

Mr. W. HEINKE, after describing the improvements he had introduced in diving apparatus, said, though divers required as much light as could be obtained, and attached but little importance to the brass slide; yet its utility was clearly proved at the Westminster Bridge works, where a diver accidentally broke his glass, by striking it against a spike in one of the piles. By immediately closing the valve, he was able to rise to the surface, scarcely wetted by the accident, whereas, with other descriptions of apparatus, he would, in all probability, have been drowned. The chances of accident had also been lessened, by the application of a double safety-cap to the ordinary hose screw, which it was almost impossible to break. It had the additional advantage of permitting, in a great measure, the valve at the back of the helmet to be dispensed with, which thus rendered it a loose helmet. Another improvement which had been effected in this apparatus, was the india-rubber band at the joints of the dress. In cold weather, the leather band formerly in use, became hard, and could not be depended on. There was also an arrangement for fixing on the weights, by means of which the diver could easily divest himself of them, when desirous of rising; and even if, by accident, he should not succeed, the closing of the valve, which was under his control, to the extent of two-thirds, would be sufficient to inflate the dress, and bring him to the surface immediately. He believed, that the diving apparatus had now been rendered almost perfect; and that by its aid, a man might work for four, or five hours, consecutively under water, with as much ease as in a workshop: this, indeed, was daily exemplified, at the Westminster Bridge works.

Mr. ALFRED GILES said, that he had successfully used this apparatus for some time, and he thought, that all its advantages had not been described. The old helmet and spencer were merely tied round the waist, and the water frequently got in, whereas, with this dress, the diver might turn a complete somersault, without fear of such an accident. He thought the front valve was of the greatest possible use, as it enabled the diver to regulate the escape of air, whereas in the old plan, with the escape-valve behind, the diver was entirely dependent on the perfect acting of the apparatus. During his experience, the dress of one of his divers became too much inflated, either by the pumpers working too fast, or by the valve behind getting out of order; the result was, that the diver rose to the surface, heels upwards. This could not have occurred with the front valve. It might be useful to know what was the expense of this apparatus, and of diving generally. The cost of a diving apparatus complete, including pumps, hose, and dress, was about £130, and the daily cost of working was £1 1s. to £1 10s. The art of diving was very quickly learnt, but all persons were not able to practise it, as many could not

support the increase of pressure. With an ordinary diver, the expense averaged about £8 per week, for four hours' work per day, including men to pump in air and to assist generally. He had seen the value of this dress, in the examination of the screws of steamers, so clearly demonstrated at Southampton, that he thought no screw-steamer ought to go to sea, without being furnished with an apparatus which was so easy of application. He thought, that the feet of the diver required more weights than were generally used, and that the weights on the shoulders being above the centre of gravity, tended very much to upset him, if any accident occurred.

Mr. SIEBE, jun., stated that in 1831, Mr. Siebe, sen., introduced the tube into the helmet, to bring air to the front of the face, and to prevent the breath from dimming the glasses : and it was not until 1832, that the valve was introduced, for which the credit was claimed by Mr. Heinke.

Mr. SIEBE, sen., thought the apparatus was well adapted for river operations, but at a depth of 100 feet, the pressure would be so great as almost to burst the dress. He recollected, that on one occasion, at Spithead, Mr. Deane rose so rapidly, that his helmet struck against the bottom of a vessel, and he was in great danger of being killed.

Mr. SIEBE, jun., added, that after that occurrence, the divers at the 'Royal George' preferred to trust to the signal-line for being drawn up. He did not consider there was any novelty in the manner of attaching the weights. The common valve allowed the air to enter but not to return, so that the air was retained in the dress ; and in cases of any accident to the pipe, fracture generally occurred above the water.

Mr. W. HEINKE remarked, that this valve was only used in extreme cases, when danger was imminent. At the Southampton Docks, the divers preferred to have the apparatus under their control, rather than to depend entirely on the signal-men. He repeated, that in the case of the Westminster Bridge works, if the diver had not been provided with this valve, he would probably have been drowned.

Mr. WEST thought, that both the valves were of the greatest service. With regard to the front valve, it was not supposed, that it was to be entirely shut, but it could be moderated, so as to prevent the diver rising too rapidly. The diver could use his own discretion, as the valve was entirely under his control. He also considered the back valve to be an excellent contrivance.

Mr. GIBBS had taken great interest in Deane's diving apparatus, when it was first introduced, and he was gratified at the improvements which it had since undergone, and the great perfection to which it had now been brought. He thought every contingency

that could happen to the diver, had been now provided for, so that diving operations could, henceforward, be carried on with facility and safety. He remembered, that Mr. Deane attached considerable value to the valve in front of the helmet, and he was rather surprised to hear a contrary opinion expressed, with regard to that portion of the arrangement. That valve he considered to be indispensable, inasmuch as by its means, the diver could regulate the speed at which he rose to the surface.

LIEUTENANT-GENERAL SIR CHARLES PASLEY said, he had had considerable experience with regard to diving operations, having received *carte blanche* from the Admiralty and the Board of Ordnance, and having been engaged for five successive summers, commencing with that of 1839, in operations against the wreck of the 'Royal George,' of which he effected the entire demolition and removal, during that period. In the summer of 1845, he also cleared away the remains of the wreck of the 'Edgar,' a 64-gun ship, which was blown up by accident, near St. Helen's, about the beginning of the last century, when every man on board perished. The Author of the Paper had collected with great industry and research, a number of important facts connected with diving. He had himself seen in an old edition of Vitruvius, published at Venice, some centuries ago, a drawing of a diver crossing the wet ditch of a fortress, with an air-pipe leading from his helmet to above the surface, but if air had not been supplied by other means, it would have been inoperative. For his own part, he believed Mr. Tracey would, with proper assistance, have succeeded in raising the 'Royal George,' but being an outfitter at Gosport, the Commissioned Officers of the Navy could not be employed under him. He could only have the aid of midshipmen and seamen, who would not attend to his directions; instead of working throughout the whole of every slack tide, so long as day-light permitted, they left off to take their meals, whenever it suited their convenience. The consequence was, that the apparatus failed, and Mr. Tracey himself was ruined. By permission of the Admiralty, Messrs. Deane, (Brothers,) and Mr. Edwards afterwards worked at the wreck of the 'Royal George,' from 1834 to 1836, and they succeeded in recovering a number of brass and iron guns, for which they received from the Board of Ordnance, half the value as salvage, but their operations were barely remunerative, on account of the upper decks having been eaten away by the worms, and the lower decks and hold being filled with stones and mud, whilst the hull itself was partially embedded in a shoal formed by the action of the tides. They therefore, at the end of three years, gave up further operations.

