ON THE

CONSTRUCTION OF LARGE SLUICES

FOR

IRRIGATION AND NAVIGATION;

ALSO

A LETTER

TO THE

LANDED PROPRIETORS AND GENTLEMEN

INTERESTED IN THE

DRAINAGE OF THE SHANNON.

BY

F. G. M. STONEY,

MEMBER OF THE INSTITUTION OF CIVIL ENGINEERS OF IRELAND,
ETC., ETC.

Reprinted from the Transactions of the Institution of Civil Engineers of Ireland.

DUBLIN:
PRINTED FOR THE AUTHOR,
BY JOHN FALCONER, 53, UPPER SACKVILLE-STREET.

1875.

TO

THE LANDED PROPRIETORS AND GENTLEMEN

INTERESTED IN THE

DRAINAGE OF THE SHANNON.

GENTLEMEN,

The problem of improving the drainage of the River Shannon has of late years been kept prominently before you, and presented to your view in many aspects, practicable and impracticable, according to the several ideas of such gentlemen as have written on the subject, and put forward schemes more or less matured; and you have lately considered the plans of an eminent engineer in conjunction with the Government proposal, and have declined to embark in the scheme as then put forward.

Considering all that has been written and done by others, and the constant attention given to this important subject by the landed proprietors and gentlemen interested, it may seem somewhat superfluous in one hitherto unconnected directly with the Shannon to obtrude on your notice any further views on the subject.

Nevertheless, I venture to address a few remarks to you in the hope that a straight and simple line of reasoning out the practical philosophy of the case may commend itself to your intelligent discrimination, and that there may be some useful result to apologise for my intrusion.

Looking at the past and present condition of the River Shannon, there appears to be sufficient reason that the proprietors should hesitate to involve their properties in renewed charges to carry out projected improvements, and that they should jealously criticise each scheme in all its bearings, political, commercial, and practical, before embarking their capital in any.

Comparing the large amount of capital already expended on the Shannon drainage and navigation works with the advantages which have accrued to the proprietors, there seems little encouragement to further projects; but carefully considering and keeping clearly in view the landowners' interests and requirements, together with the conditions of the river and works necessary to their fulfilment, in comparison with the nature and practical bearing of the works hitherto carried out, there is every reason to anticipate that with a reasonable expenditure of capital directly and efficiently applied, an engineering project may be carried out, practically and commercially successful, resulting in permanent solid benefit to the landowners.

As to the political point of view, with respect to the former works, the landowners were heavily taxed to provide a large share of the funds, while it does not appear that they had any share in the control or carrying out of those works, which may have placed them at some disadvantage, and in all probability had the effect of confining within narrower limits the scientific discussion of the principles involved. It would seem but fair that the landowners who contribute largely and are taxed to provide capital for an enterprise should have a corresponding voice in the control of the expenditure, and be scientifically represented and satisfied as to the efficient carrying out of the works.

The former works carried out on the Shannon were designed to accomplish two main objects—namely, to improve the drainage of the river so as to prevent injurious flooding of low-lying lands, and to increase the facilities for navigation. Theoretically speaking, drainage and navigation involve conflicting principles, but, under certain conditions, they may be successfully combined in a river. Judging from the results of past years, it would seem that the combination as represented by the existing works in the Shannon has failed to realise its intention. There is no doubt a good many natural shoals and obstructions were removed, and the drainage so far much improved, but the fixed artificial obstructions, which were placed in the river to meet the requirements of navigation, have more or less curtailed the advantages derivable from the drainage works, as is evidenced by the lands being still flooded in season and out of season, while the proprietors are helpless, without any means of controlling those floods.

It may be argued from these facts and the nature of the works executed, that the real interests of the proprietors were overlooked in the design and certainly are not fulfilled in the results.

What are the requirements of the landed proprietors? First, and paramount, *controllable irrigation;* secondly, *perfect drainage* essential; and lastly, navigation as a collateral interest.

The lands bordering on the Shannon, if not altogether, are for the most part low-lying meadow lands depending for their chief source of wealth on periodical and seasonable floods bearing rich alluvial deposits; but, unfortunately, in the present condition of the river the same crops which are nourished by the deposits of seasonable floods, are carried away or destroyed by untimely ones. Surely in these days of enlightened progress this is too melancholy a state to allow such a river as the Shannon to remain in; and, evidently, under such circumstances there could not be any remunerative return for capital expended inasmuch as the two great requirements of the proprietors are unfulfilled; for the uncontrolled flooding of the lands cannot be called irrigation, and certainly it is not drainage.

These deplorable results, if not caused by, are at all events aggravated by the presence of the existing artificial weir mounds; but supposing these fixed weirs altogether removed from the river it is still questionable how far the excavations, &c., already carried out enable the river to discharge its maximum floods. It is, at all events, evident the weir mounds cannot in anywise facilitate the drainage, for it is unreasonable to suppose that any weir or other obstruction, fixed or movable, can improve the drainage capacity of a river. It is only by removing obstructions and improving the watercourse this can be effected. Let it for the moment be granted that these fixed weirs do not at all obstruct the drainage, do they then fulfil the requirements of the important question of irrigation? Under the conditions, certainly not, for they could not then cause the river to flood its banks. Suppose, on the other hand, as is most probably the case, that the fixed weirs obstruct the stream so as to cause the waters to overflow the banks in flood seasons, do they in this case meet the irrigation requirements? Certainly not, for the same obstructions exist at all seasons, and the lands are not only irrigated beyond control, but are also inundated by untimely and injurious floods. So far the fixed weir mounds not only fail to meet, but are simply pernicious to the two great interests of the landed proprietors, and it is only natural to infer that the importance of judicious controllable irrigation was entirely lost sight of in the former design.

To what end were these fixed weirs placed in the river? Apparently with the sole object of retaining water for navigation during the dry season. Even for this purpose they are but a compromise, as they can only be built a certain height with a view of allowing flood waters to pass over them, and so cannot retain as high a navigation level as might be wished. So it is plain the fixed weirs are not desirable; they materially obstruct the drainage, and are unfit for irrigation, while they but indifferently suit the navigation.

The want in sound theoretical principles, and the general unfitness of fixed weirs for such rivers as the Shannon, has long since been pointed out.

What are the conditions to be fulfilled on the Shannon so as to meet the requirements of the landowners? First, the river must, of itself, be capable of discharging its maximum floods without overflowing its banks; then some suitable form of movable weirs or sluices must be placed where required in the river, so as to give the proprietors a means of intercepting the floods and irrigating their lands at will.

It follows from these conditions that, for a river such as the Shannon, having an exceedingly limited natural fall, and subject to heavy floods, any form of sluice which, when opened to its greatest capacity, still presents such obstructions to the stream as to cause appreciable loss of head, must be commercially and practically unfit in proportion to the obstruction and loss of head caused, which can only be compensated for by so much extra expensive and otherwise unnecessary excavation in the river.

It is then evident that, to fulfil the conditions perfectly at a minimum of cost, both as regards the river channel and the special appliance, the best form of sluice is that which, when fully opened, presents the smallest amount of obstruction to the passing stream, and especially that which leaves the bed of the river unobstructed. It also follows that the sluice which perfectly meets these conditions, and, when open, interferes not with the drainage capacity of the river, is also that which, when shut down, can, with safety, be made to retain the highest water level, and consequently gives the greatest facility and power of controlling irrigation, while, for the same reasons, it is that which best suits the navigation, and so fulfils, in the highest degree, the complete interests of the proprietors.

