INSTITUTE OF MARINE ENGINEERS
INCORPORATED.

SESSION 1917-18.

President: RICHARD H. GREEN, ESQ.

VOLUME XXIX.

Paper of Transactions No. CCXXVI.

Marine Salvage Operations.

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READ

Tuesday, February 6, 1917.

CHAIRMAN: MR. H. A. RUCK-KEENE (Chairman of Council).

The CHAIRMAN: We are indebted to Mr. Wright for preparing a paper on "Marine Salvage," and also for coming from Hull to read it. I hope it will open out a good discussion.

WHEN anyone wishes to know how a vessel is designed, constructed, or navigated, plenty of books by the best authorities on each of these particular subjects can be got, but when an unfortunate vessel becomes a wreck the knowledge of the methods by which the salvage officer recovers and restores her to her former useful sphere is singularly meagre.

The duties of a marine salvage officer are often of a most difficult and onerous nature. He must be able to estimate approximately the weight, buoyancy, trim and stability of a ship in her damaged condition, quick to form a plan of operations, taking into account the position of the vessel, the nature and extent of the damage she may have sustained, and the character of the plant at his disposal. While it is very seldom that any two cases he may be called upon to handle will be alike, still marine salvage operations may be divided into two groups, viz., "Submerged vessels" and "Stranded vessels."

Let us consider in the first instance the case of a vessel sunk in deep water that is entirely submerged at all states of the tide. Before any decision can be arrived at regarding the method by which the vessel is to be raised, it will be necessary to send a diver down to examine and report on her condition. The modern diving gear is fairly familiar to those who have to do with the sea and ships, but as it—more than any other invention—has made possible the salvage of ships sunk in deep water a few descriptive remarks regarding the development of the same may not be out of place. The first really practicable diving bell was invented by Dr. Halley, Secretary to the Royal Society, and described by him in the Philosophical Transactions of 1717. It was constructed of wood covered with lead, and shaped in the form of a truncated cone. Air was supplied by two small barrels which were alternately lowered and raised as quickly as possible. A most important improvement on Halley's Bell was made by Smeaton in 1778, he having substituted force pumps for the imperfect method of obtaining air formerly in use.

Kleingert's dress invented at Breslau in the year 1798 was actually a small diving bell, enclosing the head and body to the waist and having holes through which the arms were thrust.

Siebe's open dress invented in 1819 was the next step in advance. It consisted of a helmet and waterproof blouse extending to the waist. The air pumped in at the helmet escaped at the bottom of this garment and thus the dress was termed open. Although a great improvement, this dress had one serious defect. It was necessary for the diver to always maintain a nearly upright position, because if he bent down and brought the helmet to nearly on a level with the bottom of the open blouse the air escaped so rapidly that he was in danger of being drowned, and to correct this defect the present form of close dress was introduced in the year 1837. The outfit consists essentially of an air pump, generally treble barrelled, and fitted with a dial pressure gauge for indicating the pressure required at any depth up to 200 feet, the whole being enclosed in a strong wooden box.

The helmet is made of copper, tinned inside, and is fitted with three glass eyes, the front one being arranged to unscrew. The air tube coming from above passes under the divers left arm and is connected with a union joint at the back of the helmet. A non-return valve is fitted here so that should the air tube be cut by accident, the passage is at once closed and sufficient air is generally contained in the body of the dress to allow the diver time to signal to be drawn up. The air as it enters the helmet is conducted into three flat passages which cross over and terminate just above the glasses inside so that a thin stream of pure air is continually removing the condensed breath and keeping them transparent. The outlet valve by which the air escapes is placed at the side of the helmet towards the back and is perfectly self-acting. In addition to the water pressure a small metal spring is fitted which bears the valve down on its seating, and the force exerted by this spring can be varied by a screw regulator. The helmet is secured by a segmental screw to the shoulder piece or corselet, which is fastened to a water-proof dress made of double tanned twill, with india-rubber between.

Were the diver to attempt to descend without being specially weighted he would probably come to the surface feet uppermost, therefore in order to enable him to sink and maintain a vertical position he is provided with front and back weights and the sole of each boot is formed of lead. When ready to descend the diver carries a total weight of about 170 lbs. and a man who can work at a depth of 120 feet may be considered fully qualified physically. During his descent the diver must go down gradually as he passes through a range of pressures varying with each foot of submergence, and the air supplied to him must be compressed so as to equal the hydrostatic pressure at the particular depth.

When he is ascending, particularly from depths of over 15 fathoms, great care must be excercised, otherwise he may develop serious symptoms. The greater the depth at which the man has been working and the longer the time he has been submerged, the greater is the danger of returning to the surface without allowing the body to adjust itself gradually to the altered conditions.

Diving operations are usually conducted from a surface boat subject to all the influences of wind, waves, and tides, and a line with knots at regular intervals is lowered to the bed of the sea. Clinging to this line an expert may by regulating his air valves, inflate or deflate his dress so that the volume of water displaced at any given depth is equivalent to his total weight and by so doing descend or ascend at a rate which allows the pressure on his body to be increased or decreased gradually. Some misconception seems to exist regarding the depth to which a diver can safely descend. With the ordinary equipment at present available the utmost depth attainable appears to be about 35 fathoms (210 feet). Several forms of diving dress have been invented to enable the diver to withstand the pressure due to greater depths, but so far, these have only proved useful for such simple operations as pearl gathering, etc.

The methods generally adopted for raising wrecks sunk in deep water may be classified as pontooning, pumping, and air pressure. Pontooning is the name generally given to that system of raising wrecks by which pontoons or barges having the necessary buoyancy, lift the sunken vessel by means of chains or wire ropes passed under her. This method is an old and well tried one, and for vessels up to 2,000 tons sunk in over 30 feet of water, is one of the safest and most certain plans that could be adopted. The barges employed should be strongly built and when carrying the weight of the wreck should have at least 25 per cent. reserve buoyancy to allow for contingencies. When a salvage officer decides to pontoon a vessel he has generally to take whatever barges or old vessels he can find handiest and nearest the scene of operations. Improvised plant of this kind adds greatly to the difficulties to be encountered, because it is necessary when taking in and making fast the lifting cables to have each one carrying its proper proportion of the weight, and without suitable appliances this is not easily arranged.

Should the wreck be lying on a soft bottom the cables or ropes are generally passed under her to the position required by being drawn back and forward with two tugs working with a sawing movement. If on a rocky bottom the divers go down with a long slender rod to one end of which is attached a light chain, this they pass under her wherever practicable, and by means of the small chain the larger cable or wire can be pulled through, the ends are then buoyed up till required. When all is ready they are taken in and made fast at low water. The tide on rising lifts the wreck through the buoyancy of the pontoons and it is then towed in shore as far as can be got while the flood tide lasts. The ropes are then hauled in as the tide ebbs, and this operation is repeated every tide until the vessel is got far enough inshore for the water to fall below the level of the deck, any holes are then closed up, she is pumped out and refloated. It is obvious that the distance the vessel can be raised and towed inshore each tide by this arrangement depends on the range of the tide in the locality of the wreck and the slope of the bottom. When the pontoons are efficiently subdivided and provided with pumps the operation is greatly facilitated by flooding and sinking them as low in the water as it is compatible with safety, then after making fast the ropes they are pumped out, and the lift is increased by the difference due to the sinking of the pontoons. The greatest objections that can be offered against this system is the length of time required, and the danger of bad weather occurring after the ropes are fast, and causing damage to the pontoons.

The second method mentioned, that of pumping, consists of closing up all openings in the submerged structure, introducing suction pipes, and pumping out the water by means of powerful pumps. It is only applicable to vessels lying in comparatively shallow water as the strains set up by the superincumbent water when the interior is pumped out may cause the decks to collapse. If the ship founders in a light condition the divers can get inside and shore up the decks so that they will stand considerable pressure, but even then, the depth at which the operation may be carried out is limited to the lift of the pump.

Much ingenuity and constructive skill is often displayed by marine salvors in closing up the openings on deck and holes caused by damage to a ship. In the case of a ship sunk by collision having a large rent in the side, a template is generally made to fit the side round the damaged portion, the patch or shield is then got ready at the surface, sunk into position, and attached by tee-head or hook bolts to the hull. Plenty of hair felt is employed so that on screwing up the patch to the ship's side the joint will be as watertight as possible. In several cases a plate large enough to cover the hole, has been fitted round the rim with a channel iron, into this channel was packed an india-rubber hose, capable of standing considerable pressure, and when the shield had been attached in its place water was forced into the hose causing it to swell and fill all irregularities between the shield and the skin of the vessel, thus forming a very efficient joint.

In closing up deck hatches, etc., a very stong job must be made, as the strain on them is considerable, when the pumps have started. A hatch 20ft. × 12ft, at a depth of 10ft. below the surface would have distributed over its area a weight of $68\frac{1}{2}$ tons. Air pipes have to be fitted to each compartment so that the atmospheric pressure may be admitted to the surface of the water inside the ship. The pumps almost universally adopted by salvage engineers are of the direct driven centrifugal type. They occupy less space and can raise a larger quantity of water in less time, and at smaller cost than any other kind of pump. Their principal recommendation from a salvor's point of view is the absence of all valves and contracted passages which are liable to choke at the most critical times. They will pass pieces of coal, wedges and stuff which would at once choke any other kind of pump and being provided with hand holes can be very quickly cleared. The metal suction pipes are generally provided with telescopic lengths; and flexible pipes made of leather or india-rubber strengthened with coiled wire are frequently used.

