Part 3

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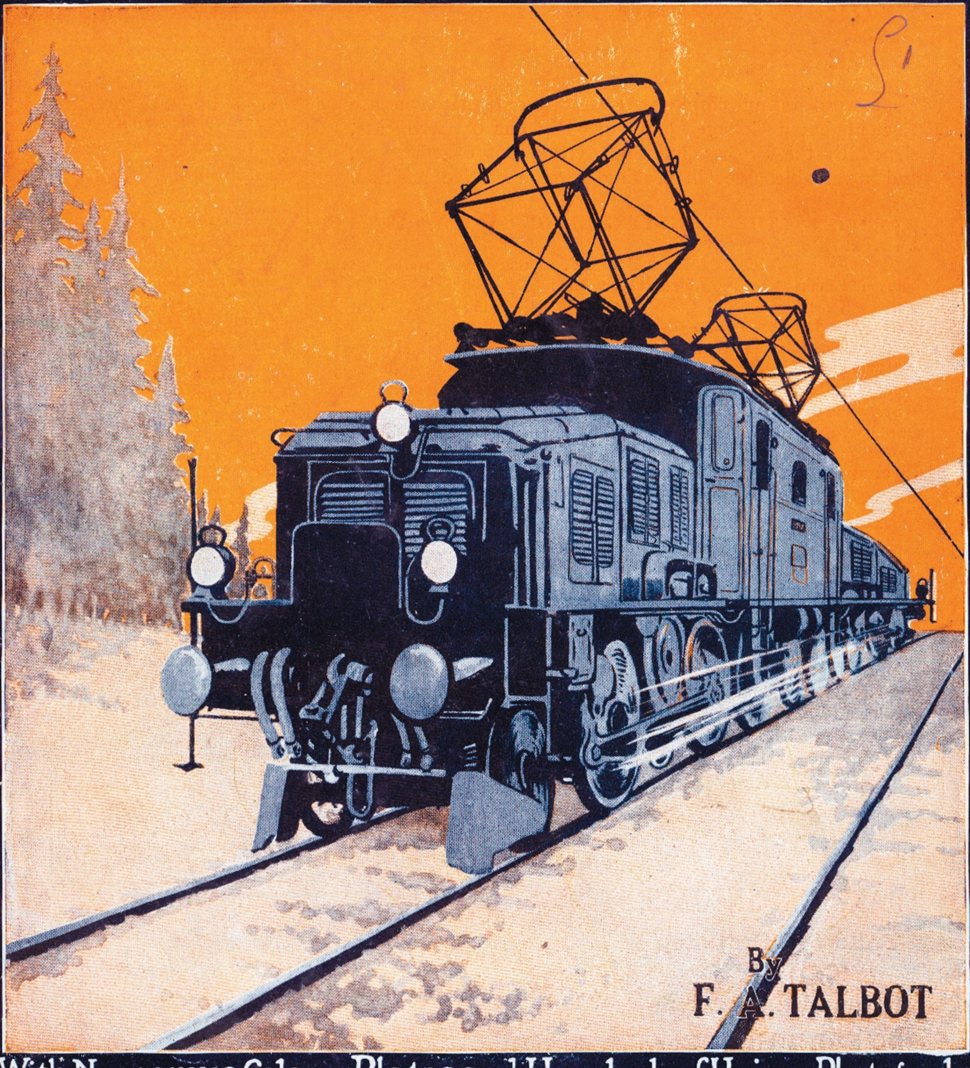

