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Report on Experiments carried out on Models of Standard Vertical Screw Gates adopted in the Lloyd Barrage and Canals Scheme

BY

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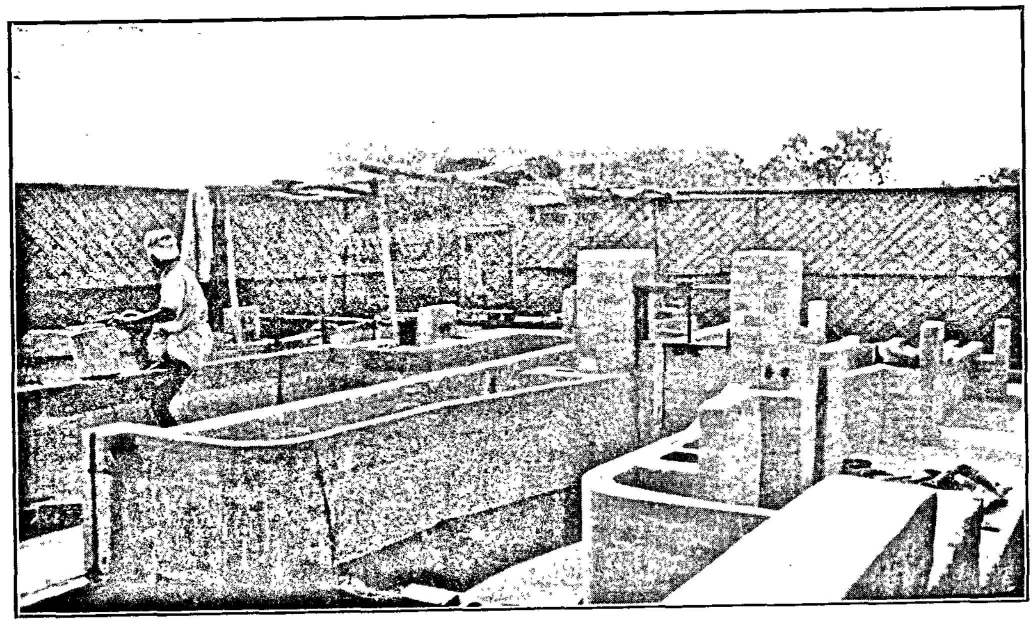
LIST OF PHOTOGRAPHS.

LIST OF PLATES.

DEVELOPMENT AND RESEARCH DIVISION.

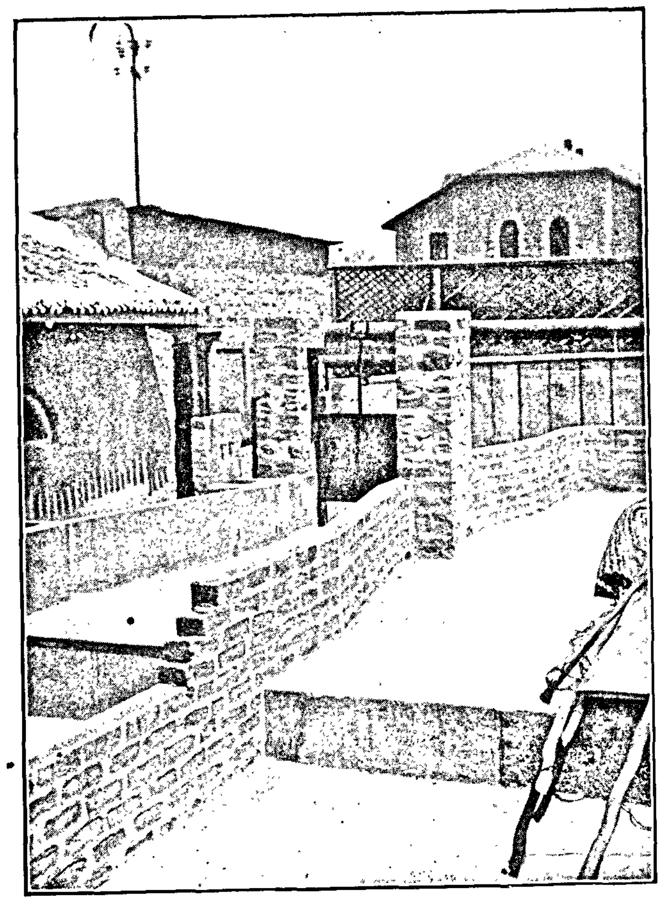
VERTICAL SCREW GATE MODEL.

