The Author. tortoise; the canal-boat went steadily and reached its destination in practically a fixed time, while the goods-train rushed for a certain distance and then slept in a siding. On canals there were no sidings, no signals, and merely a delay of fixed duration at either lock or lift. Mr. Inglis had compared the Kennet and Avon Canal with the Great Western Railway, but naturally he had not compared the Aire and Calder Navigation with the North Eastern or the Weaver Navigation with the London and North Western Railway. His statement that the first cost of the Kennet and Avon Canal was £1,000,000, or £11,500 per mile, went far to confirm the Author's estimate of £15,000 per mile for improvements, and it was certain that with modern plant very considerable improvements could be made for the figure named in the Paper. The heavy cost of sidings, to which Mr. Inglis had alluded, was absent with canals. The Author was pleased to have the general support of Mr. Dykes, but he hoped that gentleman would be more willing to support a large lock when he had read the foregoing description of the working of lifts. The whole question essentially was—Could the cost of transport be reduced by improving the waterways? The railway-companies said they were now carrying goods at the lowest possible rates. The traders said it was essential to the well-being of the country that the rates on heavy goods should be reduced. Could this be done? If so, ought it not to be done? The only means of ascertaining was to hold an inquiry.

With regard to improvements in foreign waterways, as to which Sir Leader Williams had suggested information should be added to the Paper, the Author had seen a considerable number of miles of foreign waterways, and in 1898 he wrote a Report for the Weaver Trustees on the Belgian and other canals. He would be glad to supply a copy to any member wishing for one.

Correspondence.

Mr. Keeling. Mr. GEORGE WILLIAM KEELING, having been more or less intimately connected for nearly 50 years with some of the waterways leading to the estuary of the Severn and the Bristol Channel, and the docks connected therewith, contributed the following notes on the subject. For the past 20 years he had been Consulting Engineer to the Sharpness Docks and the Gloucester and Birmingham Navigation Company; and from 1894 to 1898 he had acted as Consulting

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Engineer to the Committee of the allied navigations which commenced the restoration work of the Thames and Severn Canal. The Author had omitted to mention, in the Table on p. 22, the Gloucester and Berkeley Ship Canal, for which an Act was obtained in 1793. Financial difficulties arose in carrying out the works, and the Government assisted the company by advancing £165,000 on mortgage, by means of Loan Exchequer Bills. The ship-canal and docks were eventually completed and opened for traffic in April, 1827. The Aire and Calder Navigation and the Weaver Navigation were no doubt two of the most successful in the kingdom, their proprietors having had the wise enterprise to meet the traffic requirements by important improvements ably designed and carried out by their engineers. But the circumstances as to sources and volume of traffic were particularly favourable on those navigations, and had led to these satisfactory results; and it did not follow that expensive improvements on other canals, where similar favourable circumstances did not exist, would be financially satisfactory. The Severn Commission, of which body Mr. Keeling was a member, had canalized the River Severn between Gloucester and Stourport (42 miles); and the improvements made by the Commissioners under the advice and guidance of the late Mr. H. J. Marten, M. Inst. C.E., had been continued under Mr. E. D. Marten, M. Inst. C.E., the present Engineer. The minimum depth of water on the sills of the locks between Gloucester and Worcester was 9½ feet, and the channel in the river had been dredged to a depth of 10 feet. Vessels of 8 feet draught could readily navigate between Gloucester and Worcester, and of 6 feet draught between Worcester and Stourport. Westgate Bridge at Gloucester, a stone arched bridge with a headway of 18 feet above weir-level at the centre of the arch, was an obstruction to coasting vessels of more than 150 tons burden. Two other low-level bridges were girder bridges of uniform headway throughout the span and had opening spans for use if required. The remaining bridges between Gloucester and Worcester had a headway varying between 25 and 28 feet. Among the considerations to be taken into account in the enlargement of canals, sources of traffic and water-supply were very important. With regard to the latter, some of the existing main canals had been constructed of dimensions proportionate to the supply of water available at the summit, and could not be enlarged without very costly works and compensation to secure a larger supply. In 1884 he proposed the "Birmingham and Bristol Channel Improved Navigation" schemes, and prepared drawings and estimates for the enlargement of the Worcester and Birmingham Canal. In

Mr. Keeling. the years 1886–90, inclusive, this scheme was promoted by an influential committee of thirty-five members, representing Birmingham, Wolverhampton, Wednesbury, Kidderminster, Dudley, Gloucester, Bristol, Cardiff and Swansea, of which the Hon. Philip Stanhope, M.P., was chairman. The waterway between Birmingham and the Bristol Channel was composed of the following four sections:—

1. The Worcester and Birmingham Canal, 30 miles in length. Width of existing locks 7 feet; depth on sill 5 feet. Width of canal about 33 feet; navigable depth about 4½ feet. Fifty-eight locks, thirty-six of them in one group near Tardebigge. Total rise from the River Severn at Worcester to Birmingham about 425 feet.
2. The River Severn between Worcester and Gloucester, 30 miles in length. Rendered navigable by weirs and locks at Worcester, Tewkesbury and Gloucester. Diglis Lock, at Worcester, 150 feet in length, and 30 feet in width; lock at Tewkesbury longer. Minimum depth of river 9 feet; river navigable for vessels carrying 200 tons of cargo. Bevere Lock, above Worcester and between Worcester and the entrance of the Droitwich Canal, 100 feet in length and 20 feet in width.
3. The Gloucester and Berkeley Ship-Canal, between Gloucester and Sharpness, 17 miles in length; no locks, except at its connection with the River Severn at each end. Width of top water 86 feet 6 inches; depth 18 feet, navigable for vessels of 800 tons register, 15 feet draught, to Gloucester Docks; accommodation for vessels of 2,000 tons register at Sharpness Docks.
4. The estuary of the River Severn.

This enlargement of the Worcester Canal was intended to allow coasting vessels carrying 200 tons to navigate to Birmingham, so as to place that town, and the manufacturing districts connected with it by canals, in direct communication by water with ports in the Bristol Channel. To make provision for this class of vessels involved widening, deepening and straightening the Worcester and Birmingham Canal, the construction of a hydraulic incline at the long flight of thirty-six locks at Tardebigge, the lengthening, widening, deepening and increasing the lift of the remaining locks, and the enlargement of the bridges and tunnels. A vessel which could navigate the Bristol Channel and yet be capable of navigating between Gloucester and Worcester and between Worcester and Birmingham, with a carrying-capacity of 150 to 200 tons, must be of

special design in order to economize space and headway. It should be approximately 100 feet in length by 18 feet in width, and 6 feet in draught, and be provided either with bilge-keels or with a sliding keel to be let down when in the river or channel below Sharpness. Such a vessel involved locks in the Worcester and Birmingham Canal 110 feet long—or, to hold tug and vessel or two vessels, 210 feet long—by 20 feet wide, by 8 feet minimum depth. The new locks were intended to have a lift of not less than 14 feet, and to be built alongside the existing locks, in order to avoid stopping the traffic; but where there was a flight of locks it would be more economical in cost, water and time, to adopt hydraulic inclines, similar in principle to the inclined lift in use on the Monkland Canal in Scotland, and at places on continental canals, where the ascending trough was balanced to some extent by the descending trough, and the motive power used was hydraulic or steam. The new locks were to be fitted with large sluices, and the gates with balanced weights, so as to fill or empty the lock and open the gates quickly. The canal was to be deepened throughout from 5 feet 6 inches to 9 feet, widened from 33 to 66 feet, and straightened in places; and the sides were to be protected with dwarf walls or piling. All the road-bridges were to be widened and raised, or, if the latter course was not desirable, girders were to be substituted for arches, so as to obtain the greatest possible headway for the full width of the canal. The tunnels, aggregating $2\frac{1}{4}$ miles in length, were to be enlarged throughout. Increased dock- or quay-space would have had to be provided near Birmingham so as to form a depot for transferring traffic from the canal-boats navigating the numerous canals in the manufacturing districts and converging at Birmingham; but as regarded the city itself, it was intended that vessels should load and discharge at the Worcester wharf, Birmingham, the canal being widened there for the purpose. It was considered that the existing water-supply would be sufficient for the enlarged canal if hydraulic inclines were adopted. The Worcester and Birmingham Canal had two outlets into the River Severn, namely, via Worcester and via Droitwich. The latter was recommended as being better and less costly, if arrangements could be made to remove the impediments on the River Severn above Worcester due to the short lock at Bevere and the low arches of the Worcester Bridge. There were only three locks between Sharpness and Worcester, and by the proposed scheme the minimum number between Worcester and Birmingham would be thirteen; total, sixteen locks and one incline in a distance of 77 miles, which should be accomplished by steam-barges, with others in tow, in 20 to 24 hours.

