THE MANCHESTER SHIP CANAL

Reprinted from "ENGINEERING" January 26th 1894

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SECOND EDITION.

LONDON:
OFFICES OF "ENGINEERING," 35 AND 36, BEDFORD STREET, STRAND, W.C.

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THE MANCHESTER SHIP CANAL.

I.—THE HISTORY OF THE CANAL.

It is now eleven and a half years since the first practical step was taken to give life to the project of making a ship canal to Manchester, a scheme which, however, had long been maturing in the minds of some of the leading men of the great cotton centre. As one recalls the difficulties and dangers that have been passed, it is hard to realise, even with the substantial evidence of advertisement handbills announcing ocean sailings before us, that Manchester is in truth a port, with a shipway leading to all the coast lines of the world. It is a great triumph for an inland city, but the victory has not been bought without price; so that even in the hour of fruition the great canal appears to some chiefly as a memorial to those who strove so well in the past, when the fight was thickest, but who have not lived to see the end.

It was in June, 1882, that the late Mr. Daniel Adamson called a meeting at his house for the purpose of discussing the best means of giving Manchester access to the sea. Five years previously the Manchester Chamber of Commerce passed a resolution to the effect that a water-way capable of being traversed by large vessels was required—and, indeed, a scheme of the kind had been matured sixty years before, when it was proposed to make a canal through Cheshire to the Dee estuary—but until Mr. Adamson took the matter so vigorously in hand, nothing very practical was done. The meeting at his house was attended by a majority of the leading business men of the district, and a committee was then formed to consider such engineering schemes as might be brought forward. Two plans were submitted; one for a tidal navigation at one level all the way, and a second for a canal with locks. The first-named scheme was presented by Mr. Hamilton Fulton, but, though the more popular, it did not meet with the approval of Mr. James Abernethy, who had been appointed to bring his great professional knowledge and matured judgment to the weighing of the rival suggestions. Mr. Abernethy, it may be added, has acted as consulting engineer to the ship canal from the first. It was very properly argued that, though it might appear in itself a good thing to save the expense of making locks, that would prove false economy, as the surface of the canal would be about 60 ft. below the level of the land at Manchester. This would either necessitate considerable excavation to bring the quay walls to a proper level, or the ships would be lying at the bottom of a deep ravine. In any case, the goods would have to be lifted to the level of the roads, and this could be better done by raising them in the ship by means of locks, rather than hoisting them up piecemeal with cranes. Mr. Fulton's scheme having been disposed of, Mr. E. Leader Williams, who had submitted the second-named scheme, remained in possession of the field. It is, perhaps, hardly necessary to state that the canal, as carried out, is a very different work from that put forward originally by Mr. Leader Williams. As first proposed, the main entrance of the canal was to be at Runcorn, and from thence to Garston there was to be a channel dredged, which was to be kept open by means of half-tide training walls. It was with this scheme that the promoters went to Parliament in 1883, and from that time commenced one of the hardest fights that was ever carried out in the Legislature on behalf of any engineering project.

Before proceeding further, it may be well to give a brief outline of Mr. Hamilton Fulton's project; and, indeed, that engineer now deserves a word of recognition for his long previous labours in the cause of a ship canal, although his scheme was rejected—and rightly so—in favour of that of his more successful rival. The distance along the old Mersey and Irwell navigation with which he proposed to deal was 42 miles, and included the nine locks between Manchester and Warrington, equalling in all a fall of about 50 ft. At ordinary spring tides the rise and fall at Warrington was about 6 ft., and from the latter town to Manchester there was depth of water for vessels drawing no more than 4 ft. From Warrington to Runcorn the limit was 9 ft.; whilst from Runcorn to Liverpool it was 12 ft. Mr. Fulton proposed to deepen and widen the Irwell and the Mersey between Trafford Bridge—which is almost at the head of the present ship canal—and Liverpool, giving a depth of 22 ft. at low-water spring tides all the way. This would have been effected by a practically straight and newly excavated channel, with passing places every three or four miles. The tidal portion of the river between Warrington and Runcorn would have required straightening, widening, and deepening, by means of excavating, by retaining walls, and by dredging, so as to secure a similar depth of 22 ft. at low-water spring tides. Lower down, in order to establish one channel for the ebb and flow of waters, it was proposed to regulate a low-water channel by means of training walls in such a direction as would induce the flowing and ebbing currents to pass along one channel. By the formation of this channel Mr. Fulton proposed to lead the tide to Manchester, and there to construct a dock, and he considered that the rise of the spring tide would give an additional depth of 15 ft. of water. In regard to the obstructions above water, it was proposed that the main lines of the London and North-Western Railway, and of the Cheshire Lines Railway, should cross by means of swing bridges; whilst two other railway bridges were to be raised to give the required height. The Bridgewater Canal, where the swing aqueduct now is, was to be dealt with in a very original manner; Mr. Fulton proposing to lift the section of the Bridgewater Canal crossing the ship canal through a vertical distance of 10 ft. by means of hydraulic presses. The water-way itself would naturally have taken the form of a long tank, as at present reconstructed, the main difference being that it would have been raised bodily in place of being made to swing. It should be further added, that for ten years previously Mr. Fulton had been calling the attention of the public to the necessity for a ship canal to Manchester, and now that the project has been carried out, though in different shape, a word of recognition of his early labours is, as we said before, but a common act of justice.

The story of the fight before Parliament upon the Manchester Ship Canal Bill has already been told in Engineering, and to repeat the narrative in full would take up more columns than we can afford, even with the space we are now giving to the matter; but no engineering record of the great work would be even approximately complete without recalling once again the main incidents.

Mr. Leader Williams' first proposal was for a canal 22 ft. deep and 100 ft. wide, and having three locks. The channel through the shoals and shifting sandbanks of the Mersey estuary was to be maintained by means of training walls. The deep navigable water practically ends at Garston (see pages 3 and 7), where there are docks. From Garston upwards to Runcorn, where the river narrows, and the first bridge crosses at a height of 75 ft. above high water of the highest spring tides, the channel was to be, as stated, maintained by training walls. From thence upwards the river was to be deepened, straightened, and generally improved, until Latchford, near Warrington, was reached, and here would be the first lock; the tide flowing so far upwards. Between Latchford and Manchester the old river would be canalised completely; in fact, it was to have been dealt with in somewhat the same manner as has since been carried out; for the natural course of the Irwell and Mersey was too tortuous to be of use for the conveyance of large vessels, even if the necessary depth were provided. It was also a part of the scheme that docks were to be made at Latchford, Irlam, and Barton, as well as the terminal docks at Manchester. The total estimate for this work was 5,160,000*l*.

This, however, was not exactly the scheme that was taken to Parliament by the provisional committee promoting the canal, it being so far altered that, instead of utilising the existing river channel to Warrington, the river bed was to be abandoned about 1½ mile above Runcorn, and a new cutting mainly depended on. In going to Parliament, the ship canal promoters did not have a clear field, for the ground was already in possession of a powerful company. Although so little had been done to improve the navigation of the Irwell and Mersey, the right to water traffic was held by a rich and influential corporation, the Bridgewater Navigation Company, whose capital was over a million and a quarter; so that before the promoters could carry out their scheme and appropriate the rivers, they had either to buy out the Bridgewater Navigation, or compensate them in some way. The Bridgewater Company were amongst the early opponents of the ship canal, but terms were ultimately made so that the whole of the Bridgewater Navigation was merged into the ship canal scheme.

At the close of 1882, the Bill which was to authorise the construction of the Manchester Ship Canal, according to the plan last briefly described, was deposited, and the promoters soon began to gain experience of the difficulties and delay attendant upon getting an Act for such a vast engineering work. In the first place, Mr. Frere, the Examiner of Bills to the House of Commons, reported that the Standing Orders had not been complied with, inasmuch as plans of the channel and training walls of the estuary had not been prepared, and that 4 per cent. of the estimated cost of works in the estuary had not been deposited. This check showed at once the strength and weakness of the promoters' position. The provisional committee decided to petition both Houses that the Standing Orders might be dispensed with, and this petition was supported by no less than 38 municipal bodies, 91 local boards, 31 chambers of commerce, 108 companies, and many landowners along the route. Opposition was made to the petition by the London and North-Western Railway Company, the Mersey and Irwell Navigation, the Bridgewater Navigation Company, the Mersey Docks and Harbour Board, the Upper Mersey Commissioners, the Trustees of the Weaver Navigation Company, and the Salt Chamber of Commerce. All these bodies viewed with "extreme anxiety" the "hurried and immature" scheme before Parliament. The incident well illustrates the difficulties that beset the inauguration of any great engineering scheme in this long settled and thickly inhabited country, scarce a square mile of which is not the seat of vested interest and ancient right. It also illustrates the extremely conservative, not to say obstructive and retrograde, policy of big corporations and companies. Much of the opposition to the Manchester Ship Canal was quite easily to be accounted for, but a great part was mere dog-in-the-manger obstructiveness; indeed, many of those who were likely to reap most benefit from the creation of the work were amongst the most obstinate of its opponents. However, the petition was so far successful that the Commons determined to dispense with the Standing Orders; and, after thirty-seven days' discussion in Committee, the Bill passed the Commons, though saddled with conditions entailing a further application to Parliament in a subsequent session. The promoters, however, thought well to proceed, so the Bill was carried to the Lords. Unfortunately, the Special Committee of Peers took a different view of the matter from the Commons Committee, declining to allow a Bill to proceed, which would, in part, depend upon a second Bill yet in the future, and the scheme was, therefore, dead for that session.

The ship canal promoters were not easily discouraged. In spite of the large sums spent to no purpose, they came forward next session with a new scheme. In regard to the canal itself, the main features were very similar to the old plan, only the lower locks were to be brought nearer the sea. The capital of the proposed company was to be 10,000,000*l.* Of this sum the works on the canal proper were to cost nearly four millions, which was a reduction on former estimates, and the probable cost of the estuary work was given at 1,390,419*l.*, making a total of 6,904,186*l.* for the whole work. Training walls were to be made down to Garston, where they were to be 1000 ft. apart, the distance narrowing to 400 ft. opposite the Weaver mouth, from whence the channel would gradually close into the canal proper. It was on this estuary work the parliamentary fight was to rage strongest. That nothing should be done to ruin the approaches to the Mersey, was of course evident; indeed, the ship canal promoters were as much interested in this as any. The great fear—and it was a legitimate one—was whether the training works in the estuary would lessen the tidal flow. The entrance to the Mersey is much narrower than the upper part. The tide, therefore, runs harder where the sectional area is less, and this keeps the channel clear by scour. It was said by the opponents of the Bill that if the upper part of the estuary were interfered with, banks would increase, and there would be less water to flow in and out, so that the tidal scour would be less, and the channel over the bar would silt up. This, roughly, was the contention of the Mersey Docks and Harbour Board and those who acted with them; and they were so well supported by counsel and expert evidence, that the Commons threw out the Bill, although the Lords passed it. So far, then, no headway had been made, although it was said at the time that close on a quarter of a million had been spent by both sides on legal and other expenses.

As supporters of the canal scheme were the designers of the works, Mr. E. Leader Williams and Mr. Abernethy; Mr. (now Sir John) Fowler, Mr. (now Sir B.) Baker, Mr. Bateman, Mr. Brunlees, Mr. Messent, engineer to the Tyne Commissioners; Mr. Deas, engineer to the Clyde; Mr. Fowler, engineer of the Tees; Mr. Lionel B. Wells, engineer to the Weaver Navigation; besides other engineers more or less eminent in their respective walks. On the opposite side were: Sir J. W. Bazalgette, then President of the Institution of Civil Engineers, and engineer to the Metropolitan Board of Works; Sir Frederick Bramwell, Mr. Thomas Stevenson, of the Northern Lighthouse Board; Mr. G. F. Lyster, engineer to the Mersey Dock and Harbour Board; Mr. Robert Manning, chief engineer of public works in Ireland; Mr. Harcourt, engineer to the Hull Albert Dock; Mr. Deacon, engineer to the Liverpool Water Works; Sir William Thomson, now Lord Kelvin; and Captain Hills, R.N., surveyor. With this imposing array it may be imagined how money was lavished, and it has been said that during the twenty-eight days of the inquiry the expenses were at the rate of five guineas a minute. The most expensive man of the whole number, however, remains to be mentioned. This was the late Captain Eads, the great American engineer, who opened the mouth of the Mississippi to the sea. He was retained by the Mersey Dock and Harbour Board, who paid him what is said to have been the highest fee ever received by an engineer for consultation, 4000*l.* The expenditure, large as it was, was fully justified by the results, for Captain Eads proved himself a valuable witness. He had a popular style and a confident manner, two excellent things when before a Parliamentary Committee. It was largely on Captain Eads' evidence that the Bill was thrown out. As to this evidence, it is but right to say that the distinguished American had himself no personal knowledge of the tidal and other conditions of the estuary of the Mersey, and that his statements were necessarily based upon information supplied to him by others. Part of this information was furnished in the shape of tidal diagrams, which were hung upon the walls of the Committee-room when Captain Eads was in the box. The engineers of the company, who had themselves made exhaustive experiments as to the tides and currents in the estuary, disputed and still dispute the accuracy of the diagrams *in toto.* With this important difference as to facts before us, we must be understood here to put forward only the case as stated by the opponents of the Bill.

The diagrams which were produced showed that for a distance of six miles above Garston the surface of the water for 2 hours and 40 minutes remains comparatively level, during which time the water falls at each one of these places about 13½ ft. The area of shoals in Liverpool Bay exposed during low tide was estimated at 35 square miles. At equinoctial spring tides, the rise and fall is 30 ft. at Liverpool, and the immense volume of water to fill the estuary, rushes across the shoals in the bay, and then up through the comparatively narrow channel opposite Liverpool—about 2800 ft. wide and 70 ft. deep—over a sandstone bottom. During low water about 20 square miles, of the total 37 square miles of the estuary between Dingle and Runcorn, is occupied by shoals of sand and earthy matter. These extensive sandbanks are 20 ft. to 25 ft. above water when the tide is down, but when the tide has covered them and the water is almost at rest, the sand with which the water has been charged settles on the tops of these banks as well as in the channels between them. It has already been said the contention was that there was little or no current for 2 hours and 40 minutes after high water, and by the time this period had elapsed, the tops of the banks had been left dry, so that it necessarily followed that the banks themselves were not subject to any scour of tide on the ebb; in fact, when water was over them, it was comparatively still water, which naturally dropped the sand, hitherto held in suspension through having been borne along by the current. When the tide had fallen 13½ ft., or 2 hours and 40 minutes after high water, it was maintained that a gradient of the water level in this part began to be set up, and rapidly increased, and with it naturally the velocity of the tidal current. The phenomena here set forth are somewhat novel, not to say startling, but it is well to point out that a river or estuary may "swell" or "sink" without there necessarily being any swiftness of current. In the Thames, for instance, the tide will often be rising or "swelling," though the current will be still flowing towards the sea; and though the conditions are entirely different for the two rivers, the fact is illustrative. Distinguishing, therefore, between the swelling or sinking of the tide and the flow of tidal current, we find, according to the facts adopted by Captain Eads, that in this part of the Mersey estuary, supposing, for instance, high water to be at noon, little or no slope of water surface will occur during the first 2 hours and 40 minutes. At the expiration of another hour and 20 minutes, namely, by 4 o'clock, the slope has increased to 10½ in. per mile. In another hour, by 5 o'clock, the slope has grown to 17½ in., and at 6 o'clock it will be found to be 26 in., whilst at 7 o'clock the remarkable slope of 29½ in. per mile will be found to exist. After this there is a decrease in the slope, and the consequent rapidity of the flow. To repeat: therefore, for a period of 5 hours and 20 minutes after the tide has fallen 13½ ft., a more or less vigorous current is maintained in the low-water channels of the estuary, but the sandbanks at this time are dry and unaffected by the current excepting at their sides. A process of undermining of the shoals is therefore constantly going on, by which the banks are reduced when the tide is at the lower level, just as they are built up by deposition of sand formerly in suspension at the period immediately following high water, when the tidal current has ceased to flow. In this way the constant shifting of the channel, which is so prominent a characteristic of the Mersey estuary, is explained. By observations taken, it has been found that between 1825 and 1880 every part of the estuary above Garston has been occupied by the low-water channel in its wanderings; and that what are high sandbanks to-day were deep low-water channels a few years ago. From the facts stated—which, however, are but a brief outline of the interesting evidence of the late Captain Eads—it will be seen that, in order to carry out to sea again the sand brought in from Liverpool Bay by the flood, the undermining of the banks and shoals in the estuary is necessary, and therefore, if the sides of the channel were protected by walls, such undermining, and consequent deposit of material in the channel, would cease to take place. At the same time, if the walls were not carried up to high-water level, the tidal water charged with sand would flow over the banks, the sand would be deposited, and the shoals, as shoals, would therefore soon cease to exist, becoming, in fact, permanently dry land, except perhaps in time of land flood or at exceptionally high tides. The volume of the tidal flow would thus be reduced, by reason of the lesser quantity of water flowing into the estuary, and the bar outside Liverpool would grow up.

We have repeated the main features of this part of the original suggestion, as they form one of the most interesting engineering problems in connection with the ship canal. When Captain Eads brought his remarkable powers of observation to bear on the question of opening up the Mississippi, he probably had no premonition that the knowledge he then gained would be put to use in an attempt to solve the difficulties incidental to dealing with the Mersey estuary.

The arguments of those opposed to the ship canal were considered sufficient, and the promoters were not given the parliamentary powers necessary for dealing with the estuary. Although the canal syndicate had spent a vast sum and had nothing to show for it, it was possibly for their ultimate good that Captain Eads gave his evidence; for had the original plan of training the estuary been carried out, they might have found themselves in a very unpleasant position. That is a matter, however, upon which opinion remains yet divided; still, one cannot help speculating what might have been the result had the influential American engineer been retained on the other side. It is possible that he, who showed the way to open out the Mississippi to the sea, might also have suggested a practical method of dealing with the Mersey bar, and yet have obviated that enormous rush of water in and out of the estuary which is a source of so much inconvenience to the port of Liverpool. However that may be—and it is a matter of pure speculation—it was Captain Eads and another of the opponents of the canal, Mr. Lyster, who showed the ship canal promoters how to beat their adversaries in the next parliamentary fight.

The result of the second application to Parliament was that the Lords passed the Bill, but the Commons threw it out, so that once more the whole business had to be fought out again. In 1885 a new scheme was brought before Parliament, and from this the debatable estuary works were eliminated. Captain Eads had been asked, when

THE MANCHESTER SHIP CANAL; GENERAL PLAN.

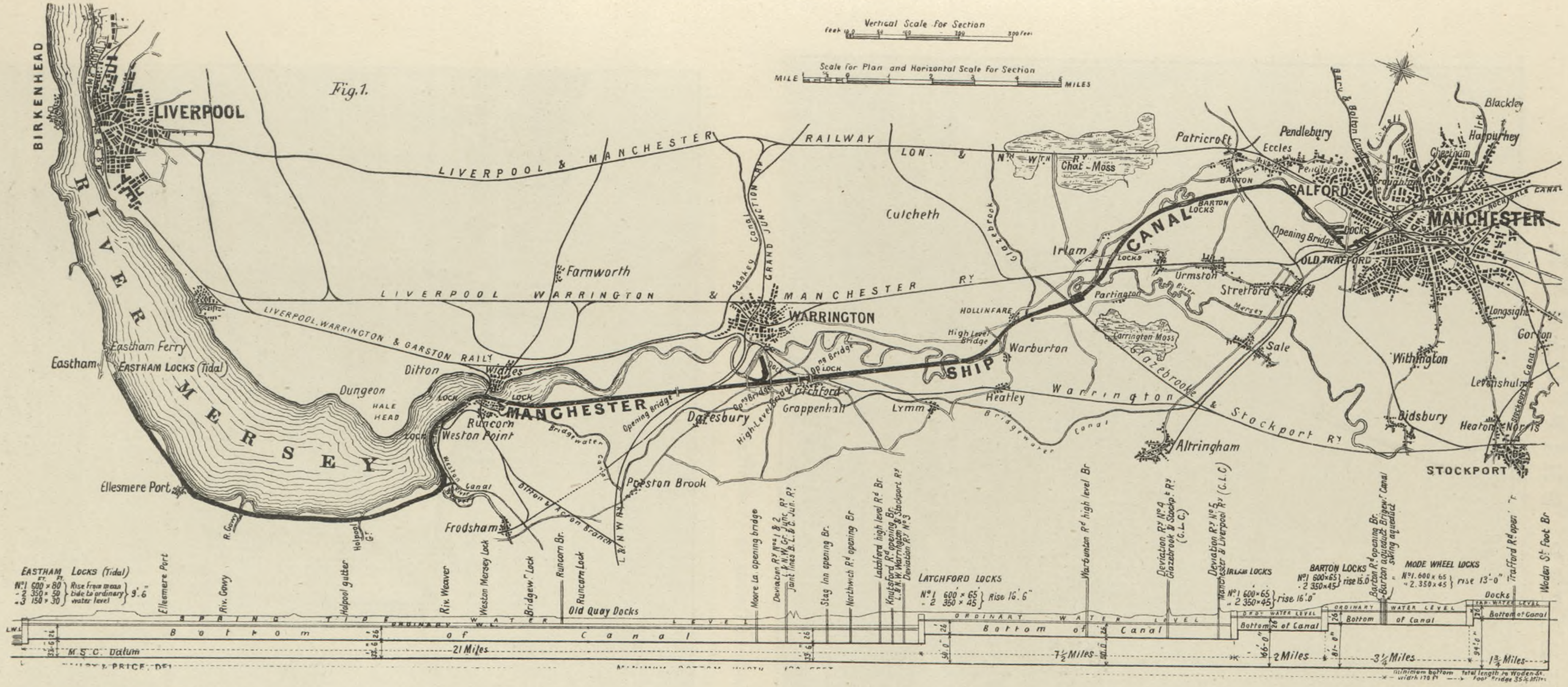

Fig. 1.

before the House of Lords, how he would proceed were the problem his to make Manchester a port. He had said, "I would bring the canal down through the land to Garston, and have its terminus there." That was the impression he had formed without having given any study to the subject. Later on he had amended this opinion when giving evidence in the Commons, by which time he had seen a plan proposed by Mr. G. F. Lyster, the engineer to the Mersey Docks and Harbour Board. Mr. Lyster had suggested that the canal should be brought down the Cheshire shore, in place of the Lancashire side, and a crossing of the Mersey would be thus avoided. Captain Eads approved of this plan, which he thought would not be more costly on the whole than coming down the middle of the estuary as first proposed, and, in addition, there were benefits to be gained by its adoption. The whole ten miles of the lower part of the navigation in the original scheme would be of benefit to no one but the Manchester people, whereas, if the canal were brought round the Cheshire shore, it could be constructed with less money and with less uncertainty as to cost. The dredging operations could be carried on without being affected by the tide, and though Captain Eads had not given sufficient study to the matter to speak authoritatively as to matters of detail, he would not hesitate to pronounce the plan entirely practicable, and he believed that if it were adopted it would remove the objections which he understood the Mersey Docks and Harbour Board made to the original proposals. This new scheme, it will be seen by the map of the canal as executed (Fig. 1 above), is substantially that which has been carried out. Thus out of the mouths of their adversaries did the promoters gain testimony; and it was no small proof of their sagacity that they hastened to profit by the occasion thus offered.

In 1885, for a third time did the promoters go to Parliament, on this occasion with a proposal for a canal brought down to Eastham, on the Cheshire shore. The details of this scheme we need not dwell upon here, as it is substantially the one which was carried out, and which it is the main purpose of these articles now to describe. After a due amount of parliamentary fighting, which occupied thirty days with the Lords and thirty-five days with the Commons, the promoters successfully passed the ordeal of both Houses, and their Bill became an Act by receiving the Royal Assent on August 6, 1885. Thus, after two years' arduous fighting, and, it is said, the spending by both sides of 350,000*l.*, did the promoters find themselves at liberty to commence their canal.

But though the parliamentary ordeal was passed, the engineers were by no means in a position to begin work, the very necessary preliminary of obtaining the money having first to be gone through. Messrs. Lucas and Aird, the great contractors, had undertaken to do the work of construction for the sum of 5,750,000*l.*, which was nearly half a million less than the engineers' estimates. The almost omnipotent Rothschilds took the matter up, and a prospectus was issued on July 20, 1886. Probably no one had any misgivings as to the success of the appeal to the public, but the result was most disastrous. How much money was subscribed we do not know, but it could hardly have been a large sum, otherwise it is not likely that Rothschilds would have allowed failure to be inscribed on their record.

The promoters had now a new difficulty to face, as great as it was unexpected. Some persons thought that the proposal for subscriptions should not have emanated from London, but that the lists should have been opened in Manchester. There was little in that contention, as if the Manchester people had wished to take shares they could have done so as easily by paying the deposit in London as in Manchester. As a matter of fact, although Manchester and the neighbouring towns wished to see ships brought to their district, so that manufacturers and merchants might share in the advantages of lower freights, they did not believe in the canal as a commercial and paying speculation. Lancashire was quite willing to let the rest of the world find the capital, and receive any dividends that might be forthcoming, provided that the more solid advantages that would accrue by extension of trade were reserved to the district. Unfortunately for the scheme, the rest of the world appeared to be of the same mind as to the commercial value of the undertaking, so that Manchester found she would be little likely to get her canal unless she paid for it. The result was that a consultative committee of prominent local magnates, with the Mayor of Manchester at their head, was appointed to inquire into the financial soundness of the scheme. For five weeks this committee sat nearly every day; at the end of which time, namely, on November 26, 1886, they reported the project to be a thoroughly sound commercial undertaking, which would speedily become remunerative on the completion of the works, and promised a steady and continuously increasing revenue. As a final result, Rothschilds and Barings joined in submitting fresh proposals to the public, and this time the money asked for was forthcoming. As satisfactory terms could not be arranged with Messrs. Lucas and Aird, a

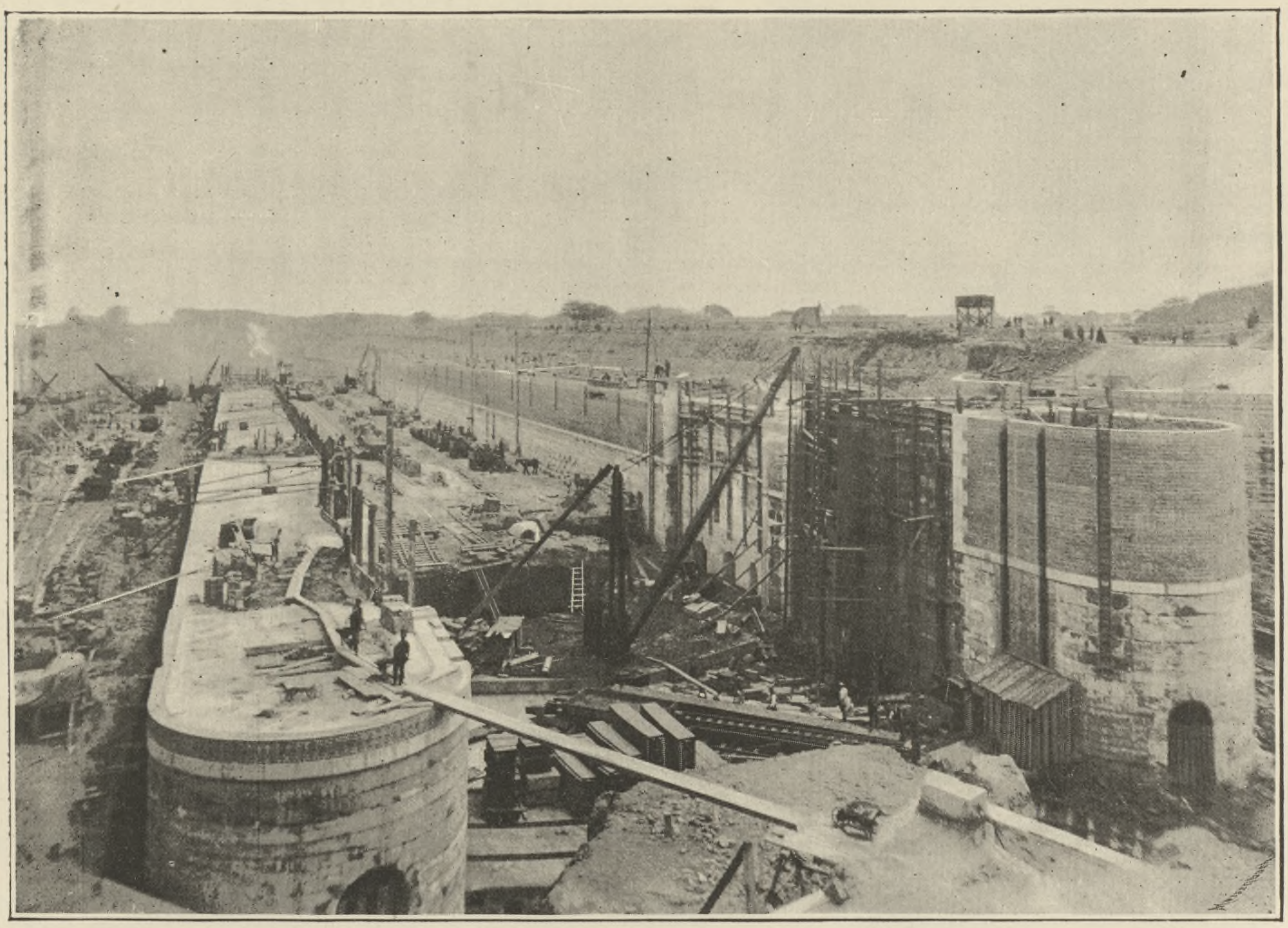

Fig. 3. Eastham Lock in Course of Construction. (*See Page* 14.)

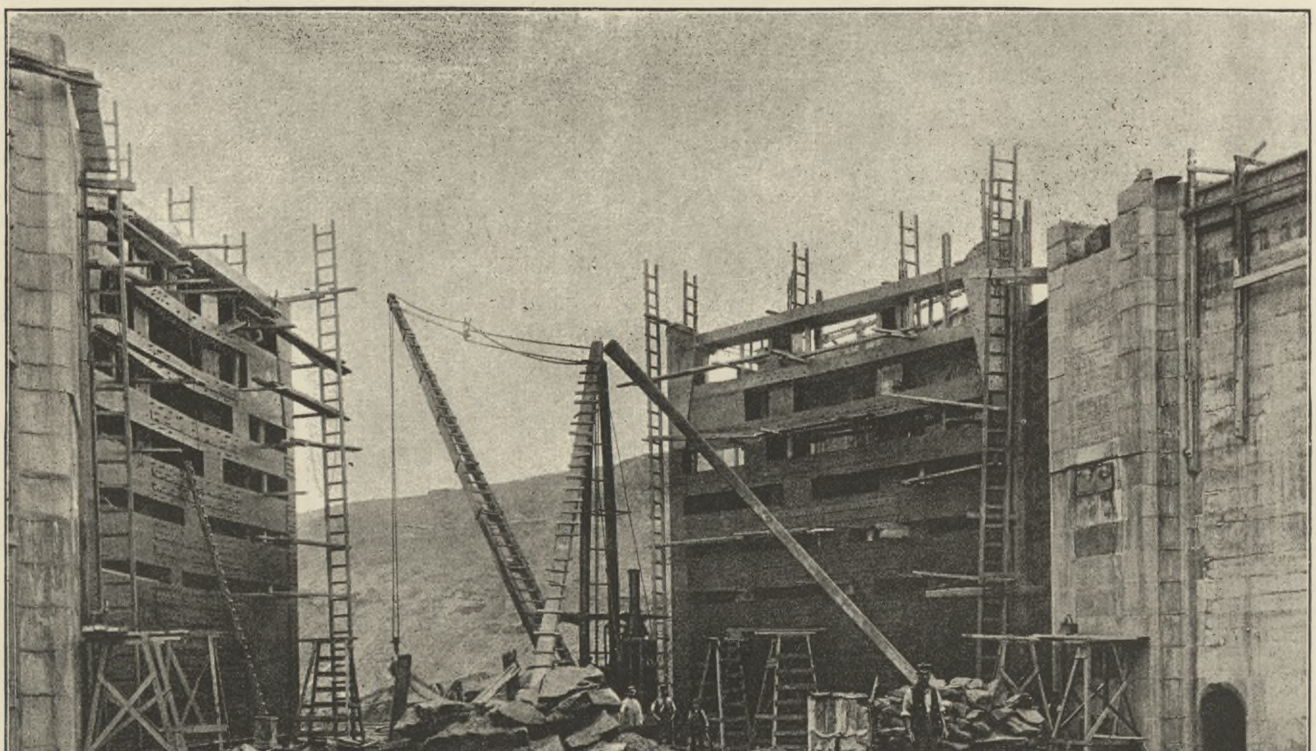

Fig. 4. 80-Ft. Gates, Eastham Lock. (*See Page* 14.)

THE MANCHESTER SHIP CANAL.

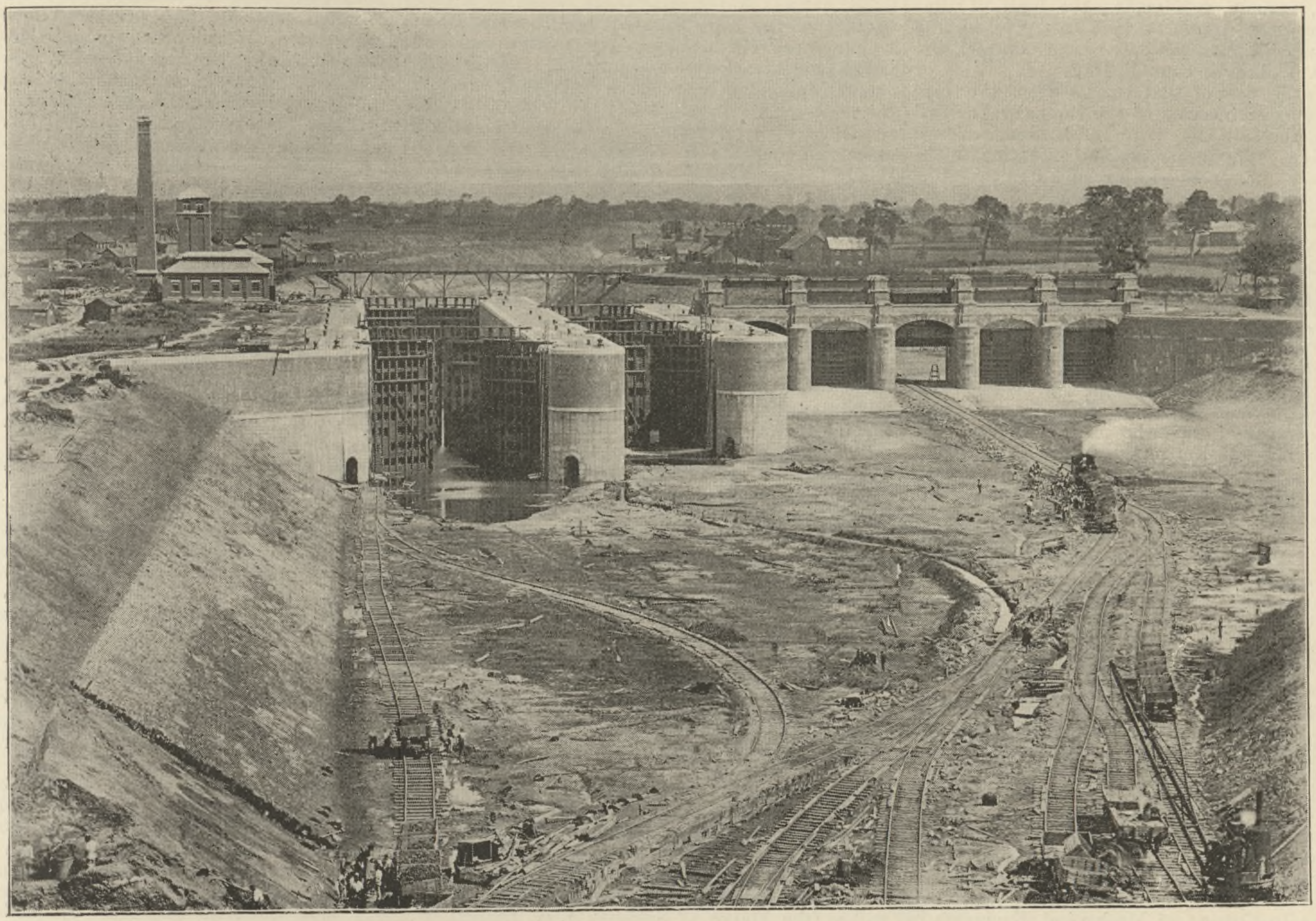

Fig. 5. Irlam Locks and Sluices. (*See Page* 14.)

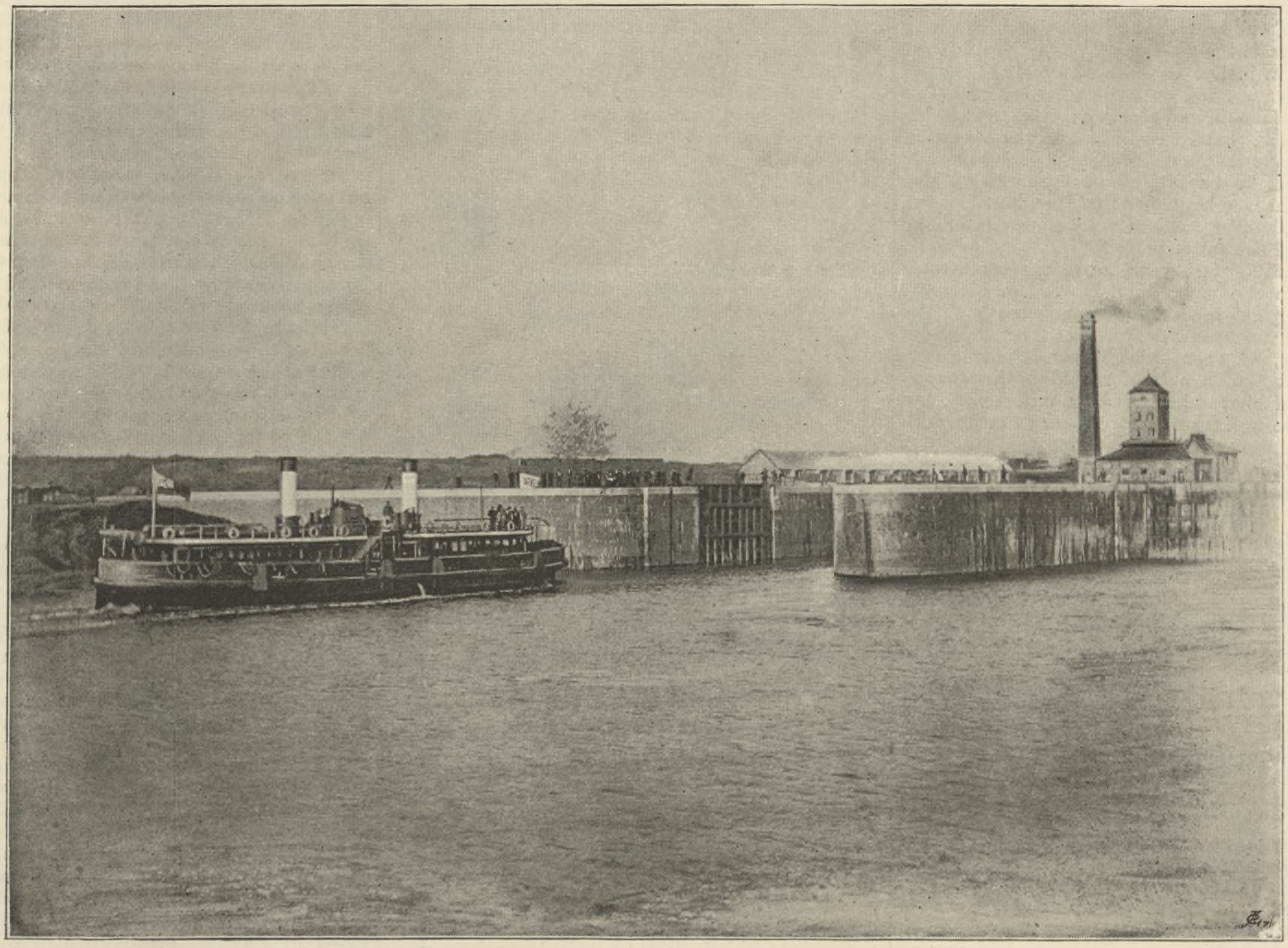

Fig. 6. Irlam Locks, after Completion of Canal. (*See Page* 14.)

contract was entered into with the late Mr. Thomas A. Walker, who undertook the whole work for the same sum as formerly arranged with Lucas and Aird, namely, 5,750,000*l.*, the limit of time being four years from the date that possession of the ground was handed over. The contract was let to Mr. Walker on June 8, 1887.

In the early part of that year, 1887, at the third ordinary general meeting of the company, the first chairman, the late Mr. Daniel Adamson, resigned his position. We do not propose reverting to the unfortunate differences which resulted in this step. Referring to the incident at the time, we spoke of the vigour and energy shown by Mr. Adamson, and pointed out how "his indomitable perseverance had many times buoyed up the scheme when all forces, human and divine, seemed gathered together to destroy it." Now Mr. Adamson has passed from amongst us the great qualities which he possessed come more prominently forward in our retrospect of the work he did. Certainly no name deserves to stand higher in the roll of the Manchester Ship Canal than that of the first chairman of the company; he who called the original meeting which was the foundation of the scheme. With Mr. Adamson, certain other of the directors resigned, and the board was reconstituted, with Lord Egerton of Tatton as chairman. On November 11, 1887, the chairman of the board of directors cut the first sod, and from that time until the completion of the canal the work has gone forward continuously, though not without vicissitudes.

The Bridgewater Canals undertaking had been purchased for 1,710,000*l.* in the previous August, and this has been a paying part of the Ship Canal Company's property ever since.

For just two years from the cutting of the first sod, the work was pushed on vigorously by the late Mr. T. A. Walker, and in some sections a really wonderful amount of excavation was done; perhaps such as had hardly been before equalled in any work of the kind. The plant that the contractor brought on the ground was of a very elaborate and costly nature, and the mechanical appliances enabled the shifting of material to be carried on in the extraordinary manner it was. Speaking before the Institution of Mechanical Engineers in Liverpool in 1891, after Mr. Walker's death, Mr. Leader Williams pointed out that "Mr. Walker, with his great experience in the Severn Tunnel and many other large works, had been an admirable judge of the best class of machinery to use in such work as the ship canal." It is but fair we should add, in justice to those who had the control of work when carried on by administration, after Mr. Walker's death, and also in fairness to succeeding contractors, that the easiest work in one respect, in regard to excavation, came first; for not only had the spoil to be lifted higher as the cutting deepened, but it so happened that the plan of operations devised, as a general rule, necessitated the excavation of the softer parts first.

At the end of two years after the commencement of the work, namely, on November 25, 1889, one of the great misfortunes connected with the undertaking occurred. This was the death of Mr. Walker, an event which was announced in ENGINEERING,* with a brief record of his career. Mr. Walker's decease had not been unforeseen, and arrangements had been made to carry on the work by his executors; this was done for exactly a year, when the contract was dissolved by mutual agreement, and the construction of the canal was further pursued by the administration, the existing plant being used. In our brief reference, on another page, to the principal contractors engaged, we state how, after this, the work proceeded to the end, partly by administration, and partly under Messrs. Jackson and Wills. The contracts with these two gentlemen were entered into in the spring of 1892.

We now come to a part of the history of construction upon which we do not propose to dwell with the detail its importance would demand, were it not that the engineering features of the canal are more especially within our province. The contract with the late Mr. Walker was, as stated, for 5¾ millions, which, it will be remembered, was less than the engineer's estimates prepared by Mr. Leader Williams, and confirmed by Mr. James Abernethy. What would have happened had Mr. Walker lived it is useless to speculate, but as a matter of fact it was found necessary to dissolve the contract. After the company had been working for some short time, it was seen that more capital would be required, and, moreover, that unless public aid was forthcoming there would be a probability of the work being brought to a standstill. Under these circumstances the matter was laid before the Manchester Corporation, and the city council appointed a special committee to consider the matter. In March, 1891, the committee presented its report, recommending that the "pecuniary assistance requisite to complete the undertaking should be rendered." This report was adopted, according to the chronicles of the time, "amid loud applause." Whatever else the ship canal may have lacked, local approbation has not been wanting.

In the following month a Bill was deposited by which powers were sought by the corporation to lend the canal company three millions sterling, and in the next July it became an Act by receiving the Royal assent, a million and a half of corporation stock being immediately issued. The large stake the corporation now had in the venture warranted them in demanding a commanding position in the management of affairs, and five corporation directors were placed upon the board, whilst Mr. Hill, the corporation engineer, was given a voice in the control of engineering matters. Revised estimates were submitted in November of the same year, 1891, and a fortnight after, an executive committee, consisting of four corporation and three shareholders' directors, was appointed by the board, with full power to carry on the work.

In March, 1892, the second issue of a million and a half of Manchester Corporation Stock was made. Then further revised estimates were got out, and it was found still more money was wanted; consequently further parliamentary powers were obtained in May, 1893, to advance another two millions sterling, and a third million and a half sterling was issued in June of the same year. Eleven directors were appointed by the city council, in accordance with the Act which gave powers for the further advance to be made. It will be well, perhaps, here to give the names of the directors. Appointed by the shareholders: Lord Egerton of Tatton, chairman; Messrs. W. H. Bailey (the Mayor of Salford), J. K. Bythell, W. J. Crossley, C. J. Galloway, A. Henderson, Sir E. G. Jenkinson, K.C.B., Sir J. C. Lee, J. Leigh, M.P., and S. R. Platt. Appointed by the Manchester corporation: Sir J. J. Harwood, deputy chairman; Messrs. J. Mark, S. C. Thompson, J. W. Southern, B. T. Leech, A. Marshall (Lord Mayor of Manchester), J. Thompson, W. Smith, G. Clay, A. McDougall, and H. C. Pingstone.

The following concise statement of the capital powers and expenditure of the company may be added here:

	£	£
Ordinary shares ...		4,000,000
Preference shares ...		4,000,000
		8,000,000
First mortgage debentures—1896 and 1914	1,812,000	
Second mortgage debentures—1914 ...	600,000	
New mortgage debentures – 1897 (Manchester Corporation Loan)	5,000,000	
		7,412,000
		15,412,000

Capital Expenditure to June 30, 1893.

	£
Bridgewater Canals undertaking ..	1,782,172
Land purchase, compensation, and expenses	1,161,347
Construction of works (including plant)	8,861,760
Engineering and surveying... ...	125,432
Interest on share and loan capital, after deducting balance of general interest account	1,038,500
Parliamentary expenses — 1885 to 1893	163,593
Law charges and disbursements ...	20,820
Brokerage, advertising, and other expenses of issues of debentures...	108,833
Expenses incurred by the Manchester Corporation in the creation and issue of corporation stock... ...	31,700
Other general expenditure—including directors', auditors', and public accountants' fees; salaries of secretary, manager, and staff; office expenses, and interest on Parliamentary deposit, &c. ...	176,064
	£13,470,221

Bridgewater Canals Undertaking—Net Revenue Account.

	£
Accumulated credit balance at June 30, 1893	355,909

In regard to the amount debited for land, it may be stated that the area purchased amounted to 4520 acres. In this the amount claimed was 2,195,519*l.*, the amount actually paid being 1,139,354*l.* There now remains as surplus land available for resale no less than 2500 acres. Much of this has been greatly improved by the deposit of spoil, raising what was formerly marsh land, subject to flood, into good building or factory sites. If the canal produces anything like the effect in bringing trade along its route, which is anticipated, the value of this land will advance immensely. At present, the ship canal appears in the position of a suppliant for patronage; it may grow richer and more powerful than any of the great monopolies which it now aspires to supplant. We can even imagine a sanguine shareholder looking forward to the time when the corporation loan will be paid off, and the canal company will have purchased, out of profits on land rents, the railways between Manchester and Liverpool, in order to stifle a troublesome competition.

A good deal has been said at various times about the excess of capital required over that estimated. As we have said elsewhere, it is impossible to provide for all possible contingencies in schemes of this kind, otherwise great engineering enterprises would never get the capital required to meet the estimates. So far as the ship canal is concerned, it must be remembered that unlooked-for circumstances have arisen. Mr. Walker's death, and the failure of the carrying out the work by contract within the original sum agreed upon, was a serious blow, and it involved a good deal of complication in regard to the taking over of the plant. The work done by the contractor was that which could be executed most cheaply. That was a necessity of the case; and the Ship Canal Company had therefore thrown back on their hands the more costly operations relatively to the bulk of work done. The delay of two years in the completion is another matter which has had an immense influence on the cost of this work: for not only were there the enormous establishment expenses, but the second of the Ship Canal Company's Acts, that of 1886, provides for the payment of interest out of capital, and the interest upon so large an amount for two years is a serious item. The floods of 1890 were a most disastrous feature; what they cost the company will never be known, but, at any rate, it must have been an enormous sum. As will be remembered, the unfinished excavations were completely flooded for a long distance, plant being submerged, and much of the work already completed, quite destroyed. It may be said that provision should have been made against floods, but such a flood as this was quite exceptional. We understand that the water not only poured in over the dams across the canal where the channel of the river had been crossed, but that the surrounding land was covered, and water poured in at the sides of the cuttings. Therefore, to provide against an exceptional flood of this kind, embankments would have had to be made along the sides of the channel; a work which would have been quite impracticable. It was a chance that had to be run, as many chances must in this imperfect world. The point has been urged, that the course of the canal should have been laid on higher ground and not in the bed of the river; but this is, we think, fairly met by the two objections that it has been trouble enough now to get mast-height under the bridges, and also that the greater elevation of the canal surface would have rendered the water supply a very difficult, if not an insoluble, problem. It would, however, be unprofitable to pursue this question of the difference between estimated and actual cost further; and, indeed, it is one of such magnitude, and contains so many uncertain factors, that it cannot be decided —or rather it can be decided either way according to the fancy or prejudices of the engineer.

Leaving these money questions for the present, and returning to our brief chronicle of events, we find the water was first admitted into the canal from the estuary of the Mersey at Ellesmere Port on June 19, 1891. This lower part of the ship canal was hurried forward before the rest, in consequence of a desire to provide transit for the barge traffic from Ellesmere Docks down to Eastham, and thus into the Mersey. It was provided by the Act which invested the Ship Canal Company with powers of construction, that the

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* See ENGINEERING, vol. xlviii, page 635.

THE MANCHESTER SHIP CANAL.

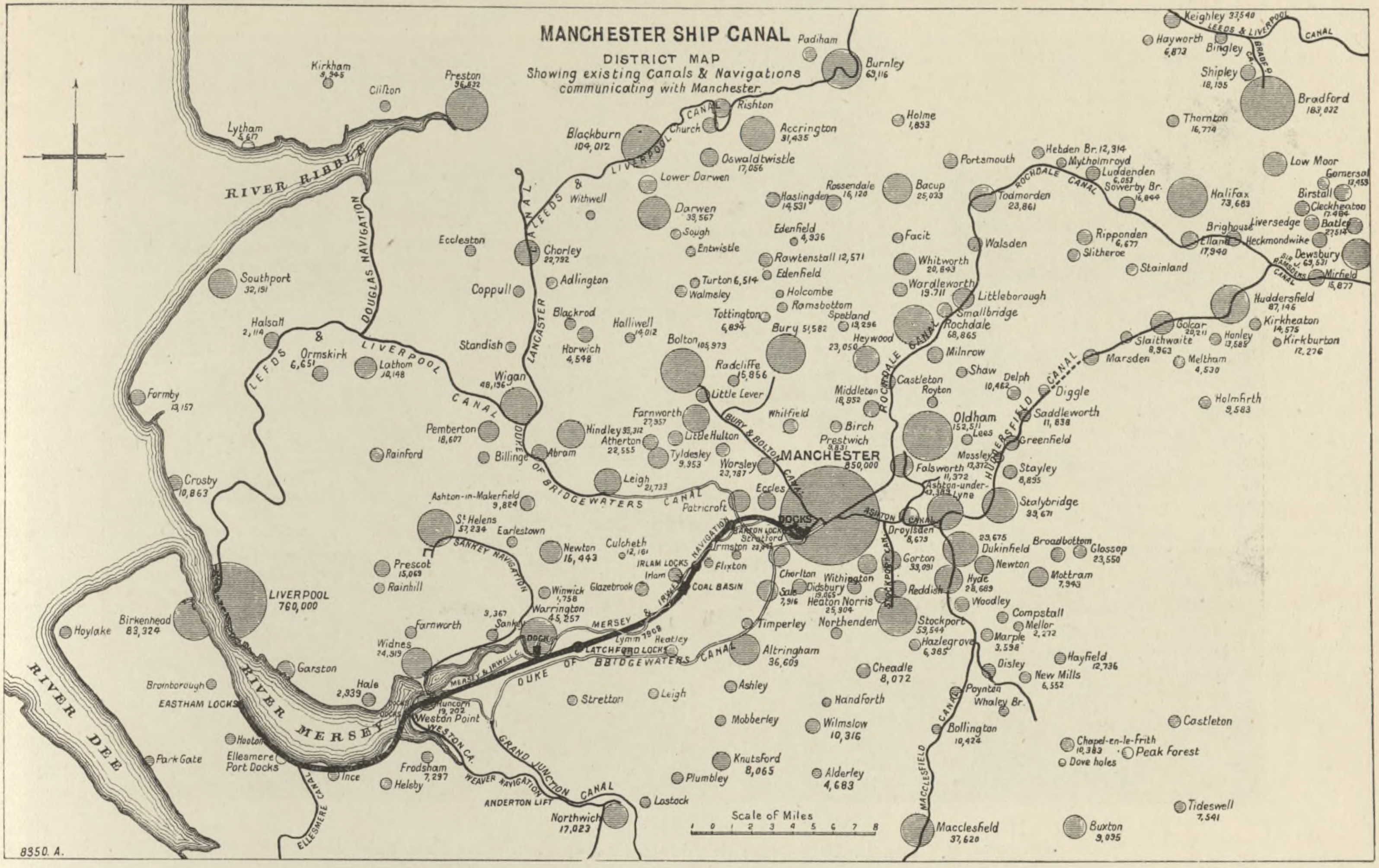


Fig. 2. Map showing Industrial Centres affected by the Canal.

channel to Ellesmere Docks should not be closed until another waterway was provided, and hence the desire to open this part before the rest. We shall make further reference to this feature in a later part of this record. Water was admitted into Eastham Locks on July 2, 1891, and traffic to and from Ellesmere Port through the locks and the lower part of the ship canal was opened on the 16th of the same month. On the 28th of the following September navigation was opened up to Weston Marsh Lock, at the mouth of the River Weaver, and the important waterways debouching by this lock were thus brought into connection.

On July 22, 1892, Saltport was established; an event which it is expected will prove the precursor of mighty changes by the ship canal enthusiast—no uncommon object just now in the neighbourhood of Market-street and the Infirmary. As was the spreading of the gourd which sheltered Jonah compared to that of ordinary vegetation, so should the upspringing of Saltport be beside the growth of average towns and cities; if the anticipation of the enthusiasts are to be fulfilled. In truth, Saltport has an exceptional chance. In America we see instances of marvellous rapidity of urban growth, the virgin soil of the prairies seeming at times almost as stimulating to frame buildings and electric light as to cereals. In our own more thickly populated country over-competition is the enemy of the would-be town creator. Nearly all available sites are occupied, and promising avenues closed. Mr. Marshall Stevens, the general manager of the ship canal, and the father of Saltport, has had, however, one of those rare chances which occur about once in a century. He is more fortunate than Transatlantic speculators because there is a stream of business ready to flow into his new port, and a population of something like 5000 per square mile within easy distance (taking the rest of the United Kingdom, the average is 280 per square mile); although, it must be acknowledged, the jostling of souls is not yet very apparent in the neighbourhood of the quays and boulevards of Saltport. It is satisfactory to learn, however, from the *Manchester Guardian*—which reads at times almost like the inspired chronicle of the ship canal—that Atlantic liners visited Saltport; but it is somewhat of a disappointment that they were only attracted to the spot for the purpose of "resting," which is presumably the inland expression for laying-up. A good deal of trade has, however, been done at this infant port, and laden vessels of a size that would entitle them to rank high amongst ocean liners could be accommodated at its quays, the length and breadth being practically unlimited, and the draught 26 ft. Our illustration, Fig. 111 (see Plate IV), will give an idea of the quay arrangement. A landing stage, which is 700 ft. long, and is fitted with cranes, runs parallel to the shore, the ship lying outside and the barges in the space between the quay and stage. This space is 35 ft. wide, and has 12 ft. of water. The cranes can take from the ship's hold and deliver on to the quay or into the barge at will. A good deal of traffic has been handled here; the *Manchester Guardian* informing us that on one occasion 1100 tons of farina were discharged from the steamship Berlin into flats between the morning of one day and the evening of the next. When it is remembered that at neap tides there may be, for several days, greater depth of water at Saltport than in any dock in Liverpool, the pious hope of the writer in the above-named organ, "that when knowledge has had time to grow from more to more the trade of Saltport will expand until there are not twenty ships merely in its broad inland waters, but a fleet with choice goods from all parts of the world."

