derangement commenced, as described in Mr. James Walker's report, after the accident.

The chains for the bridge at Kieff in Russia, erecting by Mr. Vignoles, were manufactured on this new system; and the chains for lifting the Conway Tubes, as also those to be employed for the like purpose at the Britannia Bridge, over the Menai Straits, were made at Rotherhithe on this plan.

Mr. Howard exhibited a model of the bars used in forming the suspension chains of the Pesth Bridge, erected from the design of Mr. W. Tierney Clark. He had found no difficulty in bringing out the bars so accurately, that they were produced within half an inch of the necessary length, between the heads. Every bar was rolled within one-hundredth part of its required thickness, and when they were proved, not one out of the very large number was found defective; this was calculated to give Engineers great confidence in the soundness of the work they designed. The bars for the bridge at Kieff, now erecting under Mr. Vignoles, had been manufactured by Mr. Thorneycroft, under a licence from Mr. Howard.

Mr. Farey said, this process was a great improvement on the system of welding on the heads, which must be a bad plan, for any bars that required strength, as the fibrous texture which had been acquired by rolling, was necessarily injured by the heat necessary for welding. If the heat was only slight, so as to do the least injury to the fibrous quality of the iron, the weld would probably be defective, and if a good welding heat was obtained, the fibrous quality was certain to be destroyed; so that he thought the plan of avoiding the process of welding was of great importance, and it had been effected in a manner equally simple and ingenious.

Mr. Howard, in answer to questions from the President, explained, that wrought-iron rollers 5 feet in length were used for the purpose of forming the heads, to effect which, the bar, when at one-half its finished thickness, was offered transversely to the rollers, the middle part of which did not touch the bar at all; it was then passed longitudinally through plain rollers without grooves, and brought to its proper thickness and elongation, arrangements having been previously made for its exactly reaching the required length. The bars made in that manner for the Pesth Bridge, weighed from 5 cwt. to 7 cwt. each, and were each finished at one heat.

In answer to a question from Mr. Gregory, Mr. Howard stated, that the machine used was not powerful enough to test any of the bars to the breaking strain; they were occasionally proved up to

15 tons or 16 tons, but never beyond that tension. They were all proved to the extent of 9 tons to the square inch, although the actual strain they were intended to sustain would not exceed 6 tons per inch. The whole of the Austrian and Hungarian armies had lately unexpectedly passed over the bridge, and had imposed a load from one end to the other equal to a strain of 7½ tons per inch on the chains, and though the structure was not completed, no injury was received by it.

Mr. Croker said, that under Mr. W. Tierney Clark he had superintended great portions of the work at and for the Pesth Bridge. Before giving out the contract, many experiments were made on different qualities of iron, and that prepared by Mr. Howard's process was found to be the best. The desire to furnish so large a quantity of links at a comparatively low price, led to the adoption of Mr. Howard's ingenious method of rolling the bars, and it had proved most efficient. Each link, or bar, was made of the best scraps, faggoted; seven faggots, 1 inch in thickness, composed a pile 4 feet long; this was rolled to 6 feet, and was taken to the wrought-iron rollers with the bosses on them, which rolled the heads transversely, and the bar was then extended to the required length under plain longitudinal rollers, the whole process being completed at one heat, in about four minutes. After the bar was rolled, the eyes were bored, and it was then taken to a pair of shears, where the heads were pared round to the required shape. The bar was now subjected to a strain of 9 tons per square inch, by which the metal at the back of the hole was compressed. During the process of proving, a rod 10 feet long with steel points was used, to show the extension of the metal. The condition in the contract was, that every bar which showed any permanent set, when the strain was taken off, should be rejected, and with a magnifying glass, no difference could be detected in any one of them; the eyes were all also examined carefully, by means of a radius rod from the throat of the bar. As soon as the bars were proved, they were placed together in sets of ten and eleven alternately, and the eyes were bored through altogether, under a powerful boring-machine, to a diameter of exactly 4½ inches.

Each chain was composed of sets of links of ten and eleven bars alternately; the dimension of each bar was 12 feet, from centre to centre of the bolt-holes, varying in thickness from 1·25 inch at the summit, to 1·08 inch at the apex, and all of them were 10¼ inches wide. There were four chains, two on each side of the bridge, having a total sectional area at the summit, of 520 square inches, and at the apex, of 487 square inches. The span of the centre opening was 665 feet, and those of the two side openings were 297 feet each, and the versed sine, or deflection of the chain, was 47 feet 6 inches. The length of chain in the tunnel was 125 feet, and the platform was 45 feet wide over all. The coupling bolt was 4½ inches in diameter, with a square thread of ¼ inch pitch cut in each end for receiving a cast-iron nut. The dimensions of the links were definitely fixed, by experiment. The head was 7 inches deep behind the bolt, and 5½ inches on each side, which gave ½ an inch more of section in the metal of the head than in the body. It was doubtful which part would break first. One link, which was broken by a torsive strain, parted at 11 inches below the head. All the dimensions were arrived at by actual experiment, as well as by calculation.

