Discussion.

The Author. The AUTHOR, in introducing his Paper, exhibited a number of lantern-slides of dredging plant.

The President. The PRESIDENT, in moving the vote of thanks to the Author, remarked that he had not only dealt with a most interesting subject, but had presented a Paper that would be extremely useful both for discussion and for reference. He himself was particularly interested in it because he knew all the ports and harbours that the Author had mentioned. He had worked in the construction of some of them, and was therefore glad to hear of their subsequent history. The engineer and the contractor often left some troubles to be dealt with by the maintenance staff!

Mr. Wentworth-Sheilds. Mr. F. E. WENTWORTH-SHEILDS remarked that in *Fig. 16* (p. 445) the Author showed that the costs of the dredging for which he was responsible had been reduced since 1929 from 4·7*d.* per cubic yard to 2·5*d.* per cubic yard. Such a reduction indicated remarkable improvements in the organization.

On p. 441 the Author stated the total output in tons; that revived a question which had often been discussed, namely, was it possible to adopt a standard unit for dredging? Dredged material could be measured in cubic yards in situ or in barge, and also in tons, and it would be most convenient if one method could be standardized. He had to admit, however, that on the Southern Railway it had not been found possible to adopt one method only. At a port such as Folkestone, where there was sand, it was very difficult to take soundings and to measure in situ, because the site was exposed and because the changes in the level were very rapid. It was, however, comparatively easy to measure sand in barges, because the sand settled down quickly, the measurement obtained corresponding fairly well with the original measurement in the ground. At a port such as Southampton, on the other hand, where a very soft mud had to be dealt with, measurement in barge was most unsatisfactory. Such mud was colloidal, weighed only about 1·0 ton per cubic yard, and in its original state contained about three-quarters of its bulk of water. When that mud was dredged and filled into a barge it did not displace the water which was already in the barge but mixed with it; the resulting mixture, although perhaps only about 5 to 10 per cent. lighter than the original mud, was very much more bulky. Moreover, the increase in bulk varied considerably. Generally speaking, it was found that 1 cubic yard of mud in situ became about 1·6 cubic yard in the barge. Hence, if the cost of the dredging were found to be 4*d*. per cubic yard in barge, the real cost per cubic yard in situ would be about 7*d*. On the other hand, it was comparatively easy to measure soft mud in situ ; soundings could be taken both before and after dredging and the results computed with fair accuracy, provided that the work were carefully done by an experienced surveyor. For the reasons which he had stated, the Southern Railway Company adopted the cubic yard in situ for measuring materials such as soft mud, and the cubic yard in barge for hard materials such as sand. They had abolished measurement by tonnage, as it seemed to have very little value for ordinary purposes. **Mr. Wentworth-Sheilds.**

The Author had stated that the Great Western Railway employed bucket-ladder dredgers for the bulk of its work ; the Southern Railway employed similar machines for most of its work, and he thought that on the whole they were the most useful type, as they were most adaptable and could give very large outputs. An interesting attempt had, however, been made 2 years ago to try to cheapen the dredging at Southampton, where it was very expensive because the barges had to be taken over 25 miles before they could dump their load. He had thought that the mud might possibly be removed more cheaply by stirring it up and allowing it to be washed away, but investigation had proved him to have been wrong. That investigation had, however, given very interesting information. The velocities of the currents, the salinity of the water, the rate of silting per annum, the silt-content of the water and the nature of the silt had all been studied. The latter investigation had been especially interesting, and had been carried out by Dr. Bernard Dyer, F.R.S., an agricultural chemist. He had found that the silt was very fine, 70 per cent. of the particles being less than 0·01 millimetre in size. Although it was sticky, being apparently a kind of very soft clay, it was not really a clay, as 70 per cent. of it was silica and only 5 per cent. was alumina. It also contained 10 per cent. of chalk, presumably because the rivers which flowed into Southampton Water passed largely through chalk country. The most interesting discovery had been that, though when shaken up in distilled water that fine mud settled very slowly (so slowly that after standing for 3 weeks in a glass jar there was still a very large proportion of the mud left in suspension), when it had been shaken up in salt water and allowed to stand the whole of the mud had settled within ½ hour. That showed clearly that it was useless to stir up the mud in a dock where the currents were small, as it would settle again in a very short time. His Company had therefore abandoned the idea of removing mud by that means.

Mr. Wilson.

Mr. M. F.-G. Wilson observed that the Author had referred at some length to the accumulation of material at an obstacle projecting from the foreshore, and had mentioned Madras and other places where there had been a good deal of deposit. He had not, however, referred to the erosion on the lee side of the obstruction, which was often much more harmful than the deposit on the weather side. At Madras there had been a great deal of trouble on the lee side of the harbour, where the beach had all travelled to the north, the material from the south, which should have replenished it, having been cut off by the projection of the breakwaters forming the harbour. Much damage had been done, and it had cost a great deal of money to build up the foreshore. Similarly, at Dover the Admiralty Pier had trapped all the material coming from the westward, and the preservation of the beach facing the town, by means of groynes and other works, had been very expensive. At Brighton the beach in front of the town was retained by groynes, but to the eastward it was disappearing, and costly works were now being built in order to protect the cliffs. It would be seen, therefore, that accumulation caused by a projection was not the only resulting problem to be dealt with.