During the first two summers, Sir Charles Pasley had the assistance of two good divers, one of whom, Mr. George Hall, of Whit-

stable, he considered the best in England. In the following August, Mr. Hall's health failed, and he was obliged to return home, after having most faithfully and zealously performed his duty. From that period until both wrecks were cleared away, the diving was undertaken by volunteers from the Royal and the East India Company's Sappers and Miners, four and afterwards five of whom were daily employed during the summer months, from 1841 to 1845 inclusively. The divers were sometimes changed, but those who most distinguished themselves by their zeal and sagacity, were Corporals David Harris and Richard Jones. By the end of October 1844, the whole of the 'Royal George' had been removed: during the greater part of that month, it had been carefully swept over in every direction, so that no obstruction might be left, and on the return of the experimental squadron from a cruise, the Port-Admiral's flag-ship anchored over the spot where the wreck once lay. Sir Charles Pasley knew, however, that several guns still remained deeply buried in the mud; he therefore advised, that every summer, some petty officers and seamen of the gunnery ship 'Excellent,' should be trained, and when qualified, rated as divers, and he submitted a plan, drawn up from his own experience at Spithead, with rules for the extra pay which the men should receive, when actually employed. This plan, having been approved of by the Admiralty, was carried into effect the following year, when a number of volunteers from the 'Excellent,' in concert with the experienced military divers, worked at the wreck of the 'Edgar.' If therefore, a ship's anchor should, at any future time, be caught by the guns, there would always be naval divers at hand to raise them. He also suggested the desirability of having a diver on board every Admiral's and Commodore's flag-ship, and even in every line-of-battle ship.

As soon as he saw Siebe's diving apparatus, he considered it to be the safest and most convenient, and he never afterwards ordered any other. Mr. Hall always preferred working in his open dress of Deane's pattern: once, however, in examining the bottom of a line-of-battle ship that had run aground, he used Siebe's diving dress instead of his own, because he had to be hauled under the keel on his back. One of the military divers was annoyed at the clicking of the escape-valve of Mr. Siebe's dress, and he took it off: the consequence was, that the pipe burst, and the diver was nearly drowned before he could be hauled up. Sir Charles Pasley thought the double safety-cap joints useless: they required a spanner to undo them, and the ordinary joints could always be carefully examined, whenever the diver came up. Neither did he see any advantage in inflating the dress with air; he thought, on the contrary, that it might have the effect of driving the diver against some obstruction, and of seriously injuring him. With

regard to the pressure, he himself experienced no inconvenience from it when he went down at Spithead: and although he did not consider, that every strong healthy man was fit for a diver, yet he thought, that the pressure had no pernicious effects upon persons of certain constitutions. He added, that in the third year of the operations upon the 'Royal George,' a comparative trial was made of the water-tight diving apparatus of Mr. Siebe and that of Mr. Bethell, the former of which was screwed up round the diver's neck, just above his shoulders, the latter, round his body. Corporal Harris was equipped in Mr. Siebe's dress, in which he went down, plunging head foremost from the deck of the lighter, placed a charge on the wreck, in readiness for the voltaic battery, and came up again, before the other military diver, who was to go down in Mr. Bethell's dress, could be got ready. The Earl of Minto, First Lord of the Admiralty, was present at this trial, and fired the charge of powder, himself. Mr. Bethell's apparatus was sent back to the maker, as that of Mr. Siebe was considered decidedly preferable. The contrivances introduced by Mr. Heinke were ingenious, but they only rendered the apparatus more complicated, more expensive, and, he might also add, rather more dangerous.

Mr. W. HEINKE remarked, that his improvements did not add to the cost. With regard to the other objections, he could only say, that his apparatus had been in practical use at the Southampton Docks, and so valuable was it considered that he had had to adapt his improvements to the dresses of other makers, for the Dock Company. With the valve and the slide, he believed, that an accident would be almost impossible.

Mr. BIDDER, V.P., said, the historical portion of the Paper was so interesting, that it was highly desirable, that it should be strictly correct. Now he believed, that the wreck of the 'Boyne' was cleared away by Mr. Abbinett, who had been extensively engaged in similar undertakings: he might, however, have employed Mr. Deane in the operation.

SIR C. PASLEY remarked, that when he first met Mr. Abbinett and Mr. John Deane, he understood they were in partnership. He believed, that Mr. Abbinett employed divers to remove the wrecks, but that he was not actually a diver himself.

Mr. BIDDER, V.P., repeated that his statement was correct, for to his own knowledge, Mr. Abbinett had dived in Vigo Bay, as well as directed similar operations elsewhere.

Mr. BETHELL could add his testimony to the fact of Mr. Abbinett having dived previously to 1833, and before the operations on the 'Royal George.' He used one of Deane's diving apparatus. He believed the period to which Sir Charles Pasley referred, was 1839, or 1840.

He stated, that it was now twenty-three years since his attention had been directed to the subject of diving. At that time, he became interested, with others, in experiments for the recovery of property from submerged wrecks. As they did not prove successful, he was led to examine into the causes of failure, and the result was the suggestion on his part, of certain improvements in the apparatus. With respect to the history of diving apparatus generally, he might remark, that although many patents for diving dresses had been taken out previous to Mr. Deane's, they had all, more, or less, failed in their application, from the ignorance, at that time, of the true principles of Pneumatics and Hydrostatics. The great error consisted in the diver not being supplied with air of equal density with the water around him. It was somewhat singular, that the apparatus which was destined to effect this object, should have been originally invented by Mr. Deane, for the purpose of entering buildings on fire, and have been successfully used at the burning of Drury Lane Theatre. It consisted of a leather dress, supplied with air by a pair of bellows, which, however well it might answer against fire, could not sufficiently condense the air for operations under water. Some few years afterwards, in 1830, Mr. Deane became acquainted with Mr. Hall, of Whitstable, who had been engaged in operations with the diving bell, and who suggested, that this dress might be made available for diving purposes. By adapting to Mr. Deane's helmet, the pipes and force-pump, that were used for supplying air to the diving bell, the diver could be furnished with air of a density equal to the pressure of the water around him; and the, then, recent introduction of the Macintosh cloth, permitted the covering for the body of the diver to be made water-proof. In the first instance, a metal helmet was employed, of a form similar to the diving bell, and being open at the bottom, the air escaped from underneath. The diver was thus supplied with air of the same density as the water, at any particular point, and the pressure upon the lower part of his body was very slight indeed. So long as these essential conditions were attended to, a complete diving dress might be made in a variety of ways and with various materials. It was not essential to have a metal helmet; india-rubber cloth, he believed, would serve the purpose quite as well, for there was no strain upon the helmet, as the condensed air inside was equal to the pressure of water outside. It was sufficient, that the dress should be air-proof and water-proof. In like manner, diving-bells might be made of a mere framework of iron, or wood, with a bag of india-rubber cloth for a covering outside. It was not necessary, that a diving bell should be made of thick cast-iron, although, of course, it must be sufficiently weighted to sink it; but it might be constructed of almost any water-proof material. In the operations upon the 'Thetis,' one of

