The chief point of difference, between this and the other modes of constructing permanent way, consists in the rails being riveted to the joint-plates, so as effectually to prevent motion at the joints, and also to insure a more uniform deflection along the rails.

The rails and the joint-plate are riveted together at each joint with eight $\frac{3}{4}$ inch rivets. To allow for contraction and expansion, and also for the slight irregularity which, in practice, is found to occur between the holes in the rails and those in the chair, or joint-plates, the holes in the joint-plates are made 1 inch in diameter, or $\frac{1}{4}$ of an inch larger than the rivet. In riveting, care is taken to heat one end only of the rivets, which is effected by passing them through a plate of iron, punched for the purpose, which protects the head and a part of the rivet from the fire.

Several miles of this road are now laid, and portions of it have been run over during nearly twelve months; and it appears, at present, to answer very well.

The Paper is illustrated by two drawings, (Nos. 4,450 and 4,451.)

Mr. HAWKSHAW explained, that the nature of the joint used was the principal novelty in this mode of laying the permanent way: for many years past, he had used both the continuous bearing and cross-sleepers, but up to within a comparatively recent period, he had employed the latter system in preference; he thought, however, that for high speeds, a better road could be made with continuous bearing longitudinal timbers, than with cross-sleepers. Formerly, he used as the fastening for the cast-iron joint-chairs, short bolts, the heads of which were countersunk at the under-side of the chair, and the nuts were screwed on from the top-side; he found, however, after some time, that the screws became so corroded, that they were obliged to be cut off, when it was necessary to remove them, so that there was neither economy, nor facility afforded by their use; he had therefore dispensed with the screws and nuts.

In laying a line, it was an important point to prevent there being any greater amount of deflection at the joint, than at any other part of the rail, and he thought the best way of doing that, was to unite the two abutting ends of the rails, in such a manner as to be exactly equal in strength to the body of the rail itself; he therefore adopted the wrought-iron plate-chair, with a projection on the upper side, fitting into the cavity of the bridge-formed rail, and having such a large bearing surface on the timber and such a length for attaching to both rails as rendered the joint as strong as the

other parts of the rail. In order to provide for proper contraction and expansion, he used, as fastenings for the rails to the chair, wrought-iron rivets $\frac{3}{4}$ths of an inch in diameter, exactly filling the holes in the rail, but having some play in the holes of the chairs. Twenty miles of line, thus laid, had recently been carefully examined, and in the whole of that length only three rivet-heads were found to have been knocked off; whilst the rest of the joints were as good as when they were first laid down. The arrangement of the longitudinal and transverse timbers might be varied to any extent: the first he laid, had cross-sleepers at intervals of 6 feet, or 7 feet, and on another line, the longitudinal timbers were simply connected together by tie-bolts. One great advantage of the present plan of placing the cross-sleepers was, that it prevented the twisting of the longitudinal timbers, which frequently occurred, when the platelayers were packing the permanent way. He thought, that longitudinal timbers would last longer than cross-sleepers, from their being laid nearer to the surface of the ground, so as to be dried by the air, and he made a point of keeping their surfaces clean, and properly drained. This system of construction was rather cheaper, as less iron was required, and two men would do as much, in repairing a line of that description, as three could do, upon a line laid on cross-sleepers. He had never yet seen any cross-sleepers which were good enough to receive a second set of rails, but these longitudinal timbers had done so. The line was certainly smoother for the traffic, and any impediments, from the rising of the ends of the rails which had been much talked of, would not be likely to occur.