He agreed that it was very difficult for an engineer to foresee the exact effects of interference with tidal currents. The Author had referred to the Mersey bar, and implied that it had been formed by the material brought down by the river. The river Irwell, however, which fed the upper estuary, was very small, and it did not bring down very much silt. The bar consisted of material brought up from the south by the littoral drift, with the result that in 1890, when the bar had first been cut through, it filled up again as fast as it had been dredged, owing to the northward travel of the beach, which accounted for the very large amount of dredging that had been required, as referred to in the Paper. It appeared, however, to be diminishing, and there was now less dredging at the bar than there used to be.

With regard to the Bristol Channel ports, the Author referred to the silt which was brought down by the rivers. He did not think, however, that the silting in the ports was chiefly due to silt being, at the present time, brought down by them. On the Bristol Channel foreshore there were many miles of mud flats, being accumulations of mud which had been brought down during thousands of years; the first wash of the flood tide stirred up that mud, which was then carried by the tidal currents into the neighbourhood of the various docks, where it was deposited at slack water, causing the trouble and inconvenience referred to in the Paper.

Mr. Gedye.

Mr. N. G. GEDYE desired to call attention to two matters upon which there might legitimately be a difference of opinion. On p. 424, referring to the beach accumulation at Dungeness, the Author mentioned that pebbles from Budleigh Salterton, near Exmouth, as well as Cornish pebbles, had been picked up there, and on p. 425 he suggested that the Dungeness deposit consisted of "sea-borne material from the more westerly littorals of Devonshire and Cornwall." Under existing geological conditions, however, the principal source of supply of the Dungeness shingle was flint derived from the cliffs between Dungeness and Beachy Head. Relatively little came from further west than Beachy Head, and he doubted whether any was derived from west of the Isle of Wight. The late Mr. W. H. Wheeler had been of opinion that the pebbles of remote origin, for instance, those from Cornwall and Devon, found at Dungeness, might have been derived from ballast contained in vessels formerly wrecked in the locality.[1] A list of the "foreign" pebbles found at Dungeness was given in a report of 1895.[2]

On p. 432 the Author, in enumerating the available methods of maintaining waterways, included the "physical removal by dredging or sluicing" of accumulations of sand and shingle, and again at the end of p. 433 he stated that under favourable conditions channels could, at least in part, be cleared by sluicing with impounded water released at or about the time of low tides. He would like to ask the Author whether he could name any harbour where sluicing was now employed with success on any important scale, excepting purely local sluicing to remove accumulations at dock-entrances and in the neighbourhood of dock-gates. The only instance mentioned by the Author where sluicing was employed, except in that very limited manner, was at Port Talbot, which seemed to be a very special case with limited effect, and the Author himself pointed out that the lowering of the dock water-level due to the discharge of sluicing water had to be balanced by pumping in channel water; under such circumstances the expedient could hardly be regarded as economical.

In former times many of the ports on the coasts of Northern France and Belgium, including Calais, Ostend, Boulogne and Dunkirk, as well as similar ports elsewhere, had been provided with large sluicing-basins, but all of them had now disappeared or were disused.

[1] W. H. Wheeler, "The Sea Coast," p. 200. London, 1902.

[2] "The Rate of Erosion of the Sea Coasts of England and Wales, and the Influence of the Artificial Abstraction of Shingle or other material in that Action." Fourth Report of a Committee of the British Association, p. 352. London, 1895.

Mr. Gedye. The tide had been allowed to flow into those basins in order to augment the natural tidal scour. The water had been shut in at high tide by gates or sluices, and had been released at low water, producing a strong current through the channel. The sluicing current, however, had rapidly lost its velocity in passing down the channel and had only been effective near the basin-outlet and down to a moderate depth below low water. The sand and silt removed by scour had been re-deposited to form a bar or shallow in some other part of the entrance or approach-channel. The President would no doubt recall that at Ostend a few months after the Armistice they had experimented with using the old sluicing-basin there, but had found that material which they removed from the channel had been immediately deposited in front of the one usable quay which had been available for shipping. The introduction of powerful mechanical dredging appliances had led to the abandonment of sluicing-basins, and it would, he suggested, be unfortunate if the Author's references to sluicing were to be read by others, only partly informed of the facts, as implying more than the Author intended.

The figures given on p. 437 relating to the Mersey Docks and Harbour Board's sand-pump dredgers seemed to him to contain a numerical error. The Author stated that one of the sand-pump dredgers "is capable of dealing with some 120,000 cubic yards a day of 10 hours, working in a depth of 70 feet." The largest suction-dredger now employed by the Board in dredging sand from the bar and channels was the *Leviathan*, built in 1909; that vessel had a hopper-capacity of 10,000 tons, and, he believed, filled her load in about 1 hour, but the effective dredging-capacity of the vessel per day of 10 hours could not possibly be as much as 120,000 cubic yards, or even 120,000 tons, for the time occupied in steaming to and from the place of deposit would be more than the actual dredging-time. The four sand-pump dredgers of most recent construction employed by the Mersey Docks and Harbour Board all had a hopper-capacity of 3,500 tons, and were wholly employed in removing sand from the bar and the sea and river channels. The latest of them, the *Hoyle*, built in 1935, lifted 3,500 tons of sand in 50 minutes and had a maximum dredging depth of 70 feet. It should be noted that the average distance travelled by the Mersey suction-dredgers between dredging-positions and the place of deposit at sea was about 7 nautical miles. He quoted these figures from authoritative data supplied to him last year by the Board's Engineer. In connexion with the Author's statement on p. 428 that 9 million tons had been dredged in 1934 from the Mersey bar and channels, he would remark that that figure had been in former years largely exceeded, the quantity of material removed having sometimes amounted to about 20 million tons in a year. As a result of the training works begun in 1908 and of intensive dredging, the depths in the Mersey approach channels had been increased over considerable areas, although the shallowest or governing depth on the site of the old bar, which in 1907 had been 26 feet at lowest low water, had been still only 27 feet in 1935. Mr. Gedye.

