.5	4.80 5.17 4.80	Silky. Silky; a few hard spots. Do.
0.706	20.5	59.0	4.92	
0.706 0.739 0.715	18.4 19.9 20.1	58.6 55.1 57.2	4.63 5.11 5.11	Silky. [hard spots. Silky, somewhat irregular, a few Silky, with slight lamination.
0.720	19.5	57.0	4.95	
0.704 0.721 0.693	21.1 21.2 20.4	57.5 58.2 56.5	5.27 5.38 5.09	Silky, with slight lamination. Silky, very slight lamination. Do.
0.706	20.9	57.4	5.25	

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TABLE XXXVII. (continued from preceding page)

SERIES XIV. Elasticity and

Test number, and Mark on piece.	Dimensions of Strips of 10 inches length.			Limit of Elasticity per square inch.		Breaking Load per square inch.	
	Breadth.	Thickness.	Area.	Lbs.	Tons.	Lbs.	Tons.
	Inch.	Inch.	Sq. Inch.				
13067 M 1	1.000	0.988	0.988	44,650	19.94	62,010	27.68
	0.988	0.988	0.972	41,600	18.57	62,540	27.92
	1.000	0.988	0.988	45,350	20.25	63,570	28.39
			Means	43,870	19.59	62,710	28.00
13068 M 2	0.994	0.993	0.987	46,110	20.59	63,410	28.31
	0.994	0.987	0.981	43,530	19.44	63,670	28.43
	0.994	0.988	0.982	44,920	20.05	63,810	28.49
			Means	44,850	20.03	63,630	28.41
13069 M 3	0.965	0.985	0.950	42,720	19.07	63,490	28.35
	0.963	0.985	0.948	44,290	19.77	63,490	28.35
	0.964	0.985	0.949	41,290	18.43	62,972	28.12
			Means	42,770	19.09	63,320	28.27
				GENERAL AVERAGES.			
13037-39 A				37,570	16.77	57,270	25.57
13040-42 B				38,150	17.03	55,860	24.94
13043-45 C				39,560	17.67	58,930	26.31
13047-48 D				42,340	18.90	62,320	27.82
13051 E				42,920	19.16	63,550	28.37
13052-54 F				47,110	21.04	64,370	28.74
13057 G				51,200	22.86	64,400	28.75
13058-60 H				47,200	21.08	64,190	28.65
13061-63 K				41,610	18.58	61,980	27.67
13064-66 L				43,760	19.53	61,580	27.49
13067-69 M				43,830	19.57	63,220	28.23

(see continuation on opposite page)

(concluded from page 550) TABLE XXXVII.

Tenacity of Steel Plates used.

Ratio of Limit to Break.	Extension in length tested. Per cent.		Reduction of Area at fracture. Per cent.	Calculated Work of fracture per cubic inch. Inch-Tons.	Nature of Fracture.
0.720	In length of 10 inches.	18.9	59.9	4.74	Silky. Do. Do.
0.665		20.2	59.0	5.01	
0.714		17.0	52.4	4.37	
0.700		18.7	57.1	4.71	Silky; a hard spot in centre. Silky. Do.; a few minute crystalline spots.
0.727		18.7	49.7	4.81	
0.684		20.5	58.3	5.21	
0.704		16.4	55.2	4.21	
0.705		18.5	54.4	4.74	Silky. Do. Do.
0.673		18.3	60.0	4.62	
0.698		15.0	58.1	3.82	
0.656		19.0	59.6	4.73	
0.676		17.4	59.2	4.39	
GENERAL AVERAGES.					
0.656	23.3	49.6	5.33	13037-39	A
0.683	19.3	47.9	4.29	13040-42	B
0.672	18.2	48.3	4.26	13043-45	C
0.679	21.7	59.5	5.40	13047-48	D
0.676	22.0	56.7	5.55	13051	E
0.732	22.1	58.4	5.81	13052-54	F
0.795	18.9	55.6	5.06	13057	G
0.736	19.2	57.6	5.02	13058-60	H
0.671	21.3	59.2	5.25	13061-63	K
0.711	20.3	57.8	5.04	13064-66	L
0.694	18.2	56.9	4.61	13067-69	M