Mr. SAMUEL said, too much stress could scarcely be laid on the importance of obtaining a surface, which, if not absolutely an inflexible plane, should be equally flexible throughout, and yet should not have any loose parts, on which the wheels should produce the effect of a blow. It was generally admitted, that there was a constant succession of blows, between the rails and the chairs, and that those blows were comparatively harmless in the intermediate chairs, but were very mischievous at the joints. The cause of this difference was, that where the rails abutted against each other, the resisting strength was probably less than one-fourth, either laterally, or vertically, that of the intermediate portions of the rails. Thus, however well the rails might be laid, if a rolling load travelled over them, of greater insistent weight than the joint-portion was capable of sustaining, the result would be, not a curve-like flexure, but a positive angle, of greater, or less depth, the action at the same time loosening the rails and keys in the joint-chair, and forming cavities

between the rails and the chairs, and also between the sleepers and the ballast. After the load had passed, the rails by their elasticity recovered their usual position, and the next rolling load produced a positive blow, tending to increase the depth of these cavities. If wet weather occurred, the water, getting in between the rail and the chair, induced corrosion, which was soon beaten off by the traffic, and the rain between the sleeper and the ballast softened the latter beneath the rail on each side. By a continuance of this action, the sleeper, being pressed down at the ends beneath each rail, and not so heavily pressed in the centre position between the rails, became a spring, and for the injury produced by this action there did not appear to be any present practical remedy; or, in other words, no method of rendering the sleepers firm in the ground by packing: because the density of the packing driven in by the plate-layer, was limited by the actual gravity of the sleepers and rails. When the wedging action of the packing was in excess of the total weight, the rails and sleepers were lifted. The piling principle, formerly resorted to by Mr. Brunel on the Great Western Railway, was an attempt to surmount the difficulty. Had the piles been close together, or had the longitudinal timbers been sufficiently rigid to prevent springing, it was possible, that the plan might have been mechanically successful, although, probably, not commercially advantageous.

The sinking of the sleepers between the rolling loads, which had been received as evidence of want of sufficient bearing surface, had induced the practice of increasing the number of transverse sleepers, and to this the only limit would be a solid platform, if heavy rolling loads were persevered with. The greater the number of the cross-sleepers, or, in other words, the greater the amount of surface, the longer, probably, would be the duration of the road. It was, at one time, the practice to use transverse sleepers at intervals of 5 feet; they were now laid at intervals of only 3 feet. Their dimensions were at one time 7 inches by 4 inches; they were now frequently 12 inches by 6 inches: this gave about 46 square feet of surface in one length of rail, or about 23 cubic feet of timber. If this amount of $1\frac{1}{2}$ foot of surface to each foot-run of rail, could be disposed longitudinally under each rail, instead of being spread out beyond and between the rails, greater durability would be the result.

But in whatever way the timber might be disposed, it must be clear, that the greater the depth of the rail vertically, consistent with its lateral strength, the better the metal would be disposed to resist strains of deflection. In this view, the form of rail which had been adopted by Mr. Hawkshaw, which was similar to that of the Great

Western, was, in Mr. Samuel's opinion, defective, and the form known as the double T was preferable. This would appear more evident in considering the question of uniting the rails at the joints, in order to render them equally strong with the other portions. The depth of Mr. Hawkshaw's rail was 3½ inches; a double T rail, with the same amount of metal, was 5 inches deep: it was obvious, therefore, that the double T would sustain the load best. The chair or '*union*' plate of Mr. Hawkshaw was broad and flat with a rising centre of only 1¼ inch in depth. In the system proposed of uniting the double T rail, the depth of the side-fishes was 3¾ inches, and in the cruciform rail with the deep centre, it was 5 inches deep. Again, the rivets of Mr. Hawkshaw's rail were subjected to a direct pressure, tending to shear off their heads, if the joint yielded, whereas in the other, the direct pressure was in the vertical direction of the fishes, producing, indirectly, an end tension on the bolts. The holes in the rails were oblong, to permit of expansion and contraction. The rails thus prepared were laid in cast chairs, with wooden keys in the ordinary manner, but the joint-chairs were altogether dispensed with.

A number of these fish-joints had been laid down, under Mr. Samuel's directions, between London and Stratford, and had been travelled over with heavy traffic, for a period of five months. Their utility was obvious, for on observing a heavy engine pass over the joints, the deflection was seen to extend over the whole surface of the rails, which weighed nearly 92 lbs. per yard, while the joint was equally as strong as the intermediate portion. The joints thus strengthened rendered the rails as perfect as when they were first laid down, while the joints that were laid in the ordinary manner were all loose, and the rail-ends were hammered out of shape, by the wheels of the engines.