It would add to the value of the cost figures given by the Author on pp. 441 and 445 if he would state the amounts which should be added to the total and unit costs in respect of interest on capital, depreciation, renewals, and repairs not already included.

Mr. G. J. Griffiths, referring to sluicing as a means of removing silt, remarked that from his experience he would advise that, unless it was unavoidable, it should not even be contemplated; the remedy was often worse than the disease. The Author justified his own use of sluicing by saying that he only wanted to put the silt somewhere where he could get at it; but how much scour would be brought about? The scour was often more troublesome than the silting that it was intended to cure. Mr Griffiths.

The question of littoral drift was so important that the experience of harbour engineers as to the effects of their breakwaters was always of interest, and he hoped that such engineers would give further information regarding the success or otherwise of the breakwaters erected to safeguard the entrances to various harbours. The quality of the silt was also a very important factor in each case. Did the flood-tides or the ebb-tides carry the most matter in suspension, and how did those quantities compare with that brought down by a river in flood?

An interesting instance of littoral drift was the shingle bank opposite Totland bay. For years it had existed just east of the Needles, extending to Totland bay pier, but last winter it had disappeared; he believed that that had been caused by the gales of last winter, but further information about it would be of value. Referring to Dungeness, some protective works had recently been carried out at Rye, where groynes had been put up to check the littoral drift so as to maintain the harbour entrance; protective works had also been carried out to stop the tide getting through into what was becoming a bungalow town. It would be interesting to know whether the designs of the groynes and other works had proved effective or not.

With regard to the rivers Severn and Wye, during the War he had been in command of Nos. 1 and 2 shipyards at Chepstow, and

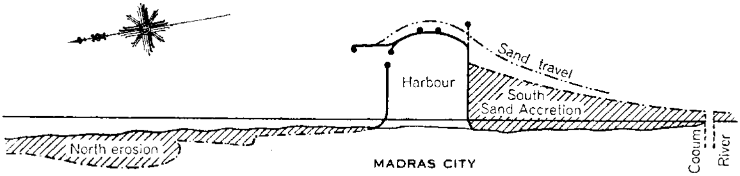
Mr. Griffiths. the suggestion had been put forward at one time that there should be a berthing wharf on the left bank of the Wye just at its junction with the Severn. However, it was hopeless to think of berthing ships there; so much matter was brought down by the Wye that a dredger would have to be kept there all the time. He believed the wharf had been constructed, but he doubted whether it had ever been used. The Mersey bar had been mentioned by the Author and by speakers. There was a similar bar on a much smaller scale across the entrance to the Manchester Ship Canal channel at Eastham locks; it was yet another instance of trouble arising at the junction of two streams, and it had not been found possible to prevent it. The experiment had been tried of sluicing the silt down from immediately below the entrance to the locks, but it had not proved effective and had had to be given up because the resulting scour had caused more trouble than the silt.

Mr. Buckton. Mr. E. J. BUCKTON observed that variations in waterways were infinite, and no two were alike, but they had certain similarities which could be traced and used to practical advantage; the Author gave eight types of such similarities on p. 426. *Fig. 7* showed an unusual case, but there had been a good example of it in Canada. In the estuary of the Nelson river in Hudson bay a solid jetty had been built running out from the shore to the deep channel. However, as the jetty had been built out so the ground had accumulated on each side of it, and very deep scour had taken place in front of it; it had finally had to be abandoned. After that failure an open pier structure had been built, ending in an island of cribwork with breakwaters to form a harbour in the estuary. The resulting conditions were as shown in *Fig. 8* of the Paper, where there was an open arm with a protective structure at the end of it. As a structure, it had been a success, but the scheme had been abandoned because it was uneconomic.

On p. 427, referring to Madras harbour, the Author stated that "siltation commenced even during the construction of the work, and has caused considerable trouble and expense ever since. Unlike Cearà harbour, that at Madras has been maintained by dredging." He did not think that was correct; very little dredging was done at Madras, and the total silting there, if no dredging were done, would be 1 inch per annum. Madras harbour had been built on a shore running north and south, with an entrance facing east. It had no sooner been built than littoral drift began to accumulate against the southern breakwater, and worked round towards the entrance. The coast a few miles to the northward had been eroded very badly, owing to the obstruction of the drift that would otherwise have replenished it. At first the harbour had not been a success, because the entrance had been entirely exposed to the waves, which always approached from directions between north-east and south-east. A new entrance had therefore been made on the northern side, the old entrance closed, and a protective arm added as shown in *Fig. 17*. Since then sand had begun to drift along the eastern side; to prevent that action a new arm had been added a few years ago, as shown dotted in *Fig. 17*. For the time being that had lessened the accumulation along the east side, but a stage had now been reached when the next step would have to be seriously considered. At present, therefore, Madras harbour was really kept open by the protective action of the breakwaters rather than by dredging. Mr. Buckton.

