March 21, 1876.

GEORGE ROBERT STEPHENSON, President,
in the Chair.

No. 1,468.—“Hydraulic Canal Lift at Anderton, on the River Weaver.” By SIDENHAM DUER, B.Sc., Assoc. Inst. C.E.

THE river Weaver, running east and west through the centre of Cheshire, forms an important, though not generally known, system of inland navigation, which of late years has increased greatly in utility, owing principally to the development of the salt trade in that part of the county. It is navigable for a distance of 21 miles for steam barges of 200 tons burden, from a little above Winsford to Western Point, near Runcorn, where it flows into the Mersey. The river has, during the last one hundred and fifty years, been improved from time to time by the Trustees by whom it has been managed. But as trade has increased so much lately, it devolved upon Mr. Edward Leader Williams, Jun., M. Inst. C.E., late Engineer to the Weaver Trust, and now Engineer to the Bridgewater Navigation Company, to carry out many important works for its development, and to initiate others, some of which have already been successfully accomplished, as well as others designed by Mr. John Watt Sandeman, M. Inst. C.E., the present Engineer to the Weaver Trustees.

Among the facilities for traffic which Mr. Williams considered necessary was a ready means of communication, at Anderton, between the Trent and Mersey Canal and the river Weaver, so as to save the expense and loss of time involved in the transhipment of salt, pottery, and other goods. The first expedient which suggested itself for achieving this object was, that the barges should be raised and lowered between the canal and the river by a chain of locks; but this idea had to be abandoned, on account of the great space which would have been required by the locks, of the great delay in passing boats through them, and of the scarcity of water in the canal. Mr. Williams then thought that the barges might be lifted and lowered by hydraulic presses, without taking any water from the canal, and he consulted Mr. Edwin Clark, M. Inst. C.E., upon the subject. The canal, which for some miles runs parallel and close to the river, is on the top of a bank, while

the river is below. The difference between the levels of the water in the canal and in the river is 50 feet 4 inches. The problem, therefore, to be solved consisted in devising an expeditious means of raising and lowering laden barges through this height, and one which at the same time should both occupy as little land and use as little water as possible. It was thought advisable that the barges should be lifted while floating in a trough of water, to obviate all danger of straining, in the event of their cargoes shifting. This necessitated lifting the weight of the water in the trough as well as the barges, and was found to require a large steam-engine. It was then proposed to make the lift double, or to have two equal troughs which, being by some means connected, should counterbalance each other, like a pair of scales, when only one-half of the engine power would be required. It was further improved by the idea of taking a little water into the upper trough from the upper level, so as to make it heavier than the lower one, and that in its descent it should do nearly all the work of lifting the other trough. After the various designs had been considered, the works, of which the following is a description, were decided upon, and the arrangement of the details was intrusted to the Author by Mr. Edwin Clark, under his own supervision and that of the Engineer to the Weaver Trustees.

GENERAL DESCRIPTION OF THE WORKS.

In what is called the Anderton basin, there is an island in the river Weaver which was fixed upon as the best site for the lift. It was decided that the water of the canal should be carried in an aqueduct, at its normal level, across the river between the bank and the island, and that the boats should be lifted and lowered between the end of this aqueduct and a cutting from the main river into the island.

The works constructed at Anderton consist of a basin opening into the Trent and Mersey Canal; a wrought-iron aqueduct to lead the water of the canal from the basin across an arm of the river to the end of the lift pit; a double hydraulic lift, situated on the island, capable of lifting from the level of the water in the river to that in the aqueduct or canal, and a channel cut through the island from the lift pit to the main bed of the river, for barges to pass to and from the lift and the river. The sides and closed end of the lift pit are of red sandstone from the neighbourhood. The sides of the basin at the canal end of the aqueduct are brickwork, faced with red sandstone. This basin is much wider than

the aqueduct, so that barges can there wait their turns to be lowered into the river, or to pass into the canal, as may be required, without hindrance to the traffic of the canal.

Plate 2, Fig. 1, shows a side elevation, and Fig. 2 a plan of the works. Figs. 3 and 4 are cross sections of the lift and aqueduct. Fig. 5 gives some details of the arrangement of the gates for the aqueduct and troughs, as well as the method of making the joints between the aqueduct and troughs. Fig. 6 is a section of one of the siphons for insuring the proper depth of water in the troughs; and Fig. 7 gives some details of the main valves for working the apparatus, and of the method of controlling them.