the water-tanks of the ship was used, and it made a very good diving bell: it was loaded with ballast iron, and the air was supplied by the pipes and pumps of the fire-engine.

Several accidents had, however, occurred with the open dress, and five, or six persons had lost their lives. For greater safety, he introduced, in 1835, a tightly-closed dress, which comprised a helmet of metal and a frock of air-proof cloth, connected by a metal belt to the trousers, which were also of air-proof cloth; and the whole was screwed together. The glasses were made to unscrew, and they were not fixed into the helmet, till the diver was quite ready to descend. The descent having been accomplished, the air was pumped through the india-rubber pipe, and was distributed round the glass in a thin stream, which prevented its becoming clouded by the breath of the diver, and enabled him to see clearly throughout all his operations. This arrangement he had found to answer very well. The respired air rose to the top of the helmet, and passing through a pipe, reached a lantern affixed to the side of the helmet, whence it escaped into the water. He had thought it desirable to have a lantern, because in working in the hold of a sunken ship, or at night, a strong light, burning at the side of the face of the diver, was of great advantage. A man required about one-sixth of a cubic foot of air per minute to support life, but the supply was equal to 20 cubic feet per minute, so that there was amply sufficient to keep the light burning. The dress being closed, the diver had the power of raising and lowering himself, on the same principle as a fish. When a fish wanted to rise, it expanded its air-bladder; in like manner, the diver, by stopping with his finger the escape of air, caused the dress to become inflated, and by this means, the ascent, or descent to any required point, as for instance, the sides of a ship, or a rock, was easily effected at will. In diving apparatus, it was most important, that the air-pumps should be sound, and capable of condensing air to a point rather beyond the pressure, at the depth at which the operations were intended to be carried on. It was also of the greatest consequence, that the air-pipes should be made very strong: the portion of the pipe next the surface, had to sustain the greatest pressure; at a depth of 200 feet, it was as much as 100 lbs. to the square inch; but lower down, the pipe was supported by the increased pressure of the water outside. Mr. Bethell's dresses had been sent to all parts of the world; to Egypt, to Smyrna, to Greece, to the East and West Indies, and to the pearl fisheries of Ceylon, and they had been used without hesitation, and with perfect safety, by persons who had never before seen a diving dress. He had been informed, that when it was used at Alexandria, the diver was not permitted to descend by a ladder, but he was thrown into the water to find his way to the bottom as best he could.

Notwithstanding the total want of experience and practice in the use of this dress, of which great numbers had been employed, he had not heard of a single loss of life.

In connection with the application of the diving dress to engineering purposes, he would call attention to an instrument which he had constructed, by means of which, objects could be discerned at the bottom of the sea, at a depth of from 50 to 100 feet. The clearness of the water was more important than the depth, for if it was at all muddy, the object would appear more, or less indistinct, as when seen through a fog; but in clear sea-water, if the bottom was lighted up, and the tube extended to below the level of the ripple of the water, the object was readily perceived. A lantern, which was supplied with air by a small pump, and from which the exhausted air escaped into the water, was first lowered by a rope to within a few feet of the bottom, and by means of the reflector at the top of the lantern, a strong light was thrown down. Then by means of a zinc tube 3 or 4 inches in diameter, and about 8 feet long, so as to reach below the ripple of the water, which was excluded by a piece of common glass at the lower end, when the water was moderately clear, the objects at the bottom became clearly discernible, and by allowing the boat to drift with the lantern, a complete survey of the bottom could be made. If the depth was very great, a telescope might be used to magnify the objects.

There was one interesting circumstance connected with the use of Mr. Bethell's diving apparatus, viz., that the foul air being carried off by the exit-pipe as described, the divers breathed only pure air of considerable density, which had the effect of elevating their spirits in a remarkable degree, and enabled them to work below with great ease, for five, or six hours at a time. Condensed air was, indeed, considered so beneficial to health, that a French physician at Nice, had applied it to the cure of diseases; the patients were placed in an air-tight room, and air was pumped in till it acquired the proper density.

He had already mentioned, that the experiments in which he was engaged for recovering property from wrecks had been, for the most part, unsuccessful. The great obstacle was, that in the majority of cases, a ship sank in a sandy, or in a muddy soil. The opposition which the sides of the ship offered to the tide, caused a bed to be cut underneath her, and she gradually sank until her decks were about level with the ground, when they became covered with a bed of sand, which there was no possibility of penetrating. This was the cause of failure with the 'Lutine' frigate, which went down with a million of gold on board: the futtocks were still standing, but it was found impossible to get into the hold. It was supposed, that the vast number of wrecks on the

Goodwin Sands, were not, in reality, covered with a greater thickness than about a foot of sand.

He would next direct attention to a plan he had introduced for repairing ships afloat. A cage of wrought-iron, jointed with friction rollers, was suspended against the sides of a ship; by means of ropes, it could be made to conform itself to the shape of the vessel, and in tropical regions, it acted as a protection against sharks.

