Mr. P. M. Parsons, after describing the rolls employed for producing the tapered wrought-iron wedges, used with the joint chairs on his system of permanent way, now being laid on the East Kent Railway, remarked, that Mr. Adams' paper omitted all notice of the class of fastenings employed previous to the introduction of the wood key. This class consisted either of iron pins, small iron wedges, or screw bolts, all embodying the same principle of small metal surfaces, bearing upon small points of contact. The fit was generally very imperfect, owing to the unyielding nature of the materials and the inevitable imperfections of the surfaces, so that the fastenings rapidly deteriorated. When, from any irregularity of fit, an undue strain came upon the bolt, the thread of the screw was stripped, or the nut took a particular set, to which it always returned even after being screwed up.

These fastenings were abandoned simultaneously by all Engineers in favour of the wooden keys, which were the very reverse in principle, presenting an elastic medium to compensate for inaccuracies, and bringing comparatively large surfaces into contact. The wood keys, or wedges, were first tried, as an experiment, in 1835, on the Liverpool and Manchester Railway, under the direction of Mr. Locke, M.P., V.P., previous to their general employment on the Grand Junction Railway, with the double-headed rail designed by Mr. Locke, at the same time, and first used on that line. If wood keys had not possessed some decided advantage over the old system of screw bolts and pins, he thought they would not have been so unanimously adopted, by so many practical men. That he considered to be an important fact, and one well deserving attentive consideration.

Mr. Parsons was led to make these observations from the circumstance, that the whole of the arrangements proposed by Mr. Adams, with a view of superseding the present plan, depended entirely on screw bolts and nuts, and as he thought, to a dangerous extent. If the bolts failed, the whole permanent way went to pieces, and at the best their efficiency could only be maintained by unremitting care and attention, involving considerable expense. Most Engineers knew the style of screw bolts which were obtained at the present time, for fastening the parts of the permanent way together. They were manufactured and sold by the ton, and were of necessity very imperfectly made. He did not mean to say, that a screw bolt could not be produced to perform its office properly, but the price at which (on the score of economy) it was necessary to purchase them, precluded their being made in a proper manner. A screw bolt, to be efficient, ought to have the thread of the bolt and the nut accurately fitting each other. In fact, the bolt should be turned, and the hole rimered out to insure perfect adjustment. The face of the nut and the bolt-head ought both to be square and flat; and to secure this the nut and the shoulder of the bolt-head should both be faced in a lathe, or machine. The bearing surface for the nut and bolt-head should also be flat, and square with the hole, to insure a fair bearing. Unless these points were attended to, it was probable, that by far the larger portion of the bolt-heads and the nuts would only take a bearing on one side and on a small surface. That such was the result of the bolt and nut system, in a majority of instances, was notorious; he had been invariably so informed by plate-layers, and had witnessed it himself on many occasions.

Recently he had examined some of the brackets, or fish-plates, on the Great Northern Railway, which had been laid down about twelve months, and were secured by bolts and nuts. This examination showed, that in one hundred and twenty-five pairs of joints, each pair having eight bolts, two hundred and sixty-one bolts were loose, and six were out altogether, though they had been tightened up within 48 hours. The number of loose bolts at each joint varied from one to eight. He therefore contended, that such bolts and nuts as were ordinarily used, were unsafe, inefficient, and expensive fastenings, for connecting together the parts of a permanent way, and that they were not to be relied on.

In discussing a point of this kind, it was natural to inquire, what was the office of a bolt? It was simply to bind certain parts together. Then was a bolt the simplest and most efficient means of doing this? He argued that it was not, and that the iron wedges, in connection with the end-grain cushions, described in his Paper, were preferable. They were always capable of performing their office, and were tightened up by a blow of a hammer. Each wedge had a bearing surface of $6\frac{1}{4}$ square inches in the intermediate and 25 square inches in the joint-chairs, whereas in a bolt, it would probably not amount to $\frac{1}{4}$ of a square inch, and if screwed up beyond a certain point, the thread would strip, and the bolt be spoiled. The wedges for the intermediate chairs, weighed about 4 lbs. each, and cost $2\frac{1}{2}$ pence. The creosoted elm blocks, or cushions, cost about one farthing each, and were calculated to last fifteen years. With these blocks, and a suitable chair, each wedge would exert a pressure of from $2\frac{1}{2}$ to 3 tons. Now, a bolt, $\frac{7}{8}$ths of an inch in diameter, to put on the same pressure, would weigh $1\frac{1}{2}$ lb., and as the cost of bolts was now £28 per ton, or 3 pence per lb., each bolt and nut would cost about $4\frac{1}{2}$ pence.

With regard to the objections which had been made to the chair system, he must confess, that he did not know of any instances in which the rails were supported by the keys. He had found that, generally speaking, the key simply held the rail sideways, whilst the chair offered a fair surface for the rail to rest upon. In the intermediate chairs on his system, the action of the key was to force the rail down on its seat in the chair, as well as sideways against the jaw, so that the injurious hammering of the rail on its seat, which had been spoken of, could not take place. The surface of the rails was $6\frac{5}{8}$ inches above the sleeper, and the chairs were $12\frac{1}{2}$ inches in length.

With regard to the "girder" rail, he did not see why it should have received that designation, as all rails were girders, the difference between the "girder" rail, and the ordinary double-headed rail, being in the dimensions only, and not in the principle. The "girder" rail had a depth of 7 inches, whilst the double-headed rails in general use had a depth of about 5 inches. Now, experience had proved that the latter was sufficient for the weights which had to be carried, with bearings 3 feet apart; for the deflection of a rail of 70 lbs. per yard suspended between chairs 3 feet apart, would not, he believed, exceed ·025 of an inch, with an engine having 10 tons weight on the driving wheels. This was scarcely more than the thickness of a scale of iron. If a rail of greater depth was adopted, and it was supported along its whole length, then there would be an injurious amount of rigidity, for practical purposes. The upper surface of the rail would soon laminate and be destroyed, owing to the want of a sufficient amount of elasticity. This he had noticed was already the case, with the rails of this kind on the Great Northern Railway, although they had only been laid a short time. He had heard of an engineer who, in cutting through a bed of sandstone, placed the chairs upon the rock, and the result was, that the rails were destroyed at a very rapid rate. The effect of deepening and reducing the thickness of the middle web, would be to increase the cost of the rails at least £1 per ton, owing to the greater difficulty induced in the manufacture. He believed, that the middle web of a rail, to be kept within the ordinary market price, should not be much thinner than $\frac{5}{8}$ths of an inch.

It had been stated, that the cost of a line laid with the "girder" rail, angle brackets, cross ties, and seven thousand and forty bolts and nuts, would be £2,197 per mile; the cost of ordinary rails and chairs on the system which he advocated, with cross sleepers (creosoted), would not amount to more than £1,645 per mile. Now, if this difference in first cost, or £552, was put out at compound interest, at the end of twelve years, (by which time the sleepers, trenails and cushions would probably require to be renewed), the sum of £438 would have accumulated, which with the value of the old sleepers would be more than sufficient to effect the renewals, without touching the sum of £552 originally invested. This might be carried on to an indefinite period, and when the whole of the rails, chairs, &c., had to be renewed, the £552 would be partly available for that purpose, so that the increased cost of the "girder" rail system would more than outweigh any advantage, that might arise from the greater durability of the material employed. It had been supposed, that the bolts and nuts on the "girder" rail system would last twelve years, but from what he had observed, he thought it probable that they would require to be renewed long before that time. Each renewal would entail an additional cost of about £70 per mile for materials, exclusive of the labour of taking them out, putting them in, and the constant tightening they required. Looking therefore at the question on the score of economy, exclusive of the injury the rolling stock and the rails would sustain from excessive rigidity, he could not see any advantage in the "girder" rail system; and though credit had been taken for a saving in the quantity of ballast, Mr. Parsons did not think engineers generally would consider it either safe, or wise, to diminish the amount of ballast on a railway.

Mr. P. W. BARLOW wished to reply to the assertion "that the result of the experiment of his cast-iron sleepers was a failure on the South-Eastern Railway, while on the Enniskillen Railway, where they were double in weight, the result was favourable mechanically, but not at a low cost." This was not an accurate statement. It was true that the Enniskillen sleepers were increased in weight beyond what was originally intended; but, the lightest road on the South-Eastern Line, was still 5 per cent. heavier than the heaviest portion of the Enniskillen, and the average was 18 per cent. heavier. The rails on the Enniskillen line were 60 lbs. per yard, whilst the lightest on the South-Eastern were 70 lbs. per yard, and the heaviest were 80 lbs. per yard. The weights per mile were :—

			Tons.	Tons.
South Eastern.—	Heavy road ;	Rails	126	287
		Sleepers	161	
	Light road ;	Rails	110	255
		Sleepers	145	
Enniskillen.—	Heavy road ;	Rails	94	239
		Sleepers	145	
	Light road ;	Rails	94	212
		Sleepers	118	

With reference to the experiment on the South-Eastern Railway, which had been denominated a failure, the facts were, that in 1850 and 1851, one hundred miles of his iron sleepers were laid, of which about ten miles had been taken up, having been principally laid with old rails; and these were of the arched form, but not lighter than the others. This road was defective from the old rails not fitting the joint sleepers, and thus a blow took place on the passage of a train, producing a hard and unpleasant road, and causing breakage of the joint sleepers, unless care was taken by the platelayers. He was not aware of a single instance of an intermediate sleeper having broken. For heavy traffic and high speeds, he recommended that the joint sleeper should be abandoned, in favour of two intermediate sleepers and the fish joint, as this could be effected without increase of cost.