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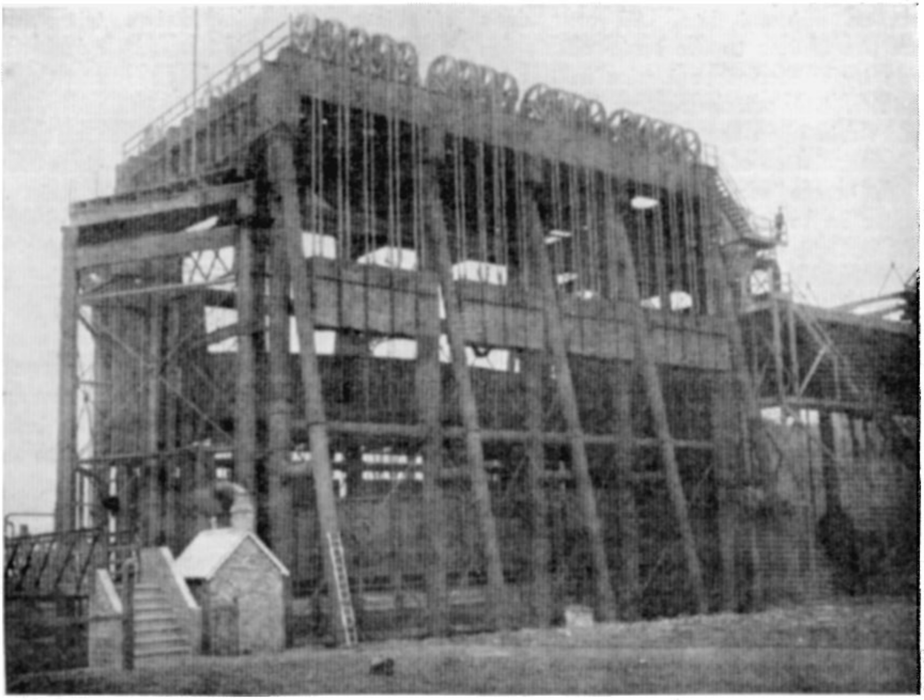


GENERAL VIEW OF THE ANDERTON BOAT LIFT AFTER ELECTRIFICATION.

The illustration shows the overhead gear, including the 72-inch pulley-wheels, over which are passed the cables attached to the counterweights. By means of this lift, canal craft are passed vertically through the 50-feet difference between the levels of the river Weaver and the Trent and Mersey Canal System.

A Novel Lift for Boats

HOW THE ELECTRIC CURRENT FACILITATES CANAL TRANSPORT IN ENGLAND

IN the days preceding the weaving of the railway network now enmeshing Great Britain, industry was dependent upon the various waterways for the cheap transport of its raw and manufactured materials. Among the links of this character to be pressed into such service was the river Weaver. This modest Cheshire waterway became of decided commercial importance by extending to the Cheshire salt and chemical industries, pivoted upon Northwich, an outlet to the sea via the river Mersey, into which it empties near Runcorn. The control of this channel of communication became vested in the River Weaver Navigation Trustees; through their enterprise it was rendered navigable by steam barges of 300-tons burden to Winsford, about twenty-one miles above its confluence with the Mersey. To-day the tributary does not discharge directly into the river, but into the Manchester Ship Canal, through the locks at Weston Point.

Water communication extending into the Midland area was desired, and, in fact, was possible because at Anderton the river Weaver flows alongside the Trent and Mersey Canal system. Interchange of traffic between the two set in and developed rapidly, but was seriously handicapped by the necessity to tranship the goods at this point, because the river flows 50 feet below the canal. Transhipment of cargo not only proved expensive but involved loss of time, to avoid which the question of the feasibility of effecting a physical junction between the two waterways was raised. The advocates of the scheme suggested the obvious means to such an end, namely, locks, but when the engineer-in-chief to the Weaver Trust, who at that time was the late Sir Edward (then Mr.) Leader Williams, investigated the problem, he discovered that such a solution was impracticable. The introduction of locks would have necessitated the acquisition of a large tract of land, their construction would have occupied considerable time, while, finally, the operation of the locks would have withdrawn a huge volume of water from the canal.

Inasmuch as connexion was imperative, the engineer was forced to evolve another solution, if he could, and this assumed the form of a lift-lock between the two waterways, and operated in such a manner as to involve no loss of water from the canal.

