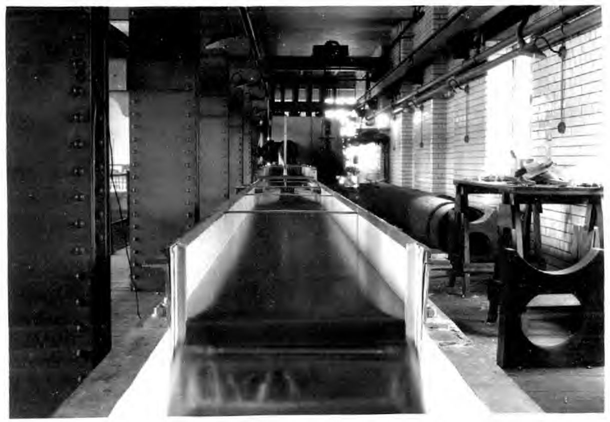
PHOTOGRAPH SHOWING WATER FLOWING THROUGH VENTURI FLUME MODEL I, LOOKING DOWN STREAM. THE BOTTOM OF THE DROPPING WATER SURFACE CURVE IS SHOWN AT THE REFLECTION OF THE POINT GAUGE G

PHOTOGRAPH SHOWING WATER FLOWING THROUGH VENTURI FLUME MODEL I, LOOKING UP STREAM. THE DROP INSIDE THE THROAT IS MARKED BY THE LIGHT REFLECTIONS.



PHOTOGRAPH SHOWING WATER FLOWING D.S OF MODEL & OVER THE REGULATION WEIR L, LOOKING U.STREAM

PHOTOGRAPH SHOWING PIPE CONNECTIONS BETWEEN THROAT PRESSURE HOLES & THROAT PIEZOMETER GAUGE.

EXPERIMENTAL STEEL FLUME. LOOKING U.S FROM THE BOTTOM END.

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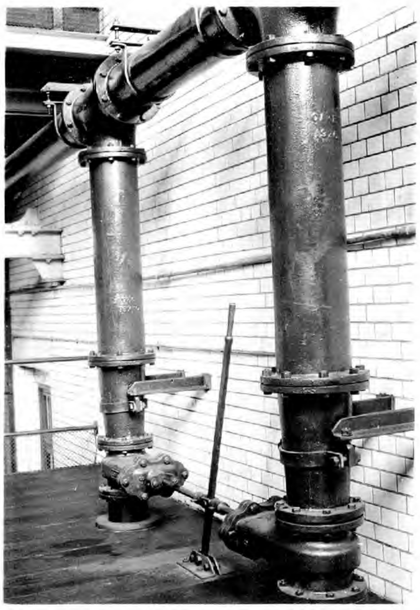

PHOTOGRAPH SHOWING PIPES O & O, ON TOP OF DISCHARGE TANKS, LEVER R & VALVES P & P, .

F L O W O F W A T E R I N C A N A L S
F I T T E D W I T H
V E N T U R I F L U M E S.

THESIS

ON

RESEARCH WORK CARRIED ON AT THE CITY AND GUILDS (ENGINEERING)

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FOR

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P L A T E S.

INTRODUCTION.

One of the problems often met by an irrigation or water supply engineer is the design of a discharge measuring device in an open channel to satisfy the following conditions.

1. To be inexpensive and simple to construct and maintain.
2. To contain as few working parts as possible.
3. To cause as little disturbance as possible in the moving mass of water.
4. To cause no sudden reduction in section or checking of a part of the flowing mass of silt laden water and hence no liability to silt deposit.
5. To be simple in operation.
6. To be accurate enough for practical requirements.
7. To require minimum loss of head or ponding up.
8. To have a wide range of flow.
9. To require no alteration in formula or in coefficient of discharge with the changes of tail water levels.

The sharp edged weir is the standard permanent gauge of flow in open canals at present. It satisfies conditions 1, 2 and 5 but it has the following disadvantages:-

1. In the general formula of flow $Q = C\ H^{3/2}$

   where Q = discharge in cubic feet per second

   H = head above sill in feet

   and C which depends on the coefficient of discharge is not definite.

2. The coefficient of discharge changes with H and with the relative dimensions of approach channel and weir.

3. The velocity generated by fall is destroyed in

forming eddies in the tail water.

4. To give consistent results, the tail water is kept well below the crest of the weir to admit air under the nappe.

5. If tail water rises, the weir becomes drowned and another discharge formula has to be used.

6. The intermediate transition condition between free over fall and complete drowning is uncertain.

7. The approach channel tends to silt up and thus alters the coefficient C.

8. Sharp edged weirs are expensive to construct and are liable to damage from floating material.

The Venturi Flume.

The main features of a flume of that name is a gradual contraction in the section of the stream followed by a short length of contracted section leading to a gradual divergence increasing the section again to its normal width. There is no water fall as in the case of a weir and also there is no obstruction across the bed of the channel. The shape of the cross section of the flume may be rectangular, trapezoidal, triangular or semi-circular according to the shape and size of the section of approach.

The above features satisfy conditions 1, 2, 3 and 4 as stated above and valuable information furnished by well known investigators proves that such a device if properly designed will satisfy the rest of the conditions 5, 6, 7, 8 and 9.

The shape of the above mentioned flume and its similarity to the Venturi Tube suggests its name "Venturi Flume".

The effect of passing liquids through a converging and diverging tube was known to the Romans. In 1797

Professor Giovanni Battista Venturi, an Italian Philosopher, studied this phenomenon and after careful investigations at the University of Modena, established a definite law of flow. About 100 years later, Clemens Herschel applied the Venturi principle for the practical measurement of water flow through pipes.

The Venturi Flume is also an adaptation of the same principle. The water is exposed all through the flume to atmospheric pressure only but the reduction in depth of water passing through the contraction is analogous to the drop in pressure head in applying the Venturi principle.

The following shows plainly the analogy between the principles of working of the Venturi Tube and Venturi Flume as derived from theory.

Venturi Tube.		Venturi Flume.	
H_1 =	Pressure head in main pipe at entrance to converging inlet	d_1 =	Depth of water in main channel at entrance to converging inlet.
H_2 =	Pressure head in the throat.	d_2 =	Depth of water inside the parallel throat.
H =	$(H_1 - H_2)$	h =	$(d_1 - d_2)$
a_1 =	Area of cross section of main pipe at entrance to converging inlet.	A_1 =	Area of cross section of flowing stream in main channel at entrance to converging inlet.
a_2 =	Area of cross section of throat.	A_2 =	Area of cross section of flowing stream inside the throat.
Q =	Theoretical discharge in cubic units.	Q =	Theoretical discharge in cubic units.
	$= \dfrac{a_2\sqrt{2gH}}{\sqrt{1-\left(\frac{a_2}{a_1}\right)^2}}$		$= \dfrac{A_2\sqrt{2gh}}{\sqrt{1-\left(\frac{A_2}{A_1}\right)^2}}$

In the case of Venturi Tubes the actual discharge is equal to the theoretical discharge multiplied by a coefficient which was found to be nearly unity having an average constant value of o.98. In the case of Venturi Flumes a similar coefficient is also required for the computation of actual flow.

The original idea in the development of the rectangular section Venturi Flume was to invent a device to replace the ordinary rating flume that was being used in irrigation canals. This rating flume consisted of a constant contracted section through which the water passed. In the majority of cases such a flume was found unreliable due to changes in velocities of approach, silting conditions and accumulation of suspended bodies in the checked stream above it.

The Venturi Flume has another advantage from the point of view of data required for determination of water flow. In the application of usual formulae for contractions viz., d'Aubuisson's formula (16a) Section (c) Appendix (3) or Weisbach's formula (17) Section (d) Appendix (3), the water depths upstream and inside or downstream the contraction as well as the velocity of approach are required. In general practice the velocity of approach is at first neglected and then approximately allowed for, which means a long process.

In consulting formula (15) Section (b) Appendix (3) as deduced from first principles it will be found that the velocity of approach is automatically cared for in the application of the formula in the theoretical deduction of which the velocity of the water at each gauge was taken into account.

If the water flowing through a venturi flume is drawn from a still water basin, there will be definite heads in the upstream and in the throat and also a definite difference between these two heads for a given quantity of flow. If the same discharge were to approach the flume with a velocity, both the upper and throat gauge readings would be less but the difference between the two readings would be greater in order to pass the same discharge. Thus the water depths in the convergence and in the throat automatically adjust themselves for any change in the velocity of approach.

Also the gradual change of section through the converging parts reduces the total loss of head that results from the sudden contraction in an ordinary straight flume. Also when the depth of water inside the contraction is above the critical (see Appendix (6)) the gradual divergence of the outlet of the venturi flume helps to recover the normal depth with a loss of head much smaller than that due to the abrupt change from the width of contracted section to the original channel width.

Object of this research.

Tests and investigations were carried out with object of finding the most suitable design of rectangular Venturi Flumes. To test different shapes of rectangular flumes and to decide on the most suitable shape for practical use under different conditions of flow, several shapes of flume models with different lengths and widths of parallel throat were used.

After deciding on the best design of flume the formula of flow was also investigated to find whether the coefficient of discharge required is also constant as in the case of the Venturi Tube or having a certain relation with any of the variables in the discharge formula.

Experimental Plant.

The experimental plant on which the writer carried out his tests in the City and Guilds (Engineering) College Hydraulic Laboratory was built up in the form of a hydraulic circuit the rough outline of which is shown on small diagram on plate (1). This diagram shows that water can be pumped up from the sump W into the constant discharge tank A, then through ~~through~~ the experimental steel flume F and then through a pipe line N down to the discharge measuring tanks T which discharge back into the sump W from which the water is pumped up again and so on. As the head in the tank A is required to be constant the water is kept at a constant level by means of an overflow pipe which discharges the excess water back into the sump.

On plate (1) the actual experimental plant is shown to scale in plan, elevation and sections. The three centrifugal pumps are specified and shown as CP(1), CP(2) and CP(3). They could be used one two or three at a time depending upon the flow required. The pipes leading from these pumps into the tank A are shown as (S_1 , S_2 and S_3) respectively. The tank A is a reinforced concrete tank of inside dimensions (11.5 feet long X 5 feet wide X 6 feet deep). The top of the funnel (B) that leads to the overflow 12" pipe C is 4 feet above the centre of the 14" outlet pipe E so that the head of water is always maintained in the tank at about 4 feet above the centre of the outlet pipe E. It does vary a little with the amount of outflow from the tank. Any required steady discharge into the experimental flume F depends upon the opening of the valve D. The head in the tank A adjusts itself and remains steady so long as the opening of the valve D is not altered.

The experimental steel flume.

This is built of steel channels and plates as shown in fig. plate 2 and is two feet wide all through its 80 feet length. Its depth is 2 feet in the first 30 feet, 1.5 feet in the middle 30 feet and 1 foot in the last 20 feet. It is so designed to be given any required slope but for the purpose of this work the tests were started with the flume supported in a horizontal position on large wooden wedges about 12 feet apart.

To damp down the waves caused by the inflow of water from the pipe nozzle E into the flume, a baffle G was made of 4 separate partitions of alternate vertical and horizontal strips of wood fixed with small spaces between. Down stream of this baffle a floating wooden raft H damped down the surface waves and thus the water in the upstream reach had a steady and smooth surface.

Along each of the top edges of the vertical sides of the middle section of flume a brass angle ($2\frac{1}{2}'' \times 1\frac{1}{2}'' \times \frac{1}{4}''$) was fixed as shown in fig. on plates II and III The top edges of the vertical sides of both angles were carefully filed and scraped and made exactly level and even. They were tested during the operation by means of a spirit level and a 5 feet straight steel edge. Not only each edge was made level but both edges were made exactly at the same level and tested in the same way.

On these level edges was fitted a brass frame E shown in fig. on plate III . This frame was so designed so as to slide smoothly along the top of the angles and be exactly at right angles to the axis of the flume in any position and to carry a boss B of a micrometer screw point gauge described in a following paragraph. This boss was made to slide along the frame in the transverse direction i.e. at right angles to the axis of the flume.

At the bottom of the flume the water is discharged into a small tank M and then through the pipe line N to the discharge measuring tanks. These as shown as T and T_1 in plate (1) are two large steel tanks of rectangular sections the areas of which are 155 square feet in T and 152.5 square feet in T_1 . The lever arm R opens either of the two valves P or P_1 and closes the other at the same time. Both tanks discharge into the sump by opening their bottom valves (V or V_1). This is done by turning the wheels (U or U_1). The depth of water in any of the tanks can be read to three decimals of a foot on piezometer glass tube gauges (Z or Z_1) fixed to the side of T.

<u>The micrometer screw point gauge</u> is shown in plate III The pointer P is fixed to the top of a $\frac{3}{4}''$ screwed brass

spindle S. The pitch of the screw on this spindle is .12 of an inch i.e. the teeth are 10 to each one tenth of a foot. There is a groove g ($3/16''$ wide X $1/16''$ deep) slotted along the surface of the spindle. The spindle fits and can be moved up and down smoothly but not loosely through a vertical hole bored through the centre of the boss B and is prevented from turning round by means of a set screw C that fits into the groove g. By turning a nut N resting always on the top surface of the bracket R the spindle can be moved up or down through a distance depending upon the number of turns of the nut N. Through a hole bored through the bottom end of the spindle, a $\frac{1}{8}''$ rustless steel rod T is fitted and fixed in position by a set screw C_1. This rod has a sharp point (t) at its bottom end. To the bracket R is fixed a vertical scale L about 18" long and is divided into large divisions of $\frac{1}{10}$ th of a foot each and each one of these is divided into ten parts so that the small division on the scale is a $\frac{1}{100}$ th part of a foot. As the pitch of the screw on the spindle is .12 of an inch or $\frac{1}{100}$ th of a foot then by one complete turn of the nut N the spindle and thus the pointer P moves vertically a distance equal to .001 of a foot or one small division of the scale. The top part of the nut N is 2.375 inches in diameter and the circumference of the top surface is divided into 100 divisions so that by turning the nut through one division only or .001 of a complete turn the pointer P moves through .0001 of a foot upwards for a clockwise turn and downwards for anticlockwise turn. When the pointer P reads zero on the scale or reads exactly a round number of one hundredths of a foot, the zero of the divisions on the nut coincides exactly with an index mark on an arm r fixed to the bracket R. One end of the pointer P is bent so that its sharp bevelled edge is exactly parallel to the division marks on the scale L and a small spring q fixed to P presses lightly against the back of the scale L and keeps the bevelled edge of P always just touching the face of the scale. To read the gauge the pointer P gives directly the first two decimals of a foot and the reading opposite the index on the nut gives the third and fourth decimals i.e. if the vertical scale reads 1.44 and the nut reads 6.3 the whole reading of the gauge is 1.4463 feet.

Venturi Flume Models.

The different shapes of flume models tested were built up of different combinations of blocks shown on plate IV . These were made of yellow pine 4" thick. Each block was made of 4 pieces cut to the required shape and dimensions and bound together by bolts after being immersed in boiled paraffin, at a temperature of 110°C for 45 minutes and then left to cool in the melted wax for about one hour. This was done in order that the hot liquid paraffin enters through the pores on the outside surface of the wood and replaces the air and moisture and thus renders it proof against change in shape when the models are tested and then taken out of the water.

The pieces A are for simple round entrances and outlets. Pieces B and C are for the straight parallel throats. Pieces D are for convergent inlets and divergent outlets of venturi flume models of straight walls. Pieces E are similar to D but with different taper or rate of convergence and divergence. Pieces F are with curved faces and can be screwed on the faces of the blocks D in order to form models with curved walls at either entrance or outlet or both. They are cut to a curve the ordinates of which are shown in plate IV on block D . Pieces G are made to fit on faces of blocks E for the same purpose. The ordinates of the curves are as shown on blocks E . These curves were not specially designed by the writer to given dimensions. For example in the case of G curve it was simply through trying to fit on the main parabola a suitable reverse curve that the given dimensions were found to give a suitable shape. The effects on the results of observations that such a curve will show will give an idea of the effect of similar curves of the same general shape but of different dimensions.

Any one model of flume was built up of two similar halves. Each half consisted of an inlet piece, an outlet piece and one or two parallel throat pieces. These were securely bound together by short bolts that passed through opposite holes in the adjacent faces of blocks.

A layer of putty about $\frac{1}{8}$" thick was spread on the bottom of the flume in the space to be covered by the base of the model. The two halves were then lowered and placed symmetrically opposite one another and then were firmly held down by two wooden beams wedged at both ends under the steel cross bars of the steel channel as shown in figure on plate II . The putty was then scraped off round the edges at the bottom. The vertical sides against the walls of the flume at inlet and outlet were also puttied. The bottom layer of putty and the putty at the sides prevented any leakage of water underneath or behind the model which was then ready for test.

Methods of observations.

A complete test on a model consisted of 4 runs. During each run a constant flow of water was discharged into the steel channel. The water levels upstream and downstream the models were then varied during each constant flow. During tests 1-10 the tail level was changed 5, 6 or 7 times during each run. Each level constituted one observation during which levels of the water surface curve extending from a point five feet upstream to another six feet downstream. Distances were measured upstream and downstream from the centre of the parallel throat. During each run the actual discharge passing was measured at least three or four times and the mean was taken as the average constant flow during the run.

Changing water level in flume.

The levels were changed by means of raising or lowering the tail water level. This was done by means of inserting horizontal sticks between angles fixed to the sides of the channel as shown in figure on plate II The sticks were made about $\frac{1}{8}$" thicker at their ends so that when they were laid on top of one another a gap of $\frac{1}{8}$" was left between the sticks. This was done in order to let the water that was backed up behing the sticks flow as uniformly as possible right through the depth of stream unlike what would have happened had the regulating sticks been just laid on top of one another to form an ordinary weir that allows water to flow only over the top and would have reduced ~~with~~ the velocity of the bottom layers of stream through the models especially at low flows.

Measurement of horizontal distances.

These were measured from the centre of the parallel throat of each model. A 12 feet wooden scale was placed alongside the vertical edge of the brass angles. The top edge of the scale was flush with the top edge of the angle. It was marked C at the centre and then graduated in feet and inches and marked from 0' to 6' towards each end. On the frame carrying the micrometer point gauge an index was so fixed opposite the centre of the spindle and moved on top of the graduated side of the horizontal wooden scale so that it indicated the distance from the throat centre at which the measurement of water depth was taken.

Measurement of water depth.

The horizontal plane parallel to the level edges of the brass angles on top of the channel and passing through the point on centre line of the bed and at the centre of throat length was taken to be the datum plane of measurements. This plane was supposed to coincide exactly with the bed of the flume in its horizontal position but due to some slight irregularities in joining the bottom plates this was not exactly the case.

During the first ten tests, only the point gauge was used. At the commencement of measurement of water depth, the frame carrying the gauge was brought to the centre so that its index I' read zero on the horizontal wooden scale. The boss B was then adjusted at the centre of the frame. The steel rod T at the bottom of the spindle S was then loosened by unscrewing the set screw C, and its sharp point was adjusted to touch the bottom of the channel when the pointer P read zero on the scale S and the index I coincided with the zero on the nut divisions. The set screw was then tightened to keep the rod T in position. In this case by turning the nut N the reading of the gauge which depended on the vertical movement of P or t indicated the height of the point t above the plane of reference or above the bed of the flume at the centre of the throat. In other words when the point t just touched the surface of the running water at any point the gauge read directly the depth of water at that point. Such readings were taken during each observation at every 3 inches along the parallel throat and at longer distances of 1 foot or more outside the throat. Inside the throat readings were also taken to the side of the centre line in the neighbourhood of the lowest point. All readings were recorded to four decimals of a foot and the nearest three decimals were taken in the computations.

For test number 11 and the following ones, both the point gauge and the pressure gauge readings were recorded.

Starting a run.

During tests on models with 6 inches throat only one pump had to be used as the flow did not exceed 2.0 cubic feet per second. With the models of wider throats two pumps were sometimes used. When the water was pumped into the concrete tank the valve (D) was opened gradually until the water surface touched the point t of the gauge that was set to a certain reading. No sticks were put in the regulating weir down stream of the model through which the water was then flowing with lowest tail level. The latter was raised by means of the regulating weir and a fresh observation was started. After finishing a run the opening of the valve D was altered to give another flow and a fresh run was started.

Measurement of actual discharge.

As previously mentioned the water discharged from the flume flowed through the pipe N and then through either of the vertical pipes O or O_1 depending upon which valve P or P_1 was open. At the beginning of a run the valves P_1 and V_1 were opened so that the water flowed into tank T_1 and back to the sump. For measuring the discharge the valve V at the bottom of T was opened until the surface of the water inside the tank dropped to a level that could be read on its piezometer tube gauge and then V was closed. The reading of the piezometer gauge was noted to the nearest third decimal and gave the depth of water in the tank T in ft. The lever arm R was then pulled to open valve P and shut P_1 and the time was recorded to the nearest second. The water by so doing was colleted in T instead of flowing to the sump through T_1. After a few minutes ranging from 5 to 10 and depending upon the rate of flow. the lever arm was pulled back, closing P and opening P_1 to let the water take its original course. The piezometer gauge was then read and the difference between the two readings gave the rise of water in the tank in feet in the given number of minutes. Knowing the cross section area of the tank to be 155 square feet the discharge in cubic feet per second was equal to

$$Q = \frac{\text{rise in tank in feet} \times 155}{\text{time in min} \times 60}$$

During each run the discharge was measured at least three times and the mean was computed for each run.

PIEZOMETER TUBE GAUGES.

These were fitted in the experimental steel flume for the purpose of measuring the actual hydrostatic pressures upstream, in the throat, and downstream on the tested venturi flume model as shown in the detail of the middle section of steel flume in Plate II. At the centre of the throat, three parallel rows of $\frac{1}{4}$" holes were drilled in the bottom plate of the steel channel at right angles to the centre line. The three sets of holes were 3" apart. The distance from centre to centre of the holes in each row was $1\frac{1}{8}$" for the 5 holes in the middle 6" width and the remaining holes on each side were 1" from centre to centre. These dimensions were so chosen in order to give the mean static pressure from side to side in a 6" and in an 8" throat. A similar row of holes was drilled 4ß 6" upstream the centre of throat and another one 6' downstream the centre of throat. The holes in each row were connected by means of short connectors to branch pressure pipes which were connected to one main pipe leading to the pressure glass tubes as shown in figure. The main and branch pressure pipes were fitted with suitable cocks to obtain the right connection between the sets of holes and their corresponding glass tube gauges. Also at the throat, the mean pressure along the row of holes 0.25' upstream centre, at the centre, and 0.25' downstream centre could be connected and observed either separately or together on the throat gauge. In this way, four separate throat mean pressures were observed, one for each row of holes and one for the three holes as shown in the observation sheets of tests 11 and 12.

Adjustment of the zeros of the scales of Tube Gauges.

Behind each glass tube gauge a vertical scale reading to three decimals of a foot was fixed. To adjust the zeros of these scales to coincide exactly with the inside horizontal bottom of the flume, about 2" of still water was dammed inside the flume by a thick layer of putty laid across the bottom. The cocks separating the three glass tubes were opened so that the water inside the tubes was exactly level with the horizontal surface of the still water inside the flume, the actual depth of which was measured by the Micrometer screw point gauge. The three scales were then screwed in their position and each one was adjusted to read the actually measured depth of water opposite the water level inside its corresponding tube.

COMPUTATIONS.

The water depths were taken in the computation of results to the nearest third decimal from the four decimal figures of observations. Discharges were measured to the nearest thousandth of a cubic foot per second and the coefficients were computed to three decimals. A 10" slide rule was used.

TEST No.1.

on

Model shape A.

Throat width 6 inches. Throat length 18 inches.

Distance from centre of throat in feet.	Depth of water in feet = Point gauge readings Observation No. 1	2	3	4	5	6
	Run No.(1) Mean discharge = 0.485 cusecs.					
5.00 U.S.	0.4737	0.4888	0.5456	0.6137	0.7764	
2.00 "	0.4713	0.4882	0.5436	0.6144	0.7785	
1.00 "	0.4340	0.4540	0.5169	0.5920	0.7764	
0.75 "	0.3850	0.4120	0.4930	----	----	
0.50 "	0.3194	0.3566	0.4642	0.5735	0.7576	
0.25 "	0.2850	0.3463 wave	0.4600	----	----	
0.00 "	0.2760	0.4282	0.4681	0.5690	0.7572	
0.25 D.S.	0.2650	0.3550	0.4810	----	----	
0.50 "	0.2595	0.3735	0.4949	0.5690	0.7567	
0.75 "	0.2380	wave	0.5041	-----	-----	
1.00 "	0.2088 2.5 Jump	"	0.5060	0.5737	0.7567	
6.00 "	0.2010	0.4061	0.4900	0.5761	0.7567	
	Run No. (2) Mean discharge = 0.742 cusecs.					
5.00 U.S.	0.6298	0.6313	0.6985	0.8315	1.0441	1.2383
2.00 "	0.6295	0.6305	0.6985	0.8315	1.0441	1.2380
1.00 "	0.5874	0.5862	0.6654	0.8035	1.0268	1.2249
0.75 "	0.5250	0.5288	0.6130	0.7758	1.0106	1.2162
0.50 "	0.4454	0.4412	0.5645	0.7626	1.0118	1.2151
0.25 "	0.3950	0.3843	0.5786	0.7993	1.0094	1.2149
0.00	0.3648	0.3707	0.6645	0.7644	1.0093	1.2133
0.25 D.S.	0.3520	0.3845	0.6123	0.7813	1.0093	----

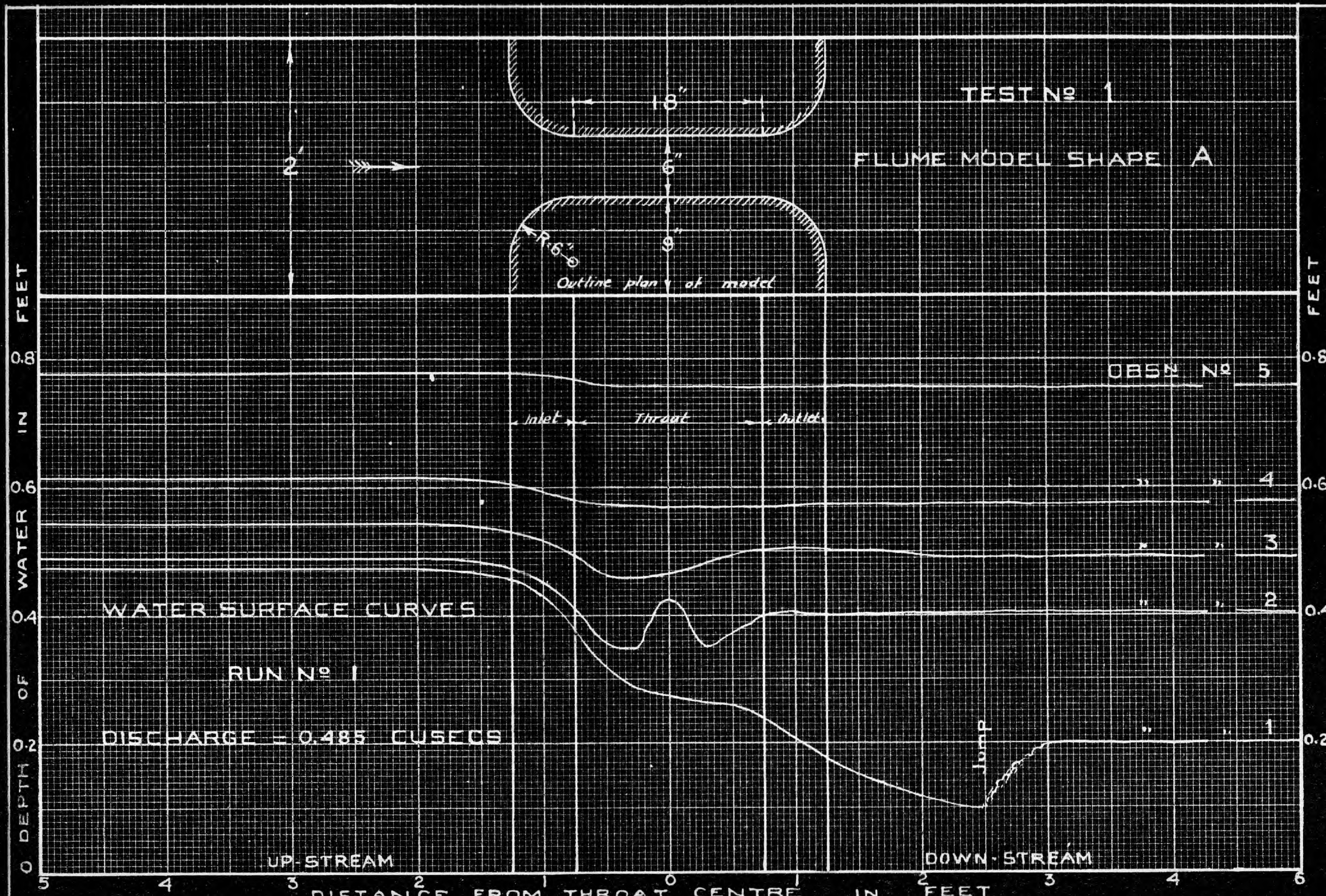
Distance from centre of throat in feet.	Depth of water in feet = Point gauge readings Observation No. 1	2	3	4	5	6
0.50 D.S.	0.3462	0.3672	0.5729	0.7771	1.0093	1.2145
0.75 "	0.3150	0.3500	0.5856	0.7619	----	----
1.00 "	0.2616	Jump	wave	----	1.0222	----
	1.25' Jump					
6.00 "	0.3245	0.4195	0.6262	0.7862	1.0197	1.2144
	Run No. (3). Mean discharge = 1.439 cusecs.					
5.00 U.S.	0.9828	1.0095	1.0457	1.1163	1.1834	1.3226
2.00 "	0.9797	1.0069	1.0430	1.1162	1.1823	----
1.00 "	0.9282	0.9565	0.9964	1.0710	1.1399	1.2867
0.75 "	0.8561	0.8852	0.9330	1.0115	1.0829	1.2412
0.50 "	0.7471	0.7828	0.8374	0.9306	1.0159	1.1905
0.25 "	0.6489	0.6997	0.7695	0.8875	0.9977	wave
0.00	0.5870	0.6600	0.7658	0.9339	wave	1.2660
0.25 D.S.	0.5639	0.6747	0.8673	wave	1.1171	1.2167
0.50 "	0.5711	0.6880	0.8400	1.0257	1.0577	1.2175
0.75 "	0.4898	wave	wave	0.9715	1.0431	1.2371
1.00 "	0.4168	----	0.9625	wave	wave	1.2560
	1.5' Jump					
6.00 "	0.5344	0.8282	0.9468	1.0172	1.0888	1.2586
	Run No. (4). Mean discharge = 1.808 cusecs.					
5.00 U.S.	1.1372	1.1414	1.1686	1.1923	1.2426	
2.00 "	1.1320	1.1389	1.1654	1.1923	1.2409	
1.00 "	1.0767	1.0852	1.1127	1.1400	1.1898	
0.75 "	1.0014	1.0074	1.0399	1.0667	1.1272	
0.50 "	0.8875	0.8963	0.9322	0.9570	1.0212	
0.25 "	0.7753	0.7862	0.8240	0.8669	0.9491	
0.00	0.6988	0.7130	0.7712	0.8277	0.9316	
0.25 D.S.	0.6592	0.6777	0.7592	0.8388	0.9812	
0.50 "	0.6324	0.6578	0.7580	0.8700	1.0149	
0.75 "	0.5820	0.6273	wave	wave	1.0467	

Test No.1. Continued.

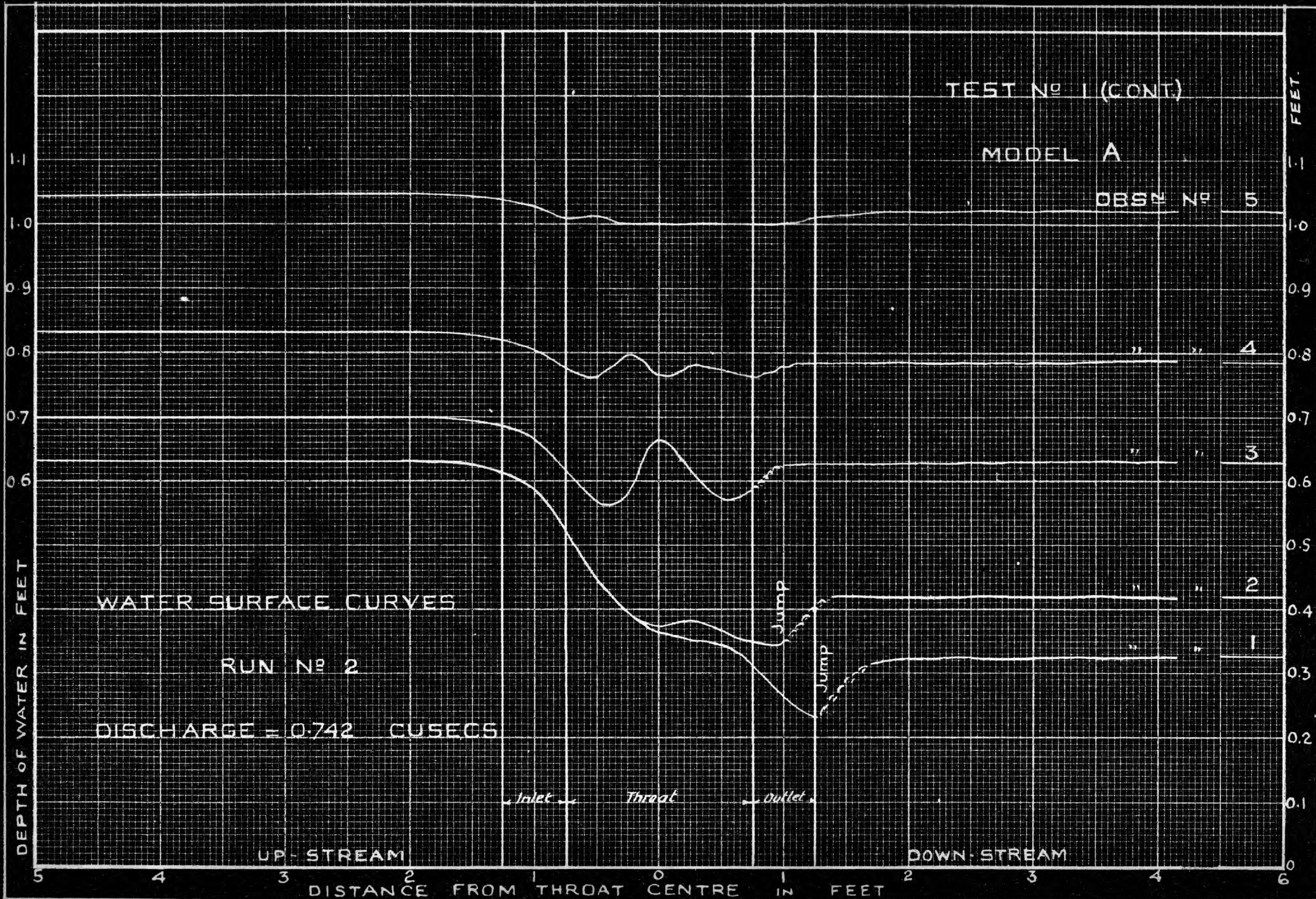
Distance from centre of throat in feet.	Depth of water in feet = Point gauge readings Observation No. 1	2	3	4	5	6
1.00 D.S.	0.5136	wave	----	----	-----	
2.0	0.1450J.					
6.00 D.S.	0.6890	0.7800	0.9300	1.0186	1.1260	

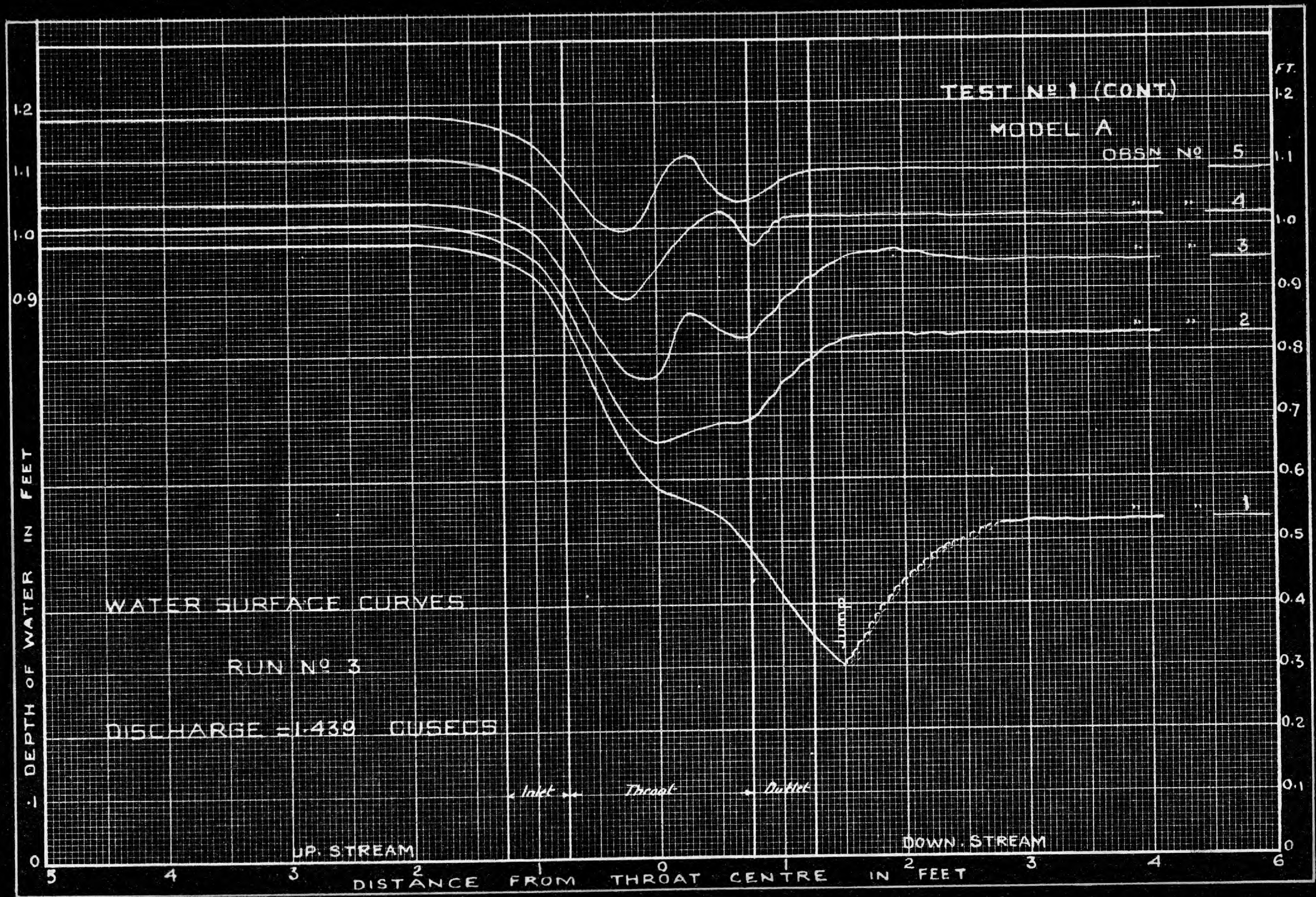
Discharge Observations.

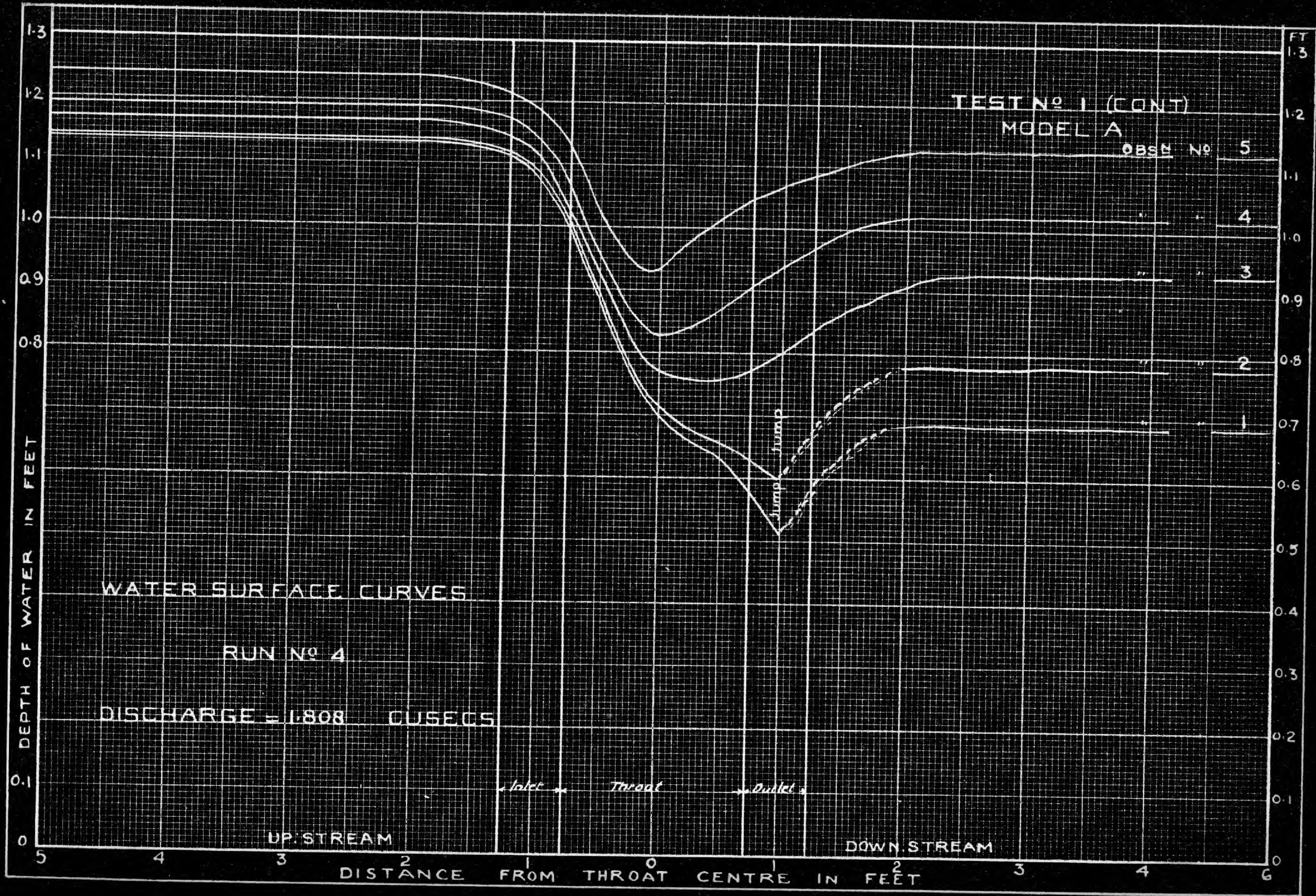
Obsn. No.	R = Rise in Tank in feet.	M = Time in Mins.	Dis-charge in cusecs.= $\frac{R \times 155}{M \times 60}$	Obsn. No.	R = Rise in Tank in feet.	M = Time in Mins.	Dis-charge in cusecs.= $\frac{R \times 155}{M \times 60}$
	Run No. (1)				Run No. (2)		
1	1.120	6	0.482	1	2.86	10	0.738
2	1.130	6	0.486	2	2.85	10	0.736
3	1.870	10	0.483	3	2.89	10	0.747
4	1.880	10	0.486	4	2.90	10	0.748
		Mean =	0.485 cusecs.			Mean =	0.742 cusecs.
	Run No. (3)				Run No. (4)		
1	3.900	7	1.440	1	4.200	6	1.808
2	3.885	7	1.432	2	4.185	6	1.805
3	3.910	7	1.494	3	4.205	6	1.810
4	3.900	7	1.440	4	4.205	6	1.810
		Mean =	1.439 cusecs.			Mean =	1.808 cusecs.


TEST Nº 1
FLUME MODEL SHAPE A
18"
2'
6"
9"
R 6"
Outline plan of model
Inlet
Throat
Outlet
OBSN Nº 5
4
3
2
1
Jump
WATER SURFACE CURVES
RUN Nº 1
DISCHARGE = 0.485 CUSECS
DEPTH OF WATER IN FEET
0
0.2
0.4
0.6
0.8
UP-STREAM
DOWN-STREAM
5
4
3
2
1
0
1
2
3
4
6
DISTANCE FROM THROAT CENTRE IN FEET

22


TEST Nº 1 (CONT.)
MODEL A
OBSN Nº 5
" " 4
" " 3
" " 2
" " 1
WATER SURFACE CURVES
RUN Nº 2
DISCHARGE = 0·742 CUSECS
Jump
Jump
Inlet
Throat
Outlet
UP-STREAM
DOWN-STREAM
DEPTH OF WATER IN FEET
FEET
DISTANCE FROM THROAT CENTRE IN FEET


TEST Nº 1 (CONT.)
MODEL A
OBSNº Nº 5
" " 4
" " 3
" " 2
" " 1
WATER SURFACE CURVES
RUN Nº 3
DISCHARGE = 1·439 CUSECS
Jump
Inlet
Throat
Outlet
UP STREAM
DOWN STREAM
DEPTH OF WATER IN FEET
FT.
DISTANCE FROM THROAT CENTRE IN FEET
0
·1
0·9
1·0
1·1
1·2
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
5
4
3
2
1
0
1
2
3
4
6


TEST Nº 1 (CONT)
MODEL A
OBSNº Nº
5
4
3
2
1
Jump
Jump
WATER SURFACE CURVES
RUN Nº 4
DISCHARGE = 1·808 CUSECS
Inlet
Throat
Outlet
UP STREAM
DOWN STREAM
DEPTH OF WATER IN FEET
DISTANCE FROM THROAT CENTRE IN FEET
FT
1·3
1·2
1·1
1·0
0·9
0·8
0·7
0·6
0·5
0·4
0·3
0·2
0·1
0
5
4
3
2
1
0
1
2
3
4
6

TEST No. 2.

on

Model shape B.

Throat width 6 inches.   Throat length 18 inches.

Distance from centre of throat in feet.	Depth of water in feet = Point gauge readings					
	Observation No.					
	1	2	3	4	5	6
	Run No. (1)	Mean discharge = 0.470 cusecs.				
5.00 U.S.	0.4747	0.4758	0.5280	0.6429	0.8302	0.9480
2.00 "	0.4691	0.4729	0.5231	0.6374	0.8302	0.9480
1.00 "	0.4359	0.4362	0.4957	0.6243	0.8160	0.9400
0.75 "	0.3879	0.3889	0.4623	0.6047	0.8080	0.9342
0.50 "	0.3222	0.3273	0.4270	0.6100	0.8042	0.9338
0.25 "	0.2801	0.2864	wave	0.5928	0.8023	0.9304
0.00	0.2778	0.3049	0.4524	0.6100	0.8023	0.9304
0.25 D.S.	0.2860	0.3119	0.4375	0.6006	0.8023	0.9304
0.50 "	0.2526	0.3159	0.4676	0.6090	0.8023	0.9304
0.75 "	0.2261	0.3580	0.4701	0.6041	0.8023	0.9304
1.00 "	0.1919	0.3742	0.4500	0.6092	0.8068	0.9304
2.00 "	Jump	-----	0.4705	0.6119	0.8098	0.9345
6.00 "	0.2891	0.3725	0.4608	0.6100	0.8076	0.9317
	Run No.(2)	Mean discharge = 0.734 cusecs.				
5.00 U.S.	0.6386	0.6391	0.7201	0.8891	0.9984	1.0720
2.00 "	0.6365	0.6364	0.7201	0.8914	0.9971	1.0720
1.00 "	0.5946	0.5939	0.6962	0.8706	0.9795	1.0560
0.75 "	0.5378	0.5378	0.6438	0.8421	0.9616	1.0390
0.50 "	0.4555	0.4556	0.5955	0.8351	0.9736	1.0454
				wave		
0.25 "	0.3867	0.3951	0.6060	0.8455	0.9533	1.0372
0.00	0.3835	0.3772	wave	0.8401	0.9657	1.0336
0.25 D.S.	0.3640	0.3720	0.6240	0.8484	0.9547	1.0356
0.50 "	0.3350	0.3580	0.6047	0.8355	0.9598	1.0401

Test No. 2.Continued.

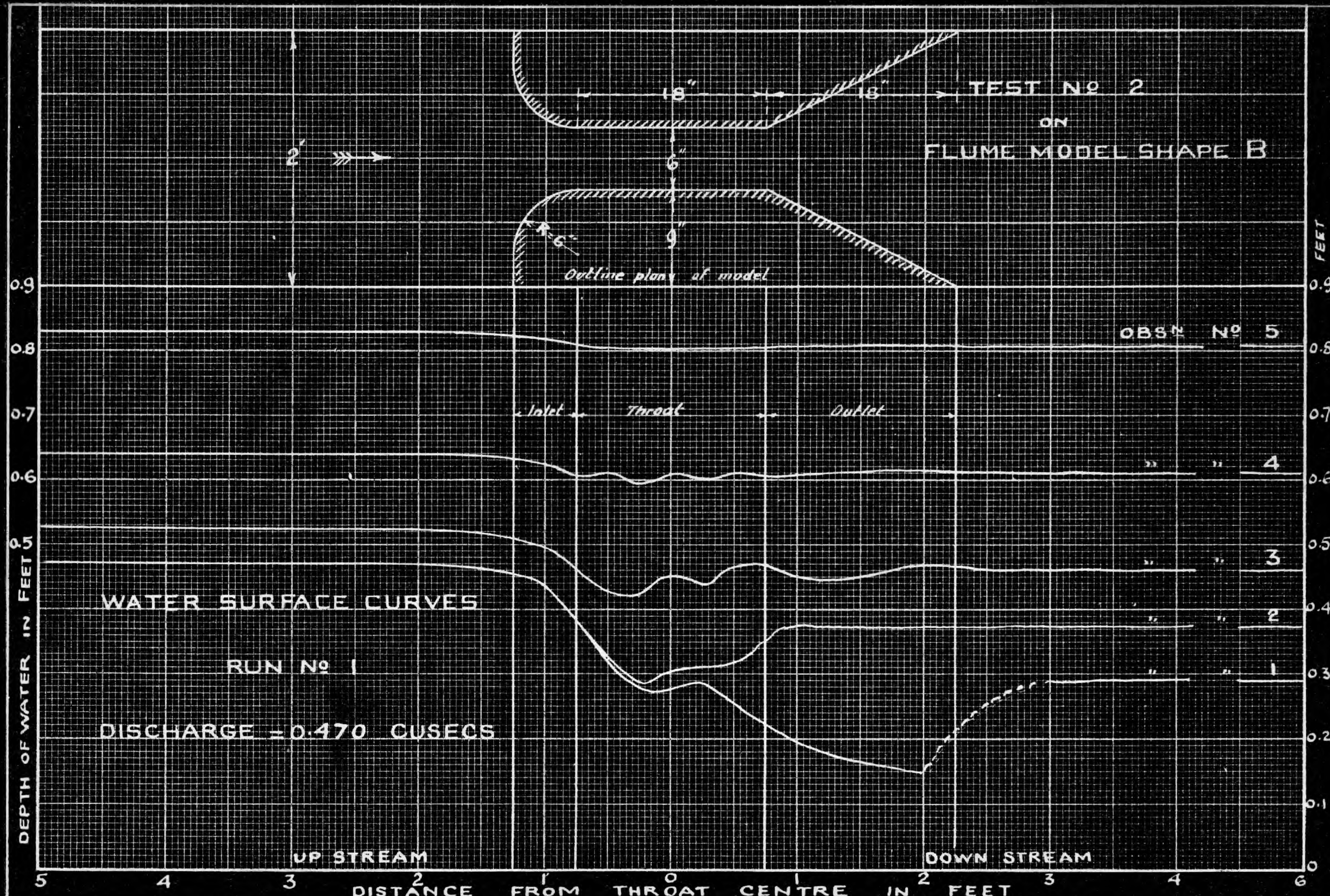
Distance from centre of throat in feet.	Depth of water in feet = Point gauge readings					
	Observation No.					
	1	2	3	4	5	6
	Run No. (2). Continued.					
0.75 D.S.	0.3002	0.3635	0.6196	0.8462	0.9576	1.0402
1.00 "	0.2450	Jump	wave	0.8398	0.9606	1.0395
2.00 "	0.0932J	----	----	0.8458	0.9635	1.0413
6.00 "	0.3251	0.3986	0.6401	0.8475	0.9655	1.0406
	Run No.(3) Mean discharge = 0.974 cusecs.					
5.00 U.S.	0.7741	0.7806	0.8390	0.8995	0.9755	1.0489
2.00 "	0.7741	0.7747	0.8351	0.9005	0.9740	1.0466
1.00 "	0.7248	0.7302	0.7961	0.8672	0.9396	1.0144
0.75 "	0.6580	0.6669	0.7430	0.8152	0.9045	0.9922
0.50 "	0.5702	0.5819	0.6688	0.7629	0.8662	0.9608
0.25 "	0.4927	0.5134	0.6415	0.7668	wave	wave
0.00	0.4621	0.4908	0.7062	wave	0.9146	0.9645
0.25 D.S.	0.4490	0.4945	wave	0.8026	0.8787	0.9700
0.50 "	0.4290	0.5160	0.7589	0.7672	0.8862	0.9879
0.75 "	0.4000	0.5215	0.6943	0.7856	0.9191	0.9757
1.00 "	Jump	wave	0.7100	0.8300	0.8954	0.9800
2.00 "	----	0.5800	0.7320	0.8100	0.9108	0.9835
6.00 "	0.4425	0.6077	0.7305	0.8130	0.9083	0.9900
	Run No.(4) Mean discharge = 1.307 cusecs.					
5.00 U.S.	0.9459	0.9520	0.9626	0.9832	1.0425	1.0906
2.00 "	0.9391	0.9500	0.9616	0.9816	1.0415	1.0906
1.00 "	0.8903	0.8984	0.9127	0.9351	0.9946	1.0505
0.75 "	0.8212	0.8318	0.8467	0.8717	0.9344	0.9943
0.50 "	0.7154	0.7286	0.7521	0.7769	0.8585	0.9191
0.25 "	0.6205	0.6418	0.6653	0.7049	0.8051	0.8954
0.00	0.5731	0.5979	0.6313	0.6884	0.8336	wave
0.25 D.S.	0.5574	0.5750	0.6385	0.7090	wave	1.0456
0.50 "	0.5229	0.5740	0.6547	0.7556	0.9700	0.9802

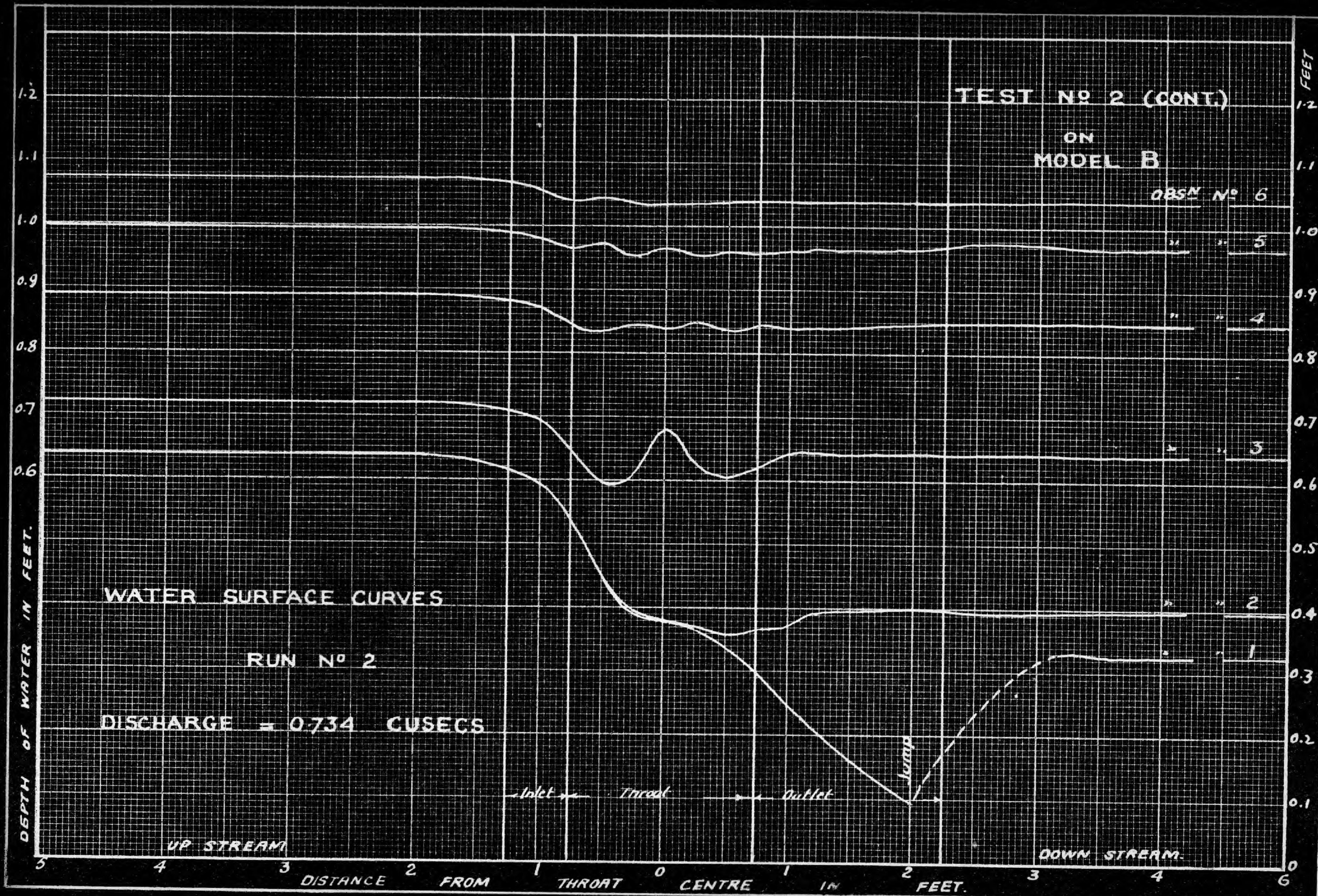
Test No.2 Continued.