The first cost of the heaviest road on the Enniskillen Line did not exceed that of an ordinary timber sleeper road fished; but the lightest road was sufficiently strong for the ordinary traffic, which, though light, compared with English lines, consisted principally of goods. This railway was, with the exception of ten miles, a single line. The length of road laid with the cast-iron sleepers was forty-six miles. The portion of the road on which the light cast-iron sleepers had been used, had only been in operation five years, and there were six trains daily each way. The engines weighed about 22 tons, and the speed maintained was twenty miles an hour. The cost of maintenance, during the last half year, including bridges, ballasting, and stations, was £1,144, or at the rate of £32. 14*s.* per mile of single line per annum. On the Coleraine Line, there were fifteen miles of road laid with the cast-iron sleepers, the maintenance of which was let for 9*s.* 6*d.* per mile per week, or at the rate of £24. 14*s.* per mile of single line per annum. It might be said, that these results were no test for English traffic, but he believed, there were many miles of railway yet to be constructed, where the traffic would not exceed that on the Enniskillen, for which this construction was peculiarly adapted, as it had been proved, that one half the cost of renewal and maintenance was saved. From some recent experiments he could state, that with a heavier rail, fished, this description of road was sufficient for the heaviest traffic.

Mr. Adams had omitted to state in his Paper, that, on the Midland Railway, there were fifty-four and a half miles laid with the cast-iron sleepers, and exposed to the heavy traffic of that line. They had been laid from four to five years, and were still in good order. They were generally of the arched form, and rather lighter in weight than those used on the South-Eastern. On the East Lancashire, and the Eastern Counties Railways, ten miles had been laid with these sleepers. Altogether two hundred and twenty-five miles had been laid on this system, for an average of five years, of which little, if any, more than 5 per cent. had been renewed, or 1 per cent. per annum from all causes, including imperfect casting, bad ballast, neglect of platelayers, and the ten miles of defective road on the South-Eastern previously alluded to.

In regard to other cast-iron sleeper roads, it was due to Mr. Greaves to state, that his spheroidal sleepers had been adopted extensively on many foreign lines, and to some extent in England.

Summary of Experiments on the Strength of Cast-Iron Sleepers, by the Permanent Way Company.

LONGITUDINAL SLEEPERS FOR DOUBLE-HEADED RAIL.

Number of Experiment.	DESCRIPTION OF SLEEPER.	Length.	Width.	Weight.	Bearing Surface.	Number of Inches' Bearing Surface to a Pound of Metal.	Fall of Ram at which Sleeper broke.	Width of Bearing Surface forward at 100 Tons per Mile.	Weight per Mile to give 12 Inches' Bearing Surface.
		Ft. in.	Ft. in.	Lbs.	Sq. in.	Sq. in.	Ft. in.	Inches.	Tons.
1	Cast-iron half-sleeper, bolted under the rail, as laid on the Midland, South Eastern, and other lines	3 2	1 2	131	532	4·06	4 0		
2	Cast-iron half-sleeper, bolted under the rail, as laid on the Midland, South Eastern, and other lines	3 2	1 2	131	532	4·06	4 6	$7\frac{1}{8}$	$168\frac{1}{2}$
3	Cast-iron half-sleeper, bolted under the rail, as laid on the Midland, South Eastern, and other lines	3 2	1 2	$130\frac{1}{2}$	532	4·07	2 6		
4	Cast-iron half-sleeper, with wood cushions (large size)	4 5	1 3	182	795	4·36	1 6	$7\frac{3}{4}$	155
5	Cast-iron half-sleeper, with wood cushions (large size)	4 5	1 3	182	795	4·36	2 0		
6	Cast-iron half-sleeper, with wood cushions (small size)	3 2	1 2	137	532	3·88	4 6	$6\frac{7}{8}$	$174\frac{1}{2}$
7	Cast-iron half-sleeper, with wood cushions (small size)	3 2	1 2	137	532	3·88	4 0		
8	Cast-iron sleeper, with wood cushions in detached cast-iron pockets	4 6	1 3	127	810	6·37	1 6	$11\frac{1}{4}$	$106\frac{5}{8}$
9	Cast-iron sleeper, with wood cushions in detached cast-iron pockets	4 6	1 3	127	810	6·37	2 6		
10	Cast-iron altered pattern of sleeper, with wood cushions in detached cast-iron pockets . . .	4 11	1 3	141	885	6·27	2 6	11	109
11	Cast-iron third pattern of sleeper, with wood cushions in detached cast-iron pockets	5 0	1 3	151	900	5·96	3 6	$10\frac{1}{2}$	$114\frac{1}{3}$
12	Cast-iron third pattern of sleeper, with wood cushions in detached cast-iron pockets	5 0	1 3	151	900	5·96	2 0		
13	Cast-iron ordinary intermediate sleeper, with wood cushions in detached cast-iron pockets . .	4 8	1 $1\frac{1}{2}$	147	756	5·14	3 6	9	$133\frac{1}{3}$
14	Cast-iron ordinary intermediate sleeper, with wood cushions in detached cast-iron pockets . .	4 8	1 $1\frac{1}{2}$	147	756	5·14	3 0		
15	Cast-iron sleeper, with wood cushions in attached cast-iron pockets	5 0	1 3	182	900	4·94	3 6	$8\frac{3}{4}$	$137\frac{1}{8}$
16	Cast-iron sleeper, with wood cushions in attached cast-iron pockets	5 0	1 3	182	900	4·94	2 6		
17	Cast-iron timber-bedded sleeper, as laid for experiment on the Midland Railway	3 6	1 4	156	672	4·30	3 0	$7\frac{5}{8}$	$157\frac{3}{8}$
18	Cast-iron timber-bedded sleeper, as laid for experiment on the Midland Railway	3 6	1 4	156	672	4·30	2 6		
19	Cast-iron timber-bedded sleeper, as laid for experiment on the Eastern Counties Railway . .	3 6	1 4	132	672	5·09	3 6	9	$133\frac{1}{3}$
20	Cast-iron sleeper, with wood cushions, similar to timber-bedded sleeper	4 6	1 3	155	810	5·22	3 6	$9\frac{1}{4}$	$130\frac{1}{8}$
21	Cast-iron sleeper, with wood cushions, similar to timber-bedded sleeper	4 6	1 3	153	810	5·29	2 6	$9\frac{3}{8}$	$128\frac{1}{3}$

TRANSVERSE, OR SINGLE-CHAIRED SLEEPERS.

Number of Experiment.	DESCRIPTION OF SLEEPER.	Length.	Width.	Weight.	Bearing Surface.	Number of Inches' Bearing Surface to a Pound of Metal.	Fall of Ram at which Sleeper broke.	Width of Bearing Surface forward at 100 Tons per Mile.	Weight per Mile to give 12 Inches' Bearing Surface.
22	Transverse cast-iron sleeper, with wood cushions, similar to timber-bedded sleeper, each end .	2 $2\frac{1}{2}$ / 2 $2\frac{1}{2}$	1 0 / 1 0	164	318 / 318 636	3·87	2 0 / 2 6	$6\frac{3}{4}$	$177\frac{3}{4}$
23	Transverse small sleeper, single chair, similar to timber-bedded sleeper, each end	2 6 av.	1 $1\frac{1}{4}$	96	405	4·22	2 6	$7\frac{1}{2}$	160
24	Transverse small sleeper, single chair, similar to timber-bedded sleeper, each end	2 6 av.	..	82	405	4·95	2 0	$8\frac{1}{2}$	141
25	Transverse (Pernambuco Railway) circular cast-iron joint sleeper, diameter	1 10	..	119	380	3·19	2 6	$5\frac{5}{8}$	$213\frac{1}{8}$
26	Transverse (Pernambuco Railway) circular cast-iron intermediate sleeper, diameter . . .	1 10	..	88	380	4·31	2 0	$7\frac{5}{8}$	$157\frac{3}{8}$

SLEEPERS FOR SINGLE-HEADED, OR FLAT-BOTTOMED RAIL.

Number of Experiment.	DESCRIPTION OF SLEEPER.	Length.	Width.	Weight.	Bearing Surface.	Number of Inches' Bearing Surface to a Pound of Metal.	Fall of Ram at which Sleeper broke.	Width of Bearing Surface forward at 100 Tons per Mile.	Weight per Mile to give 12 Inches' Bearing Surface.
27	Flat corrugated cast-iron sleeper with wood cushions, similar to timber-bedded sleeper, diameter .	5 0	1 3	128	900	7·10	3 6	$12\frac{1}{2}$	96
28	Flat corrugated cast-iron sleeper, with wood cushions, similar to timber-bedded sleeper, diameter .	5 0	1 3	122	900	7·37	2 6	13	$92\frac{1}{3}$
29	Flat corrugated cast-iron sleeper, with wood cushions, similar to timber-bedded sleeper, diameter .	5 0	1 3	$123\frac{3}{4}$	900	7·27	4 0	$12\frac{7}{8}$	$93\frac{1}{8}$
30	Flat corrugated cast-iron sleeper, without wood cushions, similar to timber-bedded sleeper, diameter	5 0	1 3	116	900	7·75	2 6	$13\frac{3}{4}$	$87\frac{1}{3}$
31	Curved corrugated sleeper, without wood cushions, similar to timber-bedded sleeper, diameter .	2 0	1 3	73	360	4·93	3 0	$8\frac{3}{4}$	$137\frac{1}{8}$
32	Curved corrugated sleeper, without wood cushions, similar to timber-bedded sleeper, diameter .	2 0	1 3	73	360	4·93	2 6		
33	Mr. De Bergue's cast-iron sleeper for flat-bottomed rail, as laid on the South Western and Lancashire and Yorkshire Railways, tested two together.	1 8	1 2	$46\frac{3}{4}$	280	5·99	5 6	$0\frac{1}{2}$	$114\frac{1}{3}$
34	Mr. De Bergue's cast-iron sleeper for flat-bottomed rail, as laid on the South Western and Lancashire and Yorkshire Railways, tested singly.	1 8	1 2	$45\frac{3}{4}$	280	6·12	3 6	$10\frac{3}{4}$	112
35	Mr. De Bergue's cast-iron sleeper for flat-bottomed rail, as laid on the South Western and Lancashire and Yorkshire Railways, tested singly.	1 8	1 2	48	280	5·83	3 0	$10\frac{1}{4}$	117
36	Mr. De Bergue's cast-iron sleeper for flat-bottomed rail, as laid on the South Western and Lancashire and Yorkshire Railway, tested singly.	1 8	1 2	56	280	5·00	3 6	$8\frac{3}{4}$	$137\frac{1}{8}$

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Presented by Mr. P. W. Barlow, M. Inst. C.E.