The vertical boiler and steam driven pumps have now been to a large extent abandoned in favour of centrifugal pumps driven by oil engines. As the pumps have frequently to be lifted into very awkward positions, the machine having motor and pumps all on one bed plate is much easier handled. The lift of a centrifugal pump, however, is a comparatively limited one, being under ordinary practical conditions about 20ft. One of the greatest advances with regard to pumps for salvage work is undoubtedly the "Submersible Motor Pump." For many years, efforts have been made to enclose electric motors with different types of casings so as to make them watertight and airtight, and the result has always been failure, as the heat generated sets up condensation and destroys the insulation. The submersible motors made under the Macdonald Patents have, however, effected a revolution in this respect as the windings are insulated by a new process to stand continuous immersion in water. Its great feature is that it only needs enclosing to keep floating debris from the working parts, but allows water to circulate through it internally. There are no glands or other details which are likely to give trouble, and they will start submerged without the slightest hitch or trouble. The submersible motor in combination with a suitable centrifugal pump opens up possibilities such as have never hitherto been contemplated. It can be lowered down to any deck below water, placed in position by the diver, and worked from the generators on the salvage steamer either alongside or from any distance away. In many cases it is only necessary to suspend the pumps from the steamer's derricks and lower them into the water without coupling up any suctions. Pumping can be commenced immediately after one length of delivery hose is attached, the whole operation being carried out very quickly.

When the depth at which the wreck lies is so great that the deck will not stand the pressure due to the head of water over it, a plan commonly known among salvors as "stanking" is adopted. The word "stanking" is derived probably from the old sea term "to staunch" or "staunching," and it means, in the wreckers' terminology, the construction of a coffer-dam or trunk on a sunken vessel. It is in fact a continuation of the vessel's sides to above the surface of the water. Heavy logs of timber are secured along the sides or to the decks. From these logs a strong frame-work is erected and very efficiently stayed with diagonal shores from the centre of the deck, and opposite gunwales. This frame-work is then planked vertically with strong planks, the edges of which may be half checked in the manner known as ship-lap. Platforms for the pumping plant are fitted and the water is then pumped from the interior of the erection. As the vessel gradually rises she is towed inshore to shallow water, the superstructure is then removed, and the pumps are placed on deck. This method has been adopted with successful results in the case of several very large vessels. It is however an operation at once tedious and risky, the cost depending greatly upon the nature of the weather experienced while conducting it. The third method mentioned, that of air pressure, is one which is yet not generally practised in connection with wreck raising. It has been successfully adopted in several cases but the majority of salvors seem to look upon it unfavourably. Generally speaking it is a case of treating the submerged ship as if she were a huge diving bell, driving compressed air into the interior and forcing the water out. All openings in the compartments into which air is to be forced have to be very efficiently secured. In some cases very strong wooden box-shaped caissons were fitted over the hatchways and fastened to the deck; to these, air locks were attached, by which men descended into the hold of the submerged vessel and effected some repairs. Large discharge pipes with non-return valves have to be fitted far enough below the deck to get the buoyancy required to raise the vessel. It is also necessary to fit escape valves for relieving the pressure as the vessel rises to the surface. The principal objection that can be offered against this system is the great difficulty of closing up the deck openings sufficiently air-tight to obtain the pressure required.

A modification of this air pressure system has been tried by introducing specially prepared canvas bags under the decks and forcing air into the bags until sufficient displacement is obtained to lift the weight of the vessel. There are, however, so many projecting scantings inside a ship that it is practically impossible to get the air bags sufficiently strong to lift any great weight.

The most practical method of employing compressed air for the lifting of submerged vessels would be to have specially constructed pontoons, which could be sunk alongside the wreck. These pontoons would have to be constructed with a longitudinal well in the centre and efficiently subdivided, or vertical tubes might be fitted between the keel plate and deck at longitudinal intervals. The lifting ropes being brought up through the centre of buoyancy of the pontoons they would be in stable equilibrium when taking the lift.

The objection raised by most marine salvors to the employment of submerged pontoons is that it is impossible for divers working underneath the surface to take in the lifting ropes and make them fast, so that each is bearing its proper proportion of the weight. Anyone who has ever attempted to handle a 10in. steel wire rope will quite appreciate this. This practical difficulty could, however, easily be overcome, and this method possesses the following great advantages over ordinary surface pontooning.

(1) On arrival at the position of the wreck the submersible pontoons could be sunk at any time, and so escape any damage likely to happen through bad weather.

(2) Specially built pontoons of this kind could be blown out and exercise their lifting capacity at depths where pumping would be impracticable.

(3) The wreck could be raised to the surface in one lift and towed direct to a safe beach, whereas ordinary barges depending on a tidal lift the operation can only be done in stages, often requiring weeks to perform.

We will now consider another class of wreck with which many of you are no doubt more familiar, that of the stranded ship driven ashore by a gale, or may be, after vainly fighting against the storm she is run ashore to escape a worse fate.

Some of the most varied and interesting marine salvage operations ever carried out, have been done in the refloating of stranded vessels. The method adopted will depend on the position of the wreck, the extent of the damage, and the depth of water at high tide. Take the common case of a vessel ashore on a reef, her bottom penetrated and admitting water freely to several compartments. Being embedded on the rocks it will be impossible to patch up the holes from the outside. When the vessel has a double bottom throughout, the damage will probably be confined to the outside plating; should the double bottom inner plating be started it is a comparatively easy matter fixing that watertight. Many a vessel with her bottom plating practically destroyed has been floated on her tank top.

If, however, the vessel is constructed with ordinary floors, that is without a double bottom, the problem is very much complicated. When the perforations in the bottom are few and not very large it is usual to deposit a mound of cement reinforced with strips of thin steel over each. In a case of this kind, however, if the bottom is very badly damaged the plan generally adopted is known as "platforming," and consists of fitting inside the vessel a platform or deck of timber low enough in the ship to cut off the necessary buoyancy. Timber beams having been taken inside in two lengths and bolted together in a position, a deck of 11 × 3 planks is then laid, roughly caulked, and shored down from the deck above. A sump or well must be provided at the lowest part in each compartment for placing the end of the suction pipe in, and it is also necessary to fit a small air hatch, about 30ins. square at the highest part, to allow the air to escape from underneath as the tide rises. This hatch also serves another useful purpose; when the platform is completed and the attempt to refloat is to be made it is kept open until the rising water is just about lipping over. The cover is then put on and secured with a tricker shore, so that if anything goes wrong and it becomes necessary to scuttle the ship this shore can be easily knocked out, and she will sink back on her old bed, so damaging her bottom as little as possible. As there is always considerable difficulty in making a platform watertight, especially round the frames and reverse bars, and as the work has to be done in the shortest possible time, it is usual to provide pumps capable of dealing with a large inflow of water.

Cases have occurred where vessels have gone stem on to the rocks, the serious damage being confined to the fore-end, and it has been found expedient to cut away the damaged fore-part, refloat the remainder of the vessel and having towed her stern first to the nearest repairing port a new fore-end has been built on. Such an operation is one calling for great judgment and experience.

A vessel stranded on rocks is in a bad enough predicament, but it may surprise you to learn that a ship ashore on a sandy beach is often in a much worse plight. Probably, by force of heavy seas, driven so far up the beach that there is not sufficient depth of water to float her, she may have sunk some distance in the sand, and in that case will have to be raised with powerful hydraulic jacks, launching ways introduced under her, and shipped out to deep water on these. Cases have also occurred where a channel has been dug, lined with sand-bags to keep it from falling in, and the vessel worked down gradually to deep water in this manner.

It would be impossible within the time at my disposal to describe fully, many of the varied problems presented in recovering this class of wreck, as every case presents so many different factors which have all got to be taken into account in determining what method will be adopted as the best in the particular circumstances, but I trust the brief, though perhaps not very lucid descriptions of those I have given you will have proved of interest. I have refrained from describing the numerous patented inventions mooted from time to time for wreck raising. Excellent in theory though many of these may be, they are generally quite impracticable. The inventors seem to forget or never saw the sea during a storm, and although their device may work fairly well in a tub at home, it is generally useless when tried under the ordinary conditions of wind and sea. It is astonishing the number of people of all sorts and conditions who imagine they have discovered the best possible method of raising sunken ships. There must be something attractive in the idea of recovering from the sea the victims in the shape of the ships it has engulphed, but he who would undertake this onerous task must be prepared to live laborious days and sleepless nights, and in the end may be doomed to bitter disappointment. Many a marine salvor having conceived a plan and by dint of incredible labour carried it out in the shortest possible time has had to stand by and watch the sea rend to pieces not only his own plant and gear but the ship they were intended to save.

In the conduct of "marine salvage operations" the qualities of resource, energy and engineering skill are required in a high degree, and I think it is a matter for regret that we have not, at the present time, more and better equipped salvage companies in this country.

We, as a maritime nation are proud, and justly so, of our vast shipbuilding and engineering industries. Our shipbuilders and engineers have led the world in the design and construction of ships, but it must be admitted we have not shown that energy and enterprise in the recovery of sunken or stranded ships displayed by some of our Continental neighbours. A nation possessing the largest mercantile and naval fleets in the world and situated as we are, should be in the very foremost position with regard to appliances for salvage work.

