

Mr. Lyster. sities of the case, and of the force of the calls made for improvement, and was also, perhaps, better able than many others to appreciate the physical and financial difficulties to which he had referred as surrounding the question. At present, as would be understood, he was not in a position to discuss fully and freely the several interesting points as to training-walls and other such remedial expedients, and he would have merely to say that the Board had quite recently decided to try an experiment in dredging, no doubt in some degree moved thereto by the fact that a measure of success had attended certain dredging operations in New York, with which port the shipping interests of Liverpool had a close connection. Personally, he was not to be considered as of opinion that the sand-pumping experiment would approach the results which some people expected from it; but it would give an amount of experience which would be interesting, and not without its uses in connection with the study of the general question of the amelioration of the sea channels of the Mersey. He could not now speak as to what works ought ultimately to be undertaken, nor as to the manner in which the cost of those works should be defrayed.

Correspondence.

Mr. Carr. Mr. R. CARR enquired the cost of the sluicing appliances laid down at the Canada Basin, so that it might be compared with that of other systems of keeping dock-entrances clear from sand or mud silting. In addition to first outlay, what was the cost of maintenance, and was there any special cost for labour whilst sluicing? It might be that this was done by the men employed in locking vessels, in and out, as part of their ordinary daily duty. And what was the effect within the Langton Dock, which was drawn down about two hours every tide, with the double purpose of sluicing the entrance and meeting the rising tide, to make a level? Did the volume of flood-water, brought in by the tide, leave a deposit of silt that had to be taken out; if so, what cost did it involve, and how was the silt removed? At the Tilbury Docks on the Thames, there was a tidal basin, bearing a close resemblance to the Canada Basin, with a wide entrance, open to the tide at all times. It was 19 acres in area, and, when first opened, it cost a large sum annually to maintain a depth of 26 feet below low-water level by the bucket-ladder system of dredging, and depositing the mud on the land. At present it was kept clear to that depth by an invention of Mr. Tydeman, one of the West India Dock staff.

This was a tug-boat fitted with American pumps, that discharged Mr. Carr. high-pressure water through jets, in suspended pipes, close to the surface of the mud, which was stirred up as the steamer moved about the basin, and went out with the ebb-tide, about five hours in every tide. This was effected at a cost, including all labour, stores, repairs, depreciation, and interest on capital, of £1,680 per annum. Another thing would be interesting to know, whether the lock gates at the Liverpool Docks were of greenheart, or whether the more modern fashion of iron and steel had been adopted.

Mr. W. DYCE CAY observed that he had been engaged for Mr. Cay. thirteen years, up to the beginning of 1880, in designing and carrying out works for the lowering of the bar at Aberdeen. His opinion, as to the cause of the formation of the submarine ridge of sand at the harbour mouth called the bar, was that it was occasioned by the sudden breaking of the waves, travelling shorewards, owing to the constriction of the channel at the entrance, and the opposition to them there of the outward river and tidal flow; the bar, once begun, aided in breaking the waves, and formed, as it were, a shelter for the deposition of the sand they carried. The works under his superintendence widened, deepened, and regulated the channel, and removed old constricting works, while extending new piers seawards; and the effect had been to increase the depth about 2 feet, while adding greatly to the width and navigating room of the entrance. He thought that this principle, of forming a channel gradually widening and deepening as it entered the sea, would be found to have a pretty general application, though necessarily each case must be judged on its own circumstances, and to have an analogy in those natural estuaries where there were no bars. He was glad the function of the river water of the Mersey estuary had been so distinctly described by the Author, namely that it maintained the tidal receptacle by scouring it at low-water, while the receptacle, on its part, maintained the navigation and sea-channels by the flow and reflux of tidal water into and from it; for there were many harbours, with rivers flowing into them, where the river had no function to fulfil, and was a source of great disadvantage and expense, owing to the silt brought down and the dangers to navigation it caused when in flood. In such cases, where possible, it would be better to divert it out of the harbour. With regard to the durability of Portland cement in sea-water, he thought that, as in the case of hydraulic limes, one sample of Portland cement, manufactured of chalk and clay, got from one place, might be more durable than another sample made from materials obtained in a different place;

Mr. Cay.

also that one kind might be suitable for one place, but not for another. Some simple test of durability was a desideratum; meanwhile, manufacturers might indicate to users where their cement had stood a sufficiently long trial. No doubt all lime compounds, including cements, were liable to injury more or less from the action of the salts contained in sea-water; but as there were no other cementing materials, all that could be done was to use those least liable to damage, and in the most efficacious manner. The cause of this injury was well described by Vicat upwards of thirty years ago; he said:¹ "Si l'on verse de l'eau de chaux dans de l'eau de mer, il s'y forme sur-le-champ du sulfate et du chlorhydrate de chaux, et il se précipite de la magnésie rendue libre;" he further stated that the affinity of sulphuric and hydrochloric acids for lime was not only sufficiently powerful to produce these effects, but even to detach this base from its combinations with silica and alumina. Vicat made experiments on the durability of lime compounds and cements in sea-water, by immersing them in a very dilute solution of magnesium sulphate, namely, 4 to 5 grams of anhydrous salt, or 8 to 9 grams of the same with its water of crystallization, dissolved in 1,000 grams of pure water. The mortar or cement to be tested was first allowed to set for a month or more in a hermetically-closed glass vessel; this was then broken from the specimen, and the cement was immersed in the solution, which was renewed as often as the test with ammonium oxalate showed the magnesia solution to be charged with sulphate of lime. Those specimens, apparently intact after ten months of this treatment, he cut into two or three pieces, and if sound in the interior, he again subjected them to the magnesia bath; and, if they stood for five or six months intact, he held them to be indestructible in the open sea. He said that if kept for ten months more, or in all twenty months' immersion, the best mortars, such as that of Teil lime, which had stood for ten years intact in the blocks at Marseilles and Port Vendre, showed slight signs of alteration; but for all that it was good for sea-work. Some of the results of these experiments were that the greater number of mortars succumbed to them; natural hydraulic limes containing five or six times more silica than alumina alone resisted. Few cements did so. Some cements were improved by heavy burning so as to resist change completely for seven or eight months, and were not much damaged after two years, which might give time for a crust

¹ Traité pratique et théorique de la composition des mortiers, ciments et gangues à pouzzolanes, &c.; par L. J. Vicat, p. 79, Grenoble, 1856.

to be formed by the sea. Vicat also found, as to the composition Mr. Cay. of the cements of commerce, relatively to their durability in the sea—1st, That there was no relation between the durability and the hardness. 2nd, Independently of the composition of the clay in silica, alumina and magnesia (if any), the chance of stability was so much the greater as the sum of these three substances was nearer equal the amount of the lime in the cement, and taking the latter at unity, 0·80 was the limit below which the quantity of clay, iron not included, ought never to be; it followed, he said, that cements charged with lime, whatever the degree of calcination, were not suitable for sea-works. This appeared to point to Roman cement, the analysis of which, as given by Mr. George R. Burnell,¹ was for the Sheppey stone, 55 lime, 38 clay and 7 iron, and as analyzed chemically by Berthier—

Carbonate of lime . . .	0·690	=	{	Lime	0·380
			(say)	Carbon dioxide	0·310
				Total . . .	0·690
Magnesia	0·002				
Oxide of iron	0·037				
„ manganese	0·012				
Silica	0·180				
Alumina	0·066				
Water	0·013				
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If, however, the use of Roman cement only was obligatory, evidently the construction of sea-works would be much restricted; but Mr. Vicat approved of the hydraulic lime of Teil in Ardèche, France, for works in the Mediterranean. This lime, besides being used in the works mentioned above, was adopted for the Port Said works and those at Trieste. Its analysis had been given by Mr. F. Bömches.² There the lime was to the soluble silica, alumina, and magnesia, as 1 to 0·28; while Vicat supplied an analysis of the waters of the Mediterranean, the Atlantic, and the English Channel,³ from which it would appear that the destructive salts were in greater quantity in the Mediterranean than in the Atlantic, and that the lime of Teil had a less proportion of soluble silica and alumina than English Portland cement, the averages of the consti-

¹ “Rudimentary Treatise on Limes, Cements, Mortars, &c.,” by George R. Burnell, 8th edition, 1869, p. 58.

² Minutes of Proceedings Inst. C.E., vol. lxii. p. 209.

³ *Traité pratique et théorique de la composition des mortiers, ciments et gangues à pouzzolanes, &c.*; par L. J. Vicat, p. 78.