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Mr. Keeling. The approximate estimate of the cost of the new works on the Worcester and Birmingham Canal was—

	£
Alteration of bridges and culverts	45,000
Alteration of tunnels	203,000
Hydraulic incline and works	52,000
New locks	96,000
Widening the canal from 33 feet to 66 feet, deepening it from 5 feet to 9 feet, and lining side (including land)	144,000
	540,000
Add for additional water space, and water accommodation at and near Birmingham	60,000
	£600,000

Having regard to all the physical data, supply of water, etc., this £600,000 scheme, providing for vessels of 200 tons, was the utmost that could wisely be suggested at a reasonable cost. A smaller and less expensive scheme would be to improve the canal for vessels of a class similar to the salt-barges trading between Bristol and Droitwich, and carrying about 95 tons of cargo. Such a scheme would not necessitate the enlargement of the tunnels and bridges, and would reduce the estimate of cost to about £300,000; but it was doubtful if so small a vessel would answer the purpose, and be seaworthy in all weathers to trade to and from Bristol Channel ports. A still less costly scheme would be to adhere to the dimensions of the present canal, to substitute an incline for the long flight of locks at Tardebigge, and to line the sides of the canal and deepen it for steam-towage, etc., at an estimated cost of £100,000, but the traffic could be carried only in 35-ton canal-boats, and would be confined of course to the port of Sharpness. In 1897 Mr. E. D. Marten, on instructions from a committee appointed by the Bristol and Wolverhampton Chambers of Commerce, made a survey of the Staffordshire and Worcestershire Canal and reported as to the best means of improving the waterway to Wolverhampton. Mr. Marten pointed out that the Staffordshire and Worcestershire Canal branched out of the Severn at Stourport, at the head of the canalized navigation of that river, where the summer level was 53 feet above Ordnance Datum. Between Stourport and Aldersley Junction, near Wolverhampton, its length was 25 miles, with a rise from the Severn at Stourport of 287 feet, overcome by thirty-one locks. The canal averaged 40 feet wide by 4½ feet deep; its locks had the same dimensions as those of the Worcester and Birmingham Canal, and were capable of passing the ordinary canal-boat carrying 25 to 35 tons. At Aldersley Junction the canal was

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connected with the northern end of the Birmingham Canal Navigation, the summit pound of which was reached at Wolverhampton in 2 miles by a flight of twenty-one locks with a rise of 132 feet, making the total rise from Stourport 419 feet in 27 miles. Mr. Marten recommended that the canal should be made navigable for the class of vessel which (with some very trifling alterations) could at present come up the Severn as far as Stourport, and which would have a length of about 85 feet, a beam of 19 feet, and a draught on even keel of 6 feet, carrying, if an ordinary barge, 225 tons, or if a coasting steamer, 135 to 150 tons. Mr. Marten proposed that the improved canal should have a bottom width of 40 feet, a top width of about 60 feet, and a depth of 7 feet. With the exception of two pounds the increased depth was to be obtained by raising the surface level of the canal $2\frac{1}{2}$ feet, aided, as regarded getting the full bottom width, by dredging. For the greater part of its length the canal had been constructed along the contour of a gently sloping hill, so that it was almost invariably the case that one side of it was in cutting and the other in embankment, and the first step, therefore, would be to build a new embankment outside the existing embankment, and at a level $2\frac{1}{2}$ feet higher. This embankment was to be faced with a thick and impervious cement-concrete wall, well bedded into the most impervious part of the flank of the existing embankment. When it was completed, the old escape-weir was to be blocked up, and the water allowed to rise to the new level. Dredgers would then be set to work, and the old embankment and the remainder of the bed would be dredged out. Mr. Marten stated, as a result of personal experience, that there was no difficulty about such an operation. As already mentioned, the rise of the canal between Stourport and Aldersley Junction was 287 feet, which was overcome by means of thirty-one locks. For six of these locks it was proposed to substitute four large locks, each 100 feet long between gates, 20 feet wide, and with $6\frac{1}{2}$ feet of water over the sills. The remaining twenty-five locks, however, were so situated that it was found desirable to substitute seven deep lifts for various groups of them. The form of lift recommended by Mr. Marten was a modification of the Monkland incline, an invention of Mr. Gordon Thomas, the Engineer to the Grand Junction Canal Company. Its leading feature was that the caisson travelled sideways (instead of endways) up a much wider incline, the effect of which was to obviate the oscillation almost entirely. The number of canal-pounds was to be reduced from thirty-one to eleven, and, incidentally, the travelling distance along the canal from 25 to $22\frac{1}{2}$ miles. The method of construction proposed would enable traffic on the canal to be carried on practically

Mr. Keeling. continuously during the alterations. It was found that with the introduction of hydraulic lifts the water-supply would be ample. It was intended to improve the canal by these means as far as Aldersley Junction, but the cost of continuing the improvement over the twenty-one locks on the main line of the Birmingham Canal Navigations, leading into Wolverhampton, was found to be excessive when compared with the advantage to be gained, and a transhipping basin was therefore projected at Aldersley, in which goods collected from the Wolverhampton district in the ordinary canal-boat might be transhipped into the larger vessels. The cost of the work, including the transhipping-basin, land, parliamentary and legal expenses, and contingencies, was estimated at £360,000. It was suggested that if the local authorities whose districts were to benefit would guarantee it, the interest on this outlay need not exceed 3 per cent., or £10,800 per annum. Neither of the foregoing schemes had made progress to a definite result leading to the construction of the new works proposed. The experience of Mr. Keeling and Mr. Marten, and probably of other engineers engaged on similar schemes, had been that a large amount of sympathy, enthusiasm and moral support could be obtained in favour of schemes for the improvement of canals—from merchants, manufacturers, trading communities, chambers of commerce, city and town corporations, rural district councils and county councils; but little or no financial support was forthcoming. This might be due to the fact that business men, while appreciating the effect of navigable waterways on carriage of heavy goods in respect of convenience and rates, had had no faith in their being remunerative; and this feeling had probably given rise to the proposals that the waterways should be improved and maintained by the State or by county councils, at the expense or risk of the tax-payers or rate-payers.

Mr. Lowcock. Mr. Sidney R. Lowcock mentioned that in preparing 2 or 3 years ago for the Corporation of Evesham a scheme for reopening and enlarging the Upper Avon Navigation, which formed part of the route suggested by the Author for the waterway between Bristol and Birmingham, his greatest difficulty had been in ascertaining what traffic would be likely to be obtained by such enlargement and improvement. That with improved facilities throughout the main lines there would be a large increase in traffic he was quite convinced, but what this increase would amount to, in comparison with the existing traffic, it was practically impossible to say. The capacity of the existing canals was so inadequate to present requirements that a large amount of material which would be sent by canal, were it

possible, had to be sent by other routes. For instance, some large boilers required by him for works near Birmingham had been constructed close to Wolverhampton, both the boiler-maker's yard and the works for which the boilers were destined being on the side of a canal. The boilers being 8 feet in diameter and the locks only 7 feet 2 inches wide, it had of course been impossible to convey them by canal, and they had had to be taken by road, involving a great deal of trouble and expense. The same thing had actually occurred with the boilers for the canal-company's own pumping-station. In another case a large shaft could not be sent by canal because it was longer than the locks. He considered that in any comprehensive scheme for the improvement of the waterways the locks should be designed to take boats of at least 300 tons, and the canals of course in proportion; as anything smaller would only mean progressive enlargement and alteration, as had been found necessary on the Weaver Navigation, on the Aire and Calder Navigation, and on continental canals. Locks of this size would be impracticable near the summit-levels owing to difficulties of water-supply, but with lifts and inclines these difficulties could readily be overcome. He quite agreed with the main lines suggested by the Author, but would put them in the following order of desirability:—1st, Liverpool to Birmingham; 2nd, Liverpool to Hull; 3rd, Birmingham to London; 4th, Birmingham to Hull; 5th, Birmingham to Bristol. He was strongly of opinion, however, that it would be a great mistake to arrange the termini of the four canals meeting at Birmingham as suggested by the Author. They should all four meet at one point, and the canal between Liverpool and Birmingham should run through the Black Country between Birmingham and Wolverhampton, as there was at present considerable traffic throughout this length, and would be much more. The real difficulty in any such scheme was the reconciliation of existing interests, and the crux of the problem was the position occupied by the railway-owned and railway-controlled canals. If this difficulty could be overcome, he did not think the financial difficulties would be very serious, although he did not believe that the necessary works could be carried out for the amount estimated by the Author. It was not to be expected that the railway-companies would give up the control of their canals without a desperate fight, so long as they considered that the canals were or might be competitors for the traffic. Personally he did not think they should be looked upon as competing with, but rather as complementary to, the railways, and this was the light in which they were regarded on the Continent. At present the railways had either to incur enormous expense in putting down separate

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Mr. Lowcock. tracks for the goods-traffic, or else had to run this traffic at a high speed, which meant largely increased working-expenses, in order to get the goods-traffic out of the way of the fast passenger-traffic; and it appeared to him that it would be really to the interest of the railway-companies to send heavy goods, in respect of which the time occupied in transit was not of much importance, by canal. If they could be brought to see this, and if the other interests could be brought into line, the whole system of main canals could be worked by a trust, the county councils and the councils of the principal cities and towns served by the canals and the railway-companies and existing canal-companies being represented on the board of the trust. In whatever way the details could be arranged, he thought a bold and complete scheme should be put forward without waiting for a syndicate of American financiers to show the way.