At no time in the history of our country has there been such a necessity for men with good scientific training and practical experience to apply their talents to the recovery of sunken or stranded vessels, and if the reading of this paper will induce any of the members of this Institute to take a practical interest in this subject, my object will have been attained.

The CHAIRMAN: I am sure we will all agree this has proved to be a very interesting paper, especially at this time when there are so many wrecks all round the coast. I hope many will join in the discussion.

Mr. PETER SMITH: I have much pleasure in congratulating Mr. Wright upon his paper, which forms a very good text for discussion. I note that, in the opening paragraph, it is stated we have plenty of text-books for designing a vessel and constructing it, and all the other appliances, but we have very little to help us to recover a vessel that has been sunk. It is a remarkable fact that the greatest maritime nation in the world seems to have given no thought to salvage work. Within the last twenty years—and it might be a little more—we have been depending entirely upon German and Scandinavian resources for salvage work. What we have been dealing with has been close to our hands, stranded vessels near our own ports, while the Germans and Scandinavians have fitted out large steamers with appliances, and have gone to all the seas in the world waiting to be called. They have divers on board, and very large pumping appliances, and everything ready at their call, for salving purposes. After the war no doubt we shall be contemplating the raising of vessels sunk in the British Channel and all round. It is deplorable that we have not the vessels and the appliances to deal with the situation. It is not possible to deal with all kinds of salvage operations, as these differ so widely. It was my misfortune nearly twenty years ago to be chief engineer of a vessel that ran ashore under different conditions to any depicted in the paper. The vessel, at a speed of 16 knots, went stem-on to an island. When the danger was realised, the old cry was raised "Hard-a-port." Had it been "Hard-a-starboard" the vessel would have been all right; so also had the course been kept on the rocks. As it was, it was "Hard-a-port," the ship turned at right angles to her previous course, and ran on to a reef abutting from an island, in 18 feet of water. She climbed over it about one-third of her length, lifted herself up three feet, and there she held. The result was that the weight of the vessel forced the keel, thus crushing the hull upwards. The holds got full of water—first of all No. 1 hold, which was loaded with Australian wheat; next No. 2 hold, containing several hundred tons of copper, lead, skins, wood, etc., then came the second compartment, filled with China and Ceylon tea; abaft of this came the stokehold, the engine-room, and then the after part of the vessel which was filled with fruit. In the first place, the wheat began to ferment, and then the skins and wool began to give out a very offensive smell. Soon the tea began to infuse, and on the whole it was a very nice situation. That vessel stuck on a reef running down from the main island, at about 23 degrees from the perpendicular, and there she remained. A vessel sunk in deep water can be lifted as described in the paper. But you could neither lift nor sink this particular vessel; there lay the difficulty. Three weeks of a very anxious time for all concerned went past, and had it not been for the engineers that vessel would have remained there to this day. Two German salvage steamers came to the wreck; then a Swedish one, on her maiden voyage, fitted out with all the up-to-date appliances—everything you could possibly think of. The Germans were there first, and they took charge and carried out the work. But when the Swedish vessel came along the diver went down. He had a telephone apparatus over his head, and he walked along from one end of the vessel to the other, talking to his commander on deck and describing the state of the vessel and all details. At that time this country had not got a vessel to look at a job like that. I do not know what we have now. The ship's bottom was set up in some places six feet, and to get at the damaged parts the divers were employed from 6 a.m. to 6 p.m. There were twelve divers drilling holes in the rock, putting in dynamite charges, about 2 lbs. of dynamite in a tin case. The charges were laid along with a fuse attached, which was exploded from the ship's dynamo. They displaced a few tons of rock on each occasion, carefully picked up with the ship's lifting power and cranes, and passed over. They dug a trench along the ship's side, about three feet wide, and probably six feet deep, and then they got platforms—that is to say, shields, lowered over the side and screwed up from the inside by divers inside, and at last the whole pumping power that could be applied was put on; eventually it reached 18,000 tons of water per hour. That was with the ship's own pumps, auxiliary pumps put on board, and the salvage pumps. It took ten days, at an average of one foot per day, to lower the water in the ship. We had 500 passengers on board, and all the soiled linen—table cloths, napkins, etc.—also several thousand coal bags obtained from the nearest port, were being fed in by the divers over the side to stop the rush of water getting through to the fracture. When the ship lifted it was a sight to see all that gear hanging around. When she got buoyancy enough she lifted three feet right away, and went off with a breeze of wind. The vessel was then anchored, the holes were plugged up by the divers, and she was towed into harbour. It took six months more to do what the author describes as platforming, then filling up with cement, after which the vessel came home under her own steam.

Mr. Robt. Balfour: At the outset, the author refers to the invention and introduction of diving bells and dresses in connection with maritime salvage operations. This reminds me of an interesting article given in the *Shipping World Series* some years ago, by a Mr. John James Fletcher, entitled "Salvage and Wreck Raising," in which reference is made to the invention of "Submarine Navigation," and I think will bear quoting, especially in these days when this method of navigation which was originally invented for peaceful purposes has now upset the equilibrium of the whole maritime world by the barbarous uses it has been put to by our enemies. It runs as follows:—

"As early as the reign of James I. a sub-navigating boat tried upon the Thames, carried twelve rowers and several passengers. The Hon. Robert Boyle states that the chief secret was in the composition of a liquid that would quickly restore to the troubled air such a proportion of vital parts as would make it again, for a good while, fit for respiration."

"Bishop Walkins in 1648 devised a project for an ark for sub-navigation, in which he states all kinds of arts and manufactures might be carried on. After a fanciful description of its uses, he adds, 'I am not able to judge what other advantages there may be suggested or whether experiments would fully answer to these notional conjectures.'"

"In 1771 Bushnell of Connecticut invented a submarine vessel propelled by screws, and later on Mr. Babbage suggested the plan of such craft, the power of breathing the air over and over again to be afforded by the absorption of the carbonic acid gas by a strong solution of ammonia."

With regard to submerged vessels, I believe that the water pressure is roughly calculated as being about $2\frac{1}{2}$ lbs. per square inch for every fathom in depth, thus at 200 feet the pressure would be about 86 lbs. per square inch.

As regards the actual weight to be lifted, tables showing the proportion between actual weight and gross tonnage of a vessel are given in Winton's *Modern Workshop Practice*, from which it will generally be fair to consider that a good working constant is that the actual weight of a ship or steamer is about ·80 of her gross tonnage. This constant will supply the necessary percentage of buoyancy in the lifting tackle. In addition to this, the weight of water filling those parts of the vessel not occupied by cargo, and if a dead lift is to be attempted, the weight of the cargo calculated in relation to its specific gravity and displacement of water.

In the conduct of salvage operations, say in lifting with pontoons, I understand that wire ropes have the advantage of chains, as it is impossible to get the slack out of the chains until the weight of the wreck comes upon them, thus losing the rising force of the tide; besides, the wire ropes are easier handled. Mr. Smith gave a most graphic description of his experience in salvage work in the East, and specially referred to the operations having to be carried out by a German company. I remember well at that time much regret was felt in this country regarding our position in that direction, the leading maritime nation in the world having to depend upon foreign organisations such as the Neptune Company,of Stockholm; the Svitzer Company, of Copenhagen; and the German Company, for salving our maritime property abroad. So far as the former companies are concerned, doubtless their high position in salvage work was due to the numerous wrecks around their rugged coast-line, and narrow fairways and belts, necessitating prompt salvage work. With regard to the latter, I feel confident that Government subsidy played a prominent part in enabling their plants to be sent abroad, as it has done since in connection with other industries in that country. I wish to thank Mr. Wright for his valuable contribution to our Transactions. It has been most instructive. The only suggestion I can make is that its value might possibly have been augmented had he been able to reproduce sketches to illustrate the various phases of the work of salvage.

Mr. J. Thom: I have been in places where salvage vessels could have assisted the steamers I have been in, but we were fortunate enough to get out into deep water before they arrived. This is a very interesting paper, especially to marine engineers and shipowners. It is also interesting in that the two Members who have spoken, have brought before us the small number of companies which take up salvage work as a business. There are some in this country but they do not go far afield, and probably their plants are unable to take up heavy jobs. As the author has mentioned, in salvage work there are a great many different kinds of operations where a wide engineering knowledge is required, also the knowledge of everything connected with diving. There are lots of divers in this country but some milder countries have many more. Some years ago, when work under pressure had to be done in tunnels where the working conditions were carried on with an air pressure of 40, 50 or 60 lbs. to the square inch, our countrymen did not suit very well, I have been told that natives of other nationalities with less muscle are better suited for work of this kind. The Italians are about the best for working under pressure, which, I conclude, is very similar to the work of a diver. The greatest difficulty, I understand, in working under pressure without undue pain or suffering in health, is that you must be trained to this class of work. In speaking of pressures per square inch, 80 lbs. seems a very big pressure, then in a very short time to come back to the normal. When working in tunnels, the pressure is changed gradually from the working to a medium pressure, or there may be two rooms of different pressures to enter before proceeding to the atmosphere. Thus it was found that the effect upon the man going out and in every day was less than in going suddenly from the high pressure to the atmospheric pressure. I believe that men working six days a week felt very uncomfortable on the seventh afternoon and wished to enter a pressure room to get rest and sleep. I do not know whether divers are similarly affected. The author has spoken of electric motors not being satisfactory under certain conditions. I think electric motors can now be made to work satisfactorily for the purpose without much difficulty. If a pipe from the pump is brought to the higher level it can be used as an air pipe. Motors are at work in machine shop premises in the open, and for wet weather provision is made so that air is drawn from a dry position and delivered to the vital part of the motor with quite satisfactory results. There is no difficulty in putting a gland between the pump and the motor, while the motor itself can be entirely enclosed. The benefit to salvage work is enormous, having electric motor driven pumps, the weight also is in its favour. Another advantage is that the position of the motor may be determined without regard to the pump. From the delivery point of view, modern pumps can be made to work under almost any conditions of service. Platforming has been mentioned. There seems no reason why a ship should not be built provided with a deck for a platform that would give sufficient buoyancy to float with all the part underneath full of water. It does not appear possible to include the engine rooms, but it might be done.

