

The Author. mixture to prevent the water from getting through without passing through the concrete cube. Upper covers were fixed, with a pressure inlet, and the bottom was left open. Blocks were tested both with the brackish water from the dock and with fresh water from the Metropolitan Water Board's mains. There was no observable difference in the percolation or in the rate at which the percolation decreased. On the underside of the blocks, as the percolation proceeded, small stalactites were formed, and these, on analysis, were found to be sodium carbonate (Na_2CO_3 , H_2O). It appeared probable that this was the substance which caused the closing of the pores. Typical percolation diagrams for 4-to-1 concrete and for 6-to-1 concrete were shown in *Figs. 17* and *18* (pp. 406 and 407) to the same scale as the 8-to-1 diagram given in the Paper (p. 391). A comparison had been made between the safe load on the ballast (5 tons per square foot) and the breaking strength in compression of 8-to-1 concrete (103 tons per square foot). Notwithstanding the great improvement in the quality of cement in recent years, the Author would not advocate the use of a weaker mixture than 8-to-1 for works of this class.

Correspondence.

Mr. Buckton. Mr. E. J. BUCKTON remarked that the Paper placed on record, in a clear and concise form, very useful data for the dock- and harbour-engineer. It was difficult to see how the site available could have been used to better advantage. The jetties, although not new in principle, were novel in their extensive application. This method of working ships by cranes on jetties had been in use in isolated cases for many years, and with certain classes of shipping it had proved a success. The result of its adoption on such a large scale would be watched with interest. In the work described, it had been possible to construct a lighter section of quay-wall behind the jetties, thus effecting a considerable saving in the cost of the wall, as a set-off against the cost of the jetties. The ballast formation was good enough to permit of a safe slope of 1 in 5; but, of course, in some materials such a slope would not be possible. It might prove cheaper and better in certain formations to build a deep-water quay-wall along the outer face-line of the jetties, with gaps forming entrances to comparatively shallow barge-areas surrounded by lighter quay-walls. That would permit of the easy filling-in of any of the barge-areas at a later date, should

changes in shipping methods make it desirable. As usual, bores had been made and trial holes sunk, but nothing was said of any tests of the bearing-pressure of the ground. In this particular case, the foundations being in ballast or chalk, it might have been considered that there was already sufficient local knowledge, and that tests were unnecessary. If, however, tests had been made, it would be instructive to know how they had been carried out and what the results were. No particulars were given of the loads for which the quay-walls were designed, but both the north and south quay-walls appeared to have an excess of concrete at all the steps, or, alternatively, the horizontal sections of the walls at the dock-bottom were too weak. Although an appreciable batter was a disadvantage in working shipping, a slight batter could usually be adopted without causing inconvenience, and, in general, was to be preferred to a vertical face. On any ordinary foundation some movement, however slight, must take place in dock-walls, first due to the general compression of the ground during the construction of the walls, and later due to the compression at the toe caused by the thrust of the filling and surcharge behind the walls. The former was more or less uniform, and usually resulted in a vertical settlement, which was taken up in the construction of the walls; but the latter tended to tilt the walls forward and occurred when a wall was nearly or entirely completed. It was better to have walls with variations in batter than walls leaning forward. Every care seemed to have been taken in the design of the entrance lock and the dry dock. Keeping the sills of the entrance all at one level, although it added to the initial cost, was certainly a great advantage to the dock-maintenance engineer over the usual practice of building the inner sill at a higher level than the outer sill, since the gates were not then interchangeable. Most of the wrought fittings were galvanized. It would be interesting to have evidence of the necessity for galvanizing, when fittings were submerged and never exposed to the air. Two features of interest were the spring spear-post and scrapers of the lock-gates. The Author's opinion as to whether those were likely to prove a success would be welcome. The dry dock was exceptionally well equipped. It was not usually economical, as regarded initial cost or maintenance, to build a very long dry dock to allow for possible future developments in ship-design. The building of a relatively light arched end wall, with the side walls slightly extended to allow of easy lengthening of the dock at a later date, was a wise provision. The general design of the buildings on the north side of the dock was well adapted for dock-buildings, but it was doubtful if the use of the underslung cranes on the first