The secret of successful marine works was that the engineer ought to work with nature as far as possible. A recent case of the interception of littoral drift had occurred at the new harbour of Vizagapatam,

Fig. 17.



in India, and had been fully described.[1] Vizagapatam was on the same coast as Madras, but the problem there was being dealt with in a different manner. The harbour was inland; the approach-channel had been dredged, and it was partly maintained by the river-action and partly by dredging. There was a heavy northward littoral drift, of the order of 2,000,000 cubic yards per annum. That had been dealt with by sinking two ships and piling stones around them, thus forming an island breakwater under whose lee a dredger could work in a sand-trap. The problem was, what was to be done with the dredged material? It would be cheaper to send it out to sea and dump it, but actually the town of Vizagapatam was north of the channel, and would be endangered by erosion. It had therefore been decided that, to avoid incurring very heavy protective works outside the town, the proper method was to provide a sand-pump dredger and to pump across the channel to the northern shore,

[1] W. C. Ash and O. B. Rattenbury, "Vizagapatam Harbour." Journal Inst. C.E., vol. 1 (1935–36), p. 235. (December, 1935.)

Mr. Buckton. working with the natural process. Another interesting example of trying to work with nature was the maintenance of the port of Chittagong. The river Karnafuli had formed a sharp bend about 4 miles from its mouth, and in an ordinary river, such a bend would be expected to go on increasing in severity until a cut-off occurred. Actually, however, there was a very strong tidal action, and the ebb-tide tended to draw the current of the river by the shortest path—that was, by the convex side instead of the concave side. A training work had therefore been required on the convex side to stabilize the channel. The action of natural forces on waterways differed in every case, and every case had to be studied individually. The Author dealt with the Great Western Railway's ports in South Wales; they were all on the same tidal river and yet they differed greatly. Whilst some of the harbours and docks of the world were on tidal rivers, others were on oceans, inland seas, great lakes and non-tidal rivers, and the briefest summary of their conditions could fill a Paper in itself.

Mr. Du Plat-Taylor. Mr. F. M. G. Du-Plat-Taylor referred to the maintenance of the approach-channels to docks by the use of sea-going sand-pump dredgers. The outstanding instances of the use of those vessels had been at the ports of Liverpool and New York, and more recently at Bordeaux. All such vessels were self-propelling and self-loading, and were not adapted for loading independent hopper-barges. Almost the only loss of working time was that due to weather, so that the vessels had to be large and seaworthy, and the suction-pipes and connexions had to be designed for working in a considerable seaway.

The original dredgers on the Mersey bar, as well as the New York dredgers, had embodied a number of patents of the late Mr. A. G. Lyster, Past-President Inst. C.E., at that time Engineer-in-Chief of the Mersey Docks and Harbour Board. One of the first of those vessels, the *G. B. Crow*, had a hopper-capacity of 3,000 tons of sand and could load itself in 40 minutes. The suction-pipe was 45 inches in diameter; it was housed in a well amidships, and could work to a dredging-depth of 47 feet. The pipe sloped aft in the dredging position, but that had proved to be a mistake, as, in the event of the anchors dragging, the pipe-nozzle was forced into the ground and the pipe sometimes buckled or the joint at the top fractured. In later dredgers the pipe or pipes were fixed outside the hull and sloped forward. The hoppers were provided with hydraulically-operated cylindrical valves instead of hopper-doors. The load was often so solid that a man could walk about on it, and water had to be forced into the hoppers through special pipes to assist discharge. These dredgers could work in a beam sea, with waves of a height of about 5 feet from crest to trough, the pipe-joint allowing sufficient lateral movement, but in a head sea there was risk of buckling the pipe. The largest dredger in the Mersey, the *Leviathan*, had a capacity of 10,000 tons raised in 50 minutes, and was 465 feet 9 inches long between perpendiculars, 69 feet in beam, and 30 feet 7 inches deep. It had two suction-pipes fitted outside the hull and sloping forward. Those vessels maintained a channel 1,000 feet wide, originally to a low-water depth of 29 feet, but now to 30 feet. Before dredging had been begun the low-water depth over the bar was only 11 feet. In addition to the dredging, a submerged training-wall or revetment had been constructed to direct and confine the currents in the low-water channel. **Mr. Du-Plat-Taylor.**

At the entrance to the Port of Bordeaux a deep-water channel with a low-water depth of 36 feet and a width of 3,280 feet was being dredged through the bar of the Gironde by sand-pump dredgers. The weather conditions on that bar were very severe, as it was exposed to westerly and south-westerly gales from the Atlantic, and it was necessary to employ vessels which could work in heavy seas. With that object, flexible suction-pipes had been adopted, with ball-joints at the top and with three intermediate flexible joints of the Guilloux or of other types. The pipes were fitted outside the hull, the suction-nozzle being dragged astern while the vessel moved slowly ahead. The largest dredger, the *Pierre Lefort*, had a daily output of 30,000 cubic metres and a hopper-capacity of 3,132 tons. The vessel was 337·9 feet long, 54 feet in beam, and 19 feet in loaded draught, and dredged to a depth of 65 feet, being able to work in seas with waves of 11 feet 6 inches from trough to crest. It seemed probable that future deep-sea sand-pump dredgers would develop along those lines.

Mr. Chalmers. Mr. ROBERT CHALMERS hoped to elicit from the Author some further information as to the reasons for his statement, on p. 438, that trials of sand-pump dredgers "including those with the more efficient drag-suction dredgers, were not carried out, as it was not anticipated that they would result in any improvement in economic working." He himself had had some experience, under the President, of dealing with the material at Newport, Mon., in connexion with the later stages of the construction of the new lock-entrance. The local material had been dredged with bucket-ladder dredgers, and, at one stage, the contents of the barges had been pumped ashore with the idea of raising the level of certain low-lying areas around the docks. Those low-lying areas had formed a settling-pond; the surplus water, after leaving it, had passed through another