(continued from opposite page)

TABLE XXXVIII. (continued to page 564)

SERIES XIV. *Shearing Resistance of Steel Rivet-Bars.*

Lot.	Test number.	Diameter sheared. Inch.	Double Sectional Area. Sq. Inch.	Shearing Load per square inch.		Nature of Fracture.
				Lbs.	Tons.	
First Lot of 0·8 inch Bar.	9051-1	0·560	0·4926	57,730	25·77	
	9051-2	0·561	0·4944	56,430	25·19	
	9051-3	0·561	0·4944	56,180	25·08	
	9051-4	0·561	0·4944	55,880	24·95	
			Means	56,555	25·25	
Second lot of 0·8 inch Bar.	10688-3	0·505	0·4006	53,700	23·98	{ One end silky; other crystalline-granular. Silky and crystalline- [granular. One end silky; other silky and crystalline-granular.
	10688-4	0·505	0·4006	54,000	24·11	
	10688-5	0·503	0·3975	54,420	24·29	
	10688-6	0·503	0·3975	53,810	24·02	
			Means	53,982	24·10	
<i>Averages of two lots of 0·8 inch Bar</i>				55,268	23·17	<i>Averages of two lots.</i>
First lot of 0·7 inch Bar.	9052-1	0·561	0·4944	56,240	25·11	
	9052-2	0·560	0·4926	56,270	25·12	
	9052-3	0·561	0·4944	55,700	24·87	
	9052-4	0·563	0·4980	55,120	24·61	
			Means	55,832	24·92	
Second lot of 0·7 inch Bar.	10689-3	0·504	0·3991	52,090	23·26	{ One end silky; other silky and crystalline-granular at centre. Silky. Silky; crystalline-granular in centre.
	10689-4	0·504	0·3991	53,440	23·86	
	10689-5	0·502	0·3958	52,910	23·62	
	10689-6	0·502	0·3958	51,690	23·08	
			Means	52,532	23·45	
<i>Averages of two lots of 0·7 inch Bar</i>				54,182	24·18	<i>Averages of two lots.</i>

TABLE XXXVIII. (*continued from preceding page*)
SERIES XIV. *Shearing Resistance of Steel Rivet-Bars and Rivets.*

Lot.	Test number.	Diameter sheared. Inch.	Double Sectional Area. Sq. Inch.	Shearing Load per square inch.		Nature of Fracture.
				Lbs.	Tons.	
First lot of 1·1 inch Bar.	9050-1	0·800	1·005	58,020	25·90	
	9050-2	0·800	1·005	58,580	26·15	
	9050-3	0·800	1·005	58,160	25·97	
	9050-4	0·800	1·005	58,370	26·05	
			Means	58,282	26·02	
Second lot of 1·1 inch Bar.	10674-1	0·803	1·013	57,170	25·52	Silky.
	10674-2	0·800	1·005	49,450	22·08	Silky.
	10674-3	0·800	1·005	53,840	24·04	Silky.
	10674-4	0·801	1·007	53,380	23·83	Silky.
			Means	53,460	23·87	
<i>Averages of two lots of 1·1 inch Bar</i>				55,871	24·94	<i>Averages of Bars.</i>
Rivets from first lot of 1·1 inch Bar.	10682-1	0·805	1·018	43,810	19·56	Silky ; reedy.
	10682-2	0·805	1·018	43,940	19·62	Silky.
	10682-3	0·810	1·031	45,140	20·15	
	10682-4	0·810	1·031	45,140	20·15	Silky.
	<i>Averages of 1·1 inch Rivets</i>			44,507	19·87	<i>Averages of Rivets.</i>

TABLE XXXVIII. (*continued from preceding page*)
SERIES XIV. *Shearing Resistance of Steel Rivet-Bars and Rivets.*