With the hints we have had to-night about our inefficiency in this class of work, I am sure the Government ought to have a word of advice on the subject, and a marked copy of the paper ought to be sent to those concerned. Probably nothing will be done at the present time, but it can be pigeon-holed and referred to at the right moment.

Mr. W. McLaren: I quite appreciate Mr. Wright's endeavours to enlist marine engineers to interest themselves in salvage work, especially at the present time. But all salvage operations rest upon the individual circumstances of each casualty and each ship; but when we get to the standardising of the ship, the idea of providing for platforms in the design of new ships may be possible. There are many minor cases where small platforms have been formed and filled in with cement, and these have helped in the salvage of the particular ship. I remember an instance on the Firth of Forth which brought the man on the job to the front. On a vessel which was wrecked he filled the hold with barrels, floated her, and brought her into Leith harbour. Another case I was interested in myself, I do not know how it happened but the ship got into three or four fathoms of water and stranded. We had a diver on board, indeed we always carried a diver. We got him into his suit and over the side, and put about 30 lbs. pressure for the depth. The man asked to be drawn up; he was sick. I should like to ask Mr. Wright what is the maximum pressure for a man reasonably to work under. I have been twice sunk in the Thames through the ship being holed, but a case of cement and a little slating saved the situation. I had also an experience in the Bristol Channel; we were a light ship and we put a sail over the side to cover the hole, but the boatmen took that away. The ship was stranded and it was three weeks before we got her afloat. They packed the broken plate every tide, and it was many tides before we got clear and into port. There was another big boat ahead of us in the dock, ripped from stem to stern, and the tank top was the means of saving her in the Bristol Channel. It has been said that we are very slow; I think the Swedes are far ahead of the Germans in salvage operations. Now that we have had an introduction on the French side with the pontoon dock for salving submarines, it does not seem impossible to do something similar for ships. We have coaling stations all over the world; surely this scheme of submarine pontooning or something of that description could be at these, and then it would be within five or six days of salvage operations, now that we have such fleets traversing the seas.

Mr. Donaldson: The last speaker mentioned coaling stations with the idea that some salvage plant should be maintained there. The coaling stations are held by companies who have to consider the commercial aspect of things and not the question as to whether it is of national benefit or not. So that is the whole sum total of the matter. I had an occasion to be at a coaling station where some salvage work occurred. In one case the vessel ran on to a ledge of rock and cut the stem right away, and into No. 1 hold. The vessel was loaded with coffee practically from stem to stern—she came from South America—and the age of the vessel was about 20 years. So it was very questionable whether the bulkhead would stand. The method of procedure was instead of touching No. 1, No. 2 hold was securely battened up. After that was done, No. 1 hold was lightened as far as possible, and the coffee from there put to the after end, and she came off and floated to harbour with a tug. The actual repairs were carried out in harbour and she steamed to Marseilles. The whole of the work was done by native divers under supervision, which necessitated a certain amount of timbering before she could be pumped out. After, it was a question of pumping and reinforced concrete inside. She took part of the cargo that was damaged to Marseilles. There was another case in the same locality. A vessel was lying in the outer harbour; this vessel was lying at anchor. Another vessel, which was also lying at anchor, was arranging to come out; she lifted her anchor and came ahead too much, ramming the other vessel with the fluke of her anchor, cutting a 3 foot hole in her, right amidships. Before they could get down to the engine room the place was flooded out. Fortunately there were docks there, and she was towed in a short distance before she sank to the bottom. She was a turret ship and the upper turret deck was not submerged. That was a simple case of the divers plugging the hole and pumping the vessel out. Mr. McLaren made some remarks about divers and pressure. Anyone who is accustomed to going down in a diving suit ought to know what pressure is required for the various depths. In the paper, the exhaust valve is referred to as being automatic; it is really a regulating valve. The pressure at the bottom has little to do with the pressure on the diver, for the diver regulates his own pressure. The valve in the helmet, when he is going down, regulates the pressure as he sinks. When he comes on his feet he regulates that valve until he feels he has just enough to work and have a decent foot-hold. If he wants to rise, he closes the valve gradually and may rise without being pulled up at all. This is a subject that deserves far more attention than it has received. The difficulty is to get men to do what they are wanted, as the inducements are not sufficient. You cannot get the proper man on an emergency, as a rule he is employed elsewhere, and one cannot afford to keep a good man standing by all the time.

Mr. J. Clark: I gather that there are two classes of vessel to be dealt with. One is where the diver can reach it, and the other where he cannot reach it, and the limit is put at 210 feet. The subject of pressure and decompression is well understood. I think the Americans are giving attention to a new form of diving dress, so that the diver works below at ordinary atmospheric pressure, and there is no limit as to where he can work. The dress is entirely of metal, to withstand outside pressure and enable the man to work. There are limitations to that motor pump referred to. The voltage, I believe, is very low on account of the conditions. The trouble has always been with ordinary sized motors that you must have fairly high voltage. No motor I have heard of, working under conditions where dry air has been supplied, has been able to withstand condensation. It may be that it will come in the future, but so far as I am aware it has not come yet.

Mr. PETER SMITH: As this is a very important subject, and will become more important as time goes on, I would propose to adjourn the discussion for another evening. When members read the paper I think a lively discussion later on would follow.

Mr. R. BALFOUR: Most interesting salvage operations have recently been carried out, and I agree that the subject is a most important one. If it is possible to extend this interest, by all means let us do so. I think we can get access to the operations which took place in salving these vessels and others. I have pleasure in seconding the proposal to adjourn the discussion.

The CHAIRMAN: I quite appreciate what Mr. Smith and Mr. Balfour have said, but I think we ought to bear in mind that many of the vessels now being salved are vessels employed by the Admiralty, and the Censor would not allow us to discuss any of these operations at present. I think it would be a good thing if we invited observations in writing from members, as it is difficult to arrange for many meetings at present, everyone is so fully occupied with work. If we could get those connected with the salvage associations to write some of their experiences I think it would be better than discussing the matter at an adjourned meeting.

This view having been accepted, the author was called upon to reply.