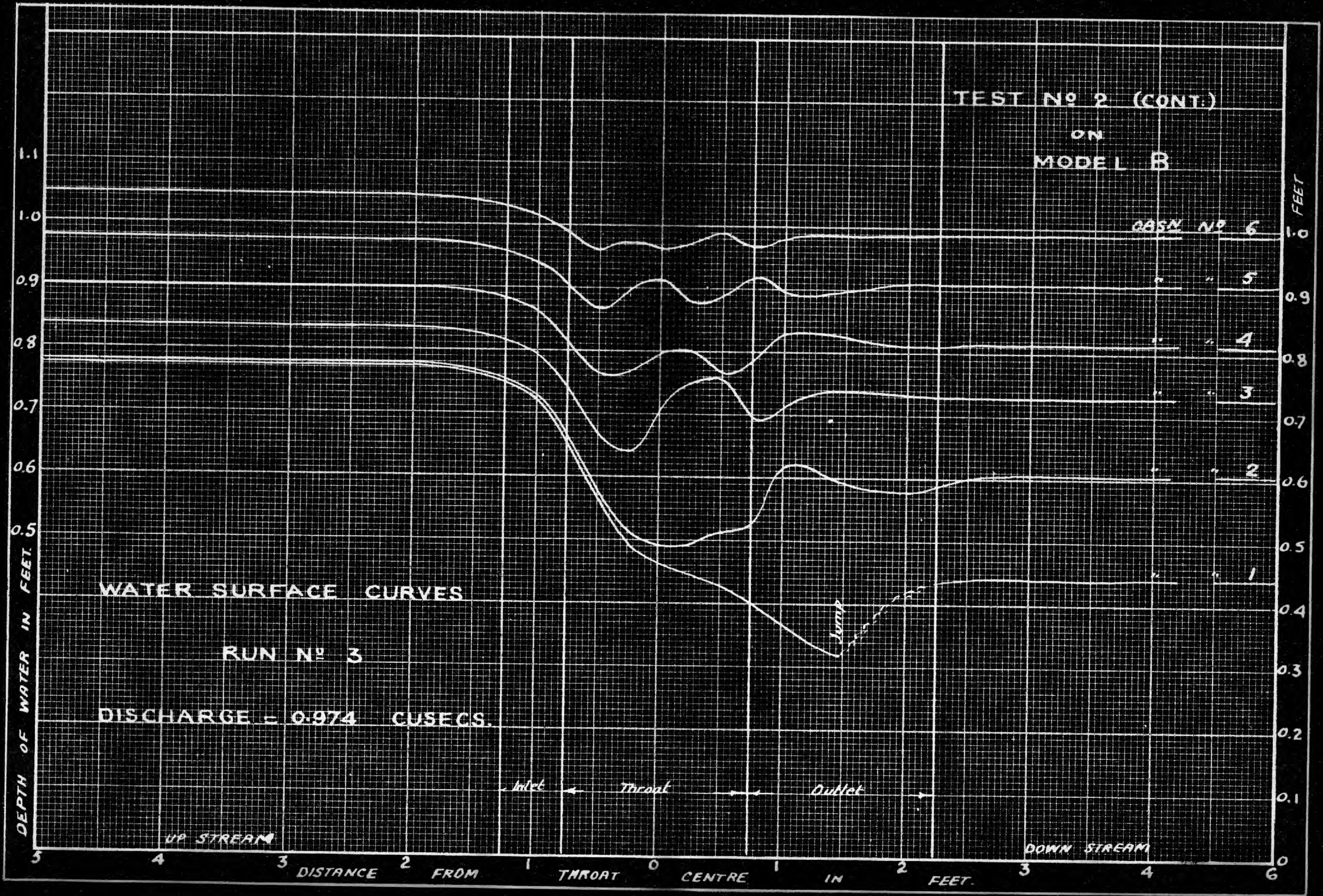
Distance from centre of throat in feet.	Depth of water in feet = Point gauge readings — Observation No. 1	2	3	4	5	6
	Run No. (4) Continued.					
0.75 D.S.	0.4789	0.5837	wave	0.7790	0.9028	0.9388
1.00 "	0.4053	wave	-----	0.8539	0.8862	0.9720
X	1.5 Jump					
2.00 "	-----	0.6800	-----	-----	0.9300	0.9885
6.00 "	0.5200	0.6722	0.7653	0.8430	0.9339	0.9816

Discharge Observations.

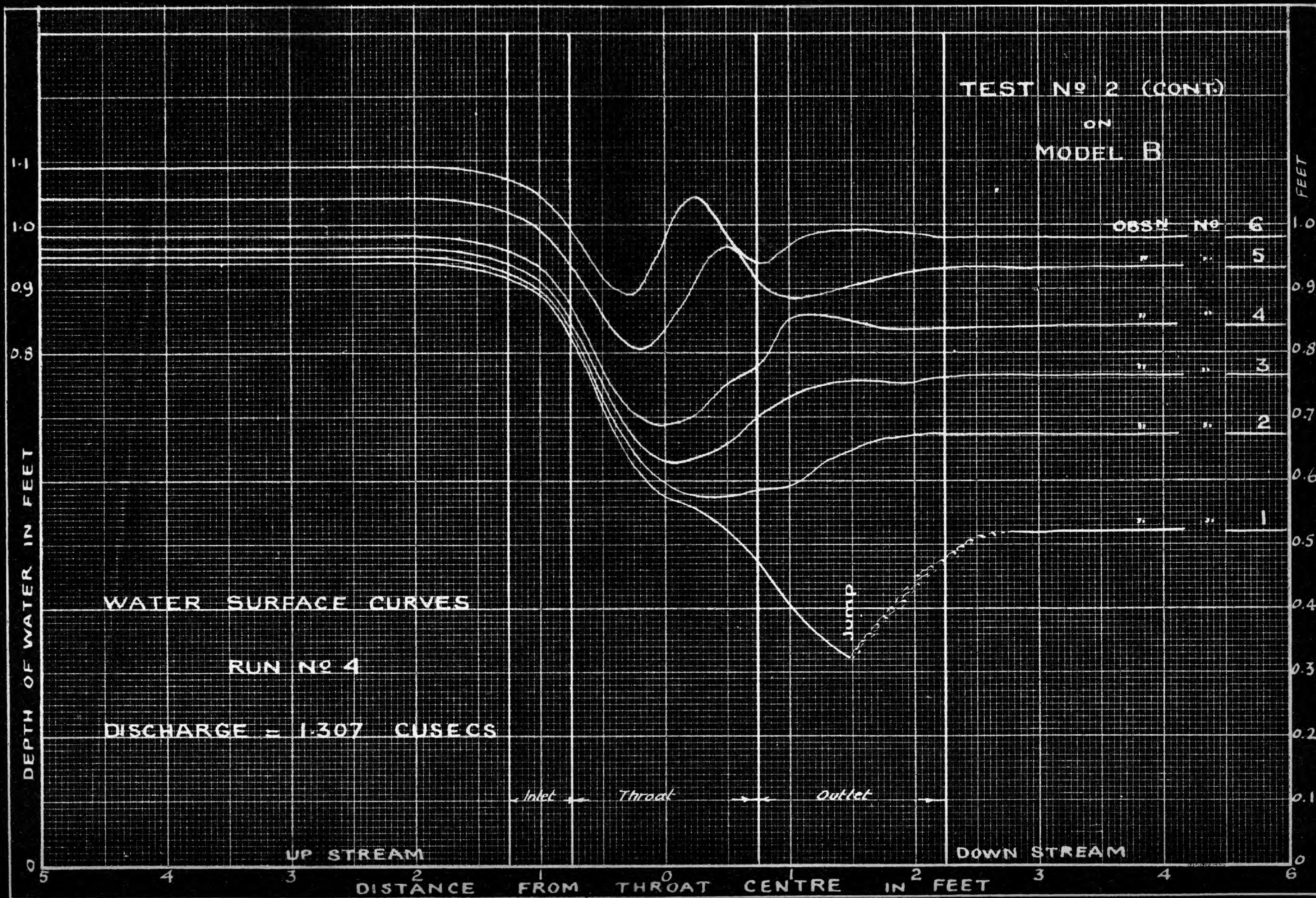
Obsn. No.	R = Rise in Tank in feet.	M = Time in Mins.	Discharge in cusecs. = $\frac{R \times 155}{M \times 60}$	Obsn. No.	R = Rise in Tank in feet.	M = Time in Mins.	Discharge in cusecs. = $\frac{R \times 155}{M \times 60}$
	Run No. (1)				Run No. (2)		
1	2.925	16	0.472	1	2.260	8	0.730
2	3.260	18	0.468	2	1.150	4	0.743
		Mean =	0.470 cusecs.	3	1.690	6	0.727
				4	1.138	4	0.735
						Mean =	0.734 cusecs.
	Run No. (3)				Run No. (4)		
1	2.239	6	0.963	1	1.515	3	1.304
2	1.512	4	0.975	2	2.510	5	1.296
3	1.520	4	0.982	3	3.520	7	1.298
4	1.512	4	0.975	4	3.085	6	1.328
		Mean =	0.974 cusecs.			Mean =	1.307 cusecs.


TEST Nº 2
ON
FLUME MODEL SHAPE B
18"
18"
6"
9"
2'
R=6"
Outline plan of model
Inlet
Throat
Outlet
OBSN Nº 5
" " 4
" " 3
" " 2
" " 1
WATER SURFACE CURVES
RUN Nº 1
DISCHARGE = 0.470 CUSECS
DEPTH OF WATER IN FEET
FEET
UP STREAM
DOWN STREAM
DISTANCE FROM THROAT CENTRE IN FEET
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
5
4
3
2
1
0
1
2
3
4
6


TEST Nº 2 (CONT.)
ON
MODEL B
OBSN Nº 6
" " 5
" " 4
" " 3
" " 2
" " 1
WATER SURFACE CURVES
RUN Nº 2
DISCHARGE = 0.734 CUSECS
Inlet
Throat
Outlet
Jump
UP STREAM
DOWN STREAM.
DEPTH OF WATER IN FEET.
FEET
DISTANCE FROM THROAT CENTRE IN FEET.
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
5
4
3
2
1
0
1
2
3
4
6


TEST Nº 2 (CONT.)
ON
MODEL B
WATER SURFACE CURVES
RUN Nº 3
DISCHARGE = 0·974 CUSECS.
OBSN Nº 6
5
4
3
2
1
Jump
Inlet
Throat
Outlet
UP STREAM
DOWN STREAM
DEPTH OF WATER IN FEET.
FEET
DISTANCE FROM THROAT CENTRE IN FEET.
5
4
3
2
1
0
1
2
3
4
6
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0

31


TEST Nº 2 (CONT.)
ON
MODEL B
OBSN Nº 6
" " 5
" " 4
" " 3
" " 2
" " 1
FEET
DEPTH OF WATER IN FEET
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
WATER SURFACE CURVES
RUN Nº 4
DISCHARGE = 1.307 CUSECS
Jump
Inlet
Throat
Outlet
UP STREAM
DOWN STREAM
5
4
3
2
1
0
1
2
3
4
6
DISTANCE FROM THROAT CENTRE IN FEET

TEST No. 3

on

Model Shape C.

Throat width 6 inches. Throat length 18 inches.

Distance from centre of throat in feet.	Depth of water in feet = Point gauge readings Observation No. 1	2	3	4	5	6
	Run No. (1) Mean discharge:- for observation 1-3 = 0.475 cusecs. for observations 4-6 = 0.567 cusecs.					
5.00 U.S.	0.4667	0.4716	0.5195	0.6143	0.6801	0.7819
2.00 "	0.4667	0.4692	0.5183	0.6162	0.6832	0.7819
1.00 "	0.4322	0.4338	0.4915	0.5896	0.6611	0.7672
0.75 "	0.3836	0.3874	0.4555	0.5512	0.6312	0.7483
0.50 "	0.3181	0.3208	0.4212	0.5224	0.6238	0.7544
					wave	
0.25 "	0.2796	0.2840	wave	wave	0.6310	0.7466
0.00	0.2790	0.2957	0.4480	0.5421	0.6201	0.7466
0.25 D.S.	0.2740	0.3089	0.3249	0.5348	0.6413	0.7466
0.50 "	0.2576	0.3035	0.4489	0.5517	0.6264	0.7466
0.75 "	0.2436	0.3567	0.4636	0.5640	0.6268	0.7466
1.00 "	0.2253	0.3830	0.4400	0.5232	0.6320	0.7466
2.00 "	1.5 J.	0.3867	0.4681	0.5667	0.6400	0.7592
6.00 "	0.2220	0.3842	0.4618	0.5703	0.6472	0.7587
	Run No. (2) Mean discharge = 0.719 cusecs.					
5.00 U.S.	0.6338	0.6337	0.6789	0.7872	0.8522	0.9388
2.00 "	0.6296	0.6314	0.6795	0.7864	0.8522	0.9400
1.00 "	0.5873	0.5912	0.6443	0.7514	0.8302	0.9278
0.75 "	0.5267	0.5342	0.5935	0.7157	0.8012	0.9000
					7"	0.8949
0.50 "	0.4451	0.4513	0.5361	0.6940	0.7960	wave
					wave	
0.25 "	0.3894	0.3954	0.5415	wave	0.8105	0.8915
0.00	0.3697	0.3849	wave	0.7109	0.7906	0.9077

Test No. 3 Continued.

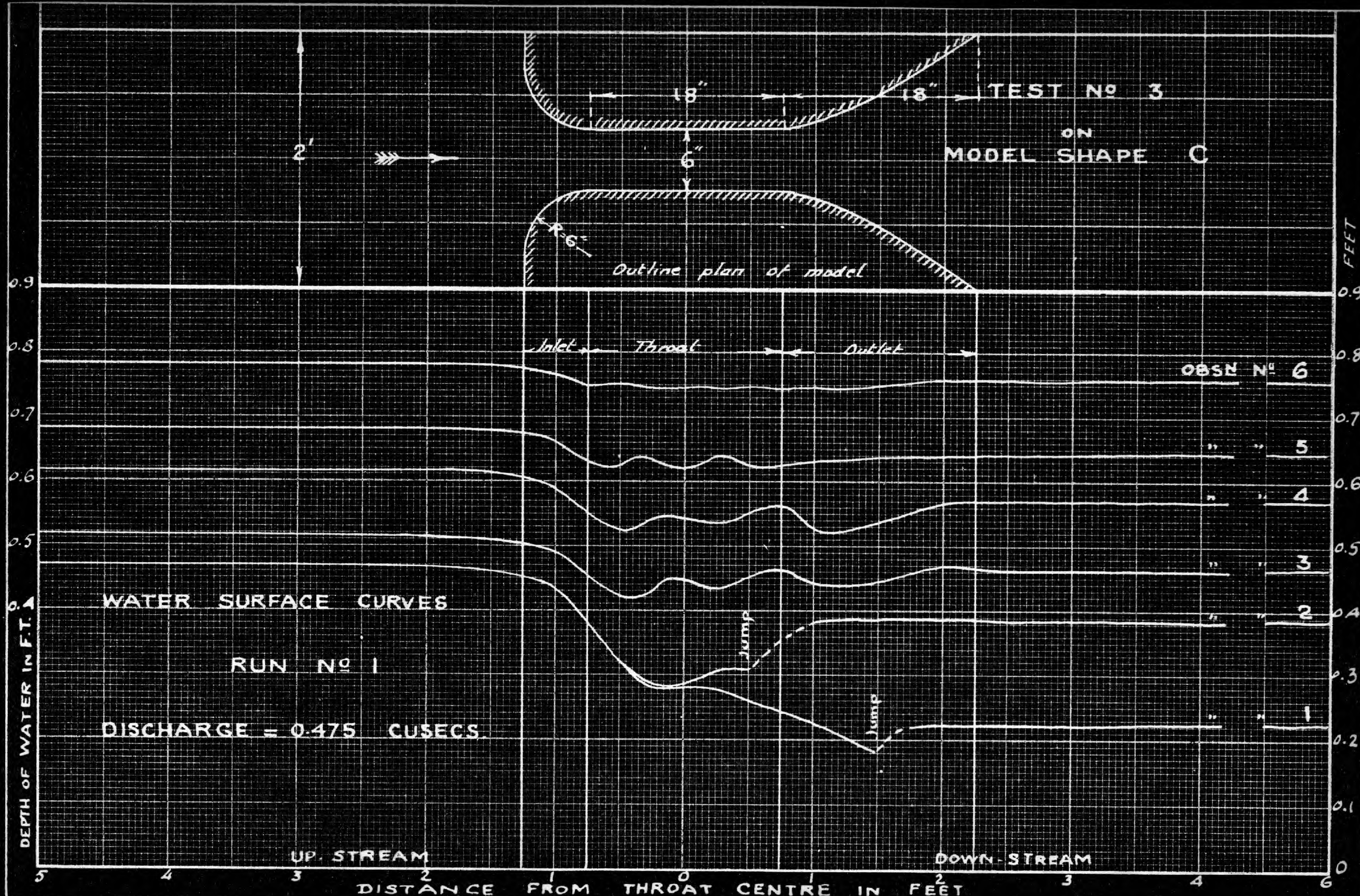
Distance from centre of throat in feet.	Depth of water in feet = Point gauge readings. Observation No. 1	2	3	4	5	6
	Run No.(2) continued.					
0.25 D.S.	0.3655	0.3955	0.6141	0.7110	0.8126	0.8921
0.50 "	0.3460	0.3985	0.5505	0.7344	0.7964	0.9000
0.75 "	0.3130	0.4186	0.5359	0.7660	0.7963	0.9000
1.00 "	0.2759	0.4675	0.5459	0.7079	0.8060	0.9000
2.00 "	0.1128	J.0.5096	0.6024	0.7436	0.8099	0.9116
6.00 "	0.3191	0.5150	0.6000	0.7381	0.8198	0.9100
	Run No.(3) Mean discharge = 1.095 cusecs.					
5.00 U.S.	0.8238	0.8266	0.8767	0.9457	0.9966	
2.00 "	0.8219	0.8245	0.8745	0.9430	0.9957	
1.00 "	0.7741	0.7745	0.8283	0.8998	0.9597	
0.75 "	0.7091	0. 7215	0.6725	0.8433	0.9067	
0.50 "	0.6105	0.6195	0.6729	0.7691	0.8453	
0.25 "	0.5259	0.5408	0.6100	0.7413	0.8383	
0.00	0.4915	0.5163	0.6023	wave	wave	
0.25 D.S.	0.4725	0.5109	0.6209	0.8500	0.9291	
0.50 "	0.4550	0.5300	0.6500	0.7957	0.8680	
0.75 "	0.4283	0.5200	wave	wave	0.8570	
1.00 "	0.3800	Jump	0.7691	-----	-----	
2.00 "	Jump	-----	0.7700	0.8366	0.9204	
6.00 "	0.5142	0.6722	0.7706	0.8583	0.9177	
	Run No.(4) Mean discharge = 1.310 cusecs.					
5.00 U.S.	0.9477	0.9533	0.9597	0.9903	1.0526	1.0983
2.00 "	0.9442	0.9475	0.9567	0.9892	1.0523	1.0978
1.00 "	0.8970	0.9010	0.9089	0.9411	1.0111	1.0535
0.75 "	0.8238	0.8280	0.8499	0.8802	0.9529	0.9987
0.50 "	0.7159	0.7252	0.7366	0.7855	0.8692	0.9285
0.25 "	0.6255	0.6378	0.6527	0.7044	0.8265	0.8962
0.00	0.5735	0.5892	0.6104	0.6992	0.8600	wave
0.25 D.S.	0.5535	0.5747	0.6038	0.7220	wave	1.0444

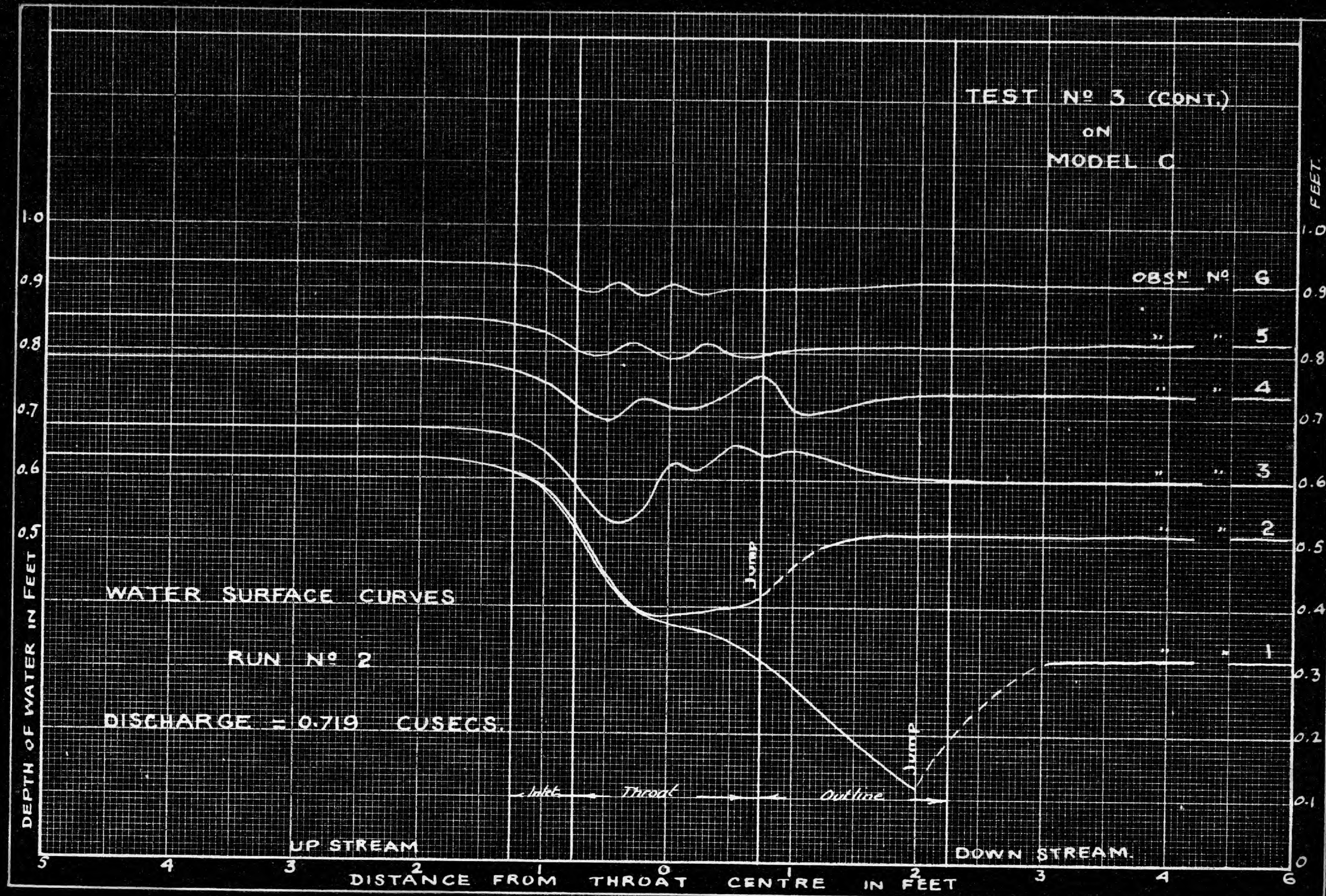
Test No. 3 Continued.

Distance from centre of throat in feet.	Depth of water in feet = Point gauge readings, Observation No. 1	2	3	4	5	6
	Run No. (4) Continued.					
0.50 D.S.	0.5268	0.5580	0.5980	0.7610	0.9729	0.9856
0.75 "	0.4768	0.5391	0.6118	0.8162	0.9162	0.9433
1.00 "	0.4280	Jump	Jump	0.8610	0.8923	wave
	1.5 Jump				wave	
2.00 "	----	----	----	0.8600	0.9444	1.0010
6.00 "	0.5922	0.6538	0.7509	0.8765	0.9561	1.0057

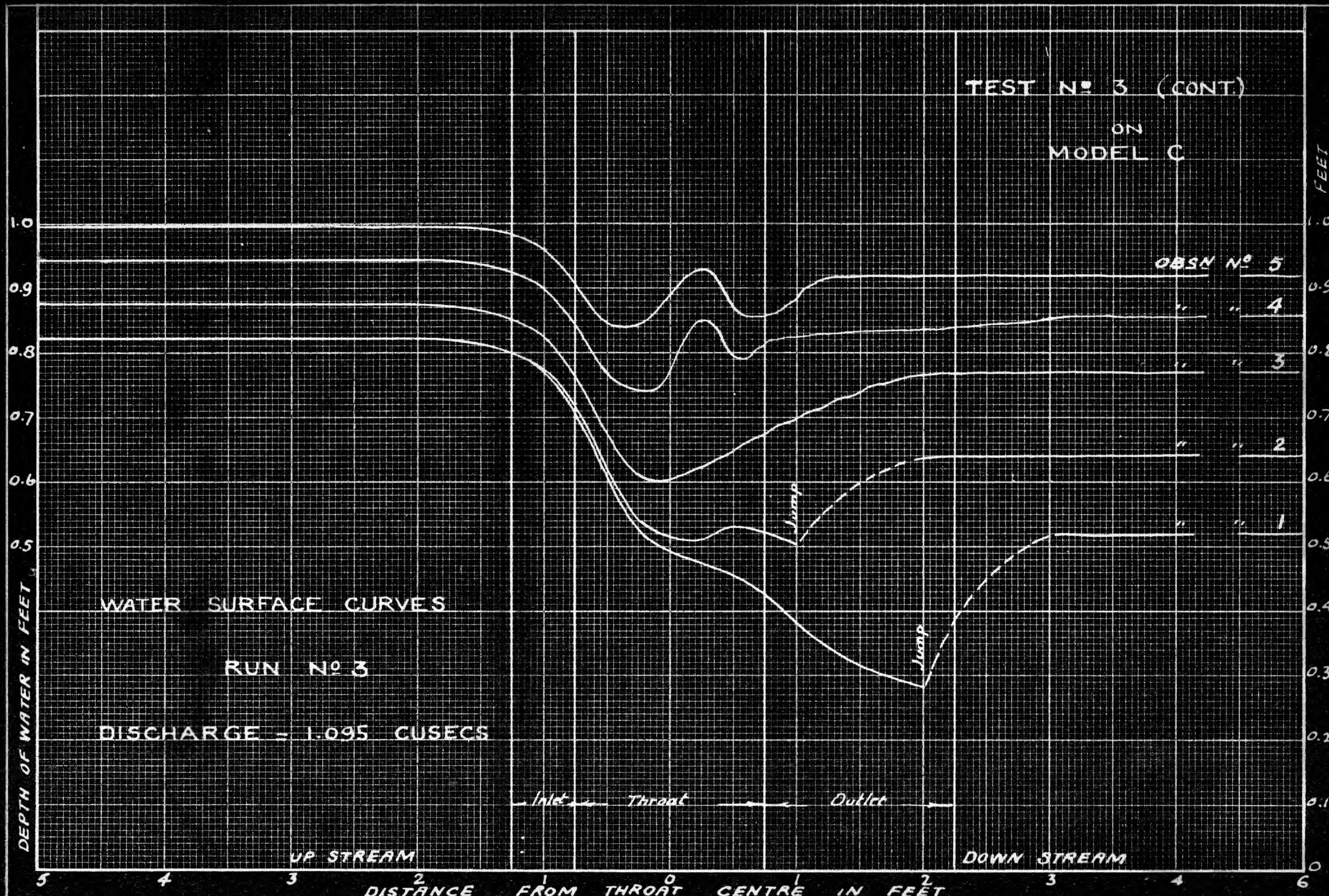
Discharge Observations.

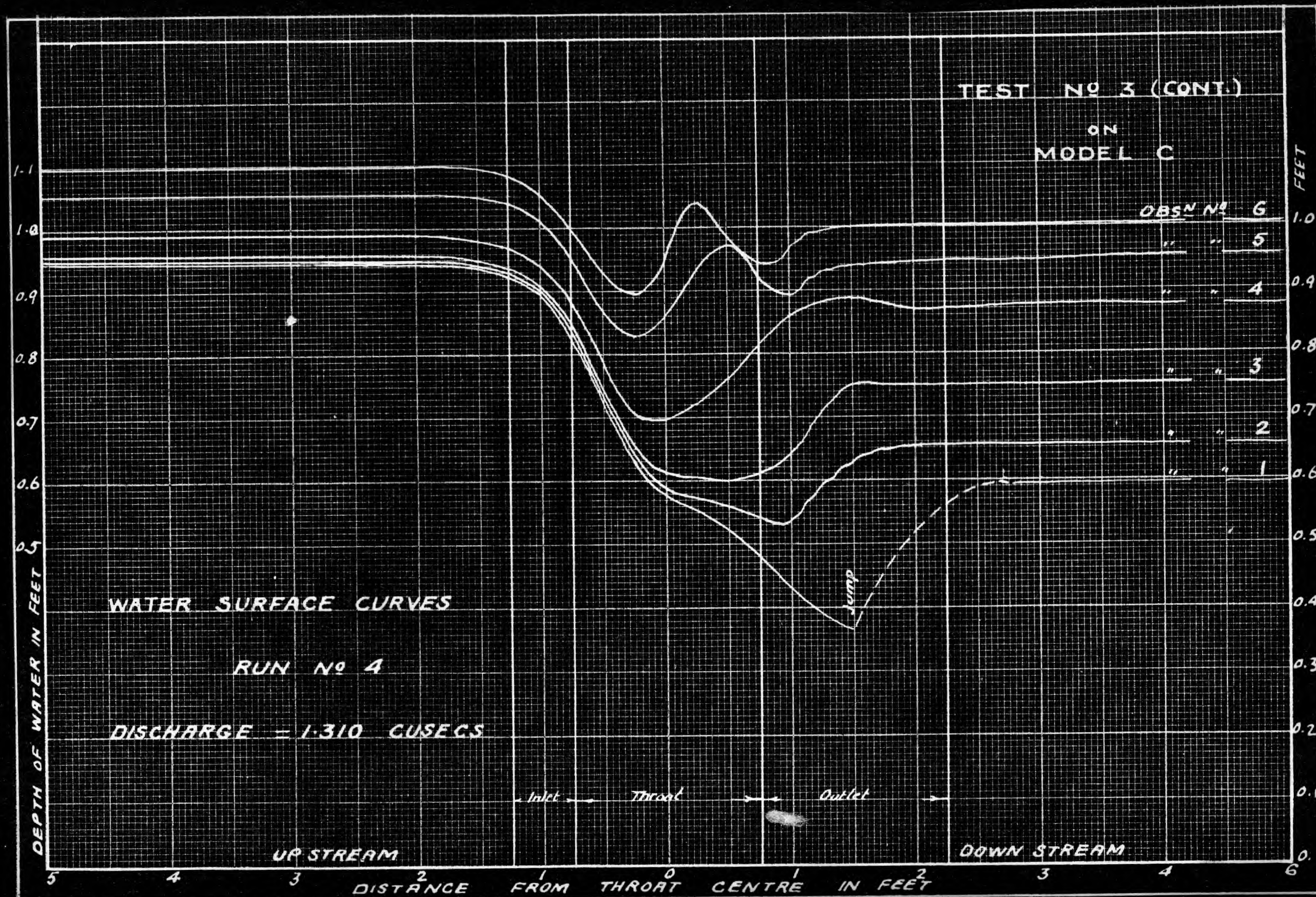
Obsn. No.	R = Rise in Tank in feet.	M = Time in Mins.	Discharge in cusecs. = $\frac{R \times 155}{M \times 60}$	Obsn. No.	R = Rise in Tank in feet.	M = Time in Mins.	Discharge in cusecs. = $\frac{R \times 155}{M \times 60}$
	Run No. (1)				Run No. (2)		
1	2.390	13	0.475	1	1.115	4	0.720
				2	3.505	12.5	0.724
2	1.085	5	0.561	3	3.315	12	0.713
3	2.330	10.5	0.573			Mean =	0.719 cusecs.
	Mean of 2 & 3 =		0.567 cusecs.				
	Run No. (3)				Run No. (4)		
1	3.685	9	1.056	1	4.070	8	1.312
2	3.060	7	1.128	2	4.050	8	1.308
3	1.280	3	1.101	3	4.060	8	1.310
		Mean =	1.095 cusecs.	4	4.055	8	1.310
						Mean =	1.310 cusecs.


TEST No. 3
ON
MODEL SHAPE C
2'
18"
18"
6"
R-6"
Outline plan of model
Inlet
Throat
Outlet
OBSN No. 6
" " 5
" " 4
" " 3
" " 2
" " 1
Jump
Jump
WATER SURFACE CURVES
RUN No. 1
DISCHARGE = 0.475 CUSECS.
DEPTH OF WATER IN F.T.
FEET
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
UP. STREAM
DOWN-STREAM
5
4
3
2
1
0
1
2
3
4
6
DISTANCE FROM THROAT CENTRE IN FEET



TEST Nº 3 (CONT.)
ON
MODEL C
WATER SURFACE CURVES
RUN Nº 2
DISCHARGE = 0.719 CUSECS.
OBSN Nº 6
" " 5
" " 4
" " 3
" " 2
" " 1
Jump
Jump
Inlet
Throat
Outline
UP STREAM
DOWN STREAM.
DEPTH OF WATER IN FEET
FEET.
DISTANCE FROM THROAT CENTRE IN FEET
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
5
4
3
2
1
0
1
2
3
4
6


TEST No 3 (CONT.)
ON
MODEL C
WATER SURFACE CURVES
RUN No 3
DISCHARGE = 1.095 CUSECS
OBSN No 5
" " 4
" " 3
" " 2
" " 1
Jump
Jump
Inlet
Throat
Outlet
UP STREAM
DOWN STREAM
DEPTH OF WATER IN FEET
FEET
DISTANCE FROM THROAT CENTRE IN FEET
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
5
4
3
2
1
0
1
2
3
4
6


TEST Nº 3 (CONT.)
ON
MODEL C
OBSN Nº 6
" " 5
" " 4
" " 3
" " 2
" " 1
Jump
WATER SURFACE CURVES
RUN Nº 4
DISCHARGE = 1·310 CUSECS
Inlet
Throat
Outlet
UP STREAM
DOWN STREAM
DEPTH OF WATER IN FEET
FEET
DISTANCE FROM THROAT CENTRE IN FEET
1·1
1·0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.
5
4
3
2
1
0
1
2
3
4
6

TEST No. 4

on

Model Shape D.

Throat width 6 inches. Throat length 18 inches

Distance from centre of throat in feet.	Depth of water in feet = Point gauge readings Observation No. 1	2	3	4	5	6	7
			Run No.(1) Mean discharge = 0.427 cusecs.				
3.00 U.S.	0.4445	0.4481	0.4855	0.5110	0.5619	0.5943	0.6356
2.00 "	0.4445	0.4450	0.4855	0.5110	0.5619	0.5943	0.6356
1.00 "	0.4187	0.4204	0.4668	0.4964	0.5510	0.5854	0.6284
0.75 "	0.3879	0.3882	0.4398	0.4766	0.5309	0.5702	0.6160
0.50 "	0.3251	0.3275	0.3963	0.4409	0.5067	0.5447	0.6085
			5"0.3822	wave	wave	wave	wave
0.25 "	0.2621	0.2638	wave	0.4779	0.5245	0.5552	0.6003
0.00	0.2484	0.2565	0.4306	0.4513	0.5226	0.5718	0.6038
0.25 D.S.	0.2630	0.2850	0.4036	0.4656	0.5226	0.5559	0.6080
0.50 "	0.2440	0.2865	0.4036	0.4627	0.5162	0.5652	0.6050
0.75 "	0.2088	0.3215	0.4300	0.4479	0.5162	0.5523	0.6050
1.00 "	0.1758	0.3515	0.4078	0.4688	0.5162	0.5602	0.6105
	1.75Jump						
2.00 "	----	0.3458	0.4252	0.4600	0.5182	0.5602	0.6100
6.00 "	0.2269	0.3300	0.4212	0.4486	0.5085	0.5602	0.6100
			Run No.(2) Mean discharge = for observations 1-4 ... 0.724 cusecs. ,, ,, 5-7 ... 0.681 cusecs.				
3.00 U.S.	0.6335	0.6345	0.6424	0.6953	0.7637	0.8305	0.9003
2.00 "	0.6304	0.6316	0.6374	0.6932	0.7628	0.8300	0.8999
1.00 "	0.5978	0.5994	0.6073	0.6679	0.7403	0.9115	0.8847
0.75 "	0.5613	0.5644	0.5718	0.6375	0.7134	0.7862	0.8645
0.50 "	0.4919	0.4908	0.5014	0.5772	0.6659	0.7487	0.8372
				4.5"	0.6542		wave
0.25 "	0.4034	0.4097	0.4239	0.5349	wave	0.7880	0.8501
				1" wave			

Test No. 4 Continued.

Distance from centre of throat in feet.	Depth of water in feet = Point gauge readings — Observation No. 1	2	3	4	5	6	7
			Run No. (2) continued.				
0.00	0.3571	0.3630	0.3932	0.6200	0.7074	0.7643	0.8463
0.25 D.S.	0.3575	0.3667	0.4221	0.6256	0.6784	0.7751	0.8522
0.50 "	0.3682	0.3648	0.4691	0.5788	0.6805	0.7756	0.8947
0.75 "	0.3086	0.3487	0.4762	0.5662	0.6963	0.7607	0.8565
1.00 "	0.3409	Jump	0.5217	wave	0.6848	0.7857	0.8490
2.00 "	0.0899J.	0.4100	0.4975	0.6000	0.6848	0.7765	0.8490
6.00 "	0.3255	0.3976	0.5061	0.5848	0.6987	0.7710	0.8490
		Run No.(3)	Mean discharge = 1.005 cusecs.				
3.00 U.S.	0.7958	0.8120	0.8271	0.8517	0.8765	0.9346	0.9875
2.00 "	0.7902	0.8062	0.8240	0.8502	0.8737	0.9390	0.9875
1.00 "	0.7536	0.7751	0.7911	0.8164	0.8735	0.9065	0.9646
0.75 "	0.7184	0.7363	0.7525	0.7843	0.8086	0.8810	0.9359
0.50 "	0.6363	0.6615	0.6803	0.7133	0.7409	0.8218	0.8836
						4"	0.8565
0.25 "	0.5376	0.5675	0.5923	0.6417	0.6756	0.7752	wave
					1.5"0.6658		
0.00	0.4686	0.5154	0.5456	0.6244	0.6800	wave	0.9285
0.25 D.S.	0.4412	0.5300	0.6062	wave	wave	0.8625	0.9088
0.50 "	0.4237	0.5570	0.6500	0.7841	0.7949	0.8240	0.8841
0.75 "	0.4094	0.5800	0.6775	0.7525	0.7306	0.8151	0.8935
1.00 "	0.3256	wave	wave	0.6869	0.7231	0.8370	0.9111
1.5'(0.1847)J.						wave	
2.00 D.S.	---	0.6123	0.7000	0.7266	0.7661	0.8400	0.9078
6.00 "	0.4579	0.6335	0.7012	0.7218	0.7637	0.8400	0.9051
		Run No. (4)	Mean discharge = 1.418 cusecs.				
3.00 U.S.	1.0029	1.0232	1.0601	1.0858	1.1396	1.1726	1.2474
2.00 "	0.9983	1.0192	1.0546	1.0821	1.1342	1.1707	1.2446
1.00 "	0.9581	0.9797	1.0175	1.0457	1.1014	1.1381	1.2155

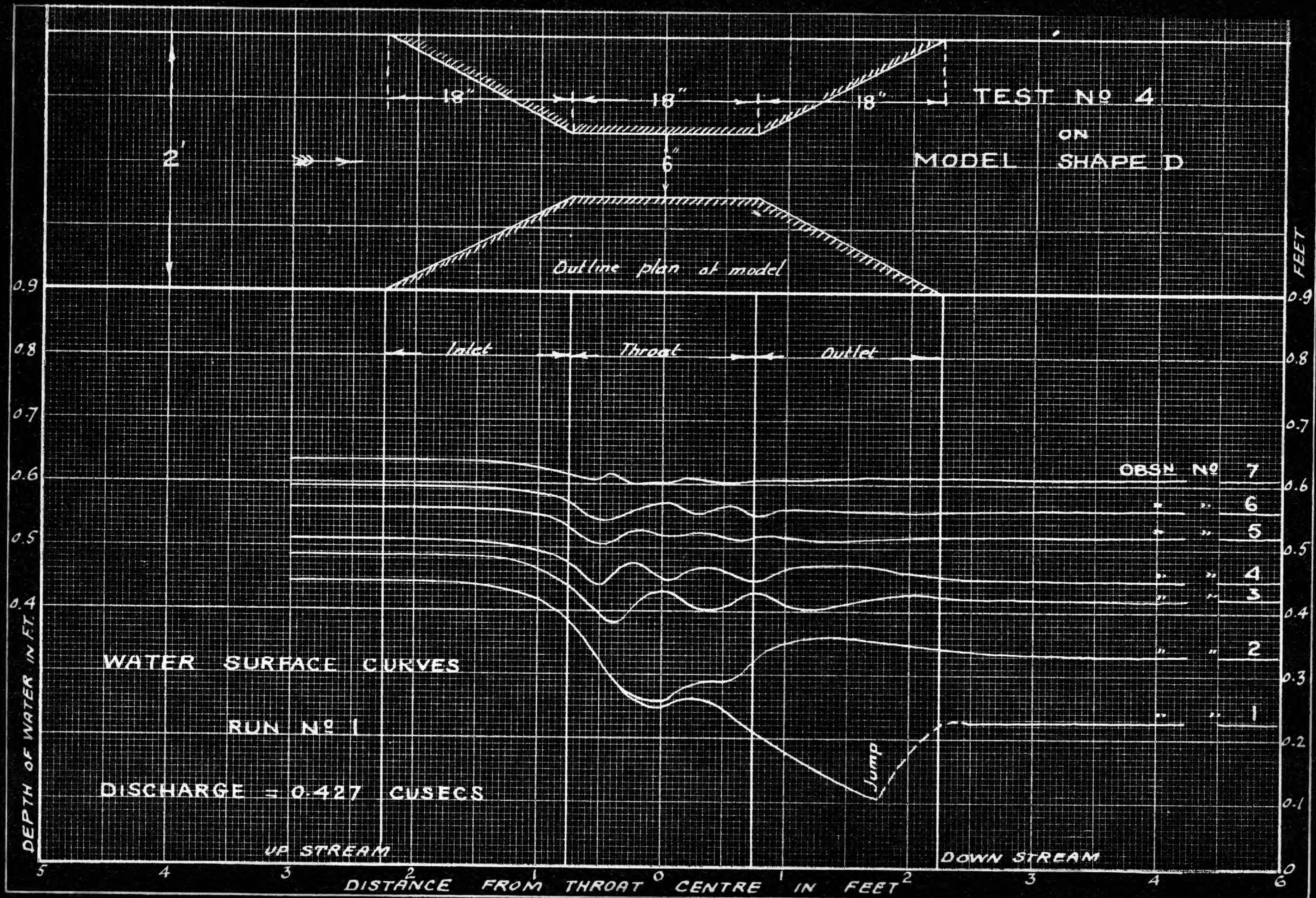
Test No. 4 Continued.

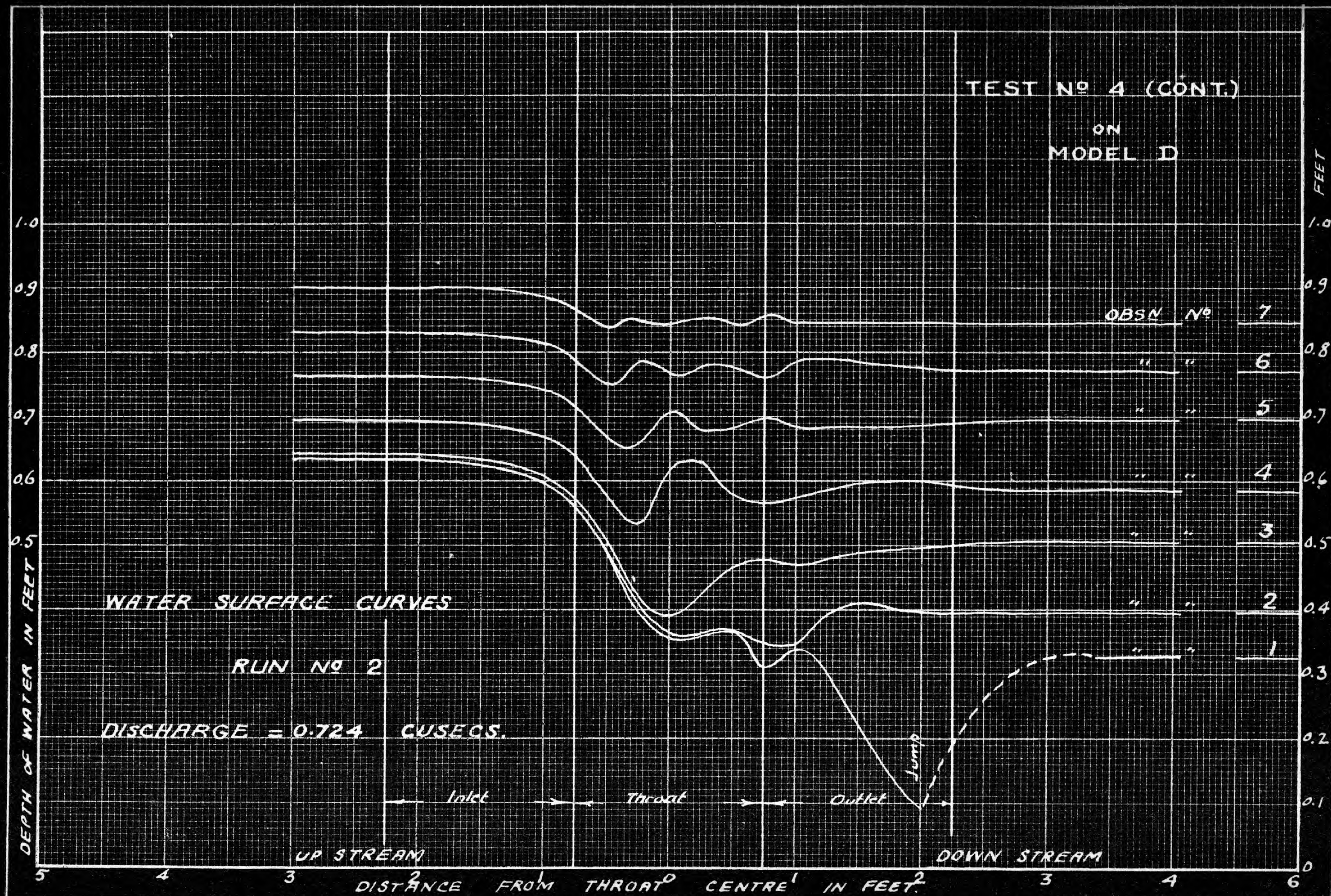
Distance from centre of throat in feet.	Depth of water in feet = Point gauge readings Observation No. 1	2	3	4	5	6	7
			Run No. (4) Continued.				
0.75 U.S.	0.9166	0.9401	0.9815	1.0080	1.0680	1.1060	1.1850
0.50 "	0.8283	0.8581	0.9052	0.9388	0.9974	1.0385	1.1249
0.25 "	0.7161	0.7455	0.8031	0.8407	0.9185	0.9684	1.0714
0.00	0.6224	0.6657	0.7446	0.8139	0.9035	0.9684	wave
		1.5"	0.7421			wave	
0.25 D.S.	0.5724	0.6398	0.7603	0.8378	0.9850	----	1.1818
0.50 "	0.5526	0.6420	0.8007	wave	1.0682	1.0976	1.1500
0.75 "	0.5046	wave	0.8352	0.9288	1.0222	1.0361	1.1207
1.00 "	0.4637	----	wave	wave	0.9772	1.0235	1.1207
1.25' Jump							wave
2.00 "	----	-----	----	----	----	1.0603	1.1400
6.00 "	0.6168	0.7449	0.8963	0.9439	1.0040	1.0588	1.1460

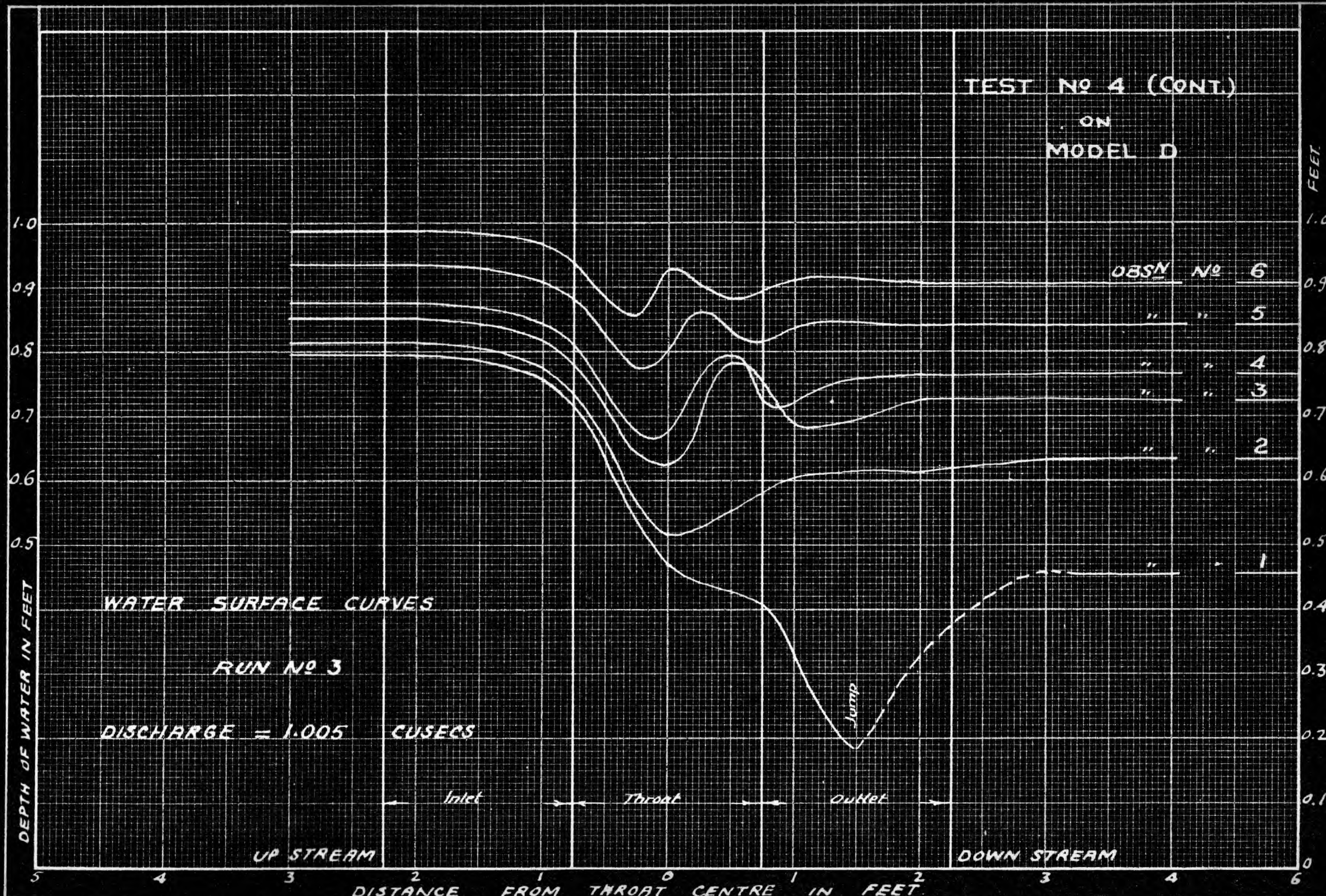
Test No. 4 Continued.

Discharge Observations.

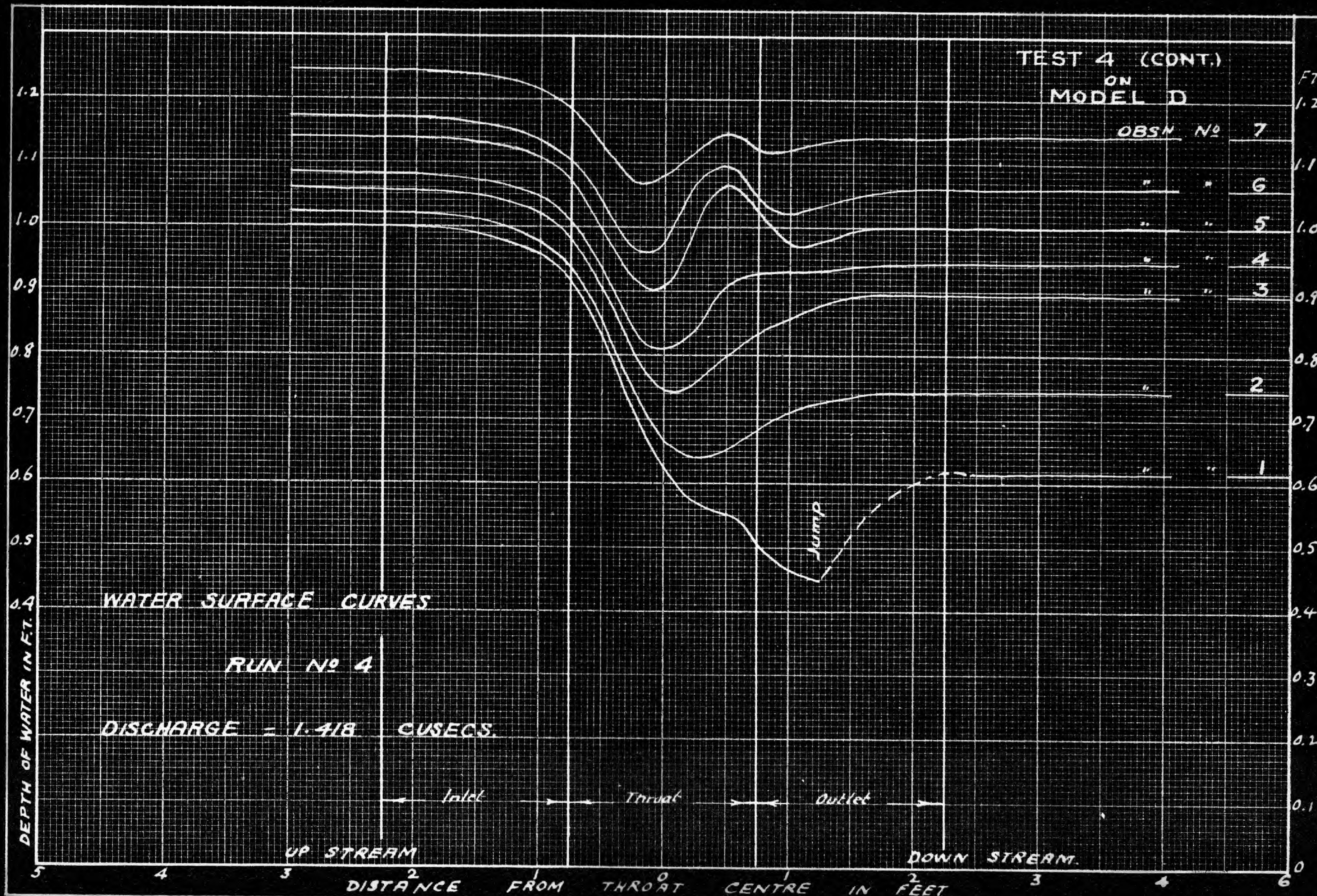
Obsn. No.	R = Rise in Tank in feet.	M = Time in Mins.	Discharge in cusecs. = $\frac{R \times 155}{M \times 60}$	Obsn. No.	R = Rise in Tank in feet.	M = Time in Mins.	Discharge in cusecs. = $\frac{R \times 155}{M \times 60}$
	Run No. (1)				Run No. (2)		
1	1.000	6	0.428	1	1.395	5	0.722
2	0.985	6	0.423	2	2.210	8	0.718
3	1.135	7	0.418	3	1.705	6	0.733
4	0.680	4	0.439			Mean =	0.724 cusecs.
5	0.830	5	0.427	4	1.835	7	0.677
6	0.660	4	0.427	5	1.060	4	0.685
		Mean =	0.427 cusecs.			Mean =	0.681 cusecs.
	Run No. (3)				Run No. (4)		
1	1.940	5	1.001	1	3.305	6	1.421
2	1.935	5	0.999	2	3.860	7	1.421
3	1.950	5	1.007	3	3.280	6	1.410
4	1.945	5	1.005	4	3.285	6	1.415
5	1.570	4	1.012	5	1.655	3	1.421
		Mean =	1.005 cusecs.			Mean =	1.418 cusecs.