AQUEDUCT.

The aqueduct is of wrought iron, 162 feet 6 inches in length, and 34 feet 4 inches in width, in three spans of 30 feet, 75 feet, and 57 feet 6 inches. A central web divides it into two channels, each 17 feet 2 inches wide. This central web and the sides of the aqueduct are 8 feet 6 inches deep, and form continuous girders, which carry the aqueduct, and the water, 5 feet 3 inches deep, contained within it. The total weight of the aqueduct and the water is 1,050 tons, or about $6\frac{1}{2}$ tons per lineal foot. The webs of the aqueduct girders are strengthened by wrought-iron gussets, to resist the outward pressure of the water, and they are also strengthened by wrought-iron overhead arches, which tie them together where the outward pressure and the compression on the top flanges are at a maximum. The bottom skin plates are supported by transverse floor girders, 1 foot 9 inches deep and 5 feet apart, which transmit the pressure on the bottom to the centre and side girders. There is also a small floor girder, 9 inches deep, connecting the larger floor girders in the centre of each half of the aqueduct, and extending from end to end. The aqueduct rests on a cast-iron bed plate, on the masonry of the basin at the canal end, and at all other points it is supported on cast-iron columns.

To insure a water-tight connection between the aqueduct and the basin, the cast-iron bed plate on which it rests is built into the masonry of the basin. The top of this bed plate was covered with red-lead, and the bottom skin of the aqueduct was bolted to it. The inner edge of the bed plate was chamfered off, and the space between this chamfer and the skin of the aqueduct was caulked with wooden wedges. The sides were made water-tight with the

masonry, by running in Portland cement at the backs of wooden fenders which protect the ends of the aqueduct girders.

The columns A B bear on Portland-cement concrete, contained in cast-iron cylinders, which rest upon a foundation of masonry supported on piles. The columns C, and all other columns round the lift pit, are carried down to below the bottom of the pit, and stand on foundations of brickwork and concrete. Each end of the aqueduct is fitted with wrought-iron lifting gates for controlling the ingress and egress of barges. As the aqueduct is divided into two separate channels, it follows that two such gates are required at each end. The weight of each gate is about 27 cwt. This is principally counterbalanced by weights D working over pulleys. The gates are lifted perpendicularly by a small crab and pulleys attached to cast-iron frames, which also serve as guides while the gates are being lifted or lowered. There is one crab to each gate, and one man can lift the gate 7 feet 6 inches clear of the water in about a minute and a half. This is quite high enough to allow the largest barges to pass under. The gates have a strip of indiarubber fastened to the back of the flange, round their sides and bottom, and the internal pressure of the water forces it against a corresponding angle-iron flange fixed to the aqueduct, so that a water-tight joint is made.

LIFT.

The lift is double, and the barges are raised or lowered while floating in a box or trough, full of water, so arranged that one trough containing barges, in coming down to the river, assists in lifting barges in the other trough up to the canal. Each trough is 75 feet long, and 15 feet 6 inches wide, and is long enough to hold the largest barges that can be used on the canal, and wide enough to hold one of the largest or two of the small ordinary barges. The small barges each carry from 30 to 40 tons, the larger barges from 80 to 100 tons, of goods. The troughs are constructed entirely of wrought iron, their sides forming girders 9 feet 6 inches deep in the centre, and 7 feet 6 inches deep at the ends. These girders support the entire weight of the trough, with its load of barges and a depth of water of 5 feet. The sides of the trough are stiffened to resist the outward pressure of the water, by external gussets like those of the aqueduct, but there are no overhead arches. The pressure on the bottom is transmitted to the side girders by transverse floor girders 1 foot 9 inches deep, and by longitudinal floor girders 9 inches deep.

At each end of a trough there is a lifting gate, similar in construction and mode of operation to those described for the aqueduct. At the sides there are a number of cast-iron siphons for securing whatever depth of water the circumstances of lifting may require. Each of the troughs is attached to the head of a cast-iron ram by a central wrought-iron socket 3 feet 6 inches deep, bored to fit the turned head of the ram. From this socket wrought-iron cantilevers radiate to the side girders of the trough to transmit the weight from the side girders to the ram. Each trough is thus entirely supported and moved up and down by one central vertical ram 3 feet in diameter.