Mr. De Bergue's sleepers had also been laid extensively, and with very satisfactory results, as compared with wooden sleepers.

It had been shown by the President,[1] that about two millions of wooden sleepers required to be renewed annually, which would cost about £450,000. Now, it was desirable, that this heavy expenditure should be saved, and he maintained that the experience with the cast-iron sleepers so far, had shown how this might be accomplished. It had been proved, that the maintenance was much less than that of an ordinary wooden sleeper road, and the durability was unquestioned. He thought, therefore, that this experiment, on a comparatively new principle, could not be regarded as a failure, but on the contrary, it demonstrated that the ordinary wooden road would, before long, be superseded by cast iron.

If the cast-iron road was found to be more rigid in practice than was desirable, it might be completely remedied by the system proposed by Mr. J. Samuel, which consisted of introducing wood cushions between the half sleepers. An experimental length on this plan had been laid for six years on the Eastern Counties Railway.

With the view of testing the strength of the different forms of cast-iron sleepers, an extensive series of experiments had been made at Derby, for which purpose a ram, weighing 12 cwt., was employed. Twenty-three forms had been experimented upon, and the result was, that an ordinary rail weighing 80 lbs. per yard, with 3 feet bearings, was destroyed, by bending, with a fall of 2 feet, whilst the South-Eastern cast-iron sleeper bore a fall of 4 feet 6 inches, being one foot more than any other which had been tried. A summary of these experiments was given in the accompanying Table.

Mr. HEMANS thought great credit was due to Mr. Adams for the invention of the fish-joint,—but in his opinion, the merits of that contrivance had been exaggerated. It was described as producing an effect analogous to a beam fixed at both ends, but he could hardly realise that idea. A beam fixed at both ends he understood to be, one so tied down to immovable abutments, that whatever weight might be put upon the centre of the beam the ends could not rise. He did not think this was the case with a rail under pressure, as the advancing wheels producing deflection in the middle caused the ends to rise, and then the adjoining rails and sleepers were raised, the ballast acting as the fulcrum. He doubted whether any great additional strength was given to the rail by the fish-joint, although it conduced to the smoothness of the rolling surface, and thus imparted an equable motion, and increased the

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xv., p. 127.

safety of travelling. He had used it to a considerable extent with satisfactory results. The tendency of the rails to overturn, in consequence of the oscillation of the engine, and the blows from the flanges of the wheels, had also been overrated. The principal effect of these oscillations was a tendency to widen the gauge. Much time and labour had been wasted in the endeavour to improve cast-iron chairs. The two objects which seemed to have been present in the minds of those engaged on their improvement, were to increase the bearing on the sleepers, and to prevent the overturning of the rail, from the action of the wheels. It was important to extend the bearing upon the sleeper; but, in order to effect this, it was not necessary to expend £500 per mile for cast-iron chairs, especially when bridge and other flat-bottomed rails could be fixed by screws and bolts, directly upon the sleepers. These rails were always inclined in a direction contrary to overturning, and they were undoubtedly kept down by the weight of the engine. It had been supposed that the double-headed rail would be capable of being reversed, but this could not be done advantageously, as the lower side was always more or less indented from the pressure on the bearing point, and therefore operated injuriously on the rolling stock. He had used in Ireland, and had seen on the Continent, hundreds of miles of rails attached to the sleepers without any chairs: and even where the base of the rail was less than the height, these rails had never overturned, nor had they shown any tendency to move. It had been argued, that great advantage would result from placing the surface of the rails lower than usual. He did not believe that this was at all important, and one great practical difficulty would occur in consequence. When the surface of the rails was close to the ballast, the wheels were rendered greasy by the mud, in the frequent cases of impure ballast, which was splashed over them in wet weather. This had often been observed with the bridge rails laid upon longitudinal timbers.

Mr. James Samuel's cast-iron trough, lined with a wooden cushion, to be used with a double-headed rail, seemed to have merit. In that case they had the imperishable sleeper, the break of joint, the wooden cushion, and every facility for reversing the rail, when the upper table was worn. Unless the expense of that system was too great, he thought it should be tried.

Being anxious to get rid of the perishable sleeper, he had tried five miles of Mr. W. H. Barlow's "saddle-back rail" of 100 lbs. to the yard, and was sorry to be obliged to pronounce it a failure. It formed a very rigid way, and, he believed, the surface of the rails was rapidly injured from the absence of elasticity. Perhaps the rails he used were not quite so well rolled as they might have been; but he found, for a considerable distance, the whole surface of the rail torn off. He had been informed, that the same results had occurred on other lines where this description of rail had been used. Another defect was, that it had too little hold in the ballast. The blows of the wheels in travelling soon caused the rivets to get loose, so that bolts which could be tightened up had to be substituted. With regard to Mr. Adams' rail, it appeared to him to be one of the best inventions for an entirely iron way that had been brought forward. It was very strong, and had a good hold of the ballast; at the same time, he could not see how the bolts were to be kept fast, as they were entirely out of sight, under the flanges, and were buried in the ballast, so that when they became loose, as undoubtedly must occur, the ballast would have to be disturbed. Bolts had a constant tendency to become loose, especially on curves, and under this system, this might go on to a great extent before the mischief could be detected.

On a portion of the Dublin and Galway Line, of about twenty-five miles in length, which passed through a soft and boggy soil, he had adopted bridge rails, with longitudinal timbers, and a fish-joint,—not like that of Mr. Adams', but simpler and lighter, though perhaps not of the same strength. Each joint had four rivets, and one long bolt which was passed through the rail, fish-plate and longitudinal sleeper, so that the joint was rendered quite immoveable. He admitted, that it was not so strong as the cast-iron bridge rail joint; but in the situation in which it was applied, he found it extremely effective, solid, of sufficient strength, and trains ran easily over it without blows at the joints. The expense of the plan was inconsiderable. He had used it, with some modification, over the whole of the Midland Great Western Railway of Ireland, now about one hundred and eighty miles in length.

Mr. Robert Richardson asserted his claim, as the joint inventor, with Mr. W. B. Adams, of the "fish-joint" for rails. He produced correspondence with Mr. Adams in the years 1846-47, in which the invention was discussed. This invention was afterwards brought out and secured to them by patent as the joint-inventors.

Mr. J. K. Arthur remarked, that the rigidity of the iron way, and the effects mentioned by Mr. Hemans, did not in the least apply to the Londonderry and Enniskillen Railway. Upon the general question of the rigidity of iron roads, he could give no opinion; but he could state, that the travelling upon the iron portion of the line he had mentioned, was preferable to that upon the portion where wooden sleepers were employed. The run of the carriages was smoother and more agreeable; the noise less, and the comfort to the passengers greater. Mr. Adams, in the Paper under discussion, had described the iron road upon this line as "mechanically successful." The practical experience of nearly five years' working had proved the correctness of this opinion. Mechanically its success was perfect. Some doubt had been suggested, as to whether the prime cost had not been too great, but after the explanation given by Mr. Barlow, respecting the comparative weights of the sleepers on the South-Eastern and the Enniskillen Lines, he thought this impression would be removed. With regard to the alteration of the sleepers during the progress of the works, he thought it but just to state, that all the officials connected with the working of the line were of opinion, that the best portion of the line, and the easiest maintained, was the section from Strabane to Newtown-Stewart, which was laid with the exact pattern and weight recommended by Mr. Barlow. The evidence obtained, from year to year, of the small annual cost, at which the road laid on this system could be maintained, and the certainty of great saving in renewal, had satisfied those interested in the Companies, that not only was it mechanically, but financially, successful.

Mr. BURLEIGH remarked, that as allusion had been made to the trials on the Great Northern Line, he would state a few facts which might not be uninteresting. A small length of the line was laid down with Mr. Parsons' chairs, with end-grain wood packing, and the result of the trial was favourable. The wood cushions firmly sustained the wedges, although he had been told that one, or two of the cushions had split and become loose, owing to exposure to the sun; but, as a general result, it was satisfactory.

In March 1855, a short length, of about one hundred feet, of Mr. De Bergue's cast-iron sleeper way, was laid down, on one of the coal sidings, at the London Goods Station. The rail used was a flat-bottomed T rail, about 60 lbs. to the yard. It was fixed to the sleeper-plates, in a small dovetail groove, cast on one side of the plate; the other side of the rail being clipped by a small wedge-shaped casting, through which was passed a vertical eye-bolt, for holding down the rails, and securing the tie-bars. The sleeper-plates were 18 inches long, by 14 inches broad, and were laid at intervals of 2 feet from centre to centre. The upper surface of the plates was intersected by vertical ribs, crossing each other, and on these the rails rested. The thickness of the plates was about $\frac{1}{4}$ of an inch throughout. It was said, that a difficulty was experienced in the cooling of the castings, and to meet this, Mr. De Bergue invented an ingenious method of annealing them, and a certain apparatus for facilitating the moulding. The rail-ends were jointed with ordinary wrought-iron fish-plates and bolts. The system, as remarked by Mr. Adams, was an ingenious contrivance for diminishing the weight of metal; but in this instance the parts were evidently too weak, as was proved by the result of the trial. When taken up, after 18 months' wear, about 20 per cent. of the sleepers were found to be broken; some of them longitudinally, some transversely; and there was no doubt, that had they been laid in hard shingly ballast, instead of in burnt clay, a much larger proportion would have been broken, especially if subjected to high rates of speed. Mr. De Bergue doubtless arrived at the same conclusion, and prudently increased the strength of those afterwards laid down on the South-Western Railway, by which means they might be made to bear the traffic. It was shown, by the trial on the Great Northern Railway, that the plate-sleepers required a less amount of attention, in the way of packing and lifting, than the ordinary transverse wooden sleepers. This might, in a great measure, be attributed to the fact of the plate-sleepers having but little tendency to partake of the rocking motion, which was one of the great sources of disturbance on the transverse sleeper system. One of the chief defects of the system was the method of fixing the rail to the sleeper, for if the small dovetail lip of the casting, which confined the foot of the rail, should break, or the holding-down bolt be neglected by the plate-layers when it became loose, it was obviously unsafe, as the outward thrust of the wheel would act with a considerable amount of leverage on the rail, and the hammering thus produced would have a tendency to break the sleeper. In point of economy, or first outlay, this system might have its advantages, and, with some modifications, it would doubtless answer well for light traffic, in certain situations.