Mr. Buckton

Mr. Buckton. floor would prove to be the best way of handling goods. The transit-sheds on the south side of the dock appeared to have insufficient headroom to take full advantage of modern stacking-machinery. It was to be regretted that such fine, long, straight quays should have been provided with two lines of rail. If the quays were to be used for railway work at all, three lines were necessary for the efficient handling of the wagons. It was difficult to see, from Fig. 2, Plate 7, how the rails on the south side of the dock could be worked properly.

Dr. Cuning-
ham.

Dr. BRYSSON CUNNINGHAM desired to express his appreciation of the Paper. He asked whether it would be possible to amplify somewhat the simple statement of cost. Despite the fact that the war had interfered materially with the standard of prices for comparative purposes, such information was always serviceable as a general guide, *mutatis mutandis*, and he would suggest that the approximate costs, respectively, of (1) the lock, (2) the dry dock, and (3) the wet dock proper, would enable engineers to form some idea of the financial allocation of the whole outlay. The presence of suitable gravel on the site had enabled a considerable saving to be effected in the cost of the concrete work. In the construction of the south West-India dock, Millwall, where a similar bed of gravel was in evidence, the cost of the concrete was as low as 12s. 6d. per cubic yard; it would be interesting to know the unit cost of the concrete at the King George V Dock. The dock was a notable undertaking, and not the least interesting feature of the design was the system of jetties on the south side. Perhaps the Author would state how far the arrangement had proved suitable for the conditions it was intended to meet, and whether the quantity of goods deposited directly into barges bore a sufficiently high ratio to that deposited primarily on the quay for sorting (before loading into barges) to justify the special provision made for that method of working. Also, he noted that the width between the jetty and the quay, 32 feet, was considerably more than was requisite to admit a single barge, while it was inadequate to admit two barges of usual width side by side. What was the explanation of that? The quay cranes were of several types, and a comparison of their working-efficiency or, at any rate, a statement of their merits under similar conditions, would be instructive. Was the disposition of six cranes per jetty a satisfactory arrangement, and, if so, in what proportion were the cranes allocated to the hatchways of vessels at the berths? Assuming, say, four holds to be working simultaneously, there would be an excess of quay cranes available per berth, unless two cranes were worked at a single hold, in which case the number would be

insufficient. To what extent did the use of ships' appliances supersede the employment of the cranes? The subject of cargo-handling was complex, and it was not altogether easy to put questions which, without causing a good deal of trouble in reply, would enable some general idea to be formed of the precise conditions under which the berths were worked, and the suitability of the arrangement to meet those conditions. The Author might, perhaps, in a few words, give his experiences of the method of dealing with traffic conditions at the new dock. The construction of the dock was a notable achievement, and the solidity and finish of the work was such as to command general admiration. At one time he had been a whole-hearted advocate of strength and durability; but of late years, in view of the transitory character of most enterprises of the kind, and their rapid obsolescence, he could not help feeling that it was possible to execute such works too solidly. He had recently had an opportunity of inspecting piers and jetties of quite light construction at American ports, some of them piled structures of a very flexible character, which accommodated ships of tonnage equal to that of any vessel which entered an English port. The accommodation was obviously provided at far less outlay, and the important consideration was that it served its purpose. Moreover, the future renewal of such structures, called for by rapid developments in the size of vessels, did not entail so heavy an expenditure as would be the case if it became a question of demolishing half a million cubic yards of concrete and a quarter of a million cubic feet of solid granite. A number of years ago he had some experience in the carrying out of a scheme of dock-improvements at the port of Liverpool, which involved cutting through a series of obsolete graving-docks; and the time, labour, and outlay involved in merely destructive operations had greatly impressed him. The question, therefore, was one which should receive the careful consideration of dock-engineers; and, while he did not by any means intend to imply that it had not received every consideration in the present instance, the reflection inevitably obtruded itself during a perusal of the Paper.