Almost the first diving dress he sent out, was in 1836, to the Bahama Islands. In January 1837, H.M.S. 'Thunder,' striking upon a rock in the vicinity, sustained such severe injury, that she was run upon a sand-bank to prevent her foundering. It was almost decided to land her stores at Nassau, and break her up; but finding a diving apparatus at hand, the carpenter, by its aid, was enabled in twenty minutes, to repair the damage. The ship was got afloat again, and on its return to Portsmouth, it was admitted, that the repairs could not have been better executed in the dock-yard. As all were unfortunately aware, it was most difficult to move the Government authorities upon any scientific subject: but after this successful trial, the Admiralty ordered a few dresses, one of which was supplied to H.M.S. 'Wellesley.' In 1838, that vessel, in entering the harbour of Trincomalee, met with an accident similar to that which occurred, the year before, to the 'Thunder.' She was on the point of sinking, for she made water so fast, that it could not be kept under with the pumps, when the diving apparatus was rigged, and although the ship was in 20 fathoms water, twenty minutes were sufficient to stop the leak; she afterwards proceeded on her voyage to China, and was, he believed, still afloat.

The diving apparatus was capable of being successfully applied to engineering purposes, in the construction and repair of dock-walls and stone piers in clear water. The stones being previously fitted and numbered, they could be lowered, placed, and cemented with the greatest possible ease. Mr. Bethell then drew attention to a drawing of an apparatus, which was sent to Mr. Galloway, in 1839, to be used at Alexandria. It was decided to remove some rocks inside the harbour, by boring and blasting; the charges being ignited by means of the voltaic battery. The fractured pieces of rock were shackled with chains and suspended from a row-boat, which dropped them into deep water, out of the way of shipping. An ordinary ship's boat of 8 tons would, under these circumstances, be able to carry away 16 tons at a time, on account of the weight being under water.

He would now advert to a plan which he brought under the notice of this Institution eighteen years ago, and which had since been successfully adopted. In 1838, Sir Charles Pasley presented to the Institution, a Paper "On the Application of Bickford's

Fuses to Blasting under Water,"¹ which was read on the 10th of April, and in which that system was exclusively recommended. After the discussion, Mr. Bethell mentioned, that he had used the voltaic battery for the ignition of gunpowder under water, and that, so far as he knew, he was the first who had done so successfully. It had been previously attempted by Professor Babbage, on the works of the Great-Western Railway, but had failed. He attributed the success which had attended his own experiments, to his having read a description of the employment of the galvanic battery in America, by Professor Hare, who, up to that period, was the only person who had ignited gunpowder by that means, at any considerable distance. He remarked, that although Professor Hare succeeded, in dry weather, in igniting powder at a distance of 100 yards, yet on a wet day, he could not accomplish the discharge at a greater distance than 30 yards. It immediately struck Mr. Bethell, that this was owing to the wires not having a waterproof covering, the plan, at that period, being to insulate the wires with common cotton. He, therefore, covered the wires with india-rubber, and he found, that with Professor Daniell's battery, he could ignite gunpowder under water, at any distance. On mentioning that fact, he was requested by the President of the Institution, to furnish a Paper on the subject at the next Meeting. He did so on the 24th of April 1838, and exhibited the experiments before Colonel Pasley and other Officers of the Royal Engineers, who were present. In that Paper, he gave the following description of the process:—

"It is well known, that when two ends of copper wires, leading from the poles of the battery, are connected by a piece of platinum, or iron wire, the latter becomes red hot. To apply this method, the top of the tin canister which contains the charge, is fitted with two copper wires, about 6 inches long, passing through a piece of cork, and connected at their lower ends, by a piece of platinum, or iron wire. The canister being charged, the platinum, or iron wire, is pushed down into the middle of the charge, and the top of the canister cemented on with putty. The wires are well coated with a non-conducting medium, as a mixture of resin, wax, and tallow, or caoutchouc, excepting at their lower ends, where they are connected by the platinum, and at the upper, where they are to be connected with the two long copper wires which proceed to the battery. These connecting wires, covered with cotton thread, are coated with the caoutchouc varnish, and then tied together so as to form one rope; the diver having connected the wires of this rope with the wires of the canister, and uncoiled a sufficient length of rope, descends and deposits the canister in the wreck, or hole pre-

¹ *Vide* Minutes of Proceedings Ins. C.E., 1838, vol. i., p. 33.

pared for the blast, and returns to the surface. The other ends of the wire are then dipped into the mercury cups of the galvanic battery, and the platinum wire becoming instantly red-hot, the charge is exploded. There are not more than about 6 inches of the wire rope lost at each discharge.

"The security, certainty, and convenience, of this plan are evident. In quarries, any number of charges could be fired at the same instant, or in rapid succession; and this method possesses incalculable advantages over every other, for the Military Engineer, since any number of mines could be exploded, at the precise moment that is desired."¹

On the 16th of March, 1839, some experiments on firing gunpowder under water by the voltaic battery, were tried at the gunwharf at Chatham, under the direction of Colonel Pasley, and a report of the results was made to the Institution, in a Paper by Mr. F. Bramah, jun., and Mr. C. Manby, at the Meeting of the 19th of March. The concluding words of that Paper were: "It is not necessary to describe the preparation of the connecting wires, or the manner of discharging the battery, as they are exactly the same as those detailed in Mr. Bethell's Paper, read to the Institution, last Session."² To these experiments, he, of course, could not have the slightest objection: he had published the process in April 1838, it had been copied into many of the newspapers of the day, and he was anxious, that it should be employed. But he confessed he was considerably surprised to see, a short time afterwards, a long letter in the 'Times,' written, he believed, by an Officer of the Royal Engineers, describing the successful application by General Pasley, of the voltaic battery to the ignition of gunpowder under water. The letter began with a history of all that had been previously done, and after alluding to the experiments of Professor Hare, it completely passed over those made before the Institution of Civil Engineers, and ignored the improvements he had introduced into the invention.

While on the subject of the voltaic battery, he would just allude to the statement, that in blowing up the docks of Sebastopol, the whole of the charges of powder were not ignited. The failure had been attributed to the wires having been broken and soldered together again, by which the flow of the electric current was intercepted: but this explanation was entirely erroneous, for it was well known, that copper wire broken and joined again, formed a good conductor of electricity. The real cause, no doubt, was, that the water-proof covering of the wires at the joints had been neg-

¹ *Vide Minutes of Proceedings Inst. C.E., 1838, vol. i., p. 35.*

² *Vide M.S., O.C., No. 300, published in abstract in the Minutes of Proceedings Inst. C.E., 1839, vol. i., p. 50.*

lected, and thus the electric current was allowed to escape into the water, before reaching the powder. In using the voltaic battery for that purpose, either in water, or on land, it was most essential, that the wires employed should have a water-proof coating: like the wires of the submarine telegraphs, which unless perfectly insulated by gutta-percha, would be incapable of conveying messages across the sea.