Mr. Cay.

tuments of five qualities of which, given by the late Mr. John Grant,¹ were:—

Lime.	Silica.	Alumina.	Oxide of Iron.	Magnesia.	Sulphuric Acid.	Potash Soda.	Carbonic Acid Water.	Insoluble residue.
59·23	21·87	6·61	5·86	0·73	1·31	1·48	1·00	1·29

The lime of Teil was, however, used in strong and impermeable proportions; from the figures given by Mr. F. Bömches about 1 part of lime to 2½ parts of sand.

The experiments of Messrs. L. Durand Claye, and Paul Debray,² showed that sea-water, filtered under pressure through permeable Portland cement mortar, had a destructive effect; their conclusion that the dislocating effect was caused by the crystallization of sulphate of lime, formed by the action of the sea-water salts on the lime, was not new, it having been previously mentioned by Mr. G. R. Burnell,³ as having taken place in the mortars used at Fort Boyard. Their experiments, demonstrating what proportion of water made the most dense and least permeable concrete, were valuable. Engineers would naturally, if they had not before done so, take precautions against filtration under pressure of sea-water through cement mortar or other lime compound, and though nothing very distinct had yet been brought out as to the constitution of the Portland cement, most durable in sea-water, it would appear that any disturbance of the molecules of cement by excess of water in gauging, or by passing loose through water in deposit, so as to separate the lime from the silica, would render it more liable to attack by the chemical salts contained in sea-water. He had found that excellent Portland cement was supplied to a specification based on Mr. Grant's researches, namely, 90 per cent. to pass through a sieve having 5,800 meshes per square inch, and sample briquettes made of 1 part sifted cement, 3 parts standard sand, and 10 per cent. water, kept one day in air, and twenty-seven days in water, to bear a tensile-strain of 200 lbs. per square inch. The addition of a seven-day test to ascertain the rapidity of setting, the "hardening energy" mentioned by Dr. Michaëlis,⁴ would be an improvement, as quickness of setting was an additional protection against the sea-salts.

Mr. Crawford.

Mr. ROBERT CRAWFORD, of Greenock, observed that on the 20th of June, 1882, Mr. Kinipple submitted a report on proposed jetties,

¹ Minutes of Proceedings Inst. C.E., vol. lxii. p. 130.

² Annales des ponts et chaussées, 6^e série, tome xv., 1888, p. 816; and Minutes of Proceedings Inst. C.E., vol. xevii. p. 445.

³ "Rudimentary Treatise on Limes, Cements, Mortars, &c.," by George R. Burnell, 8th edition, 1869, p. 58.

⁴ Minutes of Proceedings Inst. C.E., vol. lxii. p. 232.

sheds, and travelling cranes, for the Albert Harbour, Greenock. The plans accompanying it showed the jetties and a cross-section of the sheds with the cranes on the roof. The travelling cranes designed and superintended by Mr. Kinipple for the James Watt Dock had proved the most serviceable cranes at the Greenock Docks, running as they did along the verandah in front of the sheds and warehouses, and of sufficient height and width to allow two lines of railway wagons to pass under them. He had carefully gone into the question of harbour cranes lately, and could safely assert that the overhead cranes proposed by Mr. Kinipple for the Albert Harbour in June, 1882, and the cranes erected by him at the James Watt Dock, were the most suitable type of crane for general purposes at the Greenock Docks. He was at present designing a 30-ton steam crane, to be erected on a travelling gantry of sufficient height and width to allow two lines of wagons to pass under it. This crane was intended to work on a jetty where there were no sheds nor warehouses.

Mr. D. CUNNINGHAM remarked that the West Tidal Harbour of the Port of Dundee, in the River Tay, occupied a position in the estuary somewhat similar to that of the Canada Basin at Liverpool to the estuary of the Mersey, though the Canada Basin was relatively nearer the sea. The silting within such a basin was naturally considerable, more particularly when depths suitable for modern sea-going vessels had to be maintained. The West Tidal Harbour at Dundee formed the vestibule to the older or shallow docks. The amount of dredging required, up to twenty years ago, to keep it in a serviceable condition for the passage of vessels of comparatively light draught, was 45,569 tons per annum. For the last eight years it had been 29,575 tons, or less than two-thirds the former amount. This improvement had not been caused by the introduction of additional sluices, such as those constructed for the Canada Basin, but by the removal by dredging of a large sandbank which lay in the river opposite the entrance. The effect of this sandbank was to cause the ebb-tide water to flow into the harbour on the surface; it made the circuit of the walls and passed out again below the incoming current, in its course always depositing considerable quantities of mud. The construction of such culverts and sluices as those described was most desirable in such situations, and the very creditable example of Liverpool would, no doubt be followed with much advantage whenever it could be carried out. The estuary of the Mersey was somewhat similar in shape and circumstance to the estuary of the Tay. But while the tidal water, which passed up the estuary of the Mersey, par-

Mr. Cunningham.

Mr. Cunningham. ticularly at high spring-tides, was a good deal more than what passed up the Tay above Tayport, the position of which was similar to that of New Brighton, the fresh river water passing down the Tay was upon an average about three times that of the Mersey. The ebb-current therefore became, in relation to the flood in the Tay, stronger than it was in the Mersey, and hence the improved scouring effect manifest in the former. For instance, the highest points of the sands stretching across the mouth of the River Tay, where vessels entered, ranged between 18 and 23 feet below lowest low-water of spring-tides, whereas the navigating depth over the bar at lowest low-water of spring-tides in the Mersey was only 10 feet. There were also no practicable by-channels in the Tay. It was manifest that, with an improved scour on the ebb, the condition of the lower channel of the Mersey would approximate to that of the Tay. Large and costly works had been, from time to time, proposed for this purpose, and it was considered that the attainment of the desired end was surrounded with physical and financial difficulties of no ordinary character. He scarcely agreed with this manner of viewing the question, for his experience upon the River Tay led him to conclude that the satisfactory deepening of the bar of the Mersey would be by no means such a very difficult, costly, or hazardous operation. Three years ago it was resolved to widen the navigable channel of the River Tay, some 3 miles below Dundee, where it was about 500 yards across (between the 18 feet below low-water contour lines), but at a bend where vessels coming up experienced some difficulty in clearing the north shore. The Newcome spit, projecting from the southern shore, and thus restricting the channel, consisted of a vast mass of clean and perfectly free coarse sand. The ordinary ladder dredger employed at the harbour was stripped of its buckets, and a longitudinal propeller-shaft with propeller, fixed upon the ladder instead, by means of which a strong current was produced at the time of ebb-tide when the lower end of the ladder was lowered to the surface of the sands. In three months, at a very moderate cost, the point of this spit was so much lowered, as to enable the buoy defining the south side to be shifted in position 500 feet to the south-west, the channel having thus been satisfactorily widened. Such an effect might be produced on the bar of the Mersey, at a moderate cost, by the employment of one of the large ocean-going steamers ballasted aft, and moored so as to bring the power of the engines to the fullest practicable extent on the moving sands which constituted the bar. The effect of such action would be to immediately lower the bar at the point attacked.

There having been thus produced a freer passage for the flood and ebb waters over the bar, the minor side channels would rapidly close up, particularly if such work were carried out in winter when the weather was unsettled. Once such channels became partially closed, and in the degree in which they became so, the improvement carried out in deepening the bar would tend to become permanent. In such simple and economical manner he was sure that, without the execution of any sea-works, the present depths on the bar might be much improved.

Mr. Cunningham.

Mr. G. FINDLAY pointed out what, in his opinion, was a considerable drawback to the efficiency of the dock arrangements at Liverpool. The railway facilities should be in many respects greater, and should include convenient access for railway wagons to and from the berths and quays; and the unloading of vessels, instead of being mainly dependent on the ship's gear and tackle, should be provided for by hydraulic cranes, such as existed at the docks in London and at most of the other important docks, as, for instance, Hull and Cardiff. He thought no great system of docks, such as the Liverpool Docks, could be considered complete in the absence of appliances such as he had mentioned.

Mr. Findlay.