Lot.	Test number.	Diameter sheared. Inch.	Double Sectional Area. Sq. Inch.	Shearing Load per square inch.		Nature of Fracture.
				Lbs.	Tons.	
First lot of 1·3 inch Bar.	9049-1	0·798	1·000	55,090	24·59	
	9049-2	0·802	1·010	56,000	25·00	
	9049-3	0·798	1·000	55,160	24·62	
	9049-4	0·800	1·005	55,170	24·63	
			Means	55,355	24·71	
Second lot of 1·3 inch Bar.	10675-1	0·801	1·007	60,130	26·84	Silky ; partly granular.
	10675-3	0·801	1·007	49,350	22·03	Silky ; partly crystalline.
	10675-4	0·801	1·007	62,500	27·90	Silky ; slightly granular at centre.
	10675-6	0·801	1·007	49,010	21·88	
			Means	55,247	24·66	
<i>Averages of two lots of 1·3 inch Bar</i>				56,818	24·68	<i>Averages of Bars.</i>
Rivets from first lot of 1·3 inch Bar.	10681-1	0·812	1·036	56,080	25·04	Silky.
	10681-2	0·805	1·018	58,450	26·10	Silky.
	10681-3	0·805	1·018	59,200	26·43	Silky.
	10681-4	0·804	1·015	52,970	23·65	Silky.
			Means	56,675	25·30	
Rivets from second lot of 1·3 inch Bar.	10678-1	0·805	1·018	49,710	22·20	Silky ; one end a little
	10678-2	0·810	1·031	52,750	23·55	Silky. [granular at centre.
	10678-3	0·806	1·021	49,020	21·88	Silky.
			Means	50,493	22·54	
<i>Averages of two lots of 1·3 inch Rivets</i>				53,584	23·92	<i>Averages of Rivets.</i>

TABLE XXXVIII. (continued from preceding page)

SERIES XIV. *Shearing Resistance of Steel Rivet-Bars and Rivets.*

Lot.	Test number.	Diameter sheared. Inch.	Double Sectional Area. Sq. Inch.	Shearing Load per square inch.		Nature of Fracture.
				Lbs.	Tons.	
First lot of 1·6 inch Bar.	9048-1	0·800	1·005	51,890	23·16	
	9048-2	0·800	1·005	51,340	22·92	
	9048-3	0·798	1·000	52,080	23·25	
	9048-4	0·800	1·005	51,760	23·10	
			Means	51,765	23·11	
Second lot of 1·6 inch Bar.	10686-3	0·792	0·9854	49,300	22·01	{Silky; slightly granular in centre. Silky; crystalline-granular [in centre. Silky. Silky; crystalline-granular in centre.
	10686-4	0·792	0·9854	49,510	22·10	
	10686-5	0·792	0·9854	54,050	24·13	
	10686-6	0·792	0·9854	49,660	22·17	
			Means	50,630	22·60	
Averages of two lots of 1·6 inch Bar				51,197	22·85	Averages of Bars.
Rivets from first lot of 1·6 inch Bar.	10680-1	0·802	1·010	54,330	24·26	{Silky. Silky; crystalline-granular [at centre. Silky.
	10680-2	0·810	1·031	51,110	22·82	
	10680-3	0·816	1·046	56,010	25·01	
			Means	53,483	24·03	
Rivets from second lot of 1·6 inch Bar.	10677-1	0·808	1·026	48,300	21·56	{Silky at one end; finely crystalline at centre. Silky. Silky.
	10677-2	0·807	1·023	49,130	21·93	
	10677-3	0·807	1·023	50,630	22·61	
			Means	49,353	22·03	
Averages of two lots of 1·6 inch Rivets				51,418	23·03	Averages of Rivets.