In November 1855, an experiment was tried, on the Great Northern Railway, with Mr. Adams' "suspended girder rail." A short length was laid on the up-line, near the junction of the goods and coal sidings, south of Copenhagen Tunnel, where the gradient was 1 in 100. The rail was of the double-headed section, $1\frac{3}{4}$ inch wide on the tread, presenting an unusually small amount of bearing surface to the wheel. When laid in place, with the wing-plates, it formed a compound rail and longitudinal sleeper, about 13 inches wide, with a vertical web 7 inches deep. The result of the trial had, in some respects, been highly satisfactory, though the system perhaps had some defects. It possessed the great advantage of being nearly equally rigid in all its parts, and there was a certain amount of elasticity, derived from the springing of the wings, and a very slight amount of longitudinal deflection. In travelling over it, the difference in the smoothness of the way, as compared with the transverse sleeper system, was very perceptible. The sleeper-bed being very near the surface of the rail, was found to afford great facilities for packing, as there was no necessity for opening the ballast. It was easily lifted, with an ordinary lever, when the ballast was beaten up in the usual manner. A road laid in this way was lifted in less than half the time

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required by the wood-sleeper system. The sample on the Great Northern Railway was laid down under somewhat unfavourable circumstances, as there was a dressing of only about 6 inches of good clean gravel, while the lower ballast was composed of burnt clay, in a very soft and wet condition. Some objection to the system might perhaps be urged, on account of the difficulty in replacing the rails when worn out, as the cross-bolts lay beneath the wings, and a rail could only be replaced by opening out the ballast. The break-joint in the plates also increased the difficulty of removal. These defects might, however, be much lessened, by the introduction of a proper box-spanner, for reaching the bolts. No difficulty was experienced in laying the road. The parts being bolted together in lengths, upside down, were then turned over, and the different sections, when brought end to end, were bolted together from below. The wing-plates, as at present constructed, were perhaps ill adapted for laying in station curves, as they could not be bent with the ordinary screw-press used by the plate-layers. The plates would, however, answer every purpose, if made in short lengths—say of 2 feet, or 3 feet—for sharp curves; or longer wing-plates might, possibly, be purposely bent, in the hot state, when leaving the rolls. The rails themselves were easily bent. The sample laid down on the Great Northern Railway was placed on a curve, and did not present so nice an appearance to the eye as it would have done had the plates been properly prepared. Mr. Burleigh considered, also, that the tread of the rail was too narrow—an evil easily remedied, but one which had doubtless caused much of the deterioration of the rail, though it should be remarked, that these rails had lasted longer than others of the ordinary section adjoining them.

With regard to the statement, that a great number of the bolts applied to the brackets used on wood sleepers had become loose, it should be observed, that those identical bolts were made too large for the holes, and the bolts had the worm of the screw partly shorn off in the driving, which would quite account for all the defects that had been spoken of.

Mr. W. H. Barlow said, that as there were more than eight hundred miles of single line laid with the "saddle-back rail," it must speak for itself. If it was an advantageous construction, it would continue to be used, but if other systems were found to be better, they would supplant it. He wished, however, to correct a statement which had been made, that wooden sleepers were finally adopted in laying this rail. Mr. Barlow had laid a few miles in this way, and, he believed, Mr. Ashcroft had also done so. But the latest, and what appeared to him the best, samples of this road were laid without sleepers. There were two difficulties which stood in the way of this description of road: the difficulty of manufacturing a sound rail of that form, and the rigidity of the road when made.

The wrought-iron road was more rigid than that of cast-iron. There were nearly thirty miles of double line, of cast-iron road on the Midland Line. Between Leeds and Bradford the whole of one line, as well as a portion of the other, was laid with cast-iron sleepers. This had been done about five years, and had to sustain a very heavy traffic. It was laid in ash ballast, and the condition of the road was good in every respect. He had observed, that where cast-iron sleepers were laid in gravel, or sand ballast, a sensation of rigidity was felt. At first, when the rails were new, nothing could run better; but as the wear of the rail went on, the unevenness of the surface produced this effect of rigidity. He believed that effect might be remedied, and he looked to the sleeper of Mr. Samuel, in which the rail was held by means of wooden cushions, or a sleeper constructed on that principle, as the proper remedy. The elasticity attained by the wood, so employed, would, he believed, from recent experiments, remove the only remaining objection to the employment of iron in the substructure of permanent way.

Looking at the question generally, he thought, that as more than a thousand miles of single line of iron road were laid and in operation, enough had been done to show the practicability of using that material. They might not have got the right construction, but he felt confident that iron was the right material. In fact, it did appear to him absurd, in a country abounding in iron, that there should be spent, annually, hundreds of thousands of pounds, in bringing timber from foreign countries, to lie and rot in the railways.

With regard to the difficulty of keeping the bolts and nuts tight on fish-jointed roads, he must say, that he had used fish-joints on more than three hundred miles of double line on the Midland Railway, and though he could not say there were no loose bolts, yet the difficulty experienced in this respect was very little, when ordinary care was bestowed. Of this length, about fifty miles were fitted with the supported fish, and two hundred and fifty miles with the suspended fish. The suspended fish-joint had proved the best, and that was the mode at present used throughout the line.

Mr. Errington observed, that about a quarter of a mile of double way had been laid with Mr. Adams' open bracket chairs, on the South-Western Railway, at Putney, in a rather unfavourable position. From a recent examination of this road, he could state, that the bolts were fast, and the road itself was in excellent order. At first, four, or five of the brackets broke within two, or three days, and caused some misgivings as to that particular form of chair. But, subsequently, the results had fully satisfied all their anticipations, and not the slightest casualty had since occurred, during the twelve months the way had been laid. The Inspector on that part of the line, told him that not more than three, or four bolts had required to be replaced during the last three months. In fact, he could not desire to see a better road than that at Putney. A little nearer to London, on the same line, a new form of this bracket-chair had been tried, for the last ten months. It had a piece underlapping the rail, like the bottom of an ordinary chair; but the result was not quite so satisfactory as in the other case. At Kingston the result was more favourable. There was but little destruction of bolts and nuts, and the fastenings were all quite tight; these facts were not consistent with some of the statements which had been made.

On the same railway, the "fish-joint" had been partially used for about three years. In the first eighteen months, they experienced considerable difficulty, but now the road was in good condition, and not more than one bolt in fifty was in the slightest degree loose. The wear of the rails, particularly at the joints, appeared to be less at those parts of the line where the "fish" had been used, than at other places, where the ordinary system had been followed. He might remark, that at the first introduction of "fishes," the plate-layers were not accustomed to bolts and nuts, and therefore it was not surprising, that there was a want of expertness and success in their use, which practice would remove. In this case, at the end of three years, it was found quite easy to maintain a road in a good, serviceable condition, with their aid.

He had also tried on the South-Western, at the same time, and near the same place, as the bracket-chairs were laid, some of Mr. De Bergue's cast-iron plate sleepers. There was no lamination of the rails, which were only 58 lbs. per yard, and he had found that the upper surface was less injured, and there was less difficulty in keeping the road in order, than with rails weighing 80 lbs. per yard, laid on cross-timber sleepers; as in the latter case the rails were stripped and much injured.

With regard to the remark, that the double-headed rail could not be turned, because the chairs indented the lower table, his experience led him to an entirely different conclusion. He found it used almost everywhere in that way, without the slightest difficulty, and few, if any, rails of that description were finally rejected, as being worn out, before they had been reversed in the chairs; on the South-Western Railway the plan of reversing the rails had been followed with great advantage. On that line the original rails weighed 75 lbs. to the yard, and the bearings were 5 feet apart. A considerable portion of the original road, which had been laid sixteen years, was still in existence, and was in a very good condition, notwithstanding that the weight of the engines and of the trains, as well as the speed, had been much increased in the interval. In fact, the joint was the main thing to be attended to. There was such a thing as too great strength, or rather rigidity, in a permanent way, in which case the iron was crushed; and he doubted whether rails 80 lbs., or 90 lbs. to the yard were more efficient than those of 75 lbs. to the yard.

Mr. C. May could confirm several of the statements made by Mr. Errington, with regard to the South-Western Railway. When "fish plates" were first tried on that line, it was only as a small experiment, so small, indeed, that it was not deemed necessary to prepare rolls purposely to roll the "fish plates," so as to fit the rails, and the bolts supplied were of a very inferior character. The rails used had also lain by for a long time, had become rusty and scaled very much. He was happy to hear, however, that the experiment, in spite of these disadvantages, had succeeded, and with a trial under better conditions they might look for more favourable results.

He thought that the matter of the first Paper did not accord with its title, and that it did not give a correct representation of the state of this question at the present time. It omitted to notice, that which formed a large part of the general system of permanent way throughout this kingdom; for instance, the continuous bridge rail of Mr. Brunel was not mentioned in such a way as to give an idea of the extent to which that rail was used, what was its proportionate adoption, compared with the whole of the lines in operation, and what were its merits. There was little notice of the ordinary double-headed rail, and its usual application in chairs; but he found a passage, in which it was stated, "The rail is placed in the chair on a slope, and is only kept up by the keys." Now, nothing could be more remote from the fact than that. In the ordinary chair the rails rested on a curve in the chair. The rails were keyed in fast by the wooden keys, and he did not think they received any material support from the keys, further than being kept in their place. The wooden keys were, he believed, first introduced by Mr. Locke, M.P., V.P. They were afterwards improved by himself, by the introduction of the system of continued compression, in a heated state; and he calculated, that they had been used on six thousand miles of railway. Yet there was no notice in the Paper of the general adoption of that system. Again, it was stated, that the seat of the chair was about 2 inches above the sleeper, whereas the customary thickness of the bottom of the chair was from $1\frac{1}{2}$ inch to $1\frac{3}{4}$ inch. The effect of the elevation of the rail, above the top of the sleeper, in producing lateral motion of the trains, and a tendency to upset the chair, had been greatly exaggerated. In fact, he believed, no such effect took place. There were instances in which the same chairs, trenails, and keys, which had been laid down twelve years since, were now in existence and in good order. It was pure assumption, therefore, to say, that the elevation of the rail by the use of the chair produced any injurious leverage.

