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### On the Improvements in Diving Dresses and Other Apparatus for Working Under Water

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*Naval.*

Model of the Raft "Nancy," constructed and used at the capture of Taganrog. By Captain Cowper P. Coles, R.N.

2 Models of Rafts for shipping Horses.

Model of Mortar Raft.

Model of the first Life Boat.

*Presented by Captain Cowper P. Coles, R.N.*

*Presented by the Hon. J. T. Carnegie.*

*Miscellaneous.*

Clock Watch, time of James II.

*Lt.-Col. J. Percy Neville.*

One of the Iron Plates for holding-together grape shot, found in the open space in front of the Redan, Sevastopol.

*Presented by T. Longmore, Esq. Dep-Inspector-General of Hospitals.*

3 Medals in Bronze: viz., of Miss Nightingale, Victor Emanuel, and Lord Raglan, in case.

3 Ditto ditto, commemorative of the battles of the Alma, Inkerman, and Balaklava, in case.

1 Ditto ditto, commemorative of the fall of Sevastopol, in case.

*Presented by Mr. T. R. Pinches.*

Cast of the Statue of "Mars in Repose," the original in the Ludovisi Villa Museum at Rome.

*Presented by E. Jekyll, Esq. late Gr. Guards.*

## ON IMPROVEMENTS IN DIVING DRESSES AND OTHER APPARATUS FOR WORKING UNDER WATER.

By JOHN WILLIAM HEINKE, Assoc. Inst. C.E.

ALTHOUGH the invention of the diving bell has been generally assigned to the sixteenth century, yet there are evidences of others, although rude modes, having been adopted long anterior to that era. Beckmann, in 1770, quoted a passage from Aristotle (problem xxxii.) to show that the divers of his time used a sort of kettle to enable them to remain longer under water; but the inference drawn does not seem very clear. The renowned friar Roger Bacon, who flourished about 1250, has been considered by some to be the originator of the diving bell, or of some machine to facilitate working under water; but little credit can be attached to the tradition. The earliest mention of anything of the kind that can be depended upon is by John Taisner, who says he saw the experiment made by two Greeks at Toledo, in Spain, in 1538, before the Emperor Charles V., and ten thousand spectators. Gaspar Schott (Nürnberg, 1664) repeats the story, and calls the vessel an "aquatic kettle;" but prefers another apparatus which he designates "aquatic armour," that enabled those covered with it to walk under water. The plate accompanying the description represents a man walking in the water, with something like a small diving bell over his head.

In an edition of Vegetius, on "The Art of War," published in 1511, there is an engraving which represents a diver with a cap on his head, from which rises a long leather pipe, with an open end floating on the surface of the water.

Lorini, in his work on Fortification, published at Venice in 1609, gives a plate and a description of a diving apparatus, or chest, which he describes as "a square box bound with iron, furnished with windows, and has a stool affixed to it for the diver;" but he does not lay claim to the discovery, and seems to consider it as a machine already known.

Francis Kessler, of Oppenheim, in 1617, gave a description of a suit of water armour, which, however, Beckmann and others declared could not be used with safety.

About 1620, Cornelius Debrell contrived a submarine vessel, or boat, to be rowed and used under water. This was tried upon the Thames, by order of James I., and is said to have succeeded admirably; it carried 12 rowers, besides passengers. This vessel is mentioned by Robert Boyle, in his "New Experiments Physico-Mechanical," wherein he professes to give Debrell's secret from authority; he says, "the composition was a liquid that would speedily restore to the troubled air such a proportion of vital parts as would make it again, for a good while, fit for respiration." This novelty induced his Most Serene Highness Charles Landgrave of Hesse Cassel to have a diving vessel constructed for the same purpose; some years afterwards it was described (with a diagram) in the "Gentleman's Magazine."

The celebrated Lord Bacon, in his "Novum Organum," 1645, suggested a machine where the diver "stood upon a stool of 3 feet as a tripod, which was in length somewhat less than a man, so that the diver, when no longer able to contain his breath, could put his head into the vessel, and having breathed again, returned to his work."

Bishop Wilkins, in his "Mathematical Magic," 1648, proposes a machine "whose benefits shall be incalculable: 1st. Privacy, as a man may go to any part of the world invisible, without being discovered or prevented. 2nd. Safety, from the uncertainty of tides and tempests that vex the surface, from pirates, robbers, and ice, which so much endanger other voyages towards the poles. 3rd. It may be used to undermine and blow up a navy of enemies, or to relieve a blockaded place." His plans were, however, wholly theoretical.

In 1663, the Marquis of Worcester published the heads of his "Century of Inventions," the necessary directions for carrying out these projects having been lost, as it is stated in his observations on the title page. Proposal 9 is—"A ship destroying engine, portable in one's pocket, which may be carried and fastened on the inside of the greatest ship, and at any appointed minute, though a week after, either of day or night, it shall irrecoverably sink that ship." Proposal 10—"Away from a mile off, to dive and fasten a like engine to any ship, so as it may punctually work the same effect, either for time or execution." Proposal 11—"How to prevent both. How to prevent and safeguard any ship from such an attempt by day or night."