Taking into consideration the excavation and other improvements already carried out in the Shannon, there are fair grounds for calculating that, in addition to the removal of the existing weirs, the river would not require any preclusive amount of excavation or clearing to render it capable of discharging its maximum floods, while suitable sluices of practically proved reliability, capable of completely fulfilling all the required conditions, can be obtained and erected in the river at a moderate cost, as compared with the magnitude of their capacity and the solid advantages they afford, so that the whole work may be carried out at a reasonable expenditure, yielding a remunerative return, and resulting in a practical and commercial success.

Gentlemen, having so far reviewed the general principles of this interesting question, it now devolves on me to point out the special appliance needed.

While engaged, some years since, on large irrigation works in India, my attention was drawn to the necessity for large sluices, easily worked under pressure; and, from time to time, I have been successful in bringing out some useful appliances, the largest of which I have the honour of presenting to your notice. In the accompanying paper, read to the Members of the Institution of Civil Engineers in Ireland, some of these sluices are described and illustrated, the special appliance suitable to the Shannon being the last described, commencing at page 9 and illustrated by Figures 16 to 22. This sluice is a large door or gate, 30 feet wide and 7 feet high, supported on iron piers in such a manner as to enable one man to raise it completely out of the water. The piers are only ten (10) inches thick, so that, when a set of these sluices are open, there is only ten inches thick of smooth iron pier standing in the water for each 30 feet of clear span, and the sill of the sluice is flush with the bottom of the river, so that a set placed across the Shannon, and open during floodtime, would not practically obstruct the stream, and could not cause any perceptible change of head in the water passing through, while one man could actuate and take charge of the entire range.

Simple telegraphic communication could be established from work to work, so that the up-stream caretaker could always give timely notice to the down-stream men, and, with a little organization and the experience of a few seasons, a beneficial system of seasonable irrigation and drainage might be established, to the improvement of the lands and the saving of the crops.

Hoping your patience is not already exhausted, I solicit your kind and attentive consideration of the description and illustrations of the large sluices above referred to.

I am,

Gentlemen,

Your obedient Servant,

F. G. M. STONEY,

Mem. Inst. C.E.I

SEATOWN PLACE, DUNDALK.

ON THE

CONSTRUCTION OF LARGE SLUICES

FOR

IRRIGATION AND NAVIGATION.

ON THE CONSTRUCTION OF LARGE SLUICES FOR IRRIGATION AND NAVIGATION.

Read before the Institution of Civil Engineers of Ireland—May 5, 1875.

THE construction of large sluices for irrigation, drainage, and navigation, has, from time to time, occupied the attention of various engineers, especially in countries where irrigation is extensively used. While engaged some years since on irrigation works in India, the author's attention was forcibly drawn to the subject of sluice construction, because of the difficulty frequently witnessed when large sluices of ordinary construction had to be raised under considerable pressure.

The problem of constructing a good sluice, of large capacity, and easily worked, was constantly before him, and it gradually became a fixed principle in his mind that some means and form should be adopted to equilibrate or relieve the pressure in the first instance, so as to eliminate or reduce the amount of work to be done, instead of devising powerful machinery to overcome the great friction due to heavy pressures on large sliding surfaces, and that the principles involved, as well as the mechanical details, should be as simple as possible.

It is not proposed in the present paper to review what has been done by others, but to lay before you some few of the appliances the author has worked out during the last six years.

The first is an equilibrium valve, made for a deep irrigation reservoir, having a head of water of about 100 feet. It is made to suit a 2 ft. 6 in. pipe, and has a clear area of valve-opening of about five square feet. Its general construction will easily be understood from the plans (Fig. 1, Plate I.). It is a vertical section, and shows the valve, made of four pieces—a bend leading from the pipe, an enlarged valve-chamber placed above the bend, a suitably-shaped hood resting on the chamber, and a cylindrical piston-valve, which is capable of motion vertically. This piston is cast with a central guide-tube, which travels freely in a prepared guide in the upper portion of the hood, while the piston itself is guided by passing through a bored guide in the main chamber, and is continued down till it meets a coned valve-seat in a lower surface of the chamber. In this position the piston forms a continuation of the bend passing right through the valve-chamber, so that the water fills up into the hood, and the pressure terminates in the fixed parts.

While in this position all communication from the pipe and hood to the chamber is shut off, as the head of the piston is so arranged as to fit into a coned valved seat in the upper surface of the chamber, while its foot fits into the valve-seat in the lower part, and a good water-tight joint on both seats is secured by means of a metallic ring, fitting freely on the head of the piston, and made water-tight to it by a protected india-rubber ring. This metallic ring is capable of a little vertical play, and is coned on its lower surface to accord with the upper valve-seat, which arrangement compensates for expansion under pressure. The lifting screw is carried in the head of the hood, and works inside the central tube, which forms a convenient chamber for it.

It will be seen that the water presses all round the piston horizontally, having no unbalanced surface to act on except the annular area due to the two valve seats; and the pressure on this comparatively small area disappears very soon after the valve is started. Fig. 2 represents a sketch of this valve attached to the reservoir, and shows a pipe passing through the embankment, having the equilibrium valve at its outer end, at foot of the slope, and a safety clack-valve at the inner end of the pipe. This clack usually remains open, except in the case of a leak, or for the purpose of cleaning the main valve. When it is required to shut the clack, the main valve is screwed down, and, the pipe being full, the water is at rest, when the clack is easily lowered by means of a chain. Then the outer valve may be opened and the pipe emptied. When it is required again to open the clack the outer valve is replaced and closed, and the chain from the clack screwed up a little, which acts first on a lever hinged with the clack, and having on its extremity a valve which covers a small orifice in the clack. This orifice, when opened, allows the pipe to fill in time, when farther screwing up of the chain will now easily open the clack, the pressure being equalised.

Fig. 3 shows an external view from a photograph of this valve with its clack, as made for the Madras Government. A useful modification of this valve may be made to suit as a safe outlet-valve from deep reservoirs for water works, and may be placed on the inner end of the pipe or culvert, as it can easily be worked under heavy pressure, and in this position shuts off the water from the pipes, in case of leak or accident.

Figs. 4 and 5 represent a useful application of this principle, for the purposes of an automatic regulator for the water-level in a large cistern. For this purpose, the valve is inverted and actuated by a suitable float. As it is easily moved, and and has but a short range of action, it is very suitable for such purposes.

The next apparatus introduced to your notice was designed for the head works of an irrigation canal; it is an equilibrium sluice on an easy principle and of simple construction, and can be applied to large sluices working under heavy pressures. The principle upon which this sluice is constructed is that of causing two bodies of water to flow to the sluice from opposite directions, so that the pressure of one body counterbalances that of the other. The principle will be easily understood upon inspection of the perspective drawing

(Fig. 6), which shows the general arrangement of this sluice in its masonry, and the exact details of the ironwork will be seen from the photographs (Fig. 7) of the actual sluice as constructed.