TEST Nº 4
ON
MODEL SHAPE D
18"
18"
18"
2'
6"
Outline plan of model
Inlet
Throat
Outlet
OBSN Nº 7
" " 6
" " 5
" " 4
" " 3
" " 2
" " 1
Jump
WATER SURFACE CURVES
RUN Nº 1
DISCHARGE = 0·427 CUSECS
UP STREAM
DOWN STREAM
DEPTH OF WATER IN FT.
FEET
DISTANCE FROM THROAT CENTRE IN FEET
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
5
4
3
2
1
0
1
2
3
4
6


TEST Nº 4 (CONT.)
ON
MODEL D
WATER SURFACE CURVES
RUN Nº 2
DISCHARGE = 0.724 CUSECS.
OBSN Nº 7
" " 6
" " 5
" " 4
" " 3
" " 2
" " 1
Inlet
Throat
Outlet
Jump
UP STREAM
DOWN STREAM
DISTANCE FROM THROAT CENTRE IN FEET.
DEPTH OF WATER IN FEET
FEET
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
5
4
3
2
1
0
1
2
3
4
6



TEST № 4 (CONT.)
ON
MODEL D
WATER SURFACE CURVES
RUN № 3
DISCHARGE = 1.005 CUSECS
OBSN № 6
" " 5
" " 4
" " 3
" " 2
" " 1
Jump
Inlet
Throat
Outlet
UP STREAM
DOWN STREAM
DEPTH OF WATER IN FEET
FEET
DISTANCE FROM THROAT CENTRE IN FEET
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
5
4
3
2
1
0
1
2
3
4
6


TEST 4 (CONT.)
ON
MODEL D
OBSN Nº 7
" " 6
" " 5
" " 4
" " 3
" 2
" " 1
Jump
WATER SURFACE CURVES
RUN Nº 4
DISCHARGE = 1·418 CUSECS.
Inlet
Throat
Outlet
UP STREAM
DOWN STREAM.
DEPTH OF WATER IN FT.
FT.
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
5
4
3
2
1
0
1
2
3
4
6
DISTANCE FROM THROAT CENTRE IN FEET

TEST No. 5

on

Model Shape D.

Throat width 6 inches. Throat length 24 inches.

Distance from centre of throat in feet.	Depth of water in feet = Point gauge readings Observation No. 1	2	3	4	5	6	7
	Run No. (1) Mean discharge = 0.461 cusecs.						
4.00 U.S.	0.4694	0.4830	0.5309	0.5639	0.5914	0.6277	
2.5 "	0.4679	0.4818	0.5287	0.5636	0.5914	0.6277	
1.0 "	0.4064	0.4254	0.4828	0.5207	0.5544	0.5940	
0.75 "	0.3300	0.3554	0.4380	0.4889	0.5332W	0.5821W	
0.50 "	0.2894	0.3362	0.4523W	0.5226W	0.5504	0.5841	
0.25 "	0.2735	0.3667	0.4728	0.4985	0.5383	0.5913	
0.00	0.2761	0.4256	0.4481	0.5133	0.5461	0.5787	
0.25 D.S.	0.2716	0.3810	0.4641	0.5116	0.5404	0.5864	
0.50 "	0.2302	0.3424	0.4641	0.4945	0.5454	0.5800	
0.75 "	0.2648	0.3407	0.4445	0.5151	0.5374	0.5800	
1.00 "	0.2514	0.3630	0.4533	0.5016	0.5488	0.5880	
2.00 "	0.0900J	0.3765	0.4638	0.5122	0.5460	0.5800	
6.00 "	0.2641	0.3824	0.4660	0.4996	0.5446	0.5800	
	Run No.(2) Mean discharge = 0.660 cusecs.						
4.00 U.S.	0.6021	0.6267	0.6423	0.6714	0.7049	0.7533	
2.50 "	0.6020	0.6266	0.6413	0.6714	0.7049	0.7500	
1.00 "	0.5316	0.5618	0.5802	0.6202	0.6574	0.7060	
0.75 "	0.4589	0.4956	0.5219	0.5644	0.6048	0.6632	
0.50 "	0.3790	0.4485	0.4846	0.5630	0.6331W	0.7044W	
0.25 "	0.3570	0.4633	0.5396	0.6204	0.6504	0.6877	
0.00	0.3460	0.5448W	0.5799	0.5936	0.6173	0.6788	
0.25 D.S.	0.3432	0.5424	0.5297	0.5643	0.6152	0.7002	
0.50 "	0.3333	0.4860	0.5027	0.5768	0.6390	0.6835	
0.75 "	0.3086	0.4654	0.5153	0.6056	0.6280	0.6758	
1.00 "	0.2879	0.4654	0.5407	0.5929	0.6110	0.6958	
2.00 "	0.1127J	0.4711	0.5456	0.5746	0.6397	0.6852	
6.00 "	0.3060	0.4932	0.5434	0.5809	0.6323	0.6847	

Test 5. Continued.

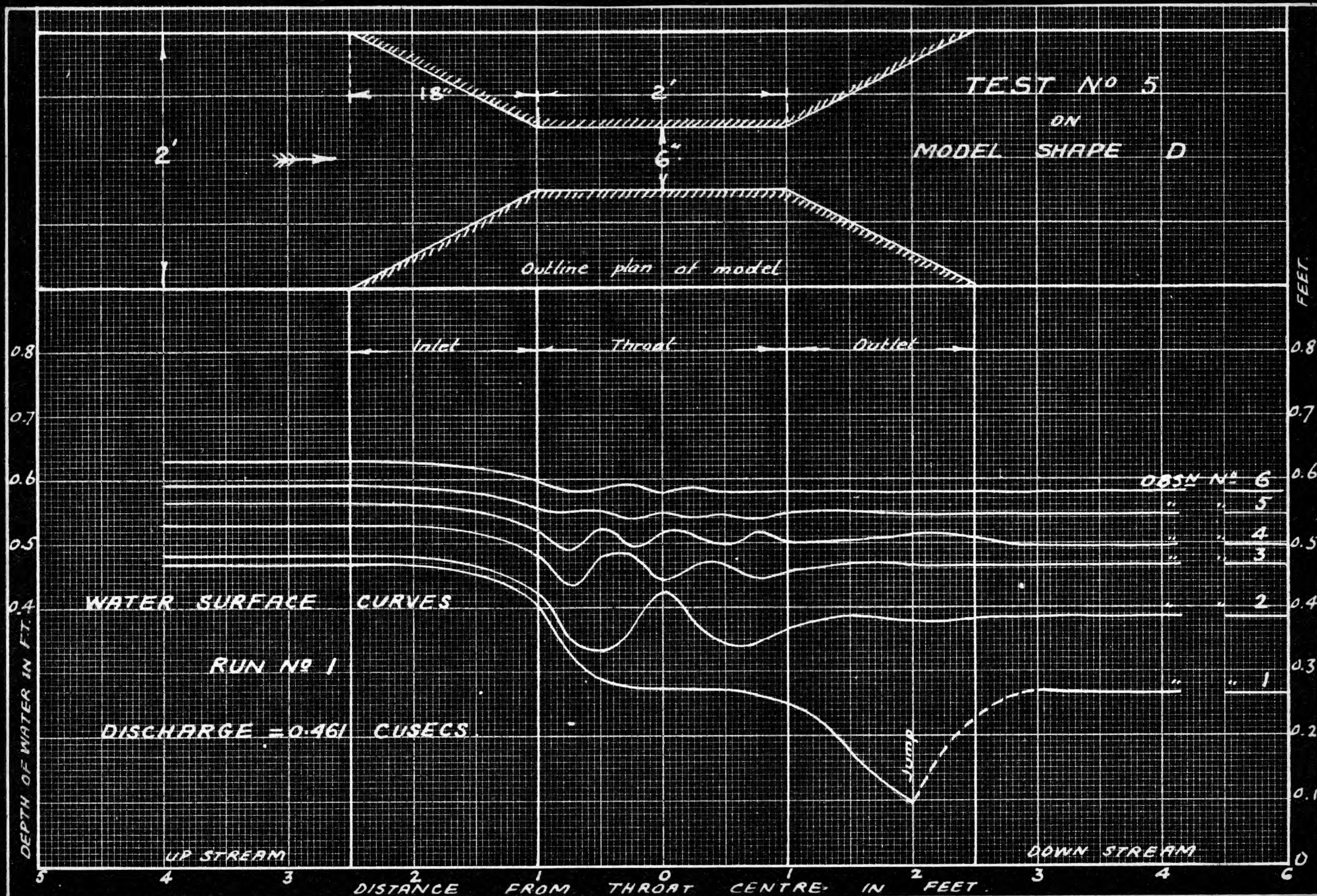
Distance from centre of throat in feet.	Depth of water in feet = Point gauge readings Observation No. 1	2	3	4	5	6	7
		Run No. (3)	Mean discharge = 1.064 cusecs.				
4.00 U.S.	0.8243	0.8283	0.8513	0.9042	0.9354	0.9690	0.9867
2.50 "	0.8207	0.8245	0.8513	0.9019	0.9342	0.9690	0.9867
2.00 "	0.8140	0.8211	0.8458	0.8999	0.9288	0.9661	0.9827
1.00 "	0.7411	0.7476	0.7730	0.8346	0.8713	0.9107	0.9270
0.75 "	0.6614	0.6700	0.6970	0.7656	0.8071	0.8479	0.8633
0.50 "	0.5608	0.5724	0.6017	0.7093	0.7650	0.8187	0.8412
		Rose to	0.6248	4"0.7045			
0.25 "	0.4931	0.5329	0.5480	0.8390W	wave	wave	wave
		Rose to	0.6012				
0.00	0.4840	0.5115	Contin-uous		0.8590	0.8939	0.9048
0.25 D.S.	0.4474	0.5132	pulse due to				
0.50 "	0.4574	0.5250	side current	0.7631	0.8014	0.8510	0.8761
0.75 "	0.4363	0.5356	----				
1.00 "	0.3993	0.5660	0.6730	0.7464	0.8123	0.8800	0.9000
2.00 "	Side	current	0.6834	0.7631	0.8245	0.8840	0.8945
6.00 "	0.4103	0.6116	0.7000	0.7631	0.8245	0.8840	0.8925
		Run No. (4)	Mean discharge = 1.449 cusecs.				
4.00 U.S.	1.0120	1.0290	1.0434	1.0507	1.0936	1.1700	
2.50 "	1.0101	1.0276	1.0392	1.0479	1.0928	1.1690	
2.00 "	1.0018	1.0205	1.0340	1.0424	1.0863	1.1637	
1.00 "	0.9222	0.9433	0.9574	0.9688	1.0158	1.0993	
0.75 "	0.8369	0.8618	0.8753	0.8858	0.9391	1.0316	
0.50 "	0.7213	0.7493	0.7711	0.7808	0.8480	0.9620	
						4" 0.9563	
0.25 "	0.6351	0.6723	0.7013	0.7146	0.8266	0.9700	
0.00	0.6123	0.6645	0.7367	0.7255	0.8356W	wave	
0.25 D.S.	0.5830	0.6624	0.7169	0.7497	wave	1.0780	
0.50 "	0.5624	0.6719	0.7616	0.7960	0.9790	1.0372	

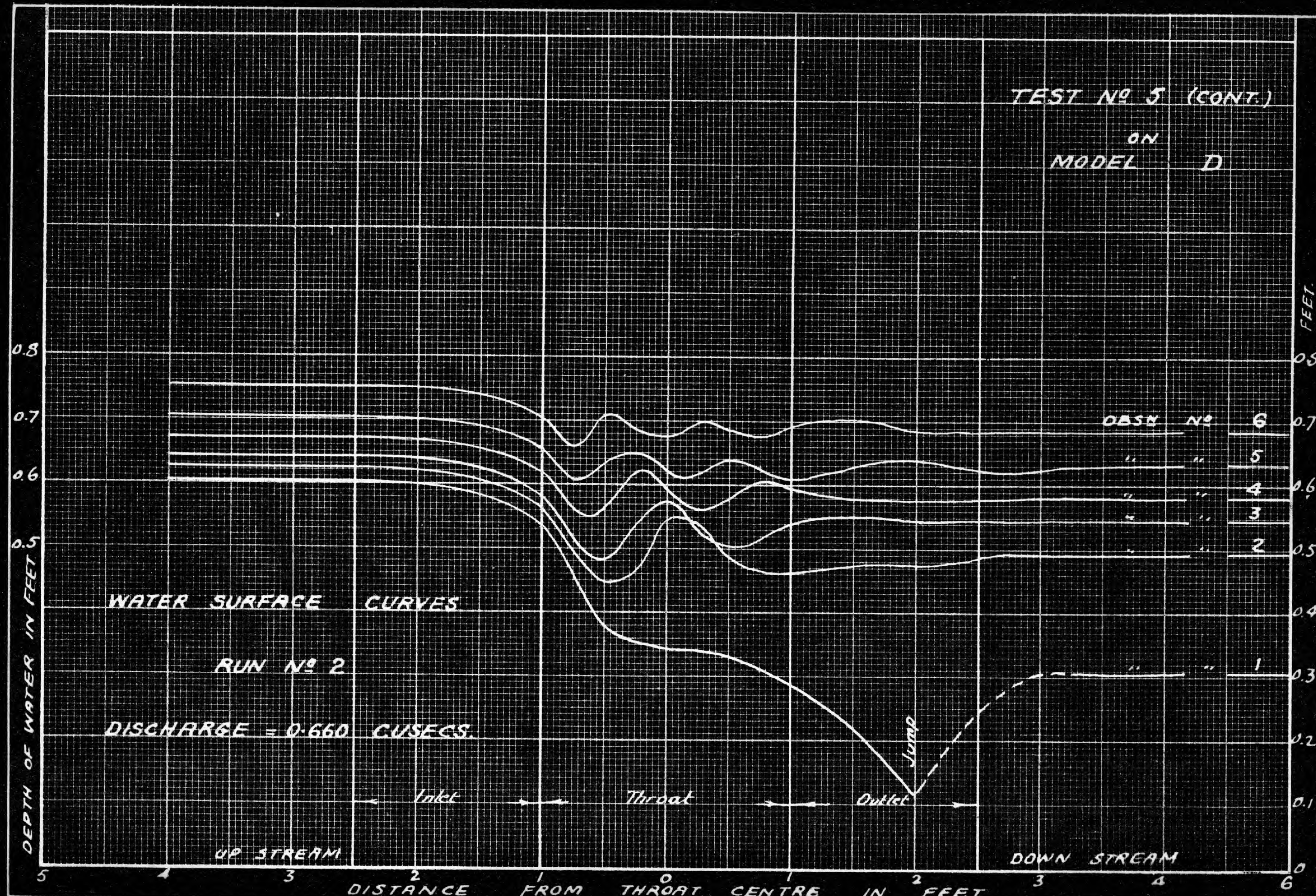
Test 5. Continued.

Distance from centre of throat in feet.	Depth of water in feet = Point gauge readings — Observation No. 1	2	3	4	5	6
			Run No.(4) Continued.			
0.75 D.S.	----	0.6800	0.7716	0.8352	0.9615	1.0166
1.00 "	0.4963	0.7150	0.8676	0.9055	0.9222	1.0149
2.00 "	0.3700J	0.7800	0.8169	0.8416	0.9534	1.0160
6.00 "	0.4800	0.7994	0.8676	0.8783	0.9461	1.0277

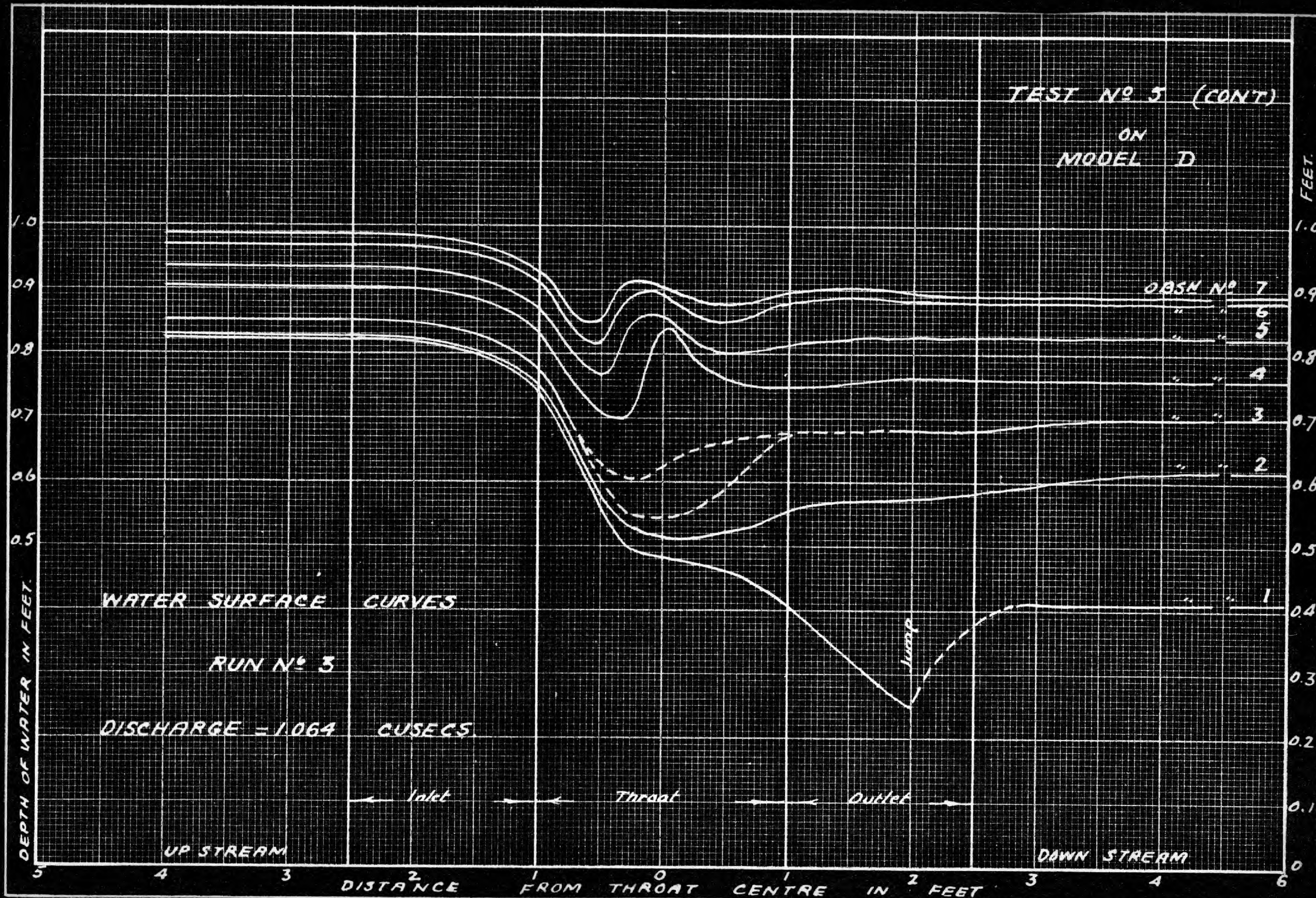
Discharge Observations.

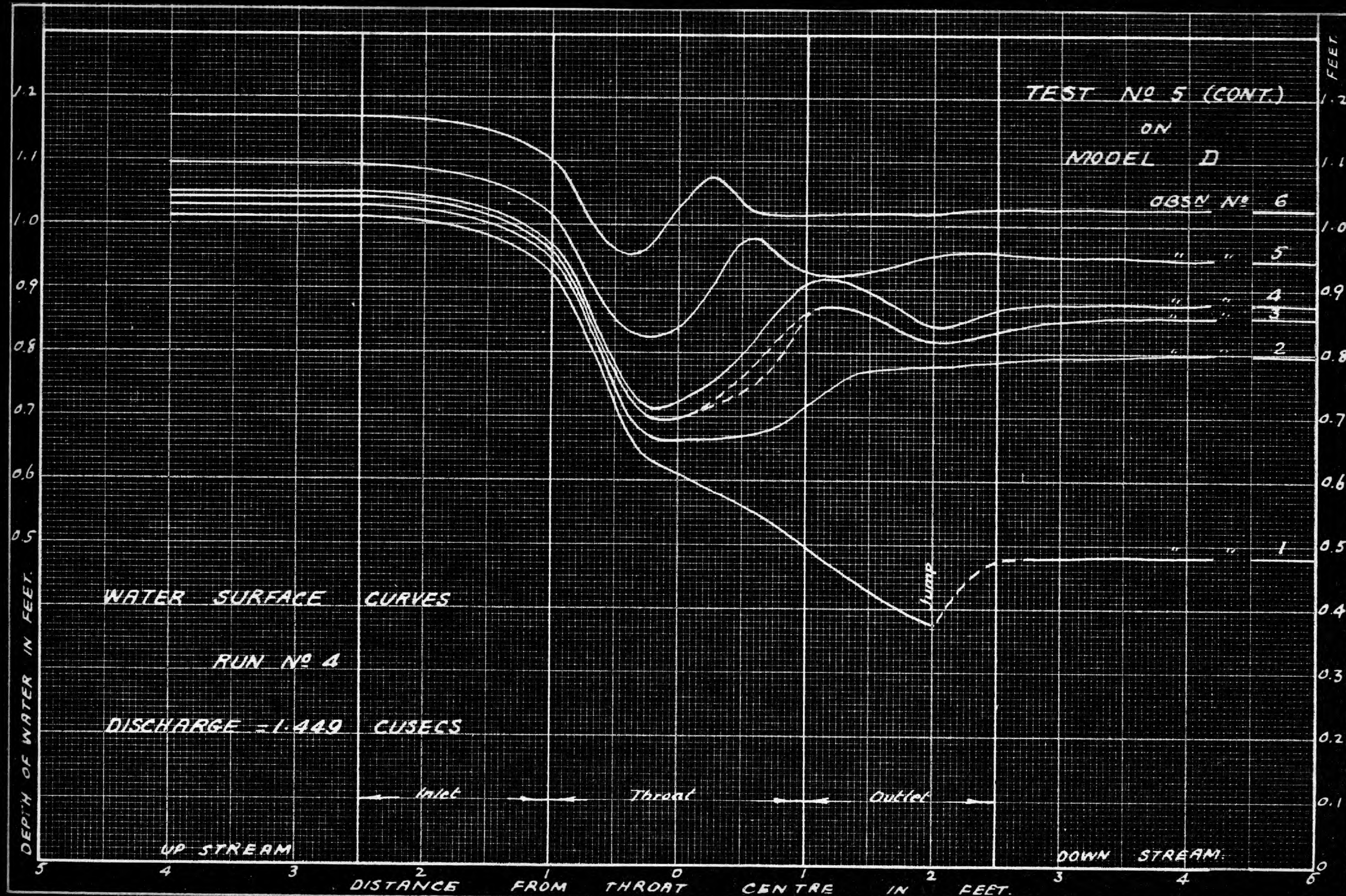
Obsn. No.	R = Rise in Tank in feet.	M = Time in Mins.	Discharge in cusecs. = $\frac{R \times 155}{M \times 60}$	Obsn. No.	R = Rise in Tank in feet	M = Time in Mins.	Discharge in cusecs. = $\frac{R \times 155}{M \times 60}$
	Run No. (1)				Run No. (2)		
1	3.76	21	0.462	1	2.266	9	0.650
2	1.95	11	0.457	2	2.322	9	0.667
3	1.62	9	0.465	3	1.217	5	0.630
		Mean =	0.461 cusecs.	4	1.050	4	0.679
				5	1.025	4	0.663
				6	2.075	8	0.668
						Mean =	0.660 cusecs.
	Run No. (3)				Run No. (4)		
1	2.890	7	1.066	1	3.900	7	1.440
2	3.280	8	1.058	2	2.790	5	1.440
3	3.720	9	1.066	3	2.830	5	1.462
4	3.295	8	1.065	4	2.830	5	1.462
		Mean =	1.064 cusecs.	5	2.790	5	1.440
						Mean =	1.449 cusecs.


TEST Nº 5
ON
MODEL SHAPE D
Outline plan of model
18"
2'
6"
Inlet
Throat
Outlet
WATER SURFACE CURVES
RUN Nº 1
DISCHARGE = 0·461 CUSECS
OBSN Nº 6
5
4
3
2
1
Jump
UP STREAM
DOWN STREAM
DEPTH OF WATER IN FT.
FEET
DISTANCE FROM THROAT CENTRE IN FEET
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
5
4
3
2
1
0
1
2
3
4
6



TEST Nº 5 (CONT.)
ON
MODEL D
OBSN Nº 6
" " 5
" " 4
" " 3
" " 2
" " 1
WATER SURFACE CURVES
RUN Nº 2
DISCHARGE = 0·660 CUSECS.
Jump
Inlet
Throat
Outlet
UP STREAM
DOWN STREAM
DEPTH OF WATER IN FEET
FEET.
DISTANCE FROM THROAT CENTRE IN FEET
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
5
4
3
2
1
0
1
2
3
4
6


TEST Nº 5 (CONT)
ON
MODEL D
WATER SURFACE CURVES
RUN Nº 3
DISCHARGE = 1.064 CUSECS
OBSN Nº 7
6
5
4
3
2
1
Jump
Inlet
Throat
Outlet
UP STREAM
DOWN STREAM
DEPTH OF WATER IN FEET.
FEET.
DISTANCE FROM THROAT CENTRE IN FEET
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
5
4
3
2
1
0
1
2
3
4
6


TEST Nº 5 (CONT.)
ON
MODEL D
OBSN Nº 6
" " 5
" " 4
" " 3
" " 2
" " 1
WATER SURFACE CURVES
RUN Nº 4
DISCHARGE = 1·449 CUSECS
Jump
Inlet
Throat
Outlet
UP STREAM
DOWN STREAM.
DEPTH OF WATER IN FEET.
FEET.
DISTANCE FROM THROAT CENTRE IN FEET.

TEST No. 6

on

Model Shape F.

Throat width 6 inches. Throat length 18 inches.

Distance from centre of throat in feet.	Depth of water in feet = Point gauge readings. Observation No. 1	2	3	4	5	6	7
Run No. (1) Mean discharge = 0.375 cusecs.							
3.00 U.S.	0.4046	0.4191	0.4639	0.5057	0.5382	0.5730	0.6187
2.00 "	0.4007	0.4191	0.4670	0.5017	0.5387	0.5748	0.6175
1.00 "	0.3558	0.3836	0.4372	0.4773	0.5151	0.5556	0.6013
0.75 "	0.3088	0.3479	0.4124	0.4571	0.5031	0.5467	0.5903
		6.5"	0.4077	8" 0.4565			
0.50 "	0.2624	0.3271	0.4174"	0.4731	0.5113	0.5467	0.5894
0.25 "	0.2436	0.3633	0.4113	0.4501	0.5213	0.5476	0.5894
0.00	0.2490	0.3540	0.4136	0.4693	0.5020	0.5440	0.5930
0.25 D.S.	0.2455	0.3362	0.4233	0.4554	0.5005	0.5433	0.5911
0.50 "	0.2387	0.3362	0.4087	0.4626	0.5071	0.5433	0.5900
0.75 "	0.2443	0.3544	0.4046	0.4570	0.5009	0.5427	0.5900
1.00 "	0.2348	0.3635	0.4259	0.4705	0.5043	0.5414	0.5900
2.00 "	----	0.3727	0.4341	0.4715	0.5129	0.5527	0.5984
6.00 "	0.2764	0.3700	0.4325	0.4681	0.5100	0.5530	0.5980
Run No. (2) Mean discharge = 0.699 cusecs.							
3.00 U.S.	0.6249	0.6266	0.6340	0.6658	0.7274	0.7635	0.8375
2.00 "	0.6197	0.6226	0.6311	0.6631	0.7258	0.7614	0.8333
1.00 "	0.5602	0.5631	0.5724	0.6076	0.6805	0.7222	0.7991
0.75 "	0.5038	0.5049	0.5193	0.5611	0.6410	0.6963	0.7749
						7"	0.7690
0.50 "	0.4293	0.4333	0.4526	0.5140	0.6165	0.6747	0.7788
			4.5"	0.5049			
0.25 "	0.3833	0.3890	0.4122	0.5140	0.6722	0.7311	0.7826
0.00	0.3677	0.3827	0.4243	0.5990	0.6583	0.6840	0.7758
0.25 D.S.	0.3640	0.3913	0.4918	0.5990	0.6256	0.6814	0.7900

Test No. 6 Continued.

Distance from centre of throat in feet.	Depth of water in feet = Point gauge readings. Observation No. 1	2	3	4	5	6	7
			Run No.(2) Continued.				
0.50 D.S.	0.3541	0.3902	0.5428	0.5441	0.6256	0.7000	0.7707
0.75 "	0.3155	0.4047	0.5315	0.5168	0.6515	0.7006	0.7700
1.00 "	0.2814	0.4445	0.5100	wave	0.6575	0.6780	0.7962
		(0.4590R)	(0.5100R)			wave	
		(0.3962L)	(0.4760L)				
2.00 "	0.1105J	0.5020	0.5453	0.5860	0.6734	0.7125	0.7963
6.00 "	0.3233	0.4912	0.5360	0.5832	0.6749	0.7125	0.7935
			Run No. (3). Mean discharge = 1.126 cusecs.				
3.00 U.S.	0.8584	0.8646	0.8725	0.8977	0.9313	0.9625	1.0173
2.00 "	0.8525	0.8572	0.8660	0.8909	0.9300	0.9575	1.0149
1.00 "	0.7852	0.7870	0.7978	0.8269	0.8691	0.9019	0.9657
0.75 "	0.7166	0.7241	0.7357	0.7713	0.8147	0.8499	0.9186
0.50 "	0.6296	0.6363	0.6516	0.6932	0.8465	0.7926	0.8762
0.25 "	0.5557	0.5656	0.5869	0.6432	0.7186	0.7796	0.8855
0.00	0.5146	0.5323	0.5603	0.6587	0.7580	0.8400	0.9800
0.75 D.S.	0.5041	0.5323	0.5715	0.6917	wave	0.9100	0.9368
0.50 "	0.4939	0.5184	0.5944	0.7347	0.8532	0.8607	0.8871
0.75 "	0.4503	0.5046	0.5956	0.7881	0.7952	0.8094	0.8044
1.00 "	0.3889	Jump	wave	0.7980	wave	wave	wave
	1.5' Jump			wave			
2.00 "	----	----	----	----	----	----	----
6.00 "	0.5522	0.6230	0.7153	0.7990	0.8300	0.8724	0.9433
			Run No. (4). Mean discharge = 1.425 cusecs.				
3.00 U.S.	1.0008	1.0051	1.0191	1.0391	1.0821	1.1000	1.1460
2.00 "	0.9941	0.9994	1.0133	1.0338	1.0789	1.0973	1.1423
1.00 "	0.9182	0.9244	0.9425	0.9623	1.0100	1.0345	1.0866
0.75 "	0.8515	0.8552	0.8745	0.8995	0.9513	0.9753	1.0314
0.50 "	0.7554	0.7632	0.7843	0.8082	0.8793	0.9064	0.9675

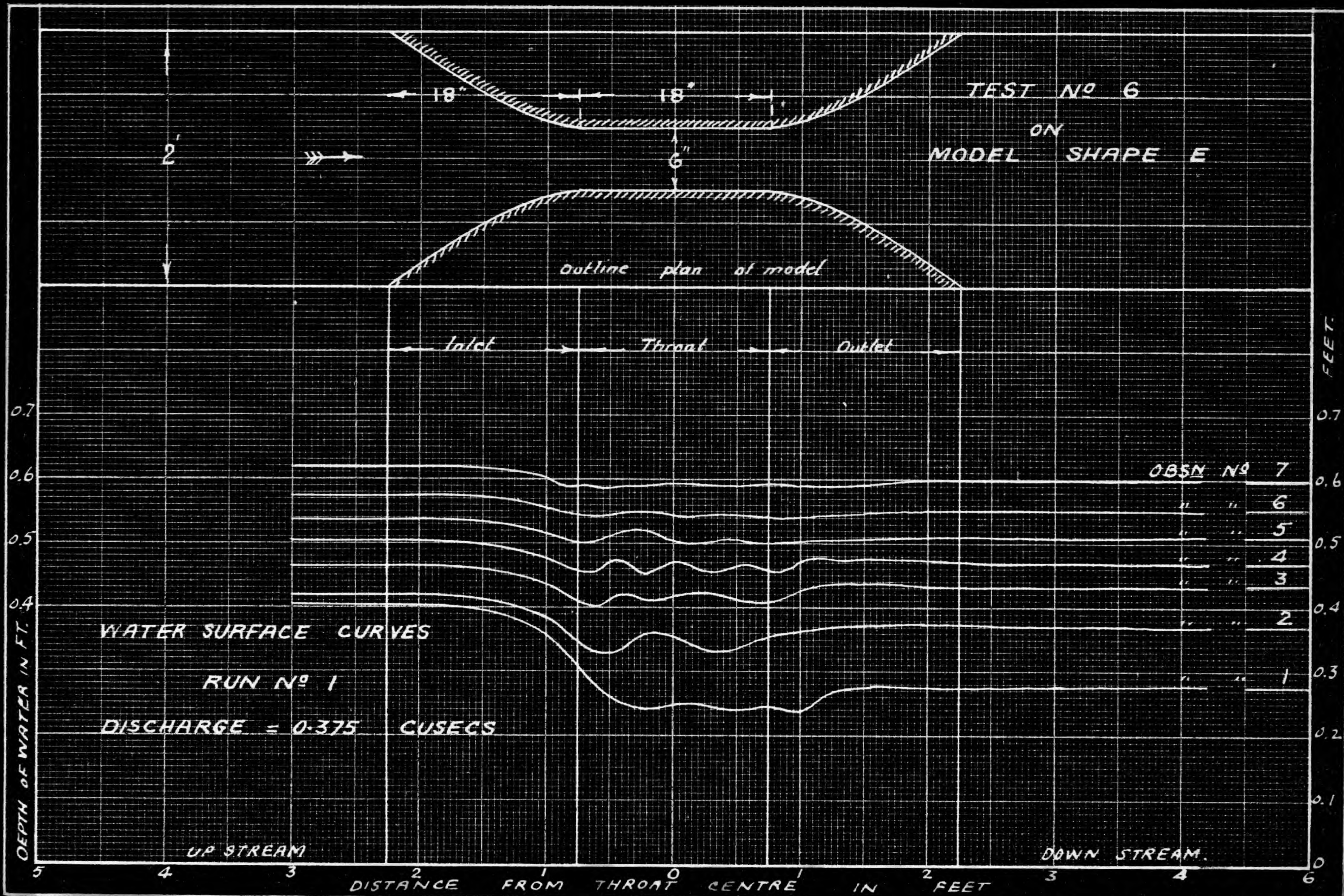
Test No. 6 Continued.

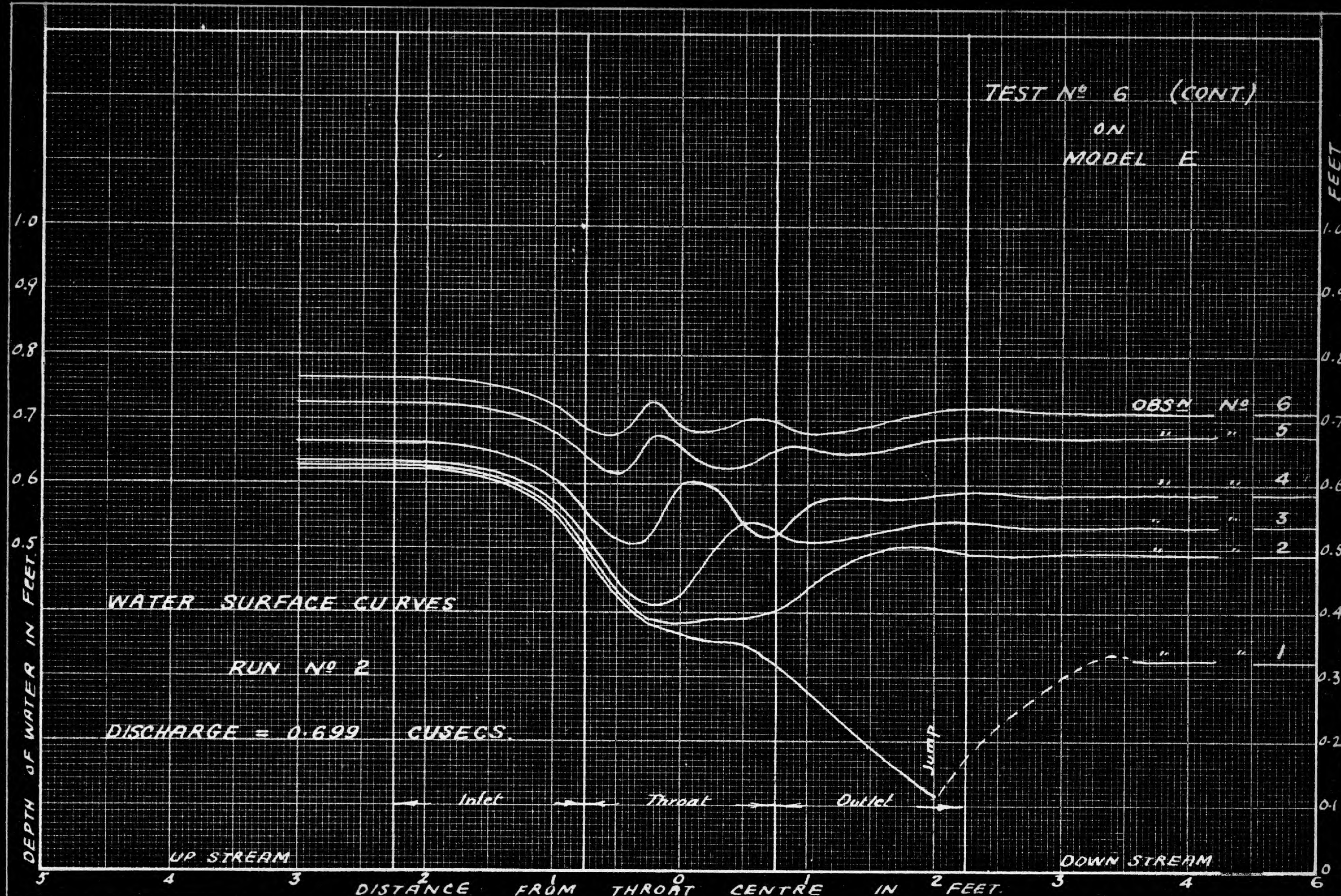
Distance from centre of throat in feet.	Depth of water in feet – Point gauge readings Observation No. 1	2	3	4	5	6	7
				Run No.(4) Continued.			
0.25 U.S.	0.6685	0.6776	0.7064	0.7407	0.8277	0.8745	0.9393
					1.5" 0.8197		
0.00	0.6143	0.6263	0.6694	0.7186	0.8314	0.8892	0.9971
0.25 D.S.	0.5884	0.6060	0.6747	0.7467	0.9060	0.9588	1.0800
						wave	
0.50 "	0.5693	0.5918	0.6742	0.7693	0.9294	1.0100	1.0555
0.75 "	0.5442	0.5770	0.6858	0.7858	1.0000	1.0023	0.9954
			wave	wave			
1.00 "	0.4900J	wave	----	----	0.9600	wave	wave
					1.5' wave		
2.00 "	----	----	----	----	----	----	----
6.00 "	0.6559	0.7166	0.8200	0.8973	0.9819	1.0058	1.0612

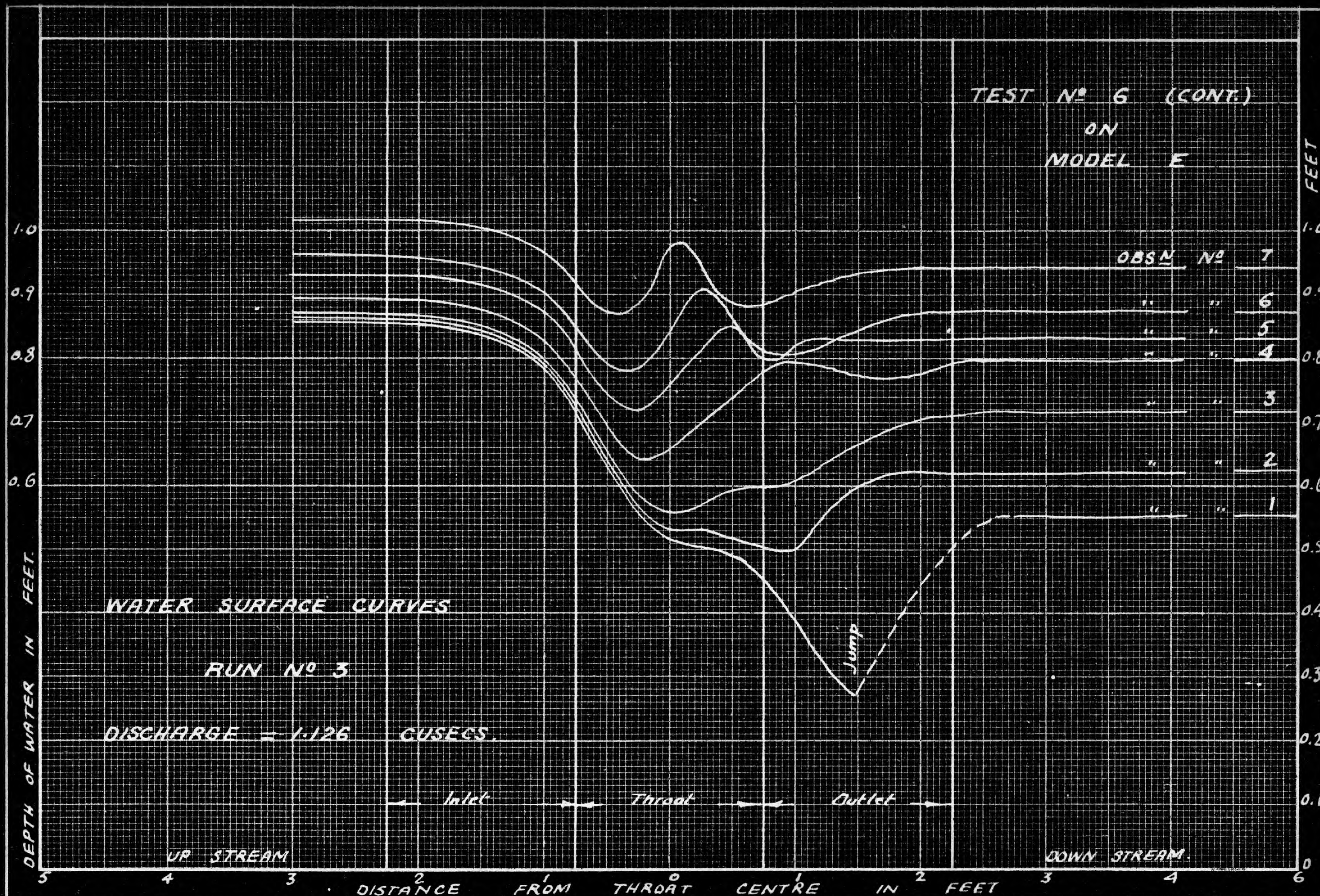
Test No. 6 (Continued)

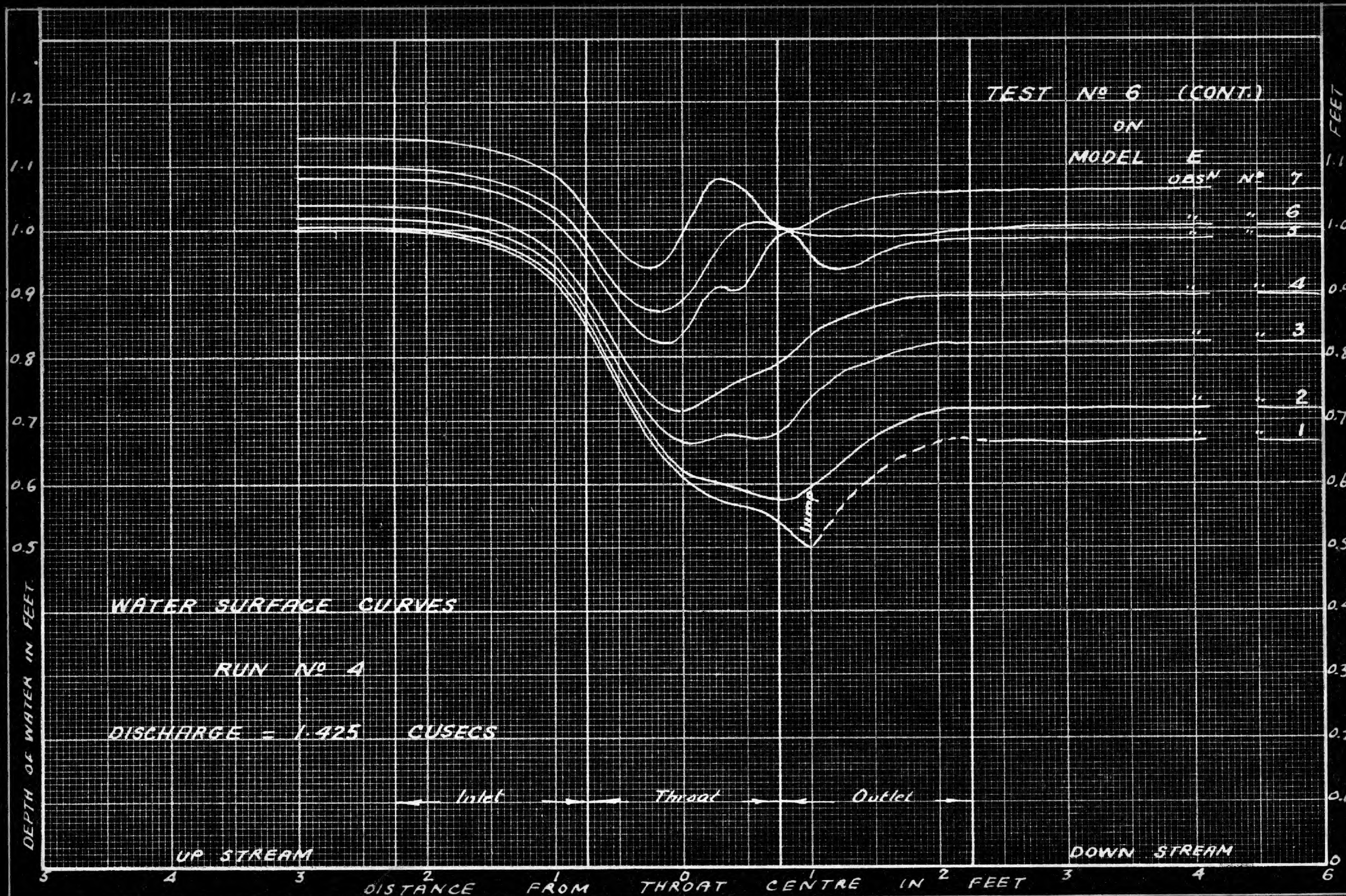
Discharge Observations.

Osbn. No.	R = Rise in Tank in feet.	M = Time in Mins.	Discharge in cusecs. = $\frac{R \times 155}{M \times 60}$.	Obsn. No.	R = Rise in Tank in feet.	M = Time in Mins.	Discharge in Cusecs. = $\frac{R \times 155}{M \times 60}$
	Run No. (1)				Run No. (2)		
1	0.870	6	0.375	1	3.195	12	0.688
2	0.870	6	0.375	2	3.310	12	0.713
3	0.865	6	0.373	3	2.470	9	0.710
4	0.860	6	0.370	4	1.850	7	0.685
5	0.735	5	0.380			Mean =	0.699 cusecs.
6	0.725	5	0.375				
7	0.725	5	0.375				
		Mean =	0.375 cusecs.				
	Run No. (3)				Run No. (4)		
1	3.935	9	1.130	1	3.305	6	1.424
2	3.960	9	1.136	2	3.315	6	1.426
3	1.735	4	1.124	3	3.890	7	1.433
4	2.175	5	1.124	4	3.290	6	1.417
5	1.725	4	1.115			Mean =	1.425 cusecs.
		Mean =	1.126 cusecs.				


TEST Nº 6
ON
MODEL SHAPE E
18"
18"
2'
6"
outline plan of model
Inlet
Throat
Outlet
OBSN Nº 7
6
5
4
3
2
1
WATER SURFACE CURVES
RUN Nº 1
DISCHARGE = 0·375 CUSECS
DEPTH OF WATER IN FT.
FEET.
UP STREAM
DOWN STREAM.
DISTANCE FROM THROAT CENTRE IN FEET


TEST Nº 6 (CONT.)
ON
MODEL E
WATER SURFACE CURVES
RUN Nº 2
DISCHARGE = 0·699 CUSECS.
OBSN Nº 6
" " 5
" " 4
" " 3
" " 2
" " 1
Inlet
Throat
Outlet
Jump
UP STREAM
DOWN STREAM
DEPTH OF WATER IN FEET.
FEET
DISTANCE FROM THROAT CENTRE IN FEET.
5 4 3 2 1 0 1 2 3 4 6
1.0 0.9 0.8 0.7 0.6 0.5 0.4 0.3 0.2 0.1 0


TEST Nº 6 (CONT.)
ON
MODEL E
FEET
OBSN Nº 7
" " 6
" " 5
" " 4
" " 3
" " 2
" " 1
Jump
WATER SURFACE CURVES
RUN Nº 3
DISCHARGE = 1·126 CUSECS.
Inlet
Throat
Outlet
UP STREAM
DOWN STREAM.
DEPTH OF WATER IN FEET.
DISTANCE FROM THROAT CENTRE IN FEET
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
5
4
3
2
1
0
1
2
3
4
6



TEST Nº 6 (CONT.)
ON
MODEL E
OBSN Nº 7
" " 6
" " 5
" " 4
" " 3
" " 2
" " 1
Jump
WATER SURFACE CURVES
RUN Nº 4
DISCHARGE = 1.425 CUSECS
Inlet
Throat
Outlet
UP STREAM
DOWN STREAM
DEPTH OF WATER IN FEET
FEET
DISTANCE FROM THROAT CENTRE IN FEET

TEST No. 7

on

Model Shape F.

Throat width 6 inches. Throat length 18 inches.

Distance from centre of throat in feet.	Depth of water in feet = Point gauge readings Observation No. 1	2	3	4	5	6	7
			Run No. (1) Mean discharge = 0.417 cusecs.				
3.00 U.S.	0.4324	0.4476	0.4974	0.5413	0.5704	0.6184	0.6461
2.00 "	0.4298	0.4447	0.4967	0.5413	0.5698	0.6184	0.6461
1.00 "	0.3828	0.4032	0.4628	0.5156	0.5463	0.5978	0.6267
0.75 "	0.3371	0.3608	0.4356	0.4983	0.5289	0.5867	0.6183
				8" 0.4925	8" 0.5271		
0.50 "	0.2855	0.3244	0.4292	0.4986	0.5417	0.5945	0.6193
0.25 "	0.2603	0.3477	0.4594	0.4891	0.5225	0.5942	0.6193
0.00	0.2630	0.3808	0.4246	0.5032	0.5330	0.5867	0.6159
0.25 D.S.	0.2670	0.3645	0.4443	0.4981	0.5288	0.5901	0.6138
0.50 "	0.2449	0.2363	0.4457	0.4966	0.5349	0.5873	0.6183
0.75 "	0.2452	0.3301	0.4169	0.5006	0.5271	0.5863	0.6183
1.00 "	0.2398	wave	0.4665	0.5127	0.5382	0.5961	0.6183
	1.2" Jump						
2.00 "	----	0.3803	0.4515	0.5131	0.5454	0.5986	0.6282
4.00 "	0.2900	0.3813	0.4575	0.5150	0.5417	0.6000	0.6284
6.00 "	0.2900	0.3810	0.4575	0.5124	0.5417	0.6000	0.6255
			Run No. (2) Mean discharge = 0.783 cusecs.				
3.00 U.S.	0.6715	0.6803	0.7230	0.7487	0.7988	0.8797	0.9312
2.00 "	0.6693	0.6765	0.7208	0.7456	0.7946	0.8781	0.9276
1.00 "	0.6046	0.6182	0.6696	0.7000	0.7518	0.8430	0.8960
0.75 "	0.5504	0.5633	0.6232	0.6548	0.7109	0.8130	0.8721
0.50 "	0.4733	0.4929	0.5732	0.6100	0.6819	0.8093	0.8709
0.25 "	0.4185	0.4517	0.5700	0.6262	0.7200	0.8468	0.8866
0.00	0.3969	0.4527	0.6455	0.7077	0.7344	0.8067	0.8715
0.25 D.S.	0.3969	0.4898	0.6300	0.6702	0.6937	0.8177	0.8801

Test No. 7. Continued.

Distance from centre of throat in feet.	Depth of water in feet = Point gauge readings.						
	Observation No.						
	1	2	3	4	5	6	7
Run No. (2) Continued.							
0.50 D.S.	0.3818	0.5089	0.6056	0.6202	0.6973	0.8329	0.8735
0.75 "	0.3317	0.5370	0.5858	0.6214	0.7153	0.8098	0.8735
1.00 "	0.2813	0.5539	wave	wave	wave	wave	0.8925
2.00 "	0.1302J	0.5856	0.6474	0.6826	0.7334	0.8378	0.8952
4.00 "	----	----	0.6532	0.6800	0.7428	0.8384	0.8943
6.00 "	0.3370	0.5883	0.6500	0.6800	0.7424	0.8433	0.8970

Run No. (3) Mean discharge =
For observations 1-4 .. 1.035 cusecs.
,, ,, 5-7 .. 1.095 cusecs.

3.00 U.S.	0.8057	0.5167	0.8378	0.8821	0.9355	0.9829	1.0570
2.00 "	0.7990	0.5129	0.8329	0.8821	0.9323	0.9803	1.0569
1.00 "	0.7327	0.7477	0.7684	0.8320	0.8798	0.9348	1.0112
0.75 "	0.6731	0.6874	0.7144	0.7767	0.8251	0.8862	0.9692
0.50 "	0.5877	0.6054	0.6390	0.7181	0.7697	0.8436	0.9431
0.25 "	0.5179	0.5438	0.5954	0.7003	0.7588	0.8586	0.9765
0.00	0.4795	0.5252	0.5931	----	----	----	1.0012
0.25 D.S.	0.4674	0.5289	0.6470	0.8238	0.8704	0.9111	0.9550
0.50 "	0.4574	0.5100	0.6642	0.7976	0.8478	0.8591	0.9512
0.75 "	0.4115	0.5557	----	0.7484	0.7858	0.8538	0.9842
1.00 "	0.3390	wave	----	wave	wave	wave	0.9987
1.5'	0.2380J						
2.00 D.S.	----	----	0.7179	0.8018	0.8542	----	0.9987
4.00 "	0.5420	0.6744	0.7415	0.8123	0.8580	0.9236	0.9996
6.00 "	0.5390	0.6744	0.7400	0.8123	0.8600	0.9132	1.0046

Run No. (4) Mean discharge = 1.468 cusecs.

3.00 U.S.	1.0076	1.0171	1.0326	1.0513	1.0906	1.1389	1.1859
2.00 "	1.0006	1.0126	1.0267	1.0461	1.0858	1.1352	1.1859
1.00 "	0.9294	0.9404	0.9555	0.9768	1.0230	1.0691	1.1299

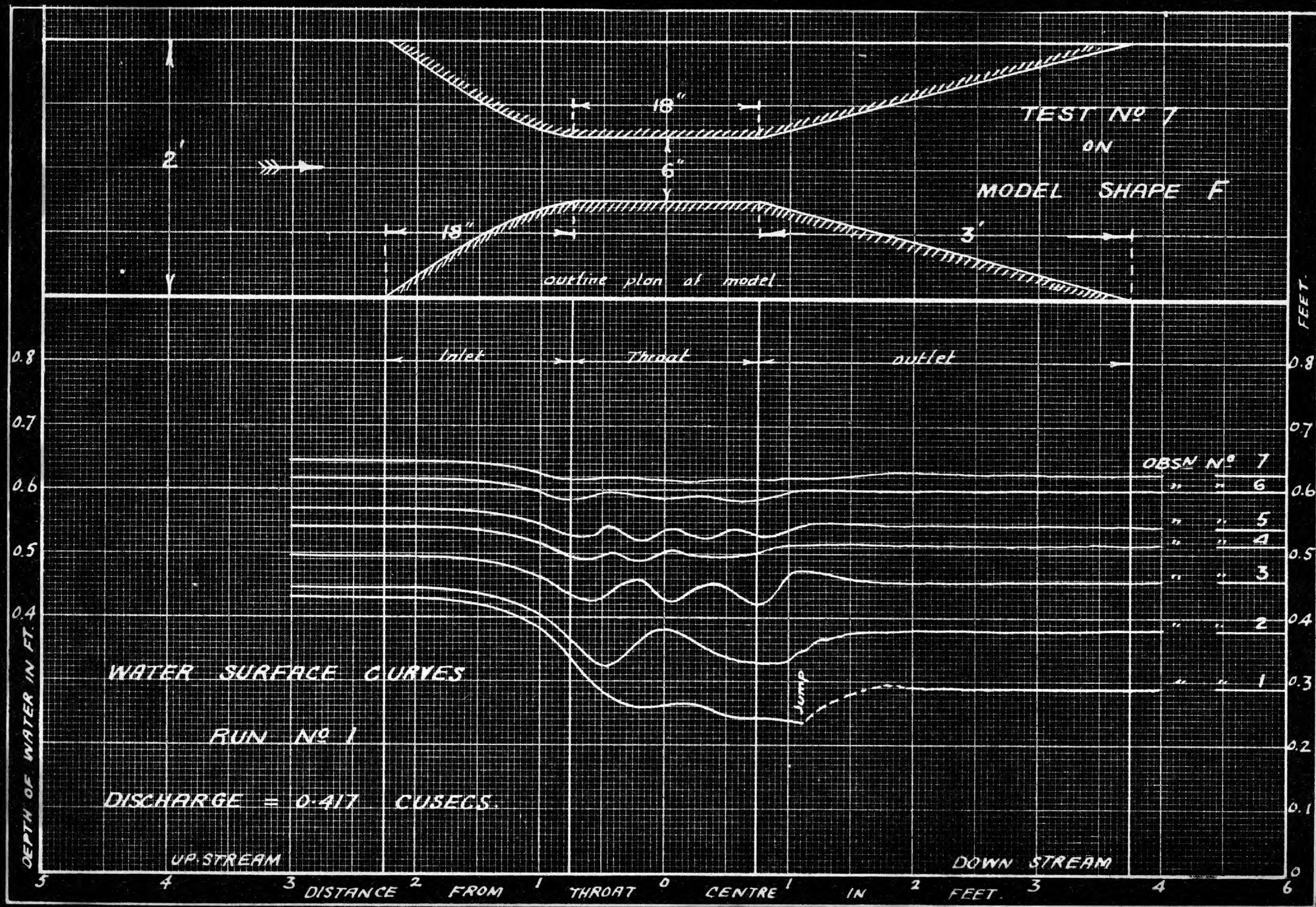
Test No. 7 Continued.