Dr. H. R. Mill. Dr. H. R. MILL felt sure that there need be no apprehension whatever on the ground of possible insufficiency of the water-supply of the British Isles for the further development of waterways. Given sufficient storage, the storm-water alone would furnish an amply sufficient quantity in any part of the country without trenching on the gathering-grounds yielding water of the quality required for domestic supply. Undoubtedly there had been a serious falling-off of rainfall during the last 30 years, and this was no mere local phenomenon; but he doubted whether it was generally recognized that the British Isles were now far on in a spell of very dry years (he believed near the end of it), which had been preceded, and would be followed, by spells of wet years. The duration of such wet and dry spells could not be foreseen exactly, but there was no doubt as to their alternation. He had recently calculated the variation of rainfall over an area of 2,500 square miles in the east of England, and found that the mean rainfall of the 16 years 1887-1902 was 9 per cent. below, and that of the 12 years immediately preceding was 13 per cent. above the average of 35 years, which was practically a true average. He believed that a succession of wet years was not far off.

Mr. Paterson Mr. MALCOLM PATERSON observed that internal waterways naturally divided themselves into two principal classes: (*a*) canalized rivers, which might be called navigations; and (*b*) canals proper, not connected with, and generally not fed by, rivers. Natural conditions rendered it no difficult matter, as a rule, to reconstruct navigations, with their advantages of slight fall, complete water-supply, practical immunity from coal-mine subsidence, and, above all, their comparatively small first cost. On the other hand, the reconstruction of an old canal extending through a populous

district, was a complicated and difficult problem, to accomplish which within, say, 30 or 40 per cent. of a very carefully detailed estimate, would tax the powers of the most experienced engineer. On referring to the Paper, whose merits as a résumé of the position of this important subject he fully appreciated, it would be seen that nearly all the waterways which had been brought in some degree towards the needs of the present day, were in fact the lower sections of rivers, with seaports as their termini. As an illustration, the Aire and Calder Navigation might be compared with the three important canals which fed it, and which discharged their waters into it, namely, the Leeds and Liverpool Canal, the Rochdale Canal in its Yorkshire section, and the Calder and Hebble Navigation, which in several short sections was a navigable river. The Aire and Calder Navigation at the outset found its weirs built for the ancient water-mills, and its water-rights made good. It lay in a district which had easy levels, and which, between its termini, was almost entirely an agricultural and coal-mining district; and the mines generally, as its owners had declared in Appendix I. to the Paper, could not be worked to the injury of the navigation, even where the Coal Measures were passed through, because the colliery-owners dared not risk letting the river into their workings. The water-supply was trebly sure. The navigations had not only, first, the waters of the three basins of the Aire, the Calder and the Don; and, secondly, the storage-reservoirs made at a heavy cost by the canal-companies above them; but they had, thirdly, probably the finest system of stream-compensation flow in the kingdom from the waterworks of Bradford, Keighley, Shipley, and other smaller places on the Aire; of Halifax, Huddersfield, Todmorden, Morley, Wakefield and Batley on the Calder; and of Sheffield, Rotherham, Doncaster and Barnsley on the Don; amounting to an aggregate flow of more than 40 million gallons daily. Lastly, and of greater importance than all the other sources put together, was the entire flow of sewage-effluents from all the boroughs and nearly all the urban districts in the West Riding; a flow almost as well regulated for purposes of navigation as the bulk of the compensation-flow. Besides all this, there was the fact that the Aire and Calder Navigation was now almost the sole outlet by water to the coast for the great industrial centres of the Riding. All these things the navigation had as a free gift; and six locks on perfectly flat ground, at intervals of many miles, and in rural districts, were its only obstacles. The canals possessed few of these advantages. They had made their own reservoirs, and their water-supplies could be increased only from districts depleted of their best gravitation resources by the public authorities to such an

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Mr. Paterson. extent that it was difficult to store and convey water at less than 4*d.* per thousand gallons, even when used daily and fully; whereas water stored only against the exigencies of drought could only be used at rare intervals and might not be needed for a whole year. The coal-workings through which the canals extended caused subsidence destructive of works, loss of water, and interruption of traffic, and were a running sore on the undertakings, compensation not being recoverable. The levels were difficult, and demanded costly water at high elevations, and also tunnels, aqueducts, and a large number of locks, some in long flights which were so hemmed in by valuable buildings and other obstacles, that lengthening and duplication were impracticable. On the back of all this came the inevitable and unknown loss of traffic throughout the period of reconstruction. It seemed clear, therefore, that the river-navigation undertakers might indeed themselves in many cases accomplish something like the improvements effected by the Aire and Calder Navigation under the able guidance of Mr. W. H. Bartholomew, but the canal undertakers, who from their somewhat precarious position could borrow only at high rates, could not, as a rule, in any sense reconstruct their entire systems of works. The suggestion that Government might step in and find the money for reconstructing the canals, and then throw the whole under county or other management, as free to the public as the highways, also seemed to him impracticable and impolitic. Such a policy, following upon the use of the highways by motor-cars and short motor-trains, and also by the lines of light railways, would, he thought, in the end, mean the paralysis of railway development, and thus defeat the object aimed at, namely, the commercial economy of the nation. The formation of public trusts to acquire and put the canal-undertakings into a thoroughly efficient state, chiefly on their present lines, with power to charge such tolls as would not yield more than a certain limit of profit, as in the case of gas-companies, would seem to be a more practicable course; also effective control of the proper use of those canals owned by railway-companies and more or less disused, should be provided, even to the point, if need be, of compulsorily acquiring them. In any case, there should be a uniform and equitable system of rating throughout any one system of canals.

Mr. Shoolbred. Mr. JAMES SHOOLBRED considered that the Paper, while adding interesting matter to recent information[1] on the subject of water-

[1] A. Lee, "The British Canals Problem." Journal of the Society of Arts, 1904, p. 40. B. H. Thwaite, "Transport Possibilities of our Inland Navigable Waterways," Transactions of the Society of Engineers, 1905.

ways, could not but leave a painful impression as to the low ebb to which England had allowed the utilization of her waterways to drift. In the meantime France, Belgium, Germany, Holland, the United States, and Canada, more alert and in touch with the scientific progress of the age, had outstripped England, at certain places, in the management and efficiency of their respective waterways. The deficiencies of English canals, being mainly due to apathy, would, it was to be hoped, be only temporary. Of the various points upon which, according to the Author, improvement was needed, Mr. Shoolbred proposed to deal with mechanical haulage, which divided itself into two distinct forms: first, haulage effected—like horse-haulage—from the banks of the canal, and secondly, haulage upon the waterway itself, quite independently of the banks. The improved methods of haulage with electricity as the motive power, which were being tried in France (Douai to Bethune Canal), in Belgium (Charleroi and Brussels Canal), in Germany (Finon Canal), and in the United States (a part of the Ohio to Lake Erie Canal), all came under the first method. They all made use of an electric railway of some form, current being supplied to the locomotive from an overhead trolley-system. Considerable differences occurred between the different localities in the mode of generation and distribution of the electrical energy. Both direct and alternating current was made use of; and, with the latter, three-phase, two-phase and single-phase systems were employed: also in the electrical pressure a wide range occurred, between considerable high pressure, and ordinary low pressure. In England, proposals only appeared to have been made. The River Lee Conservancy Board had under consideration a proposed method of electric traction, which was understood to be somewhat similar to that in use in Belgium on the Charleroi and Brussels Canal. Another system had been put forward by Mr. B. H. Thwaite,[1] Assoc. M. Inst. C.E. The second method of mechanical haulage was from self-propelled boats. Steam-tugs, which had been in use for some time on a few of the larger waterways in Great Britain and on the Continent, caused considerable inconvenience, in some cases by causing a wash which damaged the banks of the canal. In order to avoid this it was necessary to limit the speed considerably. The recent motor-exhibition at "Olympia" had shown that there were in England several firms ready to supply petrol-driven motor-boats for canals, at a cost comparing favourably with existing steam-tugs, which latter had certainly proved to be more economical in their work than was horse-

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[1] See *post*, p. 143.

Mr. Shoolbred. towage. The Electrical Exhibition recently held at the same place had shown that boats driven by electric storage-batteries were available for use on canals; though the details of construction of the storage-cells still left much to be desired. But the main difficulty was the want of a supply of electrical energy, at a cost which would be commercially remunerative. Any improvement in the canal system, whether constructive or administrative, must, in order to be of a permanent character, be based essentially on financial economy. The introduction of the improvements in canal-haulage already referred to, especially on the Continent, were so few and so recent, that the results could only be accepted as tentative. So far, however, they might be taken to give promise of a satisfactory solution of the problem. English experience of steam-tug haulage had demonstrated its economy over horse-towing; and everything pointed to the realization of still further economy by the use of petrol motor-boats. Electricity gave promise of considerable economy; but its future, economically speaking, depended largely upon that of the electric-power schemes. For, until greater confidence was reposed in them than was at present the case, either by giving to manufacturers and public bodies, representing the interests of transport, a share in their control, or in some other way, no adequate reduction in the cost of electrical energy would be secured—sufficient, at least, to enable this power to compete successfully, from a financial point of view, with the other motive powers in use. A real comparison of the costs of various methods of haulage was difficult to arrive at, owing, first, to the variety of the local circumstances of each waterway, which rendered it very difficult, and sometimes misleading, to arrive at one uniform rate for one type of motive power, such as might be taken to hold good for all waterways; and, secondly, to the experimental character of the results already arrived at. However, the following figures might be of some interest, as an approximation to the relative cost per ton-mile hauled:—Horse towage 3*d.*, steam-tug 2*d.*, electricity 1*d.*, and petrol probably less, although there were at present but few examples to be guided by. Electric haulage on land was certainly very much handicapped by the high charges for electrical energy.