No. 1



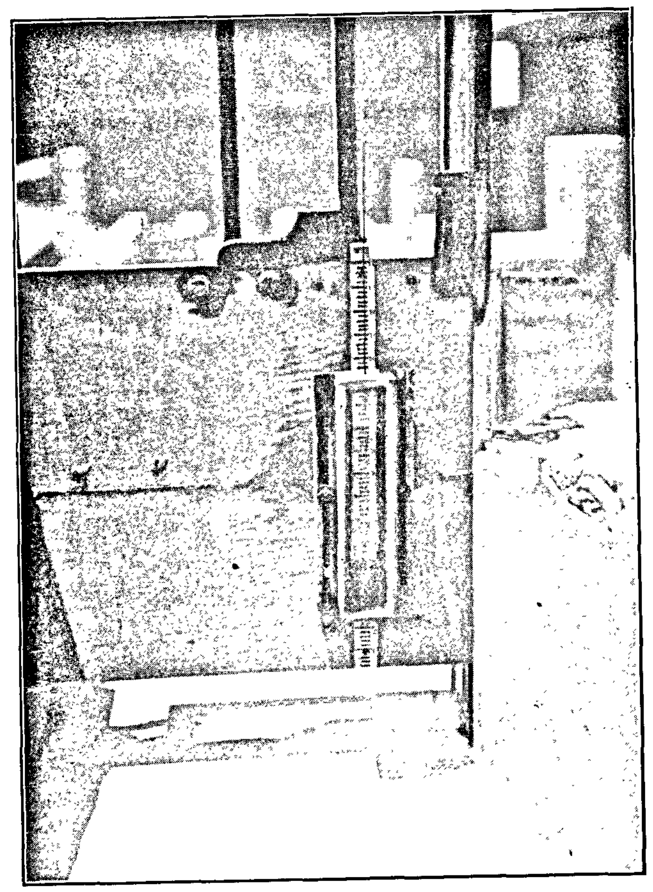
View of model from upstream with gauge on gate.

No. 2



Downstream view of model.

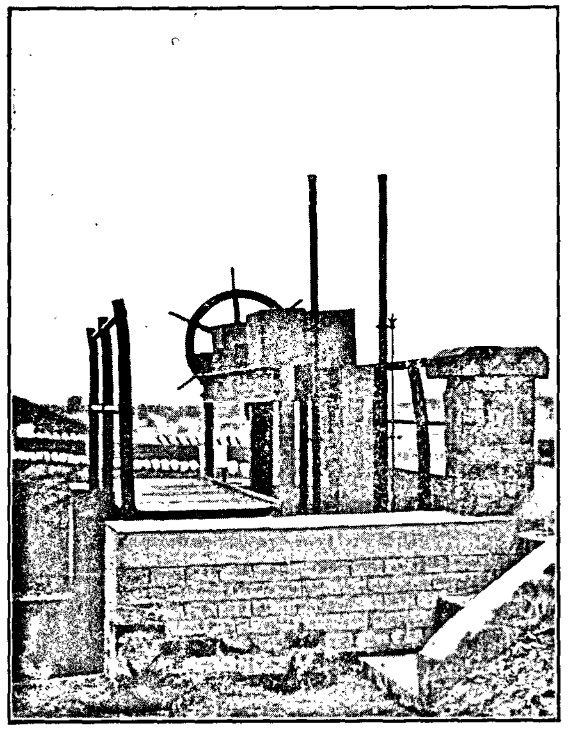
No. 3



Downstream view showing depth indicator and float in gauge well fastened to the gate.

DEPTH INDICATORS.

No. 4



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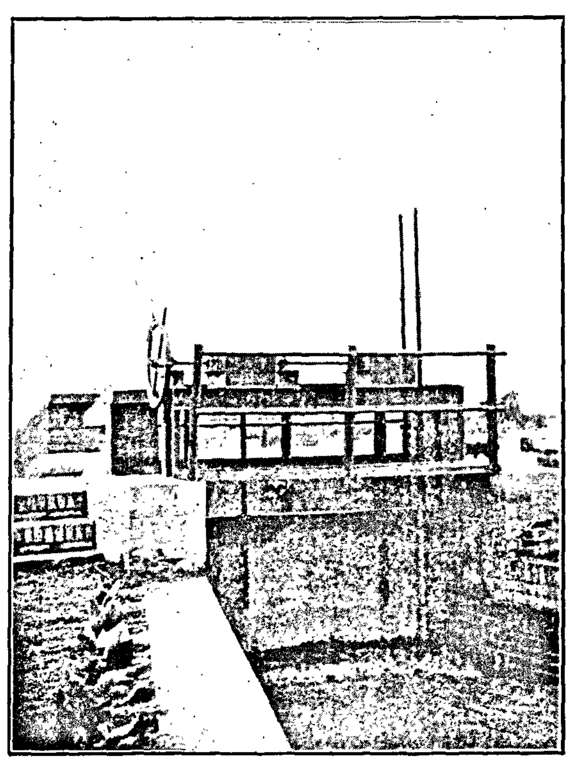

REPORT ON EXPERIMENTS CARRIED OUT ON MODELS OF STANDARD VERTICAL SCREW GATES ADOPTED IN THE LLOYD BARRAGE AND CANALS SCHEME.

