Mr. Mitchell. was unfortunately true that the most difficult and costly portion of the dock-improvement scheme had been carried out without corresponding benefit from a commercial point of view, but so far the owners of the dock had not seen their way to proceed with the remainder of the work.

Correspondence.

Mr. Box. Mr. EDWARD BOX observed that the widening of docks and lock-entrances was much to the fore at the moment, owing to the increase in beam not only of warships but also of commercial vessels in general, which rendered many of the older docks in this country out of date. The remarks made by Admiral Earl Jellicoe, "that August, 1914, found us with a superiority in ships, but woefully lacking in dock accommodation," recalled to his mind how the late Mr. John Standfield, M. Inst. C.E., under whom he had gained his early experience, periodically pressed upon the Admiralty the necessity of adopting one or more floating docks which could be based wherever the fleet might require them: but apparently he failed at that time to make any impression on those responsible. A different view was taken later, and when war broke out in 1914 the Admiralty were fortunate to find themselves in possession of two such docks, one of which did good service on being transferred to the Tyne. In Admiralty works carried out under contract it was or had been usual to have an item included in "sea works" for exceptional risks. With private works it was more usual to supply contractors with the fullest possible information and to specify that before tendering they must satisfy themselves upon all points that might in any way influence their price and take the full responsibility for carrying out the work at the rates they quoted, with only a meagre possibility of being able to claim extras. Some contractors were willing to take the responsibility at competitive prices, speculating upon a favourable result on the principle that what they lost on one item they made up on another. Work could only be done to advantage departmentally when the necessary plant and facilities were available, or when the interference with business made it imperative. It would appear that the engineers were entitled to claim a considerable saving by the carrying-out of the work at Devonport departmentally. The foundations were favourable, which probably had been ascertainable from records and confirmed by borings. It was fortunate that the work had not been begun until 1925, as the years previous to that, more particularly 1919–1923, were very difficult, as regarded both materials and labour. The method of carrying out the works, so lucidly described by Mr. Jacob, appealed very much to Mr. Box. Much needless expenditure could be saved by utilizing the means available to the best advantage. At Ardrossan, towards the end of the war, he was interested, as consulting engineer, in the widening of the lock-entrance to the old wet dock and the reconstruction of a dry dock situated within the wet dock. The whole of the wet dock was pumped out in about a week, the cost of which was insignificant. For this purpose the dry-dock pumps were coupled to a pipe-line leading through the sea wall. After pumping out, the inner portion of the lock was widened to where a flap gate was placed, conveniently behind the existing gates. The flap gate having been installed, the outer gates were removed, and at the same time a partial tidal dam was placed across the outer entrance to the lock, and pumps were installed on the quay. The outer widening was done by trenching the new wall on the extended side of the lock. The old wall was then removed, in very much the same way as Mr. Jacob described. The water in the foremost part of the lock, enclosed by the partial dam, was rapidly pumped down during low tides, and the remainder of the old wall was demolished and repairs were made to the opposite wall. The outer dam was a framed structure with vertical sheet timbering along the front. The structure was completed on shore and launched, the sheet piling being driven down to suit the uneven and uncertain rock formation. Bags of clay were employed to fill the inside of the framed dam and were also deposted along the front. The dam was substantial enough to hold the water for about 3 hours at the lower tides, and the demolition was carried out accordingly. The flap gate, which then closed the dock and necessarily folded inwards, was efficiently shored against a full tide head and thus became the main dam. The reconstruction of the entrance to the wet dock was carried out in the dry, and the walls of the wet dock were repaired. As soon as the entrance to the dry dock was completed and the gate placed, the outer entrance to the lock being also completed, the shores holding the lock-gate and the outer coffer-dam were removed, and the wet dock was again flooded. As vessels were being built on berths outside the wet dock, the work had to be done against time to allow the vessels to be fitted out in the dock. As it was made possible to proceed with so much work concurrently, there was no doubt that much time and money were saved by the method adopted. He was interested to learn from

Mr. Box. Mr. Jacob's Paper that superfluous granite was being dispensed with in the works now being carried out by the Admiralty. He remembered how difficult it had been to get those primarily responsible to modify that and many other things to conform to commercial practice. Mention was made of blasting with a charge of $1\frac{1}{2}$ lb. Was that correct? He had used gelignite for similar purposes, usually $2\frac{1}{2}$ oz. Was he correct in assuming that administrative costs were not included in the items of cost given, in which case it was necessary to add a percentage for administration and contractor's profits for comparison? Excessive expenses of administration often caused the larger contracting firms to be undercut by the small but practical contractor.

