Discussion.

Sir JOHN WOLFE BARRY, K.C.B., President, was sure the Institution would be gratified at having on its Minutes a description of such a highly interesting and monumental work as the Manchester Ship-Canal. It was a work which required the greatest pluck and tenacity to carry to a successful issue, and much ingenuity and large resource to deal with the various eventualities and casualties which had taken place during its construction. He thought the Members would admit that the mode of execution of the work reflected great credit both upon the profession of the Civil Engineer and upon the contractors, and would congratulate Sir Leader Williams and his able assistants on being able to give so excellent a description of the work achieved. It must be a great pleasure to be able to contemplate the work as an engineering enterprise. At the same time they could not but feel much regret at the circumstance that their Past-President, Mr. Abernethy, had not lived to hear the work described before the Institution to which he was so closely attached. He should only be speaking the minds of all the members if he offered, in their name, to Sir Leader Williams, Mr. Whately Eliot and Mr. Meade-King their hearty thanks for the contribution they had made to the Minutes of the Institution. Sir John Wolfe Barry.

Sir LEADER WILLIAMS regretted that the length to which the Papers had already grown had prevented his dealing more fully with the estuary question; but he hoped on a future occasion Mr. Hunter, who had succeeded him as Chief Engineer to the Manchester Ship-Canal, might present to the Institution an account of this important subject. It was well known that the tidal openings, provided in the original scheme, had been found to act injuriously by bringing in silt from the river. In accordance with the Parliamentary powers obtained in 1896, the openings had been closed, and the relation between the heights of the water in the canal and in the estuary, before and after the closing, was very interesting. The tidal portion of the canal was now filled through the entrance-locks and sluices at Eastham after the tide rose above the ordinary water-level of the canal, 14 feet 2 inches above Old Dock Sill datum at Liverpool. This tidal water was returned again to the estuary through the sluices at the Sir Leader Williams.

Sir Leader Williams. River Weaver and at Randle's Creek. He desired to acknowledge the valuable assistance he had received from Sir Benjamin Baker, in addition to the staff of Resident Engineers, who had all worked well together, and without whose harmonious co-operation so great a work could not have been carried out.

Mr. Pilkington. Mr. WOODFORD PILKINGTON thought the Papers, relating as they did to the canalization of one of the most important rivers and estuaries in England, and throwing much light on the system of canalization which should be adopted all over the world, would be of great value to engineers. According to the original scheme, training-walls, running out into the multitudinous sand-banks of the Mersey, were to be constructed, but they had not been approved, and the channel had been laid down, as shown in the Papers, along the southern side of the estuary. He thought mention should have been made in the Papers of the name of the late Captain J. B. Eads, M. Inst. C.E., who had been brought forward by the opponents of the canal to show that it was not a possible work, but who had afterwards given his opinion that, if the canal was not led out into the estuary but was taken down to the south and brought out, as at present, by the locks at Eastham, the work would be a success. The testimony of Captain Eads, which, he thought, had been instrumental in throwing out the Bill, had, however, been considered the following year by the promoters, when they turned the channel to the south. It would, therefore, have been but just to associate his name with the work. He did not wish to detract from the great credit due to the engineers of the undertaking. It was impossible to have foreseen all the difficulties encountered, and although the canal had been a failure, in a commercial sense, Sir Leader Williams deserved all praise for the energy and perseverance he had exhibited.

Mr. Hunter. Mr. W. H. HUNTER, who had, for 15½ years, been closely connected with the work under review, first as Chief Assistant Engineer and latterly as Chief Engineer, desired to offer, as far as he fittingly could, some correction upon the observations of the last speaker with regard to Captain Eads. Those who knew Captain Eads, and valued him, would agree that, had he been alive and present, his first observation would probably have been, "Save me from my friends, and leave me to deal with those who may take an adverse view of my proceedings." Expression had been given by Captain Eads before a Committee of Parliament, in common with many others in England and elsewhere, to predictions which had received the support of other engineers of great eminence, with the result that the unstable mind of that Committee of