Dr. Cunningham.

Mr. F. W. DUCKHAM considered that the Paper formed an excellent and well-balanced record, which should be useful for future reference. Procedure had been smooth and had followed the programme except for interruption by the war. Thus there had been no failures such as might point the way to improvements. From his point of view, as agent for construction during the first 6 years, there were a few matters which might be amplified. It was not quite correct that electric power had not been used for cranes. Two jib cranes for

Mr. Duckham.

Mr. Duckham. excavation, specially built by Messrs. Booth with electric drive, showed considerable saving in working-costs, in comparison with an otherwise identical pair driven by steam and used on the same work. The chief novelty in the contractors' plant was a pair of concreting machines of a universal character, built on the site at the instance of Sir Ernest Moir. Each was fitted with a large Ransome mixer, served by two winches, one of which excavated the ballast, and the other distributed the concrete by means of a Stoney skip. Those machines also were entirely electric and were most efficient in all respects. By improvements in constructional methods the whole of the open excavation had been done in the dry; the seven inside jetties had been modified in reinforced concrete with a great saving in cost; and the dry dock had been completed by a new method which saved much time and money. The broad and open-minded attitude of the Engineers to the Authority, in accepting such innovations at the instance of the contractors provided an exceptional instance of mutual efficiency.

Sir Cyril
Kirkpatrick.

Sir CYRIL KIRKPATRICK remarked that to him it was a matter of regret that, being in Sweden at the time, he had been unable to take part in the discussion upon the King George V Dock. He desired to make special reference to the great part taken by Mr. Palmer in the design and construction of the work. The dimensions of the dock and the design were his conception, and he was the responsible engineer for 6 out of the 9 years during which the work was in hand, Sir Cyril Kirkpatrick acting as second in command during that period and only taking full control from 1918. At that date the Authority made an amicable arrangement with the contractors to finish the work by departmental labour, owing to difficulties arising out of the war, which prevented the contractors from obtaining the necessary labour. The Author, as Resident Engineer throughout, had shown himself equally capable and resourceful in supervising the work carried out by the contractors and in carrying out the work departmentally.

In the execution of any great work experience was gained for future operations; and he proposed, therefore, to describe how certain difficulties had been surmounted. All who were responsible for executing work during the war realized that many unforeseen contingencies arose, and that unless adequate "priority" was obtained, progress could not be kept up. Thus all steel construction was brought to a standstill, and the lock-gates, having been put on one side for more urgent Government work, were not available when required. In 1918, however, the Government came to the conclusion that the new dry dock would be a great asset, and an