In 1669 Borelli contrived a "vesica," or bladder, which was, in fact, a copper vessel two feet in diameter, with glass fixed before the face of the wearer. This contained the diver's head, and was fixed to a goat-skin habit, exactly fitted to the shape of the body. He carried an air-pump by his side, by means of which he condensed or rarified the air in the vessel, and thus made himself heavier or lighter on the same prin-

ciple as fishes. Within this "vesica" there were pipes, by means of which a circulation of air was contrived; thus equipped, and with artificial webbing to the feet, to enable him to tread the water, the inventor supposed that he had overcome all difficulties hitherto known or objections to which such machines were liable. Hooke, in 1681, in his "Philosophical Collections," speaks of Borelli's apparatus, of which he gives a plate, as also of one which he claims to have himself constructed. This he describes as "another way of swimming under water, and breathing by the help of a leather pipe, kept open by wreathed wires, and extending from the diver's head to the top of the water." In 1678, a German named Sturm was enabled to make some further improvements in Borelli's apparatus, but neither seem to have answered the intention, or ever to have been used.

Mersennius, in his publication at Amsterdam in 1671, proposed a submarine boat, by which persons might pass from place to place under water, move it to and fro, and make it rise or sink in a river or sea; this project failed, however, like all its predecessors. Another proposal for a diving machine appears also in the same place and in the same year, from Nicolas Witsen; he describes his invention very explicitly, and gives instructions to the divers, as to its proper use and management, but there is not any account of its real utility or success.

The Duke of Argyle, among others, joined in the mania, and determined upon examining the wreck of a vessel sunk off the Isle of Mull in 1588, being, in fact, one of the Spanish Armada, and supposed to be richly laden. He engaged for the task a man named Colquhoun, of Glasgow, who went down several times, but merely surveyed the wreck as well as he could. The apparatus he employed seems to have been made after that suggested by Hooke, and consisted of a long pipe of leather by which the air was communicated, his head being covered with some sort of bell. In 1688 Sinclair, a professor in the university of Glasgow, published his principles of navigation, in which, in a postscript, he gives directions how to buoy up any ship of burden from the ground to the surface of the sea, and he speaks of the apparatus employed in searching the vessel as being similar to that which Colquhoun had previously used.

The most successful adventure of the period was undertaken by one Phipps, a ship's carpenter, the son of a blacksmith at Boston in America. He began to operate in 1687, with an apparatus, the character of which is now unknown, upon the wreck of a Spanish galleon lying off the coast of Hispaniola; but what he then recovered did not repay the outlay. Nothing daunted, he determined upon trying again, and assisted with money (though most usuriously) by the Duke of Albemarle, son of the well known General Monk, he eventually, but with much difficulty, rescued property of the value of nearly £300,000, of which sum he received about £20,000 for his own share. In other ventures he was equally successful. He was afterwards knighted, became sheriff of New England, and founded the present noble family represented by the Marquis of Normanby.

With the publication of a work by Pasch at Leipsig in 1700 the century closes. His plan was merely an alteration of others that had preceded, and was never probably tried with success.

The celebrated Dr. Edmund Halley, Secretary of the Royal Society, paid great attention to the subject for some years, and from his continued experiments, and the very different structure of his machine, he was considered as the inventor of the diving bell; that notion has, however, long been exploded.

In 1716 he read his paper entitled "The Art of Living under Water" before the Royal Society, and the following extract conveys his views. He says—

When there has been occasion to continue long at the bottom, some have contrived double flexible pipes to circulate air down into a cavity, enclosing the diver with armour, to bear off this pressure of the water, and give leave to his breast to dilate upon inspiration, the fresh air being forced down by one of the pipes with bellows or otherwise, and returning by the other of them not unlike an artery or vein. This has been found sufficient for small depths not exceeding twelve or fifteen feet, but when the depth surpasses three fathoms, experience teaches us that this method becomes impracticable; for, though the pipes and the rest of the apparatus may be contrived to perform their office duly, yet the water, its weight being now become considerable, does so closely embrace and clasp the limbs that are bare or covered with flexible covering, that it obstructs the circulation of the blood, and presses with so much force on all the junctures where the armour is made tight with leather skins or such like, that if there be the least defect in any of them the whole engine will instantly fill with water, endangering the life of the man below.

To remedy these inconveniences the diving-bell was next thought of.

He then describes his contrivance, which was a truncate cone of wood, containing 60 cubic feet in its concavity, the diameter at the top being 3 feet, and at the bottom 5 feet. In the top was placed a strong clear glass to give light, and a cock to let out the air that had been breathed. The machine was coated with lead and otherwise weighted, that it might sink steadily; when below it was supplied with air by two barrels of 36 gallons each, which were alternately lowered and raised, full and empty. In this instrument he says that he remained without inconvenience, wholly dressed, with all his clothes on, for one hour and a half at a depth of 10 fathoms.