The reconstruction of such works as dock- and lock-entrances—which was likely to be common in the near future—often demanded more ingenuity than the design and construction of more pretentious works when unhampered by foundations of previous structures. Many of the difficulties which had been experienced were due to the facts that the piling of the coffer-dam enclosing the works had not been driven far enough to control efficiently the head of water to be shut off, and tidal "working" of the dam had given rise to a combination of forces which ultimately brought about its destruction. The difficulty, invariably met with when approaching the bed of a river, of preventing deflection of the piles when driven to a desired depth, often through stony and variable strata, had no doubt accounted for many failures. In that respect interlocking steel sheet piling was of considerable assistance. Another factor in the stability of coffer-dams was weight, and the pitching of ballast behind a coffer-dam was often the saving factor in maintaining its stability. Where back staying was resorted to it was often possible to support the dam from the existing works and then transfer the support to the reconstructed works, as had been done in the case described in Mr. Mitchell's Paper. That, of course, involved much shifting and refitting of the strutting and did not lend itself to dock-entrances where ordinary mitre gates had to be erected in place. A gate which could be built clear of the site and floated into place after the sill works were completed was of great assistance in saving time. When the coffer-dam was constructed to enclose the entrance to the dock at Hebburn the adoption of the flap gate was not contemplated; consequently the coffer-dam had not been designed to give facilities for floating such a gate into place. Taking all the conditions as they existed, he had recommended the method adopted for putting the gate into place as being the only one feasible. The depth of water available between the inside of the coffer-dam and

Mr. Box.

the dock-sill prohibited any method of ballasting which would have increased the draught required for tipping the gate. The alternative of lifting the gate into place by a floating crane would have been more expensive than the method adopted, which had been followed without the slightest hitch. That was the first gate of this design to be so placed. The first gate to be constructed on the flap principle, as advocated by him, was for Messrs. Clover, Clayton & Company, Ltd. (now Messrs. Grayson, Rollo & Clover Docks, Ltd.), for the extension of their No. 1 dock at Birkenhead. The width of entrance was 76 feet, and the depth on the sill 22 feet, the weight of the gate being 82 tons. The lower part of the gate could be anchored back to the sill, so that a 7-foot head of water could be impounded. By that means the local deposit of mud, caused by the abrupt setting forward of the quay-wall within a few feet of the dock-entrance, had been scoured away by the opening of four sluice-valves in the gate. That gate when lowered sank partly below the foreshore. Previously the dock had been closed by a floating caisson, and it had been necessary to dig away the mud at low water. A second gate of similar dimensions had been built for their No. 6 dock, and a third dock had been completely reconstructed, and fitted with a flap gate. Those works were carried out during 1916–1918 under the exceptional difficulties of the period. The setting of the sill under tidal conditions caused some anxiety. The sills were surprisingly true, with one exception, but any error in alignment was allowed for by the carpenter, who worked to a diagram carefully prepared to levels, showing the errors at each joint in the cast-iron sill, and the fitting was adjusted accordingly and found to be entirely satisfactory. The gates were delivered in sections, put together and completed on the quay alongside the docks, lifted by a floating crane, and lowered into place at about high water. They had not been lifted out of their place since then, a little truing of a side timber in one or two cases being all that was required. Those gates were not designed to be self-floating. Two of them were worked by means of ordinary multiple block-and-fall tackle, operated by hydraulic bollards at the head of the docks, which were also used for warping vessels. The third gate was operated by single-power horizontal rams with multiple rope gear, the return of the rams being effected by a balance-weight. Those gates were not recessed under projecting copings, as was done in the case of all later gates. It had been intended to apply hydraulic jets to move any object that might get deposited in the groins on each side. The general opinion of those who were to be responsible for operating the gates was that the jets were not necessary, which, he