In conclusion, he directed attention to a method he had introduced for raising wrecks, or heavy weights, where there was no rise of tide. The ordinary mode of raising a vessel, was to fasten to it at low-water, large barges, or pontoons, and as the tide rose, the ship was lifted, if of sufficient buoyancy; but where there was no rise of tide, it was a difficult undertaking. He proposed, therefore, in such cases, to pass chains from the wreck through pipes, in a hulk, or large ship, and to attach them to an apparatus similar to a hydraulic press, which could be fixed to a vessel, from which it could be worked. In the case of the 'Red Rover,' running between London and Margate, which sank off the Nore Light, and was rapidly settling in the sand, a great number of divers and lighters were employed, within thirty-six hours of her going down. The divers passed chains round the paddle shaft, through the hawse-pipes and rudder holes, and under the stern: they were then made fast to the lighters, and the operation was performed, just in time to get the sunken ship out of her bed. If it had required another tide, he had no doubt, that the attempt would have been unsuccessful.

SIR C. PASLEY altogether repudiated the notion, that his idea of the application of the voltaic battery to the purposes for which he had employed it, had arisen from having witnessed the discharge of a small quantity of gunpowder under water, during the exhibition of the experiments before the Institution, in 1838. His own experiments had been conducted at the public expense, he therefore neither took out a patent, nor asked any reward for his inventions and improvements, but he published them for the public benefit. He had not claimed either for himself, or for the Corps to which he belonged, any credit which was not fairly due, as he had always made a point of acknowledging the merits of those, by whose researches, or advice they had profited.

It appeared, that the invention of the open diving dress was generally ascribed to Mr. John Deane, known as the partner of Mr. Abbinett; Mr. Hall, of Whitstable, had also been named, but he had, actually, nothing to do with it. The real inventor was Mr. Charles Anthony Deane who, in November 1823, took out a patent for it, as a dress to be used for recovering goods from houses on fire, but it was not till many years afterwards, that, with the assistance of the capital of his younger Brother, Mr. John Deane, he brought it to perfection, and applied it to the recovery

of goods from sunken vessels. As the patentee, he obtained in May 1832, the permission of the Board of Admiralty to work at the wreck of the 'Royal George' for his own benefit; operations were, accordingly, carried on by him and his Brother, in partnership with Mr. William Edwards, of Whitstable, during the summers of 1834, 1835, and 1836. In consideration of the services rendered by Mr. C. A. Deane, as the inventor of an efficient diving apparatus, which facilitated the removal of the 'Royal George,' Sir Charles Pasley supported a petition which he made to the Board of Admiralty in May 1844, and which resulted in a gratuity of £500. A claim for a portion of the reward was put in by Mr. John Deane and Mr. Abbinett, who by this time had become partners, but it was not admitted.

His attention was first drawn to the applicability of the voltaic battery for the purposes of submarine explosion, from reading an account of the blowing up of a bridge in Russia by that means, in the presence of the Emperor, the particulars of which were given in the 'United Service Journal' of January 1840.¹ In 1837-38, he made a great many experiments upon the subject, and he thought it would be allowed, that he was the first to apply the voltaic battery to mining on a great scale. With regard to the different diving apparatus employed in the removal of the 'Royal George,' as soon as he heard of Mr. Bethell's, he gave it a fair trial: it had not the lantern attached, nor did he think that of any advantage. Though safer than the open dress, the great objection to it, was the screwing together of the dress at the waist, which occasioned great difficulty in fitting it on; and after trying both, he gave a decided preference to Siebe's. He considered, that the segmental neck-screw in Siebe's helmet did away with all difficulty, and rendered the apparatus the most perfect he had seen: Siebe's pumps also, were superior to those of other makers. Hall and the other expert Whitstable divers, preferred the open-helmet apparatus, in which they felt themselves perfectly safe, and although the water-tight apparatus was much safer for tyros, they depreciated it, probably, because the exclusive use of the former, would narrow the competition in their often lucrative art.

Mr. BETHELL remarked, that he would not contend about the relative advantages of his diving apparatus, as compared with others, but the question in which he was most interested was, to whom belonged the merit of the discovery of a perfect and certain mode of igniting gunpowder under water, by means of the galvanic battery. General Pasley saw the experiments at the Institution in April 1838, and it was most singular, that if he had already discovered the process, that he should not then have alluded to it.

¹ *Vide United Service Journal*, January, 1840, page 72.

Such being the case, there was good ground for complaint, that a letter should appear in the newspapers a year afterwards, which was totally silent upon the subject of the experiments performed at the Institution of Civil Engineers.

CAPTAIN SIR EDWARD BELCHER, R.N., said, that in December 1835, when fitting out the 'Terror' for one of the Polar voyages, he was introduced to Colonel Pasley, who then discussed the possibility of using the galvanic battery, for exploding gunpowder to disrupt the ice:—a plan which was carried out with complete success in 1852. Colonel Pasley then stated, that he was about to undertake some experiments upon the subject. He believed that, previously to that period, Lieutenant Peter Lecomte had fired gunpowder under water from a galvanic battery on board ship; and Colonel Pasley might possibly have seen, or heard of it.

Mr. VIGNOLES deprecated the revival of matters which had occurred eighteen years ago. He recollected, that prior to 1838, the question of discharging gunpowder under water, was introduced before the Royal Institution, and that Professor Daniell and others had their attention called to it; and he also recollected the discharge by the voltaic battery at the Institution of Civil Engineers, in 1838. He did not consider, that any one was open to reproach for repeating those experiments, a year afterwards, nor did it follow, that because General Pasley was present, that his idea of their applicability to practical purposes, originated from what he had then witnessed at the Institution.

He could bear testimony to the importance of the diving dress for engineering purposes, and its utility was demonstrated at Portland, where the water was clear, and where the apparatus was continually in use. He was glad to hear, that a helmet made of cloth, was quite as serviceable as one of metal, for he thought it would be found more convenient.

Mr. PEARSALL suggested, that insulation of the wires might be obtained by first heating them, and then coating them with sealing-wax. It was a simple but effectual mode, at least for temporary purposes, and was introduced, many years ago, by Professor Ritchie.