Early in last year the high-level viaducts of the various railway deviations, rendered necessary by the construction of the ship canal, were opened for traffic. In January, No. 5 Deviation was put into use for goods trains; and in February, Deviations Nos. 1, 2, 3, and 4, also for goods traffic. On the 9th of June last, water was admitted up to Runcorn; and in the following month the further section from Runcorn to Old Quay. On July 9, Deviations 1, 2, and 3 were opened for passenger traffic—Nos. 4 and 5 having been previously opened for passenger trains—and the last piece of land requiring to be cut through was thus released to the use of the engineers. Water was admitted to the canal up to Latchford on the 17th of last November, and finally the whole of the ship canal was filled from end to end on the morning of November 25, 1893.

So was the greatest canal of England, and one of the greatest in the world, completed eleven years and a half after the enterprise first took definite shape through the meeting in the house of the late Daniel Adamson; eleven years after the first Bill was deposited in Parliament; eight years and a quarter after the Act authorising the construction was obtained; and six years after the work of construction was commenced. On December 7, 1893, the directors made a voyage over the whole length of the canal; and finally, on New Year's Day of 1894, the Manchester Ship Canal commenced the struggle for existence which is the dominant feature of this latter-day civilisation, and through which the sympathetic hopes of all well-wishers to the commerce of England should accompany it.

It is too early yet to make any forecast of the future of the canal from the business already done. Lines of coasting steamers between Manchester and other ports have been organised, and at the time of writing, the first two cotton ships, the Argosies of the ship canal, have arrived from across the Atlantic. The Manchester manufacturers and merchants have already felt the benefit of the greater ease of communication, and engineering contractors, amongst others, have taken early advantage of this feature; for amongst the first items on the books of the ship canal was a large parcel of boiler-plates for Galloway's, whilst "unbreakable pulleys" from West Gorton were despatched to London and Glasgow, as the first engineering consignments outwards. As a further example of the traffic of the canal it may be noted that the same firm have sent machinery by the ship canal to France, Belgium, and Holland.

Perhaps a word may be said here about the water supply. As to quantity, it is stated to be ample for all probable needs. We learn that

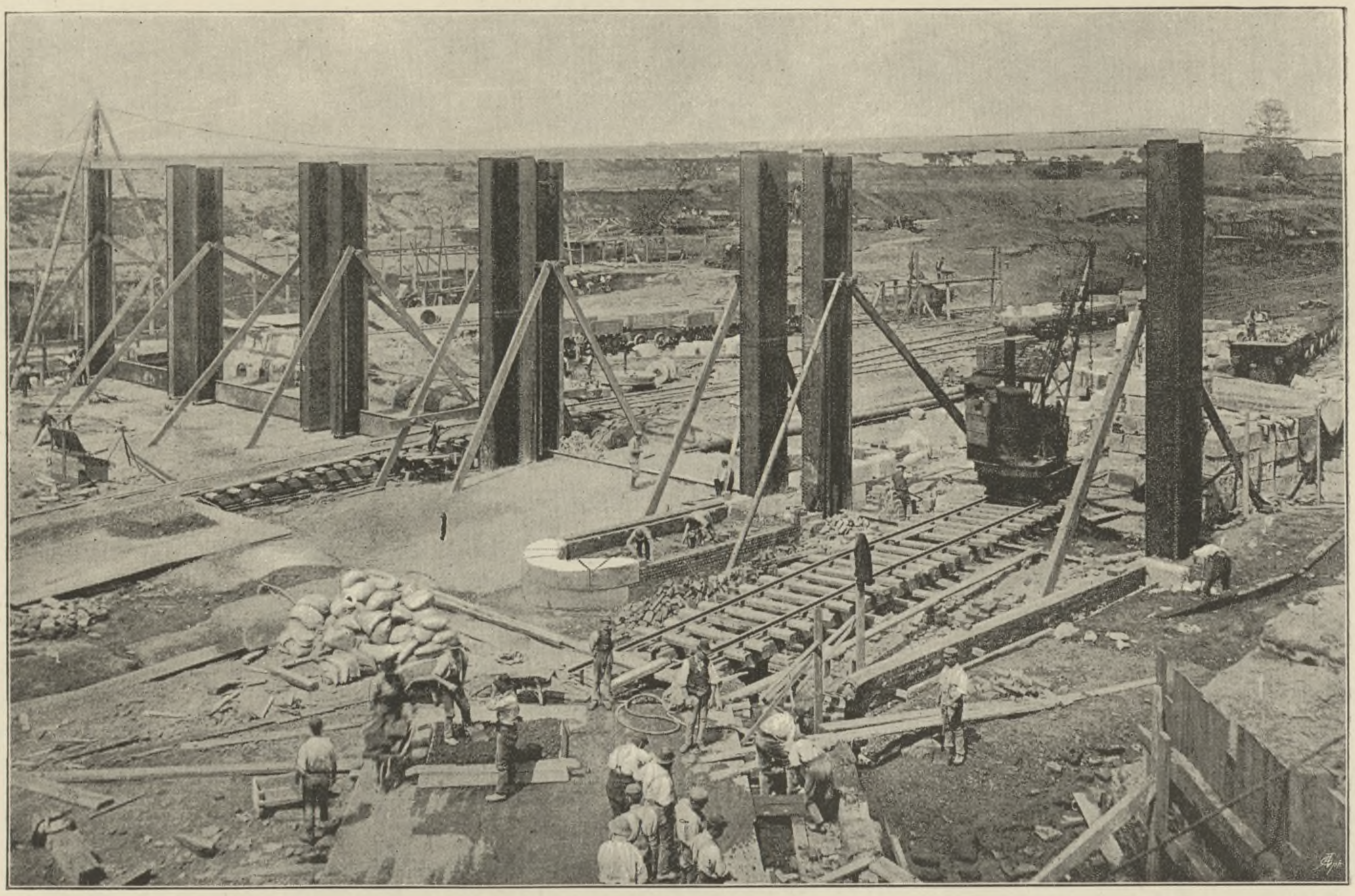


Fig. 7. The Irlam Sluices in Course of Erection. (*See Page* 15.)

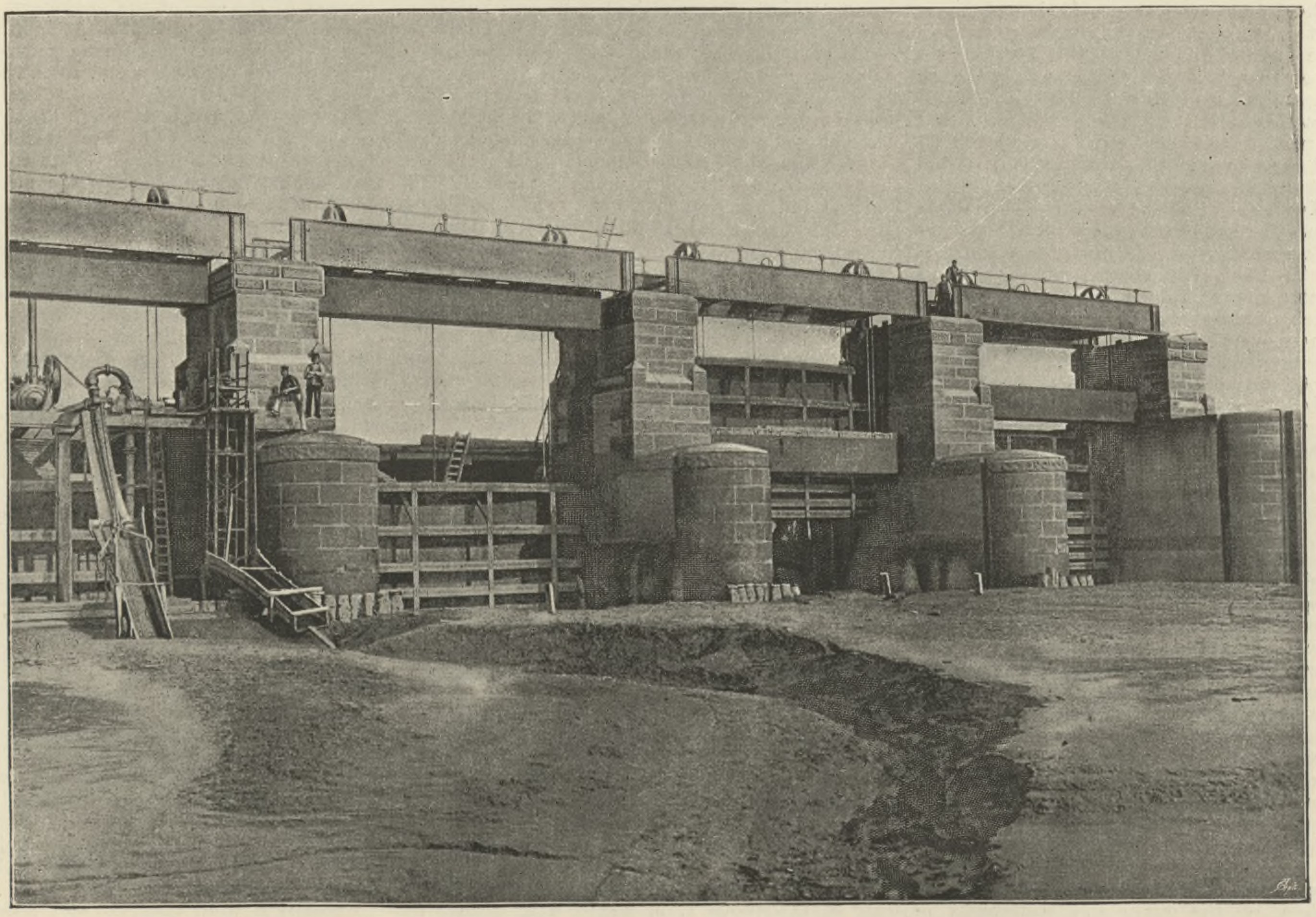


Fig. 8. Storm Water Sluices on the Estuary Section. (*See Page* 15.)

THE MANCHESTER SHIP CANAL

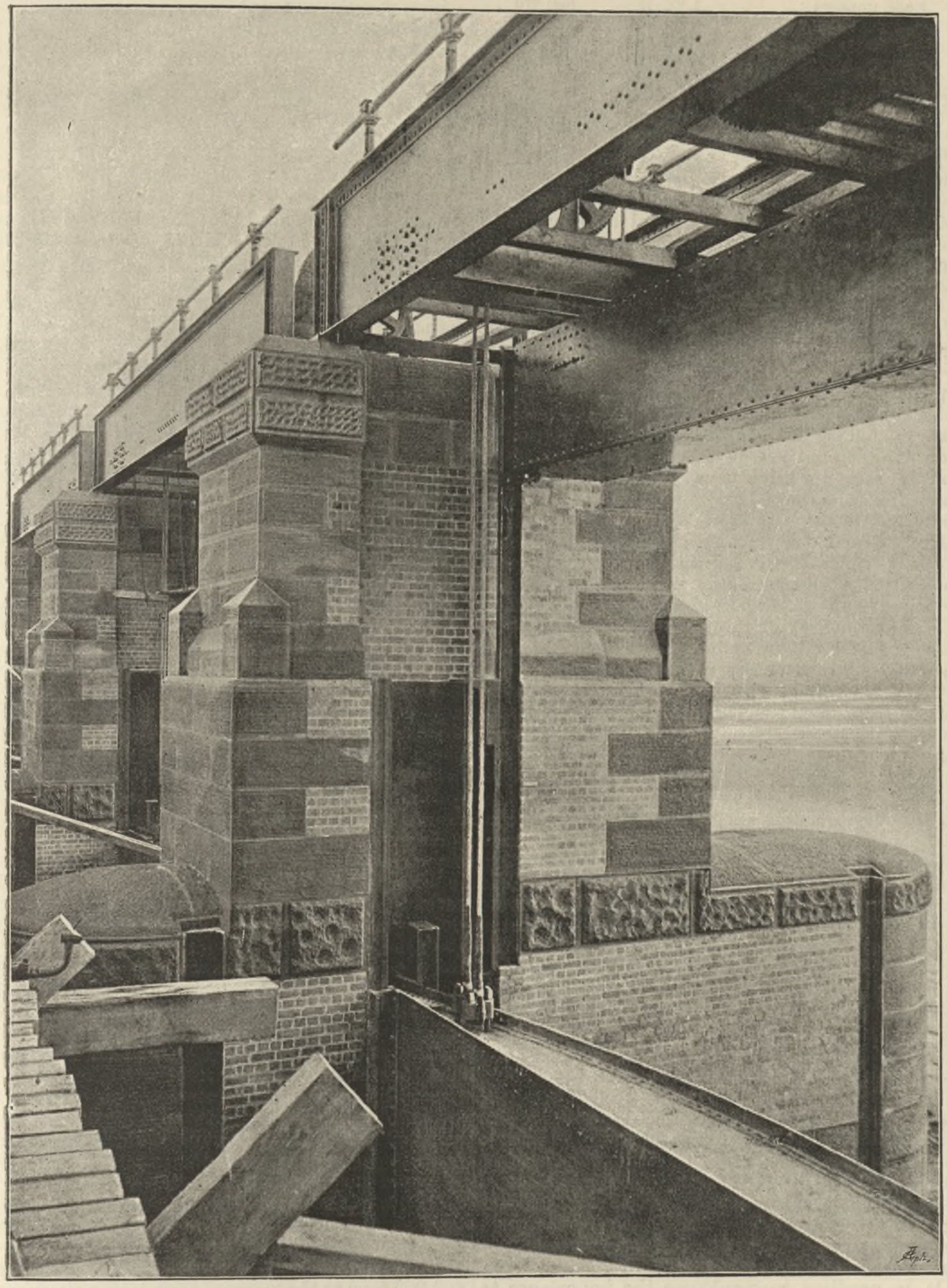


FIG. 9. STORM WATER SLUICES, ESTUARY SECTION. (*See Page* 15.)

the Rivers Irwell, Mersey, Bollin, and other small streams, have been proved to supply ample water for sending up 120 ships a day. We have not the figures before us as to water supply for the upper reaches of the canal, but doubtless they are to be got; at any rate, the authorities express themselves confident on this point. As to the quality of the water, much remains to be done; in fact, the Irwell is as inky a stream as one often sees. Manchester has, however, bestirred herself, and has a sewage system now which will improve matters greatly. Salford also purifies her sewage, and pressure will be put on other places to do the same; so we may hope that the canal waters will cease to be repulsive, if they do not become exactly pure.

II.—THE COMMERCIAL ASPECT OF THE CANAL.

It is necessary for our present purpose that we should give some account of the need for a ship canal; that is to say, of the commercial side of the question, and in considering this we may have to repeat some of the facts recounted in the preceding section. Unfortunately, the anticipations formed on calculations made before operations commenced have not been fulfilled, owing to the fact that the work has proved more costly than was estimated. That is a subject which we have already considered, and we will simply glance at the figures put forward originally. Their consideration will be profitable to those who may be called on to form estimates in regard to future undertakings of this nature.

The authorised total capital of the company provided by the 1884 and 1885 scheme was 10,000,000*l.*, of which eight millions were to be in shares and two millions in debentures. Three-quarters of a million were allotted before Messrs. N. M. Rothschild and Sons made their unsuccessful appeal to the public for the balance of seven and a quarter millions. Mr. Leader Williams' estimate of the work was 6,311,000*l.* Messrs. Lucas and Aird had undertaken to complete the whole of the construction for 5,750,000*l.*, a sum which it will be seen was more than half a million under the engineer's estimate. The value of the land that had to be purchrsed was 802,000*l.* The price to be paid for the Bridgewater Canal and the Mersey and Irwell Canal systems was 1,710,000*l.* Added to this were preliminary expenses to the extent of 146,000*l.*, which were to be repaid to the subscribers in shares. These items brought the total expenditure up to 8,408,000*l.*

Such was the estimated debit side of the account; it now remains to be seen what was to be said for the credit side, necessarily quite a hypothetical part of the balance-sheet. That a great traffic would come to the canal there could be no doubt, supposing the work were once completed and properly conducted. The map of the district (Fig. 2, page 7) shows in a graphic form the wealth of the neighbourhood which the canal will serve, and the excellent communication afforded by barge canals already existing. The amount of paying traffic that might be carried on the canal was put down at 21,000,000 tons per annum, but the promoters contented themselves with a basis for calculation of 3,000,000 tons a year. The income from this amount of traffic, together with the 60,000*l.* a year earned by the Bridgewater Canal, was estimated to produce a revenue of 885,000*l.* a year. From this would have to be deducted the working expenses, which were set down at 176,000*l.* per annum. On these figures a dividend of over 7 per cent. per annum would have been payable, besides allowing a large sum being put aside for reserve fund.

It is no unfair thing to say that Manchester and its neighbourhood suffered from the high charges of the great distributing port of the district—the port of Liverpool. These high charges were partly due to the want of facilities for distribution; an evil which Liverpool did not put forward proper exertions to remove, suffering herself little or nothing from this cause, and, indeed, often largely profiting. As illustrating this point, we may quote some figures which we have used on a former occasion. The following are the former charges for the transport of a few leading commodities from vessels in Liverpool Docks to the railway in Manchester, and also the cost of carrying such goods to the quays of the then proposed Manchester Docks *viâ* the ship canal. To transport cotton by railway used to cost 13s. 8d. per ton; the statutory charge by ship canal was 7s. per ton. Wool cost *viâ* Liverpool 16s. 5d. per ton, by canal the charge was to be 7s. 9d. Raw sugar 12s. 2d. per ton, as against 4s. 11d. per ton. Loaf sugar 17s. 11d. per ton, as against 6s. 8d. per ton. Wheat in sacks 9s. 4d. per ton, as against 4s. 10d. per ton. Petroleum 14s. 5d. per ton, as against 5s. 11d. per ton. Timber 9s. 5d. per ton, as against 4s. 9d. per ton. Iron ore 6s. 11d. per ton, as against 2s. 10d. per ton It will be seen, therefore, that by the construction of the ship canal, manufacturers and merchants would save 6s. 8d. per ton on cotton, 8s. 8d. on wool, 7s. 3d. on raw sugar, 11s. 3d. on loaf sugar, 5s. 1d. on wheat, 8s. 6d. on petroleum, 4s. 8d. on timber, and 4s. 1d. on iron ore. The foregoing figures, which refer to the old order, include dock charges and railway rates; charges payable by the ship are not included in either case, being taken as equal in both. It will be interesting to separate the items. Thus the railway charges per ton between Liverpool and Manchester for the foregoing articles were as follows: Cotton, 7s. 2d.; wool, 9s. 2d.; raw sugar, 6s. 8d.; loaf sugar, 10s. 10d.; wheat in sacks, 6s. 8d.; petroleum, 9s. 2d.; timber, 6s. 8d.; and iron ore, 4s. 2d. A further analysis of these figures gives the following remarkable results. To compete with the ship canal when charging its maximum tolls, the railway companies would have had to reduce their rates to the following extent, if the Liverpool dock charges remained the same. They would have had to carry cotton at 6d. per ton, wool at 6d. per ton, sugar for nothing, wheat at 1s. 7d. per ton, petroleum at 8d. per ton, and timber at 2d. per ton; for only at these rates would the combined dock and railway charges have been brought down to the level of the ship canal charges. As the rates of the Manchester Ship Canal were fixed by the Act authorising its construction, one can easily understand the desire of the traders and manufacturers of the district that the canal should be made.

With regard to the bulk of trade of the district—that is, the amount of business to be competed for—it would take too much space to quote full details. There is no need, indeed, to multiply figures to prove the enormous bulk and value of the business done in that part of the country affected by the ship canal, containing, as it does, a larger wealth of manufacturing industry than is to be found in any other part of the world within a like area.

It was said at the time that shipowners would prefer to use the Liverpool Docks, rather than make the passage of the canal, as they would be able to get to sea again sooner, and so make more voyages; indeed, it was argued that, in any case, the ship had to be unloaded, and her cargo transferred into land carriages, and as this handling of freight had to take place, it was little matter whether it was done in Liverpool or a few miles farther inland, excepting in the case of goods required within easy carting distance of landing-places on the canal. With regard to the argument that the ship would save time by using the Liverpool Docks, it is true they are nearer the sea, but notwithstanding this it might be that with two ships crossing the Mersey bar at the same time, one bound for the Liverpool Docks, and the other for the Manchester Docks, the latter vessel might reach her destination as soon as the former reached hers. The reason for this would be that the Liverpool ship would have to wait for water to get into the docks, the time of entrance being limited to a period of within one hour from high water, whilst the Manchester ship would proceed at once to Eastham, where she would be locked into the canal, and would then be certain to have ample depth of water right up to her berth. With regard to the second point, that of transference of freight to land carriages, what might be described as the natural conditions are alike in both cases, excepting that goods for Stockport, Oldham, or Bolton, and towns similarly situated with regard to Liverpool and Manchester, would have extra railway travel if landed at the latter port. It is not, however, natural obstacles, but those artificially created by a too religious observance of vested interests, that have so largely saddled freighters with the additional burden of cost set forth in the foregoing comparison of charges. The general manager of the canal, Mr. Marshall Stevens, has given many good examples of this fact, but space forbids us dealing with more than typical instances. Mr. Stevens is himself one who has had experience in the past of the defects of the Liverpool system. The son of a west-country shipper, he came to Lancashire many years ago to watch the interests of his father's firm, and settled at Garston. As a large quantity of goods passed through his hands, an invitation was sent him to transfer his operations to Liverpool. His objection was that Liverpool Docks were not "railway" docks, whilst at Garston the London and North-Western Railway ran their trucks alongside the vessels. It is pretty generally known that Mr. Stevens had an interview with the Liverpool Docks authorities at their invitation, in order that he might put his views before them. He then showed that by proper railway communications towns at a distance would be put in a position of much greater advantage. His facts could not be gainsaid, but at the same time his proposals were not carried out, because other traders, out of the district, would be put on an equality with those close at hand.

The procedure in the Liverpool Docks is expensive and cumbrous. Vessels entering the docks discharge their cargoes on to the quays. The ship pays dock dues upon her tonnage, and finds the necessary labour for discharging goods on to the landing-plank over the ship's side. The merchant pays dock dues upon the goods, and bears the charges upon them from the time they leave the landing-plank. An official, peculiar to the Liverpool Docks, here comes on the scene. This is the master-porter, who takes charge of the goods and delivers them to the carrier, who, of course, in turn, makes his charge for the work done. There are railways round some of the docks, but they are not generally used for the transport of merchandise; and cartage, whether performed or not, is charged for. A further tax, known as quay attendance, is made upon the owner of the goods by the carters, when instructions are given to them for the collection of the goods from the master-porter.

It requires no great economic intuition to see how detrimental to the interests of the country such a system must be in a port serving so important a district as that which Liverpool has hitherto commanded. It was not a local question between Liverpool and Manchester, but one of wide national importance; and certainly the thanks of the country are due to all those who have supported the ship canal through its many vicissitudes.

Returning to a consideration of the volume of trade likely to pass over the ship canal, Mr. Marshall Stevens has prepared some very elaborate tables, from which we may extract a few figures with advantage. He estimates that seven years after the canal has been opened there will be a traffic of 9,649,316 tons, the revenue from which would be 1,492,282*l.* The chief items making up these totals are as follows:

	Tons	£
Food imports	1,337,752	309,270
General imports ...	1,353 964	337,684
Exports	3,357,600	402,828
Coastwise	3,000,000	375,000
Traffic with Liverpool	500,000	62,500
Local traffic	100,000	5,000
	9,649,316	1,492,282

With a sum of 187,500*l.* on ship dues in reserve, the sources of income from the Bridgewater Canal (65,000*l.*), and rent of lands held by the company (50,000*l.*), make up a grand total of 1,607,282*l.*, and if from this we deduct 107,000*l.* odd for working expenses, we arrive at a net revenue on the whole undertaking of a million and a half per annum.

The forecast appears somewhat roseate in view of the dismal things that have been said about the prospects of the shareholders since the work was found to be far more costly than was originally anticipated. Mr. Stevens, however, supports his final estimate by many details, and certainly he seems to have spared no trouble to arrive at a just conclusion. The amount of each class of traffic is set forth, and the bases for calculation given, whilst in many cases the facts quoted and the opinions formed are confirmed by an important body of the traders or manufacturers dealing with the particular class of goods to which reference is made. Thus, in regard to cotton, a memorandum was sent out to the principal firms dealing in the article, no less than 335 of whom signed the document. These firms owned over 18 million spindles, and consumed more than 320,000 tons of raw cotton per annum. It is evident, therefore, that the memorandum must carry great weight. It states that the average annual quantity of cotton imported into Liverpool during the period between 1880 and 1884 inclusive was 765,656 tons, and that more than 500,000 tons are consumed within carting distance of Manchester. In the memorandum occurs the following: "The advantages which would accrue to the cotton trade by the direct importation of cotton into Manchester, and the saving which would be effected by using the canal, would be so great that we think nearly all the cotton we consume would come by the ship canal as soon as it is completed." Under these circumstances, probably Mr. Marshall Stevens is not over-sanguine in taking the whole 500,000 tons, and crediting the canal, at the end of seven years after completion, with the 150,000*l.* that would be derived from toll and wharfage at 6s. per ton, especially as the charges per ton on cotton between Liverpool and Manchester were as follows at that date: viz., dock and town dues, 3s.; master-porterage, 1s. 3d.; quay attendance, 1s.; carting to rail or barge, 1s. 3d.; railway or canal carriage, 7s. 2d. We thus had a total of 13s. 8d. per ton from Liverpool—the sum has been reduced somewhat of late—as against 6s., estimated as the charge of the canal company, although the company's Act gives them a maximum limit of 7s. per ton.

It is needless to emphasise the importance to the consumer of this difference of cent. per cent. in the cost of carriage between Liverpool and Manchester, and it is here the strength of the canal company's position is manifest, that for every shilling earned in this way a shilling is also put into the pockets of manufacturer, merchant, or consumer. The advantage to the manufacturer does not necessarily rest with the saving in freight, for if he be an exporter, he will get a like advantage when he returns his manufactured cotton to the ocean route; added to which, he will probably get his coal, stores, &c., at a cheaper rate; while the indirect advantages due to lower cost of machinery, &c., should be taken into consideration. In brief, many of the old arguments and promises advanced sixty years ago in favour of railway construction—which have been exceeded a thousandfold, though ridiculed and scorned at the time—may be again brought forward in support of the Manchester Ship Canal; and, indeed, of many other waterways now all but unused in this country. Cheap transit is the keynote of industrial prosperity.

Although cotton naturally takes the leading position in a consideration of the trade of Manchester, there are other commodities which are hardly of less interest. Turning to food, we find a statement signed by a number of leading corn merchants in which it is set forth that the consumption of cereals is greater in the district of which Manchester is the centre than in any other part of the United Kingdom. Cereals are now imported through Liverpool, Hull, West Hartlepool, Fleetwood, &c.; Manchester having become a large distributing centre for grain and flour. It is estimated that one-half the imports of cereals to Liverpool will come over the canal, and this will give 649,252 tons per annum, the income from which, at 4s. 2d. per ton, would amount to 135,260*l.*, which is the sum for which credit is taken in Mr. Stevens' estimate of total income for seven years after the canal has been opened. The Liverpool charge for grain in sacks was, it will be remembered, 9s. 11d. per ton. The returns for food imported into the United Kingdom during 1891 give a total weight of 11,588,074 tons, excluding 852,453 head of animals, and 3,683,588*l.* worth of articles, such as poultry, game, vegetables, &c., not readily convertible into tonnage, the weight of which is estimated to bring the total of food up to twelve million tons. Of this total for the United Kingdom the quantity estimated (on census figures as to population) to be consumed within a district which is nearer to the Manchester Ship Canal than to any other port, is three million tons. In Mr. Stevens' forecast he took 1,337,752 tons as the quantity of food carried over the ship canal seven years after completion; so it may be allowed he was not over-sanguine in this item. Timber Mr. Stevens ranks next in importance for revenue to cotton, it being an article especially attracted by cheap rates of carriage. The canal rate is 4s. 9d. per ton (made up of 3s. 9d. canal toll, 6d. landing charges, and 6d. wharfage), whilst the cost from Liverpool by rail was 9s. 5d. (made up by 1s. dock and town dues, 1s. 9d. master-porterage, quay attendance, and carting, and 6s. 8d. railway carriage). Timber now comes to Manchester *viâ* Liverpool, Fleetwood, Garston, Grimsby, Hull, and West Hartlepool. The Manchester district consumes more timber than is imported into Liverpool; but half the latter quantity is taken as the traffic by Mr. Marshall Stevens in his balance-sheet. The canal toll and wharfage on this at 4s. 3d. per load would amount to 66,238*l.*

With regard to the 402,828*l.* credited to the revenue of the ship canal on account of exports, textile manufactures stand first in interest. In 1883 the export value of textile manufactures for the United Kingdom was valued at 101,355,310*l.* The weight of textile manufactures is not obtainable from the Board of Trade returns; but, as 1½ million tons of raw material can be traced to their manufacture, and allowing 500,000 tons for home consumption, it is thought reasonable to take 1,000,000 tons as the export, including a known quantity of 174,241 tons of yarns. At any rate, the movement of traffic in the Liverpool Docks is known, not being given, however, in weight, but in packages and pieces; and it is stated that at least a million tons per annum of textile manufactures pass through Manchester, and half this amount, 500,000 tons, is thought a fair proportion to be credited to the canal traffic. Mr. Stevens, however, takes 400,000 tons as the volume of this traffic, the income from which at 4s. 6d. per ton would be 90,000*l.* per annum. It may be noted that to India and China alone 200,000 tons of textile fabrics are exported yearly, and these pay 75,000*l.* in carriage from Manchester to Birkenhead, and 10,000*l.* in Liverpool Dock dues, &c.

With regard to other articles of export, space will allow us to do little more than give the amounts allocated to some articles by Mr. Stevens in his anticipatory balance-sheet. Thus, from chemicals the revenue is estimated at 21,183*l.*; from coals and fuel, 116,666*l.*; from metal and machinery, 86,255*l.* Salt and earthenware and glass supply 12,000*l.* each, and textile manufactures, as already stated, 137,500*l.* The balance to make up the grand total of exports of 402,828*l.* is contributed by classes of goods less important individually. The ship canal authorities have always strongly insisted on the advantages that the coasting trade will be to them. In this country we do not attach much importance to coastwise traffic, the reason being that the railways monopolise so much of the business. That is natural, for the railways are generally more conveniently situated for both collecting goods from the manufacturer and distributing them to the merchant. We know, however, that where factories are situated close to a port, water carriage can more than compete with the railways, and this is especially true in the case of heavy cargoes or large quantities of materials shipped in bulk. An example of this is seen in the case of the Thames barges, which are simply sailing craft. These remarkable vessels work round the south and south-east coasts, and will transport goods in bulk at a price with which the railways—in spite of their big organisation, and the general principle of stifling competition at any cost—cannot compete. London, however, has a large coasting trade, no less than 4,500,000 tons per annum, which is a good example of the benefit of an extended length of free inland navigation touching a large district. Lancashire in old times recognised the necessity of transit for a manufacturing district, as the canals still existing show. Unfortunately, the railways came and choked canal development, though the Mersey never could have been navigable in the sense that the Lower Thames is, and therefore barge traffic alone was possible in the existing canals, even where their facilities were not paralysed by the control obtained over them by the railway companies, so that competition might be checked.

The Manchester Ship Canal will inaugurate a new era in coast traffic. It is not likely ever to fall into the hands of the railway companies, and it has more than capacity to carry the largest ships engaged in any coasting trade. The manufactures of the Manchester district are, of course, sent all over the country, and the following are some of the rates of carriage by railway: To London from Manchester the average is 40s. per ton; to Bristol, 35s. per ton; to Plymouth, 46s. 8d.; to Newcastle, 35s.; to Leith, 40s.; to Cardiff, 43s. 4d.; to Penzance, 55s.; to Dublin, 25s.; to Cork, 42s. 6d.; to West Hartlepool, 42s. 6d.; and to Dundee, 45s. The general manager of the ship canal says he is prepared to convey the same classes of goods either to or from any of these places and Manchester, at the rate of 15s. per ton, including canal toll.

With these figures before us, it is difficut to put a limit to the probable extension of the coastwise traffic of the ship canal, for the advantage to the manufacturer will not be only in regard to raw material and coal, but also in distributing his produce. A good example is afforded by the large consignment of boiler-plates which were amongst the first things to arrive by the canal. Messrs. Galloway, the purchasers, will certainly find the canal a more advantageous method of transport than the railway for some of the large boilers they make, and for other heavy machinery. There is also the benefit to the workmen from cheap carriage of food, &c., wherever there is a distributing centre. If Lancashire has been able to do such great things in the past, how much more favourably is she situated now that she has determined no longer to sacrifice so much to her spoilt child at the mouth of the Mersey; and one can hardly doubt but that the factories on the banks of the canal, already started, will be multiplied in number to a large extent, and that the dock accommodation of the route will be yet further extended by cuttings and basins to serve back districts. As an instance of the manner in which the canal will make work for itself, we may refer to the growth of Saltport, a depôt which had already arrived at some importance before the ship canal was fully opened for traffic. Our illustration, Fig. 111, Plate IV, gives a view of Saltport taken some time before the opening of the canal.

The estimates we have quoted, referring to a period of seven years from the opening of the canal, necessitate a rather long look ahead. Recognising this, Mr. Marshall Stevens has prepared a similar balance-sheet, taking a period within two years of the completion of the work. We will quote the chief of these figures without further comment, leaving our readers to form their own conclusions by the aid of such statistics as we have already given. The estimated traffic in cotton is 336,000 tons, which, at 6s. per ton, amounts to 100,800*l.*; on corn, 474,550 tons, at 4s. 4d., equals 102,819*l.*; sugar, 100,000 tons, at 5s., 25,000*l.*; provisions, 63,386 tons, at 6s., 19,015*l.*; fruit and vegetables, 105,000 tons, at an average of 4s 9d., 25,000*l.*; timber (not including colliery or coastwise timber), 311,710 tons, at 4s. 3d., 66.238*l.*; textiles, 400,000 tons, at 5s. 1d., 101,666*l.*; machinery, 120,000 tons, at 5s. 7d., 33,500*l.* The totals of these figures are 1,910,646 tons, and 474,038*l.* Other articles, details of which are given in the balance-sheet, add another 269,610 tons, with a revenue of 65,023*l.* Low-class traffic (metals, minerals, coal, salt, &c.) are estimated at 1,348,276 tons, giving a revenue of 102,791*l.* The coastwise traffic is set down at 600,000 tons, with a revenue of 107,500*l.* Taking all these money figures together, we have a total of 794,173*l.*, which, with the Bridgewater revenue and other sources of income, would, Mr. Stevens says, be sufficient to pay all working expenses and provide interest upon a capital outlay of fifteen million pounds.

We have given above the estimates of Mr. Marshall Stevens, the general manager of the ship canal. Mr. Stevens was one of the original promoters of the scheme, and a large part of the matter which we quote formed a part of his evidence in favour of the ship canal given during the parliamentary inquiry. It will be evident that we cannot give an exact estimate of the soundness and value of Mr. Stevens' conclusions, but we may say that, in instances where we have been able to test his statements by information obtained from other sources, we have found the general conclusions to appear just and reasonable. If, however, we say that with regard to revenue, we do not look so favourably on his estimate of working expenses, and we think he has not made sufficient provision for unforeseen contingencies in the matter of upkeep. In the case of so novel a work as the Manchester Ship Canal, there being no precedent to which it may be referred, much must be roughly, not to say blindly, estimated. We have, however, given Mr. Stevens' figures, and it will remain for time to prove whether they are sufficient. One thing is in favour of the canal: the cost of maintenance does not rise with the increase of traffic to the same extent as with the permanent way of a railway; it being assumed that the supply of water is ample, and there being no need to have recourse to pumping.

Although we have to proceed so largely without precedent in the case of the ship canal, there is one matter in which its early history supplies us with an unfortunate example of the manner in which the most careful estimates may be falsified by the unforeseen. The "picked body of leading Manchester commercial men" who, we are told, entered into a ship canal inquiry as sceptics in 1886, fully indorsed the estimate of cost of construction then put forward. How much that estimate has been exceeded in the actual carrying out of the work is now a matter of history, and has resulted in the capital of the company being increased 50 per cent. In justice to the gentlemen who formed the committee, it must be remembered that if they erred, they did so in company with some of the best engineers of the day, and, further, that the estimates had received the very practical approval of the two largest firms of contractors of that time, who had undertaken to do the work at the prices named. The discrepancy between promise and performance arose chiefly, as we have pointed out, through an insufficient margin for the unforeseen; in defence of which it may be said that if full precautions were always taken in this regard, half the big engineering feats of the world would be yet uncommenced.

III.—THE CANAL AS AN ENGINEERING STRUCTURE.

The engineering difficulties in the construction of the Manchester Ship Canal have arisen chiefly through the vastness of the undertaking, the extent of ground to be covered, the diversity of the work, and the continuous and bitter opposition of the different vested interests affected by the project. The waterway itself has comprised two entirely different classes of work, the lower part being estuarial, while the upper section is inland. In the latter case the difficulties have by no means been only those which arise from digging a vast trench through varying geological formation, for a difficult river has had to be obliterated in its course, and the canal made largely on its site. To plan the railway deviations has necessitated a knowledge of some of the most difficult parts of this branch of civil engineering—namely, the construction of viaducts or bridges at a great height over a watercourse where a comparatively large span is required, and the formation of heavy abutments upon soft and treacherous bases. The swing bridges necessary for the passing of masted vessels are all important structures; one of them, that which carries the roadway between the Manchester and Salford Docks, being the heaviest structure of this kind constructed in this country, though not of the longest span. The swing aqueduct which carries the old Bridgewater Canal over the ship canal, is a difficult piece of engineering of an entirely novel kind; the locks are of the largest dimensions; the sluices and movable weirs are new in many features of their design, and are constructed to pass enormous volumes of water; whilst difficulties, forced on the engineers by the action of Parliament in the protection of vested interests, have imposed conditions which have only been overcome by the exercise of ingenuity and resource of the highest order.

It is now our purpose to refer to the more salient features in the construction of the canal, but before proceeding to do so, it is well we should briefly state the chief elements of design. The main features of the ship canal may be briefly stated as follows: It extends from Eastham, which is situated on the Cheshire side of the Mersey estuary, about six miles above Birkenhead, to the very heart of Manchester, a total distance of 35½ miles, of which the 21 miles from Eastham to Latchford are partially tidal, as will be presently more fully described. In a general sense its course lies in a south-westerly direction from Manchester out—but owing to the fact of its having to follow for many miles of its inland course, the main direction of the Rivers Irwell and Mersey, and, after reaching the estuary at Runcorn, the contour of the southern or Cheshire shore, it has to make considerable deviations from a straight course. Between Latchford and Manchester, the Rivers Irwell and Mersey become practically canalised—that is, they are replaced and absorbed by the canal, and discharge into it the whole of the flow of their upper waters, as well as that of their tributaries along its course to the sea.

The canal is divided into five main sections —one, as already stated, semi-tidal, and four others pounded up at various higher levels by four sets of locks, the last of which gives access to the Salford and Manchester Docks. The normal depth of the canal will be 26 ft. right through, but in the semi-tidal portion, although the depth of water can never be less, it will during spring tides rise to greater depths, varying from 26 ft. to 34 ft. The mean tide level in the Mersey at Liverpool (or, in other words, Ordnance datum) is 9 ft. 6 in. below the normal level in the ship canal, and this figure might therefore represent the amount of rise between the estuary and the entrance locks at Eastham on ordinary occasions. We give subjoined a table of distances and of water levels in reference to mean-tide level in the Mersey estuary.

Section.	Distance from Eastham Locks.	Length of Section.	Rise in Locks.	
			Lift at each Lock.	Above Mean-Tide Level in Estuary.
	miles	miles	ft. in.	ft. in.
Eastham	21	21	..	9 6
Latchford	28½	7½	16 6	26 0
Irlam	30½	2	16 0	42 0
Barton	33¾	3¼	15 0	57 0
Mode Wheel	35½	1¾	13 0	70 0
Total	35½	35½	60 6	70 0

It will thus be seen that the level of the water in the docks at Manchester is 60 ft. 6 in. above the normal level in the semi-tidal portion of the canal, and 70 ft. above the mean-tide level in the estuary.

On the occasion of very high spring tides, the rise at the Lachford Locks, instead of being 16 ft. 6 in., would be less by so much as the tide-rise is above the normal level of the ship canal.

The minimum depth, as already stated, is 26 ft. throughout, but all lock sills are constructed with a depth of 28 ft., in order to allow the whole of the channel being dredged to a uniform depth of 28 ft., should such be found desirable at some future time.

The dimensions of the canal as to width are ample, and in excess of any existing canal. The batter of the sloping banks varies, of course, with the nature of the soil through which the channel is cut.

In the upper section, from Manchester to Barton, 5 miles in length, the width of the canal is 170 ft. at bottom. Between Barton and Eastham the width at bottom is 120 ft., and 172 ft. at water level. The narrowest portion of the canal—apart from the locks—occurs at Runcorn, where the canal passes between the south abutment and the first river pier of Runcorn High-Level Bridge. Here the clear passage-way is only about 92 ft. Both above and below the locks the canal is considerably widened to allow ships to lie out of the

RAILWAY BRIDGES; THE MANCHESTER SHIP CANAL. (*See Page* 18.)

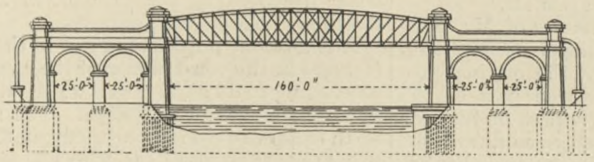
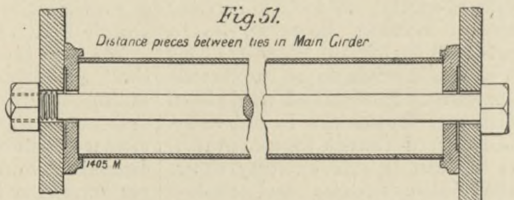


Fig. 14.

Fig. 51.



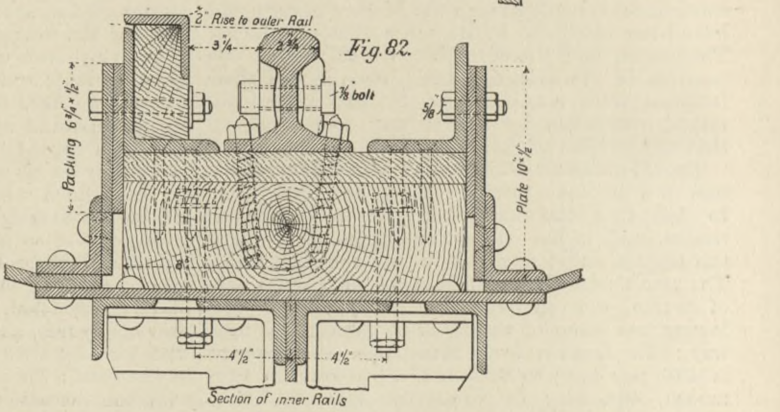


Fig. 82.

Fig. 15.

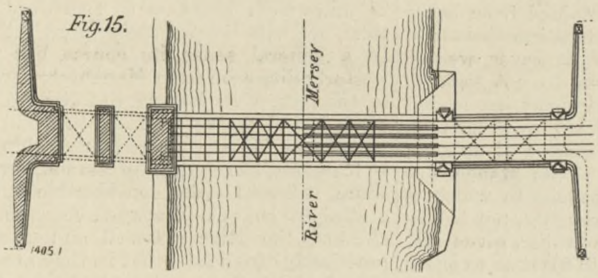


Fig. 16.

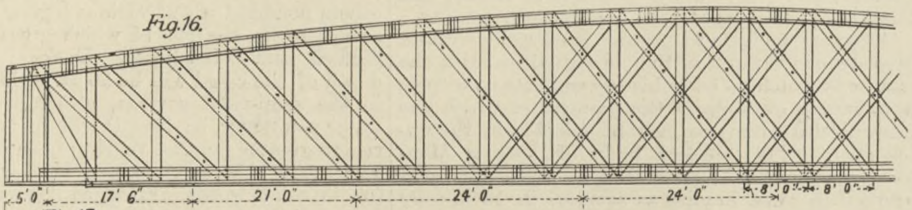


Fig. 17.

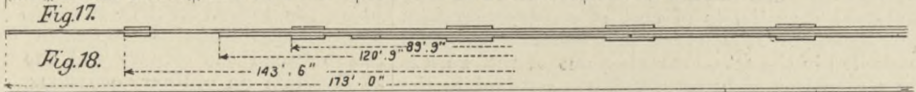


Fig. 18.

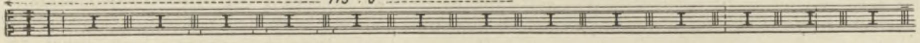


Fig. 19.

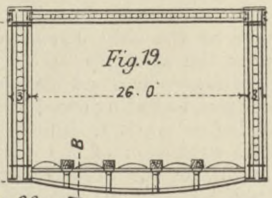


Fig. 20.

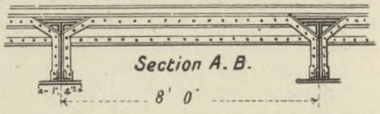


Fig. 22.

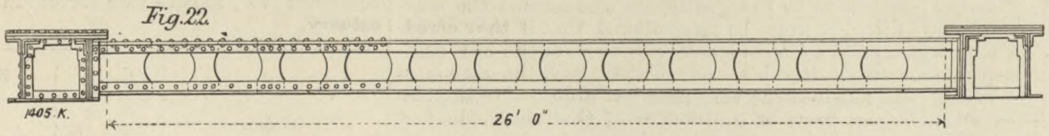


Fig. 21.

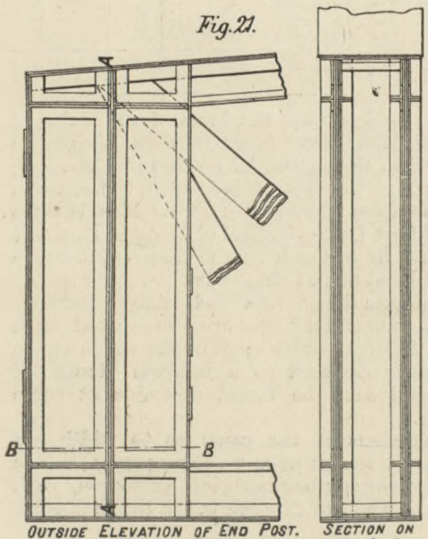


Fig. 23. (*See Page* 19.)

RAILWAY BRIDGES; THE MANCHESTER SHIP CANAL.

Fig. 24. Bridge over River Mersey; Railway Deviation No. 1. (*See Page* 18.)

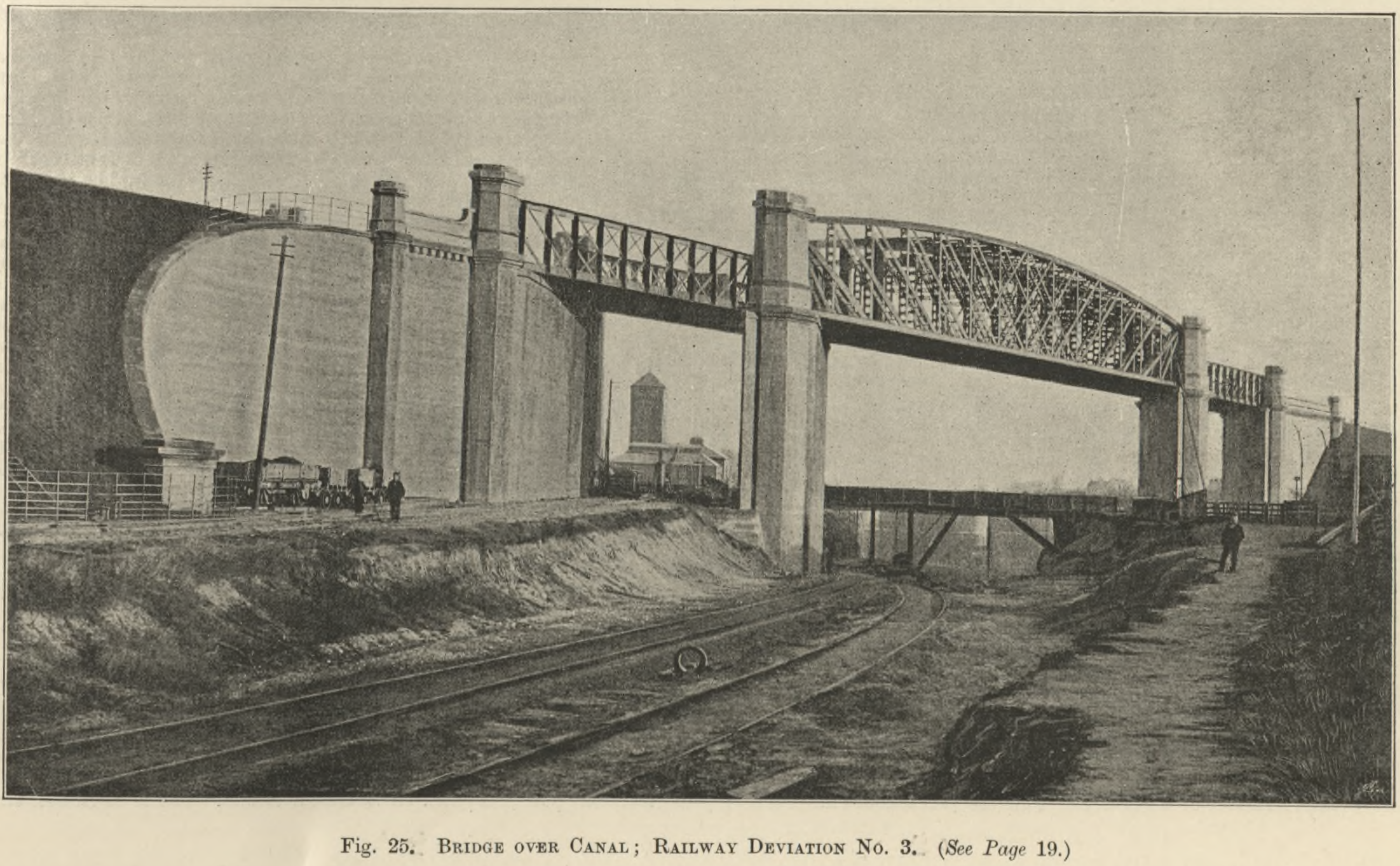


Fig. 25. Bridge over Canal; Railway Deviation No. 3. (*See Page* 19.)

fairway. At each set of locks sluice gates are provided to deal with the surplus of water flowing down the canal, and to pass down all flood water the result of storms and heavy rainfall. These sluices are large, and act as movable weirs. They are in all cases of such capacity as to pass the greatest floods without sensible rise at the locks. Their number varies with the volume of water which is likely to require passing. At Mode Wheel and at Barton are four gates of 30 ft. in width. At Irlam Locks there are five sluice gates 30 ft. in width. At Latchford Locks only three sluice gates are provided, because between Irlam and Latchford, arrangements are made by which a portion of the surplus water can flow over into the old river bed of the Mersey, and thence past Warrington into the Mersey estuary. At Eastham only two sluice gates of 20 ft. in width are provided, owing to the great tidal openings at Runcorn, in the Weaver estuary, and at Ellesmere Port, which act as weirs to that portion of the canal.

Communication between the two banks of the ship canal — other than at the locks—is established in three different ways :

1. For railway traffic, by high-level bridges, giving a clear headway above water-level of 75 ft., this being the headway under the existing Runcorn Bridge, and therefore the standard height.
2. For road and foot traffic, by high-level bridges, as in No. 1, or by swing bridges with generally a clear headway of 16 ft., which is sufficient to allow flats, or canal barges, or steam barges without masts to pass under.
3. By ferries with inclined roads up the banks on both sides for light carts and foot traffic. These are established more particularly in places where ancient rights of way exist, but where the traffic is not sufficiently important to justify the construction of an opening bridge.

In order to save the banks from the destructive effects of heavy and continuous running wash, the speed of vessels passing through the canal will be limited to six miles per hour.

IV.—THE LOCKS.

We will now proceed to our more detailed description of the various principal engineering works which go to make up the canal. Beginning at the lower end and working upwards, at the entrance we come to the Eastham Locks, which are the most important and the most capacious on the ship canal. They are three in number, placed side by side. The rise from mean level in the Mersey to the normal level in the canal is 9 ft. 6 in. in all three locks. The dimensions of the locks are as follows : One 600 ft. in length by 80 ft. in width ; one 350 ft. in length by 50 ft. in width ; one 150 ft. in length by 30 ft. in width.

Each lock on the estuary side is provided with a pair of storm gates, opening outwards—as a protection against heavy seas in rough weather. These gates formed no part of the original designs of the engineers to the canal, but were added in deference to the views of the Conservators of the Mersey, and, as a matter of fact, they have never been used in any way up to the present time. At some little distance from these are the ordinary gates, and a similar pair of gates at the upper end of the lock, both of these opening inwards. The dimensions given above refer to the distances between centres of heelposts of lock gates proper. The distances between heelposts of storm gates and those of lock gates are 15 ft., 14 ft., and 13 ft. respectively, in addition to the lengths given above. Recesses are formed in the masonry walls at each side, into which the gates are withdrawn so as to leave the full width of the lock clear for the fairway of the shipping.

The depth of water over the sills of the three locks at the estuary end is the same in all cases, in order that ships of all sizes may be allowed to pass out or enter at all times when the depth in the approach channel will permit them to do so.

The division walls between the locks and the side walls, terminating in long wings carried into the banks, are all founded on the solid rock. They are built of concrete made of Portland cement and excellent gravel, which is found in abundance along the course of the canal. Below water level the concrete walls are faced by a layer 9 in. in thickness of much stronger concrete ; above water this facing is of hard blue clinker brick, a novel feature of the design being the way in which this brick-faced portion of the walls is "oversailed" so as to project beyond the line of the lower or concrete-faced portion. This feature is carried throughout the canal from the locks at Eastham to the docks at Manchester. The fender courses, the coping, the corners of the gate chambers, the roller paths for the gates, and the lock sills are all built of dressed Cornish granite ; which, like all the granite on the canal works, has been supplied by John Freeman & Sons, of Penryn. Within the side walls are constructed the necessary passages or culverts for filling or emptying the locks, and these also are throughout lined with blue brick or stone.

On the land side of the three locks are situated the sluice gates. These are 20 ft. in clear width, and can be raised 15 ft. Their sills are at the same level as the top sills of the locks—that is, the bottom of the ship canal above locks. The sluices are arranged on Stoney's principle—balanced—and can be worked by the application of a very slight power. All the masonry and concrete walls in connection with these locks have been built in the dry, a pumping station with powerful machinery having been erected to remove all water which had found its way into the foundations.

The top of the lock walls and side walls is 10½ ft. above normal ship canal level, and will, therefore, on the recurrence of the highest known spring tides, which rise 8 ft. above canal level, still be 2½ ft. above water.

The illustrations which we publish give a good idea of the Eastham Locks. Fig. 3 (page 4) shows the locks during construction, the view giving the largest lock. One of the gates is shown in course of construction in the recess provided in the opening left for it in the masonry. The wall, as shown, is not carried to its full height, the fender and upper courses not having been constructed when the photograph, from which our engraving has been prepared, was taken The half-round openings, to be seen in front of each wall, are the outlets through which the water from behind the great gates is discharged when a vessel leaves the canal to enter the Mersey estuary. Between the right wall and the farther bank upon the same side may be seen the flood-water channel. On the left of the picture is the excavation for the second lock, 350 ft. by 50 ft. Still further to the left, but not included in the engraving, is the smallest lock, 150 ft. by 30 ft.