By an arrangement of masonry piers; the water-ways are diverted into the required directions—a row of piers is placed in front, and another row of piers behind, not in line with the front ones, but in line with the water-ways; and a little to the rear, immediately behind the front piers and extending across the space between the back ones, is placed the sluice, which consists of two iron frames or openings, each equal to half the sluice area, and connected together by strong iron tie-bars. Owing to the position of the piers, the water must flow through these frames, but the orifices in these frames are closed by a pair of doors connected to each other by strong iron struts, and adjusted to fit against planed faces in the frames, so that the two doors being equal and opposite, the pressure on one balances that on the other, and the doors as one piece may be raised or lowered vertically, totally independent of the water pressure. In the particular instance illustrated the sluice was constructed to work under a head of 20 feet, and to have a clear area of water-way equal to 36 square feet, so that each opening is equal to 18 square feet, which is given by a doorway 6 feet high by 3 feet wide. The door frames are strongly made and rigidly connected, so as to be parallel, by wrought-iron bars, the upper connections being above the line of current, and the lower ones below the level of the sill, so that when the sluice is open there is not any obstruction in the water-way. The planed bearings in the frames are not vertical, but inclined outwards towards the top, so that the two doors form a wedge which comes down and fits accurately between the frames; this taper is made to such an angle as prevents the doors wedging, while it also provides a simple means of insuring a fair water-tight joint capable of being easily separated. It will quickly be seen that this taper causes a certain proportion of the water pressure to communicate an upward thrust to the door. In the present case the amount of taper is so arranged that the vertical component of the pressure, under 20 feet head, is equal to the weight of the doors, so that at starting the sluice—usually the most difficult part of the lift—the only work to be done is to overcome the adhesion of the surfaces, which it must be remembered are not under pressure.

The doors are actuated in this case by a strong lifting screw, and are guided by vertical ribs on the frames below, and by a strong guide-rod above.

This arrangement represents only one form of this sluice, but it is capable of considerable range of application, both in magnitude and in modification of details.

The next sluice noticed was chiefly designed for the navigation department of canals, and is intended to supply very large sluices to canal locks, so as to facilitate the speedy filling and emptying of the chambers The principle upon which it is constructed possesses the utmost simplicity, and may be applied to such cases as where a large area of sluice is required under a moderate head of water.

The arrangement consists of a circular orifice placed horizontally and closed by means of an open cylinder, which carries at its foot a coned face to fit a similarly coned valve-seat in the orifice.

The cylinder when closed down is in water-tight contact with the valve-seat, and is continued upwards until its head reaches above the maximum water-level, so that the column of water is displaced from above the area of the sluice, and the water simply presses round the cylinder without impeding its vertical motion. We have now, instead of the great weight of the large column of water, simply to deal with the weight of the hollow cylinder displacing it, and this being a constant weight or nearly so, is easily accomplished by means of a counterbalance. The drawing (Fig. 8) represents a vertical section through the masonry chamber in the side of a canal lock, in which the sluice is placed, the cylinder and lifting gear appear in elevation, while the orifice frame and valve-seat appear in section; the latter is cast with six arms or feathers supporting a central boss, which is bored out and forms a steady guide, through which passes a strong spindle attached to the cylinder, insuring a true vertical motion and an accurate meeting of the valve faces. The counterbalance arrangement is of peculiar construction and works without fixed centres to avoid friction. Fig. 9 is one of the working plans from which these sluices were made, and represents the counterbalance gear. Attached to the head of the cylinder is a pair of brackets, carrying on their inner faces toothed racks; a similar pair of fixed brackets project downwards from a frame covering the sluice chamber; the racks on these brackets face those on the cylinder, leaving spaces between them for pinions to roll in accordance with the motion of the cylinder. Fixed on the axles of each pinion is a pair of chain wheels, carrying chains to a counter weight; in this arrangement the teeth of the fixed racks are fulcrums, while the diameter of the pinions at the pitch-line forms the short arm of the lever, and distance from the centre of the hanging chain to the pitch-line of the fixed rack forms the long arm. In this case the proportion in favour of the counter-weight is 3 to 1; this forms a differential counterbalance; as the cylinder is raised the pinions roll through half the distance, causing the chain wheels to revolve and allowing the weight to fall faster than the cylinder rises, according to the relative proportions of the chain wheels and pinions.

The drawing represents one of these sluices made for a canal in England; it is 5 feet 9 inches external diameter, and has an available water-way of 25 square feet. It is fully opened by three turns of a handle keyed on the axle of a small cast-steel pinion, which actuates a lifting rack. It will be seen that this is an equilibrium sluice, having but one surface of contact, and that free to seek a good joint, while there is not any sliding friction. These sluices are also suitable for large graving docks, especially where it would be inconvenient and costly to introduce hydraulic power to work ordinary sliding sluices; and for this purpose certain modifications are introduced into the details to meet all the requirements of graving docks, and render the sluices a sound, lasting piece of work, thoroughly protected and accurately made water-tight.

Fig. 10 represents a very simple modification of this sluice, as proposed for an irrigation reservoir; it is placed in a chamber situated in the embankment, and is actuated by a simple iron lever, carrying on its outer end an adjustable weight. In this case the levers are 8 to 1 in favour of the counter-weight, so that a small weight suffices, care being taken in adjustment that the cylinder shall have the preponderance of weight, so as to keep tight when shut down, and to allow the man when actuating it to utilise his weight, which is the approved native Indian's method of applying his power. This sluice is arranged so as to have an unobstructed water-way, being guided below by a fixed external ring, through which the cylinder moves.

In addition to the cylindrical sluices already described, the author has designed a method of constructing large sluices to meet such cases as where the masonry of a dock or lock has been built without provision for any or sufficient sluiceways, and it becomes a question of building new masonry, or devising some means of putting large openings in the gates.

The latter plan may be carried out in a very simple and effective manner by means of a duplex system of double-beat valves, arranged horizontally in the gate, as shown in Figs. 11 to 15.

From Fig. 13 it will be seen that between the ordinary beams of the gates two strong cast-iron frames, forming horizontal valve openings, are placed; these may extend nearly the entire length of the gate, and be as wide as the thickness of the gate will allow. The portion of plating on the front of the gate lying between the two frames is removed, and placed at the back of the gate, so forming between the two frames and the plated back, a water-chamber, open to the front, and leaving two inlet openings equal in length to the gate; any water passing through must then enter at these inlets, and pass vertically through the frames.

The openings in the frames are closed by doors so connected to each other that the water pressure on one balances that on the other; and instead of having the doors to extend the entire length of the openings, they are made in two pairs—one pair opening downwards, and the other upwards, by which arrangement the doors are balanced, both as regards water pressure and weight of materials.

They are suspended from a rocking lever, and are actuated by means of a screw and handle, as shown.

The whole arrangement involves simple and easy workmanship, and is capable of accurate adjustment, while it leaves the gate without any external projections, and may be carried out without taking away from the structural strength of the gate.

All moving parts being in every way balanced, and there being no sliding friction, the work to be done in actuating them is practically *nil*.

In the case illustrated the gate is 15 feet over all, and only 15 inches thick, while the area of sluice-way obtained is 16 square feet, which may be fully opened in a few seconds.

In applying this invention to the gates of graving docks, where absolute tightness is essential, the author would add to the above arrangement a brass-faced sliding door on front of the gate to cover the inlet openings; this door would be actuated by means of a pair of toothed racks, not directly fixed to the door, but formed on their lower ends into valves covering small orifices in the door, so that when actuated they would first uncover these orifices, through which the water-chamber in the gate would quickly fill, and balance the pressure on the door, which could then be easily raised to its full height by the racks, after which the duplex equilibrium system, above described, would come into action, as in the lock gate. By this arrangement very large sluices can be made in dock gates, having all the security and tightness of well-made sliding valves, without the difficulty of actuating them under pressure.

The author has now the pleasure of introducing to notice an apparatus, for which he solicits the kind consideration of engineers engaged in large drainage or irrigation works.