He subsequently conceived a method by which the diver could leave and walk about some distance. This he also described to the Royal Society in 1721. He says—

I bethought myself how to enable the diver to go out of the bell to a considerable distance, and to stay a sufficient time without it, with full freedom to act as occasion served. . . . I procured pipes to be made which answered all that was hoped from them. They were secured against the pressure of the water by a spiral brass wire, which kept them open from end to end.

This appears to have been an adaptation of Hooke's apparatus, or of that used by Colquhoun. These tubes, of which the diameter of the cavity was about one-sixth of an inch,

were coated with thin glove-leather curiously sewed on, and then we dipped the leather into a mixture of oil and beeswax hot. Then we drew several folds of sheep's guts over them, which, when dry, we painted with a good coat of paint, and then secured the whole with another coat of leather, to keep them from fretting. The pipes, of which we made several, were about 40 feet long, the size of half an inch rope, the one end thereof being fixed in the bell, and the other fastened to a cock, which opened in the cap. . . . The diver, therefore, putting on his cap, and coiling his pipe on his arm, like a rope, as soon as he is discharged from the bell opens a cock and marches on the bottom

of the sea, seeing that the coils of his pipe are clear which serves as a guide to direct him back again, &c. The leaden caps were made to weigh half a hundred weight, to which I added a girdle of large weights of lead, of about the same weight in the whole, to be worn about the waist, and two clogs of lead for the feet of about 12lbs. each.

About the same time that Dr. Halley read his first paper to the Royal Society, in 1716, a person named John Lethbridge, of Newton Abbot, near Exeter, invented a machine which was made under his directions by a cooper in Stanhope Street, Clare Market, the particulars of which he published about thirty-three years afterwards in the Gentleman's Magazine. He thus describes it:—

It is made of wainscot, perfectly round, about 6 feet in length, about  $2\frac{1}{2}$  feet in diameter at the head, and about 18 inches diameter at the foot, and contains about 30 gallons. It is hooped with iron hoops without and within, to guard against pressure; there are two holes for the arms, and a glass about 4 inches diameter, and  $1\frac{1}{2}$  thick to look through, which is fixed in the bottom part, so as to be in a direct line with the eye; there are two air-holes upon the upper part, into one of which air is conveyed by a pair of bellows, both of which are stopped with plugs immediately before going down to the bottom. At the foot there is a hole to let out water; sometimes there is a large rope fixed to the back, or upper part, by which it is let down, and there is a line called the signal line by which the people above are directed what to do, and there is fixed a piece of timber as a guard for the glass. I go in with my feet foremost, and when my arms are got through the holes, then my head is put on, which is fastened with screws. It requires 5 cwt. to sink it, and taking 15 lbs. from it, it will buoy upon the surface of the water. I lie straight upon my breast all the time I am in the engine, which hath many times been more than 6 hours, being frequently refreshed upon the surface by a pair of bellows. I can move it about 12 feet square at the bottom, where I have stayed many times 34 minutes. I have been 10 fathoms deep many hundred times, and have been 12 fathoms, but with great difficulty.

Another claimant appeared nearly at the same time in the person of Nathaniel Symons, of Harburton, near Totnes. He produced a diving machine in the shape of a boat, in which, before many hundred persons, he sank himself in the river Dart, where he remained three-quarters of an hour, and then reappeared. He complains with evident disappointment that, "though a great number of gentlemen of worth were present, he received but one crown piece from them all."

In 1724 Jacob Leupold, of Leipzig, describes an apparatus then in vogue, but of which he does not claim the invention. Later still, Martin Triewald, military architect to Frederick, King of Sweden, greatly improved upon Halley's invention, by making a machine both lighter and less expensive. In the head of his apparatus, which was of tinned copper, and which was managed by two men, he used, in lieu of plain glass, convex lenses to admit the light. He published the particulars at Stockholm, in 1732, and the description was subsequently read before the Royal Society.

About 1750 a Mr. Rowe invented a diving machine for searching wrecks, which consisted of a hollow copper vessel of sufficient dimensions to contain the body of a man, with holes at the sides through which his arms protruded. At the end of the "engine" glasses were placed, through which he could see the objects of his search. The diver was lowered by a rope, and could remain below for half-an-hour without any difficulty.

A daring but unfortunate attempt to use a submarine vessel was made in 1774, by Mr. Day, in Plymouth Sound. So confident was he of success, that he had a small ordinary vessel prepared for the purpose according to his directions, and at the time appointed for making the experiment, all being ready, he sank the vessel and himself, in the presence of a great many spectators, but he never rose again.

In 1775 Mr. Spalding brought out an improvement upon both Dr. Halley and Triewald's apparatus, and was rewarded by the Society of Arts with twenty guineas; he was followed by Faurey, who rendered it still more complete and more applicable to the required purpose.