Messrs. D. and C. Stevenson. Messrs. D. and C. STEVENSON agreed with the Author that it was unfortunate, to say the least, that the canals were so largely in the hands of railway-companies; and the fact that this was the case showed the shrewdness and foresight of those responsible for railway-management. There could be no doubt of the importance of cheap carriage to manufacturers and to the general prosperity of the

country; and in certain localities, and under certain conditions, barge-canals, with which the Paper was primarily concerned, might be of great assistance in securing this. They thought, however, that any general extension of the barge-canal system—or even improvement of existing barge-canals—would not greatly assist the country in meeting foreign competition; and they were still more convinced that the time had not yet come, even if it ever would come, when a standard size of barge-canal, which the Author seemed to think desirable, should be decided on. The nature and amount of the traffic, and the present and prospective wants of the districts served, must rule the cost, and hence the extent, of the canal-works that could in each case be legitimately undertaken. They were inclined to think that in the immediate future the waterways which would assist the prosperity of the country—apart from sea-to-sea canals—were those that would enable the sea-going vessel to get as far as possible into the heart of the manufacturing district; such waterways were wanted, and would be commercially successful. The improvement of existing river-channels, so as to enable sea-going vessels to get into the heart of the country, as had been done by the extension of the River Mersey to Manchester by the Manchester Ship-Canal, was the kind of work that was needed. The Clyde, for the lower portion of which, between Greenock and Port Glasgow, Messrs. Stevenson were Engineers, the Nith, the Lune, the Ribble, the Dee, the Foyle, the Forth, for all of which they had designed and executed works with this object, and the numerous other inlets around the British coasts, had a great future if the public were sufficiently enterprising to undertake the work of deepening them and improving them as the requirements of trade demanded. The advantage of shipping and unshipping cargo on or from the sea-going ship, close to the head offices of the shipowner and manufacturer, was incalculable; not to speak of the avoidance of more handling of the cargo than was absolutely necessary. The barge-canal could only deal with purely local traffic, or act as a feeder to the shipping-port. There were signs that this view was forcing itself on public opinion, and Messrs. Stevenson had recently prepared, for a committee of the county and city councils interested, a scheme for the further improvement of the Chester Dee, as also for the Firth of Forth. The Author referred to the proposal to form a Forth and Clyde ship-canal, for which they had made designs as long ago as 1889, and for which they had recently, at the request of an important syndicate, made detailed surveys, borings and plans, with a view to acquire parliamentary powers to construct it. Such a canal would greatly facilitate traffic by water-carriage between

Messrs. D. and C. Stevenson.

Messrs. D. and C. Stevenson.

ports on the west and east coasts of the country, and between west-coast ports and those of the Continent, by shortening the distance between them and avoiding the risks inseparable from the north-about or south-about voyages. They were glad that the Author's view agreed with the opinion they had formed as to the probable commercial success of such a scheme, should it be carried out, and that he recognized its strategical importance. This could hardly be doubted when it was considered that a vessel could pass from the Forth to the Clyde by the proposed canal in about 8 hours; that it would put at the disposal of the Admiralty an anchorage for a fleet in Loch Lomond, absolutely safe from sudden submarine or torpedo attack, and yet in a position to operate quickly on either the west or the east coast; and that this anchorage was within a short distance of the large yards on the Clyde, where repairs could be rapidly effected. Such advantages could all be attained by an expenditure on which the annual interest would not much exceed the cost of one ironclad. As the scheme had been fully described and discussed at engineering congresses and in the Press, they would only further say here that the important feature of their scheme as formulated was the fact that vessels could be passed from the Forth to the Clyde with only two locks at low water, and one at high water, at each end, and that an ample supply of water was available for locking. The absence of such natural facilities as to water and ground-configuration gave rise to difficulties which precluded the effective improvement of the existing Forth and Clyde Canal or the Caledonian Canal, and had led them, after careful consideration, to recommend the Loch Lomond route for the proposed canal, in place of following the line of the present Forth and Clyde barge-canal.

Mr. Thwaite.

Mr. B. H. THWAITE regarded the fate of the canals, through the indifference of the State during the early period of the Railway Era, as a proof that when the true interests of the State clashed with those of an aggregation of financially powerful persons, the interests of the State often had to suffer. This might be applicable only to England; but it was nevertheless true. The unrestricted depreciation of English canal-companies' property (the policy adopted by the railway-companies in the middle years of the nineteenth century) was one of the most disgraceful episodes of English commercial history. English statesmen of the forties seemed to have forgotten that efficient and economic means of transport were all-important factors of industrial and commercial prosperity. Subsequent governments had realized the mistake of this policy, but the Act of 1888, forbidding railway-companies, in the absence of special and statutory authority, to take over the control of canals, was only an illustration of the policy of

locking the stable-door after the horse had been stolen. The policy of the scientifically-controlled German government had been quite different; and now the German canal system and its proposed extension for strategical and commercial reasons commanded admiration, even if it did not excite envy.[1] The acquisition by the State of, or, as an alternative, the establishment of public rights over, the control and maintenance of waterways, would secure the recovery of a means of transport which was intrinsically superior, for raw materials, to railway transport;[2] but the efficiency of the American methods of railway transport, which were now being gradually adopted as far as practicable on British railways, rendered it imperative that only the most efficient methods of electrification should be adopted for English canals. The efficient and useful transformation of English waterways was only practicable on the following lines:—The employment of a method of electric haulage which would permit the existing tow-paths to be more or less entirely removed; in which the haulage locomotor relied for its adhesion on the transformed effect of the pulling strain set up by the tow-rope, the adhesive effect being always proportionate to the pull; and in which the locomotor could be controlled from the boat. The system of electric haulage devised by himself and Mr. George Cawley[3] had these qualifications, and would secure an increased width of canal and proportionate cross-sectional area, without involving the purchase of adjoining property, which in villages and towns might prove absolutely prohibitive. The system, which with some minor modifications has been copied and applied to

Mr. Thwaite.

[1] See B. H. Thwaite, "Transport Possibilities of Our Inland Navigable Waterways," Transactions of the Society of Engineers, 1905.

[2] The value of the nationalized canals of France was shown some years ago by the British Consul at Rouen. He pointed out that though Rouen was a point of contact of three of the great railway lines of France and was really well situated for distribution by rail, the share of the railways in the carriage of goods from Rouen was very inferior to that of the waterways. Also that improvements were being effected year by year in the French canals, and these were making out-of-the-way districts more and more accessible from Rouen, while industrial and commercial competition was forcing producers and distributors to water-carriage whenever time was of secondary consideration. The traffic was not limited to large quantities of agricultural products; colonial produce, wines and petroleum, as well as various chemicals, were despatched from Rouen to remote points, by the same interior waterway. The influence of the French canals was such that the value of the land increased or diminished as the banks were approached or receded from, in consideration of the facility afforded by the waterway for the cheap transport of the fertilisers of which the land stood in need. The Vice-Consul stated that goods traffic by canal had increased by 27 per cent. against 17 per cent. by rail.—B. H. T.

[3] British Patent No. 1087 of 1894.

Mr. Thwaite. the Erie Canal, would provide the maximum efficiency of haulage-energy, and would render the remodelling of the system of canal transport by modern engineering methods comparatively easy, even if the work involved the enlargement and reconstruction of some of the tunnels and bridges. In addition to the important advantages of canals over railways mentioned by the Author, including the possibility of loading or unloading boats anywhere, there was the advantage possessed by canals in the fact that they provided a water-supply of which full advantage was taken by canal-customers in the industrial areas of Lancashire and Yorkshire. Further, the canals would permit conductors for transmitting electrical power to be carried on the supports which carried the electric locomotor for haulage without necessitating special Acts of Parliament; so that an electrified canal could supply manufacturers and others not only with a service of water, but also with a supply of electric energy, as well as exceptionally cheap transport facilities. When Mr. Thwaite began (with Mr. George Cawley) to advocate the electrification of the canals many years ago, the work was like flogging a dead horse, but persistency and the success of land methods of electric traction had at last revived public interest in the future of the canals, and when the time arrived for consideration of the question whether or not the State should acquire the canals, some of the data collected and tabulated by the Author might prove of service in deciding upon the proper proportions of the canal-boats and the associated cross-sectional area, to permit efficient through traffic over the entire canal system. The difficulties of enlarging canals which passed through towns and other built-in areas might restrict the extension of the cross-sectional area to that secured by the removal of the tow-path. The Author's suggestion that electric batteries could be used for goods-haulage was unfortunate, because of the low efficiency of the system, due to the transformation and other losses and objections, including the drawback of the use of a screw-propeller, with its eroding effects on the banks of the canal. The Author's suggestion of the use of electric locomotives on the tow-paths of British canals was impracticable and defective; first, because of the width and constructional character of the tow-path—especially under bridges and tunnels; secondly, because of the waste of electric energy involved in propelling the electric rail-motor itself, the weight of which was constant and must be sufficient to overcome the inertia of the heaviest loads; and thirdly, because the use of electric locomotives running on rails on the tow-path would prevent the removal of the latter and the increased width of canal

that such an improvement would provide. In the Thwaite-Cawley system of electric canal-haulage locomotives ran on grip-rails of ⅂ section, carried by standards. The arrangement was such that a leverage effect proportionate to the tension of the tow-rope established a grip on the rolling surface. By increasing the height of the channel section or other supports, a telepherage system for carrying parcels, etc., could be associated with the haulage arrangement. The electric conductor was placed in a safe position. The two rails, one for running in each direction, were superposed. The system was applicable to bridges and tunnels of average size. The grip-rails were diverted from the side of the canal to a position placed centrally beneath the soffit of bridges and tunnels, or along their side walls. As the haulage locomotors were intended to be standardized, it would be possible to transfer the tow-ropes from one locomotor to another. The main question relating to the promotion of ship-canals in Great Britain—and one untouched by the Author—was the means of restoring public confidence in order to secure the necessary financial support for such costly undertakings. Of course the State might undertake such a scheme as the extension of the Manchester Ship-Canal to Hull, which every Yorkshireman would like to see carried out. When the Manchester Ship-Canal was first proposed, Mr. Thwaite put forward the view that if the promoters secured options over a considerable strip of land along each bank of the canal, for a long period after the completion of the canal, or purchased the rights thereto, then the appreciation of this land would ultimately provide for repayment of a considerable part of the cost incurred in the construction of the canal. That this appreciation was taking place in connection with the Manchester Ship-Canal and certain navigable rivers was well known, and it formed one argument that might be advanced to meet objections to a ship-canal uniting Hull with Liverpool.

