Mr. EDWIN CLARK remarked, that his object was to court the fullest discussion on the subject of these docks, and with that view, he had endeavoured to make the Paper as comprehensive in its details as he could. He took this opportunity of expressing his obligations to those gentlemen who had assisted him in bringing these docks to their present state, (more especially Mr. Bidder and the late Mr. Robert Stephenson,) not only in the designs, but also in the financial part of the undertaking, by taking upon themselves personally a large share of the first outlay. He had also to thank Mr. John Heppel for the very ingenious suggestion, which had been described, of arranging the presses in three groups, instead of in the mode originally intended. Mr. Clark expressed his readiness to elucidate any point upon which further information was desired.

Mr. ABERNETHY inquired whether the statement of cost included all the necessary excavation in connection with the lift, in fact all the preparations for receiving the machinery. Some information on that point was necessary, to enable a comparison to be made of the cost of this dock, with that of graving docks of the ordinary description. It was stated, that the cost of the operation of lifting was about £3 per vessel. He presumed that was the average price.

Mr. CLARK replied, that the cost of the excavations had not been given. Obviously the excavations for receiving the pontoons, if any were required, would form a considerable item in the cost of the work. In some places, however, the whole work consisted simply of sinking columns. But he would before the close of the discussion, give this information in detail. The cost of lifting named was an average for all the vessels lifted.

Mr. CHARLES CAPPER, having had opportunities of seeing a great deal of the operations of this dock, was satisfied that, as a mechanical contrivance, it was perfect. The commercial success of the undertaking was, however, the question which came more within his own province; for however successful it might be as a mechanical contrivance, if it were not commercially successful it would be of no use. The Author had described the circumstances under which this dock was a commercial failure, in the first instance. It was assumed, incorrectly, that the mere charge for lifting the ships, and the rental for the use of the pontoons would be sufficient to pay a remunerative return upon the outlay. There were about twenty-seven docks on both sides of the river, the proprietors of which docks were repairers of ships, as well as dock owners, and it was to their interest to sink the charge for the use of the docks in order to get the repairs of the vessels. This Company having at first no mechanical appliances for repairs, and being subject to the competition referred to, the commercial failure of the project would be readily conceived. It did not matter where dry docks were situated in this country, whether on the Tyne, or at Southampton; the system of charges for merely docking and undocking, and for the use of the dock, would not pay. The Tyne dry docks did not pay more than $2\frac{3}{4}$ per cent. if the profits were reckoned by these charges only; and the docks at Southampton only yielded a similar return, viz., $2\frac{3}{4}$ per cent. upon the £166,000 of outlay. It was obvious that, to make these docks, or any ordinary graving docks, successful speculations, the proprietors must, to a certain extent, go into the business of repairing the ships. If they did that, as was the case in this instance, they would turn a loss into a respectable profit. The last year before the Thames Graving Dock Company undertook repairs, the loss upon this dock was about £4,000, but since the repairing had been superadded, although it had only been as yet perfectly carried on for nine months, a profit had been realized of between £11,000 and £12,000 per annum, which of course made a very material difference in its commercial character. This dock experienced another drawback. Being the first of the kind on the Thames, many modifications were required to adapt it to the peculiar requirements of the port. These were all additional expenses, of course, as usual, charged to capital; and when revenue had to pay upon capital employed in making experiments, it affected the result. He was bound to say, that the undertaking was now approaching that state in which he wished to see it; and he believed before long it would be one of a highly remunerative character.

Mr. P. HEDGER endorsed all that had been said as to the unremunerative character of the docks at Southampton, the return being not more than $2\frac{3}{4}$ per cent., or 3 per cent. upon the outlay. The repairing of ships formed no part of the business there. At Southampton there were three dry docks, one of which could accommodate any ship yet built, except the 'Great Eastern.'

Mr. A. GILES said, the Paper contained much that was interesting, and the mechanical arrangements of this dock were no doubt of the most admirable and perfect character; but he thought the ordinary graving docks had been undeservedly condemned. Before the advantages of this dock could be compared with those of ordinary graving docks, it was necessary to be informed what had been the total cost of the existing works.

Mr. J. SCOTT RUSSELL, V.P., thought additional information was required to enable a comparison to be made between this system and that of a floating dock to be filled with water by a steam engine, and emptied of water by the same means; and especially was information required in order to form an approximate estimate of the comparative cost of the system under discussion, and that of simply filling and emptying the tanks in the floating dock, which accomplished all that was done by the hydraulic apparatus. He yielded to no one in admiration of the ingenuity and ability displayed in the whole of this apparatus, but he thought there was a difficulty in comparing it fairly with stone docks. Information was also needed as to the advantages and disadvantages of having a vessel which was 'hogged,' or out of shape, placed upon an elastic pontoon which would yield to its distortion, or of placing it on a rigid pontoon which would not yield to its distortion, but which would compel it to come back to the straight line on which it was originally built, and which it was very desirable it should come back to, before it was repaired.

Mr. EDWIN CLARK stated, that the cost of the excavations for the lift pit proper was £2,000, the contract being let at 1*s*. per cubic yard. The cost of the whole of the excavation, including the lift pit and the deep channel leading from the lift pit to the Victoria Dock basin on the one hand, and to the shallow water used for the pontoons on the other hand, amounted to £3,593. The lining of the dock with concrete and masonry was executed at a cost of £4,473; and the timber platform all round the dock was provided at a cost of £4,618. The outlay upon the coffer-dam in the dock was £6,543. In addition to this the engine-house and valve-house were erected at a cost of £2,200, making the total cost in connection with the lifting apparatus, £21,427.

Sir CHARLES FOX thought the term "power," as applied in the paragraph of the Paper which stated "That power, when required, is increased by cutting off one or more of the pumps," was an erroneous use of that word. The word "force" would more correctly convey the notion of the Author, inasmuch as no reduction in the number of the pumps could affect the power of the prime mover, in this case, a steam-engine of 50 H.P. The only result of cutting off pumps would be, to let the whole of the above power be expended upon a smaller number of pumps, and consequently to increase the pressure in the cylinders in work, and so to spread the operation of lifting over a longer period of time, but in no way could the power be interfered with by that operation. It was stated in the Paper, that the rams were each 10 inches in diameter, having, of course, an area of 100 circular inches: that their lifting capacity being 2 tons per circular inch, was therefore (less the weight of the ram) 200 tons each. It was further stated that these rams had been proved, to the extent of 2½ tons only per circular inch. Now it seemed to him, that if some of these pumps were thrown out of work, and the pressure thereby increased in the cylinders still in operation, the limit of half a ton for proof was far too little. It was known, that the Board of Trade in dealing with a bar, which was considered to be capable of carrying, as a minimum, 20 tons, would not permit it to be loaded to more than 5 tons; but then that rule was applied to structures which were exposed to many trying circumstances and influences, such as corrosion, vibration, &c., and therefore, though he did not think the proof of hydraulic presses need be anything like that of double the actual pressure employed, still it should not be less than 50 per cent. more. He should not be satisfied with exerting a pressure of 2 tons per circular inch, unless he had proved the press to about 3 tons; and, if it were his intention to increase the pressure in any individual cylinder beyond the 2 tons, he would prove that cylinder to at least 3 tons and perhaps 4 tons. After a very long experience in the use of hydraulic presses, he had arrived at the conclusion, that a pressure of 2 tons per circular inch was the one practically the most desirable, and with that as a maximum, he would not feel comfortable with a press proved to less than 3 tons; and if any real advantage was to be obtained by cutting off any of the pumps, the presses ought to be proved to the extent of 4 tons; and, therefore, this operation of cutting off pumps could not be performed, with safety, with a proof of only half a ton beyond the ordinary working pressure of 2 tons in the cylinders. As to the commercial element of the Hydraulic Lift Graving Dock, compared with the old form of dry or graving docks, he thought the statements contained in the Paper failed to carry conviction in its favour to the minds of those who would take the trouble of making a careful comparison between the two. It was admitted, that in consequence of the competition of dry docks in the Thames, it was not till about nine months ago, when the Company took upon themselves the additional business of repairing vessels, one open to but little competition, that the plan ceased to be attended with considerable loss. Up to that period the revenue account of the Company showed a debt of £4,000 against the working of the hydraulic lifting apparatus, and it was only by the Company having embarked in the new business of ship repairers that its pecuniary position was improved—not by the use of this lift, but by the profits of their new avocation; while the dry or graving docks at Southampton, where ships were not repaired, paid a return of 3 per cent. upon the capital embarked in them. The conclusion at which he had therefore arrived was, that this description of dock *per se* had hitherto failed to show satisfactory commercial results.

Mr. F. J. Bramwell would, in the first instance, add a few words on the history of floating-docks. This history had been touched on by the Author, but he had not carried it back to the earliest times. Mr. Bramwell found it recorded that, in 1785, one Watson, a shipwright on the Thames, constructed a wooden floating-dock in which a large vessel called the 'Mercury' was repaired. In this construction of floating-dock there was an end-gate, which was lowered to admit of the vessel entering, and the gate being afterwards raised, the water was pumped out of the dock. Mention was also made, in 1776, of one Aldersley having constructed "a large portable dock in which to float vessels."

As regarded the more modern history of floating-docks, the Author had alluded to the box-dock and the sectional dock, both of which had been used in America; but he had omitted to mention a dock that was used in that country prior to either of the other two docks; and Mr. Bramwell was somewhat surprised at this, as, in its modified construction, it appeared to him to be one that ought to have found favour with those who advocated the raising of vessels by hydraulic presses. He alluded to the dock which, from its original construction, was known in the United States as the Screw Dock, but which was afterwards worked by hydraulic power. He had placed on the wall a rough drawing, showing this dock as thus constructed with hydraulic power. It would be seen that it consisted of two parallel rows of piling placed at right angles to the shore; these rows of piling being wide enough apart, sufficiently roomy, and in a sufficient depth of water to take in between them the largest ships the dock was competent to lift. The piles in each row were connected at the tops by timbers, on which was a gangway. From one row of piles to the other there were, at frequent intervals, transverse timbers. These timbers were lowered into the water, and the ships to be docked brought over them. At each end of each timber there was a chain, by which it was suspended. These chains went upwards, and passed over pulleys placed on the frames connecting the heads of the piles, and then all the chains on each side were connected to a horizontal traction-bar, which was a very strong wooden bar extending the whole length of the dock, and supported on rollers. To each traction-bar, there was a powerful hydraulic cylinder, and on this being worked, the traction-bar was moved endways, and thereby the whole of the chains attached to it were uniformly drawn; and in this manner the presses on the two sides being worked at equal rates, the whole of the beams below the vessel were simultaneously and uniformly raised, lifting the vessel that was upon them out of the water. He had seen that dock when at New York in 1853, and he believed it had been in operation for many years previously, and with perfect success. It appeared to him to be interesting as regarded the present Paper, to the lifting of vessels by means of hydraulic presses.

Having made these few remarks upon some points omitted from the history of floating docks and of docks worked by hydraulic power, he would now remark on the subjects mentioned in the Paper. He understood the Author to lay considerable stress on an advantage possessed by the Hydraulic Lift Graving Dock, that the bilges of the vessels were supported almost immediately upon the keel taking the blocks, and a contrast was made between this mode and that practised in ordinary dry docks, where until the whole of the water was removed, so as to admit of the workmen fixing the shores, the bilges remained unsupported. He believed, with the Author, that this ability to give support to the bilge of the vessel at once was an important matter. He thought that in all cases after the natural support of the water was removed, it should be compensated as speedily as possible by some other support. But although he entirely agreed with the Author in this view, he thought it ought to be clearly understood, that that ability to support the bilge at once was not a property peculiar to the dock under consideration. It would be found that it existed in the New York Screw Dock, to which he had just referred, and it existed also in the Sectional Dock. The Author, therefore, in availing himself of the system of blocks to support the bilges, had done no more than had been done in previous docks, nor than might be done in any other dry dock; at the same time he was glad to find that the Author approved of that which he (Mr. Bramwell) believed to be a most useful precaution in the docking of ships.