Introductory.—In the Lloyd Barrage and Canals Scheme, the design of gates for the smaller regulators has been standardized and, in all, some 900 gates of exactly similar design have been supplied by Messrs. T. Cosser & Co. of Karachi. The gates range in span from 2 to 9 feet and in height from 2 to 8 feet, the variations in span and in height being in even feet only.

The gates work undershot and their sills are smooth, the top of the opening under the gate is the sharp edge of the smooth steel plate forming the face of the gate itself and the sides of the openings have shallow grooves, composed of two angle irons welded together, in which the gate moves.

Conditions of flow for all gates will thus be the same, except for the dimensions of the side grooves (which naturally become less in width with the size of gate), and the factors likely to affect the value of the coefficient in the discharge formula are constant with the exception of the varying of side grooves, the effect of which variation would, for practical irrigation purposes, be negligible.

It was considered, therefore, that it should be possible to calibrate the gates by means of experiments on a model and thus to use the gates themselves as a means of measuring discharge.

Experiments were made on a model of an $8' \times 5'$ gate at $\frac{1}{4}$ full size scale at the Karachi Model Testing Station. The Model, photographs of which are seen at the beginning of this paper (Photos Nos. 1, 2 and 3) was accordingly constructed. The plan of the model is seen in Plate I, and the various details of the design are seen in Plate I-A. Plate I shows the positions of all the various gauge wells etc.

2. *Object of the Experiments.*—The object of the experiments was to ascertain the equations connecting the discharge passing the gate, with the size of the opening and the Head of water under which the gate is operating for two different sets of conditions : (*a*) with a Standing Wave formed clear of the gate on the downstream side, and (*b*) with the gate opening drowned.

The equations of discharge having been ascertained by experiments, it is a simple matter to prepare graphs showing discharges per foot width of gate for different values of gate opening and Head, and these graphs will be of universal application all over the Barrage canal systems, wherever standard vertical screw gates are installed.

3. The model was constructed in the year 1930 and experiments for the Standing Wave conditions were completed in July 1930. Experiments for drowned conditions were also taken up in the year 1930 (when various difficulties, which are referred to later in this paper, were experienced) but were dropped owing to other urgent experimental work and not completed until April 1932.

4. *Description of the Model.*—A reference to photographs Nos. 1, 2 and 3 and is Plates I and I-A will show the arrangement of the model quite clearly. The model to constructed of Brick-in-cement for the most part and all surfaces exposed to the water are cement-plastered. The gate itself is a scale model of the full size gate, except that it is higher to allow of greater depths of water being used and is operated by a screw rod in exactly the same way. It is provided with a scale and a vernier, the vernier being attached to the gate, by means of which gate openings can be read quite accurately. From Plate I it will be seen that no less than 7 gauge wells were constructed for use in the various series of experiments, which are shown in Table III, and it will also be seen that the discharge passing through the model was measured by means of the Meter Fall at the downstream end of the model, the depth over the crest for purposes of calculation of discharge being measured in gauge well G-5. Plate I shows the data of the full sized gate and of the model, and Appendix I shows the calculations of dimensions etc. for the model itself.

5. *Experiments carried out.*—The various series of experiments which have been carried out and the approximate dates covering each are shown in Table III. From this table, it will be seen (*vide* item 1) that no difficulty was experienced