Mr. I. J. MANN remarked that the tendency of the bar to move seaward would, no doubt, as in the majority of similar cases, be considered as unfavourable; on the other hand, as its position became less sheltered by the land, it would become more exposed to the action of large waves, which would have a decided tendency to prevent undue accretion. In the year 1867, the depth over the bar at low-water of spring-tides was 12 feet;¹ and in the present Paper it was given as 10 feet at low-water springs. The depth, therefore, seemed to have decreased by 2 feet in twenty-two years; if this was so, it would be interesting to know whether this diminution of depth was regular, or fluctuating, and whether the present tendency of the bar was to increase or otherwise. The greater size and draught of ocean steamships, and the element of time becoming so important, naturally rendered the impediment of a bar additionally formidable. With regard to the datum to which all levels in the Mersey were referred, it was usual at other ports to adopt as a datum a standard low-water of equinoctial, or other tides, and although a standard tide at Liverpool seemed to be taken as rising 21 feet above, and falling 10 feet below the Old Dock Sill, it seemed peculiar that the low-water of that tide was not adopted without the intervention of an intermediate datum. With regard to

¹ Minutes of Proceedings Inst. C.E., vol. xxvi. p. 425.

Mr. Mann.

the dock accommodation, every increase of trade had been promptly met, but not overdone, by providing larger and deeper docks, and greater storage room. The Author had not entered into the details of dock construction; considerable variation was, however, noticeable in the batter given to the faces of the walls of different docks, the reason for the variation not being apparent. Mr. Mann's experience had led him to the conclusion that a batter of 1 in 12 fulfilled all the requirements of vessels lying alongside, and in addition enabled the centre of pressure on the foundations to be kept near the centre of the structure. In view of some comparatively recent failures of Portland cement concrete exposed to the action of sea-water, it was satisfactory to find that although very large quantities of that material were used by the Author, during a long period of years, he had not had to record any instance of failure, but the reverse.

Mr. McConnochie.

Mr. J. A. McCONNOCHIE observed that the Author stated, that "men of energy and enterprise" and "pioneers of progress" of Liverpool "had the honour of devising and constructing the first wet-dock built in England." This was a mistake, as the first wet-dock in England was undoubtedly the still existing Greenland Dock of the Surrey Commercial Dock Company at Rotherhithe, originally called the Howland Great Wet-Dock. The honour therefore belonged to the Thames, and singularly enough was due to the enterprise of a lady, Mrs. Elizabeth Howland, widow of John Howland, of Streatham, whose daughter and heiress married, in 1695, Wriothsley Russell, Marquis of Tavistock, who afterwards became second Duke of Bedford. The dock and adjoining property passed to the Bedford family under this marriage settlement, and continued in their possession till 1763, when they were sold to John and William Wells, and after passing into other hands were purchased by the Commercial Dock Company in 1807. The Act for constructing a wet-dock at Liverpool received the Royal assent on the 24th of March, 1709. The Act for constructing a wet-dock at Rotherhithe received the Royal assent on the 10th of April, 1696. The short title of the latter was "An Act to enable trustees to raise money for the making a wet-dock and improving the estate of the Marquis and Marchioness of Tavistock at Rotherhithe, in the county of Surrey." The Act recited that the Marquis and Marchioness were both minors, and that the said Elizabeth Howland, widow, had advanced and lent £2,500, which had been laid out in a considerable improvement made upon part of the lands adjoining to the River Thames, by making a dry-dock for the benefit of shipping, and that the residue of the said lands

was capable likewise of being greatly improved, by laying out a further sum of money, which they had computed might amount to the sum of £12,000, in making a wet-dock there for the benefit of shipping. Certain lands were mortgaged to raise the money, and the dock was proceeded with; a second graving-dock was also added, and Mrs. Elizabeth Howland appeared to have purchased them in 1703, and paid off the mortgage. The date of the opening of the dock was not recorded, but it was in use in 1703 as appeared from the following description, which was printed, with an old engraving of the dock, retained in the Board room of the Surrey Commercial Dock Company.¹ The docks and works at Liverpool,

Mr. McConchie.

¹HOWLAND GREAT WET-DOCK,

In the Parish of Rotherhithe, or Redriff, belonging to Mrs. Howland, of Streatham.

This dock hath been found a very safe repository for ships, which was fully proved in that terrible and violent storm which happened on the 27th November, 1703, when by the extremity of the wind all the ships in the river, which rode either at chains or their own moorings, were forc'd adrift, and confusedly driven on the north shore, where some were left, and most received great damage. Then, of all the several ships deposited in this wet dock, there was only one injur'd, and she only in her bowsprit, which was in a great measure imputed to too secure a negligence in the persons who moor'd her there. This may remain a lasting evidence of the great service such a repository for shipping is to our navigation; especially if it be consider'd that this fatal storm happen'd soon after the planting of those trees, which are on the south and north as a fence to the dock from winds, and which are now grown to a considerable bulk; and also before that range of houses were built to the west, and the pailings set up to the east, and on each side; so that now, in the hardest gales of wind that have within these late years happened, notwithstanding the large extent of the water, the wind does not give any such motion to it, as can endanger the smallest boat in passing it any way over, and tho' very deep loaded. And as ships are here so well secur'd from any storm that may happen, so they are entirely defended from the hazard and damage which accrueth to them often in the river, by hard frosts. For by the driving of the ice in the river, if they should continue in the stream on float, their cables would be cut; to prevent which, and to preserve their bottom, they are forc'd to take up with shore births, which often are straining and uneasy to the ships, and require a constant care and charge to preserve them, by shoring or shifting, as it may happen, by the ice's driving under them. And notwithstanding all the care which can be taken, the bottoms of ships are so raked by the ice, that it is often a considerable addition in the charge of refitting, if no other more material damage happens to them thereby. Whereas the ships here deposited, lye always waterborne, without the least rubbing of the ice, or any farther care or charge for their preservation, as fully appear'd by the last great frost in 1715. Ships are likewise here more effectually secur'd from the peril of fire; there being proper cook-rooms provided on shore, and no fire suffer'd to be on board. But if neither storms, nor ice, nor fire, be consider'd, ships are here deposited at a much less charge and a much greater security than in the river; which any one may easily

Mr. McConnochie. described in the Paper, were undoubtedly unrivalled, both as regarded the care bestowed on the designs, and the substantial manner in which they had been executed. They were an example of what the works of a public trust ought to be. Many engineers, however, were compelled, by the exigencies of providing dividends for shareholders, to proceed on less satisfactory, if more economical, lines. The narrow width of quay, between the sheds and the docks, at Liverpool, always appeared to him inconvenient, and had necessitated the design of the crane travelling on the roof of the sheds. This crane, for the rapid working now demanded in the steam-shipping trade, was, in his opinion, from its elevation, inferior to the ordinary crane travelling on the quay, as the greater length of chain, between the jib head and the load, when being swung, imparted a motion to the load which entailed loss of time in steadying. This, perhaps, accounted for the somewhat slow rate of working stated in the Paper, 80 lifts per hour being common with the quay cranes at the Surrey Commercial Docks.

Mr. Redman. Mr. J. B. REDMAN observed that Liverpool had for nearly two centuries been the rival and compeer of the Port of London, over

evince, if he will calculate the wearing their cables or the charge of the chain, the frequent shifting of the moorings, and other necessary incidents, which do and will happen in the river, and compare them with the moderate rates wet-docking is by this work reduc'd to.

Description of the Dock.

The outward gates of the wet-dock, leading to the Thames, 21 foot high, and 44 foot wide, open'd to let in the ship.

The bason, or gut, leading to the great wet-dock, 44 foot wide, 150 foot long.

The inward gates, of the same height and breadth with the outward, but stronger, by reason they bear the great weight of water in the dock, which sometimes flows within a foot of the top of these gates, and is kept pent up within four foot thereof.

The great wet-dock, wherein at good spring tides there is seventeen foot of water, over the cell against which the bottom of the gates shut; so that it would commodiously receive his Majesty's third-rate ships.

The dimensions of the dock are from east to west 1,070 feet; from north to south, at the west end, 450 feet, and from north to south, at the east end, 500 feet; so that it would contain upwards of 120 sail of the largest merchant ships, without the trouble of shifting, mooring, or unmooring any in the dock, for taking in or out any other.

This dock when full at a spring tide, contains, by a moderate computation of 40 foot solid to the ton, 228,712 tons of water, being much larger than the famous bason of Dunkirk, or any pent water in the world.