Parliament had been disturbed; so that its members had declined to follow the course of the Committee of the first House (which had passed the Bill for the canal works) in 1884, and had thrown out the Bill. He thought that Captain Eads' suggestion as to the canal on the Cheshire shore had been derived from a plan on the wall of the Committee-room; he did not think Captain Eads claimed any credit for it. That suggestion had been worked out by the promoters in the first instance, by Mr. G. F. Lyster, M. Inst. C.E., of the Mersey Dock and Harbour Board in the second place, and Captain Eads came in the third place and adopted it, simply because it stared him in the face on the wall. With regard to Sir Leader Williams' reference to the question of the estuary, he hoped to be able, in a future session—perhaps the next session—to ask the Council to permit him to deal with the matter of the tidal openings in the canal and with the estuary generally. The matter was more or less at present *sub judice*, and as an official of the Manchester Ship-Canal, he could only say he would do his best at a future day to show that the works as projected in 1883 and 1884 would not have been the disastrous failure that had been suggested. The last speaker had referred in all friendliness, and apparently in compassion, to what he called the financial failure of the canal works. It would be a disastrous day for the Institution when its members felt themselves able to shut their eyes to the fact that, however great the success of an engineering work might be, the commercial success had been of a negative character. Anyone who knew Manchester 15 years ago would bear him out in saying that on every side it then presented the appearance of incipient decay; and anyone who knew Manchester to-day would bear him out in saying that it had renewed its youth—that there never was a city in which there was so little appearance of decay of any kind. He claimed that the change had been due to the Manchester Ship-Canal. A very candid friend —one of those whose criticisms were most searching—in summing up the benefits and the cost of the canal to Manchester, had estimated the benefit derived by that community from the canal, directly and indirectly, for the year 1896 at £800,000. A much higher authority, Mr. Reuben Spencer, than whom no man was better able to form an opinion, had said that was not enough. He maintained from figures which he was prepared to give, that the benefit amounted to at least £1,000,000. Therefore, whatever might be the present financial position of the Company, he hardly thought that the construction of the canal could be described as a commercial disaster. The cost of the canal had been a subject of

Mr. Hunter.

Mr. Hunter. wide discussion. Approximately accurate and authentic figures as to the real cost of the works were given in the following Table :—

	£	£
Canal proper, including excavation, pitching, sea-walls, embankments, drains, soiling, fencing, &c.		4,650,000
Manchester Docks, including excavation, walling, hydraulic machinery, dock-sheds, Trafford Bridge, roads, railways, &c.		1,010,000
Locks—		
Eastham	210,000	
Weston Marsh, Weston Mersey, Bridgewater, Runcorn	320,000	
Latchford	180,000	
Irlam	180,000	
Barton	160,000	
Mode Wheel	160,000	
Walton, Stockton Heath	32,000	
		1,242,000
Roads, swing-bridges, high-level bridges, and Barton aqueduct		385,000
Railway deviations		875,000
Subsidiary works, including Weaver and Randle sluices		358,000
		8,520,000

The Parliamentary estimate, leaving land out of the question, was £6,300,000, but that estimate was for a very different canal from that which had been constructed. In the first place, the Committee of the House of Commons, presided over by the late Mr. Forster—the Committee which finally passed the Bill—thrust the line of the canal inland, instructing the promoters to take advantage to the full of the limits of deviation on the landward side. It thrust the line in many places into a series of high cliffs, thus largely increasing the cost of that difficult estuary section. Many works also were imposed upon the Company by outside bodies. The Commissioners of the Mersey required, for instance, or, at any rate, desired, that reverse gates should be added to each of the locks at Eastham. That requirement had cost the Canal Company about £100,000, and the gates had never been moved since they had been constructed. Those who remembered the plan of 1885 would know that the dock system at Manchester was entirely different from that which had been carried out. An amending bill had been applied for, and in 1888 docks had been constructed with about three times the water area and five times the quay space of those proposed in 1885 and included in that year's estimate.

Mr. Hunter.