Mr. Thwaite.

Mr. W. Noble Twelvetrees thought there could be no doubt that the regeneration of the British canal system was regarded as a distinctly practical idea among the manufacturing and mercantile classes. On the other hand, many persons were of opinion that the expenditure of capital on remodelling works upon a large scale would not be justified by the subsequent return. Mr. Twelvetrees firmly believed that if isolated canals, or groups of canals, were incorporated in a complete system of remodelled waterways, all difficulties and doubts would vanish. The only successful way of dealing with the problem was to accept a comprehensive scheme, analogous to that of the Author, whereby the great manufacturing districts would be placed in direct communication with the chief ports of the country,

Mr. W. Noble Twelvetrees.

Mr. W. Noble Twelvetrees.

and whereby sections of canal which were incapable of independent existence might be revived in the subordinate capacity of arteries and veins in a newly-constituted body, and nourished by the circulation of traffic to and from the industrial heart of the entire system. In his opinion it was about as reasonable to expect that a detached canal-route could be made to pay as to hope that the connecting-rod of a steam-engine would work when separated from the other parts of the machine. Still, assuming the existence of a well-designed system of thoroughly modern canals, of ample cross section and provided with locks suitable for dealing with vessels of large carrying-capacity, the main point was whether inland waterborne traffic could be developed to such an extent, within moderate limits of time, as would justify the undoubtedly heavy cost of constructional and remodelling works. Further, there remained two important questions, each of them inseparable from financial considerations, and consequently of duplex character. The first question was whether sufficient water could be provided for working the canals, and if so, whether the cost would be in a reasonable ratio to the traffic that might be anticipated within a reasonable number of years; the second was whether ordinary locks could be replaced to such an extent as to overcome any difficulty on the score of water-supply, without involving such an increase of the dues as would prevent the development of traffic, or, alternatively, without doing injustice to shareholders or others providing the necessary capital. On the question of water-supply, having regard to the serious difficulties encountered during the drought of recent years in the working of the existing canal crossing the Chiltern Hills, it must be admitted that there were reasonable grounds for reserving judgment. Moreover, in view of the activity displayed by local authorities all over the country in appropriating the remaining catchment-areas available for public water-supplies, the question of water-supply for a remodelled canal system would evidently demand very careful investigation. The computation of probable traffic on a given system of canals appertained to experts in commercial statistics, and inquiries into the feasibility and cost of water-supply to engineering experts. From the particulars contained in a Paper by Mr. Vernon-Harcourt,[1] and the subsequent discussion, it appeared to be clearly established that canal-lifts formed an economical substitute for locks from the constructional standpoint; and having regard to the probable cost of future water-supplies upon an extensive scale, it was probable that the installation and operation of lifts and other

[1] Minutes of Proceedings Inst. C.E., vol. xcvi. p. 182.

mechanical appliances would not involve heavier annual charges than those arising from the capital expenditure and maintenance of canal waterworks systems. The financial aspect of the question was necessarily one for searching inquiry. Much as the advocates of inland navigation might desire the guidance of civil engineers, they could scarcely expect to derive much definite assistance on points of detail from a general discussion such as the present. In his opinion, if careful selection were made of through routes, and capacious canals were established thereupon, with locks in places where water could be obtained without difficulty, and with lifts or inclines at other places where adequate water-supplies would be economically impracticable, a great development of waterborne traffic would inevitably result, with consequent advantage to the industrial classes and even to the railway-companies, who were inclined to regard with a somewhat jealous eye the present movement for the rehabilitation of the British canal system. In Belgium, where the canals served to place the great industrial districts in communication with each other and with the sea, there was no rivalry between the railway- and canal-departments of the Government. It was thoroughly recognized in that country that the true function of the railway was the transportation of merchandise quickly, and at comparatively high rates, and that the canals had an equally useful sphere of action in conveying goods in a more or less leisurely manner at purely nominal charges. The Belgian Government had been working for many years past to bring the canal system to a state of perfection with the view of benefiting the trade and commerce of the country, and the practical success attained showed the value of persistent efforts by a central authority working upon a comprehensive and well-considered scheme. Mr. W. Noble Twelvetrees.

Mr. L. F. VERNON-HARCOURT considered that the statement as to "the proposed lift connecting the Danube and Oder rivers," on p. 36, appeared to imply that only one lift, rising 114¾ feet (in reality an inclined plane surmounting a difference of level of 117⅘ feet), would suffice to connect these rivers across the water-parting of their basins, whereas seven inclines, with rises of 49 to 148 feet, would be required on the proposed Danube-Oder Canal. The instance alluded to by the Author was a special site on the projected canal at Aujezd near Prerau, selected by the Austrian Government for inviting competitive designs, for which large prizes were offered, for overcoming a difference of level of 117⅘ feet between two reaches of the canal, with a view to carry out at this place, as an experiment, the most approved scheme, which, if successful, would be adopted at the six other sites. The designs sent in com- Mr. Vernon-Harcourt.

Mr. Vernon-Harcourt.

prised locks with large rises, inclined planes, and vertical lifts; and he had pointed out, in a Paper[1] contributed to the Milan Navigation Congress held in September, 1905, the special conditions under which, in his opinion, each of these systems was most suitable for considerable differences of level between the reaches of canals. At Aujezd, the land had a very fairly uniform slope of 1 in 25 along the line chosen for the canal, and consequently the Vienna International Jury of 1904, appointed to decide upon the designs, had selected an inclined plane, with a caisson supported horizontally on a truck running on a number of wheels, travelling longitudinally on the incline, and propelled by electric motors, in which the barge would be waterborne. The insular position of Great Britain, together with its comparatively small area, which caused its river-basins to be very limited, so that its rivers were small except in their tidal estuaries, rendered it far less suitable for inland navigation than the large continents of Europe and America. Moreover, canals of fair length in England, having to traverse two or more river-basins, had necessarily to surmount considerable differences in elevation, causing great delays in transit, and forming a serious impediment to a large traffic. Thus, for instance, the Ludwigs Canal, though connecting two such important navigations as the Rhine and the Danube, having to rise 601 feet from the River Main to its summit-level, had had a small and decreasing traffic during the last 30 years, in strong contrast to the progress of the main waterways of Germany; and the Southern Canal of France, providing a short cut by water between the Bay of Biscay and the Mediterranean, and conforming to the standard size of the main French waterways, but having to rise to a summit-level 610 feet above sea-level, had always had only a small amount of traffic. Germany furnished an illustration of physical conditions in respect of inland navigation which were totally different from those of England: its large rivers, the Rhine, the Weser, the Elbe, and the Oder, traversed the country from south-east to north-west, and the Rhine-Elbe Canal, about to be constructed, ran from west to east, with a level reach, 130 miles long, between Münster and Hanover. Having been requested to write a Paper for the Birmingham meeting of the Federated Institution of Mining Engineers in 1895 on inland navigation,[2] he had specially investigated the

[1] "Investigation of the Methods best suited for surmounting great differences of Level between the Reaches of Canals." Milan Navigation Congress, 1905, Section I., Inland Navigation.