TABLE XXXVIII. (concluded from page 560)

SERIES XIV. *Shearing Resistance of Steel Rivet-Bars and Rivets.*

Lot.	Test number.	Diameter sheared. Inch.	Double Sectional Area. Sq. inch.	Shearing Load per square inch.		Nature of Fracture.
				Lbs.	Tons.	
First lot of 1.75 inch Bar.	9047-1	0.800	1.005	54,290	24.24	
	9047-2	0.798	1.000	52,500	23.44	
	9047-3	0.798	1.000	52,570	23.47	
	9047-4	0.800	1.005	51,890	23.16	
			Means	52,812	23.58	
Second lot of 1.75 inch Bar.	10685-3	0.792	0.9854	52,420	23.40	One end crystalline, the [other silky. Silky. Silky, slightly granular at centre.
	10685-4	0.792	0.9854	53,700	23.97	
	10685-5	0.792	0.9854	51,150	22.83	
	10685-6	0.792	0.9854	51,570	23.02	
			Means	52,210	23.30	
<i>Averages of two lots of 1.75 inch Bar</i>				52,511	23.44	<i>Averages of Bars.</i>
Rivets from first lot of 1.75 inch Bar.	10679-1	0.810	1.031	52,950	23.64	Silky. Silky. Silky, a little granular at centre.
	10679-2	0.810	1.031	53,770	24.00	
	10679-3	0.810	1.031	53,900	24.06	
			Means	53,540	23.90	
Rivets from second lot of 1.75 inch Bar.	10676	0.809	1.028	51,000	22.77	Silky.
			Means	51,000	22.77	
<i>Averages of two lots of 1.75 inch Rivets</i>				52,270	23.33	<i>Averages of Rivets.</i>

TABLE XXXIX, *see next page.*

TABLE XXXIX. (see continuation on opposite page)

SERIES XIV. Double-Riveted Lap and Butt Joints

Nature of Joint, Mode of Riveting, and Pressure on Rivets.	Test number, and Mark on piece.	See Plates 105 and 106. Dimensions.		Visible Slip began.	Total Breaking Load.	Tearing Area.	Tensile Stress per sq. inch.
		Thick- ness.	Breadth.				
		Inch.	Inches.	Tons.	Tons.	Sq. Ins.	Tons.
LAP-JOINTS. Hand-riveted.	13037 A 1	0.400	11.6	29.26	86.20	3.348	25.74
	13038 A 2	0.404	11.6	31.15	87.34	3.381	25.83
	13039 A 3	0.397	11.6	25.05	89.34	3.323	26.88
	See Figs. 1 to 3.		Means	28.48	87.63		26.15
		Tensile strength per square inch of original plate					25.57
LAP-JOINTS. Machine-riveted, 30 to 35 tons.	13040 B 1	0.400	11.6	41.66	82.65	3.348	24.68
	13041 B 2	0.399	11.6	37.64	87.16	3.339	26.10
	13042 B 3	0.403	11.6	32.52	88.82	3.373	26.33
	See Figs. 1 to 3.		Means	37.27	86.21		25.70
		Tensile strength per square inch of original plate					24.94
BUTT-JOINTS. Machine-riveted, 30 to 35 tons.	13043 C 1	0.367	11.0	59.77	85.90	3.002	28.61
	13044 C 2	0.378	11.0	61.63	80.16	3.092	25.92
	13045 C 3	0.388	11.0	54.52	79.64	3.174	25.09
	See Figs. 4 to 6.		Means	58.64	81.90		26.54
		Tensile strength per square inch of original plate					26.31
LAP-JOINTS. Hand-riveted.	13046 D 1	0.752	12.39	50.42	136.5	5.993	22.78
	13047 D 2	0.751	12.37	49.47	168.2	5.971	28.17
	13048 D 3	0.745	12.37	40.23	164.7	5.924	27.82
	See Figs. 7 to 9.		Means	46.71	156.4		26.26
		Tensile strength per square inch of original plate					27.82
LAP-JOINTS. Machine-riveted, 60 to 80 tons.	13049 E 1	0.750	12.40	43.29	136.9	5.980	22.89
	13050 E 2	0.743	12.40	52.05	139.5	5.930	23.52
	13051 E 3	0.745	12.38	54.62	173.8	5.930	29.30
	See Figs. 7 to 9.		Means	47.79	150.1		25.27
		Tensile strength per square inch of original plate					28.37
BUTT-JOINTS. Machine-riveted, 60 to 80 tons.	13052 F 1	0.749	13.21	108.10	191.8	7.408	25.89
	13053 F 2	0.748	13.20	86.00	190.1	7.390	25.73
	13054 F 3	0.751	13.20	85.30	188.1	7.420	25.35
	See Figs. 10 to 12.		Means	93.13	190.0		25.66
		Tensile strength per square inch of original plate					28.73