Again, owing to the death of Mr. T. A. Walker, the contractor for the whole of the works, the Directors of the Company, after a great deal of negotiation, agreed to take the works over on the 1st November, 1890, from Mr. Walker's executors. On the 20th November, 3 weeks after they had assumed the entire responsibility of the works, they experienced in the Mersey and Irwell valleys a flood the like of which had not been seen for quite a century. He had studied the matter as closely as possible, and with all the figures from time to time before him he had arrived at the conclusion that that flood had cost the Manchester Ship-Canal Company a million of money. If those facts were considered, with the fact that the actual cost of the works had been £8,300,000, and that the Parliamentary estimate was £6,300,000, engineers who understood the contingencies naturally attaching to the execution of public works, would agree that £2,000,000 was not an extraordinary increase over the estimate. It should be remembered that the work had not cost double or three times the amount of the estimate. With regard to the construction of the work, he would say at once that he considered that one or two mistakes had been made in carrying it out. So far as the estuary embankments were concerned, after all the experience he had had of them, he hardly knew whether he should suggest any serious change. He thought he should revert to the original suggestion, and make the outer slope 1 to 1 instead of $1\frac{1}{2}$ to 1. That, again, had been imposed by the Commissioners of the Mersey, who thought the $1\frac{1}{2}$ to 1 would be an improvement, and the promoters gave way. There had been no difficulty with regard to the embankments, but from what he had seen and known of them, if he had to do the thing again, he should revert to 1 to 1 on both sides. Also, if he had to undertake the canal again, or to make a similar one, he should not adopt the system of slope protection in the cuttings that had been carried out. It would be seen from the sections that a heavy stone pitching was carried from the bottom of the canal to about 10 feet above ordinary water-level. He should abandon that stone pitching, and should form, about 5 feet below the level of ordinary water, a berm about 6 feet wide. He had had a number of experiments made as to the effect of the wash, and he had never found any effect at a depth of 4 feet below the surface of the water. From that level of 5 feet below the water he should form a slope of about $1\frac{1}{2}$ to 1, protecting it with stone, the berm being solely for the purpose of providing a footing for that stone. Above that, for a height of about 5 feet, he should form a steeper slope of

Mr. Hunter. about 1 in 3, and should protect that with stone; 5 feet above and 5 feet below the water-level was the only protection he should suggest. In the first place the stone pitching had cost nearly £300,000; in the second place, with the large twin-screw steamers now in vogue, the pitching presented an element of danger to navigation; and in the third place—he was speaking from the bitterness of experience—in such a canal as that, where already works were developing at a somewhat rapid rate, the stone pitching had been a great difficulty when it became necessary to construct quays or wharves on the side of the canal. If, therefore, he were doing the work again, he should abandon the stone pitching so far as the extension to the bottom of the canal was concerned. Reference had been made to the "canalization" of rivers, and Mr. Pilkington had said that he thought that from the point of view of the "canalization" of rivers, something was to be learnt from the Manchester Ship-Canal. The canal for 21 miles—namely, from Eastham to Latchford—was a semi-tidal canal; he referred to the matter because the distinction did not appear to be commonly understood. At high-water all the gates of Eastham lock opened, and it was an open cut from the sea. From Latchford locks, where the tidal influence ended, to Rixton Junction, where the River Mersey left the canal, it was a canal. For 9 miles, namely, from Rixton Junction to Mode Wheel locks, it was a canalized river. From Mode Wheel locks to the end it was a system of docks. Therefore there was only a length of about 9 miles or 9½ miles as to which one could speak of the Ship-Canal as bearing upon the subject of the "canalization of rivers."

Mr. Vernon-Harcourt. Mr. L. F. VERNON-HARCOURT had listened with astonishment to the remarks of Mr. Pilkington with regard to Captain Eads having thrown out the Manchester Ship-Canal Bill. He had heard Captain Eads give his evidence before the House of Commons' Committee on the Bill in 1884, and although he was on the same side with him, his evidence had not impressed him. He had a great respect for Captain Eads as the engineer of the St. Louis Bridge and the jetties at the mouth of the Mississippi, which had proved remarkably successful undertakings; but he thought it was quite a mistake to say that Captain Eads had any particular influence in throwing out the Bill of 1884. The statement that Captain Eads had originated the idea of a canal along one shore of the estuary was, he believed, equally mythical. The same gentleman had spoken of the canalization of the estuary; but the Manchester Ship-Canal was merely a lateral canal with a tidal influence. When the tide rose more than 14 feet 2 inches above the Old Dock Sill, it flowed up

