Discussion.

The AUTHORS exhibited slides illustrating the construction of the dock and the preparation of the site. Those shown by Dr. Salmon included photographs (Figs. 1 and 2, Plate 5) of the tests of the elm and oak top blocks of the keel-blocks, referred to in the Paper (p. 227). Fig. 1 showed the keel-block with the oak top block carrying a load of 382 tons, and Fig. 2 showed the second keel-block with the elm top block under a load of 328 tons. Dr. Salmon drew attention to the fact that when the oak block was loaded to a maximum of 1,565 tons, not only the timber blocks but also the steel wedges opened out at the ends, showing that the load preferred to go directly through to the supports rather than spread out laterally. At the centre the bottom steel wedge was embedded 1 inch into the oak longitudinals. The Authors.

Sir ARCHIBALD DENNY, Bart., remarked that Dr. Salmon's Paper was the third communication to The Institution from members of the firm of Clark and Standfield. The first Paper, by Mr. Edwin Clark, was read in 1866. The second, by Mr. Lyonel E. Clark, was discussed on the 31st January, 1905, the President in that year being Sir Guilford Molesworth. One of the principal speakers on that occasion was Sir William White, under whom he had had the honour of serving his pupilage. Sir William remarked that he "thought it would be agreed that the Paper displayed a generous spirit, in placing a vast amount of information at the disposal of all interested in the building of floating docks"; and Sir Archibald Denny thought the members had to thank the Authors that evening for having placed further valuable information before them. The cost of a site for a floating dock, Sir William White also said, had to be added to the cost of the floating dock, and Mr. Wentworth-Sheilds's Paper indicated that that might occasionally be a considerable amount. Mr. Clark, in his Paper, stated that the largest dock at that time belonged to the United States; it was at New Orleans, and its lifting power was 18,000 tons. Now the Authors gave an account of a dock which was at present more than three times as powerful, while provision was made for adding another section, which would raise the lifting-power to 70,000 tons. Sir William White, in the same discussion, expressed a decided preference for the double-wall floating dock over the single-wall; and the Papers showed that the Sir Archibald Denny.

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double-wall off-shore design had been adopted for the largest floating dock in existence. Dr. Salmon's Paper was so complete that there was nothing to criticize, and not much additional information to ask for. Mr. Clark 20 years ago did not give scantlings—which were of great interest to naval architects—neither did Dr. Salmon, and probably for good reasons, with which he sympathized. In connection with the question of the relative advantages of floating and graving docks, Lloyd's Registry had prepared for him a schedule, from which he found that in Great Britain there were forty-nine graving-docks belonging to the Admiralty and 252 belonging to private or municipal owners, a total of 301. In Holland there were eight graving-docks in all. Of course, many of the graving-docks in this country were very small, but taking the docks which were more than 500 feet in length—a very substantial dock—he found they numbered eighty-two in this country, and there were forty-eight exceeding 600 feet. The record showed that in Great Britain there were six floating docks belonging to H.M. service, of a total lifting-power of 70,700 tons, of which two were of 32,000 tons each; and there were twenty-one others of more than 104,700 tons total lifting capacity, including the Southampton dock. In Holland there were thirty floating docks, with a capacity of 202,000 tons, against the twenty-seven in this country. The largest was one at Rotterdam, with 46,000 tons lifting-capacity. He had had the advantage of being in Holland 2 years ago, and it was then that he first took a keen interest in floating docks. Mr. Clark had considered that the main condition which determined whether floating or graving docks should be used was one of situation; and he thought that was the principal point. In the ports of Rotterdam and Amsterdam the waterways were locked, and there was no rise and fall of tide, but in Great Britain there was generally quite an appreciable rise and fall, and in the Severn ports, for example, the rise and fall was excessive. It might be that that was the reason for the fewer floating docks in this country. Also, in Holland water-area appeared to be plentiful or easily obtained, and the land was not suitable for graving-docks; whereas generally the ground here was suitable and sometimes docks could be found hewn out of the solid rock. There was no doubt that the question of situation had governed the practice in this country as compared with the practice in Holland. One point that had struck him particularly was the much better lighting and airiness of the floating dock as compared with the graving-dock. Speaking as a naval architect, he could say that it was important to have good light, but more so to have plenty of air. In Dumbarton one of their specialities was the building of fast

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cross-Channel steamers, and it was essential on trial to have the very best conditions of the surface of the bottom of the ship. He had known cases in Scotland, in the early spring and late autumn, when the weather was not very dry, of vessels being specially docked for the purpose of obtaining a good surface for the trial, and then having their paint stripped off again by action of the water, on account of imperfect drying of the paint. The floating dock provided a good draught—the best condition for the proper drying of paint, which shipbuilders and shipowners knew was very necessary for the preservation of a good surface. The graving-dock was absolutely immobile, but the floating dock could be shifted; and it would probably be remembered that, during the war, docks were taken to Scapa Flow and Invergordon and were of very great use. He would like to read a paragraph of Mr. Clark's reply to the discussion on his Paper, namely: "The design of a floating dock lay certainly more within the province of the naval architect than in that of the constructing engineer; but he was not sanguine enough to imagine, as some of the speakers would seem to imply, that the naval architect was in any way going to oust the engineer." For Dr. Salmon's comfort Sir Archibald Denny might say that the naval architect had made no such attempt. A matter of interest to naval architects were the Tables giving the weights and times of building, and especially the stability graph. It was quite evident that the time taken to build a floating dock was very much shorter than that required for a graving-dock. He was interested also in the tests of the dock that had been made after completion, and the figure cited as being safe for steel plating in tension. A few months ago Mr. Foster King, the Principal Surveyor of the British Corporation, a man well recognized as being skilled in such matters, had given just that same figure of 7 tons as, in his opinion, a proper one to adopt for ocean-going vessels. The deflection figure of $4\frac{1}{8}$ inches was very moderate, and the transverse deflections with the "Olympic" on board were also quite reasonable. It seemed to him that the members must congratulate Dr. Salmon upon the fact that his designs so carefully worked out had realized success. It was impossible not to admire the great completeness of the equipment of the dock and the exceedingly simple arrangements which were made for control.

Referring to Mr. Wentworth-Sheilds's Paper, he had had the advantage of seeing the site being worked on, under the guidance of the Author, and it seemed to him that all the arrangements made there were excellent and worked very smoothly. On p. 233 the Author observed that the disadvantage of the site was that, being just

Sir Archibald Denny. outside the main stream of the river, it formed a backwater, and was therefore liable to be gradually silted up. In Dumbarton they had a wet basin which was in very much the same situation, on a river that brought down a good deal of silt, and that dock had to be dredged from time to time. The dredging was done with a home-made grab dredger and the dredged holes filled very rapidly. He asked how Mr. Wentworth-Sheilds would ascertain the clearance underneath the bottom of the pontoon. Appendix B was exceedingly interesting, especially the scheme developed for finding the tension that should be put on the mooring-chains. Probably if that tension had been increased, all that would have happened would be that the dock would not have moved quite so much fore and aft. The Authors and all the engineers connected with the work were to be much congratulated on the success of their efforts, and he thought the ailway company was also to be congratulated on having such a magnificent piece of machinery.

