Mr. MUNDAY, in answer to questions from the PRESIDENT, said he did not claim any originality in the design for the dams, but he had thought it desirable to lay the plan before the Institution, as a record of proceedings which he considered desirable to have in the archives, and in order to afford an opportunity of comparing it with other methods of effecting similar objects. The clay was sufficiently tenacious for all practical purposes, and it made excellent puddle; it did not materially differ from the London clay, and though the transition was often abrupt from clay to gravel, there were not any holes, or troughs of any importance, so that no extra length of piles was requisite. By caulking between the piles and the pipes, at the extremities of the dams, all leakage was prevented.

Mr. HACK stated, that the description was very accurate, the construction had been very carefully and speedily executed, and the work throughout was thoroughly good. When the contract was entered into, it was not presumed that the dams would have been so extensive, but it was found that more space would afford greater facility for laying the pipes, which required to be laid and jointed with more than ordinary care. The alternate couples of pipes were connected by turned spiggot and faucet joints, a length of 2 inches of the spiggot end being turned down, to permit the insertion into the socket of a collar of rolled lead soldered, and caulked up from the inside, after the joint was screwed up. The common socket joint used was about 6 inches in depth, grooved all round and run solid with lead. So expensive a mode would not have been pursued, if it had been positively known that the dams would have been so tight, and he now thought the turned and bored joints might have been dispensed with.

Mr. R. STEPHENSON, M.P., V.P., said the elliptical form given to the dams appeared to him to add to the difficulty of rendering them water-tight, as the piles could scarcely be so perfectly driven, as in straight lines; the form, under certain circumstances, might be stronger, but there was not sufficient depth of water to give any pressure requiring a curve to resist it.

Mr. MUNDAY explained, that an elliptical form was given to resist the pressure anticipated from freshes. No peculiar difficulties were experienced from the form, the length being great and the curve only slight. The gauge piles were driven first, and the intervening space then filled-in tight, and the whole were fastened by cramps; the only variation made was at the extreme ends, which were in fact more like two sides of a triangle, than a portion of an ellipse.

Mr. R. STEPHENSON, M.P., V.P., said he should be sorry, by his silence, to induce the belief of his admitting the assumed accession of strength from the elliptical form of the dam. The curve was too flat, and there was too little abutment, for that form to be of any use in resisting pressure; in fact, all the actual resistance proceeded from the individual strength of the piles, which, if they were properly driven, would amply suffice for all the pressure to which they were subjected in that position. He therefore objected to the elliptical form, as possessing inherent inconvenience, without any corresponding advantages. During his last visit to Canada, he had an opportunity of seeing a method of forming a coffer-dam, which possessed certain advantages for peculiar positions, such as that of the site of the Victoria Bridge, across the St. Lawrence, near Montreal. The bottom of that river was composed of hard trap rock, and the stratification being at an angle, with the ends of the beds protruding, considerable irregularities existed; there was some little gravel, but generally the rock was exposed and water-worn. The general depth of the water was 14 or 15 feet, and the velocity of the current being between four and five miles per hour, with, occasionally, masses of ice floating down, it was necessary to have a construction possessing great strength and stability, and yet capable of being removed to the sites of the several piers consecutively, as only a certain number of the foundations could be completed during each season. Mr. Hodges, the representative of Messrs. Peto, Brassey, Betts, and Jackson, on the Grand Trunk Railway, of Canada, therefore devised a system of excluding the water, by means of a dam of timber, framed together on the shore, and floated to the position where the pier was to be built. The apparatus consisted of two concentric dams of sheathing piles, leaving a space of 5 or 6 feet between the two dams, with bracing timbers and waling pieces, so arranged that the piles could be driven down, or drawn up, to suit the inequalities of the rocky bottom, upon which the lower ends of the timbers rested, when the whole was anchored and sunk by heavy weights, around the position of the pier. The sheathing piles being fitted to the bottom, the clay was filled in, and well rammed down between the sets of piles, the joints of which were tightly closed up. Although the clay only rested upon the bottom, the joint was so effective that comparatively small power sufficed to keep the interior quite dry. Another external ring of piles was placed in the same manner, at a distance of about 20 feet all round, to support the timbers and planks, forming a platform for the materials, &c., used in building the piers. When the masonry had arrived at a certain height above the water, the down-stream end, which was square, was detached, and the apparatus was floated away to the site of another pier.

Sir JOHN RENNIE was not aware of the previous use of any apparatus exactly similar to that described by Mr. Stephenson; it had, however, some analogy with the system introduced by

M. Poirel, at Algiers, where he formed masses of "béton" in cases 30 feet long, lined with canvas, which after the consolidation of the mass were removed to other positions.

In the construction of the sea-lock at Corpach, the western end of the Caledonian Canal, Mr. Telford employed a very ingenious and successful method: putting together the guide frames on the shore, driving temporary piles, boring through the sand and mud, jumping holes in the rock, to receive iron dowels projecting from the extremities of the main piles, and then driving down a double dam of sheathing piles, so as just to touch the rock, and excluding the water by means of clay puddle.[1] In these proceedings much careful consideration and great skill were displayed, as the difficulties of execution in deep water and a heavy sea, were not to be undervalued with impunity.

A coffer-dam had been also constructed in a somewhat similar manner, at the New Docks at Sunderland, from the designs of Mr. John Murray (M. Inst. C. E.), only there a large mass of clay was first deposited, and the piles being driven through it and tightly closed up, a very good dry enclosure was formed, when the interior was excavated.