in obtaining the equation for the Standing Wave conditions, and for these experiments, depth of water was read only in well No. G-1 for gate reading; G-5 also being read to give the discharge passing through measuring flume. From items 2, 3, 4, 5, 6 and 7 it is clear that considerable trouble was experienced with the model working under drowned conditions. Particularly was this the case when the difference of head operating to pass water through the gate was measured at gauges G-2, G-3, G-2A, G-3A and G-1—G-4. It was found that the value of the coefficient in the equation for the discharge passing the gate, as ascertained from experiments, varied very considerably, both with the depth of water downstream of the gate and with the amount of discharge passing through the model. The results were examined by Mr. Inglis, Superintending Engineer, Irrigation Development and Research Circle, during a visit to Karachi and he suggested that further experiments should be made with measurements of water levels taken immediately upstream and downstream of the gate itself. This was done and it was found eventually that, by fixing two ordinary gauges to the gate itself—one on the U/S face and the other on the D/S face—and reading these gauges by the eye, a fairly constant value for the coefficient C was obtained for the complete range of conditions, and it was therefore decided to fix to the gate upstream and downstream the gauge wells with glass fronts which are seen in photograph No. 3, and in Plate I-A for the purpose of damping out oscillations in the water surface and allowing of more accurate readings of the difference of head upstream and downstream of the gate. This was further extended afterwards by the addition of floats inside the glass fronted gauge wells bearing indicators attached to wires rising from the floats through the top of the gauge wells. These indicators show, from a common zero on a scale above the gate, the levels of water on the up and downstream sides and the difference between the two readings is, therefore, the actual head operating on the gate. The float indicators worked very satisfactorily in practice and a design has been worked out by Mr. Cumming, Executive Engineer, Draglines Division, for actual practical application to the gates of the various regulators. This design has been tried out on one gate and worked very satisfactorily. It is now being tried out on a number of gates on various regulators scattered throughout the Barrage command with a view to testing its operations under working conditions. The depth indictor is seen in Plates IV and V.

6. *Description of the Experiments: (a) Standing Wave Conditions.*—First of all the model was filled with water which was allowed to drain away over the crests of the Standing Wave Flume, and of the model, and the zeros of the Hook Gauges in the Gauge wells were taken when this water had just finished draining away.

Experiments for Standing Wave conditions were carried out as follows :—

A fixed gate opening was maintained and the discharge passing through the gate, which was varied, was measured on the meter fall at the downstream end of the model. Readings were taken for each discharge on gauges G-1 and G-5 and the utmost care was exercised in order that conditions should be as steady as possible before the gauge readings were taken. In this connection it is well to mention that considerable time had to be allowed for the discharge to settle down, when a variation was made, so as to avoid errors in the depths as registered in gauge wells G-1 and G-5. The pumps supplying water to the model are worked off the Karachi Electric Supply Corporation mains, and the voltage is subject to a variation of at least $\pm$ 5 per cent. In addition to the voltage variation, there is the variation due to the reservoir capacity of the stilling tanks in the Model Testing Station and to the reservoir capacity on the Model itself, on its up and downstream sides. These factors all combine to render the carrying out of the experiments a very tedious business. At one time it was thought that it would probably be necessary to construct a special Equalizing tank with arrangements for ensuring that the discharge leaving the tank should be as constant as possible. On examining the results of the experiments obtained, however, (the results for Standing Wave conditions are shown in Plate II) it was considered that the variation of the points representing experiments from the graph representing the deduced equation were so small that, *for practical purposes*, the equation as deduced could be taken as satisfactory. It was, therefore, decided not to construct the equalizing tank, but to continue the experiments taking care, so far as possible, to allow conditions to settle down after each change in discharge etc. before reading the gauges. For a given gate opening the discharge was increased from a minimum value to the maximum possible for the gate opening and then decreased again, points being taken on both the rising and falling discharges. The equation worked out from the experimental results is as follows :—

$$Q/A = 4 \cdot 52 \sqrt{H}$$

where H is measured from the centre of the gate opening to the water surface measured at G-1 in ft. and is equal to $d_2 - \frac{x}{2}$.

In the above equation :

Q is the total discharge in cusecs passing through the model.

A is the area of gate opening in sq. ft.

H is the Head of water above the centre of the gate opening, measured at G-1, in ft.

X is the height of the gate opening above crest in ft.

d_2 is the depth of water, measured at G-1 over the crest of the gate opening.

Thus, in practice, the depth of water over the crest of the gate opening would be measured by reading the U/S gauge which is fixed above the converging flume in all regulators which have been constructed in the Barrage.

The results of the various experiments carried out for Standing Wave conditions are shown in Table I. (These experiments are those described in item 1 of Table III). The various experiments have been given numbers, *vide* column 1, Table I, and the corresponding numbers have been shown on the graph of the results as plotted, *vide* Plate II.

(*b*) *Drowned conditions.*—As mentioned above, considerable difficulty was experienced with the expriments under drowned conditions and very irregular results were obtained when the experiments were carried out by the reading of gauges G-1 — G-4, G-2 — G-3 and G-2A — G-3A. The irregularity of these results was mainly due to recovery of head in the downstream expansion of the model and also in the throat of the gate opening itself. The degree of recovery of head varies with the discharge passing, the depth of water on the downstream side of the gate and so on, and it was not until this fact was realised and measurements of the difference of head on the upstream and downstream of the gate were made as indicated in items 6, 7 and 8 of Table III, that any satisfactory results were obtained. The final experiments—*vide* item 8 of Table III—were carried out with moveable gauge wells with glass fronts fixed on to the upstream and downstream sides of the gate itself. These gauge wells enabled the fluctuations in the water level to be damped out and the difference of head operating at the gate to be ascertained accurately.