The mast crain, for taking out and setting in masts in ships in the wet-dock, which answers the end of an hulk, with proper pits and crab for careening three or four ships at once.

which it possessed certain physical advantages, namely, greater proximity to the seat of manufactures, and to the ocean; and a somewhat loftier oscillation of tide—27 feet as compared with 20 feet. But, on the other hand, the minimum depth of the ocean approach was only one-half that of London—10 feet as compared with 20 feet—so that high-water depth was less by 3 feet—37 feet as compared with 40 feet. However, to blame the Mersey Docks and Harbour Board without reservation, for a state of things inherent from the physical conditions of the estuary, would be hypercritical; for Liverpool was by no means alone in having an outer threshold carrying much less water than the sills of its deep-water docks. Three Royal Dockyards and two commercial depots might be selected in illustration. Portsmouth Dockyard, on which vast sums of money had been expended for extension works, could command 7 fathoms immediately into the harbour; but to enter or leave this anchorage a low-water channel, 2 miles long, very narrow and carrying only 20 feet at low-water, must be navigated; so that practically this depot could only be approached by large vessels at or near high-water. The same applied to Chatham and Sheerness, and to the Port of Victoria, the South Eastern Railway Station, the entrance to either of which was gauged by shallows below the Nore carrying only 20 feet. Again, the Tilbury Docks were in the same predicament; commanding as they did an ample depth of water in Gravesend and Northfleet reaches, the approaches were gauged by shallows in the lower part of Gravesend and Sea reaches, and below the Nore carrying only 20 feet at low-water spring-tides. The new eastern channel into the Black Deep off the North Foreland, called in Macartney's and other charts of the last century, "Fisherman's Gatway," and then carrying 40 feet for half its length north, and 20 feet for the rest southward, was found to have 40 feet throughout by Captain Bullock, R.N., in his surveys of the Downs and approaches to the Thames, fifty years ago, and was afterwards called Bullock's Channel. Subsequently, when buoyed, and now recently lighted, it had been called the Duke of Edinburgh Channel, in compliment to the present Master of Trinity House. A detour of several miles was involved in the use of this channel, and most vessels would continue to use the Alexandra channel to the westward, except heavily draughted ships arriving at dead low-water, as it only commanded a minimum depth of 20 feet, and several large ocean steamers had taken the ground there, from this circumstance. As regarded the removal of the bar at Liverpool, the question was so large, and involved so many considerations, that it would be rash in a discussion like this to advance very

Mr. Redman.

Mr. Redman. specific opinions. The Mersey estuary, like that of the Seine, was circumstanced to receive and retain the highly flocculent and shifting sands heaped up in either, and any one who had slept a night in New Brighton, during a gale of wind could well appreciate this, for it was difficult in the morning to get abroad, due to heavy drift of the light flocculent sand over the thresholds. To remove the Mersey bar meant dredging down for 20 feet, which, unaccompanied by other measures, would somewhat resemble the labour of Sisyphus; to erect guiding-banks on the crests of the outlying, partially submerged sands would, to say the least, be a game of speculation, and a very costly one. Groynes run out over the forelands, to be subsequently connected near their extremities as their effect was developed, might do much in directing the ebb current against the bar; but any method would demand a long course of study of the various charts as far back as printed, as well as of the progressive stages of tidal storage in the estuary. A naval friend, years back, who was well acquainted with Liverpool, repeatedly urged on his attention the connecting of the Mersey and Dee estuaries by a tidal cut, as affording a second deeper and less encumbered entrance; and this idea has been put forward recently in other quarters. The same remark applied here, that before seriously entertaining such a project the progressive stages of these estuaries must be studied, by a comparison of early and modern charts. Those estuaries, like that of the Seine, appeared specially planned by Nature for the reception and retention of their easily moved, light drifting sands. As regarded the arrangement of the Liverpool Docks, an interesting feature of dock construction was well illustrated. In the early metropolitan and provincial docks, a large area was required for the swinging of sailing ships, and the quay value compared to the area enclosed was a low one. This value had been raised in later years by running out jetties into the docks, and this, to a certain extent, temporary measure had become a recognized feature in the planning of modern docks, brought about by the inner recessed portions of the area subdivided by permanent projecting piers of similar construction as the rest of the margin. Again, a lower area compared to the tonnage accommodated, was now necessary from the fact that a large steamer of the present day, of from 5,000 to 6,000 tons burthen, might be said to represent five 1,200-ton East Indiamen of yesterday, and whilst making double the number of voyages per annum performed by its predecessor, would occupy berthage in a dock for days as compared with weeks formerly; so that it was really no mere figure of speech to say that one of these large steamers, as regarded work

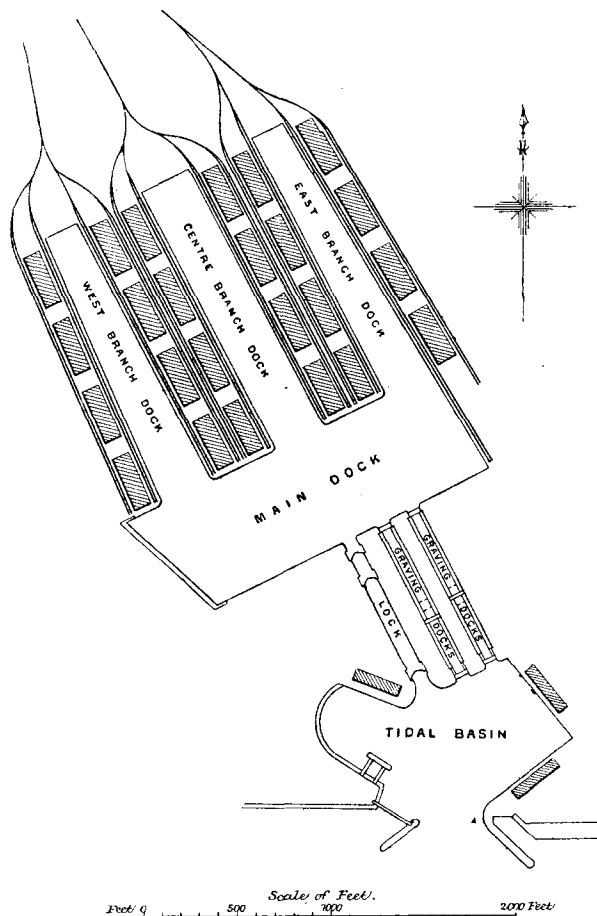
done, represented a fleet of ten East Indiamen of the past. Mr. Redman. Another feature of practice was illustrated by these works. Mr. Jesse Hartley was, like his compeers, most exact and careful in the execution of the ashlar masonry of the quay walls; in his later days he revolutionized his practice by adopting cyclopean masonry in random courses, and this again had been shelved by modern hydraulic concrete in mass, no doubt affording great facility of execution and reduction of cost; but these walls did not bear comparison with earlier works, at least in the Port of London, and they bore on their face a more battered, ruinous appearance than the ashlar walls of the early part of the century. Doubtless in the future this material for such works would be generally measured, mixed, and applied by machinery. The trade of the United Kingdom had so wonderfully increased, the figures, while appealing powerfully to the imagination, were so extraordinary, that he hesitated to quote them; but the Board of Trade Returns appeared to show that the aggregate amount for last year was represented by £680,000,000 sterling, and that the increase over the year before last amounted to £1,000,000 sterling per week, or £52,000,000, or one-seventh of the whole, the largest amount ever received; and possibly the result was greater than in any commercial community during the world's existence. This showed plainly enough that there was ample field for such works, and this record of the Liverpool Docks would prove an invaluable guide to those planning or superintending them.