The first experiments were made with a bolt 3½ inches in diameter, but when a load of 9 tons to the square inch of section of the bar, was laid on, the metal of the head of the link immediately behind the pin was found to be very much compressed; the object, therefore, of having a pin so much larger than was actually necessary, was to obviate that injurious tendency. It resulted also from the experiments, that more strength could be obtained in the head by enlarging the bolt. The proof load used was 9 tons per square inch, but this was often increased to 13 tons, in order to test the quality of the material used. The bolt-holes were ⅛th of an inch oval in front of the bolt, to admit of the chain being put together with facility.

Some links which had been hammered were found not so regular in the proof, as those rolled in the manner described, but not one single bar was rejected, out of upwards of five thousand supplied by Messrs. Howard and Ravenhill. On the retreat of the Hungarians across the river into Pesth, when they were immediately followed by the Austrians, seventy thousand men and three hundred and fifty pieces of artillery passed over the bridge in one day.

Mr. C. H. GREGORY remarked, that in the absence of a test up to the point of fracture, a larger area of section at the eye, beyond that shown by Mr. Howard, would have appeared desirable, on account of the disadvantageous way in which the pressure was applied; the tendency being to tear the iron, by giving a greater strain at the inner part of the eye, than at the outer part. For that reason, he conceived, that the head was not so strong as the other part of the bar.

Mr. CROKER said, that in the bars for the Pesth Bridge the pin was made three times as strong as was necessary for its own work, in order to avoid the compression of the metal at the back of the eye, which was inevitable in using a smaller pin. When the bridge was completed, there would be six rows of trussing, 10 feet deep, running longitudinally, to prevent oscillation, and undulation. When the army passed over, none of those had been erected, and the platform was only temporary, yet there was scarcely any prejudicial motion.

Mr. FIELD,—President—in answer to questions from Members, said, that a series of experiments had been made, before the Menai Bridge was built, the object of which was to ascertain the best dimensions of the pin, the head, and the body of the link. Those experiments were recorded in the account of the Menai Bridge published by Mr. Provis.*

Mr. HOCKING said, he was present at the making of the greater portion of the links for the Hungerford Suspension Bridge, which were manufactured at the Copper-house Foundry, Hayle, Cornwall, and having seen the majority of them tested, he could vouch for none of the welds having failed. Out of about twenty bars which were purposely broken in a machine, under a strain of about 24 tons per inch, only one gave way at the weld. The heads were all welded on to the bars at about 18 inches below the eyes; the bars were rolled 7 inches wide by 1 inch in thickness, and an additional thickness was given near the summit of the piers. Some of the eye-plates were rolled and some were hammered, yet little difference was found in their strength. Many experiments were tried, to ascertain the best size and shape for the eyes, and the result arrived at induced the adoption of dimensions, which gave rather more iron round the eyes, than the proportions shown in the model of the links of the Pesth Bridge. The pins were $4\frac{5}{8}$ inches in diameter, which was much larger in proportion than was shown in the model. Mr. Hocking was of opinion, that the size of the pins was a point of great importance. The two eyes of each link were drilled simultaneously under a machine constructed for the purpose, which only admitted one link at a time; extreme precision, in the distance between the centres, was, however, obtained.

In answer to a remark, that some of the eyes on the Hungerford Bridge were not accurately drilled, as they did not fit the pins closely, but might be shaken by the hand, Mr. Hocking observed, that no complaint of that kind had been made of them; that he was not cognizant of the fact, and should like to know by what means it was ascertained, that the links were loose on the pins. One of Mr. Brunel's assistants was present during the whole process, and he tested each bar as it was finished. As to the remark, that

* *Vide* "An Historical and Descriptive Account of the Suspension Bridge constructed over the Menai Strait," &c. By W. A. Provis. London, 1828.

changes of temperature in the links would prevent their being accurately drilled singly at both ends at the same time, he observed, that there was no difficulty experienced on that score, with the machine used on the occasion to which he had referred. In the heads which were purposely strained up to the breaking point, three fractures usually occurred, one at the back of the eye, opening at the periphery of the semicircular head, and one on each side, opening at the inner diameter of the eye.

Mr. Hocking was not aware of the comparative expense of the two modes of manufacture.

Mr. Croker, in answer to questions from Mr. Wyndham Harding, said, that by rubbing the head with chalk, before the strain was put on in proving the links, it could be seen how the pressure affected the head; the chalk being thrown off in small flakes, as the pressure extended. By making the bearing surface larger, at the back of the eye, the crushing effect of the pin upon the metal was counteracted.