Mr. Wilson. Mr. MAURICE F.-G. WILSON remarked that a Paper dealing with something greater than had been done before was always especially interesting, and the dock described appeared to be about 30 per cent. larger than any similar dock previously made. It had been of interest to him to learn that the oak tops of the keel-blocks were so much inferior to the elm. Usually keel-blocks were of oak with a soft-wood capping. When the Prince of Wales dock was being built at Southampton, a good deal of discussion took place as to whether metal wedges should be adopted in connection with the keel-blocks, the objection being that such wedges had a tendency to get jammed; but he noticed that steel wedges had been adopted in the dock under discussion, and it would be of interest to know if there had been any trouble in that way. With regard to the question of floating docks versus graving-docks, there were at Southampton both large graving-docks and the new floating dock, which would provide some useful comparative figures; and it would be of value a generation hence to know which type of dock had in the long run been the more expensive. The floating dock was cheaper in the first instance, but no figures had been given as to the costs of the preparation of the site, construction of dolphins, etc., which, he imagined, would bring the total cost up to £550,000 or £600,000. A graving-dock of corresponding size would cost probably twice as much, if not more. In the case of the floating dock there was the cost of maintenance, painting, and looking after the dock generally, and also the maintenance of the dredged site. He did not know how the silting underneath the dock, which was sure to take place, was to be dealt with—it would be a very considerable inconvenience to remove the dock from its moorings each time in order to dredge away the deposit. There was also a certain amount of inconvenience in connection with the use of floating docks: the materials and workshops for carrying out large repairs were not so handy as in the case of repair shops in the immediate vicinity of an ordinary graving-dock. The latter, also, required practically no maintenance. He had been particularly interested in the dredger, because it happened that his firm had been asked to negotiate with regard to her, on behalf of some clients. Her normal dredging depth was 60 feet, but by an arrangement whereby the ladder could be unhinged at the top, lowered, and hinged on again lower down the framing, more buckets and links of course being added, it was possible to dredge to 76 feet without increasing the weight or length of the ladder. It would be useful if Mr. Wentworth-Sheilds would show rather more clearly by means of a diagram how the somewhat troublesome operation of driving the raking piles had been carried out. The upper works on the dolphin would have had the advantage of permanency if made of reinforced concrete; possibly timber was a little cheaper. The difficulty encountered in sinking piles by means of jets might have been due to the employment of three jets on a square pile, and he asked whether a single jet or four jets would not have been preferable. The mooring-blocks seemed to work out to about 8 feet 6 inches cube, and it would be interesting to know their shape and the depth below the surface to which they had been sunk. The Appendixes to Mr. Wentworth-Sheilds's Paper were very valuable. It might be thought at first that it was easy to moor a large pontoon alongside a set of dolphins; but there were evidently many things to be considered, and these matters had clearly been gone into very minutely. It would be interesting to know how in actual practice the dock took up her position in accordance with the height of the tide and the strength of the wind, and whether that position agreed fairly well with the calculations. Mr. Wilson.

Mr. FREDERICK PALMER remarked that, as an advocate for the graving-dock, he had been rather struck by the fact that the floating dock—which type, he understood, had been chosen because the dock was wanted in a particularly great hurry—actually took 21 months to build, from the date of placing the order to the date of the trials. To some extent, of course, that was due to strikes. The entrance width was given as 130 feet 8 inches, and the length of each central section as 130 feet 3 inches; that left 5 inches margin when self-docking, which seemed to him to be rather a tight fit. Mr. Palmer.

Mr. Wentworth-Sheilds modestly described his Paper as dealing with subsidiary work; but the work done, including 1 million cubic

Mr. Palmer. yards of dredging, appeared to involve expenditure approaching £200,000. Mr. Palmer would like to know the total cost involved in the establishment of the dock, up to the date of its being put into working order, because then those who were in favour of concrete docks would be able to judge as to comparative costs. His own feeling was that floating docks were a necessary evil. In Holland there were no foundations, and it was necessary to use floating docks or do without accommodation; but in this country engineers were lucky enough to find good foundations in most cases. Even at Southampton there were graving-docks for which good foundations had been discovered. The site of the floating dock had been selected with great difficulty, apparently because of he conditions at Southampton; and it seemed to him that, although the selection might be the best possible, it was an unhappy one. Referring to Figs. 2, Plate 4, section AA showed that the original ground-level crossed one-third of the site of the dock at L.W.O.S.T., and that the remainder was high and dry at low water. Section BB showed similar conditions, three-eighths of the original ground-level being at L.W.O.S.T. He could not help thinking that a hole 61 feet deep would silt up rapidly. No doubt Mr. Wentworth-Sheilds could say whether silting was going on under the dock. What would be done when appreciable silting took place? Would the site be dredged by some special means, or would the dock have to be put out of use for a period? He would not be surprised to find that the best way out of such difficulties would prove to be to level the bottom, sink the pontoon, fill it with concrete, and make it into a graving-dock.

Mr. Staples. Mr. S. F. Staples remarked that he would not be expected to criticize either his partner's Paper or the dock itself, but there were one or two interesting points to which he might refer. The method of painting the dock was novel. The painting of such a semi-submarine structure was of the utmost importance, and a large amount of attention had been paid to it. The paint adopted for the inside of the dock between the intermediate longitudinal bulkheads had a basis of crude vaseline, and never became dry. He had suggested its use many years ago to the owners of a dock in Trinidad, and they had used it on both new and old work. He had occasion to make a survey of that dock 14 years afterwards, and he found the new work absolutely in the same condition as it was when the paint was put on. On the inside of the pontoon of a floating dock in the tropics, paint was subjected to about as severe a test as could well be imagined. The paint in question was of no use on the outside of the dock, because it got washed away. There were other sorts of paint which never became dry. A dock at Sunderland had been coated with a non-drying paint that had been on for about 18 years, and to all intents and purposes both the paint and the steel below it were in new condition. Such preparations marked a very considerable advance in the eternal fight against rust. For the inside of docks, or any structures where there was not much traffic, it seemed to him that paints of that sort were bound to be the paints of the future. They could not be used, however, where men walked about, as the surface was exceedingly slippery. He wished to draw special attention to the ease of operation of the dock. The interior of the valve-house appeared complicated; it was necessarily much sub-divided, but in actual working the control was particularly simple. A rather curious thing had happened just after docking the "Olympic." Before that there had been water in some of the air-chambers, and men had been caulking in order to prevent its ingress. About ½ hour before the dock was sunk, the men came out and the manholes were screwed up. The "Olympic" was then brought in and raised. As soon as she was high and dry, men were sent down to see if the air-chambers were still without water in them, as they should be. To their astonishment, directly they got the sounding-plugs clear of the manholes, the former were blown out, followed in each case by a blast of compressed air. It was a puzzle to know where the compressed air came from, but eventually it occurred to the engineers that the deck had a camber, and when the water came up very nearly to the top of the pontoon, the ends of the vent-pipes were submerged. Thus the air in the air-chambers was compressed under a head of 60 feet of water, which worked its way into the air-chambers and produced the rather astonishing result when the plug was taken out. Drainage-holes were placed along each side of the pontoon close to the face of the wall, to allow the water to run off the top of the deck when a ship was very nearly lifted, and those holes were carried down below the pontoon deck and then turned out horizontally at the backs of the walls. In the ordinary way drainage-pipes were laid straight through the pontoon and out at the bottom, which was a much simpler and cheaper way and had many advantages. But another system had to be adopted, on account of an occurrence brought to his notice some time before. During the war, the King's Harbourmaster at Invergordon asked him to explain an obscure trouble with a big dock brought there from Portsmouth. Although the deck of that dock in every part was 6 inches above the level of the sea, the water would not run off the deck through the holes. The explanation occurred to him when he remembered that Scotland Mr. Staples.

Mr. Staples was a place where it sometimes rained. A ship had been in dock for a considerable time, and the drainage-holes had probably become full of rain-water. A very little calculation showed that 18 feet of sea-water would support 18 feet 6 inches of rain-water, and, as the deck was slightly concave longitudinally, the water could not run off. The risk of straining ships on a floating dock was often cited, but the fact that ships themselves deflected considerably under normal conditions was lost sight of. On the Southampton dock sights were carefully taken in the early morning in the summer, and the dock was found to be perfectly straight, but in the middle of the day, after the sun had been out, there was a deflection exceeding 4 inches, due to the sunshine. A ship floating in the sea was in exactly the same circumstances as a dock floating in the sea; when the sun was shining on the ship it behaved as the dock behaved, only there were no instruments to show it. In lifting the "Olympic" it was found that there was no trouble either in taking out the bend put in by the sun shining or in putting it back again to maintain alignment when the sun went in. By pumping from the ends or the middle it was possible to do just what one pleased.