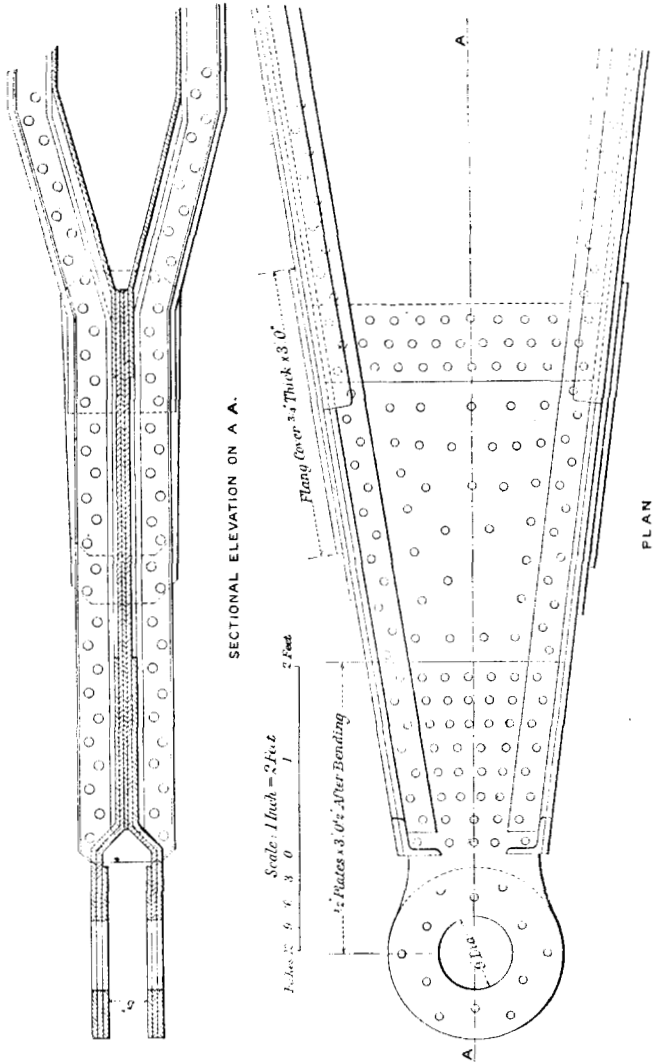
acceleration order was therefore given, with high "priority" for all the necessary steelwork. One of the conditions made was that the dry dock should be available for use at the earliest moment possible, before the entrance and lock-gates were ready to take shipping from the river. Vessels making use of the new dry dock would thus enter the Albert dock and pass to the new dry dock by means of the passage between the old and new docks. This course necessitated the immediate completion of the inner pair of lock-gates, and the use of them as a dam against the full head of water until the completion of the middle and outer gates enabled the lock to be flooded. That was a risk which the exigencies of the war rendered imperative, and, had not the armistice taken place, it would have been necessary to take very special precautions to prevent any vessel from accidentally fouling the dam. The armistice, however, took place in November, 1918, and the flooding of the dock was not commenced till January, 1920. It was thus possible to proceed slowly until the second pair of lock-gates were completed, and to step the water down in the inner lock-chamber, thus avoiding the use of a single pair of gates as a dam against the full head. In the flooding of the works in two cases some anxiety was caused. In the first instance a small temporary earthen dam formed of ballast in the lock-chamber, with a slope of $1\frac{1}{2}$ to 1 when dry, flattened out to a slope of 6 to 1 when wet. In the second instance the earth dam in the passage between the old and the new dock had to be fortified by making a toe of heavy rubble to prevent it from flattening out as the water was admitted to the new dock. A point of great interest arose in connection with the construction of the pumping-station for the dry dock (Fig. 5, Plate 7), the floor being fixed at a level of 22 feet 6 inches below dock water-level. In view of the fact that the motors were designed for a pressure of 6,600 volts, it was with some anxiety that the amount of moisture percolating through the walls was observed as the dock was flooded, and it was hoped that it would take up automatically in the course of a few weeks. All endeavours to dry the atmosphere by ventilating fans and heating failed to procure the desired condition, but the difficulty was finally conquered entirely by the building of a $4\frac{1}{2}$ -inch brick wall inside, with a cavity behind, 3 inches wide, drained into the sump. A difficulty arose, about 18 months after the opening of the dock, at the lock-gates, which required careful investigation. The design adopted for connecting the crocodile lever was shown in *Figs. 19* (p. 414). It was understood that the late Sir John Wolfe Barry had laid down that gates for an 80-foot entrance should take $1\frac{1}{2}$ minute to operate. Tests showed that the King George V

Sir Cyril
Kirkpatrick.

Sir Cyril
Kirkpatrick.