He would now go to another point which was raised by the Author, which was this—that, in his judgment, not only was it unnecessary that the bed on which a vessel was received while being docked should be rigid, but that it was absolutely undesirable that it should be so. Now he must say he entirely dissented from this view. For although at the present day there were many iron ships which were so well built as to be efficient girders in themselves, and although even wooden ships were now much better trussed and braced than they used to be in days of yore, when they were little more than an assemblage of timbers side by side, without proper trussing and fastening, nevertheless he considered that a properly-constructed dock should be one in which any vessel might repose in the certainty of not being called on to rely upon its own strength as a girder to compensate for the want of strength in the dock, and where, therefore, a ship, however weak in its construction, or however old or damaged, might be taken with the assurance it would not get out of shape.

To explain himself still further, he might say that when he had been consulted on the subject of floating docks, he had laid it down as an axiom, that the dock, if properly made, ought to possess so much likeness to a stone dock in its rigidity, that if a ship placed in the dock were cut into slices, these various slices ought to retain their relative position to one another, although the weights of the various slices would, if of equal thickness, be very different. As bearing on this point of the difference of weight per foot run, he wished to call attention to the Author's mode of taking the weight of a ship, which he had done, as being, in extreme cases of armour-plated vessels, 20 tons per foot run, or 6,000 tons for a ship 300 feet in length. But Mr. Bramwell objected to the construction of a dock being based on the assumption, that a vessel had a uniform weight per foot run. Take the case of a ship 300 feet long, and weighing a not unusual weight for that length of 3,000 tons, it would be very wrong to assume that that ship weighed 10 tons per foot; the fact would probably be, that for each foot run amidships, she would weigh about 14 tons, and for each foot at the end only about 7 tons. The assumption, on the part of the Author, of uniformity of weight per foot run must, he thought, be admitted to be a mistake; and yet, upon this theory alone could the practice of a non-rigid bed be admitted, and certainly such an eminently non-rigid bed as the Author had put forward as his ideal of excellence, viz., a sheet of india rubber large enough to secure the vessel.

Having thus endeavoured to explain the reasons why non-rigid beds were bad, he thought he might be allowed to refer to the practice of ship-builders, to show that that practice coincided with the principles he had been advocating. It would be admitted that in building vessels, the greatest possible pains were taken to obtain a thoroughly solid bottom for the slip-way whereon they were built; and it was well known that considerable damage had arisen from the ground of a slip-way having occasionally yielded in parts. This showed the importance attached by ship-builders to having a rigid bed on which to build a ship. It seemed to him that that which required a rigid support while being built, required a rigid support while being repaired. He wished, on this point, to be allowed to refer to the very pertinent observation made by Mr. Scott Russell, that if a ship got out of shape while afloat, the thing wanted in repair was a dock that should bring her back into shape. Mr. Bramwell believed he was correct in saying, that about ten or twelve years ago, an impression existed in the mind of an inventor, that a rigid bottom to a dock was a bad thing; and he proposed to remedy this, by placing on the bottom of a stone dock a number of small hydraulic presses, on which the keel of the ship was to rest, in lieu of resting on the ordinary keel blocks. These presses were all to be connected by pipes, so that they might adjust themselves to the pressure of the keel. This arrangement was tried in one dock in London; but, as might, according to Mr. Bramwell's views, have been expected, was found to be injurious to the vessels, and had to be removed, and the rigid system of blocks restored.

It appeared to him that following upon this reference, to the effect of endeavouring to use for keel-block hydraulic presses, when coupled up into a system, came not improperly the consideration of the operations which took place in the Hydraulic Lift Dock, when raising vessels by the system of presses at each side of the dock. It was quite clear that so long as these were all united into one system, there was no remedy whatever against the vessel tilting either sideways or endways in the act of being lifted, and the Author had given well-merited praise to Mr. Heppel, for the suggestion of dividing the presses into three distinct groups. No doubt by this arrangement perfect command had been obtained over the raising, so far as related to keeping the lift horizontal; but this arrangement of grouping did not get over the fact, that the presses at the ends were exerting the same upward force as those in the middle; that was to say, a force representing the average load, and that, therefore, as a vessel was undoubtedly lighter at the ends than in the middle, it was lifted by an excess of force at the ends, and a deficiency of force in the middle; and the difference between the forces employed at the respective parts, and those forces actually required there to balance the weight of the ship at those parts, had either to be taken off by the ship itself acting as a girder, or by the strength of the pontoon or saucers so acting; and he feared, looking at the want of depth in the saucer, that it was upon the ship itself the strain must come; and this he looked upon as an undesirable point in the construction of the dock.

Upon this question of preventing an undue lifting of one press as compared with another, he would allude to a plan he had prepared for the use of hydraulic presses in certain operations in the manufacture of iron, where he had introduced a system of wedges, the withdrawal of which could be regulated at pleasure, and thereby whatever might be the simple power of any press, its advance could only be at the rate allowed by the controlling wedges. He feared that such an apparatus could not be introduced to the presses in the dock without its being made somewhat complex; but, nevertheless, he called attention to it, as a means by which the want of uniformity of load on the presses might be overcome.

He would now say a few words on the subject of floating docks, which the Author indicated as proper objects of comparison with his system. The Author had referred to the failure of several floating docks, but he thought it would be found the failure had been confined to the American sectional dock. To Mr. Bramwell's mind, the failure of these docks was clearly to be traced to two defective points in their design, and to their having been built of wood. The error in design was, first, the making them in sections unconnected by any girder; secondly, the absence of proper water-tight bulkheads. The first error caused the ships to be strained, the second produced the liability to turn over while in the act of lifting the ships, but nothing was easier than to diminish to an insignificant amount this tendency. As by the introduction of a few water-tight bulkheads the tendency to turn over, caused by any accidental inclination of the dock having sent the water contained in it to one side, would be diminished, so as to have no practical importance; the decrease of the tendency would be in a very rapid ratio, that was to say, it would be in the ratio of the square of the number of chambers into which the dock was divided by bulkheads; so that a dock divided by three bulkheads into four chambers would only have $\frac{1}{16}$th the tendency to turn over, that a dock would have in which there were not any bulkheads.

He would, in conclusion, say a few words on a floating dock which was now being constructed from his designs for St. Thomas's in the West Indies; and he begged leave to refer to it, because the Author had said in effect that all floating docks were bad and unsafe things. Mr. Bramwell could not concur in this opinion, and he thought it would be a matter of regret, if a class of docks, which could be used wherever there was water enough to float them, and which were wholly independent of the nature of the bottom, and might therefore possess peculiar advantages in certain weathers, were to be stigmatized as bad and unsafe unless they really deserved that character, which he hoped to convince the meeting they did not. The dock he now alluded to was made of wrought iron, and was 300 feet long by 100 feet wide, and the bottom part was 9 feet 6 inches deep; this bottom was, for convenience of manufacture and repair, made in six separate pontoons; each pontoon extended from side to side of the dock, and was in breadth 50 feet, or $\frac{1}{6}$th of the length of the dock. Inside the pontoons there were a proper number of water-tight bulkheads and a due system of trussing, to distribute the weight of the vessel. Upon the pontoons at the sides of the dock were two girders: these were lattice girders, of about 35 feet high, and sufficiently strong to transmit the surplus floating power of the end pontoons to the assistance of the more heavily loaded central pontoons, and in this way it was believed the fundamental points of keeping all strain off the vessel had been arrived at.

In order to prevent the dock from tilting out of level while lifting a vessel, there were smaller pontoons, or floats, which were contained within the open work of the side girders, and the position of which, in relation to the dock as it rose, was maintained by suitable machinery. He had preferred trussed girders to the ordinary close sides of a box dock for several reasons: one was, that greater strength was got for the same amount of metal; another was, that the open side afforded good ventilation, a most important point in a tropical climate; and another was, that the open girders, when immersed, displaced but little water, whereas the closed sides of a box dock displaced several thousand tons, which had to be overcome by the admission of that extra weight of water into the dock, all of which had afterwards to be pumped out. For these reasons he had preferred the open girders, and had employed the adjustable floats to play the same part in preserving the level of the dock, while being raised or lowered, that the closed sides effected in the box dock. The adjustable float, in fact, represented just that portion of the close side which, from time to time, was at the surface of the water. In using this dock the water would be admitted into the pontoons, which would cause the dock to rush past the floats which would remain on the surface; then the vessel would be drawn over the keel blocks, the water be pumped out, and the float apparatus worked, so that as the dock rose the floats would still remain at the surface, the bilge shores being brought to act on the vessel as soon as her weight was fairly on the keel floats. He thought that this dock and the box dock were, when properly constructed, absolutely safe, and that they would put far less strain on a ship when docked, than would be put on by the Hydraulic Lift Dock as now constructed.

Mr. Abernethy, while admitting the great ingenuity which had been displayed by the Author and the other Engineers who had advised with him relative to the construction of the hydraulic dock at the Victoria Docks, was, nevertheless, somewhat at issue with him in the conclusion, that this description of dock was likely to become of universal application; on the contrary, he thought the Hydraulic Lift would be adopted only in exceptional cases. In the Paper, the Hydraulic Lift had been compared with the graving dock system generally, and also with floating docks; and the subjects of comparison instituted were, first, the question of economy, and secondly, certain advantages which were claimed for the Hydraulic Lift. He was at a loss how to institute a fair comparison from the information contained in the Paper, because the Author had selected, in respect of the economy of the question, one of the most recent docks constructed at Portsmouth in connection with the national dockyard at that place. The dimensions of that dock, and the quantity of stone and other material used in it were given, but not the cost. As far as economy was concerned, the Author could hardly have selected a more costly example; because the graving docks in connection with the Government naval establishments were generally built entirely of finely dressed granite ashlar, throughout the whole of their parts, the whole system of construction being of the most expensive character; and it was not therefore a fair subject of comparison with the Hydraulic Lift system; yet it would seem, from these examples, the Author had arrived at the conclusion, that the graving dock system must of necessity be more costly, and, in many cases, even impracticable. But the cost of the Hydraulic Lift had been £66,705 for the machinery, and £21,427 for the masonry and works connected with the lift, making a total cost of £88,132; the results of which, up to the present time, had been to provide seven pontoons of an aggregate length of 1,496 feet.

Mr. Abernethy had, during late years, constructed a number of graving docks at present in use, and proved to be very effective. Several of them possessed, it was true, advantages in respect of site, but there were numerous sites as favourable in all parts of the kingdom. He would, in the first place, allude to the graving docks on the river Mersey, in the red sandstone rock. The dimensions of five docks at Birkenhead, which he had constructed years ago, were as follows: No. 1, 300 feet long, 35 feet wide at the floor, and 18 feet 3 inches of water over the sill at ordinary spring tides; No. 2, 200 feet long, 40 feet wide, and 18 feet 3 inches of water over the sill; No. 3, 400 feet long, 64 feet 6 inches wide, and 22 feet 3 inches of water over the sill; No. 4, 440 feet long, 70 feet 9 inches wide, and 26 feet of water over the sill; No. 5, 350 feet long and 69 feet wide, and depth of water over the sill 22 feet 3 inches—making a total length of docks of 1,690 feet, which had been constructed at a cost of £86,000. Those were instances of graving docks in a favourable site, hewn out of the solid sandstone rock. He had also recently constructed two other docks at Falmouth, of the dimensions respectively of 350 feet by 51 feet, and 15 feet 6 inches of water over the sill, and 400 feet by 66 feet, and 17 feet 6 inches of water over the sill: making a total length of dock of 750 feet, at a cost of £29,000. In the construction of these latter docks, a considerable amount of pumping was necessary, in consequence of the open character of the rock. Then again on the question of economy, it was obviously impracticable to carry out the Hydraulic Lift system near the existing London Docks, on account of the large area occupied; it would be an expensive item to secure such an extent as 26 acres, the area occupied in connection with the Hydraulic Lift at the Victoria Docks.