Sir Cyril Kirkpatrick. Sir CYRIL KIRKPATRICK said the Papers were of exceptional interest to all dock- and harbour-engineers, and their value was very much enhanced by the fact that they were being read almost immediately after the dock had been constructed. He did not wish to labour the point of costs, because that had been touched on by several speakers; nevertheless, if Mr. Wentworth-Sheilds could give, not only the total cost, but also some comparative costs of the floating dock and a fixed graving-dock, they would be very valuable. He was quite certain that the Southern Railway Company thoroughly investigated the matter before they embarked on the scheme. He asked Mr. Wentworth-Sheilds not only to state the first cost, but to give also the estimated charges for interest, sinking-fund, maintenance, dredging, etc., for the two alternatives. He was interested in the fact that the width of the dock had been fixed at 130 feet, which was the figure for the nearly completed lock-entrance at Liverpool; he thought that width was now generally accepted as the maximum width to be provided, looking to the future. To his mind the design and spacing of the keel-blocks was very interesting. It was mentioned on p. 227 that the average load per linear foot was taken as 80 tons. The alteration of the width from 1 foot 6 inches to 1 foot 3 inches was a wise decision, so as to allow of the intermediate blocks being used at the bow and the stern and under the machinery, which would, he assumed, allow for a loading of 160 tons per foot where required. He did not know whether Dr. Salmon could state the actual heaviest loads anticipated. Such information was not easy to obtain, and after it had been obtained from the best data possible, it was somewhat uncertain, even more so with a floating dock than with a dry dock. The figures for the crush of the keel on the blocks under the "Olympic"—$3\frac{9}{16}$ inches at the bow and stern and $2\frac{1}{8}$ inches at the centre—appeared to be rather high. If the actual estimated load could be given, it would be possible to calculate the compression and see how the two compared. Was it found at Southampton that the steel wedges were really used? His experience was that the setting of the blocks for large vessels was done on the soft-wood caps rather than by any variation of the steel wedges. Was the advantage of steel wedges as great as was contemplated, or was the wedge action unnecessary? A sketch of the bollard heads would be of value; that was always an interesting point, because no two dock-masters agreed as to what they wanted. It was made more interesting here by the fact that the mooring-ropes had considerable elevation, and he presumed the head had been rounded off with a hook. What Mr. Staples had said with regard to painting was very important to those who had had to maintain steelwork. It seemed to him to open up a new era. He supposed every engineer had tried, and been disappointed with, the so-called bitumastic and tar paints, which seemed almost invariably to come off. If "Humidine" would preserve steel for 14 years without any deterioration, it was a valuable material and would be very largely used in the future. Sir Cyril Kirkpatrick.

Mr. Wentworth-Sheilds's design of the booms and dolphins was very satisfactory, and the manner in which he had got over the difficulty of vertical movement for the 70-foot range, and also the fore-and-aft movement, by the cruciform bolts, was very interesting. Mr. Wentworth-Sheilds must have been highly gratified at the result of the unexpected "test" imposed by the dock on the dolphins.

Mr. G. E. W. Cruttwell remarked that the dock appeared to have been very carefully designed and completely equipped. With regard to the mechanical side-shores, was the 10 tons push the maximum working resistance which each shore could exert? If so, the four shores on the lee side of the vessel would have a total resisting-power of 40 tons. He found from the elevation[1] of the "Olympic" that that vessel, when drawing 31 feet 3 inches, which was the draught when she made her trial entrance into the dock, had a broadside area of about 47,000 square feet, after deducting the lower part of her hull which was then sheltered by the windward Mr. Cruttwell.

[1] *Engineering*, vol. xci (1911), plate xxxix.

Mr. Cruttwell. side-wall of the dock. A 20 miles-per-hour wind would produce a side pressure on that vessel, when she was being put on the blocks, of about 94,000 lbs., which appeared to be in excess of the resisting-power of the side shores. It seemed that there was no ready means of ascertaining the level of the silt beneath the bottom of the dock. It would have been easy, while the dock was being built, to put a series of open vertical tubes through the dock from top to bottom, through which a sounding-line could have been dropped. If the dock had to be removed when the site required to be re-dredged, it would be a very serious matter, involving the provision of suitable moorings in another situation and also loss of revenue while the dock was out of service for several weeks, or possibly months. Mr. Wentworth-Sheilds stated that the site was liable to be silted up. From his own recollection of Southampton, Mr. Cruttwell thought it would not be many years before re-dredging became necessary, and that was one of the chief objections to a floating dock as compared with a graving-dock. As Sir Archibald Denny had said, the floating dock had the advantage of more light and air; but he rather doubted if in severe weather the men working at the bottom of the outside of the vessel would like the additional air. Certainly a floating dock could be constructed much more rapidly, especially if the subsidiary work could be proceeded with concurrently. One of its great advantages was the possibility of bringing the 150-ton crane alongside, so that any heavy loads could be handled with facility. On the other hand, a graving-dock had a great deal more space on the adjoining quays for workshops and stores; it also gave much better access from the shore, bridges being the only means of communication between the shore and a floating dock. On the question of cost no general rule could be laid down as to which was the more favourable system to adopt; each had to be considered in connection with local conditions. In the present case the cost of the dock itself was £375,000, to which must be added the cost of extra fittings. Unfortunately, Mr. Wentworth-Sheilds did not give the cost of the subsidiary work. He gave, however, a figure of 1 million cubic yards of dredging for the site, and that must have cost more than £100,000; and Mr. Cruttwell imagined that the total cost must have been well over £500,000. He had not made any estimate of the cost of a graving-dock at Southampton, but he thought it would not be very much more. Taking into account the extra cost of future dredging, working, and maintenance, it would be found that, on the whole, the graving-dock would be less costly. In 1907 his firm had to prepare comparative estimates when making an investigation as to dry-dock accommodation at Immingham.

Mr. Cruttwell. They made comparative estimates for a graving-dock and a floating dock, each having a floor-area of 900 feet by 100 feet. Taking the first cost of the graving-dock at 100, the cost of the floating dock came to 84, but the additional cost of dredging, moorings, etc., raised the latter figure to 108. The question of future dredging and working on both systems was considered, and it was found that the cost of the maintenance dredging and the annual working and maintenance of the floating dock came to £7,000 a year in excess of the working-cost of the graving-dock. Capitalizing that £7,000 at 20 years' purchase brought the total outlay on the floating dock to no less than 174. Judging from the particulars given by Mr. Wentworth-Sheilds as to the dredging, the conditions appeared to be very much the same at Southampton as at Immingham, except that at Immingham there was no sandstone. If there was any hard rock or marl, such as was found at Barry graving-docks, then the case of the graving-dock became much more favourable than that of the floating dock. He thought, on the whole, it would have been better policy if another graving-dock had been laid alongside the existing Trafalgar dry dock, with sufficient space between the two for workshops and stores, which would serve both docks. There would have been a good deal more space than could be obtained on the floating dock, and the water-area would not have been so seriously curtailed. In addition, better access to the graving-dock would have been afforded and money would have been saved, if not in the first instance, at any rate in the future, when dredging and maintenance charges came to be taken into account.

Mr. Moncrieff. Mr. J. Mitchell Moncrieff said that, with regard to the relative advantages of floating docks and graving-docks, the choice rested almost invariably on local conditions. He had been connected in the past with works carried out where there were both floating docks and graving-docks in the same place, and it might be interesting to know what his clients found to be the relative advantages. A floating dock was put in where it was impossible to get a graving-dock, and vice versa. The floating dock was more convenient for inspection and painting, and for those purposes was more easily worked, but there was no doubt that for heavy and lengthy repairs a graving-dock was better. With regard to the mechanical shores of the Southampton dock, he wondered what would happen if one of the large vessels came in in a damaged condition with a heavy list, because the shores seemed to him very slight indeed in relation to a large vessel in such a condition. He noticed that the central intervals between the shores were 390 feet, which indicated to him that the dock was not intended to be used for anything but very large vessels.