Before entering upon any detailed description of the large relieving sluices, it is best to explain the general considerations and line of reasoning which led to the working out of such a structure. It is now generally recognised by engineers that for the purposes of inland navigation fixed weirs are objectionable, because of the obstructions they oppose to the natural drainage of the river and the country through which it flows. For his own part, the author believes fixed weirs to be a mistake, and the theories upon which they were founded to be wanting in sound principles. For the purposes of navigation, and even for the requirements of the mill-owner, the fixed weir is, at best, but a half measure; it can only be built a certain height under given circumstances, and so does not amply meet the purposes of navigation, and certainly the miller would like to retain more water, but in both cases the flood waters must pass over the crest of the weir, and it must be built accordingly. There are but few circumstances under which fixed weirs are desirable, such as for the purposes of some of the great weirs constructed in India for irrigation; but in these cases it is not a consideration of navigation or drainage, nor is there much question as to the flooding of a certain portion of river margin; practically the portion of river immediately above the weir becomes a reservoir, and the weir its embankment, and besides this, the great magnitude of these works does not admit of any other resource. Some of these weirs are about a mile long, and have at flood times as much as 20 feet of water passing over their crests. In one case, such as mentioned, this great weir does not fulfil all the requirements, and the habit is to build a rough temporary wall on its crest every dry season, so as to retain a few more feet of water, while the wall is allowed each year to be washed away by the floods. We see that, even in this gigantic instance, it would be very desirable to have a portion of this weir removable, but it presents great difficulties—no piers or standards could be allowed. The author proposed a very simple but novel kind of self-acting weir-cap for this work, but it was not adopted, as no interference would be allowed with the crest of the existing weir.

For the requirements of our own rivers here at home the author fails to see the philosophy of removing natural obstructions if great artificial ones are to be deliberately fixed in the water-way. The French engineers have long since recognised this principle, and have notably turned their attention to the construction of movable weirs, many of which are in operation in some of their chief rivers; most engineers are familiar with these French barrages; they are designed to meet a great want, but whether they accomplish their object in the best manner is questionable. As mechanical contrivances they are made up of too many small moving parts, which is a serious objection, and the greater proportion of the materials and workmanship are but indirectly applied, while they shut down into the water, which is inconvenient, and renders their manipulation very difficult, and in some cases dangerous. The arrangement illustrated is, as nearly as may be, the reverse of the French system, as the author has worked on the principle, that the best form of movable weir or sluice is that which comes most completely out of the water, and when raised leaves the least amount of obstruction in the water-way, and which is composed of the fewest working parts. To fulfil such conditions, the spans or sub-divisions of the work must be as large as possible, and the doors or pannels closing each span must be one single working part; and if so, some means must be provided for taking up the great pressure on so large an area, so that the sluice shall be workable by simple means and small power. The whole work must possess simplicity of construction, great strength and durability, and be not liable to get out of order. In considering this plan he has not endeavoured to provide a series of sluices capable of discharging the maximum floods of great rivers. This point of view would lead to the question of, what is the smallest area of sluice-way which will suffice? This would quickly lead to increasing the head at the sluice, which can only be done by robbing the approaching stream of some of its too scarce natural fall. The author has looked at the question from the opposite point of view, and has endeavoured to provide sluices to retain water when desirable, but in such a form as to leave the river during flood seasons in its natural or improved condition, and unobstructed.

To this end the sill of the sluice must be on a level with the bottom of the river, the pier between each span must have a minimum thickness, and the net area of the water-way must be at least equal to that of the approaching stream, and have the same depth and width, while the entire work must be placed at right angles to the stream, so that, practically, when the sluices are raised, the river shall be *totally unobstructed.* How this is carried out will now be explained, which will be the more easily done from being fully acquainted with the object and principles of the plan, which consists of a series of unusually large sluice gates, arranged to lift completely out of the water; they are not allowed to work on sliding surfaces as in ordinary sluices, but are made to roll freely, on simply-arranged sets of free rollers, so that the great pressure is entirely sustained by these rollers, and the gate moves on a pure rolling contact, entirely free from sliding friction; to each end of the gate is securely attached a suitable vertical beam, having a chilled roller-path or rail, and attached to the fixed piers are corresponding rails; between the movable and fixed rails are suspended the frames carrying the rollers. Above the sluice, resting on the piers, is a convenient foot-bridge, from which the sluice is actuated. The weight of the door is counterbalanced in a simple manner, which is practically frictionless, so that the water pressure being carried on a free rolling contact, and the door so counterbalanced, there is a comparatively small amount of power required to actuate the sluice. These sluices may be arranged for masonry piers, which would suit very well where only a few spans were required, but in a more extended work the necessary thickness of many masonry piers would add considerably to the additional width, which should be added to the river, to preserve the full area between the piers; for this and other considerations iron piers are much preferable, as they occupy a minimum space, and give facilities of construction, and compactness of arrangement not possible with the masonry piers, while the whole work so arranged could be placed in a river in much shorter time.

From Figs. 16 to 22, it will be seen that without any useless expenditure of materials great stability is obtained;

in each pier there are two cast iron columns, the front one having little else to do than support half the weight of the bridge, the column at the rear has to sustain the pressure on the sluice; from the water-line downwards this column is cast in the form of two **H**-rails, leaving a space between them for scour; these rails have straight chilled surfaces, and constitute the fixed roller paths above the water-level; the columns are rigidly connected to each other by means of a vertical web, half of which is cast with each column, a joint being made in the middle, by means of double flanges and bolts; the columns are further stiffened by means of a strong strut, projecting at a suitable inclination from the rear column, and ending in the bed plate, on which the columns rest, so constructing in the iron work a completely braced triangle; from the water level downwards there is a vertical standard placed between the columns, and connected to the front one by means of plates, so as to form a smooth pier; this standard is planed on the back face, and is adjusted to fit easily against a planed face on the front of the movable rail, and so form a sufficiently close water-joint between the ends of the gates and the piers, while the foot of the gate is provided with a planed toe-bar, which makes a fair water-joint with a planed cast-iron sill, which connects the bed plates; the sill and the bed plates are cast in the form of inverted channel irons, and are set into the foundations, so as to be flush with the floor of the sluice

Fig. 20 represents an enlarged cross section through the piers below water-line, and shows the end of the horizontal girders constituting the frame-work of the gates, and a section of the vertical beam connecting them, which also forms the movable roller-path; the rollers also appear in section, and the relative position of these parts will easily be understood. Fig. 21 is a section above the water-level, and clearly shows the web connecting the piers; it may be noticed in this section that there is a projecting rib at each side of the rear column;

this rib extends from the water-level to near the top of the column; a suitable channel cast in the movable roller-beam travels freely on this projecting rib and forms a strong guide for the gate when raised, and secures it against any injury from the effect of storms; it is chiefly to carry out this provision that the piers are so connected by the web shown.

The gates are very strongly made, and are composed of three horizontal girders connected at each end by the roller-beams and strongly plated in front, while the backs of the girders are connected by suitable bracing.

The weight of the gate is counterbalanced by means of a solid cast-iron beam extending from pier to pier, its ends travelling freely in suitable T-iron guides; the chains sustaining this weight pass over a pair of chain pulleys of such circumference as to make but one revolution for the complete lift of the gate; the cast-steel axles of these pulleys are not carried in bearings, but are allowed to roll freely on chilled cast-iron beams, while they are maintained in true position by means of small pinions, on their ends, working in suitable racks on the beams, and so do not require oiling or any attention, and work almost frictionless.

The gates are raised and lowered by means of cast-iron racks actuated by pinions and suitable gearing, which can easily be driven by one man working at a small pillar placed on the bridge, carrying a handle and suitable bevil gearing; time being no object, the power of the man is greatly multiplied through the gearing, so as to insure ample power to control the sluice at all times. The sluices, here represented, have clear spans of 30 feet, the doors are 7 feet high, and have a lift of 8 feet, so that when fully raised there is a clear unobstructed water-way equal to 30 feet by 8 feet, or 240 square feet of opening, while each pier occupies but 10 inches lateral space.