Many experiments were carried out, the results of which are given in Table II.

From these, it will be seen that the method adopted was to fix the height of gate opening and to vary the discharge passing, while maintaining the upstream depth of water above the zero of the indicator on the gate as nearly as possible to a constant figure, by the manipulation of the level of water on the downstream side of the gate, this manipulation being effected by placing *karies* in the grooves shown at B, *vide* Plate I. Various series of experiments were made and the results are shown in Table II. The experiments are numbered, *vide* column 1 of the Table and the 3 graphs, which have been plotted for various values of gate opening, *vide* Plates III and III-A, bear numbers corresponding to the experimental results in the Table. A study of Plates III and III-A will show that the value of the coefficient in the discharge formula varies from 0·61 to 0·64 and for the purposes of working out discharge curves to be used in practice with the Standard Vertical Gates, a value of 0·625 has been adopted for the coefficient.

The actual equations obtained from the experimental results are as follows :—

For a gate opening of 0·15 ft. $Q/A = 0 \cdot 61 \sqrt{2gh}$

For a gate opening of 0·2 & 0·3 ft. $Q/A = 0 \cdot 62 \sqrt{2gh}$

For a gate opening of 0·35 ft. $Q/A = 0 \cdot 61 \sqrt{2gh}$

For a gate opening of 0·45 ft. $Q/A = 0 \cdot 63 \sqrt{2gh}$

For a gate opening of 0·7 ft. $Q/A = 0 \cdot 64 \sqrt{2gh}$

In the above equations Q= The total discharge passing the model in cusecs.

A= The area of gate opening in square ft.

g= 32·2.

h= The difference in level of the water immediately upstream and downstream of the gate itself in ft.

7. *The application of the results in practice.*—Two sets of graphs have been prepared (*a*) for Standing Wave conditions and (*b*) for Drowned conditions. These graphs are seen in Plates VI and VII, and from these graphs it is possible to read off at a glance the discharge per foot-width of gate opening for any difference of head. It is intended that the graphs shown in Plate VI for Standing Wave conditions are to be used in practice by the reading of the ordinary gauge, which has been fixed on the upstream side of all regulators in the Barrage canals above the 1 in 5 contraction leading to the regulator itself and from this computing the value of d_2. It has been necessary to evolve "depth indicators" for use with the vertical gates to facilitate measurement of discharges with the graphs shown in Plate VII for drowned conditions.

These indicators are shown in Plates IV and V and are composed of tubes containing floats which carry vertical rods having indicators at their ends. These indicators operate against scales which are arranged so that they have a common zero level and the difference of the readings given by the float pointers on the upstream and downstream of the gates thus gives the difference of water level (i.e. the head "h") immediately upstream and downstream of the gate. The pipes containing the floats are provided with small holes for the admission of water and the damping out of rapid fluctuations in level.

In practice, it has been necessary to place the downstream depth indicator at a small distance from the gate itself, this being due to the fact that the indicators rise with the gate as it is opened, and have to be arranged so that they will not foul the top members of the gate superstructure.

Photographs Nos. 4 and 4A show the gate indicators in position on an actual regulator gate.

It is quite possible that trouble will be experienced with the depth indicators referred to on account of their becoming blocked up with fine silt from the water. To this end provision has been made for a flap valve at the lower end of each pipe, and for the removal of the float from the top of the indicator tube. This will allow of silt being washed out by pouring water from above. It is intended to test out a number of these indicators on various sizes of gates in order to find whether it is necessary in practice to provide means for washing the tubes as described above or not. It is possible that some arrangement, such as a portable force pump, could be used for the cleaning out of such deposit as may occur in the tubes which, if satisfactory, would eliminate the provision of the valves and the necessary rods for their operation and thus simplify, and reduce the cost of, the "depth indicators".

8. It is hoped that, by the adoption of the two sets of graphs and of the "depth indicators" described in paragraph 7, and by noting at fixed intervals the gate opening, the upstream gauge above the regulator, and the readings on the two "depth indicators", it will be possible to obtain a much more accurate measure of the discharge which has passed any Head Regulator, having standard vertical gates, than would be possible if measurements of discharge were made with velocity rods in the ordinary way.

The elimination of velocity rod measurements will mean the saving of a considerable amount of tedious work for the canal staff, and may possibly result in an actual saving of staff due to this reduction of work.

