Discussion.

Mr. ALFRED GILES, President, said when the importance of this subject was considered—the forging by hydraulic pressure of large masses of steel of dimensions which were not dreamed of twenty-five or thirty years ago—and when it was remembered how many shafts of steam-vessels had failed in consequence of their not being sufficiently amalgamated under the steam-hammer, it was evident how important was the subject brought by the Author before the Institution. He did not quite know whether the steam-hammer would be able to forge the immense shafts now required for the largest class of steamships, but he knew that they often produced a very inefficient forging. He thought that with the great squeeze of the hydraulic press a better amalgamation of the metal would be obtained in those large forgings than had ever been effected before. He hoped that members would join him in a cordial vote of thanks to the Author. Mr. Giles.

Mr. TWEDDELL said the Paper dealt with the subject from a historical, as well as a critical, point of view. The greater part of the work illustrated was not his own, but that of others, in which, however, he had taken great interest, and he had had, perhaps, opportunities in the last twenty years of learning more than many people were in a position to do on this subject. He wished to thank Messrs. Sir Joseph Whitworth & Co., Messrs. Walker, of Leeds, Mr. Davy, Messrs. Fielding and Platt, Messrs. Greenwood and Batley, and others for the free-handed way in which they had furnished information to enable him to place the Institution in possession of what he believed was the latest information on the subject. Mr. Tweddell.

Mr. A. TANNETT WALKER said the Author had not himself said, but had allowed somebody else to say, that the introduction of hydraulic forging was due to Mr. Gledhill, who for many years had been managing-director of the well-known firm of Sir Joseph Whitworth & Co. Mr. Walker would be the last person to detract from Mr. Gledhill's merits; great credit was due to him, and everyone had the greatest admiration and respect for the memory of the late Sir Joseph Whitworth; but he would like to associate one or two other names with those of Sir Joseph Whitworth and Mr. Gledhill. He would have liked a Mr. A. T. Walker.

Mr. A. T. Walker.

little more prominence to have been given to the work of Mr. Haswell, and also to that of Sir Henry Bessemer in that department. He would also like to associate with Sir Henry Bessemer the names of two celebrated steel makers—John Devonshire Ellis, and the late George Wilson. He would also mention the name of the late Benjamin Walker, who had done a great deal in connection with hydraulic forging. There was one sentence in the Paper to which he would take some exception, and that was Colonel Dyer's statement quoted, that, "Everything which has been done as regards hydraulic forging, both in England and abroad, is an imitation of the system which Mr. Gledhill perfected." Mr. Walker could not speak for other systems of presses, but he could for the system of presses with which his late father, his brother and he himself had been associated, and could state that their press was in no sense an imitation of the Whitworth press. He had never seen a Whitworth press or a drawing of it, nor had his father nor his brothers, so that it was hardly fair to say that their press was simply an imitation. It had been said by the Author, "Supposing the difficulty of obtaining a sufficiently strong cylinder of the required length to be overcome, the only remaining question is that of relieving the rams from undue strain." With this he entirely agreed. There had been a cylinder produced at the Atlas Works, Sheffield, in forged steel 43¼ inches in diameter, fitted with a leather, and having an 8-foot stroke. That would show that there was no difficulty in producing such heavy forgings. Reference had been made by the Author to a very large press being constructed—no doubt the one that had been made by Sir Joseph Whitworth and sent to America—but he had added, that it was not quite evident for what class of work such a pressure would be necessary. Mr. Walker believed that it was necessary. It was a thing that was advocated by his father for a good many years for the forging of very broad armour-plates. Captain Jaques, one of the managers of the Bethlehem Works in America, had told him that this press had been used for forging armour-plates, and that it could press a surface of 16 feet by 3 feet. Mr. Walker had always advocated the working of armour-plates under the press, and it was a well-known fact that a great many of the plates made by Messrs. Schneider & Co. in France were made very successfully under the press. That firm had been so impressed with the work that could be done by the press that they had decided to forge plates by means of a horizontal and a vertical press, and were at that moment constructing such a press on his firm's patent at Creusot, which would forge the plate horizontally