The gates of the Eastham Locks, like those throughout the canal, are of greenheart. They are remarkably massive structures, and as gates of the kind are exceptional in this country, and, moreover, as they possess certain novel features in construction, we shall describe them and also the up-stream gates somewhat in detail. The gates for the 80-ft. lock are estimated to contain about 230 tons of timber in each leaf, whilst, with the ironwork, the weight is increased by at least another 20 tons, making in all 250 tons in each leaf. Our illustration, Fig. 4, on page 4, shows the 80-ft. gates almost erected. Each leaf is composed of three panels vertically connected by wrought-iron plates and greenheart fishing pieces. There are a heelpost, two sets of panel posts, and a mitre post to each leaf. The gates are 5 ft. in thickness through the centre. The length of one leaf is 45 ft. 9 in., and the height is 45 ft. 5 in. from bottom rib to top rib. Each leaf is built up of a series of transverse ribs, the bottom rib being 16 ft. high, and constructed of timbers 16 in. deep. The other ribs are of the following dimensions : 3 ft. 9 in., constructed of three timbers ; 3 ft. 3 in., with three timbers ; 2 ft. 6 in., with two timbers ; 2 ft., with two timbers ; the two remaining ribs being each a single timber of 1 ft. 4 in. and 1 ft. 3 in. in vertical extension respectively. The heelposts are in two continuous pieces longitudinally, each part being of the full length, but only of half the cross-sectional area. It has been stated that there are in the canal works sixty pieces of greenheart close on 50 ft. long, to be used for heel, centre, and mitre posts of lock gates. The weight of each of these would be about 1¾ ton when dressed. We understand there are heavier pieces than this, though not quite so long, and our readers will gather from this the character of the work. The timber is tied together with iron plates and bolted with iron bolts, most of which are 1⅝ in. in diameter. There is on each side a diagonal steel strap, 8 in. by 1½ in., extending from the bottom of the heelpost to the top of the mitre post, and another in the opposite direction. Reinforcing the top rib are two steel ties 9 in. by 1¼ in., hardened up at each end by keys, gibs, and cotters. The beams are tenoned into the heel, panel, and mitre posts, the heelposts being 13 in. radius. The mitre posts are bolted together with diagonal bolts. The heelpost caps and plates are of steel ; the pivot plates are of steel, cast solid in one piece with their pivots. Steel collars are fitted to the mitre and panel posts top and bottom. On the compression sides of the gates there are six wrought-iron plates varying in size from 9 in. to 7 in., all by ¾ in. The struts and ties of the whole structure, and fastenings of the gates, have been designed and proportioned so that they would be self-borne, and that it would be possible to work them without rollers. As an additional precaution, and also for the purpose of steadying the gate whilst working, twin rollers with anti-friction bearings have been provided These are carried on spear posts at the other ends of the gates.

It will be seen from our description that these gates are of very substantial construction, and the ample manner in which they are supported by metal fastenings renders them exceptionally strong. They have now been tested for some time in practical use, and work admirably, keeping exceptionally tight at the greatest head to which they are subjected.

The power for working the locks is obtained from an hydraulic installation, the machinery being provided by Armstrong, Mitchell, and Co. The opening and closing machinery of the gates has double rams, an opening and closing ram being provided for each leaf of the gates. The system of chains employed is that adopted first at the docks at Burntisland on the north side of the Firth of Forth, and afterwards at Liverpool, Bombay, and other large ports. It is of what is known as the "overgate" type, in which the ends of the hauling chains are fixed to the lock wall—instead of to the gate—whence they pass over swivelled sheaves on the back and front of the gate, and then over other conveyance sheaves on the top of the gate and at the heelpost, to the hydraulic cylinders and rams, which are fixed in a chamber below the quay, and are provided with multiplying sheaves for increasing the travel of the ram. It is to be regretted that the direct-acting ram, working immediately on the gates, was not adopted in this case, so as to avoid the complication of chains and multiplying gear. At these locks there are also eight 5-ton hydraulic ship-hauling capstans of the direct acting type. The hydraulic power for working the machinery at the Eastham Locks is supplied from a pumping station close by. There are two duplicate pairs of pumping engines of the compound jet-condensing type, with accumulators and accessories. The boilers are of the Galloway type, working to a pressure of 100 lb. to the square inch. The pressure in the hydraulic mains at this and other stations is 50 atmospheres.

The locks on the upper part of the canal at Latchford, Irlam, Barton, and Manchester, are generally like those at the entrance, but have not storm gates, the provision of which seems an excess of caution in a sheltered and obstructed waterway like the estuary of the Mersey is at Eastham. In some details the upper locks differ, but generally all the locks are of the same design throughout. The height of lift is different, and the number of sluices also varies. The general design of the upper locks is to have two locks placed side by side, with an intermediate wall. Our illustration, Fig. 5, on page 5, gives an excellent idea of the Irlam locks and sluices, as they appeared when the construction was practically completed, the excellent photograph from which our illustration has been prepared having been taken last July. The view is taken looking up stream, one of the five 30-ft. flood sluices being raised so as to allow the traffic on the contractor's line to pass. The building with the high chimney on the left is the hydraulic installation house. In the foreground men are at work completing the last of the excavation and pitching the slopes before letting in the water. The view was taken by Mr. Killon, a member of the engineer's staff, from the top of the canal viaduct of Deviation Railway No. 5, so it really gives a bird's-eye view of the scene. We owe many of our illustrations to Mr. Killon's photographic skill. In Fig. 6, on page 5, we have another view of Irlam Locks after the water was in the canal. Our illustration shows the Snowdrop entering the locks in passing from Liverpool to Manchester on December 7 last ; she being the first vessel to make the trip.

The two locks are, as shown, placed side by side, with an intermediate wall. One is 65 ft. between fenders, and the other 45 ft. The wider lock is 600 ft. between hollow quoins, and 725 ft. 6 in. long over all. The 45-ft. lock is 350 ft. between hollow quoins, and 460 ft. over all. On the 65-ft. lock intermediate gates cut off 150 ft. in length, and in the smaller lock 120 ft. is cut off. The 65-ft. lock has a main sluice in each wall 6 ft. by 12 ft., having four openings each side, so as to spread the discharge over the whole length of the lock. The sluice-way is lined with brickwork having a blue-brick facing. The smaller lock has two main sluices, one on each wall. They are 4 ft. 6 in. by 8 ft., and are lined as the others, and also have four outlets in each wall. The intermediate wall between the locks is 29 ft. 6 in. thick, and is built in concrete. All walls are of concrete up to water level ; above that they are lined with brick with a blue-brick facing, and have a fender course of granite 18 in. thick, which is placed between the brick facing and the concrete. All up-steam locks are fitted with an intermediate sluice in the middle wall, so as to save water if necessary. Each end of the lock is arranged with a groove to take a caisson in case of accident or repairs being required. The sills are all granite with sandstone back, and the roller paths are of granite.

The gates to these locks differ in detail of construction from those of the entrance locks at Eastham. They are, however, built of greenheart, and each leaf is constructed in two panels. The height is 47 ft. 3 in. over the ribs, and the length 36 ft. 3 in. on the sill face, the thickness being 4 ft. 1½ in. in the centre. The radius of the heelpost is 11½ in. The centre post consists of two timbers, and each rib consists of a fish-piece and four smaller ribs. On the bottom of the grate the ribs are fixed together in threes, and are fastened by 1⅜-in. bolts. The supplementary parts of each rib have through bolts from 1¼ in. to 1⅜ in., and have wrought-iron plates ⅞ in. thick at the joints with the heelpost, centre post, and mitre post. The heelpost plate is the whole height of the gate, and is made in three lengths riveted together with cover plates. At the top of the mitre posts are two large plates, one on either side, 12 ft. 9 in. long, which receive the thrust from the strut. These plates are connected together with an iron angle frame ; the end of the strut fitting into the frame, and the whole being securely fastened with 1½-in. bolts on the mitre post, thus forming a secure end to the top of the gate. The strut is built of horizontal timbers placed between the ribs and fixed in with keys and through bolts. The gates of these up-stream locks are provided with two rollers to each leaf, working on roller bearings. They are fitted in a single frame consisting of wrought-iron plates and angles, on to which the spear post fits in a steel casing which is attached to the two top ribs by 1½-in. bolts. The space between the ribs is filled with timber work. Each leaf is also provided, on each face of the top rib, with two horizontal steel straps 9 in. by 1⅛ in. They are secured by gib and cotter on to the heelpost plates and the mitre-post plates, receiving the horizontal tension due to the thrust from the strut. There is a steel diagonal tie 8 in. by 1¼ in. on each side of each leaf, securely fastening the bottom of the mitre post on to the top of the heelpost to prevent the gates getting out of winding. On the top of the heelpost plates there is fixed a steel cap which is fastened by twenty-four 1½-in. bolts, so that the whole of the strain comes on to the plate instead of on to the ribs. At the bottom of the heelpost is a shoe which consists of a steel casting 3 in. thick, and the gate turns on a cap hollowed in the shoe. The pivot is also of cast steel, the pivoting being 1 in. eccentric, in order to clear the hollow quoin in opening. Vertical fenders are provided.

In the case of the Irlam Locks the construction was carried on by means of trenches, the walls being built each in separate cuttings in place of the whole area being excavated at first. There are certainly advantages in this method of procedure, the chief being greater facility in handling materials, which only require lowering from the surface, in place of lifting, and there is also the benefit of the contractor being able to proceed with the most important part of the construction very early in the work, and a great part of the main excavation can be carried on simultaneously with the building of the walls if necessary. The engineer is also able to dispense with a great deal of heavy timbering. There is the further benefit of facility for strutting shutters against the sides of the trench in putting in concrete walls. The excellent natural rock foundations on which all the locks of the canal are fortunately placed, is a point worthy of notice. The bottoms are all formed by this natural rock, and thus the construction has been simplified by the invert only requiring a simple facing of concrete.

The up-stream locks are all worked by hydraulic machinery from stations conveniently placed. The Irlam Locks are operated by the same installation that is used for the Partington coal-basin, which is on this section. The pressure main in connection with this group extends over a length of 1½ mile, an auxiliary accumulator being placed near the Partington coal hoists.

There are, in connection with the ship canal navigation, four subsidiary locks. These are more particularly referred to in our general description of the whole work.

V.—THE SLUICES.

There are no fixed weirs in connection with locks on the ship canal, all being of the lifting type, or flood sluices, on the rolling principle patented by Mr. F. G. M. Stoney, and made and erected by Messrs. Ransomes and Rapier, of Ipswich. The number and capacity of the sluices attached to the locks vary with the duty required from them. At the entrance locks at Eastham, which are the most important on the canal, there are, for instance, only two sluice gates, 20 ft. each in width, whilst higher up, at Irlam—as shown in Fig. 5, on page 5—there are five 30-ft gates. The four sluices at Barton have an easy capacity of 26,000 cubic feet per second, which is ample for the heaviest flood yet recorded in the Irwell. At Irlam, lower down, the greater capacity provided by the five sluices is in order to let off the water that has been contributed by inflowing streams. At Latchford, although lower again still, the three sluices are sufficient, as here the old channel of the Mersey is kept open, and as communication between the Mersey and the canal is made higher up by means of a weir, an outlet is formed for any great quantity of water that might otherwise accumulate. The lower part of the canal being on the estuary, with only a wall or bank between the canal and the natural waterway, provision can be made for letting off an excess of land water ; and, indeed, the lower part of the canal up to Warburton being semi-tidal, openings have been constructed to allow of the partial ebb and flow.

In all there are thirty of these flood sluices on the canal ; four being at the Mode Wheel Locks—the first locks just below the Salford Docks—four at Barton Locks, five, as stated, at Irlam Locks, three at Latchford Locks, two at Old Randles, ten at the Weaver mouth, and two at Eastham Locks. They are alike in width, being all 30 ft., with the exception of the two at Eastham, which, as stated, are 20 ft. They vary, however, in lift, the majority being capable of being raised 20 ft., whilst the ten Weaver sluices have only a range of 13 ft.

In Fig. 5, page 5, the Irlam sluices completed are shown, and in Fig. 7, on page 8, we reproduce an illustration of these sluices in an earlier stage of their construction, by which an excellent idea of the manner in which the work was carried out may be formed. The intermediate piers, which may be seen in Fig 5, are of concrete, with brick lining and blue-brick faces. The piers form abutments for an arch which runs as a roadway across in the manner shown. The sills are built in concrete having a meeting face on a steel joist embedded in the concrete, so as to carry out the principle of meeting faces, being metal to metal. The edge of the sluice is almost as sharp as a knife ; and the joist, which forms the sill, is machined on its upper surface. The doors roll up grooves faced with Bramley Fall stone; they are built up of steel joists with a steel skin plating.

In Fig. 7, page 8, the six sets of upright girders, which are built into the masonry and brickwork piers, have been erected. The lower part of one of these piers is well shown. Three of the steel joists forming the sills are in place in the three further openings. The locks are in progress on the left of the picture, the view being taken looking up stream, as in Fig. 5, though the point of view is different, being from the right side of the canal. On the extreme right of Fig. 7 may be seen the commencement of the wing wall, which is shown completed in Fig. 5, and into which the shoremost upright girder is built. The wall is of concrete faced with stone ; and our illustration shows the operation of building this wall. In the foreground may be seen the platform upon which the men are preparing and mixing concrete. A large square measure is filled with gravel, and upon this several sacks of Portland cement are thrown. The mass is mixed dry at first, water being afterwards added. The concrete is then taken by wheelbarrows and tipped into the space at the back of the facing wall, which is built up a few courses ahead. A number of large blocks of stone were built in with the concrete, but care was taken to keep them at least 6 in. apart in all directions. The photograph from which our engraving has been prepared was by Mr. Harrison Garside, of 21, Cannon-street, Manchester, from whose work many of the illustrations we now produce have been taken.

In Figs. 8 and 9, on pages 8 and 9, we give two further views of sluices. These are those which are placed in the bank separating the canal from the estuary, and which are provided to pass the storm water from the River Weaver. As stated, there are ten such sluices, the whole not being shown in our engravings. It was a condition imposed by the Ship Canal Act that the water from the Weaver, the most important tributary to the Mersey estuary, should be passed directly into the estuary so as to maintain the channels of the latter. The sluices and tidal openings opposite the mouth of the Cheshire river had, therefore, to be constructed. The general design of the sluices is similar to that of those at Irlam, which we have already dealt with ; so that Figs 8 and 9 serve to illustrate both structures. The capacity of these ten sluices is a discharge of 50,000 cubic feet per second. The construction was a matter of some difficulty, and required careful planning. The whole area was inclosed by sheet piling 12 in. thick, which was driven into the hard and strong clay which forms the base of the foundations. The space so inclosed by sheet piling was subdivided by cross rows of similar piling under the centre line of each pier, the whole of the sheet piling being left sufficiently long to act as a half-tide dam, thus enabling the work to proceed without recourse being had to cofferdams. Excavation was then proceeded with until the clay was reached, and the whole area was filled in with Portland cement concrete. A platform was thus formed, upon which steel caissons were placed over the cross lines of sheet piling in such a manner that the rows of piling acted as dowels in the centre of each. These caissons were 36 ft. long by 9 ft. wide by 9 ft. deep, and were of the same form in plan as the piers they carried. The caissons were then filled up with concrete, and upon them the remaining portions of the piers were constructed, the semicircular ends being built of ashlar, and the intervening portion made up of Portland cement concrete faced with brickwork. Upon these piers the superstructure to carry the girder bridges between the piers was erected.

The sluices are, of course, required for filling and emptying the various locks, but a still more important function has to be performed by them, for they have to be practically responsible for the whole watershed of the district. The canal in its course absorbs all the rivers, and impounds their waters in the successive ponds formed by the locks. But, in return, the canal affords a new discharge for flood waters, and hundreds of square miles now obtain a gratuitous benefit from it ; for whereas, heretofore, the whole countryside was liable to frequent floods, it will now be at all times effectually drained by the canal, and flooding will be soon a matter of ancient history.

As already stated, Mr. Stoney's system of roller sluices was adopted. In this system the whole pressure of the water is received on a series of rollers instead of on a flat face, and the consequence is that the gates can be opened and shut with such facility that it becomes possible to make them of very large size, and so obtain a freedom of discharge which is not otherwise to be had.

It has already been mentioned that the normal depth of the water in the canal is 26 ft. above, and 10 ft. below, the sluices ; but to cover all contingencies, the doors were designed by Mr. Stoney to carry the maximum load that can possibly come upon them, viz., that due to 26 ft. head. Shortly before the completion of the canal, it happened to be convenient to fill the Manchester pond quite up, at a time when the water below was considerably lower than the sill of the sluices. Thus, for some time, the sluices at Mode Wheel had the full head

RAILWAY BRIDGES; THE MANCHESTER SHIP CANAL. (*See Page* 19.)

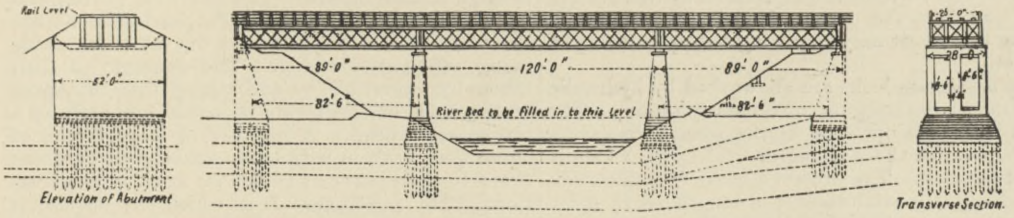


Fig. 26

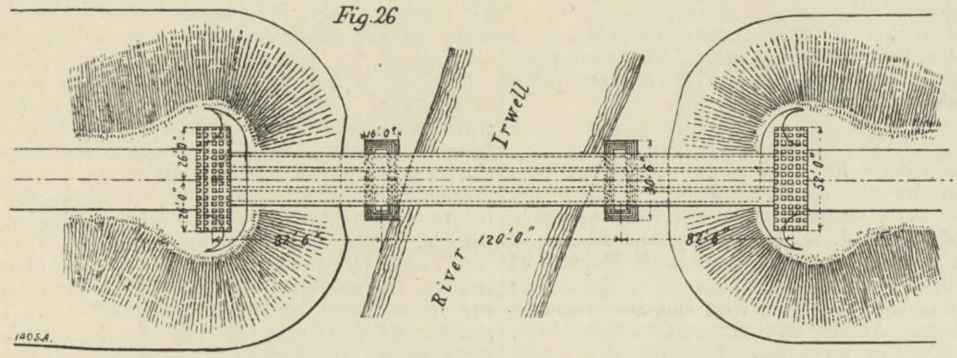


Fig. 37.

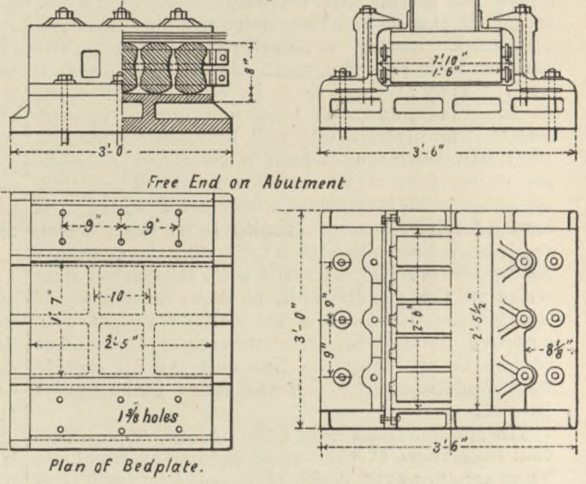


Fig. 28.

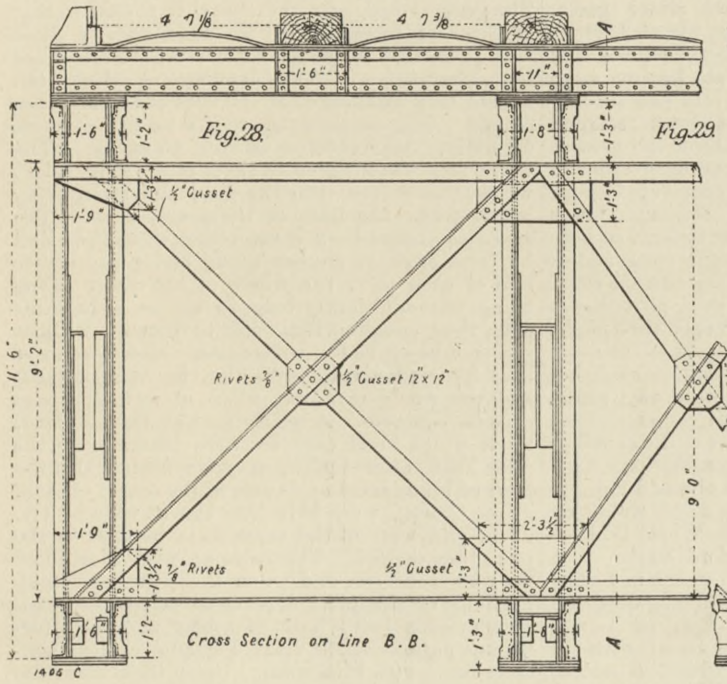
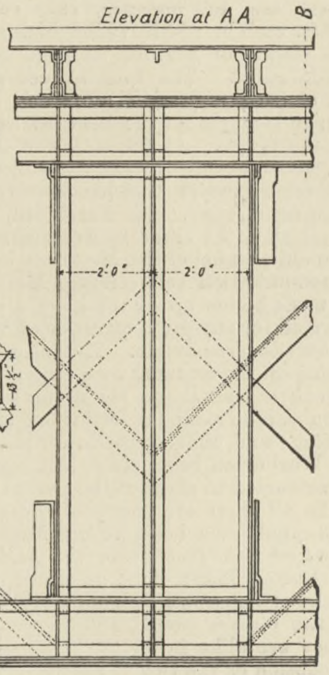


Fig. 29.



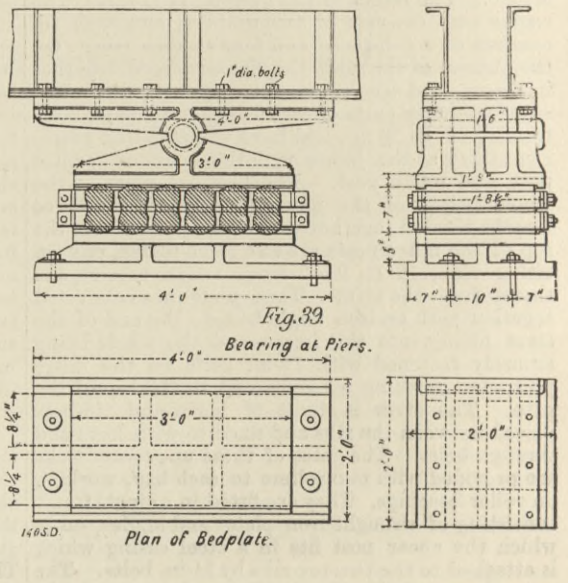
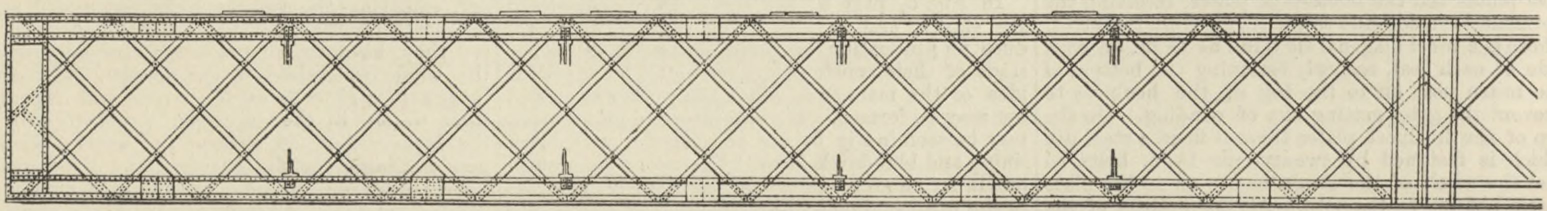


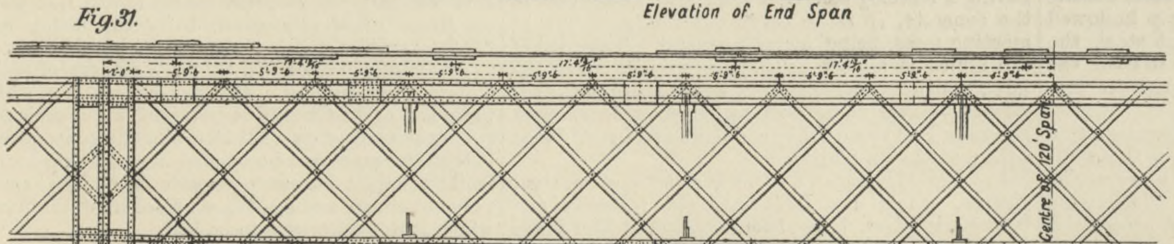
Fig. 39.

Fig. 30. Details of Steel Bridgework — Inside Girders



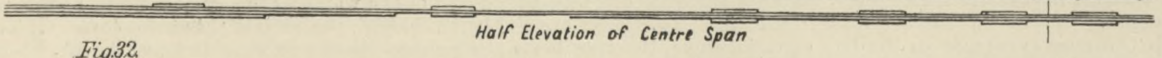
Elevation of End Span

Fig. 31.



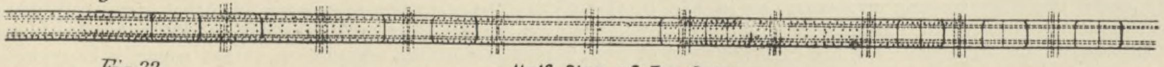
Half Elevation of Centre Span

Fig. 32.



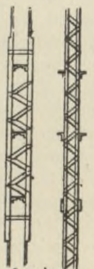
Half Plan of Top Boom.

Fig. 33.



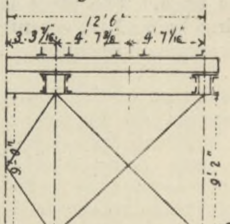
Half Plan of Bottom Boom

Fig. 34.



Bracing of Struts

Fig. 27.



Half Cross Section.

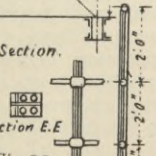


Fig. 35.

Details of Standards

BRIDGE OVER THE MANCHESTER SHIP CANAL; DEVIATION No. 4. (*See Page* 22.)

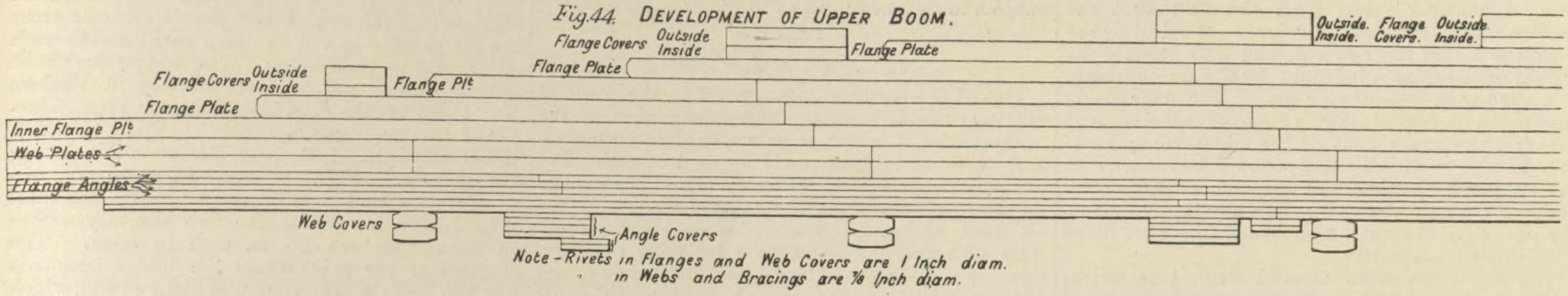


Fig.44. DEVELOPMENT OF UPPER BOOM.

Note – Rivets in Flanges and Web Covers are 1 Inch diam.
in Webs and Bracings are ⅞ Inch diam.

Fig.42. PLAN OF UPPER BOOM.

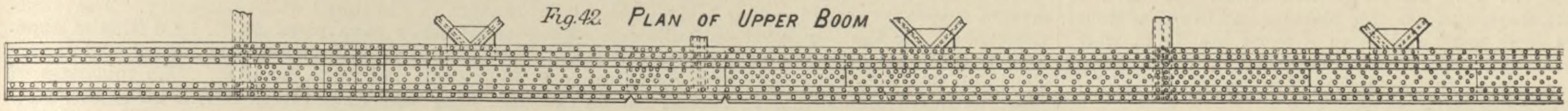
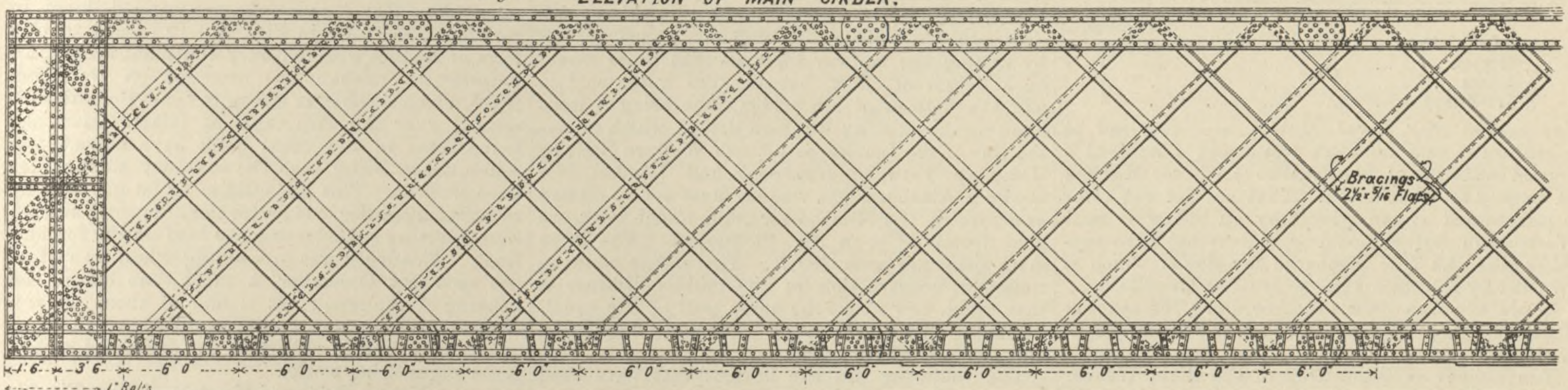


Fig.41. ELEVATION OF MAIN GIRDER.



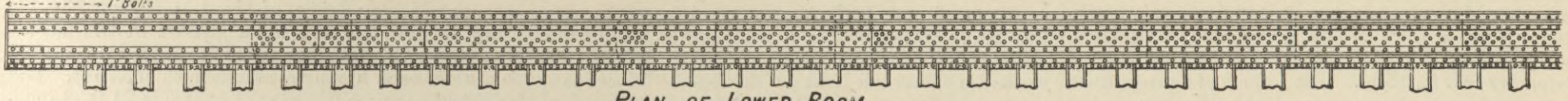


Fig.43. PLAN OF LOWER BOOM.

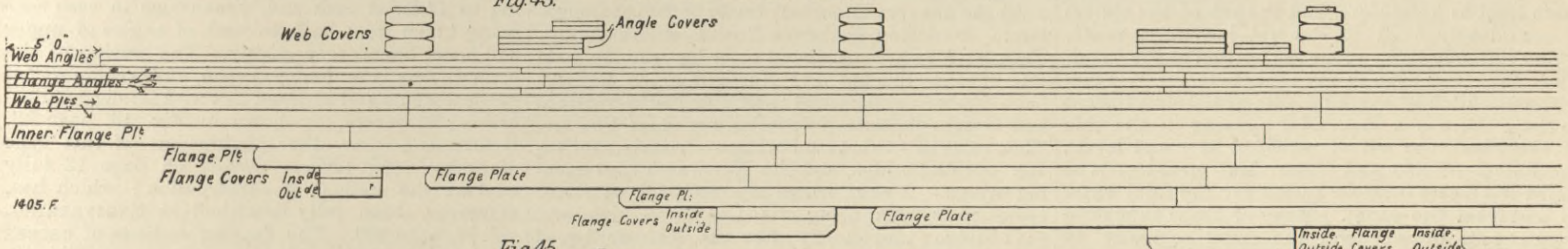


Fig.45. DEVELOPMENT OF LOWER BOOM

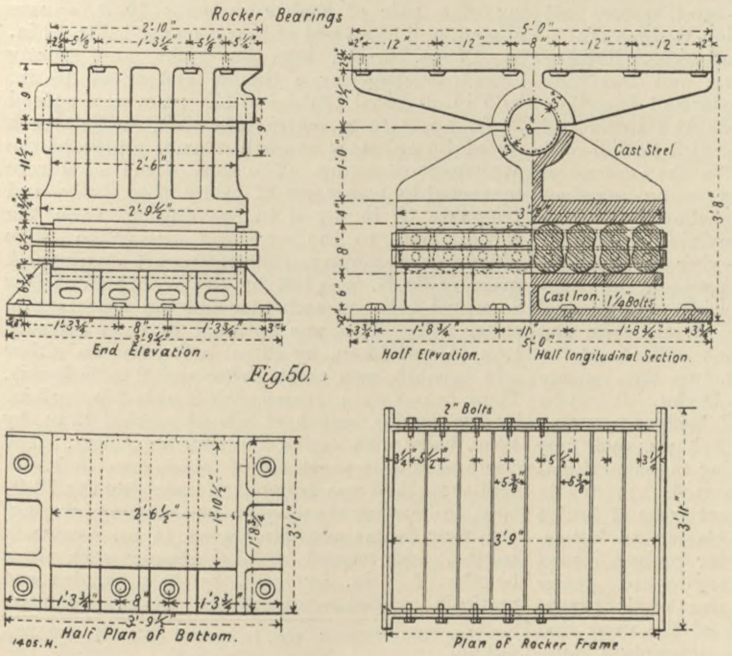


Fig.50.

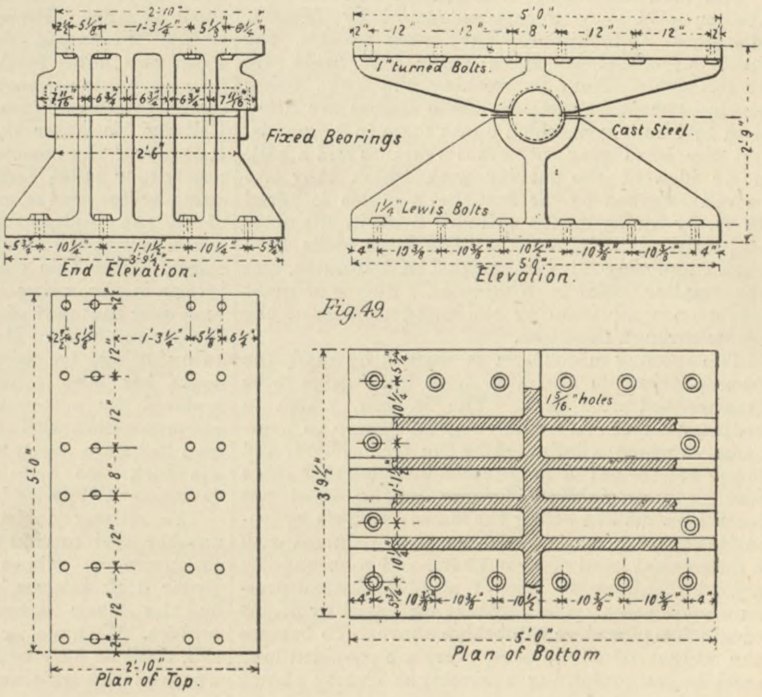


Fig.49.

of 26 ft. upon them ; and it was interesting to see that under that head there was absolutely no leakage, either at the sides or on the sill ; and also that two men could easily open or shut any sluice. This ease of working arises from the fact that the friction due to the head of water is got rid of by the rollers to a very large extent, and also because the weight of the door is balanced by a counterbalance box filled with concrete or gravel, the door being suspended on four steel wire ropes which pass over sheaves, the other ends of the ropes being made fast to the counterbalance ; the friction due to the weight of the door and the counterbalance, together 64 tons, is reduced to a minimum by mounting the rope sheaves on gudgeons which are fitted with antifriction rollers.

The doors are made of mild steel, ½ in. thick, stiffened with eleven girders across the back of each door, and all the plates composing the doors are 30 ft. long, and some of them are 4½ ft. wide, each such plate being about 25 cwt. The sluices were all made by Messrs. Ransomes and Rapier, of London and Ipswich.

The number of these flood sluices is as follows :

	Sluices.
At Mode Wheel...	4
„ Barton	4
„ Irlam	5
„ Latchford	3

The reason why fewer sluices are required at Latchford is that between Irlam and Latchford a branch leads out of the canal to the River Mersey, on its way to Warrington. That part of the river is maintained at canal level by an old weir near Warrington, but the said weir does not give anything like the free discharge for floods which is afforded by the sluices in the canal at Latchford.

There are also sluices further down the canal at Norton, Gowy, Weaver, and at the entrance at Eastham.

The sluices at the outfall of the River Weaver into the Mersey, already referred to, are remarkable. They are, as before stated, ten in number, and each door is 30 ft. wide, thus affording a clear waterway 300 ft. wide. The object of these sluices is to discharge the waters of the Weaver at the same level as heretofore, and the sill of the sluices is accordingly fixed at the old low-water mark, which is about 12 ft. above the bottom of the canal. They have now been in use every tide for 3½ years without a hitch of any kind. Immediately adjacent to them there is a long tidal opening in the side of the canal, the sill of which is at canal level ; the object of this and other tidal openings is to afford the freest possible access for the tidal water to and from the canal. Many of these expensive works were forced upon the canal company by various bodies who conceived that their interests might be infringed. It is to be noted, however, that the tidal water goes up and down the canal with far greater freedom than it does in the upper part of the estuary of the Mersey, and some of the tidal openings act quite differently from the expectations of those who insisted on their provision.

The lock sluices are also all on Mr. Stoney's system, and they were constructed by Messrs. Ransomes and Rapier. They vary in size, the most important of them being 6 ft. wide by 12 ft. high. Time in working the locks being of the utmost importance, these sluices are fitted with hydraulic gear which opens them in 5 seconds, but the hand gear only takes a minute and a half. Some idea of the facility with which they are moved is given by the fact that a sluice is lifted 12 ft. by an hydraulic cylinder 6 in. in diameter and only 2 ft. 6 in. stroke. The large locks have been frequently filled or emptied in 8 minutes, and the smaller locks in 6 minutes. This is of great importance for insuring the rapid passage of the traffic through the locks.

The opening mechanism is worked by hand, the Stoney principle enabling these large gates to be manipulated with ease. The friction, which in ordinary sluices it requires great power to overcome, is almost eliminated by the free rollers, and it has been found in the present instance that there was no appreciable difference in the effort put forth by a man in lifting the sluices with no hydrostatic pressure upon them, and that required with a differential head of over 10 ft., and consequently a load of about 45 tons of absolute statical pressure upon them. The shutters are raised by means of winches placed on the bridge above. To balance the weight of the sluices, there are provided long steel boxes containing concrete, as clearly shown in both Figs. 8 and 9, pages 8 and 9. These are connected with the sluices by double steel wire ropes, carried over sheaves as shown. The winches are geared so that one man may easily lift a sluice when subject to the pressure due to the greatest head.

VI.—THE BRIDGES.

One of the most important parts of the work of making the ship canal was the construction of the bridges over it which were required to accommodate lines of existing traffic by road or rail. For ordinary road traffic swing bridges have been mostly introduced, but the railway deviations are all fixed bridges. When parliamentary powers were obtained by the railways for their construction, it was made a condition that, should the Mersey navigation be so improved as to allow masted vessels to ascend, swing bridges should be substituted for the low fixed ones allowed. The railway traffic has grown to such unforeseen dimensions that it was frankly recognised the running of trains at such frequent intervals could not be carried on with opening bridges. The canal company, therefore, frankly abandoned this position, and determined to solve the difficulty once for all by raising the railway lines, so that there would be a height of 75 ft. between the water surface and the bottom of the bridge, that being a limit fixed by the existing Runcorn Bridge, which carries the line of the London and North-Western Railway Company between Liverpool and London, *viâ* Crewe. Although this viaduct must not be classed as a part of the Manchester Ship Canal work, we give a view of it in Fig. 10, Plate I. The three main spans are each 300 ft. The embankment in course of construction in the middle distance is that which now forms the outer wall of the canal, cutting it off from the river. The canal here occupies one-half of the span.

The following are the bridges that have been constructed in order to allow masted vessels to pass. Old Quay swing bridge, a road bridge a short distance above Runcorn, which takes the traffic to the works on the north bank of the canal. Moore-lane swing bridge is next, and has been constructed to carry the not very important traffic of that thoroughfare. Deviation Railways Nos. 1 and 2 follow. They have been constructed to bring over the main line of the London and North-Western Railway from Crewe to Scotland, and the North-Western and Great Western Joint Railway from Chester. Then come two swing road bridges—namely, the Stag Inn opening bridge, and the Northwich-road opening bridge. A road bridge of a different character comes next, this being the Latchford high-level road bridge ; and shortly after the Knutsford-road swing bridge is passed. Another railway deviation, No. 3, which takes the London and North-Western Warrington and Stockport line, follows immediately, and after this there is some distance without a bridge. The convergence of traffic towards Warrington is well shown by the number of bridges in this section, there being no less than eight between Moore-lane and Latchford Locks, or within a distance of about 3½ miles. Proceeding up the canal, we come to the Warburton-road high-level bridge, and about two miles further Deviation Railway No. 4, for carrying the Glazebrook and Stockport Railway of the Cheshire Lines Committee, and Deviation Railway No. 5 for the Manchester and Liverpool Railway of the same committee. At a distance of nearly four miles further up we reach Barton-road swing bridge, and immediately after the most novel of all the bridges—namely, the swing aqueduct which carries the Bridgewater Canal over the ship canal. After this the only remaining permanent bridge is the swing bridge carrying the Trafford-road over that part of the canal between the Manchester and Salford Docks. However, a temporary swing bridge for railway traffic to and from the docks has been constructed, but will shortly be replaced by a permanent structure for railway communication with the Salford Docks. It will be seen there are seven swing road bridges, a swing aqueduct, two high-level road bridges, and four deviation railway bridges spanning the main canal.

The railway deviations, as stated, are five in number, and contain three distinct types of bridge construction. These may be classed as lattice-girder deck bridges, lattice-girder bridges loaded on the lower flanges, and hog-backed girder bridges. We have, in previous issues of Engineering, dealt so fully with this part of the work that we need not give any detailed description here. The illustrations we now publish serve to show the construction, and for the dimensions of the parts we must refer our readers to Engineering.[*]

Proceeding up after leaving Runcorn, we reach first Deviations 1 and 2, which may be taken together. Both No. 1 and No. 2 viaducts cross the River Mersey and the ship canal beside each other close to Warrington. The bridges over both the ship canal and over the Mersey in Viaduct No. 1 are of the hog-backed girder type, illustrated in our engraving (Fig. 11, Plate I), which shows the span of Railway Deviation No. 1 over the Mersey. Figs. 14 and 15, page 12, are an elevation and plan of the viaduct. The chief span is 160 ft., whilst the two masonry arches on each side are 25 ft. each in span. The gradient at the point where the bridge occurs is 1 in 135, and there is a curve of eight chains, which renders an additional width necessary. The abutment arches have piers 29 ft. by 6 ft., the abutments at the ends being respectively 38 ft. by 15 ft. 6 in. and 38 ft. by 10 ft. The thickness of the wing walls ranges from 10 ft. 3 in. to 3 ft. 6 in. Their construction is shown in Fig. 15, on page 12. The foundations are carried down to rock level, as shown in Fig. 14. In regard to this form of viaduct with masonry abutment arches, an unfortunate mishap has occurred on Deviation No. 5, which carries the Cheshire Lines Committee's railway over the ship canal at Irlam. Here the foundations in the canal bank have moved, the consequence being that the masonry side arches have cracked. This difficulty is to be got over by substituting girder bridges for the brickwork arches, thus reducing considerably the load on the foundations. This work was proceeding when we visited the spot last December, a short time before the opening of the canal. It is one of those unforeseen events, to which we have formerly made reference as so greatly adding to the estimated cost of great engineering works.

In the Mersey Bridge of No. 1 Deviation, Fig. 11, Plate I, there are two main girders in the superstructure ; they are spaced 29 ft. apart from centre to centre, each having a total length of 173 ft. The height of each main girder at centre is 21 ft., tapering to 14 ft. at each end, dimensions in each case being taken from back to back of angles of upper and lower booms respectively. The bracing of the main girders is in double system, and is composed of vertical struts and inclined ties with strong counterbracing at centre, as shown in Fig. 16, page 12. Referring to our other illustrations of this type of bridge, the various details on page 12 fully explain the method of construction ; which has, moreover, been fully described in Engineering, vol. lv, page 309. The flooring consists of curved iron plates rolled to the shape shown in Fig. 19, page 12, the ends being flanged to make connection with the plates carrying the troughs.

The erection of the viaduct over the River Mersey, Deviation Railway No. 1, was performed on timber staging with trussed beams, angles and wire ropes being employed to aid in the temporary structure (see Fig. 24, page 13). Two piers were driven, spaced 70 ft. apart, each consisting of a pair of timber supports 10 ft. square in plan, and composed of four vertical balks 12 in. by 12 in. driven into the river, and stoutly braced together by a double system of 10 in. by 5 in. diagonal timbers. The piers were spaced 29 ft. apart from centre to centre, so that each rested immediately beneath a main girder of the permanent structure. The tops of the piers were connected by transverse 12 in. by 12 in. balks, and diagonals 12 in. by 6 in. passing up from the vertical piles to the overhead transverse balks added to the stability of the temporary staging. A space of 35 ft. was left by the arrangement just described between each pier and the abutment on either side. This was spanned in each instance by a pair of 12 in. by 12 in. balks, one on either side beneath each main girder and 2 ft. below it. These beams were trussed with double 3 in. by 3 in. by ⅜ in. angles, and short legs of vertical 12 in. by 12 in. balks with angles of similar scantlings. The depth of this arrangement of trussing was 5 ft. A similar method was adopted of spanning the 70-ft. opening between the piers of the temporary staging, viz., four beams averaging some 14 in. square in section, and trussed in like manner with three lengths of 3 in. by 3 in. by ⅜ in. angles and verticals as before described. Raking timbers

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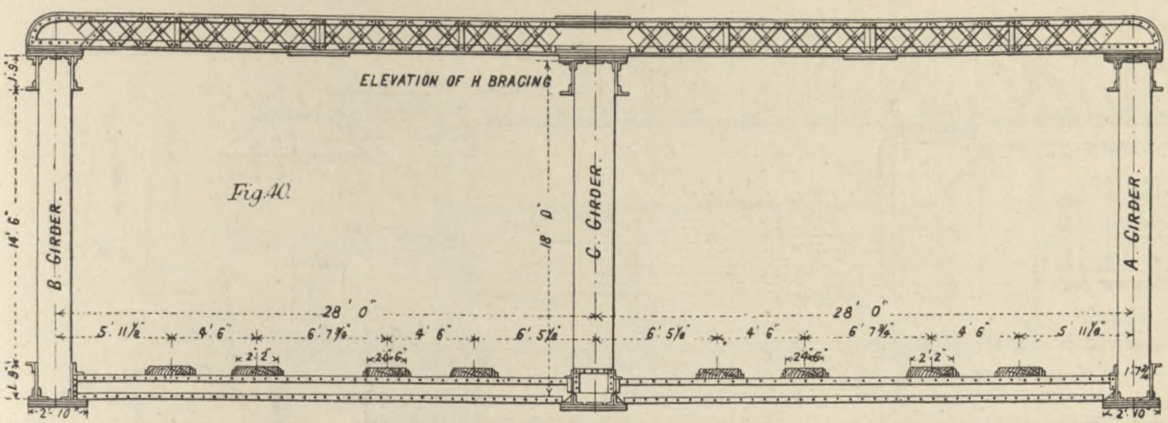
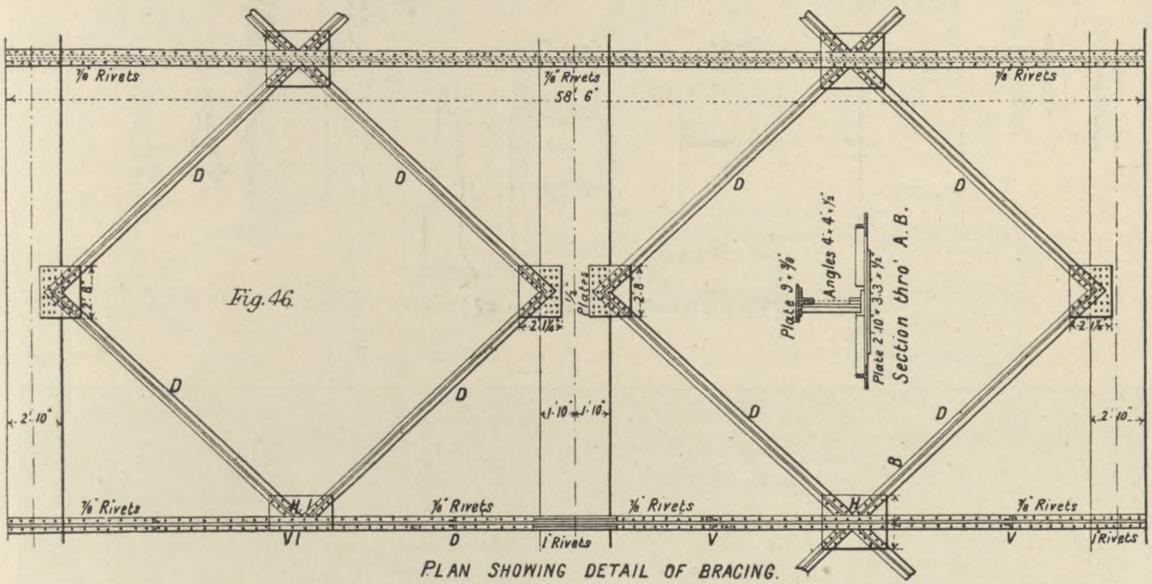
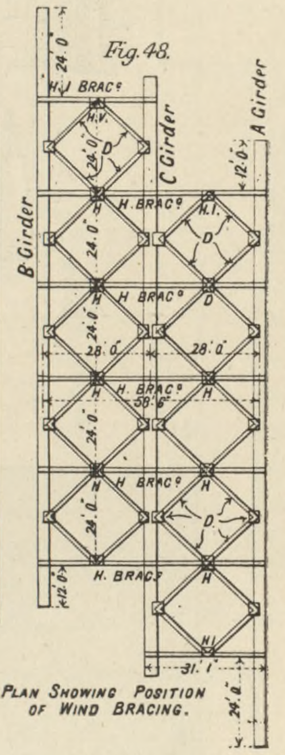
[*] See Engineering, vol. lv, pages 125, 181, 280, 309, and 340.

DETAILS OF RAILWAY BRIDGE; DEVIATION No. 4. (*See Page* 22.)





PLAN SHOWING DETAIL OF BRACING.



PLAN SHOWING POSITION OF WIND BRACING.

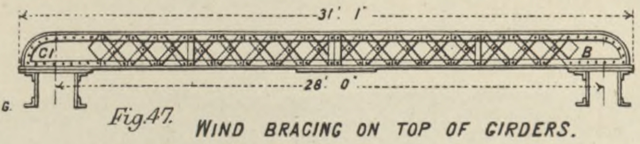


Fig. 47. WIND BRACING ON TOP OF GIRDERS.

from the piers were employed to strengthen these beams. The remainder of the staging was formed by laying 12 ft. lengths of 3-in. planking on the pair of 12 in. by 12 in. balks beneath each main girder. These in their turn carried the blocks and wedges upon which were erected the lower booms of the main girders. The erection of the permanent structure was carried out by erecting at each end the whole girder for about 45 ft. from the abutments, viz., as far as the temporary timber piers. The bottom boom was then completed by erection on the trussed beams already described as spanning the 70-ft. opening between the temporary piers. This completed, the remaining bracing and upper booms were built out by overhang from each side until junction was established at centre, and the structure completely erected. A derrick crane was used for the erection. The height of the lower side of the main girder above ordinary water-level is 44 ft.

We illustrate another bridge of the hog-backed girder type in Fig. 23, on page 12. This is the bridge which spans the ship canal, carrying Deviation No. 2. Fig. 25, page 13, shows yet another railway viaduct, being that which carries Deviation No. 3 over the ship canal, the main span being also of the same type. The photographs from which our engravings have been prepared were, it will be seen, taken before the excavation of the canal was completed.

We will now pass to Railway Deviations Nos. 4 and 5, which are alike in design, although they differ in proportions. Deviation No. 4 is close to the Partington coaling basin, whilst Deviation No. 5 is close to the Irlam Locks; and it was from this viaduct that the view of Irlam Locks (Fig. 5, page 5) was taken. About half-way between these two railways is the confluence of the Irwell and the Mersey. Taking the latter deviation as our example, we find a three-span viaduct, as shown in Fig. 26, page 16, carrying the Cheshire Lines Committee's Liverpool, Warrington, and Manchester Railway across the old channel of the River Irwell, it being understood that the river will be here entirely obliterated, its old bed being filled in, and its waters flowing through the ship canal.

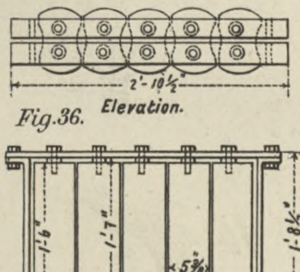


Fig. 36.

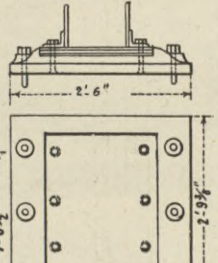


Fig. 38.

The spans are square, that at the centre being 120 ft., and each of those at the sides 89 ft. The girders are continuous. The river bed will be eventually filled up. The batters of the piers are 1 in 18 and 1 in 36, each pier being 28 ft. 6 in. by 6 ft. at the top and 39 ft. 6 in. by 16 ft. at foundation level, and having two recesses each 8 ft. 6 in. in width in each face. Memel piles 12 in. square carry the whole of the foundations, and the bank on each side is finished with slopes of 1½ to 1. The abutments at each end of the viaduct are 6 ft. and 17 ft. in width at top and bottom respectively, and have a breadth throughout of 52 ft.

The superstructure consists of four main girders, which are spaced 3 ft. 3$\frac{9}{16}$ in. and 12 ft. 6 in. respectively from the centre line of the bridge, and have a total depth of 11 ft. 6 in. from back to back of flange angles throughout. Further details of this type of bridge are given in Figs. 27 to 39, page 16. These illustrations largely explain themselves, but a full description will be found in ENGINEERING, vol. lv, page 125.

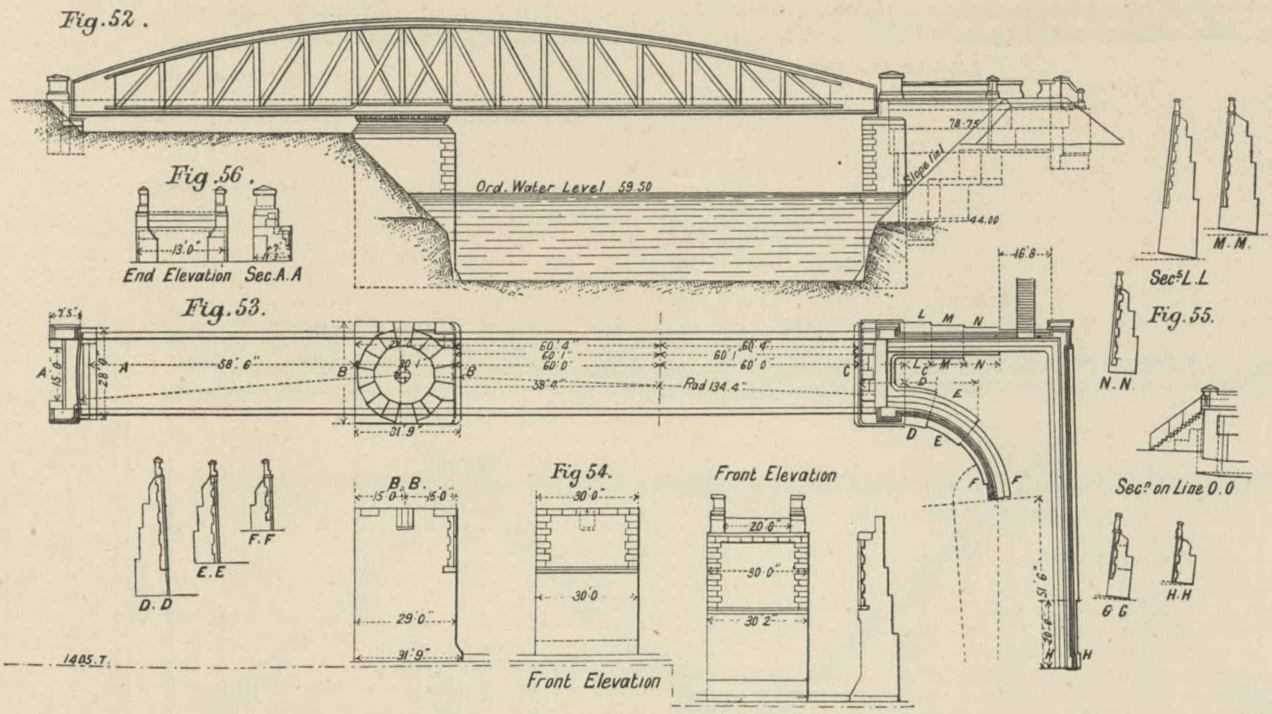
The remaining viaduct in the group of railway deck bridges, viz., that over the River Mersey on Deviation Railway No. 4, carries the Cheshire Lines Committee's Glazebrook and Stockport Railway over the River Mersey, not far from Partington, and consists, like the viaduct just dealt with, of three continuous square spans, one of 150 ft., and the two side ones of 103 ft. each.