About the same time (1775) a Mr. Bushnell, of Connecticut, endeavoured to realise the project of Bishop Wilkins, and with the apparatus he constructed he offered the newly formed Republican Government of America to destroy the British shipping then lying in their different harbours and rivers; but, although he found it quite practicable to travel under water, he did not succeed in the rest of his design. His machine had a resemblance to two upper tortoise shells of equal size joined together, and it was capable of holding the operator with sufficient air to support him for thirty minutes. He could swim so close to the surface of the water as to approach unperceived very near any ship during the night. He could sink quickly at any depth he pleased, could rise to the surface for fresh air, and descend again at pleasure, as described in his publication of 1787.

This scheme was resuscitated in 1822 by Mr. Samuel Colt, who proposed to the Government of the United States to construct a machine which would effectually realise all that Bushnell had suggested. In order to test its utility, the Secretary of the Navy was instructed to render Mr. Colt every assistance and facility, and to appropriate 15,000 dollars for the purpose. A vessel was actually destroyed at some distance from the shore, but the means employed were not made public.

Benjamin Martin, originally a plough-boy in Surrey, but afterwards a celebrated optician and globe manufacturer in Fleet Street, published in 1778 a description of his diving apparatus. It consisted of strong leather, so prepared that no air could pass through it, fitted to his arms and legs, and had a glass window in the front part. This apparatus held half a hogshead of air, and when dressed in it he could walk on the ground at the bottom of the sea, or enter the cabin of a submerged ship and take out any valuables. He appears to have used this apparatus rather successfully. In his work he speaks of a machine for the same purpose by a gentleman in Devonshire: it is presumed that he alludes to Lethbridge's apparatus previously described.

Smeaton, in 1779, first employed the diving bell for civil engineering operations; it was used in repairing the bridge at Hexham, in Northumberland. The apparatus was an oblong wooden box, 4 feet high, 2 feet wide, and 3 feet 6 inches long. It was supplied with air by a pump fixed on the top. He afterwards constructed an improved apparatus, of which he made use in the construction of Ramsgate Harbour, in 1778. Mr. Rennie subsequently made great improvements in it, adapted it to local circumstances, and extensively used it at the works of Howth Harbour, near Dublin.

The apparatus designed by Mr. Kleingert, of Breslau, was first described in a pamphlet published in 1798. The harness, or armour, was made of strong tin plate, in the form of a cylinder, which inclosed the diver's head and body; it consisted of two parts, that he might easily get it on. Besides this, he had a jacket with short sleeves, and a pair of drawers of strong leather, water-tight, and joined by brass hoops round the metal on the outside, so that he was relieved from pressure on all parts except the legs and arms. With this apparatus, on the 24th of June, 1798, a man named Joachim under his direction, and before many spectators, dived and sawed through the trunk of a large tree at the bottom of the river Oder, near Breslau.

At this time there were many projects of analogous character, but none particularly worth notice, except that by Robert Fulton, who first introduced steam navigation on the rivers of America. At the close of the last century he made a submarine boat or chest, which he exhibited under the patronage and at the expense of the French Government on the Seine, at Havre and Rouen, and afterwards at New York and other places in America.

In the year 1786, Messrs. John and William Braithwaite were engaged in recovering the guns from the floating batteries which were sunk off Gibraltar; and they presented eight pieces of fine Spanish ordnance to the Emperor of Morocco. In the year 1789 and 1790, they successfully searched for and recovered all the dollars and a large quantity of tin and lead from on board the *Hartwell* East Indiaman, lost off Bonavista, Cape de Verd Islands. This was accomplished, in depths varying from 5 to 7 fathoms, by means of Mr. John Braithwaite's diving machine. On their return from Bonavista, they negotiated with the Government to commence operations on the *Royal George*, and they made all the necessary preparations. But, although the ship ostensibly belonged to the Admiralty, its guns were claimed by the Ordnance; hence difficulties arose between the Government departments, which induced Messrs. Braithwaite to relinquish their designs. From the wreck of the ship *Earl of Abergavenny*, outward-bound East Indiaman, of 1,300 tons burthen, they succeeded in recovering nearly all the cargo, and £75,000 in dollars. This vessel was lost in 1805, and after having laid under 10 fathoms water for 16 months, during which time many unsuccessful experiments were made by Mr. Tucker, Mr. John Braithwaite, by means of his peculiar diving machine (but which was not a diving bell), succeeded in raising the ship and cargo, amounting in value to many thousands of pounds. By this apparatus he was enabled to remain under water eight or ten hours at a time, and to conduct the various operations which were effected by machinery exclusively his own, and by the aid of gunpowder. The diving machine which he employed is now the property of his son, Mr. John Braithwaite (M. Inst. C.E.), who, with his brother, was present on several occasions to witness the operations.

The Plymouth Breakwater, for which many plans had been suggested, was commenced on the 12th of August, 1812, the first stones being deposited with much ceremony. In the progress of a work of such magnitude, extending over many years, and which, in fact, is scarcely yet completed, this mode of working below has been found of essential

service, and has been adopted wherever it has been necessary to have firm and substantial masonry constructed under water. At the works for the harbours of refuge at Dover and at Alderney it is extensively used by Mr. Walker.