Mr. MALLET "believed, that the operations conducted by General Pasley upon the wreck of the 'Royal George,' first directed the attention of Engineers, in Great Britain at least, to the practical importance of the facilities given by galvanic firing, to blasting operations under water; and that hence, the merit of having thus practically brought those methods into use, unquestionably seemed to belong to that Officer. As respected any question of priority to the abstract discovery of the means of firing gunpowder by electricity, Mr. Mallet was rather surprised at hearing any discussion, inasmuch as Benjamin Franklin had fired gunpowder across the

River Delaware, sometime between 1730 and 1750, and by means perfectly analogous to those now employed.¹ The ignition was effected by him by means of frictional electricity; but there was no essential difference between electricity thus developed, or by means of the galvanic battery. The value of the latter for this purpose, consisted in the quantity and in the constancy of the force developed, which the beautiful arrangement of battery, due originally to the late Professor Daniell, had placed in our hands."

Mr. R. STEPHENSON, M.P.,—President,—remarked, that without doubt, a very considerable digression had been made from the subject under consideration, but it was not, perhaps, without interest. Nothing, in his opinion, had so much contributed to extend and facilitate marine engineering, as the invention of the diving dress. Mr. Bethell, Mr. Siebe, and Mr. Heinke might each, with justice claim the merit of the improvements they had effected, as might General Pasley, for the attention he had given to the subject, and for the skill he had manifested in the practical use of the voltaic battery, in the destruction of the wreck of the 'Royal George.' The claim to the priority of introduction could only be set at rest by reference to exact dates: his own impression was, that when this subject was brought before the Royal Institution, prior to the experiments at the Institution of Civil Engineers, the difficulties attending the firing of gunpowder under water, by means of the galvanic battery, were thought to be almost insuperable. The explosion effected by Franklin, by means of the electric spark, could not be considered as analogous to that by the battery.

SIR C. PASLEY said, that the first submerged vessel destroyed by gunpowder, was the ship 'Arethusa,' of Liverpool. This vessel was blown to pieces by Colour-Sergeant Harris of the Royal Sappers and Miners, under the direction of Major, (now Colonel Sir William,) Reid, in the harbour of Barbadoes, after the great storm of 1831. This was effected by the peculiar system practised by him and the Corps of Royal Engineers, and which had already, in 1827, been brought to a certain state of perfection. An account of this explosion was to be found in the 'United Service Journal,' in which, however, it was stated by mistake, that it had taken place in 1834. The description of the operation, was first published in the 'Professional Papers of the Corps of Royal Engineers.'² At the latter end of the year 1837, the then Lord Mayor of London obtained from the Master-General of the Ordnance, permission for General Pasley to direct the

¹ *Vide* Franklin's Memoirs; and Chambers' Dictionary of Arts and Sciences, (Art. Electricity,) published in 1780.

² *Vide* Professional Papers of the Corps of Royal Engineers, vol. ii., p. 36. London 1838.

operations of blowing up the brig 'William,' which had been sunk in Gravesend Reach. After an ineffectual attempt to weigh the wreck in the course of the winter, it was blown to pieces by a charge of 2,340 lbs. of powder. A similar charge blew to pieces the wreck of the schooner 'Glenmorgan,' sunk near the north shore of the Thames, opposite to Tilbury. The first of these great explosions took place on the 28th of May, and the second, on the 5th of June, 1838; but on the bottom being afterwards examined by divers, a portion of the bow of the brig 'William,' was found to be still standing in a compact mass, 8, or 10 feet above the bottom, and part of one side was also remaining. These were subsequently blown to pieces by seventeen small charges of 45 lbs. each, contained in 5 gallon tin oil-bottles, and fired by pieces of Bickford's fuzes, 6 feet long. These charges were prepared at Chatham, and daily sent over to Gravesend to two divers of Whitstable, who were hired for the occasion, and who, by the end of October, removed all the fragments of the wreck produced by these small explosions, until none remained of sufficient magnitude to entangle a ship's anchor.

In consequence of the success of these great explosions, he was induced to propose the entire demolition and removal of the wreck of the 'Royal George,' from the anchorage at Spithead; and this, after having tried numerous experiments with the voltaic battery, he undertook in the following year, with perfect confidence of success.

Mr. Bethell was in error in stating, that in Sir Charles Pasley's Paper, "On the Application of Bickford's Fuzes to Blasting under Water," which was read to the Institution, on the 10th of April 1835, that system was exclusively recommended. On the contrary, it was chiefly recommended for blasting in rock, with charges of a few ounces of powder, in shoal water. In the Thames, he never used it for charges of more than 45 lbs. of powder in tin bottles, and at Spithead, after at first employing it for small charges of 18, or 25 lbs., he gave it up on finding, that it might be dangerous when more divers than two were employed at the same time. Mr. Bethell had stated, that he was induced to try experiments with the voltaic battery, by reading the account of those made by Professor Hare in America. Those experiments were so interesting as to have attracted general attention, and General Pasley took the first opportunity of publicly acknowledging the merit due to Dr. Hare. With the view of attempting the use of voltaic electricity in blowing up the 'Royal George,' he procured a voltaic battery from Professor Daniell, and following the rules laid down by him and by Dr. Faraday whom he consulted, he found no difficulty in using the battery for firing gunpowder in dry soil, or in a pond near the barracks, but when, with conduct-

ing wires, 500 feet in length, he attempted to do so in the tides of the Medway, such a number of unforeseen difficulties occurred, that ultimate success at first seemed doubtful. It was only after four months of incessant experiments, at least a hundred of which were consecutively tried, that this important object was at last accomplished.

A reference to several articles in the 'United Service Journal,' would completely substantiate the statements he had made. The first was published in September 1838,¹ under the title, "Details of the recent Operations of blowing to pieces the Wreck of the Brig 'William,' and Schooner 'Glenmorgan,' sunk in the Thames in Gravesend Reach." These operations were not carried on with Bickford's fuzes, nor yet with the voltaic battery, but on a system which resulted from experiments made by himself and other Officers of the Royal Engineers, and which consisted merely of a leaden pipe, containing a small powder-hose, the upper end of the pipe being buoyed out of water. The second article occurred in the Number for October 1838,² in the 'Editor's Portfolio,' wherein were described the small explosions effected with Bickford's fuzes, as before-mentioned, on the brig 'William.' Then, in June 1839,³ an article was published, "Observations on Colonel Pasley's Operations in the removal of Wrecks by Subaqueous Explosions." Again, in August 1839,⁴ in the 'Editor's Portfolio,' the mode of igniting gunpowder under water by means of the voltaic battery, was stated to have been shown at the Engineer establishment at Chatham. In January,⁵ February,⁶ and March⁷ 1840, a series of articles were published on "Colonel Pasley's Operations at Spithead, with a view to the Demolition and Removal of the Wreck of the 'Royal George.'" These articles would show the regular progress of the introduction into his proceedings, of the use of the voltaic battery.