The author does not know of any sluices that approach these in magnitude, except one, on the same principle, which he designed for Messrs. Bell and Miller, Civil Engineers, of Glasgow; it has a clear span of 20 feet, and is 8 feet 6 inches deep; it was made three years since, and has been in successful operation in a river in Brazil for upwards of two years; and though the gate is not counterbalanced, two men work it. This is a clear proof that the free rollers give great facility to the working of such large sluices. As to the expansion or contraction under changes of temperature in a long range of these sluices, the bridge is the only part requiring attention, because each sluice is laterally free at the ends, and the lattice girders of each bridge are so arranged that while they are securely bolted to the piers, they are free to expand and contract without interfering with any other portion of the work.

When the nature of the river-bed suits, Portland-cement concrete foundations might be advantageously used, and the work might be placed in the river during any fair working season, regardless of casual floods, by erecting one, two, or more spans at a time. The author wishes also to point out the great advantage secured by this apparatus in allowing any *flood waters required for irrigation to be retained when desirable*, while all other floods may be completely discharged *without flooding the lands* according to the capacity of the river itself. There is another very useful application of such large sluices for the purpose of flood regulators for irrigation or navigation canals; they can be placed, when required, in the side of a canal, and made from 30 to 40 feet, clear span, and perfectly automatic in a very simple and efficient manner, not likely to get out of order; they would maintain a constant level where they were situated (within their capacity), and would not waste any water or require constant attention. As all water passes under these sluices, they at all times discharge the water under the maximum head, and, consequently, have a large range of capacity. For this purpose they could be economically applied and give better results as regards relieving floods than any other apparatus the author knows of.

In justice to these sluices and those gentlemen interested in them, the author wishes to state that these appliances are not the sudden inspiration of a happy thought, but the result of some years' consideration, during which time they were worked out over and over again, and gradually put into such mechanical form as he now, with, confidence submits to the critical judgment of the Members of this Institution, in the hopes that his labours in this direction may prove successful in bringing out a much-needed apparatus, and eventually be of some service to his country.

F. G. M. STONEY'S PATENT PISTON VALVE FOR IRRIGATION RESERVOIRS, &c.

Fig. 1

Vertical Section through Centre of Valve and Pipe.
Valve shown shut down.

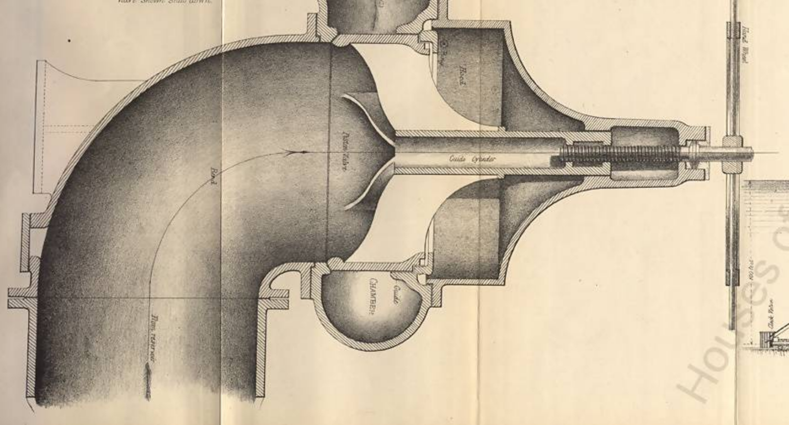


Fig. 2

Section showing general arrangement of Valve &c. in Reservoir Embankment.

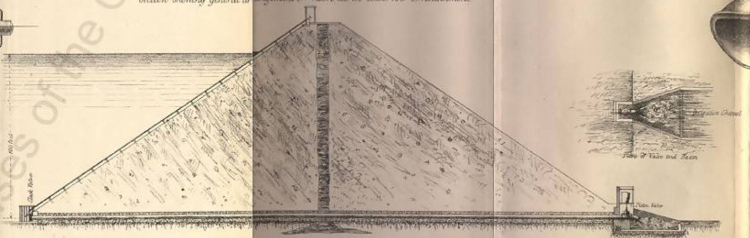
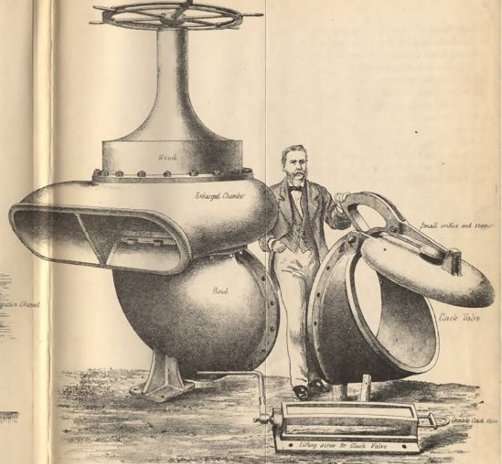


Fig. 3

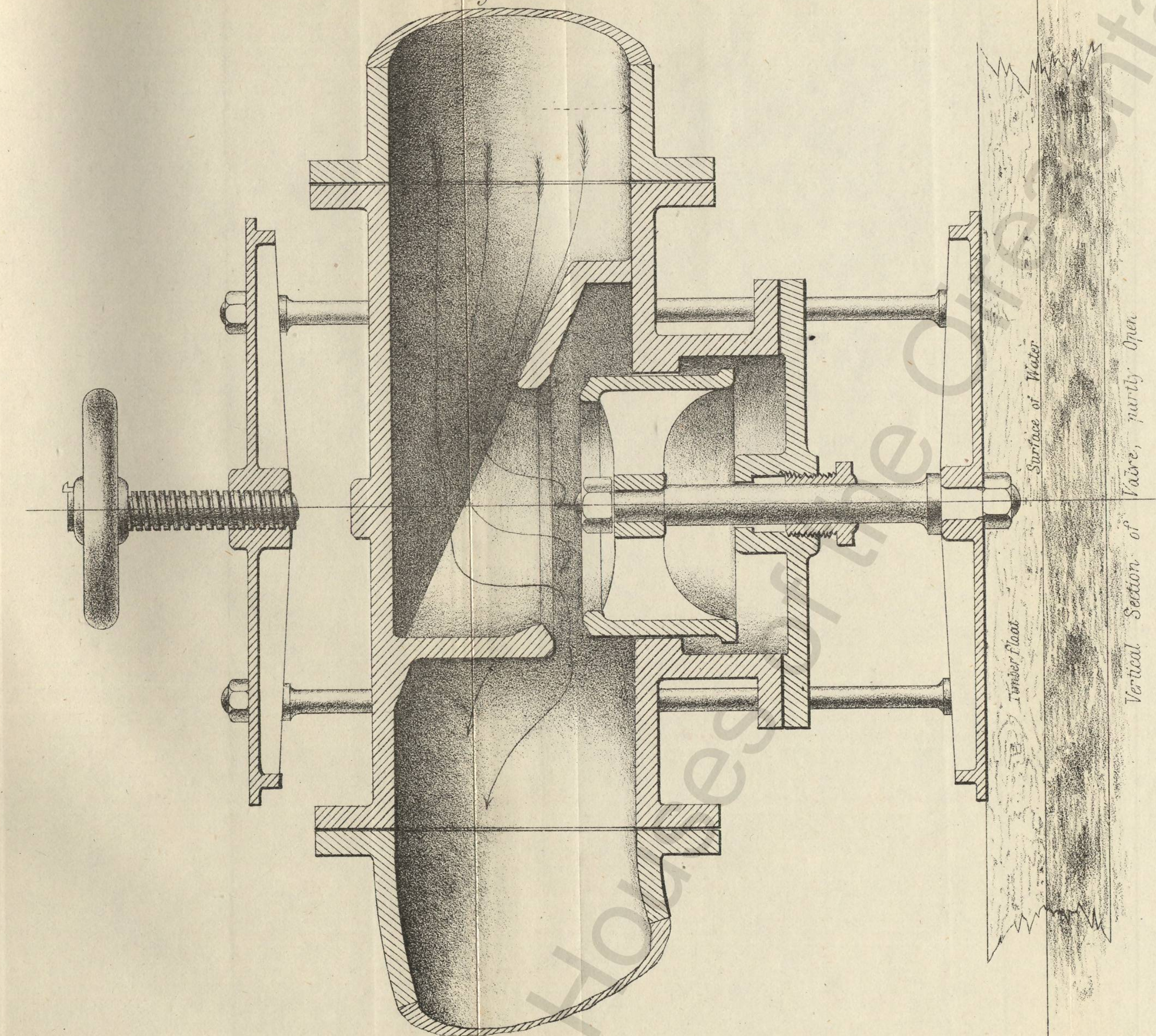
External View of Valve with its accompanying Clack Valve.