The "fish" joint was first introduced as a suspended joint in the year 1847. It was published as the invention of Messrs W. B. Adams and Robert Richardson, and therefore, he thought, it should have been so stated in the Paper, instead of the former gentleman claiming all the merit. Mr. May had been connected with the early experiments in fishing joints, and he confessed, that in the first instance, he formed an unfavourable opinion of the system. In matters connected with permanent way, it was peculiarly the case, that until they were subjected to the test of experience, opinions were of but little value. With regard to the assertion of the bolts working loose, he was able to say, that Mr. Henry Woodhouse, who had charge of the permanent way of the London and North-Western Railway, had stated, that he had experienced no difficulty whatever in keeping the bolts tight.

With respect to the "saddle-back rail" which had been introduced just before Mr. Adams' former Paper was read, in 1852,[1] it was objected, that it would not answer, because the ballast could not be packed up within the hollow, and that, therefore, it would not have the whole bearing due to its width. Now, Mr. Brunel, V.P., had most satisfactorily answered this point at the time.[2] He said, "It was presumed, that the saddle-back rail did not take a solid bearing on the ballast, in consequence of the difficulty of packing it; now it was well ascertained, that ballast of almost any kind became, in time, so perfectly rammed into the cavity, that a nearly solid mass was formed, whereon the spreading flanches took a solid bearing, at a sufficient depth to receive the necessary lateral support, without that hindrance to perfect drainage which would be likely to occur from an extreme depth of web, unless there was such a thickness of ballast as would be very expensive in practice."

The results of actual practice since that period had shown that this opinion was perfectly correct; no difficulty had been experienced in packing the ballast, so as to retain its proper position in supporting the rail. Moreover, several French engineers had adopted the saddle-back rail, and were so satisfied with it, that

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[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xi., pp. 244–273.
[2] Ibid., p. 276.

they now proposed to use it still more extensively. Already there were about nine hundred miles, of single line, laid upon this system. It was true, there had been partial failures, but he believed they were not of such a nature as would warrant the entire rejection of the system, without further trials. Some of these failures might, perhaps, be accounted for, by imperfect manufacture—whole strips of the surface had peeled off from that circumstance—and there had been some difficulty with the joints. But all new inventions had to pass through a considerable number of, what might be called, failures, and experience must be gained, before the final result could be attained. He remarked that in drawing up specifications of rails, it was usual to specify a certain amount of, what was supposed to be, superior quality of iron for the wearing part of the rail; now, it was questionable, if this was really superior for the purpose. In the saddle-back rail, whole strips had come off, as he had stated; and an experiment, in which such rails were planed down to the inferior iron, seemed to show, that the iron which had received less working in manufacture, wore better than that which was supposed to be superior metal; he considered that the rails should be more homogeneous than they were at present.

Mr. Bruff said, no allusion had been made to the importance of fixing the chair permanently to the sleeper, which was quite as essential as fixing the rail in the chair itself. He felt bound to say, the system of Messrs. Ransome and May—that of chilled chairs with compressed keys and trenails—formed a very good joint fastening: in fact, he believed, if that system had been more generally used, it would have prevented the introduction of many useless inventions, and would have insured greater safety in travelling. On the Eastern Counties lines, which were about five hundred and sixty miles in length, they had nearly every variety of permanent way, that had been prominently alluded to, in the course of the discussion. The saddle-back rail upon sleepers, of which they had a short length, made a fair road, and was easily maintained; there was also a considerable length laid with Mr. Samuel's fish chair, and he must say, that, as far as his observation extended, it made the best road on the Eastern Counties lines. It might not be the best plan, but, in this case, the Company had the advantage of using good materials—new rails, plates, chairs, and sleepers; while the "fish-joint" system had been generally applied to old rails, which were very much worn, particularly at their ends; it had been used, indeed, more to give assistance to the rails, than for making the most perfect road. The result had been that the half-worn rails, having so much strain thrown on their ends, after a short time stripped in their top table. He had also found, that the "fish-joint" system could not be so usefully applied with the single-faced as with the double-faced rail; and had observed many more failures with the former, than with the latter. With regard to the question of loose bolts and nuts, he was convinced that, if engineers were disposed to pay a proper price for those articles, there would not be any necessity to complain of them. But it was too much the custom to take that which was cheapest, without regard to the quality of the material. He had been obliged to substitute large quantities of new bolts and nuts over one hundred miles of railway, entirely on account of faulty manufacture in the first instance; while upon thirty miles of line, for some time after it was fished, it cost nearly as much to keep the bolts and nuts tight, as it had done to maintain the road before it was fished.

With reference to the "fish-joint," he believed, that Mr. Adams had nothing whatever to do with the invention, beyond giving it a name. The invention, as patented, was taken by Mr. Richardson to Mr. Adams, who had the far-sightedness to perceive that it would become valuable. At the same time, he felt it incumbent on him to state, that the fish-joint was laid down by himself prior to that period, whilst Mr. Richardson was his Assistant, in order to overcome a difficulty. A timber bridge, of about 50 feet opening, was considered too weak for a locomotive to run over it safely, at high speeds. After some consideration, it occurred to him, that the simplest mode of imparting strength, was to connect, or "fish" the rails, thereby converting them into a tension bar across the bridge. That had the effect of rendering it temporarily safe, until a stronger structure could be erected, and as far as he knew, that was the first application of the "fish-joint" to the railway system. Mr. Richardson improved upon the idea, and then went to Mr. Adams, and conjointly they brought it to its present state. He had subsequently applied it, in a similar manner, to impart rigidity to timber bridges.

Before concluding, he would observe that, about three years since, there had been a discussion at the Institution[1] on the same subject, in which he took part; when the question was raised as to the proper weight and strength to be given to rails. The general opinion, at that time, ran strongly in favour of heavy rails of from 90 lbs. to 100 lbs. per yard. Upon the Eastern Counties lines, he had found, that the heaviest rails made the worst road, were less durable, and, in course of time, became the most dangerous. Upon that line, where rails of 95 lbs. to the yard had been used, they had more breakages than with any other. Those were now being replaced with rails of 75 lbs. per yard, accurately "fished," which, compared with the cost of renewing with heavy

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xi., pp. 473-477.

rails, would effect a considerable saving; and he was certain it would make a better, safer, and more durable permanent way.

Mr. HAWKSHAW, V. P., objected to the system of endeavouring to prove the value of one particular invention, by depreciating all other attempts at improvement. He thought credit ought to be given to Civil Engineers, for inquiring into the merits of the particular forms of rail, chair, or key, submitted to them; and that there was no necessity for wholesale denunciations of all the other systems to support that advocated at the moment. The consequence of this practice was, that in discussions on permanent way, there occurred a series of contradictions, which might lead to the assumption, that nobody had ever constructed a railway fit to be used, and, in fact, that engineers had yet, in this respect, to learn their business. He had used most of the well-known systems of permanent way, and he would say of them, generally, that nearly all would make a good road if properly treated. He had a length of road laid with Mr. Greaves' spheroidal iron sleepers, which had been in operation seven, or eight years, and made a good road. He should have no hesitation, were he disposed to change the system he was then adopting, in laying down those sleepers, being quite certain that a good road could be made on that system. He had also used fish chairs, and thought both Mr. Samuel's and Mr. Barningham's helped to make an excellent road. He had used the double-headed rail, the bridge rail, and the contractor's form of rail; and had laid almost as much road upon longitudinal timbers as upon cross sleepers. Each was good if executed in a proper way, and there was scarcely a choice between them. He had also used extensively Messrs. Ransome and May's compressed keys and trenails, and during a period of more than ten years, no renewal of those fastenings had been required. With regard to bolts and nuts, if engineers were desirous of using them, and paid a proper price for them, they could be made to hold fast. For commercial reasons, engineers could not exceed a certain amount of expenditure; the cost of roads whether for the pack-horse or the locomotive, must bear some relation to traffic, and the times of their construction; but he had no hesitation in saying, that if an engineer was instructed to make the best permanent way he could devise, without regard to cost, he could make a very superior road to any now laid down, on almost any of the systems that had been brought forward.

He wished to say a few words on the subject of patents, which had been so much discussed. He was not one of those who objected to an inventor taking out a patent; he had as much right to it as the author of a book had to his copyright. He believed it did good, inasmuch as many minds were occupied in seeking after improvements, which would not be so occupied, but for the power of securing the advantage of the protection of a patent. Many persons invented, but had not the means of carrying out their inventions, and he saw no objection, generally, to persons with the requisite business habits, being associated with inventors, to work their patents, but there were certain combinations of this kind which he thought it desirable to avoid. He spoke now in the interest of the profession. He considered it was objectionable, that engineers largely concerned in the making and maintenance of railways, and having the charge of important lines, should themselves unite to buy up patent rights, for every form of rail, chair, sleeper, and fastening, and to bargain with the various Railway Companies for the use of these patented inventions. This system, he felt, was now operating in a manner, and to an extent, which the framers of it never contemplated. He had found it necessary, latterly, in making out specifications for permanent way material, to place upon the party supplying them, the liability of all charges, in respect of patent rights. He had, in some cases, when consulted by the manufacturers, told them, that with respect to particular patents, he did not consider the parties entitled to receive any payment. The reply of the manufacturers had been, that it was difficult for them to demur, when so many engineers were interested in enforcing the claims. He wished, therefore, that those patent rights were in the hands of commercial men only, who, he thought, would manage them in a more satisfactory manner than engineers would do.