[2] "Inland Navigation, with Special Reference to the Birmingham District." Trans. Federated Inst. of Mining Engineers, vol. viii. p. 511.

routes by which Birmingham might be connected with the sea by an adequate waterway, thereby following very similar lines to four out of the five schemes contemplated by the Author. Briefly stated, he had found that the route to the Humber, 136 miles long, had a total variation in level of 461 feet, and followed waterways having four different owners, two of whom, according to Mr. Wells's canal-map, were railway-companies; and the existing route by water to the Mersey through Ellesmere Port, 85 miles from Birmingham, had a variation in level of 585 feet, and consisted of canals owned by three separate companies; whilst an alternative route to the Mersey had been proposed in 1890, by a new canal with lifts, between Birmingham and the River Weaver, $63\frac{3}{4}$ miles long, with a variation in level of 832 feet, designed to accommodate vessels of 300 to 400 tons. The route from Birmingham to the Thames at Brentford, by the Warwick and Birmingham, Warwick and Napton, Oxford, and Grand Junction canals, 135 miles long, had to cross the valley of the Avon in the Severn basin, and also the basins of the Nene and Ouse before reaching the Thames, necessitating a variation in level of 1,088 feet; whereas the other southern route to the Severn below Worcester was only 30 miles long, following the Worcester and Birmingham Canal, with only the descent of 425 feet necessitated by the elevated position of Birmingham. From the above data he had come to the conclusion that, though a connection with the Mersey, and thence with Liverpool, would be very advantageous for the trade of Birmingham, the greater feasibility and much smaller cost of an improved waterway to the Severn rendered this route decidedly the best to adopt, especially as it would adequately supply the requirements of Birmingham by putting it in communication by water with Bristol and the South Wales ports, and would offer the best prospect of a proper return for the capital expended in the improvement. Scarcity of water at a high summit-level like the position of Birmingham, as the Author observed in the course of his pessimistic remarks on p. 34, would be a serious difficulty for a canal with locks having a large traffic; and this would not be made easier by the four canals radiating from Birmingham proposed in the Paper, three of which would be unnecessary for Birmingham, and could not be constructed with any prospect of financial success; but the rapid descent on portions of the Worcester and Birmingham Canal would be very suitable for inclines or lifts, which need not be given the great heights suggested by the Author. There were no insuperable engineering obstacles to the improvement of inland waterways in England, though the conditions were unfavourable; but the real difficulty was a financial one, which had

Mr. Vernon-Harcourt.

Mr. Vernon-Harcourt.

become greater in the time which had elapsed since canals were first neglected in the second quarter of the nineteenth century, by the great growth of vested interests; and this the Author, except on p. 34, was inclined to treat very lightly. His statement that cheap transport was of far more importance to the country than large dividends to comparatively few shareholders was a truism; but he did not indicate how the requisite readjustment was to be effected without leading to communism. As the Author did not suppose that the schemes he proposed would be financially successful, he suggested that the Government should guarantee the interest on the cost, or that county councils should obtain the money from the rates of the counties through which the canals passed, and should treat them like roads. Besides the doubtful policy of a Government engaging in unprofitable undertakings at the cost of the overburdened taxpayers of this country, which would only benefit a limited portion of the population living in the neighbourhood of the improved waterways, it was difficult for a Government to limit its operations to the most advantageous routes, for every community situated near a canal would have an equal claim to governmental assistance; and a serious objection to the formation or improvement of a network of waterways throughout the country was exemplified by France, where a large amount of public money had been expended on rivers and canals in the southern portion of the country which were almost devoid of traffic. Canals could not possibly be regarded as similar to roads, except in such an exceptional locality as Venice, the haven of gondoliers and pedestrians, for the Author did not propose to bring a canal to everyone's door; and it would obviously be very unjust to rate persons for the improvement of a waterway because they happened to live in a county through the opposite extremity of which the waterway chanced to pass. He did not consider that the expression of such extreme views would advance the cause of inland navigation in England. The real way to promote the improvement of the neglected waterways would be to prove by the actual enlargement of the most promising canal, such, for instance, as the Worcester and Birmingham Canal, that a work of that kind could be made commercially successful; and then money would be readily forthcoming for any other schemes that had equal prospects of success. Government aid must necessarily be limited to loans on easy terms to thoroughly sound schemes having strong local support, and to facilitating proposals for amalgamation of canal-companies and the authorization of improvement works. The Returns of the Board of Trade in regard to Canals and Navigations should give the ton-mileage along various sections of the several waterways, so that the

distribution of the traffic could be indicated, as it was on the water-ways of France, Germany, and Belgium. A full investigation before a Royal Commission would be very valuable in determining what improvements were expedient and practicable, and in setting at rest once for all the discordant views on the use and improvement of waterways in Great Britain, which found expression from time to time without leading to any practical results. The Select Committee of the House of Commons on Canals, in 1883, before whom Mr. Vernon-Harcourt and other engineers gave evidence at the request of Mr. T. Salt, the originator and chairman of the committee, and to whom also the Canal Boats' Act (1877) Amendment Bill of that session was referred, were unable to conclude their investigations in that session, and they recommended that they should be re-appointed in the next session of Parliament; but as their recommendation was never carried out, no proper investigation and no report had hitherto been made on inland navigation in Great Britain. In this respect, Italy had recently set a very good example, for having, like Great Britain, neglected for a long time the question of inland navigation, the Government had appointed a commission in 1900 to investigate the condition and means of improving inland navigation in Northern Italy; and this commission, with the aid of surveys and details prepared by a technical committee, had published in 1903 a voluminous set of reports, describing the works which they advised should be gradually carried out. It was true that England did not possess large rivers like the Po and some of its tributaries, or extensive flat plains like those of Lombardy; but, on the other hand, this comprehensive improvement of inland navigation was contemplated in a district where steam tramways, which were practically light railways, had been most extensively developed, with great benefit to the population. Moreover, the Italian Minister of Public Works had appointed another commission in 1903 to report upon measures for developing inland navigation in the other parts of the kingdom, where the conditions, as regarded the extent of coast-line in proportion to the area of the country and the smallness of the river-basins, approximated to those of Great Britain.

Mr. Vernon Harcourt.

Mr. Lionel B. Wells agreed with the Author that it was necessary manufacturers and merchants should be induced to interest themselves actively in the subject, and following them, the Government; for, without public pressure and the public purse, nothing substantial was likely to be accomplished. Unfortunately, commercial men looked for profit quickly garnered and not for distant benefits; whilst the British Government acted

Mr. Wells.

Mr. Wells. slowly, except in panic. It required a far-seeing statesman to grasp the situation—such a man as the late Mr. Gladstone, who, just before the opening of the Manchester Ship-Canal, had assured his fellow-citizens of Liverpool that they need feel no alarm for their trade, or jealousy of that canal. In his opinion the canal would increase the commercial importance of the whole district, and Liverpool, being at the gate, would reap an enormous benefit and always secure the best of the trade. It was now possible after 11 years to appraise this forecast. The Ship-Canal was opened in 1894. In 1884 the net registered tonnage of ships in and out of Liverpool, excluding coastwise, was 10,176,000 tons; in 1894 it was 10,490,000 tons, being an increase of 314,000 tons; and in 1904 it was 14,500,000 tons, being an increase of 4,010,000 tons. The increase in the latter decade was thus thirteen times as much as in the former. At the same time the Manchester Ship-Canal conveyed in 1904 4,000,000 tons of goods 35 miles inland, instead of these being left on the seaboard. The city prospered, but the shareholders received no dividend to repay them for their outlay and enterprise. Mr. Wells believed that "carriers hold the keys of trade": the rôle of the Phœnicians, Venetians, Dutch and English went to prove this; and if, as the best authorities stated, the cost of carriage by rail in England was higher than in any other country except Russia, it was imperative that the cost should be reduced, or the vital interests of the country would suffer. England's canals were made in the eighteenth century and her railways in the nineteenth. In those eras she was in advance of her foreign competitors, and the cost of carriage was less at home than abroad. Now the reverse was the case. If nothing were done, the position with reference to transit of goods would be the same as it was a few years ago in regard to technical education, when the nation awoke to the fact that it was far behind many of its competitors and something like a panic ensued, which led to extravagance, causing the want of forethought to act still more prejudicially on the interests of the country. Mulhall had put the average cost of carriage of goods generally in Europe in 1850 at 8*d.* per ton-mile, as against 1*d.* per ton-mile in recent years. At that date the chief manufacturing districts and towns of England were provided with railways, but on the Continent railway-construction was only beginning. The foreign lines were now nearly all State-owned and the charges were lower than in England. About 12 years ago Parliament and the Board of Trade revised the railway-rates; so that further relief could not be looked for in that direction. The remedy could be provided by improving the waterways and

enabling carriers by water to compete with railway-companies: the latter were to-day practically monopolists of inland carriage, and were it not for the sea being available at comparatively short distances the position would be intolerable. The Author rightly aimed at vast improvements, and Mr. Wells quite agreed with his statement as to the present condition of British waterways. He had reported on many of them in various parts of England and in Wales. But few were kept in good order; most of them were neglected. The canals and the agriculturists had tried to live as of yore, and both suffered for want of organization and neglect to advance with the times. Amalgamation and a co-ordination of interests were imperative. To send goods from the Black Country to the London Docks entailed passing along portions of the canals of five different companies; and if the Regents Canal was traversed the five became six. Neglect on the part of any one company prejudiced the route; and each company had to be paid. Some years ago the Oxford Canal had stood out for three times its mileage proportion of the through toll from the Black Country to London. The London and North Western and Great Western Railways covered the distance traversed by the five canal-companies with distinct railway-routes. The railway policy of amalgamation was in glaring contrast with the aloofness of canals. The North Western Railway was made up of fifty or sixty different companies and owned 1950 miles of line, stretching from the Midlands to deep-water docks at both London and Liverpool. The longest canal system, the Shropshire Union, aggregating 200 miles, was owned by this railway-company, and the total mileage of waterway in its hands was 460 miles, including the Birmingham Canal. The Great Western Railway was 2,700 miles in length and owned eleven canals aggregating 230 miles. There were one hundred and thirty different lengths of waterway owned by one hundred proprietors. Undoubtedly the Midlands and Birmingham district was the one where relief was most needed. The Wolverhampton Chamber of Commerce had been among the first of the public bodies to direct attention, in a report made years ago, to the need of cheaper means of access to the sea-board. Manufacturers were leaving for the coast, and consular and other reports showed that the cost of carriage from the factories in Germany and Belgium to the seaports was far less for longer distances than it was in England. The Rhine and its tributary navigations brought goods from the Rhenish provinces to compete with Birmingham and Wolverhampton, as well as salt from the German mines in competition with English salt-mines. These navigations had been made and were maintained by the State. In

Mr. Wells.