The advantages claimed for Hydraulic Lifts over the existing graving docks, beyond the question of economy, were—first, freedom from strain to the vessels docked, arising from the elasticity of the pontoons. He was not a shipwright, but he apprehended that the element of elasticity would not be regarded by shipwrights as an advantage; and he thought the rigid floor of a graving dock was to be preferred. It would, he thought, be a dangerous experiment to place a crazy old ship on an elastic bearing. Another advantage claimed for the pontoon system was the peculiar mode in which the vessel was blocked. The same mode had for a long period been adopted in the ordinary patent slip, viz., by bilge and slide blocks. That was as much a matter of necessity in the case of patent slips, as it was on this system; but it was not a matter of necessity in ordinary graving docks. As a general rule, the vessel rested on the keel blocks, and was shored from the sides; but bilge blocks if necessary could as easily be provided on the floor of a graving dock as on a pontoon or patent slip. A great advantage claimed for this mode of blocking, was the replacing the pressure of the water on the outside of the vessel. Now, he thought, very extraordinary blocking was required accurately to represent the pressure of water on the outside of a vessel. It was also stated in the Paper that the displacement of a vessel was equivalent to the weight of each particular section. That was to say, that if a vessel was divided into sections, the displacement was equivalent to the weight of each particular section. He apprehended the displacement was equivalent to the form, capacity, and weight of the vessel as a whole, and not to any particular section. It was further stated, that in the case of a vessel resting on keel blocks, the weight was nearly equally distributed over the whole keel; that, he thought, was erroneous, as the weight would be due to the particular section of the vessel resting on the blocks.

With regard to floating docks, he agreed that such docks could be constructed to dock vessels with perfect safety, and he felt certain, that floating docks would give a more profitable return, and could be worked with greater economy than hydraulic lifts occupying, as suggested, an entire pontoon for the accommodation of a single vessel at a time. One objection made to graving docks was, that on placing a vessel in dock, resting on the keel, a great length of shoring was required; and in the case of the Mersey docks he had adopted means to obviate that difficulty. At certain portions of the dock, he had upright piers in the place of the altar steps, so that a vessel could be brought in between those upright piers, and moored directly over the keel-blocks. Short shores only were required to keep her *in situ*, and those shores might be worked by machinery, so as to be adjusted immediately the vessel was on the keel-blocks. That system of piers had been adopted by him at all the docks at Birkenhead, eleven in number, and also at the two docks at Falmouth, to which he had referred. There could be no doubt, that in regard to vessels of the largest class, such as the 'Warrior,' which had a height of about 40 feet from keel to deck, it would be exceedingly dangerous to risk such vessels on pontoons merely blocked under the bilges, without horizontal shores at the sides. Therefore, he thought if pontoons were ever applied to that class of ships, it would be necessary to have side pontoons, or side frames upon the horizontal pontoons, and when that was the case, the cost of the whole would equal that of a floating dock of the same capacity. As a further use to which pontoons might be applied, the Author had pointed out the opportunities for transporting vessels on them for a considerable distance, as for instance, across the Isthmus of Suez, if the canal were ever cut; but it was quite obvious that it would be impossible to move a large ship any considerable distance on a pontoon with her masts and rigging standing and exposed to the action of the wind. In the instance given in the Paper of such transport, the pontoon, with the ship on it, made so much leeway as to sink herself in a short time with the vessel upon her. It was fortunate this took place in shallow water, instead of in the Victoria Dock itself.

Another point, was the economical working of the existing graving docks as compared with the pontoons; as in the case of repairs to steamers, taking out the boilers, machinery, &c., and putting them in again. When vessels were placed on pontoons, it was a very costly operation, either to erect staging to the level of the deck of the ship, or to lift the boilers, or other heavy weights from the ground, and then to lower them into the vessel; whereas, by means of a powerful crane, placed on such piers as he had provided in his graving docks, the boilers, or other heavy materials, could be removed from the ship, and replaced with the greatest facility. As regarded shoring in graving docks, it could be done in any position, but not so under the pontoon arrangement. While stating thus broadly his view, that this form of dock could be used only in exceptional cases, and not as a general rule, he was at the same time convinced in many positions it would prove successful, as in a tideless sea, or where the physical difficulties were so great as not to warrant the expenditure necessary for constructing the ordinary graving dock. In such a locality as the Victoria Docks, where peculiar facilities were at hand, he thought the hydraulic system was admirably adapted for its purpose; but he repeated, that he thought it must be considered altogether as exceptional.

Mr. VIGNOLES said, the history of docks having been touched upon in the Paper, he would state—as the fact had not been mentioned—that he believed the first instance of the employment of a floating dock occurred about the time of Peter the Great, in the estuary or Bay of Cronstadt, where a North-country captain, wishing to repair his vessel, found an old hulk floating in the bay, upon which he had permission to operate; and he arranged means of letting in, and pumping out the water, so as to form a floating dock, on which to carry out the required repairs to his ship. The name of that old hulk was the 'Camel,' and to the present day a contrivance of that kind was understood by the term 'camel,' which consisted of a rough wooden box, from which the water could be discharged to raise it up, and into which water could be introduced to sink it again. With regard to the invention now under discussion, he thought it was one of the most ingenious contrivances that had appeared for many years. He thought it was applicable in more instances than had been generally admitted, and he thought, the comparison of the expenses of the system with those of graving docks on other systems was quite fallacious. Every invention must be applied to its own particular case; and there were many cases in which this invention could be applied, both abroad and at home, with great advantage.

Mr. W. R. Kinipple had watched the progress of these pontoon docks with interest, and thought that great credit was due to the Author for the perfect way in which he had brought hydraulic lifts to bear so successfully upon such enormous weights. The pontoons were, however, somewhat defective, as it was impossible to render them perfectly rigid, without using such a quantity of material as would render them useless. When a pontoon was 300 feet in length, and only 6 feet in depth (which was in the proportion of only 1 to 50), to make it rigid so much metal must be inserted as to sacrifice altogether its floating powers. He remembered seeing one of the longest pontoons, which had, with a ship on it, a deflection of 7 inches or 8 inches out of the straight line. Reference had been made to the pontoon sunk at the London Docks, with which he had had to do. He believed the construction of that pontoon to have been perfect, although it had failed at present. The side girders were 180 feet long, 17 feet deep, and 3 feet wide. A ship might be put upon the deck between the girders without injury to her straight line. He attributed the sinking of that pontoon chiefly to the want of compartments and stiffeners to the bottom plates, between the cross girders, which were 8 feet apart. She was built like a long, flat tea-board. The water went in at one end, and there was a consequent depression of that end. This caused an almost instantaneous rush and accumulation of water to one spot, the parallels gave way under the violent strain thereby produced, and the pontoon went down rapidly at one end, whilst the other was some hours in sinking. Pumping at the rate of 66 tons per minute, had not the slightest effect in reducing the water; and it was not until this great pumping power had been found useless, that forcing air down had been resorted to, when her deck was blown off. With regard to the pontoon docks in these two instances, it seemed to him a great waste of money to construct them in a tidal river, in order to do artificially, that which could be done naturally by the rise and fall of the tide. He had lately finished a dock at Limehouse called the Limekiln Dock; it was 355 feet long, 55 feet wide on the floor, 53 feet at the entrance, and 20 feet of water over the sill. The outer apron was laid in Portland cement, the entrance was of brick, the sides and bottom of timber and concrete, and the cost had been only £17,000. There were, at the present time, two vessels in that dock of the aggregate tonnage of 3,000 tons.

Mr. A. M. RENDEL said, his responsibility in regard to the pontoon which was now lying at the bottom of the London Docks was small. Messrs. Rose and Crowder, who worked, for some time, the hydraulic lift at the Victoria Docks, proposed, to the London Dock Company, to lease a part of the eastern dock, and to build a pontoon there on their principle. The proposal was referred to him; he reported favourably on it, and the pontoon was constructed. He heard nothing more of the matter till he was informed, that the pontoon had gone down head foremost to the bottom of the dock. On looking into the plan of the pontoon, he found that it had no bulkheads; consequently, the water, when let into it, caused a violent oscillation; and the parallels, by which it should have been steadied, being constructed in a most inefficient manner, were torn from the ground, and the whole structure sank. The fact that the water could not be reduced by pumping led him to think that the caulking of the decks was blown out; he did not think there was a hole in her bottom. On the general subject he would say, there could be no question that the hydraulic lifts were very useful in their actual situation; but he was not prepared to admit their applicability to all docks. For instance, at the London Docks, he apprehended that land alone would cost about £40,000 per acre. He would mention that he had completed a dry dock at Leith, 400 feet long, 84 feet wide, with 24 feet 6 inches of water on the sill, the cost of which, including caisson, engine-house, pumps, and all complete, had been under £40,000. The engines worked up to 100 H.P., and were applied to a large Appold pump. So long as ordinary docks could be constructed at that cost, he did not think docks of the character under discussion would be again constructed in this country.

Mr. A. GILES thought many advantages would attend the application of this beautiful invention in ports such as London and Liverpool, and perhaps Hull; but, apart from those ports, he considered there were no others where docks upon this large scale were called for. There was one fact to be remarked, that when a vessel was placed upon this pontoon, she had the advantages of light and air which she could not have in an ordinary graving dock; at the same time the operation of lifting the vessel on the pontoon was attended, he thought, with certain disadvantages. In removing and replacing the boilers, he did not think the objection which had been stated applied, because the boilers were not generally put on board while the vessel was in a dry dock; at the same time, in matters of general repairs, it might be a disadvantage to have to raise materials to a height of 30 feet, or 40 feet, instead of their being supplied from the level of the deck. With regard to the shoring of ships on the pontoons, some merit was claimed for the absence of strain upon the ship, by the putting in of the bilge blocks. He did not know what there was to prevent the same sort of shores being used in ordinary dry docks. The fact, however, that bilge blocks were not used seemed to be good evidence that such shores were not wanted, and, during an experience of twenty years, in docking vessels of all sizes, up to 4,000 tons, he had never yet heard of an injury having arisen from the want of bilge blocks. The position of a vessel on bilge blocks was similar to that of a vessel on the beach, and there was great objection to the beaching of steam vessels from their liability to strain. He thought there must be some advantage in grounding upon the keel, and in putting in, when the ship touched the blocks, horizontal shores against the altars, for the purpose of keeping her upright on her keel. As the water was pumped out of the dock, raking shores were added. Comparing the statistics supplied by the Author with those of the Southampton Docks, it appeared, that at the Victoria Docks 1,055 vessels of an aggregate tonnage of 712,380 tons had been docked by these lifts in seven years. At Southampton, during the last seven years, 693 vessels had been docked of an aggregate tonnage of 965,000 tons. The average tonnage of the vessels docked by the pontoon system was only 675 tons per ship, while the average of the vessels docked at Southampton was 1,400 tons per ship. With that experience, if no damage had been sustained from the absence of the bilge blocks, it might be safely inferred that they were not necessary. As to the cost of docking vessels, the Author had given it at £3 per vessel, for putting on the pontoon, pumping, and lifting: if that calculation was correct, the system at the Victoria Docks had a great advantage over that at Southampton in respect of the cost of docking. His experience was, and he could vouch for the correctness of the figures, that the total expense of docking, including pumping, labour, and repairs was, on an average, £13 per ship, but that was for ships of double the average size of those docked by the Thames Graving Dock Company. It was evident that there must be some other element of expense which had not been reckoned. The charges for docking ships on the patent lift were about the same as at Southampton, viz., 6*d*. per ton for docking, and 1*d*. per ton per week, for the use of the pontoon. For a 1,000 ton ship, the charge for docking at Southampton was £25, and the rate for the use of the dock was in about the same proportion as for the use of the pontoons. With those 965,000 tons docked at Southampton during the last seven years, the Company had earned £39,000 and the expenses had been about £8,000; the average amount paid by each ship being £55, and the expenses £13. If, therefore, the charges were practically the same in both cases, and the expenses so much less in the hydraulic lift system, how was it that the Company had been such a commercial failure? These figures, if correct, ought to have shown a good profit. With regard to the first cost of the hydraulic lift docks, it was stated to be £88,000; but it must be borne in mind that sum did not include the cost of land, engineering, patent rights, and other things, which were usually included in the capital cost. The capital of the Graving Dock Establishment at Southampton was taken at £150,000; but, he believed, interest had been charged to capital to swell it to that amount, for this was considerably beyond the actual cost of the docks. If, by the system under discussion, the sum of £88,000 gave a capability of docking seven ships at a time, he confessed that, by the ordinary system, with the same number of docks, it could not be done at the same price. He then explained a drawing showing the sections of two docks which he had lately constructed at Bow Creek. In the larger one, he had drawn the sections of two ships, one being the 'Warrior,' of 6,000 tons, and the other the paddle steamer 'Napoleon Third,' of 4,000 tons; neither vessel could be docked by the hydraulic lift as constructed. These docks were placed on a part of the Thames where the foundations were notoriously deep; the cost of the two docks, including coffer-dams, pumping power, caissons, and everything complete, was £85,000. One was 400 feet long, with a 64 feet opening, and 24 feet of water over the sill. The other was 300 feet long, 46 feet opening, and 21 feet of water over the sill. If he were asked to design a system of docks, one of which should accommodate vessels of 6,000 tons or 7,000 tons, and the others, vessels of smaller size, he believed he could build six or seven docks for £150,000; but if the hydraulic lift and seven pontoons, one of which should be capable of carrying the 'Warrior,' could be constructed for £88,000, that system would surpass any other he knew of in point of economy. A system of docks, sufficient for almost any port, comprising six docks of various sizes (the largest of which was capable of docking the 'Warrior'), including six acres of land, with pumps and every necessary appliance, could be completed for £150,000.