The system of connecting the two rails together by the lateral fishes, had the advantage of obtaining equal strength throughout, and of preventing the rails from twisting in the chairs. There still remained, however, the disadvantage, peculiar to all rails of deep section as they were commonly used,—the height at which they stood above the base, which rendered them easily affected by the side lurches of the engine and carriages. To obviate this, Mr. Samuel had tried a new system, embracing the double T rail with longitudinal sleepers, without the use of chairs, or holding-down bolts. Two timbers, 7 inches square, were placed side by side, and in the matching sides a half groove was cut, corresponding to the form of the rail, and of such depth vertically, that the upper lip of the rail rested on the top of the timber. The two timbers were then bolted

together, so that the bottom of the rail bore on them laterally, at distances of 3 feet. In addition, a bolt of larger iron passed through the rails, one half in each, at the joint. The joints of the timber alternated with the rail-joints. Several lengths had been laid down on this plan, five months ago, on the Eastern Counties Railway, between Bow and Stratford, and the result, up to the present time, showed the system to be good, although the work was hurriedly done, and the joints were not fished.

Another form of rail, of deeper vertical section, illustrating the same system, gave about 40 feet of direct bearing surface, being a larger amount than by the mode of cross-timbers before described, with about the same cubic content of timber.

In this mode of construction there were fewer parts, than with the system of rails, chairs, and keys; in fact, the system was one continuous wooden chair. A length of one pair of rails on the cast-iron 'chair system,' required—10 chairs, 20 spikes, 10 keys, 5 sleepers, 2 rails, 4 fishes, and 8 bolts—total, 59 pieces; whereas the improved plan only required—4 longitudinal timbers, 1 cross-timber, 2 rails, 1 tie-rod, 10 bolts, 4 fishes—total, 22 pieces, or less than one-half the number. But as there were no loose keys, the risk from a displacement of rails was materially reduced, and in case of the wheels leaving the rails, they would probably run a considerable distance on the longitudinal timber, without any abrupt blows.

The cost of a length of 15 feet of this cruciform rail would be £6, or £2,112 per mile of single line, which was about the same as the cost of an equal length of the transverse system with chairs.

Mr. BRUNEL said, it was well known he was an advocate for longitudinal sleepers, having always adopted them, and having had, during the last ten years, much experience in their application. He agreed with Mr. Hawkshaw, as to the necessity of providing a solid resistance at the joints: when that was assured, he thought the principal difficulty was overcome, and that a different form of rail would not offer any great advantage. Some of the objections to longitudinal rails would be met, by giving a great depth to the rail itself; at present, the only one, he thought of any importance, arose from the creeping motion, produced by a rolling weight over an elastic bar of iron. The advantages of longitudinal timbers were, that they produced more safety and less liability to destruction to the rails and carriages, when there was any derangement of the permanent way, and that the wheel of an engine, or carriage, when off the line, continued to run on the flange of the rail, or the timber: such cases had frequently occurred, in consequence of bent, or broken

axles, without producing any material injury, until the train was either stopped, or had arrived at a station. He thought also, generally speaking, that they were less liable to derangement from sinking, that they were more easily kept in a proper state for running upon, and that it was easier to maintain a perfect joint in a rail resting on a continuous timber, than when resting on chairs.