But perhaps one of the most striking uses to which it has ever been applied was in the demolition of the wreck of the ill-fated *Royal George*, sunk off Spithead, in August, 1782. In less than a month after the accident several proposals were made for weighing her, and the proposition of Mr. Tracey was selected from those of 118 candidates. It was no easy undertaking, considering that the weight of the guns, stores, &c., on board, amounted to 1,031 tons, and that she had sunk 13 feet into a bed of silt, or blue clay. After a trial of three seasons, and an expense of £12,000, borne between the Government and Mr. Tracey, the project was abandoned. Thus matters rested until June, 1817, when Mr. Ansell, of the Portsmouth Dockyard, went down in a diving bell and surveyed the wreck, as far as was practicable, in a depth of water of 10 fathoms. Another respite of 17 years then took place. In the meantime, Mr. Deane, with an apparatus which was originally intended for the recovery of property from houses or factories while on fire, but which, having failed to obtain the patronage of the insurance offices, he applied to diving purposes, succeeded, in 1828, in clearing the wreck of the *Carnbrae Castle*, Indiaman, lost at the back of the Isle of Wight. He also operated upon the wreck of Her Majesty's ship *Boync*, burnt, at the latter part of last century, off South Sea Castle. He then offered to remove the wreck of the *Royal George*, and after some delay received permission to make the attempt. In 1834-5-6, having had more perfect apparatus made under his directions by Siebe, he was enabled to bring up 28 guns (of which 21 were of brass, and in good preservation), and also some other portions of the wreck.

His task being so far complete, he attempted, with success, to bring up the guns of the *Mary Rose*, which was lying not far from the other wreck. This vessel had been submerged for nearly 300 years, as she went down in July 1545, and its situation was only discovered in 1836 by some fishermen, whose nets had sustained injury from something protruding from the bottom of the sea. In 1836 he succeeded in raising twenty-five guns, five of which were of brass, and the other twenty of wrought iron. The brass guns bore date 1535, and the maker's names were Robert and John Owyn. The other guns were of peculiar construction, being manufactured of wrought iron bars, secured by thirty-three hoops;\* besides these, he brought up some iron and many granite shot, eight ancient bows,\* a number of miscellaneous articles, and part of the oak mainmast; the latter still in good preservation.

In 1839 the operations upon the *Royal George* were resumed under the direction of Colonel (now Lieutenant-General Sir C. W.) Pasley. It was determined, if possible, to clear the roadstead, although, at one time, doubts were entertained of the propriety of attempting it, unless it could be done so effectually as to entirely free the bank from all debris. The destruction of the remains by gunpowder having been resolved upon, cylinders were prepared, and being heavily charged, the first explosion

\* One of these guns, and a long bow, are in the Museum of the Institution.—Ed.

was reserved for and took place on the 29th of August, 1839, that being the fifty-seventh anniversary of the melancholy event. On the 20th of September, a charge of 260lbs. of powder was fired by the voltaic battery; and this is supposed to have been the first public practical adaptation of such means, although the applicability of the voltaic battery for such purposes had been previously demonstrated by Mr. J. Bethell (Assoc. Inst. C.E.) on the 24th of April, 1838, at the Institution of Civil Engineers. The effect was instantaneous, highly satisfactory, and grand beyond description. The surface of the water was immediately covered with dead fish and with fragments of all descriptions, curiously covered with seaweeds, and of richly tinted colours. During the season were recovered, among other things, five brass guns weighing 26,072lbs. (the value of which, as old metal, was estimated at £1,000), and seven iron guns.

In 1840 the Colonel again resumed operations, and with the same success; having an able assistant, as a diver, in Mr. George Hall, of Whitstable, with about eighty men, including Sappers and Miners. The apparatus employed was manufactured by Siebe, by whom several alterations, at Deane's suggestion, had been made in that previously used.

By the end of 1841 much valuable timber was rescued; indeed, between the months of May and November in that year, not less than 18,600 feet, or 372 loads of timber were brought up, and, being afterwards sold by public auction, great quantities were preserved as relics.

The season of 1842 was quite as satisfactory as those preceding, and in that of 1843, the harbour was finally cleared of all obstruction. The consumption of gunpowder during the operations was 52,963 pounds, and there were recovered no less than 581 cwt. 2 qrs. 14lbs. of various sorts of metal (exclusive of 86 guns), and 59,000 cubic feet of timber.

It may be remarked, as somewhat curious, that of all the money which must have been on board at the time of the catastrophe, when 1,200 persons went down, only two guineas were found. It is, moreover, satisfactory to know, that during the works no accident occurred, attended with loss of life or limb, although there were three or four narrow escapes. But perhaps the most singular incident is, that an actual fight took place below between two divers for the possession of some portion of the wreck claimed by both; in the scuffle the glasses of one helmet were broken, and the diver was nearly drowned before he could be rescued. Such an accident is now, in my apparatus, effectually provided against by helmet slides.

The operations against the wreck in question also resulted in great benefit to the practice of diving; the applicability of the apparatus having been tested in every possible manner. Many of the Sappers and Miners, both of the regular Army and of the East India Company, were fully initiated in the use of diving apparatus, and sailors from different vessels were also trained so as to be useful in cases of emergency.