Mr. Box. believed, had proved to be the case, and therefore they had not been adopted. Pneumatic jets had, however, for precaution, been adopted in the case of some of the later gates, as described by Mr. Mitchell. His design of flap gate had next been adopted by the Ardrossan Dry Dock and Shipbuilding Company, on the Clyde, in connection with the works of extension he had previously described. The conditions under which those gates worked were entirely different from those on the Mersey. A dry dock, closed by a flap gate, was entered from the old wet dock, and was therefore non-tidal. The old wet dock was shallow; hence the gate when down sank into a recess in the floor of the lock from which it displaced the water and any deposit which might accumulate. A second gate closed the entrance to the lock. There had once been three pairs of gates to the lock, the outer pair being storm gates. Only two pairs were in use when he first saw the docks. The lock was widened during 1917–1918. The lock of the wet dock had only 18 feet of water on the sill. As the dock was to be used solely as a fitting-out dock, it was not deemed necessary to adopt more than one gate, which had to retain the water in the dock and act as a storm gate as well. It was retained against storms by two heavy portable shores fixed one on each side and having a slight dip towards the gate. A recess was provided in the floor of the lock for the gate to sink into. He did not in general advocate one gate for a lock-entrance; the conditions in that case were exceptional; but he knew of no practical reason why such gates should not sink into a recess in the floor of a lock in the manner described, which had been entirely satisfactory. Those gates were operated by electric winches. A similar gate had been adopted for a new dry dock at Bangkok. It was desired to operate that gate from one side of the dock only, and he had therefore fixed one end of a single operating-rope on shore and passed the rope round double sheaves at right angles to one another and attached at the upper corners of the gate. The rope passed across the front of the gate and was operated by a single capstan fixed on one side of the dock-entrance. Messrs. Smith's Dock Company, Ltd., had adopted his design of flap gate on the Tyne in 1922, operated by electric winches, and a second one had been built in 1925. That gate was worked by a system of vertical hydraulic presses, exactly similar to those adopted at Hebburn. Since the application of the flap gate to the dock at Hebburn, a gate of similar design, but worked by electric winches, had been adopted by Messrs. Mountstuart Dry Docks, Ltd., at Cardiff, for lengthening and widening their No. 2 dock. The advantages gained there were very exceptional, since, without any structural extension, and by the adoption of a flap gate at the extreme entrance and the removal of the original double system of gates, the dock had been lengthened by 25 feet; and the cutting away of the intervening masonry between the double entrance-gates had increased the width of the entrance from 52 feet to 62 feet. The Antwerp Engineering Company were adopting his design of flap gate for closing two dry docks at Hoboken. The entrance to the larger of the two docks was 85 feet wide and would have a depth of water of 26 feet on the sill. The dock would have a length of 680 feet, and was the largest dock to which his design of gate had been applied. The weight of the gate was 146 tons. The side blocks were without caps; hence there would be no under-water connections. In that case the mud deposit was abnormal; there was 15 feet on the banks above the dock sill-level, the dock frontage being set back from the river fairway. The pumps would discharge through the sill, in order to deal with the abnormal conditions. That had not been necessary in the case of any of the previous applications of the gate, which, under more normal conditions, freed itself from silt. The pumps could be started as the gate was being lowered, so that when the gate took the rests the force of the full discharge of the pumps, about 260 tons per minute, would be retained on the sill by the gate acting as a cover. A sliding caisson was sometimes preferred to a pair of gates on account of the absence of clapping-timbers. This advantage could be secured with the flap gate merely by sliding the gate in its groove a matter of 12 to 18 inches, so that the side facing timbers of the gate and those of the dock were not directly opposite to one another; when the gate was being lifted, secondary short lengths of facing timbers would be provided well above high-water level to act as stops when the gate was lifted. The gate would be moved laterally by fixed hydraulic rams. This system would provide a gate without direct closing faces below water, retaining in addition the advantages of the present flap gate. In applying the flap gate to very large docks, a secondary system for equalizing the balance by the introduction of graduated balance-weights would be an advantage. **Mr. Box.**