Mr. Moncrieff. Had such vessels provided sufficient business to keep the dock employed? He was intensely interested in Dr. Salmon's description of the tests of the keel-blocks. The difficulty of designing such blocks was well known. Each block in the Southampton dock had to carry on an average about 200 tons; the heaviest loads he himself had had to provide for had been limited to an average of 172 tons. He much preferred the designers' original proposal, namely, the use of separate blocks, even if they had only 6 inches between them. He quite sympathized with the users' demands that they should be able to move blocks about; and he thought the cast-steel wedges were a great improvement on the wooden wedges first proposed, because the latter would have been difficult to get out. Wedge blocks were not generally made with a view to adjust the tops of the blocks. The wedge blocks he himself had put in actually had pins in certain standard positions, and any adjustment of level was made by the dock carpenters in the thickness of the capping-pieces. The real object of the wedges was to enable the blocks to be got out, and not to adjust the level. The photographs shown by Dr. Salmon, which were typical of what happened under a large vessel, proved that the removal of those blocks would be very difficult indeed. The ordinary method was to have a cutting-out piece. The wedges were useful, however, in facilitating removal and replacement of blocks. The presence of the longitudinal timbers in the Southampton dock struck him as being extraordinary. The total height of the blocks and longitudinal timbers was only 4 feet 6 inches from the floor of the pontoon, but only 2 feet 10 inches was left between the top of the longitudinal timbers and the underside of the vessel. That was very small. Nearly 20 years ago he put in blocks 4 feet 6 inches high above the dock-floor, but the centre 5 feet of the dock consisted of longitudinal timbers 6 inches deep, above which the clear height of the blocks was 4 feet. Complaints were soon made that that was very inconvenient, owing to the 6 inches height of longitudinal timbers. The electric travelling cranes on the Southampton dock were extremely light, having only 2 tons lifting-power at the centre of the vessel. Was it intended that the large floating crane should deal with any heavier loads?

Turning to Mr. Wentworth-Sheilds's Paper, he noted that the dolphins were constructed with reinforced-concrete piles. He did not wish to be a pessimist about concrete piles—he should use them again, but not in positions such as that in which they had been used by Mr. Wentworth-Sheilds. Just before the war he had an unfortunate experience in connection with reinforced-concrete piles of octagonal section and 16 to 17 inches over the flats. He made careful inquiries as to the condition of such piles in various parts of the country, and found that, though the piles were in many instances apparently quite satisfactory, they were actually cracked, although this had been unknown to the engineers. On the work he had mentioned, about 180 piles had been driven, when he observed that half of them were cracked, and he believed that the other half were cracked also. He would not have found that out but for peculiar conditions in connection with the execution of the work. The composition of the piles at Southampton was given in Mr. Wentworth-Sheilds's Paper. In his own case there was never less and generally more reinforcement, and the piles were of somewhat richer mixture. Some of the piles cracked when the set during the whole driving was never less than $\frac{1}{8}$ inch per blow ; one of those piles was only 15 feet in the ground, and it only required 15 tons to pull it out, inclusive of its own weight. The cement used was of the finest quality, and the gravel was exactly as specified in Mr. Wentworth-Sheilds's Paper. If the trouble had been occasioned by handling, the cracks would have appeared in the middle of the piles, but many of the cracks occurred within 3 feet or 4 feet from both ends, as shown in Figs. 3-6, Plate 5. Mr. Moncrieff.

Mr. L. H. Savile remarked that the Papers were particularly welcome on account of their novelty. Mr. Wentworth-Sheilds had introduced several new points, especially with regard to the mooring-dolphins. Mr. Moncrieff's remarks might make some engineers rather nervous as to whether the dolphins were going to stand, but his own experience of reinforced-concrete piles had not been, he was glad to say, the same as that of Mr. Moncrieff. The Admiralty had numerous jetties containing many thousand concrete piles, and, so far as he knew, there had been no failures. Where failure did occur in connection with reinforced concrete, it was rather above half-tide level and more particularly perhaps above high-water level—seldom below low water. The probable reason for failure, especially above high-water level, was the fact that the salt air was driven in, and, reaching the iron reinforcement, started cracks. As far as his experience of reinforced-concrete structures was concerned, many of which had been in use for 20 years or more, there had been no trouble at all below low water. A point might be mentioned with regard to the nomenclature of a dry dock ; already during the discussion four names had been given to it, namely, dry dock, graving-dock, stone dock, and concrete dock. It might be useful if the Council of The Institution would regularize the name, so that a dry dock could always be recognized by name, as distinct from a wet dock. With regard to the relative merits of graving-docks and floating Mr. Savile.

Mr. Savile. docks, there was no doubt that, generally, naval architects would favour the latter, while civil engineers would recommend the former. One of the principal advantages of a floating dock, in the view of the Admiralty, was that it could be moved. If for naval reasons it was urgent that a dock should be provided at some place, there was the possibility of taking one there in a comparatively short time, whereas it would be quite impossible to construct a dry dock. At present the Admiralty had only one large and three small floating docks in use, but they had two other large floating docks for which berths were being prepared. In case it should appear that the Admiralty were unduly partial to floating docks, he might mention that those two were originally German property. There were various means of fixing floating docks in their berths; there could be dolphins on each side, with the dock sliding between them; dolphins on one side and at one end, connected to the dock by booms; dolphins at the side and moorings at the end; dolphins on one side and moorings between the dock and the dolphins; or moorings alone. There was no doubt that, if the question of cost was not very serious, the method adopted at Southampton, with possibly the addition of the end dolphin and the additional boom, was the best. With regard to the Admiralty floating docks, one, being quite small, was placed between a jetty on one side and dolphins on the other. Another—a 30,000-ton dock—had five booms, two fixed to dolphins, two to a jetty, and one to an end dolphin, practically on the same lines as the Southampton dock. The question of mooring the two German docks had been considered, and one was to be secured by mooring-chains only. The other it had been proposed at first to moor between two dolphins and a pier; for certain reasons that scheme was altered, and booms were introduced, which added considerably to the cost. Then it was found that a wall could be spared and the necessary depth could be obtained; so finally it was decided to attach the dock by booms to the wall, with fore and aft cable moorings. Fore-and-aft movement might be controlled by the use of pairs of chains crossing from boom to boom. The dolphins to be used in the first proposal were estimated to cost £36,000 each. Several speakers had raised the question of the cost of re-dredging the berth of a floating dock. A 30,000-ton Admiralty dock had been moored for 5 years during the war in a dredged site at Jarrow Slake in the Tyne, where silting was excessive. During that period no re-dredging was required, and the dock could be lowered to its full depth. While that dock was away from its original site, silting of about 18 inches took place, and had to be taken out, but no dredging had since been required during the past 5 years.

Mr. Savile. He thought it was very probable that, in the frequent sinking and raising of the dock, a stream of water flowed from underneath at each side and at the ends, removing a good deal of light silt in the process. With 4 feet 6 inches clearance underneath the dock, as at Southampton, a certain amount of silting would probably occur; but, as the clearance was reduced, he thought the site might maintain itself, and it was highly probable that many years would elapse before any re-dredging would be required if every opportunity were taken to lower the dock to its full depth. A similar effect occurred when a caisson entered a caisson-camber. When a caisson was drawn out of a camber, silt was found in very close proximity to the profile of the caisson, but it was seldom necessary to take out the caisson to remove the silt; he thought in that case it acted as a loose piston. With reference to keel-blocks, when designing the new dry docks in Bombay, he had found that the existing dry docks had built-up, cast-steel, wedged keel-blocks, and it transpired that whenever a keel-block was removed, the timber had to be cut out, because the steel wedges had rusted firmly together. Therefore solid steel keel-blocks with timber caps had been made for the Hughes dry dock, and no inconvenience had been caused. That method resulted in considerable economy.