and vertically, and cut it off and get it ready for rolling. It might be interesting to know that small presses were at work successfully welding scrap-iron. It was done with the utmost ease. His firm had such a press which exerted a pressure of 150 tons. A dozen balls of the highest quality of scrap-iron, generally Low Moor and Staffordshire from boiler-plates, were put in piles of 12 to 14 inches into the furnace, brought out and placed one on the top of the other, and with about twelve squeezes of the press it was nobbled. It was put into the furnace again, and then drawn out for use in the smiths' shop in bars about 6 inches square and 6 feet long. That practice was carried out most successfully. He should say that one of the advantages in connection with the pumping-engine and accumulator was that they could be applied to the work of other things in the neighbourhood of the large press without putting down fresh plant, simply by increasing the lengths of the pipes. He had found a great advantage of press-work over hammer-work in that his firm manufactured an immense number of dies, and all sorts of work of cast-iron, and when they were no longer needed they were melted up. Another great advantage was that they could make all sorts of little corner tools and circular knives, by which they cut pieces into all sorts of shapes. To try to deal with a circular knife with the steam-hammer would knock it to pieces and destroy the forging which would get cold. The secrecy observed on the Continent in regard to the design and working of hydraulic forging-presses, even though manufactured in England, had sometimes given rise to comment. This was to a great extent very natural. A great many of those works had special ways of doing their own work, and they did not like people to come in and see how they did it. One of the reasons was that, he believed, in one case a manufacturer had made a press, say, for an English firm and then for a foreign firm. Now when the manufacturer went into the British works, and then went into the foreign works, it would not be quite right if he were to go and tell what he had seen in one works and another. It was, therefore, extremely difficult to give exact information on these subjects, and there was a certain degree of secrecy observed.

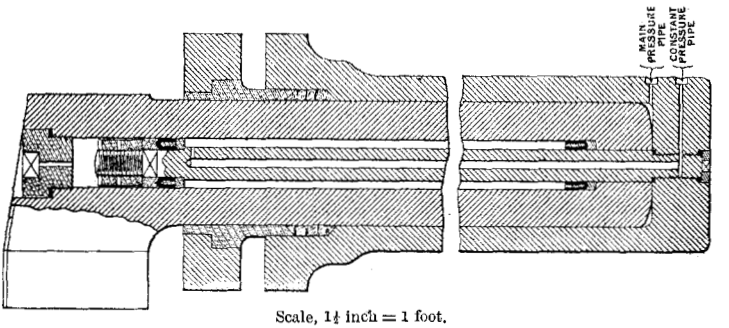
Mr. A. T. Walker.

Mr. E. W. MOIR wished to ask the Author what kind of packing he used for such very large rams. His experience at the Forth Bridge and at the Hudson River and Blackwall tunnels, where he had designed and used a great deal of hydraulic plant, had been that the old adage "There is nothing like leather" did not apply, and that tallowed hemp packing with an ordinary gland was very

Mr. Moir.

Mr. Moir. much more efficient and economical than any form of cup leather. In the forging-presses described in the Paper there was no difficulty in arranging a suitable form of draw-back cylinder or a return-stroke cylinder above the presses. A few years ago, as a Student, he had described the ordinary form of draw-back cylinder used on the Forth Bridge Works.[1] Such a draw-back arrangement as shown in *Fig. 12*, and as was used at the Forth Bridge, would have been impossible for use at the Blackwall Tunnel in the shield, where they could not have withdrawn the ram in order to replace the leathers at the bottom of the cylinders. With a view to getting a draw-back arrangement, which could be re-

Fig. 12.



Scale, 1½ inch = 1 foot.