Further, the discharges obtained from the gate discharge graphs should be more accurate than those obtained from the velocity rod measurements, particularly in the case of the smaller channels in which the "error" of velocity rod measurements may be anything up to 20 per cent.

It will be necessary, if velocity rod measurements are entirely eliminated, to take and record cross-sections below all regulators at the points where discharge measurements by velocity rods would ordinarily have been made. Such cross-sections would be of immense value for watching the movement of the bed of the channel and of its sides, and also in connection with any investigations (such as those now in hand in regard to Lacey's Theory) requiring the use of wetted perimeters, areas of flow, hydraulic mean depths etc. This information is now usually obtained from the records of soundings etc. made at the time of taking velocity rod discharges.

Experimental work has been carried out by Mr. P. R. Jivrajani, Assistant Engineer, and Mr. Pinara, Overseer, and the bulk of the experiments were carried out under the control of Mr. H. S. Kahai, Acting Executive Engineer, Development and Research Division.

The data were worked up by Mr. A. G. Maydeo, Assistant Engineer.

C. G. HAWES,
Executive Engineer,
Development and Research Division.

TABLE I.

Standing Wave Condition—Statement showing head over centre of orifice and discharge.

Experiment No.	Standing wave flume (d/s). Depth over sill.	Discharge $Q = 3 \times 1{\cdot}776D^{1{\cdot}5}$.	Height of opening of gate $B = 2{\cdot}0$.	Area of opening.	Upstream depth of water over crest.	H—Read over centre Column 6—½ Column 4.	Discharge per square foot of opening Column 3/ Column 5.
1	2	3	4	5	6	7	8
1	0·473	1·733	0·200	0·400	1·011	0·911	4·335
2	0·610	2·538	0·300	0·600	1·011	0·861	4·230
3	0·616	2·576	0·300	0·600	1·047	0·897	4·293
4	0·621	2·607	0·300	0·600	1·062	0·912	4·345
5	0·618	2·588	0·300	0·600	1·050	0·900	4·313
6	0·558	2·221	0·300	0·600	0·827	0·677	3·702
7	0·523	2·015	0·300	0·600	0·711	0·561	3·359
8	0·485	1·800	0·300	0·600	0·602	0·452	3·00
9	0·460	1·662	0·300	0·600	0·538	0·388	2·770
10	0·398	1·338	0·300	0·600	0·397	0·247	2·230
11	0·720	3·255	0·400	0·800	1·012	0·812	4·069
12	0·728	3·309	0·400	0·800	1·027	0·827	4·136
13	0·724	3·282	0·400	0·800	1·029	0·829	4·103
14	0·704	3·147	0·400	0·800	0·961	0·761	3·934
15	0·650	2·792	0·400	0·800	0·805	0·605	3·490
16	0·597	2·458	0·400	0·800	0·675	0·475	3·073
17	0·522	2·009	0·400	0·800	0·502	0·302	2·511
18	0·754	3·488	0·500	1·000	0·847	0·597	3·488
19	0·745	3·426	0·500	1·000	0·829	0·579	3·426
20	0·730	3·325	0·500	1·000	0·797	0·547	3·323
21	0·715	3·221	0·500	1·000	0·766	0·516	3·221
22	0·705	3·154	0·500	1·000	0·741	0·491	3·154
23	0·685	3·020	0·500	1·000	0·701	0·451	3·020

TABLE II.

Standing Wave drowned—Statement showing effective head and discharge.