Captain Sir Arthur Clarke. Captain Sir ARTHUR CLARKE remarked that he was confident that the dock-authorities at Southampton had had sound reasons for installing a floating dock—reasons that were probably special in that case. He had seen the "Olympic" lifted by the dock and looking like a mirage; and the dock certainly was an instructive example of engineering skill and ingenuity. He only proposed to say a word or two on floating docks versus graving-docks from the points of view of the sailor, the shipping-companies, and the pilot, and also from the point of view of dock- and harbour-authorities. He believed he was right in saying that no port in the United Kingdom was more suitable for a graving-dock than was Southampton; the docks were open, there was only a small rise and fall of tide and very little strength in the stream of the tide, and, more important still, dredgings had to be transported only a very short distance for deposition in the sea. They were carried just outside the Needles point in the summer, and just inside the ridge in the winter. Whether it was wise to deposit material inside the ridge was another question. The dumping of material anywhere near the estuary of a great port like Southampton was a grave problem for dock- and harbour-authorities. In the case of closed docks, such as the London or Liverpool docks, shipping-companies would have serious objection to taking their ships out of wet docks into a river or estuary with

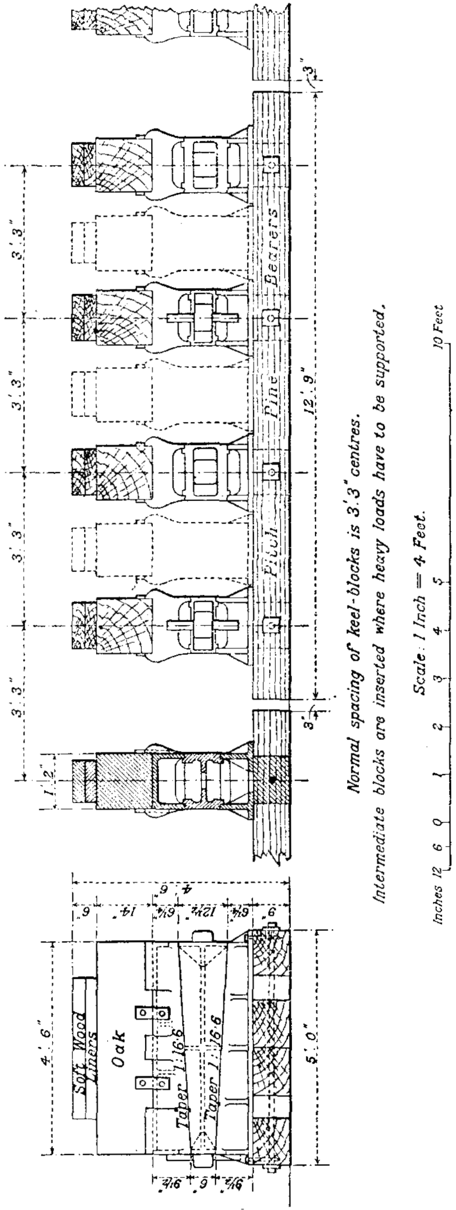
Captain Sir Arthur Clarke. a view to dock them in a floating dock. Every closed wet dock should have one or more associated graving-docks inside it. He need hardly point to the reasons for the objection. A big ship with no steam up necessitated a large number of tugs going out into the river, with consequent risk of collision, question of insurance, and so on. Those were the objections which not only the shipowner but also the sailor and the pilot had against leaving a wet dock in order to go into a floating dock outside. Mention had been made of docks cut out of solid rock, and a dock of that sort, 450 or 500 feet in length, had been built some time ago in the River Lee at Cork, in preference to having a floating dock in the river. He remembered having been, many years ago, on a damaged ship which was being docked in the Panama floating dock. A floating dock was absolutely essential for that situation. In comparing the costs of a floating dock and a graving-dock it had to be remembered that in the case of the former the dredging, insurance, danger of collision in the river, difficulties in entering and leaving in the tideway—particularly in a busy river—and the painting and repairs, had to be considered. He had been much relieved by hearing the last speaker say that probably little dredging would be necessary on the site of the Southampton dock; and he hoped that was right, because it would be a great encouragement to those who installed floating docks to know that no serious dredging would be entailed. Those who had to deal with dredging knew how costly it was, particularly when the material had to be carried out to sea. A dock- and harbour-authority ought to consider very seriously before embarking on a floating dock, and always have in view the advantages of a graving-dock where the conditions generally were favourable for construction on land. There was no doubt that the expense of maintenance of a graving-dock must be less than that of a floating dock. At the King George V dock the subsoil was particularly favourable, and the contractors had been fortunate in obtaining on the site all the ballast required for the building of the dock, with a little over for sale. He had in mind particularly the Port of London, but he was sure that every dock- and harbour-authority would study the matter very carefully before they embarked on such a scheme as had been undertaken, doubtless with every care and caution, by the Southampton dock-authority.

Mr. Deane. Mr. H. J. Deane remarked that Mr. Wentworth-Sheilds had given no information as to the cost of the subsidiary works, and without that the Paper was somewhat incomplete. Mr. Wilson had asked for information with regard to the size of the anchor-blocks. The actual weight was given in the Paper, namely, 40 tons, but Mr. Wentworth-Sheilds made no mention of the Mr. Deane. considerations which had been taken into account in fixing, not only the weight, but also the dimensions of those blocks. Mr. Deane assumed that Mr. Wentworth-Sheilds had considered the faces of the blocks as being represented by a retaining-wall with a weight of sand on the face, and had designed the resistance-areas accordingly; but information on that point would be valuable. Mr. Wentworth-Sheilds stated that the mass concrete used for weighting purposes on the dolphins was submerged at high water; and, no doubt, when the concrete was being deposited, he took good care to see that the shuttering was made practically watertight so that the sea-water did not get to the green concrete. Had any precautions been taken to prevent the sea-water from getting at the top of the concrete and so affecting it? Reference was made in the Paper to the loads allowed for the piles of the dolphins, both in compression and in tension, and a figure of 6 tons was given as the limit allowed for tension on a pile. Available information on the subject of the resistance of piles to withdrawal was extremely limited, and it would be of value, if Mr. Wentworth-Sheilds had carried out any experiments in that connection, to have the information given to The Institution. The 6 tons represented roughly a skin friction of 100 lbs. per square foot. Allowing, say, 400 lbs. per square foot as the ultimate skin-friction resistance of the pile, the factor of safety was 4 to 1. It would be interesting to know how the figure of 6 tons had been arrived at. The subject of floating docks versus graving-docks had caused a good deal of discussion, both on the present occasion and in the past, and he thought the whole matter was summed up in Sir Archibald Denny's remark that it was necessary to take into account the various circumstances of the locality before a decision could be reached. A point which he had not seen referred to before in any discussion was the question whether floating docks were ever sunk on an incline. It was well known, particularly amongst those who had to do with dry-docking ships, that there were many vessels afloat whose draught was considerably greater aft than forward. The effect, in a graving-dock, was of course very marked, because when the pumping out of the water was started, the stern post took the blocks first, and thereafter it was necessary to take special precautions in shoring the ship as she settled down. He thought there had been more than one case in which damage had occurred to the blocks and the ship as a result. It seemed to him that a floating dock was an excellent appliance for handling ships of that description. There might be some objection to submerging floating docks out

Mr. Deane. of truth, but, if there were none, it seemed to him to be a great argument in favour of floating docks for that class of vessel, because it would be possible to arrange the inclination of the dock so that the keel-blocks would take up the pressure from the keel from stem to stern, and the ship could then be raised into a horizontal position.