the canal; but except for that, it was an ordinary canal by the side of the estuary. Mr. Hunter, whose remarks he was very glad to hear, had mentioned some things that he would not do again if he had to carry out the works. No doubt a berm was introduced on the slopes of most large ship-canals. It was adopted at the Amsterdam Ship-Canal, the Suez Canal, and the Baltic Canal, and undoubtedly it had a great influence in diminishing the wash, which was so dangerous to the banks of every canal where vessels passed at high speed. A berm, however, involved additional work, because to that extent it widened the embankments and the cuttings; but he thoroughly agreed with Mr. Hunter in thinking it preferable to have a berm, except possibly in the deep cuttings, to carrying the pitching so low as in the case of the Manchester Ship-Canal. In most cases the wash extended only a short distance below low water, and also, naturally, for some little distance above the water, on account of the wave constantly seen in narrow channels following the vessels and breaking on the bank. He was sure the members would all be glad that the Papers had been brought before the Institution. It was a matter of regret that some works of great importance had been carried out in the United Kingdom of which no Papers giving full descriptions of the works had been presented to the Institution. He referred especially to two—the Severn Tunnel and the Forth Bridge. No doubt the reason of the engineers for not giving Papers with regard to those works was that the late Mr. Walker had written a book upon the Severn Tunnel, and that several accounts had been published on the Forth Bridge. He thought, nevertheless, it was a matter of great regret when any important works were carried out in the United Kingdom, that there should not be a full record of them in the Minutes of Proceedings of the Institution. With regard to the cost of the canal, that was a subject to which he did not like to refer; but he thought that one thing ought to be said with regard to a point not brought forward by Sir Leader Williams, viz., that in the three sessions in which the Manchester Ship-Canal Bill was before Parliament, 1883–84–85, there was not a single question raised with regard to the sufficiency of the estimates, notwithstanding the great opposition offered to the scheme. Anyone who had been on the canal would know how different the work was from that which received the sanction of Parliament in 1885. There were no Weaver sluices in the scheme of 1885, the Eastham locks were much smaller, and, as Mr. Hunter had said, the docks were of quite a different character. There

Mr. Vernon-Harcourt.

Mr. Vernon-Harcourt.

was one reason given for the increased cost that he did not quite understand, and he should like to ask Sir Leader Williams for an explanation of the paragraph in his first Paper stating that for 20 miles the water-level had to be lowered, causing a large addition to the amount of excavation. He had never heard of the water-level of the canal having been lowered from what it was proposed to be in 1885. Referring to the deposited plans of 1885, and the longitudinal section of the canal as executed, given him by Sir Leader Williams, he could not see that there had been any change made in the level of the bottom or the water-level of the canal. Though the cost had been so much greater than was expected in the first instance, everyone would admit, who had had any communication with persons connected with Manchester, that the trade of the city had received a great deal of indirect benefit from the canal by the lowering of the railway rates and the alternative route provided by the canal. The great novelty in the canal, and therefore a question of the greatest interest, was the tidal portion between Eastham and Latchford, 21 miles in length. He did not know of any other canal which became tidal in exactly the same way, because in most cases a regulating lock was put in to prevent the tide flowing in and out. That was the case in the Baltic Canal, where a regulating lock with reverse gates was placed at each extremity; and the same course was followed at the Amsterdam Ship-Canal, and the Loire Estuary Lateral Ship-Canal. The Suez Canal and the Corinth Canal were, indeed, open canals; but the currents through them, in the almost tideless seas into which they emerged, were mainly produced by the wind raising the sea-level more at one end than the other. In the case of the Suez Canal, the rise of spring-tides was only 11 inches at Port Said, and $4\frac{3}{4}$ feet at Suez, which latter rise died out so quickly in ascending the canal, that the tidal rise at springs in the Bitter Lakes was only $\frac{3}{4}$ inch. In going along the Suez Canal, he had observed a decided current running past the buoys marking the deep channel. The currents, however, in the canal were mainly due to the wind, which, being northerly between May and October, raised the sea-level of the Mediterranean at Port Said, and lowered the Gulf of Suez, thereby producing an almost continuous current from Port Said to the Bitter Lakes, and from the Bitter Lakes to Suez; whilst during the other half of the year, with the prevalence of southerly winds, the current was reversed, causing a very large influx of water into the Bitter Lakes from the Gulf of Suez, and an almost continuous outflow during January and February from Lake Timsah into the