A Lift-lock Projected

It was an interesting proposal, and further close investigation served to emphasize its practicability. Briefly, the project involved the provision of two troughs, of equal dimensions, each of which was to be charged with water, and in which the boats were to float to eliminate all possibility of their hulls being strained in the event of the cargoes shifting. Under this system one trough was to be elevated while the other was lowered, and they were to oscillate upon the counterbalancing system. Hydraulic operation was to be adopted by means of a vertical ram, or piston, moving up and down in a cylinder. A similar system for handling boats of larger capacity, it may be mentioned, has since been introduced upon the Trent navigation system in Canada.

The fulfilment of this accepted proposal presented some interesting problems and entailed a considerable amount of work.

Interesting Problems

There happened to be an island in the river, and it was decided that this would constitute the most favourable site for the lift. The canal had to be brought to this point, and this provision was fulfilled by building an aqueduct, as a spur to the line of the canal, at the normal level of the latter, across the river below to the island; the extremity of the spur was to form the opening for the passage of the boats to and from the lift.

The aqueduct is constructed of wrought-iron, is $162\frac{1}{2}$ feet in length, 34 feet 4 inches wide, and has a water depth within of $5\frac{1}{4}$ feet; it is built in three spans, supported on cast-iron columns, which carry it to the top of the hydraulic lift-pit. As there are two troughs constituting the lift, the aqueduct had to be divided into two channels each forming an approach to the lift, and this was done by the introduction of a central web into the aqueduct, giving a fairway 17 feet 2 inches wide on each side. Consequently, there is no risk of a boat, waiting to enter the lift, obstructing the passage of one which is leaving the elevator. The final feature was the sealing of the end of the aqueduct, when separated from the trough, to avoid loss of water. For this purpose two wrought-iron lifting gates were fashioned—one for each channel—and they were so set as to present when closed a water-tight end to the aqueduct. These gates each weigh 3,000 lb.

and are counterbalanced by weights working over pulleys. Originally they were manually operated, but have since been converted to electrical working.

The two troughs, in which the boats are lifted up and down, are of identical dimensions and weight, whether carrying a boat or not, because a boat with its cargo displaces an equal volume of water-weight. Thus it is immaterial whether a boat is lowered simultaneously with the elevation of another craft. Each trough measures 75 feet in length by $15\frac{1}{2}$ feet in width and carries 5 feet of water. The trough may be described as an immense rectangular box, fashioned of cast-iron, and of special design to prevent the sides from bulging under the weight imposed from within. Each end of the trough is fitted and sealed with a water-tight gate, similar to that provided at each end of the canal aqueduct.

Features of the Original Installation

In the original installation each of these troughs was attached to the head of the hydraulic ram or piston by which it was moved up and down, the connexion being a socket $3\frac{1}{2}$ feet deep fitting over the extremity of the ram. The latter was 3 feet in diameter, and at the bottom of the lift-pit or well passed through a stuffing-box and then through a tunnel into the press. The tunnel, which was 52 inches in diameter, was provided to allow access to the valve-box and glands of the presses, as well as the stuffing-boxes, and to the ram itself for lubrication when necessary. The presses were set below the bottom of the lift-pit within cast-iron cylinders, and as the rams themselves were over 50 feet in length they had to be continued below the floor of the lift-well for a corresponding distance.