HYDRAULIC JACK FOR TUNNELLING-SHIELD, BLACKWALL TUNNEL.

packed from without, he had designed the jack shown in *Fig. 12*. In that jack the ram was bored with a 3-inch hole, and in the centre there was a tube 2 inches in diameter screwed into the base of the cylinder. The tube fitted tightly in the base of the ram, and on it was slipped over the front end a leather to the bottom of the inside of the ram, and a little cross-hole was bored into its centre hole at the further end, beyond which was another small leather, facing the one at the back. High pressure water was admitted into the annular space round the small centre tube continuously, so that as soon as the water was allowed to escape from the lower side of the main ram, the constant pressure in the small annular space forced the large ram in. A brass cap

[1] Minutes of Proceedings Inst. C.E., vol. xci. p. 402.

was fitted in the ram-head, which could be removed from the front end, and two phosphor-bronze nuts retained the leather which was nearest the front in the jack. This could all be removed from without, and every leather could be replaced in the jack without the removal of the ram at all. Messrs. Tannett Walker had made these jacks of forged steel, and they had been most satisfactory. His excuse for mentioning the subject was that this form of draw-back was a novelty and might be of some interest in connection with the Paper. Mr. Moir

Mr. ALEXANDER MCDONNELL thought the most interesting point in connection with the Paper was not so much the construction of the press as the use of it. He had always thought engineers did not take sufficient trouble to make themselves thoroughly acquainted with the subject of forging, and that a great deal too much was left in the hands of the workmen, particularly the hammer-men who worked the large hammers. He remembered a case in which a man had the audacity to attempt to botch a stamping that he wanted to have made, and instead of carrying the work out as he was told, expressed the opinion that it could not be done. Mr. McDonnell had to stand for five or six hours over the stamping himself, and succeeded in getting it done. The funniest part of the whole thing was that a short time afterwards there was an Exhibition at Newcastle, to which this man sent the stamping, as an example of a very fine stamp-forging that he had been able to do. There were two or three things that were perhaps a little better done by the steam-hammer than by the press. He would on the whole prefer welding under the steam-hammer, though not altogether; and for the building up of a forging, such as he had drawn the attention of the Institution to some years ago, he thought upon the whole it could be better done by a quick sudden blow of the hammer that went right through the small forging than by the press. There was one thing that sometimes was very difficult to do with the hammer, and for which the press was decidedly superior, viz., punching out holes in a large core. It was extremely difficult to punch out a ring 5 or 6 inches deep with a hammer, but there was no difficulty in doing it with a press. Very often, on account of the difficulty of punching with the hammer, the piece was left solid and had to be drilled out. Of course if that drilling could be saved so much the better. There were many things in which 5 or 6 inches of metal could be punched out without any difficulty, and by that means a large quantity of drilling could be saved. Mr. McDonnell.

Mr. Whinfield. Mr. J. H. R. WHINFIELD believed the Paper was the first that had been read before the Institution in which the subject of the hydraulic forging-press had been so generally dealt with, and possibly a few years ago it would have provoked a very lively discussion. He thought all connected with the use of large ingots of steel admitted the necessity of the forging-press. With regard to the construction of the Whitworth press as shown, he would state that it was designed after a great deal of experience in connection with the manipulation of the heaviest class of forgings. Reference had been made to difficulties due to the size of the cylinder, and a cylinder of large dimensions had been mentioned. It might be interesting if he stated the dimensions of a cylinder recently sent to the United States in connection with a press that had been mentioned for the forging of armour-plates. That cylinder was 6 feet in diameter, it had a length of 9 feet 6 inches, and was made of forged steel, 77 tons in weight. The ram was 68 tons in weight, and the total weight of the press proper was over 1,000 tons. The press was intended, as had been said, for forging armour-plates. Referring to it, the Author had incidentally stated that he did not see exactly the use to which it could be put. Mr. Whinfield thought there was no doubt that the time had come when presses of that power would be required for the manufacture of modern armour-plates, and at the present time a duplicate press was being made for an English firm.