In France there had been many efforts towards establishing the practicability of submarine boats, but the great difficulty was how to supply air to the men employed. Dr. Payerne however felt convinced, that it was practicable, by chemical means, to restore the purity of the air under water, without communication with the atmosphere. This experiment

was first tried in England at the Polytechnic Institution, and was repeated with success at Spithhead.

On the latter occasion the bell was accompanied by four cylinders, each four feet long and twelve inches in diameter, containing condensed air, which was forced into them by an air pump, and allowed, when required, to flow into the bell by turning a cock. Another experiment was made without cylinders; the end of one of the diver's air pipes was conducted into the bell, and air was forced through it by one of the small pumps ordinarily used for supplying air to a helmet diver. The water was kept out of the bell as well as under the ordinary system, and the respired air was renewed in a perfectly satisfactory manner. The result was approved by Lieutenant-General Sir C. W. Pasley and other scientific men, the air for respiration being perfectly good, and the whole apparatus for purifying it so compact and simple that it could be contained in a case not larger than a common portable desk, and it could be used without any trouble.

The helmet diving apparatus has now become of comparatively common use, for the repair of lock gates and other works under water. In the building of almost all docks, bridges, &c. of any extent, it is in constant use; and in examining accidents occurring to vessels, and more especially to the shafts of screw propellers, to rudders, &c., it has been very useful. It has been so constantly exhibited at the Polytechnic Institution and at the Panopticon, that it has become familiar to all.

Besides the various alterations and improvements already mentioned, there have been many others that deserve notice.

In 1835 Mr. J. Bethell introduced several important improvements in the form and use of diving apparatus.

In 1836 Mr. William Bush, of Bishopsgate, claimed the introduction of air pumps into diving bells, instead of pumping air down from above; the application of a pump to diving dresses, whereby the diver might supply himself with air from above, and the use of an air belt, combined with a diving dress, to facilitate the diver in rising and sinking. He also applied a compass to the helmet of the dress, in order that the diver might ascertain his position when below the water.

In 1836 Mr. Frazer made an improved escape valve and other additions to the dress.

In 1838 Mr. Thornthwaite, of Hoxton, produced a diving belt, for which he was rewarded with a silver medal by the Society of Arts, and his invention was ordered to be placed in their repository. His instrument consisted of a belt of India rubber cloth, to which was attached a small strong copper vessel; into this, air was forced by a condensing pump, until it had a pressure of between thirty and forty atmospheres. The belt being put on in a collapsed state, did not give any buoyancy, nor impede the diver in his descent. If he desired to rise, he opened a valve, by which the condensed air escaped from the metal vessel into the belt, and by its expansion enabled him to rise to the surface.

In the ordinary apparatus and helmet great alterations have been effected from time to time by the various makers. The improvements introduced by Mr. E. Heinke and the author, some of which are shown in figures 1, 2, and 3, are based upon long experience of the defects com-

plained of in ordinary apparatus. The submarine dress, as manufactured at that period, was exhibited at the Great Exhibition in Hyde Park, in 1851, and obtained the award of a medal; since that time several additional improvements have been made, and so nearly perfect may the apparatus be now considered, that there are few persons who would hesitate to go down in the dress after once seeing it used.

Among the most prominent of the improvements, is that of the eye-frame, to which is affixed a brass slide, so contrived that in case of accident to the glass the diver can immediately close it, and thus save himself from drowning. A double valve fixed in the front of the gorget enables the diver to descend and rise at pleasure, with the whole of his gear, which weighs upwards of 200lbs; in fact it places the whole apparatus completely under his control, and protects him in case of anything happening to the air hose, as by its means a sufficient quantity of air, to support respiration for ten minutes, can be contained in the helmet and dress, thus giving time to ascend, even from a very great depth. The connecting joints are now so manufactured that they can scarcely be broken, as they will resist the most powerful pressure, in consequence of having a double safety cap affixed.

The new vulcanized band completely excludes the water from the dress, and enables it to fit more easily and with greater comfort to the wearer. The signal dial makes the wants of the diver known to those above, instantly and correctly, and, in fact, renders the apparatus nearly complete for the most difficult undertakings.

A woodcut is subjoined, showing a section and elevation of one of Heinke's helmets, as also a sectional view of the valve. Fig. 1 shows a front elevation of the helmet itself. It will be seen from this that the openings are also provided (as an extra safety-guard) with segmental plates, so that, by turning either disc round by means of the buttons which project from the circumference, the openings can be closed instantaneously. The regulating or safety-valve is seen in front of the helmet, just below the joint indicated by the letter A, which joint enables the whole top of the helmet to be taken off at pleasure. Fig. 2 shows a section through the head-piece, exhibiting the pipe at the back, through which the air is fed down the valve for safety in the event of the bursting of a feed pipe. From the orifice will be seen the tubes, extending over the upper internal surface of the helmet, for leading the stream of air over the glasses; and again below, and marked by the letter B, will be seen the safety-valve before-mentioned, which can be opened or shut at pleasure by the diver. This valve is shown in section on a larger scale in Fig. 3. It will there be seen that an ordinary valve, which is held in place upon its seat by means of a spiral spring, is covered with a cap perforated on the top, so as to allow of the escape of such air as passes, but so fitted as to turn upon the outside of the valve-box or seat at pleasure; this is provided with a long slotted hole, which runs some distance around its circumference, and the lower part of the valve-seat or box is provided with a similar slot. From this description it will be apparent that the cap can be turned, so as either to let the two holes be in one, and thus open to allow of the escape of the air, or be closed, should it be desired; by this simple contrivance the diver can regulate the egress of the air, and so, the extent of the supply,

FIG. 1.