Mr. P. W. Barlow said, the observations which had been made with regard to the disadvantages of a number of individuals, whether engineers, or commercial men, holding patents called for a few remarks. He thought it would be admitted, that engineers, generally, had some difficulty in dealing with patentees. Now, when the multiplicity of inventions relating to permanent way was taken into consideration, he believed the effect of an association which should hold all, or nearly all, such patents, would be to relieve engineers of a great difficulty, because the patents on this subject being so numerous, it was almost impracticable to deal with each patentee separately. He happened to be a leading member of a Company of the kind, and he would state how it originated. In 1849, before any change had been made in the ordinary construction of permanent way, several engineers of railways became sensible of two great imperfections in the old system,—the destruction of the joints of the rails, and injury to the rolling stock, by the hammering action in the ordinary chair. The cost of renewal arising from the rapid decay of timber sleepers was also very great. Patents were then taken out, for inventions to obviate these defects. It was subsequently suggested, by the mutual friends of the two parties, that greater advantages would be probably attained by co-operation than by acting separately. He must confess that he did not think such a course unprofessional; but he considered that it was not to the interest of engineers of railways to take out patents.

Mr. SOWERBY observed, that in determining the system of permanent way to be adopted upon the Indian Railways, it was desirable that it should be as free from complication as possible, so that it might be readily laid by native workmen. The weight of the rails was also an important consideration, as affecting the question of freight. He considered those best adapted for the purpose, which approached, most closely, to the common contractor's rail. They were easily laid down, and could be made very light. The expense of shipping rails from this country was so heavy, that the question of manufacturing them in India had been discussed. They were not, however, at present, able to manufacture bar iron. Mr. Sowerby had, therefore, suggested the use of cast iron. The peculiar character of Indian iron, from the fact of its being made with charcoal, rendered it very good for that purpose. It was the opinion of many engineers, that timber was liable to be destroyed in India by the white ants. His experience went to show, that this was a fallacy. He had seen timber structures, which had been erected for many years, and were scarcely affected by that cause. It had been found, that the white ants would not remain in spots where they would be subject to constant disturbance, as by the noise and blows of a passing railway train. The permanent way need not, therefore, be wholly of iron, as was at first considered necessary.

Mr. W. POLE stated, that the permanent way of the East Indian and the Madras lines, which he had superintended for the late Mr. Rendel, was composed of double-headed rails fixed in chairs in the ordinary way, with compressed wood keys, and fastened by compressed trenails to cross timber-sleepers, and with fish-joints. The rails were rather heavy; 82 lbs. per yard—but that weight had been adopted with the concurrence of the authorities of the East India Company, who wished to have a durable permanent way, to provide for the heavy traffic which it was believed would eventually come upon the line.

As trenails had been alluded to, he would mention an improvement he had lately introduced on those lines. The objection made to wooden trenails was, that they were sometimes sheared off, on sharp curves, or crossings, from the sudden lateral blow of the engine-wheels. In the ordinary way of making trenail holes, a sharp edge, or "fin" was left, which had a tendency to aid in this shearing effect, as well as to damage the trenail whilst it was being driven. The improvement made was in slightly countersinking, or coning out, the bottom side of the hole, by which the fin was removed, and the fastening was much strengthened, as the result of trials had conclusively shown.

The fish-joint system had been adopted on the Indian lines to a considerable extent, and as it was believed that its success depended, in a great measure, on the care and accuracy with which the joint was made, considerable pains had been taken to render it as perfect as possible. He considered it might be useful to state, the principal points to which attention had been directed. In the first place, the surfaces of bearing between the fish and the rail should fit perfectly, and should be straight on the section. It was a common practice to make them of a curved, or ogee shape, but this was injudicious, for wherever slight inaccuracies occurred in the rolling of either the fish, or the rail, they would not fit; but if straight inclined lines were adopted, they would allow for considerable variation, without detriment to the adjustment. The angle of inclination of these lines was also of some importance, and exercised considerable influence on the amount of strain on the bolts. The fish-plate should, in its normal condition, leave some space between its inner surface and that of the vertical web of the rail, so as to allow for accidental variations in size, or shape, without permitting the fish-plate to bed up against the web, and lose its proper bearing against the top and bottom flanches, which it was highly important, under all circumstances, to preserve. It was further essential, that the fish-plates should be quite straight and true in form, and free from "winding." The holes, both in the fishes and rails, should be of ample size to prevent the bolts from binding within them; they were frequently made too small in the vertical direction; they should be at right angles through the web of the rail and the fish-plates, and perfectly accurate in position. The bolts and nuts should be forged true, particularly as regarded the faces of the heads and nuts, which should be accurately square with the axis. The thread should be brought well up, and the nuts should fit so tight, as not to be moveable without a spanner. If these precautions were attended to, the fish-joint would be found to answer well, and to give little trouble in use. It was of course necessary, that the manufacture of all the parts should be rigidly supervised, or the required conditions could not be insured; but he had always found that with respectable manufacturers, a judicious system of inspection, so managed as to be careful in essential points without unnecessary severity, would succeed in obtaining the correctness desired.

Mr. Pole had lately tried a plan of tapping one of the fishes, either instead of a nut, or with the addition of a nut, as a lock; this appeared to answer well in the cases where it had been laid down, and offered some advantages of importance.

Mr. G. P. BIDDER, V.P., said, he could not imagine any difficulty in making a good permanent way with rails of 70 lbs. or 75 lbs. to the yard, sleepers 3 feet apart, and chairs of 25 lbs., or 30 lbs. in weight. This system had been found to be capable of adoption in Egypt and in the Crimea. In the former country Mr. Greaves' spheroidal cast-iron sleepers had been used with great success. In Norway and Denmark, Canada and portions of the United States, cast-iron chairs were inadmissible, owing to the severity of the climate. In Norway he had laid bridge rails upon longitudinal sleepers, and these again on cross sleepers: in this case it must be remembered, that during six, or seven months in the year, it was impossible to open the ground for the purposes of repairs. In Canada the contractors' rail was extensively used, and the road was laid with a bountiful supply of sleepers. At the joints a plan had been adopted which had been found to answer well in the United States, and which he had used in Denmark. A simple wrought-iron plate was laid under the joint, with one edge turned over one of the flanges of the rail, and spikes were carried through the rail and plate, down into the timber. The fish-joint was undoubtedly a valuable introduction, more particularly for repairing and maintaining a line of railway that had been much worn; and there might be some merit in the cast-iron chairs and new forms of rails that had been alluded to in the course of the discussion, but which, he thought, required the test of experience. It had been said that when a railway was flat, cast-iron rails, and a light description of locomotive might be adopted with impunity. Now all those who were acquainted with railways knew, that the question of light, or heavy engines, had very little to do with gradients, and the flattest railways had sometimes the heaviest engines.

There was certainly great simplicity in the idea of the advantages to be derived by the railway world, from concentrating all inventions for permanent way into the hands of one Company; yet, he thought, engineers, who were bound to look after the interests of the Railway Companies for whom they acted, could make a better bargain with the inventors themselves, and that they ought always to be prepared against a combination which was not for the interest of their employers, by having the means of superseding any inventions which could not be obtained on reasonable terms.

Mr. C. MAY exhibited a specimen of a bridge rail, rolled from an ingot of cast steel, made under the "Uchatius" system, of such a quality of metal that razors might be made of it. This had been accomplished by the Ebbw Vale Iron Company. He believed, that before many years, steel rails would be as cheap as iron rails were now, and that the permanent way would then deserve its name, which it was far from doing at the present time.

Mr. W. B. Adams said, he had been informed, that the "Mansel" pile joint had not been taken up on the South-Eastern Railway, as stated in his Paper. He would ask the Engineer of that line, what were its advantages and cost, and whether it was proposed to continue its use?

He remarked, in reply to observations of different Members, that if screw bolts were preferred to cotter bolts, or gibs and cotters, or other fastenings, for the parts of the permanent way, a simple method of preventing either the bolt-heads or nuts, from turning and getting loose, was by the use of plate wedges, as described in his Paper. Wedges and screws were merely varieties of the inclined plane, the one taking a straight path, and the other a circular path, in action. With regard to the price of bolts, a respectable manufacturer had offered to make them at £18 per ton. The motive of Mr. Adams in designating his rail a "girder," was to distinguish its power of carrying the load between more distant supports, than that of the ordinary rail. If a rail deflected vertically, it must, of course, increase the resistance to draughts, and the depth of a rail able to distribute the load over a larger space did not necessarily, if rightly constructed, increase rigidity, or lamination. The sample laid down at King's Cross, though not the most perfect specimen that could be constructed, sufficiently demonstrated the advantage of the principle. There could be no difficulty in slitting the horizontal webs of the angle brackets, so as to enable them to bend to any curve whatever. The "fish-joint" was simply proposed to amend the defects of the battered ends of existing rails, and was not contemplated by him, as the best mode of dealing with new rails. It was similar in principle to the plan pursued in mending a sprung spar at sea. It was quite true, that fished rails did not constitute perfect "beams fixed at the ends," owing to the ends resting on an unfirm fulcrum, but the fishing produced a condition analogous to that. If the distance between the piles of the original Great Western permanent way had been spanned by inflexible girders, the beam fixed at the ends would have been realised. The stripping off of the tread surface of the "saddle-back rail," which had been alluded to, might possibly be accounted for, by the up and down bend of the fibres across the rail, in connection with the rolling loads. The most probable mode of making the saddle-back rail useful, would be to insert the lower edges in a continuous flanged bottom-plate, so as to prevent the widening. It would thus be made a working rail with elastic action, but at a very heavy expense. He maintained, that the Barlow cast-iron sleepers used on the Londonderry and Enniskillen Railway were materially increased in weight and altered in form, as compared with those originally designed. Mr. Reynolds was the first to apply wood linings within cast-iron sleepers for rails to rest upon; the rail being of the bridge form.