(see continuation on opposite page)

(continued from opposite page) TABLE XXXIX.
in $\frac{3}{8}$ -inch and $\frac{1}{2}$ -inch Steel Plate, Hand-riveted and Machine-riveted.

Shearing Area. Sq. Ins.	Shearing Stress per sq. inch. Tons.	Bearing Area. Sq. Ins.	Bearing Pressure per sq. inch. Tons.	Load per inch breadth when visible slip began. Tons.	Breaking Load per inch breadth of nominal thickness.		Efficiency of Joint. Per cent.	Plate tore. P Rivets sheared. R
					On original Plate. Tons.	At Joint. Tons.		
4.092	21.07	2.56	33.67	2.36	9.64	6.96	72.2	P
4.092	21.34	2.61	33.46	2.57	9.45	6.98	73.9	P
4.092	21.82	2.56	34.90	2.04	9.67	7.27	75.2	P
	21.41		34.01	2.32	9.58	7.07	73.8	
Eight Rivets, holes 0.8 inch diameter.								
4.092	20.20	2.58	32.04	3.37	8.87	6.68	75.3	P
4.092	21.30	2.57	33.84	3.05	9.61	7.06	73.5	P
4.092	21.70	2.60	34.16	2.61	9.58	7.12	74.3	P
	21.07		33.31	3.01	9.35	6.95	74.3	
Eight Rivets, holes 0.8 inch diameter.								
6.24	13.77	2.07	41.52	5.55	10.37	7.98	76.9	P
6.24	12.85	2.13	37.64	5.56	10.03	7.23	72.1	P
6.24	12.76	2.19	36.40	4.79	9.20	6.99	76.0	P
	13.13		38.52	5.30	9.87	7.40	75.0	
Eight Rivets, holes 0.7 inch diameter.								
7.68	17.77	6.65	20.51	4.06	[21.27]	10.99	[51.7]	R
7.68	21.91	6.64	25.31	3.99	21.18	13.58	64.1	P
7.68	21.43	6.59	25.00	3.27	20.55	13.40	65.2	P
	20.37		23.94	3.77	20.86	12.66	64.65	
Eight Rivets, holes 1.1 inch diameter.								
7.68	17.81	6.63	20.65	3.49	[21.27]	11.04	[52.0]	R
7.68	18.15	6.57	21.23	4.22	[21.27]	11.33	[53.4]	R
7.68	22.61	6.59	26.37	4.44	21.28	14.13	66.4	P
	19.52		22.42	4.05	21.28	12.17	66.4	
Eight Rivets, holes 1.1 inch diameter.								
11.53	16.64	4.97	38.59	8.19	21.55	14.54	67.5	P
11.53	16.49	4.96	38.33	6.53	21.79	14.42	66.2	P
11.53	16.31	4.98	37.78	6.48	21.32	14.23	66.7	P
	16.45		38.23	7.07	21.55	14.39	66.8	
Six Rivets, holes 1.1 inch diameter.								