Mr. Slate was of opinion, that the bars which had been hitherto made for suspension bridges, were generally too thin in proportion to their depth; and that the compression of the pin entirely destroying the elasticity of the iron, close to the back, there was then nothing left, except the strength of the outer rim, to sustain the weight of the bridge. He considered this to be a point which, unless closely watched, would be likely to escape observation. His experiments convinced him, that the pins were generally too small, in proportion to the size of the bars. He found, that when a strain of 9 tons per inch was arrived at, the pins were compressed much more than the iron of the bar; he had, therefore, substituted steel pins of a mild temper, and he found, that they were not compressed at all. He thought the idea, that iron, once compressed, would resist further compression, was quite erroneous. If the pin was pressed strongly against the inside of the eye, it destroyed the elasticity of the iron, immediately in contact with it, and by the extent of the compression virtually increased the diameter of the pin; the elastic metal still remaining around the eye being sufficient to bear the weight.

There were many interesting facts still to be elicited, with respect to the elasticity of cast and wrought iron, and the experiments he had made induced Mr. Slate to arrive at conclusions materially differing from those ordinarily received, and which he would soon lay before the Institution.

Mr. Howard showed, that the effect of the strain of the pin on the head, extended on either side, from the diameter of the eye, in a peculiar curve to the back, and increased in proportion to the strain applied. The metal within this curve was compressed, in proportion to the distance from the eye. In practice, he had advantageously used this to resist any change of length in the chain, and the eyes were cut away at the inner side to give them the oval form necessary for the convenience of putting together the sets of links; small pins had invariably been found more injurious than those of larger diameter. The compressed metal, of the interior of the eye, actually represented a collar of steel, which prevented a further amount of compression: this was very beneficial, as his experience showed, that wrought iron was more readily compressed than extended.

His opinion was, that up to the present time, the bars of suspension bridges had not been made with a proper proportion between the bearing surface on the pin and the sectional area of the bar, below the head; all the bars were, generally, stronger than the head.

Mr. Vignoles fully concurred in the propriety of increasing the diameter of the pin. In the bridge at Kieff, in Russia, now building under his direction, the chain of which had an area of 330 square inches and a span of 440 feet, between the points of suspension, he had adopted a link very similar to the one exhibited, only enlarging the sectional area of the head, and making the pin 5 inches in diameter instead of 4½ inches, and he was inclined to think it would have been improved by being made even still larger. The result of a series of experiments made at Messrs. Fox, Henderson & Co.'s works and of other subsequent trials, induced a conviction in his mind, that the form of the head might be still further modified, so as to assume more the shape of the link of a common chain than that which was generally given to it; for the head, as now made, was generally weaker than the main body of the chain. So strong was his feeling on this point that, before he proceeded with the erection of other bridges, for which he had made the designs, he should make other and more complete experiments to satisfy himself of the best form of disposing the iron in the link. At present, he was inclined to receive a modification of that form, now exhibited, as the best, only extending the principle by increasing the diameter of the pin, so as to augment the bearing surface at the back, and cutting away the inside of the eye in a triangular form. He thought Mr. Howard's method of manufacturing was not only ingenious, but a manifest improvement upon the ordinary mode of welding on the ends, as although the greatest care and skill might be and was exercised, yet there was always a risk of an unsound weld occurring.

Mr. Brunel said, that fifteen years ago, he made a series of experiments as to the best form of links for suspension bridges, and he arrived at the same general conclusions as Mr. Vignoles, with respect to the form of the head and the diameter of the pin; he thought, that anything less than two-thirds of the breadth of the bar for the diameter of the pin was too small; that proportion would give a pin larger than was shown on the model of the link of the Pesth Bridge. With a pin of which the diameter was two-thirds the breadth of the bar, and a moderate increase of strength of metal round the eye, he believed the strength of the head would be equal to that of the body of the bar. He was disposed to think, with Mr. Vignoles, that the strength of the eye would be increased, by cutting out a triangular piece at the inside. No part of the link must be strengthened so as to destroy equality of elasticity. He thought, that scarcely sufficient attention had been given to the proportions of the bar and the heads, or to the general propórtions, which should be calculated, so that the greatest load should not produce a pressure of above 5 tons, or 6 tons per square inch; and that the strain should be equally extended over the whole structure. The method of rolling the links was, no doubt, a great improvement, still he thought that, with moderate care, the welded links were equally strong, and he disagreed with Mr. Farey's opinion as to the injury to the metal in welding, for in his experiments on welded links, Mr. Brunel had found, that the welded portion of ironwork was fully as strong as the other parts. He must also contradict the assertion as to the ill fitting of the links of Hungerford Bridge; there might be an appearance of looseness, because he had adopted the plan of making the holes oval, so that the pins might be more easily passed through; but he was convinced, that there was no perceptible difference in the length of the links, as when they were erected there certainly was not a difference of one-fiftieth part of an inch in the length of any two of them. He had never seen, nor had he received any report of the rattling of the links on the pins.