An objection had been taken to his Paper, that it did not embrace every description of permanent way that had been introduced, nor dwell upon bridge rails, chairs, trenails, and other matters. It was impossible to comprehend in one Paper all that might be said upon the subject: and the present must be taken as a sequence to that on the same subject read in the session of 1851-2.[1] He had purposely omitted some matters dwelt upon in the previous communication. With reference to the priority of the invention of the fish-joint, he could only say, that the idea did not come to him either through Mr. Bruff, or Mr. Richardson. It was true, that the latter gentleman had informed him, that he had a plan for improving the joints of rails, and wished him to join in taking out a patent. This Mr. Adams declined, on account of the difficulty of getting a rail-patent into use. Two months afterwards Mr. Richardson came to Mr. Adams again, and informed him, that Mr. Bruff would lay down the improved joints on the Eastern Union line. Then, for the first time, Mr. Richardson explained his plan, which was a scarf-joint, of which a model was upon the table. Mr. Adams said at the time that it was not new, having been tried on the Blackwall Railway; to which Mr. Richardson replied, that his was a parallel joint, whilst that used on the Blackwall line was a diagonal joint. The operation of scarfing, Mr. Adams pointed out, took away material and strength, whilst that of the ordinary nautical plan "fishing" a spar, added both. This consideration led to the invention; and it was suggested to Mr. Richardson by Mr. Adams, was approved by him, and the English patent was taken out in the names of W. B. Adams and Robert Richardson. This patent contained the fish-joint, also the scarf-joint, and many inventions in engines, carriages, springs, and wheels. The Scotch and Irish patents which were taken out in Mr. Adams' own name alone, contained the fish-joint, but not the scarf-joint. When Mr. Adams' former Paper was under discussion in 1852, this assertion was corroborated by Mr. James Samuel in the following words:—"He gathered from the Paper, that Mr. Adams claimed the invention of the fished suspended joint; the claim was perfectly valid, and Mr. Samuel had become first connected with it, by introducing it practically on the Eastern Counties Railway."[2] After the patent was taken out, it remained in abeyance for some time, as Mr. Bruff would not lay it down on the Eastern Union. About two years after the patent was taken out, a premium was about to be offered by the Eastern Counties Board for the best joint. Mr. Adams conceived the fish-joint to be the best, and he accord-

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[1] *Vide* Minutes of Proceedings, Inst. C.E., vol. xi., pp. 244 to 273.
[2] Ibid., p. 277.

ingly directed Mr. Sinclair, his foreman, to prepare the plan, which was seen by Mr. Peter Ashcroft, who had charge of the permanent way of the Eastern Counties. This resulted in ten joints being cast and put together with bolts, and from that time the plan gradually got into use. The patent subsequently passed out of his hands, in consequence of misfortunes in business beyond his own control, and the fish-joint was now the property of the Permanent Way Company.

It was simply a question of manufacture and cost, whether bolts, or keys, were made efficient, or non-efficient. The fact that roughly-made bolts did get loose, had induced Mr. Adams to devise several methods of securing them, by keys, or by plate wedges, between adjoining bolts. He thought the concurrent testimony in favour of bolts, in the case of both brackets and fishes might be considered as having settled the question of their applicability, and that, other things being equal, the question was, which mode of fastening could be supplied at the lowest cost. The mechanical efficiency of Mr. Adams' brackets had been acknowledged as at least equal to the fish-joint, and he challenged comparison, as to cheapness in cost, with any other joint. The weight of the joint brackets was 44 lbs. per pair, or about 4 lbs. heavier than ordinary joint chairs, and the intermediates were only 11 lbs. per pair, so that the total weight per mile was about $22\frac{1}{2}$ tons, showing a saving of about 20 tons of castings per mile, as compared with chairs. It was most desirable to make much squarer side channels to the rails for the fishes to lie in, in order to take the strain off the bolts, and this gave rise to the proposal to stamp the rail ends, while hot, and which had the further effect of solidifying them. Whether brackets, or fishes, were used, the same principle held good. In the suspended girder rail, the side channels were rolled square, and the bolts were not found to get loose. The effect of the bolts being set in the ballast, condensed by the pressure of the loads, also added considerably to their security. Some objection had been made, as to the difficulty of getting at the bolts. This might easily be remedied by screwing up the nut on a small cast shoe, on the edge of the bracket, so as to be always in sight, with the nut and cast shoe so formed, that a lock pin could be driven in, rendering the nut permanent in whatever position it might be placed. It had been stated that Mr. De Bergue's way, consisting of a single-headed rail, laid on flat cast-iron plates, had answered well upon the South-Western Railway. The area of bearing surface on the ballast in this case was equivalent to cross sleepers spaced 4 feet apart. This was equal to the suspended girder rail, with a continuous breadth of only 9 inches, the T angle brackets being only $3\frac{3}{4}$ inches by 3 inches. The quantities would stand thus :—

Rails . . .	.	100 tons.
T angle brackets	.	75 "
Bolts . .	.	$2\frac{1}{2}$ "
Cast-iron shoes	.	2 "
Tie-bars .	.	$3\frac{1}{2}$ "
Total	.	183 tons.

It was evident, that this would be a structure of low cost, of great efficiency, and of sufficient elastic resilience to prevent destruction. At present prices, the cost might be taken at an average of about £9 per ton, or say £1,650 per mile of single line. Moreover the rails could be turned end for end, and upside down.

After the first meeting had assembled, a sheet of diagrams of girder rails had been suspended to the wall, bearing date November 4th, 1851, being simply, not things in use, but diagrams of a patent. The apparent object of this was to make the Members believe, that there was a want of priority in Mr. Adams' suspended girder rail. Now, as the importance of dates had been spoken of, Mr. Adams had prepared two lines of consecutive diagrams, demonstrating on one, the re-patented duplicates of his forms and plans, at a subsequent date; and, on the other, the various modes of joint fastenings of the double **I** rail (Plate 2). The latter commenced with the ordinary chair and wooden key, and then followed the half-chairs of Mr. John Day, dated January 22, 1835, the fish-joint as invented and specified by him in May 1847, in which the fishes were suspended between the chairs without bolts, and the subsequent bolting. Then followed, Mr. Parsons' plan, February 1849, of notching the rails into timber cross sleepers, and keying them in without either chairs, or trenails; Mr. P. W. Barlow, in June 1849, for casting chairs in two halves, the chairs embracing the lower table of the rail and bolted together below the rail, similar to the plan of Mr. Day; Mr. Samuel's fish-chair, April 1850, a chair of one jaw, with a wrought fish on the opposite side, claimed by Mr. Greaves in 1846; Mr. W. B. Adams' chair, June 1851, fitting between the two tables of the rail and bolted below; and Mr. Alexander Doull, in November 1851, a chair in two parts, made of wrought iron, embracing only the lower table of the rail, but bolted through the rail. The Pile joint and the Socket joint, of Mr. Mansel, in April 1852, were specified as peculiar "combinations," to avoid piercing holes through the rails, and permitting expansion and contraction; in the latter a short piece of rail was placed between the rail ends, forming, in fact, two joints, connected by sockets in such a way as to permit the rails to slide in and out. The bracket system of Mr. Adams, (Plate 2, Fig. 12,) February 17, 1853, in wood, cast iron, and wrought iron, served as knees to secure the rails to the sleepers, whether of timber, or metal, the rails being either flush with, or partly sunk into the sleepers. This plan differed from the chair system of Mr. P. W. Barlow, inasmuch as it formed supports for the upper table of the rail, bolting through the rail, and bearing direct on the sleepers, like ordinary flat-footed rails; in fact it was an extended foot, or base to the double **I** rail, and thus lowered its total height above the sleeper. Mr. Wild, on the 15th of March, 1853, and Mr. Liddell, in 1854, patented a duplicate and a triplicate of this bracket. In 1855, Mr. Barningham patented an arrangement shown by Mr. Adams in his specification of 1853, viz. a chair in two halves, fitting between the two tables of the rail, and also below the lower table, and bolted through the rails. In 1856, Mr. Adams patented the recessed fish and bracket joint.

Mr. Adams considered, with many others, that it was not desirable that a Company, consisting of engineers holding official positions, should become possessed of all the patents referring to permanent way. Such a plan tended rather to retard than to promote progress, because the Company would naturally seek to extend the use only of those systems which they already held an interest in, to the exclusion of novelties; whilst individual inventors would not be strong enough to contend against such an organised opposition, and would, consequently, be obliged to sell their inventions to the Company, or to hold them in abeyance, which was a manifest grievance and disadvantageous to the community. It was an attempt to "hedge in the cuckoo" of monopoly. The practice of writing to Railway Companies to deter them from using new improvements by alleging them to be "infringements of some one or more patents the property of the Company," was simply a vague threat, but was at the same time an unfair proceeding. It was incumbent on them to publish an accurate list of their patents, and to point out the exact infringement, that engineers might be enabled to judge, for themselves, instead of being mystified. It was the interest both of the profession and the public to overthrow this combination by uniting against it.

Mr. Greaves said, as had been previously remarked at the Institution, there was no novelty whatever in the fish-joint. He had seen hundreds of tons of fish-plates, at Liverpool, twenty-two years ago. Mr. D. Stevenson, in his 'Engineering of North America,' which was published in the year 1838, thus described them: "The rails used on the Camden and Amboy Railway, which is sixty-one miles in length, are parallel edge-rails, spiked to transverse sleepers of wood, and, in some places, to wood trenails driven into stone blocks. Their breadth is three and a-half inches at the base, and two and a-half at the top, and their height is four inches. They are formed in lengths of fifteen feet, and secured at the joints by an iron plate on each side, with two screw bolts passing through the plates and rails."[1] Mr. Stevenson's remarks were accompanied by sketches.[2]

Mr. J. LOCKE, M.P., V.P., thought the members generally would be satisfied, that some light had been thrown, during the discussion, on the important subject of permanent way, and that their thanks were due to Mr. Adams for having brought it forward. There would always, no doubt, be a difference of opinion, as to whether, or not, it was desirable to consolidate patents, under the control of one Company; but he questioned whether that was a proper subject for discussion at the Institution. He had endeavoured to prevent the commercial part of the subject being touched upon, as it was in a scientific point of view alone, that questions should be examined and discussed at the Institution. He confessed it was difficult at all times to carry out this rule, and perhaps on no occasion more than the present, when the various claims of a numerous class of inventors were taken into consideration.

The duties which the civil engineer had to perform were of a varied character, and he might unhesitatingly confess how difficult it was to arrive at the truth in questions of this kind. After having spent nearly his whole life in the construction of railways, he still felt as much hesitation in coming to a conclusion, as to which was the best mode of permanent way, as if he had never seen a railway at all. How great then must be the difficulty, to those who were just entering the profession! In the course of the discussion young engineers had been strongly recommended to avoid taking out patents. Mr. Locke quite agreed with that advice, as he was aware, that many had lost good positions by patenting improvements, and introducing them on lines on which they were professionally engaged. He had never felt the necessity, or the desirability of taking out patents.