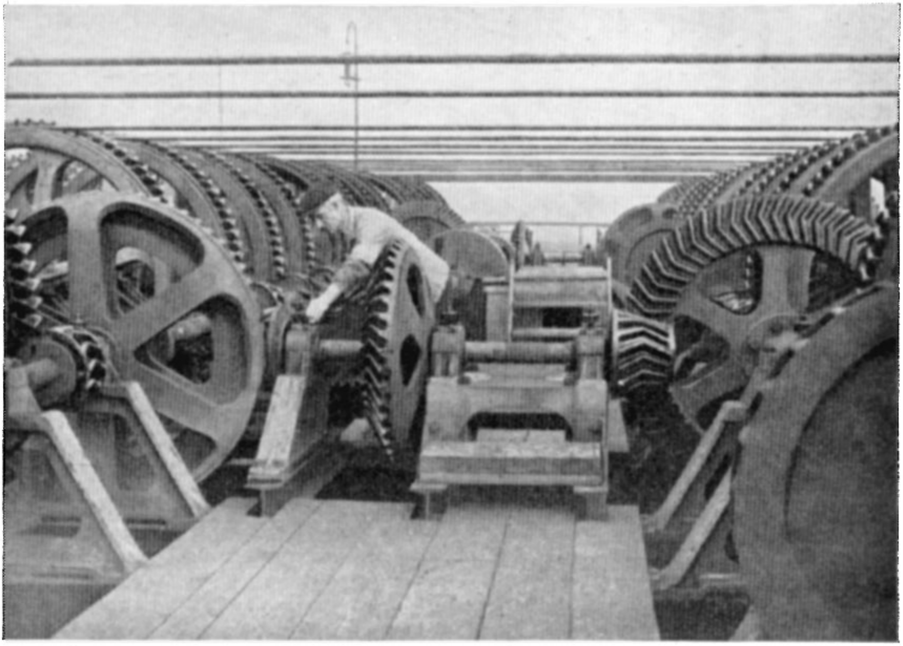
The troughs had to be guided in their vertical travel, and this was assured by fitting guide blocks to the corners of each trough, which worked against guides on the columns suitably disposed around the lift-pit. This arrangement kept the troughs steady while in motion. The method of bracing the supporting guide columns, while appearing simple, was yet intricate, inasmuch as when working there was an aggregate of 500 tons in movement; each trough with its charge of water and boat represented some 250 tons. At the top of the lift-pit these columns supported lattice girders which carried a platform.

The Counter-balancing System

To effect the smooth and efficient working of the counterbalancing system adopted involved the necessity of somewhat complex mechanism. Each of the troughs was fitted with a number of syphons enabling the level of the water within to be adjusted to requirements. The actuation of the elevator was assisted by a hydraulic accumulator having a ram 21 inches in diameter by a stroke of $13\frac{1}{2}$ feet. The two main presses were interconnected by a pipe, having a valve, for establishing or interrupting communication between them. Pipes and valves also extended from the accumulator to each of the presses, so that the accumulator could be employed to assist either or both presses. Then there were waste pipes to convey the spent water from the accumulator back into the aqueduct; it was imperative that loss of water from the canal should be reduced to the minimum.

The India-rubber Buffer

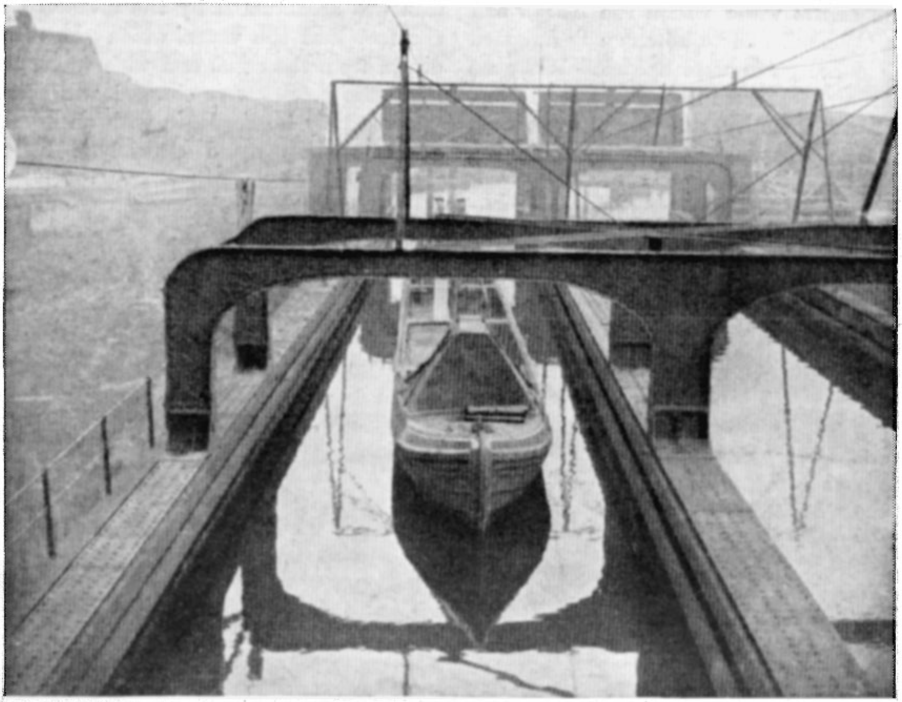
The operation of the hydraulic system demanded somewhat delicate control and skill, especially when bringing the rising trough to the level of the aqueduct, where, of course, a water-tight connexion between the trough and the aqueduct had to be made before the gates were lifted. This was done by facing the end of the aqueduct with thick india-rubber, which became compressed under the weight imposed by the trough. Then the manipulation of the level of the water within the trough and the aqueduct had to be carefully adjusted before the gates were opened. While no water was lost from the canal when lifting, a certain quantity was wasted upon each descent; this was the quantity occupying the space between the closed trough and aqueduct gates, which was carried through a pipe into the pit below. Although the greater part of the energy required to operate the lift was derived from the weight of the water in the troughs, a small volume, about one-twelfth, had to be furnished by hydraulic pressure which was produced by a steam-engine and pump.