Mr. WRIGHT: I have listened to your remarks with great interest, and am very pleased to find that you have treated the matter so favourably. With regard to Mr. Smith's remarks as to the necessity of taking up this subject, I think what he says was one of my principal reasons for preparing my paper at this time. I did not do so with the intention of being able to come down and read a paper, and then say "turn to page so-and-so, and find out how to lift her." Every case of salvage presents an entirely different problem from every other. There are factors in each case that make it a problem in itself. One can only talk generally of the methods adopted. If members who have had experience of different cases would in communications give their experiences, it would be very interesting to others interested who wish to pursue the subject. The operations such as Mr. Smith has described are very interesting—the cutting away and making of a trench through the rock. That only brought out my point that it is impossible to undertake operations such as that without first-class plant. That operation could never have been done by salvors with ordinary plant. Mr. Balfour suggests that I ought to have given sketches. I really do not see that sketches would help very much. The best way to illustrate a lecture such as this would be a collection of photographs showing typical wrecks and the method of raising them, but I could not get the necessary photographs. With regard to the weight of a vessel to be raised, it is very necessary when taking a lift to know the weight you are going to deal with; it is one of the most essential things to know, and the formula you give is, I think, nearly correct. It is so easy getting the light displacement now from the builders, which gives the weight of the ship without any cargo, and it is easy to estimate the weight of cargo from the cubic capacity; but there must be a decided allowance made for the difference while the vessel and cargo is immersed. For instance, suppose the light displacement or weight ready for cargo of the ship is 1,000 tons and that 10 per cent. of that weight consists of wood fittings; as a cubic foot of the timber generally used in shipbuilding weighs considerably less than a cubic foot of sea water, we may neglect the weight of the wood fittings altogether, leaving 900 tons of steel and (say) 2,000 tons of coal and cargo. A cubic foot of steel weighs about 490 lbs., but each cubic foot of steel in the submerged structure is displacing 64 lbs. of sea water or 13 per cent. of its own weight; therefore, we may diminish the total by 13 per cent. and 900 – 13 per cent. = 783 tons weight of steel while submerged. Similarly, taking the weight of wet coal as 100 lbs. to the cubic foot we may diminish the 2,000 tons by 64 per cent.; 2,000 – 64 per cent. is equal to 720 tons; and 720 tons of coal with 783 tons of steel gives us a weight of 1,523 tons to be raised while submerged instead of 3,000 tons. I do not know whether you have any knowledge of these foreign salvage companies being subsidised, but I never heard of that. I think the main reason of the very successful operations of these companies is due, as Mr. Smith pointed out, to their having much better plant. These salvage companies have generally paid their way and have been successful commercial undertakings, and that, to my mind, is largely due to the fact that they operate in waters where wrecks frequently occur, and are kept very much more regularly employed than what our salvors were in the past. But now we have to face a different state of matters. There have been so many vessels sunk during the war that there is ample work for salvors for many years to come, and I think it would pay for big salvage companies to come in with good plant now. Mr. Thom remarked about divers being scarce in our country. I am not quite sure whether he is right in saying that we have very few divers, because in the Navy we have the finest body of divers in the world, and the most successful, and they are brought up and trained in what one might call a diving college. It is quite correct that a stout man is not suitable for going to any great depth. One or two members have spoken about deep diving and the effect upon the body. The utmost depth ever made in the ordinary dress has been 210 feet. At that depth there would be a pressure of something like 86 lbs. per sq. in. But you must remember that the pressure inside is the same as outside. In deep diving there is a great deal of time lost in going down gradually and in slowly coming up. Where deep diving operations have been done by dock contractors, what is called a "decompression chamber" is used. Whenever the diver comes up he cannot come up too fast, but when he does come up, if he shows any symptoms of distress, he is put into the chamber and the pressure is raised equal to that at which he has been working and it is allowed to die down very gradually. With regard to the method mentioned by Mr. Clark as to deep diving, there have been several diving dresses invented to enable a man to work in greater depths than I have indicated, and one of the best that I have seen is a dress invented by two Australian engineers, and known as the Buchanan-Gordon diving dress. It consists of a series of special metallic springs, covered inside and out with very strong waterproof material. The arms are fitted with spiral springs, and the legs with jointed supports to prevent the water pressure forcing them upwards. There is also an arrangement by which the suit can be adjusted to the height of the diver. The dress is fitted with two valves —the inlet or air supply valve, and the outlet or air escape valve—both being under the control of the diver. To the escape valve is connected a floating pipe, the upper (open) end of which can be submerged to any required depth below the surface, thus allowing the air to escape more freely at whatever head of water is desired, and enabling the diver to regulate the air pressure in the dress with greater facility. The weight of the suit is about $3\frac{1}{2}$ cwt. When you have less air pressure inside than water pressure outside, you must make the dress to keep the extra pressure off the man, and, that being so, the dress is not suitable for carrying out manual operations. It was generally only fit for a man going down to make observations, and that is why they have never come to much good. There are several inventions being tried at the present time with a view to enabling divers to go down in a bell, and that bell to have decompression chambers attached to it, by means of which the men could work longer at the bottom and could come up and be decompressed as they were brought up. But I have not sufficient particulars to expatiate on that. With regard to submersible pumps, I do not know that a pump with entirely enclosed motor and with a pipe supplying it with hot air has ever proved very satisfactory. Condensation has always spoilt insulation so far as I have heard, but I have had no personal experience. It would be objectionable practically to have air pipes attached to the pumps. I am informed that the British Admiralty have adopted these submersible pumps very largely, and some of our biggest salvage companies; so they must have faith in the capabilities of the pumps. Mr. Thom also spoke of ships being built so that it would not be necessary to build a platform after the wreck occurred. But the owner of a modern cargo carrier is always crying out for clear holds and open spaces, and I am afraid he would never consider a platform for one minute. Mr. McLaren's idea of building standard ships with the means of adapting them to meet any case that might occur, would not, I am afraid, appeal to owners. Anything that destroys cargo space is touching upon the earning capacity of the ship, and is "taboo." Like Mr. McLaren, I have seen a small vessel lifted by filling her with barrels. That was what gave the idea to the inventor of these canvas and rubber bags which are taken inside vessels and blown out. I may mention that our Navy has special vessels for salving submarines, but they do not publish any details. I don't think I have anything more to say, except that I must thank you very kindly for the manner in which you have received my paper.

A vote of thanks to Mr. Wright and to the Chairman brought the meeting to a close.

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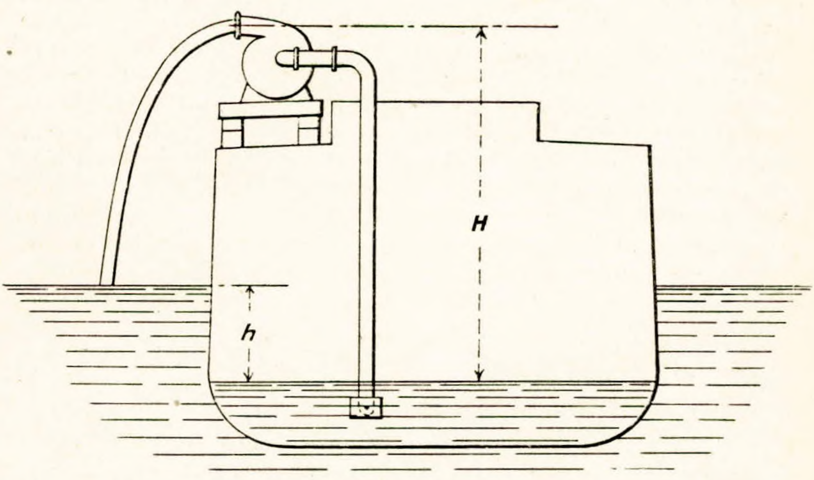
The proposal made to adjourn the discussion for another evening was, on reconsideration, withdrawn in favour of a recommendation to invite members to contribute their views and experiences by correspondence after the publication of the paper in the Transactions; the following contributions have been received by correspondence :—

Mr. JAMES WATT (Graduate): In the notices on the cover of the December Transactions of the Institute, I see that a paper is to be read by Mr. Robert Wright on "Marine Salvage Operations."

Recently on watching several salvage and other operations where pumping was necessary, it has struck me that in almost every case the pumps were not employed to their best advantage. It is very often the case in salvage operations that success or failure depends entirely on the discharge of the pumps and therefore the pumps should work under the most favourable conditions which the circumstances will permit. Generally speaking, in salvage pumps (unless a definite discharge direction is necessary) the water discharges directly from the delivery branch of the pump. Referring to the rough sketch,



when no discharge pipe is used the static head on the pump is H; but when a discharge pipe to the outside water level is used the static head is reduced to h. Now the H.P. required to drive a pump is proportional to H.Q., where H is the head and Q the quantity of discharge. Now for constant H.P., H and Q will vary inversely, that is, by reducing the head on a pump the quantity is increased. In practice due to other factors (*e.g.*, frictional losses) these do not vary absolutely inversely but vary approximately. The additional expense involved in supplying and fitting this discharge pipe is negligible compared with the advantage gained, especially if a large quantity of water is to be dealt with. In reading through Mr. John H. Anderson's most interesting contribution to the discussion on the "Utilisation of Coal" in the December Transactions, I find that he mentions a similar case in connection with a circulating pump. Lack of foresight on the part of the designer very often throws a quite unnecessary head on such pumps.

I trust that this point I have brought forward will be of use on some future operations. Often on such a small and apparently unimportant detail depends the success or otherwise of a great undertaking.

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*Mr. J. D. McArthur: I have read Mr. Wright's paper on "Marine Salvage Operations" with much interest. To be able to tackle salvage jobs with any chance of success, one must needs possess a sound practical knowledge of the structure of vessels, and of calculations pertaining to buoyancy, displacement, trim, pressures on bulkheads and other flat surfaces, etc.; a knowledge of the elements which have to be contended with, and which have a habit of knocking many of the aforesaid calculations endways; the ability to grasp and put in operation without loss of time the plan most likely to succeed under the circumstances, and with the appliances and means at command; and, finally, the determination to see it through in spite of every form of discouragement. The greater the experience I have had, personally, with this class of work, the greater the admiration I have conceived for men who have carried out successfully the really big jobs which make its history.

It is impossible to lay down any hard and fast set of rules for salvage operations, as each particular case calls for its own peculiar remedy. So far as pumping operations are concerned, the direct driven motor centrifugal possesses many advantages over steam sets, and undoubtedly will in time almost entirely

* Mr. McArthur conducted operations in connection with a record salvage case while at Las Palmas.

replace the latter for service. These units are compact and self-contained, require practically no holding down, and in the hands of men who have a knowledge of them equal to that which the average donkeyman possesses of his boiler and steam set, give as little trouble. They also assist the salvor in combating the all-important factor of time, for they can, as a rule, be got to work in as many minutes as it takes hours for a steam set. The b.h.p. of the motor should be ample in proportion to the duty of the pump, revolutions should be moderate—not exceeding 800 or 900 for a 12 inch pump, and, in view of the lengthy runs, lubrication should be forced by pump to all bearings, and water circulation should be amply provided for. Though it may seem unnecessary to say so, a discharge valve should always be used, bolted on to the pump casing discharge branch. The valve should be left closed after the pump and suction pipe have been filled until the motor has run for a few minutes and warmed to its work. It should then be opened gradually, and the full load attained by degrees; and while running, it permits of the load being decreased if necessary on account of any temporary irregularity in the working of the motor. Another point which I have often had difficulty in getting subordinates to understand is that instead of the water being discharged free from the discharge branch or bend of the pump, a discharge pipe should be jointed up, carried overboard and the end "drowned" three or four feet in the sea; or should there be too much swell to permit of this, then discharge as near the sea level as possible. It does not seem to be readily assimilated that the load on the pump varies as the difference of level at suction and delivery—or in the case of a "drowned" discharge, the difference of level of the water inside the hold and the sea outside—not according to the height of the pump above water, until the difference in the running of pumps under the two conditions has been practically demonstrated.