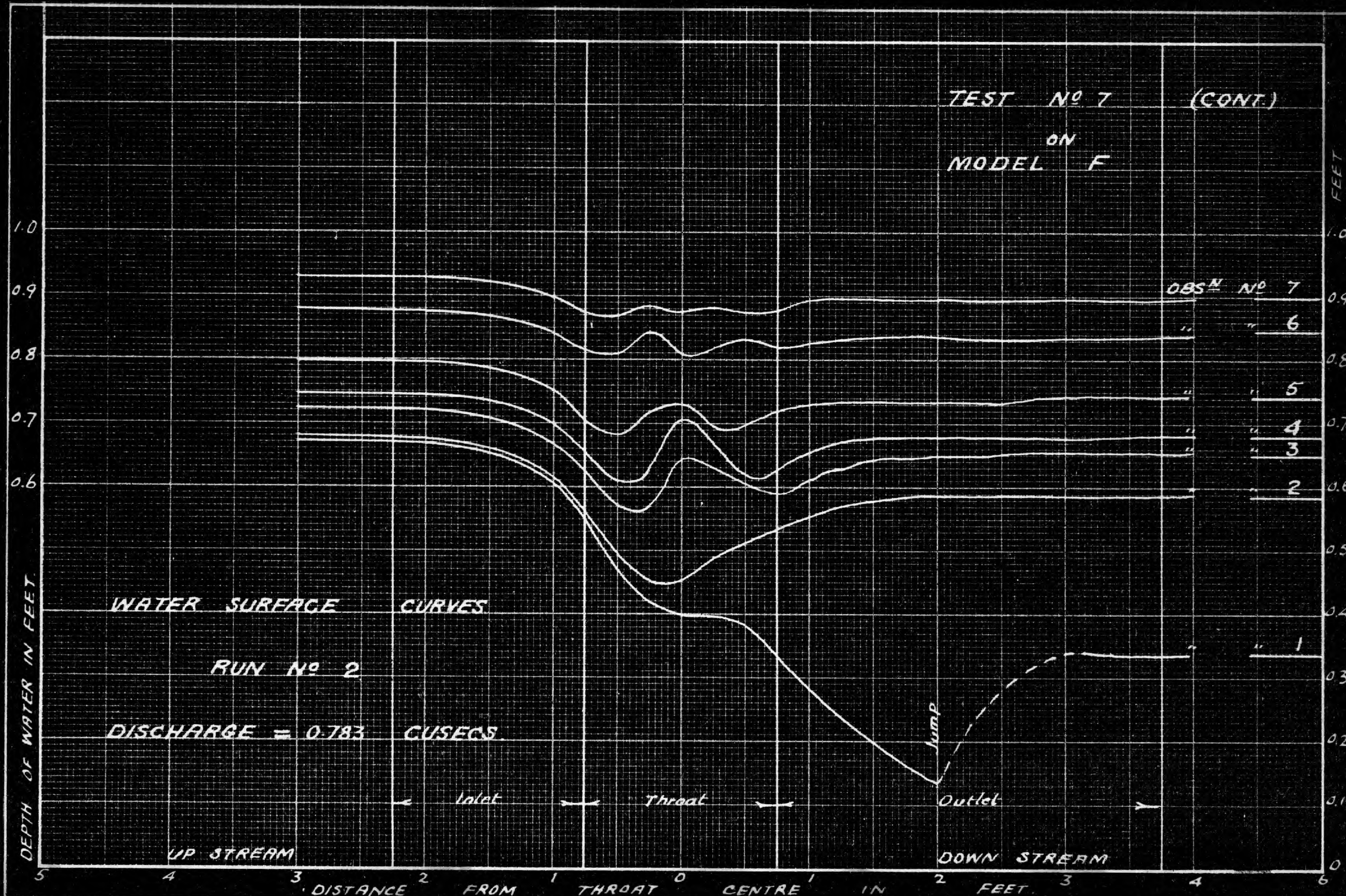
Distance from centre of throat in feet.	Depth of water in feet = Point gauge readings. Observation No. 1	2	3	4	5	6	7
			Run No.(4) Continued.				
0.75 U.S.	0.8613	0.8725	0.8893	0.9158	0.9632	1.0176	1.0749
0.50 "	0.8642	0.7775	0.8005	0.8300	0.8859	0.9513	1.0145
0.25 "	0.6740	0.6940	0.7200	0.7576	0.8320	0.9104	0.9980
0.00	0.6146	0.6398	0.6754	0.7295	0.8290	0.9351	wave
0.25 D.S.	0.5852	0.6240	0.6754	0.7536	0.8948	wave	----
0.50 "	0.5605	0.6240	0.6963	0.7880	0.9227	1.0657	1.0811
0.75 "	0.5213	0.6120J	wave	wave	wave	1.0467	1.0370
1.00 "	0.4406	----	----	----	----	wave	wave
1.5'	0.2285J						
2.00 D.S.	----	----	----	----	----	----	----
4.00 "	----	----	----	0.9190	0.9972	1.0572	1.1100
6.00 "	0.6265	0.8170	0.8400	0.9208	0.9972	1.0529	1.1100

Test No. 7. Continued.

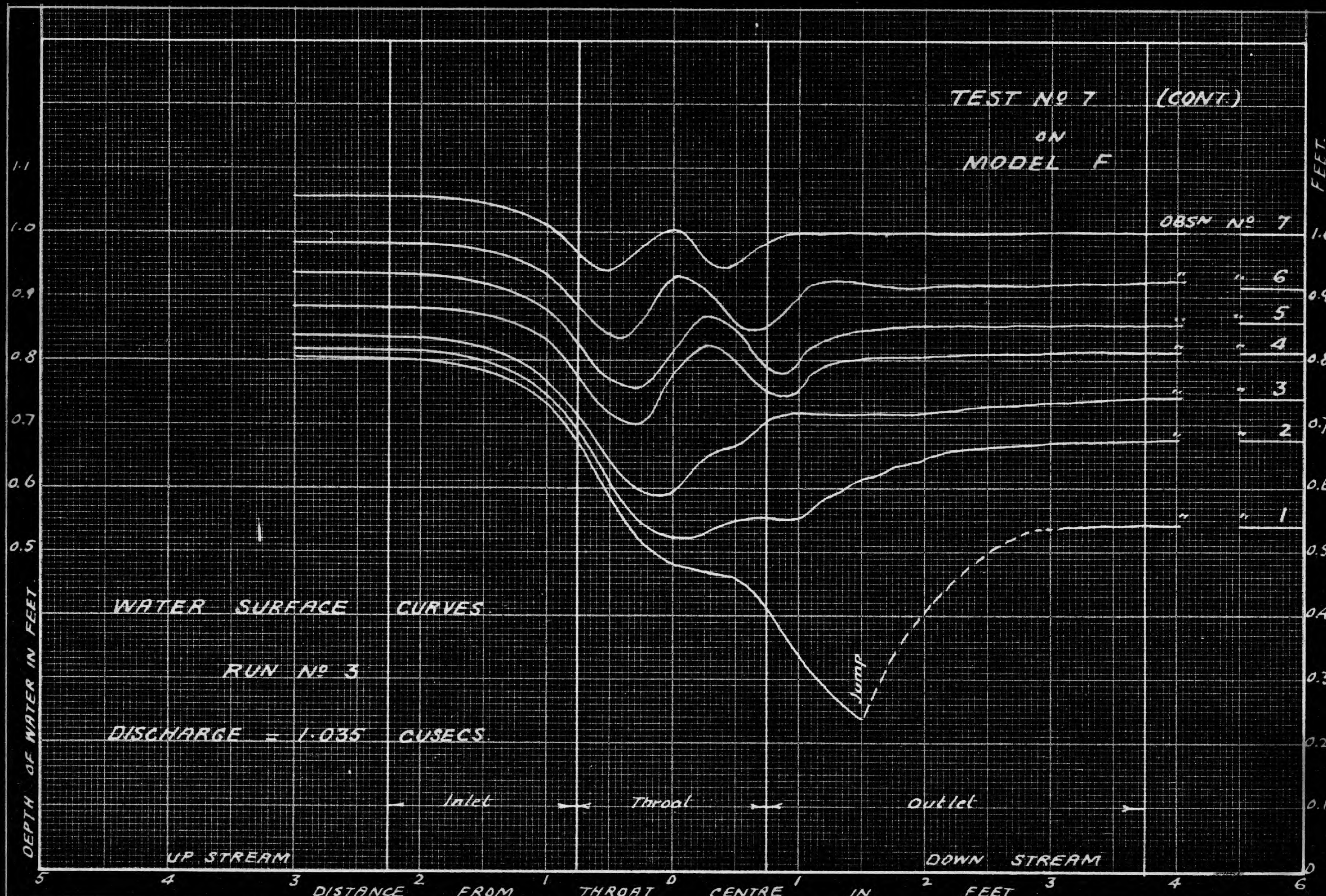
Discharge Observations.

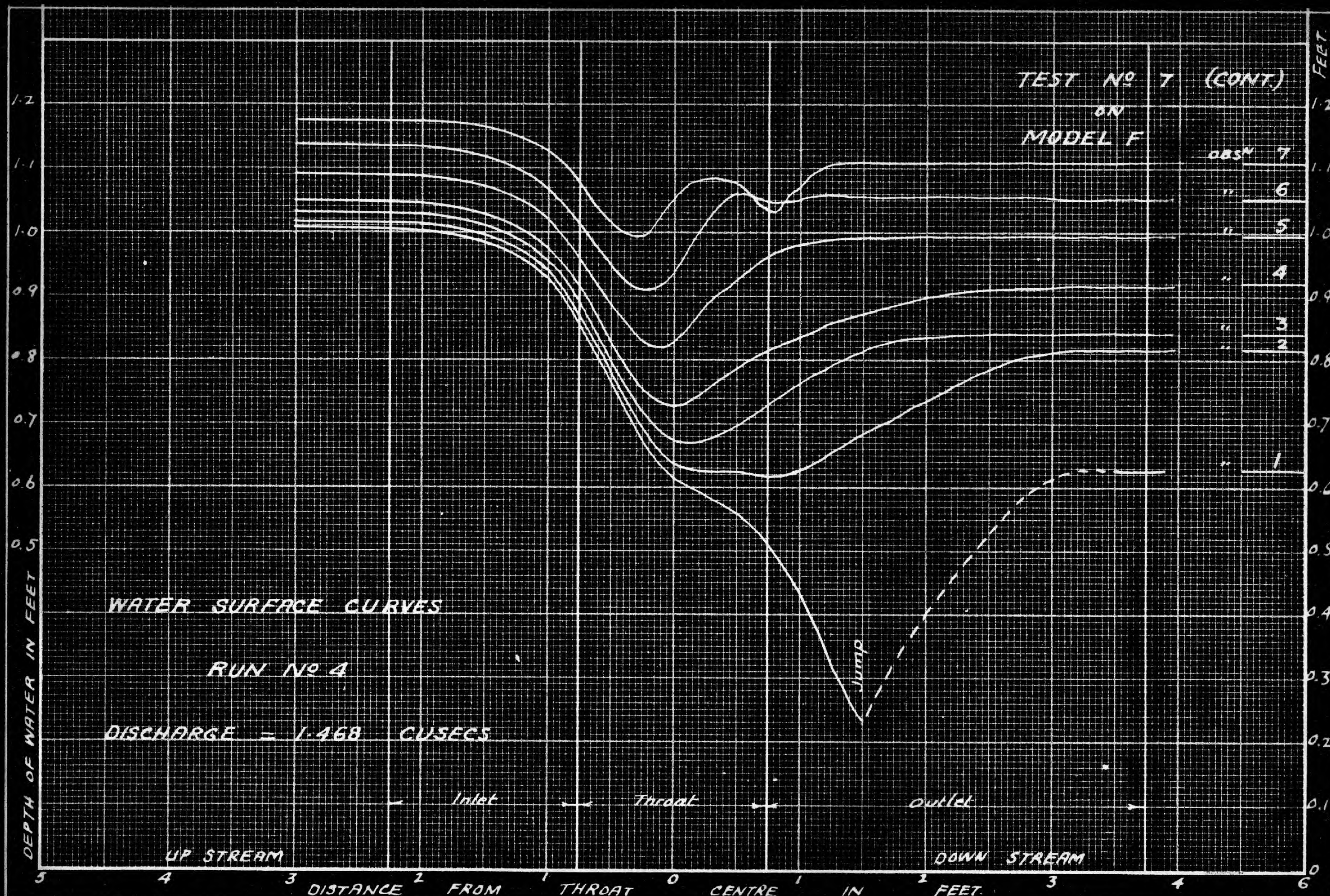
Obsn. No.	R = Rise in Tank in feet	M = Time in Mins.	Discharge in cusecs. = $\frac{R \times 155}{M \times 60}$	Obsn. No.	R = Rise in Tank in feet.	M = Time in Mins.	Discharge in cusecs. = $\frac{R \times 155}{M \times 60}$
	Run No. (1)				Run No. (2)		
1	.965	6	0.417	1	1.765	6	0.758
2	.960	6	0.413	2	1.795	6	0.772
3	.960	6	0.413	3	1.580	5	0.817
4	.795	5	0.411	4	1.530	5	0.806
5	.660	4	0.427	5	1.240	4	0.800
6	.490	3	0.422	6	0.860	3	0.747
		Mean =	0.417 cusecs.			Mean =	0.783 cusecs.
	Run No. (3)				Run No. (4)		
1	2.425	6	1.044	1	3.965	7	1.465
2	1.590	4	1.026	2	2.875	5	1.485
3	3.610	9	1.035	3	2.850	5	1.472
		Mean =	1.035 cusecs.	4	2.845	5	1.470
4	2.115	5	1.094	5	2.810	5	1.450
5	2.120	5	1.096	6	2.275	4	1.470
		Mean =	1.095 cusecs.			Mean =	1.468 cusecs.


TEST Nº 7
ON
MODEL SHAPE F
18"
6"
2'
18"
3'
outline plan of model
Inlet
Throat
outlet
OBSN Nº 7
" " 6
" " 5
" " 4
" " 3
" " 2
" " 1
Jump
WATER SURFACE CURVES
RUN Nº 1
DISCHARGE = 0·417 CUSECS.
UP-STREAM
DOWN STREAM
DEPTH OF WATER IN FT.
FEET.
DISTANCE FROM THROAT CENTRE IN FEET.
5
4
3
2
1
0
1
2
3
4
6
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0



TEST Nº 7 (CONT.)
ON
MODEL F
WATER SURFACE CURVES
RUN Nº 2
DISCHARGE = 0.783 CUSECS.
OBSN Nº 7
" " 6
" " 5
" " 4
" " 3
" " 2
" " 1
Jump
Inlet
Throat
Outlet
UP STREAM
DOWN STREAM
DISTANCE FROM THROAT CENTRE IN FEET
DEPTH OF WATER IN FEET
FEET
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
5
4
3
2
1
0
1
2
3
4
6


TEST Nº 7 (CONT.)
ON
MODEL F
OBSN Nº 7
" " 6
" " 5
" " 4
" " 3
" " 2
" " 1
WATER SURFACE CURVES
RUN Nº 3
DISCHARGE = 1·035 CUSECS
Jump
Inlet
Throat
Outlet
UP STREAM
DOWN STREAM
DEPTH OF WATER IN FEET
FEET
DISTANCE FROM THROAT CENTRE IN FEET
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
5
4
3
2
1
0
1
2
3
4
6


TEST Nº 7 (CONT.)
ON
MODEL F
OBSN 7
" 6
" 5
" 4
" 3
" 2
" 1
WATER SURFACE CURVES
RUN Nº 4
DISCHARGE = 1·468 CUSECS
Jump
Inlet
Throat
Outlet
UP STREAM
DOWN STREAM
DEPTH OF WATER IN FEET
FEET
1·2
1·1
1·0
0·9
0·8
0·7
0·6
0·5
0·4
0·3
0·2
0·1
0
5
4
3
2
1
0
1
2
3
4
6
DISTANCE FROM THROAT CENTRE IN FEET

TEST No. 8

on

Model Shape G.

Throat width 6 inches. Throat length 12 inches.

Distance from centre of throat in feet.	Depth of water in feet = Point gauge readings		Observation No.				
	1	2	3	4	5	6	7
			Run No. (1) Mean discharge = 0.403 cusecs.				
4.00 U.S.	0.4267	0.4646	0.5000	0.5548	0.60500	0.6611	0.7173
2.00 "	0.4238	0.4638	0.4992	0.5544	0.6050	0.6589	0.7161
1.50 "	0.4192	0.4596	0.4958	0.5507	0.6039	0.6584	0.7147
1.00 "	0.4005	0.4436	0.4838	0.5398	0.5959	0.6512	0.7078
0.50 "	0.3397	0.3913	0.4422	0.5109	0.5738	0.6336	0.6950
0.25 "	0.2809	0.3799	0.4455	0.5175	0.5750	0.6317	0.6944
0.00	0.2557	0.4107	0.4544	0.5051	0.5763	0.6315	0.6940
0.25 D.S.	0.2691	0.3947	0.4371	0.5178	0.5733	0.6344	0.6940
0.50 "	0.2533	0.3817	0.4524	0.5091	0.5733	0.6330	0.6940
1.00 "	0.2179	0.4105	0.4472	0.5091	0.5792	0.6322	0.6940
2.25"	0.1050J						
4.00 D.S.	0.2304	0.4231	0.4688	0.5300	0.5886	0.6443	0.7026
6.00 "	0.2231	0.4231	0.4630	0.5294	0.5886	0.6443	0.7026
			Run No. (2). Mean discharge = 0.692 cusecs.				
4.00 U.S.	0.6175	0.6338	0.6624	0.6957	0.7247	0.7506	0.8004
2.00 "	0.6161	0.6316	0.6598	0.6929	0.7229	0.7487	0.7997
1.50 "	0.6083	0.6228	0.6561	0.6856	0.7173	0.7466	0.7961
1.00 "	0.5837	0.5998	0.6346	0.6660	0.7009	0.7299	0.7819
0.50 "	0.4984	0.5195	0.5619	0.5993	0.6430	0.6762	0.7371
0.25 "	0.4257	0.4565	0.5149	0.5744	0.6234	0.6686	0.7358
0.00	0.3767	0.4433	0.5227	0.5967	0.6427	0.7052	0.7566
0.25 D.S.	0.3619	0.4620	0.5800	0.6503	wave	0.6777	0.7319
0.50 "	0.3594	0.5061	0.5984	0.6027	0.6275	0.6742	0.7464
1.00 "	0.3015	----	0.5208	0.5990	0.6656	0.6993	0.7262
1.50 "	0.2502J	----	wave	wave			

Test No. 8 Continued.

Distance from centre of throat in feet.	Depth of water in feet = Point gauge readings Observation No. 1	2	3	4	5	6	7
				Run No. (2) Continued.			
4.00 D.S.	0.4254	0.5564	0.6041	0.6446	0.6791	0.7117	0.7634
6.00 "	0.4254	0.5649	0.6019	0.6446	0.6791	0.7107	0.7650
		Run No.(3)		Mean discharge = 1.018 cusecs.			
4.00 U.S.	0.7950	0.8205	0.8960	0.9406	0.9900	1.0374	1.0858
2.00 "	0.7922	0.8169	0.8917	0.9395	0.9877	1.0366	1.0858
1.50 "	0.7843	0.8090	0.8854	0.9320	0.9818	1.0306	1.0813
1.00 "	0.7542	0.7816	0.8630	0.9105	0.9623	1.0130	1.0651
0.50 "	0.6569	0.6889	0.7843	0.8409	0.9007	0.9565	1.0133
0.25 "	0.5727	0.6127	0.7343	0.8060	0.8769	0.9433	1.0062
0.00	0.5026	0.5743	0.7313	0.8202	0.9095	0.9814	1.0406
0.25 D.S.	0.4654	0.5663	wave	wave	wave	wave	wave
0.50 "	0.4520	0.3010	0.8373	0.8582	0.8899	0.9500	1.0120
1.00 "	0.3939	0.7339	0.7474	0.8177	0.9134	0.9747	1.0130
2.00 "	0.2290J	0.7303	wave	wave	0.9218	1.0005	1.0389
4.00 "	0.4705	0.7303	0.8325	0.8873	0.9377	0.9965	1.0458
5.00 "	0.4427	0.7261	0.8325	0.8873	0.9377	0.9950	1.0458
		Run No. (4).		Mean discharge = 1.469 cusecs.			
4.00 U.S.	1.0159	1.0463	1.0746	1.1029	1.1325	1.1669	1.2325
2.00 "	1.0110	1.0430	1.0713	1.0985	1.1289	1.1626	1.2286
1.50 "	1.0036	1.0350	1.0600	1.0910	1.1202	1.1572	1.2195
1.00 "	0.9719	1.0033	1.0316	1.0614	1.0963	1.1310	1.1991
0.50 "	0.8643	0.8999	0.9320	0.9675	1.0015	1.0427	1.1200
0.25 "	0.7642	0.8079	0.8515	0.8868	0.9299	0.9751	1.0643
0.00	0.6719	0.7338	0.7940	0.8416	0.8991	0.9562	1.0544
0.25 D.S.	0.6131	0.7032	0.7817	0.8404	0.9100	wave	wave
0.50 "	0.5779	0.7000	0.8077	0.8938	wave	----	----
1.00 "	0.5189	wave	wave	wave	1.0115	1.0243	1.0866

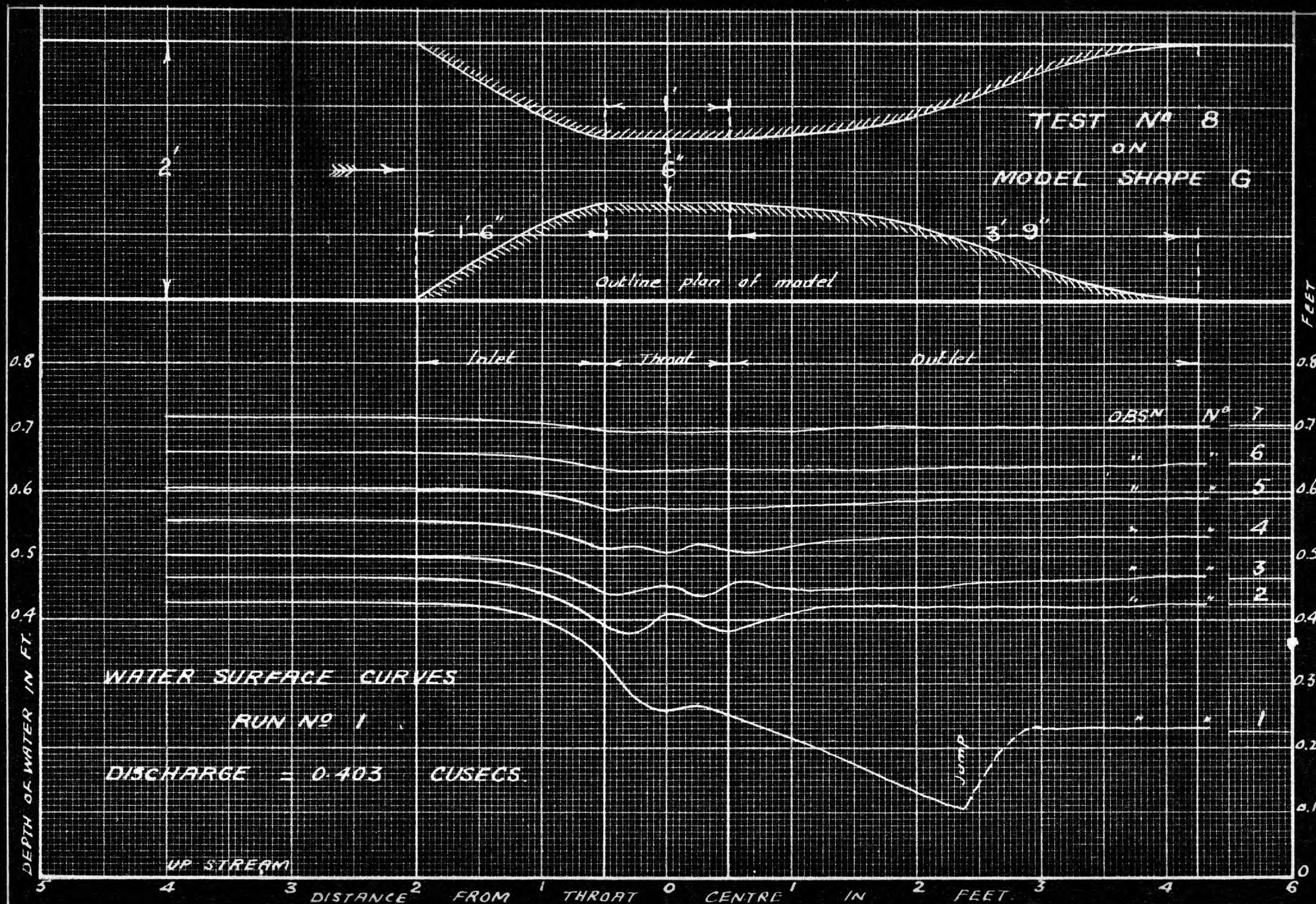
1.5'0.4000J

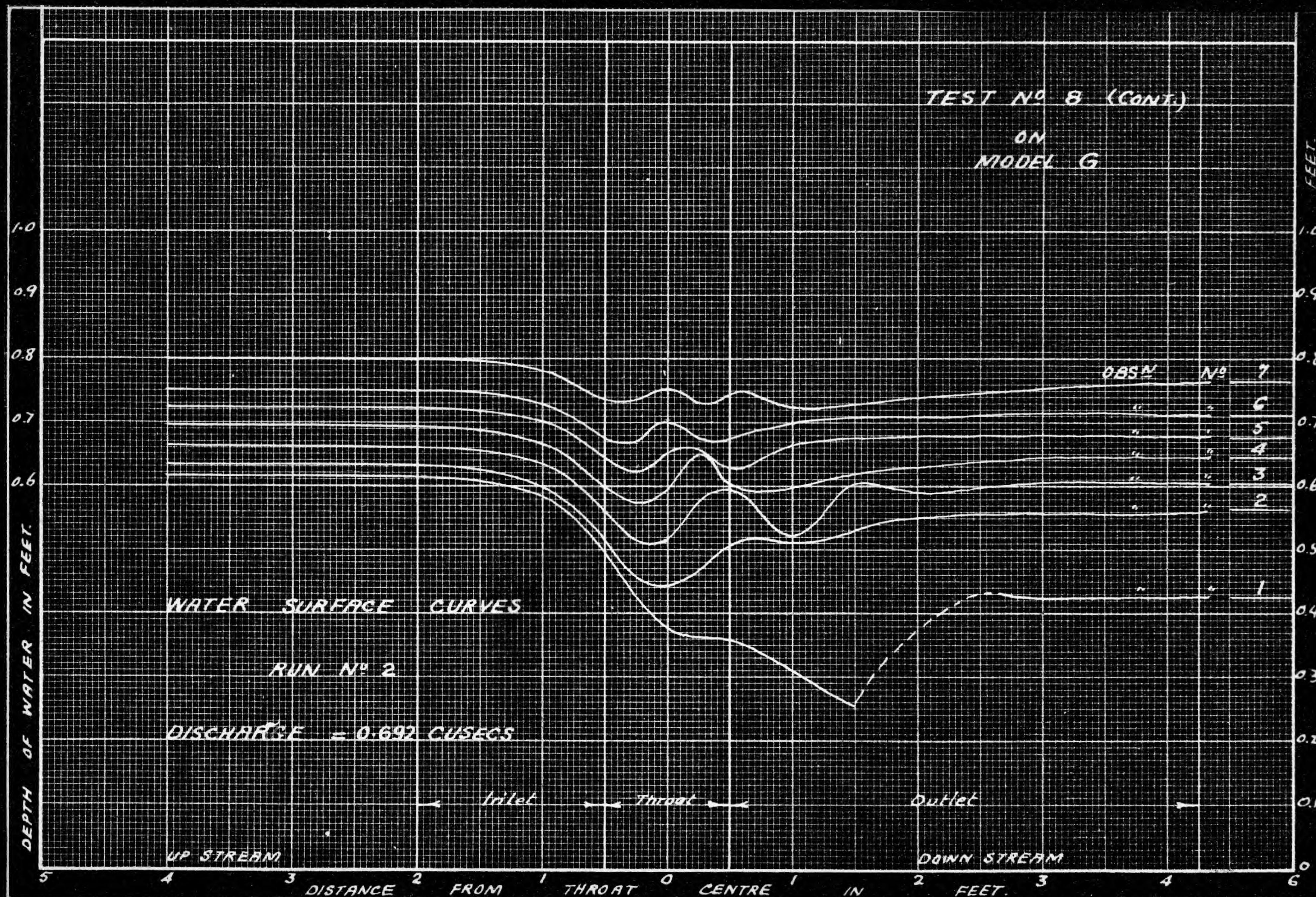
Test No. 8. Continued.

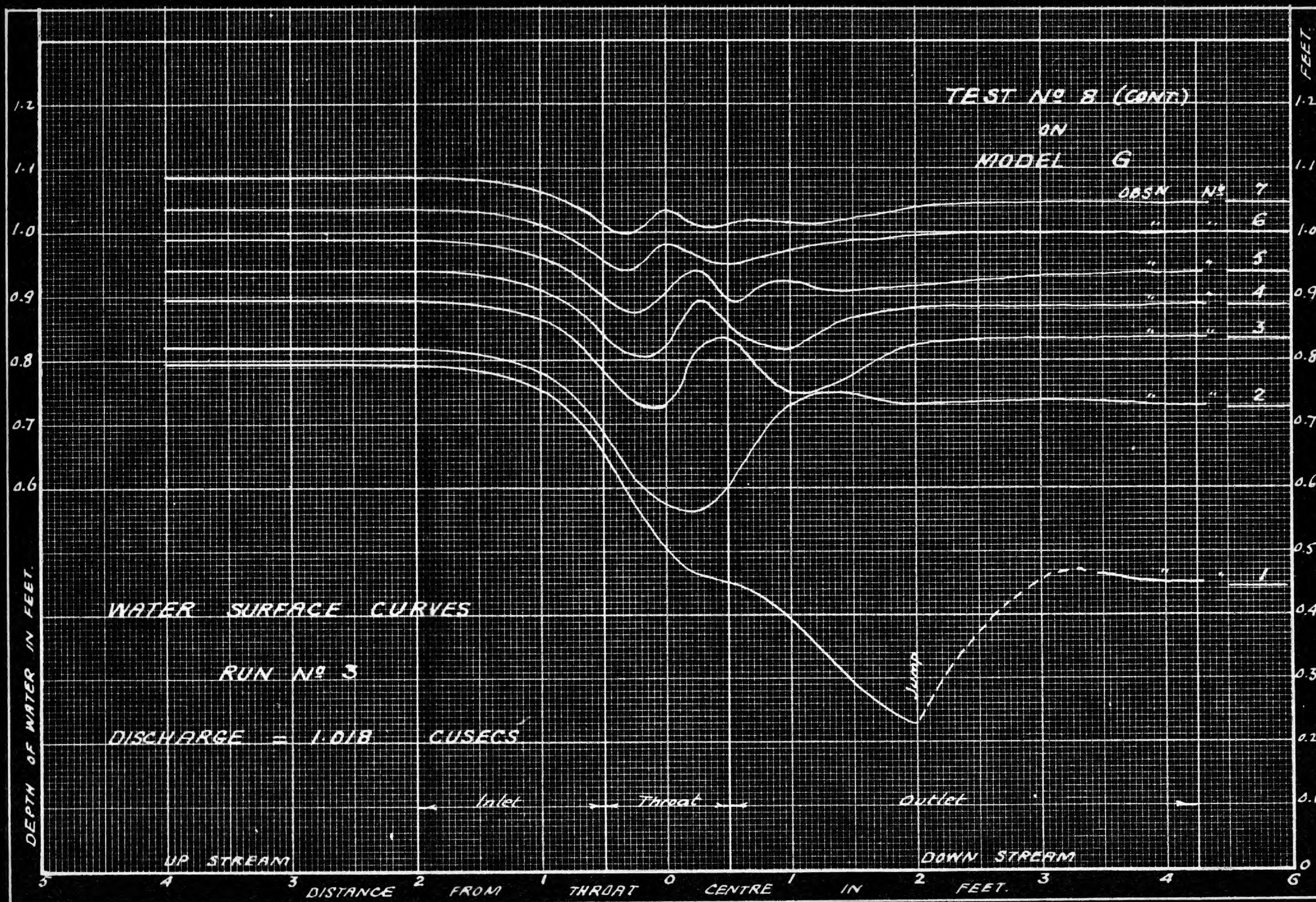
Distance from centre of throat in feet.	Depth of water in feet = Point gauge readings						
	Observation No.						
	1	2	3	4	5	6	7
	Run No. (4). Continued.						
2.00 D.S.	----	0.9000	0.9300	1.0018	1.0356	1.0777	1.1657
4.00 "	0.6523	0.9132	0.9566	1.0177	1.0491	1.0858	1.1636
6.00 "	0.6683	0.9100	0.9700	1.0177	1.0472	1.0858	1.1650

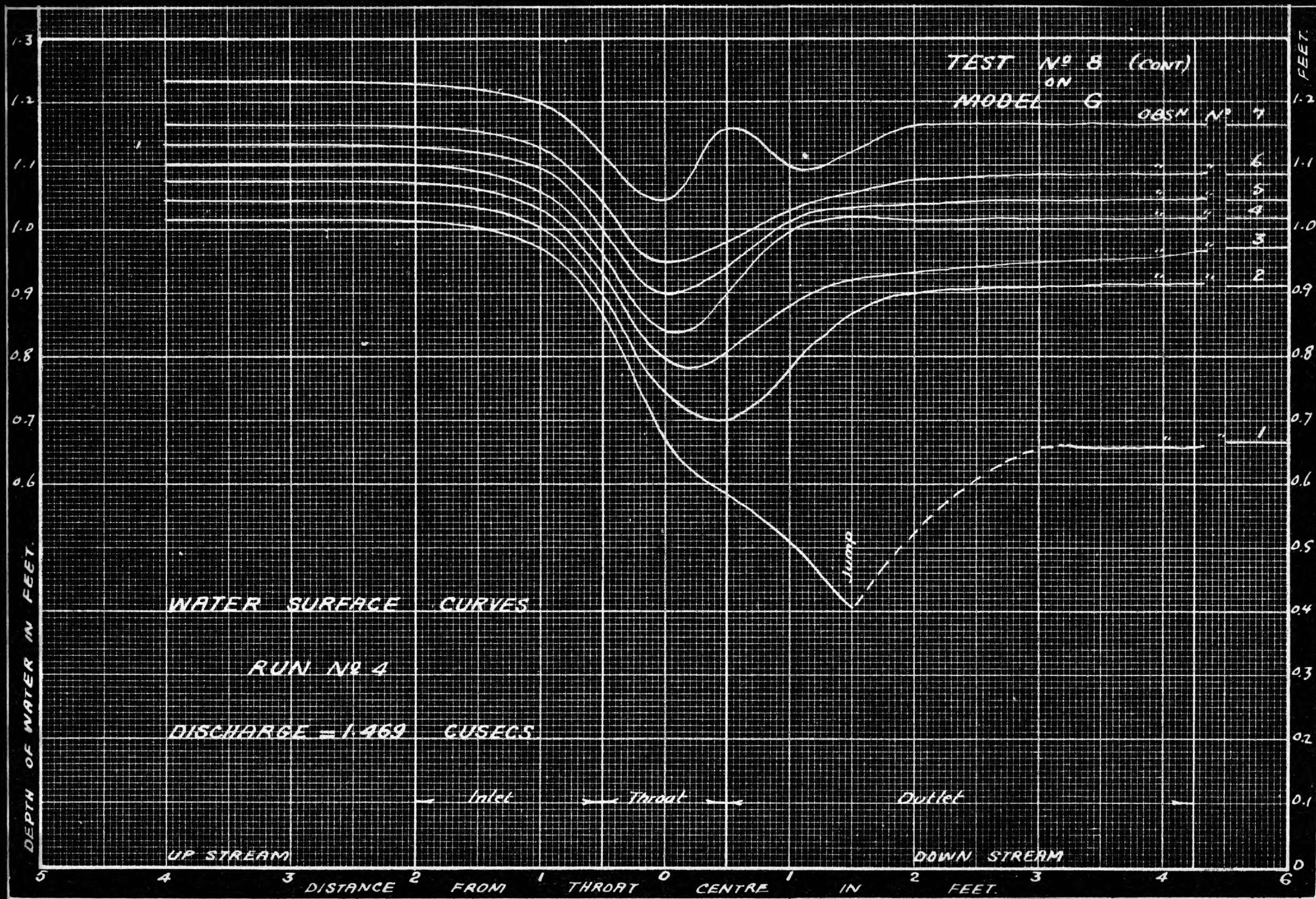
Discharge Observations.

Obsn. No.	R = Rise in Tank in feet.	M = Time in Mins.	Discharge in cusecs. = $\frac{R \times 155}{M \times 60}$.	Obsn. No.	R = Rise in Tank in feet.	M = Time in Mins.	Discharge in cusecs. = $\frac{R \times 155}{M \times 60}$.
	Run No. (1)				Run No. (2)		
1	1.725	11	0.405	1	2.420	9	0.695
2	1.400	9	0.402	2	2.905	11	0.682
3	1.115	7.25	0.398	3	2.410	9	0.693
4	1.100	7	0.406	4	2.160	8	0.698
		Mean=	0.403 cusecs.			Mean =	0.692 cusecs.
	Run No. (3)				Run No. (4)		
1	3.590	9	1.030	1	3.970	7	1.465
2	3.965	10	1.025	2	3.920	7	1.450
3	2.730	7	1.007	3	4.570	8	1.472
4	3.125	8	1.010	4	4.015	7	1.480
		Mean=	1.018 cusecs.			Mean =	1.469 cusecs.


TEST Nº 8
ON
MODEL SHAPE G
2'
1'
6"
1'-6"
3'-9"
Outline plan of model
Inlet
Throat
Outlet
OBSN Nº 7
" " 6
" " 5
" " 4
" " 3
" " 2
" " 1
WATER SURFACE CURVES
RUN Nº 1
DISCHARGE = 0.403 CUSECS.
Jump
UP STREAM
DEPTH OF WATER IN FT.
FEET
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
5 4 3 2 1 0 1 2 3 4 6
DISTANCE FROM THROAT CENTRE IN FEET.


TEST No 8 (CONT.)
ON
MODEL G
OBSN No 7
6
5
4
3
2
1
WATER SURFACE CURVES
RUN No 2
DISCHARGE = 0.692 CUSECS
Inlet
Throat
Outlet
UP STREAM
DOWN STREAM
DEPTH OF WATER IN FEET.
FEET.
DISTANCE FROM THROAT CENTRE IN FEET.
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
5
4
3
2
1
0
1
2
3
4
6


TEST Nº 8 (CONT.)
ON
MODEL G
OBSN Nº 7
" " 6
" " 5
" " 4
" " 3
" " 2
" " 1
WATER SURFACE CURVES
RUN Nº 3
DISCHARGE = 1.018 CUSECS
Jump
Inlet
Throat
Outlet
UP STREAM
DOWN STREAM
DEPTH OF WATER IN FEET.
FEET.
DISTANCE FROM THROAT CENTRE IN FEET.
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
5
4
3
2
1
0
1
2
3
4
6



TEST Nº 8 (CONT)
ON
MODEL G
OBSN Nº 7
6
5
4
3
2
1
Jump
WATER SURFACE CURVES
RUN Nº 4
DISCHARGE = 1.469 CUSECS
Inlet
Throat
Outlet
UP STREAM
DOWN STREAM
DEPTH OF WATER IN FEET.
FEET.
DISTANCE FROM THROAT CENTRE IN FEET.

TEST No. 9

on

Model Shape H.

Throat width 6 inches. Throat length 18 inches.

Distance from centre of throat in feet.	Depth of water in feet = Point gauge readings Observation No. 1	2	3	4	5	6
	Run No. (1) Mean discharge = 0.456 cusecs.					
5.00 U.S.	0.4531	0.4659	0.5402	0.6925	0.8563	
4.00 "	0.4531	0.4661	0.5370	0.6925	0.8563	
3.00 "	0.4510	0.4661	0.5367	0.6925	0.8557	
1.00 "	0.4086	0.4254	0.5061	0.6772	0.8454	
0.75 "	0.3963	0.3999	0.4851	0.6654	0.8401	
0.50 "	0.3293	0.3564	0.4593	0.6631	0.8380	
0.25 "	0.2773	0.3254	wave	0.6553	0.8380	
0.00	0.2541	0.3661	0.4794	0.6638	0.8333	
0.25 D.S.	0.2689	0.4061	0.4638	0.6650	0.8333	
0.50 "	0.2545	0.3722	0.4826	0.6620	0.8333	
0.75 "	0.2217	0.3375	0.4792	0.6676	0.8333	
1.00 "	0.1953	wave	wave	0.6716	0.8333	
2.00 "	0.0843	0.4007	0.4931	0.6700	0.8408	
3.00 "	0.0652J	0.4028	0.4960	0.6717	0.8394	
5.00 "	0.2062	0.4020	0.4942	0.6681	0.8403	
	Run No.(2) Mean discharge = 0.900 cusecs.					
5.00 U.S.	0.7376	0.7834	0.9127	0.9802	1.0570	1.1305
4.00 "	0.7363	0.7827	0.9104	0.9770	1.0570	1.1305
3.00 "	0.7314	0.7810	0.9090	0.9761	1.0546	1.1305
1.00 "	0.6658	0.7318	0.8746	0.9446	1.0260	1.1070
0.25 "	0.6333	0.7011	0.8495	0.9241	1.0196	1.0926
0.50 "	0.5685	0.6480	0.8126	0.8984	0.9984	1.0770
0.25 "	0.4912	0.6049	0.8059	0.8935"	wave	wave
0.00	0.4462	0.6068	0.8630	0.9220	0.9870	1.0830
0.25 D.S.	0.4110	0.7010	0.8264	0.8995	1.0073	1.0918

Test No.9. Continued.

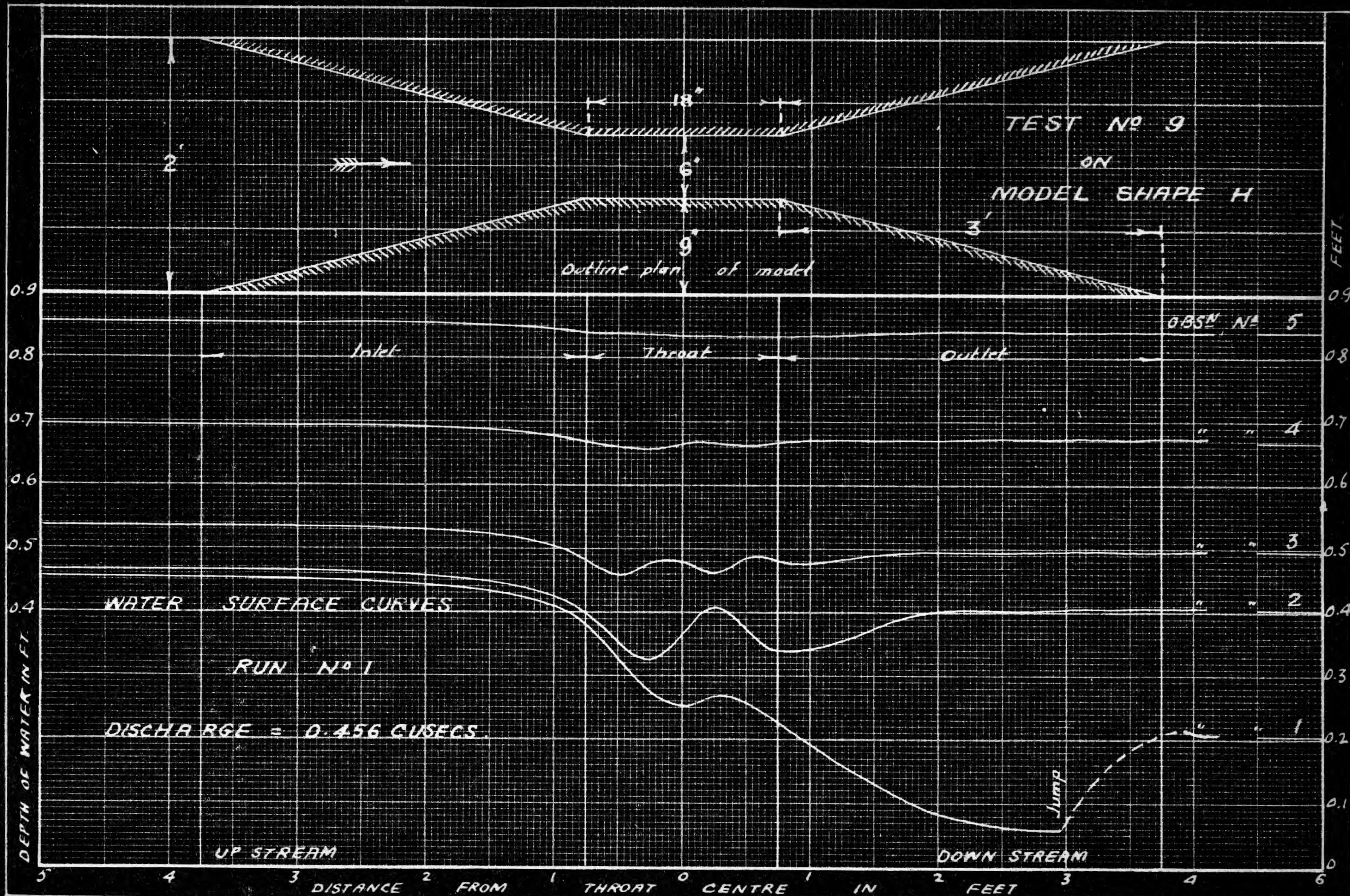
Distance from centre of throat in feet.	Depth of water in feet = Point gauge readings					
	Observation No.					
	1	2	3	4	5	6
			Run No. (2) Continued.			
0.50 D.S.	0.4105	0.7063	0.8195	0.9200	1.0069	1.0814
0.75 "	0.3830	0.6652	0.8365	0.9200	0.9922	1.0923
1.00 "	0.3173	0.6181	0.8566	wave	wave	wave
1.4" wave						
2.00 D.S.	----	0.6985				
6.00 "	0.5127	0.7026	0.8592	0.9334	1.0197	1.1003
		Run No. (3)	Mean discharge = 1.209 cusecs.			
5.00 U.S.	0.8789	0.8848	0.9051	1.0069	1.1190	1.1450
4.00 "	0.8769	0.8827	0.9039	1.0047	1.1190	1.1450
3.00 "	0.8720	0.8794	0.9017	1.0030	1.1189	1.1436
1.00 "	0.8056	0.8131	0.8394	0.9540	1.0775	1.1029
0.75 "	0.7669	0.7737	0.8027	0.9208	1.0540	1.0800
0.50 "	0.6984	0.7103	0.7430	0.8739	1.0143	1.0430
0.25 "	0.5918	0.6264	0.6686	0.8308	0.9918	1.0307
0.00	0.5415	0.5636	0.6140	0.8300	1.0630	1.0960
0.25 D.S.	0.5017	0.5320	0.6130	wave	1.0476	1.0714
0.50 "	0.4798	0.5290	0.6669	0.8298	1.0126	1.0420
0.75 "	0.4574	wave	wave	0.8800	1.0106	1.0535
1.00 "	0.3941	----	----	wave	wave	1.1055
1.5 Jump						
2.00 D.S.	----	----	----	0.9275	1.0580	1.0871
6.00 "	0.5640	0.7145	0.7614	0.9290	1.0598	1.0957
		Run No. (4)	Mean discharge = 1.541 cusecs.			
5.00 U.S.	1.0335	1.0472	1.1112	1.1804	1.2582	1.3110
4.00 "	1.0315	1.0452	1.1097	1.1793	1.2600	1.3110
3.00 "	1.0264	1.0399	1.1045	1.1763	1.2580	1.3110
1.00 "	0.9514	0.9616	1.0423	1.1164	1.2106	1.2723
0.75 "	0.9081	0.9269	1.0022	1.0834	1.1786	1.2417

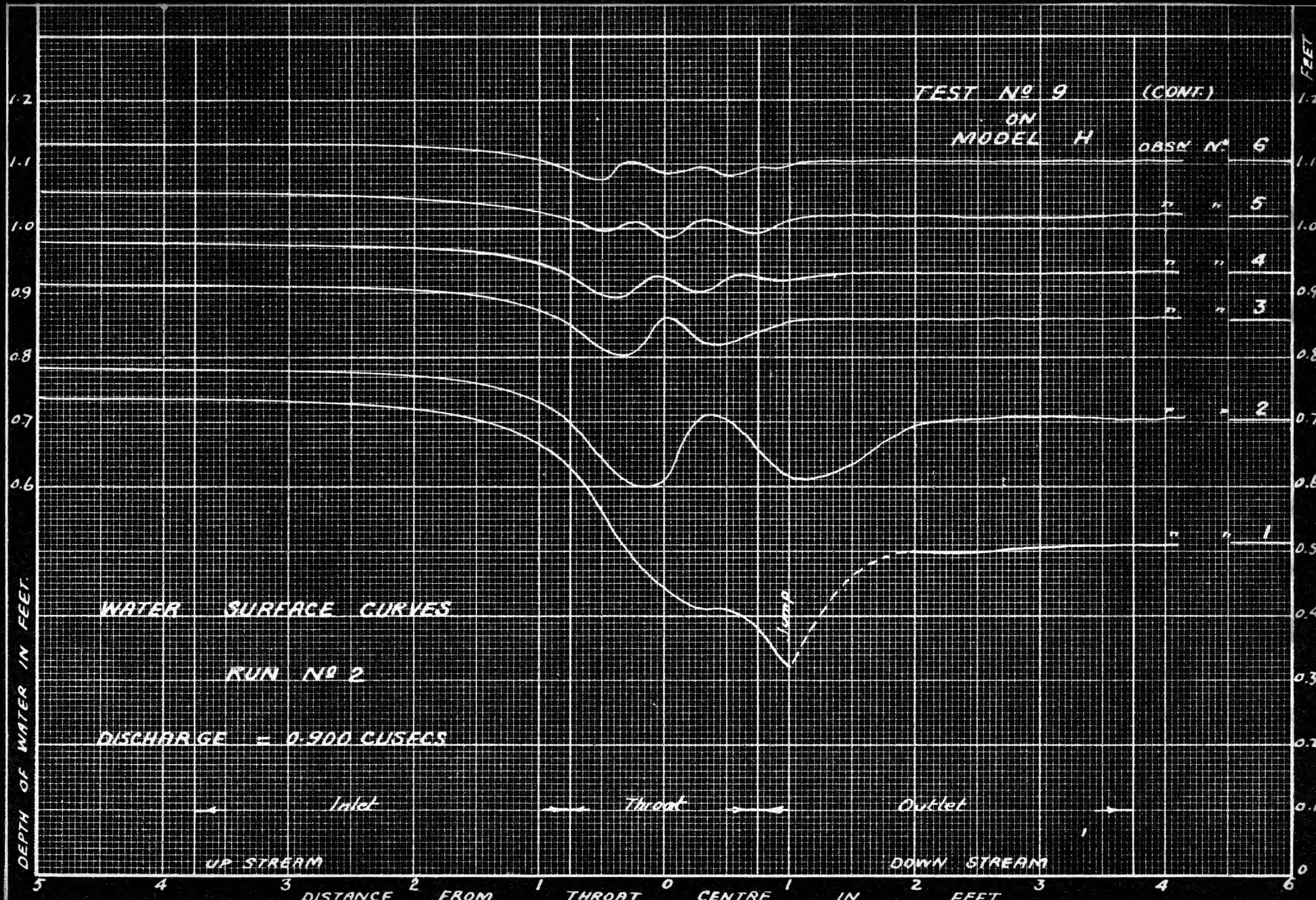
Test 9. Continued.

Distance from centre of throat in feet.	Depth of water in feet = Point gauge readings. Observation No. 1	2	3	4	5	6
			Run No.(4) Continued.			
0.50 U.S.	0.8396	0.8565	0.9406	1.0305	1.1304	1.1963
0.25 "	0.7466	0.7709	0.8680	0.9726	1.0803	1.1578
0.00	0.6623	0.6924	0.8207	0.9485	1.0828	1.1834
0.25 D.S.	0.5993	0.6475	0.8319	1.0080	wave	wave
0.50 "	0.5650	0.6334	0.8981	wave	1.1982	1.2350
0.75 "	0.5315	wave	wave	----	1.1398	wave
1.00 "	0.4723	----	----	----	wave	----
2.00 "	Jump	-----	----	----	1.1839	1.2400
6.00 "	0.6332	0.8476	0.9850	1.0892	1.1818	1.2450

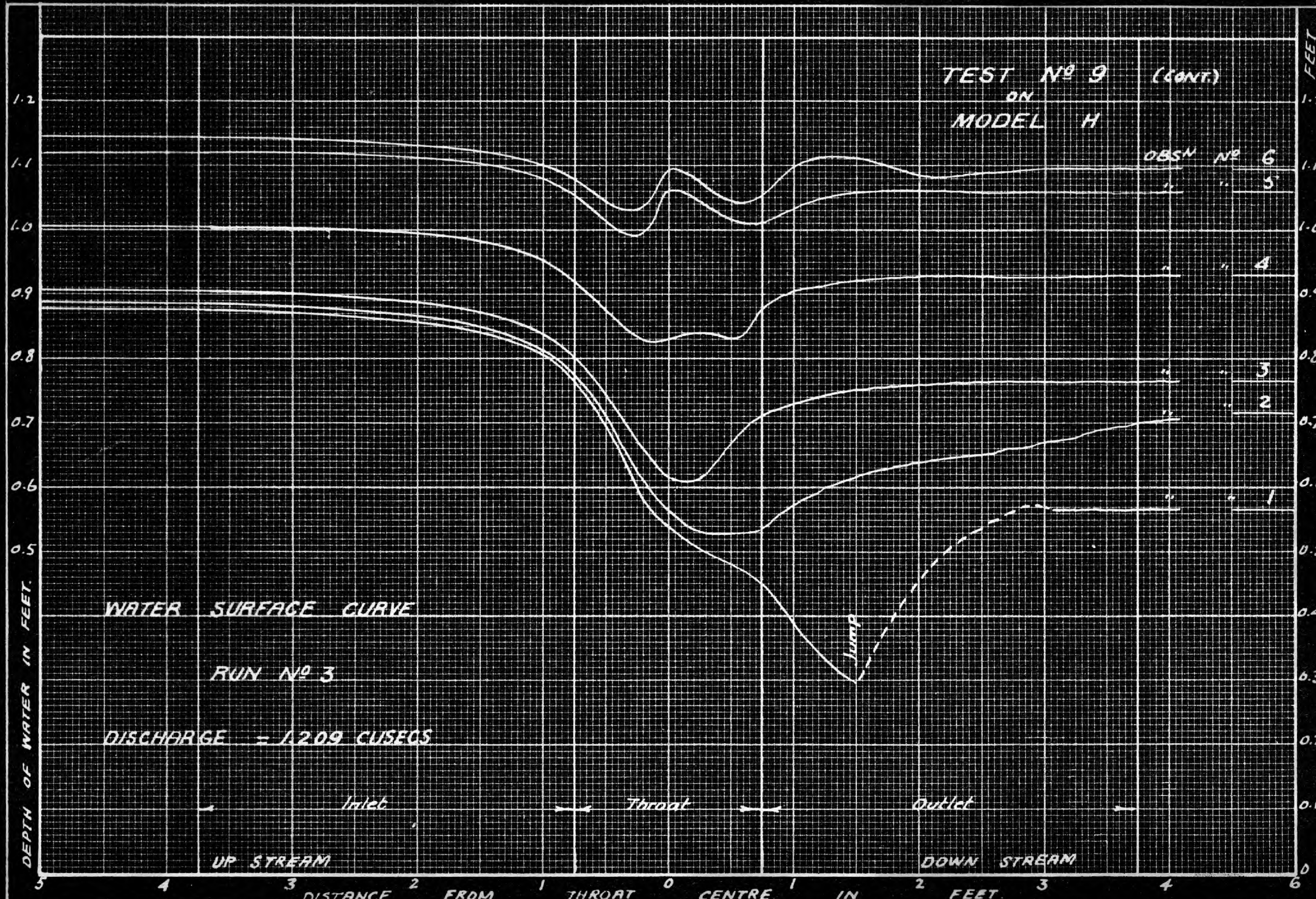
Discharge Observations.