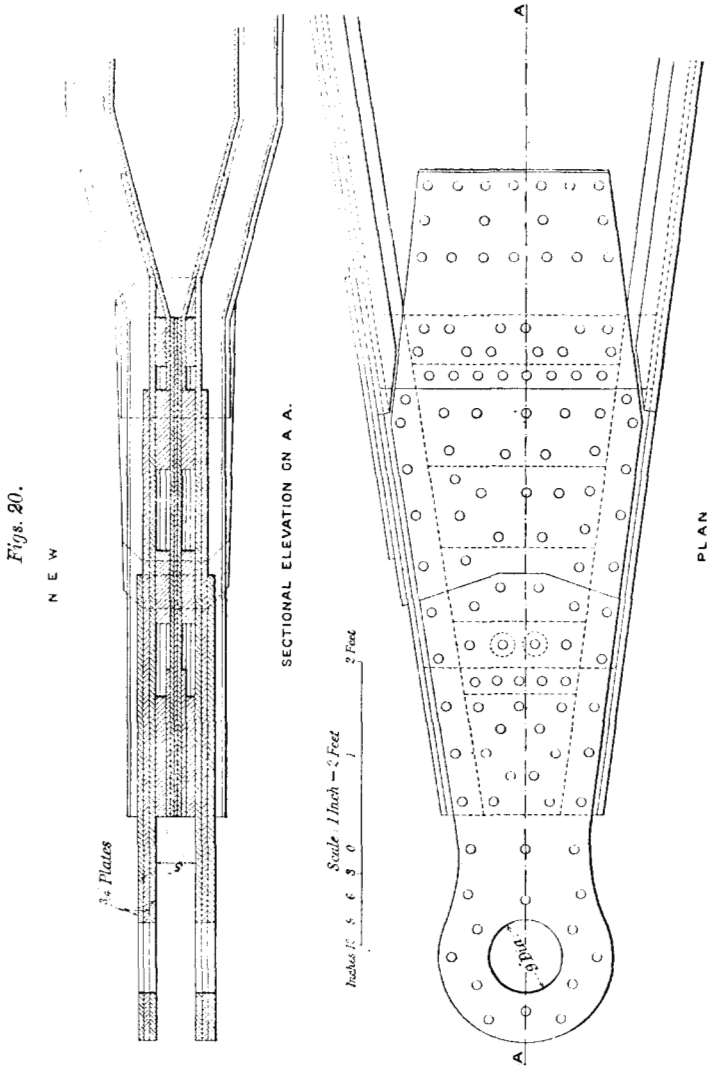
gates for a 100-foot entrance were operated in a minimum time of 1 minute 12 seconds. It was clear, however, that that high speed

Figs. 19.



was not the cause of trouble. In the course of a few months several of the opening levers developed either a fracture or a crack at the cranked plate near the heel-post. Investigations showed clearly

that the cranked plate was most undesirable, and strengthening had therefore been effected, as shown in *Figs. 20.* Sir Cyril Kirkpatrick.



The single-storey sheds on the south side of the dock were built on concrete piles about 37 feet long. The material driven through was 15 feet of newly-tipped excavation from the dock, including

Sir Cyril
Kirkpatrick.

the upper 8 feet of ballast, 18 feet of peat and clay, and 4 feet into solid ballast. The framework of the sheds was erected in December, 1915, and the level of the columns on the piles was duly checked, but nothing more was done to them until the Government acceleration order enabled progress to be made in August, 1918. It was therefore a surprise, when work was recommenced, to find that the piles had sunk by 1 to 4 inches in the period; and the only possible conclusion was that the settlement of the newly-excavated material had forced the piles downwards. He desired to add his testimony to the able manner in which the work had been carried out by the contractors and the excellence of the plant used by them.

Mr. Reid.