Mr. G. E. Howorth observed that Mr. Mitchell's Paper described work in the carrying-out of which there must have been many practical difficulties and anxieties. The usefulness of the drawings would be enhanced by the inclusion of the information shown by the trial borings mentioned in the Paper. A cross section showing typical trench timbering and some indication regarding the points of the compass would be of interest. The cutting of gaps through quay-walls to enable sheet piling to be driven continuously through **Mr. Howorth.**

Mr. Howorth. them was, as the Author stated, a tedious operation. Eight slots such as the Author described had been cut through quay-walls at the London docks in 1912 to permit of the driving of the steel-pile return ends of four coffer-dams. The depth of water, which was not subject to tidal variation, was 35 feet above the old foundation-level. The old walls were built of brick with stone string courses, quoins, etc., and had a curved batter on both the face and back of 6 or 7 feet. The lower courses were consequently bedded at a considerable angle. There was a single row of timber sheet piling under the old toe, and the wall was founded on a timber platform. It was found possible in those cases to cut the slots in one operation. An ordinary Ingersoll-Rand steam-driven percussion drill having a fairly long stroke was used. The steels were about $1\frac{1}{2}$ inch in diameter, and the starters had a cross-bit head about 6 inches in diameter. The whole machine was mounted on a heavy steel horizontal bar about 5 inches in diameter and long enough to extend over the whole length of the slot to be cut. The machine was traversed along this bar, which with its legs formed a four-legged trestle, by means of a long rack and pinion. By a constant traversing motion the drilling was successfully done in the form of a slot. The timber foundations either split under the steel pile during driving or were dealt with as described in the Paper by a heavy steel slice. There was a tendency when using the long drill steels for the bottom surface of the slot to become hog-backed, but this could always be remedied by careful traversing with a slow vertical feed. The only difficulty was in clearing the debris from the slot. It was generally necessary to clear the slot by side raking from the open edge, and occasionally in the lower parts a diver had to be employed for this work. A pile-extractor gear which had been found very useful on the same works consisted of a pile-frame from the head of which the extractor was hung by a six-fold purchase. One end of the purchase wire was taken to the winch, and from the other an ordinary monkey of a weight corresponding to the capacity of the winch was suspended at the back of the leaders. That rig had the advantage of keeping the winch alive and at the same time keeping a powerful steady pull on the pile. It was particularly useful when the pile-frame was worked on land or on a staging where without it the pull would have been very dead. The Author claimed for the type of dock-gate used that, among other advantages over the double-leaf type, it afforded considerable increase in the effective length of the dock. When in its open position the gate as erected projected considerably beyond the entrance bull-noses, and its upper surface in that position was only about 9 feet below L.W.O.S.T. The present dredged level appeared to be about 18 feet below L.W.O.S.T., and the "future dredging level" (Figs. 1, Plate 2) about 25 feet below L.W.O.S.T. What protection was afforded to the gate when in that position? Mr. Howorth.