The following extract from the 'United Service Journal,' for January 1840, page 72, would confirm all that he had now advanced:—"Having thus described the results of the experiments tried by Colonel Pasley and the Officers and men under his command, at Chatham, we must now pointedly advert to what appears an error in the 'Civil Engineer and Architect's Journal' for August last, in which the merit of having led the way to these experimental investigations is ascribed to Mr.

¹ *Vide* United Service Journal, September, 1838, page 36.

² *Vide* *ibid.*, October, 1838, page 271.

³ *Vide* *ibid.*, June, 1839, page 183.

⁴ *Vide* *ibid.*, August, 1839, page 561.

⁵ *Vide* *ibid.*, January, 1840, page 72.

⁶ *Vide* *ibid.*, February, 1840, page 149.

⁷ *Vide* *ibid.*, March, 1840, page 319.

Bethell, who read a Paper on that subject before the Institution of Civil Engineers, accompanied by experiments, and reported in the same Journal for May 1838, (vol. i., p. 198.) We have ascertained from the best authority, that Colonel Pasley first began to try experiments, with a view to the firing of mines, with a private voltaic battery, in October 1837, assisted by Ensign R. B. Smith, of the East India Company's Engineers; that he officially applied for two voltaic batteries, in his annual demand of stores, forwarded to the Master-General and Board of Ordnance on the 21st of the same month, for the public service, and with a view to the instruction of the Officers and men under his command in the use of that instrument, for the purposes of military mining; and that he was led to this investigation, not by reading Dr. Hare's papers on the same subject, the first of which appeared in 'Silliman's American Journal of Science' for October 1831, and the last in the 'Transactions of the British Association' for 1836, (vol. v.), though that gentleman was undoubtedly the first to apply the voltaic battery to the blasting of rock, and the first author we have met with who suggested the idea of using it for blasting under water also, as well as for the purposes of military mining; but from having perused an article, which appeared in all the newspapers, some time in the autumn of 1837, stating that a wooden bridge had been blown to pieces by a Russian Officer, by the voltaic battery, in the presence of the Emperor Nicholas, some fragments of which had been thrown over His Imperial Majesty's head, and had killed and wounded two, or three soldiers. The knowledge of this incident was the immediate cause of attracting Colonel Pasley's attention to the subject now under discussion. . . . Mr. Bethell's Paper on the same subject was not read at that Institution, until a fortnight afterwards, viz., on the 24th of the same month, and therefore, Colonel Pasley was in no way indebted to that gentleman for the idea of using the voltaic battery for military purposes, and we must of course suppose, that the Editor of the very useful and able Journal alluded to, could never even have heard of Dr. Hare's well-authenticated proceedings in Pennsylvania in 1831, and in England in 1836, or he would not have ascribed to Mr. Bethell the merit which belongs to that distinguished American. In respect to Mr. Bethell's arrangements for firing gunpowder under water by the voltaic battery, they were not even exemplified by experiment at the Meeting alluded to, for no water was then used. They are precisely of the nature suited for a lecture-room, or for very short distances in still water; but we have great doubts whether they would be available in any British river, harbour, or roadstead, exposed to the action of the tides, even in a calm. If Mr. Bethell had actually 'blown off the decks of sunken vessels, in order to enable the divers to reach the cargo,' which is implied,

though not positively asserted, in the same Journal, the names of these vessels, and of some of the spectators present, together with the place and time, ought to have been stated ; otherwise, the opinion of the person who reported the substance of Mr. Bethell's Paper, or lecture, at the Institution of Civil Engineers, to the Editor of the Journal alluded to, goes for nothing."

Mr. BETHELL said, he had referred to the authentic Archives of the Institution and he had found, that in the discussion of the Paper, "On the application of Bickford's Fuzes to Blasting under Water," by Colonel, (now General Sir C. W.,) Pasley, read at the Meeting of April 10th, 1838, the General "stated, that he had been engaged for twenty years, in blasting under water, and considered the use of Mr. Bickford's fuzes superior to all other methods."¹ This paragraph would not appear to indicate, that the General was, at that period, conversant with the use of the voltaic battery, for the ignition of gunpowder under water. The General was present when Mr. Bethell described his method of proceeding, and with other Officers of the Royal Engineers, was again present at the next Meeting, April 17th, 1838, when the experiments were exhibited by Mr. Bethell; and it was a singular coincidence, that in the apparatus employed in 1839 by General Pasley, not only the same elements were used, but the same arrangement was followed;—Daniell's battery, with wires rendered water-proof, and a piece of fine platinum, or of soft iron wire, extended between the ends of the wires plunged into the charge of gunpowder. This arrangement, Mr. Bethell had considered peculiarly his own, and on reference to many Members who had been present at his early exposition of the facts, he found their impressions accorded with his own;—that until the exhibition before the Institution, on the evening of April 17th, 1838, a charge of gunpowder had never been publicly fired by the wires from a voltaic battery.

This was further confirmed by the record in the published Minutes of Proceedings of the Institution,² where it was stated by Mr. F. Bramah, jun., and Mr. C. Manby, (now Secretary Inst. C.E.), in an "Account of the Firing of Gunpowder under Water by the Voltaic Battery, at Chatham, March 16th, 1839, under the direction of Colonel Pasley," that "the wires in this experiment were of common copper bell-wire, about 1-16th of an inch in diameter. The voltaic battery used, was one of Professor Daniell's improved construction. The preparation of the conducting wires, and the manner of discharging the battery, appeared the same as described in Mr. Bethell's communication of last Session.