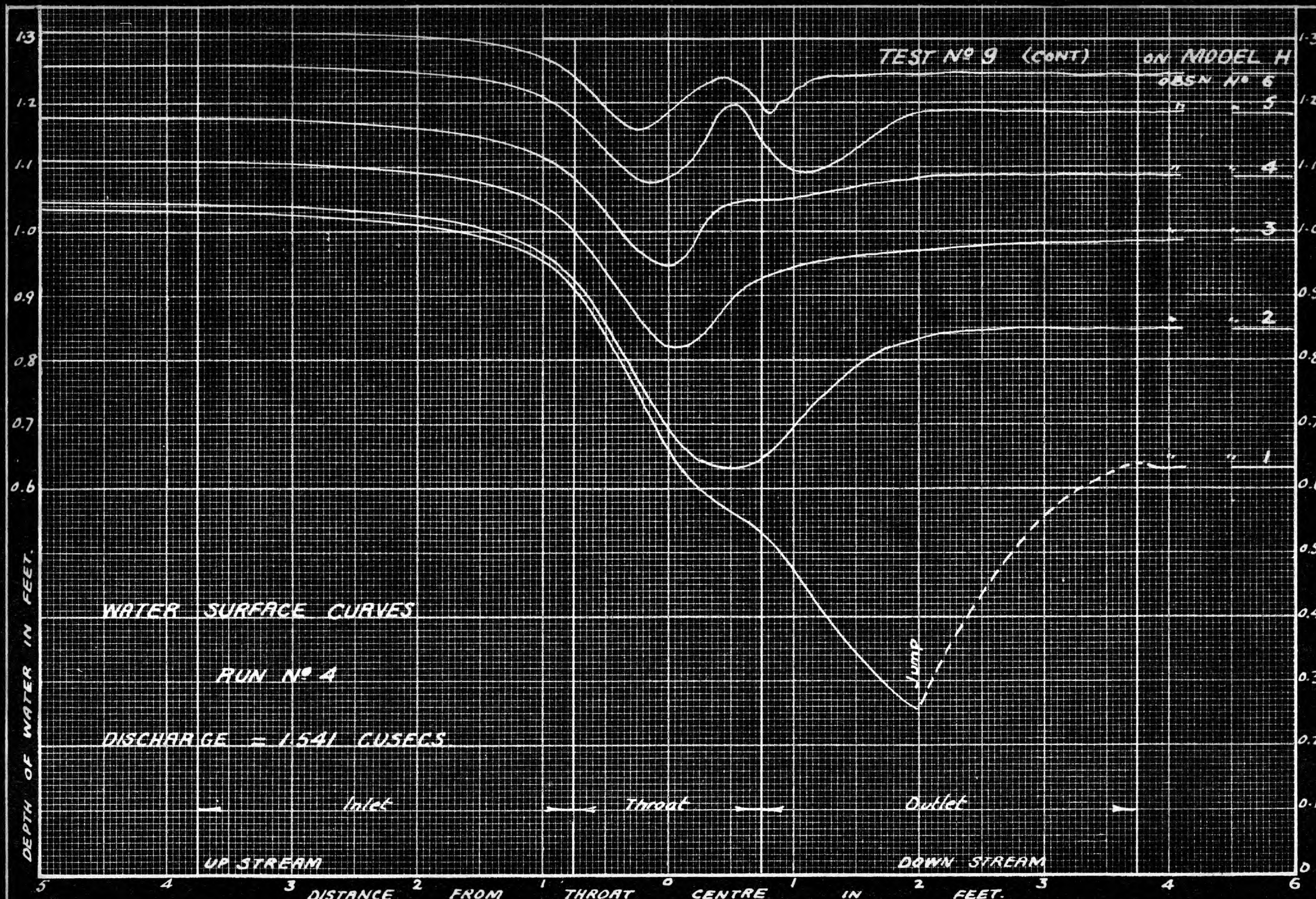
Obsn. No.	R = Rise in Tank in feet.	M = Time in Mins.	Discharge in cusecs.= $\frac{R \times 155}{M \times 60.}$	Obsn. No.	R = Rise in Tank in feet.	M = Time in Mins.	Discharge in cusecs.= $\frac{R \times 155}{M \times 60.}$
	Run No. (1)				Run No. (2)		
1	1.235	7	0.456	1	2.440	7	0.900
2	1.230	7	0.453	2	2.450	7	0.903
3	1.240	7	0.458	3	2.440	7	0.900
4	1.235	7	0.456	4	2.430	7	0.897
		Mean =	0.456 cusecs.			Mean=	0.900 cusecs.
	Run No. (3)				Run No. (4)		
1	3.280	7	1.210	1	3.580	6	1.541
2	3.275	7	1.209	2	2.980	5	1.540
3	3.270	7	1.207	3	3.585	6	1.543
4	3.275	7	1.209	4	3.575	6	1.540
		Mean =	1.209 cusecs.			Mean =	1.541 cusecs.


TEST Nº 9
ON
MODEL SHAPE H
18"
2'
6"
9"
3'
Outline plan of model
Inlet
Throat
Outlet
OBSN Nº 5
" " 4
" " 3
" " 2
" " 1
WATER SURFACE CURVES
RUN Nº 1
DISCHARGE = 0.456 CUSECS.
Jump
UP STREAM
DOWN STREAM
DEPTH OF WATER IN FT.
FEET
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
5 4 3 2 1 0 1 2 3 4 6
DISTANCE FROM THROAT CENTRE IN FEET



TEST Nº 9 (CONT.)
ON
MODEL H
OBSN Nº 6
" " 5
" " 4
" " 3
" " 2
" " 1
Jump
WATER SURFACE CURVES
RUN Nº 2
DISCHARGE = 0.900 CUSECS
Inlet
Throat
Outlet
UP STREAM
DOWN STREAM
DEPTH OF WATER IN FEET.
FEET
DISTANCE FROM THROAT CENTRE IN FEET
5 4 3 2 1 0 1 2 3 4 6
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1 1.2


TEST Nº 9 (CONT.)
ON
MODEL H
OBSN Nº 6
" " 5
" " 4
" " 3
" " 2
" " 1
WATER SURFACE CURVE
RUN Nº 3
DISCHARGE = 1.209 CUSECS
Jump
Inlet
Throat
Outlet
UP STREAM
DOWN STREAM
DEPTH OF WATER IN FEET.
FEET
DISTANCE FROM THROAT CENTRE IN FEET
5 4 3 2 1 0 1 2 3 4 6
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1 1.2


TEST Nº 9 (CONT) ON MODEL H
OBSN Nº 6
" " 5
" " 4
" " 3
" " 2
" " 1
WATER SURFACE CURVES
RUN Nº 4
DISCHARGE = 1.541 CUSECS.
Jump
Inlet
Throat
Outlet
UP STREAM
DOWN STREAM
DEPTH OF WATER IN FEET.
DISTANCE FROM THROAT CENTRE IN FEET.
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
5
4
3
2
1
0
1
2
3
4
6

TEST No. 10

on

Model Shape I.

Throat width 6 inches. Throat length 12 inches.

Distance from centre of throat in feet.	Depth of water in feet - Point gauge readings. Observation No. 1	2	3	4	5	6	7
Run No. (1) Mean discharge = 0.410 cusecs.							
5.00 U.S.	0.4399	0.4714	0.4995	0.5539	0.6040	0.6654	0.7192
4.00 "	0.4399	0.4714	0.4993	0.5532	0.6034	0.6643	0.7192
2.00 "	0.4206	0.4560	0.4857	0.5412	0.5951	0.6583	0.7131
1.00 "	0.3588	0.4074	0.4429	0.5101	0.5709	0.6383	0.6981
0.75 "	0.3128	0.3878	0.4368	0.5023	0.5639	0.6328	0.6920
0.25 "	0.3017	0.3900	0.4346	0.5017	0.5622	0.6309	0.6904
0.00	0.2955	0.3872	0.4346	0.5017	0.5609	0.6306	0.6898
0.25 D.S.	0.2869	0.3823	0.4308	0.5017	0.5609	0.6306	0.6898
0.50 "	0.2741	0.3823	0.4330	0.5017	0.5609	0.6300	0.6895
1.00 "	0.2360	0.3876	0.4328	0.5017	0.5648	0.6327	0.6895
2.00 "		0.4285	0.4493	0.5208	0.5756	0.6404	0.7027
2.5'	0.1031J						
4.00 D.S.	0.2118	0.4219	0.4551	0.5208	0.5790	0.6425	0.7005
6.00 "	0.2095	0.4219	0.4609	0.5208	0.5790	0.6434	0.7005
Run No. (2) Mean discharge = For observations 1-4 .. 0.760 cusecs. ,, ,, 5-7 .. 0.800 cusecs.							
5.00 U.S.	0.6640	0.6932	0.7419	0.8186	0.8865	0.9426	0.9936
4.00 "	0.6635	0.6914	0.7404	0.8179	0.8862	0.9426	0.9936
2.00 "	0.6375	0.6693	0.7186	0.8025	0.8673	0.9268	0.9829
1.00 "	0.5493	0.5914	0.6590	0.7559	0.8263	0.8928	0.9516
0.50 "	0.4725	0.5370	0.6312	0.7456	0.8161	0.8817	0.9463
0.25 "	0.4470	0.5344	0.6355	0.7456	0.8175	0.8817	0.9439
0.00	0.4281	0.5436	0.6480	0.7456	0.8156	0.8817	0.9439
0.25 D.S.	0.4137	0.5660	0.6419	0.7401	0.8123	0.8785	0.9424
0.50 "	0.3996	0.5628	0.6279	0.7417	0.8143	0.8785	0.9443

Test 10. Continued.

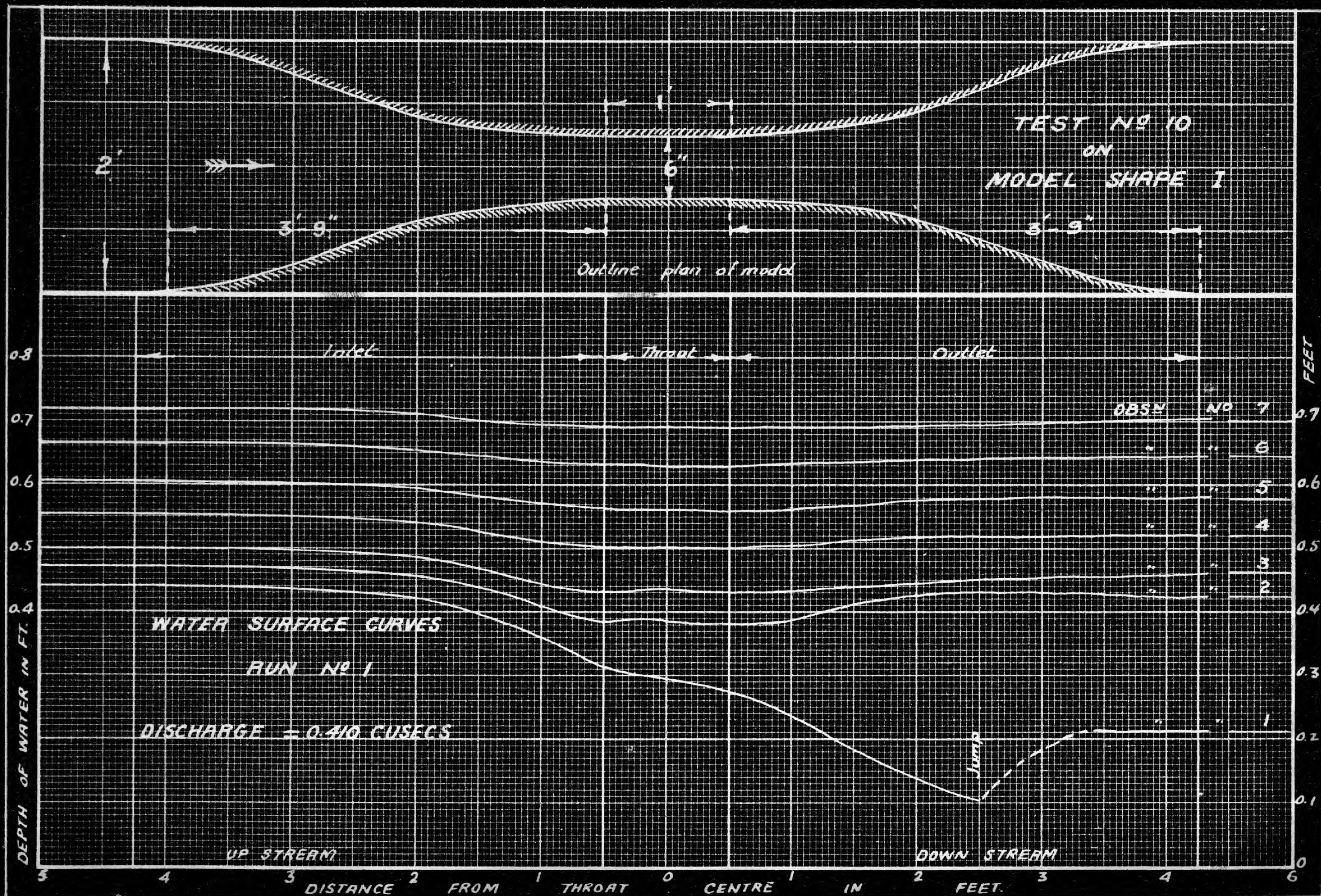
Distance from centre of throat in feet.	Depth of water in feet = Point gauge readings. Observation No. 1	2	3	4	5	6	7
	Run No.(2) Continued.						
1.00 D.S.	0.3425	0.5432	0.6391	0.7400	0.8106	0.8755	0.9408
1.7"	0.2612J	wave					
2.00 D.S.	----	0.5840	0.6832	0.7784	0.8457	0.8986	0.9629
4.00 "	0.4252	0.6123	0.6804	0.7706	0.8395	0.9007	0.9601
6.00 "	0.4252	0.6123	0.6761	0.7706	0.8395	0.9054	0.9616
	Run No. (3) Mean discharge = 1.014 cusecs.						
5.00 U.S.	0.8070	0.8217	0.8584	0.8940	0.8309	0.9960	1.0670
4.00 "	0.8069	0.8212	0.8518	0.8890	0.9310	0.9945	1.0670
2.00 "	0.7760	0.7915	0.8316	0.8617	0.9075	0.9761	1.0479
1.00 "	0.6748	0.6949	0.7466	0.7887	0.8925	0.9222	1.0014
0.50 "	0.5849	0.6157	0.6827	0.7367	0.8025	0.8948	0.9847
0.25 "	0.5477	0.5860	0.6768	0.7224	0.8052	0.9018	0.9912
0.00	0.5210	0.5728	0.6800	0.7475	0.8249	0.9140	0.9901
0.25 D.S.	0.5008	0.5728	0.7107	0.7811	0.8345	0.9064	0.9849
0.50 "	0.4808	0.5800	0.7207	0.7735	0.8147	0.8912	0.9849
1.00 "	0.4129	0.6415	0.7108	0.7364	0.8018	0.9059	0.9800
		1.5'	wave	wave	wave		
2.00 "	0.2259	0.6860	0.7564	0.7979	0.8644	0.9432	1.0179
2.5'	Jump						
4.00 D.S.	----	0.6860	0.7670	0.8059	0.8594	0.9403	1.0174
6.00 "	0.4019	0.7033	0.7871	0.8109	0.8586	0.9400	1.0174
	Run No. (4) Mean discharge = 1.520 cusecs.						
5.00 U.S.	1.0543	1.0748	1.1010	1.1378	1.1862	1.2338	1.2551
4.00 "	1.0543	1.0748	1.1000	1.1364	1.1857	1.2338	1.2532
2.00 "	1.0140	1.0370	1.0626	1.1038	1.1545	1.2056	1.2230
1.00 "	0.8966	0.9229	0.9554	1.0067	1.0646	1.1245	1.1493
0.50 "	0.7826	0.8217	0.8648	0.9196	1.0000	1.0788	1.0946
0.25 "	0.7275	0.7757	0.8282	0.9008	0.9853	1.0656	1.0955

Test No. 10. Continued.

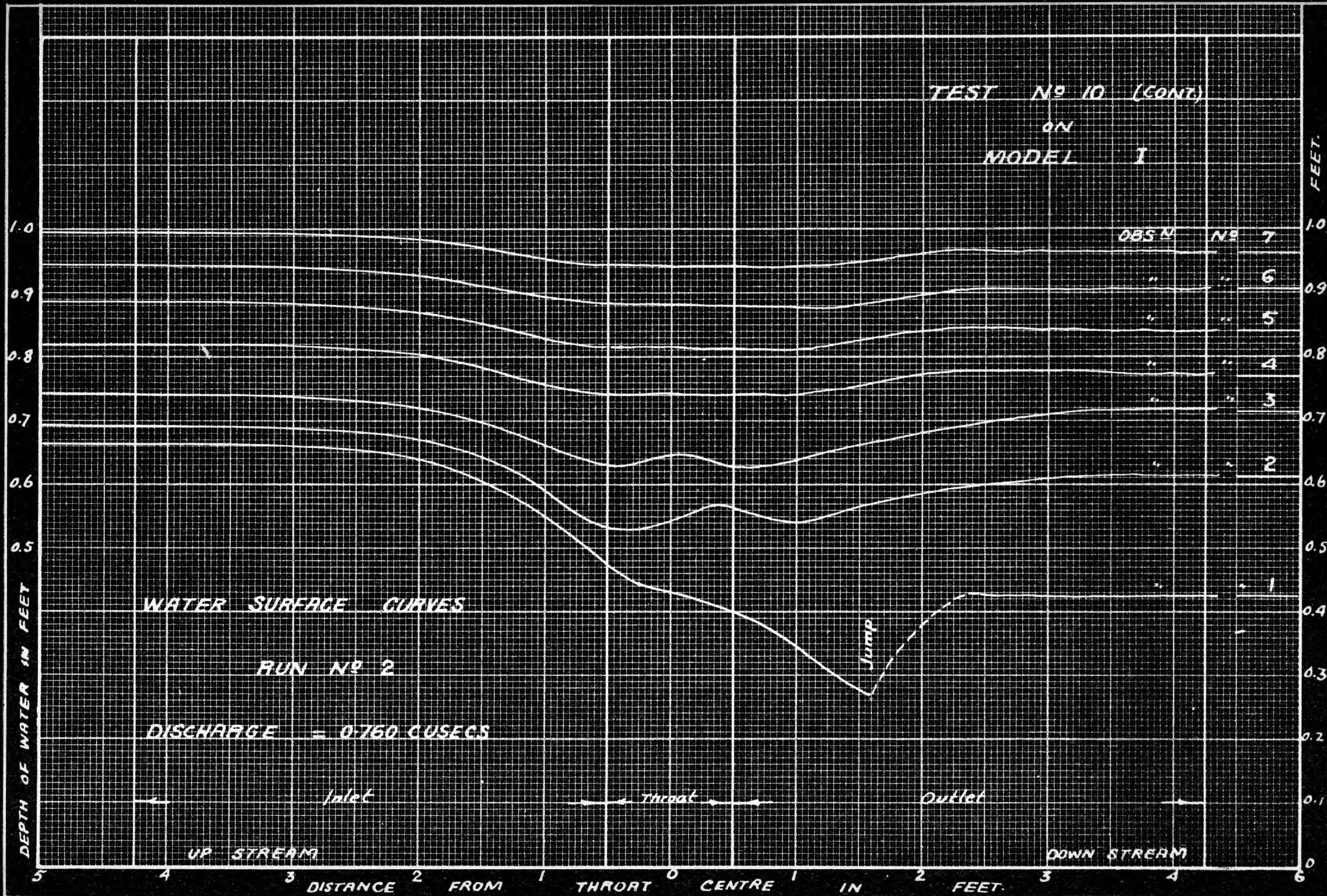
Distance from centre of throat in feet.	Depth of water in feet = Point gauge readings Observation No. 1	2	3	4	5	6	7
			Run No.(4) Continued.				
0.00	0.6813	0.7430	0.8084	0.8957	0.9974	1.0831	1.1158
0.25 D.S.	0.6471	0.7297	0.8126	0.9071	1.0125	1.1160	1.1415
0.50 "	0.6182	0.7351	0.8251	0.9424	1.0505	1.1212	1.1405
1.00 "	0.5369	0.7402	0.8854	0.9930	1.0441	1.0784	1.0971
		wave		1.5	wave	wave	wave
2.00 "	0.2994J	0.9093	0.9534	1.0330	1. 0805	1.1356	1.1559
4.00 "	----	0.9054	0.9623	1.0290	1.0890	1.1422	1.1692
6.00 "	0.6341	0.9104	0.9830	1.0344	1.1045	1.1520	1.1810

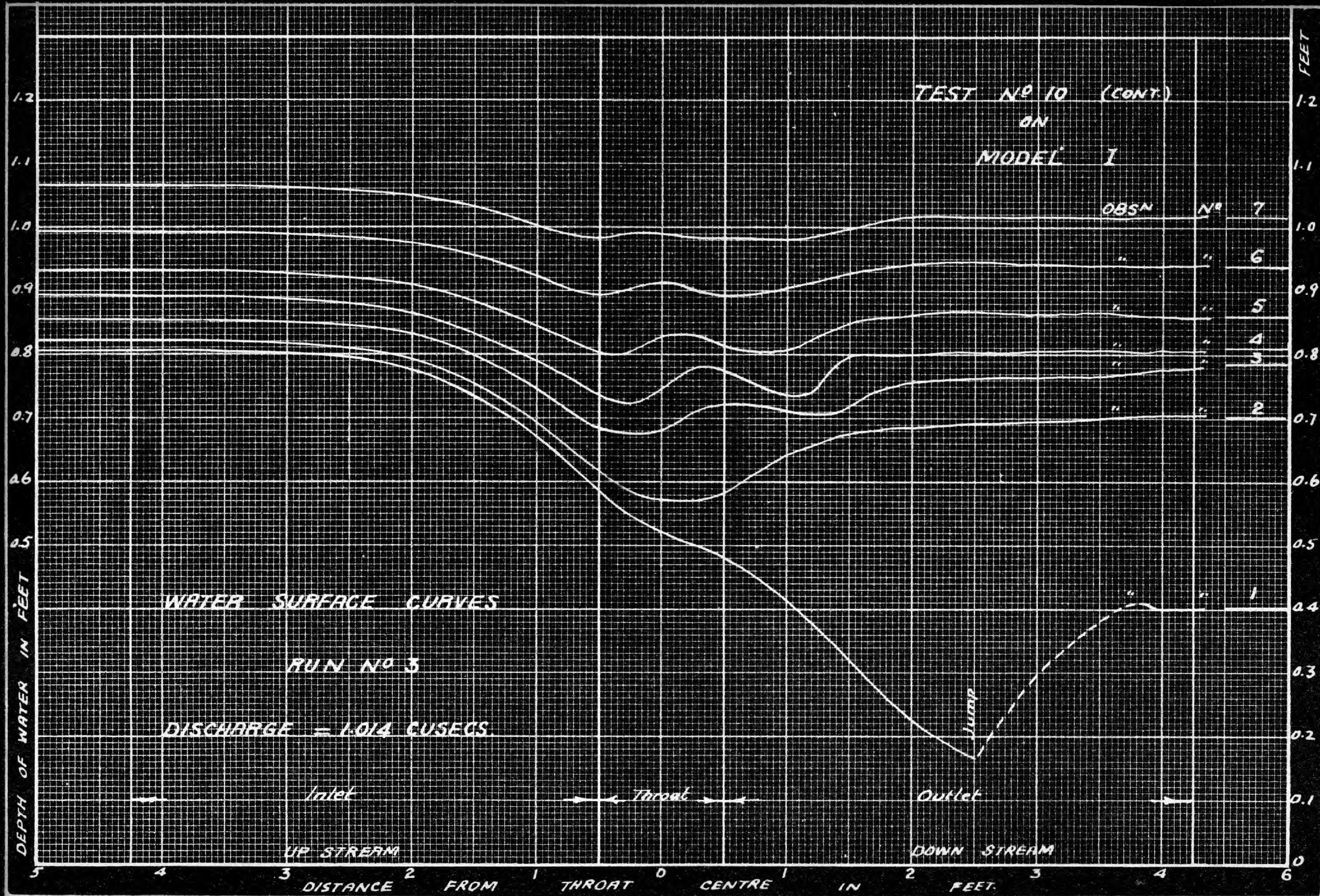
Discharge Observations.

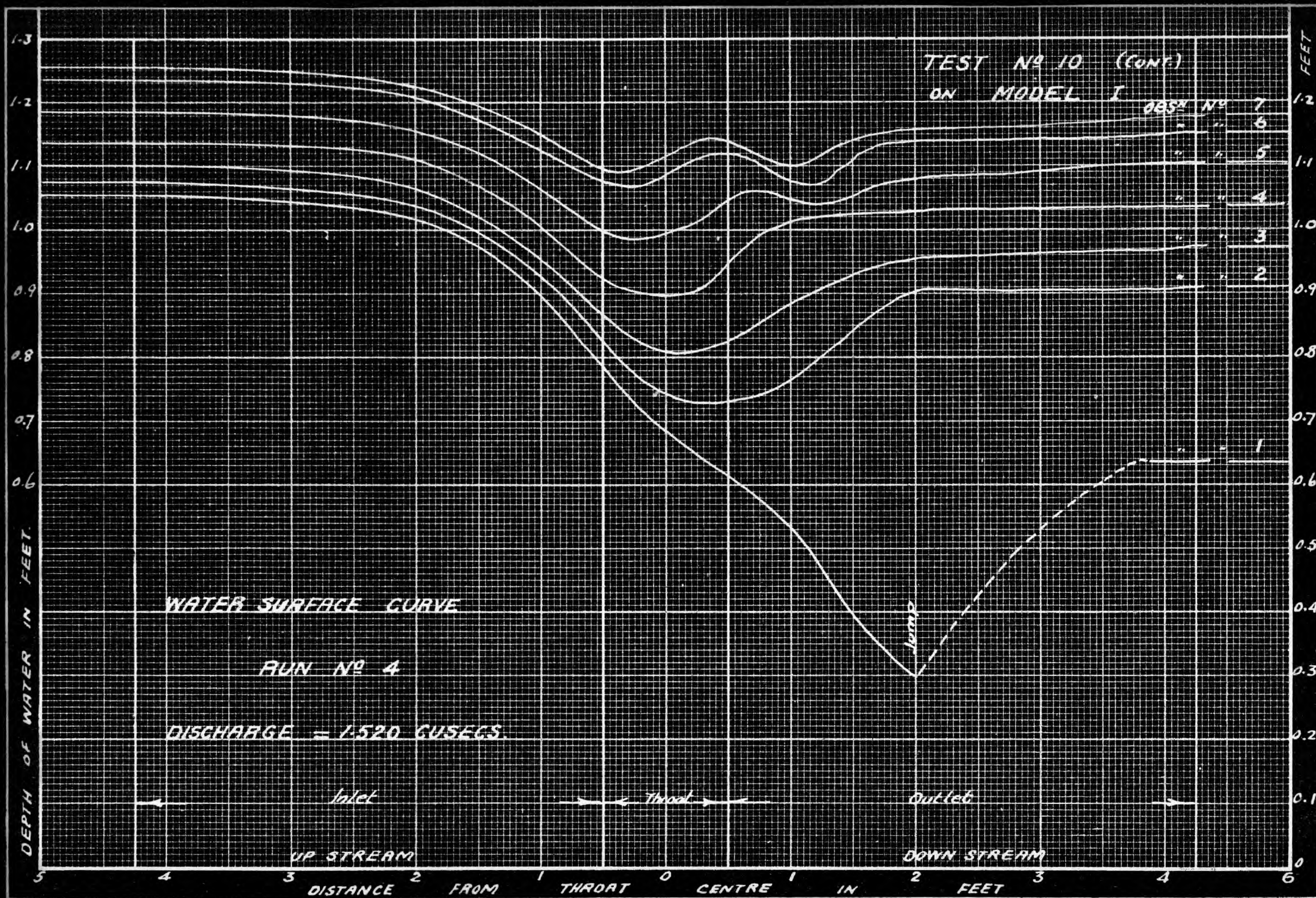
Obsn. No.	R = Rise in Tank in feet.	M = Time in Mins.	Discharge in cusecs. = $\frac{R \times 155}{M \times 60}$	Obsn. No.	R = Rise in Tank in feet.	M = Time in Mins.	Discharge in cusecs. = $\frac{R \times 155}{M \times 60}$
	Run No. (1)				Run No. (2)		
1	1.115	7	0.412	1	2.08	7	0.767
2	0.800	5	0.413	2	1.75	6	0.753
3	1.110	7	0.409			Mean =	0.760 cusecs.
4	0.785	5	0.406				
		Mean =	0.410 cusecs.	3	1.86	6	0.800
				4	1.86	6	0.800
						Mean =	0.800 cusecs.
	Run No. (3)				Run No.(4).		
1	2.700	7	0.997	1	3.540	6	1.523
2	3.540	9	1.015	2	4.100	7	1.513
3	2.745	7	1.013	3	4.130	7	1.524
4	2.390	6	1.030	4	4.120	7	1.520
		Mean =	1.014 cusecs.			Mean =	1.520 cusecs.



TEST No 10
ON
MODEL SHAPE I
2'
1'
6"
3'-9"
3'-9"
Outline plan of model
Inlet
Throat
Outlet
OBSN No 7
6
5
4
3
2
1
WATER SURFACE CURVES
RUN No 1
DISCHARGE = 0.410 CUSECS
Jump
UP STREAM
DOWN STREAM
DEPTH OF WATER IN FT.
FEET
DISTANCE FROM THROAT CENTRE IN FEET
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
5 4 3 2 1 0 1 2 3 4 6


TEST Nº 10 (CONT.)
ON
MODEL I
WATER SURFACE CURVES
RUN Nº 2
DISCHARGE = 0.760 CUSECS
OBSN Nº 7
6
5
4
3
2
1
Jump
Inlet
Throat
Outlet
UP STREAM
DOWN STREAM
DEPTH OF WATER IN FEET
FEET.
DISTANCE FROM THROAT CENTRE IN FEET.
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
5
4
3
2
1
0
1
2
3
4
6


TEST Nº 10 (CONT.)
ON
MODEL I
WATER SURFACE CURVES
RUN Nº 3
DISCHARGE = 1.014 CUSECS.
OBSN Nº 7
" " 6
" " 5
" " 4
" " 3
" " 2
" " 1
Jump
Inlet
Throat
Outlet
UP STREAM
DOWN STREAM
DEPTH OF WATER IN FEET
FEET
DISTANCE FROM THROAT CENTRE IN FEET.


TEST Nº 10 (CONT.)
ON MODEL I
OBSN Nº 7
6
5
4
3
2
1
WATER SURFACE CURVE
RUN Nº 4
DISCHARGE = 1.520 CUSECS.
Inlet
Throat
Outlet
Jump
UP STREAM
DOWN STREAM
DEPTH OF WATER IN FEET.
FEET
DISTANCE FROM THROAT CENTRE IN FEET
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
5
4
3
2
1
0
1
2
3
4
6

TESTS NO. 11 AND 12.

These two tests were carried out on Model "I" of test (10) one with the same 6" throat and the other on the same model but with 8" throat. During each test the observations were taken from a practical point of view. No readings for water surface curves were taken. For each run a constant flow was passed and a set of observations were taken with different upstream and downstream levels. The levels were varied in the same way as before by means of the tail level regulation weir. For the observation of levels, the Micrometer screw point gauge shown on Plate III as well as the Piezometer Tube Gauges shown on Plate II were used. Each observation consisted of upstream and throat point and tube gauge readings and downstream tube gauge reading. The point gauge was not used in the downstream due to eddies. Point gauge readings were taken along the centre line of flume and due to uniform flow and absence of central surface waves, gave the mean depths of water at the point of measurement at each row of pressure holes inside the throat the actual water depth was measured by the point gauge and the mean pressure was observed on the tube gauge. The throat tube gauge was then connected to the three sets of holes and the mean static pressure on the bed of the throat from a point 3" upstream to a point 3" downstream the centre was thus observed. The corresponding mean actual depth was taken as the calculated mean of the three point gauge readings.

On the observation sheets d_1, d_2, and d_3 denote the upstream, throat, and downstream gauge readings respectively.

The actual discharge was measured in the same way as before.

TEST NO. 11

on

Model I.

Throat length 12 inches. Throat width 6 inches.

Obsn. No.	d_1 in feet. Point Gauge Readings.	d_1 in feet. Piezometer Gauge Readings.	Distance from throat centre in feet	d_2 in feet. Point Gauge Readings.	d_2 in feet. Piezometer Gauge Readings.	d_3 in feet. Piezometer Gauge Readings.
	Run No. 1.					
	0.3002	Free flow.				
1	0.3131	0.310	mean	0.2498	0.250	0.280
2	0.3282	0.328	,,	0.294	0.292	0.315
3	0.3652	0.365	,,	0.3313	0.330	0.350
4	0.3963	0.395	,,	0.3642	0.365	0.385
5	0.4272	0.425	,,	0.4015	0.400	0.415
6	0.4638	0.460	,,	0.4441	0.442	0.455
7	0.5015	0.500	,,	0.4848	0.485	0.495
	Run No. 2.					
	0.445	Free flow.				
1	0.445	0.445	0.25 U.S.	0.2977	0.300	
			0.00	0.2892	0.288	
			0.25 D.S.	0.2795	0.288	
			Mean	(0.2888)	0.295	0.365
2	0.4536	0.454	0.25 U.S.	0.3418	0.342	
			0.00	0.3418	0.340	
			0.25 D.S.	0.3535	0.352	
			Mean	(0.3457)	0.345	0.395
3	0.4658	0.466	0.25 U.S.	0.3800	0.380	
			0.00	0.3820	0.380	
			0.25 D.S.	0.3769	0.380	
			Mean	(0.3800)	0.380	0.425
4	0.4872	0.485	0.25 U.S.	0.4110	0.410	
			0.00	0.4060	0.410	
			0.25 D.S.	0.4060	0.410	
			Mean	(0.4073)	0.410	0.445
5	0.5165	0.515	0.25 U.S.	0.4521	0.455	
			0.00	0.4521	0.455	
			0.25 D.S.	0.4521	0.455	
			Mean	(0.4521)	0.455	0.490

Obsn. No.	d_1 in feet.		Distance from throat centre in feet.	d_2 in feet.		d_3 in feet
	Point Gauge Readings.	Piezometer Gauge Readings.		Point Gauge Readings.	Piezometer Gauge Readings.	Piezometer Gauge Readings.
	Run No. 2 (Continued)					
6	0.5490	0.548	0.25 U.S.	0.4948	0.500	
			0.00	0.4948	0.500	
			0.25 D.S.	0.4948	0.500	
			Mean	(0.4948)	0.500	0.525
7	0.5806	0.578	0.25 U.S.	0.5358	0.538	
			0.00	0.5358	0.538	
			0.25 D.S.	0.5358	0.538	
			Mean	(0.5358)	0.538	0.560
8	0.6040	0.600	Mean	0.5645	0.565	0.585
9	0.6215	0.620	Mean	0.5848	0.585	0.608
10	0.6293	0.628	Mean	0.5970	0.598	0.620

Obsn. No.	d_1 in feet. Point Gauge Readings.	d_1 in feet. Piezometer Gauge Readings.	Distance from throat centre in feet.	d_2 in feet Point Gauge Readings.	d_2 in feet Piezometer Gauge Readings.	d_3 in feet Piezometer Gauge Readings.
	Run No. 3.					
	0.6450	Free flow.				
1	0.6481	0.6450	0.25 U.S.	0.4325	0.4450	
			0.00	0.4171	0.4180	
			0.25 D.S.	0.4062	0.4080	
			Mean	(0.419)	0.4280	0.510
2	0.6495	0.648	0.25 U.S.	0.4479	0.4650	
			0.00	0.4436	0.4500	
			0.25 D.S.	0.4427	0.4550	
			Mean	(0.445)	0.4550	0.560
3	0.6575	0.655	0.25 U.S.	0.4710	0.492	
			0.00	0.4698	0.485	
			0.25 D.S.	0.4764	0.500	
			Mean	0.473	0.495	0.575
4	0.6771	0.675	0.25 U.S.	0.5236	0.545	
			0.00	0.5376	0.545	
			0.25 D.S.	0.5600	0.555	
			Mean	(0.540)	0.550	0.615
5	0.6896	0.688	0.25 U.S.	0.5605	0.572	
			0.00	0.5633	0.570	
			0.25 D.S.	0.5843	0.580	
			Mean	(0.569)	0.575	0.625
6	0.7150	0.715	0.25 U.S.	0.6104	0.618	
			0.00	0.6249	0.612	
			0.25 D.S.	0.6197	0.620	
			Mean	(0.618)	0.618	0.655
7	0.7352	0.735	0.25 U.S.	0.6450	0.645	
			0.00	0.6543	0.645	
			0.25 D.S.	0.6453	0.648	
			Mean	(0.648)	0.645	0.685
8	0.7517	0.750	0.25 U.S.	0.6647	0.665	
			0.00	0.6684	0.662	
			0.25 D.S.	0.6644	0.665	
			Mean	(0.666)	0.665	0.705
9	0.8240	0.820	0.25 U.S.	0.7587	0.758	
			0.00	0.7547	0.758	
			0.25 D.S.	0.7527	0.760	
			Mean	(0.755)	0.758	0.795
10	0.8569	0.852	0.25 U.S.	0.7947	0.798	
			0.00	0.7947	0.795	
			0.25 D.S.	0.7947	0.795	
			Mean	(0.795)	0.795	0.830

Obsn. No.	d_1 in feet. Point Gauge Readings.	d_1 in feet. Piezometer Gauge Readings.	Distance from throat centre in feet.	d_2 in feet Point Gauge Readings.	d_2 in feet Piezometer Gauge Readings.	d_3 in feet Piezometer Gauge Readings
	Run No. 4.					
	0.7636	Free flow.				
1	0.7721	0.770	0.25 U.S.	0.5360	0.558	
			0.00	0.5186	0.530	
			0.25 D.S.	0.5091	0.550	
			Mean	(0.521)	0.550	0.665
2	0.7838	0.784	0.25 U.S.	0.5667	0.600	
			0.00	0.5744	0.592	
			0.25 D.S.	0.5822	0.610	
			Mean	(0.574)	0.600	0.695
3	0.7989	0.796	0.25 U.S.	0.6035	0.638	
			0.00	0.6115	0.632	
			0.25 D.S.	0.6321	0.646	
			Mean	(0.616)	0.640	0.715
4	0.8179	0.815	0.25 U.S.	0.6539	0.675	
			0.00	0.6600	0.675	
			0.25 D.S.	0.6912	0.675	
			Mean	(0.668)	0.675	0.740
5	0.8373	0.830	0.25 U.S.	0.6868	0.708	
			0.00	0.7067	0.708	
			0.25 D.S.	0.7235	0.708	
			Mean	(0.706)	0.708	0.765
6	0.8635	0.855	0.25 U.S.	0.7360	0.750	
			0.00	0.7574	0.750	
			0.25 D.S.	0.7574	0.750	
			Mean	(0.750)	0.750	0.795
7	0.8820	0.876	0.25 U.S.	0.7705	0.775	
			0.00	0.7906	0.775	
			0.25 D.S.	0.7821	0.775	
			Mean	(0.781)	0.775	0.815
8	0.9005	0.898	0.25 U.S.	0.8020	0.805	
			0.00	0.8151	0.805	
			0.25 D.S.	0.8052	0.805	
			Mean	(0.807)	0.805	0.845
9	0.9263	0.925	0.25 U.S.	0.8385	0.835	
			0.00	0.8423	0.835	
			0.25 D.S.	0.8300	0.838	
			Mean	(0.837)	0.835	0.875
10	0.9643	0.965	0.25 U.S.	0.8915	0.885	
			0.00	0.8869	0.885	
			0.25 D.S.	0.8823	0.885	
			Mean	(0.887)	0.885	0.920

Obsn. No.	d_1 in feet: Point Gauge Readings.	d_1 in feet: Piezometer Gauge Readings.	Distance from throat centre in feet.	d_2 in feet: Point Gauge Readings.	d_2 in feet: Piezometer Gauge Readings.	d_3 in feet: Piezometer Gauge Readings.
	Run No. 5.					
	0.8459	Free flow.				
1	0.8504	0.847	0.25 U.S.	0.5866	0.615	
			0.00	0.5609	0.588	
			0.25 D.S.	0.5541	0.595	
			Mean	(0.567)	0.600	0.705
2	0.8582	0.856	0.25 U.S.	0.6016	0.640	
			0.00	0.5941	0.620	
			0.25 D.S.	0.5927	0.635	
			Mean	(0.596)	0.640	0.745
3	0.8661	0.865	0.25 U.S.	0.6207	0.655	
			0.00	0.6140	0.645	
			0.25 D.S.	0.6216	0.660	
			Mean	(0.619)	0.655	0.765
4	0.8762	0.875	0.25 U.S.	0.6558	0.688	
			0.00	0.6410	0.675	
			0.25 D.S.	0.6606	0.692	
			Mean	(0.652)	0.685	0.785
5	0.9047	0.905	0.25 U.S.	0.7018	0.745	
			0.00	0.7091	0.740	
			0.25 D.S.	0.7430	0.752	
			Mean	(0.718)	0.745	0.825
6	0.9287	0.930	0.25 U.S.	0.7581	0.795	
			0.00	0.7844	0.790	
			0.25 D.S.	0.8125	0.805	
			Mean	(0.785)	0.795	0.865
7	0.9522	0.952	0.25 U.S.	0.7986	0.828	
			0.00	0.8261	0.828	
			0.25 D.S.	0.8342	0.835	
			Mean	(0.820)	0.830	0.890
8	0.9730	0.9730	0.25 U.S.	0.8464	0.8600	
			0.00	0.8698	0.860	
			0.25 D.S.	0.8747	0.865	
			Mean	(0.864)	0.860	0.920
9	0.9985	0.997	0.25 U.S.	0.8847	0.897	
			0.00	0.9024	0.895	
			0.25 D.S.	0.9024	0.900	
			Mean	(0.897)	0.898	0.945
10	1.0248	1.022	0.25 U.S.	0.9229	0.925	
			0.00	0.9386	0.925	
			0.25 D.S.	0.9304	0.930	
			Mean	(0.931)	0.925	0.968

Obsn. No.	d_1 in feet. Point Gauge Readings.	d_1 in feet. Piezometer Gauge Readings.	Distance from throat centre in feet.	d_2 in feet Point Gauge Readings.	d_2 in feet Piezometer Gauge Readings.	d_3 in feet Piezometer Gauge Readings.
	Run No. 6.					
	0.9447	Free flow.				
1	0.9650	0.962	0.25 U.S.	0.6918	0.738	
			0.00	0.6672	0.705	
			0.25 D.S.	0.6672	0.722	
			Mean	(0.675)	0.720	0.840
2	0.9799	0.978	0.25 U.S.	0.7227	0.765	
			0.00	0.7107	0.755	
			0.25 D.S.	0.7236	0.765	
			Mean	(0.719)	0.765	0.870
3	1.002	0.996	0.25 U.S.	0.7617	0.815	
			0.00	0.7594	0.805	
			0.25 D.S.	0.7851	0.818	
			Mean	(0.769)	0.815	0.905
4	1.0238	1.020	0.25 U.S.	0.8104	0.855	
			0.00	0.8196	0.850	
			0.25 D.S.	0.8471	0.865	
			Mean	(0.826)	0.860	0.940
5	1.0456	1.043	0.25 U.S.	0.8553	0.895	
			0.00	0.8711	0.890	
			0.25 D.S.	0.9023	0.900	
			Mean	(0.876)	0.895	0.960
6	1.0680	1.065	0.25 U.S.	0.8921	0.930	
			0.00	0.9148	0.925	
			0.25 D.S.	0.9448	0.935	
			Mean	(0.917)	0.930	0.985
7	1.0883	1.085	0.25 U.S.	0.9265	0.960	
			0.00	0.9514	0.955	
			0.25 D.S.	0.9737	0.965	
			Mean	(0.951)	0.960	1.010
8	1.1130	1.115	0.25 U.S.	0.9684	0.995	
			0.00	0.9996	0.990	
			0.25 D.S.	1.0094	1.000	
			Mean	(0.992)	0.995	1.050
9	1.1424	1.142	0.25 U.S.	1.0155	1.030	
			0.00	1.0347	1.028	
			0.25 D.S.	1.0435	1.035	
			Mean	(1.031)	1.030	1.085
10	1.1586	1.158	0.25 U.S.	1.0406	1.052	
			0.00	1.0623	1.050	
			0.25 D.S.	1.0649	1.055	
			Mean	(1.056)	1.055	1.100

Obsn. No.	d_1 in feet. Point Gauge Readings.	d_1 in feet. Piezometer Gauge Readings.	Distance from throat centre in feet.	d_2 in feet Point Gauge Readings.	d_2 in feet Piezometer Gauge Readings.	d_3 in feet Piezometer Gauge Readings.
	Run No. 7.					
	1.0752	Free flow				
1	1.1012	1.098	0.25 U.S.	0.7968	0.840	
			0.00	0.7708	0.815	
			0.25 D.S.	0.7578	0.825	
			Mean	(0.775)	0.820	0.945
2	1.1160	1.112	0.25 U.S.	0.8243	0.875	
			0.00	0.8027	0.855	
			0.25 D.S.	0.7984	0.870	
			Mean	(0.808)	0.870	0.985
3	1.1337	1.132	0.25 U.S.	0.8613	0.915	
			0.00	0.8526	0.900	
			0.25 D.S.	0.8555	0.920	
			Mean	(0.856)	0.910	1.020
4	1.1489	1.148	0.25 U.S.	0.8945	0.948	
			0.00	0.8912	0.940	
			0.25 D.S.	0.8965	0.955	
			Mean	(0.894)	0.950	1.045
5	1.1728	1.172	0.25 U.S.	0.9323	0.985	
			0.00	0.9323	0.975	
			0.25 D.S.	0.9574	0.995	
			Mean	(0.941)	0.985	1.075
6	1.1857	1.185	0.25 U.S.	0.9574	1.010	
			0.00	0.9574	1.005	
			0.25 D.S.	0.9913	1.015	
			Mean	(0.969)	1.010	1.090
7	1.1984	1.198	0.25 U.S.	0.9821	1.030	
			0.00	0.9917	1.028	
			0.25 D.S.	1.0242	1.040	
			Mean	(0.999)	1.030	1.105
8	1.2137	1.214	0.25 U.S.	1.0073	1.056	
			0.00	1.0259	1.045	
			0.25 D.S.	1.0578	1.060	
			Mean	(1.030)	1.055	1.125
9	1.2256	1.225	0.25 U.S.	1.0270	1.070	
			0.00	1.0460	1.065	
			0.25 D.S.	1.0753	1.075	
			Mean	(1.049)	1.070	1.135
10	1.2417	1.240	0.25 U.S.	1.0572	1.098	
			0.00	1.0756	1.095	
			0.25 D.S.	1.1035	1.100	
			Mean	(1.079)	1.098	1.155

Test No. 11. Continued.

Discharge Observations.

Obsn. No.	R = Rise in tank in feet.	M = Time in minutes.	Discharge in cusecs. = $\frac{R \times 155}{M \times 60}$.	Mean discharge = Qa in cusecs.
		Run No. 1.		
1	0.670	7	0.250	
2	0.755	8	0.245	
3	0.585	6	0.252	0.249
4	0.580	6	0.520	
		Run No. 2.		
1	1.705	10	0.441	
2	1.855	11	0.435	0.445
3	0.875	5	0.452	
4	0.870	5	0.450	
		Run No. 3.		
1	2.950	10	0.762	
2	2.070	7	0.764	0.756
3	2.345	8	0.757	
4	1.445	5	0.746	
		Run No. 4.		
1	2.290	6	0.984	
2	2.680	7	0.990	0.989
3	1.905	5	0.984	
4	2.315	6	0.997	
		Run No. 5.		
1	2.635	6	1.134	
2	1.825	4	1.180	1.152
3	1.785	4	1.153	
4	2.215	5	1.142	
		Run No. 6.		
1	2.115	4	1.365	
2	2.120	4	1.360	1.358
3	2.125	4	1.372	
4	2.065	4	1.336	

Test No. 11. Continued.

Discharge Observations (Continued).

Obsn. No.	R = Rise in tank in feet.	M = Time in minutes.	Discharge in cusecs. $= \frac{R \times 155}{M \times 60}$.	Mean discharge = Qa in cusecs.
		Run No. 7.		
1	3.145	5	1.622	
2	3.170	5	1.640	1.634
3	3.190	5	1.650	
4	3.150	5	1.625	

TEST Nº 11 ON MODEL I

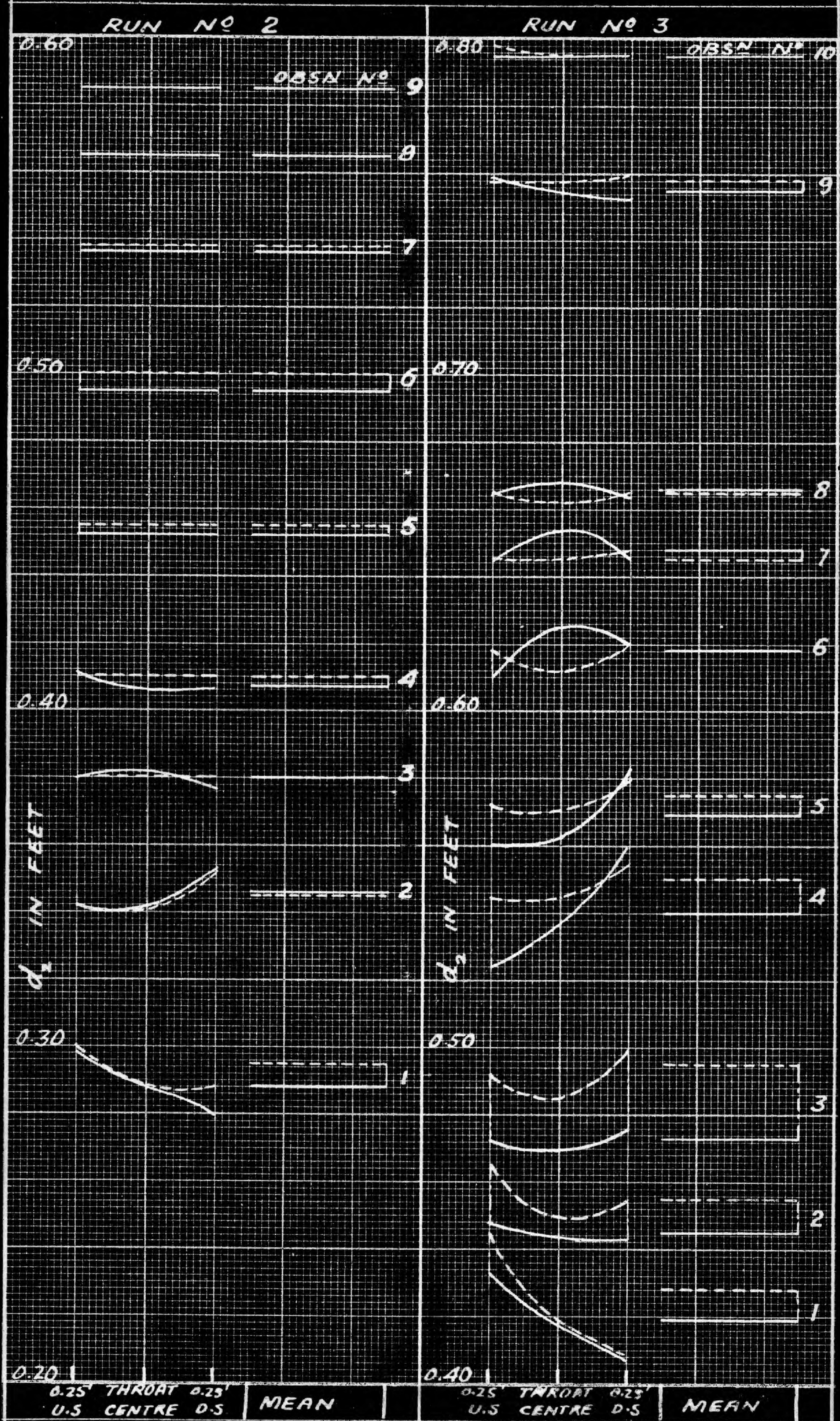


DIAGRAM SHOWING ACTUAL WATER DEPTHS INSIDE THE THROAT PLOTTED (——) AND THEIR CORRESPONDING PIEZOMETER GAUGE READINGS PLOTTED (- - - -)

TEST Nº 11 ON MODEL I

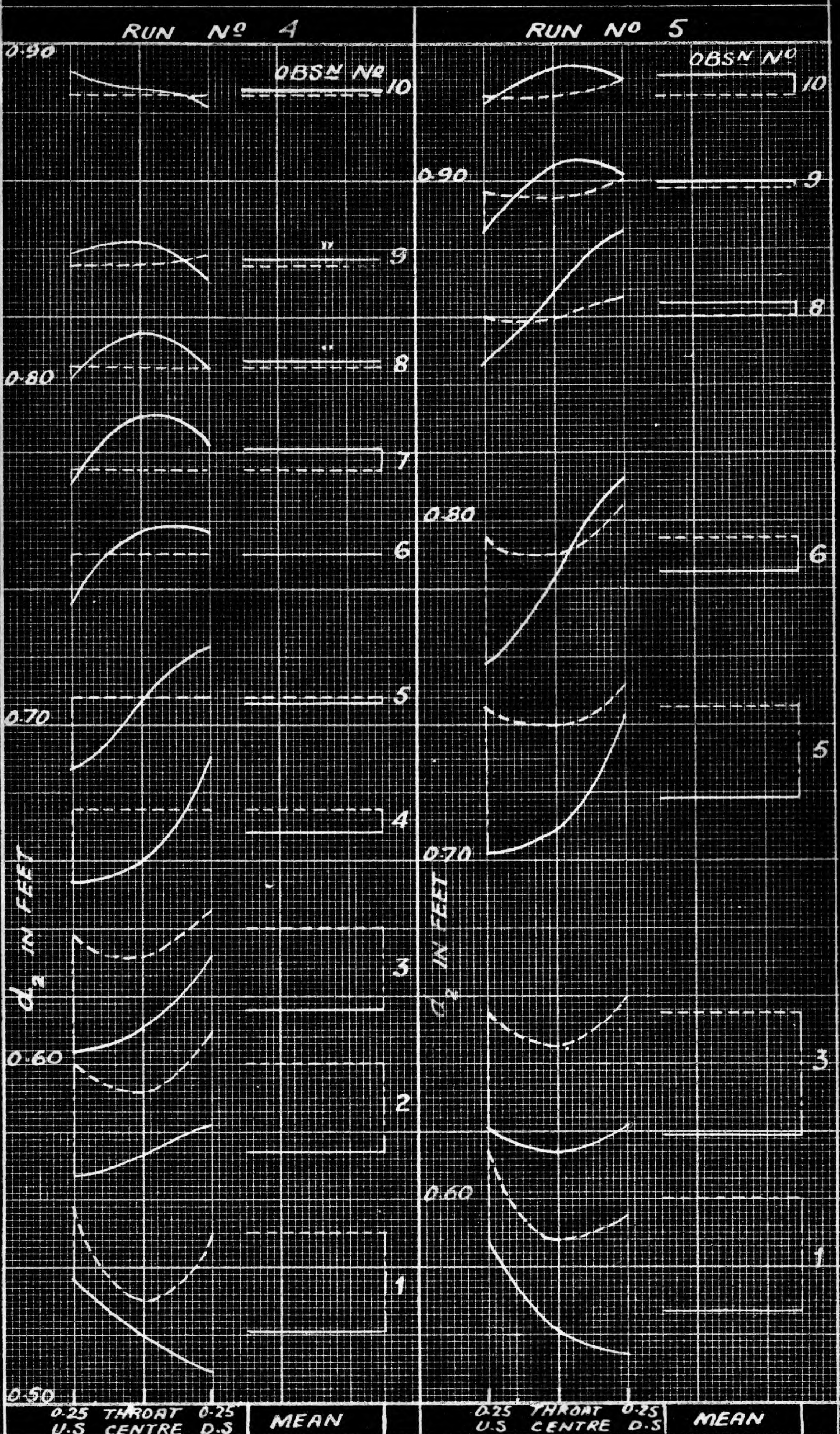


DIAGRAM SHOWING ACTUAL WATER DEPTHS INSIDE THE THROAT PLOTTED (——) AND THEIR CORRESPONDING PIEZOMETER GAUGE READINGS PLOTTED (- - - -)

TEST No 11 ON MODEL I

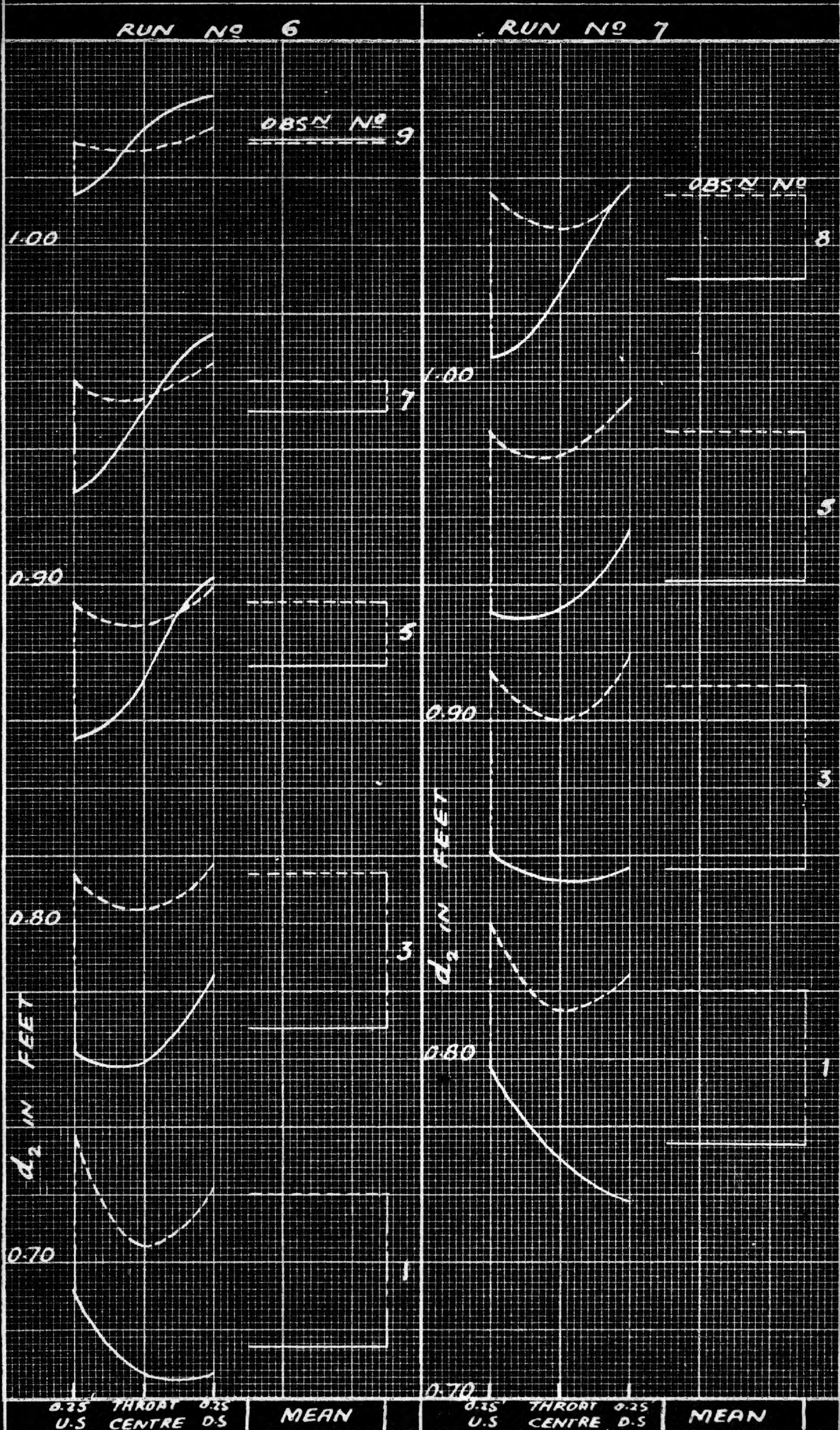


DIAGRAM SHOWING ACTUAL WATER DEPTHS INSIDE THE THROAT PLOTTED (—) AND THEIR CORRESPONDING PIEZOMETER GAUGE READINGS PLOTTED (-----)

Test No. 12

Model I.