Mediterranean. The special peculiarity, therefore, resulting from the Suez Canal being perfectly open, was the existence of currents in opposite directions according to the changes in the prevalent winds at certain seasons, which were merely modified to a certain extent by the small rise at spring-tides. On the contrary, the peculiar feature in the Manchester Ship-Canal, between Eastham and Latchford, was the rapid raising and lowering of the water-level of the canal at spring-tides, as well as the currents thereby produced in the canal. At high springs the tide rose 7 feet above the normal water-level of the canal at Eastham in $1\frac{3}{4}$ hour, and not merely filled the canal formerly up to this level with the help of the tidal openings, but actually raised the water-level of the canal about $9\frac{1}{2}$ feet above the ordinary level at the Latchford end of the tidal reach, about $\frac{1}{2}$ hour after high water at Eastham, 21 miles further down the canal. The canal also was lowered again to its normal water-level throughout in about $2\frac{1}{2}$ hours after high water at Latchford. This very rapid tidal oscillation had no parallel in any other canal. He had been specially interested in that portion of the Papers dealing with the embankments. It was evident that great difficulties were experienced in constructing the estuary embankments upon the uncertain foundations and in the old channels of the Mersey estuary, which were always so difficult to deal with. In hearing of the difficulties experienced in constructing those embankments, he had felt doubtful whether Mr. Forster's line, throwing back the canal, was really of so much detriment in regard of cost to the canal as had been supposed, because setting it farther back into the land gave a better chance of obtaining good foundations. In 1885, the year in which he first supported the Ship-Canal, when the Company had ceased trying to obtain authority to make a channel through the estuary with training walls, and proposed to carry the canal along one side so that it did not interfere with the estuary—one of the arguments raised by the opponents was that the embankments along the side of the estuary would have the same effect as two training walls in the middle of the estuary, and would cause the channel, instead of going rather towards the Garston side, to be permanently fixed on the Cheshire side of the estuary. The low-water chart of that portion of the estuary showed that the channel had not gone over the Cheshire side; and he did not think that the difference produced by Mr. Forster's alteration of line had really had very much influence in preventing its going over. At Widnes, since the embankment to Runcorn had been made, the channel had

Mr. Vernon-Harcourt.

Mr. Vernon-Harcourt.

rather gone to the Widnes side than to the Runcorn side. He desired to ask another question which was of some interest. The outer sill of the large Eastham lock was put at a very low level indeed. It appeared to be 13 feet below low water of equinoctial spring tides in the Mersey, and about 11 feet below the bottom of the canal. In order to utilize that low sill, the object being no doubt to bring in vessels earlier on the tide, and, if necessary, to let them out before the tide had risen much, or some time after high water—it was necessary to provide an approach by dredging. It was not stated how deep that dredging had been carried, and it would be interesting to know how far the engineers had succeeded in carrying the bottom of the approach channel down to the level of the outer sill of the large Eastham lock. Another interesting novel work in the canal was the Barton aqueduct, where a trough filled with water was swung like a swing bridge on a central pivot, leaving a passage on each side for vessels to pass along the canal, and at other times it was shut across the canal, enabling the Bridgewater-canal vessels to pass over. That was an interesting way of dealing with the crossing of the two canals. He thought it was really a variation of another problem of raising vessels vertically by hydraulic power which was first accomplished in another work that Sir Leader Williams had to carry out, viz., the Anderton hydraulic canal lift on the River Weaver, and, at a later period in two other similar canal lifts of larger size on the Continent which he had had the opportunity of seeing—the Fontinettes lift on the Neufossé Canal in France, carrying vessels of 300 tons, and raising them 43 feet, in less than 3 minutes, and the Louvière lift on the Canal du Centre in Belgium, upon which he had stood when it had lifted a weight equivalent to a vessel of 400 tons floating in a trough, 50½ feet in 2½ minutes. One of the great peculiarities of the canal was that its estuary embankment passed right across the mouth of the tidal river Weaver, shutting off the river from the Mersey estuary. One of the difficulties undoubtedly put upon the Canal Company by Mr. Forster's Committee was what was known by all who had had to do with the Manchester Ship-Canal as the Weaver Clause, by which it was necessary for the Company to let the tidal and other waters of the Weaver out into the Mersey estuary in the same period of each tide as they would have passed out into the estuary if the Ship-Canal had not existed. That problem had been solved in a most ingenious manner by the Stoney sluices upon free rollers. There were ten sluices each 30 feet in width in the embankment

Mr. Vernon-Harcourt.