THE WINDING GEAR OF THE ANDERTON BOAT LIFT.
At the top of the lift a strikingly simple winding gear has been erected, to which the power from a 30-horse-power electric motor is delivered through shafting, worm and bevel-wheels. All the teeth are helical to eliminate noise and back-lash.

For some ten years the hydraulic system worked uneventfully and satisfactorily, except for the bursting of one of the presses. Then signs of the wear and tear imposed began to become manifest. This depreciation was accentuated by the discovery of the fact that the water, which was being drawn from the canal and with which the hydraulic presses were charged, was somewhat heavily impregnated with chemicals, which set up acute electrolytic action between the copper and iron entering into the construction of the rams. Many expedients were adopted to arrest this action, but no appreciable benefits were observed until the use of the canal water was abandoned and a condensing plant was laid down.

This first material overhaul of the plant was notable for another important development—the introduction of electricity at the lift. It was a modest commencement, entailing the installation of a dynamo and a battery for lighting the lift and workshops, as well as furnishing power for some



THE APPROACH TO THE LIFT FROM THE TRENT AND MERSEY CANAL.
The upper-level connexion between the waterway and the caissons is by an aqueduct divided into two distinct channels. Electrically operated gates control admission to the lift.

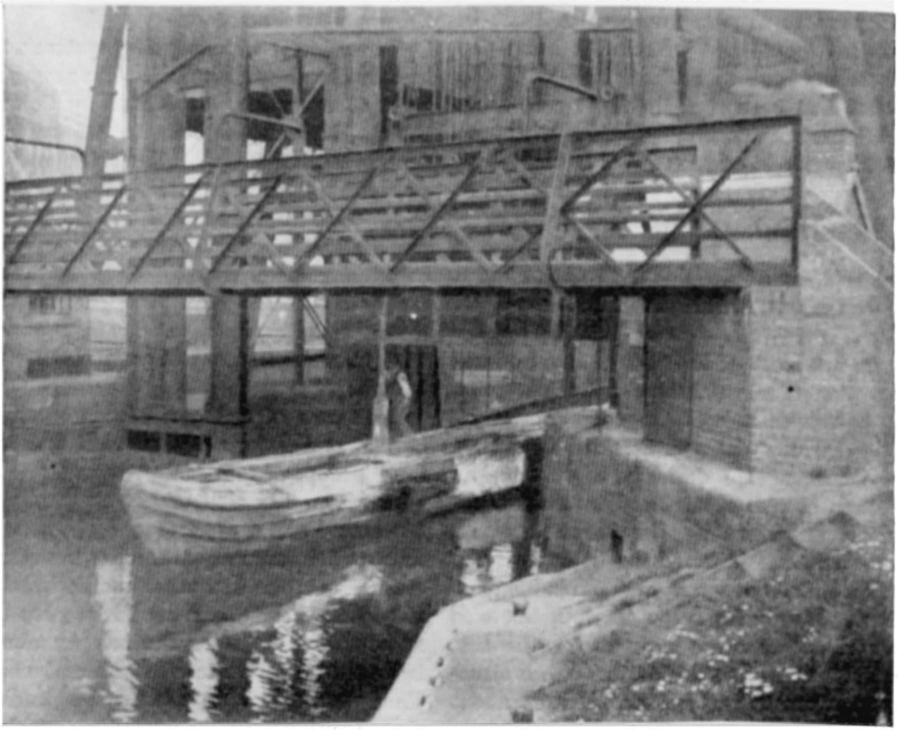
warehouses and cranes on the adjoining wharves. At the same time advantage was taken of this power-supply facility to convert the aqueduct and other gates to electrical operation, bringing about the first reduction in labour. The three men hitherto maintained in constant attendance at the gates were no longer required.