Throat length 12 inches. Throat width 8 inches.

Obsn. No.	d_1 in feet. Point Gauge Readings.	d_1 in feet. Piezometer Gauge Readings.	Distance from throat centre in feet.	d_2 in feet. Point Gauge Readings.	d_2 in feet. Piezometer Gauge Readings.	d_3 in feet Piezometer Gauge Readings.
	Run No. 1.					
	0.3645	Free flow				
1	0.3719	0.370	0.25 U.S.	0.2926	0.290	
			0.00	0.2894	0.290	
			0.25 D.S.	0.2811	0.288	
			Mean	(0.288)	0.290	0.320
2	0.3989	0.398	0.25 U.S.	0.3386	0.340	
			0.00	0.3348	0.340	
			0.25 D.S.	0.3391	0.340	
			Mean	(0.338)	0.340	0.368
3	0.4287	0.430	0.25 U.S.	0.3825	0.385	
			0.00	0.3825	0.385	
			0.25 D.S.	0.3813	0.383	
			Mean	(0.382)	0.385	0.410
4	0.4557	0.455	0.25 U.S.	0.4149	0.418	
			0.00	0.4141	0.418	
			0.25 D.S.	0.4141	0.418	
			Mean	(0.414)	0.418	0.440
5	0.4861	0.485	0.25 U.S.	0.4512	0.453	
			0.00	0.4512	0.453	
			0.25 D.S.	0.4510	0.453	
			Mean	(0.451)	0.453	0.472
6	0.5195	0.518	0.25 U.S.	0.4883	0.490	
			0.00	0.4895	0.490	
			0.25 D.S.	0.4876	0.490	
			Mean	(0.488)	0.490	0.506
7	0.5470	0.546	0.25 U.S.	0.5206	0.522	
			0.00	0.5206	0.522	
			0.25 D.S.	0.5206	0.522	
			Mean	(0.521)	0.522	0.538
8	0.5819	0.578	0.25 U.S.	0.5538	0.560	
			0.00	0.5575	0.560	
			0.25 D.S.	0.5575	0.560	
			Mean	(0.556)	0.560	0.575
9	0.6024	0.602	0.25 U.S.	0.5829	0.585	
			0.00	0.5829	0.585	
			0.25 D.S.	0.5809	0.585	
			Mean	(0.582)	0.585	0.600
10	0.6320	0.628	0.25 U.S.	0.6120	0.612	
			0.00	0.6120	0.612	
			0.25 D.S.	0.6120	0.612	
			Mean	(0.612)	0.612	0.626

Obsn. No.	d_1 in feet. Point Gauge Readings.	d_1 in feet. Piezometer Gauge Readings.	Distance from throat centre in feet.	d_2 in feet. Point Gauge Readings.	d_2 in feet. Piezometer Gauge Readings.	d_3 in feet. Piezometer Gauge Readings.
	Run No. 2.					
	0.4602	Free flow.				
1	0.4659	0.466	0.25 U.S.	0.3407	0.355	
			0.00	0.3547	0.355	
			0.25 D.S.	0.3626	0.355	
			Mean	(0.353)	0.355	0.400
2	0.4885	0.488	0.25 U.S.	0.4042	0.402	
			0.00	0.4042	0.402	
			0.25 D.S.	0.3915	0.402	
			Mean	(0.400)	0.402	0.440
3	0.5049	0.505	0.25 U.S.	0.4326	0.430	
			0.00	0.4288	0.430	
			0.25 D.S.	0.4228	0.425	
			Mean	(0.428)	0.430	0.465
4	0.5379	0.538	0.25 U.S.	0.4738	0.478	
			0.00	0.4738	0.478	
			0.25 D.S.	0.4738	0.478	
			Mean	(0.474)	0.478	0.505
5	0.5682	0.566	0.25 U.S.	0.5061	0.518	
			0.00	0.5137	0.515	
			0.25 D.S.	0.5120	0.515	
			Mean	(0.511)	0.515	0.540
6	0.5963	0.594	0.25 U.S.	0.5446	0.550	
			0.00	0.5509	0.550	
			0.25 D.S.	0.5466	0.550	
			Mean	(0.547)	0.550	0.570
7	0.6257	0.625	0.25 U.S.	0.5816	0.585	
			0.00	0.5871	0.588	
			0.25 D.S.	0.5835	0.585	
			Mean	(0.584)	0.588	0.605
8	0.6449	0.645	0.25 U.S.	0.6089	0.612	
			0.00	0.6089	0.612	
			0.25 D.S.	0.6084	0.612	
			Mean	(0.609)	0.612	0.625
9	0.6668	0.668	0.25 U.S.	0.6349	0.640	
			0.00	0.6349	0.640	
			0.25 D.S.	0.6349	0.640	
			Mean	(0.635)	0.640	0.652
10	0.6820	0.680	0.25 U.S.	0.6471	0.650	
			0.00	0.6467	0.650	
			0.25 D.S.	0.6467	0.650	
			Mean	(0.647)	0.650	0.665

Obsn. No.	d_1 in feet Point Gauge Readings.	Piezometer Gauge Readings.	Distance from throat centre in feet.	d_2 in feet. Point Gauge Readings.	Piezometer Readings.	d_3 in feet Piezometer Gauge Readings.
	Run No. 3.					
	0.5610	Free flow.				
1	0.6161	0.615	0.25 U.S.	0.5340	0.530	
			0.00	0.5329	0.525	
			0.25 D.S.	0.5193	0.525	
			Mean	(0.529)	0.525	0.580
2	0.6426	0.640	0.25 U.S.	0.5726	0.565	
			0.00	0.5648	0.565	
			0.25 D.S.	0.5600	0.565	
			Mean	(0.566)	0.565	0.610
3	0.6778	0.676	0.25 U.S.	0.6157	0.615	
			0.00	0.6085	0.612	
			0.25 D.S.	0.6085	0.612	
			Mean	(0.611)	0.612	0.655
4	0.6990	0.700	0.25 U.S.	0.6366	0.645	
			0.00	0.6366	0.645	
			0.25 D.S.	0.6444	0.645	
			Mean	(0.639)	0.645	0.680
5	0.7246	0.725	0.25 U.S.	0.6673	0.672	
			0.00	0.6665	0.670	
			0.25 D.S.	0.6695	0.670	
			Mean	(0.668)	0.670	0.705
6	0.7555	0.755	0.25 U.S.	0.7037	0.705	
			0.00	0.7072	0.705	
			0.25 D.S.	0.7045	0.705	
			Mean	(0.705)	0.705	0.740
7	0.7782	0.778	0.25 U.S.	0.7292	0.732	
			0.00	0.7289	0.730	
			0.25 D.S.	0.7290	0.730	
			Mean	(0.729)	0.730	0.760
8	0.8033	0.800	0.25 U.S.	0.7579	0.760	
			0.00	0.7579	0.760	
			0.25 D.S.	0.7573	0.760	
			Mean	(0.758)	0.760	0.785
9	0.8392	0.840	0.25 U.S.	0.8041	0.805	
			0.00	0.8041	0.805	
			0.25 D.S.	0.8038	0.805	
			Mean	(0.804)	0.805	0.830
10	0.8563	0.855	0.25 U.S.	0.8147	0.816	
			0.00	0.8147	0.816	
			0.25 D.S.	0.8147	0.815	
			Mean	(0.815)	0.816	0.845

Obsn. No.	d_1 in feet. Point Gauge Readings.	Piezometer Gauge Readings.	Distance from throat centre in feet.	d_2 in feet. Point Gauge Readings.	Piezometer Gauge Readings.	d_3 in feet Piezometer Gauge Readings.
	Run No. 4.					
	0.6474	Free flow.				
1	0.6517	0.650	0.25 U.S.	0.4492	0.475	
			0.00	0.4492	0.465	
			0.25 D.S.	0.4558	0.465	
			Mean	(0.451)	0.468	0.562
2	0.6730	0.672	0.25 U.S.	0.5184	0.540	
			0.00	0.5420	0.542	
			0.25 D.S.	0.5500	0.545	
			Mean	(0.537)	0.542	0.605
3	0.6965	0.694	0.25 U.S.	0.5745	0.585	
			0.00	0.5961	0.582	
			0.25 D.S.	0.5957	0.585	
			Mean	(0.589)	0.585	0.640
4	0.7239	0.722	0.25 U.S.	0.6336	0.632	
			0.00	0.6384	0.628	
			0.25 D.S.	0.6278	0.628	
			Mean	(0.633)	0.628	0.675
5	0.7481	0.747	0.25 U.S.	0.6677	0.660	
			0.00	0.6675	0.662	
			0.25 D.S.	0.6532	0.660	
			Mean	(0.663)	0.660	0.705
6	0.7680	0.765	0.25 U.S.	0.6945	0.686	
			0.00	0.6922	0.686	
			0.25 D.S.	0.6794	0.683	
			Mean	(0.689)	0.685	0.730
7	0.7913	0.790	0.25 U.S.	0.7241	0.716	
			0.00	0.7174	0.713	
			0.25 D.S.	0.7099	0.715	
			Mean	(0.717)	0.715	0.760
8	0.8094	0.810	0.25 U.S.	0.7486	0.746	
			0.00	0.7463	0.746	
			0.25 D.S.	0.7437	0.746	
			Mean	(0.746)	0.746	0.780
9	0.8254	0.824	0.25 U.S.	0.7615	0.760	
			0.00	0.7563	0.760	
			0.25 D.S.	0.7559	0.756	
			Mean	(0.758)	0.760	0.797
10	0.8362	0.833	0.25 U.S.	0.7745	0.770	
			0.00	0.7671	0.770	
			0.25 D.S.	0.7671	0.770	
			Mean	(0.770)	0.770	0.805

Obsn. No.	d_1 in feet. Point Gauge Readings.	d_1 in feet. Piezometer Gauge Readings.	Distance from throat centre in feet.	d_2 in feet. Point Gauge Readings.	d_2 in feet. Piezometer Gauge Readings.	d_3 in feet Piezometer Gauge Readings.
	Run No. 5.					
	0.7646	Free flow.				
1	0.7732	0.770	0.25 U.S.	0.5336	0.562	
			0.00	0.5251	0.555	
			0.25 D.S.	0.5286	0.552	
			Mean	(0.529)	0.555	0.666
2	0.7885	0.786	0.25 U.S.	0.5752	0.615	
			0.00	0.5839	0.610	
			0.25 D.S.	0.6024	0.615	
			Mean	(0.587)	0.612	0.705
3	0.8006	0.802	0.25 U.S.	0.6317	0.655	
			0.00	0.6470	0.662	
			0.25 D.S.	0.6812	0.660	
			Mean	(0.653)	0.660	0.735
4	0.8287	0.827	0.25 U.S.	0.6745	0.700	
			0.00	0.7000	0.700	
			0.25 D.S.	0.7141	0.700	
			Mean	(0.696)	0.700	0.765
5	0.8477	0.846	0.25 U.S.	0.7221	0.735	
			0.00	0.7417	0.735	
			0.25 D.S.	0.7545	0.735	
			Mean	(0.739)	0.735	0.787
6	0.8706	0.866	0.25 U.S.	0.7555	0.760	
			0.00	0.7790	0.760	
			0.25 D.S.	0.7774	0.760	
			Mean	(0.771)	0.760	0.808
7	0.8819	0.878	0.25 U.S.	0.7757	0.778	
			0.00	0.7946	0.775	
			0.25 D.S.	0.7915	0.775	
			Mean	(0.787)	0.775	0.825
8	0.8917	0.890	0.25 U.S.	0.7901	0.795	
			0.00	0.8102	0.792	
			0.25 D.S.	0.8015	0.790	
			Mean	(0.801)	0.792	0.835
9	0.9021	0.900	0.25 U.S.	0.8067	0.805	
			0.00	0.8277	0.805	
			0.25 D.S.	0.8095	0.805	
			Mean	(0.814)	0.805	0.850
10	0.9181	0.916	0.25 U.S.	0.8300	0.828	
			0.00	0.8409	0.828	
			0.25 D.S.	0.8244	0.825	
			Mean	(0.832)	0.828	0.870

Obsn. No.	d_1 in feet. Point Gauge Readings	d_1 in feet. Piezometer Gauge Readings.	Distance from throat centre in feet.	d_2 in feet. Point Gauge Readings.	d_2 in feet. Piezometer Gauge Readings.	d_3 in feet Piezometer Gauge Readings.
	Run No. 6.					
	0.8502	Free flow.				
1	0.8600	0.855	0.25 U.S.	0.5981	0.625	
			0.00	0.5823	0.610	
			0.25 D.S.	0.5776	0.600	
			Mean	(0.586)	0.615	0.735
2	0.8711	0.868	0.25 U.S.	0.6327	0.666	
			0.00	0.6274	0.662	
			0.25 D.S.	0.6373	0.665	
			Mean	(0.632)	0.665	0.775
3	0.892	0.886	0.25 U.S.	0.6785	0.720	
			0.00	0.6896	0.720	
			0.25 D.S.	0.6989	0.718	
			Mean	(0.698)	0.718	0.805
4	0.9185	0.913	0.25 U.S.	0.7369	0.766	
			0.00	0.7433	0.766	
			0.25 D.S.	0.7864	0.770	
			Mean	(0.755)	0.768	0.840
5	0.9402	0.936	0.25 U.S.	0.7785	0.808	
			0.00	0.8041	0.808	
			0.25 D.S.	0.8350	0.808	
			Mean	(0.806)	0.808	0.875
6	0.9633	0.960	0.25 U.S.	0.8209	0.845	
			0.00	0.8470	0.845	
			0.25 D.S.	0.8717	0.845	
			Mean	(0.847)	0.845	0.900
7	0.9904	0.987	0.25 U.S.	0.8636	0.882	
			0.00	0.8958	0.880	
			0.25 D.S.	0.9030	0.880	
			Mean	(0.887)	0.880	0.935
8	1.0080	1.005	0.25 U.S.	0.8949	0.910	
			0.00	0.9212	0.905	
			0.25 D.S.	0.9209	0.905	
			Mean	(0.909)	0.905	0.955
9	1.0340	1.030	0.25 U.S.	0.9387	0.940	
			0.00	0.9401	0.938	
			0.25 D.S.	0.9410	0.935	
			Mean	(0.940)	0.938	0.985
10	1.0616	1.058	0.25 U.S.	0.9749	0.975	
			0.00	0.9863	0.972	
			0.25 D.S.	0.9686	0.972	
			Mean	(0.977)	0.972	1.015

Obsn. No.	d_1 in feet. Point Gauge Readings.	Piezometer Gauge Readings.	Distance from throat centre in feet.	d_2 in feet Point Gauge Readings.	Piezometer Gauge Readings.	d_3 in feet Piezometer Gauge Readings.
	Run No. 7.					
	0.9500	Free flow.				
1	0.9635	0.962	0.25 U.S.	0.6786	0.708	
			0.00	0.6561	0.695	
			0.25 D.S.	0.6375	0.675	
			Mean	(0.657)	0.695	0.805
2	0.9732	0.972	0.25 U.S.	0.7028	0.735	
			0.00	0.6852	0.725	
			0.25 D.S.	0.6837	0.720	
			Mean	(0.691)	0.730	0.850
3	0.9879	0.985	0.25 U.S.	0.7398	0.778	
			0.00	0.7259	0.768	
			0.25 D.S.	0.7426	0.775	
			Mean	(0.736)	0.775	0.885
4	0.9977	0.997	0.25 U.S.	0.7669	0.815	
			0.00	0.7823	0.815	
			0.25 D.S.	0.7900	0.815	
			Mean	(0.780)	0.815	0.925
5	1.0250	1.025	0.25 U.S.	0.8233	0.865	
			0.00	0.8221	0.865	
			0.25 D.S.	0.8719	0.865	
			Mean	(0.839)	0.865	0.955
6	1.0442	1.043	0.25 U.S.	0.8677	0.900	
			0.00	0.8725	0.900	
			0.25 D.S.	0.9039	0.905	
			Mean	(0.881)	0.900	0.980
7	1.0738	1.070	0.25 U.S.	0.9150	0.945	
			0.00	0.9352	0.940	
			0.25 D.S.	0.9670	0.945	
			Mean	(0.939)	0.945	1.010
8	1.1013	1.098	0.25 U.S.	0.9564	0.985	
			0.00	0.9882	0.982	
			0.25 D.S.	1.0054	0.980	
			Mean	(0.983)	0.985	1.045
9	1.1238	1.120	0.25 U.S.	0.9957	1.015	
			0.00	1.0243	1.015	
			0.25 D.S.	1.0373	1.012	
			Mean	(1.019)	1.015	1.075
10	1.1534	1.150	0.25 U.S.	1.0415	1.055	
			0.00	1.0595	1.055	
			0.25 D.S.	1.0688	1.055	
			Mean	(1.057)	1.055	1.105

Obsn. No.	d_1 in feet. Point gauge Readings.	d_1 in feet. Piezometer Gauge Readings.	Distance from throat centre in feet.	d_2 in feet. Point Gauge Readings.	d_2 in feet. Piezometer Readings.	d_3 in feet. Piezometer Gauge Readings.
	Run No. .8.					
	1.054	Free flow.				
1	1.0705	1.070	0.25 U.S.	0.7525	0.795	
			0.00	0.7325	0.772	
			0.25 D.S.	0.7113	0.760	
			Mean	(0.732)	0.775	0.905
2	1.0832	1.081	0.25 U.S.	0.7894	0.828	
			0.00	0.7613	0.815	
			0.25 D.S.	0.7558	0.800	
			Mean	(0.769)	0.820	0.940
3	1.1002	1.095	0.25 U.S.	0.8185	0.865	
			0.00	0.7998	0.850	
			0.25 D.S.	0.8085	0.860	
			Mean	(0.809)	0.860	0.980
4	1.1078	1.105	0.25 U.S.	0.8441	0.900	
			0.00	0.8335	0.895	
			0.25 D.S.	0.8462	0.890	
			Mean	(0.841)	0.895	1.010
5	1.1175	1.115	0.25 U.S.	0.8568	0.905	
			0.00	0.8509	0.900	
			0.25 D.S.	0.8580	0.905	
			Mean	(0.855)	0.905	1.015
6	1.1332	1.130	0.25 U.S.	0.8883	0.940	
			0.00	0.8859	0.940	
			0.25 D.S.	0.8992	0.935	
			Mean	(0.891)	0.940	1.035
7	1.1580	1.155	0.25 U.S.	0.9364	0.990	
			0.00	0.9364	0.980	
			0.25 D.S.	0.9736	0.990	
			Mean	(0.949)	0.990	1.075
8	1.1879	1.185	0.25 U.S.	0.9844	1.030	
			0.00	0.9942	1.030	
			0.25 D.S.	1.0322	1.030	
			Mean	(1.004)	1.030	1.110
9	1.2202	1.215	0.25 U.S.	1.0353	1.075	
			0.00	1.0567	1.075	
			0.25 D.S.	1.0896	1.075	
			Mean	(1.061)	1.075	1.140

Test No. 12 Continued.

Discharge Observations.

Obsn. No.	R = Rise in Tank in feet.	M = Time in Minutes.	Discharge in cusecs. $= \frac{R \times 155}{M \times 60}$	Mean discharge in cusecs.
		Run No. 1.		
1	1.380	8	0.435	
2	0.860	5	0.435	0.439
3	0.845	5	0.437	
4	1.040	6	0.448	
		Run No. 2.		
1	1.475	6	0.636	
2	1.475	6	0.636	0.634
3	1.475	6	0.636	
4	1.460	6	0.628	
		Run No. 3.		
1	2.615	8	0.845	
2	1.340	4	0.865	0.849
3	1.305	4	0.845	
4	1.625	5	0.839	
		Run No. 4.		
1	1.600	4	1.034	
2	2.015	5	1.041	1.053
3	2.470	6	1.065	
4	2.055	5	1.072	
		Run No. 5.		
1	3.090	6	1.328	
2	3.105	6	1.332	1.325
3	3.045	6	1.308	
4	3.100	6	1.332	
		Run No. 6.		
1	2.470	4	1.595	
2	3.050	5	1.575	1.575
3	3.635	6	1.570	
4	3.025	5	1.563	

Test No. 12 Continued.

Discharge Observations (Continued).

Obsn. No.	R = Rise in Tank in feet.	M = Time in Minutes.	Discharge in cusecs. $= \frac{R \times 155}{m \times 60}$	Mean discharge in cusecs.
		Run No. 7.		
1	2.190	3	1.885	1.883
2	2.905	4	1.880	
3	2.835	4	1.835	
4	2.840	4	1.835	1.835
5	2.850	4	1.840	
		Run No. 8.		
1	2.555	3	2.205	
2	2.560	3	2.205	2.205
3	2.560	3	2.205	

TEST Nº 12 ON MODEL I

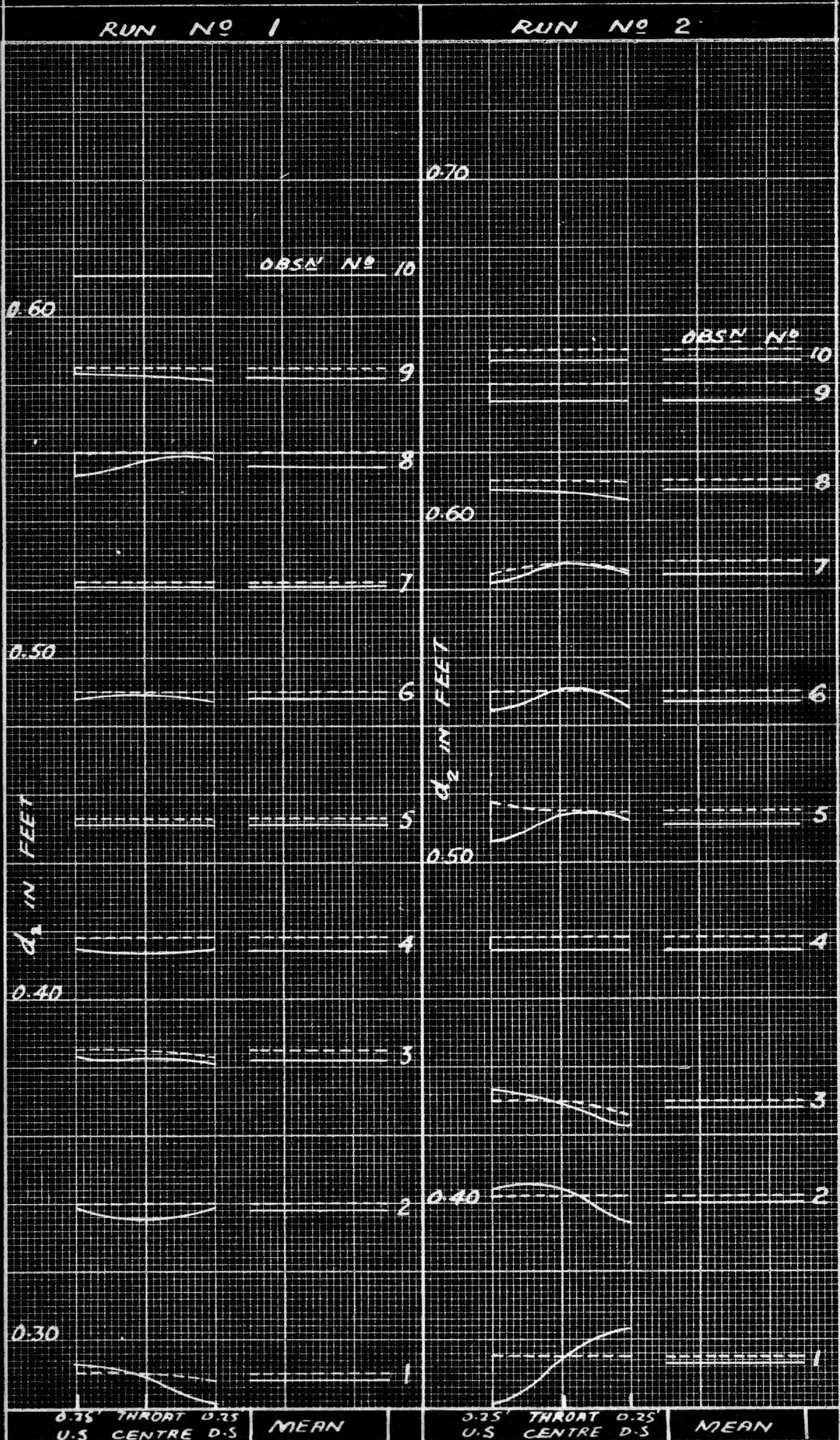


DIAGRAM SHOWING ACTUAL WATER DEPTHS INSIDE THE THROAT PLOTTED (——) AND THEIR CORRESPONDING PIEZOMETER GAUGE READINGS PLOTTED (- - - -)

TEST Nº 12 ON MODEL I

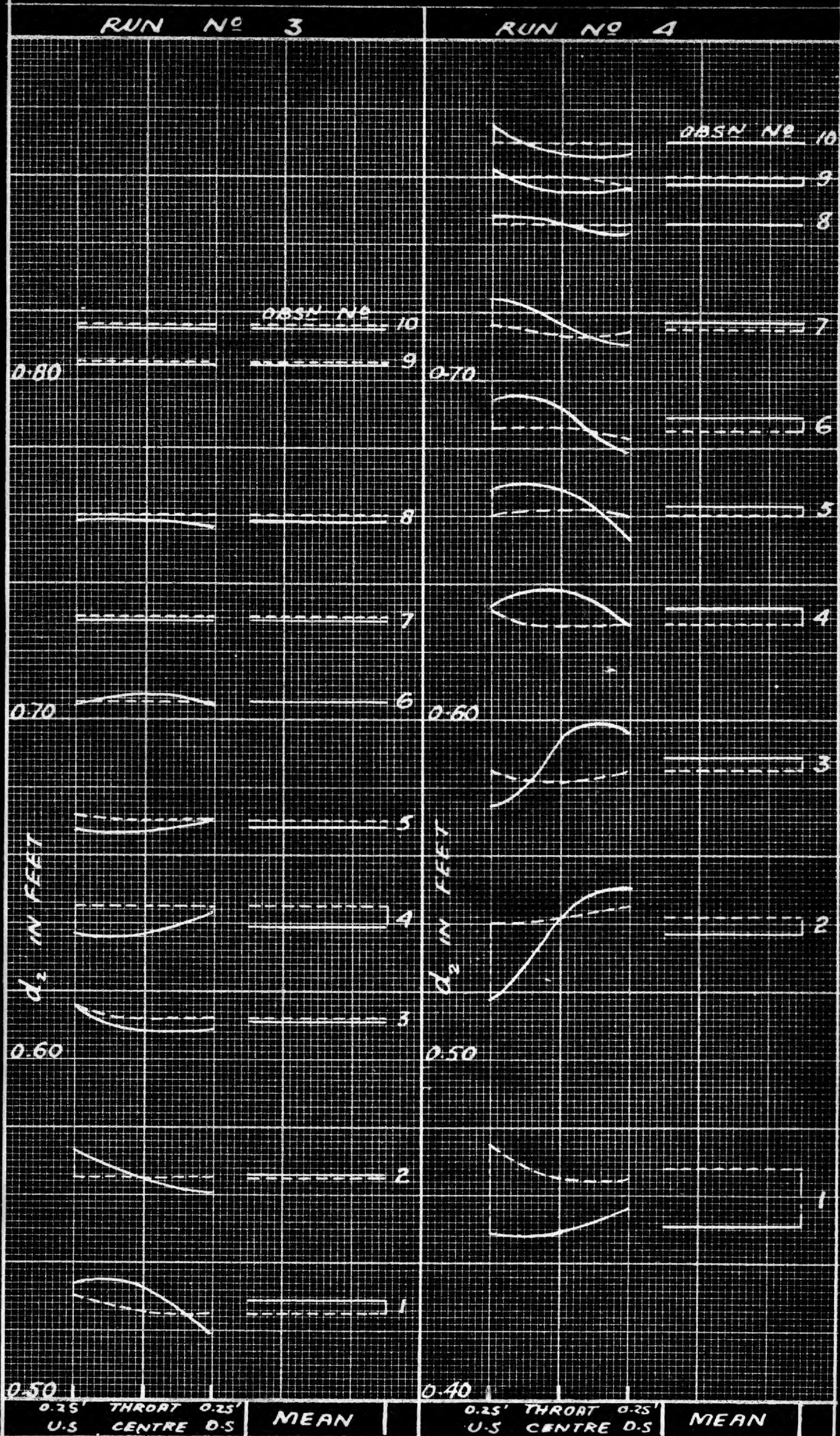


DIAGRAM SHOWING ACTUAL WATER DEPTHS INSIDE THE THROAT PLOTTED (——) AND THEIR CORRESPONDING PIEZOMETER GAUGE READINGS PLOTTED (----)

TEST Nº 12 ON MODEL I

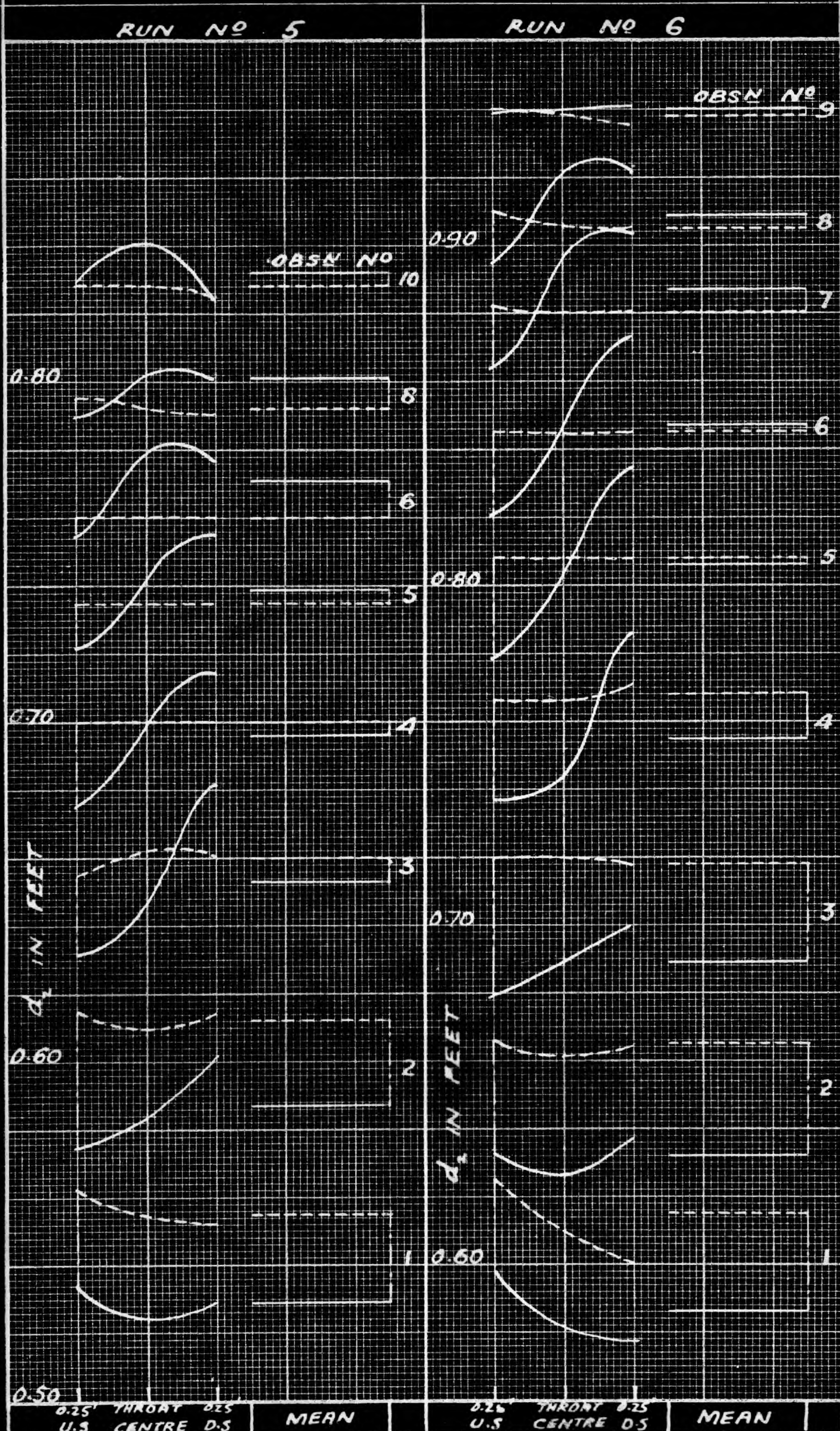


DIAGRAM SHOWING ACTUAL WATER DEPTHS INSIDE THE THROAT PLOTTED (—) AND THEIR CORRESPONDING PIEZOMETER GAUGE READINGS PLOTTED (----)

TEST NO 12 ON MODEL I

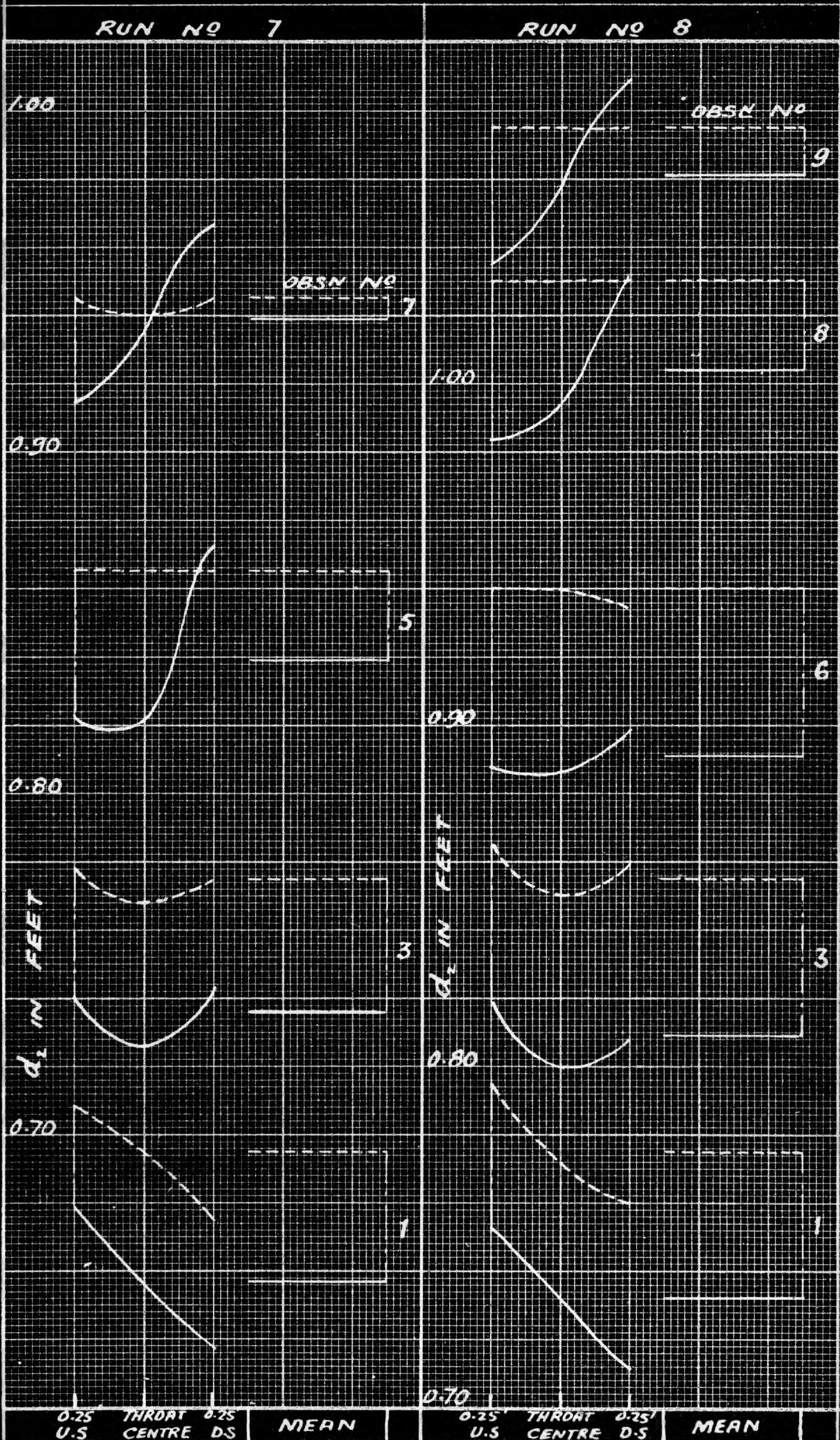


DIAGRAM SHOWING ACTUAL WATER DEPTHS INSIDE THE THROAT PLOTTED (——) AND THEIR CORRESPONDING PIEZOMETER GAUGE READINGS PLOTTED (----)

RESULTS OF TESTS 1 - 10.

The following tables show the values of the coefficient of discharge "C" computed from the formula

$$Q = \frac{C b_2 d_2 \sqrt{2gh}}{\sqrt{1 - \left(\frac{b_2 d_2}{b_1 d_1}\right)^2}}$$

and the values of the loss of head through the different models of flumes tested.

List of notation used.

d_1 = depth of water up-stream a flume model in ft.

d_2 = depth of water inside the throat in ft.†

d_3 = depth of water downstream a flume model in ft.

h = $d_1 - d_2$ = drop inside the throat in ft.

h_L = $d_1 - d_3$ = head lost through flume in ft.

Q_a = Actual discharge in cusecs.

Q_t = discharge computed by the above equation.

C = coefficient of discharge = $\frac{Q_a}{Q_t}$.

The values of Q_t are read from diagram on plate VI which give values of Q_t by above formula when $C = 1$

The tabulated results for each test are plotted in corresponding diagrams. Values of the loss of head $h_L = d_1 - d_3$ are plotted against values of d_3 for the different flows corresponding to different runs. The curves for each model show the amount of heading up behind the model when the latter is placed in the channel while a certain discharge Q is flowing at a certain normal depth d_3. For example the diagram of test 1 page (121) show that if water is originally flowing in the experimental rectangular channel at a rate of 0.742 cusecs and a uniform depth of one ft, then by placing flume model A in the channel the water will rise upstream the flume to a depth 0.032 ft higher than the original depth i.e. U.S. depth will be 1.032 ft. The values of the coefficient of discharge C are plotted against the corresponding values of h.

† d_2 was taken as the mean of the three readings 0.25′ U.S, 0.00′, 0.25′ D.S centre of throat.

TABLE OF RESULTS OF TEST NO.1 ON MODEL "A"

d_1	d_2	d_3	h	h_L	Q_t	Q_a	C
	Feet				cusecs		
	Run No. (1)						
0.473		0.201			0.520	0.485	0.932
0.489	0.376	0.406	0.113	0.083	0.535	..	0.907
0.545	0.470	0.490	0.075	0.055	0.540	..	0.897
0.614	0.569	0.576	0.045	0.038	0.505	..	0.960
0.778	0.757	0.757	0.021	0.021	0.470	..	1.030
	Run No. (2)						
0.630		0.325			0.790	0.742	0.938
0.631		0.420			0.790	..	0.958
0.699	0.595	0.626	0.104	0.073	0.800	..	0.927
0.832	0.764	0.786	0.068	0.046	0.840	..	0.883
1.044	1.009	1.020	0.035	0.024	0.800	..	0.927
1.238	1.214	1.214	0.024	0.024	0.820	..	0.905
	Run No. (3)						
0.980		0.534			1.540	1.439	0.935
1.008	0.678	0.828	0.330	0.180	1.580	..	0.911
1.044	0.801	0.947	0.243	0.097	1.650	..	0.872
1.116	0.911	1.017	0.205	0.099	1.730	..	0.833
1.182	1.057	1.089	0.125	0.093	1.750	..	0.823
1.323	1.233	1.259	0.090	0.064	1.580	..	0.910
	Run No. (4)						
1.135		0.689			1.920	1.808	0.942
1.140		0.780			1.920	..	0.942
1.167	0.785	0.930	0.382	0.237	2.000	..	0.905
1.192	0.845	1.019	0.347	0.173	2.050	..	0.883
1.242	0.954	1.126	0.288	0.116	2.100	..	0.862

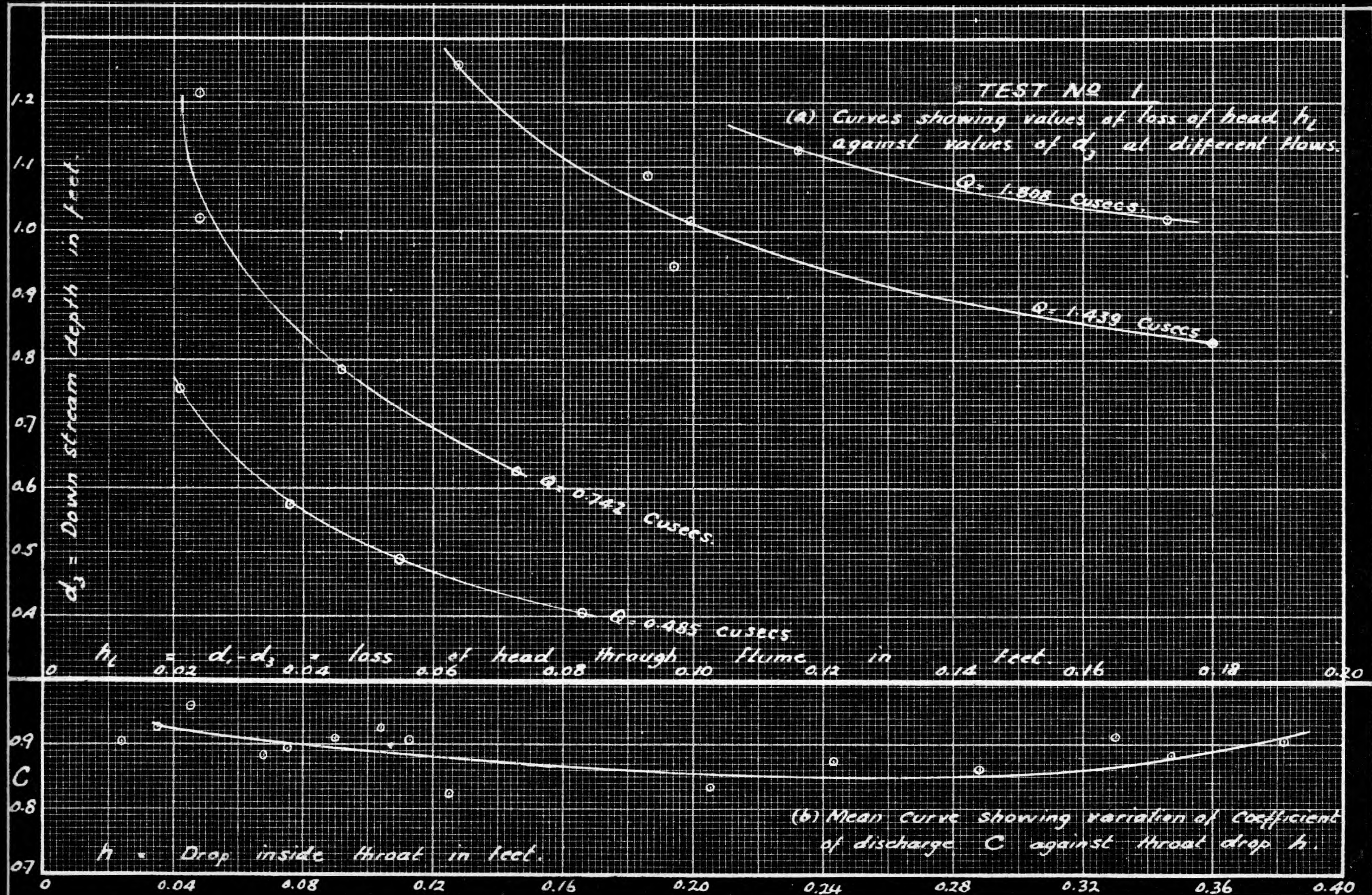

TEST No 1
(a) Curves showing values of loss of head h_l against values of d_3 at different flows.
Q = 1.808 Cusecs.
Q = 1.439 Cusecs
Q = 0.742 Cusecs.
Q = 0.485 Cusecs
d_3 = Down stream depth in feet.
$h_l = d_1 - d_3$ = loss of head through flume in feet.
C
(b) Mean curve showing variation of coefficient of discharge C against throat drop h.
h = Drop inside throat in feet.

TABLE OF RESULTS OF TEST No.2 ON MODEL "B".

d_1	d_2	d_3	h	h_L	Qt	Q_c	C
	Feet				cuccess.		
	Run No. (1)						
0.472		0.289			0.520	0.470	0.905
0.475	0.301	0.373	0.174	0.102	0.520	,,	0.905
0.526	0.439	0.461	0.087	0.065	0.540	,,,	0.871
0.640	0.601	0.610	0.039	0.030	0.500	,,	0.941
0.830	0.802	0.808	0.028	0.022	0.570	,,	0.825
0.948	0.930	0.932	0.018	0.016	0.530	,,	0.887
	Run No.(2)						
0.638		0.325			0.805	0.734	0.912
0.638		0.399			,,	,,	0.912
0.720	0.615	0.640	0.105	0.080	0.830	,,	0.885
0.890	0.845	0.848	0.045	0.042	0.770	,,	0.953
0.998	0.958	0.966	0.040	0.032	0.805	,,	0.913
1.072	1.035	1.041	0.037	0.031	0.840	,,	0.875
	Run No. (3)						
0.774	0.	0.443			1.080	0.974	0.902
0.778	0.499	0.608	0.279	0.170	1.100	,,	0.885
0.837	0.674	0.731	0.163	0.106	1.140	,,	0.853
0.900	0.785	0.813	0.115	0.087	1.120	,,	0.870
0.975	0.897	0.908	0.078	0.067	1.060	,,	0.918
1,047	0.968	0.990	0.079	0.057	1.150	,,	0.947
	Run No. (4)						
0.943		0.520			1.450	1.307	0.902
0.951	0.605	0.672	0.346	0.279	1.460	,,	0.897
0.963	0.645	0.765	0.318	0.198	1.480	,,	0.885
0.982	0.701	0.843	0.281	0.139	1.540	,,	0.850
1.042	0.820	0.934	0.222	0.108	1.610	,,	0.813
1091	0.976	0.988	0.115	0.103	1.400	,,	0.935

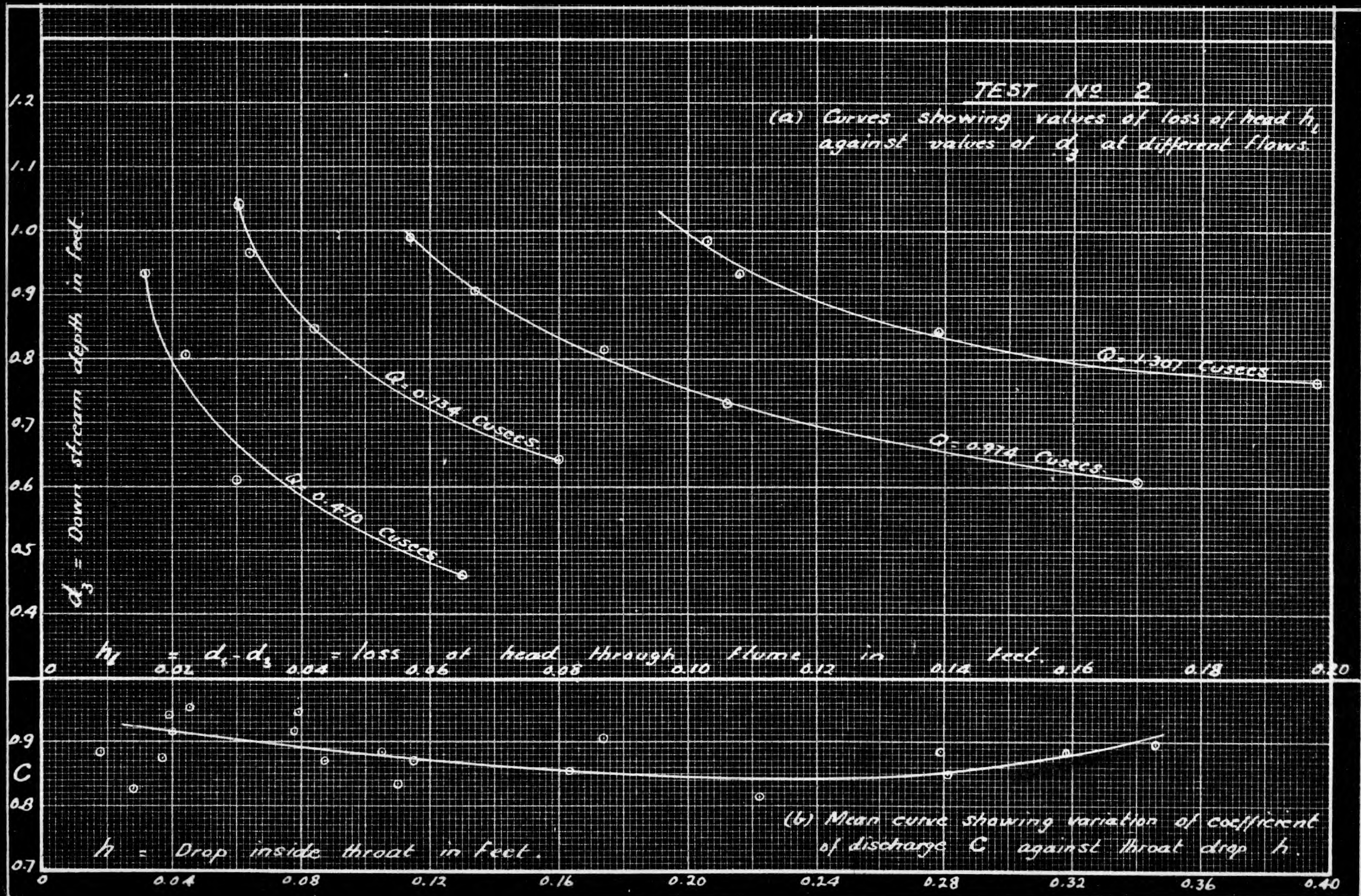

TEST No 2
(a) Curves showing values of loss of head h_l against values of d_3 at different flows.
d_3 = Down stream depth in feet
Q = 0.470 Cusecs
Q = 0.734 Cusecs
Q = 0.974 Cusecs
Q = 1.307 Cusecs
$h_l = d_1 - d_3$ = loss of head through flume in feet.
0
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18
0.20
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
C
0.7
0.8
0.9
(b) Mean curve showing variation of coefficient of discharge C against throat drop h.
h = Drop inside throat in feet.
0.04
0.08
0.12
0.16
0.20
0.24
0.28
0.32
0.36
0.40

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TABLE OF RESULTS OF TEST No. 3 ON MODEL "C".

d_1	d_2	d_3	h	h_L	Q_t	Q_a	C
	F e e t				c u s e c s		
	Run No. (1)						
0.467		0.222			0.505	0.475	0.942
0.471	0.296	0.384	0.175	0.087	0.520	,,	0.914
0.519	0.434	0.462	0.085	0.057	0.525	,,	0.905
0.615	0.533	0.570	0.082	0.045	0.630	0.567	0.900
0.682	0.631	0.647	0.051	0.035	0.605	,,	0.938
0.782	0.747	0.759	0.035	0.023	0.595	,,	0.953
	Run No. (2)						
0.632		0.319			0.800	0.719	0.900
0.633		0.515			0.800	,,	0.900
0.679	0.578	0.600	0.101	0.079	0.780	,,	0.922
0.787	0.711	0.738	0.076	0.049	0.830	,,	0.867
0.852	0.805	0.820	0.047	0.032	0.740	,,	0.973
0.940	0.897	0.910	0.043	0.030	0.790	,,	0.912
	Run No. (3)						
0.823		0.514			1.180	1.095	0.930
0.825		0.642			1.180	,,	0.930
0.876	0.611	0.771	0.265	0.105	1.200	,,	0.914
0.944	0.796	0.858	0.148	0.086	1.280	,,	0.857
0.996	0.853	0.918	0.143	0.078	1.350	,,	0.813
	Run No. (4)						
0.946		0.592			1.460	1.310	0.897
0.950		0.654			1.460	,,	0.847
0.958	0.622	0.751	0.336	0.207	1.460	,,	0.897
0.990	0.709	0.877	0.281	0.113	1.550	,,	0.847
1.053	0.843	0.956	0.210	0.097	1.620	,,	0.809
1.098	0.940	1.006	0.158	0.092	1.570	,,	0.835