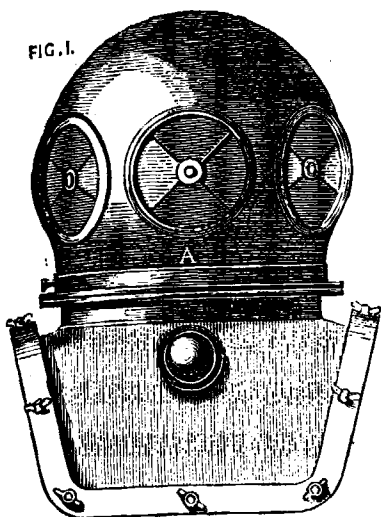


FIG. 2.

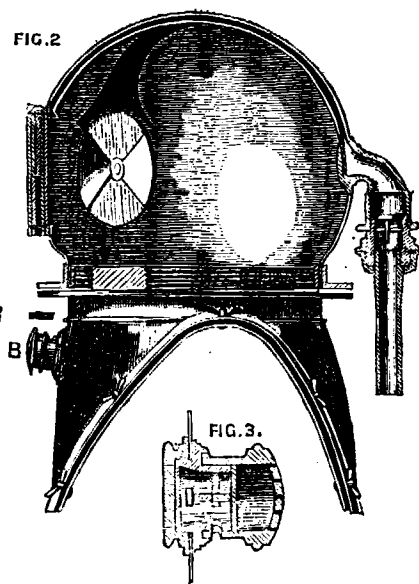


FIG. 3.

FIG. 4.

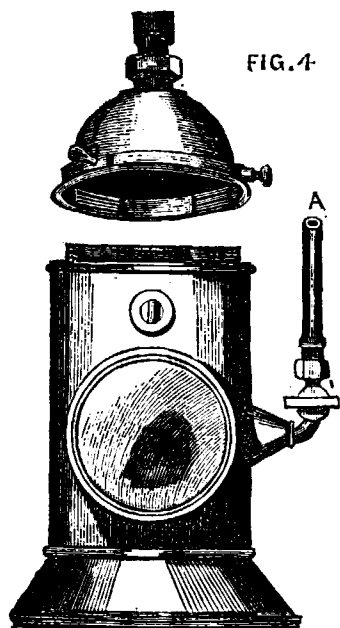
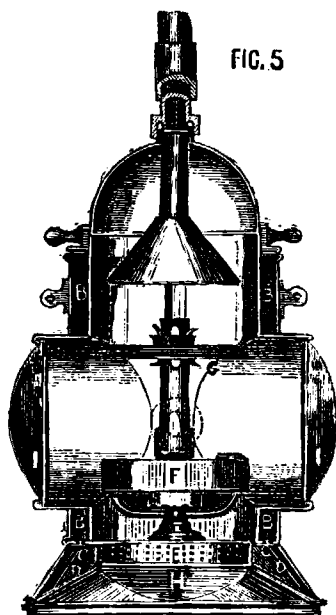


FIG. 5.



to the greatest nicety. Figs. 4 and 5 show a side elevation and longitudinal section of my lamp, which, it will be noticed, possesses the following peculiarities and advantages. The amount of air which is supplied through the pipe A, Fig. 4, can be regulated by means of the tap; the air thus admitted flows into the external ring or case, which is shown by the letters B B in the sectional elevation, Fig. 5; it then finds its way through the perforated plate C C, at the bottom of the ring, into the receptacle D D, and thence through the strainer E into the lamp itself, for the support of combustion. The burner itself is of the form commonly called Argand, and supplied with oil or gas from the ring F, which is made open, so as to allow of the light from the lamp being thrown down from the reflector G, through the lense H, so that by this means the bottom surface of the sea can be examined without removing the lamp from its upright position. The lamp is also provided with two side lenses I I; or three can be used if required. The upper cap is fitted with an internal cone, which is connected with a pipe leading to the surface of the water for the escape of the products of combustion. This lamp gives a brilliant light, and the air supplied percolating through the lower ring enables it to burn steadily, a matter of considerable importance in such cases.

In 1855 a number of interesting trials took place with my apparatus in various places. The experiments which were conducted at Portsmouth, in the month of June, in the presence of the Admiral Superintendent and Dockyard officers, gave great satisfaction; the diver remaining below, half an hour at a time, in a depth of water of  $3\frac{1}{2}$  fathoms. At Chatham dockyard, in October, a similar trial took place, in the presence of the Captain Superintendent and several gentlemen connected with the establishment, as well as many officers of the corps of Royal Engineers and others, who all expressed their gratification at the result of the experiment.