This ram passes through a stuffing box in the bottom of the lift pit, and through the tunnel into the press. The wrought-iron tunnel under the lift pit, 4 feet 4 inches in diameter, is to afford easy access to the valve box E, and to the glands of the presses and stuffing boxes, for the adjustment of the packing, and for lubricating the rams. The weight of each trough, with the water and barges contained in it, is 240 tons, which is equal to a pressure of about $4\frac{3}{4}$ cwt. per square inch of the area of the ram. The rams and presses are of cast iron, in three lengths, joined together by flanges and bolts. The flanges of the rams were covered with red-lead before being bolted together. The flanges of the presses, besides red-lead, have a ring of lead wire between them, which, being squeezed flat by the pressure of the bolts, makes a water-tight joint up to the required pressure. The presses, pipes, and all other parts of the apparatus were tested to a pressure of 6 cwt. per square inch before being used. The presses are below the bottom of the lift pit, within cast-iron cylinders 5 feet 6 inches in diameter, sunk to the required depth by the pneumatic process. They fit into cast-iron bed-plates, laid on two layers of wood, each 4 inches thick, resting on the Portland-cement concrete at the bottom of the cylinders. These bed plates are fixed in their places laterally by Portland-cement concrete between them and the inside of the cylinders. Besides resting on the bottom bed plates, the presses can also rest on the tops of the cylinders containing them, which have large external flanges, so as to give a great area of foundation. At the corners of each of the troughs there are cast-iron guide blocks, which work against guides on the columns round the lift pit, so as to keep the troughs steady while they are in motion. The guides and guide blocks are accurately planed and carefully fitted.

The guide columns are supported, below the bottom of the lift

pit, on foundations of brickwork and concrete. They are filled with ballast, and built into the masonry round the lift pit to increase their weight and stability. At the aqueduct end of the lift pit they are braced to the columns supporting the aqueduct, and are tied to the aqueduct itself. At the river end they are braced together, and to a central column 10 feet 6 inches distant from the centre guide column, so as to form a large triangular buttress of great strength. This is tied at the top to the guide columns at the aqueduct end of the lift pit by the lattice girders, which also carry a platform; and halfway between the ground and this lattice girder this buttress is again tied to the same columns by other small lattice girders, placed horizontally to resist wind, and slung from the platform girders so as not to sag. These girders are thus kept straight, and form efficient tie rods.

The distance between the guide columns is sufficient to allow a trough, when disconnected from the top of the ram, to be floated between them out of the lift pit; and as wooden gates can be fitted to close the river end of the lift pit, the water can be pumped out, and all parts of the apparatus easily got at for repairs. A platform round the aqueduct and lift pit, at the height of the water in the aqueduct, for the manipulation of the gates, for moving barges in and out, &c., allows all parts of the apparatus to be easily seen from it. There is an accumulator, to assist in working the lift, having a ram 1 foot 9 inches in diameter, with a stroke of 13 feet 6 inches; it has a capacity equal to that of one of the main rams for a stroke of 4 feet 6 inches. The two main presses are connected by a pipe 5 inches in diameter (Fig. 7), fitted with an equilibrium valve, E, for opening or closing communication between them.

There is also a pipe, 4 inches in diameter, for each of the presses, passing from the accumulator through continually open passages in the valve box E. These pipes are opened or closed separately, as required, to the accumulator by valves, F, situated under the end of the aqueduct. Thus the accumulator can be opened to either or both of the presses as may be wished. From a T piece on each of the 4-inch pipes, between the valves for controlling them and the presses, a waste pipe, 2 inches in diameter, goes up to the valve house, and there passes into a valve box by which the water in the press with which it is connected can be run to waste into the aqueduct. A branch on each of these waste pipes contains a small safety valve, which is lifted whenever an ascending trough may be going too high, and the water running to waste prevents danger. These pipes and valves, excepting those for carrying the water from a

steam-engine to the accumulator, are all that are required to work the lift; and are controlled, by means of shafting and gearing, by one man in the valve house, who turns one of five wheels according as he wishes to open or close the valve between the two presses, to open or close either of the presses to the accumulator, or to let the water in either of the presses run to waste. The relative position of the wheels in the valve house is the same as that of the valves themselves; so that the man stands, as it were, in the centre of a model of the lift. This man works the lift in accordance with signals from others whose business it is to bring the barges into and out of the lift. The valve house is on the top of the aqueduct, and commands a good view of the whole apparatus.