Mr. H. CARTWRIGHT REID remarked that the Author described very succinctly works which might be considered one of the finest commercial dock-projects of modern times. The Port of London Authority was to be congratulated on making such an important addition to the premier port of the world. From the autumn of 1918, when facilities were given by the Government for completing the work, to the 21st February, 1921, when he accompanied the first vessel into the new dock, it had been his duty to make periodical visits to the works. To those familiar with the progress of large engineering works during that critical time it would be well known that the difficulties had placed a great strain upon the engineers in charge; and the Author and those associated with him might well feel proud of completing that great work in a satisfactory manner. He had found little to criticize and much to admire in the way the work was being done. When the progress of the work was almost suspended by the war, the Port Authorities had spent a large sum towards the construction of the works and had no immediate prospect of remuneration in the way of additional port-dues to meet the cost of interest during construction. Had they postponed the completion of the work until war prices had ceased, they would probably have found then that the interest during construction equalled the extra cost of finishing the work; and though the new dock had been very expensive, due to these untoward circumstances, the Port Authority, with the primary object of additional port-facilities in view, had adopted the better course of pressing the completion of the works at the earliest possible date. The Author did not attempt to give the probable extra cost due to the war, but it was evident that that must be considerable. It would be interesting, however, if he could state the approximate value per berth of the fourteen berths which had been provided. Omitting the cost of the dock and other items which were to be deducted from the total cost, the value

per berth would, Mr. Reid presumed, be about £250,000. Only a **Mr. Reid.** premier port like London was likely to make sufficient profit from port- and landing-dues to pay the interest on so large a figure. Could the Author give any figures of the probable earnings of those berths, after deducting the expense of working them? The most striking feature of the design was the arrangement of the jetties on the south side of the dock. That bold attempt to meet the special condition prevailing in the Thames of a large proportion of unloading into barges would be watched with interest. If the Author could give an approximate idea of the relative values, per linear foot, of the berths on the south side compared with those on the north side, that information would be valuable. Were similar rates charged to ships for the berths on both sides, and had shipping firms had sufficient experience to indicate any preference for one type of berth? The water-level of the new dock, which had direct communication with the existing system of docks, was maintained at the same level of 2 feet 6 inches above Trinity high water. The maintenance of that high level, no doubt, simplified the locking arrangements and prevented any silting due to river-water entering the dock, but the cost of pumping must be considerable, in view of the large area of the dock and the dimensions of the lock. Figures showing the annual cost of pumping would be very instructive.

The **AUTHOR**, in reply, observed that he had noted with interest **The Author.** Mr. Buckton's suggested alternative for the jetties in the dock. It was doubtful, however, if the system proposed would effect any substantial saving in initial cost; and, although the Author did not regard the filling-in of the bargeways as a likely contingency, the bridging of the gap by a reinforced-concrete structure similar to the jetties would present no difficulty. No tests had been carried out to ascertain the bearing pressure on the ground at the formation-level of the quay-walls. The calculated intensity of pressure at the toe of the walls was 5 tons per square foot, and, the level of the foundations being in all cases in ballast or chalk, tests had been considered unnecessary. The quay-walls were designed to carry a surcharge of 3 tons per square yard. The vertical face was adopted for convenience in working shipping and simplicity in construction, and there had been no tilting forward. The spring spear-posts and scrapers of the lock-gates so far had proved satisfactory.

The underslung cranes on the first floor of the north quay-sheds were at present an unqualified success, being especially useful in stacking bales of wool and hogsheads of tobacco for storage purposes. The sheds on the south side of the dock were seldom used for storage

The Author. over long periods, and the necessity for using stacking-machinery did not frequently arise. Such piling as might be required was carried out by means of 15-cwt. runabout electric cranes, which could be easily worked in the sheds, and had proved adequate for the requirements. The two lines of rails had been installed as an additional facility in cases of emergency, and the double crossovers at the end of each shed had enabled the necessary traffic to be worked satisfactorily. Practically the whole of the rail traffic was dealt with at the rear of the sheds, where three lines of rails had been provided, with all the necessary crossovers and connections.