As to the capability of doing work in hydraulic docks compared with ordinary docks, the time occupied in lifting a ship had been given as twenty-five minutes. That could not, however, be meant to include the whole operation of putting a ship on the pontoon, lifting, and moving her into her berth; for he understood that, practically, the time actually occupied in preparing a ship for the pontoon, taking her lines, preparing the bilge blocks, floating her into position, sinking the pontoon, lifting the ship, and getting her into berth, occupied about four and a half hours; whilst the operation of undocking occupied about one hour and a half. If that were so, the capability of work on one lift (though there might be fourteen pontoons or fifteen pontoons), was limited. By the ordinary system, one ship could be docked at each tide; but in the large dock at Southampton, which had been constructed twelve years, more had been accomplished. Upon one occasion, three large ships, each of more than 2,000 tons, required to be docked in a hurry; two were docked and undocked, and the third was docked and placed on the blocks between daylight and dark. He therefore believed the capability of that dock was almost as great as that of one lift.

Mr. JOHN HEPPEL said, having had the advantage of being associated in the preparation of the plans for this work, a few words from him might not be out of place. He necessarily became intimately acquainted with all the mechanical details of the construction, and the considerations which led to the adoption of them. To this part of the question he proposed strictly to confine himself, leaving the commercial and general aspects of the case to those who were better qualified than himself to deal with them. In doing this, however, he might perhaps be anticipating what would be better left to the Author; but he could not help thinking, it would be satisfactory to that gentleman to know, that those who concurred with him so many years ago in the views which he took concurred with him still, and were able to give some reasons for that concurrence.

Many observations had been made as to the flexibility of the pontoons in connection with these operations; and great doubts had been expressed whether some disadvantages to the vessels raised did not result from this flexibility. This was a subject which was carefully discussed at the time the apparatus was designed, although no great point was made of it; for even if the pontoons had been rigid, he did not remember that either the Author or himself thought any great harm would result. But a certain amount of flexibility appeared rather advantageous than otherwise, and he thought, reasons might be shown for it. It had been admitted, that if the vessel itself possessed the quality of rigidity in a sufficient degree, the rigidity of the pontoon became comparatively unimportant. He agreed in that view, and he thought, therefore, it was not necessary to say much about the raising of iron vessels, because it was known that all those vessels possessed such an amount of rigidity, that when once placed on the pontoon, however flexible the latter might be, the rigidity of the two together would prevent any deflection which could possibly be considered injurious. That being the case, he thought the small amount of flexibility the pontoon possessed was an advantage, because it acted upon every wedge and block as a spring to keep it fairly up to its work. In fact, as compared to a rigid floor, it stood in the same kind of relation, as a spring mattress to a deal board.

A strong point was however made with respect to wooden vessels, and an instance was adduced of an old crazy vessel which had a considerable amount of 'hogging.' He would even admit, for the sake of argument, that it might be considered desirable to bring such a vessel to a straight keel, though he thought that was admitting a great deal; but if this was desirable, he could hardly conceive anything better calculated to straighten the keel, without injury, than the apparatus in question.

To follow the steps of the operation: the vessel came upon the lift, the keel blocks having been prepared approximately to correspond with the curve of the keel when afloat, the vessel, having taken the keel blocks, the lifting began. As this went on, the slight difference in the distribution of the force between the weight (which was more in the middle than at the ends) and the lifting force, which was uniformly distributed, produced an action tending to deflect the pontoon, to a certain extent, and that tended to bring the keel nearer to a straight line, and so far to accomplish the desideratum. If any strain, or symptom of strain manifested itself, this apparatus gave instant means of obviating it, because, by cutting off a pair of the presses, the lifting power might be brought to correspond with the distribution of the weight to be lifted; so that, by the time the vessel was lifted out of the water its keel might be, by a simple process of manipulating the presses, adjusted to any line required; and that was done not by any violent process, as in a dry dock, where the vessel would be left to settle at once to a straight line, but was effected by means that were always under the most perfect control. When the pontoon was lowered into the water, after having been emptied, the same thing which was done by manipulating the presses, might be done by letting in water in the required proportion into the compartments, by which the lifting power of the pontoon might be brought into perfect adjustment with the weight above it. Nothing was more calculated to deal with the requirements of the kind noticed than this apparatus; and if it were correct, as had been stated, that some vessels had suffered injury from deflection (and an instance had been given of a hogged vessel which when set afloat on the pontoon was found to be deflected the other way), he could not help thinking it must have been from some want of judicious management in the operation; because he could not conceive that anything inherent in the apparatus itself could lead to such a result; on the contrary, he thought the Author had claimed for the machinery, in this respect, less applicability to the requirements of the case than was due to it.

He would not go into the question of comparison between this mode of lifting vessels and the system pursued in dry docks, because everything that could be said on that subject had been already very clearly stated. The matter had been put in a very fair point of view, because a comparison had been drawn between pontoons of this kind and an equal number of graving docks. A few observations of a qualifying character had been added, but it was a fair comparison; and he understood it to be admitted, that a series of dry docks, equal in number to the pontoons of this lift, could not be established for the same amount of expenditure. With regard to floating docks, a great number of examples had been instanced. Those which could only accommodate one vessel at a time could not be put in comparison with the apparatus under discussion, in respect of the amount of accommodation. A model had been placed on the table, in which, by a system of railways and cradles, something like the same results were proposed to be accomplished as by the present apparatus. He was far from being disposed to say that the proposed plan was not a good one; but he thought, it must be obvious that dragging a vessel about upon cradles must expose it to greater strains than the smooth and easy way of dealing with it by the hydraulic lift. However, it might be said, with regard to such a lifting dock, it would be easy to use it in connection with pontoons, in the same way as the hydraulic lift; and in that case the Author of the Paper would be entitled to the credit of the most original and valuable portion of it; but even then it would be inferior. He spoke under correction; but he hardly imagined, that a floating dock of that kind, having equal lifting power with the hydraulic presses at the Victoria Docks, could weigh less than 2,000 tons. If his conjecture was correct, it was obvious, that for every vessel, large or small, lifted with that apparatus, a dead weight of 2,000 tons was being lifted with it, instead of less than 700 tons at a maximum, which was capable of reduction in proportion to the load to be raised. He therefore thought the floating dock, even in the best form, must be inferior, in respect of efficiency, and economy of power, to that which was now the subject of discussion.

There was one other point. It was admitted, that for a fixed water-level, the Hydraulic Lift was not an inconvenient apparatus;

but it had been asserted that its use would be confined to exceptional cases. He only wished to draw attention to the fact, that in this case, there was a free choice between the Victoria Docks and the tideway of the Thames, and it was considered, on all accounts, more desirable to establish the graving dock in connection with the former, than with the latter, the greater facility of communication with the dock being considered of more value than the mechanical power derived from the tide, and he thought, that similar considerations would prevail in most cases where there was a similar choice. But if it were not so, and if the use of this system was to be confined to cases of fixed, or nearly fixed water level, there would still be the Baltic, the Mediterranean, and nearly all the ports on the Pacific; and he thought, perhaps, the Author would be satisfied with that to begin with. He had recently seen this apparatus, and he was struck with the remarkably good condition in which it was kept. Every part was in good working order, and in charge of highly intelligent people. He thought the mechanical results had been such as to place the professional reputation of the inventor beyond all danger; and he hoped the commercial results that would follow would be such as to remunerate those individuals who had ventured to try, what was considered at the time, a very bold experiment.

Mr. J. B. Redman said, it must be acknowledged, that the thanks of the commercial community were due to the Author for this attempt to facilitate the raising of vessels in the port of London. Some years ago he placed a Paper before the Institution on the variety in direction of the different Metropolitan dry docks, and he was bound to say that the variety in direction, in reference to the tideway, was as greatly exemplified in the mode of construction of the various docks upon the Thames. Whether the Thames—a tidal river, which had hitherto done what was now attempted by means of this most ingenious apparatus—was the best site, remained to be proved by experience. Undoubtedly, a graving dock, at the end of the Victoria Docks, might have been drained by the action of the tide, and the dock might have been arranged as others had been on the Thames. Certainly the element of cost was one of great importance; but, he could not help thinking, a comparison of the cost of this system, with that of the docks at some of the outports where the formation was different to the valley of the Thames, must be to a great extent illusory. The former were artificial docks in all respects, but the geological formation of the districts was so different, as to afford no comparison on the question of expense with the port of London, to which the system of the Author had been applied.