Mr. Gedye. Mr. N. G. GEDYE observed that the keel-blocks seemed to have come in for some little criticism. In the case of a dry dock that had recently been completed under his direction at Swansea, cast-iron keel-blocks were used, consisting of three tapered sections with oak capping-blocks and soft-wood liners, the whole section being carried on four lines of pitch-pine balks laid longitudinally (*Figs. 7*). The blocks were arranged on the longitudinal timber bearers so that the thick ends of the middle or wedge blocks were placed alternately on the right- and left-hand side, thus preventing risk of the ship forcing all the wedge pieces one way. The dock authorities had given the design of the blocks a great deal of thought. So far as the cast-iron blocks were concerned, they were of very much the same form as the cast-steel blocks adopted by Dr. Salmon, but he observed in the illustration given in the Paper no indication of any means of keying the wedges. He considered that some means of keying or securing the blocks by cotter-pins or otherwise was a desirable safeguard where taper sections were used. In Swansea a system was adopted which he believed was fairly common: the thin end of the wedge-block was provided with an eye, through which a steel cotter-pin was driven when the block was in position. When the cotter-pin was struck out, the block could be driven out by a sharp blow with a battering-ram. In view of the remarks made to the effect that it was seldom, if ever, necessary to remove the blocks, he had written to ask Messrs. Palmer's dock-manager at Swansea whether he could confirm his own general observations. In reply, it was stated that only a fortnight ago it had been necessary to knock out, for the purpose of repairing the bottom plates of a ship, no less than twenty-one blocks at one time; that it was a matter of very frequent occurrence to take out blocks; and that hardly a week passed without two or three occasions arising for one or more blocks to be taken out, in order to get at some point in the bottom; also, that a section of four blocks could be removed in about 10 minutes. At Swansea the pitch-pine balks on which the blocks rested were framed together in sections carrying four cast-iron blocks; each frame was about 13 feet long. A whole section, carrying four blocks, could be knocked down and put out of the way by tackles or shores *en bloc*, and that had been found very advantageous. The nominal spacing of 3 feet 3 inches from centre to centre of blocks permitted of the blocks being doubled in Mr Gedye.

Figs. 7.



places where exceptional loads had to be carried, such as near the

Mr. Gedye. stern-post. He could confirm what Mr. Moncrieff had said about the great disadvantage of having any part of the bearings of the blocks standing above the floor. That had become important recently at certain ports where the Platers' Union insisted on extra pay, ranging from 25 to 50 per cent., when the space underneath any part of the ship where the men were working was less than 4 feet 6 inches. The blocks at Swansea had never given any difficulty in regard to rusting up. The faces were machined, and he did not think they were greased, beyond the ordinary shop greasing when assembled; and there had been no difficulty in knocking them down. The old-fashioned method was to cut away the soft-wood capping with mallet and chisel, which often took hours for a single block. He thought many speakers had hardly realized the fact which must have undoubtedly influenced very largely the minds of the Southampton dock-authorities in selecting a floating dock for the situation; they had been faced, he believed, with the necessity of providing very much increased accommodation in a short time, and they thought, and were justified in thinking, that a floating dock of that capacity could be provided in about 12 months, whereas no advocate of dry-dock construction would have guaranteed a similar masonry and concrete dock under 3 years. That, he thought, had been one of the main factors which had led to the decision. It appeared that the berth in which the floating dock was moored, dredged as it was to a depth of about 45 feet below the level of the surrounding channel-bed, and situated in an embayment clear of the river-channel, was very liable to silting. It would be of interest if Mr. Wentworth-Sheilds could state whether any appreciable silting had taken place since the dredging was completed more than a year ago. The berth in the river Tyne, prepared for the Admiralty floating dock early in the war, was in some ways, but not altogether, an analogous case. That dock was moored in Jarrow Slake, where a berth was dredged for it considerably deeper than the normal dredged depth in the river-channel, and forming a deep pit in the banks which constituted the Slake. Contrary to all expectations, the berth did not silt up to any appreciable extent in the 5 years during which the floating dock remained in position. That freedom from silting might have been due to the scouring effect of the rise and fall of the dock, as suggested by Mr. Savile, but Mr. Gedye thought that it might also have been due in part to the fact that the berth adjoined the main channel of the river at a point where there was considerable tidal flow, the scour of which might have been effective in keeping the berth free from silt. In connection with the dredging of the

Southampton berth, Mr. Wentworth-Sheilds mentioned veins of hard sandstone rock which were broken up and lifted by the dredger-buckets. It would be interesting to know what were the average and maximum thicknesses of those veins. Mr. Gedye.

Dr. SALMON, in reply, thanked the members for the very kind way in which they had received his Paper, and in particular Sir Archibald Denny, for his kind reference to the work of his firm. Sir Archibald had referred to the great preponderance of graving-docks in Great Britain and the much larger proportion of floating docks on the Continent—and, Dr. Salmon might add, in America. No doubt, particularly in years gone by, the physical characteristics of the site had been the determining factors, but the skill of the civil engineer was such that in most cases either type of dock could be installed; and it was singular that such diametrically opposed views on the question should be taken on the two sides of the North Sea. In this country there was a considerable body of opinion which still appeared to regard the floating dock as a make-shift, to be adopted when a graving-dock could not be installed. If the user of a floating dock, however, were asked what he thought about the question, he would say that he was convinced that it was a far more convenient and handy appliance than the graving-dock, being quicker and less expensive. He himself thought that neither of those views was the unadulterated truth. On the one hand, in view of the work which the floating dock was accomplishing all over the world, he really thought the time had gone by when it should be referred to as a makeshift. On the other hand, the graving-dock certainly possessed some undeniable advantages. He thought Mr. Moncrieff's view was quite right, that for long and heavy repairs the graving-dock was the better; but for light repairs, scraping, painting, and examination, the floating dock was more efficient. Sir Archibald Denny's remark regarding light and air around the ship in a floating dock was another point in its favour. He thought, in fact, that an up-to-date ship-repairing establishment of any magnitude should have both a graving-dock for the heavy repairs and one or more floating docks for the lighter repairs, because there was far more scraping and painting done than heavy repairs. Both classes of work could be done in either dock with equal success, but he thought that was the main differentiation between the two types. Mr. Palmer had commented on the fact that, although the contract time for delivery was 10 months, 21 months elapsed before the dock was ready. Dr. Salmon thought the significant fact was that a firm of the standing of Messrs. Sir W. G. Armstrong, Whitworth and Company were prepared to enter into a contract to supply Dr. Salmon.

Dr. Salmon. a floating dock of that magnitude in 10 months. He did not think it could be shown that a floating dock was more liable either to strikes or to accidents than was any other kind of dock. In reply to Mr. Palmer's other point, the upper stages were removable, and therefore there was plenty of room for self-docking. He proposed to leave the question of cost to Mr. Wentworth-Sheilds, who, he hoped, would see his way to give the figures; he did not think they would be quite so high as some of the speakers anticipated. He doubted if it were possible to build a graving-dock of a size equal to that of the Southampton floating dock for the £500,000 suggested by Mr. Cruttwell. Mr. Wilson, it would be noted, had suggested that the cost would be twice as much. But, as Sir Cyril Kirkpatrick had remarked, it was not merely a question of first cost, but also of maintenance and running-costs. Several speakers had suggested that, whereas the cost of maintenance in a graving-dock was small, it would be very large in a floating dock. That was not the case. He had some figures of maintenance-costs for seven floating docks, over a period of 7 years in the case of the shortest example, and 24 years in the case of the longest example. The average cost of maintenance worked out at 1·2 per cent. per annum of the original first cost, the highest being 1·5 per cent. per annum and the lowest 0·64 per cent. per annum. In confirmation of that he quoted[1] a statement by Mr. Edward Box, M. Inst. C.E.: "From actual practice he found that 1·6 per cent. was an ample allowance, including re-dredging every 5 years." The site to which Mr. Box referred silted up 1 foot per annum, and the cost of re-dredging worked out at 0·3 per cent. per annum. It was too early to say how the Southampton dock would compare with those figures, but he thought they were sufficient to show that the cost of maintenance was quite small. In the experience of his firm, silt had not been found to be such a terrible bugbear as would appear from the remarks made in the discussion. At the worst, the quantity of silt under the dock at Southampton could be determined by a diver, and when it had to be removed the proposal was to move the dock. That would be quite a simple operation, and preparations had been made for the purpose. With regard to the loss of revenue, he imagined the authorities at Southampton would choose a slack time for re-dredging when that became necessary. As to running-costs, he did not think it was generally realized that the power consumed in a graving-dock was very much greater than in a floating dock.