Sir Edward Harland. Sir EDWARD HARLAND said he was afraid when looking at an early portion of the Paper, that the great advocates of hydraulic forging were somehow or other losing sight of its great advantage, and seeming to think that for ordinary practical work the ordinary steam-hammer would be able to do the work as efficiently as the hydraulic press. It would be found, however, that subsequently in the Paper the Author had very clearly set forth what Sir Edward Harland held to be the great advantage of hydraulic presses, viz., that the action of the pressure was brought to bear upon the very centre of the mass; whereas in a hammer it was brought chiefly to bear on the surface — principally upon the surface next to the hammer, and next on the surface of the anvil — but the centre of the mass was scarcely approached, and it was on that particular point that the whole virtue of the hydraulic press appeared. For large forgings he should never think of attempting or even adopting any forging where the hammer was intended to be the operator. He looked upon forging by hydraulic pressure as quite as great an improvement upon the

hammer as the latter was upon the splendid old sledge-hammer forging of 100 years ago, which produced the magnificent anchors of those days in a way which always excited his wonder and admiration. He would also draw attention to the great improvement which this principle had brought about in riveting; he referred to hydraulic- or steam-riveting. A step in the same direction was arrived at by the use of heavy hammers as against the old-fashioned light riveting-hammers. In his early days, when first going into this class of work, he found that with the light riveting-hammer it was impossible to make good work; and dealing with perhaps exceptionally large pieces, he had found it necessary entirely to stop the use of the ordinary riveting-hammer, and the riveters were not permitted to use anything but the plying-hammer, a hammer twice the weight of a riveting-hammer. The effect of the blow from the heavy hammer was something in the direction of the effect of pressure by the hydraulic ram. It had the effect of setting up the centre of the rivet and so filling the hole, which was done even yet more efficiently by the hydraulic method, but which, as practical men knew, could not be applied in all parts of a structure. He therefore with very great pleasure offered his record of experience in the direction of the manipulation of iron and steel; and in all circumstances that, if possible, should be done by a steady pressure as opposed to concussion. He looked upon concussion as quite a mistake. If a solid cylinder of iron were placed under a hammer—for instance, cold iron—and the strokes of the hammer were brought to bear on the cylinder, it would be found that the upper surface next the hammer would become exfoliated and the lower portion slightly so also; but the centre of the cylinder would be scarcely affected or swelled by the stroke; whereas, if the same cylinder were placed under a hydraulic press and the pressure brought to bear on it, the curious fact was that neither end would be affected in the slightest, but the centre of the cylinder would become expanded—showing how perfect that method of application of power was for riveting or forging as compared with the blow of the hammer. The truth was, a great deal of the power in concussion was wasted; it passed away to the anvil or its foundations or injured the surface of the material, whereas the silent and unyielding pressure of hydraulic or similar power found its way to the centre of the mass and produced an effect of perfect combination of the parts vastly superior to any method of applying the hammer.

Sir Edward Harland.

Mr. Arthur D. Ellis wished to say a word for an old servant of

Mr. Ellis.

Mr. Ellis. the members of the Institution for the last fifty years, viz., the steam-hammer, without which he did not think Sir Edward Harland could hold, as he now did, the blue ribbon of the Atlantic. He had come to the meeting expecting to read an inscription for his own tombstone, but he was glad to find that inscription would be *non omnis moriar*. The fact was that the Author himself had admitted that hydraulic forging could not do everything. If hydraulic forging could not do everything, it was quite possible that the last word had not been said for the steam-hammer. It had been stated by the Author that the hydraulic press should be subsidiary to the steam-hammer, that the steam-hammer should do the work first and the hydraulic press should finish it. He was inclined to think that the Author had reversed the position of things, and with that humility which Mr. Ellis was quite ready to assume, he would prefer that the 4,000 or 5,000-ton press of which he spoke should prepare the large ingot—to be finished under their modest little 20-ton and 30-ton hammers, such as had been at work during the last twenty or thirty years. The 5,000-ton press was right for the big armour plates, gun-forgings, screw-shafts, &c., but when it came to general ordinary use in English works, such as locomotive crank-axles, he did not think anything would be found much better than the 10-ton or 20-ton hammer. It was a question of price to a certain extent; it was necessary to look at the commercial aspect of all these things, and when a man was laying down works for a particular class of manufacture, he had a certain amount of money to spend; and he was inclined to think that for a given sum of money, up to a certain limit, say £3,000 or £4,000, better work and more means of doing a variety of work could be obtained with the steam-hammer than with the hydraulic press. Certainly, as regards small work, more could be done for a certain amount of £. *s. d.* by putting up steam-hammers, and quite as good work, in many cases better, with the steam-hammer than with the press. It had been stated by Mr. Walker that when welding with the press he took out balls of iron, and with twelve squeezes could make the weld. If there was any advocate of Low Moor iron present, he thought he would state that with Low Moor iron it would be impossible to do that under a press, and that the hammer would do it more effectively and more quickly. He was speaking of Low Moor as a generic term, and the remark would apply to welding iron of a similar character to Low Moor. In reference to a statement by the Author that more work could be turned out by the press than by the steam-hammer in a given time, the largest