The Trafalgar Graving Dock, at the west end of Woolwich Dockyard, was constructed for the Admiralty, by the late Mr. James

Walker, after the failure of a prior experiment, by Mr. Ranger, of a dock of concrete. That dock was never free from a percolation of water through the sand and natural substratum; and the invert blew up. With that experience before the designing of the present dock, it was natural that every care should be taken that the work should be sound. When he said the pit of that dock was 40 feet from the surface, it was clear it was not comparable with a dock like that at Sunderland, where the rock was so close to the surface, that the work involved did not commence before an amount had been expended which came to more than 30 per cent., or 40 per cent. of the total expenditure incurred in a case like that at Woolwich, where there was 9 feet of concrete, a floor of 18-inch brickwork set in pozzolana mortar, and an invert of solid granite 3 feet 6 inches thick. The entire surface of the dock was faced with granite. The section of the dock was parallel to that of the 'Trafalgar,' a 120 gunship, and of course the work was carried out in the most costly manner. The early timber docks of London, including the old Pitcher's Dock at Blackwall, which was subsequently rebuilt by the present owners (the Messrs. Soames), were built entirely of timber, and of clay puddle. The bottom was piled, over the entire surface, the larger number of piles being placed in the direction of the line of the keel. The old Pitcher's Dock had failed in a similar way to that at Woolwich, from the hydrostatic pressure. Another reason why the comparison of cost would hardly hold good was, that almost all the London docks, with few exceptions, were dry docks in two senses of the word; they were not only dry when the gates were shut and the vessel was docked, but any amount of leakage which accumulated in the dock was drawn away at low water. There was never any attempt made to resist the hydrostatic pressure, but the water was led away to the engine-well and taken away by steam power; so that such docks as these were not comparable with the deep-water dock at the mouth of the Lea. He would say generally (having taken the trouble to classify these early docks, taking the internal capacity, the length, breadth, and depth, *i. e.*, the cubical contents), that he found the cost had been from 12*s*. to 15*s*. and £1 per yard cube of the internal sectional capacity of the dock, while the figures stated for the docks at Southampton would work out a cost of £1 17*s*. 6*d*. to £1 18*s*. 6*d*. per cubic yard of internal capacity, and the value of the dock at Woolwich was no less than £4 10*s*. per yard cube. The dock at Boston, United States, by published documents, was about equivalent to the latter value. He thought if the eight pontoons at the Victoria Docks were assumed to represent eight timber docks of equivalent superficial dimensions by the depth, with the 18-feet draught over the hoisting gear, the result, taking the

Author's figure of £80,000, would give a value for that capacity of something equivalent to the timber-dock value; that was to say, the eight docks, by the mean length and breadth given with the 3 feet above, would be worth about 12*s.* per cubic yard. If there had been an outlay there of double that sum, then the value would be double; and if, again, the outlay had been £200,000, the value would be 25*s.* per cubic yard. Taking the cheapest value, the comparison was not favourable to the Southampton Docks. There was an example at Sunderland, frequently quoted, in which he believed the value and the dimensions gave about 27*s.* 6*d.* per cubic yard of internal capacity. Some surprise had been expressed, that no notice had been made of the hydrostatic screw dock at New York: it was equally surprising, he thought, that no notice had been taken of the patent of John Evans, of New York, which was described, very minutely, in the first number of Weale's 'Quarterly Papers' in 1845, as consisting of a series of cylinders and presses, precisely similar in principle to the Bramah Press, and connected by vertical chains to the ends of the transverse beams, underneath the pontoon gridiron. When the enormous increase of the trade of the port of London was considered, and the efforts which had been made to develop the commerce, the thanks of the commercial community were due to the Author. He had, however, had one advantage which no other Engineer, acting for a public Company, had previously possessed. The Victoria Docks was the first Company that obtained powers to construct a graving dock. The old Wapping Dock Act contained clauses for graving docks, but the ship-building interest was too powerful in that day, and those clauses were struck out in every Dock Act afterwards. Whether a dock Company could build and repair ships with the same expedition as private builders, was another question; but he felt convinced, from the experience of some years, that that exclusive principle, together with the tyranny of trade unions amongst shipwrights, had, to a great extent, driven the old shipbuilding trade from the port of London. The late Mr. Duncan Dunbar had frequently told him, that on the Tyne and other outports, he could get his ships built, with lower masts and standing rigging, at the same price as that which he paid for the hull alone, in the port of London.

Mr. John Murray remarked, that in the discussion which had taken place, he considered they had not arrived at the full cost of this pontoon dock. Mr. Clark had given the expense of the excavations, the coffer-dams, and other details; but he had not alluded to the land occupied by the works—some 26 acres in extent, 16 of which were water, and ought to be added to the sum of £88,000. A comparison between this pontoon dock and ordinary dry docks of masonry or brickwork might fairly form a subject of discussion.

He had ascertained the cost of graving docks in various parts of the country, which, combined with the information already given, might prove useful. Mr. Abernethy had stated that the average cost of the seven docks at Birkenhead and the two at Falmouth was about £14,000 or £15,000. The dock at Holyhead, constructed by Mr. Telford, cost £14,419; that at Dundee, £26,000; that at Belfast, in 1840, £19,362; and the dock built by himself at Sunderland, including pumps, engine, and enclosure, cost £16,185. Taking an average of the four docks, it amounted to £18,990. Those docks were all nearly of the same class, viz., from 240 feet to 320 feet long, and 70 feet across at the coping, and 36 feet at the bottom, and they were each capable of admitting two ordinary vessels, or one large ship. The dock at Sunderland had altars on the side, with a temporary end, so that it might be lengthened when required. Docks of this kind had been constructed, therefore, at an average cost of £18,000 to £20,000 each. They were all of good masonry and substantial workmanship. But in the port of Sunderland and on the River Tyne docks of a slighter description had been constructed, capable of holding one ship at a time, and at a cost of from £3,000 to £5,000. Besides these, the shipbuilders generally had floating docks alongside of their shipbuilding yards, into which vessels were brought for repairs. One of the earliest of these docks was an old gun-brig cut down for the purpose. The deck and upper works being taken away, moveable gates were placed across her stern, and she was thus changed into a floating dock. The shipbuilders had since constructed other floating docks in the ordinary manner. Docks of a better description, such as those at Liverpool, lined with granite and of a large size, had been constructed at a cost of from £25,000 to £50,000. Another class, capable of admitting men-of-war, had amounted to £100,000 and upwards. But in general a good graving dock of ordinary construction might be said to cost from £15,000 to £20,000, capable of admitting all ordinary vessels, and two at a time of the smaller class; and when once properly constructed they wanted no repairs, and therefore might be called permanent structures. He thought they might well be compared with floating pontoons, admitted separately into one entrance or receptacle, having a great amount of apparatus connected with it, liable to get out of order, and requiring much manipulation, which he considered a more costly affair than a substantial graving dock of the ordinary form.

Mr. G. B. Rennie said, in reference to a model, which he had placed on the table, that it represented the works constructed at Carthagena, and was designed for the purpose, after the vessels were lifted on the floating-dock, of hauling them ashore by hydraulic presses, or on cradles. The ways were perfectly level, and the amount of power required to haul them on shore might be calculated on the consideration, that the launch-ways of a heavy vessel were made with an incline of $\frac{1}{2}$ inch to the foot, or 1 in 24: so that, about $\frac{1}{24}$th of the weight of the vessel had to be pulled by a hydraulic pump and portable ram. This was not altogether a new idea, for it was in operation at the present time at the arsenal of Pola, on the Adriatic, where there were four lines of horizontal ways, which were used for hauling the vessels on shore. He believed the largest vessel operated upon by this system, was the 'Kaiser,' a screw line-of-battle ship of 84 guns. The floating-dock at Pola was of wood.

With regard to the Hydraulic Lift Graving Dock, he had several times seen vessels lifted, and it seemed to be done with great ease, regularity, and apparent safety. He did not agree with the Author as regarded the flexible pontoons. It seemed to him, if there was flexibility in the pontoons, there must be a strain on the vessel; and it was always desirable to prevent undue strain, as far as possible. However strong a ship might be, there must be some extra strain if it had to support the pontoon in a horizontal position, instead of the pontoon supporting the vessel. With regard to bilge-blocks he might state that it was proposed to use them in the floating-docks at Carthagena and Ferrol. When those docks were designed it was also thought desirable, that breast-shores should be used: for where a heavy vessel began to rest on the keel-blocks, it was difficult, with 25 feet of water under her, to place the bilge-blocks properly to support the vessel and prevent canting. He hoped on a future occasion, when this work had been tried more fully, to describe it in a Paper, before the Institution.

Mr. Scamp exhibited three drawings. The first was a section of the hydraulic lift, provided with shoring-altars for supporting vessels with breast-shores, as in an ordinary dock, showing also a pontoon with shoring-altars, for shoring under a vessel's bilge, precisely as in an ordinary dock; and a midship section of the 'Himalaya,' with the breast-shores, &c., attached.

The second drawing represented an ordinary stone dock (that referred to by the Author in his Paper), showing half midship sections of the 'Bellerophon' and the 'Lord Warden.'

The third represented the side view of a ship, with gauge-marks parallel with the original straight line of keel, for ascertaining precisely the hogging or cambering of the vessel.

Referring to the first drawing, he stated that he considered, by the addition of shoring-altars attached to the lift, and shoring-altars attached to the pontoons, that vessels of the tonnage of the 'Himalaya,' in a sea-going state (4,000 tons), might be safely docked by the lifting-dock, with the additional precautions shown by the section. The shoring-altars attached to the lift were only required for about a third of the midship length of the ship, and only to each alternate column; and though he considered the breast-shores to be absolutely necessary, especially if employed in the war establishments of the Navy, yet no great strain would be brought against them, as it was obvious, that the centre of gravity of the load being placed precisely perpendicular over the centre of support on the keel-blocks, it was only necessary to employ the shores for precisely fitting the space between the side of the ship and the abutment at the altars attached to the dock. The shoring-altars attached to the pontoons were not proposed to be continuous; but to extend to about a third of the midship section, in lengths of about 20 feet, and spaces of about the same lengths alternately, and it was proposed to attach them to such pontoons only as were required for vessels of more than 1,000 tons; vessels of less than that tonnage might be safely docked as at present. The breast-shores being carefully fixed (the keel being only just clear of the blocks), the dock should be lifted sufficiently for the keel to bear on all the blocks; in this position some of the blocks might be drawn under the bilges of large ships, or of those appearing to require them; for small vessels this operation at that time was not necessary. The pontoon might then be lifted, until the keel-blocks were out of the water, and the vessel might, then, be as completely shored, as in an ordinary dock; and such bilge-blocks might be added as might appear to be required. The vessel being completely secured on the pontoon, the breast-shores would be removed, and the vessel might be safely floated away from the dock on the pontoon to a shallow dock, as at the Victoria Docks, or to a wharf, or basin; or for executing extensive repairs, the pontoon might be grounded on a 'gridiron' at a basin wharf.

The docking duties in times of war, for Her Majesty's naval establishments, might be classed under three divisions:

1. Previous to the actual commencement of hostilities.
2. During an action.
3. After an action.

As regarded the preparations, probably every available vessel, certainly those provided with steam power, might have to be commissioned for the service; those already commissioned as well as those taken from the moorings—out of 'ordinary,' as it was called—might require to be docked; until a vessel was in dock, the time that she might require to be there could not be known. For that division of the docking duties, he considered the Hydraulic Lift Dock, with its ten pontoons, or fifteen pontoons, might prove an incalculable advantage, being equal to as many additional docks.

He thought this plan peculiarly adapted for the great naval establishments, particularly in time of war, when all the duties of those establishments had to be carried on with the greatest despatch, and with unerring accuracy, under great pressure. It might probably not be prudent to carry this system to the extent of dealing with ships of war of 10,000 tons, as proposed by the Author of the Paper some years ago, yet it was desirable that the Institution should give an opinion as to that proposition being carried into practice for vessels up to a certain class; he had suggested, that vessels up to 4,000 tons, equipped and in a sea-going state, might safely be docked by the method proposed.

The system of shoring he had described was equally applicable to every form of graving dock. He had submitted the drawing of the two half midship sections, to show that the 'Bellerophon' did not require the bilge-blocks, but that the 'Lord Warden' did require them to a certain extent. That form of support was the best in his experience, and it might be applied to the Hydraulic Lift Dock. It was a matter of great national importance, to determine whether the Author's method of docking ships for repairs, with the additional security proposed by him, was or was not applicable to the war establishments of Her Majesty's Navy; and for arriving at a sound conclusion he considered that the opinion of the Members of this Institution could not fail to afford useful assistance.

There were three establishments which must be greatly taxed in event of war, Portsmouth, Devonport, and Malta. If, by a method of this kind, ships could be docked, and prepared to join the fleet again with great despatch, the advantage might be equal to almost double the number of ships; whereas if ships had to be kept waiting to be docked, the most disastrous consequences might be the result.