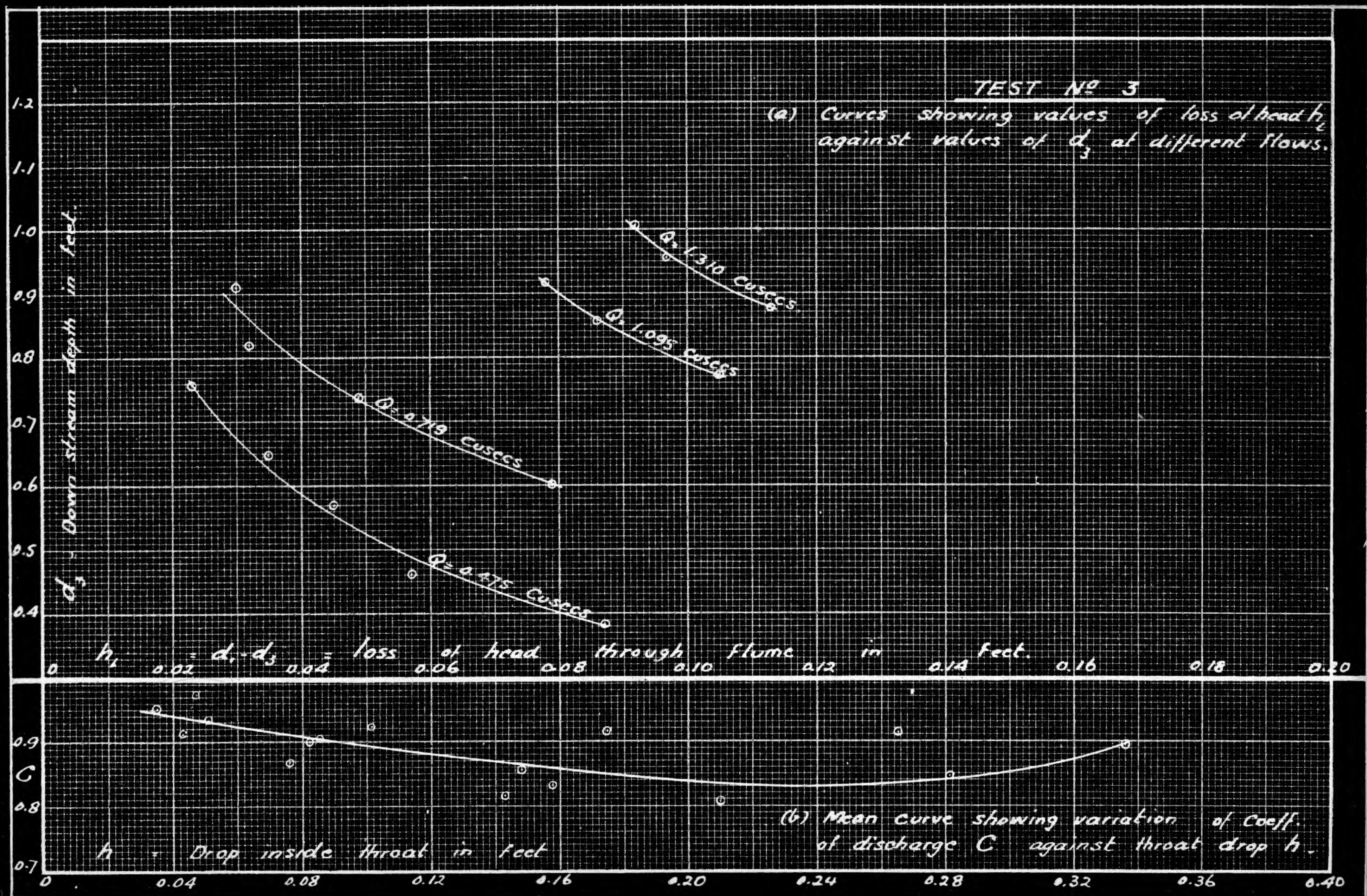

TEST No 3
(a) Curves showing values of loss of head h_L against values of d_3 at different flows.
Q = 1.310 Cusecs.
Q = 1.095 Cusecs
Q = 0.719 Cusecs
Q = 0.475 Cusecs
d_3 = Down stream depth in feet.
$h_L = d_1 - d_3$ = loss of head through flume in feet.
0 0.02 0.04 0.06 0.08 0.10 0.12 0.14 0.16 0.18 0.20
0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1 1.2
(b) Mean curve showing variation of Coeff. of discharge C against throat drop h.
C
h = Drop inside throat in feet
0 0.04 0.08 0.12 0.16 0.20 0.24 0.28 0.32 0.36 0.40
0.7 0.8 0.9

TABLE OF RESULTS OF TEST No. 4 ON MODEL "D"

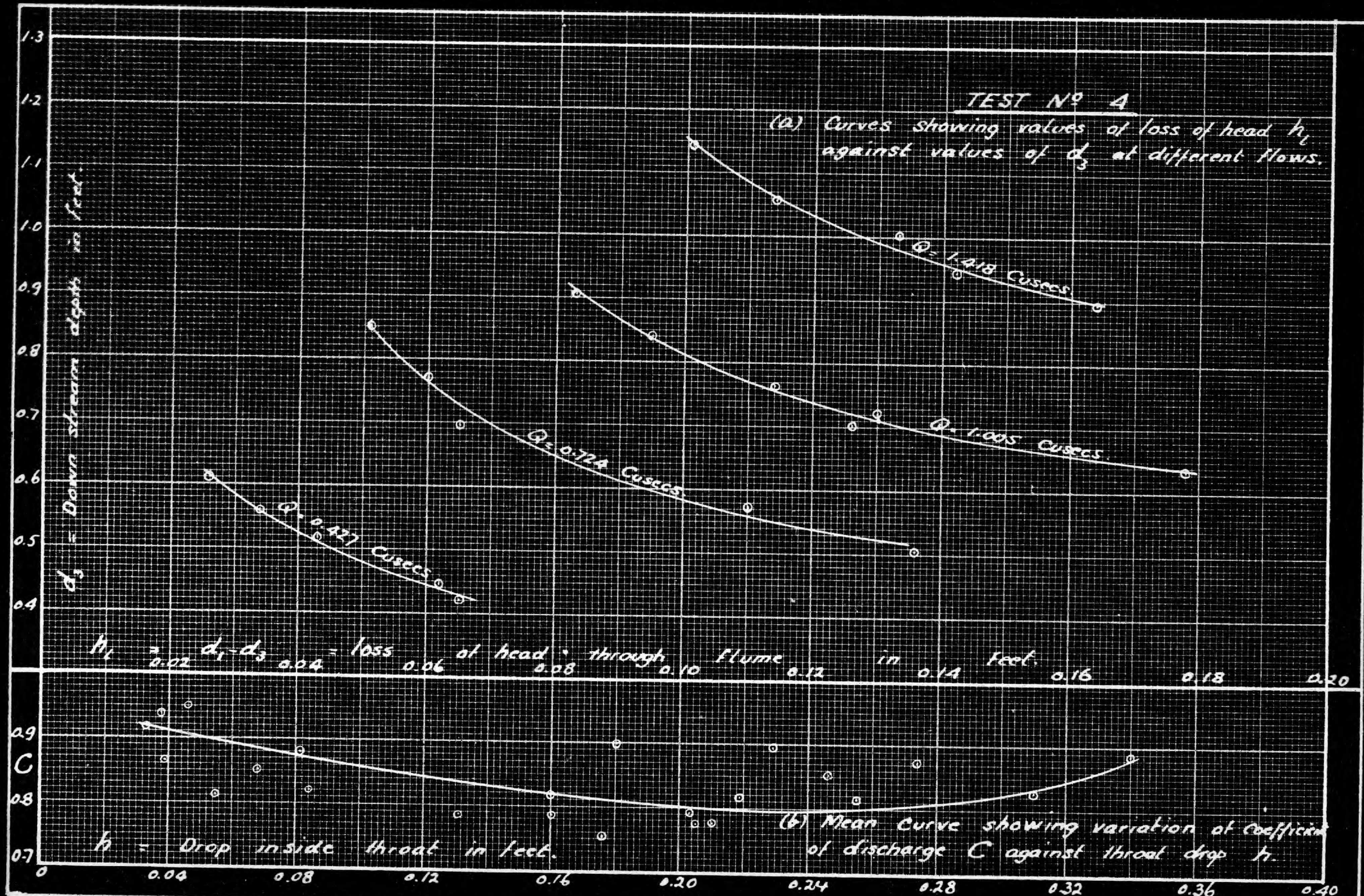
d_1	d_2	d_3	h	h_L	Q_t	Q_a	C
	Feet				Cusecs.		
	Run No. (1)						
0.445					0.475	0.427	0.900
0.448	0.268	0.330	0.180	0.118	0.475	,,	0.900
0.486	0.405	0.421	0.081	0.065	0.485	,,	0.881
0.511	0.465	0.449	0.046	0.062	0.450	,,	0.950
0.562	0.523	0.519	0.039	0.043	0.495	,,	0.863
0.594	0.556	0.560	0.038	0.034	0.455	,,	0.939
0.636	0.603	0.610	0.033	0.026	0.465	,,	0.918
	Run No. (2)						
0.634					0.800	0.724	0.906
0.635					0.800	,,	0.906
0.642	0.413	0.506	0.229	0.136	0.810	,,	0.895
0.695	0.535	0.585	0.160	0.110	0.885	,,	0.818
0.764	0.680	0.699	0.084	0.065	0.830	0.681	0.820
0.831	0.763	0.771	0.068	0.060	0.800	,,	0.852
0.900	0.845	0.849	0.055	0.051	0.840	,,	0.811
	Run No. (3)						
0.796					1.120	1.005	0.898
0.812	0.538	0.634	0.274	0.178	1.150	,,	0.873
0.827	0.581	0.701	0.246	0.126	1.180	,,	0.852
0.852	0.633	0.722	0.219	0.130	1.230	,,	0.817
0.877	0.674	0.763	0.203	0.114	1.270	,,	0.792
0.935	0.775	0.840	0.160	0.095	1.280	,,	0.786
0.988	0.857	0.905	0.131	0.083	1.280	,,	0.786
	Run No.(4)						
1.003					1.580	1.418	0.898
1.023	0.683	0.745	0.340	0.278	1.600	,,	0.887
1.060	0.750	0.896	0.310	0.164	1.720	,,	0.876
1.086	0.831	0.944	0.255	0.142	1.750	,,	0.812

TABLE OF RESULTS OF TEST No.4 ON MODEL "D" (continued)

d_1	d_2	d_3	h	h_L	Q_t	Q_a	C
	Feet			cusecs			
	Run No.(4) continued.						
1.140	0.910	1.004	0.230	0.136	1.830	1.418	0.776
1.173	0.968	1.059	0.205	0.114	1.830	,,	0.776
1.247	1.071	1.146	0.176	0.101	1.880	,,	0.755

TABLE OF RESULTS OF TEST No.5 ON MODEL "D"

d_1	d_2	d_3	h	h_L	Q_t	Q_a	C
	Feet			cusecs			
	Run No.(1)						
0.469							
0.483	0.340	0.382	0.143	0.101	0.530	0.461	0.870.
0.531	0.462	0.466	0.069	0.065	0.515	,,	0.895
0.564	0.495	0.500	0.069	0.064	0.555	,,	0.830
0.591	0.543	0.545	0.048	0.046	0.500	,,	0.922
0.628	0.579	0.580	0.049	0.048	0.540	,,	0.855
	Run No. (2)						
0.602							
0.627	0.463	0.493	0.164	0.134	0.780	0.660	0.847
0.642	0.535	0.543	0.107	0.099	0.730	,,	0.905
0.671	0.593	0.581	0.078	0.090	0.695	,,	0.950
0.705	0.618	0.632	0.087	0.075	0.755	,,	0.863
0.753	0.689	0.685	0.064	0.068	0.735	,,	0.897
	Run No. (3)						
0.824							
0.828	0.519	0.612	0.309	0.216	1.200	1.064	0.887
0.851	.....	0.700	....	0.151	....	,,	.....
0.904	.....	0.763	....	0.141	....	,,	.....
0.935	.....	0.825	.....	0.110	....	,,	.....
0.969	......	0.884	.....	0.085	....	,,	.....
0.987	.....	0.893	.....	0.094	....	,,	.....


TEST Nº 4
(a) Curves showing values of loss of head h_l against values of d_3 at different flows.
Q = 1.418 Cusecs.
Q = 1.005 Cusecs.
Q = 0.724 Cusecs.
Q = 0.427 Cusecs.
d_3 = Down stream depth in feet.
h_l = d_1-d_3 = loss of head through flume in feet.
C
h = Drop inside throat in feet.
(b) Mean curve showing variation of coefficient of discharge C against throat drop h.

TABLES OF RESULTS OF TEST NO.5 ON MODEL "D"(continued)

d_1	d_2	d_3	h	h_L	Q_t	Q_a	C
	F e e t			c u s e c s			
	Run No. (4)						
1.012							
1.029	0.666	0.799	0.363	0.230	1.650	1.449	0.879
1.044	0.718	0.868	0.326	0.176	1.680	,,	0.863
1.051	0.730	0.878	0.321	0.173	1.700	,,	0.853
1.094	0.831	0.946	0.263	0.148	1.750	,,	0.828
1.170	...	1.028	...	0.142	...	,,	

TABLE OF RESULTS OF TEST NO.6 ON SHAPE "E".

d_1	d_2	d_3	h	h_L	Q_t	Q_a	C
	F e e t			c u s e c s			
	Run No. (1)						
0.405		0.276		0.410	0.410	0.375	0.916
0.419	0.331	0.370	0.088	0.049	0.409	,,	0.917
0.464	0.416	0.433	[illegible]	[illegible]	[illegible]	,,	0.962
0.506	0.458	0.468	0.048	0.038	0.425	,,	0.883
0.538	0.508	0.510	0.030	0.028	0.325	,,	1.000
0.573	0.542	0.553	0.031	0.020	0.400	,,	0.938
0.619	0.591	0.598	0.028	0.021	0.396	,,	0.948
	Run No. (2)						
0.625		0.323			0.780	0.699	0.897
0.627	0.388	0.491	0.239	0.136	0.790	,,	0.886
0.634	0.418	0.536	0.216	0.098	0.800	,,	0.875
0.666	0.557	0.583	0.109	0.083	0.770	,,	0.908
0.727	0.621	0.675	0.106	0.052	0.850	,,	0.823
0.764	0.683	0.713	0.081	0.051	0.740	,,	0.947
0.838	0.783	0.794	0.055	0.044	0.770	,,	0.908

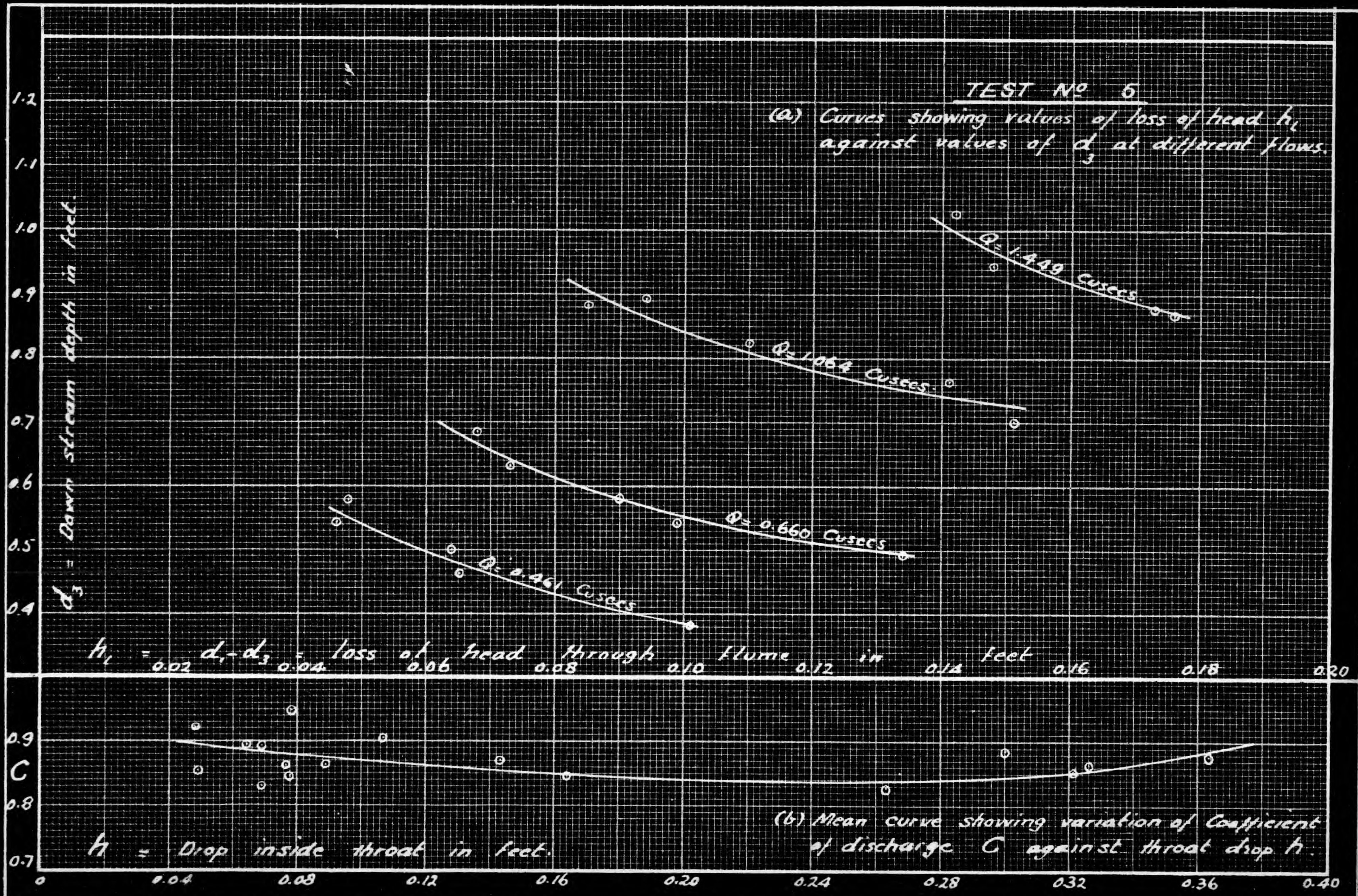

TEST No 6
(a) Curves showing values of loss of head h_l against values of d_3 at different flows.
Q = 1.449 Cusecs.
Q = 1.064 Cusecs.
Q = 0.660 Cusecs
Q = 0.461 Cusecs
d_3 = Down stream depth in feet.
h_l = $d_1 - d_3$ = loss of head through flume in feet
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18
0.20
C
0.9
0.8
0.7
(b) Mean curve showing variation of Coefficient of discharge C against throat drop h
h = Drop inside throat in feet.
0
0.04
0.08
0.12
0.16
0.20
0.24
0.28
0.32
0.36
0.40

TABLE OF RESULTS ON TEST NO. 6 ON SHAPE "E"(continued)

d_1	d_2	d_3	h	h_L	Q_t	Q_a	C
		F e e t			c u s	e c s	
	Run No. (3)						
0.858		0.552			1.260	1.126	0.893
0.865		0.623			1.280	,,	0.880
0.873	0.573	0.715	0.300	0.158	1.290	,,	0.873
0.898	0.651	0.799	0.247	0.099	1.340	,,	0.841
0.931	0.738	0.830	0.193	0.101	1.360	,,	0.828
0.963	0.810	0.872	0.153	0.091	1.370	,,	0.822
1.017	0.886	0.943	0.131	0.074	1.370	,,	0.822
	Run No. (4)						
1.001		0.656			1.580	1.425	0.902
1.005		0.717			1.590	,,	0.897
1.019	0.683	0.820	0.336	0.199	1.650	,,	0.863
1.039	0.735	0.897	0.304	0.142	1.680	,,	0.848
1.082	0.852	0.982	0.230	0.100	1.680	,,	0.848
1.100	0.879	1.006	0.221	0.094	1.730	,,	0.825
1.146	0.939	1.061	0.207	0.085	1.800	,,	0.792

TABLE OF RESULTS ON TEST NO. 7 ON SHAPE "F"

d_1	d_2	d_3	h	h_L	Q_t	Q_a	C
		F e e t			c u s	e c s	
	Run No. (1)						
0.432		0.290		0.142	0.450	0.417	0.927
0.448	0.364	0.381	0.084	0.067	0.440	,,	0.948
0.497	0.443	0.458	0.054	0.039	0.430	,,	0.970
0.541	0.497	0.512	0.044	0.029	0.435	,,	0.960
0.570	0.528	0.542	0.042	0.028	0.455	,,	0.917
0.618	0.590	0.600	0.028	0.018	0.420	,,	0.993
0.646	0.616	0.626	0.030	0.020	0.448	,,	0.930

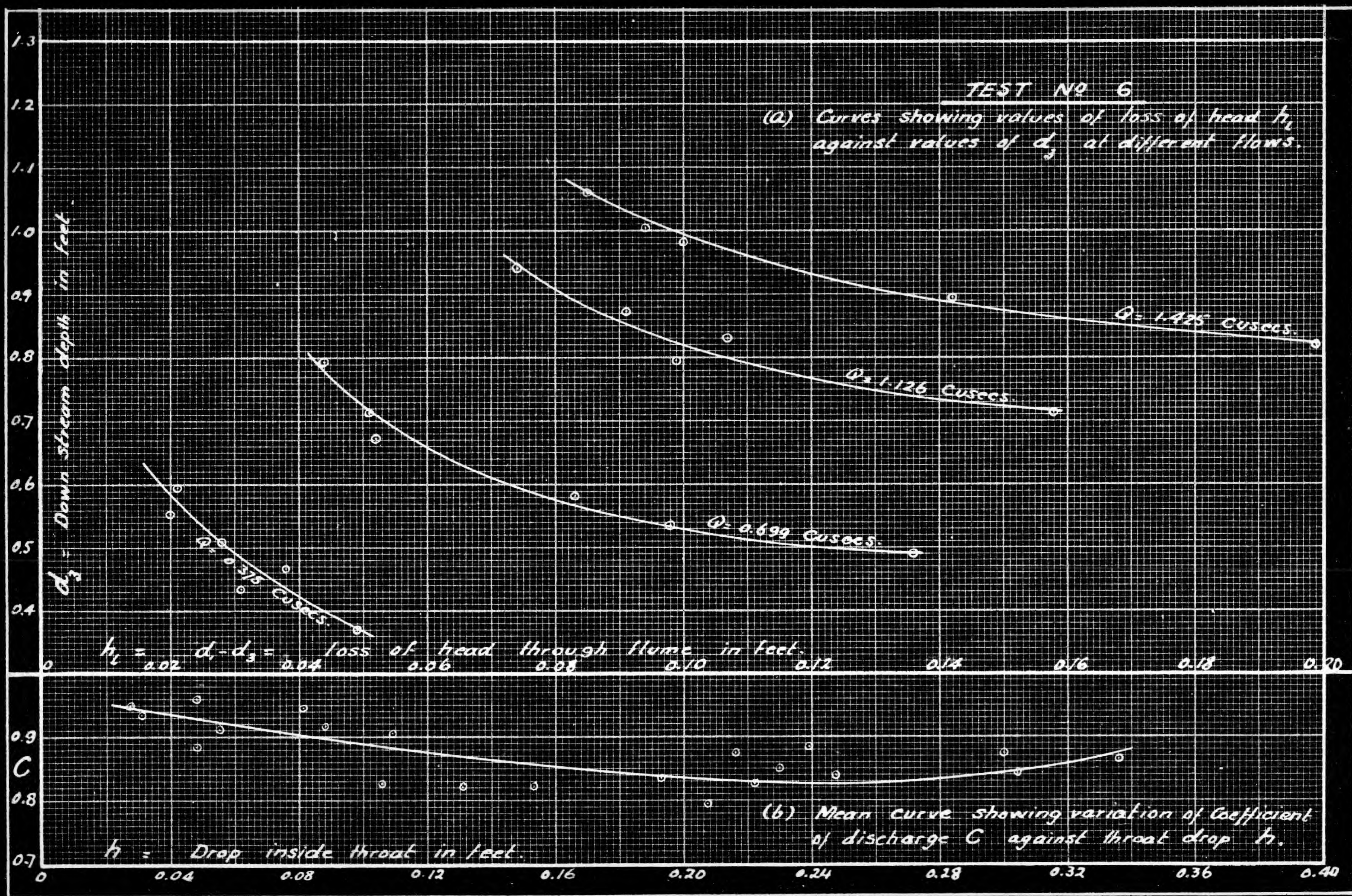

TEST Nº 6
(a) Curves showing values of loss of head h_l against values of d_3 at different flows.
Q = 1.425 Cusecs.
Q = 1.126 Cusecs.
Q = 0.699 Cusecs.
Q = 0.315 Cusecs.
d_3 = Down stream depth in feet.
h_l = d_1 - d_3 = loss of head through flume in feet.
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18
0.20
(b) Mean curve showing variation of Coefficient of discharge C against throat drop h.
C
0.9
0.8
0.7
h = Drop inside throat in feet.
0
0.04
0.08
0.12
0.16
0.20
0.24
0.28
0.32
0.36
0.40

TABLE OF RESULTS ON TEST NO. 7 ON SHAPE "F" (continued)

d_1	d_2	d_3	h	h_L	Q_t	Q_a	C
F	e	e	t		c u s	e c s	
Run No. (2)							
0.672		0.337			0.870	0.783	0.902
0.680	0.465	0.588	0.215	0.092	0.890	,,	0.880
0.723	0.615	0.650	0.108	0.073	0.845	,,	0.927
0.749	0.648	0.680	0.101	0.069	0.865	,,	0.905
0.799	0.715	0.742	0.084	0.057	0.870	,,	0.901
0.880	0.824	0.873	0.056	0.037	0.880	,,	0.889
0.931	0.880	0.897	0.051	0.034	0.840	,,	0.932
Run No. (3)							
0.806		0.539			1.150	1.035	0.901
0.817	0.533	0.674	0.284	0.143	1.170	,,	0.885
0.838	0.612	0.740	0.226	0.098	1.200	,,	0.863
0.882	0.700	0.802	0.182	0.080	1.250	,,	0.828
0.936	0.759	0.860	0.177	0.076	1.330	1.095	0.826
0.983	0.859	0.913	0.124	0.070	1.280	,,	0.857
1.057	0.978	1.005	0.079	0.052	1.170	,,	0.938
Run No. (4)							
1.008		0.627			1.600	1.468	0.918
1.017	0.673	0.817	0.344	0.200	1.630	,,	0.902
1.033	0.690	0.840	0.343	0.193	1.650	,,	0.890
1.051	0.750	0.921	0.301	0.130	1.700	,,	0.864
1.091	0.852	0.997	0.239	0.094	1.730	,,	0.848
1.139	0.923	1.053	0.216	0.086	1.810	,,	0.812
1.186	0.998	1.110	0.188	0.076	1.820	,,	0.807

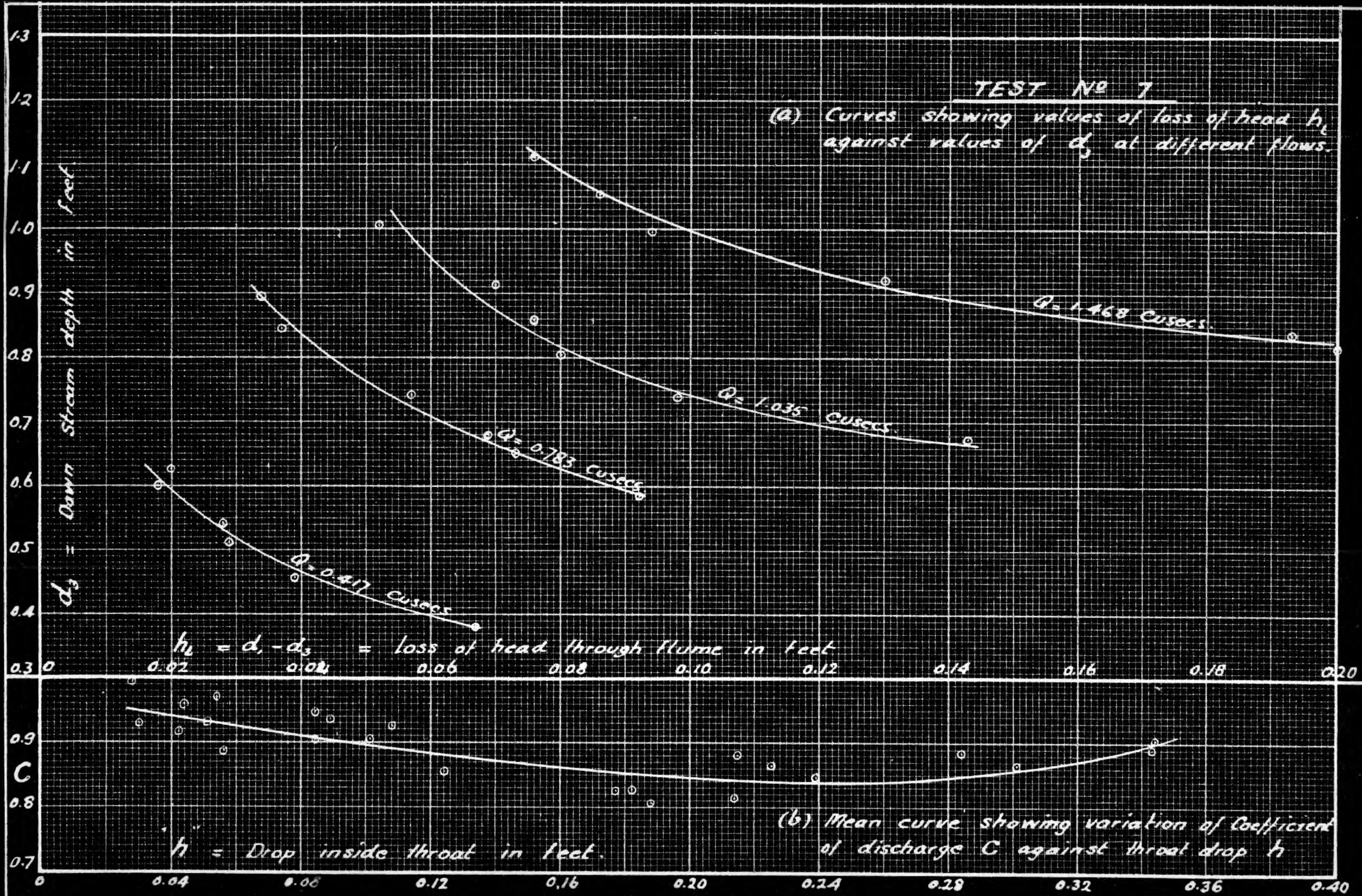

TEST No 7
(a) Curves showing values of loss of head h_L against values of d_3 at different flows.
Q = 1.468 Cusecs
Q = 1.035 Cusecs
Q = 0.783 Cusecs
Q = 0.417 Cusecs
d_3 = Down stream depth in feet
$h_L = d_1 - d_3$ = loss of head through flume in feet
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18
0.20
C
0.9
0.8
0.7
(b) Mean curve showing variation of Coefficient of discharge C against throat drop h
h = Drop inside throat in feet
0.04
0.08
0.12
0.16
0.20
0.24
0.28
0.32
0.36
0.40

TABLE OF RESULTS ON TEST NO. 8 ON SHAPE "G".

d_1	d_2	d_3	h	h_L	Q_t	Q_a	C
	F e e	t		c u	s e	c s	
	Run No. (1)						
0.427		0.223			0.450	0.403	0.897
0.465	0.395	0.425	0.070	0.042	0.450	,,	0.897
0.500	0.446	0.463	0.054	0.037	0.435	,,	0.928
0.555	0.513	0.529	0.042	0.026	0.445	,,	0.907
0.605	0.575	0.589	0.030	0.016	0.425	,,	0.950
0.661	0.633	0.644	0.028	0.017	0.450	,,	0.897
0.717	0.694	0.703	0.023	0.014	0.445	,,	0.907
	Run No. (2)						
0.618		0.425			0.770	0.692	0.898
0.634	0.454	0.565	0.180	0.089	0.800	,,	0.865
0.662	0.519	0.602	0.143	0.060	0.815	,,	0.850
0.696	0.588	0.645	0.108	0.051	0.800	,,	0.865
0.725	0.633	0.679	0.092	0.046	0.810	,,	0.854
0.751	0.684	0.711	0.067	0.040	0.750	,,	0.922
0.800	0.741	0.765	0.059	0.035	0.760	,,	0.910
	Run No. (3)						
0.795		0.443			1.130	1.018	0.902
0.821	0.584	0.726	0.237	0.095	1.170	,,	0.871
0.896	0.733	0.833	0.163	0.063	1.230	,,	0.828
0.941	0.813	0.887	0.128	0.054	1.230	,,	0.828
0.990	0.893	0.938	0.097	0.052	1.160	,,	0.878
1.037	0.962	0.995	0.075	0.042	1.150	,,	0.886
1.086	1.023	1.046	0.063	0.040	1.080	,,	0.942
	Run No. (4)						
1.016		0.668			1.630	1.469	0.902
1.046	0.771	0.910	0.275	0.136	1.650.	,,	0.891
1.075	0.809	0.970	0.266	0.105	1.700	,,	0.865
1.103	0.856	1.018	0.247	0.085	1.800	,,	0.816
1.133	0.913	1.047	0.220	0.086	1.800	,,	0.816
1.167	0.966	1.086	0.201	0.081	1.800	,,	0.816
1.233	1.059	1.165	0.174	0.068	1.880	,,	0.782

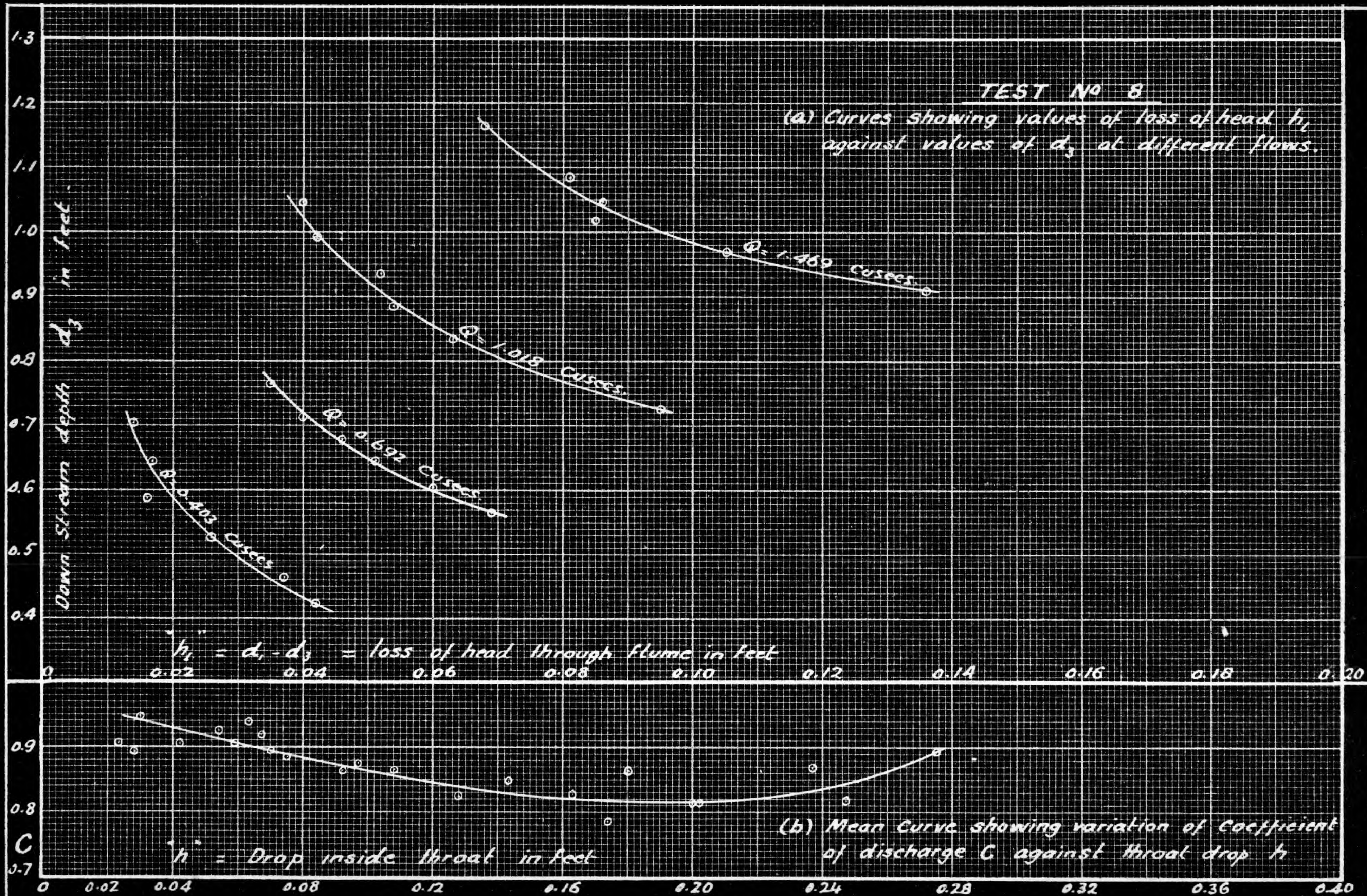

TEST No 8
(a) Curves showing values of loss of head h_1 against values of d_3 at different flows.
Q = 1.469 Cusecs.
Q = 1.018 Cusecs.
Q = 0.692 Cusecs.
Q = 0.403 Cusecs
Down Stream depth d_3 in feet.
"h_1" = $d_1 - d_3$ = loss of head through flume in feet
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18
0.20
(b) Mean Curve showing variation of Coefficient of discharge C against throat drop h
"h" = Drop inside throat in feet
C
0.9
0.8
0.7
0
0.02
0.04
0.08
0.12
0.16
0.20
0.24
0.28
0.32
0.36
0.40

TABLE OF RESULTS ON TEST NO. 9 ON MODEL "H"

d_1	d_2	d_3	h	h_L	Q_t	Q_a	C
	F e e t				c u s e c s		
Run No.(1)							
0.453					0.482	0.456	0.945
0.466	0.366	0.402	0.100	0.0644	0.480	,,	0.949
0.540	0.468	0.494	0.072	0.046	0.520	,,	0.876
0.693	0.661	0.668	0.032	0.025	0.505	,,	0.903
0.856	0.835	0.840	0.021	0.016	0.515	..	0.885
Run No. (2)							
0.738					0.990	0.900	0.900
0.783	0.638	0.703	0.145	0.080	1.030	,,	0.875
0.913	0.832	0.859	0.081	0.054	1.010	,,	0.891
0.980	0.905	0.933	0.075	0.047	1.050	,,	0.857
1.057	0.997	1.020	0.060	0.637	1.040	,,	0.865
1.131	1.087	1.100	0.044	0.031	0.980	,,	0.917
Run No. (3)							
0.879					1.300	1.209	0.930
0.885	0.577	0.715	0.308	0.170	1.320	,,	0.917
0.905	0.632	0.761	0.273	0.144	1.360	,,	0.889
1.007	0.830	0.929	0.177	0.078	1.450	,,	0.833
1.119	1.034	1.060	0.085	0.059	1.270	,,	0.952
1.145	1.066	1.096	0.079	0.049	1.260	,,	0.960
Run No. (4)							
1.034					1.650	1.541	0.935
1.047	0.704	0.848	0.343	0.100	1.700	,,	0.907
1.111	0.841	0.985	0.270	0.126	1.820	,,	0.847
1.180	0.976	1.084	0.204	0.096	1.820	,,	0.847
1.258	1.082	1.182	0.176	0.076	1.910	,,	0.807
1.311	1.171	1.245	0.141	0.066	1.860	,,	0.828

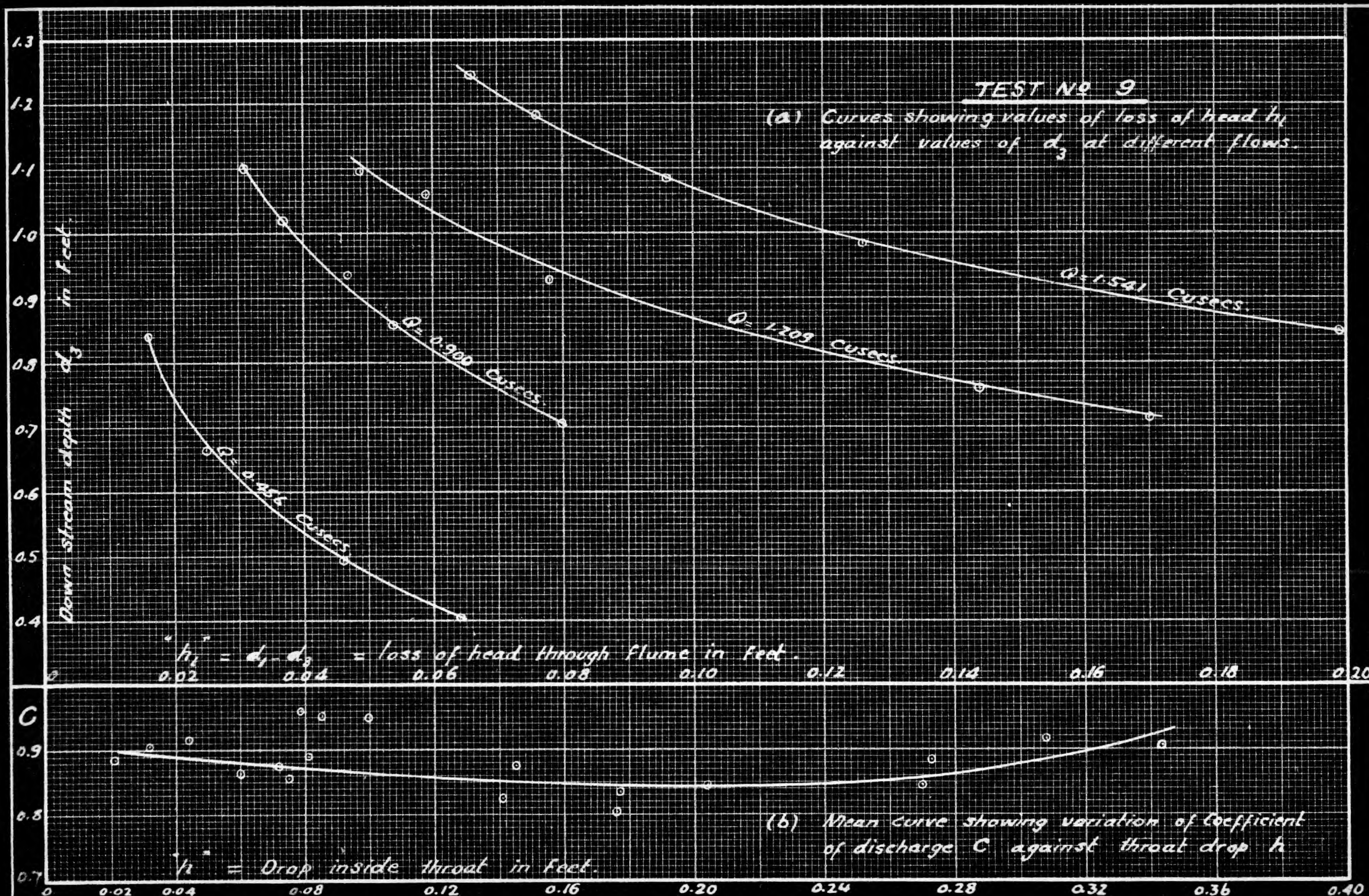
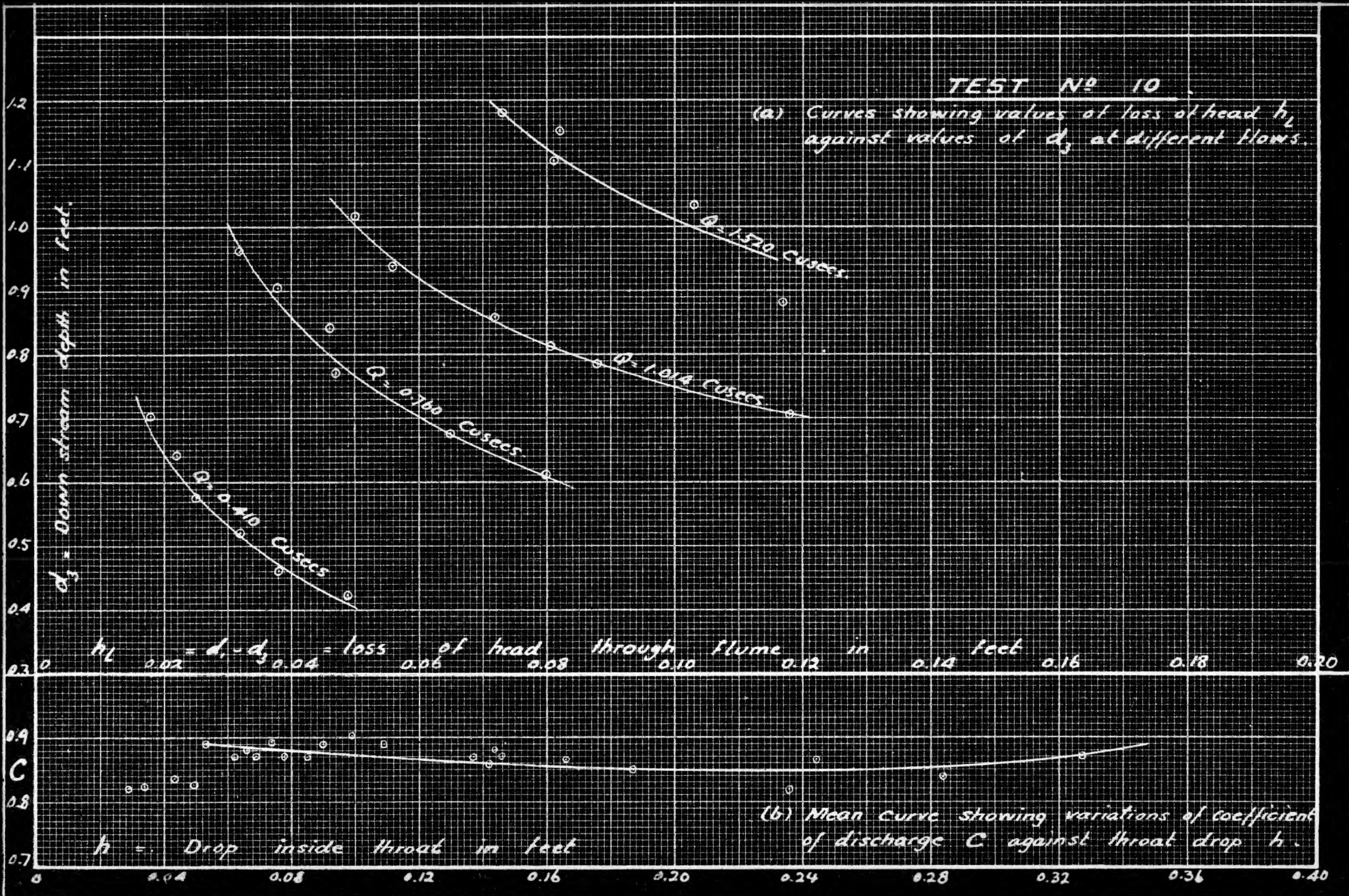

TEST No 9
(a) Curves showing values of loss of head h1 against values of d3 at different flows.
Q = 1.541 Cusecs.
Q = 1.209 Cusecs.
Q = 0.900 Cusecs.
Q = 0.456 Cusecs.
Down Stream depth d3 in Feet.
"h1" = d1 - d3 = loss of head through Flume in Feet.
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18
0.20
C
0.9
0.8
0.7
(b) Mean curve showing variation of Coefficient of discharge C against throat drop h
"h" = Drop inside throat in Feet.
0
0.02
0.04
0.08
0.12
0.16
0.20
0.24
0.28
0.32
0.36
0.40

TABLE OF RESULTS OF TEST NO.10 ON MODEL "I".

d_1	d_2	d_3	h d_1 d_2	$d_1 - d_3$	Q_t	Q_a	C
	Run No. (1)						
0.440	(0.293)	0.210	(0.147)		0.460	0.410	0.892
0.471	0.386	0.422	0.085	0.049	0.470	,,	0.872
0.499	0.433	0.461	0.066	0.038	0.465	,,	0.883
0.553	0.502	0.521	0.051	0.032	0.495	,,	0.828
0.604	0.561	0.579	0.043	0.025	0.490	,,	0.837
0.665	0.631	0.643	0.034	0.022	0.495	,,	0.828
0.719	0.690	0.701	0.029	0.018	0.500	,,	0.820
	Run No. (2)						
0.664	0.440	0.425	0.224		0.855	0.760	0.890
0.692	0.544	0.612	0.144	0.080	0.865	,,	0.880
0.741	0.642	0.676	0.099	0.065	0.845	,,	0.901
0.818	0.744	0.771	0.074	0.047	0.855	,,	0.895
0.886	0.815	0.840	0.071	0.046	0.920	0.800	0.871
0.943	0.881	0.905	0.062	0.038	0.920	,,	0.871
0.994	0.943	0.962	0.051	0.032	0.895	,,	0.893
	Run No. (3)						
0.807	0.522	0.402	0.285		1.150	1.014	0.883
0.821	0.577	0.703	0.244	0.118	1.170	,,	0.867
0.855	0.689	0.787	0.166	0.088	1.170	,,	0.867
0.892	0.750	0.811	0.142	0.081	1.180	,,	0.861
0.931	0.822	0.859	0.109	0.072	1.140	,,	0.891
0.996	0.906	0.940	0.090	0.056	1.140	,,	0.891
1.067	0.989	1.017	0.078	0.050	1.160	,,	0.871
	Run No. (4)						
1.054	0.695	0.634	0.359		1.700	1.520	0.896
1.075	0.748	0.910	0.327	0.265	1.750	,,	0.869
1.100	0.816	0.983	0.284	0.117	1.810	,,	0.840
1.137	0.901	1.034	0.236	0.103	1.850	,,	0.822
1.186	0.999	1.105	0.187	0.081	1.800	,,	0.846
1.234	1.088	1.152	0.146	0.082	1.750	,,	0.870
1.254	1.117	1.181	0.137	0.073	1.750	,,	0.870


TEST No 10.
(a) Curves showing values of loss of head h_l against values of d_3 at different flows.
Q = 1.520 Cusecs.
Q = 1.014 Cusecs
Q = 0.760 Cusecs.
Q = 0.410 Cusecs
d_3 = Down stream depth in feet.
$h_l = d_1 - d_3$ = loss of head through flume in feet
(b) Mean curve showing variations of coefficient of discharge C against throat drop h.
C
h = Drop inside throat in feet

RESULTS OF TEST NO.11 ON MODEL "I" RUN No. 1.

Obsn. No.	d_1	d_2	d_3	h	h_L	Q_t	Q_a	C
(a) Piezometer Gauge readings.				Mean d_2				
1	0.310	0.250	0.280	0.060	0.030	0.259	0.249	.962 ~~19~~
3	0.365	0.330	0.350	0.035	0.015	0.265	,,	.940
4	0.395	0.365	0.385	0.030	0.010	0.268	"	.930
5	0.425	0.400	0.415	0.025	0.010	0.268	"	.930
6	0.460	0.442	0.455	0.018	0.005	0.252	"	.988
7	0.500	0.485	0.495	0.015	0.005	0.252	"	.988
(b) Piezometer Gauge readings				Mean d_2 at centre.				
1	The same as in (a)							
(c) Point Guage readings				Mean d_2				
1	0.310	0.250		0.060	0.030	0.259	0.249	0.962
3	0.365	0.334		0.034	0.015	0.260	"	0.938
4.	0.395	0.364		0.031	0.010	0.270	"	0.923
5.	0.425	0.402		0.023	0.010	0.258	"	0.966
6.	0.460	0.444		0.016	0.005	0.240	"	1.040
7.	0.500	0.465		0.015	0.005	0.252	"	0.990

RESULTS OF TEST NO.11. RUN NO.2.

Obsn. No.	d_1	d_2	d_3	h	h_L	Q_t	Q_a	C
	(a) Piezometer Tube readings				Mean d_2			
1	0.445	0.295	0.365	0.150	0.080	0.470	0.445	0.947
2	0.454	0.345	0.395	0.099	0.059	0.465	,,	0.958
3	0.466	0.380	0.425	0.086	0.041	0.465	,,	0.958
4	0.485	0.410	0.445	0.075	0.040	0.470	,,	0.947
5	0.515	0.455	0.490	0.060	0.025	0.470	,,	0.947
6	0.548	0.500	0.525	0.048	0.023	0.455	,,	0.978
7	0.578	0.538	0.560	0.040	0.018	0.475	,,	0.938
8	0.600	0.565	0.585	0.035	0.015	0.446	,,	0.999
9	0.620	0.585	0.608	0.035	0.012	0.465	,,	0.958
10	0.628	0.598	0.620	0.030	0.008	0.440	,,	1.001
	(b) Taking d_2 at throat centre							
1	0.445	0.288		0.157		0.470	0.45	0.947
2	0.454	0.340		0.114		0.472	,,	0.943
	(c) Run No.2. taking Point gauge readings.							
1	0.445	0.289		0.156		0.470	0.445	0.947
2	0.454	0.346		0.108		0.475	,,	0.937
3	0.466	0.380		0.086		0.465	,,	0.958
4	0.487	0.407		0.080		0.480	,,	0.928
5	0.517	0.452		0.065		0.475	,,	0.937
6	0.549	0.495		0.054		0.480	,,	0.928
7	0.581	0.536		0.045		0.480	,,	0.928
8	0.604	0.565		0.039		0.475	,,	0.937
9	0.622	0.585		0.037		0.475	,,	0.937
10	0.629	0.597		0.032		0.452	,,	0.986

RESULTS OF TEST NO.11 on MODEL I. RUN NO.3.

Obsn. No.	d_1	d_2	d_3	h	h_L	Q_t	Q_a	C
	(a) Taking Piezometer Gauge readings (mean d_2)							
1	0.645	0.428	0.510	0.217	0.135	0.830	0.756	0.910
2	0.648	0.455	0.560	0.193	0.088	0.825	,,	0.917
3	0.655	0.495	0.575	0.160	0.080	0.820	,,	0.921
4	0.675	0.550	0.615	0.125	0.060	0.820	,,	0.921
5	0.688	0.575	0.625	0.113	0.063	0.815	,,	0.927
6	0.715	0.618	0.655	0.097	0.060	0.810	,,	0.933
7	0.735	0.645	0.685	0.090	0.050	0.810	,,	0.933
8	0.750	0.665	0.705	0.085	0.045	0.810	,,	0.933
9	0.820	0.758	0.795	0.062	0.025	0.795	,,	0.950
10	0.852	0.795	0.830	0.057	0.022	0.805	,,	0.938
	(b) Taking Piezometer readings(mean d_2 at centre of throat)							
1	0.645	0.418		0.227		0.830	0.756	0.910
2	0.648	0.450		0.198		0.825	,,	0.917
3	0.655	0.485		0.170		0.830	,,	0.910
4	0.675	0.545		0.130		0.820	,,	0.921
5	0.688	0.570		0.118		0.820	,,	0.921
6	0.715	0.612		0.103		0.820	,,	0.921
7	0.735	0.645		0.090		0.810	,,	0.933
8.	0.750	0.662		0.088		0.825	,,	0.917
9.	0.820	0.758		0.062		0.795	,,	0.950
10.	0.852	0.795		0.057		0.805	,,	0.938
	(c) Taking Point Gauge readings.					Mean d_2		
1	0.648	0.419		0.229		0.830	0.756	0.911
2	0.650	0.445		0.205		0.830	,,	0.911
3	0.658	0.473		0.185		0.840	,,	0.900
4	0.677	0.540		0.137		0.845	,,	0.893
5	0.690	0.569		0.121		0.825	,,	0.916
6	0.715	0.618		0.097		0.815	,,	0.927
7	0.735	0.648		0.087		0.805	,,	0.938
8	0.752	0.666		0.086		0.820	,,	0.922
9	0.824	0.755		0.069		0.840	,,	0.900
10	0.857	0.795		0.062		0.840	,,	0.900

RESULTS OF TEST NO.11 ON MODEL I RUN NO.4.

Obsn. No.	d_1	d_2	d_3	h	h_L	Q_t	Q_a	C
(a) Piezometer Gauge readings (mean d_2)								
1	0.770	0.550	0.665	0.220	0.105	1.060	0.989	0.933
2	0.784	0.600	0.695	0.184	0.089	1.070	,,	0.925
3	0.796	0.640	0.715	0.156	0.081	1.050	,,	0.942
4	0.815	0.675	0.740	0.140	0.075	1.060	,,	0.933
5	0.830	0.708	0.765	0.122	0.065	1.040	,,	0.952
6	0.855	0.750	0.795	0.105	0.060	1.030	,,	0.961
7	0.876	0.775	0.815	0.101	0.061	1.040	,,	0.952
8	0.898	0.805	0.845	0.093	0.053	1.020	,,	0.970
9	0.925	0.835	0.875	0.090	0.050	1.060	,,	0.933
10	0.965	0.885	0.920	0.080	0.045	1.070	,,	0.925
(b) Piezometer Gauge readings - mean d_2 at centre.								
1	0.770	0.530		0.240		1.070	0.989	0.925
2	0.784	0.592		0.192		1.070	,,	,,
3	0.796	0.632		0.164		1.060	,,	,,
	Rest of observations as in (a)							
(c) Point Gauge readings (mean d_2)								
1	0.772	0.521		0.251	0.105	1.070	0.989	0.925
2	0.784	0.574		0.210	0.089	1.080	,,	0.915
3	0.799	0.616		0.183	0.081	1.090	,,	0.907
4	0.818	0.668		0.150	0.075	1.080	,,	0.916
5	0.837	0.706		0.131	0.065	1.070	,,	0.924
6	0.864	0.750		0.114	0.060	1.070	,,	0.925
7	0.882	0.781		0.101	0.061	1.040	,,	0.952
8	0.901	0.807		0.094	0.053	1.050	,,	0.942
9	0.926	0.837		0.089	0.050	1.050	,,	0942
10.	0.964	0.887		0.077	0.045	1.040	,,	0.942

RESULTS OF TEST NO.11 ON MODEL I RUN NO.5.