works for making plates in Scotland, to his knowledge, was one in the neighbourhood of Glasgow, where 100 tons of steel slabs per shift were made under a 12-ton hammer. He had never heard of any hydraulic forging-press turning out that quantity in an ordinary shift of eight to ten hours. It was said in the Paper, "Apart from this, the art of forging large masses has made distinct advances since the introduction of hydraulic pressure; for it was formerly impracticable to forge the hollow marine-shafts at present used, or to draw out gun-tubes or hoops on mandrils supported on suitable standards." He did not think that, in the course of the last five or ten years, at the outside limit, since these large hydraulic forging-presses had been made, all the large steel guns had been made that were in use in the British Army. Forges had made the guns, even under the 35-ton hammer, for years before the press was ever thought of; and he believed a gentleman present could tell of a Nasmyth hammer, put up very many years ago, that had been making coils for wrought-iron guns for he did not know how many years. There was nothing new in making large coils on mandrils under hydraulic forging-presses. It had been done, and quite as well, under the steam-hammer; and certainly there were many very large guns in which there was no hydraulic-forged work. He knew that the hydraulic-press was an excellent thing; but, at the same time, the steam-hammer was not dead. Mr. Ellis.

Sir EDWARD CARBUTT said he was naturally much in love with the steam-hammer, because he believed, without any egotism, he had made more tons of steam-hammers than any other individual in England during the time that he was engaged in their manufacture. He would not go into the argument which had been so ably dealt with by Sir Edward Harland as to what the steam-hammer could do and what the press would do; but he would give one illustration to show that the steam-hammer was still thought necessary by some gun makers. The United States Government had for some years had what they called a Gun Foundry Board in this country, finding out what was done, not only in England, but in France, Germany and Russia. They had ordered one of Sir Joseph Whitworth's presses, which he believed was at work, and to show that they thought they ought to have steam-hammers, they had put up the largest steam-hammer in the world, namely, one of 125 tons. The Americans were shrewd enough not to spend their money on such a large article as a 125-ton hammer unless there was some necessity for it. This, Sir Edward Carbutt.

Sir Edward Carbutt.

therefore, proved that there was still use for the steam-hammer—at any rate, that the manufacturers thought so, at the same time that there was use for the presses. The press as a practical tool owed its life to the steam-hammer. Many years ago he had made a hammer for Sir Joseph Whitworth, whose works were situated in the middle of the town of Manchester. Unfortunately there was in the neighbourhood a school, which was stated to be so seriously damaged by the noise and vibration of the steam-hammer that heavy compensation was claimed, and a long trial was the result. An endeavour was made to prevent the vibration, and a cofferdam was placed round the hammer, but that did not succeed. In the end, much attention had been directed to the hydraulic press, so that it was the steam-hammer that led to the introduction of the hydraulic press. If the steam-hammer had gone altogether, it might, therefore, still claim some credit. Great credit, of course, had been given to Sir Joseph Whitworth and his managing director for having been the first in the field, but there were several others working in the same direction. He believed that Messrs. Vickers of Sheffield and the late Mr. Benjamin Walker of Leeds were working on the same lines; but where Sir Joseph had contributed so much to the improvements achieved was in showing the way in which forgings could be manipulated. To Sir Edward Carbutt it was a revelation when he first saw the press at work, to observe the way in which the workmen, every one of whom was an ordinary mechanic—there was not even a single forgeman—manipulated the forgings, entirely owing to the mechanical arrangements which had been suggested by Sir Joseph Whitworth or Mr. Gledhill. That showed that what was mainly wanted was to get the mechanics to work, and that getting mechanics to work as they did, they were able to produce forgings cheaply and expeditiously. Some twenty years ago, he had made a 30-ton hammer for the Russian Government. He was then asked to design arrangements for turning the gun-forging under the hammer. The arrangement he carried out was a series of four winches with anchors for turning the forging round; but when several years later he saw Sir Joseph Whitworth's arrangements, he admitted their infinite superiority. He had had the opportunity of seeing every one of the large presses in this country, when a member of Lord Morley's Committee appointed to report on the re-organisation of the workshops of the War Department. The opinion he then came to, and which he now held, was that the hydraulic forging-press was far superior to the steam-hammer for producing sound steel forgings of large dimensions. He also considered that