The piers, which have batters of 1 in 10, and are 28 ft. 6 in. by 6 ft. at the top and 39 ft. 6 in. by 17 ft. at foundation level, are carried on two rows of 3-in. elm battens, one row laid down longitudinally, the other transversely, resting on 12 in. by 12 in. Memel pine piles. The bank on either side is finished off with a slope of 1½ to 1. The bridge carries a double line of rails, the gradient being 1 in 135. The main girders are four in number, and are spaced 3 ft. 1¾ in. and 11 ft. 6 in. on either side of the centre line respectively. The main bracing of the main girders is in six systems, inclined at an angle of 45 deg., with which exception and some slight modifications arising therefrom, the whole arrangement of details and design is identical with that of the Irwell Viaduct on Deviation Railway No. 5.

In the case of both viaducts forming the subject of this article, mild Siemens-Martin steel is used throughout the entire superstructures, with the exception of the floor-plates, which are of iron.

The method of erection at site of these bridges may be briefly noted. In each case the side spans

RAILWAY SWING BRIDGES OVER THE MANCHESTER SHIP CANAL.



OLD QUAY SWING BRIDGE. (See *Page* 22.)

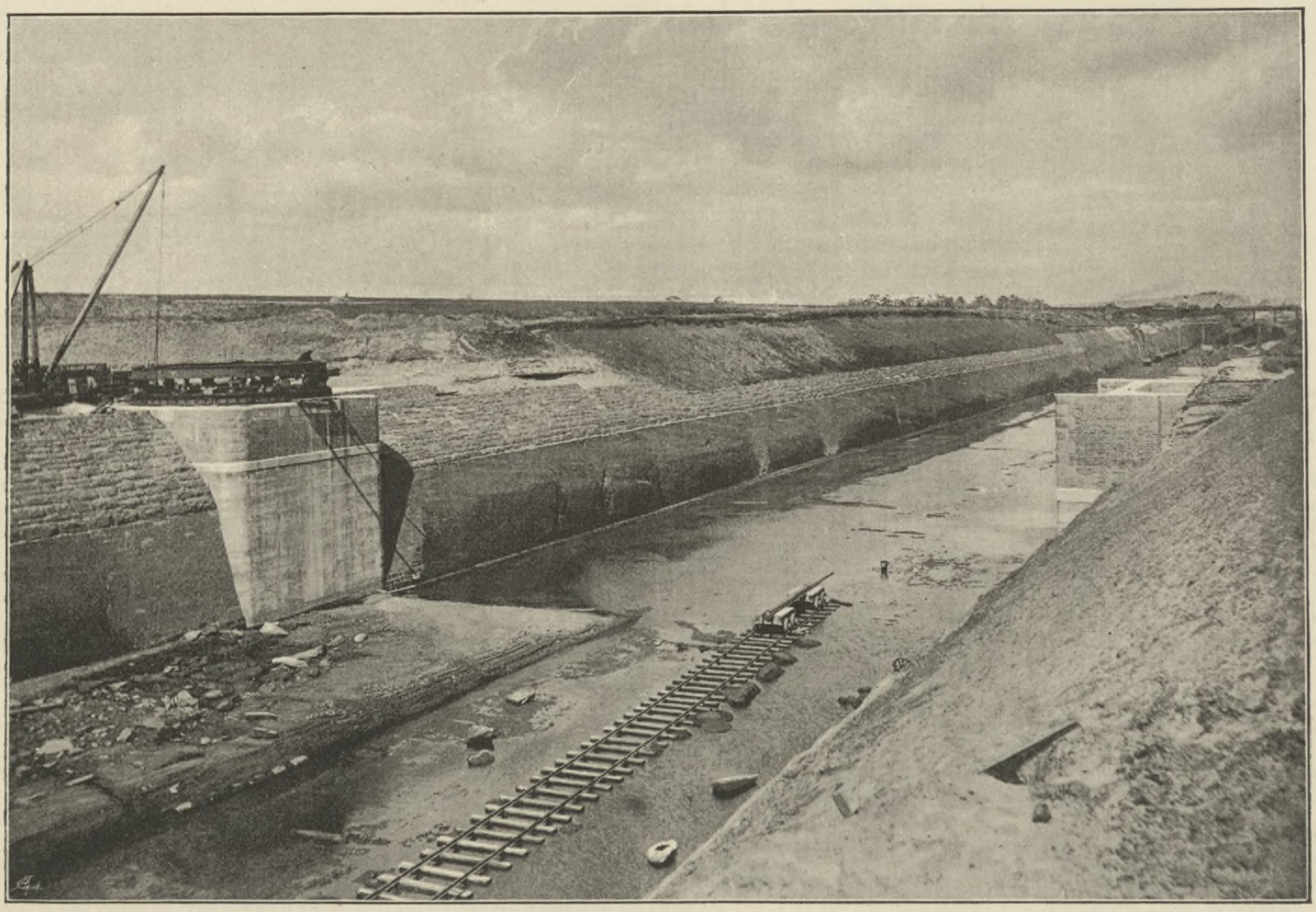


FIG. 57. MOORE-LANE SWING BRIDGE. (*See Page* 22.)

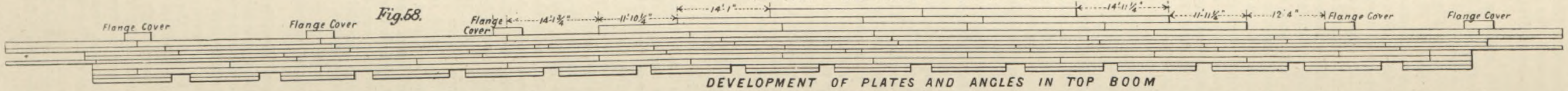
were first erected by timber staging beneath them, running, however, only about two-thirds the length of the span, the remaining portion being placed in position by overhang until the piers were reached. The main centre spans were then erected as cantilevers from either side, until junction at centre was formed. Light cranes secured to the cantilevers were employed for handling the material, and greatly expedited the work of erection. The girders being continuous in both viaducts under consideration, materially assisted this mode of erection. No difficulty was experienced in putting in the closing length at the centre, the girders being sufficiently light to admit of any slight adjustment of position necessary to secure an exact junction. The timber staging necessitated by this mode of erection consisted in the case of the Irwell Viaduct of a main column, of eight vertical 9 in. by 9 in. balks, braced with 9 in. by 3 in. timbers, the centre being placed 29 ft. from that of the pier; 19 ft. nearer the abutment a single row of 9 in. by 9 in. vertical balks afforded further support to the platforms, which consisted of 9 in. by 9 in. balks, carrying a pair of longitudinal 12 in. by 2 in. balks running the entire length of the staging, and spaced so as to come immediately beneath each main girder.

A double row of 12 in. by 12 in. balks, 10 ft. long in the case of the central girders, and 3 ft. 6 in. long for each of the outside girders, afforded a bearing to the girders during erection. The temporary timber staging for erection of the Mersey Viaduct was of similar type.

DETAILS OF MOORE-LANE SWING BRIDGE OVER THE MANCHESTER SHIP CANAL. (*See Page* 22.)

OUTSIDE ELEVATION OF A GIRDER.

Fig. 58.



DEVELOPMENT OF PLATES AND ANGLES IN TOP BOOM

Fig. 59.

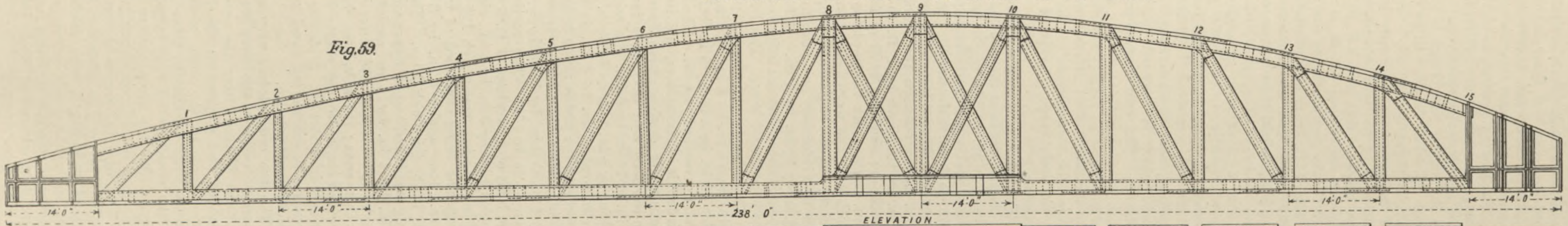


Fig. 60. DEVELOPMENT OF PLATES AND ANGLES IN BOTTOM BOOM.

Fig. 62. SECTION THROUGH BRIDGE SHEWING CROSS GIRDER.

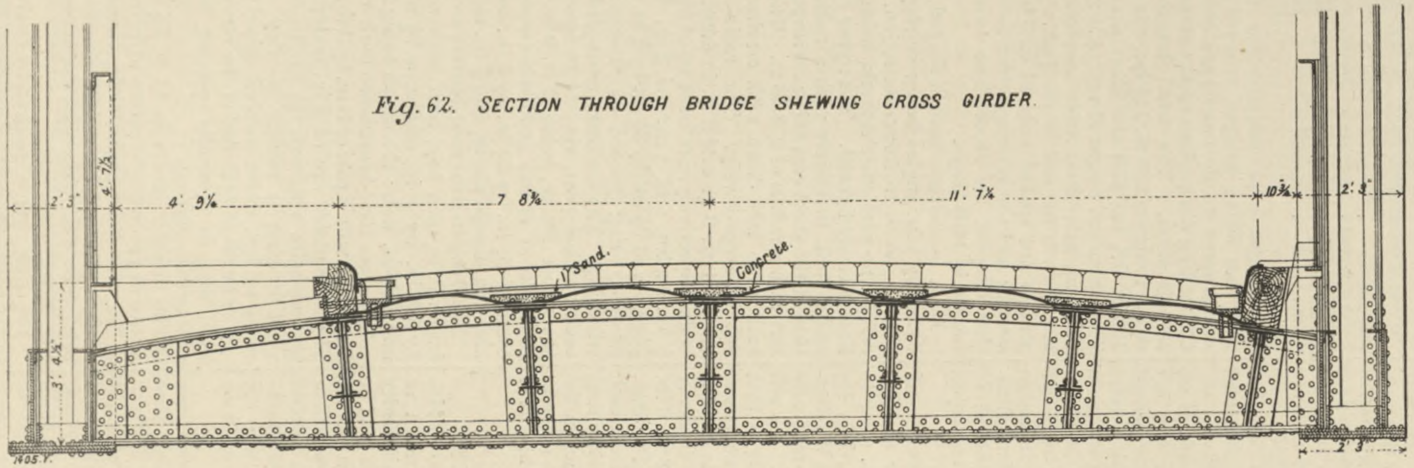


Fig. 63. LONGITUDL. SECTION ON CENTRE OF BRIDGE.

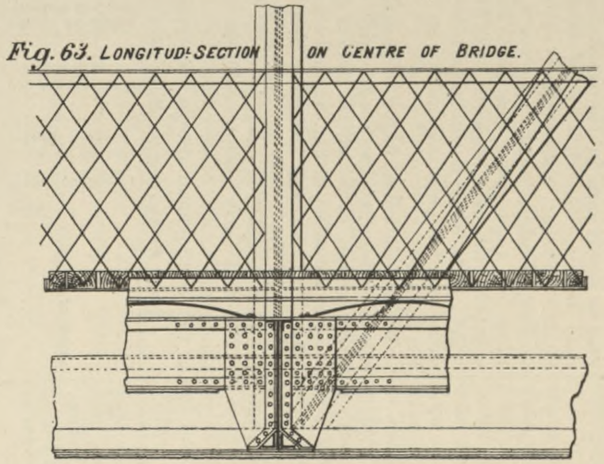
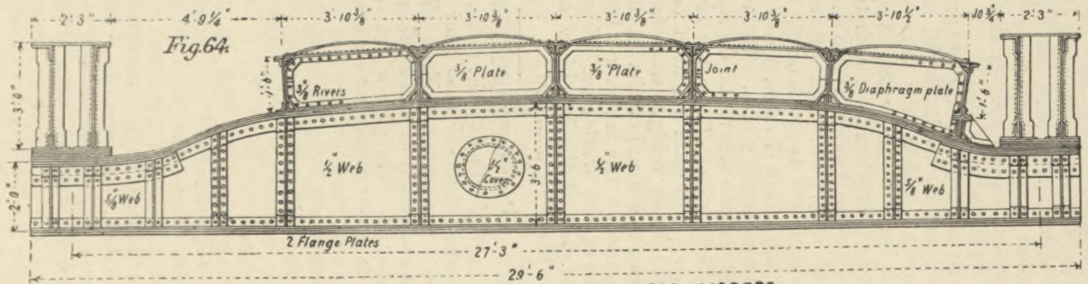


Fig. 64.



ELEVATION OF CENTRE CROSS GIRDERS

Fig. 65. CURB ON ROAD END OF SHORT ARM.

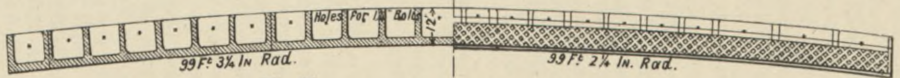


Fig. 66.

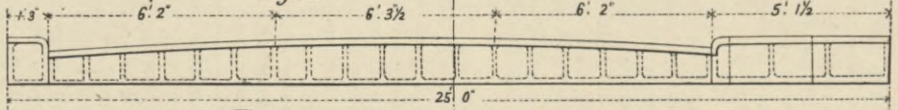
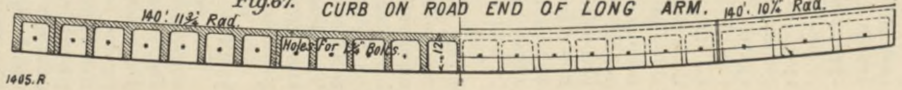


Fig. 67. CURB ON ROAD END OF LONG ARM.



The bridges which carry Railway Deviations 4 and 5 over the ship canal itself—those just described being above the ancient waterways of the Irwell and Mersey—are both of the lattice-girder type, loaded on the lower booms.

No. 4 Deviation bridge is a skew one of single span, with superstructure consisting of three main girders, each having a total length of 156 ft., and spaced 28 ft. from centre to centre of each other (see Fig. 40, page 19). A pair of arches, each 45 ft. span, connect the main superstructure with the bank on either side. The approaches on both sides have gradients of 1 in 135. Four pairs of rails are carried by the bridge. The main girders are 18 ft. in depth (from back to back of angles) throughout, and have trough-shaped upper and lower booms with main bracing in six systems (see Fig. 41, page 17). Other details are shown in Figs. 42, 43, 44, 45, 46, 47, 48, 49, and 50, pages 17 and 19.

The erection of the viaduct over the ship canal, Deviation Railway No. 4, was performed by means of timber staging supporting the entire structure during building. Travelling cranes were arranged to traverse the entire length of the bridge on light rails between each pair of girders, and facilitated both erection and hydraulic riveting. The flooring was of necessity riveted up by hand; the remainder of the superstructure was, as far as possible, dealt with by hydraulic riveters.

The approximate total weight of the structure just described may be stated at from 550 to 600 tons.

The remaining viaduct in the group now under construction, viz., lattice girder bridges loaded on the lower booms, is that over the ship canal on Deviation Railway No. 5. Four pairs of rails are carried over the canal by the structure, which is on the skew, and has a single span. The rails approach and leave the bridge with the standard gradient given, viz., 1 in 135. The headway beneath the bridge is in conformity with that given throughout, viz., 75 feet. The main girders are three in number, 18 ft. in depth, and are spaced 28 ft. from centre to centre, each having a total length of 168 ft. 4 in. The overlap of each main girder beyond its immediate neighbour is 23 ft. With this exception, and that of slightly increased span, this viaduct in no way differs either in design or details from that already described and illustrated as typical of the group. The method of erection and temporary timber staging employed were likewise identical.

As already stated, there are two high-level road bridges, one at Latchford and the other at Warburton; both having the necessary 75 ft. clear to the level of the water. Our illustration, Fig. 13, Plate I, is taken from a photograph of the Warburton bridge, but as the two structures are practically alike, one description will serve for both. As will be seen, the design is on the same principle as that of the Forth Bridge, there being two cantilevers, with a central girder. The central span is 206 ft., and the two side spans 58 ft. each. The roadway is 18 ft. wide. There are two footpaths 3 ft. 6 in. wide. The total weight of each bridge is 780 tons. Both these bridges were built outward from each shore to the end of the cantilevers, and the central portion of the bridge was lifted from barges in the case of the Warburton bridge, and from a stage in the case of the Latchford structure, the height of the lift being about 75 ft.

VII.—THE OPENING BRIDGES.

In proceeding up the canal, the first road bridge passed under is that near Runcorn, known as Old Quay swing bridge. There is a similarity between many of these bridges, so that it will be unnecessary to give a general description of all, as it would necessitate a great deal of repetition. We will, therefore, content ourselves with typical descriptions, supplementing them by general dimensions of the principal structures. The Table in the next column gives the chief dimensions of these bridges.

Our engraving, Fig. 12, Plate I, shows one of the important road bridges, namely, that which carries the public thoroughfare at Barton, and serves the important centres of Patricroft and Barton on the north side of the canal, and Stretford, Urmston, &c., on the south. These places may almost be said to be suburbs of Manchester. Barton swing bridge is notable also as being situated close to the swing aqueduct, which carries the Bridgewater Canal over the ship canal. As will be seen by our illustration, Barton bridge pivots on an island which has been formed in the centre of the canal, and it is on this island also that the aqueduct pivots. The latter structure may be partly seen in the illustration beyond the road bridge, the view being taken looking up stream towards Manchester. Part of the old masonry bridge, which was not quite removed when the photograph was taken from which our engraving has been prepared, may be seen on the right; from which it will be gathered that the ship canal here has been constructed on the old bed of the Irwell.

We will, however, follow our usual plan of working up-stream, and will begin with the Old Quay swing bridge, of which we give a general outline view in elevation in Fig. 52, and a plan in Fig. 53, page 20. As will be seen, this bridge differs essentially from that at Barton, in the fact that the pier on which it pivots is on the bank.

The Old Quay swing bridge is the smallest of this type. As in every particular of construction, as well as in general design, Old Quay swing bridge follows the type adopted for Moore-lane and Stag Inn swing bridges, referred to later, we do not propose to do more than succinctly glance at the leading dimensions of the structure now under consideration. The total length of Old Quay swing bridge is 235 ft. 11⅛ in., the long arm being 139 ft. 0$\frac{9}{16}$ in., and the short arm 96 ft. 10$\frac{9}{16}$ in. The maximum height at centre is 28 ft.; whilst at the long and short ends respectively the girders are 7 ft. 9 in. and 9 ft. high. The two main girders are spaced only 22 ft. 3 in. from centre to centre; and the bracing, which follows in character that adopted for Moore-lane swing bridge, is arranged in 14-ft. bays.

Swing Bridges over the Manchester Ship Canal.

Name of Bridge.	Span.	Width of Road.	Length of Long Arm.		Length of Short Arm.		Depth of Main Girders at Centre over Angles		Number of Rollers.	Diameter of Roller Circle.		Weight.
	ft.	ft.	ft	in.	ft.	in.	ft.	in.	ft.	ft.	in	
Old Quay, Runcorn	120	20	139	$\frac{9}{16}$	96	10$\frac{9}{16}$	28	0	60	22	11	650
Moore-lane .	120	25	140	0	98	0	27	8½	64	27	10½	790
Stag Inn	120	25	140	0	98	0	27	8	64	27	10½	790
Northwich-road ..	120	36	148	0	100	0	30	0	60	38	9	1350
Knutsford-road ..	120	36	148	0	100	0	30	0	60	38	9	1350
Barton Bridge ..	90	25	111	0	81	0	26	0	64	27	10½	640
Trafford-road ..	75	46	127	0	78	0	30	0	64	49	6	1800

Both booms are trough-shaped, stout 6½ in. by 3½ in. by ½ in. angles being employed in each outside the webs to form connection. The end posts call for no particular remark, being built upon the lines already figured. The upper boom of the long arm is built to a curve with a radius of 490.87 ft., that of the short arm being correspondingly curved, but with a radius of 258.08 ft. The long and short ends were laid down with cambers of 1½ in. and 1$\frac{5}{16}$ in. respectively. The main cross-girders at centre, 2 ft. 8 in. and 2 ft. in depth at middle and ends respectively, are built up of 6½ in. by 3½ in. by ½ in. angles, and ½ in. and ⅜ in. webs; strut diaphragms of 3½ in. by 3½ in. by ½ in. angles and ½ in. gussets being spaced at frequent intervals for stiffening. The ordinary cross-girder occurring at each vertical post, viz., 14 ft. apart, is curved on the upper flange, being 2 ft. 9 in. and 2 ft. 4½ in. in depth at centre and ends respectively, and are built of 3½ in. by 3½ in. by ½ in. angles, with ⅜ in. and ⅝ in. flange plates, and ⅜ in. and $\frac{7}{16}$ in. webs.

Five longitudinal road-bearers are spaced at equal intervals in each bay, each built up of four 3½ in. by 3½ in. by ½ in. angles, a 7½ in. by ⅜ in. flat, and a $\frac{5}{16}$-in. web; the depth being 1 ft. 3 in.

The cross road-bearers are built of 8 in. by ⅜ in. bulb flats, with a pair of 3 in. by 3 in. by ⅜ in. angles. The floor-plates are of ⅜ in. material, and support the asphalte roadway, 1½ in. in thickness. The wind bracing is similar to that of Moore-lane swing bridge, which we shall describe later.

The kerbs at each end of the structure are of cast iron, and in a similar manner follow the type adopted throughout.

The annular girder is 11 ft. 5½ in. radius from centre of two webs to centre of pivot, with a depth of 16 in. Four radial arms connect it with the central pivot. The rollers are sixty in number, being 2 ft. 4 in. long, with diameters 1 ft. 3 in. and 1 ft. 0¼ in.

The live ring is secured by twelve radial beams to the casting at centre bearing on the central pivot. The roller-paths are each in eight segments, being, like the rollers, of cast iron.

In principle of design the type adopted for the Moore-lane bridge, described below, has been followed on a smaller scale in dealing with the annular girder of the Old Quay bridge and the working parts in connection therewith, rendering it unnecessary to further describe such.

The leading dimensions of the Moor-lane swing bridge are 140 ft. and 98 ft. for span of the long and short arms respectively. A perspective view of the site of this bridge is given in Fig. 57, on page 20, while details will be found in Figs. 58 to 80, on pages 21 and 24. The maximum height of the girders at the centre is 27 ft. 8 in., and at the ends of the long and short arms respectively the height is 6 ft. and 8 ft. 9½ in. The two main girders are spaced 27 ft. 3 in. from centre to centre, the roadway being carried by cross-girders, spaced 14 ft. apart, and connecting the main girders. The cross-girders are connected with each other by six longitudinal road-bearers carrying the flooring and roadway. The main girders are carried at the centre by four stout cross-girders resting on the annular girder, to the lower portion of which is bolted the upper roller-path bearing on the rollers, which are connected together by the live ring framing, and in turn bear on the lower roller path, which is fastened down to the masonry beneath. The centre pivot casting, around which both annular girder and live ring rotate, is similarly secured to a steel box foundation built into the masonry. Our illustration, Fig. 57, page 20, shows the construction of the Moore-lane bridge in an early stage, the pivot being in course of erection.

The booms of the main girders are trough-shaped in section, those at the top being built up of four 6 in. by 6 in. by ⅝ in. angles, connecting the flange-plates and webs, and flange-plates ranging from ½ in. to $\frac{9}{16}$ in. in thickness. The lower edges of the webs are stiffened internally by 3¼ in. by 3¼ in. by ½ in. angles between the bracing. The webs are ½ in. in thickness by 2 ft. in depth. The lower booms are similarly built of four 6 in. by 6 in. by ⅝ in. angles, with flange-plates ½ in. and $\frac{9}{16}$ in. in thickness, the webs being ½ in. metal and 2 ft. in depth, and the angles stiffening the upper edge of the web internally being of similar scantlings, viz., 3¼ in. by 3¼ in. by ½ in. A feature in the lower boom is the additional height of the web—3 ft.—in the two central bays. The boom is strengthened in these bays by horizontal plates 8 ft. 9 in. by 1 in., and 6 in. by 6 in. by ⅝ in. angles, stout channels 12 in. by 4 in. by ½ in. being attached to the web for vertical support. The bracing of the main girders is in one system, and in 14-ft. bays, and is built up of double plates, four angles and a web. In the long arm the plates range from 10 in. by ⅝ in. to 16 in. by ⅝ in., the angles from 3¼ in. by 3¼ in. by ⅜ in. to 5 in. by 3 in. by ½ in., and the webs from $\frac{5}{16}$ in. to ⅜ in. in thickness. In the short arm the plates range from 14½ in. by ½ in. to 16 in. by ⅝ in., the angles from 3¼ in. by 3¼ in. by ⅜ in. to 5 in. by 3 in. by ½ in., and the webs from $\frac{5}{16}$ in to ⅜ in. The vertical posts at centre are built of two plates 1 ft. 6 in. by ⅝ in., four angles 5 in. by 3 in. by ½ in., eight angles 3¼ in. by 3¼ in. by ½ in., and a web 12¾ in. by ½ in.; the diagonals being composed of two plates 16 in. by ⅝ in., four angles 5 in. by 3 in. by ½ in., and 12¾ in. by ⅜ in. webplates. The end post of the long arm is built up of upper and lower framing of 4 in. by 4 in. by ½ in. angles, joggled over the angles of the upper and lower booms respectively at their ends; the webplates, both parallel to and at right angles to the centre line of the bridge, being ⅜-in. material. A similar type of end-post, arranged to suit the increased height, occurs at the end of the short arm.

The top cross-girders vary considerably in appearance, owing to the curve of the upper members. In those furthest from the centre of the bridge a rounded end is given at the attachment to the upper boom of the main girder to gain the requisite height, whilst in those toward the middle of the structure no such arrangement is necessary. The top cross girders accordingly range from a girder 2 ft. in depth, with a pair of 4 in. by 4 in. by ½ in. angles at top and bottom, and double 3 in. by ½ in. flats for bracing, to a girder 5 ft. 4¼ in. in depth, with double 4 in. by 4 in. by ½ in. angles at top and bottom, and four systems of bracing at an angle of 45 deg., composed of 3 in. by ½ in. flats secured at their junctions with each other by ⅞-in. rivets.

Passing on now to some consideration of the flooring, the ordinary cross-girders are spaced 14 ft. from centre to centre, and have the upper flange curved, as shown in Fig. 62, page 21; the depth at centre being 2 ft. 9 in., and at the ends 1 ft. 11 in. Both flanges are made up of two 4 in. by 4 in. by $\frac{9}{16}$ in. angles, the upper one having additionally a $\frac{3}{8}$-in. and a $\frac{1}{2}$-in. plate, and the lower one having two plates $\frac{1}{2}$ in. and $\frac{9}{16}$ in. thick respectively. Both flanges are 15 in. wide. The web is $\frac{3}{8}$ in. throughout. The cross-girders rest directly on the bottom flanges of the main girders, and are riveted up both to the flanges and web of the same. The longitudinal road-bearers are six in number between each cross-girder, and are built up of two 3 in. by 3 in. by $\frac{7}{16}$ in. angles, and a 7 in. by $\frac{7}{16}$ in. plate for each beam. The depth from back to back of angle is 1 ft. 6 in., and the web throughout is $\frac{5}{16}$ in. A $\frac{3}{8}$-in. gusset-plate and pair of 5 in. by 3 in. by $\frac{3}{8}$ in. angles form connections with the cross-girder at either end, the upper ends of the angles being joggled to pass over the upper angles—4 in. by 4 in. by $\frac{9}{16}$ in.—of the cross-girders, and the lower ends being bent so as to connect, not only with the web, but also with the bottom flanges of the same. The cross-road-bearers connect the longitudinal road-bearers, dividing the space between two adjacent cross-girders into three divisions, which are covered by as many buckle plates.

The cross road-bearers are built up of an 8 in. by $\frac{7}{16}$ in. bulb plate, the bulb of which forms the lower flange; whilst two 3 in. by 3 in. by $\frac{3}{8}$ in. angles, attached to the flat end of the bulb-plate, form the upper flange; and, being carried round, pass down the webs of the longitudinal road-bearers, thus forming secure connections thereto. The two extreme ends of the bulb are reduced to the same thickness as the remainder of the bulb-plate, viz., $\frac{7}{16}$ in., to permit the 3 in. by 3 in. by $\frac{3}{8}$ in. angles to pass without joggling, the arrangement thus forming an exceedingly neat and stiff cross road-bearer. Three-quarter inch rivets having a 4-in. pitch are employed throughout the cross road-bearers.

The buckle-plates are of iron, 4 ft. $5\frac{1}{4}$ in. by 3 ft. $9\frac{1}{4}$ in. by $\frac{3}{4}$ in. thick, and having a rise of $2\frac{3}{4}$ in., and secured by $\frac{3}{4}$-in. rivets with a 3-in. pitch. The hollow between the floor-plates is filled with concrete, above which 1 in. of sand and $\frac{3}{4}$ in. of asphalte are spread; 5-in. wood sets being laid on the top for the roadway.

A stout pitch-pine kerb, 16 in. by 10 in., with a guard-plate nosing $\frac{5}{16}$ in. in thickness, is placed at each end of the roadway; inside the kerbs 9 in. by 6 in. cast-iron gulleys are introduced for drainage. The pathway is built of 7 in. by 4 in. battens, with $\frac{3}{4}$-in. spaces, spanning from the kerb to a 3 in. by 3 in. by $\frac{3}{8}$ in. angle fastened to the vertical posts of the bracing. Beneath the pathway an arrangement of heavy 6 in. by 6 in. by $\frac{5}{8}$ in. angles binds together the main girders, cross-girders, and longitudinal road-bearers. The cross-girders at centre, carrying the main girders, and resting themselves on the annular girders, are built with a curved upper and straight lower flange, being 3 ft. 6 in. and 2 ft. in depth at centre and ends respectively. The girders are of 4 in. by 4 in. by $\frac{5}{8}$ in. angles, with $\frac{1}{2}$ in. and $\frac{3}{8}$ in. flange plates, and $\frac{1}{2}$ in. and $\frac{5}{8}$ in. webs, stiffened by 6 in. by 3 in. by $\frac{1}{2}$ in. tees spaced closely together, with ends joggled over upper and lower flange angles. Internally the girders are stiffened by tees of similar dimensions and $\frac{3}{8}$-in. diaphragm plates, in which 15 in. by 13 in. manholes are provided.

The annular girder has an outside radius of 15 ft. 5 in., and is built of two concentric $\frac{5}{8}$ in. webs, each 1 ft. 10 in. in depth (Figs. 70 to 76, page 24). At both edges of each web a pair of 6 in. by 4 in. by $\frac{9}{16}$ in. angles form the upper and lower booms respectively, whilst below a $\frac{5}{8}$ in. plate 2 ft. $11\frac{1}{2}$ in. in width connects the two concentric webs, and runs around the entire annular girder; whilst above a plate only 12 in. in width, of similar thickness, is attached to each circle, and completes the upper boom. Diaphragms of 3 in. by 3 in. by $\frac{3}{8}$ in. angles and $\frac{3}{8}$ in. plating are introduced at frequent intervals to stiffen the girder. Four radial beams connect the annular girder with the central pivot. The beams are 1 ft. $8\frac{1}{2}$ in. depth by 1 ft. 6 in. over the flanges, and are box-shaped, each web being of $\frac{3}{8}$ in. material, and the upper and lower flanges of similar thickness, all being held together by four 3 in. by 3 in. by $\frac{3}{8}$ in. angles placed outside.

The junction of the arms is formed by top and bottom plates $\frac{3}{8}$ in. and $\frac{5}{8}$ in. respectively, and 3 in. by 3 in. by $\frac{3}{8}$ in. angles forming vertical connection. The ends of the radial beams are secured to the annular girder by riveting, as shown; 3 in. by 3 in. by $\frac{3}{8}$ in. angles, placed inside the beam webs, being employed for attachment. The annular girder centre is secured by $1\frac{1}{4}$ in. bolts to the casting carried by the centre pivot.

The upper roller-path, which is similarly secured to the annular girders by $1\frac{1}{4}$ in. bolts on both sides, is $4\frac{1}{4}$ in. in depth on the outside and $5\frac{1}{2}$ in. in depth on the inside; nine segments are comprised in the circle, connected together with $1\frac{1}{2}$-in. turned bolts. The maximum width of the path is 2 ft. $11\frac{1}{2}$ in. Both upper and lower surfaces and joints are carefully planed.

The rollers are sixty-four in number, each being 2 ft. $5\frac{1}{2}$ in. long, with bosses at either end giving an additional length of 3 in. each; they are conical in shape, with diameters 1 ft. $4\frac{1}{4}$ in. and 1 ft. $1\frac{3}{4}$ in. A central web inside strengthens the casting. A 2-in. bolt passing through the roller connects it with the live ring on both sides, gun-metal washers $1\frac{1}{2}$ in. thick being placed between the boss of the roller and the web of the live ring. The bearing surfaces of the rollers are $2\frac{1}{2}$ in. metal, all being turned (see Fig. 77, page 24).

Passing now to the live ring (see Figs. 68 and 69, page 24), the outer web consists of a web 12 in. by $\frac{1}{2}$ in., stiffened by two external 3 in. by 3 in. by $\frac{1}{2}$ in. angles at top and bottom respectively. Stout forgings and $1\frac{1}{4}$-in. turned bolts form the junctions of these segments. The inner web is similarly constructed of $\frac{1}{2}$-in. material top and bottom, $\frac{5}{16}$-in. plates being connected to it by 3 in. by 3 in. by $\frac{1}{2}$ in. angles; $2\frac{1}{2}$ in. by $2\frac{1}{2}$ in. by $\frac{3}{8}$ in. angles stiffening the inner edges of the $\frac{5}{16}$-in. plates. The webs are connected together at every fourth roller by a $\frac{1}{2}$-in. plate 12 in. deep, secured by two pairs of 4 in. by 4 in. by $\frac{1}{2}$ in. angles to the webs. Sixteen radial arms of 6 in. by 4 in. by $\frac{1}{2}$ in. angles connect the outer framing of the live ring with the centre casting resting on the central pivot. A $\frac{5}{8}$-in. plate, octagonal in shape, 5 ft. 2 in. by 5 ft. 2 in., is secured to the top and bottom of the casting, revolving on the central pivot, and forms connection for the radial arms.

The lower roller-path is of cast iron, like the upper roller-path and rollers themselves, and is divided into nine segments. The thickness of metal is $5\frac{1}{2}$ in. and $4\frac{1}{4}$ in. at the inside and outside respectively (see Fig. 77, page 24).

The kerbs (Figs. 65 to 67, page 21) are of cast iron, that for the long span being in three portions. The maximum depth is 8 in., 2 in. by $1\frac{1}{2}$ in. metal being employed in the upper and lower flange respectively. The upper flange is chequered. The corresponding kerb on the abutment is similar in design, but of increased depth, and is strongly built with $1\frac{1}{2}$ in. webs, being held down by $1\frac{1}{4}$ in. Lewis bolts. This kerb is divided into four segments fastened together with 1-in. bolts, and is chequered on the upper flange similarly to the kerb opposite it on the long arm. The kerbs at the end of the short span are of similar material and of identical design, modified in detail to suit the reduced radius of the lesser arm. The construction of this bridge and the roller path is clearly shown by Figs. 61 to 76, page 24.

Stockton Heath swing bridge and Latchford swing bridge are two large swing bridges, similar to each other in every detail, being constructed from the same drawings. Stockton Heath swing bridge carries the main road, leaving Warrington in a southerly direction, over the canal to the west of Latchford; whilst Latchford swing bridge similarly carries the main road between Warrington and Latchford over the canal at a point not far from Latchford itself. As both bridges, with one or two exceptions, with which we shall proceed to deal, follow, on precisely similar lines, the type already illustrated and described for Moore-lane swing bridge, we merely purpose dealing with the leading dimensions of these structures. The long arm of each is 148 ft. in length, and the short arm 100 ft. in length. The radii of upper booms of long and short arms respectively are 535.60 ft. and 304.82 ft., the cambers given to these arms being $1\frac{3}{4}$ in. and $1\frac{7}{16}$ in. The maximum height of the structure is 30 ft.; the heights of extremities of long and short arms being 9 ft. and 13 ft. respectively. The bridge is divided into 17 ft. bays, the main girders being spaced 38 ft. 9 in. from centre to centre. Both booms of main girders are trough-shaped and 2 ft. 4 in. in depth, with four 7 in. by 4 in. by $\frac{5}{8}$ in. angles, two 4 in. by 3 in. by $\frac{1}{2}$ in. angles, $\frac{5}{8}$ in. and $\frac{9}{16}$ in. web-plates, and flange-plates 2 ft. 9 in. in width, of $\frac{1}{2}$ in., $\frac{9}{16}$ in., and $\frac{5}{8}$ in. metal. The lower booms are of uniform height throughout, whilst the cross-girders are curved both on upper and lower flanges. The roadway is 24 ft. wide, and a footpath 6 ft. in width is placed on either side of it.

A point of interest and departure from the types already described is the cast-iron annular girder adopted in these heavy structures. The annular girder is built up of eighteen cast-iron segments. The upper and lower flanges are 3 ft. 3 in. and 2 ft. 10 in. in width respectively, the upper flange and webs being of 2-in. metal, and the lower flange of $3\frac{1}{4}$-in. metal, each segment being strengthened at centre by a diaphragm of $2\frac{1}{2}$-in. metal. A view of the live roller ring is given in Fig. 81, page 25.

The segments are secured together by $1\frac{1}{4}$-in. bolts turned and fitted. The whole of the scantlings and dimensions are, of course, in conformity with the increased weight and size of these structures; but, as we have already indicated, they follow, in all respects, the type already dealt with in the previous instances, rendering further comment unnecessary.

Having now dealt in full detail, both by illustration and description, with the types of bridgework involved in the carrying out of the Manchester Ship Canal, we naturally pass to some account of the execution of the work. The bridgework throughout has been executed in accordance with the latest and most approved practice, the highest class of workmanship and materials having been exacted with every detail and in all cases. All plates and bars have been required to be planed at edges or sawn, no sheared edges being permitted. In cases where curved edges have occurred, hand-dressing by chisel has been performed, except in such instances as the webplates of the vertical posts, &c., of the hog-backed girder railway viaducts, which have been readily and effectively dealt with by a high-speed emery wheel. The junctions of plates and bars have required to be truly and accurately made; and where a number of plates of similar width are piled together, as in the booms of the girders, exact dimensions have been rigidly maintained, securing flush edges to the booms.

In the case of struts, cross-girders, longitudinal floor girders, &c., the method of execution has not unfrequently been to build up the member in question, and then saw the ends to any required angle, in one operation; such procedure yielding excellent results, flange-plates, angles, and webs being cut to an exact and uniform flush surface, cold steel saws of about 2 ft. to 3 ft. diameter by $\frac{1}{4}$ in. in thickness, and driven at a speed of from 5 to 15 revolutions per minute, being employed for such purpose. Drilling has been required throughout the entire work, a special feature being the building up of members and their subsequent drilling in one operation through all thicknesses of material. By such method, as will readily be perceived, discrepancies in position of holes cannot occur, and the frequent trouble experienced when assembling together for riveting up parts which had been drilled independently of each other, and consequently often do not coincide, is entirely obviated and done away.

Such improved methods of drilling lead at once to much higher class riveting. Hydraulic riveting was employed throughout, except in special circumstances where hand-riveting was necessitated by the impossibility of using the hydraulic riveters. The usual requirements to secure the highest standard of rivet-work were duly exacted, all rivets being of sufficient length to fill the holes and make a full-sized cup head. Rivets were required to be heated to the same heat throughout, and burnt rivets were forthwith condemned, loose rivets being, of course, *ipso facto*, rejected. The smithwork in the undertaking now under consideration received special care, the joggles, corners, curves, and bends required being performed either by hand or in hydraulic presses. The end-post frames formed an important feature of this portion of the work. Where four-sided framing was required, the frame was built up of two angles, each bent to form two sides, the junctions with each other being welded and subsequently well hammered, the flux employed for welding being sand.

We turn now to glance briefly at the plant employed in the fabrication of the superstructures of the Manchester Ship Canal bridges, in so far as it presents features of novelty or interest.

The planing machines employed were of the usual

DETAILS OF MOORE-LANE SWING BRIDGE OVER THE MANCHESTER SHIP CANAL. (*See Page* 23.)

Fig. 61.

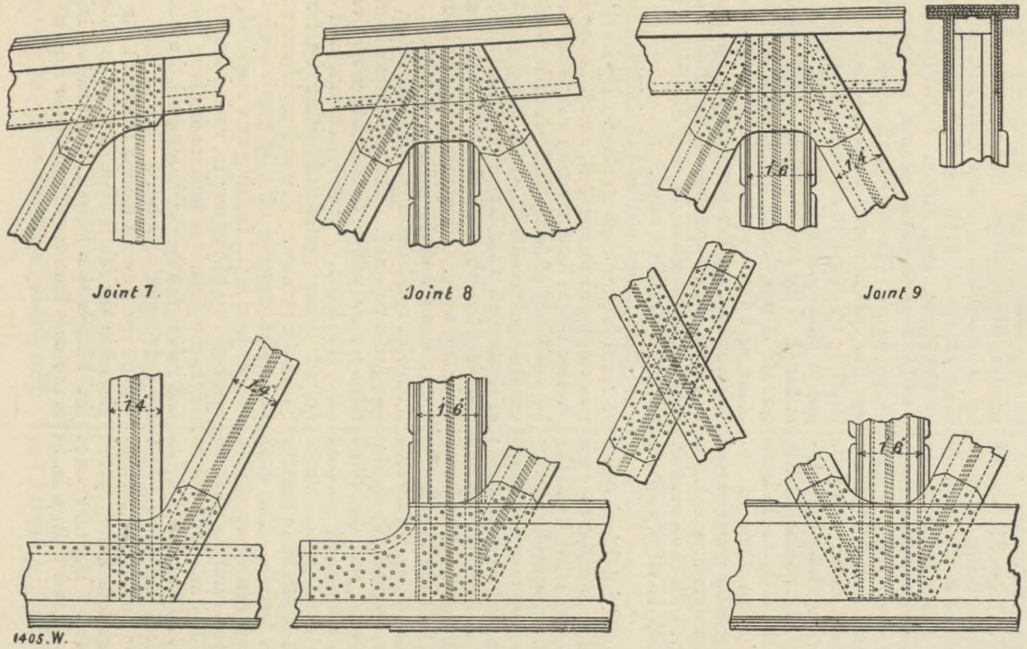


Fig. 78.

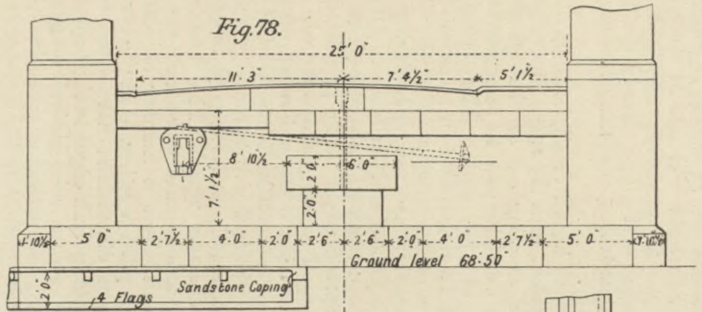
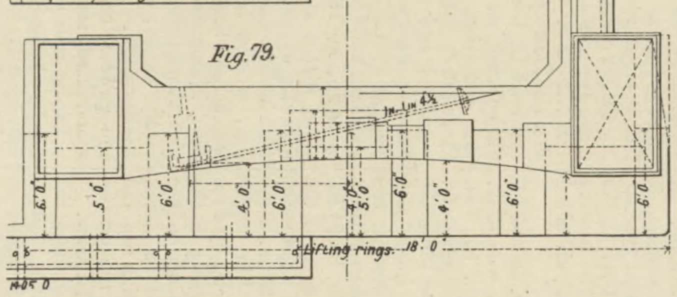
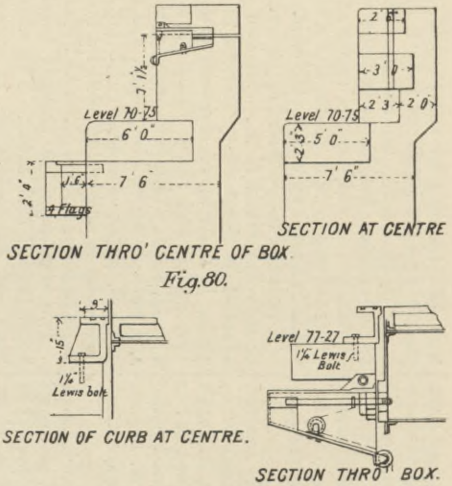


Fig. 79.





SECTION THRO' CENTRE OF BOX.

SECTION AT CENTRE

Fig. 80.

SECTION OF CURB AT CENTRE.

SECTION THRO' BOX.

Fig. 70.

Fig. 71.

Fig. 76.

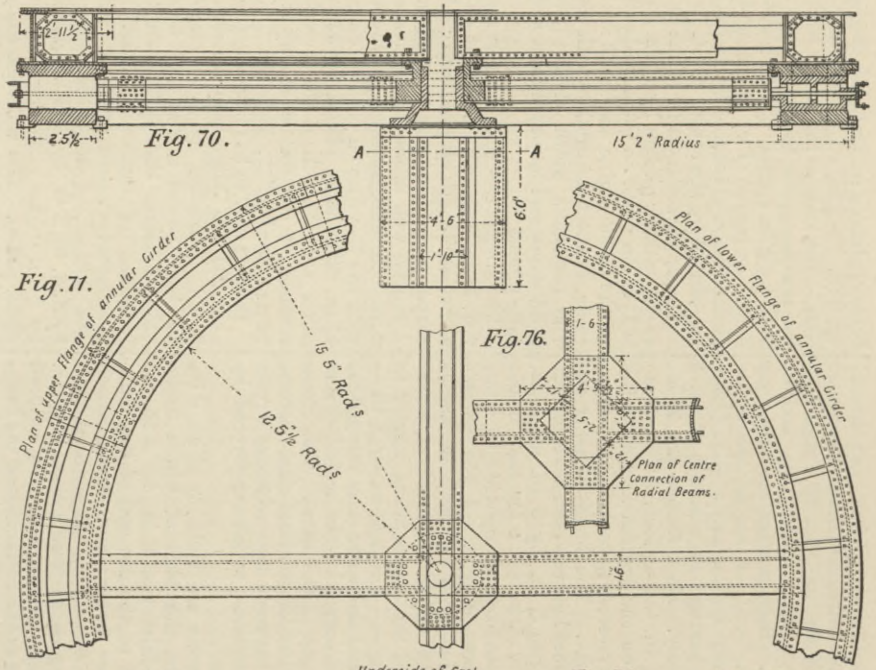


Fig. 68.

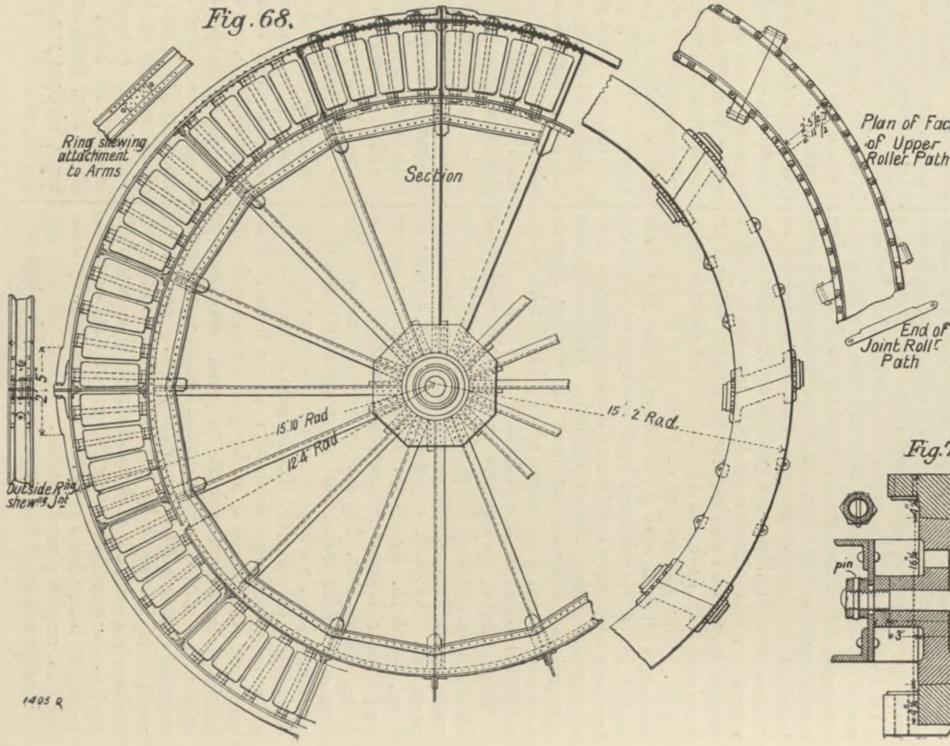


Fig. 69.

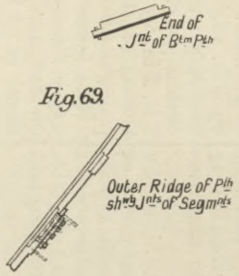


Fig. 77.

Section of Paths and Rollers.

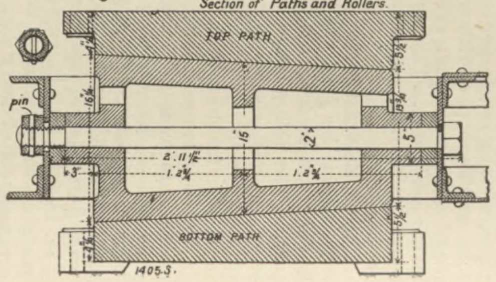


Fig 72.

Underside of Cast-Iron annular Centre Foundation Plate.

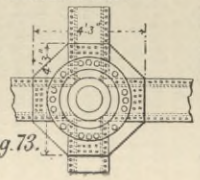
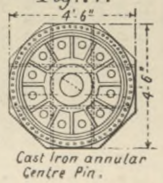


Fig. 73.

Fig. 74.



Cast Iron annular Centre Pin.

Section of Foundation of Centre Pin on Line A.A.

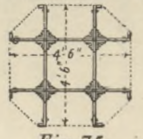


Fig. 75.

SWING BRIDGES OVER THE MANCHESTER SHIP CANAL.

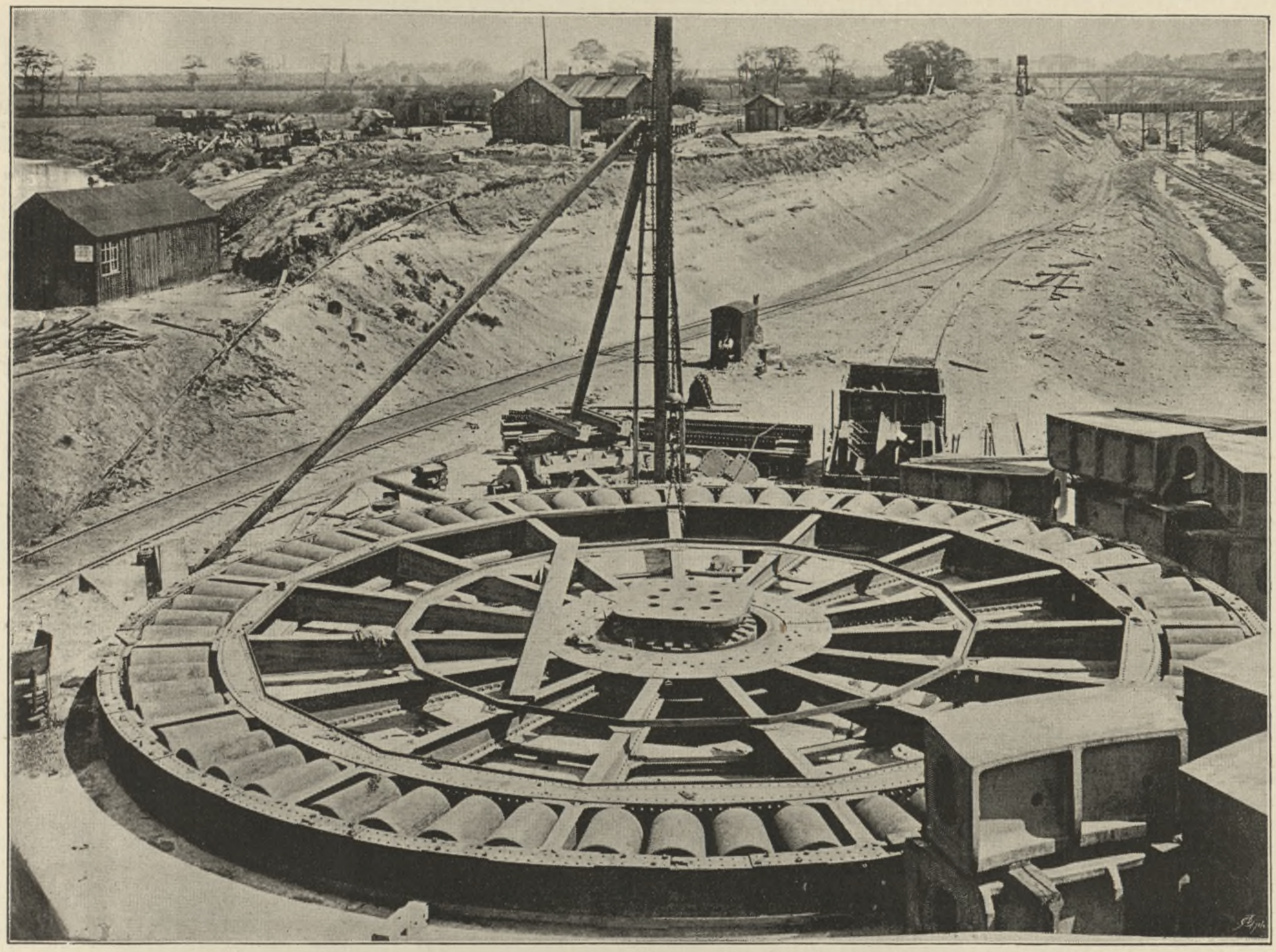


FIG. 81. VIEW OF ROLLER RING; STOCKTON HEATH SWING BRIDGE. (*See Page* 23.)