MODE OF WORKING.

To understand the principle of action of the lift, let it be granted, in the first place, that for a given depth of water in a trough, the weight on the ram supporting it is constant, whether there are barges floating in the trough or not. Again, let it be granted that, if the weight of the two troughs and their inclosed loads be the same, and the communication between the two presses open so that the water can pass freely from one press to the other, the apparatus will be in equilibrium when the two troughs are at the same level. On the other hand if one trough be heavier than the other, the heavier will fall nearer to the lower level and force the lighter one up as much nearer to the level of the canal. Suppose now that all the valves are closed, that one trough is at the aqueduct level, while the other is down in the lift pit, that the upper trough contains water 5 feet deep with or without barges floating in it, and that the lower one contains water 4 feet 6 inches deep with or without barges floating in it. If the valve E on the 5-inch pipe is now opened, so as to allow a free communication between the two presses, the upper trough will descend and cause the lower or lighter one to ascend, until, by becoming partially immersed in the water in the lift pit, it loses part of its gravitation, and has lifted the other trough to within about 4 feet 6 inches of the top of the lift.

The communication between the two presses is now closed, the water still remaining in the press supporting the descending trough is allowed to run to waste into the aqueduct, and the trough consequently descends into the water of the lift pit, and the barges contained in it have now been lowered from the level

of the canal to the level of the river. The gate at the river end of the trough can accordingly be raised, and the inclosed barges floated out into the river and be replaced by others waiting to be lifted. Meanwhile the man in the valve house opens the connection between the accumulator and the press of the ascending trough, and the accumulator forces this trough up to 6 inches below the top of the lift. It does not force it up all the way, because it is necessary that the water should be 5 feet deep instead of 4 feet 6 inches when the trough is descending, and the simplest way of increasing the depth of water is by running it in from the aqueduct. Before the barges can be transferred from this trough to the aqueduct, or even water can be allowed to flow between them, a water-tight joint must be made between the end of the trough and the end of the aqueduct. For this purpose the ends of the trough and aqueduct are bevelled, as shown in Fig. 5, and a facing of wood is fitted on to the end of the trough and correctly adjusted to the bevel of the face of the aqueduct. A round piece of indiarubber, 3 inches in diameter, is fixed on the face of the aqueduct by attachments of malleable cast iron, and as an ascending trough is lifted by the pressure of the accumulator the indiarubber is squeezed between the two bevelled surfaces, and makes a water-tight joint. After this joint is made, a valve is opened in the aqueduct gate, to allow water to pass between it and the gate of the trough, and the aqueduct gate is lifted as soon as the water-level is the same on both sides. The trough gate is now pushed just clear of its indiarubber face by the pressure of the extra 6 inches head of water in the aqueduct, and can therefore be lifted directly after the aqueduct gate, when the water flows rapidly into the trough from the aqueduct to make the two levels identical, and the depth of water in the trough becomes 5 feet instead of 4 feet 6 inches. Barges can now of course be transferred between the trough and the aqueduct as required.

When the gates have been again closed, and the trough is allowed to descend, the water between the two gates falls through a hose pipe into the lift pit below. It will be observed from the shape of the gates that the space between them is made as small as possible to prevent waste of water.

When a trough descends into the lift pit it is always immersed to a depth of fully 5 feet, to get barges in and out easily, and when the river is swollen the immersion may be still greater. It being, however, absolutely necessary for the working of the lift that the depth of water while the trough is being lifted should not be more

than 4 feet 6 inches, the extra water in the trough is drawn off by the siphons already alluded to. While a trough is descending into the lift pit, as each of the siphons dips into the water, the air within the siphon is driven out through its shorter leg inside the trough, which becomes nearly filled with water; and consequently, when the trough is again lifted, the siphon, having a partial vacuum within it, draws water out of the inside of the trough down to the bottom of its leg, or until air is admitted into the outer leg by the water falling below the bottom of a small adjustable pipe connecting it with the water in the inside of the trough. Siphons for letting the water out of the troughs are preferred to valves because they are automatic, whereas if valves were used each of them would have to be opened while the trough was at the bottom of the lift to let water out, and closed again when at the top of the lift to prevent the loss of the 6 inches depth of water which comes into the trough from the aqueduct. As there are twelve siphons to each trough, this would seriously delay the operations of a machine required to work so quickly as the one being described. It was stipulated that the lift was to be performed in three minutes; it has been done in about two minutes and a half, and by increasing the quantity of water taken from the canal it could be effected more speedily even than this.