Mr. Chalmers. very large low-lying area, which had constituted a further settling-pond, and had then been discharged into the timber-float which was shown in *Fig. 10.* Those operations had had to be stopped because, in spite of the settling-ponds, the timber-float had silted up and had had to be dammed off, pumped out, and the silt excavated. Not only that, but the timber-float was, or had been, connected with the North Alexandra dock by a small canal in which was the intake of the power-station that supplied water under pressure to the hydraulic cranes around the quays; the dock management had complained that the silt in that water was spoiling the valves of the hydraulic cranes. He and his colleagues representing the contractor had been very sceptical, but the case had been so well established that they had had to pay for the damage caused. That was an illustration of the character of the material at Newport, Mon., and also, he submitted, of the waste and inefficiency involved in dealing with it by any method which would involve adding any more water to it than could possibly be helped. In 1922 he had been sent to dredge mud out of Dover harbour in the area between the Prince of Wales's pier and the Marine station, and had employed a bucket-ladder dredger, and hopper-barges of a capacity of 600 cubic yards each. He had started by loading those barges with 566 cubic yards each, barge measurement, which, as the bulking factor was 18½ per cent., was equivalent to 476 cubic yards in situ. When he had sent about 100,000 cubic yards to sea his soundings had told him that about 12,000 cubic yards had been redeposited on the area already dredged, and he had had to cut down the loads in the hoppers to 470 cubic yards, barge measurement, equivalent to 396 cubic yards in situ. That again showed that there was waste and inefficiency in processes which involved adding water to the material, and it was impossible to avoid doing that if a bucket-ladder dredger were employed. In contrast, he had seen a modern drag-suction hopper dredger fill its 1,200-cubic-yard hopper in less than 10 minutes with mud so thick that a spade would stand upright in it, and containing in fact only 15 per cent. added water as compared with its original condition on the bottom. The dredger had had to travel 1¾ mile to the dumping-ground and to return to start dredging again, but it had completed the whole cycle in 50 minutes, whereas his own hopper-barges at Dover had taken over an hour each to fill alone. He had estimated that the cost of the work he had seen done with the drag-suction hopper dredger was probably less than half the cost of the same work if done with a bucket-ladder dredger and hopper-barges.

*** Dr. BRYSSON CUNNINGHAM observed that the Author's remarks on the effects of the intrusion of structures into the sea from the shore-line deserved serious consideration by all harbour-engineers. Any disturbance of the normal regimen of a coast was bound to be attended by important consequences, in particular, the accumulation of material in positions where it might be detrimental to the maintenance of harbour-approaches and river-channels. There was another aspect of the matter, moreover, which should not be overlooked in that connexion, although in the Paper it was somewhat obscured by the main consideration. In describing the accretion which followed the construction of solid structures projecting from the shore in sandy localities, the Author did not specifically direct attention to the fact that accretion was generally much more pronounced on one side of the obstruction than the other, nor was mention made of the tendency of the littoral current to produce, on the leeward side of the obstruction, erosion which might have serious results. Without definite explanation, *Fig. 7* did not bring out that important fact; no doubt, the Author was considering his subject solely from the point of view of the removal of unwelcome accumulations. At the same time, the eddying effect of the littoral current could not be disregarded, and it was to be noted that it gained in intensity if the pier, or groyne, had a returned end or curved extremity.[1] Confirmatory evidence was forthcoming from experience in various places, notably from Madras harbour, which was mentioned in the Paper. Following the construction of the breakwaters, erosion had extended northwards for a length of several miles along the coast, and had had to be checked by means of stone revetments.[2] As another instance, he had been consulted about 2 years ago regarding the serious loss of sand from Montecito beach in Santa Barbara county, California, U.S.A., where by the construction at an outstanding point of a pair of groynes, 200 feet and 250 feet long respectively, the leeward coastal frontage, formerly a fine sandy beach eminently suitable for bathing, had been denuded of sand for a distance of about 500 yards from the groynes, the level of the beach being lowered several feet until checked by a harder stratum consisting of boulders and shingle. To the windward of the Dr. Cunningham.

*** This and the succeeding communications were submitted in writing.—SEC. INST. C.E.

[1] Brysson Cunningham, "Harbour Engineering" (3rd edition), pp. 33 and 34. London, 1928.

[2] Sir Francis Spring, "Coastal Sand-Travel near Madras Harbour." Minutes of Proceedings Inst. C.E., vol. cxciv (1912–13, Part IV), p. 153.

Dr. Cunningham.

groynes, a beach of sand had been built up. Accretion and erosion, in fact, were complementary phenomena, and both could be very troublesome to the harbour engineer. In the case of certain waterways, measures to counteract erosion were as necessary for their maintenance as measures in other places for the removal of excessive accretion.

At the beginning of his Paper, the Author seemed to stress the application of his remarks to tidal waters, as if tidal conditions were essentially associated with, or mainly responsible for, the processes he described. That, if a correct inference, was hardly the case. There was marked littoral drift and change of shore-contours along the coasts of practically tideless seas, for example in the Black Sea and the Gulf of Mexico, whilst flood-waters from the mountains of Central Europe encumbered with silt and detritus the mouths of Mediterranean rivers (where tides were also negligible), as illustrated by the deltas of the Po and the Rhône. The term "silting" appeared to be used in the Paper to cover both the deposit of silt, properly so called, and the transport of coastal material. The distinction was important, since silt, or mud, and fine sand were capable of being carried in suspension by water, whereas the heavier material, such as pebbles, shingle and gravel, did not float but was moved along the shore, being largely set in motion by wave-action. The accretion at Dungeness, for instance, was almost entirely of shingle, and could not be classified as silt, nor its deposition as "silting." Dr. Cunningham was hardly prepared to agree that bars at river mouths were due to "large quantities of alluvial matter eroded from the land" and brought down by rivers (p. 428). Indeed, the illustration of the Mersey bar in that connexion seemed a little unfortunate, since that bar consisted mainly of sand of varying degrees of coarseness, and not of alluvium or silt.[1] In his opinion, the origin of bars was to be sought chiefly in the travel of littoral drift, which was partially arrested when it came into contact with a transverse current issuing from the mouth of a river.[2]