forgings would be produced by the former machine at a cheaper rate and with less strain on the workmen. He had also seen the press similar to that of Messrs. Krupp while it was being built in the works of Tannett, Walker & Co., of Leeds. Iron and steel workers owed to Messrs. Walker a deep debt of gratitude for the ability displayed in improving the machinery used by them. Sir Edward Carbutt.

Mr. J. A. F. ASPINALL thought it would be desirable if the firms who manufactured locomotive crank-axles used presses more than they did at present. Unfortunately most crank-axles were made under the steam-hammer — probably 8- or 10-ton hammers — and they did not seem to get enough work upon them. He believed if the press were used more frequently the ingots from which crank-axles were forged might be made very much larger, their shape might be altered, and the work could be put upon the axle in a place where it was more wanted. It unfortunately happened, when an axle was underneath an engine, that the maximum amount of work came upon that portion where the least amount of work had been put on to it by the hammer. That was a kind of thing which he believed could be altered by using the press, if makers would pay attention to that particular subject. He thought the use of some form of press in connection with fluid metal would be found to be very much earlier than Sir Joseph Whitworth's time. Possibly he might have been the first to use it with regard to steel; but with regard to copper, a man of the name of Hollinrake took out one patent in 1818, and in 1819 a second patent, for applying pressure to copper ingots, and actually made use of it by means of lever-presses, and he also spoke of using "hydro-mechanical" power for the purpose. Coming down to a later date, the Broughton Copper Company, whose works were then owned by John Barton somewhere in the forties, constructed a press not unlike the one shown in *Fig. 5*, with a screw for bringing down the upper block and a hydraulic cylinder below, and with that the whole of their ingots of copper were compressed; curiously enough, that same press was doing all the work of that company at the present day. It was a curious old-fashioned press, but it had been there at work compressing fluid copper in the ingot form for about half a century. Mr. Aspinall.

Mr. E. B. ELLINGTON said it appeared to him that the question raised by the Paper was, as to the relative advantages of forging by hammering or pressing, rather than the question as to which was the better machine—the steam-hammer or the hydraulic press. He did not see, on the face of it, why steam should not be applied to a press. He understood from the Paper that it was actually Mr. Ellington.

Mr. Ellington. being done. It seemed, after all, to be simply a matter of practical convenience to make use of the hydraulic press, because a steam-cylinder would have to be of such a size that it would often be impracticable to use steam in that way. In the case of steel pressing was very much better for the material, and forging-presses would certainly come more and more into favour. A hydraulic press was no doubt much more convenient than a steam-press; but he would ask if the Author could give some more particular information as to how steam had been applied to the forging-press.

Mr. Wrightson. Mr. THOMAS WRIGHTSON congratulated the Author on his excellent Paper. He noticed an arithmetical comparison made between the static load and the dynamic load—comparing the static load of a press with the dynamic effect of a blow. Although many attempts had been made to compare those, he did not remember ever having seen one which was successful. He was afraid it would be an impossible thing to make any comparison between those two effects.

Mr. Duckham. Mr. F. E. DUCKHAM said the Author had mentioned the difficulty of keeping valves and joints tight when working with water under high pressure. He would ask whether he had used any other liquid than water? A few years ago Mr. Duckham had a similar difficulty in connection with some hydraulic machines in which he was interested, and he was recommended to use oil. He found the leakage by that means almost entirely overcome, and should think that in presses of the kind mentioned by the Author, where liquid had to be used over and over again, oil might be used advantageously, for its cost would be a matter of very little importance.