I am unable to comment from personal experience on the Macdonald submersible motor pump, but I am inclined to the view that the advantages claimed for it will be, to a great extent, set off by the duplication of parts, that is to say, oil motor × dynamo + electric motor × pump against the simple oil motor × pump; by the loss of power from this system of transmission, which will be about 20 per cent., allowing for the efficiencies of dynamo and motor; and the necessarily greater cost. Regarding suction hose, I may say that I have invariably found armoured rubber and canvas to give the best results.

*I enclose a photograph of two motor driven salvage pumps, which form part of the salvage equipment of the Grand Canary Coaling Company, Las Palmas. Both pumps are 12 inch—one by Gwynne, of London, coupled to a 55 b.h.p. Tylor motor; and the other by Drysdale, of Glasgow, coupled to an Aster 45 b.h.p. motor. Each has a capacity of 1,000 tons of water per hour—the former at a lift of about 30 feet, and the latter

General View of the Salvage Pumps (Grand Canary Co.).

23 feet. The motors are arranged to start on benzine or petrol, and after a few minutes running, change over to paraffin. I have also an excellent photograph of a diver's boat and crew belonging to the Grand Canary Coaling Company, which I have pleasure in forwarding.

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* Blocks kindly lent by *The Marine Engineer and Naval Architect* from an article on The Canary Coaling Co., Sept., 1916.

Diver's Lighter and Crew. Some of the Steam and Towing Lighters in the background.

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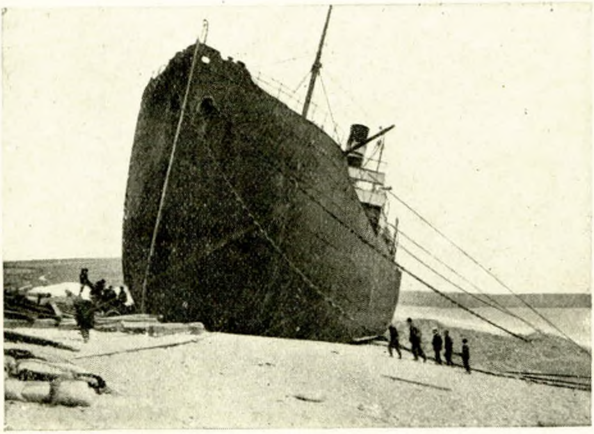
Referring to the expression of a desire that the subject of the paper might be illustrated, this has been complied with, by the courtesy of *The Marine Engineer and Naval Architect*, in the following articles:—

The interesting illustration shows this Italian steamer of 6,000 tons which was driven ashore under stress of weather on December 26th, 1912. Circumstances fortunately admitted of the vessel being guided to a sandy beach, so that she landed without much structural damage. The scene of the stranding is on the Cornish coast, on the Lizard side of Mounts Bay, round from Penzance *via* St. Michael's Mount and Prussia Cove, on the beach beyond which lie the remains of a former wreck and the now almost buried cargo of armour plate. Our first view of the *Tripolitania* was by means of a powerful glass from Penzance, and the interesting nature of the salvage operations invited further investigation. As soon as the weather served for the purpose, salvage operations were commenced by digging alongside the vessel with a view to forming a dock and canal to float her away into deep water; this was found to be impracti ble owing to the sand silting up, and timber and chocks were brought into service; then by means of powerful jacks the



The Italian Steamer *Tripolitania* (6,000 tons) stranded on the Cornish Coast.

vessel has been gradually moved out seawards. Thus with the aid of sea anchors it is hoped that she will be again afloat before the severe weather approaches. The process is a tedious one, but in the course of the early days of August the movement at the forward end was between 30 and 40 feet, while at the after end it was about 10 feet.

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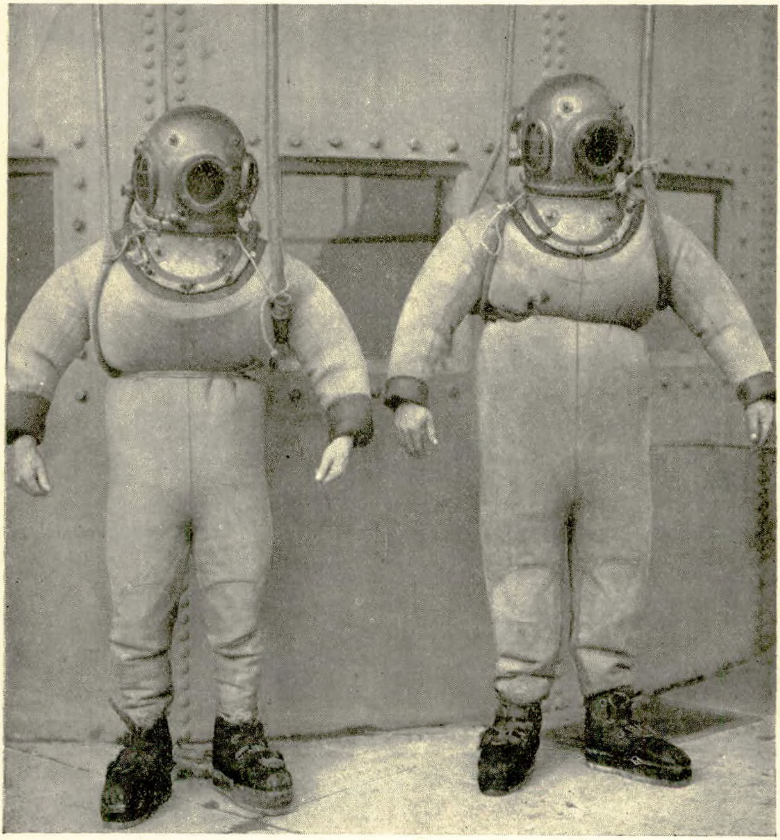
Diving and Diving Apparatus.

Various references have recently been made to the works of Jules Verne, whose vivid imagination—may we say prophetic instinct—portrayed in word pictures those stories which delighted us in our youthful day, and when we allow our thoughts to dwell on either of the subjects of aeroplanes or submarines we inadvertently turn to the suggestive title of one of his books, "Up in the air and down in the sea."

The origin of the diving apparatus appears to date back to the sixteenth century, when a crude form was tried with some success. Subsequent trials resulted in modifications and improvements, which led to a machine of some service and paved the way for its ultimate use in operations connected with the construction of harbours and docks. The difficulty experienced, after the initial stages of the shape, construction and lowering of the diving bell were worked out, was that of maintaining the air in a condition fit for the divers to live in for a length of time sufficient to accomplish work or to investigate. At a depth of water rather over 60 ft., the air, due to the open bottom of what became known as the diving bell, on account of its shape, was compressed to about two atmospheres, and although this pressure was no great annoyance to the inmates, the air soon was so vitiated as to be uncomfortable, and as in the early days of its career no provision was made to change the air, the time limit of human endurance was short. A plan was tried of sinking vessels charged with fresh air to give new supplies, an arrangement being made for the vitiated air to escape. This expedient was the stepping stone to the modern system of supply by means of an air pump. Among the first works where the diving bell was used with advantage was the building of a harbour, when Smeaton adopted an improved type fitted with a force pump connected to the chamber, by which the air was maintained at the required pressure for the depth of the working level. The length of time the bell could remain down with safety to the workers was thus materially increased. The depth to which the diving apparatus can be used depends on the human element locked up within it and to some extent on the individuality of the diver; the normal depth may be stated to be about 28 to 30 fathoms, but instances are known where 32 to 35 fathoms have been reached and work accomplished. The time spent by the diver at these depths is necessarily short, especially when account is taken of the descent, the breathing time at different stages descending and ascending, and the ascent. The balance of the pressure of the atmosphere is a head of salt water of about 33 ft., hence at 11 fathoms the pressure becomes two atmospheres, and when the diver is at work the slight variation of pressure, due to change of position from standing to stooping, may cause an uncomfortable air lock within the dress, which is readily removed by assuming the erect position, when the valves in the helmet will act and equalise the pressure within the dress. The increase in the percentage of CO_2 in the air breathed by the diver, as the pressure is increased within the dress to correspond with the pressure of water due to the depth, is not the most dangerous element to be guarded against, as the absorption of nitrogen by the blood at high pressure requires special safeguards, so that not only the absorption may take place gradually, but the elimination process also. With this object a time-table has been prepared under the direction of the Admiralty for the guidance of divers, so that they may



Divers' dresses fully inflated with air. The one to the left has laced-up legs, the other dress is of the usual pattern.

descend into the depths and remain at work and ascend to the surface with the greatest safety. The greatest depth, and the pressure consequent upon it, which has been found possible for a diver of experience and of good physique to descend to, is 35 fathoms, the pressure being nearly 100 lbs. The pressure on the outside of the diver's dress due to the head of water is counterbalanced in the inside by the air pressure delivered by the air pump.