He had experienced the difficulty which had caused Mr. Hawkshaw to rivet his rails to the plates. In order to obviate it, Mr. Brunel had placed the ends of the rail on a plate rather larger in size than that used by Mr. Hawkshaw, with a sufficient bolting power, to press it into the timber; he applied two large bolts, at the end of the rail, and two others, at a distance of about 12 inches, or 18 inches. After a few days' traffic, the plate, which was about $\frac{3}{8}$ths of an inch thick, was squeezed into the timber, and the surface became perfectly level; that method produced a sufficiently firm joint, and a good permanent way. He had not found any inconvenience to arise from the timbers turning on their axis; the transverse timbers were slightly let into the longitudinal timbers, and firmly bolted, giving a bearing surface of 7 inches deep against the side: this was repeated, at intervals of 12 feet, and produced sufficient stiffness to prevent the turning of the longitudinal timbers. Originally some difficulty had arisen, from the rails not being placed exactly in the centre of the timber; but latterly, he had caused the timbers to be slabbed and the rails centered, the transomes being bolted to them, and there was no longer any tendency to twist. He was averse to placing the transomes underneath the timber, as in lifting them, the men were liable to let loose ballast fall into the space they occupied, which was, of course, injurious. He thought the objection urged as to the rivets being liable to be sheared off, was not founded in practice, but it was certainly singular, that Mr. Hawkshaw should have succeeded in riveting up a great length of rails without being inconvenienced by their contraction, or expansion. On the Great Western Railway, from eighty to one hundred rails had been welded together, for the last four, or five months, but there not having been any hot weather in the interim, he was unable to judge of the eventual results. The men engaged in the maintenance of the way had assured him, however, that rails which had been originally laid down at distances of $\frac{1}{8}$th of an inch, had been rolled out by the passage of the trains, so that they were now close together, and that there was a perceptible difference in the effect produced by the trains on a hot, or cold day. He was, therefore, afraid, that in hot weather, the expansion would lead to considerable undulation.

He thought the bridge-rail, used by Mr. Hawkshaw, was better

than the T-shaped rail: he also thought the double-headed rail would not afford a sufficient bearing surface, though it required further time to ascertain its value. He had paid much attention to the manufacture of rails, and he thought it would be difficult to straighten those of the form proposed, on account of the mass of metal on the upper side being so much greater than that on the under side. He had adopted rails of from 60 lbs. to 65 lbs. in preference to heavier ones, for various reasons, one of which was that a rail of that weight was better manufactured, and could be made of better metal. The modes of making rails were continually changing, and it was, therefore, possible, that the proposed form of rail might be well manufactured; but at present, he approved of a rail like that used by Mr. Hawkshaw, with good plates at the joints, and secured permanently to the timbers. Wood screws would not do for that purpose; bolts with nuts underneath alone would prevent the creeping motion to which he had referred, and secure permanent adhesion. He considered the ordinary mode of laying rails on cross-sleepers was advantageous, so far as the drainage was concerned.

Mr. SAMUEL observed, that it was originally intended to put down the piece of railway referred to, with fishing-pieces, but sufficient time was not allowed; and he attributed the little motion, which was observable at the joints, to the want of those fishing-pieces.

Mr. P. W. BARLOW, from an examination of the piece of road laid down by Mr. Samuel, considered it to be the simplest and best construction, and he felt assured, that the use of timber-sleepers would soon be discontinued, by which the immense destruction of timber, which it cost half a million a year to renew, would be saved.

Mr. BRUNEL observed, that one great advantage in the use of longitudinal timbers was the great facility with which a rail could be taken up, and replaced; half an hour being sufficient for that purpose. He disagreed with Mr. Barlow as to the great destruction of timber, as from 1838 to the present time, the quantity replaced on the Great Western Railway was exceedingly small.

Mr. HAWKSHAW said he had laid rails on longitudinal timbers during ten years, and he had recently laid other rails on the same timbers, but cross-sleepers had not worn for the same length of time: the exposure of the former to the light and air tended, doubtless, to preserve them; and he believed, that they made the best road. He had no fear as to the results of the riveting, on which system he had laid down about ten thousand tons of rails; he had used plates at the joints with bolts and nuts, and the latter eventually became rivets, as they were found to be inseparable from

the bolts. Some time ago, he had riveted a cast-iron fence, 9 feet high, 800 feet long, and 1 inch thick, and although that fence had been standing for seven years, he had never observed any distortion in it during summer, or winter. He had used cast-iron sleepers for some time, but he preferred those made of wood, which he thought afforded an easier road, and were not so liable to be broken.