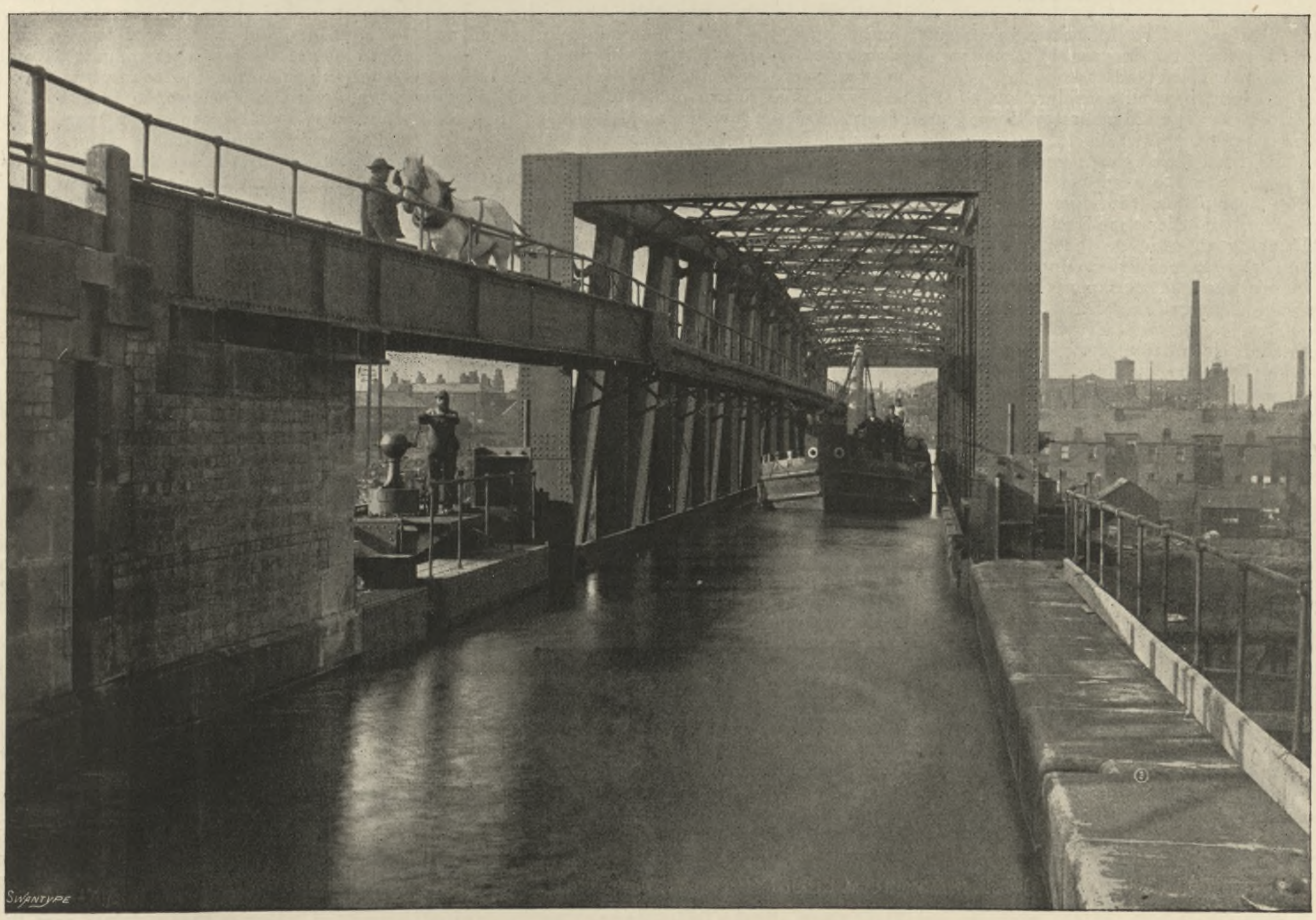


FIG. 89. BARTON SWING AQUEDUCT. (*See Page* 26.)

pattern for plate-edge planing, and call for no special remark, beyond the addition of an end slide provided with separate tool for planing one end of a plate at the same time that one of its side edges is being similarly treated. Such machines finish a plate at two settings, and with the certainty that the ends are truly at right angles to the sides. Drilling has been performed either by the Arrol patent multiple drilling machine, or by single radial drills.

The former consist of a double carriage with upright columns, connected by cross beams to other framings for shafts, pulleys, &c. Nine drills (more or less, according to size of machine) on slides attached to the cross-beam in front, and four drills on as many radiating arms at the back, were capable of boring either vertically or horizontally, in the boom fastened down beneath, and over which the machine travelled as each successive length was drilled. The fixed drills, which were self-feeding, served for all holes of the regular pitch, whilst the movable ones, which were fed by hand, dealt with the odd holes.

Such machines will therefore drill thirteen holes or more simultaneously in a single boom. These machines are driven by ropes running at speeds of 1500 or 1600 ft. per minute. At such speed about two years is the life of the rope. Considerable power is absorbed by the friction of the overhead pulleys carrying the ropes. Electricity is now being employed in some instances to drive these machines.

The single-arm radial drilling machine operating one drill is a very serviceable tool, and can make a complete revolution round its supporting column. Furnished with a bench on either side, fresh work can be laid down on the unoccupied bench, and the drill immediately turned round to command it, thus securing continuous working. Riveting has been performed by the Arrol patent hydraulic riveter of various sizes, the pressure varying up to 1000 lb. per square inch.

The rivets have been heated in small reverberatory furnaces, designed and constructed by Sir William Arrol, and burning blast-furnace residual oil, delivered in a fine spray by air at about 20 lb. pressure, through a disintegrator of special design. These furnaces have given most satisfactory results. The regulation of the heat is complete; the rivets are uniformly heated; the apparatus is more economical than hand fires, and is under perfect control, besides being clean and less liable to cause inflagration. The cost of oil for heating some 2000 rivets per day, in a small furnace $1\frac{1}{2}$ ft. square by 4 ft. long, has been calculated at 4s.

Passing on now to some consideration of the materials used in the Manchester Ship Canal bridges, the steel naturally falls to the first dealt with. As has been already mentioned in the preceding sections, with the exception of small quantities of iron floor-plates, the superstructures are built throughout of Siemens-Martin open-hearth mild steel having an ultimate tensile strength of not less than 27 tons per square inch of section, and not more than 31 tons per square inch of section, with an elongation specified to be at least 20 per cent. in a length of 8 in., and with not less than 35 per cent. contraction of area. A tensile test has been taken from every charge. The soundness of the material and its fitness for service have likewise been tested by cutting strips lengthwise or crosswise $1\frac{1}{2}$ in. in width, heating them uniformly to a low cherry red, and cooling them in clean water at 82 deg. Fahr., such samples being required to bend in a press to a curve of which the inner radius is one and a half times the thickness of the steel tested, without failure of any kind. The ductility of every plate, bar, or angle was ascertained either by this test or by bending similar shearings cold to the same radius.

The rivet steel was required to have an ultimate tensile strength of from 26 to 30 tons per square inch of section, with an elongation of at least 20 per cent. in a length of 8 in., bend tests similar to those required for the plates and bars being exacted. The angles, tee-bars, &c., were required to have clean, sound edges, and all steel was specified to be free from laminations and every surface defect. All material was required to bear the maker's name or trade mark in addition to a distinguishing number, enabling all particulars to be immediately traceable.

With the exception of a small parcel of bars from Messrs. Palmers' Shipbuilding and Iron Company, Limited, Jarrow, the whole of the material was supplied by the following well-known works in and around Glasgow: Messrs. A. and J. Stewart and Clydesdale, Limited, Mossend; the Clydebridge Steel Works, Cambuslang; the Dalzell Steel Works, Motherwell; Messrs. Goodwin, Jardine, and Co., Coatbridge; the Lanarkshire Steel Company, Flemington; the Mossend Steel Company, Mossend; Parkhead Forge, Parkhead; the Steel Company of Scotland, Limited, Newton and Blochairn.

The tensile test requirements were fully complied with, whilst the elongation specified was almost invariably exceeded by 3 or 4 or more per cent., and the contraction of area not unfrequently ranged as high as between 50 and 60 per cent. No difficulty arose in complying with the bend test requirements.

Cast iron entered into the construction of the swing bridges, as already stated, in the form of kerbs, rollers, races, central pivots, &c. All castings were required to be of the highest finish and workmanship, perfectly sound and even, with a clean skin of uniform thickness, free from flaws, such as slag, airholes, blisters, warts, lumps, inequalities, &c. Two sizes of test bars were cast, viz., 1 in. by 1 in., and 1 in. by 2 in., the bearings in each case being 3 ft. The former size broke with loads at centre up to $7\frac{1}{4}$ cwt., with $\frac{9}{16}$ in. deflection; the latter size ranged up to 26 cwt., with $\frac{5}{16}$ in. deflection. The cast-iron work was supplied by the following Glasgow firms: (1) Messrs. Alexander, Burt, and Co., of Mountblue Engineering Works, Camlachie; (2) the Barrowfield Iron Works, Limited; (3) Messrs. Crawford and Hay, Strathclyde Foundry, Bridgeton.

The saddles of the railway viaducts, and in some instances the bedplates also, were of cast steel. Tests selected at random show an ultimate tensile strength of 26 to 32 tons per square inch, with an elongation of 10 per cent. on a length of 8 in., whilst bend tests 1 in. square in section bent without failure to curves of $1\frac{5}{8}$ in. inner radius. Similar requirements as to freedom from all flaws, blowholes, &c., were exacted in the case of cast steel. The larger saddles were cast with double gates 2 ft. in depth by 1 ft. by 6 in., to insure absolute soundness, and all castings were annealed some three or four days previous to despatch from the makers' works. The steel castings were made by the Springfield Steel Company, London-road, Glasgow.

All steel work, after being thoroughly scraped and cleaned, was coated with boiled linseed oil, and subsequently, after further cleaning and scraping, if necessary, with a coat of best red-lead paint. All work was drawn out full size on mould loft floors, skeleton timber templates being then constructed, from which the work was set out.

VIII.—BARTON SWING AQUEDUCT.

The last bridge which we describe is certainly the most novel and interesting of the whole series; interesting not only in its engineering aspect, but from an historical point of view also, and it may be worth while before describing in detail this latest product of canal engineering, to glance back into the past to the events which led to its construction. The Barton Swing Aqueduct carries the Bridgewater Canal over the ship canal. The plan of carrying a waterway over a waterway was introduced more than a century ago, and was justly then considered a marvel of engineering skill. The tale of the Bridgewater Canal has already been told in ENGINEERING, but we may repeat a few details. In 1737 the Duke of Bridgewater wished to provide a better means of communication between his collieries at Worsley, and the "large village" of Manchester, and to that end obtained an Act of Parliament. The powers obtained were not made use of, but after the old duke's death his son soon took up the scheme, and in 1759 another Act was granted by which powers were given to cut a canal from Worsley Mill to Salford, and also to Hollin Ferry on the River Mersey. The young duke showed more energy in the enterprise than his father, and soon took steps to put in exercise the powers he had obtained. He took counsel with James Brindley, who had been a wheelwright's apprentice, but who afterwards became a great engineer, as in those days Great George-street pupils and technical college students had not been introduced to the profession, men becoming engineers by the light of genius when the chances of life put the few opportunities of the day within their grasp. Such a fortunate combination occurred in the case of Brindley. He was then turned forty years of age, but an unknown man, and had received no more education than generally fell to the lot of his class. He appears, however, to have possessed the entire confidence of the duke, who was twenty years his junior, and who gave way to him in many features of the design of the canal. The River Irwell crossed the route of the canal, but at a lower level, and the duke proposed to follow the orthodox plan of a flight of locks on each side of the river. Fortunately Brindley had the great and rare gift of being able to think beyond precedent—a gift more characteristic of the self-made engineer than those trained in orthodox canons of the profession—and he proposed that the canal should be carried on arches over the river. The result was the old Barton aqueduct—of which we give an illustration in Fig. 83, on Plate II. It may be interesting to add that the Duke of Bridgewater spent nearly all he possessed on the canal; but in after years it verified his predictions, and brought a large income, so that he died at the age of sixty-seven a rich man. Brindley afterwards completed the Grand Trunk, the Birmingham, Chesterfield, and other canals. He was one of the early engineers who recognised the necessity of cheap transit to commercial prosperity, and to him our fathers owed much of the canal system which was constructed in the second half of the last century and the early part of this. It is said of him that, asked, when giving evidence before a Parliamentary Committee, for what purpose he thought rivers were made, he replied, "To feed canals, of course."

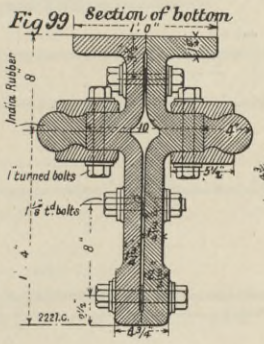
The aqueduct, with its masonry approaches, was about 600 ft. in length, and 36 ft. in width at the top, the water-way being 18 ft. wide and about $4\frac{1}{2}$ ft. deep. The centre arch had a span of 57 ft., and the two side arches 32 ft. each. In our illustration of the old aqueduct is shown the superstructure of a monkey-barge, with the helmsman leaning gracefully on his tiller. The towing-path is indicated by the position of the people standing on it.

We turn from this earlier work to that by which it has been superseded. Our illustrations (Figs. 84 to 88, Plate II, and Fig. 89, page 25) give views of the aqueduct. Fig. 84 gives an exterior view of the structure, by which it will be seen that it pivots centrally, the two arms being of equal length. The island in the centre of the canal on which the bridge pivots is the same as that on which the Barton swing bridge turns, as shown in Fig. 12, Plate I. Fig. 85 gives an interior view of the aqueduct, and is engraved from a photograph taken before the water was admitted to the long trough which forms the connecting link for the Bridgewater Canal across the ship canal. Fig. 86 shows more in detail the central part of the span, the roller-path, and circular girder. The pinions which engage in the semicircular rack by which the bridge is turned may also be seen in this view. The other two views (Figs. 87 and 88) illustrate the ingenious arrangement by which a water-tight joint is made between the ends of the canal and the ends of the aqueduct. These we shall refer to later on. Fig. 89, on page 25, gives an excellent idea of the aqueduct in service.

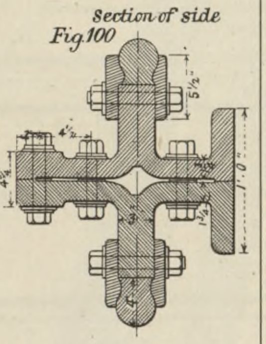
Turning to the details of construction, clearly shown in Figs. 91 to 98, page 28, and Figs. 99 and 100, page 27, we find that the opening span is built up of wrought-iron plates and angles. The top and bottom booms are trough-shaped, being 2 ft. deep by 2 ft. 9 in. wide. The plates generally are $\frac{5}{8}$ in. thick, and are strengthened by angles and diaphragms in the ordinary way. The riveting was hydraulic throughout. The general design is well shown by our illustrations. The tank, or trough, which forms the waterway, and takes the place of a roadway in an ordinary bridge, is an iron structure built up of $\frac{3}{8}$ in. plates, and supported by cross-girders (see Fig. 90, page 28). The sides have butt joints, whilst the bottom has inside and outside plating. Each joint is stiffened by angle iron $3\frac{1}{2}$ in. by $2\frac{1}{2}$ in. by $\frac{3}{8}$ in. On the water line, at each side, is a stout timber fender, and outside a framed continuous girder constructed of double angles and plates, which acts as a stiffening piece. The extreme length of the main girders is 234 ft. 6 in., and the width of the bridge to centres of booms is 22 ft. 3 in. The depth of the bridge is 33 ft. in the centre, tapering to 28 ft. 9 in. at the ends. The tank is 19 ft. wide and 7 ft. deep to the rail, and is filled to a depth of 6 ft., thus allowing vessels of that draught to pass, and giving a side above water level of 1 ft. A gain of 18 in. in draught of water is thus obtained over Brindley's old aqueduct. The towpath consists of an elevated gallery 9 ft. above water level. It is clearly shown on the left side in Fig. 85, Plate II, and Fig. 89, page 25.

The aqueduct is always swung full of water, as the limited supply of water in the Bridgewater Canal, which is sometimes a serious matter in dry seasons, rendered it undesirable that the trough should be emptied every time the aqueduct has to be opened. It was suggested at one time that the water should be run out of the trough and pumped back. There are, however, manifest objections to this arrangement. In the first place, the Bridgewater Canal water is fairly clean—it is mentioned with pride in the district that fish can live in it—and to pump up the foul liquid that flows down from the Irwell would seriously detract from its purity; and in order to meet the just demands of certain vested interests, it would be necessary to replace the same water, and tanks to hold it would have to be constructed. If these tanks were but just below the bottom of the aqueduct, they would certainly result in the pumps having less to do than if the water were taken from the ship canal level; but, in any case, the delay to traffic, whilst waiting for the trough to be filled, even by very powerful pumps, would be fatal to the success of the scheme. Mr. Leader Williams had no choice, therefore, but to keep the aqueduct always full, and swing the water at the same time. He had, therefore, to solve the novel and somewhat difficult problem of making a watertight breaking joint for the ends of the trough. In this he was doubtless much assisted by his past experience in designing a somewhat similar device when he was engineer to the Weaver Navigation, and constructed the hydraulic canal lift at Anderton. By the aid of our two illustrations (Figs. 87 and 88) on Plate II, we will endeavour to explain the way in which the watertight joint between the trough and the canal has been made. The shore end of the canal, carried on a substantial earth bank with retaining walls, ends in an iron gate which closes water-tight by means of a cast-iron and wood joint. This door is shown open in Fig. 87, the illustration being prepared from a photograph taken from the centre of the shore end of the canal before the water was let into this portion. The small quantity of water in the bottom is merely that which has drained in and been allowed to remain. The ordinary water level of the canal comes nearly up to the top of the gate. It will be understood that when this end gate is shut the water is impounded in the canal, and communication with the swinging trough is cut off. The description naturally applies to both ends, which are alike in their arrangements. The end of the swinging trough is likewise closed by a door which shuts water-tight, the joint in this case being made by a steel V-piece on the door closing on to a steel flat bar. This door is shown closed in Fig. 87, and by the details, Figs. 94 to 97, page 28. A cross section of the aqueduct is shown in Fig. 90, page 28. Figs. 91 and 92, on the same page, are longitudinal sections near the two ends of the aqueduct, the recessed bottom to take the doors being shown. Fig. 93 is a sectional plan of one side. The closing of the door is shown by the detail above Fig. 92. The doors of the canal end, and of the aqueduct, are opened and closed by hydraulic rotary engines. With the canal end doors closed and the aqueduct doors closed, it is evident the aqueduct may be swung without water escaping either from the canal or the trough. In order to make a water-tight joint between the trough end and the shore end of the canal, recourse is had to a U-shaped wedge. One half of this wedge is shown in the central part of Fig. 88, Plate II. On the left in this engraving may be seen the hinged half of the shore end gate, which is open, and on the right-hand side, in strong perspective, the swinging trough gate, which is closed. It will be understood that the end of the swinging trough does not come quite up to the end of the canal, that is to say, the trough is about 2 ft. shorter than the space between the two ends of the canal. The opening thus left is stopped by the U-shaped wedge, so that the whole wedge naturally corresponds to the section of the trough. The faces of the wedge, where they abut on the trough end on one side and the canal end on the other, are of indiarubber. Sections of the wedge on side and bottom are given in Figs. 99 and 100, annexed. A certain amount of slope is given to the end of the trough, and to the end of the canal, so that the space intervening between them is wider at the top than at the bottom, so as to fit the wedge when the latter is lowered on to the seating formed by the end of the canal and the trough end, both the wedge and the opening being of the same taper. The method of operation, when the viaduct has to be swung to allow a vessel in the ship canal to pass, is as follows: The gates at the canal ends and trough ends are closed, and the water inclosed in the short space between them is allowed to run out. The U-wedge, weighing 12 tons, is then raised by means of four hydraulic rams, two attached to the sides and two pressing up from below. In Fig. 88, the short connecting-rod forming the attachment between the ram and the top of the wedge is shown, with the guide through which it works. The wedge and the space into which it fits being taper, it is evident that by raising the wedge the space is no longer filled by it, and thus clearance is given to enable the bridge to be swung; when the bridge is closed, the wedge is again lowered into its place, the indiarubber strips press on to their seatings, and a watertight joint is thus made. It should be stated that the division between the aqueduct and the canal ends is made on the slope, that is to say, it is not normal to the sides of the canal and bridge, but is diagonal. This, of course, is done to give clearance to enable the bridge to swing. The ends could not be made an arc of the circle swept by the bridge in swinging, as that would have complicated the form of the U-wedge.

Fig 99 Section of bottom



Section of side
Fig. 100



The combined weight of the water in the trough and of the swinging span is about 1600 tons, and it will be easily understood that the pivoting arrangement was required to be designed with care. It is, moreover, especially necessary that the bridge should swing with steadiness, and in a perfectly horizontal plane, for should any oscillation of the water be set up, or any preponderance at either end owing to the trough being out of the horizontal, undesirable strains on the structure would be produced, owing to the movement of the water. In Fig. 86 the pivoting arrangement is partly shown, and in detail in Fig. 98, page 28. The main girders of the structure rest on three cross bearing girders (the ends of which can be seen both in Figs. 84 and 86), and these rest in turn upon a wrought-iron annular girder, also shown in the illustrations. To the latter girder is bolted the top roller path, which is of cast iron. Next come the rollers, which are of cast iron. They are 64 in number, their mean diameter being 14 in., and their length 2 ft. 8 in. There is a taper of 2 in. in this length. The mean diameter of the rolling circle is 25 ft. The rollers run on 2-in. steel spindles, and are attached to a radial frame. The rollers are not solid, the metal being 2½ in. thick, and there is a central annular rib of 2¼ in. In swinging, the aqueduct is guided by a central hydraulic press, which is 4 ft. 9½ in. in diameter. Before turning the bridge, pressure water is admitted to the cylinder of this press, and in this way about half the weight of the bridge and water is taken off the rollers, the total pressure on the ram equalling about 800 tons. Thus half the weight is taken by the rollers and half by the central hydraulic ram, which of course is free to turn, thus forming a central pivot. The object is to reduce the pressure on the rollers, and obviate to this extent the friction in turning. The cylinder of the central pivoting ram is naturally shallow, being no more than 2 ft. 3 in. deep. It is of cast iron, and has a stout steel hoop, shrunk on the outside at the upper edge. This cylinder also forms the centre guide for the cast-iron collar to which the radial roller frame is attached. In order to transmit the turning power the toothed steel rack (already referred to) is bolted circumferentially to the outside of the annular girder, as may be seen in Fig. 86, and the two pinions engaging in this are turned by two three-cylinder hydraulic oscillating engines of the usual type. The aqueduct is also fitted with an hydraulic buffer and a locking-bolt, which springs into its place as the bridge closes.

The aqueduct is fitted up most completely for quick handling, there being four hydraulic engines on the bridge itself, two being for the annular motion of swinging the bridge, and one at each end for working the gates. There are also the hydraulic engines for the canal end gates, besides which hydraulic power is provided for working the valves which fill and empty the space between the bridge gates and the canal end gates. In general design, however, the hydraulic machinery, as will be gathered from our description, is similar to that used on the opening road bridges.

The fixed aqueducts, which form the approaches to the swing part, are in themselves important structures, and have presented one or two difficult engineering problems, which, however, space forbids us entering upon here.

The hydraulic power station is near the aqueduct, the same engines and pumps supplying pressure-water for the aqueduct and the road bridge beside it. Both these structures are worked from a lofty and substantial valve-tower, placed between them and the central island, a commanding view thus being given to the operator.

We have more than once seen the aqueduct opened, and can speak as to the efficiency of the arrangements, the big structure swinging round with ease in a few seconds. On one occasion a barge was on the aqueduct during the swinging, a circumstance which caused alarm to certain occupants of the steamer passing, "from the danger of overbalancing by the extra weight on one end." We believe it is on record that somewhat the same cause of anxiety was expressed when Brindley first proposed his aqueduct over a hundred years ago, it being thought that mishaps would occur through the weight of barges passing, supposing a number of heavily laden craft were to crowd on at once.

IX.—THE DREDGING OPERATIONS.

The work of excavating the Manchester Ship Canal was originally all done in the dry, excepting the length in front of Ellesmere Port. This had to be dredged because the Ship Canal Act necessitated the traffic from the Shropshire Union Canal, and from the docks at its entrance, being kept open until the ship canal should be available for this traffic down to Eastham, and thus into the estuary through the entrance locks there situated. However, in the year 1890 heavy floods broke through a great many dams which had been erected for keeping back flood-water from the ship canal cutting; and in this way a vast quantity of deposit was brought into the part excavated. This was one of the great disasters which attended the prosecution of the work, and caused a large amount of delay, besides entailing heavy additional expenses and much anxiety to all engaged on the work. It was then determined that it would be preferable to dredge this deposit away in most cases rather than repair the dams and pump the cuttings dry again; for, in any case, there would have been the dams to remove after the sections had been filled, so that dredgers would have had to have been brought on to the work in any case. At first the dredging was carried on in each of the districts into which the work was divided by the agents in charge under the company, but the procedure was not sufficiently rapid to keep pace with the rest of the work. The drawbacks of divided control were apparent, as the engineer of each district was too busy with other matters to give his undivided attention to devising the best means of carrying out dredging operations; which were therefore prosecuted on ordinary known lines according to the approved methods pursued in this branch of engineering. Early in 1892 it became apparent that, if the canal was to be opened by the beginning of the present year, more vigorous methods would have to be pursued. Under these circumstances, the executive determined, under the advice of Mr. Leader Williams and Mr. G. H. Hill, the corporation engineer, to form a separate department under the superintendence of Mr. A. O. Schenk, M. Inst. C.E., an engineer who had been engaged for some time on the canal works, and who had had considerable experience in work of this class.

THE BARTON SWING AQUEDUCT; MANCHESTER SHIP CANAL. (*See Page* 26.)

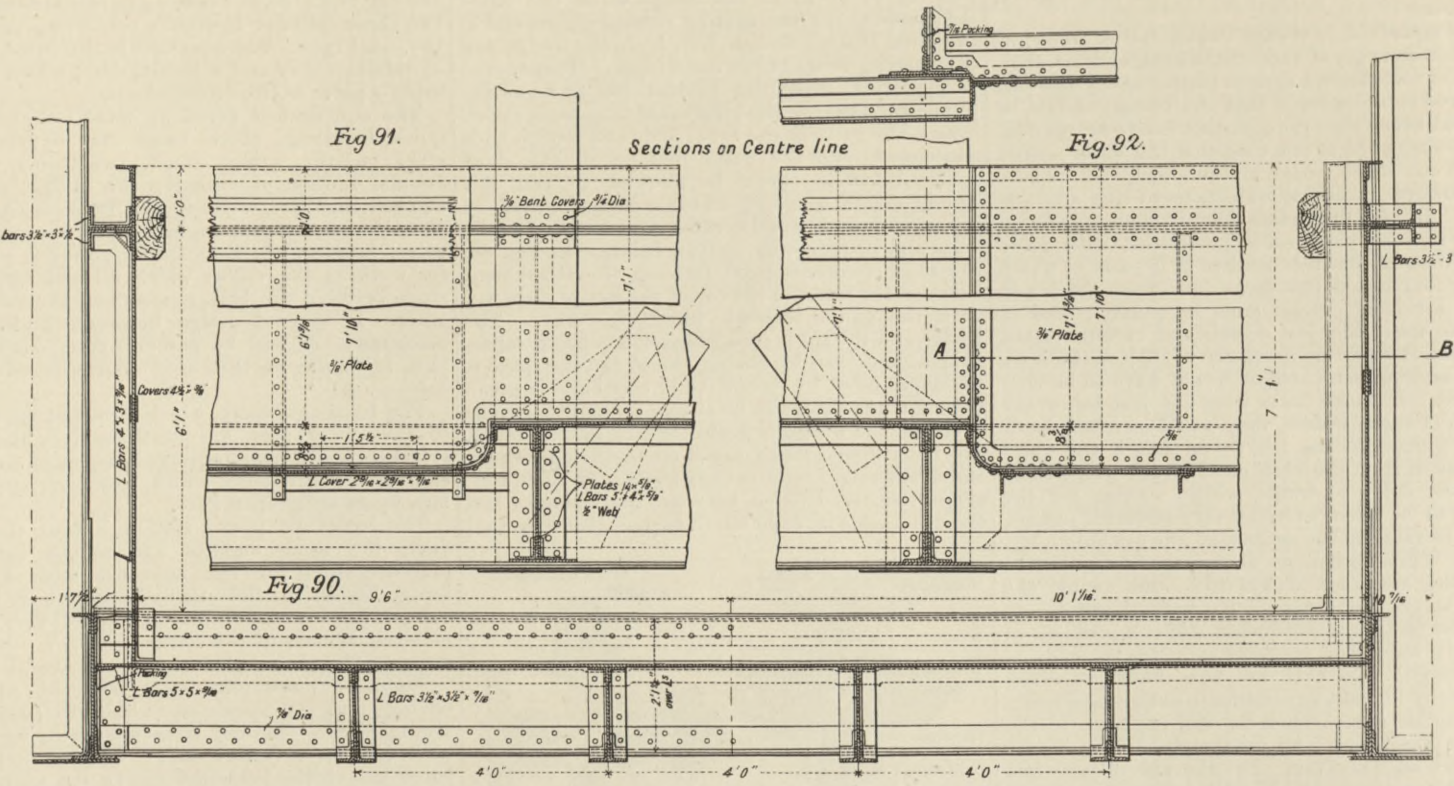


Fig 91. Sections on Centre line Fig. 92.

Fig 90.

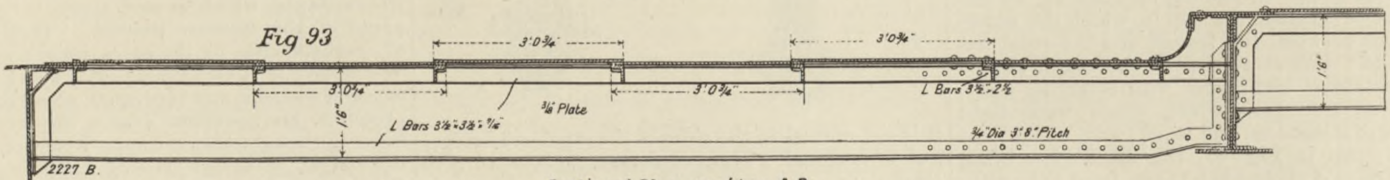


Fig 93

Sectional Plan on Line A.B

Fig. 95

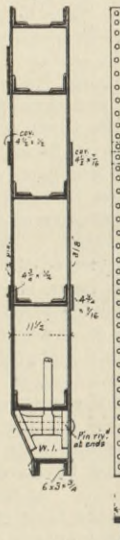


Fig. 94.

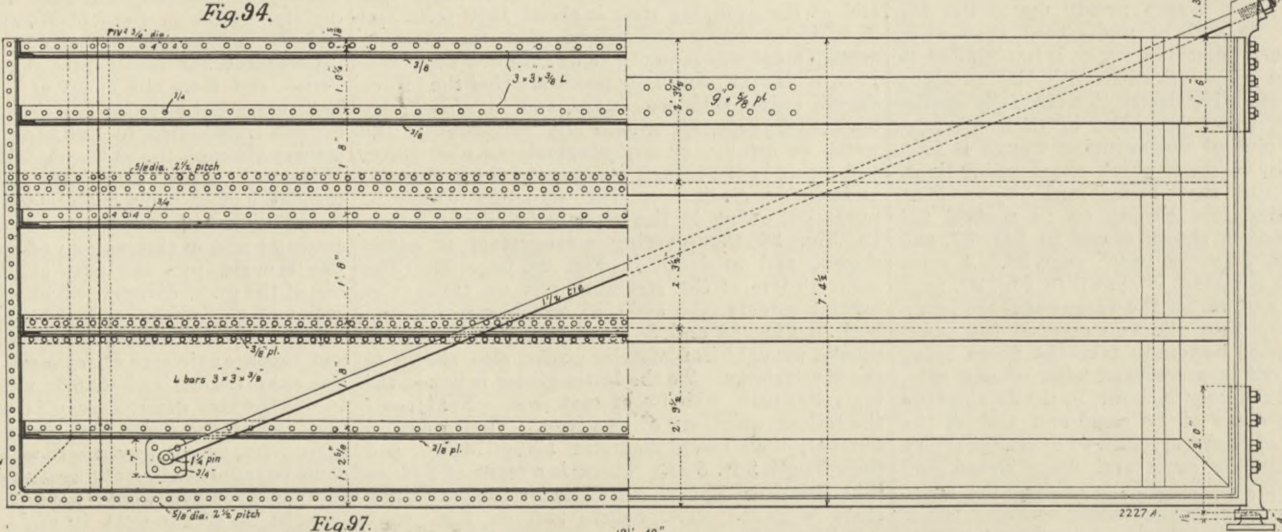


Fig. 96.

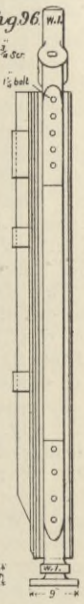


Fig 97.

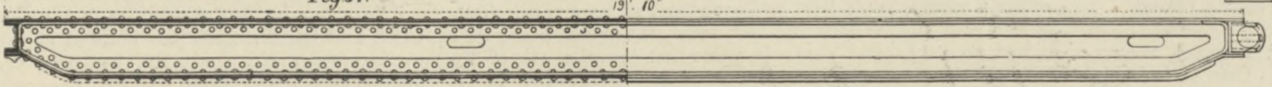
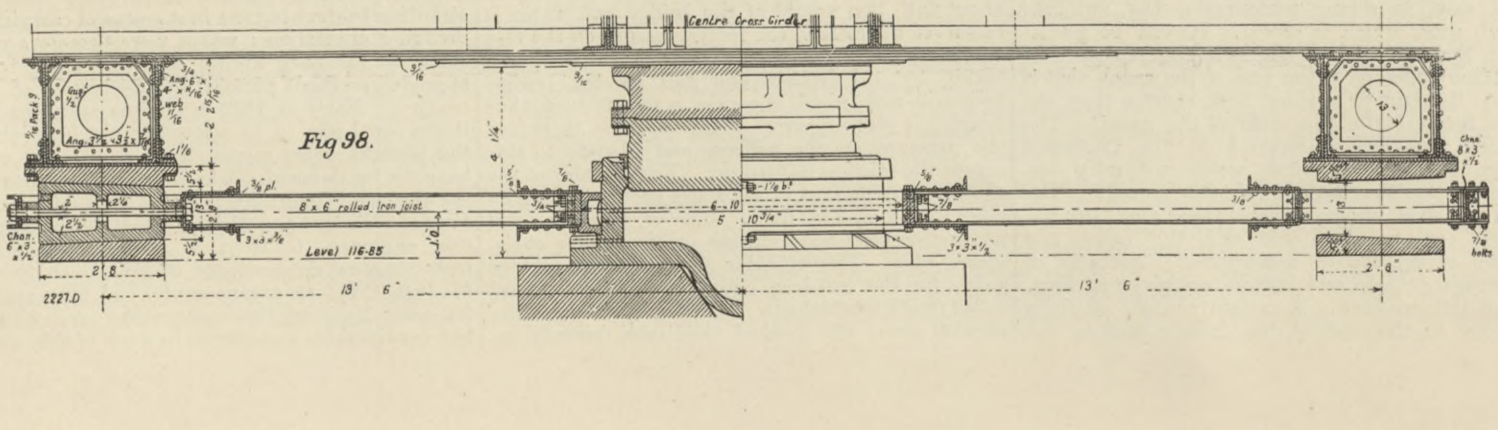


Fig 98.



THE MANCHESTER SHIP CANAL; STONEY'S TIPPING CRANE. (*See next Page.*)

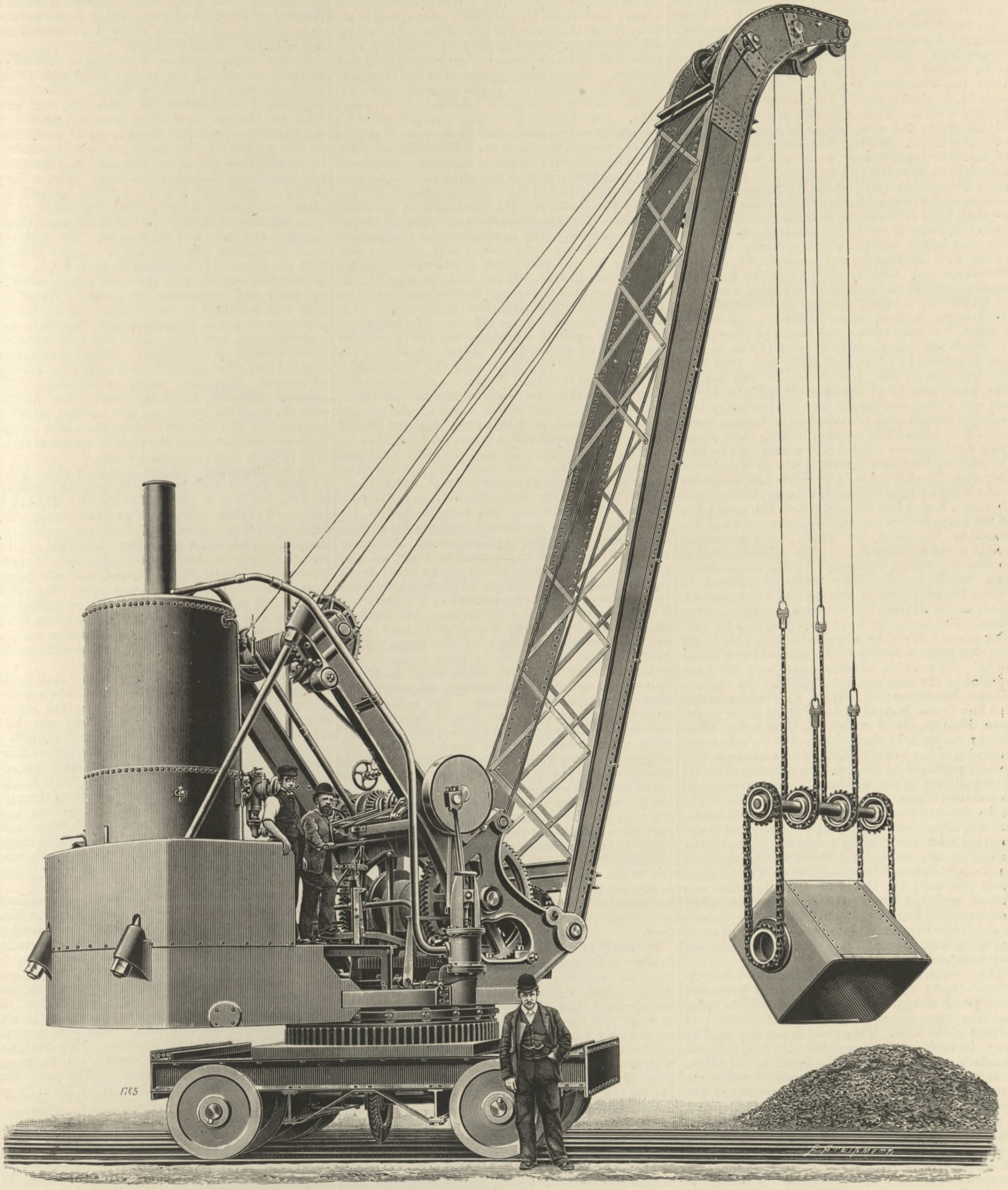


Fig. 101.

Mr. Schenk's first step was to bring on to the work a quantity of additional plant. Up to then the dredging had been chiefly carried on at the sea end, but the Manchester section most urgently required attention. In all ten dredgers have been engaged on the ship canal work, most of which are self-propelling and one a hopper dredger. This is the Manchester, built by William Simons and Co. purposely for the ship canal. The ladder is situated in the stern, which is divided to accommodate it, and the vessel was designed to steam with facility in either direction. To this end she was fitted with four screws, having lines of shafting carried from end to end. There are also three rudders, two at the stern and one at the bow. The capacity of the Manchester is 850 tons an hour, working in favourable ground, and her range for depth is 35 ft. This dredger has two sets of triple expansion engines and two steel boilers.

The Manchester was, however, installed when Mr. Schenk was appointed, and another dredger, the Bollin, was also on the ground just ready for work. Then two other vessels, the Irk and the Medlock, were built, of similar design to the Bollin and like her. Mr. Walker had had constructed two other dredgers, the Mersey and the Irwell, supplied by Fleming and Ferguson. The Bollin, the Irk, and the Medlock are each capable of raising 500 tons an hour from a depth of 30 ft. There were also ordered twenty-four steel barges especially designed for the work, and nine Stoney's tipping cranes, also especially designed for the operations to be carried on. In Fig. 101, page 29, we illustrate this new form of crane, and in Fig. 105, page 31, is shown one of the boxes used in connection with it. Figs. 102, 103, and 104, on page 31, illustrate the new barges designed to work with this crane. We will first describe the method of transporting material, which has been devised especially to expedite this work, as it is one of the most interesting and instructive features in connection with the construction of the canal, although we shall have to do some violence to chronology, and shall have to return to earlier work later on. The nine cranes ordered where specially designed by Mr. F. G. M. Stoney, and constructed by Messrs. Ransomes and Rapier, of Ipswich, to meet the requirements of the system of dredging designed, in which the dredged material is conveyed from the dredger in steel boxes, carried in the well of a barge, to wharves on the banks of the canal, on which are placed one or more of the cranes. Our illustrations (Figs. 102, 103, and 104) show the position of the spoil-boxes in the barges. The boxes are lifted successively off the barge, and are either discharged into an ordinary contractor's wagon and conveyed to a distant spoil-ground, or tipped into a shoot leading on to a low-lying spoil-ground behind the wharf. In making the inquiry for these cranes, it was specified that they were "to lift a box of 3½ cubic yards capacity—say 5 tons weight—from the barge, to slew and tip into a wagon behind, and return the empty box to the barge within one minute; the radius of the crane to be 16 ft. to 18 ft.; the maximum height of lift to be 20 ft.; the box to be constructed so that it could be discharged by the crane driver from the foot-plate. This might be effected by having hinged doors at the bottom, tumbling outward, or by tipping, by an arrangement on trunnions. The cranes to have travelling gear for running up and down the wharf, and to be able to lift and slew without having to be fastened down to the road." The above requirements have all been fulfilled in the nine cranes supplied by the makers, Messrs. Ransomes and Rapier, with the exception that the boxes, instead of being of 3½ cubic yards, have been made 4 cubic yards capacity. Mr. Stoney, as will be seen, preferred to effect the emptying of the boxes by tipping on trunnions, and he first proposed to do this by a differential travel of the lifting ropes dependent upon a reduced diameter of the winding barrel of the crane. The device acted admirably in a model which was made, and was altogether a very pretty action; but it was objected that the tipping would not be under the control of the driver, and therefore, for this and some other reasons, it was abandoned. The ultimate result was that the crane we now illustrate was devised, and has been found to answer admirably. Nothing could be more expeditious than the manner in which the boxes are picked up, are turned over, emptying their contents into the wagons, and are then returned to the barges.

The cranes, as manufactured, have two barrels independently driven, so that they can be turned together or in opposite directions at will, in order that the tipping action may be independent of balance of the load. Four steel ropes are used to carry the load. A steel crossbar with four sprocket wheels is suspended from the crane in the bights of two short pitch chains, the ends of which are attached to the four ropes. The outer ends of the crossbar are provided with similar sprockets, each of which carries a short loop of pitch chain. The buckets containing the materials to be tipped are provided with like sprockets on their ends, and the endless loops of chains are easily and quickly dropped under these sprockets, thus attaching the load to the crane.

The two ropes fixed to corresponding ends of the short pitched chains are wound as twin ropes, on the double thread groove on one barrel, while the pair of ropes fixed to the opposite corresponding ends of the pitch chains are similarly wound on the other barrel. Thus all four ropes are directly wound by the crane, and so long as the barrels move together in the same direction the load is lifted as in an ordinary crane, but when the barrels are moved in opposite relative directions, the load does not lift or lower, but a rotating motion is given to the crossbar, and is communicated to the bucket by means of the two chain loops. This rotating motion is, of course, performed by the steam power, and is entirely under the control of the driver as to extent and direction. The box may be rotated a complete revolution or more, or only through a few degrees. Also it may be rotated in one direction, and stopped and rotated in the opposite direction.

This facility is of great practical use in many ways. For example, in tipping dredged materials containing water, the water is frequently poured out in one direction, and the solid materials afterwards tipped in the opposite direction. Similarly, in tipping into trucks, it has often been found convenient to tip part of the load in the direction of one end of the truck, and the remainder in the other direction; this is easily performed by simply reversing the engines. The new system of dredging, of which Mr. Stoney's crane forms so important a part, depends on the possession of the special barges we illustrate in Figs. 102, 103, and 104, page 31. It will be seen that the barges themselves contain no spoil, the material being carried in the boxes. The method of operation is as follows. The barges are brought alongside the dredger, and are moved past the shoot by means of a warping capstan. The shoot is arranged to deliver into the boxes, which are thus filled in turn. When the loading is complete, a tug takes the barge to the nearest crane, and when it is moved within reach of the jib the ropes are lowered, so that the two bights of pitched chain can be slipped under the toothed trunnions by an attendant. This is an operation most easily performed, it being even more expeditious than putting a hook into a ring, as one part of the attachment—the trunnion—is steady, and does not require holding, so that the man has both hands free for the chain. It is attention to apparently trifling details such as this that expedites work. The boxes are lifted and tipped in the manner described, and are then immediately returned to their berth on the barge. In order to facilitate their being easily placed in exact positions — a mattter of some importance in the filling from the dredger shoot — cast-iron guides faced with hard wood are fixed to the well-deck of the barge. Each barge carries 20 of these 4-yard boxes. The well-deck upon which the boxes stand is 15 in. below the main deck of the barge, the main body of which is quite water-tight. The well-deck is somewhere about the water line, it being a little below water line while the boxes are full, but somewhat above when they are empty. There are scuppers leading from the well overboard. The consequence of this arrangement is that water which comes down the dredger-shoot and overflows the top of the box runs into the well, from whence it drains out through the scuppers, only that small part being retained in the bottom of the well which is due to the immersion of the barge when loaded, bringing the well-deck below the load-water line of the barge. When the boxes are empty the well-deck rises above the load-water line, and the well is drained dry by the scuppers, and thus the empty boxes are prevented from floating and toppling over.

Formerly the dredged material was shot from the dredger into wagon bodies, which were made detachable from the wheel frames for the purpose. At first sight this would seem the more perfect arrangement, but directly one sees both systems at work side by side—as they were for some time on the ship canal—one recognises the superiority of the new system. This lies chiefly in the ease with which the boxes are attached to the lifting gear of the crane, and also to the difficulty of placing the wagon bodies on the wheels, an operation requiring four men and a good deal of manœuvring with levers, all of which takes time, whilst the boxes are overturned into the wagons almost instantaneously, entirely by the crane driver on the foot-plate. Of course, where a shoot is used to take soft material to a spoil-ground near by, the advantage is more apparent.

The effect of the introduction of this system was soon apparent when the cranes had got fairly to work. In June, 1892, it was estimated that 2,000,000 yards would have to be dredged to enable the canal to be opened for traffic, and though the full depth of 26 ft. was not obtained throughout by the day of opening, we know that ocean-going ships have been brought up to the docks at its head. By July last one and a half million of the two million cubic yards had been deposited, and by the end of the year the two million cubic yards had been slightly exceeded. In the two million cubic yards first estimated there were 300,000 cubic yards of rock, and it is, we believe, only in one or two places where this occurred that the full depth was not obtained.

In the original system of dealing with dredged material, as carried out in the lower part of the canal, the spoil was conveyed to sea. This depositing ground was twenty-five miles out, and even then the barges were often weatherbound. As the canal company had large areas of waste land on the course of the canal, it was determined to use them for depositing purposes, and the result has been that not only has there been a large saving in time and labour, but the ground has often been greatly improved by being raised.

In removing rock from the bed of the canal, blasting often had to be had recourse to. The explosive used throughout was tonite, the charges varying with the depth of hole from 4 lb. up to 10 lb. The drilling was carried on in the usual way, sometimes by hand and sometimes by power. When the rock was stratified it was blasted off in lumps, generally of a few pounds weight, but in a few cases reaching two tons, pieces which caused some little trouble in handling. Rails, contractors' wagons, and other parts of plant which had become submerged, were also often troublesome. The greatest difficulty, however, arose when dealing with the dead red sandstone, not bedded, which is plentiful in the district. Here the effect of the explosion was to reduce the rock to a mass of sand, very difficult to get into the buckets.

In our illustration of the spoil-box (Fig. 105), on page 31, it will be noticed that the corners are rounded both in plan and elevation. The box is composed of three plates, one long one forming the sides and bottom, and two end plates, the latter being flanged. It was some time before this form of construction could be obtained, but ultimately the contractors laid down flanging plant, and 470 boxes were ultimately made on this principle. The value of rounded edges lies in the greater facility of handling and discharging, the shape lending itself to being directed with the wooden guides on the barge. The advantages in construction will also be manifest.

We have said that the barges were taken from the dredger to the crane by tugs; but this was by no means invariably the case. Along the whole line of the canal a full-gauge railway was laid down—it was known as the "overland route"—and advantage was taken of this to use locomotives for towing the barges. The plan was found exceedingly convenient, the engines taking good loads, and being far more expeditious in getting through the work than the tugs. The advantage was not so greatly apparent in the speed of towage as in the readiness of the locomotive to take another barge back immediately on the return journey, whereas the tugs had to turn round, an operation requiring some little time.

Having so far dealt with some of the more salient matters connected with the dredging work since Mr. Schenk took it in hand, we will return to an earlier period to refer briefly to an interesting feature in connection with this part of the work of constructing the canal. In Figs. 106 to 110, Plate III, we illustrate Price's soil transporter, which was designed and constructed by Mr. John Price, of Grappenhall, Cheshire, who was agent for the six lower sections of the ship canal. The arrangement is clearly shown by the illustrations. This machine was fully described in ENGINEERING, vol. lii, page 90. It was used for some time on the canal for transporting soil from the dredger to the railway trucks as shown.

X.—THE DRY EXCAVATION.

The material that was required to be removed, to form the Manchester Ship Canal, is calculated to amount to 53½ million cubic yards, of which 12 millions were sandstone rock. Of these totals 11½ million cubic yards of rock were removed by excavation, whilst half a million cubic yards were dredged. Of the softer material 38½ million cubic yards were removed by excavation, whilst three million cubic yards were dredged. In addition to the dredgers, 97 steam excavators were employed, and for the conveyance of material to the spoil grounds, 173 locomotives and 6300 trucks and wagons were used. As before stated, a 4 ft. 8½ in. gauge railroad was laid along the whole course of

SPOIL BARGES AND BUCKETS; MANCHESTER SHIP CANAL. (*See opposite Page.*)

Fig. 102.

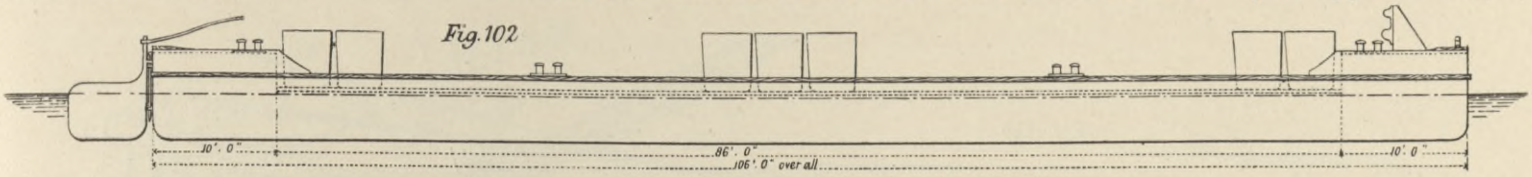


Fig. 103.

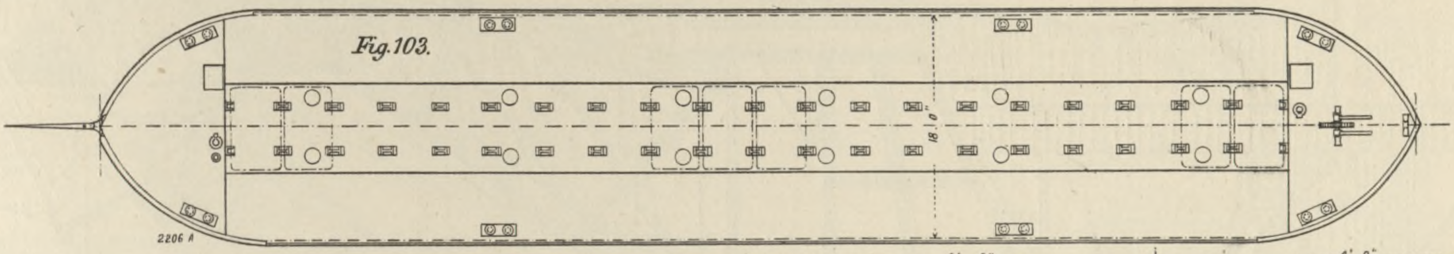


Fig. 104. Section thro' Recess.

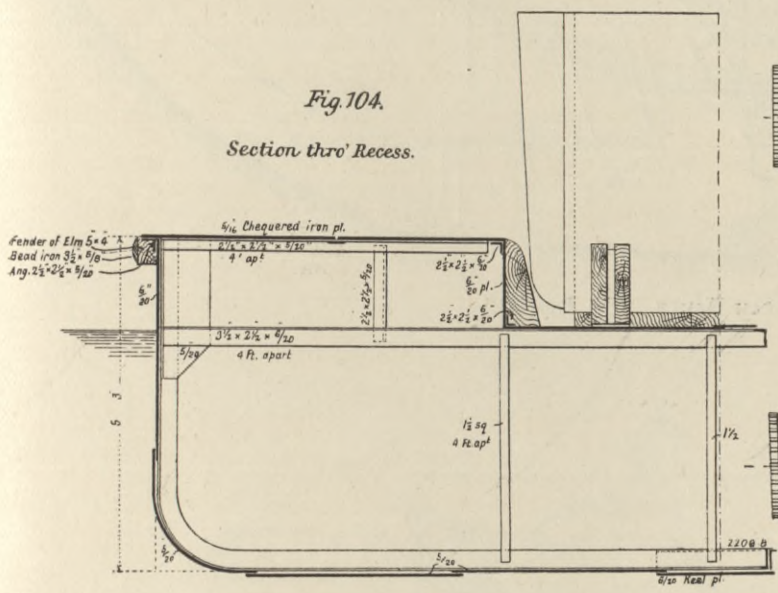
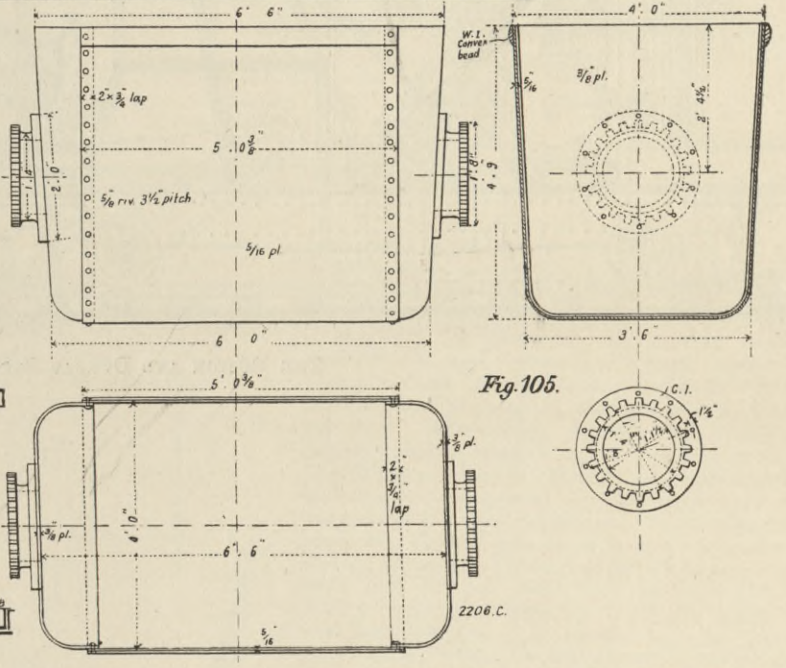


Fig. 105.



the canal, in many places on both sides. These lines, together with the numerous sidings, and those laid in the bed of the canal purely for excavating purposes, amounted to a length of 228 miles. The rate of excavation varied from ¾ million to 1¼ million cubic yards per month, according to the difficulty of the work.