An interesting book published by Messrs. Siebe, Gorman and Co., with a copy of which we have been favoured, contains much information for the guidance of those who have the conducting of diving operations, with the safety of the diver under their superintendence. The following figures quoted from the table given in this book show the care which is exercised in the movements of the diver so that he may suffer as little inconvenience as possible and minimize his risk. A table is also given showing the pump capacity and revolutions for the degrees of depth up to 34 fathoms.

Depth. ft.	Pres. lbs.	Time from leaving surface to begin ascent.	Stoppages at different depths in minutes. 80 ft.	70 ft.	60 ft.	50 ft.	40 ft.	30 ft.	20 ft.	10 ft.	Total time for ascent in mins.
66	29½	over 3 hrs.	—	—	—	—	—	—	10	30	42
78	34½	over 2½ ,,	—	—	—	—	—	—	30	30	62
90	40	over 2½ ,,	—	—	—	—	—	20	35	35	92
108	48	over 2 ,,	—	—	—	—	15	30	35	40	122
132	59	over 1½ ,,	—	—	—	15	30	35	40	40	163
156	70	over 1 ,,	—	—	20	25	30	35	40	40	193
180	80½	over 1 ,,	—	15	25	30	30	35	40	40	218
204	91½	over 1 ,,	15	20	25	30	30	35	40	40	238

The constituents of the atmosphere are given as nitrogen 79·1 per cent. by volume, oxygen 20·9 per cent. and carbon dioxide (CO_2) ·03. Air expands $\frac{1}{493}$ of its volume for every increase of 1° Fahr., and its volume varies inversely as the pressure. Normally, the volume of air breathed by an average healthy adult male is about 30 cub. ins. per inhalation = 450 cub. ins. = about ·25 cub. ft. = 7·3 litres per min. Exhaled air contains on the average 79·1 per cent. of nitrogen, 16·5 of oxygen, 4·4 per cent. of carbonic acid. The " dead space " formed by the larger air tubes is about 10 cub. ins. The air in the lung contains about 14 per cent. O_2 and 5 per cent. to 6 per cent. CO_2.

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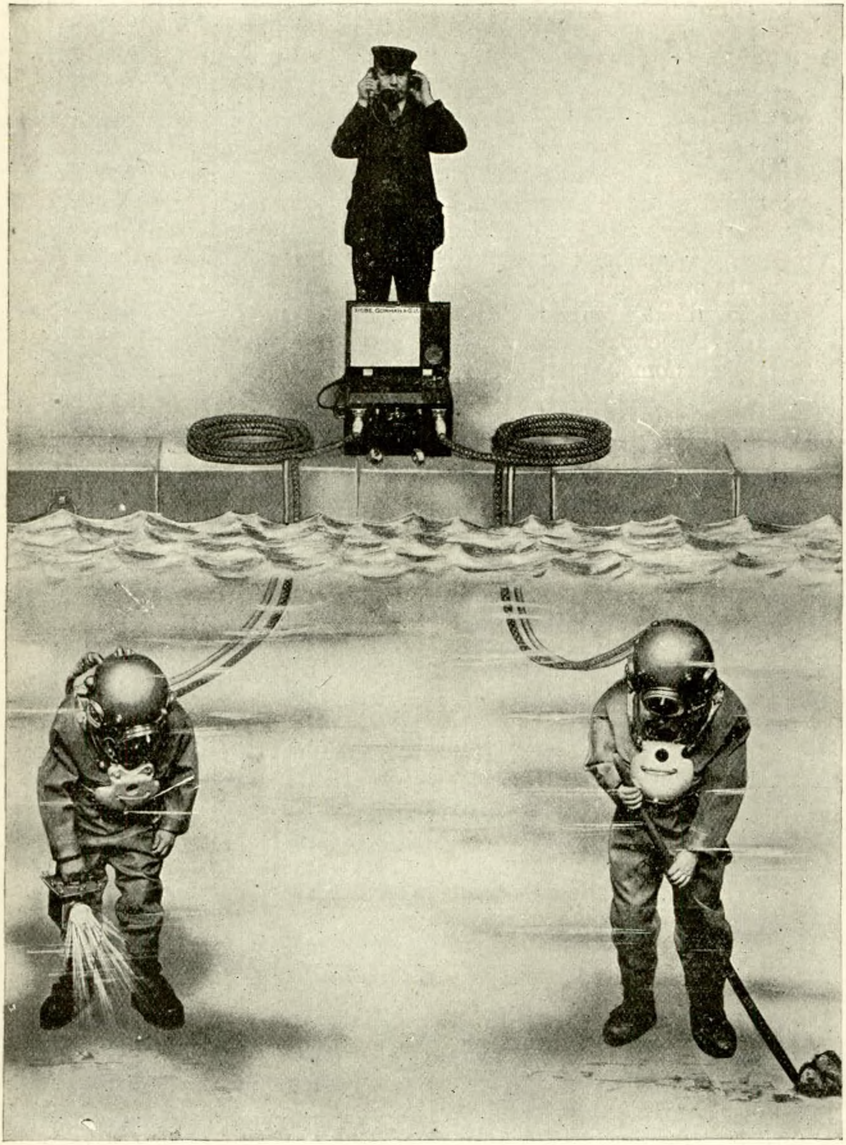
Telephones for Diving Work.

The first apparatus of this kind dates back about thirty years, but the system was naturally somewhat crude at the beginning, the wires being wound either round the air pipe or passed through the same. There were disadvantages however to both these methods, because the depth of working varies and sometimes several lengths of hose are used. In the end the life



Telephones for Diving Work.

line was substituted for the hose-pipe and by this means the wire was inserted in the line itself. This life line is, of course, a necessity to the diver and therefore the change was made without any additional complication. Whatever the depth at which the diver is working, there are only two connections, one at the helmet end and the other at the battery. Besides, by a device of the firm's, there is no strain on the telephone conductors of any kind whatever. The instruments, too, both for diver and attendant are perfectly watertight, which in submarine telephoning will be seen to be imperative. On the Admiralty pattern apparatus a bell is always fitted at the attendant's end of the line but the communication is said to be so loud that it is not necessary to fit a buzzer in the helmet to call the diver's attention.

The system illustrated is by Messrs. Siebe, Gorman & Co., worked under the Graham-Davis patent, by which it is possible for an attendant on the surface to speak to two divers separately or simultaneously, or the two divers to talk to one another when under water, the telephone wire being in the diver's signal line. It will be seen from the illustration how convenient the arrangement is. There is only one battery box and one hand telephone for the attendant's use, so that the working parts may be as few as possible, the rough usage which such apparatus receives rendering this desirable. The cable, too, can be connected and disconnected on the firm's system very readily from the helmet. Care is also taken that the transmitter and receiver in the helmet are perfectly watertight. The cells in the battery are of the best type and securely fitted in a strong teak box, while at the diver's end of the life line a plug connector is provided to screw on to the socket in the helmet. The receiver in the helmet is fitted above the diver's head and the transmitter on one side convenient for use. A loud sounding bell, which the diver operates by pressing a contact piece inside the helmet, is also fitted to enable him to ring up the attendant. When not in use the attendant's instruments are placed inside the battery box, which has a special division for holding them. The fact that the Admiralty use Messrs. Siebe, Gorman & Co.'s apparatus exclusively, is a sufficient indication of its quality for the purpose.

The superficial area of an ordinary sized man's body is about $2{,}160'' \times 15$ lbs. $= 32{,}400$ lbs. At a depth of 33 ft. of sea water the total pressure would be 64,800 lbs. So long as the pressure is equally distributed throughout the body by the body fluids, it has no effect. The total weight of a diver's equipment and the part which he actually wears, and exclusive of his air pipe, is about 175 lbs., therefore a diver (say a 12-stone man) fully equipped would have a total weight of 343 lbs.

An ordinary sized man (naked) displaces about ·075 ton of sea water; a fully equipped diver with dress deflated, about ·15 ton, and with dress fully inflated about ·31 ton. But if fully inflated he would float, and in so doing would displace exactly the weight of himself and dress, or 343 lbs. = ·153 ton, as his displacement would be greater than the equivalent weight of water if entirely submerged.

A submerged body displaces in the sea a weight of water equal to the cub. capacity of the body × 64 lbs. (the weight of a cub. ft. of sea water). Thus a pontoon or camel measuring 15 ft. long by 4 ft. diam., =188·5 cub. ft., would displace nearly 5·4 tons of sea water, if entirely submerged, and its buoyancy would be represented by this figure, minus the weight of the pontoon itself. The pumps used for supplying air to the divers for all conditions of work have been carefully thought out and constructed. Should there be two divers at work, provision is made at the pump so that the supply of air can be adjusted to meet each of them, whether at the same or different depths, by means of a patent air distributing cock.