TABLE XL. (see continuation on opposite page)

SERIES XIV. Double-Riveted Lap and Butt Joints

Nature of Joint, Mode of Riveting, and Pressure on Rivets.	Test number, and Mark on piece.	See Plates 107 to 109. Dimensions.		Visible Slip began. Tons.	Total Breaking Load. Tons.	Tearing Area. Sq. Ins.	Tensile Stress per sq. inch. Tons.
		Thick- ness.	Breadth.				
LAP-JOINTS. Machine-riveted, 100 tons.	13055 G 1	0.742	16.40	79.20	241.1	8.620	28.00
	13056 G 2	0.734	16.40	61.93	240.4	8.530	28.19
	13057 G 3	0.739	16.40	69.74	242.4	8.586	28.23
	See Figs. 13 to 15.	Means		70.29	241.3		28.14
	Tensile strength per square inch of original plate						28.75
BUTT-JOINTS. Machine-riveted, 100 tons.	13058 H 1	0.753	12.60	81.60	178.1	7.085	25.14
	13059 H 2	0.757	12.60	84.00	187.5	7.123	26.33
	13060 H 3	0.756	12.60	92.40	189.7	7.114	26.67
	See Figs. 16 to 18.	Means		86.00	185.1		26.05
	Tensile strength per square inch of original plate						28.65
LAP-JOINTS. Machine-riveted, 100 tons.	13061 K 1	0.992	12.60	60.11	223.2	7.320	30.49
	13062 K 2	0.966	12.60	60.90	222.3	7.128	31.18
	13063 K 3	0.979	12.60	66.40	224.1	7.226	31.02
	See Figs. 19 to 21.	Means		62.47	223.2		30.90
	Tensile strength per square inch of original plate						27.67
LAP-JOINTS. Machine-riveted, 100 tons.	13064 L 1	1.001	10.50		189.3	7.010	27.01
	13065 L 2	0.973	10.50	67.40	191.8	6.810	28.16
	13066 L 3	1.005	10.50	64.50	194.2	7.035	27.61
	See Figs. 22 to 24.	Means		65.95	191.8		27.59
	Tensile strength per square inch of original plate						27.49
BUTT-JOINTS. Machine-riveted, 100 tons.	13067 M 1	0.991	10.20	92.05	197.5	7.520	26.27
	13068 M 2	0.991	10.20	84.71	199.3	7.520	26.51
	13069 M 3	0.990	10.20	86.15	196.4	7.510	26.15
	See Figs. 25 to 27.	Means		87.64	197.7		26.31
	Tensile strength per square inch of original plate						28.23

(see continuation on opposite page)

(continued from opposite page) TABLE XL.

in $\frac{3}{4}$ -inch and 1-inch Steel Plate, with large Rivets, Machine-riveted.

Shearing Area.	Shearing Stress per sq. inch.	Bearing Area.	Bearing Pressure per sq. inch.	Load per inch breadth when visible slip began.	Breaking Load per inch breadth of nominal thickness.		Efficiency of Joint.	Plate tore. P = Rivets sheared.
					On original Plate.	At Joint.		
Sq. Ins.	Tons.	Sq. Ins.	Tons.	Tons.	Tons.	Tons.	Per cent.	P R
11.96	20.18	7.09	34.00	4.88	[21.56]	14.86	[69.0]	R
11.96	20.10	7.01	34.29	3.85	[21.56]	14.98	[69.5]	R
11.96	20.27	7.06	34.34	4.31	21.56	15.00	69.6	P
	20.18		34.21	4.35	21.56	14.95	69.6	
Six Rivets, holes 1.6 inch diameter.								
15.94	11.17	4.79	37.18	6.45	21.12	14.08	66.7	P
15.94	11.76	4.82	38.90	6.60	21.73	14.74	67.8	P
15.94	11.90	4.82	39.36	7.27	21.62	14.94	69.1	P
	11.61		38.48	6.77	21.49	14.59	67.9	
Four Rivets, holes 1.6 inch diameter.								
10.70	20.86	10.35	21.57	4.81	27.77	17.86	64.3	P
10.70	20.78	10.08	22.05	4.94	27.89	18.26	65.5	P
10.70	20.94	10.22	21.93	5.38	27.35	18.17	66.4	P
	20.86		21.85	5.04	27.67	18.10	65.4	
Eight Rivets, holes 1.3 inch diameter.								
9.62	19.68	7.00	27.04		26.62	18.01	67.7	P
9.62	19.94	6.81	28.16	6.60	28.04	18.70	66.7	P
9.62	20.19	7.03	27.63	6.11	27.82	18.40	66.1	PP*
	19.94		27.61	6.24	27.49	18.37	66.8	
Four Rivets, holes 1.75 inch diameter.								
10.70	18.46	5.17	38.22	9.11	28.00	19.55	69.8	P
10.70	18.62	5.17	38.55	8.32	28.41	19.72	69.4	P
10.70	18.85	5.17	38.00	8.53	28.27	19.45	68.8	P
	18.48		38.26	8.65	28.23	19.57	69.3	
Four Rivets, holes 1.3 inch diameter.								