The bulk of the work was done by the steam navvy made by Messrs. Ruston and Proctor, of Lincoln, but perhaps the more interesting, because the more novel, machines engaged were the French and German land dredgers, which we illustrate on our two-page plate in Figs. 113 and 114, Plate IV. These we will describe presently, and in the meantime will return to Messrs. Ruston and Dunbar's navvy, of which we give an illustration, as made by Messrs. Ruston and Proctor, in Fig. 115, page 32. At the 1885 summer meeting of the Institution of Mechanical Engineers, held at Lincoln, Mr. Joseph Ruston read a paper* in which much valuable information was given respecting this machine, and from which our illustration (Fig. 115) and the details given are taken. Although the steam navvy is now well known to those engaged in work of the nature in which it is employed, it has done so much work on the canal that it will be necessary to make more than passing reference to it in order to fulfil the programme we have set before us in preparing a description of the canal and its method of construction. By our engraving it will be seen that the steam navvy consists of a strong rectangular wrought-iron frame, which forms a base to which all parts are secured, and which is mounted on wheels. The motive machinery, consisting of a steam engine and vertical boiler, is placed at the back, as shown. A wrought-iron tower carries the top pivot of a crane jib, the lower pivot resting on the girders attached to the main frame. The jib is composed of two sides, which are united only at the post and at the outer end or pivot, leaving a long slot between them. In this there swings an arm, adjustable as to length, and depending from a fulcrum fixed on the upper member of the jib. At the base of the post is a circular platform, on which a man stands to regulate by a handwheel the reach of the arm. The scoop is fixed at the lower end of the arm, and is raised or lowered by the main chain, which passes over the extremity of the jib. The machine is operated by two men, known as the "driver" and the "wheelman." The method of working is as follows: Supposing the navvy to be in position for work, the bucket is lowered until its arm is vertical, as shown by the dotted lines at A (Fig. 115). The wheelman regulates the length of the arm by means of his handwheel, so that the cutting edge of the bucket shall get its proper grip of the soil. The driver throws into gear the main-chain drum, and the scoop is dragged forwards and upwards by the chain into the position B (Fig. 115), describing a circular arc of about 80 deg. By the time it reaches the top it is fully loaded, and the driver throws the drum out of gear and holds it with a foot-brake. At the same instant the wheelman, by easing his foot-brake, allows the bucket to fall back to position C, clear from the face of the bank. The contents of the bucket have now to be placed in the wagon, and to do this the driver swings the jib round till the bucket is over the wagon, when the wheelman releases the catch by means of a cord, and, the door falling open, the contents drop through. The driver then swings the jib back again, and at the same time lets go the foot-brake of the chain drum, thus causing the bucket to descend through a sort of spiral course, until he brings it up sharply by the brake in the position D. The wheelman at the same moment adjusts the fall by means of his brake, so as to lower the bucket once more to the first position at A, the reach of the arm being adjusted for the next cut. During the fall the door of the bucket closes and latches itself automatically by its own weight. After the machine has removed all the earth within its reach, the jack screws are eased, and the propelling gear being put in action, a movement of three or four feet forward is made.

The great advantage of the steam navvy is that it will excavate any material capable of being cut, such as sand, gravel, chalk, and clays of all kinds; digging out materials that would require blasting if worked by hand. It can also deal with these materials when mixed with heavy stones, cutting through seams of flint, shale, slate, &c. In the case of the ship canal this property of dealing with hard material was especially emphasised, the steam navvy cutting its way where some of the larger machines, such as the French and German excavators, would have been brought to a standstill. The bucket of the navvy has a cutting edge of steel, and is protected by four strong steel teeth, which can be removed if required. These machines were originally made to weigh about 22 tons, but the construction was afterwards strengthened and added to so as to put another 10 tons into the weight. Nearly 50 per cent. has also been added to the original capacity for work. At first 180 to 190 wagon loads were considered a good day's work, but with the improved machines 240 to 250 wagons have been often filled in a day of ten hours; or even more under favourable conditions. The steam navvy packs the material more closely in the wagons than when hand work is used. With extra large wagons of 4 cubic yards, a total of nearly 1000 cubic yards per day has been reached.

Different sized buckets are used, according to the nature of the material attacked, the number of cuts per hour remaining constant. For the very hardest clay, intermixed with stones and boulders, a bucket of 1 cubic yard is used, and for other hard stuff 1¼-yard bucket. For loose earth, sand, gravel, or drift, a 1½ or even 1¾-yard bucket can be applied. In moving the machine, laying rails, &c., about ten minutes per hour are generally occupied; the number of cuts per hour under these circumstances—*i.e.*, in 50 minutes' actual

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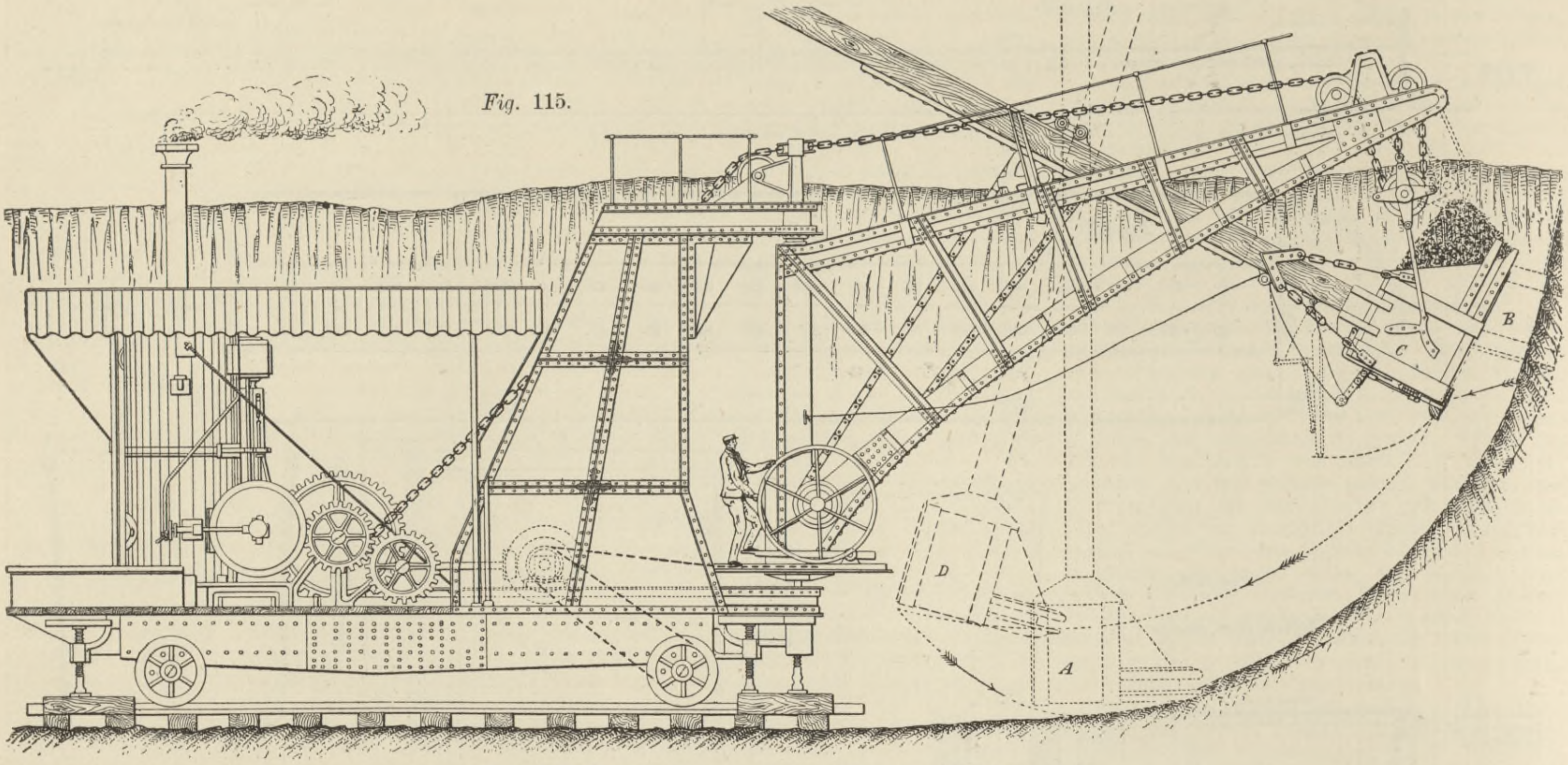
* See ENGINEERING, vol. xl, pages 178 and 202.

STEAM EXCAVATORS ON THE MANCHESTER SHIP CANAL.

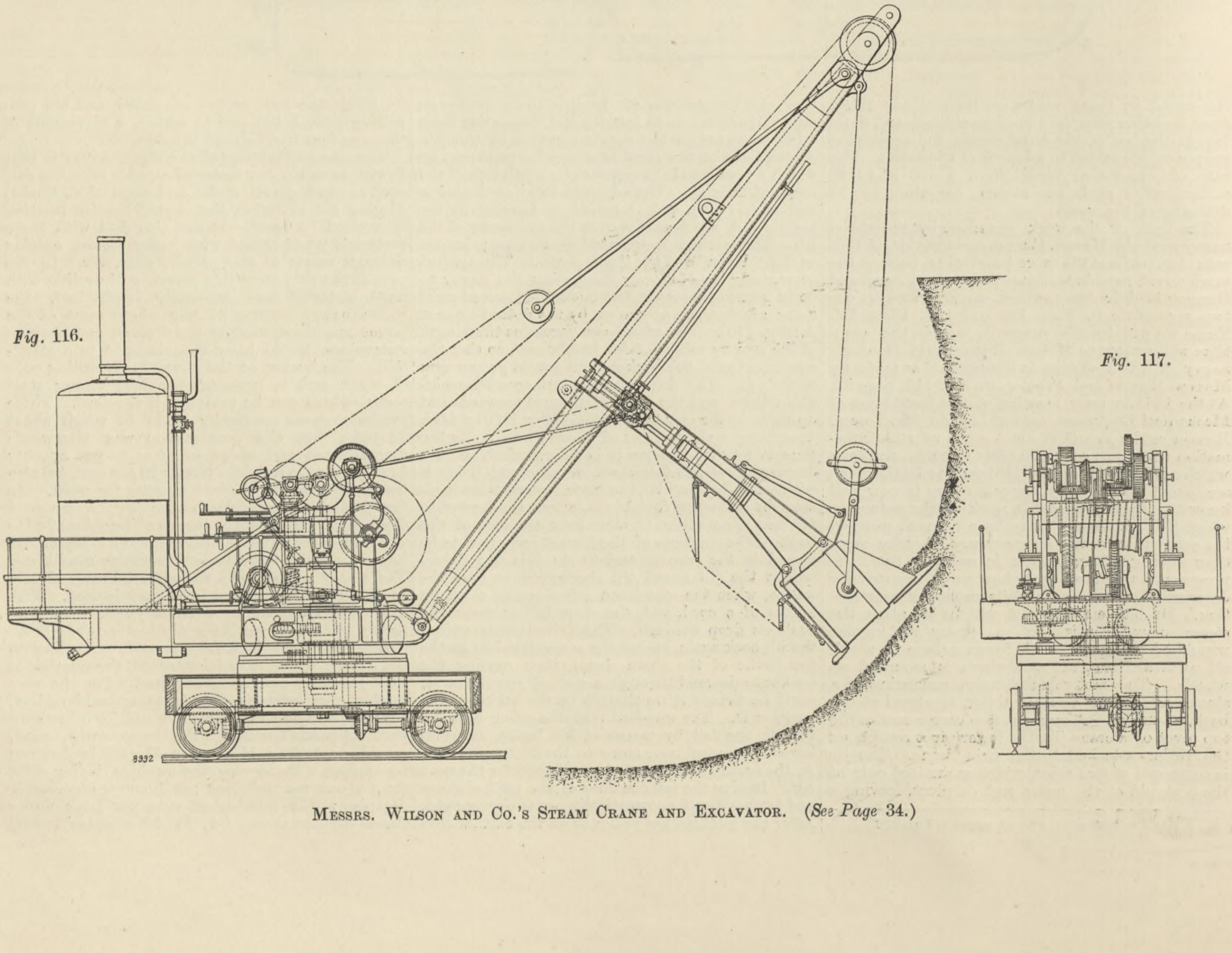
Fig. 115.



The Ruston and Dunbar Steam Navvy. (*See Page* 31.)

Fig. 116.

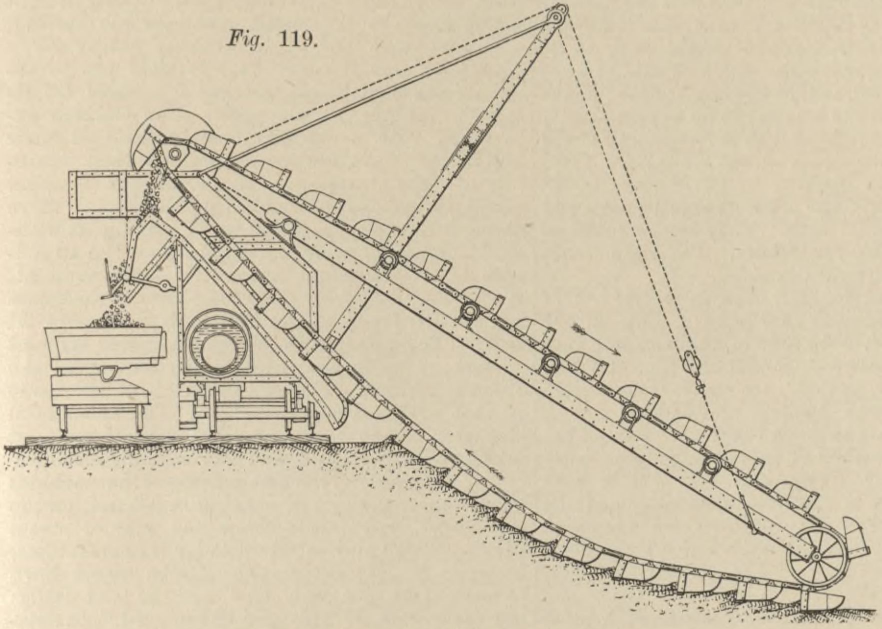
Fig. 117.



Messrs. Wilson and Co.'s Steam Crane and Excavator. (*See Page* 34.)

STEAM EXCAVATORS ON THE MANCHESTER SHIP CANAL.

Fig. 119.



The French Excavator. (*See Page* 34.)

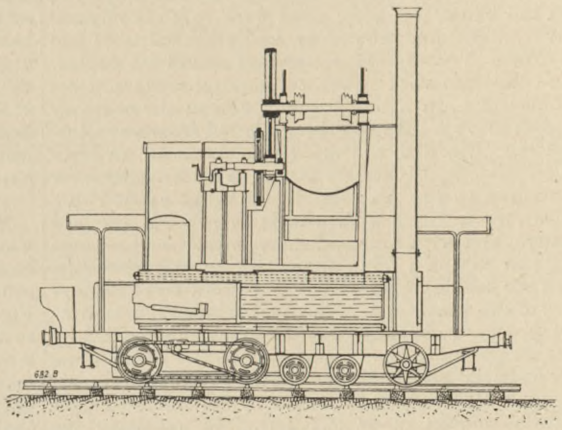
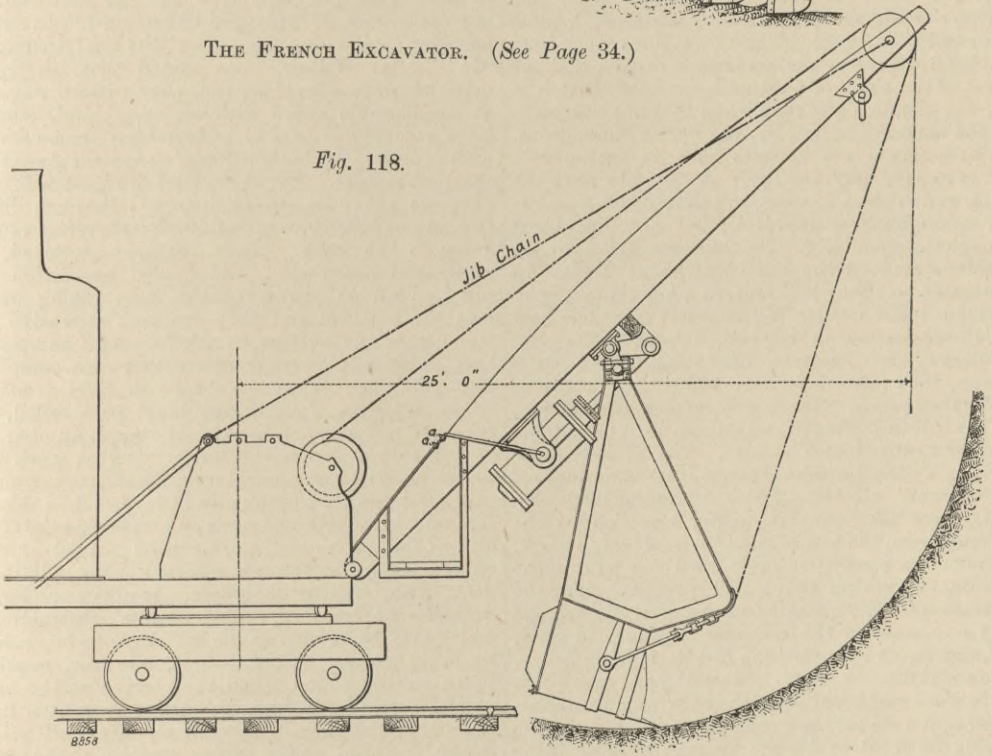


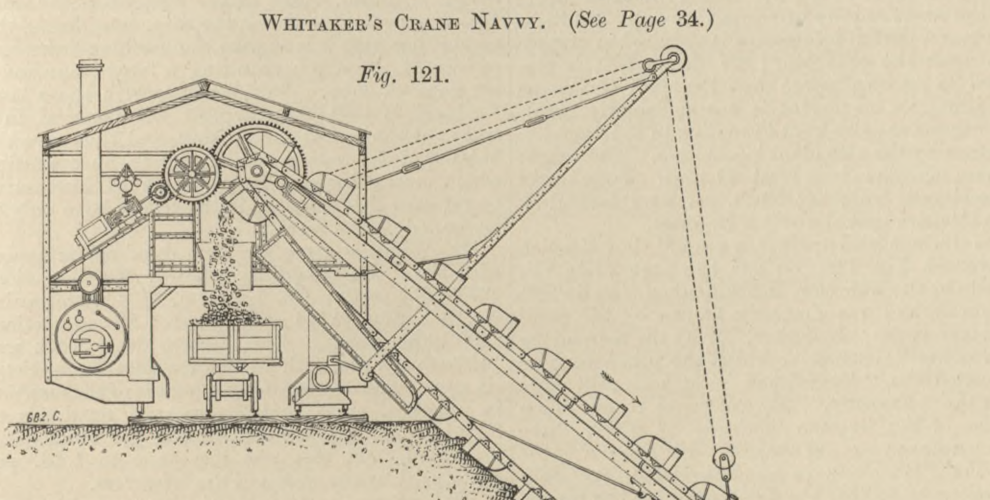
Fig. 120.

Fig. 118.



Whitaker's Crane Navvy. (*See Page* 34.)

Fig. 121.



The German Excavator. (*See Page* 34.)

cutting—is generally 60, which brings the total to 600 buckets per day of 10 hours. The average cost of working is from 3*l*. 10s. to 4*l*. per day, including wages of 12 to 14 men. For the south of England, in one case, the cost of working—10 cwt. of coal, horses and driver, stores, &c.—is put down by Mr. Ruston at 5*l*. 4s. 10d.; in another case, in Scotland, the cost was 2*l*. 18s. 9d. per day. Depreciation, repairs, and interest on capital would be another 1*l*. per day. The total cost of a 32-ton machine is 1175*l*. at the works, carriage and erection being about 75*l*. The figures naturally vary under different conditions. Reckoning by the yard, Mr. Ruston puts down as a fair price for the cost of excavation in sand or gravel 1½d. per cubic yard, and 2d. per cubic yard for hard clay. A saving ranging between 2d. to 6d. per cubic yard over hand labour may, Mr. Ruston says, be reckoned upon, taking 10¾d. per yard as cost by hand labour for stiff brown clay, and for stiff, hard, tough clay containing boulders from ½ cwt. to 4 tons, 1s. 6d. per yard. With one of the earlier machines 4¾d. per yard was the cost when working in material of the latter description. After making allowance for all attendants to the machine, and those engaged in connection with it, the work done by the steam navvy is equal to that of sixty or seventy men. The general advantages to the contractor of the quicker work of the steam navvy will be apparent.

Mr. Leader Williams says that the Ruston and Dunbar steam navvy—of which no less than fifty-eight were used on the canal works, the largest number ever employed on any work—has a power of removing hard material which is greater than that of any machine, soft sandstone rock having being excavated without blasting, explosives being required only in hard rock. He attaches importance to the self-propelling power of the machine, but its great weight leads to heavy timbering being required on very soft ground. He found 600 to 700 cubic yards per day a fair average, but these figures have been largely exceeded on the ship canal under very favourable circumstances. An analysis of the records of working on the ship canal shows that the best day's work was 1100 cubic yards, that being naturally in light soil. A fair day's work is 700 cubic yards, and a fair day's work in clay 450 cubic yards in a day of ten hours. The fact that the steam navvy will only cut forward is a disadvantage. The navvies on the ship canal differed in a few details from the type we now illustrate, and the cost was stated to be about 2000*l*., but this includes many improvements and extras. Its working expenses, including coal and wages, were found to be about 30s. per day, or 0.55d. per cubic yard excavated, but this estimate evidently does not include so much as that given by Mr. Ruston, probably only the three immediate attendants on the machine, there being sixteen men in all.

Before proceeding to deal with the French and German land dredgers, already referred to, we will briefly describe two other excavators of English make, as these, although differing in construction, act on the same principle as the Ruston and Dunbar navvy. The first of these is the steam crane excavator constructed by Messrs. J. H. Wilson and Co., of Liverpool, which we illustrate in Figs. 116 and 117, on page 32. Mr. Leader Williams states that this machine, of which several have been employed on the canal, has done good work. It is comparatively light, and, therefore, easily moved. It can perform a complete revolution round its centre, and thus can work either way, cut out corners, dress slopes, &c., in a better manner than the ordinary steam navvy. As will be gathered from our illustration, Fig. 116, the machine consists of an ordinary 10-ton locomotive crane with an excavator attached to the jib; the whole being carried on a steel truck fitted with wheels to run on standard gauge, and with four additional wheels on the same axle to run on a 7-ft. gauge packing rail when lifting the heaviest loads. The boiler and crane engines are of the usual type. The bucket is carried on arms as shown, the principal feature being the method by which the bucket is fed up to its work. This is done by a special steam cylinder bolted to the arms carrying the bucket, and by means of which the bucket can be moved in or out 2 ft. In operating the machine the bucket is first lowered to the bottom of the cutting, and then fed up to its work, the valves being controlled from the footplate. The crane lifting gear is then put in operation, and the bucket is thus swept up the face of the cutting. Should an obstruction be met, the bucket can be drawn back. Cuttings up to 20 ft. deep and 40 ft. wide have been worked. Mr. Williams says the average capacity of this machine may be taken at 600 cubic yards per day of ten hours. On the canal in actual practice the best day's work was 630 cubic yards, the average being 400 cubic yards per day of ten hours. This machine, it will be understood, only worked in light soil. Messrs. Wilson inform us that the output has gone as high as 1200 cubic yards in a day of eleven hours. On one occasion when excavating 880 cubic yards in a day of eleven hours—including time lost in starting in the morning and stopping in the evening—with fourteen men in attendance (ganger, driver, firemen, two platelayers, and eight navvies attending to roads and wagons, &c), the working expenses were 3*l*. 12s.; or a fraction under 1d. per cubic yard for excavating and delivering into wagons. Mr. Williams puts the working expenses at 25s. per day, or ½d. per cubic yard excavated, but here again, as in the case of the steam navvy, he evidently does not include so much labour as the makers do in their estimate. The total weight of the machine is 35 tons.

The remaining excavator of this type to which it remains to make reference is known as Whitaker's steam crane navvy, seventeen of which machines were supplied for the canal work by Messrs. Whitaker Brothers, of Horsforth, Leeds. Our illustration, Fig. 118, page 33, shows the arrangement. The cost of this machine was less than that of those already referred to, being but 800*l*. Mr. Leader Williams informs us that the working expenses may be taken at 25s. per day, but doubtless he forms his estimate on the same basis as in the two former cases, and therefore does not include so much labour as Mr. Ruston and Messrs. Wilson did. The average work Mr. Williams found could be turned out was 500 cubic yards per day of ten hours, the cost of working expenses per cubic yard working out at ¾d. The best day's work done on the ship canal was 720 cubic yards in light soil. The chief advantage claimed for this machine is that the portion doing the work of an excavator is merely attached to an ordinary steam travelling crane, and by a few minutes' work it can be removed, so that the crane may be used separately for ordinary purposes. The excavating arm and bucket can be fitted to any ordinary pattern of steam locomotive crane. There are two main attachments, one for the bucket arm and the other for an oscillating cylinder, which works the in-and-out rocking motion of the bucket. The cut is made in the ordinary way by the winding and hoisting chain. In the rocking motion the steam pressure on the piston of the oscillating cylinder gives a thrust equal to 5 tons, which, by means of the bellcrank lever, is multiplied to 10 tons. As the hoisting chain draws up the bucket, the cut is made by the oscillating cylinder keeping the bucket up to its work on the face of the cutting. Should a large boulder meet the teeth of the bucket with a greater resistance than 10 tons the resistance overcomes the steam pressure on the piston, and the bucket comes back from the face of the excavation without the hoisting being checked, and when the resistance is passed, the steam pressure forces the bucket back to its work. Another advantage, which is said to be of no little importance, is that the construction of the bucket arm causes the hoisting chain to pull directly over the teeth of the bucket at the beginning of the cut, thus easing the stress on the trunnions. Two of these machines working in the Salford Docks had 1½-yard buckets, the cranes being 10 tons, and weighed complete 32 tons. They are reported to have filled 800 cubic yards daily. For 5-ton cranes the buckets are of 1 yard capacity.

The French land dredgers, already referred to, of which we give a general view in Fig. 113, on our two-page Plate IV, were four in number, and were constructed by Messrs. J. Boulet and Co., of Paris. Figs. 119 and 120, page 33, are respectively a cross section showing the buckets and ladder, and a longitudinal section through the motive part of the machine. The method of operation will be clearly grthered from our illustrations. It will be seen that the machine is really a modification of the usual floating dredger; the hull of which is replaced by a large covered carriage upon which is mounted the actuating machinery. The wheels of this carriage run upon rails laid on the bank above, the machine being self-propelled by means of a pitch chain and wheel gear. These machines differ from floating dredgers in the important respect that the travel of the chain of buckets is reversed, that is to say, the business stroke is when they are approaching the machine, as will be seen by the illustrations. For this reason the buckets have no back-plates, that is to say, they are open at the side next the chain, and in place of emptying themselves over the top, as in floating dredgers, they are discharged through the open back. The first cost of the French machines used on the canal was about 2500*l*. In favourable soil they will remove a large quantity of material. Mr. Leader Williams has given the best day's performance on different sections of the canal as follows: No 3 section, 1943 cubic yards; No. 5 section, 1624; No. 7 section, 2250; No. 8 section, 2025 cubic yaads. These are remarkable figures; but the soil and other circumstances must be suitable in order to afford such results. The average day's work on all the districts is about 1500 cubic yards of soft material. If 440 wagons, containing 1650 cubic yards, were filled per day on No. 8 section by the "Frenchman," it was considered a fair day's work. A bonus of a penny per cubic yard was paid to the men on everything above this quantity. For the excavation of this quantity of material the average daily expenses of the machine in wages of crew, coal, stores, and repairs, the last item being heavy, were about 60s., or 0.44d. per cubic yard excavated. There were employed upon the excavator an engine-driver and a stoker, and round it a number of men varying from 28 to 43, the average number being 35; the roads required frequent moving. In these machines a special locomotive is required in attendance upon the excavator; for although it is traversed by its own power over the train of wagons it is filling, its movement is not sufficiently rapid. The wagons are also kept in motion in the opposite direction by the attendant locomotive. The weight of these machines is at least 80 tons. They travel on steel rails weighing 80 lb. per yard carried by cross sleepers spaced about 2 ft. apart.

The German land dredger, a general view of which is given in Fig. 114, on our two-page Plate IV, is made by the Lübecker Maschinenbau-Gesellschaft of Lübeck, and was generally known by the canal engineers as the "Lübecker," or by the men on the work as the "German"; whilst the other machine was called the "Frenchman"—perhaps still more often the "Frenchy." By reference to our illustration of the German machine—of which three were employed on the canal—it will be seen to be like the Frenchman in general design, the chief difference being that the hut containing the motive machinery—or hull, as it would be in a floating dredger—is made of such a width that the railway wagons can be run right through the centre (Fig. 121, page 33). This naturally adds to the stability of the machine, especially as the boiler can be got well away on the further side so as to oppose the pull of the buckets; it also throws the weight further back from the edge of the slope. With the French machine, where the wagons are loaded at the back, and the wheel base is therefore narrower, special precautions have to be taken in the construction of the road upon which it runs, and the machines have been known more than once, when working in light marsh clays, to tilt bodily over into the cutting, a circumstance not of a soothing nature to a contractor, for it must be a terrible job to set one of these elaborate moving structures on its legs—or, rather, wheels again. The German excavators, with a stability characteristic of their nationality, have always maintained their equilibrium. The traversing power of the German machines was also sufficient to enable them to move ahead at the speed required to fill the wagons without their having to be moved, and thus the attendance of an additional locomotive is not required. We believe, however, that the German designers had the advantage of the French experience to aid them. The weight of the German machine is about 70 tons, it being less substantially built than the French machine. The price was about the same as that of the French dredger. The substantial character of the roads required with these land dredgers, both French and German, increases the cost of working, and the first expense of the machines being heavy, the cost of excavation did not, on the ship canal, fall much below the rate of steam navvies, which may be, Mr. Leader Williams states, taken at 2d. per cubic yard. Grabs are set down to work at 3d. per cubic yard, and the land dredging excavators at 1½d. per cubic yard. In summarising briefly his experience of the land dredgers, Mr. Leader Williams has stated that, in light material and on level ground, they will fill wagons at considerable speed with economy; and, where large excavations of soft material have to be made with rapidity, the bucket-dredging system gives the cheapest results. But these land dredgers will not excavate heavy or strong material; they are difficult and expensive to maintain, and therefore cause delay to the work. They require, as stated, a costly and heavy road, and special precaution in soft ground to prevent them from tilting over into the cutting; and they are very expensive to move from one cutting to another, such an operation practically meaning re-erection of a complex machine. The cutting must be in level ground, or, at any rate, the roadway must be levelled, as they will not climb a bank. The large number of men that are dependent for keeping at work on the running of these machines makes the occurrence of a breakdown exceptionally serious. It is therefore only in certain materials and under special conditions that economical work can be got out of the land dredgers. The softest rock they will not deal with, whilst boulders, trunks or large branches of trees, or other similar obstructions which may be bedded in the soil, have to be moved by other means. They do not, however, require to be turned round when they arrive at the end of the cutting and have to return to take a further cut; for they will work equally well going astern or ahead, as the ladder projects at the side. It is fortunate that this is the case, considering the serious business it is to take the machine down and re-erect it, an action requiring a large crane and a big gang of men. An advantage with these land dredgers is that they deposit the material into trucks at the top of the cutting, and thus save the hauling of the wagons up an incline, an operation which necessitates a large excess of locomotive power over that required if the trucks have only to be hauled on the level.

Mr. Williams gives the best days' performances with the "Lübecker" as follows: No. 3 section, 2073 cubic yards; No. 4 section, 1736 cubic yards; No. 5 section, 1725 cubic yards; No. 6 section, 2400 cubic yards. The average day's work was 1416 cubic yards, with an average number of thirty-six men. The average daily expenses of the machine in wages of crew, coal, stores, and repairs were found to be about 60s., or ½d. per cubic yard excavated, and this was increased to 1.6d. per cubic yard by the wages of the labourers.

Without the powerful excavating machines we have here described, it is hardly possible to think that the canal would ever have been completed. When we look back over the short time that has elapsed since the first introduction of the steam navvy, and the absolute incredulity expressed by many engineers that anything could possibly supersede spade and barrow work until the contrary had been proved in a practical manner, it seems a remarkable thing that so many powerful machines should have been brought to bear on this work, and so much of the excavation should have been carried on by mechanical means.

The numerous sections of the canal, which we give in Figs. 123 to 153, pages 36 and 37—Fig. 122 being a key plan showing the position of the sections according to the numbers—will give an idea of the nature of the banks and the ultimate form taken by the excavation, as well as of the prodigious amount of work that was done by the various appliances we have described. The various engravings, 113 and 114, Plate IV, and Figs. 154, 155, and 156, pages 40 and 41, having been prepared from photographs taken before the water was admitted to the canal, give an excellent idea of the form of cutting. In Fig. 154 the illustration from a photograph is a view of the standard form of cutting in the lowest or Eastham section. This is a typical cutting in rock, the view being at Pool Hall, about two miles from Eastham, and is taken looking up towards Manchester, the estuary of the Mersey being, therefore, on the left. The rock here was blasted in large masses and quarried with crowbars and wedges; and it having been carried out in the ordinary well-known manner, does not require detailed explanation. The locomotive steam crane shown on the right, lifted the large blocks into the wagons. These were used for various purposes in the construction, the smaller pieces being sent to the spoil grounds, or for pitching embankments. The wooden shed in the centre contained a pump. In our series of sections this part of the cutting is shown in Fig. 125.

Another description of excavation work is shown in Fig. 155, page 40. This engraving has been prepared from a photograph taken to show the sharpest curve on the canal, which is that at No Man's Land, approaching Runcorn Bridge. Section 14, Fig. 136, shows the formation here as finished, whilst Fig. 137 is a section under Runcorn Bridge (page 37).

The large widening of the canal which constitutes the Partington coal basin is shown in Fig. 112, Plate IV. Section 25, Fig. 147, is a section here. As the illustration has been prepared from a photograph before the water was let in, the engraving serves to show the nature of the excavation. The Partington coal basin is referred to elsewhere.

A standard cutting of the Barton section is shown in Fig. 156, page 41. This engraving has been prepared from a photograph taken on the canal about $4\frac{1}{2}$ miles from Manchester. It shows the excavation completed down to formation level, the width of the channel at bottom being here 170 ft. The nature of the ground, as will be judged by the illustration, is soft soil, it being sand, and clay mixed with sand. The sandstone rock, however, crops up in a few places. The sides of the slopes are cut to an inclination of $1\frac{1}{2}$ in length to 1 in depth, and are pitched with large blocks of sandstone of the harder quality taken out in the rock cuttings. In the illustration the men may be seen at this work. The pitching is very carefully done, the stones being set on edge, having smaller pieces and chips to fill up, sand and gravel being last placed on. The pitching is about 30 in. thick at bottom, diminishing to 18 in. at and above the water level. A strong horizontal toe is formed all along the bottom of the slope to secure a firm abutment to the mass of stone.

It may be stated that where the soil is soft the stone pitching is necessary to prevent possible injury to the banks from the wash of passing steamers, though the speed is to be confined to six miles per hour. In stiff clay a slope of 1 to 1 is considered sufficient without stone pitching. In hard rock, as illustrated in the Eastham cutting, Fig. 154, the banks may be almost vertical or of a batter of 1 in 6.

The Manchester and the Salford Docks, situated at the head of the canal, naturally afforded the largest amount of excavation within a given radius. Our illustrations of the Salford Docks (Fig. 157, page 41, and Fig. 158, page 44) show respectively the excavation completed, with the quay walls approaching completion, and the putting in the foundations of the quay walls. Fig. 159, page 39, is a plan of the upper part of the canal, from just below Mode Wheel Locks, and of the Salford and Manchester Docks. Fig. 160 gives sections through the Manchester and Salford Dock piers. In the sections on page 37, Fig. 153, is shown that just below the Salford Docks, and Fig. 152 shows the cross-section just below Mode Wheel Locks. From these locks up to the Salford Docks the canal is 350 ft. wide, so that it is really a dock in itself; in fact, the whole space above the locks up to the temporary railway swing bridge forms an extensive series of docks. Below the Mode Wheel Locks down to Barton Locks the canal is 170 ft. wide at bottom, with wall sloping $1\frac{1}{2}$ to 1, so that for all this distance of $3\frac{1}{4}$ miles there will be room for one ship to lie and two to pass at once.

It would be tedious and unprofitable were we to give in detail a description of the excavation as carried out throughout the canal. There has already appeared in ENGINEERING, at various periods during the progress of the work, full descriptions of this part of the construction. Our description of the machinery used will give the best idea of the manner in which the excavation is carried on, and it cannot be necessary to describe the ordinary spade work, by which a considerable part of the digging of the canal was executed.

XI.—WALLS AND EMBANKMENTS.

A large proportion of the earth embankments made during the construction of the canal were of a temporary nature, being required for the diversion of the river when its bed had to be utilised as the site of the canal. It will be necessary, therefore, in dealing with this part of the work, to say something about the manner in which the canal has taken the place of and obliterated the old natural river. This feature, however, applies to the canal above the neighbourhood of Warburton, and therefore does not require to be dealt with just at present.

Beginning at the lower end of the canal, we find that in the Eastham section there are $5\frac{3}{8}$ miles of embankment and $4\frac{5}{8}$ miles of cutting. A reference to the key map of sections, Fig. 122, page 36, and to the sections themselves as indicated on the map (Figs. 123 to 131), will give a good general idea of the banks in the Eastham division. The embankment between the canal and the estuary is generally of clay got from the cuttings. The method of operation was, for nearly the whole of the canal, as follows, the chief exception being the embankment at Ellesmere Port, and the concrete wall at Runcorn, both described later. At first two rubble toes were tipped, the distance apart being such that they would eventually form the inside and outside toe of the embankment. This material naturally sank into the mud until it rested on the hard bottom. The space between was next filled up with clay taken from the cuttings, and a bank of the required height was raised, allowance being made for the consolidation. This clay bank was ultimately faced with stone quarried from the cuttings, and also from the neighbouring quarries of Runcorn.

Ellesmere Port is the first important point after leaving Eastham, from which it is distant about four miles, and here, where the end of the Shropshire Union Canal is situated, some difficult and interesting work was carried on. The Manchester Ship Canal Act enforced the keeping open of the Port of Ellesmere to the Mersey until the Eastham Locks were available for the traffic; that, of course, in turn, necessitated that the canal should be complete from Ellesmere to Eastham. The ship canal here encroaches on the estuary, cutting of a part of the bight forming Ellesmere Bay. In order to form the outer or estuary bank of the canal, an embankment had to be made on that part of the shore which is covered by water at high tide. This embankment now crosses the old channel leading up to the Ellesmere Docks, the fairway being down the canal; but, until the canal was made, the channel had to be kept open, and the embankment naturally had to have a gap in it. Figs. 163 and 164, on page 45, illustrate this part of the work during its progress. In Fig. 163 the view is towards Eastham, Ellesmere Port being on the left; whilst in Fig. 164 the opposite direction is shown, the Cheshire shore being on the right. The nature of the finished embankment in this neighbourhood may be judged from Sections 4 to 6, Figs. 126 to 128, page 36. The construction was one of some difficulty. The nature of the ground across the bay on the line which the canal followed was composed to a considerable depth mainly of mud and sand, the ordinary river deposit being quite unable to support the weight of an embankment. It was, therefore, found necessary to secure the stability of the embankment by the construction of a strong hearting of driven and well-connected piles. The hearting consists of two outside rows of close sheet piling of 12-in. square balks, 105 ft. distant from each other, with an inner double line of equally strong piles 33 ft. apart in cross-section, and 6 ft. longitudinally; the whole being connected by continuous longitudinal and transverse half-timbers, as well as by iron tie-rods $2\frac{1}{4}$ in. in diameter, and by heavy chains. In the execution of this work over 150,000 piles, each about 30 ft. in length, were driven. The upper part of the work is what is seen in our illustrations, and it served as a jetty on which to bring the ballast trains up close to the points of tipping. As this work was completed, the upper part was removed, but there still remains permanently buried in the ground, and completely covered by the bank, about 650,000 cubic feet of timber. It will thus be seen that the permanent timber hearting was used for a part of the jetty on which the material to form the bank was brought up, the upper part of the jetty being removed as the work was completed.

Fig. 163 shows the steam pile-drivers at work. Of these there were twenty-four going night and day. The difficulty of getting the piles down through sand of this nature is well known; but fortunately there is a ready way out of the difficulty by means of the water jet. In the present case 2-in. iron pipes had to be forced down with each pile, and high-pressure water was pumped down to clear the sand away from the point of the pile. The effect was very marked, in the present case an old hand, who, however, had not seen the jet used before, remarking that the piles went in "like a hot skewer into butter." The work could only be carried on when the tide was out, as the rise of water flooded the work. For this reason no difference was made between day and night tides, powerful electric and Wells' lights being used; the effect of Ellesmere Bay being lit up in this way being very striking across the water on a clear dark night. In the formation of the embankment the space between the inner rows of piles has been filled with the best and stiffest clay which could be procured, and with large blocks of stone. Upon these the excavation was tipped, and this in turn is covered by masses of large blocks of stone, carefully packed in, on the canal side. This jetty naturally could not be continuous, as the channel to the docks had to be kept open. This gap was required to be 60 ft. wide, and in order to make the railway on the jetty continuous, a temporary swing bridge was provided.

The Ince Bay Embankment comes next to that of Ellesmere Bay, the canal again skirting the estuary, after cutting across Stanlow Point. Here in parts the embankment has been strengthened by a timber hearting. Afterwards, however, the formation is different, as may be judged by Section 9, Fig. 131, page 36, which shows it to be sandstone rock. For a time the canal leaves tide-covered ground until the mouth of the Weaver is reached, a part we have dealt with elsewhere in describing the Weaver sluices. The section here is shown in Figs. 133, 134, and 135; Fig. 134 being a section through Weston Mersey Lock, hereafter referred to.

In passing under Runcorn Bridge there is some interesting work. Figs. 139 and 140 show sections here, whilst Fig. 10, Plate I, to which reference has already been made in dealing with the bridges, shows the mode of construction of the concrete wall which passes under the left span of the bridge, that nearest to Runcorn, and extends from a small island, known as No Man's Land, to the new Runcorn Lock, opposite the old docks of the Mersey and Irwell Navigation Board. The concrete wall, which here takes the place of the embankment, separates the canal from the estuary of the Mersey. The canal occupies only one-half the span of Runcorn Bridge on the Cheshire side, the outer side of the concrete wall being exactly in the centre of the span. The wall is built of Portland cement between two rows of sheet piling 22 ft. apart inside to inside, the space between these piles being divided into compartments, the most economical and effective being 60 ft. in length. These were pumped nearly dry and excavated by sand pump, grabs, or manual labour, according to the material. In some places rock was found, in others hard gravel was got 3 ft. below the bottom level of the canal. The wall is vertical on the inner or canal face, and on the estuary side, from low-water level upwards, it batters so as to reduce the top width to 16 ft. The coping on either side is of sandstone, and on the canal side the wall is protected by a system of vertical and horizontal fenders. Much difficulty

STANDARD SECTIONS OF THE MANCHESTER SHIP CANAL.

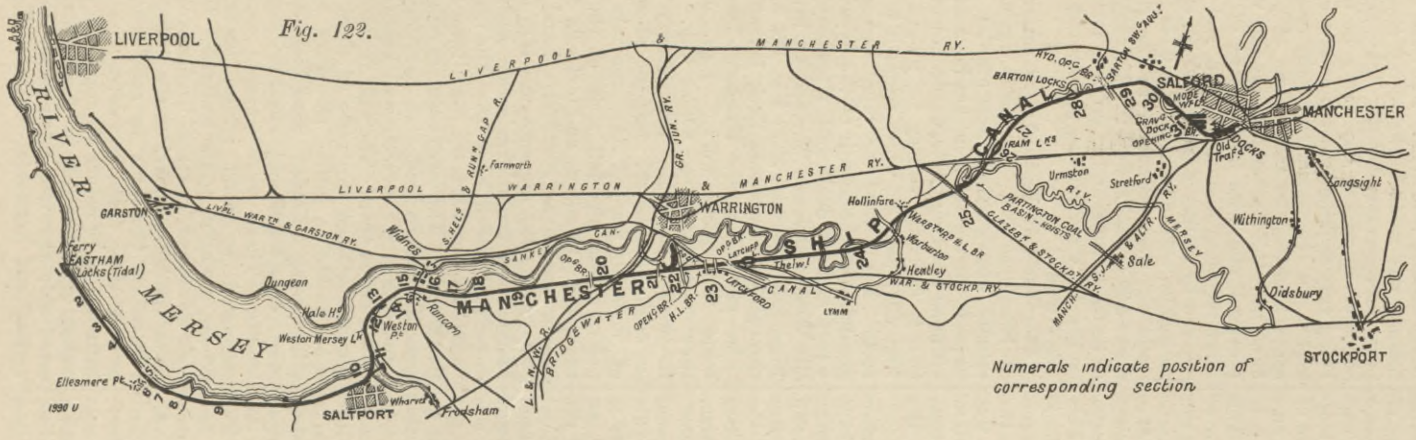


Fig. 122.

Numerals indicate position of corresponding section

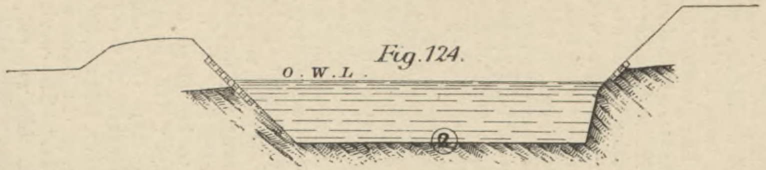


Fig. 124.

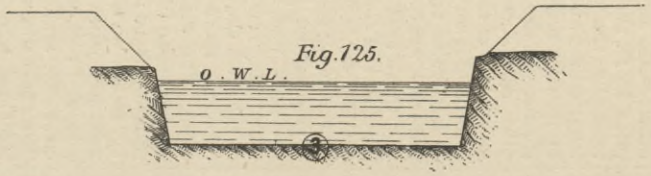


Fig. 125.

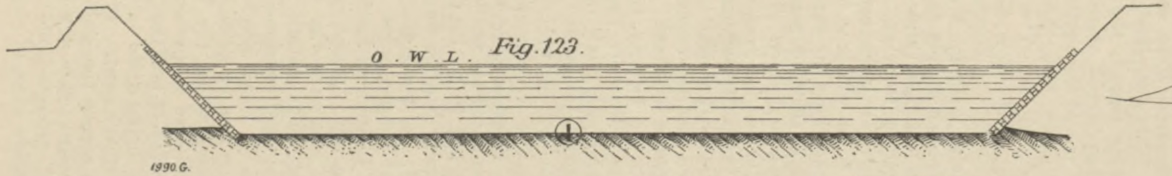
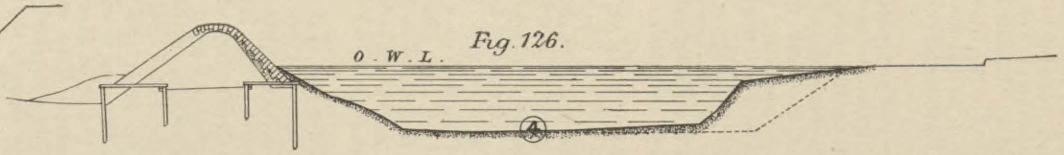


Fig. 123.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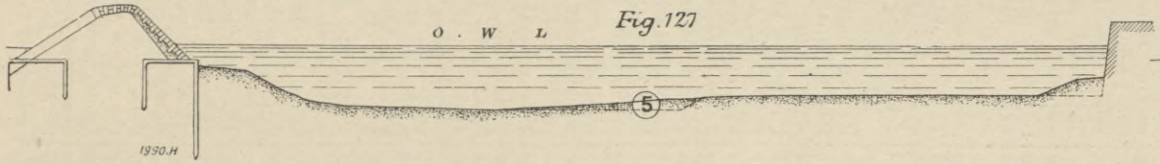


Fig. 127

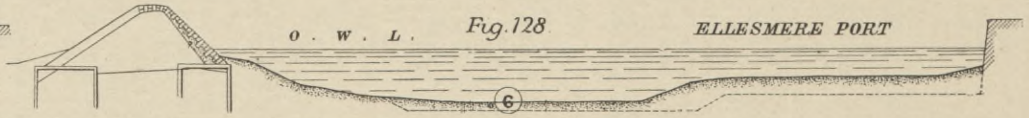
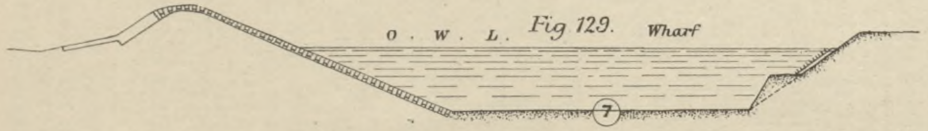


Fig. 128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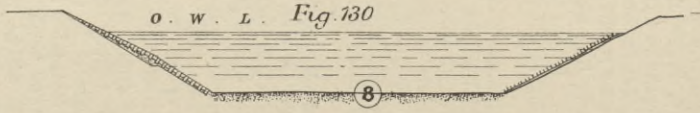
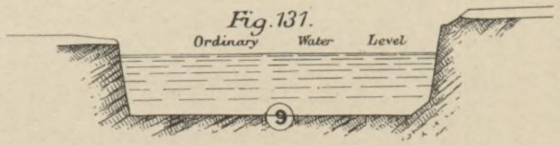


Fig. 130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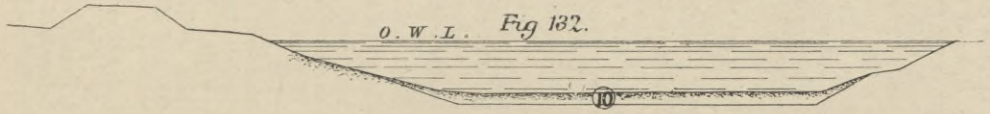
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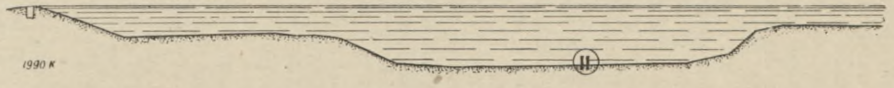


Fig 133

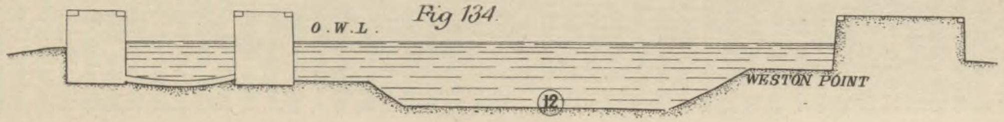


Fig 134.

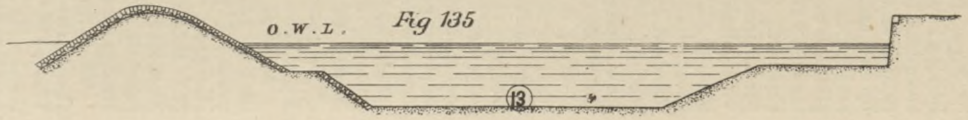


Fig 135

STANDARD SECTIONS OF THE MANCHESTER SHIP CANAL.

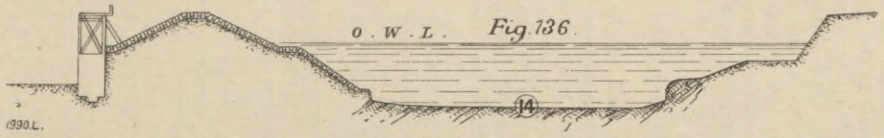


Fig. 136.

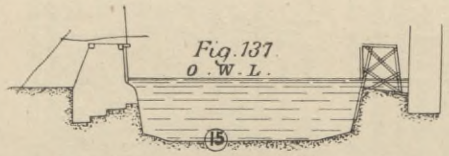


Fig. 137.

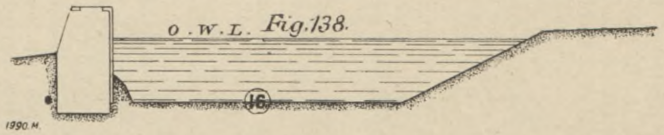
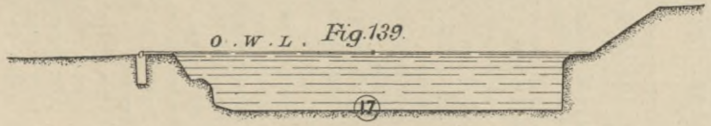


Fig. 138.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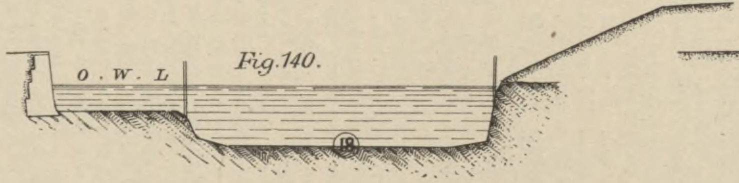


Fig. 140.

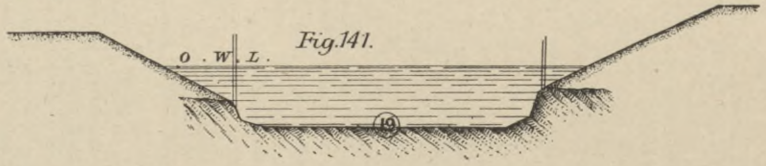


Fig. 141.

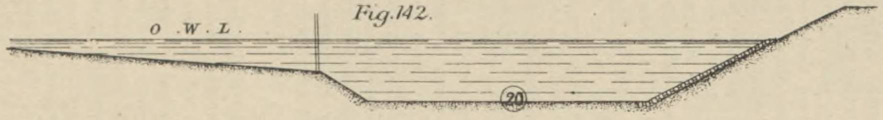


Fig. 142.

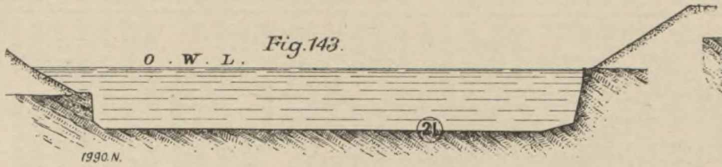


Fig. 143.

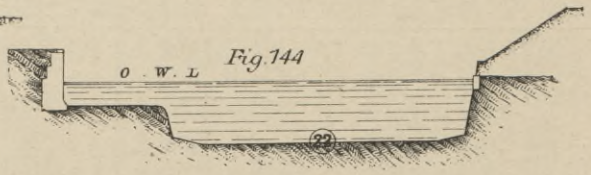


Fig. 144


Fig. 145.

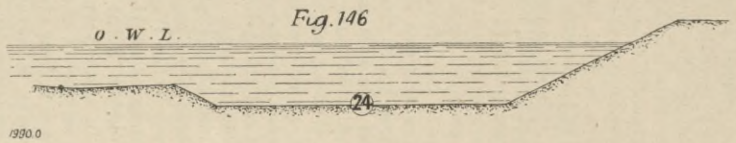


Fig. 146

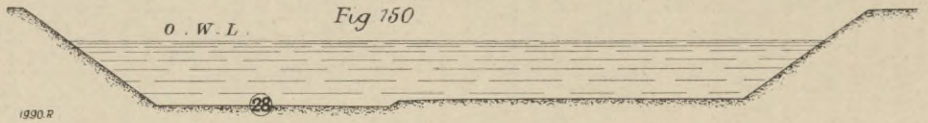


Fig 150

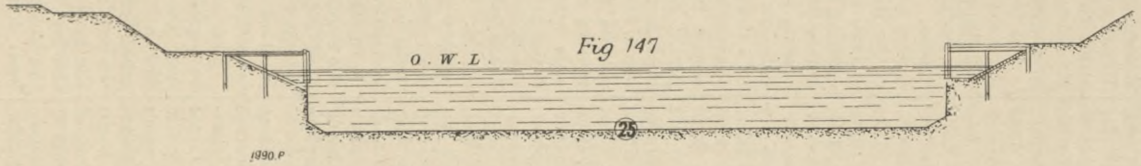


Fig 147

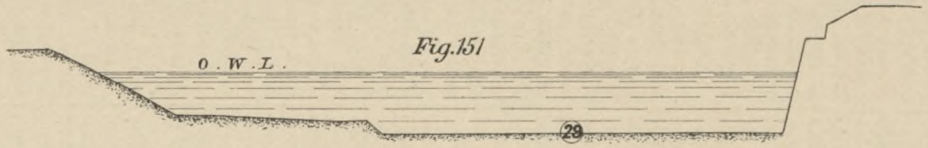


Fig. 151

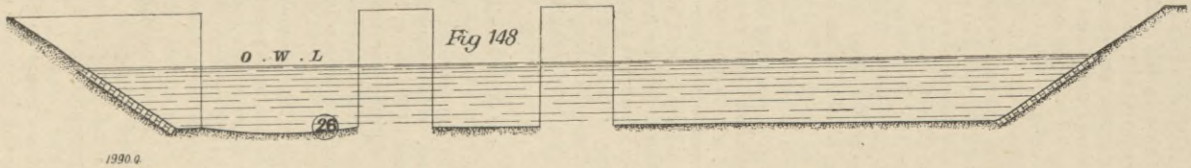


Fig 148

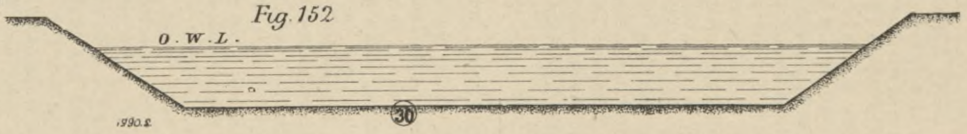


Fig. 152


Fig 149.