The helmet of the diver is a fine piece of work made of tinned copper. There are several different types with special arrangement of valves for the air supply and exhaust. There are three windows in the head piece, $\frac{1}{2}$ in. thick glass secured in brass frames; in addition to these there may be a window in the top of the helmet. The inlet valve in the helmet is non-return and is very important, as in the event of the air pipe being broken the valve closes and gives a short time for the diver to realise his danger and act for safety. The outlet valve can be regulated at will by the diver under water to suit the depth to which he descends; the outside water pressure acts on this valve to keep it on the face. The breast plate and corselet are also fine pieces of work and important, in that they join the helmet to the body dress and preserve the air-tightness of the whole. It is necessary to add weights to the diver to overcome the too great buoyancy which otherwise would cause him to rise to the surface or prevent his descent, due to his displacement. These extra weights of lead are secured by hooks at the neck. The remainder of the dress is composed of rubber, and necessarily carefully made and perfectly air-tight. The cuffs at the wrists are made secure by vulcanized rubber rings. The air-connecting pipes from the pumps to the divers are so made and arranged that the least inconvenience due to weight will be experienced by them. The boots are of stout leather with wooden soles and lead oversoles and metal toe caps. Electric lamps and telephones are provided, so that not only has the diver the best means of seeing around him, but can communicate to those above him regarding his operations and be communicated with.

There are many other interesting details regarding the diver and his work, including the various dangers to which he is exposed in his calling. These details we have read with great interest in Messrs. Siebe, Gorman and Co.'s book. The methods and apparatus employed in the removal of submerged rock and the dispersing or blowing-up of wrecks are therein described, together with an account of important salvage operations conducted by means of divers and diving apparatus, and by the courtesy of the Company we are able to give a few interesting illustrations in connection therewith.

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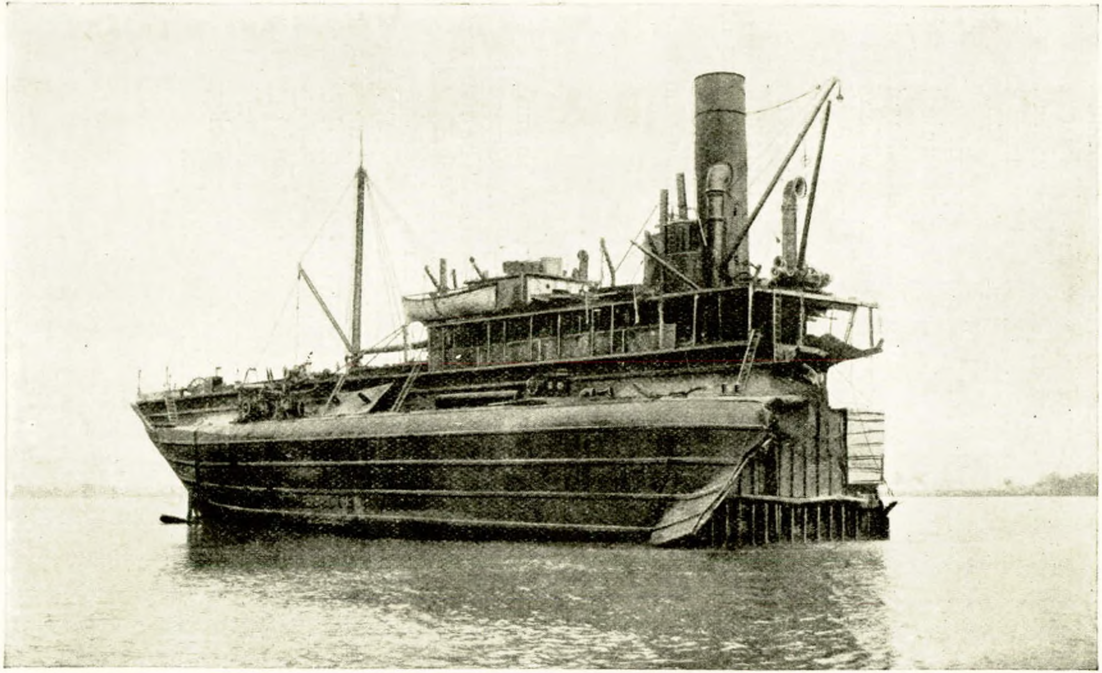
The *Fleswick*, 180 ft. long by 28 ft. beam, was sunk in Cork Harbour, going over on her side as she sank. Compressed air plant was used in the salvage of the vessel. The nett underwater weight to be handled was just on 600 tons. As it was only possible to get about 500 tons of air-lift into the vessel, a hulk was placed right aft to assist. As the air went down into the vessel, a heaving-in plant rigged ashore kept a good strain on her. When nearly full of air, she started to slide in over the mud. The air gave all the lifting power required (with exception of 20 tons or so of lift given by the hulk) to bring the vessel from the position shown in Fig. 1 to that shown in Fig. 3. Two small air compressors, having a united capacity of about 200 c. ft. free air per minute, sufficed for the job.



Steamer *Montgomery*. After end floated.
The salvage of this vessel was brought to a successful conclusion by the East Coast Salvage Co.

Fig. 1. Salvage of the Steamer *Fleswick* by Compressed Air. Before lifting.

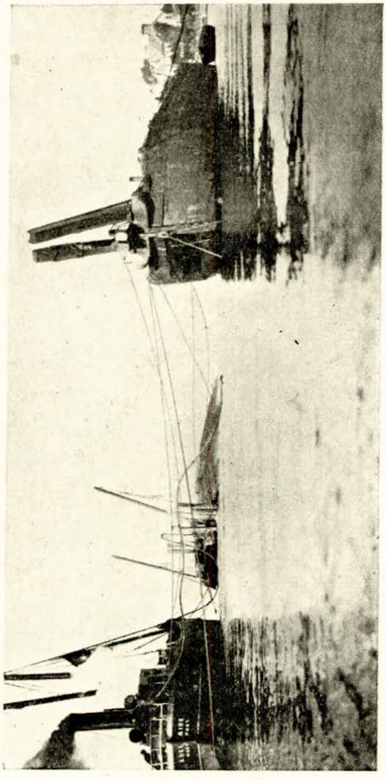


Fig. 2.

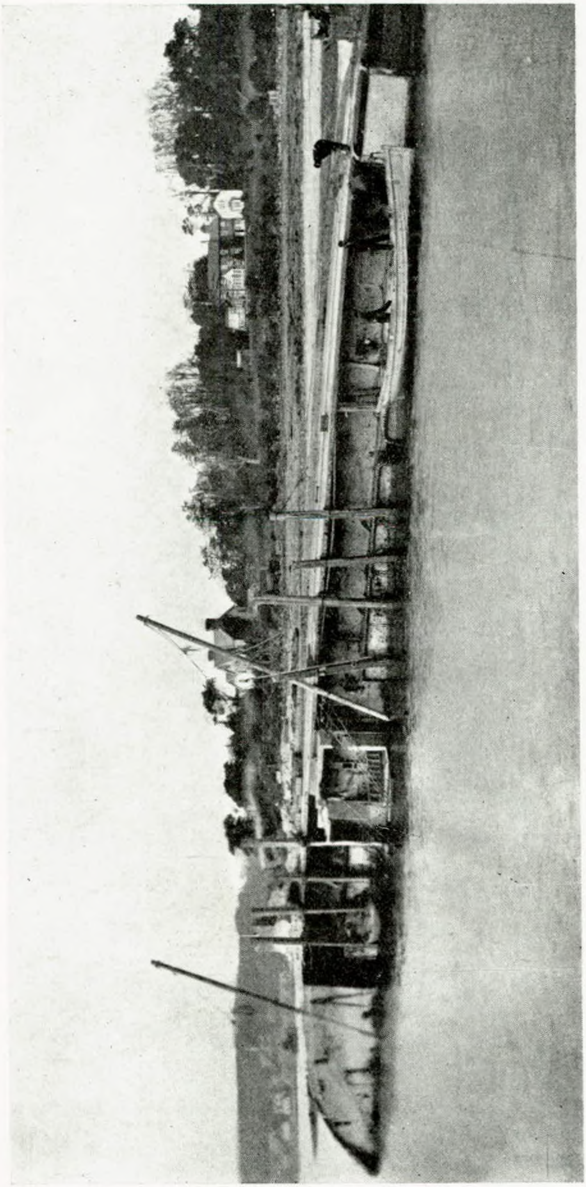


Fig. 3.

Election of Members.

Members elected at a meeting of the Council held in April, 1917:—

As Members.

Edgar George Buckwell, W.O's. Mess, R.N. Barracks, Portsmouth.
George Pounder Derry, "Deneholme," Front's Road, Dovercourt, Essex.
James Robert Douglas, 66, North View, Westbury Park, Bristol.
Arthur Campbell Miller, 75, Buchanan Street, Glasgow.
Thomas C. Nicholson, 127, Fortheringay Road, Maxwell Park, Glasgow.
James Francis Orwin, British India Steam Navigation Company, Bombay.
Daniel Edmunds Rees, 47, Marches Gardens, Grange, Cardiff.
James Stewart, Marine Engineers' Institute, Shanghai.
Thomas Richard Taylor, 59, Cambridge Avenue, Gt. Crosby, Liverpool.
Alfred Louis Thurlow, 14, Fernlea Road, Harwich.

Associate-Members.

Charles Baxter, Cleveland House, Bradford Road, Shipley, Yorks.
Merton Holland Brown, H.M.M.L. 56, G.P.O., London.
Ivan Miller Stewart Donald, 62, Nevern Square, Earl's Court, S.W.
William Jardine Martin, "Hillview," New Mart Road, Edinburgh.

Transfer from Associate to Associate-Member.

Thos. Wm. Chick, Barrodene Cottage, Grosvenor Road, Weymouth.

Transfer from Graduate to Associate-Member.

James Watt, 210, Townhill Road, Dunfermline, Scotland.