A new lease of life was given to the hydraulic system, which prevailed until 1902. It was then found that the steam-boilers, which had been in constant service since 1876, had reached the limit of useful—or, rather, safe—life. Again the situation had to be closely investigated, and this gave rise to the question as to whether it would be more advantageous to renew the boilers or to scrap the steam in favour of electric pumping-plant, the local power-supply company furnishing the power. Careful consideration of the problem resulted in the alternative meeting with favour, and forthwith the electrification of the lift may be said to have been taken in hand, although this represented only a small contribution to the complete problem. The installation of electric motors and pumps, although only for the operation of the auxiliary machinery, proved to be cheaper and more satisfactory than the original steam-power.

Unfortunately, the advantages reaped on the one hand were more than off-set in another direction. The precept concerning the inadvisability of putting a new patch into an old garment was being vindicated. The repair bill was mounting at an inordinately rapid rate; increasing difficulty was being experienced in keeping the rams and the hydraulic pipes water-tight; while the lift, as a whole, demanded drastic overhaul to render it thoroughly safe.

The chief engineer and general manager to the Weaver Navigation Trustees, Colonel J. A. Saner, M.Inst.C.E., after a thorough and minute examination of the whole fabric and its mechanism, presented a report in which he advocated the total abandonment of the hydraulic system and its supersession by electricity, combined with the reconstruction of the apparatus so far as the conditions of the site would permit. He would have preferred the elaboration of the project and its execution upon a new site, more in accordance with modern principles, but this was regarded as impossible, although it would have been easier and possibly cheaper in the long run. The engineer was necessarily compelled to comply with the conditions which existed, and these in turn precipitated three other acute problems. In the first place, there could be no interference with traffic. Secondly, there must be greater accessibility to all parts for repairs, as far as practicable, because complete renewal was out of the question; and thirdly, the reduction of the cost of the work to the minimum, compatible with the requirements of complete safety, was indispensable.

Possibly the questions of traffic interference and accessibility on account of repairs were the most conspicuous factors in the case. Some experience relating to the expense pertaining to the latter had been gathered from the frequency with which it had become necessary to attend to the



BOAT LEAVING THE LIFT AT THE LOWER LEVEL.

When the caisson has completed its descent, the end of the trough in which the craft is floating is opened, thus providing free communication with the river Weaver.

hydraulic rams. Every time these were taken in hand traffic had to be stopped. Accordingly, in order to reduce business disturbance to the minimum, repairs had been carried out as far as practicable on Sundays, when traffic was at zero; but the labour charges upon that day were always 100 per cent. heavier. In so far as traffic interference from the change-over to electricity was concerned, Col. Saner undertook, if his idea were adopted, to ask for not more than three stoppages of the lift at different periods, not exceeding fourteen days in each instance—forty-two days in all. His scheme also indicated how future repairs might be carried out with the minimum interruption of business, because he proposed to sling the troughs or caissons from the top, instead of supporting them on rams, and in such a way as to be independent of one another. A fault in one lift would not necessarily bring the whole machine to a dead stop until the defect had been remedied.

His project was adopted. Although some of the work was relatively of a heavy but more essentially of a delicate nature, it was completed in accordance with the engineer's schedule; the total stoppage of traffic was, in fact, for only thirty-eight days.