across the mouth, which controlled the waters of the Weaver; and it was certainly doubtful whether it would have been possible to carry out the provisions of the clause without those particular sluices, which could be raised and lowered as much as might be desired with remarkable facility. There were other sluices of the same type upon the canal, but it was those particular sluices which were of such great importance. He had had the opportunity of going with Sir Leader Williams in 1888 to visit the only sluices of that kind that were then in existence, viz., at Ballinasloe and Belleek in Ireland, where Mr. Stoney had erected them. He thought that great credit was due to Mr. Stoney for the way in which he had designed the sluices, which formed a most important adjunct of the Manchester Ship-Canal, by regulating the waters of the Weaver. Very little had been said in the Papers under discussion with regard to one of the most important and novel features in the canal, viz., the tidal openings. It was stated in Sir Leader Williams' second Paper, p. 42, that "Until the 7th February, 1897, the tide also flowed out of the canal through three tidal openings at Ellesmere Port, the River Weaver and Runcorn; these are now all closed." It might not be known to every member of the Institution that the question of those tidal openings involved one lawsuit and two Acts of Parliament in 1890 and 1896 respectively before the matter was settled. In the first instance those tidal openings were designed 4,500 feet in total width—forty-five openings of 100 feet each arranged in thirteen groups. Those were reduced by the Act of 1890 to 1,800 feet, viz., three openings having a width of 600 feet each; but now they had been entirely closed. He hoped that Mr. Hunter would not fail to give the Institution a Paper upon that most interesting subject. The question had been considered at great length last year before two Parliamentary Committees, and it was stated by the opponents of the scheme that there would be a very great rush of water along the canal, especially in the Pool Hall cutting, which was carried through rock, and where the canal was therefore made of smaller section with vertical sides instead of slopes. Various other objections were also raised, and it would be interesting to know how far the predictions had been fulfilled by the actual closing of the tidal openings which took place in the earlier part of the year. No doubt Mr. Hunter was already aware of the result, for he had had two equinoctial spring tides since then in the canal which he had been able to measure. He thought it would not be satisfactory that the subject of the Manchester Ship-Canal, which had been brought before the Institution,

Mr. Vernon-Harcourt.

should be closed for all time to come without a Paper, not necessarily on the proposed training-works in the estuary as suggested by Mr. Hunter, which had been set at rest by their rejection in 1884, but at any rate upon the effect of the estuary embankments upon the channel in the estuary, and also on the effect of the closing of the tidal openings upon the regime of the tidal water in the canal.

Sir John Wolfe Barry.

Sir JOHN WOLFE BARRY, K.C.B., President, said that before calling upon the Authors to reply, he would ask Sir Leader Williams to answer two questions in which he was interested as being connected with the Suez Canal. First, what was the speed of the tide now noticed in the Manchester Ship-Canal since the tidal openings had been closed? and, secondly, was any difficulty found in large vessels passing each other under way? He asked those questions not with a view of criticising the Manchester Ship-Canal, but as some guidance in discussing similar problems on the Suez Canal. At present ships were not allowed to pass each other in the Suez Canal when both were under way; one was always obliged to tie up; and of late years facilities had been given for ships to tie up anywhere by widening the canal in all parts to a bottom width of $35\frac{1}{2}$ metres, or about 115 feet, with a depth of $8\frac{1}{2}$ metres, which was a much greater width than that originally executed, which was 22 metres, with a depth of 7·9 metres; indeed the canal was now as wide as were the original passing places when the canal was first opened. He thought that Mr. Harcourt was somewhat mistaken in what he had said about currents in the Suez Canal. At the Suez end of the canal there was a considerable tide. There was a tidal current reaching to about 3 knots at that end, and in the case of heavy winds there was a current, not a tide, of something like 2 knots at the Mediterranean end. It would be interesting and some guide to their friends on the Continent to know the experience of the Manchester Ship-Canal with currents of equal or higher speed in the management of big ships. The accommodation for large ships was one of the things now pressing upon everyone's mind in connection with canals, harbours and docks, on account of the great width given to ships by modern naval architects. Ships were now constantly built with 64 feet beam with nearly parallel sides, and a length of 500 feet to 600 feet, and he did not know where they were going to stop. He should also like the Authors to correct the statement on page 28 as to the cost of the construction of the works in the light of what Mr. Hunter had stated. It was said that the cost of the construction, including plant, compensation to railway companies (he did not know the amount but he believed the London and North-

Western Railway Company received about £100,000) was put down as £10,193,979. That might give rise to misapprehension. If the actual cost was what Mr. Hunter had given, it would be better to break up the first item and state it differently, because at first sight it might be inferred from the Paper that the works of the canal had cost in round figures about £10,200,000. Sir John Wolfe Barry.