At Paris it was tested on the Seine, by command of the French Government, and in the presence of Prince Napoleon, a large number of military and other engineers, the Commissioner-in-Chief, the Secretary of the Exhibition, and the members of the International Jury. On that occasion five kinds of diving dresses were tried (of which three were English and two were French) in every variety of situation. The apparatus which was attended with the most successful results, and which it was decided possessed the greatest facilities, was that exhibited by myself. The diver, without any assistance, raised himself to the surface by partly closing the valve in the breastplate of the helmet; the compressed air thus filled the waterproof dress, and brought him up. When he wished to descend he had only to turn on the air valve.

In order to test the alertness of the divers twelve small rings were thrown into the river; of these my diver picked up ten, and the other two were not found by any of the divers. Again, at the request of Prince Napoleon, he went down with a helmet, the glass of which had been accidentally broken at the Westminster Bridge works, and which, of course, admitted water; he immediately closed the safety valve as directed, and remained under water half an hour, before coming to the surface. The under-clothing was then examined, and was found to be perfectly dry. The divers representing the other makers were then requested to submit their apparatus to the same test, but they all declined. The French

exhibitor, M. Ernoux, at once and in the most handsome manner acknowledged the superiority of Messrs. Heinke's apparatus, stating that he considered it really perfect.

At the close of the Paris Industrial Exhibition, a first-class medal was awarded for the apparatus, which was transferred to the Crystal Palace at Sydenham.

Mr. PERRER said, as far as he had examined the lamp he should say it was a very valuable and practical instrument. At the Polytechnic Institution he was most anxious to illuminate the operations of divers. The ancients had a great idea of a lamp which was to illuminate their tombs for ever; but they seemed to have lost sight of the principles which Mr. Heinke had carried out in his lamp. Suppose a lamp shut up in a subterranean place, supplied with fuel to burn for a long time, it must be extinguished by the carbonic acid gas. Now Mr. Heinke provided for that by forcing in a constant supply of fresh air. Again, the ancients had to provide a material which would burn for ever, but Mr. Heinke provided a lamp which anybody could trim and use at pleasure. He had himself tried to apply the oxy-hydrogen light for submarine purposes. It was provided with a double cylinder of glass, and answered remarkably well in his hands. It was then placed in the hands of attendants, and they soon afterwards reported to him that they had had a dreadful accident, and that the lamp was blown out. The next light he tried was the electric light of M. Du Bosc, of France. While that gentleman remained in England to superintend the operations, the lamp answered remarkably well, but the gentlemen in whose charge it was left were unable to carry them out. These two lamps were accordingly put aside. Now, if they were provided with this simple apparatus of Mr. Heinke, which was provided with common oil, and when let down into the water supplied with fresh air, he was sure it would answer remarkably well.

Captain NOLLOTH reminded Mr. Heinke of the submarine operations of Captain Dickenson, who recovered nearly a whole cargo of dollars. The ship's tanks were ingeniously converted into divingbells, and with these Captain Dickenson carried out his operations.

Mr. HEINKE said the lamp had been extensively used at Westminster bridge. The water there being thick, they could only see about eighteen inches or two feet, but it enabled the engineer to examine the granite, and to see if the divers had done their work in a proper manner. At Dover, the water not being so thick, but of a light, milky hue, caused by the admixture of chalk, they could see nine or ten feet all around. It was of great assistance, and was used extensively. The same with the diving apparatus, which was superior to the diving bell to this extent, that a diver could lay eight large blocks of stone, each block weighing about 7 tons, in four hours, whereas with the diving bell he could only lay 5 at the most.

The CHAIRMAN asked Mr. Heinke if he had seen any of the tubes used with a glass end to them, for seeing under water.

Mr. HEINKE said he had not. He thought Mr. Bethell had a kind of funnel which he dipped in the water to a certain extent. Where the water was not very thick it would answer, but at Westminster bridge it would be impossible to use it. The engineer in charge of the works, Mr.

Harris, made a point of going down every day to see if the divers had done their work properly. His apparatus had been in use these four years and a half, and all the under-water work had been done by means of it, without a single accident.

The CHAIRMAN asked whether the machinery for the diving apparatus was not less than that required for the diving bell.

Mr. HEINKE replied it was. He recommended that every ship of war should be provided with one of his apparatus.

The CHAIRMAN asked what was the expense?

Mr. HEINKE replied, with all the improvements it would cost about £140, and that the diving apparatus would cost about £7 per week for working expenses, whilst the diving bell would cost from £18 to £22.

The CHAIRMAN moved a vote of thanks to Mr. Heinke for his communication. It was a very important one. The simplicity of the lamp must make it succeed; there was nothing complicated about it. Deane's apparatus was likely to get out of order. He saw a case at the Cape where they wanted to use it but could not.