Besides being worked as a double lift, each trough can be lifted separately by the engine and accumulator; but this is a comparatively slow operation, and occupies about half an hour. With ordinary care, no accident can happen to the apparatus from frost, as all the exposed pipes are protected with felt, and at night it can be entirely emptied of water by opening two little valves placed on the lowest exposed parts.

It will be understood from this description that the motive power employed for working this lift is of two kinds. The first part, and in fact quite eleven-twelfths of the entire lift, is performed by taking a layer of water 6 inches deep over the surface of the upper trough, that is to say, a weight of 15 tons from the canal, and the remaining one-twelfth is performed by a small steam-engine continually pumping water into an accumulator.

The obvious advantages in having the lift double, so that it can be worked as described, are the saving of engine power and time. For, if eight minutes elapse between the commencement of each lift, the double lift requires an engine of 10 HP., supposing 20 per cent. of the power to be lost through friction, &c., to take up two barges and bring down two others simultaneously. A single lift could, however, only take two barges

up or bring two down in eight minutes, so that sixteen minutes would in this case elapse between the commencement of each lift. And even at this speed, and to do only half the work of a double lift, an engine of nearly 65 HP. would be required, and a very large accumulator. In the double lift, each press, with its insistent trough, is in turn an accumulator to the other, and does its own useful work of lifting and lowering.

Among the advantages possessed by this apparatus over a flight of locks is the unimportant quantity of water used; only 6 inches of water over the surface of the trough are required to work the lift, whereas in a flight of locks one lockful will always be taken from the upper level as a boat passes down, and one or several lockfuls will be taken by an ascending boat, according as the locks are full or empty. In a chain of six locks, with a total fall of 51 feet, the depth of water taken from the upper level will therefore be 51 feet if the traffic is equal in each direction, instead of the 6 inches required for a lift. There is also an immense saving of time; eight minutes are sufficient for the whole operation of transferring two barges from the river to the canal, and two others at the same time from the canal to the river. The Author is informed that in a flight of locks at Runcorn, where the difference of level is the same as at Anderton, it takes from an hour and a quarter to an hour and a half for a barge to go through. The staff required consists only of one man in the valve house, one engine-driver, and three labourers for attending to the troughs and taking boats into and out of the lift. The total working expenses, including stores and a clerk to check the tonnage, are under £10 per week.

The ironwork and machinery were supplied and erected by Messrs. Emmerson, Murgatroyd, and Co. (Limited), of Stockport and Liverpool; and the foundations, masonry, and sinking of the cylinders were carried out by the Trustees of the River Weaver, from the designs and under the superintendence of Mr. Sandeman. Since the apparatus was opened by the Trustees, in the beginning of July 1875, no alterations or additions have been required; and great satisfaction is expressed with the way in which the lift works, and the ease with which it is manipulated. .

The Author is persuaded that this method of raising barges from one level to another may always be adopted with advantage, instead of flights of locks, where considerable differences of level have to be overcome. The first cost would be less, in addition to the advantages in the saving of water and of time; and he is convinced, from his experience at Anderton, that lifts on this prin-

ciple may be constructed, not only for raising and lowering barges, but for large vessels; and if canals should be constructed to divert the goods traffic from railways, where it at present causes great inconvenience, and sometimes serious accidents, such lifts must then be frequently employed. It has been explained that at Anderton, where saving of water is of great consequence, a very small amount of engine power suffices. It will be readily understood that where water can be more easily spared a steam-engine might be entirely dispensed with, and a turbine or some other application of water power employed instead.

In conclusion, the Author has to express his best thanks to Mr. Sandeman for kind co-operation and for valuable suggestions connected with the details of the work. He has also to testify to the thoroughly efficient way in which the Contractors did their work, and to the good quality of the materials employed.

The communication is accompanied by a series of drawings, from which Plate 2 has been compiled.

[Mr. E. LEADER WILLIAMS

HYDRAULIC CANAL LIFT AT ANDERTON ON THE RIVER WEAVER.

Scale of Feet for Details
0 1 2 3 4 5 6 7 8 9 10 Feet
0 10 20 30 40 50 60 70 80 90 100 Feet