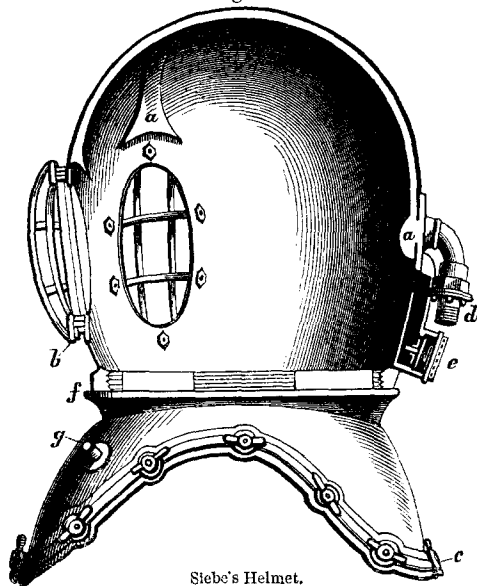
¹ *Vide* M.S. Minutes of Conversation, from January, 1837, to June, 1838, page 189.

² *Vide* Minutes of Proceedings Inst. C.E., 1839, vol. i., p. 50.

(See Minutes, April 24, 1838.)" Under these circumstances, he was not prepared for the apparent total exclusion of himself and the Institution of Civil Engineers, from all credit in the introduction of this important principle.

Mr. SIEBE, jun., through the SECRETARY, said, that about the year 1825, Mr. C. A. Deane took out a patent for an apparatus to recover property from houses on fire. As this did not meet with support from the fire-insurance offices, Mr. C. A. Deane turned his attention to diving; and, in conjunction with his Brother, Mr. J. Deane, tried some experiments on the Croydon Canal, with a canvas helmet and an ordinary pair of forge-bellows. These experiments proved so far successful as to satisfy them that diving was practicable, with proper means to supply the diver with air, &c. Accordingly, they had an air-pump and helmet constructed, but as they did not fully answer the purpose, Messrs. Deane applied to Mr. A. Siebe, who, in 1830, made others, which proved satisfactory. The helmet was what was termed an open one. The air entered by an elbow at the back, and was conducted, by means of the tubes, *a*, (Fig. 4.) to the diver's face, so that he at once inhaled

Fig. 4.



the fresh air, and, at the same time, the breath was prevented from condensing on the glasses. The foul air escaped from underneath the jacket attached to the helmet, on the same principle as the air escaped from a diving bell.

With this apparatus, Messrs. Deane undertook and executed several important diving operations. Amongst other experiments that were tried, was the introduction, in 1832, of a valve in the front of the collar of the helmet, by which the diver could regulate the exit of the foul air at pleasure. When the valve was closed, the air was retained, the dress expanded, and the diver rose to the surface. After several careful trials, Messrs. Deane came, however, to the conclusion, that the diver was safer with the air-pipe and signal-line in the care of an attendant, who could haul him up at a moment's notice; since, with the valve above alluded to, the diver was liable to get hurt, by rising up under the vessel, or boat, or by becoming entangled with the rigging of the wreck, or portions of the works upon which the operations were conducted. For these reasons, the use of the valve was discontinued.

As diving came into more general use, several accidents happened, through inexperienced divers not keeping themselves in a proper position, when using the open helmet. In consequence of this, Mr. A. Siebe, in 1837, introduced the close helmet, and at the same time, Mr. G. Edwards (M. Inst. C. E.), proposed one nearly similar. Although personally acquainted with each other, it was not until both had perfected the idea, that they found they had been working to attain the same object.

The close helmet, as represented in Fig. 4, consisted of a front glass, *b*,¹ which could be unscrewed, to enable the diver to take refreshment, or to give orders, without removing any other portion of the dress. The dress was fastened to the helmet by means of the flanges, *c*, pressed together with screws and wing-nuts. The air entered at the back, as in an open helmet. There was an entrance valve, *d*, screwed on the elbow: this allowed the air to enter the helmet, but prevented its return. If the pipe should burst, the diver had plenty of time to come to the surface. The outlet valve, *e*, allowed the foul air to escape, and prevented the entrance of the water. The valve-spindle was immediately closed on the least cessation of the supply of air, by means of a spiral spring, as well as by the pressure of the water. The valve being slightly loaded, prevented the pressure of the water acting on the body of the diver, in consequence of the internal pressure being greater than the external.

The close helmet did not come into general use until 1840. At this time, the apparatus employed by Major-General Sir C. Pasley, in his operations against the wreck of the 'Royal George,' not answering satisfactorily, a trial took place before the Lords of the Admiralty, with the ordinary apparatus, and with one made by Mr. A. Siebe. The diver, Corporal Harris, of the Royal Sappers

¹ This was introduced by Mr. A. Siebe in 1836.

and Miners, who used the improved apparatus, dressed, descended to the wreck, placed a charge of powder, and came up again, before the other diver had finished dressing. The superiority of this apparatus being thus proved, Mr. A. Siebe was appointed Diving Apparatus Manufacturer to Her Majesty's Government, and had continued to hold that office up to the present time. In the same year, during the operations against the 'Royal George,' the divers complained of the heat, whilst sitting with the helmet on. By the desire of Major-General Sir C. Pasley, Mr. A. Siebe introduced the segmental neck-screw, *f*, by means of which, the head of the helmet could be removed by an eighth of a turn. The head weights were attached to the stud, *g*, by means of sliding clips. The ropes of the back weights passed over two hooks on the head of the helmet, thus entirely preventing the head becoming unscrewed by accident.

The air-pump was also greatly improved by Mr. A. Siebe. The cylinders were surrounded by a cistern of water, supplied by a small pump, or by hand, thereby preventing the heating of the cylinders from the friction of the pistons. The supply of air was greater, in consequence of its being in a cool unexpanded state. The stench of the heated oil, which at certain times, was so great, that the diver could not bear it, was also avoided. A pressed leather cap was introduced in the pistons, and was kept in contact with the cylinders, by means of a spiral spring inside, so that if the other portion of the piston, (which was of solid leather), should not fit well, the cap was sure to do so. The solid portion was so arranged, that by screwing down a nut, the leather was made to expand, as much as it wore away. The valves were so disposed, that there was no recess in which the air could be compressed and re-expand into the cylinder, and thus cause a loss in the supply. The pressure obtained by this pump, was sixteen atmospheres, or 240 lbs. on the square inch; but it was thought capable of being worked up to twenty atmospheres. The depth already arrived at, was 150 feet, at which depth, eight men would be required at the pumps, working, alternately, in two gangs of four each.

Mr. R. STEPHENSON, M.P.,—President,—had permitted the discussion to diverge from the original Paper, on diving apparatus, because he felt, that the information introduced by General Pasley and Mr. Bethell could not fail to be interesting to the Members generally, and he was sure, that they would all feel greatly obliged to those gentlemen for the observations they had made.