Sir E. LEADER WILLIAMS, in reply, said that no difficulty had been experienced in running large vessels at a speed of 8 miles an hour, or in passing at any part of the canal. The bridges up to Barton were made wide enough for two steamers to pass through them at once, and there had been singular freedom from accidents for some time. When the canal was first opened, the captains of steamers were too timid; when they were passing near each other, instead of steering almost for each other, as he had himself seen done on the Amsterdam Canal, they slewed off to one bank, and if a large vessel "smelt" the bank, as it had been called, she crossed and canted the other way, and got into trouble. The traffic now worked smoothly day and night, and there was no difficulty. The vessels passed under way without bringing up, only slackening speed as they went into the locks. With regard to the question of the velocities in the lower part of the river, the estuary portion, owing to the tidal canal the question was still *sub judice*. The advantages of the canal to Manchester had been properly pointed out by Mr. Hunter, but that subject had not been dealt with in the Paper. The advantage to Manchester was a large reduction in the railway rates, and that advantage had arisen from the construction of the canal. There was also the fact that in the docks and in the canal about 2,500 men were employed. There was a large railway traffic from the docks, and houses that were once empty in Manchester were now filled, and others were being built in all directions. As the district had found the money, the district was receiving not indeed a dividend, but a large benefit. He had been astonished to find how well the shareholders had supported the Company all through. They had felt that the canal was a great work for Lancashire, and were determined not only to pull it through, but to look forward to better times. Constant reductions were taking place by railway and dock boards. It was difficult to get traffic out of a groove, but with the large increase of population going on, and the increase in trade generally, great benefit would ultimately accrue. With regard to the question of cost, in order to prevent any question arising, he had simply taken the figures appearing in the last balance-sheet presented to the shareholders. It would Sir Leader Williams.

Sir Leader Williams.

be understood that auditors did not always take the same view as Mr. Hunter did with regard to the way of estimating the cost. He had given details in the Paper respecting the plant and its cost to the Company, over £860,000. If Mr. Walker had lived, that money would have been repaid before the conclusion of the contract. That was his agreement, but unfortunately, owing to his death, the Company had to take the work in hand; they had to take over all the plant at the above value, while, after having been hard at work for some years, when they came to sell, there was an enormous loss, as obviously there would be. 228 miles of single railway had been laid down, and the sleepers were almost worthless. That was one of the difficulties with which they had to contend. With regard to the Parliamentary estimates, the best justification for them was given in the Paper; Messrs. Lucas and Aird had supported them and given evidence in their favour. They made a tender to construct the canal on the original plans for 10 per cent. under the Parliamentary estimate; Mr. Walker also carried out the work on that footing. As Mr. Hunter had pointed out, the work executed was entirely different from that of the Parliamentary estimate. There had been a largely increased area in the docks and other things put upon the engineers. The large sum named in the Paper also included work not mentioned by Mr. Hunter. A sum of £80,000 was included in the estimate for sheds and appliances at the docks in Manchester, but the moment trade commenced they had instructions to make large warehouses, with railways and hydraulic cranes, at a great cost. Those things were outside the Parliamentary estimates. The figures given by Mr. Hunter were correct, but they did not include the additional expenditure on account of purchase of contractor's plant, dredgers, compensation to the London and North-Western, Great Western, and Cheshire Lines railway companies and others, further dock equipment, wharves, dredging in the estuary, &c., which were included in the cost of works given in the Paper. He had been pleased to hear what Mr. Hunter had said, but it was easy to be wise after the event. He was not quite so sure as Mr. Hunter was about the berm. If the section shown in the type cross-section on Plate 1 had been the prevailing section throughout the whole canal, he should go a long way towards berms; but unfortunately there was the Latchford cutting, 4 miles long, with an average of 55 feet depth, besides other deep cuttings. A berm in that case meant a very great increase in the excavation, a great increase in the top width where there was such an enormous mass. It also meant purchasing more land.