Mr. HAWKSHAW said it would be interesting to ascertain whether any accurate investigations had been made, as to the contraction and expansion of mains of pipes underground; it was a subject of importance, as there were many miles of iron pipes laid with tight joints, without provision for movement of any kind. It was desirable to be assured, whether any motion did occur, and if so how it was compensated for, when the joints were run with lead and caulked tight. The question had been discussed with respect to railway bars riveted together, and also relative to the parapet of a viaduct similarly attached together,[2] and the inquiry should now be extended to pipes underground.

The PRESIDENT said it was now generally admitted, that there was considerable expansion and contraction in mains of iron pipes, unless they were laid very deep in the ground. In some papers left by his Father, he found a report on a main of large pipes, at Hyde Park Corner, wherein it was stated, that in consequence of their being laid in too shallow a trench, the positions of the flanges could be detected on the surface, during frosty weather; that several of the flanges were torn off, and that when the main was cut, the two portions receded from each other, giving decided evidence of being previously held in tension.

The President had seen evident traces of contraction in pipes laid with the ordinary socket joints, and on one occasion had counted seventeen distinct ridges in the lead of the joint, arising from the alternate contraction and expansion of the pipes; he

[1] *Vide* "Life of Telford," by Rickman, 4to, p. 305.

[2] *Vide* Minutes of Proceedings Inst. C. E., 1851-2, vol. xi., pp. 242, 283 and 287.

noticed that this occurred more especially under the pressure of a considerable head, and he believed that the best remedy was to have bored and turned joints, with thin narrow lead rings in front, which would permit a certain amount of motion, without admitting of any leakage.

From the evidence before the Committee of the House of Commons in 1821, on the Supply of Water to the Metropolis, it appeared that the socket joint originated in a broad iron collar being placed over the ends of two pipes, off which the flanges had been cut, the cavity being subsequently filled with lead and set-up. Prior to 1746 socket pipes had scarcely ever been used.

There was a natural hesitation in laying main pipes across and beneath the bed of a broad navigable river, and with such a pressure as 90 feet head, the President would rather have tried some other method; not because he doubted the perfection of the work, as now executed, but because it was impossible to foresee what changes might take place in the bed of the river from floods, or from excavations, or dredging, or from constructions above, or below, in which case the safety of the main might be endangered. The apprehension he entertained of the constant changes in the bed of the Thames, induced his determination to carry the new mains of the Chelsea Waterworks Company, across the river between Putney and Fulham, by means of an iron aqueduct supported upon Mitchell's screw piles.

In the well-known attempt to float into the river a length of 700 feet of jointed pipes, 36 inches in diameter, opposite the Chelsea Waterworks, the first trial failed, because, for want of the precaution of a few guide piles, the pipes could not be got into the trench which was prepared; that was, however, always a difficult task, in a tidal river, when the soil consisted of sand and gravel, which were easily washed into the trench by the force of the stream. On the second trial he used collar joints and was successful, only two joints having sprung.

Sir John Rennie mentioned a main of pipes, of 36 inches, or 39 inches diameter, which, under the direction of the late Mr. Rennie, were jointed on the shore and successfully floated out and laid in a trench, previously dredged to receive them.

It was remarkable, that socket pipes should not have been introduced earlier, when it was remembered, that one end of each of the ancient wooden pipes, bored out of trees, was diminished externally until it could be inserted into the orifice of the next pipe, which was made larger to receive it.

An attempt was made by the Grand Junction Waterworks Company to introduce bored stone pipes, with pozzuolana joints, but they were incapable of resisting the pressure, and the frost affected them very seriously; so they were soon abandoned.

Mr. Rawlinson said he had used all the three kinds of joints, the flange, the socket with lead collar, and the bored and turned spiggot and faucet; but if the degree of contraction, which had been mentioned, was to be encountered, he should be inclined to hesitate as to employing the latter, even although there was an economy of 25 per cent. as compared with lead joints. The only trouble they had given him was in curves, and he had been obliged to meet the difficulty of bends and branches, by giving them a larger diameter, from which he found great advantage in the flow of the water. At Lancaster, turned and bored joints were used, under the pressure of a head of 220 to 350 feet. The facility, as well as the economy of jointing these pipes must not be lost sight of, as a gang of men could lay three, or four times as many of them as of those with lead joints.

Mr. BEARDMORE said, that Mr. Leslie had used extensively, at Dundee, pipes with bored and turned joints, which sustained a pressure of 250 feet; and the joints of some of the pipes of the East London Waterworks, up to 6 inches diameter, were now ordinarily made with common cement composed of iron borings.

Mr. R. STEPHENSON, M.P., V.P., would recommend Mr. Rawlinson not to withdraw his confidence too hastily from the bored and turned joints. It was not correct to consider cast iron as a perfectly inflexible material; and if proper precautions were taken, in making the joints, bearing in mind the season at which the pipes were laid, it was practicable to provide against any movement. If the pipes were laid in the winter, allowance must be made for the end going deeper into the socket of the next pipe, when expansion from summer heat occurred; and on the other hand, if laid during hot weather the joints might be driven home, to permit an extent of contraction, without drawing out of the sockets. Expansion and contraction were not irresistible forces, and they might be provided for, by assuming iron, under a heavy force, to possess in a small degree the powers of extension and compression, so eminently exhibited by India-rubber, under a slight force, and also that a change of temperature of 15° would produce a pressure by expansion, equal to one ton per square inch. He would therefore prefer to lay pipes in the winter, and allow for expansion, when if the joints were originally well made, but little difficulty need be apprehended.

The PRESIDENT had laid more than a hundred miles of bored and turned pipes, and had even used Roman cement for the joints of pipes up to 12 inches diameter, without any difficulty, where due care was exercised. At Carlisle and at Manchester, pipes with bored and turned joints had been almost exclusively employed and no inconvenience had resulted; indeed, he used them in preference under all ordinary circumstances, because he found they induced an economy of nearly 50 per cent. on the cost of jointing.