Forster & Co. Lith. Dublin.

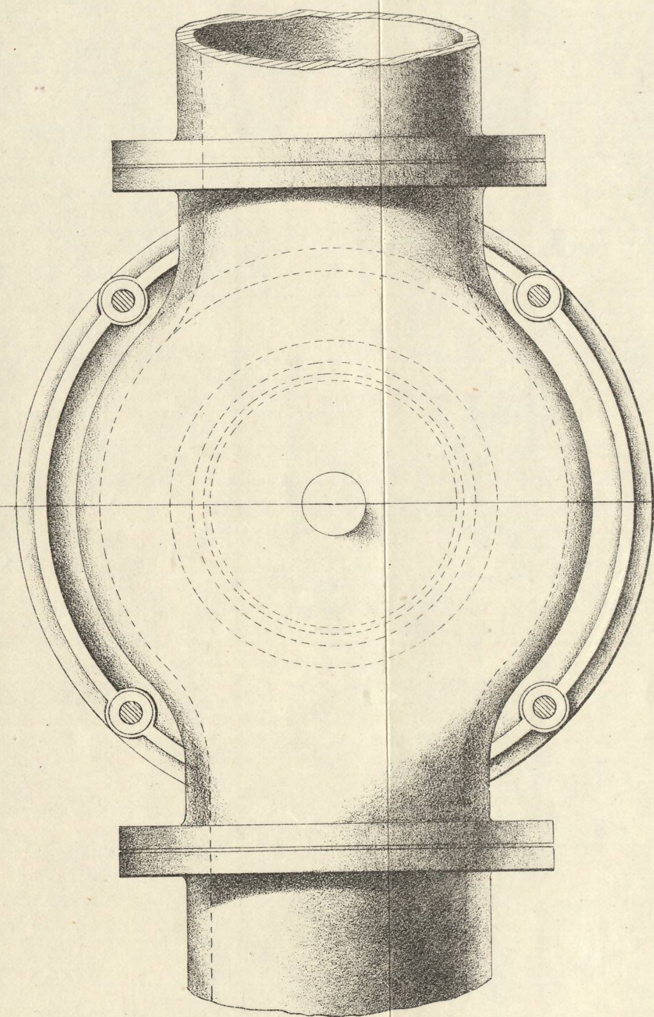
MODIFICATION OF F. G. M. STONEY'S PATENT PISTON VALVE,
APPLIED AS AN AUTOMATIC REGULATOR FOR LEVEL OF WATER IN LARGE CISTERNS.

Fig. 4.



Scale 3 Inches to 1 Foot.

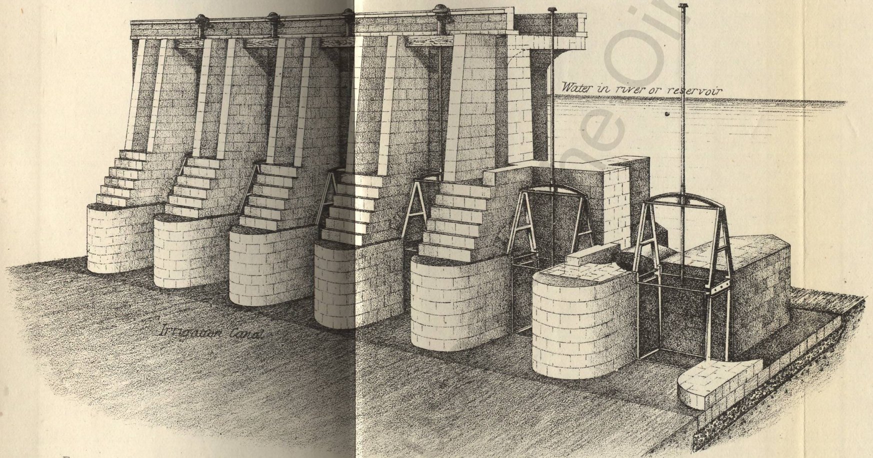
Fig. 5.



Forster & Co. Lith. Dublin.

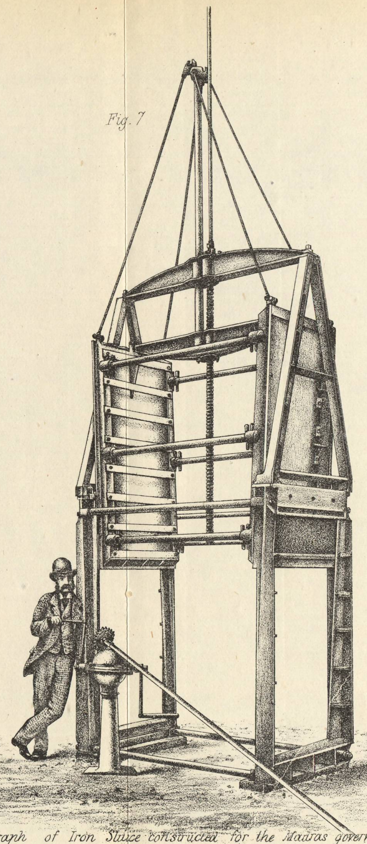
F. G. M. STONEY'S DOUBLE DOOR VALVES ARRANGED FOR HEAD SLUICES OF IRRIGATION CANAL

Fig. 6



Perspective view shewing general arrangement of Masonry with Sluice frames in position

Fig. 7

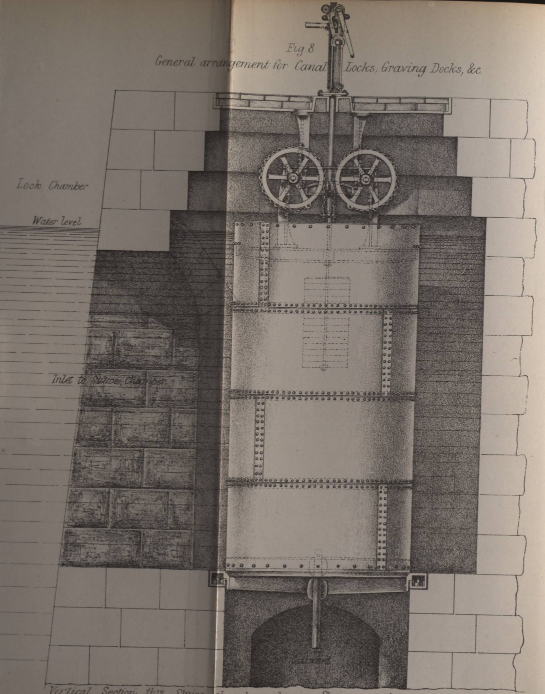


View from photograph of Iron Sluice constructed for the Madras government. Forster & Co. Lith. Dublin
Two doors 6 X 3. Area of Sluice way 36 square feet

F. G. M. STONEY'S PATENT CYLINDRICAL EQUILIBRIUM SLUICE.

Fig 8

General arrangement for Canal Locks, Graving Docks, &c.