Sir Leader Williams.

The cost of pitching the slopes to a lower level had to be considered as against the berm and extra excavation. One point that had been pressed upon him was that in a canal through alluvial light deposit, vessels passing each other must necessarily go near the slopes, and with the action of the screws, if the stone pitching was not carried down to a low level, holes would be excavated underneath. There were, therefore, two sides even to that question. The top stones were better supported by stones below. Still, if the cuttings had been no deeper than the Suez and Amsterdam canals, he should certainly have advocated berms. The next question was that of the limit of deviation of the canal put in by the Commissioners. Part of the canal near Eastham in the Parliamentary plan was on the north of the estuary. A clause was forced upon the Company to go inland by Mr. Forster's Committee, and that entailed a very heavy expense. They had also increased the size of the locks at Eastham and put in an additional lock and large sluices. Mr. Vernon-Harcourt had referred to the question of foundation. The foundation had given trouble nowhere except at or near Ellesmere Port. A full description had been given of the driving of the piling there. The bank was absolutely water-tight. An engineer who had seen the construction of the works had recently told him that he had walked down the banks and seen them at low water, and it was almost incredible how tight the banks were. In the case of an ordinary embankment as shown in Fig. 10, the secret was that where it was on sand there was a great width and weight. The clay was stiff boulder clay tipped in by wagons. The railways were laid along the top, and the bank was thus pressed down. If the embankment had not been well made and there had been no tidal action upon it, it would have been an absolute failure. He had depended upon experience obtained elsewhere, which showed that where a clay embankment was made with tides rising and falling twice a day and a heavy weight on the top, it became absolutely consolidated. It got like the original stratum of boulder clay, and the result was that there had been no trouble. He did not think he could be blamed for the Commissioners making the slope flatter than was originally designed; that required no apology from him. With regard to the sills at Liverpool they were put low for this reason. Anyone who had to do with docks, considering the increase in the size of ships mentioned by the President, knew that it was necessary to provide for larger and deeper vessels. At Liverpool a much greater depth was necessary than years ago. Perhaps the depth was too great, but the course

Sir Leader Williams. had been adopted in order to provide for some of the larger steamers to which they were looking forward, so that the fault was on the right side. It involved stoppage of trade to take out sills and deepen them and under-pin the lock-walls. It was therefore better to increase the depth at once. The approach channel to the locks has been dredged to 16 feet below Ordnance datum standard. Mr. Vernon-Harcourt appeared to have forgotten that the question of estimates was discussed by the Lords Committee in 1884, which passed the Bill. In the subsequent Committees the question of estimates was not raised by the opponents. It was proposed to raise the water-level of the lower portion of the canal from 14 feet 2 inches to 16 feet above Ordnance datum standard Liverpool, as allowed by the limits of deviation in the Act, but the Mersey Conservancy required the 14 feet 2 inches level to be adopted. In conclusion, he desired to thank the members for the kind way in which the Papers had been received.

Mr. Eliot. Mr. WHATELY ELIOT observed, with regard to the slopes of the estuary embankments, that in cases where the height of embankment exceeded 20 feet, he would prefer the inclination of $1\frac{1}{2}$ to 1 for both the inner and outer slopes. In the course of construction no difficulty had been experienced in the pitching of the outer slope, which was laid at $1\frac{1}{2}$ to 1; but in the pitching of the inner slope at 1 to 1 some of the lower courses of the pitching, where the bank was high, were forced out of position, some of the stones being crushed from the weight of the pitching above, as mentioned in his Paper; this would not have occurred if the slope had been made less steep than 1 to 1. With reference to the absolute freedom from leakage in any of the embankments, both the embankments in Pool Hall Bay and Ince Bay were thoroughly tested by the tide after they were closed, and during the construction of the canal. In his Paper he had described the means adopted to stop a leakage which occurred under the embankment in Pool Hall Bay. In Ellesmere Bay embankment this testing could not be applied, as the tidal water was not excluded from the area enclosed by the embankment. In addition to the reasons given by Sir Leader Williams for the tightness of this embankment, he considered the clay and stones placed in the trench at the back of the inside row of sheet piling, as described in his Paper, and shown in Fig. 11, Plate 4, contributed largely to the prevention of water finding its way under the embankment.