Mr. Wells

France projects were sanctioned in 1903 authorizing the Government to spend £8,250,000, of which £1,160,000 went to complete works in progress, and the balance of upwards of £7,000,000 for new works. Among the latter was a canal from Marseilles to the Rhone, estimated to cost £2,840,000, and the Canal du Nord, estimated to cost £2,400,000. In each case the district would be called upon to contribute one-half. The quantity of traffic which might be expected in England appeared to be very great, for, neglected as the waterways were, the tonnage compared very favourably with the weight conveyed in France. Some years ago Mr. Wells found that, roughly speaking, the French waterways were 8,000 miles long; in England and Wales 3,500 miles were still open, and between 400 and 500 miles were derelict or had been converted into railways. The tonnage carried on English canals was 33,000,000 tons, or about 50 per cent. more than on the French canals at the corresponding date. Since then the weight carried on the improved canal system in France had increased by 50 per cent., and was now one-fourth of the weight carried on the 22,000 miles of railway in that country; so that while 4,000 tons was carried by water, only 6,000 tons was carried per mile of railway.

	By Rail. Kilometric Tons.	By Water. Kilometric Tons.
1883	11,000 millions.	2,000 millions.
1900	16,557 ,,	4,675 ,,
1901	16,015 ,,	4,380 ,,
1902	16,200 ,,	4,465 ,,
1903	Return not yet issued.	4,955 ,,

In England the railway tonnage was 380,000,000 tons, the canal tonnage—excluding the Manchester Ship-Canal—37,000,000 tons; say one-tenth waterborne, as compared with one-fourth in France. The total tonnage on English canals exceeded the French tonnage, although the French canals were 4,500 miles longer. The trade of England was enormously greater. The Author rightly guarded himself when suggesting a standard canal for discussion. The subject needed thorough ventilation before a standard could be fixed. Mr. Wells's view was that a larger section than 680 square feet would be necessary, for the deepening of the Weaver Navigation from 8 feet to 10 feet had been at once taken advantage of. New craft had been built to utilize the greater depth, and old craft had been raised; a few had even been cut in twain and lengthened. The improvements made on the Weaver Navigation during the last 40 years were instructive. The Act of Parliament for the construction of the Runcorn Branch Railway, obtained in 1863, alarmed the

trustees of the River Weaver, who feared that this railway would divert a large portion of their traffic in salt and coal. They were enjoying a handsome revenue, and determined to devote a large portion of this to improvement of the navigation. Under the advice of Sir E. Leader Williams, Vice-President Inst. C.E., who was their Engineer at that date, it was decided to provide for steam-towing in train and for widening and deepening the navigation. The large lock-sills had been laid at a depth of 15 feet according to the programme then adopted. After completing the lowest lock Sir E. Leader Williams went to the Bridgewater Canal, and was succeeded by Mr. J. W. Sandeman, M. Inst. C.E., who began two more locks, which had been described in the Proceedings.[1] Mr. Wells succeeded Mr. Sandeman and finished these locks. The navigable depth when he went to the Weaver was barely 8 feet. In 3 years, by means of these locks and by placing movable caps on a number of weirs, the navigable depth was increased to 10 feet up to Northwich Salt-works, and to 9 feet 6 inches to Winsford, enabling the cargo to be increased from 220 tons to 350 tons. Subsequently Mr. Wells built two large locks to replace four of the old one above Northwich, and completed the improvement to the head of the navigation at Winsford. It was to assist in this work that the Author entered Mr. Wells's office. The improved navigation had five locks in lieu of nine, and at the same time was rendered a better flood-course; so much so that, whereas in 1877 he experienced a flood approaching 8 feet on the gauge in the town pond at Northwich, many years had now elapsed since a flood rose 2 feet 6 inches on the same gauge. Before the improvements carried out by Sir Leader Williams floods rose 12 feet. This question of floods should not be forgotten when advocating the improvement of inland waterways. Most of the navigable rivers were liable to flooding, especially the Thames. On the Lower Thames the Stoney sluices at Richmond, which had improved the navigation, let off floods without hindrance. The Dutton sluices, which Mr. Wells built in 1881, had helped materially to keep down floods in the Weaver Valley, and had been the forerunners of the Stoney sluices on the Manchester Ship-Canal, which had a similar beneficial effect on floods in the valley of the Mersey and Irwell. Floods were now abolished below Manchester. If the Weaver Navigation were taken as a guide, the draught there had stopped at 10 feet 6 inches, although the locks admitted of an addi- Mr. Wells.

[1] J. W. Sandeman, "The River Weaver Navigation," Minutes of Proceedings Inst. C.E., vol. lxiii. p. 261.

Mr. Wells. tion of several feet. The Aire and Calder Navigation was now 8 feet 6 inches deep, and was to have 9 feet on the sills. The new canal joining the Aire and Calder Navigation with the Stainforth and Keadby Canal had been made for 9 feet 6 inches. The Severn was 10 feet deep to Worcester. The improvements made 50 years ago in the navigation of the Seine between Paris and Rouen, a distance of 145 miles, were limited to a draught of 5 feet 3 inches, and even this was not secured. In 1866 it was determined to make the navigable depth 6 feet 6 inches. In 1878 works were authorized to increase the depth to 10 feet 6 inches, which now obtained. In Canada the Welland Canal was 14 feet and the Soulanges Canal 12 feet deep. Probably the best object-lesson was derived from the treatment of the Erie Canal. This canal, made in pre-railway days, was credited with being the chief factor in making New York the foremost port in America, and its great influence on freights had often been emphasized. The original canal was 4 feet deep; by the enlargement of 1862 it was made 7 feet deep. An additional 2 feet was proposed about 10 years ago, but the advocates of 12 feet carried the day. The work was in progress; already work to the value of more than £1,000,000 was under contract, and further work costing £750,000 was to be put in hand by the end of 1905. Traffic had dwindled on the waterway, and the necessity for enlargement was due to the fact that the smaller waterway had ceased to be an economical carrier under modern conditions. The size of locks on any improved system would be governed to a large extent by the depth of water, due consideration being given to the size of existing craft as proposed by the Author. Any enlargement of the canals would be a benefit, more especially if the locks and other works provided for towing in train. The following figures were current some years ago and would explain the position. The through rate of tolls from Birmingham to Brentford on the Thames, a distance of 149 miles, was then fixed at 2*s.* 6*d.* per ton.

	£	*s.*	*d.*
Toll, taking 24 tons as a boat-load	3	0	0
Haulage and navigation, 0·33*d.* per ton-mile . .	4	19	0
Total cost with horse-haulage . . .	7	19	0

If the haulage were taken at the rate of steam-haulage ruling on the Aire and Calder Navigation the account would stand thus—

	£	*s.*	*d.*
Toll	3	0	0
Haulage, 0·03*d.* per ton-mile.	0	9	0
Total cost with steam-haulage . . .	3	9	0

Difference, £4 10*s.* per trip.

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The Midland district, as its name implied, was farthest removed from the sea. Manchester had its Ship-Canal, the Bridgewater and Rochdale Canals, and two railway-owned canals. Three out of the four accommodated barges. Leeds had the Aire and Calder, and Sheffield the Don for barges, whereas the Midlands were served by narrow canals on which cargoes were less by one-half than those reaching Sheffield. Imported ore was used in large and increasing quantities in the Midlands, and there was a great export trade. The proportion of inhabitants engaged in industrial pursuits in comparison with other parts of the country was unusually large in the heavy trades. Iron-founders, smiths, and general metal-workers, one-half the tool-makers, the cycle- and motor-makers, one-third of the brass- and copper-smiths, and nearly all the makers of nails and pens, as well as of anchors and chains, were in this district. There were two ports in England which eclipsed all others in the magnitude of their trade, namely, London and Liverpool. The registered tonnage of shipping entering and leaving annually was—

	Tons.
London	19,000,000
Liverpool and Manchester	16,500,000
Hull	4,500,000
Bristol	2,000,000

In order to obtain the necessary relief for the export trade, either London or Liverpool must be connected with the Midlands, for these were the ports from which liners and tramps voyaged to all parts of the world. A canal between London and Liverpool, traversing the Midlands, would be an ideal project to begin with; but as there might be a disposition to go first of all to one port or the other, he agreed with the Author that the Mersey ports offered the best facilities. The Author had suggested routes from the south-east side of Birmingham and from Wolverhampton to Liverpool. Mr. Wells desired to point to another route which he thought offered greater advantages. First of all, he considered that the Mersey should be sought instead of the Thames, for physical reasons. The distance between Birmingham, the south-eastern limit of the district, and the Thames was 136 miles. There were two summits intervening, one near Rugby, the other near Tring. These had to be surmounted, entailing a rise and fall of 1,060 feet, with three tunnels to be negotiated, and water to be found for three summit-levels. The total distance to the London Docks was 146 miles. If the Mersey was made the objective, the length along the Author's route 2A from Birmingham was 109 miles, and along route 2B 102 miles. These distances Mr. Wells had been unable to verify to his satisfaction, and he