Mr. F. W. Walker. Mr. F. W. WALKER did not wish to say very much about the relative advantages of hammers and presses. With regard to the hammer, he thought the remarks of Sir Edward Harland most nearly described the aim of the manufacturers. The hammer, if large enough, undoubtedly did the work as well as the press; but that size was so altogether out of proportion that it was hardly fair to say so. If an iron billet 6 inches square was made under a 30-ton hammer, practically that iron billet was pressed; but if a steel ingot 6 feet square was put under a hammer with only 8 feet stroke, no stroke was got to begin with. Attention had been directed by the Author to the difficulty in that respect—that whereas when the forging was largest and they needed the greatest force, the smallest drop and therefore the least good was attained; and that was one of the greatest drawbacks about the hammer—

that when the most force was required it could not be got. When a smaller piece was being dealt with it could be got, but then it was too late to be of any good. Every one had noticed that a forging reduced under a very large hammer had the centre well forced out, whereas if the hammer was small in relation to the forging, the end was hammered concave, thus showing that the surface only had been affected. In work done under a press, the centre was well brought out, as by a very large hammer—thus showing that the work was done on the forging uniformly to the centre. With regard to welding Low Moor iron, Mr. Ellis must allow those who had been doing it for a long time had the right to say it could be done. Not only could his firm weld iron in their presses on the principle on which they welded their own iron, but they had welded Low Moor scrap under the instruction and guidance of the authorities of the Low Moor ironworks on exactly the same principle as it was done underneath the hammer, and with quite as satisfactory results. The late Mr. Krupp when in treaty with his firm for the manufacture of the press, said, when it was first submitted to him as to whether the forging-press was a good thing, "Yes, a forging-press is simply a very large hammer. It is your ingenious way of getting a very large hammer." He said, "The whole of my life I have been aiming at getting a large hammer; that is the largest hammer;" and he at once gave instructions to his people to go on putting up the forging-press. They had a press of 2,000 tons and one of 5,000 tons, and had added several smaller ones since. The next advantage in squeezing the material with the press was that they did away with the jars and shocks that they had under the hammer. That was where a large part of the economy was gained. In forging under the hammer, there was an enormous shock, but in the press there was none. The work could be carried out by four or five men, who could stand close to it—in fact, a lady in a muslin dress could stand close to it and incur no risk. The strain came on so nicely there were no jars which caused danger and necessitated the large porter bar and balance-weights which in its turn caused the number of men at the steam-hammer. One speaker had made a very good point about the difficulty of starting presses, when he said that they could not get the forgemen to work the steam-hammer; that the forgemen would not make the steam-hammer work properly. He did not think that forgemen ever did make presses work properly, because they had been brought up to work steam-hammers; therefore they could not be expected to unlearn all they knew and learn to work the press. The men who were

Mr. F. W. Walker.

Mr. F. W. Walker.

successful with presses were practically working them under the direction of mechanics without ordinary forgemen; and that was the only way they could be worked successfully.

Mr. Tweddell.