Vertical Section thro Sluice chamber showing Sluice complete.

Fig 9

Enlargement of Counterbalance Gear.

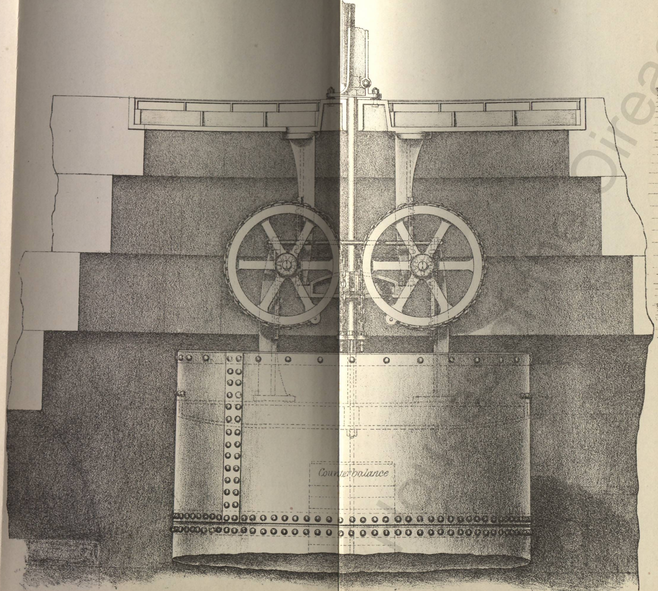
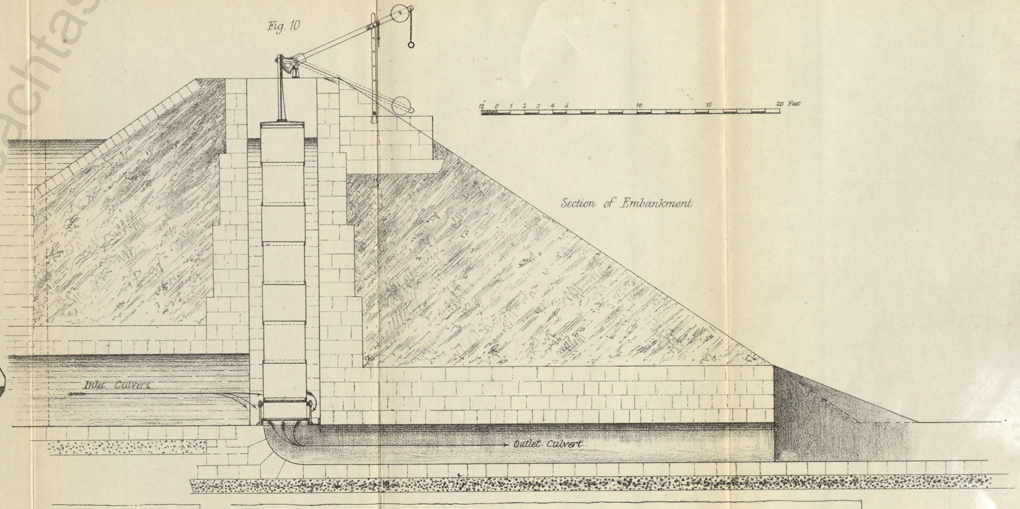


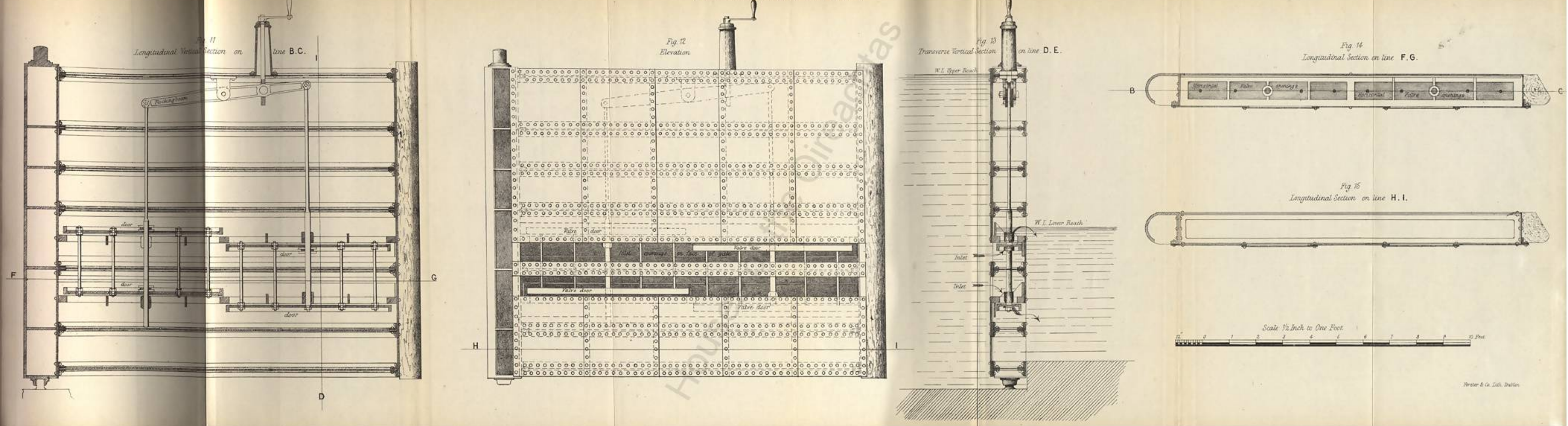
Fig 10



Section thro bank of reservoir Showing how Cylinder Sluice may be arranged for Irrigation

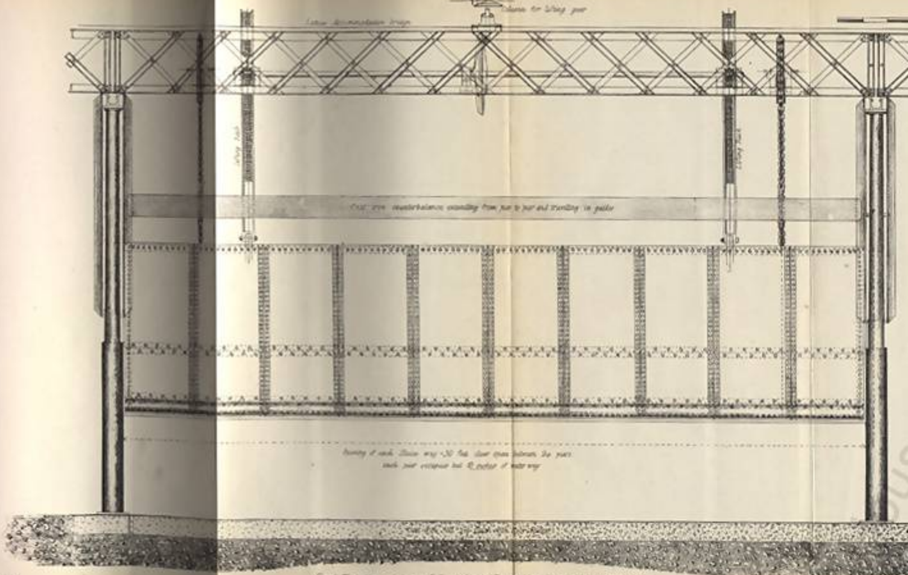
Forster & Co. Lith. Dublin.