A Well-Kept Schedule

As one part of his scheme involved renovation of the structure to such a point as to render it perfectly safe, the means whereby this end was attained is worthy of mention. He decided to convert the bottom or well of the lift into a dry dock, which was done by the insertion of an inverted arch to form the bottom of the basin. This was not only an advantage from the working point of view, but also served to extend a support for the side walls upon which rested the upper structure, representing a dead load of about 1,676 tons.

This dock measures some 80 feet in length by 39 feet in width, and the first stoppage of traffic was made to permit the subaqueous part of the scheme to be completed. A few weeks later the second stop was imposed to allow the new river gates to be put in; similar arrangements were made to permit the work to be carried through to scheduled time.

The remaining sections of the undertaking were now put in hand, but these did not impede the working of the lift in any way. These included the strengthening of the superstructure and its modification to meet the new conditions incidental to electric working. The electric drive was completed in two sections; in other words, the lifts were completed one at a time.

The new system is interesting because of its simplicity. Above the top of the lift, over the space receiving the troughs at the upper level and forming a roof as it were, a pulley system with its drive has been mounted. The new principle of operation, elaborated by Colonel Saner, depends on two equal weights counterbalancing each other; the motive power is applied to turn the pulley through worm reducing gear and double helical gearing, the weight of which is distributed over a number of ropes. There are thirty-six pulley-wheels, each 72 inches in diameter, to each caisson, set out in two rows of eighteen each, alongside and above each trough.

A Striking Pulley System

Each row of pulley-wheels is arranged in two end groups of five each and two inner groups of four each —eighteen in all. A 30-horse-power electric motor, with tramway controller, resistance automatic brake, and other auxiliaries, running at 750 revolutions per minute, has this speed reduced to 18 revolutions per minute by means of an enclosed worm and wheel. The worm-wheel actuates a longitudinal shaft transmitting the power to two short transverse shafts, making 12 revolutions per minute, spaced equidistantly from the

How the Pulleys Work

centre and each end of the pulleys. By means of bevel-wheels the worm-wheel rotates two longitudinal shafts, each 70 feet long, extending the full length of the structure, and fitted with pinions engaging with each pulley. Through this gearing the speed is reduced to 3 revolutions per minute, and as the pinions are 12 inches in diameter and the pulley-wheels 72 inches in diameter, there is a further speed reduction whereby the main pulleys make only one revolution in two minutes. It will be seen that by this arrangement each pulley-wheel is directly geared to the shaft, and as all the teeth are helical there is an entire absence of noise and back-lash. Furthermore, the disposition of the cross-shafts ensures the simultaneous movement of the pulleys by equalizing the torsion on the main shafting.

The Work Completed

The overhead work, preparatory to the actual conversion, was somewhat heavy, involving the placing of girders weighing 15 tons, but this was done without interference with the operation of the lift. When all was ready for the final touches, demanding the stopping of the lift, the third interference with traffic took place. The channel-bars were then promptly attached to each side of No. 1 caisson, ropes made fast, the hydraulic ram-head removed, and other incidentals completed, including certain repairs of a general order. Within fourteen days the first caisson was ready for its initial movement under electric power. When the current was switched on it moved without the slightest hitch.

Directly the first caisson was reopened for traffic, work was concentrated upon the fellow trough, and a few weeks later its conversion was completed. Although the caissons have been slightly modified, their weight remains virtually unaltered, since the attachment of the channel-bars and other incidentals has been off-set by the detachment of the cast-iron ram-head incidental to the hydraulic system.

The weight of each caisson, with its load of water, is 252 tons—the inclusion of a boat makes no difference, because the craft with its cargo displaces an equal weight of water, as was previously pointed out—to counterbalance which 252 tons of cast-iron, divided into thirty-six groups of 7 tons each, are distributed equally on each side. Each group is suspended by an independent rope, which passes over a 72-inch pulley, so that, whatever the stretch of the rope may be, the strain imposed upon the latter can never be in excess of the weight—7 tons plus the friction between the rope and the pulley. Taking into account that practically the whole length of the rope is hanging free when the caisson is elevated to the upper or aqueduct level, any uneven stresses which may have been exerted undergo relief, the rope starting afresh upon each occasion the caisson descends.