Experiment No.	Standing wave flume (d/s). Depth over sill.	Discharge $Q = 3 \times 1{\cdot}776D^{1{\cdot}5}$.	Height of opening.	Area of waterway $B=2{\cdot}0$.	Upstream depth of water above a common datum.	Down-stream depth of water above a common datum.	Effective depth h Column 6—Column 7.	Discharge per square foot of opening Column 3/ Column 5.
1	2	3	4	5	6	7	8	9
1	0·482	1·783	0·15	0·300	1·715	0·257	1·458	5·943
2	0·453	1·625	..	0·300	1·695	0·465	1·230	5·417
3	0·436	1·534	..	..	1·690	0·600	1·090	5·113
4	0·419	1·445	..	..	1·695	0·715	0·980	4·817
5	0·382	1·258	..	..	1·685	0·95	0·735	4·193
6	0·355	1·127	..	..	1·700	1·110	0·590	3·757
7	0·388	1·288	..	..	1·685	0·910	0·775	4·293
8	0·406	1·378	..	..	1·695	0·815	0·885	4·593
9	0·437	1·539	..	..	1·695	0·605	1·090	5·130
10	0·445	1·582	..	..	1·695	0·535	1·160	5·273
11	0·463	1·678	..	..	1·690	0·370	1·320	5·593
12	0·571	2·299	0·20	0·400	1·58	0·280	1·300	5·748
13	0·542	2·126	..	..	1·59	0·470	1·120	5·315
14	0·516	1·975	..	..	1·590	0·615	0·975	4·936
15	0·493	1·844	0·20	0·400	1·59	0·740	0·850	4·610
16	0·449	1·603	..	..	1·57	0·920	0·650	4·008
17	0·403	1·363	..	..	1·59	1·110	0·480	3·408
18	0·455	1·635	..	..	1·595	0·925	0·670	4·088
19	0·479	1·766	..	..	1·590	0·795	0·795	4·415
20	0·508	1·929		..	1·575	0·645	0·930	4·823
21	0·534	2·079	..	..	1·575	0·490	1·085	5·198
22	0·561	2·238	0·20	0·400	1·585	0·320	1·265	5·595
23	0·664	2·883	0·30	0·600	1·240	0·320	0·920	4·805
24	0·651	2·798	..	..	1·275	0·400	0·875	4·663
25	0·606	2·516	..	..	1·255	0·555	0·700	4·193
26	0·537	2·097	..	..	1·255	0·755	0·500	3·495
27	0·400	1·348	..	..	1·235	1·035	0·200	2·247
28	0·516	1·975	..	..	1·240	0·800	0·440	3·292
29	0·607	2·520	..	..	1·265	0·545	0·720	4·200
30	0·626	2·639	..	..	1·270	0·490	0·780	4·399
31	0·668	2·909	0·30	0·600	1·255	0·320	0·935	4·849
32	0·603	2·495	0·35	0·700	1·075	0·545	0·530	3·564
33	0·644	2·754	..	..	1·075	0·420	0·655	3·934
34	0·664	2·883	..	..	1·065	0·360	0·705	4·119
35	0·689	3·047	0·35	..	1·070	0·265	0·805	4·353
36	0·696	3·094	..	..	1·065	0·60	0·805	4·420
37	0·668	2·909	..	..	1·075	0·360	0·715	4·156
38	0·648	2·779	..	..	1·075	0·425	0·650	3·970
39	0·625	2·633	..	..	1·075	0·590	0·485	3·761
40	0·559	2·227	0·35	0·700	1·070	0·645	0·425	3·181
41	0·708	3·174	0·45	0·900	0·625	0·145	0·480	3·527
42	0·658	2·844	..	..	0·63	0·240	0·390	3·160
43	0·620	2·601	..	..	0·625	0·300	0·325	2·890
44	0·571	2·299	..	..	0·610	0·350	0·260	2·554
45	0·491	1·833	..	..	0·600	0·440	0·160	2·037
46	0·428	1·492	..	..	0·630	0·520	0·110	1·658
47	0·170	2·29	..	..	0·610	0·355	0·255	2·548
48	0·606	2·514	..	..	0·620	0·315	0·305	2·793
49	0·641	2·734	..	..	0·610	0·245	0·365	3·038
50	0·680	2·987	..	..	0·615	0·180	0·435	3·319
51	0·700	3·121	0·45	0·900	0·645	0·160	0·485	3·468
52	0·522	2·009	0·70	1·400	0·545	0·460	0·085	1·135
53	0·631	2·671	..	..	0·540	0·405	0·135	1·908
54	0·630	2·664	..	..	0·550	0·410	0·140	1·903
55	0·691	3·061	..	..	0·535	0·360	0·175	2·186
56	0·701	3·127	..	..	0·54	0·355	0·185	2·234
57	0·641	2·734	..	..	0·55	0·410	0·140	1·953
58	0·597	2·458	..	..	0·555	0·440	0·115	1·756
59	0·538	2·103	..	..	0·54	0·455	0·085	1·502
60	0·434	1·523	0·70	1·400	0·555	0·505	0·050	1·088

TABLE III.

Summary of Experiments carried out.