F. G. M. STONEY'S PATENT LOCK GATE SLUICES.



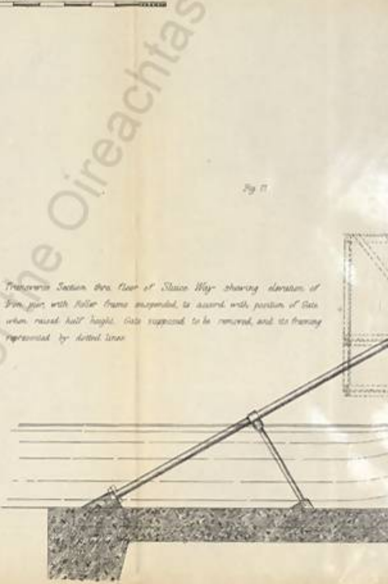
F. G. M. STONEY'S PATENT ROLLING FLOOD GATES.

Fig. 16



Front Elevation of Large Rolling Sluice, Showing Gate raised about half height.

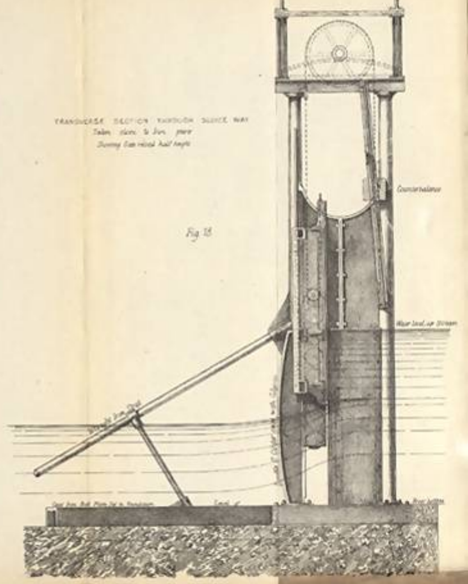
Fig. 17

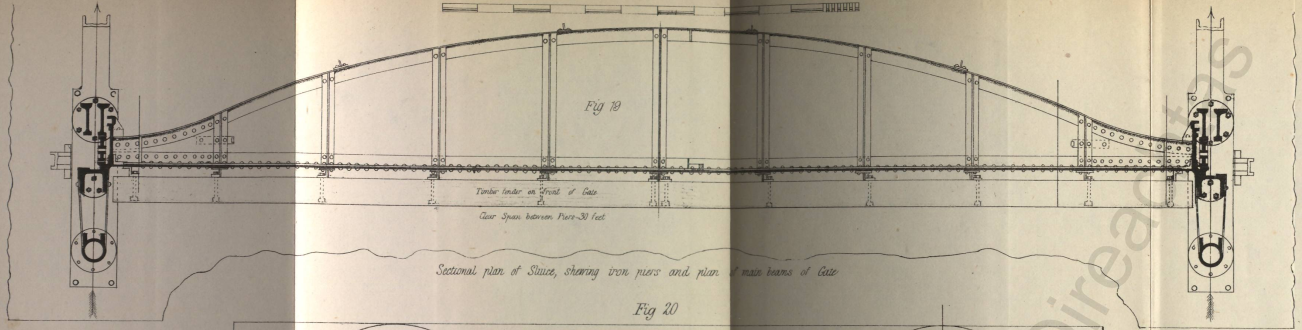


Transverse Section thro. floor of Sluice Way showing elevation of Iron pier, with Roller frame suspended, to accord with position of Gate when raised half height. Gate supposed to be removed, and its framing represented by dotted lines

Fig. 18

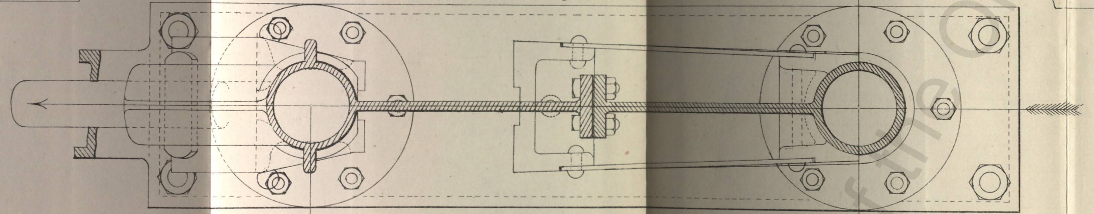
TRANSVERSE SECTION THROUGH SLUICE WAY
Taken close to Iron piers
Showing Gate raised half height





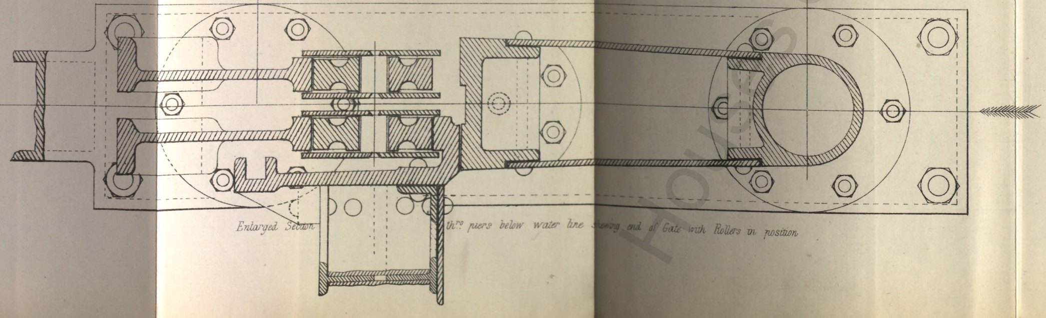
Sectional plan of Sluice, shewing iron piers and plan of main beams of Gate

Fig 20



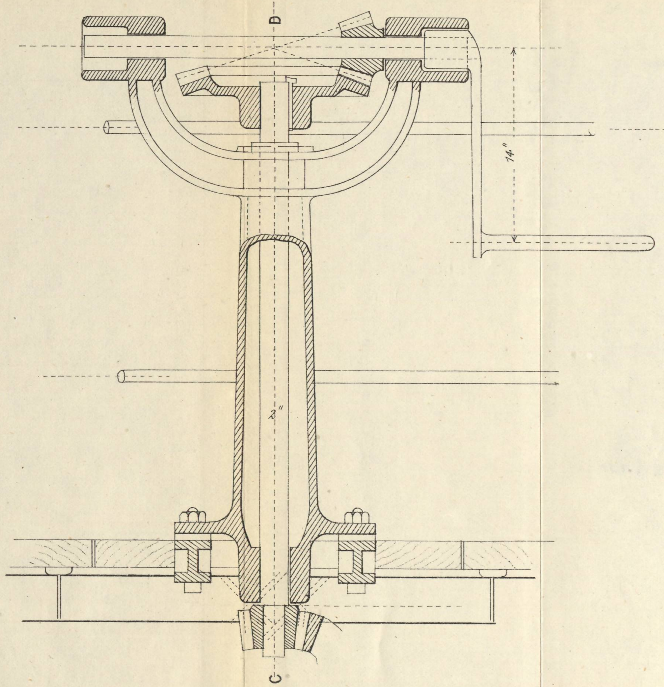
Enlarged Section thro piers, above water level.

Fig 21



Enlarged Section thro piers below water line shewing end of Gate with Rollers in position

Fig. 22



Enlargement of small column standing at centre of bridge, for lifting Sluice Gate by means of winch handle and gearing.

Forster & Co Lith. Dublin.