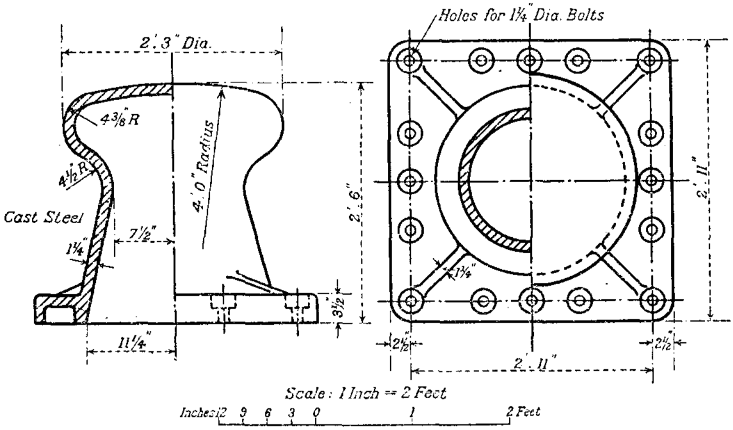
[1] L. E. Clark, M. Inst. C.E., "Floating Docks." Minutes of Proceedings Inst. C.E., vol. clxi, p. 74.

Particulars of the machinery of the Esquimalt graving-dock had recently been published.[1] The profile of that dock was practically identical with that of the Southampton dock, but the former was a little longer. The total horse-power of the main pumps at Esquimalt was almost exactly double that of the Southampton floating dock. There were in addition two auxiliary pumps, each of which was larger than one of the main pumps in the Southampton dock. No time of pumping was mentioned, so that the total power-consumption could not be compared; but he had made a calculation of the relative quantity of water pumped, and to make the comparison fair he had shortened the Esquimalt dock to 960 feet. He found that to dock the "Majestic" in the Southampton dock and to re-raise the dock, 123,160 tons of water had to be pumped. To dock the "Majestic" at Esquimalt and re-empty the dock 276,400 tons of water must be pumped. Thus the water which must be pumped from the graving-dock was two and a quarter times that pumped from the floating dock. In a floating dock there was no leakage-pump, and after the dock was lifted no more power was required, whereas a leakage-pump had to be kept constantly running in a graving-dock, at considerable cost of power. He suggested that those two items should be taken into account in any comparison between the two types. With regard to keel-blocks, like Mr. Wilson, he had usually adopted oak for the keel-blocks of large docks; but in Mr. Wentworth-Sheilds he had found an enthusiastic advocate of elm as the better wood for the purpose, and so far as they went the experiments supported that opinion. Sir Cyril Kirkpatrick had raised an interesting point regarding the distribution of pressure on the blocks. It was estimated that with a vessel of 60,000 tons displacement, bearing over the middle 750 feet of the dock, the pressure on the end blocks would rise to 106 tons per linear foot. He was sceptical of the suggestion that the distribution of pressure could be ascertained by measuring the crush of the keel-blocks. A long time was spent some years ago in measuring the crush of keel-blocks in both graving- and floating docks, and in attempting to interpret the observations by means of experiments in the testing-machine. The experiments gave exceedingly interesting results, but the difficulties of the case were such that, quantitatively, the results were quite unreliable. The cast-steel wedges had been introduced with the idea of driving them out when a block had to be removed. He did not think there was any idea of setting up the blocks by means of the wedges. He Dr. Salmon.

[1] *Engineering*, vol. cxix (1925), p. 99.

Dr. Salmon agreed that it was at least doubtful if wedges were of any value at all. His firm had built a dock in which plain timbers were used, not wedges, and there was a great deal to be said for that. Underneath the top block was a splitting-out layer, 3 inches thick, composed of short pieces placed so that the shipwrights could easily get at them. He thought Mr. Moncrieff was quite right in saying that separate blocks would be better—the longitudinal timbers were rather inconvenient. He also agreed with Mr. Gedye that it would have been better to make these timbers in short lengths, but considering the very heavy loads that had to be carried, it had been thought wise to make them continuous. The design adopted was the result of a compromise. He was glad to learn

Figs. 8.



from Mr. Gedye that somebody was able to knock wedges out, as it was the first time he had had definite information on that point. He suggested that the blocks Mr. Gedye spoke of were at a much greater angle than those at Southampton, and that that was why cotter-pins were necessary. The Southampton dock had been specially built to take large liners; but the question of taking two small ships had been considered, and certain arrangements were made for the purpose. Of course, it would not be a very convenient dock in which to lift small vessels, and he thought it would be used chiefly for the larger ships. The electric travelling cranes lifted 2 tons at the maximum radius of 80 feet and 5 tons at a smaller radius, which was the usual practice so far as cranes on dock-walls were concerned. Heavier weights would be dealt with by the floating crane. The maximum push of each side-shore was

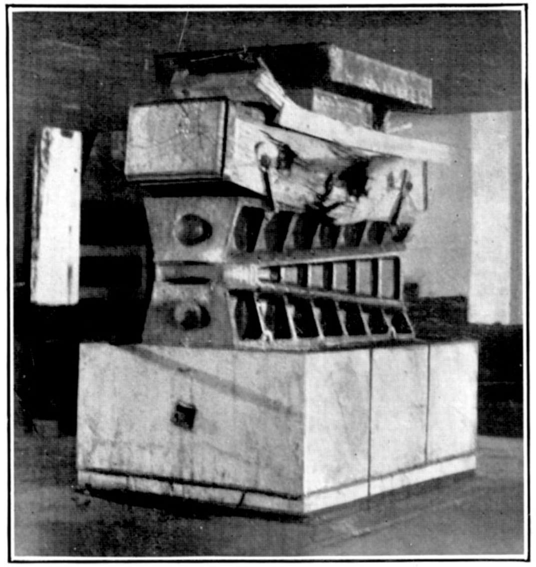
10 tons, or 40 tons total pressure on the side of the ship. That was equivalent to four capstans or four tugs. Ships like the "Olympic" were not docked unless the wind was very light. When a ship had a list, or was a great deal down by the stern, the dock could be laid over until it fitted the angle of the ship: that was one of the advantages of a floating dock. The shores were not used to upright the ship. *Figs. 8* showed the bollards used on the floating dock; the design had been adapted from that of the bollards used at Southampton. He wished to express his appreciation of the way in which Mr. Wentworth-Sheilds had dealt with the questions arising in connection with his part of the work. The design of the dolphins was both novel and very efficient, and the solution given to the problem of the mooring-chains was new and decidedly ingenious. He thought both Mr. Wentworth-Sheilds and Mr. Beare were to be congratulated on the result of their work. Dr. Salmon.

Mr. Wentworth-Sheilds, in reply, thanked the members for their cordial reception of his Paper. He regretted that he was not in a position to give the total cost of the dock, but it might be of interest to mention that before the war the relative costs of a floating dock and a masonry dock for Southampton were carefully gone into, and it was found that, taking into consideration interest on capital, depreciation, and maintenance costs, there was little to choose between the two types. Under those circumstances he had been an advocate for a masonry dock. After the war, however, the circumstances were very different. The cost of construction had then risen for both types, but to a far greater extent for masonry docks than for floating docks. This was largely due to the fact that wages in the building trades had increased very much more than in the shipbuilding trades, and also to some extent to the fact that improvements in the design of floating docks (for which improvements credit was largely due to Dr. Salmon's firm) had reduced the weight of this type of dock as compared with that of the vessel it had to lift. Consequently the floating dock now appeared to be clearly the cheaper structure of the two; and being also quicker to construct, it had been adopted. It must not, however, be supposed that a floating dock would everywhere be cheaper than a masonry dock. The water-bearing soils of Southampton were unfavourable for foundation work, and a masonry dock cost considerably more there than it would at some other ports. It had been asked how the extent of silting under the dock could be ascertained. It would, of course, have been possible to provide a number of vertical tubes in the floor pontoons through which soundings could have been taken, but these would seem to Mr Wentworth-Sheilds