Mr. Wells. thought they must be increased to 115 and 109 miles respectively following existing canals. At any rate, a glance at the map showed that the routes were not the shortest between the starting-point in the Midlands and the Liverpool Docks. That line was occupied, from within 2 miles of Wolverhampton, by the Shropshire Union Canal, No. 32 on the map (Plate 1). From the point of junction of Nos. 32 and 33 the improved canal might be taken either to the Weaver or to Ellesmere Port, where 34A joined the Manchester Ship-Canal. From Wolverhampton to Liverpool via Ellesmere Port was 77 miles. *Fig. 4* was a longitudinal section along this line, which showed a continuous fall from Wolverhampton to the Manchester Ship-Canal. There were no tunnels west of Wolverhampton; on the other route was the Harecastle tunnel, 2,900 yards long, which was known to be in a dilapidated condition, owing to coal-workings in its neighbourhood. By route No. 2 suggested by the Author the very important district between Wolverhampton and Birmingham would not be served. Two summits intervened between Birmingham and Liverpool, namely, Aston and Harecastle, with a lockage of 706 feet as compared with 488 feet of lockage via the Shropshire Union Canal—an increase of 42 per cent. The Author appeared to have set aside the Shropshire Union line because it was owned by the London and North Western Railway Company. The route he favoured followed the Trent and Mersey Canal, which was the property of the North Staffordshire Railway Company. The Birmingham Canal and Birmingham and Fazeley Canals were also traversed for 20 miles, and as this system was virtually owned by the London and North Western Railway Company, this Company's opposition would have to be met whichever route was adopted. In addition, the Coventry Canal Company would have to be satisfied. In Mr. Wells's opinion the fears of railway opposition were exaggerated. With several other engineers he had been concerned in assisting the late Mr. Thomas Hawksley to wrest the Sheffield Canals from what was then the Manchester, Sheffield and Lincolnshire Railway. The question was fought in both Houses of Parliament in 1889, and the canals were emancipated in the first year in which power was sought. The route he proposed could be utilized in part by the Pottery district of Staffordshire, but it would entail a branch canal being made to join the enlarged Shropshire Union Canal which would give a shorter route from the Potteries than via the Trent and Mersey Canal. To obtain a maximum of efficiency, a short route with a corresponding saving of time in transit was desirable, and the carriage of the traffic from the more populous district round

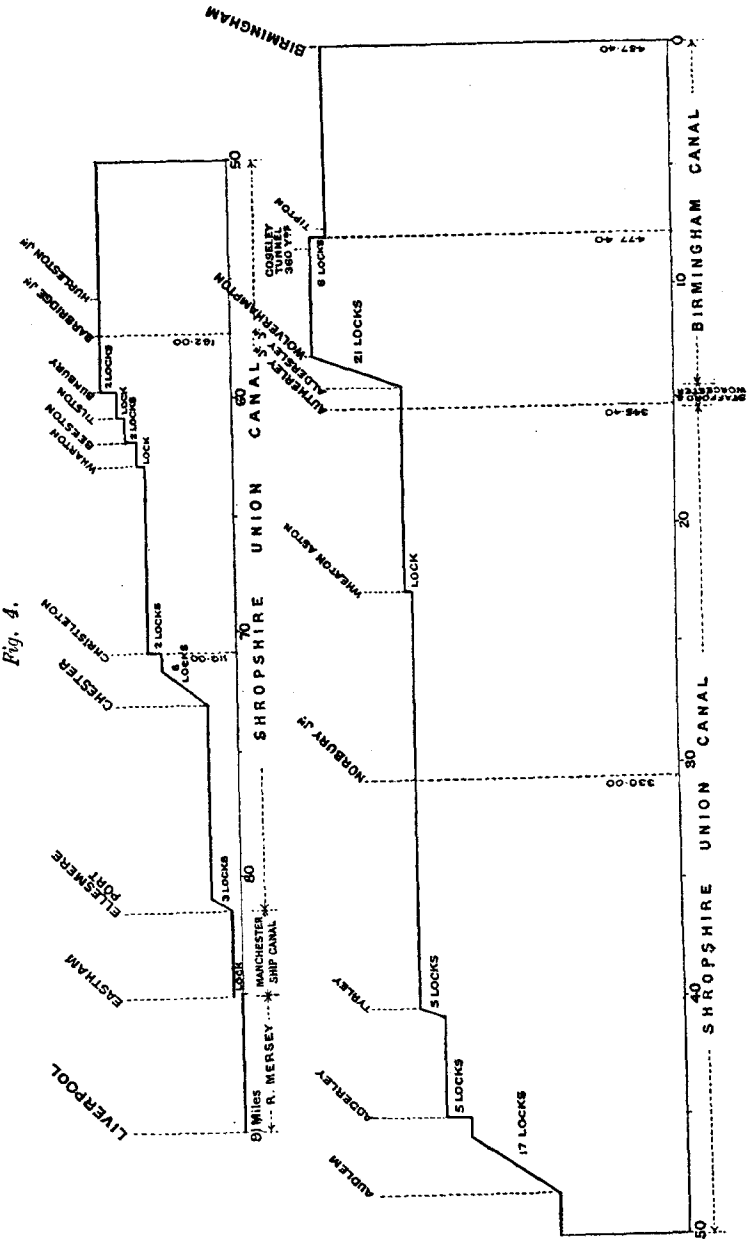

Fig. 4.

Mr. Wells. Birmingham and Wolverhampton 116 miles instead of 91 miles, and over two summit-levels, was to be avoided except under dire necessity. The question of the supply of water for the additional summit-levels would be a serious one. A large portion of the water used by the Birmingham Canal had to be pumped at present. The cost of pumping was decreasing. This expense had to be reckoned with. It was to be hoped that a thoroughly capable Royal Commission, composed of men representing the chief interests involved—manufacturers, merchants, traders and carriers by road and rail, canal and sea—would be appointed, and the terms of reference carefully drawn to enable the inquiry to be thorough and exhaustive. Each country had its peculiar circumstances affecting the methods of dealing with its products and commerce. England's insular situation and enormous trade differentiated her position from that of other nations; but it would be folly to sit still and allow competitors to enjoy cheaper means of transport than she herself possessed, without doing the utmost to recover her position.

The Author. The AUTHOR, replying to the Correspondence, was pleased to note that the estimates given by Mr. Keeling for the improvement of the Worcester and Birmingham Canal were so nearly in accord with those given in the Paper. This canal was 30 miles long, and the estimated expenditure was £600,000, or an average of £20,000 per mile, showing that the Author's estimate of £30,000 per mile of entirely new canal was probably reasonable. Having dealt fully with the question of water-supply in his reply to the Discussion, he did not think it necessary to reply further to the remarks thereon by Messrs. Paterson and Twelvetrees. Mr. Thwaite appeared to have misunderstood the Author's views as to the possibility of using electric batteries or locomotives on the towing-path. It was clearly stated in the Paper that the former were not at present available, owing to the want of a suitable secondary battery; and the latter would require the maintenance of a railway as well as the canal. What the Author wished to emphasize was that any means of traction must have the utmost flexibility, which would certainly be afforded by an electric battery, should a really efficient one be invented at some future date; but he was doubtful whether, apart from the double cost of maintenance, any fixed gear, such as a railway or ropes, could ever be as convenient as self-propelled barges, which, in addition to carrying cargo, could tow dumb barges in trains. With reference to Mr. Vernon-Harcourt's remarks, the Author had merely endeavoured to put forward the different methods of dealing with the question from a financial and political point of view, and was really

not advocating any particular method. He was quite convinced, however, that, supposing money could be found at a rate of interest not greater than it could now be borrowed by the Government or by the counties, such canals could be made to pay that interest as well as their working-expenses, with a margin for either repayment of debt or extension. Whether it was desirable to construct them out of public funds and then maintain them free of toll was a question for future consideration; but if such a scheme as that foreshadowed in the Paper was to be undertaken, it seemed almost impossible at the present time to raise money from the general public, who apparently looked for a much higher rate of interest, unless there was some substantial guarantee to fall back upon. The Author could fully endorse Mr. Wells's remarks as to the improvement in the flood-level on the Weaver, due to the modern sluicing arrangements, as since 1888, when Mr. Wells left the Weaver and the Author became Engineer, there had been no flood higher than 3 feet 7 inches at Northwich, and the only difficulty experienced had been due to the increased velocity of the water, which had at times caused detention of the traffic for a few hours. With regard to the routes, there was not much difference in length between the Author's route No. 2B from Wolverhampton to the Mersey (88 miles) and Mr. Wells's Shropshire Union route of 77 miles; but the Author considered, as he had stated in replying to the Discussion, that the Weaver route was preferable, as the 20 miles of river was of ample dimensions, and the traffic already thereon would be of material assistance so far as finances were concerned. A large portion of the remainder of the route to South-East Birmingham would also form a portion of the Hull to Midlands route, and would therefore be doing double duty; while the existing canals between Birmingham and Wolverhampton would serve as feeders both ways, being more of the nature of a collecting-basin or dock system, as suggested by the Author in the Discussion, than canals proper. The same reason, namely, existing traffic, also applied to the route through the Potteries, though this could be partly met, as mentioned in the Paper, by a branch canal. The apparent discrepancy in length was due to the fact that the Author took a line higher up the valley and passing nearer Lichfield than the existing canal.

The Author.