Mr. JESSE F. SCOTT considered there was much in the dock Mr. Scott. system of Liverpool of peculiar interest to those acquainted with the development of the dock systems of the Port of London. Both the Thames and Mersey (and some other ports in the front rank nearly half a century ago) were burdened with a great area of antiquated docks which were practically valueless. They were constructed at a greater relative expense than the docks of recent years, and in many cases upon very costly sites. These old docks could not now be utilized for vessels of modern dimensions, and in some instances it was doubtful whether the small trade they at present accommodated paid for their proper maintenance, to say nothing of interest upon the capital invested in them. The attempt at Liverpool to utilize some of these old docks, by connecting them with modern entrances and artificially raising their original water-level, so as to adapt them for ships of moderate draught, was an experiment that would be watched with interest, as offering at least a partial solution to what was felt to be a difficult problem. The depth of water upon the sills of the newer Mersey Docks was small

Mr. Scott. compared to what was usual on the Thames. The deepest sills at Liverpool and Birkenhead had but 23 feet 7 inches of water over them at high-water of average neap-tides, with occasionally some 3 feet less. It was apparent that for several days in each fortnight first-class vessels entering the port could not at neap-tides proceed to the berths in the docks, until part of the cargo had been discharged overside into lighters whilst in the tideway, the same difficulty being experienced with outward-bound vessels which must either await a suitable tide to leave the docks, or complete their loading in the river. On the Thames there were nine lock entrances having a greater depth of water at neap-tides than any on the Mersey; and, owing to this greater depth, it was never necessary in the Port of London, to discharge any portion of the ship's cargo before entering the docks, and outward-bound vessels could leave the docks and proceed at once to sea at any high-water. The two largest dock entrances on the Thames were the new entrance to the Royal Albert Docks, and the lock at Tilbury. Both these locks were 80 feet wide and had three pairs of gates. The length between the inner and outer gates was in the first case 555 feet, and in the latter case 700 feet. The depth of water on the sill at high-water of neap-tides was about 30 feet at the Royal Albert Docks, and about 39 feet at Tilbury Docks, being respectively about 6 feet 6 inches and 15 feet 6 inches deeper than the best entrances at Liverpool and Birkenhead. The depth of water at Tilbury Docks allowed a ship drawing 23 feet to be docked at the moment of arrival at low-water of spring-tides, and even in the case of ships of greater draught the delay need never exceed an hour or so, the ship in the meanwhile being accommodated in the tidal basin where facilities were provided for landing passengers and their baggage. This was a striking contrast to the state of affairs at Liverpool, where the whole of the docks were practically closed against fully-laden first-class ships for several days at frequent intervals. The system of branch docks at Liverpool, gave the maximum of quays with the minimum of water area; it brought the whole of the business within a reasonable compass for working purposes, and it lent itself to a convenient system of railway communication, provided there was sufficient land space at command at the heads of the branch docks. This arrangement had been carried out at Tilbury Docks, where the system had reached its highest present development (*Fig. 3*). At Tilbury Docks it had been found possible to provide quay berths in the three branch docks for twenty-four ships of an average length of 400 feet, in an aggregate water area of but $29\frac{1}{2}$ acres; with direct railway communication

to each berth without the use of turn-tables, or any curves less than Mr. Scott. 6 chains radius. The main dock, of 23 acres water area, served for turning the vessels as required, and could accommodate five first-class ships besides smaller craft at quay berths along its sides. In

Fig. 3.



TILBURY DOCKS. ARRANGEMENT OF BRANCH DOCKS.

regard to the relative amount of trade, and dock charges at Liverpool and London, it should be borne in mind, that at Liverpool, the Harbour Board, with slight exceptions, merely provided dock accommodation for the ship. On the Thames, it was customary for

Mr. Scott. the Dock Companies not only to provide this dock accommodation, but also to unload the ship, and warehouse on their own premises a large portion of the goods, often for a considerable period of time, besides doing much else for the convenience of the traders. Any comparison of the dock charges must therefore be fallacious, unless these important differences of services rendered were taken into account.

Mr. Strype. Mr. G. W. STRYPE said that the extraordinary number of vessels that could be passed inwards and outwards, during such a very short time upon each tide at the Liverpool Docks, deserved notice. The advantage of lowering the sills of the docks was very great, and its successful results were marked. These appeared to be chiefly due, and dependent upon, the ingenious method by which the surplus water inside the docks was employed, to disturb and scour away at suitable times the sediment that would otherwise be deposited. The adoption of large cast-iron mains in connection with the sluices had many obvious advantages. The chief drawback of the cast-iron was its perishable character, due to the oxidation of the surface exposed to the corrosive action of salt water, but this surface had been protected by a coating of Portland cement of only some $\frac{3}{4}$ inch in thickness, secured by means of ribs cast with the pipes upon the inside. It would be interesting to know how the cement was applied, and whether it was liable to cracking away in flakes from the inside. Several unsuccessful experiments had been made to coat the inside of large cast-iron pipes, to prevent their gradual destruction from oxidation, by means of enamelling; but if so thin a layer as $\frac{3}{4}$ inch thick of Portland cement when properly applied would answer the purpose, and found to be reliable as in this case, it was clearly a most valuable method of preservation to employ. It would also be of interest to know whether any difficulty had arisen by the pipes themselves becoming fouled with silt, and requiring to be cleansed, from time to time by other means than that of the scour of the water passing through them.

Mr. Stoney. Mr. BINDON B. STONEY observed that a few months ago, while inspecting several of the works described in the Paper, he was especially struck with the facility with which large steamers passed out of the Langton Dock by one entrance, while a fleet of small river craft entered through the other. The direction of the opening into the Mersey, contrary to what might perhaps at first suggest itself, answered admirably to facilitate the ingress and egress of shipping, and at the same time it sheltered the lock-gates from the influence of storms. The principal ports of the United

Kingdom might be broadly divided into two classes, namely, those Mr. Stoney. situated on sheltered tidal rivers with a moderate range of tide, such as Dublin, Belfast, and Glasgow, in which floating docks were the exception, as most of their trade was conducted along open river-quays, and ports like Liverpool and Hull, in which, on account of the great range of tide and the exposed character of the river, floating docks were essential. Ports with large tidal range had the advantage that the foundations of their dock walls were seldom laid much below low-water, whereas river quays had frequently to be founded at from 20 to 30 feet below low-water, in order to permit large vessels to lie afloat at all states of tide. On the other hand, river-quays were generally available for every foot of their length, whereas docks had locks and gates, waste corners, and often tidal basins, the cost and working expenses and maintenance of which had to be supported by the revenue derived from the quay space inside. River-quays also permitted vessels to enter or leave their berths with great dispatch, and when, as in Dublin, the depth in the river and on the bar was sufficiently great, cross-channel steamers could sail at fixed hours irrespective of tide. This latter was a matter of great importance for this class of trade. On a survey of the older docks in Liverpool, it would probably strike most observers that they were small and numerous and that the size and cost of their approaches, locks, gates and waste bits of quay, were large compared with the available quay space within the docks; and the corresponding staff to manipulate these numerous entrances seemed also great in proportion to the useful accommodation within. This faulty characteristic of the older docks had evidently not escaped the Author in designing the new works, and, in the increasing competition between various ports, engineers should study economy, not only in the first cost, but also in working expenses. On comparing the revenues of Dublin with those of other large ports in the United Kingdom, Mr. Stoney was often filled with envy at the large sums available for new works elsewhere. In Liverpool, for example, the Author stated that the revenue derived from 9,292,000 register tons was £990,500, or on an average 25·58*d.* per ton register. This, owing to the recent reduction of rates, was much less than it was a few years ago, when the receipts exceeded 32*d.* per ton. Still it was far greater than in Dublin, where the only dues on goods were those on timber and stone, and the total revenue per ton was only 7·32*d.* It had been argued that Dublin being to so great a degree a free port as regarded goods, was an encouragement to trade; but it was questionable whether this argument had not been pushed too

Mr. Stoney. far, as a very small revenue seriously limited the funds available for new works and tended to cripple desirable improvements. With reference to the proposed experimental dredging on the Mersey bar, he did not anticipate that it would have any material effect. There could be no doubt, however, that a great improvement could be brought about by adopting the principle of concentrating the scour, which in Dublin had more than doubled the former depth on the bar, having increased it from $6\frac{1}{2}$ feet to 16 feet at low-water.

Mr. Tapscott. Mr. R. LETHBRIDGE TAPSCOTT remarked that it was interesting to note how the older and smaller docks had been rendered more useful by an artificial means of increasing the depth of water, and by connecting them with the larger docks at the south end. This would prepare the way, in case of the future expansion of trade, for removing the intermediate quays and forming larger water spaces similar to those at the north end, and would thus enable the large ocean-going steamers of the regular lines to receive their passengers in dock, near the centre of the town, and avoid their exposure on the river by tender. The Author described the special features of the entrance to the new north docks, stating that it was decided to lower the level of the sill by 12 feet, and to maintain the necessary depth by means of sluices. Now this depth of 12 feet seemed considerable, and it would be worth while knowing if it was rendered necessary, by any change of natural level during the one hundred and eighty years for which actual data existed. This was the more important as the depth over the bar at low-water was now greater than it was known to have been at certain times. For, as the river walls straightened the course of the flow, and removed the little bays and sloping shores, the scouring effect of the ebb-waters must have materially increased, and should have had some effect in reducing the sandbanks. If the bar was considered as a reservoir dam, which simply kept the water in the river, then its maintenance was necessary to preserve the anchorage ground. If, however, there was a deep-water channel through the bar continuous with the anchorage ground, then any withdrawal of pressure, or severe wind storms and even under-currents, would tend to encourage an outward flow, and thus reduce the depth in the river at low-water, and endanger the usefulness of the anchorage ground, which would be a far more serious matter than the delay of ships waiting for water to cross the bar.