He had introduced wooden keys on the Liverpool and Manchester Railway, as an experiment, and preparatory to their general use on the Grand Junction Lines. These keys were similar in form to

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[1] *Vide* "Sketch of the Civil Engineering of North America," by D. Stevenson. 8vo. Maps and Cuts. London, 1838. Page 247.

[2] The following is extracted from a Paper on Rail Joints read by Mr. Elwood Morris at the Franklin Institute, as reported in the "American Engineer" of July 25, 1857:—"About twenty years ago, a large portion of the trunk of the Camden and Amboy Railroad was laid with a 40-lb. rail with link plates covering the joints on the outsides only. These link plates were about 5 inches by 2½ inches by ⅝ths of an inch, secured by two ¾-inch bolts. They formed in no sense what are called fish-plates (though on a recent discussion in England they have been so called), since they added nothing to the strength of the joints and were merely employed as a 'link' to keep the rails in place lengthwise. They have not been used in relaying that railroad, but have been supplanted by the ring joint and others."—EDITOR.

those now in general use, and they were compressed by a hydraulic machine, but in a somewhat different manner to the plan subsequently patented by Mr. May. With regard to the double-headed rail, and the assumed advantage of being able to turn it, he would ask, whether any experienced engineer ever rejected a rail of that form on account of the facility it possessed for turning? That form had been designed by him for the Grand Junction Line in 1835, partly with that object, and he believed, that in practice, advantage was taken of it to turn the rail when considered advisable; a double-headed rail was never rejected from absolute wear, without its having been turned. He thought there was sufficient evidence to show that the double-headed rail was of some value in this respect.

Mr. H. CARR remarked, through the SECRETARY, that there was one point, with regard to permanent way, which did not appear to have received the attention it deserved, that was, the relative gauges of the line and the rolling stock. It was generally acknowledged, that the Great Western Railway was a smooth running line, as compared with most of the narrow-gauge lines. This might be attributed to the width of the base, but the feature he had alluded to might prove to be far more important. This was a matter to which he had paid some attention, whilst employed on a narrow-gauge line, in conjunction with a locomotive Superintendent who had formerly been connected with the Great Western Railway. The narrow gauge referred to was the ordinary width of 4 feet $8\frac{1}{2}$ inches; the gauge of the rolling stock, when new, was 4 feet $7\frac{5}{8}$ inches; thus there was a difference, or an allowance of $\frac{7}{8}$ inch between the gauge of the line and of the rolling stock, when both were new; but when $\frac{1}{4}$ of an inch was worn off each flange there was a difference of $1\frac{3}{8}$ of an inch. The Great Western gauge was 7 feet for the line, and 6 feet $11\frac{1}{2}$ inches for the rolling stock, leaving $\frac{1}{2}$ an inch play, when new; or little more than half that before stated. Theoretically there should be no play, and practically as little as would allow for unavoidable irregularities. The play allowed on narrow-gauge lines might clearly be reduced to the same as on the broad gauge, or nearly one-half what it was at present. In order to show that this might safely be done, it was only necessary to refer to the practice of most plate-layers, in laying down switches and crossings. Crossings, more particularly, were laid on what was called tight gauge, frequently 4 feet 8 inches instead of 4 feet $8\frac{1}{2}$ inches. It was a fact, that large and varied traffic did run with perfect safety over crossings so laid down, and the general observation of plate-layers, and other advocates of tight gauge for crossings, was that "it steadied the train over them." The assertion was perfectly correct, and all that was wanted was to carry out the idea and to "steady the train" for the whole length of the line, by reducing the play allowed between the gauge of the line, and that of the rolling stock. If any one required to be convinced of the necessity of some alteration, and the importance of some improvement, in the running of heavy traffic, let him ride on the tender of a loaded coal-train, carefully watching the action of the trucks as they ran, loosely coupled. He would notice, that instead of having a smooth rolling motion, each truck advanced in a series of oscillations, varying in intensity with the velocity of the train. Every one was aware, that trucks oscillated from side to side, but the full force and regularity of this action was only to be appreciated by watching the whole length of a loaded coal-train, or other similar train, with a clear view from end to end. If a train was designed for the purpose of destroying permanent way, it could hardly be better arranged, than a loosely coupled coal-train, with plenty of play in the gauge, to be run at the ordinary speeds of 35 to 40 miles an hour, which was not an unusual rate down inclines. Spring buffers, tight coupling, and tight gauge, the two latter carried to the utmost practicable limits, would without doubt effect a considerable saving in the maintenance of permanent way, the destruction of which did not so much arise from the fair wear of the rolling motion, as from the irregularities in the running, and the consequent violent and continuous blows struck by the wheels. As stated on a former occasion at the Institution, the labour of maintenance of an up-line with a heavy coal traffic, was found to be to the maintenance of the down line as 2 to 1, the gross weight carried over being as $1\frac{3}{4}$ to 1, the cost of maintenance increasing 25 per cent. more than the weight carried. This question of half an inch in the gauge, and the matter of tight coupling, might appear to be a trifle, but the expenditure of many thousands per annum was believed to be involved. It was as important to obviate the destructive influence of the motion of trains, as to improve the permanent way, or perhaps more so, inasmuch as to get rid of, or to diminish the wear and tear caused by the trains, was better than to add to the strength of the road.

Mr. T. R. Crampton observed, through the Secretary, that he had practically used Mr. Parsons' chairs, and had carefully watched their working, for a considerable time; he thought it right therefore to state the result of his experience, which was very favourable as to the practical value of the system. The long chair made a joint quite equal to the best fish-joint, in point of evenness and smoothness, and superior to it in many other respects. He was satisfied, that it was more durable, did not require anything like the care and attention, and the method of tightening, by the hammer and iron wedge, was preferable to the use of the spanner with bolts and nuts. Its first cost was not so great, and it was also much less expensive to renew, as the only parts that could decay were the end-grain wood-cushions, the cost of replacing which was trifling. He had made numerous examinations of these chairs on the Great Northern Railway, both after wet and dry weather, and always found the fastenings perfectly tight; in fact the state of the atmosphere did not appear to have any important influence on them. A considerable length of temporary way was laid with these chairs on the East Kent Railway, and although the keys were only driven half through, not one key had been accidentally loosened, or worked out. The alteration in the direction of the grain of the wood, so as to make it take the pressure endways, instead of sideways, as in ordinary wooden keys, was one of those simple, but at the same time practical, improvements, which was likely to prove of considerable value. He believed it would be found particularly so for the Indian and Colonial Railways, where a hot and dry atmosphere prevailed. These end-grain cushions, in combination with the jagged iron keys, left nothing to be desired, as a fastening.

Mr. J. S. Perring said, through the Secretary, that as the system adopted on the East Lancashire Railway differed in many respects from any other with which he was acquainted, it might be interesting to the Institution to have a brief account of it. The joint chair rested on two sleepers, placed as near together as practicable, only sufficient space being allowed between for packing. The principal casting of the joint chair, by which the weight was borne, weighed 88 lbs., and the side plate 33 lbs. The use of the latter was to clip the ends of the rails, by means of two bolts, each 1 inch in diameter, below, and to keep them up to the outside cheek of the chair. The rails were also retained in their places, when the pressure was on them, by the action of small inclined planes, at each end of the chair. A small bolt, $\frac{5}{8}$ths of an inch in diameter, was passed through the chair and the ends of the rail, to prevent the rails from driving forwards, in such places on the line where the breaks of the train were generally applied. The nuts were fixed into recesses cast on the chair, and the bolts were turned in screwing up; this effectually prevented the nuts from shaking loose.

In another form of chair, used principally on timber viaducts, a single trough-shaped casting, with a flat bottom, was used. The rail fitted one side of the trough, and was kept in place by a "fish-plate," set up against it on the other side, by the end of a set-screw passing through a plug-nut, this latter fitting a recess in the casting. This plug-nut and set-screw had proved so satisfactory, that their use had lately been extended with success to fixing the rails of points, crossings, and checks into their respective chairs. This peculiar form of joint chair had been used for planked bridges and viaducts. In cases where the planking was thin, and ran transversely, a number of these chairs were introduced along the whole length of the rail, in order to obtain an increased bearing surface, and distribute the weight over every plank equally. The intermediate chairs were constructed with an outside cheek fitting up to the rail, while an inclined plane, on the inside, prevented any movement of the rail inwards. So long as the joint chair kept the ends of the rail firmly in position, no key was required for the intermediates, and those that had been down for the last three years without a key, showed that there was no tendency either to upset, or for the rail to get out of place.

In sharp curves an iron drop key was occasionally used for the middle chair of each length, and as it gave an appearance of security, and was not expensive to maintain, its adoption might be extended.

This iron drop piece, or key, weighed 2½ lbs., and was found to keep well in its place by its own gravity. It would thus be seen, that the use of wooden keys was abandoned. When wooden keys were placed outside the rail, Mr. Perring considered, not only that the cost of maintenance was excessive, but also that they led to many accidents; if placed inside there was so little strain upon them that they were scarcely of any use.

In designing this permanent way the following objects had been kept in view:—1st. To obtain a well-supported, good joint, of somewhat greater strength than the other parts of the rail, and thus to avoid destructive action. 2nd. To dispense with the use of wooden keys. 3rd. To allow any rail to be taken out, with the same ease as in the old road, and without unspiking the chairs from the sleepers. 4th. To allow the use of rails of any length, without having to drill for special closures, or insides of curves.

In using cast iron for joints, it was of course necessary to have a good quality of iron and a good fit, both of which had been too much neglected in chair castings. The questions of the proper depth of ballast, and also its quality and drainage, were most important, particularly in those parts of the country where the rainfall exceeded 60 inches annually. Too much attention could not be paid to the quality of the workmanship in every part of a permanent way; the neglect of this precaution led to rapid destruction of the materials composing it, and greatly increased the cost of renewal and of maintenance.