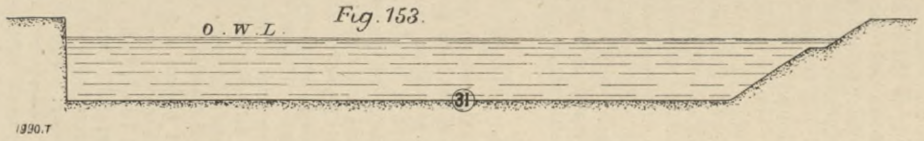


Fig. 153.

was experienced in the construction of the length of this wall immediately above Runcorn Bridge, the ground being so very treacherous, and, to increase the difficulty, timbers of all sizes were found, leading to the belief that the wreck of an old boat had been discovered. Many forms of sheet piling and other temporary dams were tried to enable the foundations to be built, amongst others cast-iron piles; but the most effective and economical method was found to be a lining of half-timbers 12 in. by 6 in., the ends being cut to an angle, with the apex cut off. There were inside and outside wallings. The space thus divided off, as it was excavated, was afterwards filled up to low-water level. The other portions of the wall were constructed with shutters. This concrete wall runs up to the Runcorn Lock, which affords entrance to Runcorn Docks. There is about half a mile of embankment further, and the canal then strikes inland, so that no further embankments are required.

XII.—OTHER ENGINEERING FEATURES.

Having so far described, under the various headings, what may be described as the leading features and principal works of the canal, it now remains to give a brief notice of those more general engineering details which must not be overlooked. Proceeding upwards from Eastham, the first object of interest after leaving the locks is a wharf, which has been constructed for the use of adjoining landholders. There are several of these in the course of the canal, and we shall not consider it necessary to refer to them in detail, although they are features of considerable importance to their surrounding districts.

At about a mile and three-quarters from the locks we arrive at a syphon, which takes the Pool Hall brook into the estuary. This may be taken as typical of much work that has been required in dealing with the drainage of the surrounding country. The brooks and streams which flow into the estuary are naturally tidal, and as the canal level has a minimum depth of water such as would be due to a 14 ft. 2 in. tide in the estuary, it will be evident that the canal could not be used for receiving the waters of these streams. Hence it was necessary there should be syphons to deal with the drainage. They are of various construction—either of iron or masonry. The chief is that which carries the waters of the River Gowy at Stanlow Point. The syphon consists of two cast-iron pipes 12 ft. in internal diameter. Each pipe is constructed of six segments on the circumference with the flanges placed inside. The thickness of metal is 1 in., the bolts being 1¼ in. in diameter, placed at 6 in. pitch. The two pipes are placed side by side in a bed of concrete, 1 ft. in thickness at the top, at the sides, and between the pipes, which rest on a 2-ft. bed of concrete. The ends of the syphon pipes on both sides are set in solid brickwork with a strong concrete base, and are thoroughly bonded and combined with the concrete casing of the pipes. On the land side, sluice gates, arranged with rollers on Stoney's principle, are placed, and by means of these, the flood water may be stored up to any extent in order to more effectually scour the pipes and clear out deposit. The water is conducted to and from the syphon pipes by a channel of ample dimensions pitched with stone. The total length of syphon, including entrance and exit chambers, is about 400 ft.

On the left bank, shortly after leaving Pool Hall Bay, there is a feature in the landscape which deserves mention. This is the considerable elevation known as Mount Manisty. Where it now stands was, before the commencement of the work, level ground, this hill having been formed by material taken from the cuttings in the neighbourhood, and being named after the contractor's agent by whom the work was done.

We have already dealt with the embankment at Ellesmere Port, which is the next point of interest we reach. The docks forming the means of communication between the Shropshire Union Canal and the Mersey have been greatly benefited by the formation of the ship canal, as they are now open at any state of the tide. Here also the Ship Canal Company have constructed new gates to the basin entrance, and have provided pumping machinery of very large capacity to pump out the tidal basin if necessary for repairing the gates. On the estuary side at Ellesmere Port we come to the first tidal opening in the embankment, by means of which the influx and efflux of tides over 14 ft. 2 in. are provided for. This provision was enforced by the company's Act in order to maintain the full volume of ebb and flow in the estuary. The opening consists of a break in the embankment 600 ft. long. It is spanned by a timber gantry to maintain through communication along the embankment. The opening forms a weir, the sill of which is at the level of lowest water in the canal, *i.e.*, 14 ft. 2 in. above old dock sill. This level is known as ordinary water level in the canal.

A short distance above the tidal opening, and on the opposite side, is a notable feature—the Manchester Dry Dock and Pontoon Company's floating dock. This structure was constructed on the Tyne, and successfully brought round by sea some time before the opening of the canal; it has been largely used since it has been in place. The dimensions are 300 ft. long by 70 ft. wide. While mentioning this pontoon we may conveniently make reference to the dry dock, the property of the same company, which has recently been finished, and will shortly be ready for use. It is situated at the head of the canal, just above Mode Wheel Locks on the Trafford side. This dock is 450 ft. long by 65 feet wide, and, having all necessary appliances for docking vessels, will form a convenient ship-repairing station. There is an advantage in the position of this dry dock near the locks, as the dock outlet delivers below the lock, whilst the water for filling is taken at a higher level. In this way a large amount of pumping is dispensed with.

Passing the syphon of the River Gowy, to which reference has already been made, we arrive at Ince Ferry. There are several of these ferries on the canal, which have to be maintained in consequence of existing public rights of way. The ferryboats used are capable of transporting horses and carts, cattle, &c., and are all worked by hand. There are substantial approaches to the ferries. After this, as may be judged from Section 9, Fig. 131, page 36, the rock formation is again entered, the cutting here being the largest on the section. Emerging from this cutting, and passing Ince Wharf and Holpool Gutter, which drains into the canal, the course enters the large tract known as Frodsham Score, a flat, marshy district in the neighbourhood of the mouth of the Weaver.

The Weaver estuary is one of considerable importance in the ship canal, both from an engineering and an economic point of view. It is here that the Eastham section ends and the Runcorn section begins. On a previous page we have described the sluices which have been formed to pass the waters of the River Weaver direct into the Mersey. There is here also, close by, in the embankment, a tidal opening for half-tide ebb and flow, similar to that before described. On the opposite side, just before coming to the Weaver mouth, is the new depôt of Saltport, which, as we have seen, bids fair shortly to be a town of some importance. The estuary of the Weaver was in old times but a sea of mud, intersected by feeble streams, excepting for a short period before and after high water. The Weaver itself is a canalised river, and found its chief opening to the Mersey by the Weston Canal. This canal skirted the estuaries of the Weaver and of the Mersey until Weston Point was reached, about a mile above. In consequence of the ship canal cutting off the estuary of the Weaver from that of the Mersey, there is now always a fair quantity of water in the former, it never becoming low tide as of old. It is proposed to dredge out the Weaver estuary at its lower part near the ship canal, to erect wharves, and, in fact, form it into a vast basin or dock. Time will show how far these expectations will be carried out; but that they are to be fulfilled in the not distant future is evidently the opinion of many persons in a position to form a good estimate, if one may judge by the transactions that have been carried on in the neighbourhood of Frodsham. In the meantime, the water space forms an excellent timber pond.

The length of the Weston Canal, to which we have made reference, connects with the ship canal near the Weaver estuary by means of Weston Marsh Lock, which has been constructed by the canal company. This lock is of the same type as the smaller locks at Eastham. It is, of course, on the land side of the canal. It is interesting from the fact that the gates are operated by turbines, the head being about 3 ft. The arrangement has been found to give every satisfaction. The two canals run side by side, as stated, until the Weston Docks at Weston Point are reached, the Weston Canal having, of course, the inside berth.

Weston Docks would doubtless have been of much greater importance in the past had they had a better sea communication, but the upper part of the Mersey estuary has always been shallow and difficult to navigate. It is a curious fact, which we pointed out ten years ago, when describing the Weaver Navigation, that the little Cheshire stream was able to take vessels of greater draught than could get to the sea after they had arrived in the Mersey. Of course this want of draught was very much against the Weston Docks, but now there is a depth of 26 ft. of water at any time leading from the deep-water part of the Mersey estuary right up to their entrances.

Opposite to the Weston Docks is the Weston Mersey Lock, the first lock in the ship canal embankment (see Section 12, Fig. 134, page 36). This, of course, forms a communication between the canal and the Mersey, and will pass vessels 45 ft. wide, it being 600 ft. long, and having intermediate gates. There are, indeed, five pairs of gates. It is constructed, in accordance with the provisions of the company's Act, to allow the Weston Docks traffic direct access to the Mersey. The Shropshire Union Canal had also power to compel the Ship Canal Company to make a lock in their embankment at Ellesmere Port, but the Shropshire Union people very fairly and wisely said that if they could get free access to the Mersey, up and down, either through the Eastham Locks or the Weston Mersey Lock, they would be quite satisfied. This liberal spirit saved the Ship Canal Company a good deal of expense and trouble, and as the older canal profits too, there is contentment all round. It should be stated, however, that the ship canal did certain work and made certain concessions in exchange.

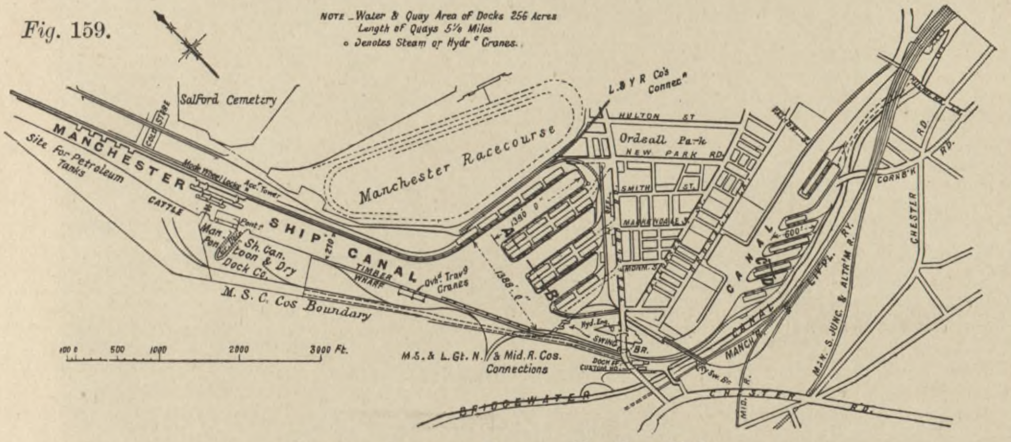
Rather less then a mile above the Weston Mersey Lock, and at a distance of 11½ miles from Eastham Locks, is another lock in the embankment. This is the Bridgewater Lock, which is similar in construction to the Weston Mersey Lock. It is 45 ft. wide and 450 ft. long. This gives direct access to the Mersey from the Bridgewater Docks (which are now the property of the Ship Canal Company), and to the system of locks, which here form the termination of the Bridgewater Canal. This lock also serves for an inlet to barges coming from Widnes, which is, as is well known, a great chemical manufacturing centre on the Lancashire side.

We have already described the formation of the canal in passing under Runcorn Bridge, about half a mile above which we come to the third lock in the canal embankment. This is Runcorn Lock, which is 45 ft. wide and 280 ft. long. It serves to give direct communication between the River Mersey and the wharves and lay-bys in this part of the canal. It will probably attract a good deal of salt traffic for the chemical industry on the Lancashire side. A quarter of a mile above is the third and last tidal opening, which is similar to those already referred to. From this point the canal strikes inland.

We now come to the first of the road bridges, namely, Old Quay or Runcorn swing bridge. This we have already described when dealing with the bridges of the canal. A lay-by here is chiefly for the use of the Old Quay Chemical Works, and enlarges the width of the canal by 40 ft., and provides a depth of water of 12ft. and 7 ft. at the two ends respectively. It is about 1200 ft. long, and has been constructed on the bed of the old Runcorn and Latchford Canal. Randle's sluices, already mentioned, follow. They are for discharging surplus land water from the ship canal into the Mersey in times of flood.

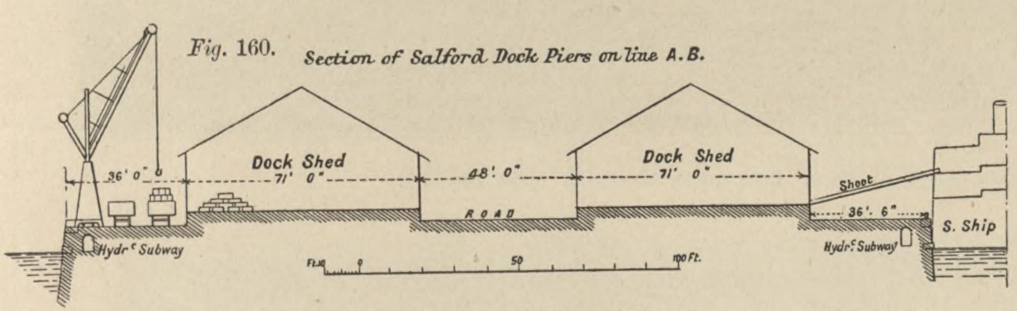
Shortly above these sluices we leave the Runcorn section, and get to the Warrington section. Proceeding towards Warrington, and about 3 miles from Runcorn swing bridge, there is a pumping station known as Bob's Bridge pumping station. It has been provided to supply water to the Old Quay Chemical Works, about 3 miles further down on the ship canal. These had originally a right to draw water from the Runcorn and Latchford Canal, but the ship canal having obliterated this, they have had to supply the chemical works with water. This system was also provided with a view to supply other works which may be started on the canal. The pumping machinery is in connection with a very extensive system, which covers more than 5 miles in the length of the canal. The main has already been laid, and is 4 ft. in diameter for a large part of its length, up to the Warrington Dock entrance. The laying of this main was a problem of some difficulty, and required very nice scheming in order to overcome the obstacles in its path. The Moore-lane swing bridge, with its hydraulic installation worked by a petroleum engine, comes next, after we leave a lay-by constructed for a colliery near by. The first of the railway crossings is a short distance above. This viaduct serves for both No. 1 and No. 2 Railway Deviations. These we have described elsewhere. Passing the Stag Inn swing bridge we come to the entrance of the Warrington Docks, the latter being still in process of execution. As our present purpose is to describe the engineering features already complete, we shall postpone any further reference to the Warrington Docks and of Walton Lock, which is in connection with them, until a future occasion.

Fig. 159.



Plan of Salford Dock. (*See Page* 35.)

Fig. 160.



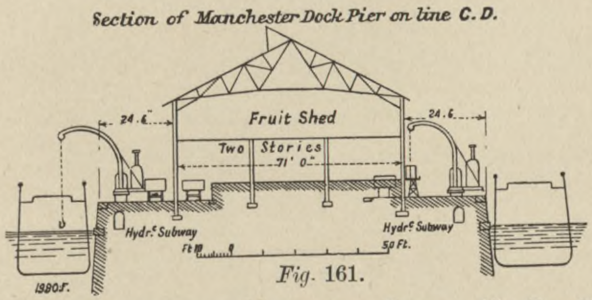


Fig. 161.

Sections of Salford and Manchester Docks. (*See Page* 35.)

About half a mile above Warrington Dock entrance is Northwich-road swing bridge, better known as Stockton Heath Bridge. Underneath the short arm of this bridge is Twenty-steps barge lock, which is 19 ft. wide and 80 ft. long, the rise being 12 ft. 6 in. It is the means of communication between the ship canal and that portion of the Runcorn and Latchford Canal which has not been absorbed by the ship canal. Barges passing through this lock and along the Runcorn and Latchford Canal gain access to the upper reaches of the River Mersey by the Latchford Locks of the river. Latchford cantilever high-level bridge, which is similar to the Warburton Bridge illustrated in Fig. 13, Plate I, and described elsewhere, and the Knutsford-road swing bridge, follow quickly after, and the viaduct of Railway Deviation No. 3. Immediately above is the first group of locks after Eastham. These are the Latchford Locks, referred to elsewhere, and which form the division between the Warrington and Latchford sections.

The hydraulic pumping station in connection with the Latchford Locks supplies the motive power for working Knutsford-road, Stockton Heath, and Stag Inn swing bridges, necessitating two miles of hydraulic main, an accumulator being provided at each end.

A short distance above, the canal passes close to one of the diversions of the River Mersey, which have been made in order to give a straight course to the ship canal. Although these river diversions are important works, and, it may be added, improve the navigation of the river itself, we do not propose to give a description of them here, as they do not form an essential part of the construction of the canal.

About 3 miles above Latchford Locks the point of departure of the River Mersey from the ship canal is reached. The confluence of the Mersey and Irwell was near Irlam, and the former river still flows into the ship canal close to the original spot. From thence to the point we have now arrived at in our description, the joint waters of the two rivers are passed down the canal, the bed of the old River Mersey being obliterated for that distance. It, however, takes its ancient way, with the exceptions of deviations at Thirlwell and Warrington, from the part of the canal we have now arrived at. The waters of the ship canal and the Mersey are here at a level, it being understood that the tide comes up the River Mersey no higher than Hooley Weir, near Warrington. Barge traffic can come from the River Mersey into the ship canal at the point of junction of the two waters. Opposite to the latter spot the river Bollin discharges into the ship canal. This stream carries the drainage of a large extent of country extending back to Macclesfield.

The high-level road bridge at Warburton is the next object of interest, and a short distance higher up we come to the Glazebrook outfall, and with that ends the Latchford section. The Glazebrook carries the drainage of the neighbouring district into the canal.

The Irlam section begins here; the first object being the Millbank Wharf and Lay-by, which is on the south side. This takes the form of a dock 400 ft. long and 50 ft. wide and 6 ft. deep. It occupies a part of the old bed of the River Mersey. It has been constructed to serve the Millbank Paper Works. Deviation Railway No. 4, known as Caddishead Viaduct, follows.

We now arrive at an important feature in the canal. This is the Partington Coal Basin, to which reference has already been made, and which is illustrated in Fig. 112, Plate IV. It is formed by the widening of the canal, the width here being 250 ft.; so that there will be room for vessels to lie on each side and two ships to pass in the middle. It is at present equipped with four coal hoists; foundation piers are, however, provided for two more. The larger coal hoists are provided to lift 19 tons through 26 ft., and the smaller hoists 19 tons through 18 ft. The hydraulic machinery has been supplied by Armstrong, and is of the type adopted in the coal-shipping ports of South Wales, with which our readers are familiar. The motive power is obtained from the Irlam Lock station. The hoists are connected with those portions of the Cheshire Lines Committee's Railway which have been replaced by Railway Deviation No. 4, and have become the property of the Ship Canal Company. Connection is obtained with the main lines at Partington on the north side, and Glazebrook on the south side. Each hoist is provided with two lines of siding, one being for empty and the other for full trucks. The trucks are brought on to the sidings leading directly to each tip by the locomotives. They are then at a higher level than the platform of the tip, so that they descend by gravity to the end of the siding. From this point they are lifted by the hydraulic hoist through a vertical distance of about 16 ft., and are tipped to discharge their contents, and are then at a sufficient elevation to be carried back to the locomotive by their own gravity, it being, of course, understood that the different lines are used for the empty and the full trucks. Between the piers of the coal hoists substantial timber quays have been constructed, as shown in Section 25, Fig. 147, page 37. These are for the discharge of timber, pit-props, &c. The Partington Coal Basin is in the rock, and some difficulty was experienced in attempting to pitch the piles; for though the rock was too hard for driving, it was not consolidated enough to support the timber structure. A dwarf wall of concrete was therefore constructed, the piles being built in.

A good deal of importance is attached to the coal traffic that is likely to follow the opening of the canal, and of which Partington will doubtless be the centre. With the four coal hoists now existing, the capacity is between 400 and 500 tons an hour. The basin is the nearest loading port to both the Wigan and South Yorkshire coalfields, being about 11 miles from Wigan, and 43 miles from Barnsley. These colliery districts are therefore provided with an outlet to the sea which cannot fail to be of great importance to them and to the trade generally.

In the Irlam section there are important wharves, two for the Corporation of Manchester and one for the Corporation of Salford; there is also a fourth, constructed for the Wholesale Co-operative Society. The three former are of timber, whilst the latter is a very strong concrete wall, with ashlar copings, fenders, &c. It is intended to construct a large soap works on the site behind this wharf, which has communication with the canal, and with that portion of the Cheshire Lines Committee Railway which is now the property of the canal company. Near these wharves is the Mersey Weir, which is the point at which the waters of the upper part of the River Mersey are received into the canal. The drainage area of the River Mersey is about 222 square miles. The weir is 100 ft. wide, the fall being 8 ft. The weir consists of a row of close piling, in front of which is another of raking piles, 6 ft. in front of the sheet piling, and of 6 ft. centres. The front of this is planked with 3-in. greenheart, the space between being filled with puddled clay. In front of this row of piles is another, supporting a concrete apron, on which the water falls vertically, and then runs over an inclined slope, carefully pitched, into a channel running obliquely into the canal, and 16 ft. deep. This weir is naturally an important feature, as much depends on its action. It has received a good practical trial of its efficiency, two floods having been discharged over it without causing any damage. It is, however, contemplated to widen the weir by another 100 ft. at a 2 ft. lower level, there being a movable cap to keep the water up to the full level when the weir is not in flood. The fall is also to

FIG. 154. EXCAVATION AT POOL HALL, NEAR EASTHAM. (*See Page* 35.)

FIG. 155. THE SHARPEST CURVE ON THE MANCHESTER SHIP CANAL. (*See Page* 35.)

FIG. 156. STANDARD CUTTING ON THE BARTON SECTION. (*See Page* 35.)

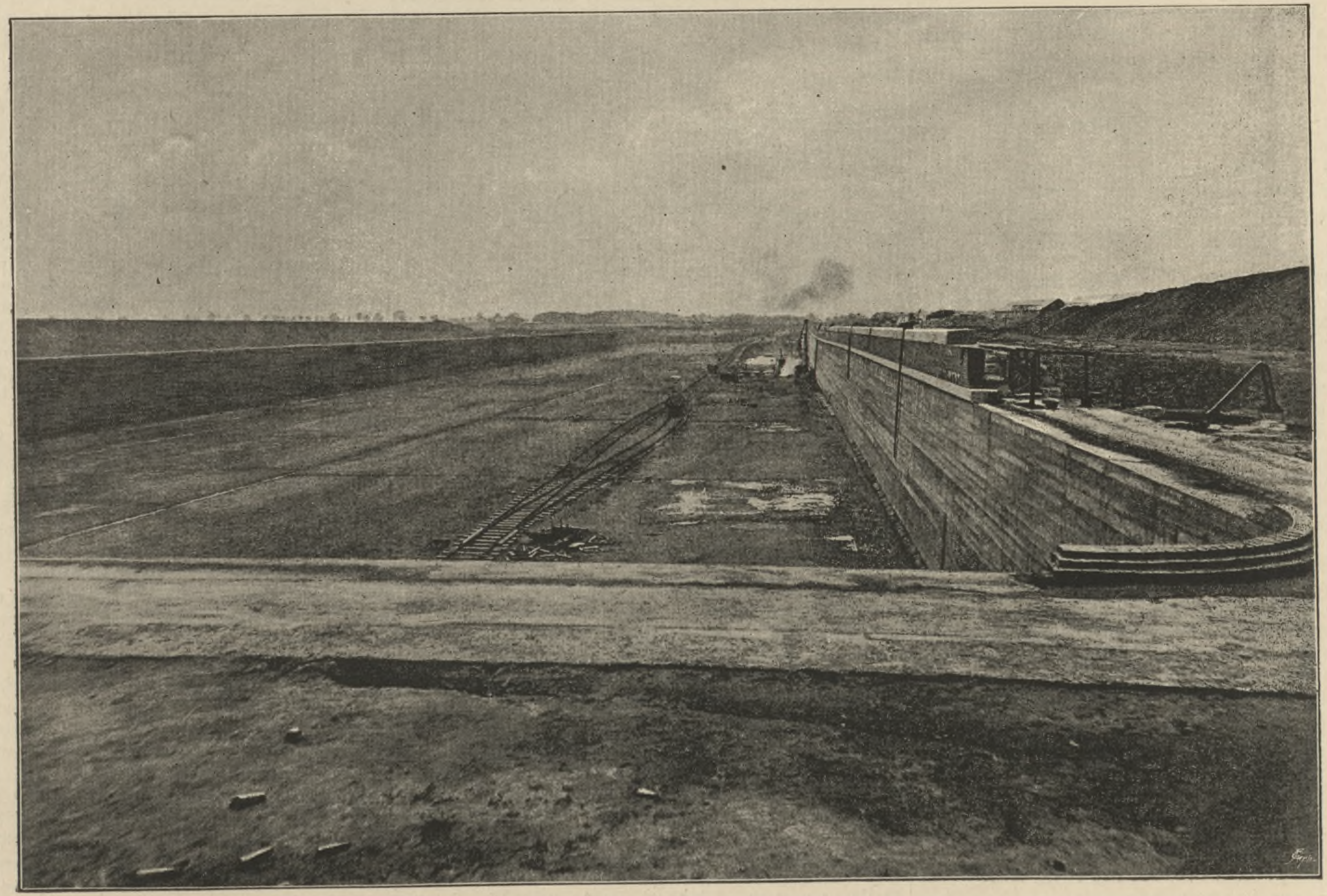


FIG. 157. THE SALFORD DOCKS, SHOWING CONSTRUCTION OF QUAY WALLS. (*See Page* 35.)

be done away with, and a slope of large blocks of stone, of 5 tons each, being placed below the weir to carry water into the canal and obviate any danger of the fall of water weakening the weir. In this part of the ship canal there was a good deal of work of a special nature required in consequence of the course of the canal so often crossing the windings of the natural river. There were fourteen intersections of this nature in the Irlam section, and they involved a large number of diversions of the natural stream, requiring the removal of a vast quantity of material. It was, of course, necessary to keep open a channel for carrying off the water of the river to the sea. The way in which this purpose was generally effected was by diverting the channel of the river where it interfered with the course of construction of the canal, the excavation being all done in the dry. When the work was complete and the canal ready to take the flow of water, the old river bed and the diversions became unnecessary, and in many places the ancient channel has already been filled up. In some cases, however, crossing of the canal course by the river was inevitable during construction, and in those cases the waters of the river were kept from flooding the work by means of dams, which naturally consisted largely of the old banks of the river ; and which were finally dredged away when all the other work was complete and water admitted. In the Irlam section the crossings of the ship canal course by the river were reduced from fourteen to two by means of deviations connecting up the bights, and the amount of dredging, as compared to excavation in the dry, was reduced from 111,000 cubic yards to 31,000 cubic yards.

The river diversions, of which we here speak generally, for they are not special to the Irlam section only, are connected with the history of the disastrous floods that occurred in November, 1890, before referred to, the recollection of which must be within the memory of most of our readers. Heavy rains brought down large quantities of flood water, which overtopped the dams and banks, flooded the surrounding country, and poured into the unfinished cutting of the ship canal. It was for this reason that in many cases dredging was substituted for dry excavation, as we state elsewhere. The delay to work and great expense entailed is one of the most unfortunate chapters in the history of the canal, and has done much to account for the additional cost over the first estimates.

Whilst referring to the method of constructing the canal in the river bed, we may conveniently here make reference to another method employed, although in doing so we have to take a step forward into the upper section. In Fig. 162, on page 44, is shown that part of the canal between the two series of docks of Manchester and Salford.

The whole bed of the Irwell has here been absorbed by the ship canal, as in the other upper parts ; and, as it was found almost impossible to cut a temporary channel in the manner formerly described for passing the river and flood water down, recourse was therefore had to a division of the watercourse during the construction of the docks and quay walls. About one-third of the river was dammed off by a dam composed of a double row of piles with puddle clay between. This is shown in our illustration. The space thus cut off was divided into sections by means of cross-dams. From these sections the water was then pumped out and the river bed excavated down to the lower level of the bottom of the ship canal. When one side of the canal had been finished, the dam was drawn, and the other side is now being completed by dredging. On the right is seen the existing Bridgewater Canal.

Passing Irlam Locks, with the hydraulic pumping station close by, we find no feature calling for special attention until we arrive at Barton Locks, about two miles higher up.

The Barton section includes Barton Locks, and extends up to Mode Wheel Locks. It includes what is perhaps the most interesting feature on the canal, namely, the Barton swing aqueduct, which we have described fully elsewhere. The other important structure on this section is the Barton swing bridge, which we have also previously dealt with, and there does not remain much else of note excepting the locks, which we have also described elsewhere. The hydraulic installation for the swing aqueduct and swing bridge, and also for the Barton Locks, is placed on the side of the canal close to the aqueduct.

The Manchester section, at which we have now arrived, is the most important part of the work, as it is that for which the canal itself chiefly exists. In it are included the Manchester and the Salford Docks, both works of considerable magnitude ; there being more area above Mode Wheel Locks than there is in the whole port of Cardiff or that of Bristol. We have already referred to the general features of this part of the work, and it therefore only remains to make reference to such matters of detail as come within the scope of our present work, and which space will allow us to put forward.

The Salford Docks alone have a water space of 71 acres, with an area of quays of 129 acres. The quays, if measured continuously, would equal $3\frac{3}{8}$ miles. To this should be added the Manchester or Pomona Docks, which have a water space of $33\frac{1}{2}$ acres, the area of quays being 23 acres, and the length of quays $1\frac{3}{4}$ mile. The plan of the Salford Docks, and of the Manchester Docks, Fig. 159, page 39, gives the general arrangement, whilst sections, Figs. 160 and 161, on the same page, will afford an idea of the arrangement of sheds and quays both in the Salford and Manchester Docks. It would be manifestly impossible here to give anything like a detailed description of these docks ; in fact, doubtless large additions to their equipment will be made, and, indeed, many are now in progress. It will be noted from the sections that a subway 3 ft. 6 in. by 5 ft. 6 in. is provided in the quay walls, and this is continuous throughout their entire length ; there being manholes every 300 ft. It provides accommodation for hydraulic mains, gas, and water supply, and it will ultimately take the electric mains when the permanent lighting installation is laid down. There are openings for hydrants to supply hydraulic cranes, &c., every 36 ft. The quay walls of both docks are monolithic in structure, being composed of concrete, 7 to 1, with a facing of 4 to 1 below water level. Above the water line is a granite fender course 18 in. in depth, above which is 4 ft. 8 in. in height of blue-brick work, and over all a 2-ft. granite coping, making a total of 8 ft. above water level. The quay walls of the Manchester Docks are carried no more than a foot below canal bottom, the natural foundation being good sandstone rock. In the Salford Docks the walls go 2 ft. 6 in. below dock bottom, and are also mostly founded on rock. In the Manchester Docks the foundations are 13 ft. 8 in. wide ; in the Salford Docks they are 20 ft. The depth of water in all docks is the standard 26 ft., and an excellent natural bottom has been obtained. On all quays are three lines of standard gauge railways, which will afford connection to the various lines of rail. The permanent way is exceptionally good, being of concrete for a large part. At the present time between Mode Wheel Locks and the head of the Manchester Docks there are 33 miles of track.

Transit sheds have been erected, as indicated on the plan and sections; their main structure being of steel, and covered with corrugated iron. The quay cranes will at first be hydraulic and steam, but doubtless before long hydraulic power will be used exclusively. There are at present ten of these cranes in use, or in course of erection, whilst others have been ordered from Messrs. Armstrong, who are the contractors for this work as for all the other hydraulic machinery. These cranes are similar in construction to those at the Royal Albert Docks, London. They are 30 cwt. capacity, and are worked by telescopic swivel pipes, having a range of 36 ft., so as to connect with the hydrants. In the Manchester Docks one of the lines of railway is inside the shed as shown, whilst at Salford they are both outside. The steam cranes shown in the cross-section of the Manchester Docks are not all in place yet, but some are at work.

The railway connections of both docks at present are obtained by a temporary railway swing bridge which crosses the canal immediately beyond Trafford-road swing bridges; the latter cross the canal on the short length that connects the two sets of docks. This bridge was originally erected for constructive purposes, and it will be superseded by a permanent steel swing bridge, carrying a single line, shortly to be erected close by. As will be seen by the plan (Fig. 159, page 39, and by our engraving, Fig. 162, page 44), the Bridgewater Canal here runs parallel with the ship canal, and another bridge spans the former to carry the line. In this way communication is gained with the Midland Railway system and that of the Cheshire Lines Committee. The permanent connections for the docks on the south side, and by the railway bridge in course of construction just mentioned, are to be with the Manchester, Sheffield, and Lincolnshire, the Great Northern, and Midland Railway Companies. At the north-east corner of the dock are now being made the connection with the Lancashire and Yorkshire Railway, joining with the main system at Windsor Bridge. Near the Mode Wheel Locks the connection with the London and North-Western Railway Company is now in progress. Opposite the Manchester Docks a large basin is to be constructed, as shown. The walls only are at present in place, as excavation and dredging remain to be done. The passage for small craft, which passes under a fixed bridge on the Trafford-road, is shown on the plan. This also forms a flood-water channel.

The hydraulic pumping station is situated on the island on which the Trafford-road Bridge is pivoted. It is of the usual Armstrong type. It supplies power for working the dock cranes, swinging the Trafford-road Bridge, and working the Mode Wheel lock-gates. The length of the main is $2\frac{1}{2}$ miles. Extensive offices have been erected for the executive staff near the Trafford-road Bridge, the city office of the company being at 41, Spring-gardens, Manchester.

The ship canal ends at a small foot-bridge which spans the old River Irwell at Woden-street. Just above this are the old Hulme Locks, and through these locks barge traffic can pass to or from the ship canal to the Bridgewater Canal. This, with the connections at Ellesmere Port and Weston Point, opens up communication with a vast network of inland navigation for barge traffic, including the following canals : Bridgewater (as stated), Leeds and Liverpool, Bury and Bolton, Rochdale, Ashton, Huddersfield, Stockport, Macclesfield, Calder and Hebble, Aire and Calder, Trent and Mersey, Weaver Navigation, and the Shropshire Union.

It will be seen, therefore, with what a large and important manufacturing district the ship canal is brought into immediate communication by water carriage. Barges from all cities and towns served by these canals can bring merchandise and produce down to the Manchester Docks, and there transfer their cargoes to ocean-going vessels without intermediate transhipment. It may well be said that the Manchester Ship Canal opens up a new era for inland navigation.

XIII.—THE GEOLOGY OF THE CANAL.

In connection with the construction of the canal, a word should be said as to the geological formation of the district through which it passes. We can, however, do little more than refer to the subject for the sake of dismissing it. For the canal engineer it is the surface geology that is of immediate importance, and the materials that had to be dealt with during the construction of the ship canal were so various that it would be impossible to give representative sections. In a former issue of Engineering (see vol. xliv, page 374) we gave in a two-page plate a number of sections, showing the strata met with. The distinguishing geological feature, from the engineer's point of view, was the cropping up of the red sandstone, often in a very abrupt manner. In some cases this sandstone was a desirable feature, as, for instance, in the case of the locks, all of which are most beautifully founded on the natural rock. If all the heavy viaducts of the railway deviations had been as fortunately situated, it would have saved some expense. For instance, in the case of Railway Deviation No. 5, the brick arches on the land approach have cracked through the movement of the piers, due, as already stated, to the slipping of the foundations. Had these been properly founded on the virgin rock, as in the case of the Irlam Locks, which are close by, instead of on a bed of treacherous clay, the arches would have stood till the crack of doom.

The greater part of the soil which had to be excavated was, however, of a soft nature, easily dealt with ; it was the quantity that made the task so formidable. At the commencement of the work it was estimated that in the total length of the canal, of 35 miles and 25 chains, the total quantity of earthwork to be removed was 44,428,535 cubic yards, which total was made up of 6,970,815 cubic yards of rock and 37,457,720 cubic yards of softer material. As we have already seen, the actual total considerably exceeded this estimate, and it may be assumed that the amount of rock and earth removed was, in round figures, 50 millions of cubic yards.

XIV.—THE PLANT AND MATERIALS USED IN CONSTRUCTION.

In dealing, under separate headings, with the dredging and dry excavation, we have already described by far the more important part of the plant—namely, the Ruston and Dunbar steam navvy, the excavating cranes of Wilson and Whitaker, and the big French and German land dredgers; these are in the dry excavation section. In the dredging department we have referred at length to Mr. Schenk's arrangements for dredging, which include the ordinary floating dredgers, the special steel barges and tipping-boxes, the Stoney's tipping cranes, and Price's soil transporter. It would be manifestly impossible to enumerate all the plant employed on this extensive undertaking during the six years it has been in progress. By a list of the plant existing in 1891, we find that, in addition to the above excavating and dredging plant, there were engaged on the work 173 locomotives, some of considerable size and power; 194 cranes, mostly steam; 182 steam engines; largely of the portable type; 212 steam pumps, besides pulsometers; 6300 wagons; 59 pile engines; 228 miles of railway. It may be added here that the number of men and boys employed at that time was 16,361; the number of horses, 196; whilst the quantity of coal used monthly was about 10,000 tons. In a work such as the Manchester Ship Canal, where time is as the essence of the contract, a great deal of night work is done, requiring a proportionate amount of artificial illumination. It is needless to point out to our readers—or, indeed, to the non-engineering public—what a help the contractor has now in this respect, compared to a few years ago. In the case of the ship canal, where interest was being paid out of capital, there was every inducement on the part of the company to urge their contractors and their own staff when working under administration. Naturally a certain amount of electric light has been used, but we believe not a great deal, although we have been unable to obtain an exact account of the temporary plants for this purpose put in operation by the Ship Canal Company and the various contractors. The Wells light has, however, been chiefly used, between five and six hundred of these lamps having been on the work at various times during the construction. At the commencement of the work, the late Mr. Walker tried two Wells lights as an experiment, and we remember very well seeing these first experimented upon when a part of the wooden town at Eastham was being constructed. The light was found to be of so good a quality, and the lamps were so easy to handle and put in operation, that a larger experiment of a dozen more was tried, with such results that shortly after an order for a hundred more lights was placed. That which we have said about our forestalling the description of the plant in other parts of this account of the canal, also applies in some degree to the question of materials. There is not much, however, that calls for attention here in the latter section. So far as we know, there has been no large quantity, if any, of material of a novel kind introduced on the work. Most of the bridges are of steel; the banks are of earth; and the quays, walls, &c., are of brick or concrete. If there is not much to say respecting the description of material, there are some rather astonishing figures as to quantity. In a paper read before the Manchester International Congress on Inland Navigation, held at Manchester in 1890, Mr. Leader Williams stated that 450,000 bricks were made per week at Thelwall, and that large quantities had been bought; the quantity for the whole of the brickwork on the canal being 70,000,000, which would equal 175,000 cubic yards. It may be mentioned here that the quality of the brickwork throughout commands universal admiration. The concrete required Mr. Williams then estimated at 1,250,000 cubic yards, to which he added 220,000 cubic yards of masonry. A large quantity of granite was used, and this was all supplied from Cornwall, John Freeman, Sons, and Co. being the contractors. The total quantity supplied from first to last was close on three-quarters of a million cubic feet. A good deal of the harder sandstone quarried out in cutting the canal was used, but where a better quality of stone was required it was brought from various sources.

In a popular lecture delivered at an early date by Mr. W. Johnson, an engineer on the staff of Mr. Leader Williams, and to whom we wish to express our sincere thanks for valuable aid in preparing this notice, some rather striking figures as to the magnitude of the work were put forward. Roundly estimating the excavation in the canal at 48 million cubic yards—which it will be seen by reference to our notice of the excavation is less than the total for all work—he pointed out that it would be equal in bulk to twelve pyramids equal in size to the Grand Pyramid in Egypt. If we include the docks and other work done, it would bring the number of new pyramids up to nearly thirteen. The rock alone would make about three of the Pyramids of Cheops. The stone on the sides of the slopes which were then to be pitched would pave about 170 miles of streets. The greenheart logs used in the fifty pairs of lock-gates, if placed end to end, would reach a distance of 29 miles. The timber used for the Ellesmere Port Embankment, elsewhere described, would reach 84 miles, and if there were added that used in the construction of the Weaver sluices foundation, the distance would be 120 miles. The reduction of the quantities to popular standards is a great help to those who are not accustomed to the consideration of statistics of this nature.

XV.—THE ENGINEERS AND CONTRACTORS.

The Manchester Ship Canal being a work of historic importance, it will be interesting at a future time if we give here a list of the names of those engineers who have taken leading parts in its construction; we need hardly say that any imperfections in this list are wholly accidental. Mr. E. Leader Williams, as chief engineer, has had the valuable help of Mr. James Abernethy, F.R.S.E., Past Pres. Inst. C.E., as consulting engineer. Mr. W. H. Hunter, M. Inst. C.E., has been chief assistant engineer, and his name should be especially associated with the Barton swing aqueduct. Messrs. J. J. Warbrick and W. Johnson have acted as principal assistant engineers.

Since the corporation has taken a leading part in the completion of the canal, Sir B. Baker, K.C.M.G., has acted as consulting engineer to that body, which has also been represented on the engineering staff by Mr. George H. Hill, M. Inst. C.E., Mr. Walter Taylor being his assistant.

The connection of Mr. James Abernethy, of 4, Delahay-street, Westminster, with the Manchester Ship Canal has been an important one, and dates from the inception of the scheme. The part this eminent engineer has taken in the enterprise may be summarised as follows:

In the year 1880 he was first consulted by the late Mr. Daniel Adamson, who, in connection with Mr. Hicks, had conceived a project for forming a waterway to Manchester, and he arranged with him to look further into the proposal and assist him, provided influential parties could be found to support and prosecute the scheme. In 1882 a Provisional Committee was formed to consider two projects: one by the late Mr. Fulton, C.E., who advocated the formation of a tidal channel up to Manchester; and the other by Mr. E. Leader Williams, for a canal from Manchester to the neighbourhood of Runcorn, and thence seaward by the River Mersey. These two schemes were submitted for Mr. Abernethy's consideration by the Provisional Committee, and, after a careful inspection of the Rivers Irwell and Mersey from Manchester to Runcorn, he reported generally in favour of Mr. Williams' views.

The tenor of this report was adopted by the Provisional Committee, and Mr. Abernethy was requested to act as consulting engineer, and in that capacity he advised and gave evidence in support of the application to Parliament in the session of 1883, and subsequently in a similar project in the session of 1884.

On the rejection of these Bills he was further requested by the Provisional Committee to reconsider the project, and suggested and reported in favour of an alternative design, viz., a canal, independent of the tideway, from Manchester to the neighbourhood of Eastham.

A Bill was deposited for this scheme in the session of 1885, and Mr. Abernethy gave evidence before both Committees in favour of it, and, as in the case of the former Bills, his name appears on the parliamentary plans and estimates in conjunction with Mr. Williams as engineer.

Shortly after the commencement of operations, he was appointed consulting engineer, visiting and inspecting the works monthly, and reporting on their progress and condition to the Works Committee, also conferring with and advising Mr. Williams on all salient points. All the principal detailed plans were submitted to him for approval or alteration, and he furnished Mr. Williams, as examples, with detailed drawings of important works of a similar character, designed and carried out under his direction.

Mr. Abernethy retained the position of consulting engineer until the works were nearly completed.

The following have been resident engineers and assistant resident engineers on the various sections during the progress of the work, some having been connected with it from its commencement; others have left to take up other work. Resident engineers: Messrs. Wheatley Eliot, H. W. Abernethy, F. P. Dixon, O. G. Brooke, G. C. H. Brown, W. O. E. Meade-King, W. L. Bourke, G. Fitzgibbon, S. H. Hownam Meek, L. H. Moorsom, W. Burch, S. G. Boag, H. Congreve, C. D. N. Parker, and J. Deas, jun. Assistant resident engineers were: Messrs. J. C. Holme, H. Sadler, W. M. Beckett, Walter Taylor, and the Hon. D. Keppel.

Mr. John Kyle, who is an engineer of some repute, should also be mentioned; he was engaged by Sir John Coode on the breakwater at Colombo; after completing this work he was the resident engineer on the Salford and Manchester Docks, and carried out, under the chief engineer, most of the works for the locks and docks. He left to take charge of the new Dover Harbour works for Messrs. Coode, Sons, and Matthews.

We will add here the names of some of the chief contractors on the work. It will, of course, be understood that the list is a very incomplete one, for it would be impossible to give the names of all of the contractors' staff who have done work or supplied material. To some of the names mentioned, prior reference has been made in the body of our description.

First on the list comes the late Mr. T. A. Walker, who was, as already stated, the contractor for the whole works at the first. There is no need here to make reference to the influence that Mr. Walker had on the progress of events in connection with this great undertaking; indeed, to do so would be to rewrite the history of the early part of the canal. It was Mr. Walker, personally, who organised the way in which the work should be executed, and it was to his energy, skill, and experience that the rapid progress made in early days was due.

The chief agent to the late Mr. T. A. Walker was Mr. W. H. Topham. The other agents were: Messrs. E. Manisty, A. Brown, E. D. Jones, C. Gregson, I. R. Walker, J. Price, C. J. Wills, L. P. Nott, and the late Mr. McNab. Mr. A. O. Schenk was contractors' engineer.

Mr. W. H. Topham held an important position on the canal works. He was appointed chief agent by Mr. Walker in the year 1887, and held that position till the time of Mr. Walker's death. When the Manchester Ship Canal Company took the works over from Mr. Walker's executors, Mr. Topham was appointed their works manager, a similar position to the one he held under Mr. Walker; and when the work was finally let out to contractors, Mr. Topham was retained by the company as consulting agent to the directors during the time of the construction. In June, 1893, Mr. Topham was requested by the company to come down every week for four days in the week, with a view to getting the canal opened by January 1, 1894. Mr. Topham is still engaged by the company in connection with the sale of the large stock of surplus plant which they have to dispose of. It was due to the energy displayed by Mr. Topham and the other contractors that the works were completed by the time specified.

The works of the Runcorn section, embracing some of the most difficult works on the canal, were carried out by the administration for the company, under the chief engineer, by Mr. E. D. Jones, who previously, as their agent, had also completed the seven miles of canal from Ellesmere Port to the River Weaver. The Runcorn section comprised the whole of the works of the canal from the River Weaver to Old Quay, Runcorn, and consisted (besides the ordinary canal excavations) of 3½ miles of river embankments and concrete walls, with three sets of locks. In addition to the difficulties attendant upon the tidal nature of the work, it was further complicated by the necessity of keeping open the traffic to two existing systems of docks during the construction. The most important part of the

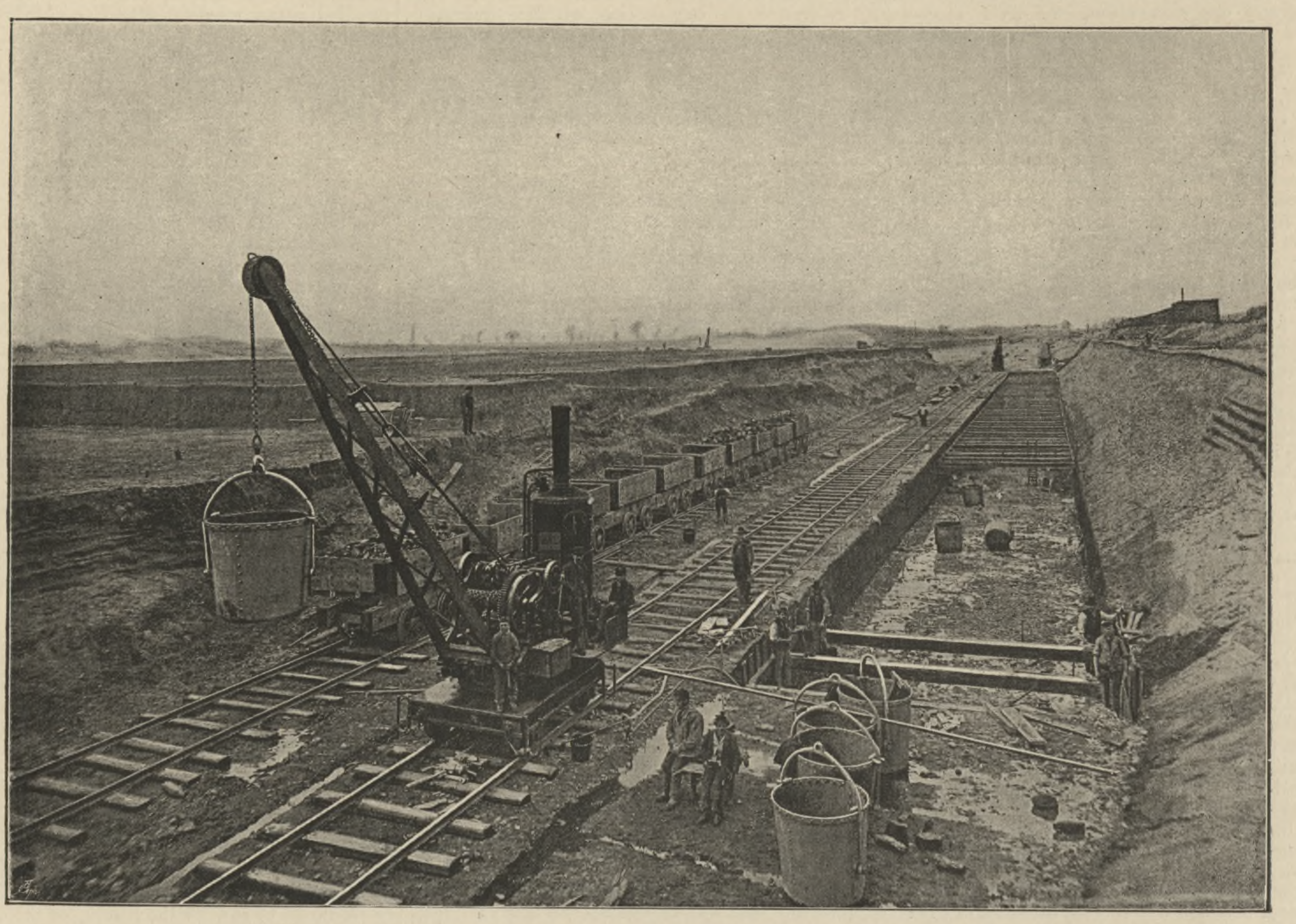


FIG. 158. LAYING FOUNDATIONS OF QUAY WALLS FOR SALFORD DOCKS. (*See Page* 35.)

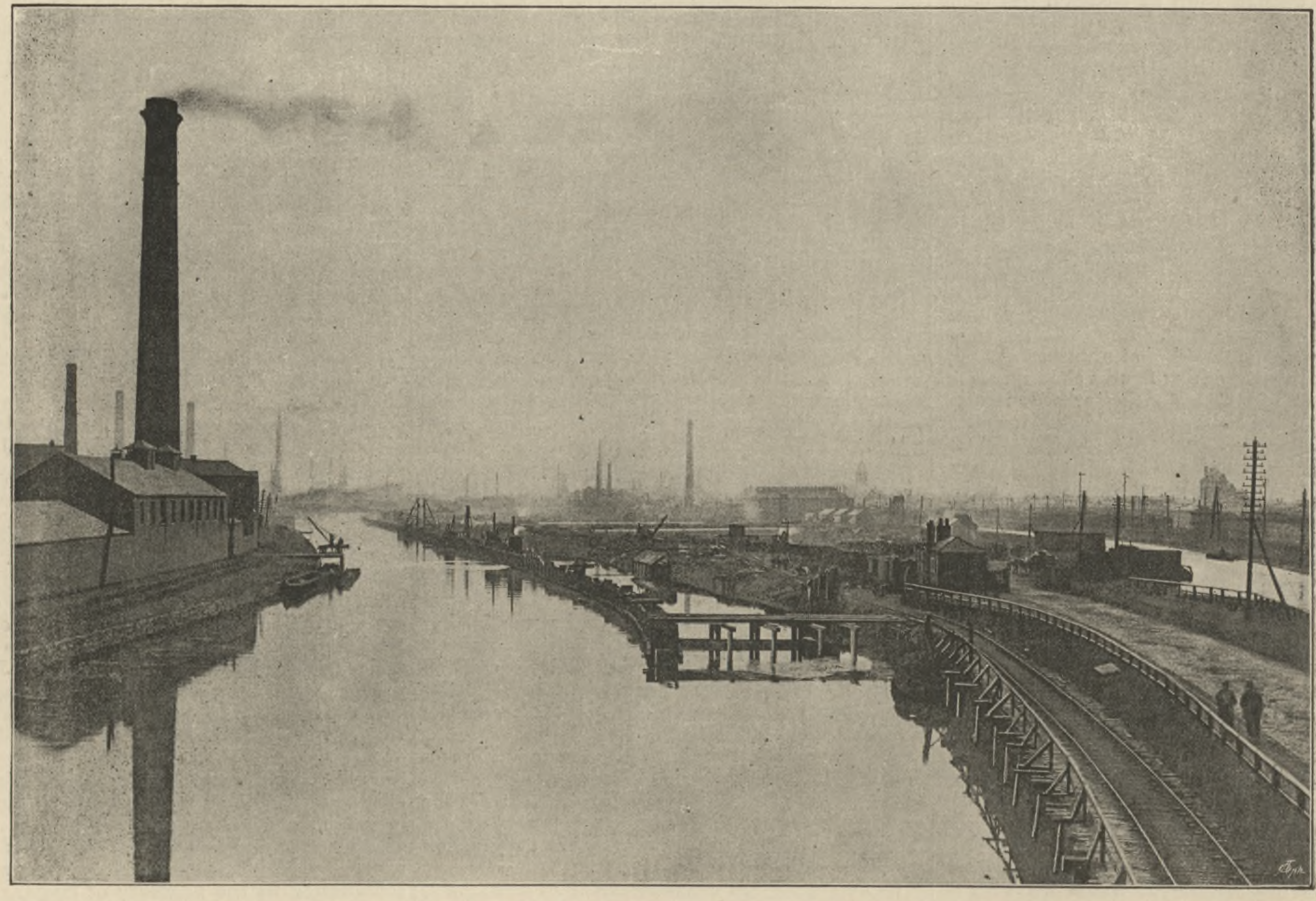


FIG. 162 VIEW OF CANAL BETWEEN MANCHESTER AND SALFORD DOCKS. (*See Page* 42.)

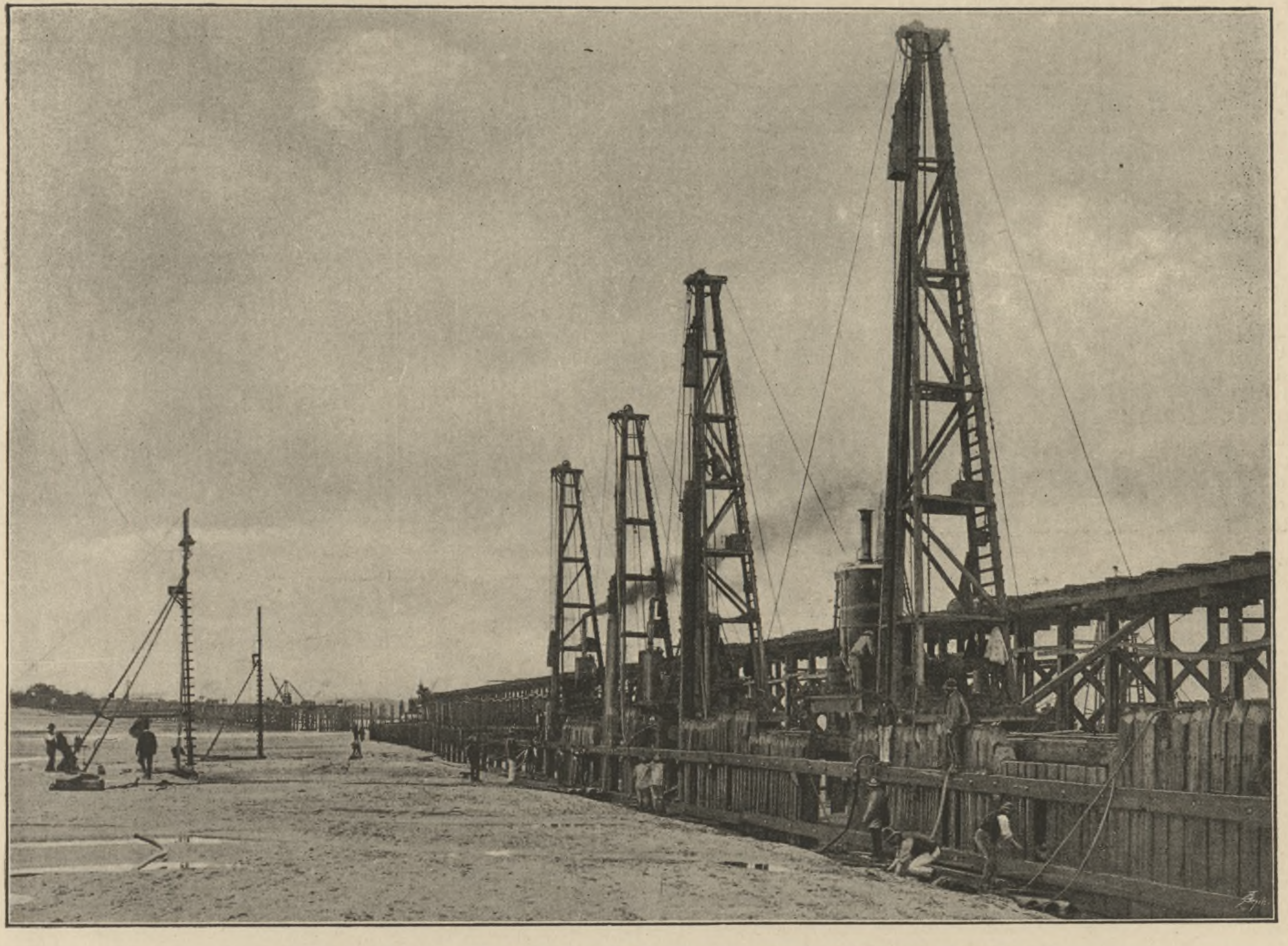


Fig. 163. Ellesmere Port, looking towards Eastham. (*See Page* 35.)