Mr. Thomas. Mr. JOSEPH THOMAS did not think the cranes in use at the Liverpool Docks would be suitable for discharging ships in the Royal Albert Docks, London; nor that the small quay space would be

of much service in unloading the general cargoes and carrying on Mr. Thomas. the work there. Tidal basins, in his opinion, without locks were only receptacles for mud, and not at all necessary; neither were basins with locks of any practical service, as the tidal basin of the Royal Albert Docks had not been used in that capacity for years, and only as an ordinary dock, the gates between the basin and the dock never being closed; and where a trade of such magnitude as at the Royal Albert Docks could be worked without difficulty, as many as twelve ships having been docked and undocked on a single tide, representing 32,700 tons, besides barges, a tidal basin was not wanted.

Mr. B. H. THWAITE believed it would be a useful measure of Mr. Thwaite. the efficiency of a dock system to compare the area of the docks, in acres, with the annual shipping tonnage; the rates arrived at would show the relative area of utility of the systems. It would be interesting if a comparison measured on this basis was instituted between the various British ports of the first magnitude. There was an impression, well founded or not, that many of the Liverpool Docks were practically useless owing to the enormous accumulation of silt in them and at their sills or entrances. With the exception of the general and admirable solidity of construction that characterized the docks of Liverpool, there was nothing that needed special comment. The main point of interest to the engineer was the sluicing arrangement devised by the Author. This arrangement, however, had a defect, which a little consideration would show it to be a serious one. Immediately at the commencement of the maximum velocity of the bottom, or ground currents of the flowing tide, just after high-tide, and the period of all others when the silt should be disturbed by the flow from the sluicing and raised into the swiftly-flowing currents, the head of water, in the catchment basin supplying the sluices, was so trivial as to be practically useless; and so the silt was removed a few feet farther into the river, not always even clearing the under surface of the pontoons carrying the St. George's landing stage. He thought the sluice principle was right, but that its application in this instance, was rather unfortunate. What was required to relieve the Mersey of the stigma of neglect, was the removal, not only of the accumulations of silt known as the Pluckington Bank, and the others that blocked up the entrances of the older docks, but of a part of the Mersey bar. Had such an obstacle interfered with a water-way of the same importance in the United States of America, it would long ago have been removed. He had suggested some years ago—in the Liverpool press—the utilization of an extension of the sluice

Mr. Thwaite. or hydraulic scouring principle to effect these objects. The idea had been successfully applied by the late General Stone in New York Harbour. It consisted essentially of the application of powerful turbines, placed on punts or barges, forcing water, at relatively high pressures, in numerous jets, obliquely and directly upon and under the surface of the silt, during the period only of the maximum velocity of the current at the bottom. The silt was thus raised into a state of suspension in the rapidly flowing currents, and was carried and deposited out at sea. By a persevering application of this nature he believed the Mersey bar and the silt accumulations would be reduced so as not to impede the progress of maritime navigation.

Mr. Wells. Mr. L. B. WELLS observed that the enormous trade, originating in the densely populated manufacturing district at the back of Liverpool, rendered anything affecting that port of much interest to the nation, the ocean-going traffic from the great harbour on the Mersey at times exceeding even that of London; whilst any improvement which would enable the port to be used during longer periods of the tide, for access and egress by ships of the Royal Navy, might in stress of war be of equal if not of greater importance. While every one was struck with admiration at the grand docks that had been constructed, and were maintained with so much skill, travellers and merchants were generally heard to complain of the delays to be encountered in using them, due in great measure to the condition of the bar, which was impassable by deep-draught vessels for several hours each tide; in fact, such vessels, when possible, avoided crossing on a falling tide, while on low neap-tides, when there was only a depth of 30 feet or a little more, at the top of high-water, it must be extremely hazardous for vessels drawing 25 feet to 26 feet, as some of the liners did, and still more for those ships of the Royal Navy, drawing 27 feet to 28 feet to cross at all even when there was no sea on. At all times deep vessels were compelled to leave the docks the tide before they went to sea, and to anchor in the river, a somewhat dangerous and inconvenient proceeding, and there embark passengers, and complete loading, in order to pass the bar at the top of the next tide; while steamers that had perfected their appliances, and, at great cost, raced across the Atlantic in a few days, lost as many hours in waiting for water; meanwhile collisions and disasters occurred which would have been avoided if they could have proceeded at once to their destination. These difficulties were on the increase, owing to the disuse of subsidiary channels of approach; this had been brought about in part by the deterioration of those channels,

as well as by the fact that ships had increased in size and draught Mr. Wells. of late years. The lighting and buoying of the sea-channels was well attended to, and necessarily so, for during the short winter days the Mersey bar could only be crossed by deep ships in the hours of darkness. The average daily traffic in 1888 in and out was one hundred and nineteen vessels; of these one hundred and two used the Queen's Channel, giving a total of thirty-seven thousand per annum; some six thousand passed by the Rock Channel, chiefly coasters, and only three hundred by the Formby Channel; the total number reaching forty-four thousand in and out, and this had been exceeded in former years. The necessity of improving the approach to Liverpool had often been before the Dock Board, and the late Mr. Laird, M.P., urged his colleagues to take action so long ago as 1874, when he stated that the depth of water on the bar was 7 feet to 8 feet, whereas it had been 12 feet previously. The normal depth that might be allowed for appeared to be about 9 feet, and meanwhile deep-water docks and entrances were being multiplied in all the chief ports, and in Liverpool upwards of 110 acres of additional water space had been provided in docks with sills deeper by 3 feet than any that were built on the Liverpool side prior to 1881; these were the busiest portion of the dock estate, and showed a far greater necessity for dealing with the bar than existed formerly. The whole trade of Liverpool suffered, for even coasting steamers trading to Ireland and Scotland were obliged to fix their "time bills" to suit the tides, and no regularity of train or steamer service was possible in connection with sea-going traffic. Such beneficial results had been obtained elsewhere from the regulation of tidal rivers, including the bars at their entrances, and in this country on the East Coast more particularly, that it could no longer be conceded to be a wise policy to leave the Mersey bar to Nature or chance. The undertaking was no doubt a great one; but the interests to be served were proportionately great, and demanded that an equivalent effort should be made. Great caution must be exercised, and rash attempts avoided; but, that the prodigious force embodied in a tide with a range of 30 feet flowing at 4 knots an hour, and in volume 500,000,000 cubic yards, could be compelled to do useful work, in a channel duly regulated with that object in view, must be admitted. Inside the bar, where a channel was confined by high sand-banks or narrowed by the Lancashire and Cheshire shores, the depth was 50 feet at low-water. The effect produced by the dock walls on either side pointed to the same conclusion. Formerly, exclusive of the Eastham Channel, there

Mr. Wells. were two channels leading to the Upper Mersey between Hale Head and Dingle, shown in the chart of 1835. These had become merged into one channel for many years, and an improved navigation to Runcorn was the result, so that vessels of far greater burden could navigate it. The direction of the main seaward channel had been much more stable since the Queen's Channel opened out, resulting no doubt from the training of the currents opposite Liverpool by the construction of the dock walls. Old surveys of Liverpool Bay were in existence, and surveys were now made at short intervals, and it did not appear that the total quantity of sand differed widely over long periods. The sand was silicious, not calcareous; the accumulation was in the main due to the subsidence of the land in perhaps not very remote periods. There was evidence of such a sinking in the Wirral district of Cheshire having taken place since the Roman occupation, and tree-trunks were found under the foreshore on the Lancashire side. The amount of fresh water entering the estuary was comparatively small, and so would be the detritus; and the latter would be greatly diminished when the Manchester Ship-Canal was made, in which much of it would settle. It was therefore the existing sands and the recurring tides that had to be dealt with. The Author pointed the way when he congratulated himself on the Rock Channel having a rock bottom which would not become deeper. Why should not this channel be closed and the Formby Channel also, thus concentrating the scour on the main channel. The proposal to dredge the bar was believed to be futile; harrowing was tried on the bar many years ago, by Admiral Denham, and more recently in the channel near Runcorn by Mr. Leader Williams, but abandoned as useless; sand that had been deposited by the elements, while the controlling conditions remained unchanged, would assuredly be deposited again. Prior to 1842 the conservancy of the Mersey, as well as the docks, was in the hands of the Corporation of Liverpool. At that time an enquiry was held with the result that the conservancy of the Mersey was vested in three Cabinet Ministers, namely, the First Lord of the Admiralty, the President of the Board of Trade, and the Chancellor of the Duchy of Lancaster. They appointed an Acting Conservator, whose salary was provided by the Mersey Docks and Harbour Board, and this officer watched the estuary, and made an annual report, which was printed under the authority of Parliament. The present Acting Conservator, Admiral Sir George Richards, was well known as a surveying officer, and a former hydrographer to the Admiralty. The ministers had no funds at