Series No. 1	Date. 2	Height of Opening. 3	With Standing wave or drowned. 4	Gauges read. 5	Other conditions of experiments. 6	Remarks. 7
1	28-7-30 to 31-7-30	0·20, 0·30 0·40, 0·50	With Standing Wave.	G-1 & G-5	Upstream gauge and discharge varying. Increasing and decreasing discharges.	Mean equation obtained when all points were plotted on a single graph was $Q/A = 4 \cdot 52 \sqrt{H}$ where H is measured from centre of opening.
2	21-7-30 to 31-7-30 & 1-8-30 to 2-11-30	Varying from 0·05 to 0–525 Openings increasing by 0·025.	Standing Wave drowned.	G-1, G-2, G-3, G-4, & G-5.	Upstream gauge G-1 was kept constant with discharges varying and also varying downstream depth.	"h" the effective head calculated as $D - D_4$. Each opening gave a different equation. Coefficients varying from 4·5 to 11·4 and indices from 0·50 to 0·87.
3	3-11-30 to 7-11-30 & 10-11-30	0·3 & 0·1	Do. ..	Do.	Upstream gauge G-1 kept constant with discharges varying. The value of G-1 was different from that of series 2.	This showed that for each different value of G-1 (kept constant) the same opening gave different equations when h was taken as $D_1 - D_4$.
4	18-11-30 to 24-11-30.	0·15 & 0·20	Do. ..	Do.	....	Experiments to study the effect of D_1 on "h" with a constant discharge. It was found that h increased as D_1 increased when h was taken equal to $D_1 - D_4$ or $D_2 - D_3$.
5	3-12-30 to 4-12-30	0·2 0·3	Standing Wave drowned.	0-1, G-2, G-3, G-4 and G-5 & also depth at gate was measured directly.	....	C′ was worked out with index 0·5 and $h' = D_2 - D_3$ also C″ was worked out with $h'' = D_2 - D_g$ (i.e. depth at gate on d/s). The values of C′ were irregular but indicated an increase with increase of h′ but the values of C″ indicated a decrease with increase of H″.
5A	5-12-30	0·3	Do. ..	h taken as the difference of water levels immediately upstream and downstream of the gate as measured by eye only.	....	This series indicated a fairly constant value of C when "h" was taken as shown in column 5 making allowance for the error due to observations being made by eye only.
6	11-12-30	0·30	Do.	One more gauge G-3A fixed downstream of gate.	....	With a constant discharge, index as 0·5 and "h" taken as $D_2 - D_{3A}$, C was found to be much more uniform.
7	19-6-31	0–20 & 0·30.	Do. ..	G-1, G-2, G-3, G-4, G-5, X_n and x_d two ordinary gauges fixed on upstream and downstream were also read.	....	This series showed that when "h" was measured as the difference of the gauges x_n and x_d, C was constant with index 0·5, i.e that the proper position for the two gauges was just at the gate.
8	8-2-32 & 19-4-32 to 30-4-32	0·15, 0·20 0·30, 0·35, 0·45, 0·70	Do. ..	h measured as difference of two gauges fixed on gate.	The rapid fluctuations damped by two glass gauge wells fixed to the gate.	The final series. The equations with 0·50 index obtained for different openings and coefficients from 0·61 to 0·64; the mean 0·625 was adopted so that $Q/A = 0 \cdot 625 \sqrt{2gh}$.

APPENDIX I.

Model for determining coefficients of discharge through vertical screw gates.

Data :— D-12-L ex Rohri Canal at R.D. 9,54,632.

Discharge 110·66 cusecs. Bed level 67·9

Full Supply Depth 3·8′. Full Supply Level $\frac{71 \cdot 98}{71 \cdot 70}$

Bed width 17′. Mean velocity in channel 1·4 ft. per sec.

Crest Level of throat—68·44. Gates—1 No. 8′ × 5′.

Design of the Model.

Model to be $\frac{1}{4}$th full size.

1. Discharge through model :

Model constant $= \frac{1}{4} \times \frac{1}{4} \times \sqrt{\frac{1}{4}} = 1/32$

$Q_m = \frac{110 \cdot 66}{32} = 3 \cdot 46$ cusecs.

2. Depth of water in model $= d_m = \frac{3 \cdot 8}{4} = 0 \cdot 95$ ft.

3. Bed width in model $= b_m = \frac{17}{4} = 4 \cdot 25$ ft.

4. Height of crest above the u/s bed in model $= \frac{68 \cdot 44 - 67 \cdot 9}{4} = \frac{\cdot 54}{4} = 0 \cdot 135$ ft.

Design of S. W. Flume (Downstream) for measuring discharges.

Width of approach channel = Bed width of the channel $= \frac{17}{4} = 4 \cdot 25$ ft.

Crest 0·2′ above bed

$\therefore D = 0 \cdot 95' - 0 \cdot 2' = 0 \cdot 75'$

$Q = C \times B \times D^{3/2} = 3 \cdot 46$ cusecs.

$= 3 \times B \times 0 \cdot 75^{3/2}$

$\therefore B = \frac{3 \cdot 46}{3 \times 0 \cdot 6495} = 1 \cdot 76$ ft.

Size of gate = 2′ × 1·25′ correct to scale.

Gate used = 2′ × 1·81′ in order to allow of greater depths for experimental work.

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