Mr. R. H. TWEDDELL, in reply to the discussion, said the work of Mr. Walker's father and others, and of Mr. Haswell was fully referred to in the Paper. His chief object in writing the Paper had been to investigate the whole facts of the case. The reference to Mr. Gledhill having emanated from Colonel Dyer, who was in the same line of business, had, he thought, a certain value of its own; but Mr. Walker might feel quite satisfied with his firm's share in the introduction of hydraulic forging. It was not very easy to invent, but it was more difficult to carry inventions into execution. The question of welding under hydraulic pressure was the rock upon which opponents of this system split. All that he could say was that he went to some works in Sheffield where crank-axles were made under the press, and out of many hundreds of those axles there had not been a single failure. They were made under a hydraulic press, but, oddly enough, the firm using it would not allow him to mention their names. He had also seen welding being done; he did not see whether it was Low Moor iron, but he had no reason to doubt it; and all that he could say was that he was perfectly certain that welding could be done under hydraulic pressure if everything was perfectly clean; but if people were working with dirty scrap, then the steam-hammer was useful. In reply to Mr. Ellis, his intention had been to convey to the Institution the idea that he considered the steam-hammer to be subsidiary to the press, and not as Mr. Ellis had put it. If the Paper had done nothing else, it had produced a very able and effective defence of the steam-hammer from one who well knew the subject. In answer to Mr. Moir's enquiry as to the packing employed, he could only say that his enquiries from different makers had necessarily reference to the general principle and effect of their presses; but he felt that it was hardly to be expected that he should ask engineers in the same branch of the profession as he was to give him details which, perhaps, they were not doing so well as, or, perhaps, might be doing better than he. At all events, he could not give any details with regard to the packing; some used leather and some hemp, and one firm said they used neither leather nor hemp. In reference to the draw-back gear shown by Mr. Moir, exactly the same arrangement might be found fully described and illustrated in Mr. Tweddell's Paper on Hydraulic Machine Tools.[1]

[1] Proceedings Inst. Mechanical Engineers, 1872, Plate 46, Fig. 12.

Mr. Tweddell.

As remarked by Mr. Whinfield, he fully believed that if the Paper had been read ten years ago, there would have been a lively discussion. He remembered being in that room when a Paper was read on fluid-compression, and the hydraulic press had a somewhat sceptical reception. The remarks of Sir Edward Harland were exceedingly valuable, and he had hit the nail or rather, the rivet, on the head. Mr. Tweddell had had some experience in closing rivets, and Sir Edward Harland's remarks would apply equally well to forgings.

He did not mean in the Paper to suggest that the hammer was equal to the forging-press. He wished to give an impartial account of both. It was no good when there was a new scheme brought out to run down every previous scheme. He believed there was room both for steam-hammers and hydraulic-presses, but it required a practical man to know when to stop using the steam-hammer; it had done good work in its day, and would continue to do a great deal more. In reference to the use of hydraulic pressure generally, it was much to be regretted that it could not be extended farther. If Sir Edward Harland, or any other enterprising shipbuilder, would give him *carte blanche* to rivet the steel of a ship it should be done, and it would be done some day, but naval constructors would have to alter the design of their ships. A few years ago he had said the same thing about marine boilers, and the boiler now was practically made to suit the riveter. With regard to Sir Edward Carbutt's remarks about the steam-hammer in America, he did not pretend to know why they put down that steam-hammer. He thought it was probably because they could not get a hydraulic press.

Sir Edward Carbutt.

Sir EDWARD CARBUTT said the hydraulic press was ordered the first.

Mr. Tweddell

Mr. TWEDDELL: And delivered the last. A question had been asked by Mr. Ellington as to how the steam forging-press would come out for size and convenience. Messrs. Massey had introduced such a press, but it was of a very moderate power. So far as he know, it was an attempt on the part of the steam-hammer maker to imitate the hydraulic hammer in its action. He did not think that it had been applied to pressure of any great amount, but it showed the tendency to substitute pressure for blow. He was afraid that he had not time to go fully into the subject of the comparison of the static pressure of the press with the dynamic effect of the hammer; otherwise he should have been very happy to have done so. There was really no comparison possible between the two. The question appeared regularly in the question columns

Mr. Tweddell. of the engineering papers, written by somebody to get information for nothing; but it was never answered, and never would be answered beyond a certain point. The fact was that the actions were entirely different. The steam-hammer had a long drop imparting a blow which went for a certain small distance into the forging. In the hydraulic press there was no blow at all, but there was a steady pressure going steadily into the forging for any desired distance, until the resistance equalled the power of the press. The element of time which thus came so prominently into the question was the chief factor. The comparison made by Mr. Davy was interesting, and the subject was dealt with in some other Papers that he had received from his friend Mr. Coleman Sellers, but practically it was not worth pursuing.

As to Mr. Duckham's reference to the use of a substitute for water, he knew of nothing that could be used but water, and he thought oil would be worse. He would rather have water with a little alcohol in it than oil.