He would not hazard a positive opinion that the system of lifts and pontoons was not applicable to ships of a larger class than that which he had suggested, 4,000 tons, but it should be borne in mind, that his suggestions had reference only to the war establishments of the navy; that vessels of the class proposed by him would not cause inconvenience in management; that to one vessel even of such tonnage, many below of smaller tonnage would have to be employed, and might have to be repaired; that the pontoons would not be unreasonably expensive, or occupy unreasonable space; that, for an establishment such as that at Portsmouth, the pontoons might pass from the basin, in which the vessel would be docked, to other basins less occupied; and if a method of the kind proposed should be adopted, the ordinary docks might not be wanted for small vessels, but would be generally available for such ships of the line as would be required to join the fleet with the utmost despatch, when the time for such duties might not admit of being measured by weeks, or days, but by hours and minutes. It should be observed further, that vessels of large tonnage might require to be docked when light, and not in a sea-going state; for such cases 4000 tons would represent a large class of line-of-battle ships.

It had been suggested that vessels 'hogged' or cambered should be put into dock on blocks, in a straight line, and that the keel of a 'hogged' or cambered vessel should fit itself to the straight line by its weight. In this opinion he did not concur, because when the vessel was again in the water and loaded, the original line of keel would certainly be formed. Three gauge marks should be put on the side of a vessel above the water line, parallel with the straight line of keel; these marks being measured from the water line, the amount of hogging or cambering might be ascertained with great facility, and the blocks on the dock might be thereby correctly adjusted.

He had given great attention to the Author's ingenious invention for many years past, with a view of ascertaining to what extent it might be usefully employed at some of the naval establishments; and recently he had given the subject a full and careful consideration. The result was what he had briefly explained, and shown by the section, and this would, in his opinion, provide what he considered to be necessary, and what he had long desired to accomplish. The section was intended to convey the principle only, not the details of his proposition. He did not anticipate that the girders between the points of suspension would, necessarily, require to be increased in length.

Mr. HAWKSHAW, Past-President, remarked that this subject, like many others, resolved itself into comparisons of cost between graving docks of different kinds. The cost of a graving dock in one place could not, however, be compared with the cost of another, unless all the circumstances were known. There could be no doubt that the Author's invention, which he had so clearly described, was, as a mechanical apparatus, perfectly successful. It did that which he proposed it should do, and did it well, and machinery which lifted 2,000 tons could, probably, be made to lift 4,000 tons. But there was one remark to be made upon that point, affecting the question of cost. Where a series of repairing docks was required for repairing vessels of different sizes, the access to the whole of which was to be by means of one lift, if the apparatus were to be made powerful enough to lift vessels like the 'Warrior,' the same apparatus would have to be used for lifting the smallest vessels. Admitting the apparatus, mechanically to be perfectly successful, there arose the question of cost. Now that question could not be usefully treated by comparing these docks with those of the Mersey, which were cut out of sandstone, or with docks in other places, where the circumstances might not be the same. It was difficult, therefore, to arrive at useful conclusions on this point. Still there was in this case, what rarely happened in other cases, something like a guiding principle on the question of cost. With respect to the repairing docks, apart from the lifting dock, it was evident, that all that could be saved, was the difference of excavation in these docks compared with the amount of excavation in an ordinary graving dock, due to the difference of their respective depths, bearing in mind, that the repairing docks must be deep enough to float the pontoons laden with the weight of the ships. On the Author's plan, the cost of the gates was also saved. Against that saving there was to be set the cost of the pontoon. Now it did not at present appear that the saving in the repairing docks, adding the pontoon, could be much; in other words, the cost of the pontoon would probably, in many cases at all events, equal the cost of deeper excavation and the gates. In fact the cost of gates and of the deeper excavation and masonry might, in many cases, be less than the cost of the excavation and masonry for these repairing docks, including the cost of the pontoon. At all events, that was the form the calculation must assume. With regard to the lifting dock, it was evident the apparatus for lifting the ship, and the machinery of the rams and steam engines, would, generally speaking, be at least as costly as the cost of pumping apparatus, even in the case of a tideless sea. For in those situations, the entrance to a lifting dock must be made deep enough, not only for the draught of the ship, but also for the additional depth of the pontoon, and of the girders beneath the pontoon. With regard to the question of economy, in cases where there was a large rise and fall of tide, as in the Severn, and where no pumping was consequently required, the ordinary graving dock would often be cheaper than the one under consideration. After all, the question of cost must be considered specially, having regard to all the circumstances in each separate case; and without going into the question in that form, no satisfactory decision could be arrived at.

Mr. F. W. Sheilds said, it would be most desirable to have the means of comparison with as many other docks of a different kind as possible; and with that view it occurred to him to describe a design he had recently made for a floating dock, and to give a few statistics about it which might be useful. It was a design for a dock 270 feet long and 55 feet wide, intended to lift sailing vessels of 2,500 tons, and the weight of wrought iron in it was calculated at 2,650 tons. In that design he did not claim any invention, as many such constructions had been made before; he had simply been guided by the best experience hitherto attained, and he had endeavoured to employ the materials in the most mechanical and economical way. It was natural to compare the system of that dock with the system of pontoons in the Author's dock, and the first point of comparison was the great difference in the depth of a dock of that nature and the depth of a pontoon which carried the vessel in the lifting dock system. The depth of the sides of the floating dock was 40 feet, while in the Victoria dock the depth of the pontoon was only from 5 feet to 7 feet; and if the ordinary girder rule were taken as an approximate guide, viz., that the deflection of each girder was as the square of its depth, there would be found, such an enormous difference in rigidity, as to make it evident that the Author had widely departed from the system hitherto in use, and had fully adopted the system of flexibility, instead of perfect rigidity. The first point to consider was, which of the two systems was most adapted for a vessel which was taken out of the water. There was no doubt that any system which would enable the vessel to assume perfectly the same position when out of water as she assumed when in the water, would be the most perfect system; but that was a difficult thing to attain in practice, and it was much to be doubted, whether the system of flexibility in a pontoon would effect it: and it was difficult to say beforehand, what form the keel of a vessel would assume, if put upon a flexible platform. It had been said, that the line of the keel could be adjusted, by managing the pontoon properly; and that if the keel took a different shape from that which it had when the vessel was water-borne, it could be corrected and rectified by letting water into the different compartments of the pontoon. Now that appeared to be a delicate operation, and if through carelessness, or any other cause, the water happened to be let into the wrong compartment, there might be serious results. On the other hand, with the system of a perfectly rigid dock bottom, the vessel would probably not be got perfectly into the same position in which she was when in the water; but an average result would be obtained, by bringing the keels of all vessels to a straight line when docked; and the line of keel would not be altered to such an extent as to be injurious, unless the ship were a very cranky one indeed; for that reason rigidity in the dock bottom was preferable, in practice, to the system of flexibility.

There was one other point which occurred to him, namely, that if a pontoon were sunk to the bottom of a dock independently of the hydraulic apparatus, then, when the water was simply pumped out of it, the vessel could be raised by the pontoon alone, without the intervention of the hydraulic lift; and thus it would also be possible to diminish the depth of the dock, as the space in the bottom of the lifting-dock, which was occupied by the cross girders, would not then be required. It seemed, at first sight, that it would be practicable to work a series of pontoons in that way, and that, as all the lifting apparatus would be thus dispensed with, it would be a simpler system; but he had no doubt, there were corresponding advantages which induced the adoption of the double system of lift and pontoons, and he mentioned the subject, in order to ask the Author to give some information upon it.

It had been said, rather in the way of objection to the system at the Victoria Docks, that it was commercially unsuccessful until the repairing shops were established. It seemed to him, with regard to such docks in London, that there was such an amount of competition from the graving docks, that if the Company did not afford the shipping public every possible convenience, they could hardly expect to get the amount of trade, which would be secured by rival establishments, and it was hardly fair to compare a dock in London without that accommodation for repairs, with a dock at Southampton, which was exposed to no opposition or rivalry, and which without a repairing establishment, might make a fair return on its capital; while a similar dock in London, where there was a great deal of opposition, would get little business.

Mr. Abernethy said, the question of economy had been dealt with only as regarded first cost; but the cost of working after construction must not be lost sight of, having regard to the various operations to be performed in graving docks. A common operation in a graving dock was the cutting of a vessel in two, and lengthening her. He would like to know how that operation could be performed upon a pontoon, more especially if it were flexible. There were several practical shipbuilders present, who would, no doubt, be able to give information as to the operations to be performed in the repairs of shipping, more particularly of steamers, and as to the advantages, or disadvantages which an ordinary graving dock had, as compared with the pontoon system.

Mr. G. H. Phipps said, it must be clear to all, that before approving of the description of dock which was the subject of discussion, they ought to be satisfied of its perfect mechanical efficiency. He could say, from several visits he had made to that dock, he was quite satisfied with its mechanical action, which was in all respects efficient and satisfactory; that the raising was done in a sufficiently short time; that the pontoons were readily floated into shallow water, and into their berths, and that the vessels were perfectly steady and firm upon the pontoons, whilst being repaired.

The next point he would touch upon was with regard to the effect, advantageous, or disadvantageous, of elasticity in the pontoon itself. He considered, that practically the elasticity was too minute to be of any consequence, either one way or the other, and this was proved by the absence of any ill effects on coppered vessels. The buckling up of the copper was a good indication of a vessel losing her sheer, or becoming 'hogged;' but no such effect had been detected, so far as he was informed; and therefore, the elasticity of the pontoon might be safely neglected in the consideration of this subject.

With regard to the comparison between this and other descriptions of graving docks; the only description of dock with which it could be fairly compared was that where the graving docks opened out of basins, wherein the water was maintained at the level of high water. No doubt the docks in the Thames—Pitcher's graving dock, and others of that class—were very cheaply constructed, but these were only suited to letting vessels in and out at particular states of the tide, and did not apply to the exigencies of the trade as it now existed. Taking a comparison between the hydraulic lift graving dock and docks of the ordinary kind entering out of basins, as above described, one of the advantages of this dock appeared to be the facility and economy, with which the docking accommodation could be increased. Supposing one ordinary graving dock to cost, in the above situation, about £45,000, and as a very full estimate, that a Hydraulic Lift Dock, with one large pontoon, cost about the same money (in both cases dams, engines, and all other expenses being included), then, by the supply of one additional pontoon, with berth for the same, at an expenditure of, at the outside, not more than £15,000, the dock accommodation would be doubled, whereas to do the same thing with the ordinary graving dock would cost £40,000, or double the original cost, less steam engines and pumps.

He would conclude with a remark as to the larger amount of quay frontage which must be destroyed in the event of constructing six ordinary graving docks out of the main basin, as had been proposed. If the entrances averaged 60 feet in width, there would be a loss of no less than 480 feet of quay, which would evidently be a serious loss commercially.

Mr. Kinipple begged to state that the 'Stuart Wortley,' of 790 tons, had her copper seriously buckled, on the pontoon.

Mr. G. P. Bidder, Past-President, said, it seemed, that this discussion had arisen to a great extent from an expression in the Paper which was hardly consistent with the context. He did not regret that expression, because it had given rise to an interesting discussion. The expression in the Paper was, that the system described was capable of universal application. The more proper expression, perhaps, might have been extensive application. It was not a system, beautiful and perfect in its machinery as it was, which could be applied in every possible case. He was designing a dock for the Indus upon a different plan, and there were various conditions which ought to influence any Engineer before he recommended its adoption.