The latter part of the Paper, dealing with dredging operations at the Great Western ports, contained much interesting and useful information. Several questions suggested themselves, but he would only ask whether any special steps were taken to secure the retention of the fine silt in the hoppers and prevent its wasteful escape overside. Had a trial been made of the adjustable coamings used on the

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[1] There was some admixture of mud on the outer slopes: the coarsest and cleanest sand was found on the inner slopes (A. G. Lyster, "Dredging Operations on the Mersey Bar," British Association Meeting, 1895).

[2] Brysson Cunningham, "Harbour Engineering," p. 347. London, 1928.

Dr. Cunningham.

Liverpool hoppers, as devised and described by the late Mr. A. G. Lyster, Past-President Inst. C.E., Engineer-in-Chief to the Mersey Docks and Harbour Board ?[1] It would be interesting to know if the good results obtained in the Mersey had been realized elsewhere.

Mr. Dawe.

Mr. J. N. DAWE observed that the Author referred on p. 433 to the disadvantages, in some cases, of solid training works, and the success of lighter structures. Further examples would have been very useful; in that connexion, the case of the lighter-port of Pamanoeken on the north coast of Java might be of some interest. The river Tjipoenagara on which that old port was situated maintained a good channel as far as the foreshore of the delta, where it had become so silted-up that mud-flats extended about $\frac{2}{3}$ kilometre or more from the edge of the maritime jungle, where the navigable channel ended. Beyond that the channels were tortuous and irregular, and the low-water depth at the bar had become reduced to about 25 centimetres, resulting in practical disuse of the port. A scheme had been drawn up for lighter docks to be built and dredged out a few miles distant in the middle of a long beach, as training the estuary of the river had been considered out of the question, owing to the high cost of stone locally. About 10 years ago he had been asked to advise on that scheme, and had said that, in his opinion the proposed lighter dock would need almost constant dredging, owing to littoral drift of sand, but that the estuary could be made navigable for lighters and small craft by works of a temporary or semi-permanent nature and low cost. Such works had been put in hand a year or two later, and followed the principle recommended by Mr. Buckton of assisting nature. Among the cheapest materials available were bamboos. Two lines of fences, composed of canes driven into the mud and sand with clear spaces of 2 to 4 inches between them, were run out about 160 feet apart, towards the sea. What was considered the most suitable direction for a straight channel was chosen irrespective of existing channels or sandbanks. Where channels of any depth were crossed, the fences were strutted by bamboos driven at an inclination and lashed with palm-fibre ropes to the walings, also of bamboo. Where banks protruded between the fences, short groynes of the same materials were used to direct the current and expedite erosion. Where wave-action was considerable, the fences were strengthened by driving king-piles and struts of young teak trees, and additional fences or groynes of shorter length were made at an angle to check the waves and littoral drift caused by the east monsoon, during which most erosion and drift

[1] Annales des Travaux Publics de Belgique, vol. v (October), 1898.

Mr. Dawe. took place. These, being of open construction, caused sand to deposit on their lee sides. The effect was that, during the first wet season, banks of silt were formed close up to the outsides of the two main fences as far out as they were driven, cross channels of depths of 12 feet being filled sometimes by a single flood. Those banks were consolidated by seedling trees of suitable kinds, some planted and some self-sown. In 2 years there was a thick growth of scrub on each side of the channel, and there was no necessity to maintain further the first part of the fences. The river scoured out its own channel to a sufficient depth to allow of the required navigation. The works had been extended each year to a diminishing extent as deeper water was reached, and when experience of the local conditions had shown the best positions of the secondary fences or groynes, a channel navigable at all stages of the tides had been, and still was, maintained throughout the wet and dry seasons, its length being about 2 kilometres from the original starting point. A few other precautions had had to be taken, but the total cost had been extremely low, and no dredging had been necessary.

Mr. Hindmarsh. Mr. R. F. HINDMARSH, referring to the Author's statement that wherever an engineer created a harbour in tidal waters, thereby causing interference with the littoral drift, he would sooner or later have to take steps to preserve the necessary depth of water for safe navigation, stated that one of the main objects in view in the design of the works at the river Tyne entrance had been the removal of the old bar, which, before the construction of such works, existed across the entrance to the river and had over it only about 6 feet of water at L.W.O.S.T. There was now a depth of 30 feet at L.W.O.S.T. and little if any dredging would be required to maintain that depth if it were not necessary to maintain a straight entrance-channel; the main current on both flood and ebb tides, however, followed a curved track to the south, and a shoal formed on the north side of the channel which was removed by dredging for a few weeks every 2 or 3 years. The littoral drift was from north to south, and, although the breakwaters extended on the north side ½ mile and on the south side 1 mile from the original shore-line, accretion had only occurred on the south side of the south breakwater, and no interference with navigation had been caused by that accretion.