A point of very considerable interest in the design for the new south wall of the Devonport basin-entrance was the bonding of the new wall to the old foundation wall of the sluices. The new wall had no earth-pressure to carry, but unless a perfectly close bond existed between the new and the old work there was a distinct possibility that water-pressure might develop on parts of that surface. Regarded merely as a gravity wall, the new wall was obviously not thick enough to carry water-pressure, over the whole of its back surface, corresponding to the difference in head between maximum impounded level in the dock and L.W.O.S.T. in the tideway. It would be interesting to know whether the 2-inch steel tie-rods shown in Figs. 3, Plate 1, were relied on to prevent the possibility of water-pressure or whether they were intended in effect to increase the thickness of the new wall as a gravity wall by adding the whole or a portion of the weight of the old work. There was always the possibility in such a situation that corrosion would occur between the new and the old work and impair the utility of the bonding-rods. It was almost impossible to make any joint between new and old concrete work perfectly watertight. The Author's reference to the manner in which the old concrete was blown off in the 4-foot lifts in which it had been originally deposited, in spite of a rendering with $\frac{1}{2}$ inch of neat cement, seemed to imply that he regarded the cement rendering as having considerable adhesive properties. Surely the function of the neat-cement rendering so often specified between new and old work, or work which was already set, was to ensure intimate contact between two perfectly sound surfaces and to obviate loose, unsound, porous patches which might easily be overlooked in beginning to place any new section of concrete. In drilling shot-holes of fairly large diameter, such as the $5\frac{1}{2}$-inch starting-holes described by the Author, it was often difficult to ensure an upward velocity of water adequate to support the particles in suspension. The Author's experimental use of a compressed-air jet in the top of the water-pipe was interesting. It would no doubt have given still better results if it had been possible to introduce the compressed air at the bottom of the pipe, in which case, by lowering the specific gravity of the rising column of water only, on the principle of an air-lift pump, it would have increased still further the flow or the lifting-capacity of the water.

Mr. Stanier. Mr. D. D. Stanier remarked that he was particularly interested in Mr. Mitchell's Paper as he had been engaged in 1913 as resident engineer on the extension of the head of the same dock. The Author was to be congratulated on his detailed and lucid description of some very interesting operations. It was mentioned that the portion of the dock which failed was founded on silt and the remainder on boulder clay. That statement required qualification. The extension at the head and a considerable portion of the dock-floor and walls was founded on water-bearing sand and fine gravel, and it was very improbable that the boulder clay would be met with at any point except at a considerable depth below the dock-bottom. During excavation of the trenches for the dock-head, the water-level stood approximately at half-tide level. When the graving-dock was dry, water found its way through cracks in the floor. Small trial-holes drilled through the floor passed water carrying sand and small particles of gravel. It seemed probable, therefore, that the cracks in the entrance-walls, etc., described by the Author were due rather to the egress of silt from underneath the structure than to the gradual squeezing out of water, a process somewhat difficult to understand. The silt might have escaped naturally into the dredged channel of the deep waterway of the river, or through cracks in the floor of the dock. Perhaps the Author would say if cracks existed in the floor of the dock, and if silt had been observed passing through those cracks when the dock was dry. Had the piles on which the new entrance was built been creosoted or treated in any way ? Why had timber piles been employed instead of concrete ? It would appear that the single piles might with advantage have been of concrete, constructed in situ similarly to "Vibro" piles. Was the sheet piling tongued and grooved ? The Author's description of the very difficult operation of dressing the horizontal heel-post raised the question of the design of the heel-post and hollow quoin. As shown in Figs. 7, Plate 2, the hollow quoin undercut the clapping-posts. The initial task of making those portions of the faces watertight must have been difficult ; and it was possible that watertightness might not be maintained at those points. Should an accident occur necessitating either a new gate or extensive repairs to the existing one, it would be necessary to refit the meeting faces. Could that operation be performed satisfactorily without a coffer-dam ? It would be interesting to know if a permanent reference template had been made with a view to provide against this contingency. The template, taken on a vertical section through the clapping-post and hollow quoin, could be constructed of a non-corrosive metal. It would have been a simple matter to dress the timbers and secure a prefectly watertight gate if both horizontal and vertical timbers had been faced in one plane and the hinge formed by independent pintles set in adjustable seatings. A gate designed on those lines would be easy to refit after an accident without a coffer-dam. It would be interesting to know if such a design had been contemplated. In his experience of the tidal waters of the Tyne and other rivers, steel castings totally submerged in dock-entrances were more durable than cast iron. It would be interesting to know exactly what were the reasons which had led to the employment of cast iron for the hollow quoin in preference to other materials. Mr. Stanier.