As stated by Dr. Cunningham, the war had interfered materially with the standard of prices for comparative purposes. It could not be stated, in respect of any particular section of the work, that the expenditure was wholly pre- or post-war. The cost covered a period when substantial variations in prices of labour and materials were of frequent occurrence. It was therefore practically impossible to reduce the costs to a pre-war basis. For this reason details were excluded from the Paper, and would, if given now, be more misleading than useful. Owing to the presence of suitable gravel on the site the cost of concrete had been very low. The prices had ranged, at pre-war rates, from 8s. 4d. per cubic yard for 8-to-1 mass work in the dock, and 9s. 9d. per cubic yard for 6-to-1 work in the lock, to 17s. 2d. per cubic yard for the 6-inch facing of 4-to-1 quality. The prices quoted included shuttering.

The experience gained in connection with the jetties in the dock had not been sufficient to enable complete and satisfactory data to be furnished with regard to their successful use. The working of ships' cargoes in the King George V Dock was entirely in the hands of the various shipping-companies. Naturally, practice varied considerably, not only as between the different companies, but in relation to the character of the cargoes. Evidence had been taken however, from more than one source, and it had been found that often upwards of 80 per cent. of a ship's cargo was removed by barge. No records were available as to the actual tonnage discharged direct into craft, but it might be borne in mind, in this connection, that the arrangement of the jetties provided additional facilities for loading into barge either direct or after sorting and marking on the quay, and it might be taken generally that there was a substantial saving in time in discharging a vessel at the south quay compared with the north quay. The width between the jetties and the south quay had been fixed at 32 feet to allow for possible development in the size of craft, and to bring the face of the jetties clear of the 5-to-1 slope at the dock-bottom. It had

been borne in mind, in fixing this dimension, that barges were then The Author. being designed 24 feet wide.

The quay cranes, although comprising several different types, were all fulfilling satisfactorily the requirements of the Port Authority, but no figures were available as to efficiency. The object of the disposition of the six quay cranes per jetty was to give the maximum facility possible without causing congestion. In practically every case the full complement of cranes was brought simultancously into use. Sometimes the cranes each worked at separate hatchways, and more generally they worked in two pairs, and two singly. For quayside working the cranes practically superseded the use of ships' appliances, these being used only for "overside" work into barges on the dock side of the ship.

The Author appreciated Dr. Cunningham's remarks as to the possible tendency to execute works of this character too solidly, and agreed that the question was one requiring careful attention. At the same time, and while he realized that the suggestion made was general and not specific in character, he deprecated the adoption of any lighter form of construction under conditions similar to those under consideration. In contrast to the American piers and jetties instanced, dock-walls not only functioned primarily as shipping-berths, but in the present instance they also formed a dam to retain water at a level approximately 10 feet above the surrounding industrial districts of North Woolwich and Silvertown.

As to the probable extra cost of the works due to the war, for reasons previously stated it was practically impossible to reduce the actual costs to a pre-war basis, but so far as could be calculated, the additional cost attributable to this cause was approximately £2,000,000. The value per berth of the fourteen berths provided, including roads, railways, sheds, cranes, and equipment, together with the whole charge of the entrance-lock and passage, was approximately £275,000. All these berths had been allocated to shipping-companies, and the direct earnings were by way of rent-charge calculated on an area basis. It was regretted that the amount of these charges and other earnings per berth could not be given. The approximate cost per linear foot of the south and north quay-walls, including trench-excavation, but excluding quay-paving, sheds, railways, etc., was £12 10s and £20 respectively, at pre-war rates. The jetties in the dock cost £40 per lineal foot at post-war rates, representing approximately twice pre-war values.

All the berths were allocated to shipping-companies before or soon after the opening of the dock. The question of preference

The Author. as between the north and south sides, based on general experience, had therefore not arisen. As already indicated, however, there was every reason to believe that the experiment of providing jetties to the southern berths had proved successful.

As suggested by Mr. Reid, the cost of pumping to maintain a water-level in the dock of 2 feet 6 inches above Trinity high water was considerable. The total area of water impounded in the King George V Dock and the Victoria and Albert Docks was 251 acres ; and the working-cost of pumping, exclusive of depreciation and interest on capital, was at present about £12,000 per annum.