their disposal, and were powerless to take action; they were, Mr. Wells, however, in a position to prevent injurious action being taken by others. They could very properly set on foot another public enquiry after the expiration of nearly fifty years since the last one was held, and at a time when the due completion of the Manchester Ship-Canal was within measurable distance, and provide that the entire question of the Conservancy of the Mersey, which was now involved in their own powers, those of the Mersey Docks and Harbour Board and the Upper Mersey Commissioners, should be reviewed and re-adjusted on a basis more suitable for the requirements of the estuary, and of the interests involved. A clearly defined authority should be made responsible for the condition of the sea-channels. The late Chairman of the Mersey Docks and Harbour Board disclaimed any responsibility resting on his board. If that was so, H. M. Government must be held responsible, and the people of Lancashire and the north-western counties should seek that conjointly with the improvement of navigation inland, steps should be taken to carry this to seaward also. When in addition to the £17,000,000 sterling spent on the Mersey Dock Estate, an additional £8,000,000 had been laid out for navigation purposes on the Manchester Ship-Canal, and a largely increased industrial population was located on the banks of the canal, the necessity for dealing with the bar would become, if possible, more urgent than heretofore. He looked upon the question of the improvement of the Upper Mersey as shelved by the construction of the Manchester Ship-Canal. He had known this estuary from 1865, when Resident Engineer at Runcorn Bridge, and being subsequently employed at Ellesmere Port, Garston and Weston Point. The Ship-Canal would accommodate all the Cheshire side and through traffic, while the Widnes trader had obtained clauses from the Ship-Canal Company. They had a traffic of some million tons per annum; but this of itself would not warrant the outlay necessary for the improvement of the upper estuary.

Mr. W. H. WHEELER observed that, amongst the various works Mr. Wheeler. carried out by the Author, he was most struck with the successful results attending the sluicing arrangements for clearing away from the entrances to the docks the sediment brought in by the tides. The upcast pipes, with disks for spreading the water, at the entrance to the Langton Docks, at the part beyond the reach of the wall sluices, were especially ingenious. The satisfactory results of these sluicing arrangements confirmed the idea, that he had long held, that the transporting power of water might be more

Mr. Wheeler. frequently applied to the removal of deposit than was the case, and he ventured to throw out a suggestion whether this principle could not be still further applied to the removal of the shoals along the river wall, which obstructed the entrance to the docks at the north end; and whether the sluicing operations for the removal of the Pluckington Bank could not be aided by mechanical erosion. He had recently been carrying out some practical experiments to test this theory for the removal of shoals. After a number of trials, with models of different forms, he had succeeded in obtaining an eroder which, while absorbing a small amount of power to work it, thoroughly disintegrated the material operated on, churned it up, and mixed it so completely with the water, that, while the effluent stream became only in the same turbid condition as when a land-fresh was coming down, it yet removed an immense amount of material. The machine, as temporarily arranged for experimental purposes, consisted of an ordinary barge, capable of carrying about 30 tons. At the stern of this was fitted a wooden frame, capable of being raised or lowered by a winch on board. This frame carried a vertical shaft having at the lower end the eroder, and at the upper a bevel-wheel driven with belting by a 6-HP. portable engine. The eroder revolved at the rate of 120 revolutions a minute. The barge being moored a-head was warped backwards and forwards by side-ropes worked by a winch, over a space from 50 to 60 feet in width, and also gradually worked a-head against the stream. The machine thus arranged was set to work on a shoal which had been gradually accumulating along the jetty at the entrance to the dock under his charge at Boston. The shoal in places had risen to 8 feet above the sill of the dock, and extended out 50 feet into the channel. It consisted of clayey silt, so compact that the water from the sluices used for clearing the entrance had no effect on it. Owing to its position, the short time at which a dredger could work at it, and other circumstances, the removal of a portion of this shoal had previously cost at the rate of 1s. 6d. per barge-ton. Working three tides, or twenty-one hours in all, the eroding dredger removed 1,500 tons, at a working cost of £4 6s. 6d., equal to 0.75d. per barge-ton, or 1.10d. per cubic yard *in situ*. The saving effected in the removal of this quantity on the old method more than repaid the whole cost of fitting up the machine, which was about £75. It had since been employed in removing the rest of the shoal, and also in lowering the approach-channel, the bottom of which was hard boulder-clay mixed with chalk and stones. The eroder disintegrated the clay, and mixed it with the water in the form of the finest mud. The

entrance being off the main channel, the velocity of the current Mr. Wheeler. was only from $\frac{1}{2}$ to $\frac{3}{4}$ mile an hour, increasing to $1\frac{1}{2}$ mile an hour in the main stream. Very careful soundings since taken showed that the whole of this sediment had been carried away by the ebb-current, and deposited in the estuary, none being left in the river. The quantity of matter in suspension in 1 cubic foot of water, at 10 feet from the eroder, was 2,424 grains, this proportion rapidly diminishing as the distance increased, and the particles became more distributed, the quantity of solid matter in suspension at 100 yards being only 67 grains per cubic foot. He would suggest, as worthy of consideration, whether this system could not also be applied to the removal of the bar of the Mersey, and the transporting power of the ebb-tide utilized for removing the sand of which it was composed. A machine designed on this plan would, he thought, be more effective in its results than the propeller sluicing adopted on the Columbia river;¹ its frame and eroder, being capable of being raised or lowered, could work effectively for a longer time than the propeller of a steamer. The frame of the eroder also being balanced, and its effect reaching some distance beyond its actual contact with the material, it would not be affected by a slight lift of the sea in calm weather at the bar of the Mersey. The machine was of a very simple character; the cost of a boat constructed for the purpose, with eroding machinery complete, he estimated would not exceed £1,500; and basing the cost of working on what had been found practicable by experience, say 1*d.* per cubic yard for the material *in situ*, the removal of 500,000 cubic yards, as was now suggested, from the bar of the Mersey, would amount to £2,083, or a total cost of £3,583, as against £10,000, the estimated cost of raising the sand by the machinery which the Mersey Docks and Harbour Board proposed to experiment with. With regard to the Author's contention, that the maintenance of the Mersey as a great tidal receptacle mainly depended on the roving character of the channels, and their incessant wanderings through the wide expanse of sand in the upper estuary, his experience of rivers passing through sandy estuaries was in direct variance to it. He had found, as the result of works with which he had been connected, and others which had come under his direct observation, that by fixing channels passing through sandy estuaries in one place, and so preventing this roving tendency, their depths and capabilities for navigation had been greatly improved. All the rivers which discharged through the sand at the

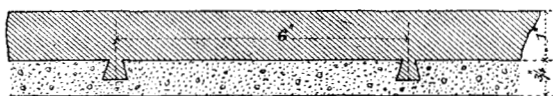
¹ Minutes of Proceedings Inst. C.E., vol. lxxxiii. p. 386.