Mr. PIM said, that on the Dublin and Kingstown Railway, Dantzic timber was laid down thirteen years ago: in the course of the two, or three following years, the whole of the rails, (45 lbs. to the yard,) which had been originally laid on stone blocks, were relaid on longitudinal wooden sleepers of common pine, and coarse Memel; and in 1839, a large quantity of elm was used. Until within the last year the timber had not given any trouble, but since that time a good deal had been replaced, and the elm was found to have suffered the most. Some of the Dantzic timber which appeared sound was found to be rotten inside, whilst other portions which had rotted outside, were found quite sound in the middle. He thought the time occupied in replacing longitudinal timbers was a great objection to their use, more especially on the Dublin and Kingstown Line, where it was necessary to replace them by night, which was an expensive and unsatisfactory plan.

He had looked at the specimen of railway laid down on the Eastern Counties Line by Mr. Samuel, and he highly approved of it.

Mr. GORDON had no experience of the relative value of different kinds of timber on railways, but in the construction of ships, elm should only be used for the keel, and those parts which were constantly under water.

Mr. BIDDER said it should be remembered, that cross-sleepers were frequently made of Scotch fir, whilst longitudinal timbers had been generally made of pine, or Memel, and great pains had been taken, in the first instance, to preserve them; he thought, however, that they might all be beneficially employed, if they were carefully creosoted, and that no other material presented the same advantages as timber. He had creosoted about two thousand cross-sleepers of fir, on the Northern and Eastern Line, and specimens which were taken up two years ago were perfectly sound, although the adjoining ones, which had not undergone that process, were rotten. If Mr. Samuel's plan of fishing the joints should succeed, lines with cross-sleepers would be made quite equal to those with longitudinal timbers.

Captain W. S. MOORSOM said, that there was, originally, great prejudice against longitudinal timbers, but after many years' expe-

rience, he was convinced, that on the whole, they made the best road, that they were quite as capable of giving a firm bearing as cross-sleepers, and that they were much easier repaired when out of order; he would always lay them where there was any apprehension of sinking.

He had been influenced, no doubt, by what he had seen in the Dublin and Kingstown Railway, which was the oldest longitudinal line, although owing to the rails themselves and the bad method of fastening them, that railway could scarcely be quoted as a successful example. There was always a jarring motion, wherever there was a continuous bearing, whether of stone, iron, or timber, but he did not think, that it had any tendency to destroy the engines and carriages: he might here mention, that on the Croydon Line, which was laid on continuous bearings, a very disagreeable motion was always experienced. The difficulty of the drainage might be overcome by making the transomes level with the ground. His opinion on the questions under discussion was,—that longitudinal bearings were preferable to cross-sleepers,—that it was more advantageous to employ wood than stone,—and that repairs could be effected more speedily with rails of the T shape on chairs, than with bridge-rails fastened with bolts and nuts. A more important point was, that after a frost, or in wet weather, the ordinary old road laid with chairs was less slippery, and became sooner fit for traffic than a road laid with bridge-rails on longitudinal sleepers. With regard to the shape of the rail, his experience led him to believe, that with an equal weight of metal, the hollow bridge-rail did not wear so well as the double-T rail.

Mr. Wyndham Harding also thought, that although stone blocks lasted longer than wooden sleepers, there were many reasons in favour of the latter, which more than counterbalanced the advantage of duration; and stone was gradually being replaced by wood. The permanent way of the Dublin and Drogheda Line, laid down by Sir John Macneill, was composed of a high bridge-rail of from 85 lbs. to 90 lbs., fastened down, without chairs, on cross-sleepers, which were placed, in accordance with mathematical calculations, at unequal distances, the rails being well straightened and accurately gauged, and the sleepers being cut with a machine to the right bevil. The road had now been down for some years, and he had never seen a line in better order; but it was only fair to add, that the traffic was small, the engines light, and the speed moderate. The objection of Sir John Macneill to longitudinal sleepers was their liability to turn on their axis; but this, Mr. Harding thought, might be remedied by keying. He had found

that the bridge-rail wore worse, with an equal weight of metal, than a rail of the T form, or a common contractor's rail.