* Both plates tore.

TABLE XLI.—*Comparative Results of Experiments in SERIES XI to XIV.**Double-Riveted Lap and Butt Joints in Steel Plates.*

Series.	Table.	Lap or Butt Joint.	Thickness of Plate. Inch.	Diameter of Rivet Holes. Inch.	Ratio of Pitch to Diameter.	Riveted by Hand or Machine.	Pressure in closing rivet. Tons.	Assumed Excess Strength. Per cent.	Comparative Efficiency of Joint. Per cent.
XI	XXIX	Lap	$\frac{3}{8}$	0·8	3·62	Hand		4·3	75·2
XIV A	XXXIX	"	"	"	"	"		"	75·2
XII	XXIX	"	"	"	"	Machine	35	"	75·1
XIV B	XXXIX	"	"	"	"	"	35	"	75·5
XI to XIII	XXX	Butt	$\frac{3}{8}$	0·7	3·93	{Hand and Machine }	35	2·7	76·7
XIV C	XXXIX	"	"	"	"	Machine	35	"	76·5
XI	XXXI	Lap	$\frac{3}{4}$	1·1	2·82	Hand		6·0	68·5
XIV D	XXXIX	"	"	"	"	"		"	68·0
XII	XXXI	"	"	"	"	Machine	35	"	69·1
XIV E	XXXIX	"	"	"	"	"	70	"	68·0
XIV G	XL	"	"	1·6	3·41	"	100	4·0	73·6
XI to XIII	XXXII	Butt	$\frac{3}{4}$	1·1	4·00	{Hand and Machine }	35	1·8	72·4
XIV F	XXXIX	"	"	"	"	Machine	70	"	76·0
XIV H	XL	"	"	1·6	3·94	"	100	2·0	76·1
XIV K	XL	Lap	1	1·3	2·42	Machine	100	7·5	63·0
XIV L	XL	"	"	1·75	3·00	"	"	5·4	70·2
XIV M	XL	Butt	"	1·3	3·92	"	"	2·1	76·1

RIVETED JOINTS.

See Table XXXIX.

Plate 105.

A1 to A3, 13037-39; and B1 to B3, 13040 - 42.

Fig. 4. C1 to C3, 13043 - 45.

Fig. 5.

RIVETED JOINTS.

Plate 106.

See Table XXXIX.

D1 to D3, 13046 - 48;

and

E1 to E3, 13049 - 51.

Fig. 7.

Fig. 8.

Fig. 10.

F1 to F3, 13052 - 54.

Fig. 11.

Scale $\frac{1}{4}$ in.

Dimensions in inches.

(Proceedings Inst. M.E. 1888.)

See Table XL.

Fig. 13. G1 to G3, 13055 - 57.

Fig. 14.

Fig. 15.

Scale $\frac{1}{4}$ in.

RIVETED JOINTS.

See Table XL.

Plate 108.

Fig 16.

H1 to H3,
13058 - 60.

Fig 17.

1/2 inch cover plates

3/4 inch plate

Rivet for Fig 16.

Fig 20.

1 inch plate

Rivet for Fig 19.

Fig 18.

Fig 19.

K1 to K3, 13061-63.

RIVETED JOINTS.

See Table XL.

Plate 109.

Fig 22. L1 to L3, 13064 - 66.

Fig 23.

Fig 24.

Fig 25. M1 to M3, 13067 - 69.

Fig 26.

Fig 27.