Mr. Wheeler. head of the Wash on the East Coast had been benefited by being trained and fixed in one course. Formerly, the tides and fresh-water currents were perpetually stirring up this sand and loading the water with detritus. The tide thus came up the river charged with sediment, which in the absence of freshets in summer was left on the bed of the river, raising it several feet. In winter the energy of the freshets was absorbed in removing this deposit, and in stirring up the sand. Since the training, the tidal water came up clear, and there was no deposit in the river. The freshets carried the alluvial matter with which they were charged away to sea, and exercised their energy in clearing and deepening the navigable channel, instead of transporting the sands from one side of the estuary to the other. It appeared to him that, making both the tidal and fresh water in the upper estuary of the Mersey pass up and down one deep defined channel, free of deposit, would have more effect in keeping open the sea-channels than if loaded with the detritus derived from the constant frets and stirring up of the sands. The training of the channel would not create any fresh material. The sands would no doubt become fixed, and the bed of the estuary raised, and even perhaps grassed over for a certain limited area; but it would not necessarily follow that there would be less cubic capacity for the tidal water; the loss in the higher part would be compensated by the increase over the area lowered by the transport of the sand to the part raised. Any decrease of tidal capacity could only arise naturally from sand brought up by the tides from the sea, or by alluvial matter brought down by the rivers, and in either case deposited and permanently left in the estuary. A deep defined stream would be more capable of carrying back sand thus brought up by the tides, or of transporting to the sea alluvial matters brought down by the rivers, than a shallow stream wandering about the estuary loaded with the silt disturbed in its course, and thus it would be more effective in preventing permanent deposit, and preserving the capacity of the estuary as a tidal receptacle. While fully agreeing with the Author that tidal water brought into an estuary was of great value in maintaining sea-channels, and that any works likely to curtail the amount of such water ought to be watched with jealous care, yet the principle might be carried too far. A better result could frequently be attained by judicious training, and causing the tidal water to concentrate its energy and exert its power with the greatest effect, than by preventing improvements by a policy of non-interference with the natural condition of an estuary.

Mr. Lyster. Mr. G. F. Lyster, in reply to the correspondence, referring to

Mr. Carr's inquiries, said that the harbour-master's ordinary staff Mr. Lyster. of dock gatemen were all on duty at high-water of every tide, but at other times few of them were on duty, so that the running of the sluices where these were numerous was generally looked after by a special staff of "water-runners." Of course, in the Langton Dock, as in all the Liverpool Docks, more especially those opening direct from the river, there was a large deposit of mud, which had to be removed from time to time by dredging. The dock gates on the Mersey were now built entirely of greenheart, which had proved in every way a most excellent material for the purpose. The coating on the inside of the cast-iron sluicing culverts was of Portland cement mixed with fine gravel, the layer being $\frac{3}{4}$ inch in thickness. It was secured by annular dove-tailed ribs 6 inches apart, *Fig. 4*. Examination, from time to time, showed that the condition of the pipes continued perfect. No trouble had been experienced from silt within the sluicing-pipes. The rush of water in the pipes prevented any deposition of silt within them, and the frequent use of the sluices cleared them of any ordinary

Fig. 4.



deposit, no other means of clearing any of the pipes had been necessitated. He could not quite follow Mr. Thwaite in certain of his remarks. As regarded the idea which Mr. Thwaite seemed to entertain, that many of the Liverpool Docks were practically useless, owing to the enormous accumulation of silt in them and at their entrances, he did not know to what this could refer unless to the Pluckington Bank, which, as stated in the Paper, extended in front of the Southern Docks, and which he had taken in flank by providing deep-water entrances at the extreme south end, from which the older docks could be approached. Certain of those docks were now impounded over neap-tides, and their depth was maintained where necessary by pumping from the river. This impounding scheme had brought into full use as deep-water docks a group 50 acres in area, and having 2 miles of quayage, which, but for such an arrangement, would have comparatively gone out of use for deep ships. A similar system of impounding had been adopted at Birkenhead, affecting about 150 acres of water-space, and 8 miles of quayage, and this would shortly come into full use.

Mr. Lyster. He hoped to contribute a Paper on the subject of these impounding and pumping systems at some future date. Again, as regarded sluicing, neither at the Canada Basin nor at the landing stage had a bank been formed by the action of the sluices, as might be inferred from Mr. Thwaite's remarks. He failed to see the meaning of the word "unfortunate" in this connection. The circumstances attending the successful working of the landing-stage sluices had been fully set forth in a Paper¹ communicated to the Institution by Mr. W. H. Le Mesurier in 1887, to which there was nothing to add except that, amid the many variations of the Pluckington Bank, the stage continued to be maintained in safe working condition. Mr. McConnochie had referred to the inconvenience of having the shed so near the dock as was generally the case at Liverpool. To this he would reply that for most cargoes the balance of convenience seemed to lie with this arrangement, although in some exceptional instances, such as where large cases or pieces of machinery had to be put aboard a ship, it might be desirable to have a wider margin. There could be no doubt, however, that the desire of the parties working the cargo was to get it under cover as soon as possible. As regarded the speed of working of the roof-cranes, he did not think the extra length of crane-chain practically diminished the rate of speed of working. As a matter of fact, the crane could work much faster than the cargo could be unstowed and slung. He had rather understated the average rate of work of the cranes. The returns for two years showed that the average number of lifts per working hour during that time was thirty-three; of course in many of these hours the rate was much higher. It was to be borne in mind that the weight lifted each time was generally much higher than in the case of steam-winchies, or such appliances. It was usual for these 30-cwt. cranes to lift more than a ton each lift. The cranes were designed to make ninety lifts an hour, and could do so if the stuff were slung and unslung with sufficient rapidity. Their position did not, in his opinion, in any way involve slow working. With regard to the remark that the small quay-space would not be of much service in unloading the general cargoes and carrying on the general work of the Albert Docks, London, one of the double-story sheds at Liverpool gave a covered floor area having a total width of over 180 feet, which could not be considered a narrow quay-space; and in fact there were few, if any, ports in which so much quay-space could be obtained. For the service of the double-story sheds, say 3,000 feet in length, twenty cranes of

¹ Minutes of Proceedings Inst. C.E., vol. xc. p. 308.

30-cwt. power were provided. As to the seniority question of Mr. Lyster. Liverpool *versus* London, it appeared from the evidence adduced by Mr. McConnochie, that at the date of the writing of the notice quoted, which date was not given, the Howland Great-Wet Dock had two pairs of gates, and although it was not distinctly stated that in 1703 (at least nine years before the notice was written) or in 1715, both of which dates were mentioned, the dock had gates, he supposed, in the absence of evidence to the contrary, the dock was at these times in the same condition as at the date of the notice. If it were so, the claim of the Liverpool Old Dock, for which the Act was obtained in 1709, and which was opened in 1715, to be regarded as the first wet-dock, could not be sustained. With respect to the Liverpool Datum, as to which an inquiry had been made, the depth of water on the Old Dock Sill was the readiest and most useful measure of the tide, so far as it affected the shipping; and as other docks were constructed their sills were also referred to the Old Dock Sill, which was thus established as the local datum. There would not be any advantage in adopting a different datum. The Ordnance Datum was a level decided on from tidal observations made at Liverpool in 1844, and was the mean level of the sea at Liverpool during those observations. He might say, in passing, that it appeared from subsequent and more extended observations, that the mean level of the sea was considerably higher than the Ordnance Datum. He could scarcely add anything further in respect to the bar. The depth of water on the bar was never quite constant, though for many years there had always been a depth of about 10 feet, more or less. The latest chart issued by the Marine Surveyor of the Board, that of 1890, showed a depth of 12 to 13 feet on the bar. This was from a survey made in August 1889. With all due respect for Mr. Cunningham's experience in the Tay estuary, he could not agree that the work of deepening the bar of the Mersey would be by no means a very difficult, costly, or hazardous operation. He fully appreciated the value of "eroders" or "disturbers" for assisting in removing accumulations of silt; but their application at New York had not been the success which Mr. Thwaite seemed to think. The "hydraulic plough," the form of disturber tried at New York, had failed to do the work for which a contract was taken by those interested in it; and the improvement in the channel of New York Harbour had been brought about by the use of sand-pumps alone. Again, he could not concur with Mr. Thwaite in referring to the Mersey bar, that "had such an obstacle interfered with a waterway of the same importance in the United States of America, it

Mr. Lyster, would long ago have been removed." The New York sea-channels, of not less importance than those at Liverpool, and the condition of which presented most grave obstacles to vessels of deep draught, had only within the last few years been seriously attacked, although in Mr. Lyster's opinion presenting a much less difficult problem to deal with than Liverpool, and although the port of New York brought a revenue in Customs dues and otherwise, compared with which that of the Mersey Dock Estate was but a trifle. There could be no doubt that the question of amelioration of the bar was a large one, and not to be dealt with rashly.

21 and 28 January, 1890.

SIR JOHN COODE, K.C.M.G., President,
in the Chair.

The discussion on the Paper by Mr. G. F. Lyster, on "Recent Dock Extensions at Liverpool," etc., occupied both evenings.