Some suspicion had been expressed, that the expenditure on this dock, as stated in the Paper, was not altogether *bonâ fide*. That misapprehension had, evidently, arisen from the fact, that whereas the cost of the lift was stated in the Paper to have been £88,000, somehow or other the capital of the Company was very nearly approaching to £200,000. Now both these statements he took to be correct. It was undoubtedly the fact, that this lift, with seven pontoons, could have been erected in the Victoria Docks for the sum stated; it was also undoubtedly the fact, that the Company had been involved in an expenditure of about £195,000. That expenditure had arisen from the circumstance, that the Company had to pay for the land: they had also to pay royalties; and there was also the profit and loss. He did not think he ought to be called upon to give the details of the figures, because, in this Institution, it had been held that Engineers should restrict themselves to the mechanical department, leaving those who had to apply the machinery to do it in the most advantageous and economical way they could. Taking, therefore, the construction of ten acres of dock for the reception of the pontoons, the cost of the land, and the erection of stores, together with profit and loss, the expenditure would have exceeded the £88,000 stated, by somewhere about £100,000.

Now, then, he thought it had been explained why there had been such a heavy profit and loss account; and yet, he was sorry to say, at this very hour, there seemed to be still some disposition to give credence to every idle rumour in respect of these works. It was suggested, that to almost any ship that entered the dock, some misadventure happened:—either she was twisted out of shape, or her copper was damaged. But he confessed he was surprised to find it stated, at this late hour, that a vessel in the dock was cambered or hogged, to the extent of 8 inches, or 9 inches; and that the vessel afterwards became depressed to a corresponding extent in the opposite direction. He had asked the name of the vessel. No name was given; but this remarkable circumstance was said to have taken place upon one of four days. Those four days had been investigated, and it was proved that during two of those days no vessel was lifted: on one day, a little vessel of 120 tons was lifted, and on the other, a ship of 870 tons was lifted: and he could state on behalf of the Dock Company, that no complaint had ever been received by them in respect of any damage which those ships had sustained in the dock, nor, in fact, any others; on the contrary, vessel after vessel that had been there before came again to the dock.

There appeared to have been an impression, that the Victoria Dock Company had established this system. They declined it; and it was done entirely by a private Company. What would have been the cost of this system if the Dock Company had adopted it? The origin of this dock was owing to the fact, that when the Victoria Docks were being made, he felt very strongly, that a graving dock added to those docks would be found to be a useful auxiliary and would tend to attract business. He accordingly set to work to design a graving dock in the ordinary way. He tried wrought iron and cast iron, with brick-work, and every other possible material he could conceive to make a durable work; and he could not get any one design to work out at less than £50,000 for a dock capable of taking in a vessel 320 feet, or 330 feet long. It was obvious that would not pay. The Dock Company would not undertake it. Then he tried all manner of contrivances for floating vessels, and he hit upon that plan of close pontoons, which accomplished the disaster mentioned in connection with the London Docks. He saw it had no stability, and he confessed himself defeated. It was then Mr. Clark took up the subject and designed this lift.

Now, if the Victoria Dock Company had established it, there would have been no occasion to have bought the 24 acres of land; there would have been no occasion to have made the dock in the manner in which it was made. All they would have had to do, would have been to establish the dock during the progress of the works. That lift cost, with the machinery, £30,000 at the most. But, it was to be borne in mind, that this was the first application of a new invention; and he did say, that the fact of its being so successful, so that there had been no failure originating from the scheme itself, from that time to this, was most remarkable. The late Mr. Robert Stephenson, who took a great interest in this work, pecuniary as well as personal, when discussing it with him, said, "Depend upon it there will be some serious disaster at starting."

In the discussion, this new experiment had been compared with docks built on established data and on the experience of years past; a new invention was compared with old and tried works. That was an element to be taken in favour of this scheme. If the London, or Victoria Dock Company had applied it they would have had the lift with all the appliances and machinery for £30,000, and £12,000 more would have given them a pontoon capable of supporting a vessel of 3,000 tons. They would have had a graving dock for £40,000 or thereabouts, and more available than a graving dock of the ordinary form. They need not have had the pontoon to have gone off the lift; but they would have had a perfect graving dock for £40,000, occupying no more space than the vessel itself lying in dock. It had been stated, that docks had been made in the beautiful stone at Birkenhead for £16,000 or £17,000 each, and that similar ones had been made at Falmouth. The cost of other kinds of docks, at Sunderland and the Tyne, had also been given. The three docks at Southampton were not made quite so cheaply, having cost, including land, £150,000. But at all events, for a sum of £40,000, the Victoria Docks might have had a perfect graving dock; for £12,000 more there might have been two; and, for a total outlay of £76,000, three; and nothing applied to the Victoria Docks could have been so useful, or economical, as the lift. But there were situations where there was a higher lift of tide, where the soil was more favourable, and where the trade was not of the enormous character of the Thames, in which, he thought, this system should not be applied. All that was contended for in the Paper, and all that he contended for, was the perfection of the invention as applied in the present instance, and that it was capable of extensive, though certainly not universal application. It had been stated that four and a half hours were occupied in the entire operation of lifting, though the lifting itself was effected in twenty-five minutes. He must be excused for saying, there was a fallacy in that statement, because all the time the blocks were being put in, the lift need not be occupied. The moment the ship was lifted, the pontoon was floated off, and another pontoon could be brought on, if necessary. The lift would raise about twelve vessels a day. The last time he was there, the lifting of a vessel was just commenced. About two hours after he could see neither pontoon nor ship. It appeared that the ship was required to be examined by the surveyors of Lloyd's after sustaining an accident, and she was lifted, lowered again, and taken away; and the pontoon was ready for another ship in two hours, and the ship gone. In the establishment of this lift, many of his friends had a pecuniary interest, as well as himself. But one thing they stipulated for, that they would have no share whatever in the patent-right of the invention, because, in the first place, the principle of the thing was objectionable, and, in the next place, being Engineers, it was not consistent with their position to recommend a thing in which they had a personal interest.

He had only one further remark to add: that he looked upon this as one of the greatest engineering feats of the last twenty years. That the system should have been brought so nearly to perfection—worked with so much safety on a first experiment—was, to his mind, something marvellous; and when it was said, it required judicious management to insure the safety of vessels on the lift, he need only state, that upwards of a thousand ships had already been lifted with perfect safety, which showed, he thought, that the amount of judicious management required was not beyond what could be practically relied on.

Mr. Giles explained, that when he stated it took four and a half hours to get a vessel on the pontoon, he did not intend to imply that it required that time to lift the vessel. He should be glad to hear what was the greatest number of vessels lifted in one day.

Mr. J. Scott Russell said, he thought it was the general opinion that the Author's invention was a very admirable one; that all the mechanical arrangements were excellent; that the idea was remarkably original, and that it had been carried out in a most successful manner: but he thought the Author did it somewhat of injustice when he brought it before them, if he considered it was better than any other description of graving dock, or floating dock; and that it was better than those inclined slips which were also used for repairing ships. They were left to draw the inference that all other plans were either very dear or very bad, and that the Author's plan was the best for repairing ships. He was of opinion that graving docks were in certain circumstances better and more economical than the Hydraulic Lift Graving Dock, that floating docks, not of this description, were in some circumstances more economical, and more applicable, and that what are called inclined slips were superior to the arrangement adopted by the Author. He should be sorry to say that the hydraulic lift was not the best thing that could have been invented under the special circumstances of the case.

He would enumerate circumstances in which it appeared to him that the plan under discussion did not possess so great merit as it might be inferred was attributed to it.

He submitted, that where there was a good rise and fall of tide, a shore with deep water close inshore, a soil able to carry the weight of a ship, and not hard to work, good hydraulic lime, and building material cheap and ready at hand, an ordinary graving dock was cheaper in first cost, and cheaper in working, than this hydraulic lift. Engineers should consider well all such circumstances before they abandoned the graving dock. In discussing graving docks as graving docks, they should not compare a costly granite graving dock, with an economical arrangement, such as they would make for a private builder. In a tideway, a dock could be easily made. He recollected having a dock made for the repair of small ships, designed by the owners, to be done at small expense. In the yard, alongside the Thames, a space was excavated large enough for the size of ship to be repaired. The bottom of that dock was gravel: it was not even lined with timber, and a simple pontoon floated in kept out the tide, and that was a graving dock of the simplest character, but of the most perfect possible description. Then they had the timber graving dock common amongst shipbuilders, and, finally, the dock lined with brick and granite.

Where they had a gently sloping bank of good solid material shelving down continuously into deep water at an angle between 1 in 24, or 1 in 50, or 1 in 60, the patent slip, as it was called, appeared to him better and cheaper than the hydraulic pontoon dock. In such a place they had nothing to do but lay down the ways and haul up the ship. If they chose simply to haul a ship up a wooden way, well greased, one twenty-fourth part of the weight of the ship would overcome the friction of the ways. If they put the vessel upon rails, he need not say that one-fiftieth of the weight of the ship would overcome the resistance of the ways; and, if the slope was up to 1 in 12, which was not the usual form of slip, a system of slips and carriages had been used, by which the ship was raised broadside out of the water. All these were arrangements of which they had had ample experience, and when he told them that each of these plans of slips might be constructed to bring up a vessel of 3,000 tons at an expense, in the way of capital, of £2 per ton of the ship, it would be seen that that also was a very economical arrangement. With regard to a graving dock, it would cost a great deal more: it might cost £5 per ton of the ship which it took in.

The last arrangement of which they had the choice, independently of the Author, was the ordinary floating dock, and the question was raised, in what circumstances was the ordinary floating dock better than that under discussion? There was one point in common with the Hydraulic Lift Graving Dock and the ordinary floating dock, and it consisted in the comparatively small depth and great breadth of the pontoon; in the Author's, he believed it was 6 feet deep by 60 feet wide and 300 feet long. The difference between this and some other floating docks consisted not in this apparatus, by which the ship was carried, but in the machinery which raised and lowered her. The Author sank a series of cylinders, each containing a hydraulic ram, and the presses were connected with a platform, and, by a steam engine and hydraulic apparatus, the platform was gradually lowered down into the water. After the platform was sunk under the water no more force was necessary to lower and raise it, and therefore the machinery was simple, and had the least possible friction; but the moment he placed a vessel on the top of the pontoons, the cost and labour of raising up the ship out of the water was incurred, and for this purpose it was supported in various ingenious ways, which had been explained. In the ordinary floating dock, instead of the hydraulic apparatus being fastened to the ground, it was put on the top of the pontoon in the shape of a long parallel caisson of the same nature as that on which the ship floated. Then, by admitting water into the longitudinal caissons, the pontoon was sunk below the vessel; the water was again pumped out of the longitudinal caissons, and the vessel was gradually raised. All that was necessary beyond this was to pump as much water out of the pontoon as was equal to the weight of the ship raised above the water. In a plan previously explained, instead of these pontoons being filled with water, the platform had been lowered by screws, and a variety of inventions had been used for lowering the platform and for raising it.

As regarded the Hydraulic Lift Graving Dock, and the ordinary floating dock, the circumstances of position were, in his opinion, of more importance than the mechanical arrangement. For example, where shallow water was abundant, where an extensive area of sheltered water existed, where there were no tides, and where foundations were met with at no great depth under the water, the Author's invention was most applicable. But where a rocky coral shore existed, as at Bermuda, or a bad foundation and great depth of water, then the ordinary floating dock was the best arrangement, and for such a position the Author's was not a good arrangement. The former condition, favourable to the Author's arrangement, existed in the Victoria Docks. He urged that by far the most valuable part of the hydraulic lift, on which he placed great weight, even more than the Author himself did, consisted in the multitude of the ships which could be floated in shallow water at comparatively small expense. The Author took, as it were, a single dock with its apparatus, and by this single dock and apparatus he had incurred the greater part of the expense and outlay; for by a simple method of detaching from this fixed apparatus the floating pontoon, he was able to multiply its usefulness, and to employ the same area for a great many ships, all of which had been lifted by the same apparatus. Therefore the following were the special circumstances under which the invention might be exclusively and profitably used—where there was protected and deep water to form the dock, where there was not much rise and fall of tide, and where it was required occasionally to put into repair, at the same time, a large number of vessels in comparatively shallow water. There it would be most useful, and better than any other mode he had described, or with which he was acquainted.