Mr. Latham. Mr. ERNEST LATHAM found the Paper of particular interest to him, especially in regard to those portions dealing with silting questions at riverine harbours, and also because the Author referred to the Paper by his late Partner, Mr. A. E. Carey, on the sanding-up of tidal harbours. Since the reading of Mr. Carey's Paper, however, as the result of experience he had ceased to agree with some of the views expressed therein. For example, he would not agree to *Fig.* 7 as being a proper representation of the arrest of littoral drift by a groyne. His own experience was that on the lee side of most groynes there was nearly always definite erosion to a much greater extent than shown in that diagram, except under the temporary reversal of littoral drift due to changes in the direction of the wind. However, he entirely agreed with *Fig. 4*, as it represented in diagrammatic form the cross-channel port of Newhaven, which was notably safe, and where the construction of the outer breakwater seemed to have been an entirely successful means of keeping the entrance clear with a minimum of dredging ; the port could generally be used by cross-channel steamers at periods when the larger ports of Dover and Folkestone were temporarily out of commission owing to heavy weather. **Mr. Latham.**

The Author's statements in regard to the conditions at Dungeness had probably been true 10 years ago, but did not properly describe the position to-day. The littoral drift passing into Rye bay from Hastings round Fairlight cliffs had now almost entirely ceased, and it had been the recent starvation of Rye bay's natural shingle supply that caused the breach at Winchelsea in 1933 by inundation of the sea. The consequent expenditure on sea-defence works carried out by him on that site for the Catchment Board concerned reached nearly £200,000. Further, instead of accreting at the moment, the Dungeness formation was being rapidly eroded on the western side, and the "Ness" was tending to form a hook towards Sandgate. Even Littlestone, on the eastern side, had lost much shingle recently, and the foreshore had been lowered by several feet, necessitating the entire reconstruction of about 1 mile of the existing sea-defences there.

The dredging by the Mersey Docks and Harbour Board in Liverpool bay was, of course, a classic example of heavy costs in maintaining the entrance to a riverine port. In 1927, when advising the Lancashire County Council on the question of coast-erosion in Liverpool bay, he had had occasion to study the matter, and the Author would no doubt be interested to hear that the quantity dredged was as high as 17 million tons in 1909. The figure had subsequently fallen to an average of 4 million tons per year, so that it would appear from the Author's figure of 9 million tons in 1934 that siltation was again on the increase in Liverpool bay.

The Author did not apparently refer specifically to any trouble at the small harbour of Burry Port, now owned by the Great Western Railway Company. Immediately before the War the original owners of the harbour, the Burry Port and Gwendraeth Valley

Mr. Latham. Railway Company, had been very much concerned with the silting up of Burry Port, and from surveys he had made on their behalf the harbour at that time had appeared to be in danger of total eclipse. From such records as were available it appeared that the Burry inlet had three channels passing through vast accumulations of sand. One of them was always the main channel, but from an examination of records a change of channels seemed to occur about three times in a century; at the time of his investigations, the north channel had been closing and the middle channel had been opening, tending to leave Burry Port more or less high and dry on the north side of the inlet. In 1914 the rate of accretion immediately to the south-west of the harbour entrance along a foreshore length of 1,600 feet had been as much as 50,000 cubic yards per year. Dredging against accretion on that scale had seemed rather a hopeless proposition for so small a harbour, and an extension of the western breakwater had been recommended. The Company, however, had come to the conclusion that they could not spend the sum involved, and it would be of interest to know what was the present position at Burry Port, and whether the Great Western Railway had extended the western breakwater in the manner suggested.

With regard to siltation, one point had now become of importance in England; namely, that for land-drainage purposes the new Catchment Boards functioning under the Land Drainage Act of 1930 were doing much up-river dredging nominally for drainage purposes, although actually it frequently resulted in improved navigation to small inland ports. The effect on the ports at or near the entrance of the river was adverse in cases where vessels took the ground at low tide. A present instance of that effect was the difficulty being experienced at Sutton Bridge, near the entrance of the river Nene into the Wash, where the increased flow of ebb and flood tide due to the increased up-river tidal compartment caused by dredging appeared definitely to have disturbed shipping berthages just below the Sutton Bridge swing-bridge. At Sutton Bridge there was an example that should be a warning to all maritime engineers. Towards the end of the last century large sums of money had been spent on excavating a large dock in the Fens, with approach-works into the river Nene. The dock had been opened to shipping for 2 months only, and as the dock company could not cope with the dredging, the site was now completely filled up and formed a golf-course.

Mr. Richards. Mr. B. D. RICHARDS observed that the littoral drift that occurred on the Dead Sea might be of interest. He had recently carried out investigations in connexion with proposed development-works there, Mr. Richards.

and as the latter included small harbours or jetties at both ends, the question of littoral drift was important. The Dead Sea was 45 miles long, with a maximum width of 10 miles, and lay north and south. It was divided by the El Lisan peninsula into two arms, of which the southern, 15 miles long, was very shallow. The sea received the inflow of the river Jordan and of several large wadis, but there was no outlet, and the inflow was disposed of by evaporation, giving rise to periodic variation of sea-level. The last peak level occurred in 1929, since when there had been a fall of about 10 feet. There was also an average seasonal variation of 2 feet, the maximum occurring during or after the winter rains. Shingle-beds occurred along the western and northern shores; the origin of the shingle was evidently the disintegrated limestone of the western hills and the stones in the marl-beds surrounding the sea, and it was brought down in considerable quantity by heavy floods in the wadis. The prevailing winds were northerly and southerly; coinciding with the lie of the sea, they caused a southerly drift at the south end and a northerly drift at the north end, and the latter drift carried the shingle along the west shore and round the north shore. It was noticeable that the shingle tended to form regular beaches which in some places projected as spurs into the sea. With a falling sea, those beaches showed ridges marking the high-water level of the preceding winter. The littoral drift being due to wind action, it seemed probable that those spurs originated from deflexion of the wind caused by irregularities in the line of the coastal cliffs. Once a spur had commenced to form, its growth was very rapid, as was shown by the fact that a small jetty at the south end, built out from one of those spurs, was, though of open construction, completely silted-up in a short time. At the north end, with longer fetch and greater depth of water, there was greater wave-action than at the south end, and 6-foot waves had been measured on the north shore. That caused a considerable travel of shingle along the north-west and north shores. Various jetties in that district, of open construction, showed no heavy accumulation of shingle against them, but a partially-closed structure had acted as a groyne and the shingle had banked up against it. Owing to the fact that the Dead Sea was tideless and that the level had been steadily falling for several years, it afforded a good opportunity of studying the subject of littoral drift under wind-action.