Mr. Jacob. Mr. Jacob, in reply, observed that Mr. Box referred to Admiralty works let by contract and stated that it was, or used to be, usual to have an item included in "sea works" for exceptional risks, and he compared that with private works. It was not known which contracts Mr. Box had in mind, but no such item appeared now in Admiralty contracts, nor had done for many years, so that private and Admiralty practice were similar in throwing full responsibility on contractors and in covering all risks by the rates. The quantity of gelignite used for the removal of the old concrete wall in the dry was about 2 oz. per charge, as stated on p. 91, but it was found that to produce the required effect below water, charges up to $1\frac{1}{2}$ lb. were necessary. Mr. Box was correct in assuming that no administrative costs were included in the cost given, and he was referred to further data on that question given in reply to the oral discussion.

The possibility of water-pressure between the new and the old work in the south wall had been considered in preparing the design, and the reinforcing-bars shown had been inserted to provide against that contingency and to combine the new and the old work so as to provide, in effect, a gravity wall. He considered that, as the $\frac{1}{2}$-inch water-pipe used for washing out the holes was carried down alongside the drill steel to the bottom of the hole, the effect of inserting a compressed-air jet in the top of this pipe was virtually the same as if it had been arranged for at the bottom of the hole.

Mr. Mitchell. Mr. Mitchell, in reply, remarked, with reference to the protection of the dock-gate while in its open position, that the gate would only be open while vessels were being docked or undocked. Such vessels would necessarily draw somewhat less than the depth of water on the dock-sill, while the upper surface of the gate, when open, was slightly below the sill-level. Through an oversight, the compass-bearings had been omitted from Figs. 1; the dock-entrance faced approximately due north. The "future dredging-level" shown in Figs. 1, Plate 2, was a provision for the handling of vessels using the quays and mooring-buoys adjacent to the dock-entrance. There was nothing mysterious about the compression of a bed of silt by the weight of a mass of masonry, acting over a period of half a century. A kindred process was exemplified on a

Mr. Mitchell. large scale by the shale rocks which had resulted from silt subjected to severe and long-continued pressure, accompanied by a large diminution of volume. There had been several cracks in the dock-floor, and a number of boreholes had been made through it. Water that flowed up through all of them was free from any trace of silt. Timber piles were cheaper than concrete piles, and quite as suitable for the particular purpose. In view of the network of timbering, they possessed advantages, from the driving point of view, over any form of concrete pile. Nothing was to be gained by creosoting timber which was to be entirely buried under water-level. The sheet-piling was not tongued and grooved, but there was reason for believing that it formed an efficient cut-off. The cutting of the grooves, where the heel-post of the dock-gate crossed the 12-inch width of the fixed clapping-posts, had been comparatively simple, as it had been done after the hollow quoin was fixed in place. The machined surface of the quoin formed an excellent guide for the 3-foot straight-edges that were used. There had been no special difficulty in making those portions of the meeting faces watertight, and there did not appear to be reason to apprehend any trouble in the maintenance of that condition. The undercutting of the clapping-posts, together with the curving-over of the hollow quoin, beyond the horizontal plane through the axis of the heel-post, formed a check against the lifting of the gate, especially at the beginning of the closing operation. Should it be necessary to renew the heel-post or clapping-sills of the gate, or to fit a new gate, it could be done from the working-drawings more satisfactorily than from a template, which in any case could not be relied on to keep its shape over a period of, say, 10 years. Watertightness was a relative term, but experience had shown that, with reasonable precautions, the leakage was likely to be small. Any extra leakage between the new and the old meeting faces would, of course, mean additional work for the drainage-pump, but this would probably be very much more than counterbalanced by the cost of a coffer-dam. Further, in the one case the dock would be ready for use as soon as the gate had been put in place, while in the other, the coffer-dam would have to be removed before vessels could be docked. It would be possible, of course, to design a gate with plane meeting faces throughout, and carried on a pintle-bearing at each end. That, however, would be distinctly inferior to a gate supported throughout its length, while the bearings would be costly. The reasons for adopting cast iron as the material for the hollow quoin had been dealt with in the reply to the discussion. It was likely to have a life as long as the useful life of the dock, and therefore any slightly greater durability which cast steel might have would be immaterial.