A 570-Tons Movement in 5 Minutes

In view of the foregoing it will be realized that the only power required is that necessary to overcome the friction of the pulleys on their bearings, and that incidental to other insignificant sources. Notwithstanding the fact that the total weight which has to be moved is approximately 570 tons, including the wheels, the actual energy demanded to move the caissons does not exceed a Board of Trade unit, while the movement is completed in 5 to $5\frac{1}{2}$ minutes.

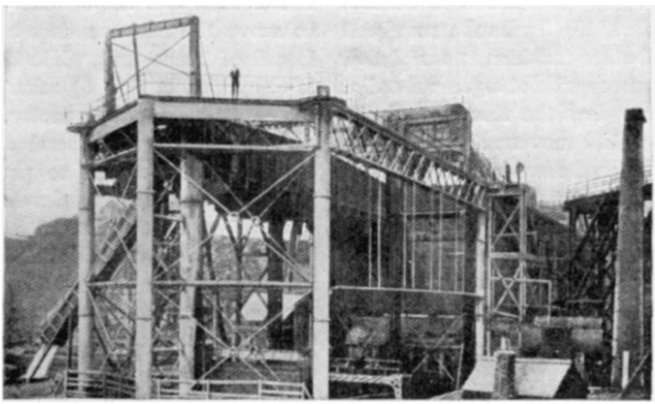
The 30-horse-power motor, which may seem to err on the liberal side for such a duty, was installed to permit possible variations in the water-levels of the two caissons, or an unbalanced load exceeding 14 tons. In actual practice, however, this is not required, because the joint at the river end of the caisson is made adjustable to meet fluctuations in level due to drought or floods.

It may be pointed out that the working ropes are merely laid on the pulleys, but the unexpected has not been ignored. A boat might knock out an end gate, and thus throw a sudden and excessive speed strain upon the ropes and counterweights, tending to precipitate running away; but this contingency is counteracted by the inclusion of an ample number of idle ropes, which coil and uncoil on the larger pulleys.

Another interesting feature of the electrical equipment is the automatic device which has been introduced for lifting the gates in the end of the aqueduct and that of the caisson simultaneously, by means of a single set of gearing. Under the original conditions, each gate was operated separately and was provided with its individual gear. Simultaneous gate movement is accomplished by a locking gear, which is brought into action as the caisson, in rising, approaches the end of its vertical travel. A lug fixed to the aqueduct gate is caused to engage with a trigger attached to a balance-weight and staple. This action brings the staple over a hook fixed to the aqueduct gate and holds it there. When the lifting effort to the gates is applied by the 5-horse-power motor in the overhead control-house, both gates are lifted together, so that a clear passage between the caisson and the aqueduct is established. When the gates are lowered the engaging hook, locking both gates together, falls by gravity, and so releases the staple, the counterweight of which then tumbles clear. There is no danger of any damage being inflicted from the hook failing to clear by gravity, because the lug on the aqueduct gate will cause it to fall as the caisson begins to move.

Electrical operation has proved superior to the former system of hydraulic operation in every respect. Two men suffice to carry out the essential tasks, one man above and the other below, although a third attendant is retained for emergency.

Some idea of the work of the lift may be gathered from the record for a recent year. During twelve months the lift made 14,302 strokes, up or down, passing 16,797 boats from the canal to the river or in the opposite direction; 213,771 tons of freight were carried, for an average consumption of electricity per stroke ranging from ·54 to ·9 of a Board of Trade unit. The circumstance that the lift has been operating with complete success, and without a single mishap, testifies to the excellence of the scheme as evolved by the engineer, and the efficiency of the principle of electrical working adopted.



THE ANDERTON BOAT LIFT BEFORE ELECTRIFICATION.
The orginal design provided for the oscillating vertical movement of the two troughs by hydraulic rams. By comparing this illustration with that on page 70, the change wrought by electrification may be realized.