Mr. Went-worth-Sheilds. be unnecessary. The highest silt level under the dock would probably be around the sides, and, if not, it would be easy at any time to ascertain the level of the silt by sinking the dock until it touched the mud. As Mr. Savile had pointed out, the rate of silting would probably decrease as the mud-level rose, but no doubt a time would come when the dock would have to be removed and the site cleaned up. This, however, need not be a very lengthy operation with proper plant. Mr. Gedye had asked what was the average and maximum size of the veins of stone encountered when dredging. As far as it was possible to tell, the maximum depth of stone was about 3 feet, but fortunately the dredger was sufficiently powerful to break it into lumps, which were brought up by the buckets. Mr. Wilson had suggested that the difficulty in sinking piles with the water-jet might have been got over by providing one, or four, instead of three jets. Probably a more effective method would have been to place the jets about 2 feet up the piles, so that the sand at the point of the shoe should not be blown away. Mr. Mitchell Moncrieff's observations on the cracking of reinforced-concrete piles were interesting and important, but experience at Southampton had been similar to that recorded by Mr. Savile, namely, that no deterioration occurred below mean-tide level. There seemed, therefore, to be no objection to using reinforced-concrete piles for dolphins such as these, in spite of the fact that no doubt they contained hair cracks. The superstructure of the dolphins had been purposely made of timber, as at these levels timber suffered less than reinforced concrete. In reply to Mr. Deane, it was intended to cover the surface of the cap-blocks with tar, or some such protective coating, although no serious deterioration was feared at that level. No special experiments had been made to ascertain the allowable tension on the dolphin piles, but in view of past experience of drawing such piles it seemed very safe to allow 5 tons. The concrete mooring-blocks were 10 feet by 10 feet at the base and 10 feet by 3 feet at the top, and 9 feet deep, the pressure face being sloped. Some endeavour had been made to ascertain their resistance to horizontal pull by calculation, but the problem of the safe pull on anchors was undoubtedly one which called for further investigation. As compared with the usual type of ship's anchor they were probably very safe.

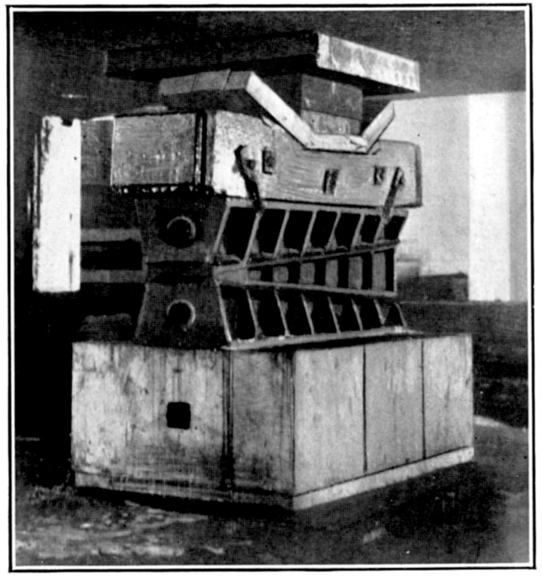
Figs. 1 and 2 illustrating Dr. Salmon's Remarks.

Fig. 1.



OAK BLOCK.

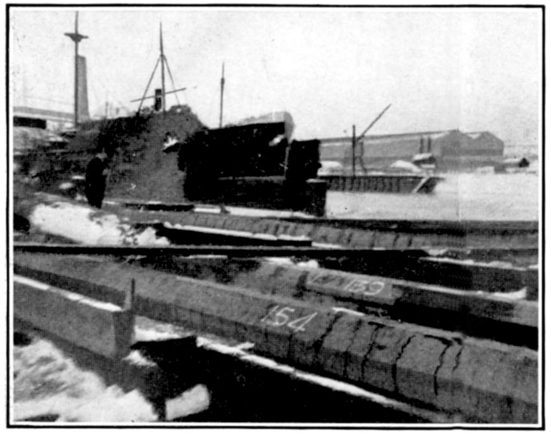
Fig. 2.



ELM BLOCK.

Figs. 3-6, illustrating Mr. J. Mitchell Moncrieff's Remarks.

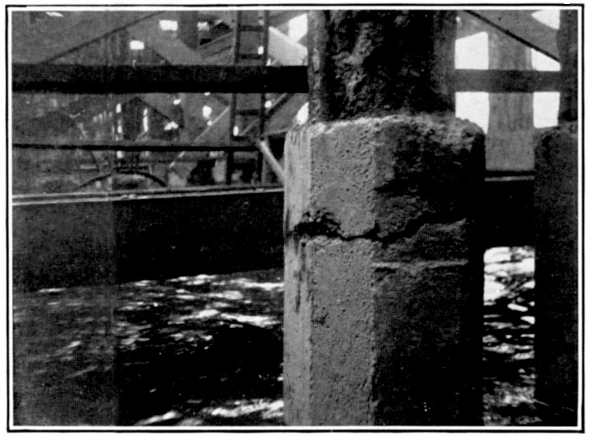
Fig. 3.



PILE No. 154. PILE No. 139,
drawn 2nd Feb., 1912.

REINFORCEMENT: Four bars 1 inch dia., four bars $\frac{7}{8}$ inch dia., Spiral $\frac{5}{16}$ inch dia.
CEMENT: British Standard.
AGE WHEN DRIVEN: No. 154, 7 weeks; No. 139, 8 weeks } Sept.—Dec., 1911.
No. 139 was about 27 feet 6 inches into ground.
No. 154 was about 15 feet into ground. Driving was not completed as so many distinct cracks were visible.
The marks on these piles are water stains issuing from very fine knife-edge cracks.

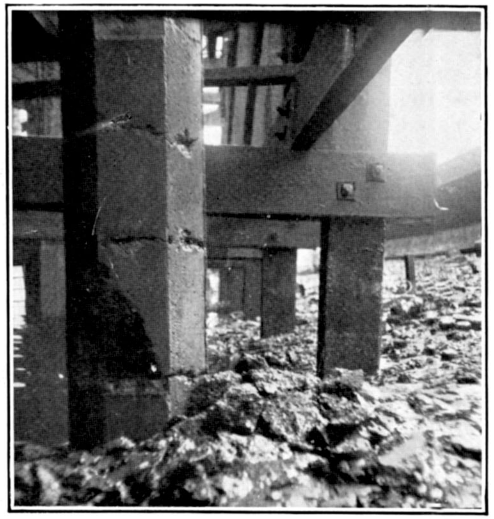
Fig. 4.



CRACK IN PILE No. 88,
about $1\frac{1}{2}$ inch deep.

REINFORCEMENT Eight bars 1 inch dia. Spiral $\frac{5}{16}$ inch dia.
CEMENT: British Standard.
AGE: 26 weeks (Aug., 1911, to Feb., 1912).
HARDEST SET: $1\frac{1}{2}$ inch in thirty blows.
FINAL SET: 3 inches in thirty blows.

Fig. 5.



PILE No. 161,
showing cracks and concrete broken off to spiral near bottom.

REINFORCEMENT: Four bars $1\frac{1}{4}$ inch dia., four bars $\frac{7}{8}$ inch dia. Spiral $\frac{5}{16}$ inch dia.
CEMENT: British Standard.
AGE: 14 weeks (Oct., 1911—Jan., 1912).
HARDEST DRIVING: $\frac{3}{8}$ inch in 30 blows, 42 cwts. ram, 2-foot 6-inch drop.
Driving stopped owing to bad cracks.

Fig. 6.

CRACKED PILES Nos. 155 AND 156.

REINFORCEMENT: Four bars $1\frac{1}{4}$ inch dia., four bars $\frac{7}{8}$ inch dia., Spiral $\frac{5}{16}$ inch dia.
CEMENT British Standard.
AGE: 13 weeks (Oct., 1911—Jan., 1912).
HARDEST DRIVING: No. 155: $\frac{1}{2}$ inch in twenty blows, 37 cwts. ram, 3-foot fall.
No. 156: $\frac{3}{4}$ inch in twenty blows, 37 cwts. ram, 4-foot fall.