Sir CHARLES FOX, remarked that, the great advantage of this mode of construction consisted in being able to frame it complete at the manufactory, to mark and take it to pieces, so as to obviate the necessity for sending skilled workmen for its erection in its place, as this could then be effected by ordinary labourers. Notwithstanding the convenience of erecting this kind of girder, he should prefer one with a continuous web of plate iron, when placed in a position exposed to accident, such as a carriage getting off the line, as he thought it would bear a blow with less danger of being destroyed. The proper sizes for the top and bottom tables of a girder could be calculated with precision, but the best mode of forming the connection between them was a matter for further investigation and experiment; at present, he was disposed to prefer it being done by a continuous web without perforations.

Mr. BIDDER, V.P., considered that the question for discussion was, the relative advantages of the Warren girder, as compared with girders constructed on other principles. Now he was prepared to maintain, that however well made this particular bridge might be, this form of girder was certainly not superior, nor even equal, to an ordinary tubular beam. The theory of the girder was now well understood. The forces applicable to the two systems were identical, and the whole question resolved itself into what was the most convenient and economical mode of filling in between the top and bottom tables. He thought the sides of the tubular girder, as well as forming the connection between the top and bottom, contributed to the stability of the bridge; and that if the separate plates were well riveted together, each side might be taken as one entire plate. With the Warren girder, the failure of one piece would hazard the destruction of the whole bridge; and an accident like that which occurred to the tubular girder at Ferry Bridge would have jeopardized the entire structure. Again, with a tubular beam, the bottom tube formed a platform, and added greatly to the stability and strength of the bridge.

He believed that the great number of bearings in the Warren girder must cause motion, and that the deflection, as stated, was double what it would have been with a tube. As to convenience of erecting by unskilled labour, he could conceive nothing easier than a tubular girder; the plates were all ready punched, there

could be no difficulty in assembling them, and they were in a convenient form to be transported. Where there was a series of openings, the tubular bridge, by its continuity over the piers, was certainly superior to any other.

As to the relative cost, this was a question of workmanship. He much doubted whether the parts of the Warren girder could be put together at a less rate than mere riveting, for great care and skill would be required in their adjustment. The Newark Dyke bridge had cost, he understood, £20 per ton, which, considering the price of iron at the time was quite as much as a tubular bridge would have cost.

Mr. VIGNOLES said, the Newark Dyke bridge was so successful, that it must be received as a practical illustration and elucidation of the soundness of the principle of the Warren girder. He thought the principles involved had opened up a new field for consideration; and that the profession was greatly indebted to the Author of the Paper, for affording an opportunity for testing them on a large scale, as well as for sending an account of the works to the Institution; also to Sir Charles Fox, as the Contractor for the works, and to Mr. C. H. Wild, for working out the dimensions of the several parts. As to the weight of this bridge, he believed, that by substituting wrought for cast iron, and altering the dimensions of some of the parts, other girders on the same principle might be made lighter.

Circumstances had necessitated his examining, in detail, the principles of the Warren girder, with a view of ascertaining its applicability for large spans. He had not adopted it, and he did not now recommend it; but still he thought it had merits. For Russia, or other cold climates, he considered it inapplicable, in consequence of its being partly composed of cast iron. In some hilly countries, where the means of internal communication were not good, it might be found useful, on account of the facility with which the separate parts could be transported. He had found much damage done to boiler plates, in transport, when the rivet-holes were punched beforehand, and a great deal of patching was required when they came to be used. He thought it had been admitted, that the strength of a tubular bridge was due to the top and bottom and not to the sides, which were chiefly for forming the connection. Where there

was more than one span, the advantage of continuity was certainly in favour of the tube. He hoped shortly to be able to show, that by other modes of connecting the top and bottom, he should be able to save one-half the weight of the tube, preserving, of course, equal strength.

CAPTAIN W. S. MOORSOM coincided in the remarks which had been made, as to the number of points of connection that must always exist, and the nicety of adaptation that would always be required, in beams of the kind under discussion. In his opinion, if the lattice system had been used, the cost would have been less, whilst the security would have been greater.

Mr. R. STEPHENSON, M.P., V.P., would be glad to offer a few remarks on some points not touched upon by preceding speakers. Treating the girders of the Newark Dyke bridge as ordinary beams, there would be little difference of opinion, that the top resisted compression, and the bottom extension. The question then was, what were the comparative merits of the close sides of the tube, the open sides of this girder, and the openings of the lattice. In the close side of the tube no one part bore more than its neighbour; there was, in fact, a diffusion of pressure, whilst in a Warren girder there was a concentration of pressure He believed diffusion to be the best; others thought concentration the best. The plates of a tube formed an infinite number of ties, conveying the compressive forces of the top to the tensile forces of the bottom. The strains were the same in amount and direction in all kinds of beams, but they were more equally diffused in a tube. In a Warren girder, the tendency of the struts was to break in the centre; and in order to prevent that effect tension bars, or lateral ties, were applied at right angles. As the struts and ties were increased in number, the lattice form was arrived at, which he considered to be a good approach to a tube, but the material was not quite so well applied. If the apertures on each side the strut were filled in by plates, the strut was supported, and the materials were retained in the position where they could be most efficiently employed. He did not think the struts, in the Warren girder, were so placed as to derive the utmost advantage from the metal. The ties were equally good in all systems, but the struts were the dangerous points.

As to the comparative convenience and economy of putting tubes together and erecting Warren girders abroad, he believed the latter would require as much care in fitting, as the former would in riveting. He was about to send out four, or five boiler-makers to superintend the riveting of the tubes for the bridge over the Nile. The actual riveting would be done by the Arabs under their direction, and he felt convinced, that they would do it as well as they had already laid the permanent way of the railway. There could be no doubt, that the plates of a tubular bridge were more portable, than the cast-iron struts and ties of the Warren-girders.

Mr. EATON HODGKINSON remarked, that he doubted very much, whether by any system one-half the weight of metal at present used for tubular bridges could be dispensed with, provided the same strength was retained. He did not like riveting the bottom of a tube, as it lessened the power to resist tension very much. In some experiments which he had made for Mr. Fairbairn, and an account of which that gentleman had given in the Transactions of the British Association, common riveting gave, at the utmost, only $\frac{6}{10}$ths of the strength of the materials, when under tension. He preferred using wrought iron not riveted in the bottom, and adding cast iron to the top, as it was a good auxiliary to resist compression.

Mr. RENDEL,—President,—said, Mr. Eaton Hodgkinson's experiments had settled the question of the top and bottom sections, but there was still much to be considered. He had recommended the employment of Warren's girders in India, for spans under 80 feet, because they could be easily put together, as they required no riveting. They were to be made entirely of wrought iron, and in pieces of a size convenient to handle, in erecting, and easy of transport. Had tubular bridges been used for this span, the plates would have been so thin, that they would soon have been destroyed in that country, by corrosion, otherwise he should certainly have recommended them.

In concluding the business of the Session, the President expressed his regret, that the time at the disposal of the meeting had not permitted Mr. Henderson's Paper "On Ocean Steamers," nor Mr. J. Leslie's "On an Incline Plane for

Canals," to be entered upon, but they would be brought forward early next season.

May 31, 1856.

The Session was concluded by a Conversazione, at which the President received the Members of the Institution, and a large circle of distinguished visitors, when the rooms were profusely decorated by works of art, with a very good display of interesting mechanical models.