Mr. Edwin Clark said, before he replied to the various questions, he begged to thank the Institution for the time which had been devoted to the discussion, and for the kind manner in which his Paper had been treated by all who had taken part in it. He was glad to find, that although he had pointed out no less than nine features, in which this kind of dock possessed advantages over others, yet the principal point which had excited discussion had been the question of cost.

With respect to the cost of these docks, some confusion had arisen, from the manner in which the subject had been treated. Throughout the discussion a dock had been spoken of as costing so much money, without regarding the dimensions of the dock. It would be as definite to speak of a ship costing a certain sum, without regard to her size, &c. It had been assumed that the dock he had made at the Victoria Docks was of a standard size, and that its cost was to be taken as the price of such docks in general, and the whole discussion had been based on this assumption. It was stated that several docks at Birkenhead had been constructed at extremely low prices, in which respect those docks appeared to contrast very favourably with the lift. In other examples, such as those at Southampton and Bow Creek, the advantage of the lift, with respect to economy, was frankly admitted. Now Birkenhead was a locality purely exceptional. The site possessed all those natural advantages which had been described as peculiarly favourable for an ordinary dock. The sandstone was easy to cut and work; it was free from fissures, and the stone itself, when cut out, was a valuable building material; and in the excavation of a dock in such a situation it was so valuable, that he could scarcely understand why the dock should cost so much as was stated, because the quarrying ought to be sufficient to pay for it. Such a dock was not a fair subject for comparison with this lift. It had indeed been stated, that this lift had been erected in the Victoria Docks under circumstances offering some peculiar facilities. He was anxious to disabuse the minds of the Members from any idea of the kind. He had had the pleasure of designing eighteen or twenty docks in various situations, and he might say, of all the number, there was no situation which presented the difficulties which he encountered at the Victoria Docks. He could hardly conceive a situation of greater difficulty. In the first place, it adjoined a deep dock full of shipping, where it was of the utmost importance that the water should be kept from running away. Nevertheless, he had to make an entrance into that dock, and for that purpose, to construct a costly cofferdam. Then an excavation was required for the lift pit, and that, in a bad soil expensive to work. The whole of the land was, besides, of a costly character, and the surrounding competition of more than eighty other docks had to be contended with. Amongst all the other docks he had designed, he had not met with a situation where the facilities were not much greater than at the Victoria Docks. Hydraulic Lift Docks, as a rule, ought to require little or no excavation. The principal feature was, that wherever he could fix a cast-iron column, there he could make his dock. In many situations, as at Vancouver, Barcelona, and Marseilles, there was no excavation. Having obtained a spot with sufficient depth of water, the sinking of the columns was the only work to be done. He wished, therefore, to correct the impression, as to there being any advantages in the site at the Victoria Docks, and if this dock could compete with others in the Thames, he was quite sure it could do so elsewhere.

Two or three questions had been asked, to which he wished now to reply. First, as to how ships could be lengthened on the pontoons in this dock; and how other works of that class could be carried out. Also what was the cost of the manipulation of such docks, and further, whether the vessels were not inaccessible on account of their being on a level with the floor of the workshop? With regard to the last point, he apprehended the object of lifting a vessel out of the water was to get access, not to the inside but to the outside, and for that purpose, he could not conceive anything better than bringing the vessel on the level of the floor of the workshop, instead of having to go down stone steps to it. On the other hand, when ships were built, it was done on a level with the building yard; and as to the lifting of iron plates and other weights, his experience showed, that no great amount of that kind of work was required in dock, the work to be done being generally painting, coppering, or partial repairs to the hull or keel, &c. As to putting in boilers, no one would think of doing that while a vessel was either in a stone dry dock, or in this dock, as a crane could scarcely reach over 60 feet of dock; but it was effected with shears alongside the wharf in a deep-water dock.

On the second point, as to the cost of manipulation, he had stated, that the average had been £3 per ton upon the 1,030 ships that had been lifted, as against £13 at the docks at Southampton with 700 ships, although doubtless, a larger class of vessels was docked at Southampton than in this dock. He had no means of knowing what the cost was at Birkenhead docks. With respect to how far it was possible to effect, on a pontoon, such an operation as that of lengthening a ship, the way in which it was done was this: The shallow dock had a level bottom, and, by running the water out of the shallow dock, the pontoon was brought down and grounded upon the floor of the dock. Then there was a platform of timber 350 feet long, or more, and 60 feet wide, perfectly true, to enable a shipbuilder to judge of his lines; and no better situation could be conceived, either for cutting a ship in two and lengthening her in the middle, or for building a ship outright; and he believed the system would come into general use for shipbuilding. The accident that had just occurred to the 'Northumberland' could not have happened if she had been lowered on a pontoon instead of by the ordinary way of launching; and the American Government attached so much importance to that plan, that they adopted it for launching their vessels; and he was sure, the interest upon the cost of the pontoon would be far less than the expenditure incurred in the preparation of the present launching ways, with so much timber cut to waste, not to speak of the risk that must attend the launching of vessels of such great weight. Then, again, by the use of pontoons, the number of places where ships could be built, was multiplied. Any of the Surrey timber ponds, in which the pontoons would float, might be used for the building of the largest ships, and in the launching, a small lift only would be required. To launch the 'Northumberland' a 1000-ton lift would be sufficient.

With respect to the general request that he would point out the difference between the system of raising with hydraulic power, and that of simply emptying the pontoon of water, he would occupy a few minutes in explaining clearly, he hoped, the difference between the two. With any floating body, such as an ordinary pontoon, the stability depended upon the fact, that some portion was out of the water, and any change of position produced extra immersion or emersion in that part; but when a body was entirely submerged, no change of position could produce any difference in that respect, and a submerged body had consequently no stability: walking from one side to the other would tilt a submerged pontoon, unless it was forcibly maintained in a horizontal position. One of the plans suggested was the parallel motion, which had been tried at the London Docks, the rods being attached to the pontoon and to the bottom of the dock by cast-iron piles driven into the ground, the object of which was to maintain the horizontality of the ship. This plan failed; the strain on those rods, which varied as the tangent of the angle made with the vertical, becoming very great as the water closed, and ultimately infinite. Hence the cause of the accident: the rods broke and went through the bottom of the vessel; the water could not be pumped out; and, in subsequently trying to force in air, the deck was blown out. The other system, usually adopted, for rendering the position stable, was to make the sides hollow and of sufficient height to remain partly out of water. The sides were towers, 40 feet high. In these towers, were placed hollow boxes, which by means of screws, or chains, or some other contrivance, could be raised and lowered: the consequence was, as these boxes were always on the surface of the water, this pontoon could be lowered and the stability maintained, so long as both chains were lengthened to the same amount and at the same time. In that way the stability was maintained in the American Canal Dock. Sometimes this was done in the form of a large chamber, which had to be filled with water. In all these cases, a great difference would be observed between this pontoon and his own. The pontoon he used was perfectly open: it was never subjected to a greater strain than a pressure equal to the draught of water which it drew; and, drawing 6 feet of water, the greatest pressure was a column of water 6 feet in depth. The pontoon was consequently light and inexpensive, but in lifting with a submerged pontoon it must be sunk 26 feet or 30 feet deep in the water, and therefore, being subjected to a proportionate pressure, the quantity of iron required to strengthen it and to form the deck made it a more costly thing than the whole of the presses and pumps put together. Then, in addition, the manipulation of a large number of these boxes required a large staff of assistants. If a vessel were 300 feet long, with eighteen boxes, about forty men would be required to work them uniformly. It was a difficult engineering operation, requiring much skill and management, and after all, it was only one dock: but with his plan twenty pontoons might be worked by a single lift, with six men.

He did not say, that his dock was of universal application: he agreed, there were many circumstances, in which docks of another description were better. There were many cases in which a slip would be better than his dock, or any other dock, and there were other cases, where a stone dock would be better than this lift; but still it was capable of very general application. The principal difficulty was, in respect of the cost of the iron columns, where the water was too deep; and to meet such cases, Mr. Walker had suggested the plan of putting the presses themselves in pontoons. But where the water was of proper depth, there were few cases in which a dock of this kind would not be far more economical than an ordinary stone dock.

With respect to the stiffness of pontoons, he wished to state, that in advocating a partially elastic pontoon, he was giving the result of practice. He had stated that, from the experience of more than a thousand ships, an elastic pontoon was best, and produced no strain; but if a rigid pontoon was wished for there was nothing to prevent the sides being made 40 feet high; and any amount of rigidity might be obtained. If a captain wanted to beach his vessel, he always preferred to do so on a soft place; but that was a matter of judgment.

A great deal had been said with regard to the commercial failure of this undertaking. He did not think he was called upon to enter into that subject, nor did he think it concerned him. An Engineer might construct a superior quartz crushing machine; but it might be sent to a bad gold mine. If proper use was not made of the hydraulic lift machine he was sorry for it.

To return to the subject of cost, he wished to put the matter in a simple form. The cost of lift, engine, pumps and all complete and fixed, would not exceed £10 per ton upon the weight to be raised—his cost £7 per ton. The cost of the pontoon might be taken at £5 per ton upon the weight to be floated. The cost, therefore, of a lift, for vessels of 1,000 tons, would be £10,000, and the cost of six pontoons of from 500 tons burthen to 1,000 tons burthen, would be £22,500. Thus six docks were respectively completed for £32,500, allowing a good margin of profit to the manufacturers. That was in the case of a lift not requiring more than ordinary excavation. If a great amount of excavation in difficult ground was required, as in the Victoria Docks, of course it increased the cost. If it were done at a place like Birkenhead, where the value of the stone was more than the cost of excavation, he imagined there must be great economy of cost.

Mr. ABERNETHY remarked that the Author had omitted comparison with the two docks at Falmouth, which were lined with granite throughout, and only cost £29,000.

Mr. CLARK said, that in his illustration, there were six docks adaptable to almost any situation, and capable of indefinite extension, by adding to the number of pontoons. The machinery was simple and durable in all its parts. In comparison with ordinary floating docks, the whole of the work was perfectly accessible, especially with regard to the painting of the iron work, as there were no closed chambers, and the pontoon was raised out of the water in every operation. The rapidity with which this description of dock could be constructed was another important feature. The dock at Carthagena, of which the model was exhibited, was stated to have been commenced in the year 1861, and now in 1866, Mr. Rennie had been good enough to promise a descriptive Paper when that dock was completed. It did not take more than a year at farthest to put up the lift, and a stone dock certainly could not be built anywhere in that time. He did not know what the cost of the dock at Carthagena would be, but he was told it would be about £200,000.

March 6 and 13, 1866.

JOHN FOWLER, President,
in the Chair.

The discussion upon the Paper, No. 1,155, on "The Hydraulic Lift Graving Dock," occupied both evenings, to the exclusion of any other subject.

The following Candidates were balloted for and duly elected on March 6th:—HUGH CARLILE, EDWARD READ NELSON DRUCE, RICHARD HASSARD, and ROBERT MORGAN, as Members; HENRY ANDERSON, CHARLES ORMSBY BURGE, EDWARD CHARLES CRACKNELL, WILLIAM DEMPSEY, HAMILTON EDWARD HARWOOD, DAVID MARR HENDERSON, GRAHAM HEWETT HILLS, GEORGE KNOWLES, JOHN LEAN, JAMES CAMPBELL LEDGER, GEORGE LEEMAN, M.P., SAMUEL HENRY LOUTTIT, EMILE MARTIN, EDWARD ADOLPHUS FENWICK MAYER, HENRY OAKLEY, JOHN ROBINSON, THOMAS HARRISON SEACOME, GEORGE THORNTON, GEORGE CARELESS TREWBY, WILLIAM VAWDREY, and HENRY WILLIAM WICKES, as Associates.