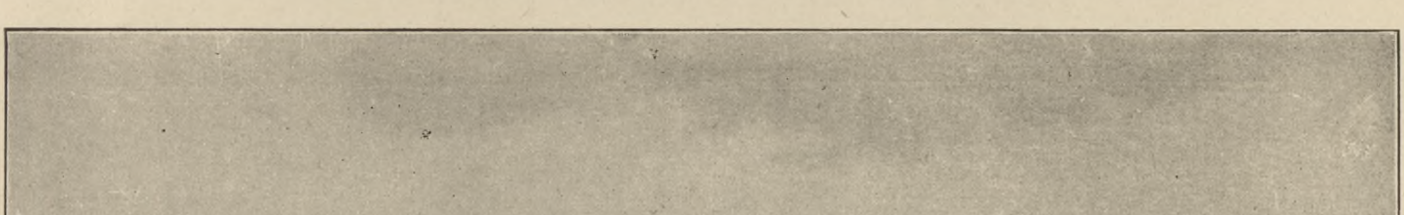


Fig. 164. Ellesmere Port, looking from Eastham. (*See Page* 35.)

work, including the Western Mersey Lock, 600 ft. long, with five pairs of gates, and a quarter of a mile of concrete approach walls, the excavation of two miles of the river bed to a depth of 26 ft., and the rebuilding of the Bridgewater Locks, was both commenced and finished in the short space of fourteen months.

As general contractors, Mr. John Jackson, of Westminster, and Mr. C. J. Wills took up the work of construction some time after Mr. Walker's death, and after the canal company had been carrying on the work some time by administration. Mr. Jackson is well known as a contractor in connection with the Tower Bridge and Dover Harbour works. His field of operations is the eight miles of the canal between Latchford and Runcorn. He has been successful in completing the work entrusted to him in less time than was specified—a fact which contributed in no small degree to the opening of the canal by the first day of the year. His agent in this work has been Mr. G. H. Scott. From 2,500 to 3,000 men were employed, and 16,000 to 20,000 tons of material were excavated per day shift.

Mr. Wills, who was formerly one of Mr. Walker's agents, was engaged in the completion of the upper part of the canal, comprising work extending from Warburton to Manchester, and including the docks. His agent was Mr. R. Hollowday, and his engineer Mr. D. Connery. This section naturally includes some of the most important features of the canal; amongst them, the Partington coal basin, the locks and sluices at Irlam, Barton, and Mode Wheel, the Barton aqueduct, and the Barton swing bridge. The contract work for the completion of these, with the exception of the ironwork, machinery, &c., has been executed by Mr. Wills, he doing the masonry, excavation, and general work. The completion of the railway deviations in this section came under the same contract.

The great firm of Armstrong, Mitchell, and Co. has, as already stated, executed all the hydraulic machinery in connection with the ship canal throughout. That it worked so successfully in the early days, even when severely tested, is the best evidence that can be given of the completeness of this work.

Messrs. Ransomes and Rapier, of Ipswich, have supplied all the Stoney sluices, and also the patent cranes and spoil-boxes before referred to in the section on dredging.

For bridges and gates there have been five principal contractors for iron and steel work. Of these, by far the greatest quantity of the work has been done by Sir W. Arrol and Co., of Glasgow. The chief part of the work done by this firm was all the viaducts for the railway deviations, and the swing bridges, with the exception of those at Barton and Trafford-road and the swing aqueduct. The iron and steel work in their contract amounted to about 10,000 tons. Messrs. Handyside and Co., of Derby, contracted for the iron and steel work in the Barton swing bridge and Barton swing aqueduct, and also for the two high-level road bridges at Latchford and Warburton respectively.

Messrs. Butler and Co., of Leeds, did on the railway deviations several of the smaller bridges which did not span the ship canal. They also contracted for the steelwork of the Trafford-road swing bridge, which is the heaviest in this country. The temporary swing bridge, close by—a remarkable structure, to which reference has already been made—was the work of this firm. The bridge, which is a steel structure, was made and erected in about two months from date of order. They are also the contractors for the permanent railway swing bridge which is to take the place of the temporary one.

Messrs. Braithwaite and Kirk, of West Bromwich, supplied the bridge over the River Mersey near Warrington. Messrs. Pearson, Knowles, and Co., of Warrington, have constructed several railway bridges of the lower levels, the connecting railway bridges to Partington coal basin, and the bridges over Randle's Sluices. They have also made foot-bridges, a coal-tip at Eastham, and other work.

BRIDGES ON THE MANCHESTER SHIP CANAL.

Fig. 10. Runcorn Viaduct; London and North-Western Railway.

Fig. 12. Barton Swing Bridge.

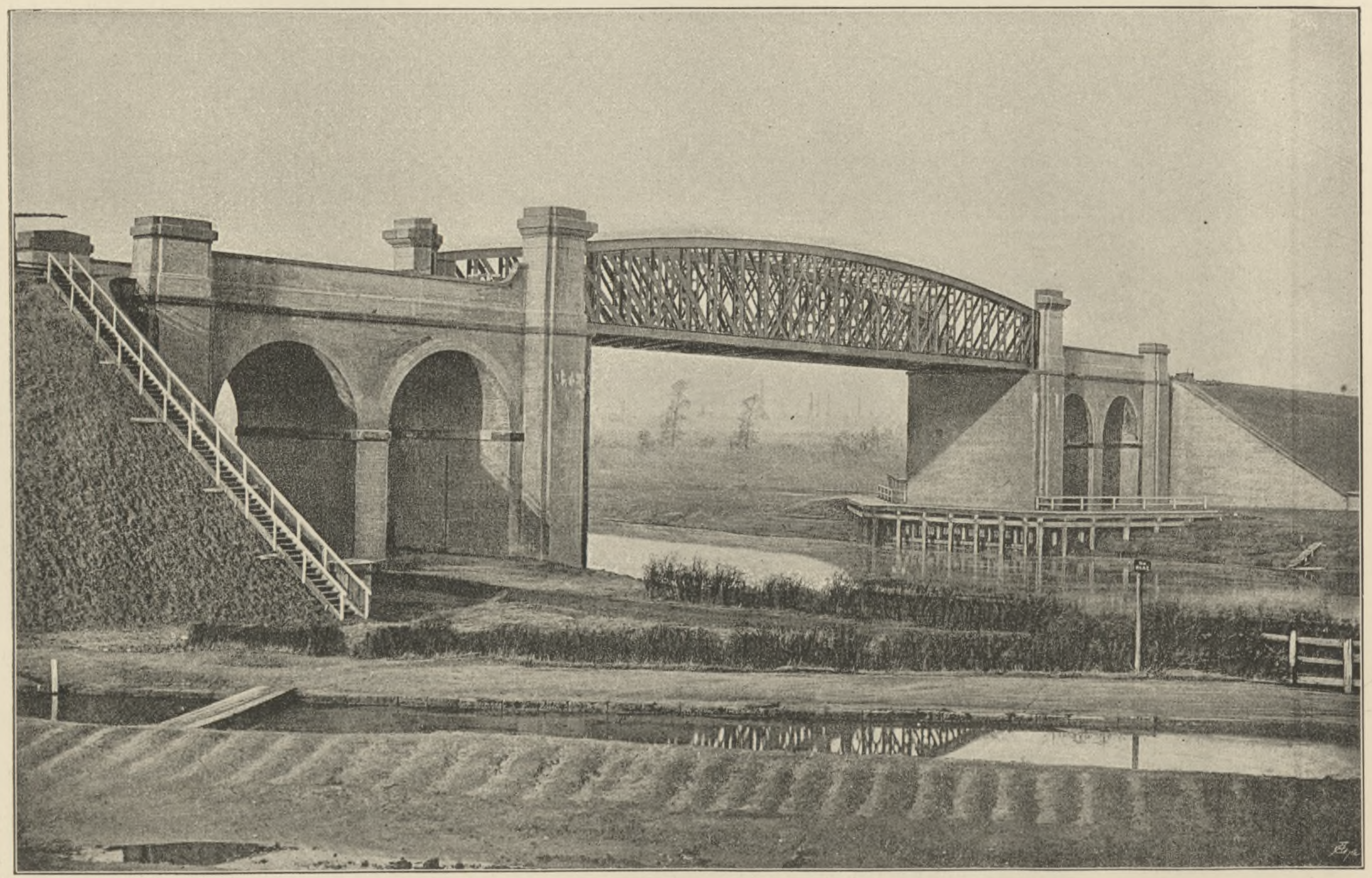


Fig. 11. Bridge over the River Mersey; Railway Deviation No 1.

Fig. 13. Warburton High-Level Bridge.

THE BARTON AQUEDUCTS; MANCHESTER SHIP CANAL.

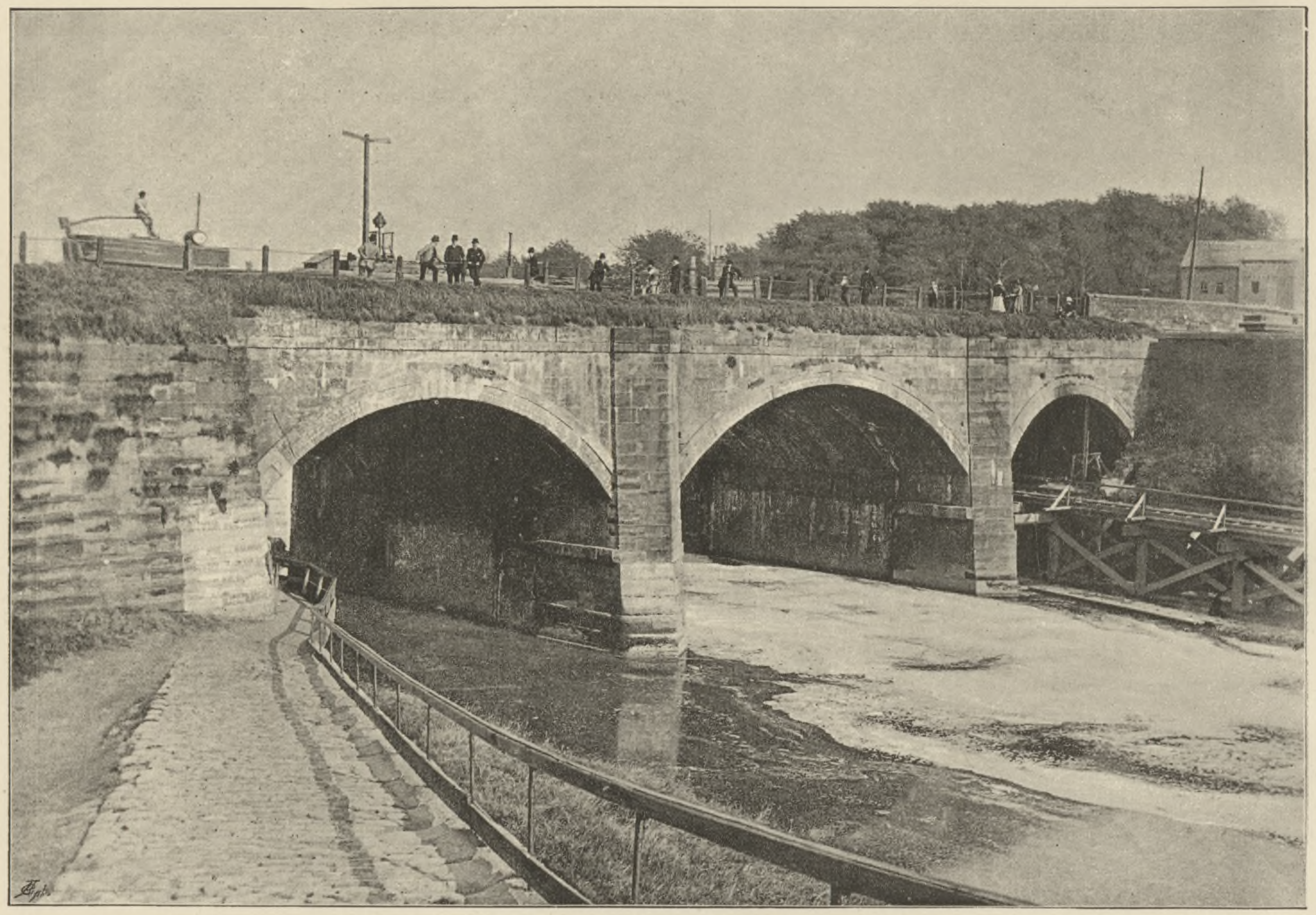


Fig. 83. The Old Aqueduct at Barton.


Fig. 85. Interior of the Aqueduct.

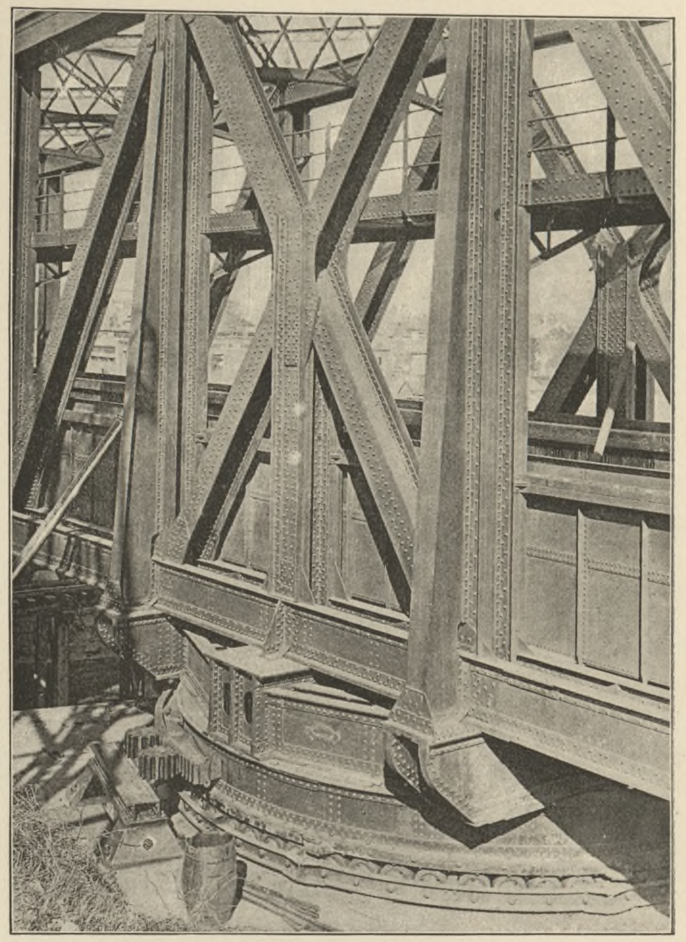


Fig. 86. The Pivot.

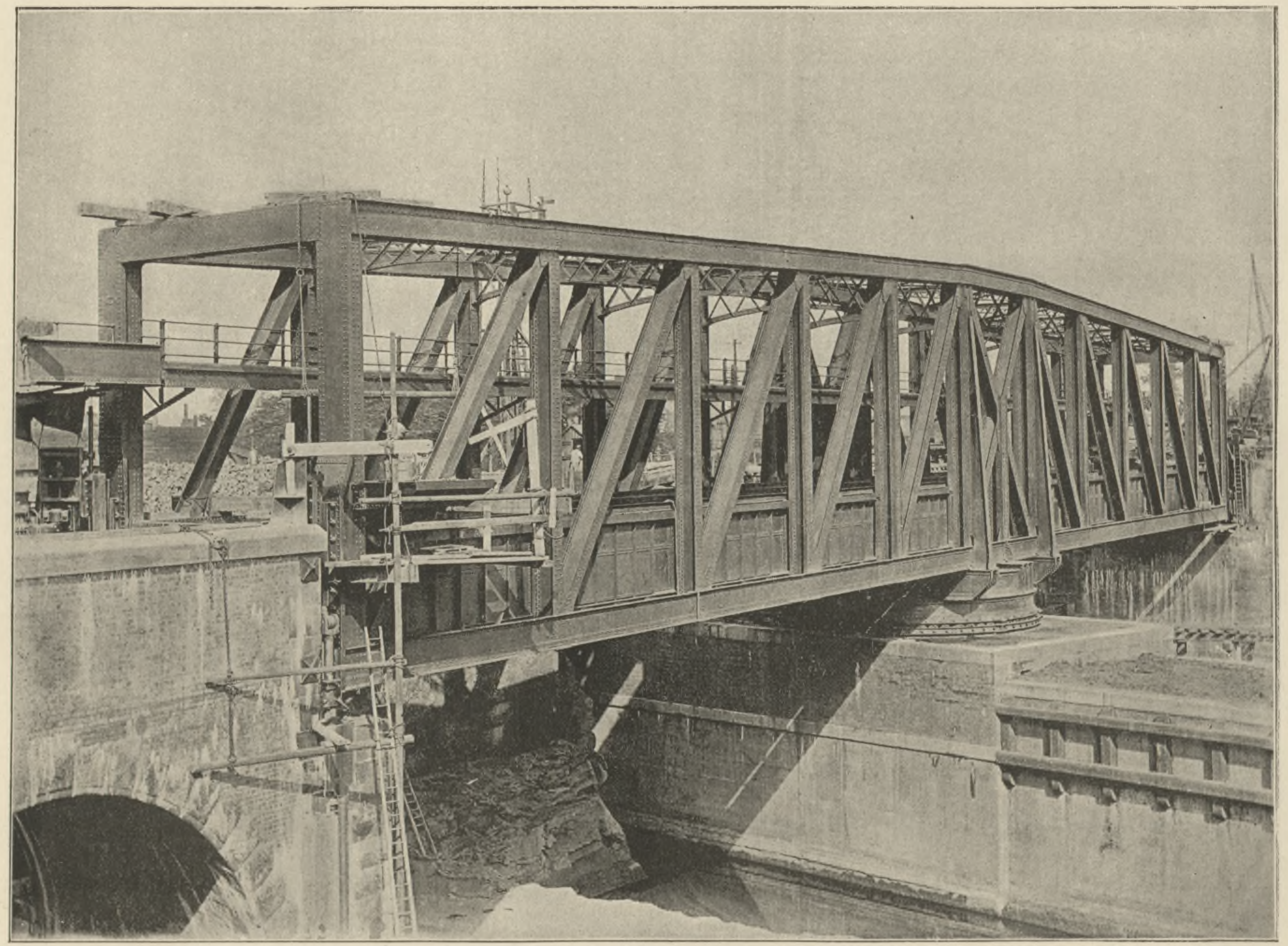


Fig. 84. The New Swing Aqueduct at Barton.

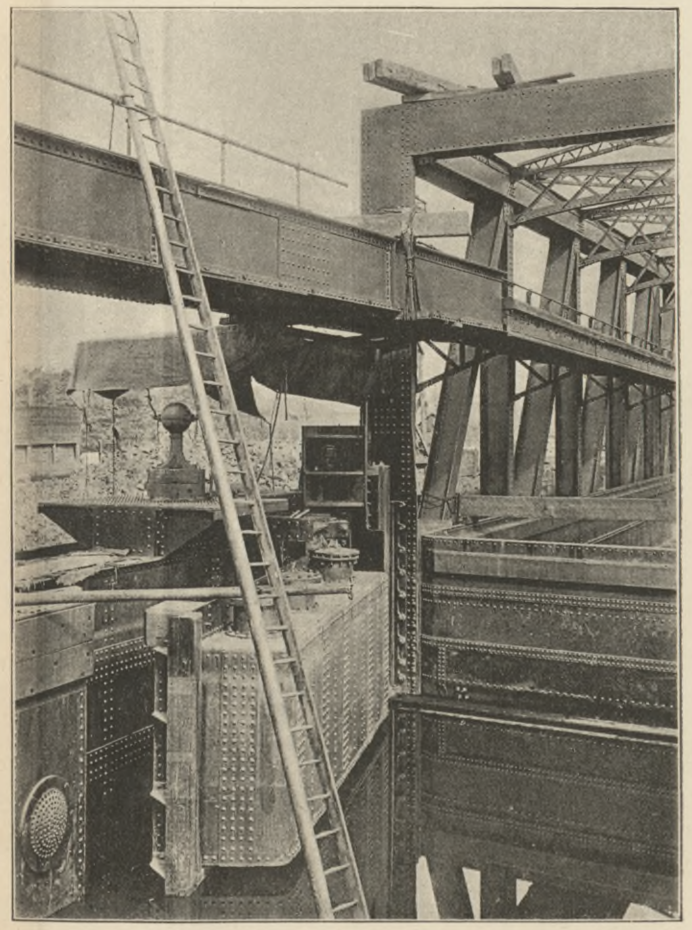


Fig. 87. The End Gates.

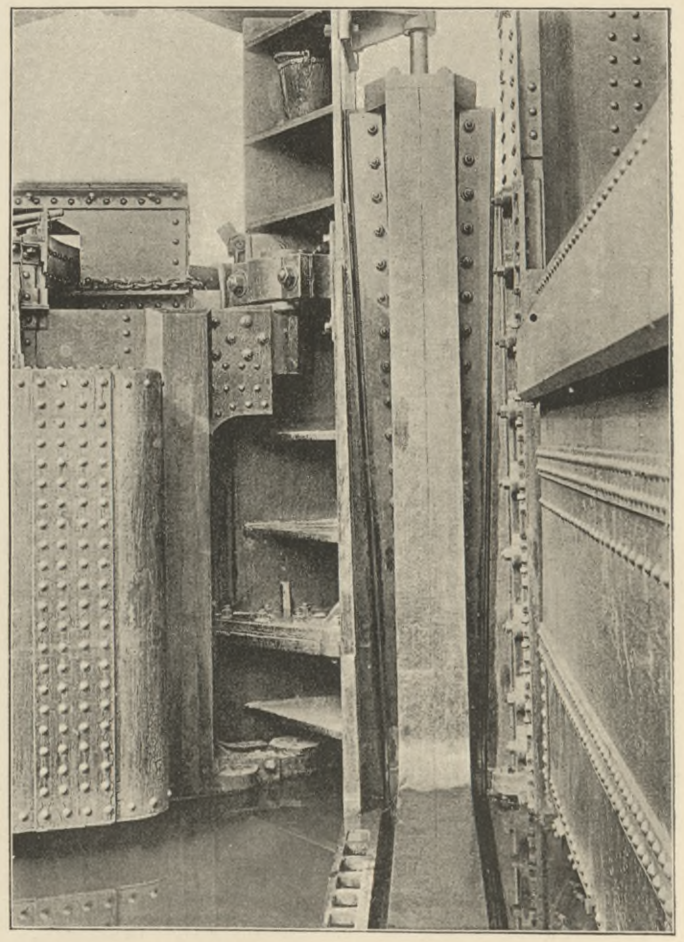


Fig. 88. The Watertight Joint.

SOIL TRANSPORTER: MANCHESTER SHIP CANAL.

DESIGNED AND CONSTRUCTED BY MR. JOHN PRICE, GRAPPENHALL, CHESHIRE.

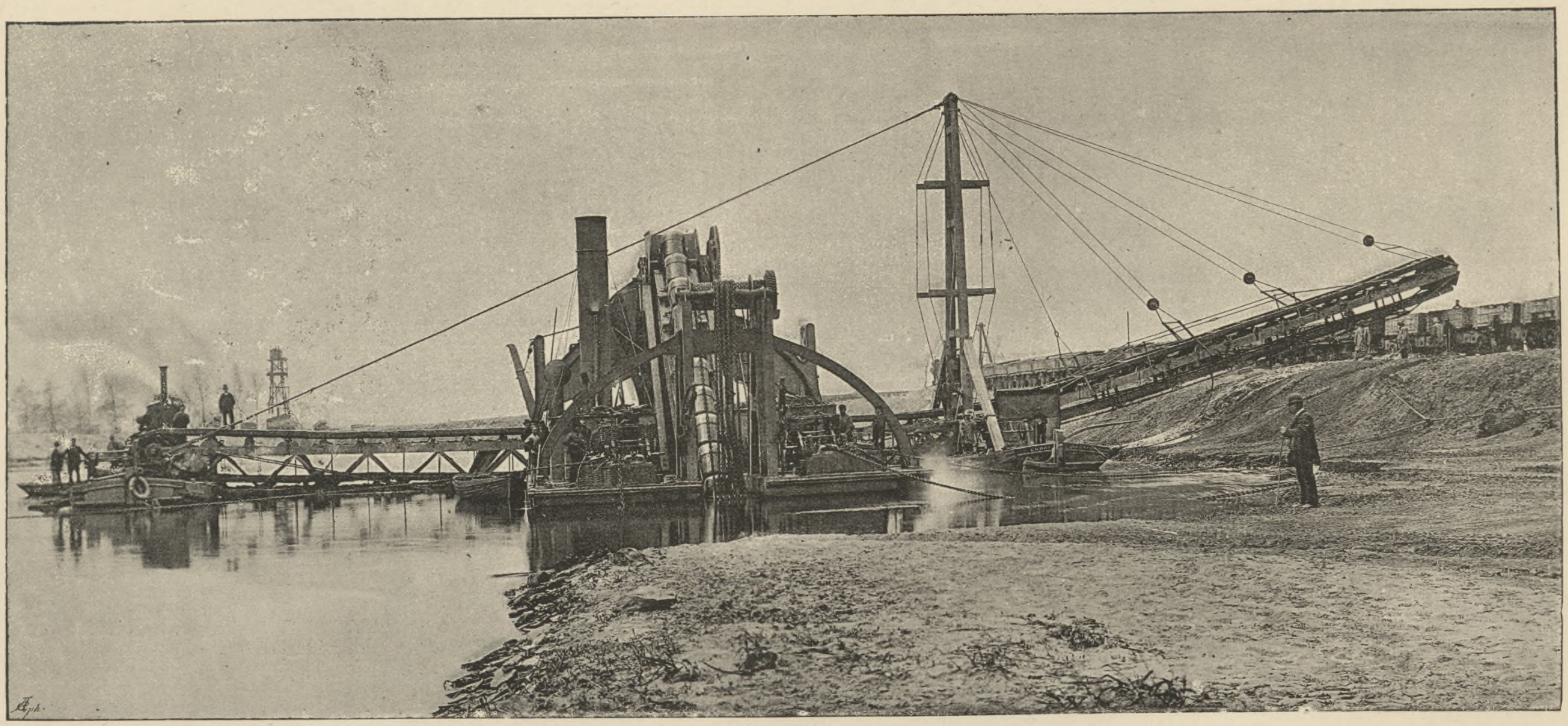


FIG. 106.

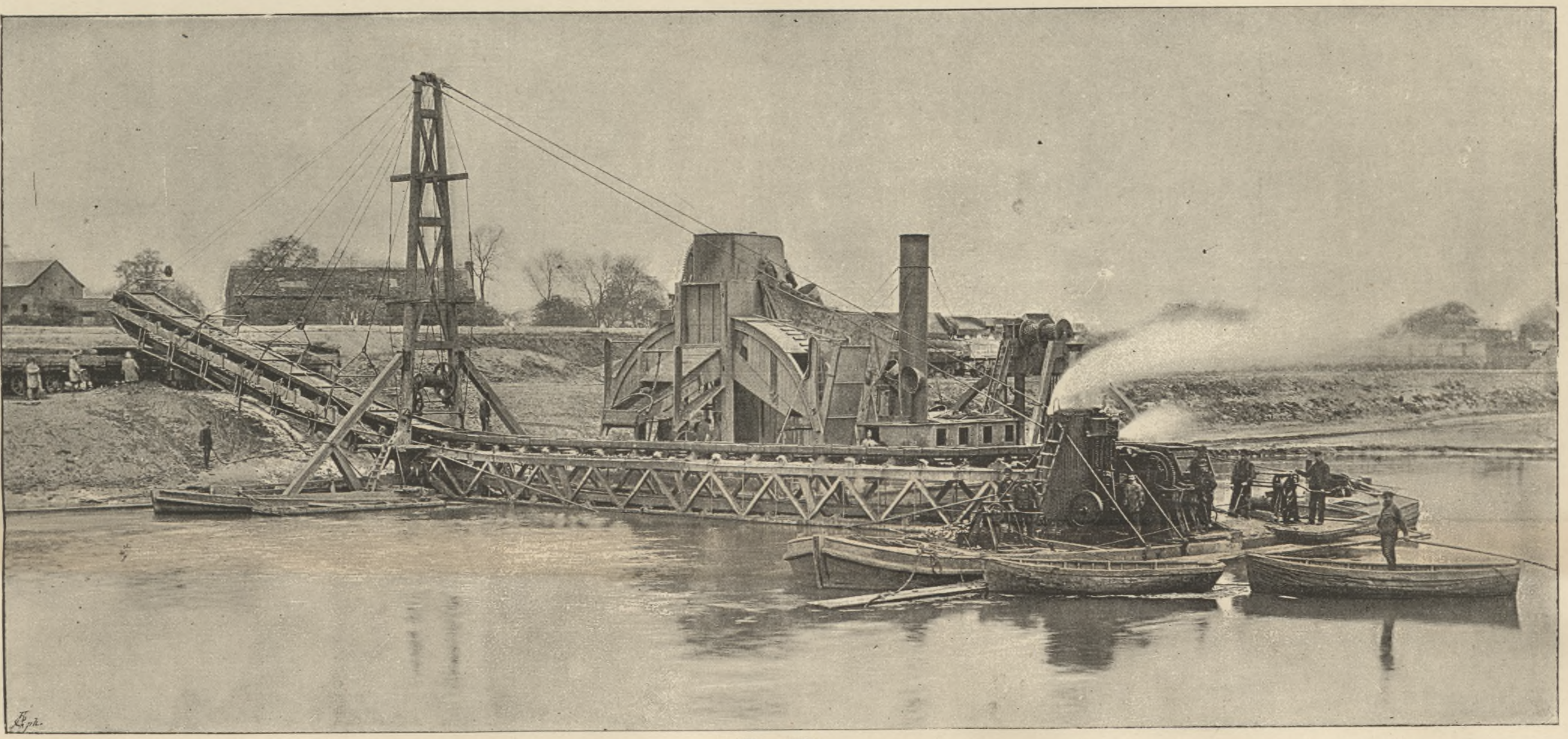


FIG. 107.

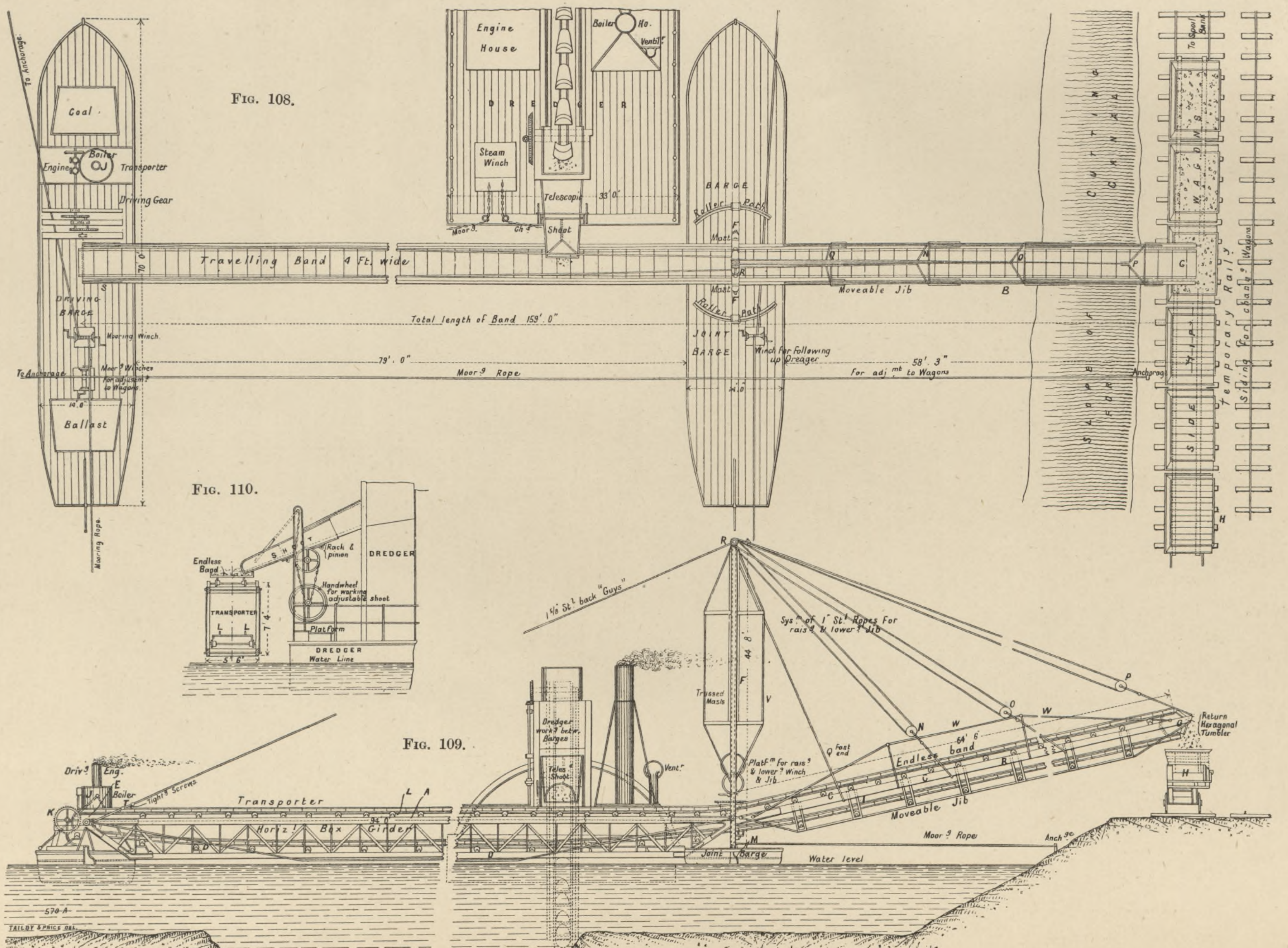


FIG. 108.

FIG. 110.

FIG. 109.

MANCHESTER SHIP CANAL.

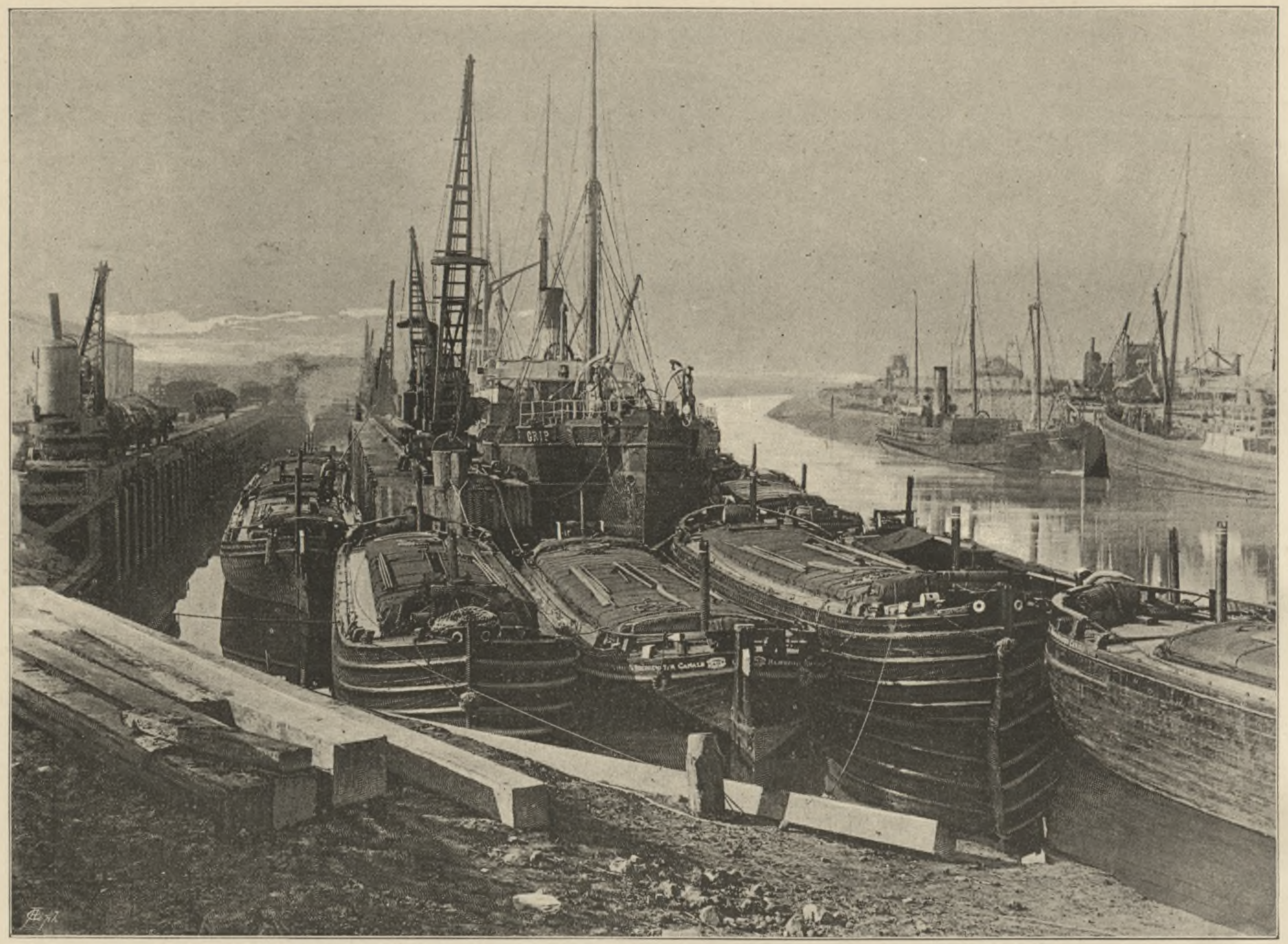


Fig. 111. Saltport; The New Depôt.

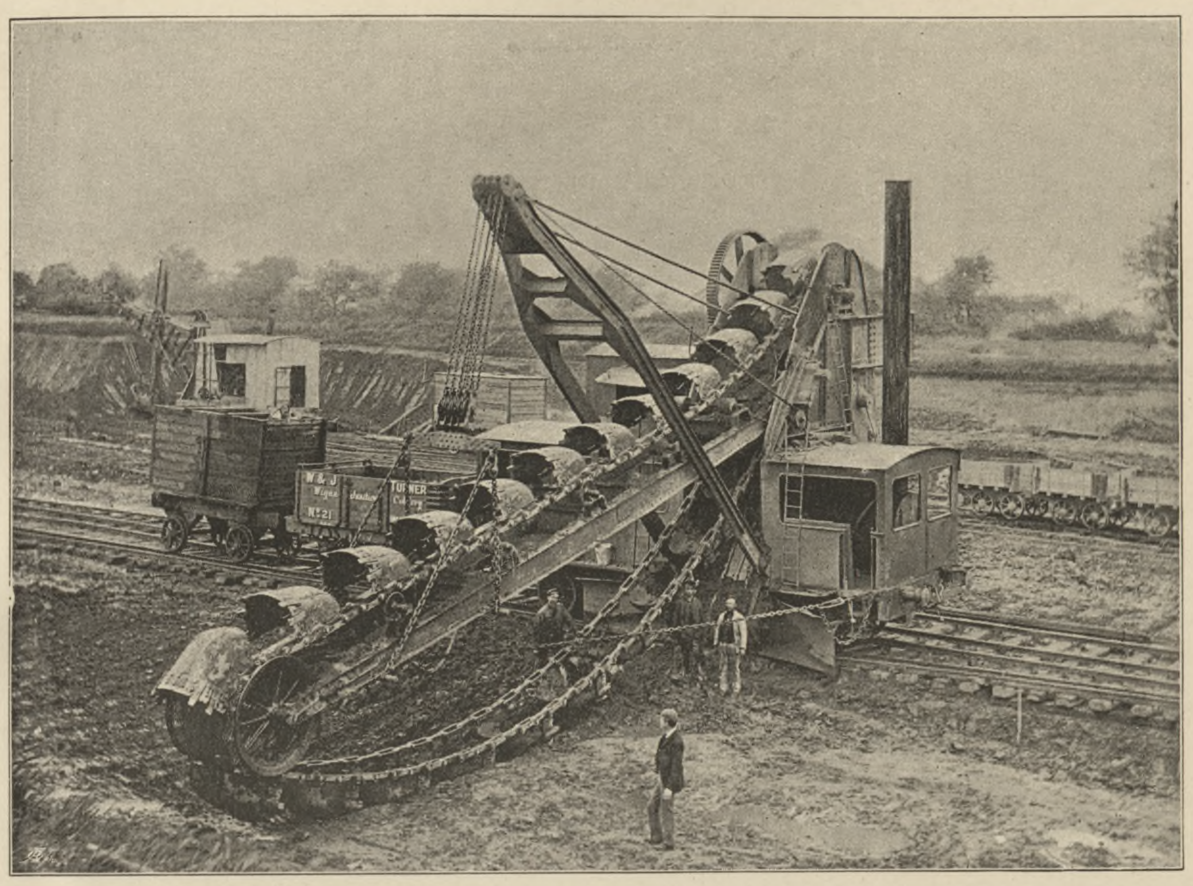


Fig. 113. Land Dredger; constructed by Messrs. Boulet and Co., Paris.

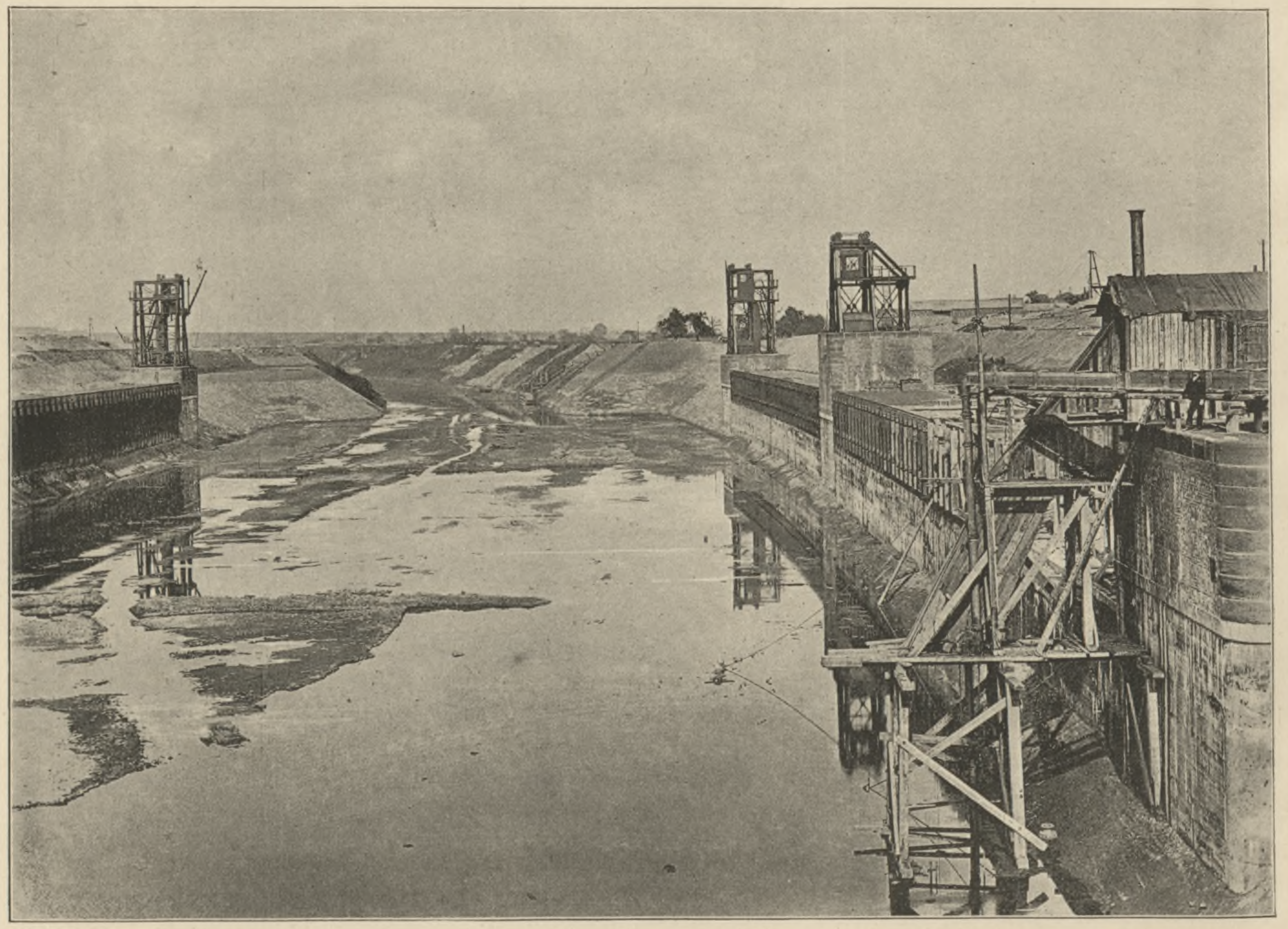


Fig. 112. Partington Coal Basin.

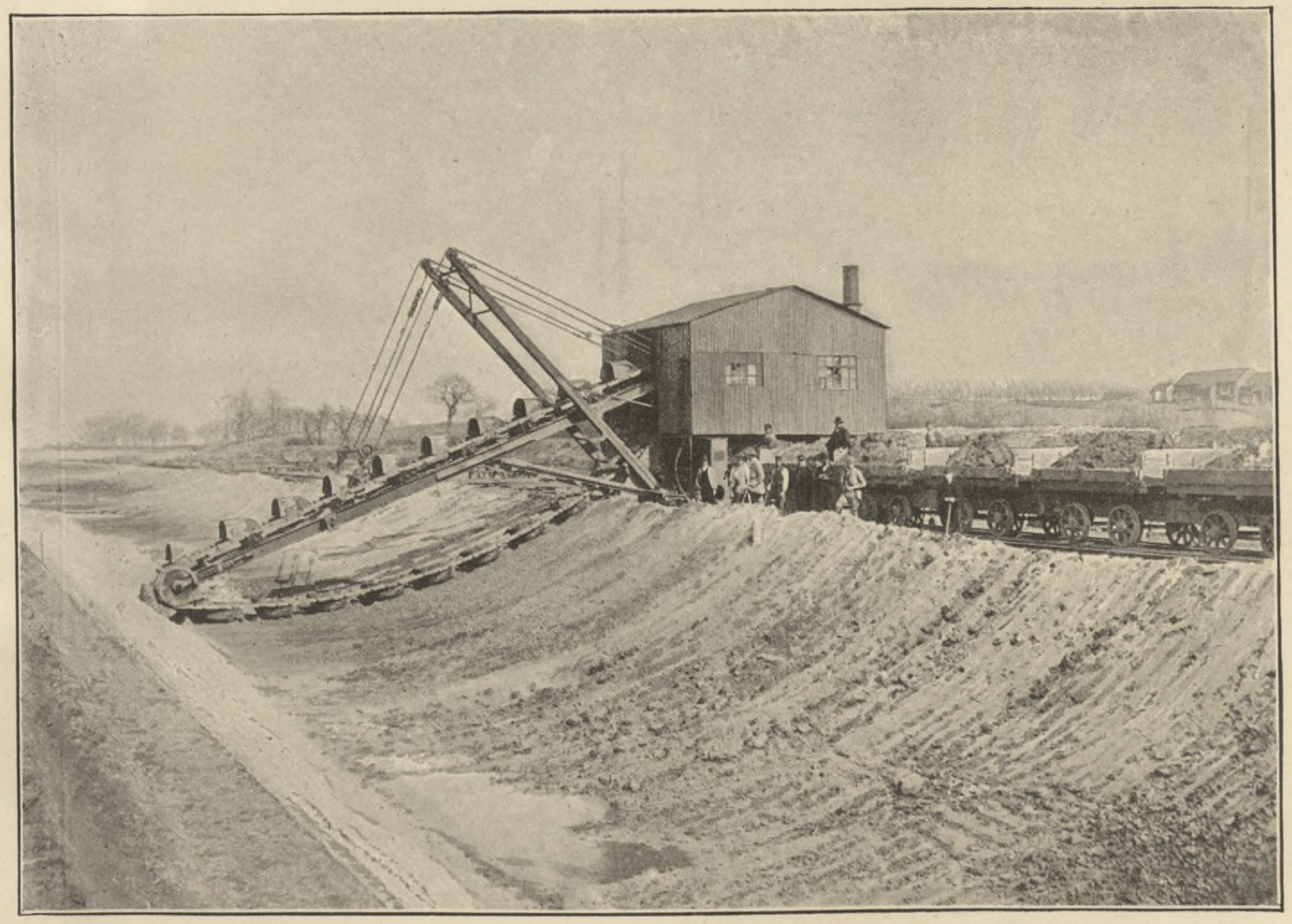


Fig. 114. Land Dredger; constructed by the Lubecker Maschinenbau Gesellschaft, Lubeck.

PORT OF MANCHESTER

(MANCHESTER DOCKS)

THE

MANCHESTER SHIP CANAL.

LENGTH, 35½ miles; BOTTOM WIDTH, 120 feet;
Excavated to a DEPTH of 26 feet.

NAVIGATED by day or night by the largest ocean-going cargo-carrying Steamers; amply demonstrated by the passage—in January, 1899—up and down the Canal of the ss. "Manchester City" (which is 461 feet long, 52 feet broad) with a draft of 25 feet (dead-weight capacity 8,500 tons).

Connected with all the **RAILWAY SYSTEMS** of Great Britain.

The Canal and Docks are in **DIRECT COMMUNICATION** with the whole of the **BARGE CANALS** of the district, embracing a Population of over 8,000,000.

PARTINGTON COAL BASIN has an area of 20 Acres of Quay Space, with a length of half-a-mile, 5½ Acres of Water Space, 5 Miles of Railway Sidings, and 4 Hydraulic Tips; directly communicating with the South Yorkshire and Lancashire Coal Fields. About 160 Tons per Hour can be loaded from each Tip.

LOCKS at Eastham, Latchford, Irlam, Barton, and Mode Wheel, 600 feet long, 65 feet wide.

2,500 ACRES OF LAND (ALONG THE SHIP CANAL) BELONGING TO THE COMPANY AVAILABLE FOR SALE OR LEASE.

Largest **GRAIN ELEVATOR** in the
United Kingdom; Capacity, 40,000 Tons,
or 1,500,000 Bushels.

HENRY BLACKLOCK & CO. LTD., MANCHESTER.

J. K. BYTHELL, ESQ., CHAIRMAN.
W. H. COLLIER, MANAGER.
A. H. WHITWORTH, SECRETARY.

OPENED BY
HER MAJESTY QUEEN VICTORIA
—MAY 21ST 1894.—

W. H. HUNTER, M. INST. C. E
SIR E. LEADER WILLIAMS, C
(CHIEF ENGINEER DURI

THE MANCHESTER SHIP CANAL DOCKS.

NOTES.

SCALE OF PLAN. FEET 100 0 — 500 — 1000 — 2000 — 3000 FEET

▨ *Denotes slope of banks or shallow water.*

🟩 *Denotes portions dredged to full depth.*

The Dock premises at present include 45 separate buildings, containing 157 extensive depots, namely:—

13	Seven-storey Warehouses	91 Depots
7	Four „ „	28 „
6	Three „ Transit Sheds	18 „
17	One „ „	17 „
1	Customs Transit Shed	1 „
1	Two-storey Fruit Shed	2 „
45 Buildings.		157 Depots.

LENGTH AND BREADTH OF DOCKS.

No. 8 Dock is 1,340 feet × 250 feet.
„ 7 „ 1,160 „ × 225 „
„ 6 „ 850 „ × 225 „
„ 5 „ 980 „ × 750 „
„ 4 „ 560 „ × 150 „
„ 3 & 2 „ 600 „ × 150 „
„ 1 „ 700 „ × 120 „

The Docks are equipped with Transit Sheds of new design, Hydraulic and Steam Cranes, Elevators, and other appliances, for giving quick despatch in loading and discharging.

The Docks are in direct communication with the whole of the Barge Canals of the district.

The Railways of the Company convey traffic direct between the various loading and discharging berths at the Docks, and are connected with all the Railway Systems of the Country.

The Water and Quay area of the Docks is 256 acres. Length of Dock Quays is 5⅛ miles. The depth of Nos. 6. 7, and 8 Docks is 26 feet, and of Nos. 1, 2, 3, and 4, 20 feet. No. 5 is not yet excavated.

W. H. COLLIER, MANAGER.

The Trafford Park Estate, adjoining the Docks, is now available for the establishment of various Commercial undertakings.

W. Henry Hunter
Chief Engineer

SEPTEMBER, 1897.
EXd W. J.

ENGINEERS OFFICE.
41 Spring Gardens
Manchester.

JOHN HEYWOOD, LITHO: MANCHESTER.

THE MANCHESTER SHIP CANAL.

The Manchester Ship Canal is 35½ miles in length, and has been excavated throughout to a depth of 26 feet, which depth will be maintained by dredging. The large Docks at Manchester have been excavated to 26 feet and the smaller Docks to 20 feet.

The bottom width at the full depth of 26 feet is 120 feet, with the following exceptions:—

(*a*) At the curve at the Weaver Outfall the width at the full depth is 140 feet, and at the bend at Runcorn, approaching the Runcorn Railway Bridge, it is 150 feet.

(*b*) For a distance of about 2½ miles, between Latchford Locks and Partington Coal Basin, the bottom width is at present only 80 to 90 feet, and large vessels are not allowed to pass each other on that portion of the Canal.

(*c*) From Barton Aqueduct to the Manchester Docks the bottom width is 170 feet.

For purposes of comparison it may be stated that the Suez Canal had, until recently (when widening operations were begun), only a bottom width of 72 feet, except at the passing places.

The tidal portion of the Ship Canal from Eastham to Latchford Locks (21 miles) is maintained at a level of 9 feet 6 inches above mean tide level. When the tide rises above this level it flows in and out of the Canal

The fixed bridges across the Canal are 75 feet above the normal water level, but as the headway is necessarily a few feet less when high tides or floods occur, to avoid detention masts should clear the bridges at 70 feet above the water level.

The Locks and Swing Bridges are all connected by telephone with each other and with the Dock Office at Manchester.

The Manchester Docks are equipped with Transit Sheds of new design, Hydraulic and Steam Cranes, and other appliances for giving quick despatch in loading and discharging.

The Railways of the Company convey traffic direct between the various loading and discharging berths at the docks and along the Canal, and are connected with all the Railway Systems of the Country.

The Canal and Docks are in direct communication with the whole of the barge Canals of the district.

The Manchester Ship Canal Company receive, warehouse, and distribute all descriptions of traffic, and quote through rates for conveyance by Railway to and from all Railway Stations.

Schedules of Charges and further information may be obtained at the Dock Office, Manchester.

February 1898.

W. H. COLLIER. MANAGER.

HENRY BLACKLOCK & Cº COLOUR PRINTERS, MANCHESTER