Mr. STATHAM said the Chichester Line had been laid with a bridge-rail of 75 lbs. to the yard and with transverse sleepers, and the system had entirely failed; it might answer on the Drogheda Line where the traffic was light, but where it was of a heavy description, a continuous longitudinal bearing was decidedly the best. The Croydon rail was not a bridge-rail, but a common contractor's rail. Time and experience only could fully test Mr. Hawkshaw's plan, but it seemed to him to be a decided improvement. The proposal of fishing the double-headed rail might, probably, succeed; the turning of the double-headed rail was only adopted when one surface had been crushed, or was imperfectly manufactured. The contraction and expansion was less injurious with that form, than in the longitudinal system. The two systems were to be seen, side by side, on the Greenwich Line.

Mr. WHISHAW was satisfied, that elm would never answer for sleepers, as it had been generally found to decay in eighteen months. He thought, that kyanizing the timber was not of the slightest use; and that light rails would not answer in practice, was proved in the case of the Great Western Railway, where, as far as Slough, the rails of 45 lbs. had been very rapidly destroyed. The system of laying the permanent way which had been alluded to as being Sir John Macneill's, was originally suggested by Mr. Giles, who did not use chairs, but spiked down the rails to the fir sleepers; that plan was found not to answer, and the road was taken up.

Captain W. S. MOORSOM said the form of rail adopted by Mr. Giles was much too weak, and that was the main cause of its failure.

Mr. EATON HODGKINSON conceived, that there must always be a sinking of the rail, from the soft nature of the timber, and the inadequacy of the bearing surface, and that the cross-bolts would do but little towards the general support. Account should also be taken of the alterations of form induced by the heavy weights rolling upon the rails.

Major-General Sir C. W. PASLEY considered the bridge-rail superior to the T rail, as it dispensed with chairs, which he believed to have been, to some extent, the cause of all railway accidents. Now as no accident had occurred on the Great Western Railway, from an engine having gone off, on account of a displaced rail, those which had happened on that line could always be accounted for; whereas on other lines, the chairs were broken, and there were often no means of ascertaining the cause of the disaster. Of the lines on which chairs were used, the best were those made by Mr.

Cubitt and Mr. Hawkshaw, in which the number of transverse sleepers had been increased; but the great point, in his opinion, was to get rid of chairs altogether, and if, from the first, wood had been employed for bearings, cast-iron chairs would never have been introduced. He was decidedly in favour of longitudinal bearings, notwithstanding that transverse sleepers afforded superior facilities for drainage.

Mr. HAWKSHAW said, although the plan might not present such superiority as to induce its general adoption, or the discarding of other systems, yet it possessed certain advantages. A portion had been laid down on a line which had some of the heaviest traffic in the kingdom, and the joints were as perfect as they could be, unless the rails were welded together. The object was to obtain uniform deflection throughout the whole of the rails, including the joints, providing at the same time for the contraction and expansion. If the part referred to remained until the end of the summer, in its present state, he should be satisfied that it would succeed, and he should lay down more on the same system. He had laid down a road for some distance on Sir John Macneill's plan, and the expense of maintaining it was found to be double that of repairing the other. He did not think the Dublin and Drogheda Line was a fair test of the system, as that railway had only been open since 1845, and the traffic on it was very light. He considered Mr. Samuel's proposal of fishing the joint of the double-headed rail well worthy of adoption, but he did not concur in the remainder of his views.

May 15, 1849.

JOSHUA FIELD, President, in the Chair.

The discussion upon the Paper, No. 805, "Description of the Permanent Way of the Lancashire and Yorkshire Railway, &c.," by Mr. J. Hawkshaw, being renewed, was extended to such a length as to preclude the reading of any other communication.

May 22, 1849.

On this evening, a Conversazione was given by the President to the Members and a large number of visitors; on which occasion, an interesting collection of Models of Engineering Construction and specimens of Works of Art, was exhibited in the rooms of the Institution.