The Author.

The AUTHOR, in reply, remarked that Mr. Wentworth-Sheilds had raised the most important question arising from the Paper—that of a standard unit or method of measurement for dredging. The ton unit was that required by the Great Western Railway

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The Author. Company's accountants—possibly because of its extremely remote relationship with that familiar railway cost unit, the "ton-mile." The reduction in working-costs, achieved mainly by centralization, was indicated in the Paper. Dredging, carried out departmentally, had as its main object the conservation as economically as possible of navigable depths, the actual method of measurement being immaterial. Should such work be undertaken by contract, however, the circumstances were entirely different and the method of measurement became of supreme importance. In the Author's opinion, whilst no hard-and-fast rule could be laid down, the subject was of sufficient importance to justify some investigation by The Institution as to the possibilities of standardization of measurement of materials to be dredged, whether " in situ " or " in barge." The Great Western Railway Company was at present carrying out investigations with the object of establishing more closely than at present the relationship between accurate measurements in barge and in situ.

In regard to the points raised by Mr. Wilson, he had indicated in the Paper the effects of disturbance of the natural balance of quantities occasioned by the construction of harbour works, involving accretion of material in excess of requirements at some places, and reduction in the supply of such material at other places where it was necessary to maintain the stability of harbours and their entrances. Although the Paper was mainly concerned with the maintenance of navigable depths at the ports discussed, the leeward-side erosion, although not actually affecting those ports to any material extent, was a question of extreme importance. As an example, the construction of the South Devon Railway at the base of the cliffs between Dawlish Warren and Teignmouth had undoubtedly checked erosion of the foreshore, and had adversely affected the foreshore of the estuary of the river Exe from Dawlish Warren to Exmouth, where erosion was in excess of accretion and was at the present time accumulative. Harbour engineers fully realized that where accreted material was artificially collected (for example, by groynes or breakwaters) some reduction in the supply of material would occur elsewhere. It was quite impossible to deal adequately with that subject in such a Paper as the present.

It was evident from Mr. Gedye's remarks that there were differences of opinion as to the source of accretion at Dungeness. The source of the accretion in a particular case was not, however, of such importance as the principle that any projection from the foreshore would intercept littoral drift.

In general, sluicing could only result in local movement of silted material to sites from which it could be more economically removed.

The only G.W.R. port where really useful results were obtained by sluicing is Port Talbot. At Burry Port, however, where the shipments were not comparable with those at Port Talbot, useful sluicing work was done, although the old sluicing pond had for some years been out of action. The Author.

He agreed with Mr. Gedye that the effective dredging-capacity of the *Leviathan* was less than that given on p. 437.

He had purposely refrained from giving particulars of other than working costs, including repairs under £100, but had indicated the relationship, so far as his Company was concerned, between working repairs and heavy repairs and overhauls. All-in costs dependent on depreciation, interest on capital, and other factors could not usefully be standardized.

He agreed with Mr. Buckton that the alteration in the position of the entrance to Madras harbour and the construction of the sheltering arm on the east side of it had removed for the present, and probably for a very considerable time,[1] anxiety in respect of siltation. Prior to that alteration, dredging had been essential, and without it, to quote Sir Francis Spring, "it might conceivably have had to be closed in heavy weather to vessels of deep draught, before the new entrance could be opened."[2] Mr. Buckton had emphasized what he had said about the inevitable effect of constructing artificial harbour-works. His statement that "the engineer ought to work with nature as far as possible" constituted the fundamental principle of harbour work, and should be in the mind of every harbour engineer.

Whilst agreeing with Mr. Chalmers that sand-pump and drag-suction dredgers would no doubt deal economically with the silt at Newport and probably also at Cardiff, he was doubtful whether corresponding economy would result from the use of that type of dredger at Port Talbot and Swansea. A main factor in the reduction of dredging-costs in the South Wales ports had been interchangeability of the craft employed, and, although reduction in costs at one port might be made by the utilization of a particular type of plant, the present reductions of cost consequent upon interchangeability would probably out-weigh local economies.

In reply to Mr. Latham, the Author had already referred to sluicing at Burry Port. His Company had not carried out any constructional works there, but the amount of siltation had been insufficient to

[1] See also Sir F. J. E. Spring, "Coastal Sand-Travel near Madras Harbour." Minutes of Proceedings Inst. C.E., vol. cxciv (1912–13, Part IV), p. 163.

[2] "The Remodelling and Equipment of Madras Harbour." *Ibid.*, vol. cxc (1911–12, Part IV), p. 96.

The Author. affect the handling of traffic to any considerable extent. Conditions in the estuary were continually changing owing to shifting of sand-banks, and during the last 10 years special steps had been taken to protect the railway between Llanelly and Ferryside. Those changes, and the protective works necessitated by them, were in themselves of sufficient importance to justify the preparation of a special Paper dealing with them.