Obsn. No.	d_1	d_2	d_3	h	h_L	Q_t	Q_a	C
(a) Piezometer Gauge readings.				Mean d_2				
1	0.847	0.600	0.705	0.247	0.142	1.220	1.152	0.945
2	0.856	0.640	0.745	0.216	0.111	1.220	,,	0.945
3	0.865	0.655	0.765	0.210	0.100	1.240	,,	0.930
4	0.875	0.685	0.785	0.190	0.090	1.240	,,	0.930
5	0.905	0.745	0.825	0.160	0.080	1.250	,,	0.922
6	0.930	0.795	0.865	0.135	0.065	1.230	,,	0.937
7.	0.952	0.830	0.890	0.122	0.062	1.220	,,	0.945
8	0.973	0.860	0.920	0.113	0.053	1.220	,,	0.945
9	0.997	0.898	0.945	0.099	0.052	1.180	,,	0.977
10	1.022	0.925	0.968	0.097	0.054	1.220	,,	0.945
(b) Piezometer Gauge readings (mean d_2 at centre)								
1	0.847	0.588		0.259		1.230	1.152	0.937
2	0.856	0.620		0.236		1.240	,,	0.930
3	0.865	0.645		0.220		1.240	,,	0.930
4	0.875	0.675		0.200		1.250	,,	0.922
5	0.905	0.740		0.165		1.260	,,	0.915
6	0.930	0.790		0.140		1.240	,,	0.930
7	0.952	0.828		0.124		1.230	,,	0.937
9	0.997	0.895		0.102		1.210	,,	0.953
(c) Point Gauge readings (mean d_2)								
1	0.856	0.567		0.283	0.142	1.240	1.152	0.930
2	0.858	0.593		0.265	0.141	1.250	,,	0.922
3	0.866	0.619		0.247	0.100	1.250	,,	0.922
4	0.876	0.652		0.224	0.090	1.270	,,	0.908
5	0.905	0.718		0.187	0.080	1.290	,,	0.893
6	0.929	0.785		0.144	0.065	1.250	,,	0.922
7	0.952	0.820		0.132	0.062	1.260	,,	0.915
8	0.973	0.864		0.109	0.053	1.210	,,	0.953
9	0.999	0.897		0.102	0.052	1.210	,,	0.953
10	1.025	0.931		0.094	0.054	1.210	,,	0.953

RESULTS OF TEST No. 11 on MODEL "I", RUN No. 6.

Obsn. No.	d_1	d_2	d_3	h	h_L	Q_t	Q_a	C
(a)	Piezometer Gauge readings				mean d_2			
1	0.962	0.720	0.840	0.242	0.122	1.450	1.358	0.937
2	0.978	0.765	0.870	0.213	0.108	1.470	1.358	0.925
3	0.996	0.815	0.905	0.181	0.091	1.440	1.358	0.943
4	1.020	0.860	0.940	0.160	0.080	1.450	1.358	0.937
5	1.043	0.895	0.960	0.148	0.083	1.440	1.358	0.943
6	1.065	0.930	0.985	0.135	0.080	1.440	1.358	0.943
7	1.085	0.965	1.010	0.120	0.075	1.400	1.358	0.971
8	1.115	0.995	1.050	0.120	0.065	1.460	1.358	0.931
9	1.142	1.030	1.085	0.112	0.057	1.450	1.358	0.937
10	1.158	1.055	1.100	0.103	0.058	1.440	1.358	0.943
(b)	Piezometer Gauge readings				mean d_2 at centre.			
1	0.962	0.705		0.257		1.460	1.358	0.931
2	0.978	0.755		0.223		0.480	1.358	0.918
3	0.996	0.805		0.191		1.450	1.358	0.937
4	1.020	0.850		0.170		1.470	1.358	0.925
5	1.043	0.890		0.153		1.460	1.358	0.931
6	1.065	0.925		0.140		1.460	1.358	0.931
7	1.085	0.955		0.130		1.470	1.358	0.925
8	1.115	0.990		0.125		1.480	1.358	0.918
9	1.142	1.028		0.114		1.470	1.358	0.925
10	1.158	1.050		0.108		1.450	1.358	0.937
(c)	Point Gauge readings			mean d_2				
1	0.965	0.675		0.310		1.510	1.358	0.900
2	0.980	0.719		0.261		1.530	1.358	0.888
3	1.002	0.769		0.233		1.550	1.358	0.877
4	1.024	0.826		0.198		1.540	1.358	0.882
5	1.046	0.876		0.170		1.510	1.358	0.900
6	1.068	0.917		0.151		1.490	1.358	0.912
7	1.088	0.951		0.137		1.480	1.358	0.918
8	1.113	0.992		0.121		1.470	1.358	0.925
9	1.142	1.031		0.111		1.440	1.358	0.943
10	1.159	1.056		0.103		1.440	1.358	0.943

RESULTS OF TEST No. 11 on MODEL "I", RUN No. 7.

Obsn.No.	d_1	d_2	d_3	h	h_L	Q_t	Q_a	C
(a) Piezometer Gauge readings mean d_2								
1	1.098	0.820	0.945	0.278	0.153	1.790	1.634	0.913
2	1.112	0.870	0.985	0.242	0.127	1.790	1.634	0.913
3	1.132	0.910	1.020	0.222	0.112	1.810	1.634	0.904
4	1.148	0.950	1.045	0.198	0.103	1.790	1.634	0.913
5	1.172	0.985	1.075	0.187	0.097	1.790	1.634	0.913
6	1.185	1.010	1.090	0.175	0.095	1.780	1.634	0.918
7	1.198	1.030	1.105	0.168	0.093	1.770	1.634	0.923
8	1.214	1.055	1.125	0.159	0.089	1.780	1.634	0.918
9	1.225	1.070	1.135	0.155	0.090	1.780	1.634	0.918
10	1.240	1.098	1.155	0.142	0.085	1.760	1.634	0.928
(b) Piezometer Gauge readings mean d_2 at centre								
1	1.098	0.815		0.283		1.800	1.634	0.908
2	1.112	0.855		0.257		1.810	1.634	0.903
3	1.132	0.900		0.232		1.810	1.634	0.903
4	1.148	0.940		0.208		1.810	1.634	0.903
5	1.172	0.975		0.197		1.810	1.634	0.903
6	1.185	1.005		0.180		1.790	1.634	0.913
7	1.198	1.028		0.170		1.780	1.634	0.918
8	1.214	1.045		0.169		1.810	1.634	0.903
9	1.225	1.065		0.160		1.800	1.634	0.908
10	1.240	1.095		0.145		1.760	1.634	0.928
(c) Point Gauge readings mean d_2								
1	1.101	0.775		0.326		1.830	1.634	0.893
2	1.116	0.808		0.308		1.850	1.634	0.883
3	1.134	0.856		0.278		1.860	1.634	0.878
4	1.149	0.894		0.255		1.880	1.634	0.869
5	1.173	0.941		0.232		1.880	1.634	0.869
6	1.186	0.969		0.217		1.890	1.634	0.865
7	1.198	0.999		0.199		1.860	1.634	0.878
8	1.214	1.030		0.184		1.870	1.634	0.875
9	1.226	1.049		0.177		1.870	1.634	0.875
10	1.242	1.079		0.163		1.850	1.634	0.883

RESULTS OF TEST No. 12 ON MODEL "I". RUN No. 1.

Obsn. No.	d_1	d_2	d_3	h	h_L	Q_t	Q_a	C
(a)	Piezometer Gauge readings				(mean d_2)			
1	0.370	0.290	0.320	0.080	0.050	0.455	0.439	0.965
2	0.398	0.340	0.368	0.058	0.030	0.455	0.439	0.965
3	0.430	0.385	0.410	0.045	0.020	0.455	0.439	0.965
4	0.455	0.418	0.440	0.037	0.015	0.450	0.439	0.977
5	0.485	0.453	0.472	0.032	0.013	0.455	0.439	0.965
6	0.518	0.490	0.506	0.028	0.012	0.460	0.439	0.956
7	0.546	0.522	0.538	0.024	0.008	0.454	0.439	0.967
8	0.578	0.560	0.575	0.018	0.003	0.430	0.439	1.022
9	0.602	0.585	0.600	0.017	0.002	0.430	0.439	1.022
10	0.628	0.612	0.626	0.016	0.002	0.440	0.439	0.999
(b)	Piezometer Gauge readings				mean d_2 at centre			
	The same as (a)							
(c)	Point Gauge readings.			mean d_2				
1	0.372	0.288		0.084		0.465	0.439	0.945
2	0.399	0.338		0.061		0.465	0.439	0.945
3	0.429	0.382		0.047		0.465	0.439	0.945
4	0.456	0.414		0.042		0.470	0.439	0.935
5	0.486	0.451		0.035		0.475	0.439	0.926
6	0.520	0.488		0.032		0.490	0.439	0.897
7	0.547	0.521		0.026		0.475	0.439	0.925
8	0.582	0.556		0.026		0.495	0.439	0.887
9	0.602	0.582		0.020		0.465	0.439	0.945
10	0.632	0.612		0.020		0.490	0.439	0.897

RESULTS OF TEST No. 12 on MODEL "I", RUN No.2.

Obsn. No.	d_1	d_2	d_3	h	h_L	Q_t	Q_a	C
(a)	Piezometer Gauge readings				mean d_2			
1	0.466	0.355	0.400	0.111	0.066	0.655	0.634	0.968
2	0.488	0.402	0.440	0.086	0.048	0.655	0.634	0.968
3	0.505	0.430	0.465	0.075	0.040	0.655	0.634	0.968
4	0.538	0.478	0.505	0.060	0.033	0.655	0.634	0.968
5	0.566	0.515	0.540	0.051	0.026	0.655	0.634	0.968
6	0.594	0.550	0.570	0.044	0.024	0.650	0.634	0.976
7	0.625	0.588	0.605	0.037	0.020	0.640	0.634	0.992
8	0.645	0.612	0.625	0.033	0.020	0.630	0.634	1.007
9	0.668	0.640	0.652	0.028	0.016	0.610	0.634	1.039
10	0.680	0.650	0.665	0.030	0.015	0.640	0.634	0.992
(b)	Piezometer Gauge readings				mean d_2 at centre.			
	The same as (a)							
(c)	Point Gauge Readings.			mean d_2				
1	0.466	0.353		0.113	0.066	0.655	0.634	0.968
2	0.489	0.400		0.089	0.048	0.670	0.634	0.947
3	0.505	0.428		0.077	0.040	0.660	0.634	0.962
4	0.538	0.474		0.064	0.033	0.665	0.634	0.954
5	0.568	0.511		0.057	0.026	0.685	0.634	0.927
6	0.596	0.547		0.049	0.024	0.675	0.634	0.940
7	0.626	0.584		0.042	0.020	0.675	0.634	0.940
8	0.645	0.609		0.036	0.020	0.655	0.634	0.968
9	0.667	0.635		0.032	0.016	0.645	0.634	0.984
10	0.682	0.647		0.035	0.015	0.685	0.634	0.926

RESULTS OF TEST No. 12 ON MODEL "I", RUN No. 3.

Obsn. No.	d_1	d_2	d_3	h	h_L	Q_t	Q_a	C
(a)	Piezometer Gauge readings (mean d_2)							
1	0.615	0.525	0.580	0.090	0.035	0.875	0.849	0.971
2	0.640	0.565	0.610	0.075	0.030	0.865	0.849	0.982
3	0.676	0.612	0.655	0.064	0.025	0.865	0.849	0.982
4	0.700	0.645	0.680	0.055	0.020	0.850	0.849	0.999
5	0.725	0.670	0.705	0.055	0.020	0.875	0.849	0.971
6	0.755	0.705	0.740	0.050	0.015	0.880	0.849	0.966
7	0.778	0.730	0.760	0.048	0.018	0.895	0.849	0.949
8	0.800	0.760	0.785	0.040	0.015	0.855	0.849	0.994
9	0.840	0.805	0.830	0.035	0.010	0.845	0.849	1.005
10	0.855	0.816	0.845	0.039	0.010	0.905	0.849	0.938
(b)	Piezometer Gauge readings mean d_2 at centre							
	The same as (a)							
(c)	Point Gauge readings mean d_2							
1	0.616	0.529	0.580	0.087	0.036	0.870	0.849	0.977
2	0.643	0.566	0.610	0.077	0.033	0.870	0.849	0.977
3	0.678	0.611	0.655	0.067	0.023	0.885	0.849	0.960
4	0.699	0.639	0.680	0.060	0.019	0.880	0.849	0.965
5	0.725	0.668	0.705	0.057	0.020	0.895	0.849	0.948
6	0.756	0.705	0.740	0.051	0.016	0.885	0.849	0.960
7	0.778	0.729	0.760	0.049	0.018	0.905	0.849	0.938
8	0.803	0.758	0.785	0.045	0.018	0.900	0.849	0.943
9	0.839	0.804	0.830	0.035	0.009	0.850	0.849	0.999
10	0.856	0.815	0.845	0.041	0.011	0.910	0.849	0.933

RESULTS OF TEST No. 12 ON MODEL "I", RUN No. 4.

Obsn.No.	d_1	d_2	d_2	h	h_L	Q_t	Q_a	C
(a)	Piezometer Gauge readings				mean d_2			
1	0.650	0.468	0.562	0.182	0.088	1.100	1.053	0.958
2	0.672	0.542	0.605	0.130	0.067	1.100	1.053	0.958
3	0.694	0.585	0.640	0.109	0.054	1.070	1.053	0.985
4	0.722	0.628	0.675	0.094	0.044	1.070	1.053	0.985
5	0.747	0.660	0.705	0.087	0.042	1.090	1.053	0.967
6	0.765	0.685	0.730	0.080	0.035	1.100	1.053	0.958
7	0.790	0.715	0.760	0.075	0.030	1.100	1.053	0.958
8	0.810	0.746	0.780	0.064	0.030	1.060	1.053	0.995
9	0.824	0.760	0.797	0.064	0.027	1.070	1.053	0.985
10	0.833	0.770	0.807	0.063	0.028	1.080	1.053	0.977
(b)	Piezometer Gauge readings				mean d_2 at centre			
1	0.650	0.465		0.185		1.100	1.053	0.958
3	0.694	0.582		0.112		1.070	1.053	0.985
5	0.747	0.662		0.085		1.075	1.053	0.980
6	0.765	0.686		0.079		1.100	1.053	0.958
7	0.790	0.713		0.077		1.110	1.053	0.950
(c)	Point Gauge readings			mean d_2				
1	0.652	0.451		0.201		1.110	1.053	0.950
2	0.673	0.537		0.136		1.110	1.053	0.950
3	0.697	0.589		0.108		1.070	1.053	0.985
4	0.724	0.633		0.091		1.060	1.053	0.995
5	0.748	0.663		0.085		1.075	1.053	0.980
6	0.768	0.689		0.079		1.100	1.053	0.958
7	0.791	0.717		0.074		1.090	1.053	0.967
8	0.809	0.746		0.063		1.050	1.053	1.003
9	0.825	0.758		0.067		1.090	1.053	0.967
10	0.836	0.770		0.066		1.100	1.053	0.958

RESULTS OF TEST No.12. RUN No.5. (MODEL I)

Obsn. No.	d_1	d_2	d_3	n	n_L	Qt	Qa	C
(a) Piezometer Gauge readings. mean d_2								
1	0.770	0.555	0.666	0.215	0.104	1.400	1.325	0.947
2	0.786	0.612	0.705	0.174	0.081	1.420	,,	0.933
3	0.802	0.660	0.735	0.142	0.067	1.380	,,	0.961
4	0.827	0.700	0.765	0.127	0.062	1.390	,,	0.953
5	0.846	0.735	0.787	0.111	0.059	1.360	,,	0.975
6	0.866	0.760	0.808	0.106	0.054	1.390	,,	0.953
7.	0.878	0.775	0.825	0.103	0.053	1.400	,,	0.947
8	0.890	0.792	0.835	0.098	0.055	1.390	,,	0.953
9	0.900	0.805	0.850	0.095	0.050	1.390	,,	0.953
10	0.916	0.828	0.870	0.088	0.046	1.370	,,	0.967
(b) Piezometer Gauge readings. mean d_2 at centre.								
2	0.786	0.610		0.176		1.420	1.325	0.933
3	0.802	0.662		0.140		1.370	,,	0.967
(c) Point Gauge readings. mean d_2								
1	0.773	0.529		0.244		1.430	1.325	0.927
2	0.789	0.587		0.202		1.460	,,	0.908
3	0.801	0.653		0.148		1.400	,,	0.947
4	0.827	0.696		0.133		1.420	,,	0.933
5	0.848	0.739		0.109		1.350	,,	0.983
6	0.871	0.771		0.100		1.380	,,	0.961
7	0.882	0.787		0.095		1.350	,,	0.983
8	0.892	0.801		0.091		1.340	,,	0.990
9	0.902	0.814		0.088		1.350	,,	0.983
10	0.918	0.832		0.086		1.350	,,	0.983

RESULTS OF TEST NO.12. MODEL I. RUN NO.6.

Obsn. No.	d_1	d_2	d_3	n	n_L	Q_t	Q_a	C
(a) Piezometer Gauge readings.				mean d_2				
1	0.855	0.615	0.735	0.240	0.120	1.650	1.575	0.956
2	0.868	0.665	0.775	0.203	0.093	1.650	,,	0.956
3	0.886	0.718	0.805	0.168	0.081	1.640	,,	0.962
4	0.913	0.768	0.840	0.145	0.073	1.620	,,	0.973
5	0.936	0.808	0.875	0.128	0.061	1.600	,,	0.985
6	0.960	0.845	0.900	0.115	0.060	1.600	,,	0.985
7	0.987	0.880	0.935	0.107	0.052	1.610	,,	0.979
8	1.005	0.905	0.955	0.100	0.050	1.600	,,	0.985
9	1.030	0.938	0.985	0.092	0.045	1.590	,,	0.992
10	1.058	0.972	1.015	0.086	0.043	1.590	,,	0.992
(b) Piezometer Gauge readings.				mean d_2 at centre.				
1	0.855	0.610		0.245		1.650	1.575	0.956
2	0.868	0.662		0.206		1.650	..	0.956
3	0.886	0.720		0.166		1.630	,,	0.967
4	0.913	0.766		0.147		1.620	,,	0.973
(c) Point Gauge readings.			mean d_2					
1	0.860	0.586		0.274		1.660	1.575	0.950
2	0.871	0.632		0.239		1.670	,,	0.944
3	0.892	0.689		0.203		1.700	,,	0.927
4	0.919	0.755		0.164		1.680	,,	0.938
5	0.940	0.806		0.134		1.640	,,	0.962
6	0.963	0.847		0.116		1.610	,,	0.979
7	0.990	0.887		0.103		1.600	,,	0.985
8	1.008	0.909		0.099		1.600	..	0.985
9	1.034	0.940		0.094		1.610	,,	0.979
10	1.061	0.977		0.084		1.580	..	0.998

RESULTS OF TEST NO.12. MODEL I. RUN No.7.

Obsn. No.	d_1	d_2	d_3	n	n_L	Q_t	Q_a	C
(a) Piezometer Gauge readings. mean d_2								
1	0.962	0.695	0.805	0.267	0.157	1.970	1.883	0.957
2	0.972	0.730	0.850	0.242	0.122	1.960	,,	0.962
3	0.985	0.775	0.885	0.210	0.100	1.960	,,	0.962
4	0.997	0.815	0.925	0.182	0.072	1.910	,,	0.986
5	1.025	0.865	0.955	0.160	0.070	1.920	,,	0.981
6	1.043	0.900	0.980	0.143	0.063	1.890	1.835	0.972
7	1.070	0.945	1.010	0.125	0.060	1.850	,,	0.992
8	1.098	0.985	1.045	0.113	0.053	1.850	,,	0.992
9	1.12o	1.015	1.075	0.105	0.045	1.850	,,	0.992
10	1.150	1.055	1.105	0.095	0.045	1.820	,,	1.008
(b) Piezometer Gauge readings. mean d_2 at centre.								
2	0.972	0.725		0.247		1.970	1.883	0.957
3	0.985	0.768		0.217		1.980	1.883	0.952
7	1.070	0.940		0.130		1.890	1.835	0.972
8	1.098	0.982		0.116		1.860	1.835	0.987
(c) Point Gauge readings. mean d_2								
1	0.964	0.657		0.307		1.980	1.883	0.952
2	0.973	0.691		0.282		2.000	,,	0.942
3	0.988	0.736		0.252		2.020	,,	0.933
4	0.998	0.780		0.218		2.000	,,	0.942
5	1.025	0.839		0.186		2.000	,,	0.942
6	1.044	0.881		0.163		1.980	1.835	0.927
7	1.074	0.939		0.135		1.910	,,	0.986
8	1.101	0.983		0.118		1.900	,,	0.963
9	1.124	1.019		0.105		1.850	,,	0.993
10	1.153	1.057		0.096		1.830	,,	1.002

RESULTS OF TEST No.12. MODEL I. RUN No.8.

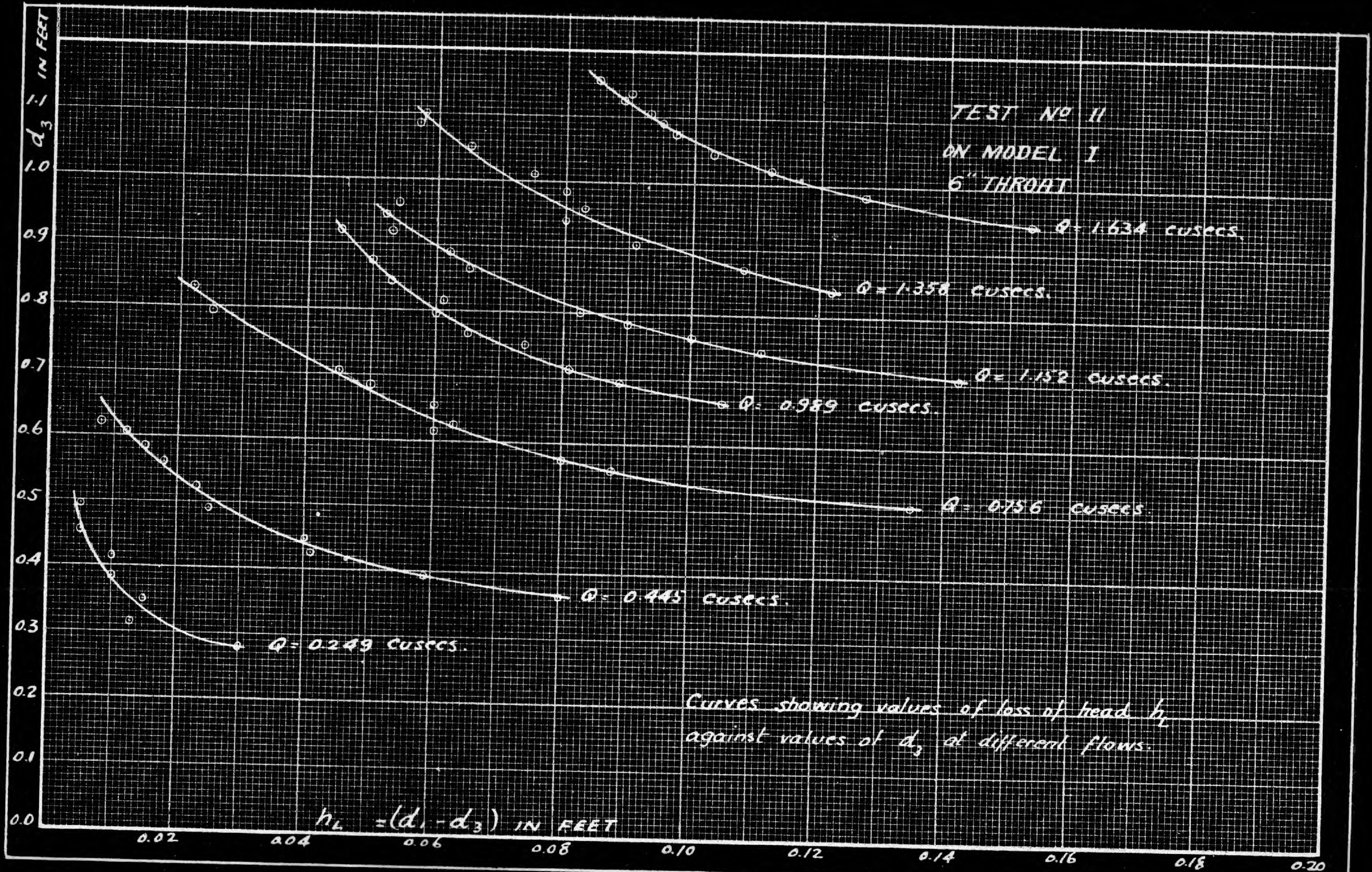
Obsn. No.	d_1	d_2	d_3	n	n_L	Q_t	Q_a	C
(a) Piezometer Gauge readings. mean d_2								
1	1.070	0.775	0.905	0.295	0.165	2.300	2.205	0.957
2	1.081	0.820	0.940	0.261	0.141	2.300	..	0.957
3	1.095	0.860	0.980	0.235	0.115	2.290	..	0.962
4	1.105	0.895	1.010	0.210	0.095	2.280	..	0.967
5	1.115	0.905	1.015	0.210	0.100	2.300	..	0.957
6	1.130	0.940	1.035	0.190	0.095	2.290	..	0.962
7	1.155	0.990	1.075	0.165	0.080	2.220	..	0.993
8	1.185	1.030	1.110	0.155	0.075	2.220	..	0.993
9	1.215	1.075	1.140	0.140	0.075	2.230	..	0.988
(b) Piezometer Gauge readings. mean d_2 at centre.								
1	1.070	0.772		0.298		2.300	2.205	0.957
2	1.081	0.815		0.266		2.300	..	0.957
3	1.095	0.850		0.245		2.310	..	0.953
5	1.115	0.900		0.215		2.310	..	0.953
7	1.155	0.980		0.175		2.290	..	0.962
(c) Point Gauge readings. mean d_2								
1	1.071	0.732		0.339		2.320	2.205	0.949
2	1.083	0.769		0.314		2.320	..	0.949
3	1.100	0.809		0.291		2.410	..	0.914
4	1.108	0.841		0.267		2.400	..	0.918
5	1.118	0.855		0.263		2.420	..	0.910
6	1.133	0.891		0.242		2.420	..	0.910
7	1.158	0.949		0.209		2.400	..	0.918
8	1.188	1.004		0.184		2.390	..	0.922
9	1.220	1.061		0.159		2.400	..	0.918

TABLE SHOWING OBSERVED VALUES OF DISCHARGE AND THEIR CORRESPONDING MINIMUM UPSTREAM DEPTHS AT FREE FLOW.

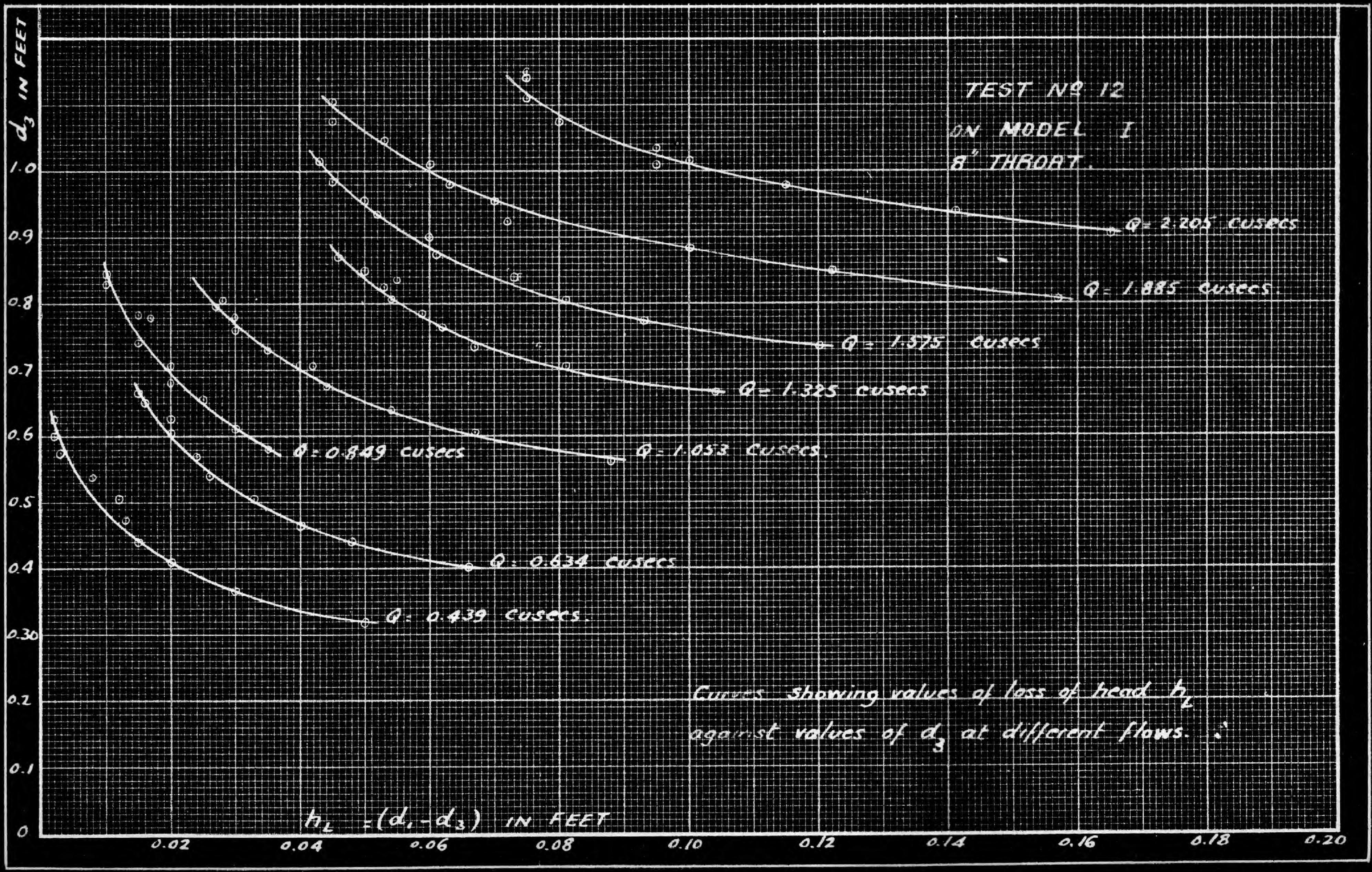
Test No.	Run No.	Upstream depth in feet.	Discharge in cusecs.		C	Mean Value of C.
			Observed	Theoretical		
1	1	0.474	0.485	0.523	0.928	
	2	0.630	0.742	0.795	0.932	0.930
	3	0.983	1.439	1.550	0.928	
	4	1.137	1.808	1.940	0.932	
2	1	0.475	0.470	0.523	0.898	
	2	0.639	0.734	0.810	0.907	0.901
	3	0.774	0.974	1.080	0.902	
	4	0.946	1.307	1.460	0.896	
3	1	0.467	0.475	0.508	0.935	
	2	0.634	0.719	0.800	0.898	0.915
	3.	0.824	1.095	1.180	0.928	
	4	0.948	1.310	1.460	0.897	
4	1	0.445	0.427	0.485	0.882	
	2	0.634	0.724	0.800	0.906	0.893
	3	0.796	1.005	1.130	0.886	
	4	1.003	1.418	1.580	0.899	
5	1	0.469	0.461	0.510	0.903	
	2	0.602	0.660	0.750	0.881	0.891
	3.	0.824	1.064	1.190	0.895	
	4	1.012	1.449	1.620	0.895	
6	1	0.405	0.375	0.408	0.920	
	2	0.625	0.699	0.785	0.892	0.904
	3	0.858	1.126	1.250	0.902	
	4	1.001	1.425	1.580	0.903	
7	1	0.432	0.417	0.450	0.927	
	2	0.672	0.783	0.870	0.901	0.913
	3	0.806	1.035	1.140	0.908	
	4	1.008	1.468	1.600	0.918	

TABLE SHOWING OBSERVED VALUES OF DISCHARGE AND THEIR CORRESPONDING MINIMUM UPSTREAM DEPTHS AT FREE FLOW (continued)

Test No.	Run No.	Upstream depth in feet.	Discharge in cusecs. Observed.	Discharge in cusecs. Theoretical.	C	Mean Value of C.
8	1	0.427	0.403	0.440	0.918	
	2	0.618	0.692	0.770	0.900	0.905
	3	0.795	1.018	1.125	0.905	
	4	1.016	1.469	1.640	0.897	
9	1	0.453	0.456	0.490	0.930	
	2	0.738	0.900	1.010	0.891	0.921
	3	0.879	1.209	1.290	0.938	
	4	1.034	1.541	1.670	0.923	
10	1.	0.440	0.410	0.463	0.885	
	2	0.664	0.760	0.860	0.884	0.887
	3	0.807	1.014	1.150	0.883	
	4	1.054	1.520	1.700	0.895	
11	1	0.300	0.249	0.262	0.952	
	2	0.445	0.445	0.475	0.937	
	3	0.645	0.756	0.820	0.922	
	4 b	0.734	0.989	1.000	0.989	0.938
	5	0.846	1.152	1.240	0.930	
	6	0.945	1.358	1.470	0.923	
	7	1.075	1.634	1.790	0.913	
12	1	0.365	0.439	0.465	0.946	
	2	0.460	0.634	0.660	0.962	
	3	0.561	0.849	0.878	0.967	
	4	0.647	1.053	1.100	0.958	0.957
	5	0.766	1.325	1.420	0.934	
	6	0.850	1.575	1.640	0.960	
	7	0.950	1.883	1.960	0.962	
	8	1.054	2.205	2.280	0.967	



Curves showing values of loss of head h_L against values of d_3 at different flows.


TEST Nº 12
ON MODEL I
8" THROAT.
Q = 2.205 cusecs
Q = 1.885 cusecs.
Q = 1.575 cusecs
Q = 1.325 cusecs
Q = 1.053 cusecs.
Q = 0.849 cusecs
Q: 0.634 cusecs
Q: 0.439 cusecs.
Curves showing values of loss of head h_L
against values of d_3 at different flows.
d_3 IN FEET
$h_L = (d_1 - d_3)$ IN FEET
0
0.1
0.2
0.30
0.4
0.5
0.6
0.7
0.8
0.9
1.0
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18
0.20

CONCLUSIONS FROM TESTS 1 - 12.

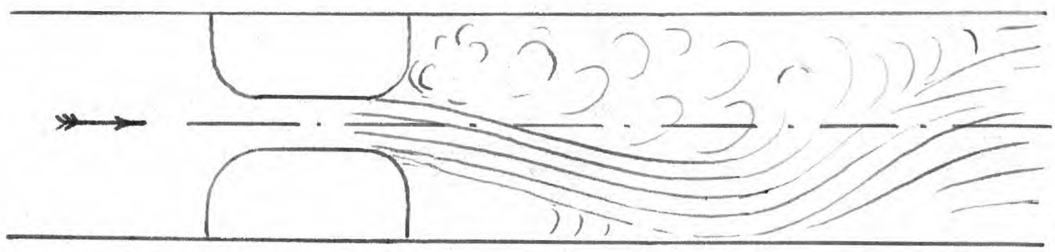
The first ten models of venturi flumes were chosen and arranged in such a way so that in each there was a special improvement on the preceding one. This was done in order that the advantages of every individual feature in the shape of the flume could be separately observed during the tests.

Model shape "A" is a simple long flume with round entrance which is an improvement on a similar flume with sharp edges at inlet and out-let. Apart from its disadvantage of a sudden check in the velocity of a stream even with its round entrance which gives a smoother drop, the downstream conditions will not only interfere with the accuracy of measurements in the throat level but are most undesirable for the maintenance of the canal bed and sides. The sudden enlargement in the stream water section just downstream the contracted throat is accompanied by considerable disturbances and eddies that increases the loss in the energy head.

DEVIATION OF THE CURRENT IN THE OUTLET OF FLUME

There is a peculiar behaviour in the way a stream leaving a contraction flows in the enlarged section down-stream. The jet may just strike against the mass of slower moving water and in so doing its high velocity is gradually checked while the main current keeps its position along the centre of the channel. This was shown by the tests to be not always the case. The eddies formed in the stream tend to deviate this main current or jet to one side or the other. This deviation may be very small at the beginning but once it is started in one direction it suddenly increases and the current is totally deflected in that direction and remains there or swings back to its central position and in so doing it may go a little bit further than the centre and then is totally shifted to the other side. The writer, however, observed that there was in most cases a tendency for the current to keep one way or the other once it was shifted except in one special case in observation No.3 Run 3 of Test No.5 on Model "D" when continual deviation of the downstream current from one side to the other took place.

The following is a simple explanation of this phenomenon. First of all when the jet of water leaves the contraction there is a transformation of velocity head into pressure head and thus there is a rise in the water level. At the entrance of the flume transformation of pressure head into velocity head takes place and thus there is a drop in water level accompanying the decrease in section. In so doing the stream lines which are generally imagined flowing parallel to one another in the steady approach channel simply take a symmetrical and smooth curved path and squeeze themselves through the contraction section without causing the slighest turbulence. As these stream lines leave the outlet of the contracted section with a high velocity they tend to diverge and take their normal course before entering the contraction but the impact of their high velocity jet against the slower stream below distorts their path and the flow becomes no longer steady and eddies are generally formed. Below the jet the water simply appears as if it is heaped up and pushed upwards by the force of the jet. When the eddies slightly deviate the direction of flow of this jet, that pushing force is weakened on one side and the heaped up water starts to flow back towards the flume. This increases the depth of water in the back current side and the pressure of the high level water on that side pushes the jet more and more to the other side until it is totally deviated and it is then observed that the level on the current side is much lower than that of the sluggish back current side. The back current only reaches the walls of the flume outlet and then whirls round under the effect of the outflowing jet and builds up a series of eddies as shown in Figure below



The same behaviour was observed by Mr E.W.Lane during his tests on contraction and in page 1207 of his paper[x] the following explanation of the cause is given:-

" When the stream from the contraction flowed in the centre of the channel the friction of this moving water on the quiescent water on both sides tended to draw this quiet water away from the contraction making the total water level near the contraction lower than at some distance downstream. The water level on both sides of the flowing stream in this unstable state, was the same. The higher water downstream, however, tended to flow back towards the contraction, and if a slightly greater quantity flowed back on one side of the stream than on the other the water level on that side became higher. The quiet water on this side, therefore, exerted a greater pressure on the flowing stream than the water on the opposite side, tending to force the flowing stream toward the lower side.

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x See footnote on page (176)

This allowed a large quantity of water to flow back on the higher side, causing a still greater deflection . The change of the flowing stream from central position to a permanent deflection to the side of the channel was a matter of only a few seconds."

It was observed by the writer that this deflection of current generally caused a slight drop in the water level inside the throat on the current side only as far as about four inches upstream the outlet. This, with an 18" throat length was not observed in the neighbourhood of the centre of the throat where the mean throat depth was taken for the discharge computations. The flumes tested by Mr R.L.Parshall * had throats 12" long and that is why the effect of this switching of the current was left at the centre of the throat and affected his measurements. In this connection the following is quoted from Mr Parshall's paper:-

"It was first thought that two points of observing the heads would be sufficient to definitely establish the conditions of flow for rectangular flumes, but due to the switching of the current in the diverging section, it was found necessary to observe the head at identical points on each side of the flume. The introduction of additional points of observing the head is not a desirable feature, but is necessary to ensure the dependability and accuracy of the device".

From the observations of flows in different outlets in the ten models tested by the writer it was found that with Model "A" in which the outlet was a short round one the downstream condition was in its worst. With Model"B" it was slightly improved by the longer tapered outlet. With the same length of outlet and curved face, Model "C", there was hardly any improvement at all and the writer is inclined to state that the same straight one was better.

* See footnote page (177).

It was expected that the curvature of the face would give a gradual divergence below the throat but it seemed that the effect of this was counteracted by the more sudden divergence a little bit further and caused greater disturbance and sharper deviation of current. With the longer straight sides outlet the disturbance and deflection was carried further downstream. Obviously, the further the point of deviation of current is from the downstream end of the throat ~~and~~ the less is the effect on the levels inside the throat. The lengthening of the throat and leaving the outlet short as in Model "D" does not improve these conditions. With Models("G" and "I") the more gradual divergence of the curved outlet just downstream the throat had the best effect on improvising the downstream conditions. A curved outlet of this shape is advantageous and economical in the same time. A straight sides outlet as in Model "H" which can give the same effect below and inside the throat needs to beavery one.

EFFECT OF SURFACE WAVES INSIDE THE THROAT.

Surface waves inside the throats of the flume have been observed by the writer to be the result of two main causes:-

(a) The drop at the entrance to the throat.

(b) The disturbance and deflection of current downstream the throat.

The drop at the entrance is the principal cause but the downstream disturbances adds to its undesirable effects. In the converging entrance to the first seven flume Models ("A" to "G"), as can be seen from the water surface curves, the water surface falls gradually as it approaches the throat and then there is a sudden drop at the throat inlet.

At this drop the water particles near the surface flow in a downward direction and due to their inertia they tend to maintain this direction and so drop lower than the amount necessary to pass the required discharge. Directly below this point of maximum drop the water surface rises again and forms a wave right across the throat or in the middle of the throat or a compound wave of the two. The centre wave is cuased by the side currents at the entrance to the throat shooting round through the throat and meeting at the centre.

In Model "A" the entrance to the throat was a short round one. The water surface drop started only 6 inches above the entrance to the parallell throat and therefore for the same flow and upstream depth it gave the most sudden drop as compared with the rest of the models tested. This caused a large surface wave across the throat below the lowest point. Also due to the short entrance the side currents were deflected at a sharp angle, meeting at the centre of the throat and forming a large central wave. By replacing the short round entrance by a longer tapered one as shown in Model "D" both waves were slightly reduced because of the less sharp drop and less sudden deflection of side currents at entrance to throat. In Models "E"-"G" the same length of entrance is curved giving still better effects. In model "H" the longer tapered entrance reduced the suddenness of the drop considerably as can be seen by comparing the water surface curves Test (9) pages..81-84 with the preceding ones.

The entrance of Model "I" gave the most ideal conditions. It can be seen from the water surface curves of Test (10) pages 88 - 91, that the water surface drop started at the entrance to the inlet and was so gradual and smooth right through and there was no sudden drop at the entrance to the parallel throat. In other words the water surface curve was practically one smooth curve from the entrance to the converging inlet to the downstream end of the throat. The writer recommends this feature in the design of a venturi flume. The surface waves in-side the throat with high flows and large total drop are only partly due to the cause (a) and as can be seen from the water surface curves of Test No.(10) Run 3 observations(4-7) and Run 4 observations(5-7), are mostly due to the down stream disturbances.

The downstream disturbance and the deflection of the outlet current cause the surface water to rush in and out of the downstream part of the throat and causes surface waves which make the level observations inside the throat very difficult and inaccurate. When the throat was made 24" long in Test No.5 on Model "D" instead of 18" as in Test No.4 on same model, the effect of the downstream disturbance and deflection of current was more noticed inside the throat and during observation (3) Run (3) Test No.(5) the pulsating wave inside the throat caused variation in the water surface as shown by the dotted line on the water surface curves. This shows that the effect of the downstream disturbance should be reduced first by improving the shape of outlet before altering the length of throat.

However, with a good long outlet as that of the venturi flume tested by Messrs Wilson and Wright see Figure (11)D a longer throat gave steadier readings in the throat.

If these surface waves take place opposite the throat level gauge the latter will give inaccurate readings. The degree of inaccuracy depends upon the magnitude and nature of the wave. If a gauge that directly records the actual water depth as for example a graduated gauge built in the wall of the flume or any other gauge working on the principle of the point gauge used by the writer (See Plate III) then the depth of water recorded may be higher or lower than the mean. In case of gauge wells which will work on the same principle as the Piezometer gauges used by the writer (See Plate II) and page (17) the waves inside the throat will affect the readings in quite a different manner. The results of test 11 and 12 illustrate these effects very plainly and seem to verify the theory that the water depth under a wave is not equal to the static pressure on the bed, the latter being slightly higher under a wave trough and lower under a wave crest. In this connection the following is an abstract of a report * on tests by Mr F.R.McMillan on wave pressure on ships. These tests have shown that it is not correct to assume that the pressure on the side of a ship is equal to the hydrostatic head of the wave. There seems to be a dragging effect of the moving water which reduces the pressure at the crest and increases it at the trough. The variation of pressure under any given point during the passage of a wave is less than the static equivalent of the wave height, the actual ratio varying from 60 to 70%. The pressure reduction is due to the hydraulic action of the moving wave. At the crest of the wave the water moving

* See Engineering News Record Vol.83 page 1,019 Dec.1918.

upwards exerts an upward thrust which tends to reduce the downward pressure due to the height of the water. At the trough the downward moving water increases the static head. The tendency is thus towards equalising the estremes of pressure.

The Peizometer and Micrometer Screw point gauge readings at points 0.25' upstream centre, at centre, and at 0.25' downstream centre of parallel throat are plotted by the writer for different observations of different runs of tests 11 and 12 as shown in the following diagrams pages (102-4 & 115-18). For the high flow runs few observations are not plotted to avoid overlapping of curve. The Piezometer Gauge reading of the mean pressure between the points of observation and the calculated mean of point gauge readings are also plotted.

By consulting the above mentioned diagrams it can be seen that:-

1. The hydrostatic pressure is greater than the actual depth below a wave trough and is less below a wave crest.

2. The mean Piezometer Gauge readings or hydrostatic pressures are nearly equal to the mean depth when the pressure holes are under part of a trough and part of a crest of a wave. On the other hand the mean hydrostatic pressures are higher or lower than the mean depth if the pressure holes are all under a wave trough or a wave crest respectively. By comparing the water surface curves of the first eight models tested with those of Model "I" of Test No.10 it will be noticed that the latter gives the most uniform curves and the least surface waves inside the throat.

POSITION OF THROAT GAUGES.

From the above the writer recommends the best place for a throat gauge to be where the effects and changes due to surface waves are least. Again by consulting the water surface curves at different water levels and flows for each model it can be seen that the longer and more symmetrical is the model the better are the conditions in the throat to make possible the existence of such a place between certain ranges of levels and flows. With Model "I" the centre of the throat fulfilled the above condition. The upstream gauge can be placed just upstream the entrance to converging Venturi Flume inlet if the latter starts with a width equal to the width of the channel of approach. Otherwise it is better to place the gauge just below the inlet to avoid the effects of disturbances due to any curvature or sudden deflection of the entering stream. In the standard type recommended by Mr V.M.Cone in FigureID the up stram gauge was placed at one third the length of the converging inlet. As for the kind of gauge to be used the theoretical formula of flow should be considered

$$Q = \frac{b_2 d_2 \sqrt{2gh}}{\sqrt{1-\left(\frac{b_2 d_2}{b_1 d_1}\right)^2}}$$

neglecting the denominator or in other words the velocity of approach we get

$$Q = b_2 d_g \sqrt{2gh}$$

The value of h is theoretically the difference between the hydrostatic pressures or the Piezometer Gauge readings. d_g is the actual depth of water i.e. the point gauge readings. An error in h of say x% cause an error in Q of ½x% while an error of x% in d_g causes an error of x% in Q. It can be seen from the throat gauge readings diagrams pages (102-4 & 115-18) comparing the actual water depth and their corresponding Piezometer Gauge readings that the mean Piezometer Gauge readings are nearer to the mean depth in the whole length of throat than the mean actual water depth at the point of measurement. When there is a wave trough above the pressure holes it is generally followed by a wave crest and vice versa and therefore the mean Piezometer Gauge readings in the middle portion of the throat will be nearer to the mean water depth along the whole length of throat while the point gauge readings will be either higher or lower than the mean unless the measurements are taken at low as well as at high points. In practice, however, the mean hydrostatic pressure in the middle portion of the throat can be observed on one gauge well working after the principle of the writer's piezometer gauges on Plate II. The mean actual ~~in~~ depth at two or three points in the throat can only be obtained by separate measurements. From the above the writer concludes that gauge wells are not only more pratical to use but give more accurate values of mean depth inside the throat. Tappings can be taken along a longer central portion of the throat if desired but as in the case of the writer tests the middle half of the throat length will be enough. Also tappings across the whole width of the throat as shown on Plate II are bound to give better results than side tappings only, especially in the cases when the deflection of the downstream current effect the level inside the throat and it will save having two gauge wells one on either side as suggested by Mr R.L.Parshall.

Float gauge wells of a good design that record the variation in the level inside the well to a sufficiently accurate number of decimal points will give far better results than a simple divided gauge built into the gauge well.

HEAD LOST BETWEEN THE UPSTREAM AND DOWNSTREAM OF A FLUME.

The theoretical energy head lost in this case will be $\left(d_1 + \frac{v_1^2}{2g}\right) - \left(d_3 + \frac{v_3^2}{2g}\right)$,

where d_1 and v_1 are the depth and velocity upstream and d_3 and v_3 are the depth and velocity downstream.

As the difference between v_1 and v_3 is generally small the velocity heads can be neglected and the drop in water level $(d_1 - d_3)$ which is refered to by the writer as h_L can be taken as the head lost. In fact it is the heading up above the normal depth d_3 due to the existence of the flume. Of course the smoother the flow through the flume is the less will be the value of h_L. The roughness of the bed and sides of the flume are an important factor. The curves showing the values of h_L for different values of Q and d_3 show that h_L increases with Q for the same d_3. In other words the higher the velocity is inside the throat the less is the recovery in the converging outlet.

Before carrying on Test No.11 on the same Model "I" and same width of throat, the steel channel was repainted and the pieces of the model were planed and smoothed. This reduced the values of H_L considerably as can be seen by comparing the diagrams of the tests Nos. 10 and 11. With the same model but a 2" wider throat the values for h_L for same values of Q and d_3 are much less. If we compare the curves of h_L for tests 11 and 12 page (158 & 159), we find, for example that with $d_3 = 1.0'$ and Q = about 1.6 cusecs, h_L = .12' with 6" throat and = 0.048' with 8" throat.

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COEFFICIENTS OF DISCHARGE.

In the computations of the value of C in the discharge formula $Q = cb_2d_2\sqrt{2gh} \Big/ \sqrt{1-\left(\frac{b_2d_2}{b_1d_1}\right)^2}$, the theoretical values of Q denoted by Q_t in tables of results and computed from the above equation taking C = 1 are read from the discharge diagrams Plates 6 and 7. Values of d_1 and d_2 were taken as the upstream depth and the mean point gauge readings 3" upstream at centre and 3" downstream the centre of throat in each case in Tests 1 to 10. Water depths below high wave crests near the centre were not taken into consideration. The values of $C = \frac{Qa}{Qt}$ are plotted against of h for each test as shown on the diagrams following corresponding tables of results.

For tests No.11 and 12 on the 6" and 8" Model "I" the values of d_1 and d_2 were taken for each run in three separate sets.

(a) Peizometer Gauge readings taking mean d_2 in the middle portion of throat;

(b) Peizometer Gauge readings taking mean d_2 at centre of throat;

(c) Point Gauge readings taking mean d_2 in middle portion of throat.

Values of C were computed separately for each set and plotted against their corresponding values of h as shown on Plates 8 and 9.

The mean curves for each set for both 6" and 8" are plotted together on Plate X showing the effect of the variation of the ratio $\frac{b_2}{b_1}$ on the coefficient of discharge.

As previously explained in the paragraph on gauges the curves (a) are the ones recommended by the writer to be taken into consideration. If the tapping for gauge well can only be at the centre of throat, curves (b) show that the difference is most at very low drops, but they tend to give the same values as (a) curves with higher drops. The (C) curves show no relation to (a) curves at all. The humps between drops of about 0.06' and 0.16' are due to the effect of surface waves and the difference between actual depth and hydrostatic pressures between this range of drop. If we compare these two (c) curves on Plate X with the coefficient curve on diagram of Test No.10 page (140) it can be seen that an alternative curve could have been drawn for Test No.10 showing the same hump. Coefficient curves for Tests Nos.2,7 and 9 show the same tendency. Apart from the doubt of the accuracy of such curves they give more complicated relation between C and h than those given by curves (a) and (b). The formula of each of the curves (a) and (b) for the Tests Nos.11 and 12 was computed by the writer and the curve plotted from points calculated from each formula is shown dotted in each case on plate X .

Computed formulae for coefficient of discharge :-

For Test No.11 with 6" throat Model "I"

Curve (a) gives :-

$$C = .905 + \frac{.00525}{h + .05}$$

Curve(b) gives:-

$$C = .909 + \frac{.00247}{h + .0127}$$

For Test No.12 with 6" throat Model "I"

Curve (a) gives:-

$$C = .947 \quad \frac{.00399}{h + .075}$$

Curve (b) gives:-

$$C = 0.946 + \frac{.00374}{h + .0567}$$

The formula for C may begiven generally :-

$$C = \alpha + \frac{\beta}{h + \lambda}$$

Where α, β and λ depend upon the dimensions and material of flume used. A formula of this shape is very easy to use.†

The general formula of flow will then be

$$Q = \left(\alpha + \frac{\beta}{h + \lambda}\right) \frac{b_2 d_2 \sqrt{2gh}}{\sqrt{1 - \left(\frac{b_2 d_2}{b_1 d_1}\right)^2}}$$

† Compare this formula with Mr R.L. Parshall's on page 182.

Curves showing minimum upstream water depth for given discharge at free flow or in other words the maximum discharges for given upstream values of d_1 are plotted as shown on Plate XI from the diagrams of Plate VI and VII.

They are very nearly straight lines giving (1) for the 6" throat

$$Q_{max} = 1.59 \; d_1^{1.486} \text{ cusecs}$$

$$= 3.18 \; b_2 \; d_1^{1.486} \text{ cusecs}$$

(2) for the 8" throat

$$Q_{max} = 2.10 \; d_1^{1.486} \text{ cusecs.}$$

$$= 3.15 \; b_2 \; d_1^{1.486} \text{ cusecs}$$

When the velocity of approach is neglected and the denominator of the theoretical formula of flow is omitted the formula for Q max

$$= 3.09 \; b_2 \; d_1^{1.5} \text{ cusecs.}$$

The velocity head is generally added to d_1 and then

$$Q = 3.09 \; b_2 \; H_1^{1.5} \text{ cusecs.}$$

In the tables showing the maximum flows, the values for Q_t were read from the curves on Plate XI. The uniformity of the computed values of C show that all the flume models can give fairly accurate results with free flow conditions and nearly the same discharge curve.

PREVIOUS TESTS MADE ON THE VENTURI FLUME.

1. The name Venturi Flume was given to a device experimental on first by Mr.V.M.Cone who published his preliminary report on same in 1917 ø.

This report was intended to bring to light the idea of using the Venturi Flume efficiently and advantageously in measuring the flow of water in canals for irrigation. The experiments were carried in the Hydraulic Laboratory at Fort Collins Colorado.

11. In a paper entitled "Experiments on the flow of water through contractions in an open channel " by Mr E.W.Lane,† valuable information is given on conditions of flow through different contractions that lead to the conclusion supporting the choice of the venturi flume as the best form of contraction for the gauging of water flow. Tests were made on sharp and round edged contractions, short flumes with round and sharp cornered entrances and on an expanding flume with round entrance and gradually expanding outlet. No tests were made on a venturi flume with converging inlet and diverging outlet.

The main purpose of the tests was not to develop a flow measuring device but to investigate the two well known formulae of flow, d'Aubuisson's and Weisbach's (see Appendix(3) Sections (c) and (d). However, Mr Lane recommended the sharp edged contraction as a discharge measuring device possessing all the requirements of an ideal one.

ø See Journal of Agricultural Research Volume IX, No.4, April 23rd, 1917.

† Proceedings American Society of Civil Engineers, Volume 83 page 1149. 1920.

III. In a paper entitled the Venturi Flume, by Mr.Ralph L.Parshall,[x] a report is given on the results of experiments conducted at the Cornell Hydraulic Laboratory and at the Field Laboratory on the Cache la Poudre River at Bellevue near Fort Collins Colorado. The tests were carried out on restangular and V notch Venturi Flumes.

IV. An article by Mr P.S. Wilson and Mr C.A.Wright ∅∅ gives valuable results on investigations on two designs of restangular Venturi Flumes.

V. Professor Alexander H.Jameson, M.Sc.,M.Inst.C.E. of King's College, London carried out some experiments on a wooden tilting flume at King's College. In the paper entitled "The Venturi Flume and the effect of Contractions in open Channels" ≠≠ valuable informations concerning this device are given.

VI. Mr R.L.Parshall with the intention of developing a simpler device made some tests and applied the same theory to what he called "The Improved Venturi Flume" ≠

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x See Bulletin 265 of the Agricultural Experiment Station of the Colorado Agricultural College, February,1921.

∅∅ See p.454 Volume 85 Engineering News Record.

≠≠ This paper was read on June 30th,1925, in a meeting of the Institution of Water Engineers in Burlington House. See also page 271 of the Water and Water Engineering of July 20th, 1925.

≠ See Proceedings American Society C.E. of September,1925, page 1340.

DISCUSSION OF PREVIOUS TESTS.

1. The preliminary experiments made by Mr.V.Cone in 1915 were made on different designs of sections and relative proportions of the different parts of rectangular, trapezoidal and triangular V.flumes and from these, a standard design for each type was chosen. Figure (1)D shows the standard type for rectangular V.flumes and also the best position recommended for gauge wells.

It was observed that as water passed through the flume there was a slight surface slope in the converging section, a rather sudden drop in the throat and a rise in the diverging section. This fall and rise of water surface curve generally takes place where the depth in contracted section is above the critical. This is shown in cases 2 and 3 of Table I Appendix (8). The sudden drop in the throat is due to the sharp corner at the throat entrance. The loss of head was small.

Referring to tests on rectangular V.flumes Mr Cone mentioned that "the greater the length of converging and diverging parts and a rounding of the throat section would result in less loss of head and greater accuracy in measurement of flow. The standard type was chosen as a compromise between accuracy and cost."

The sizes of the flumes of rectangular section experimented upon were considered by Mr Cone as not large enough to warrant a formula for general use. The writer agrees that limited tests on limited sizes of any device cannot lead to the establishment of any general law that can be used in practice for any size and material of the same device unless the laws of similarity are very carefully followed during the tests on the small models.

However, it is quite probable that if there is a definite law for a given size and material, a similar law may

STANDARD RECTANGULAR VENTURI FLUME

AS RECOMMENDED BY Mr V.M. CONE

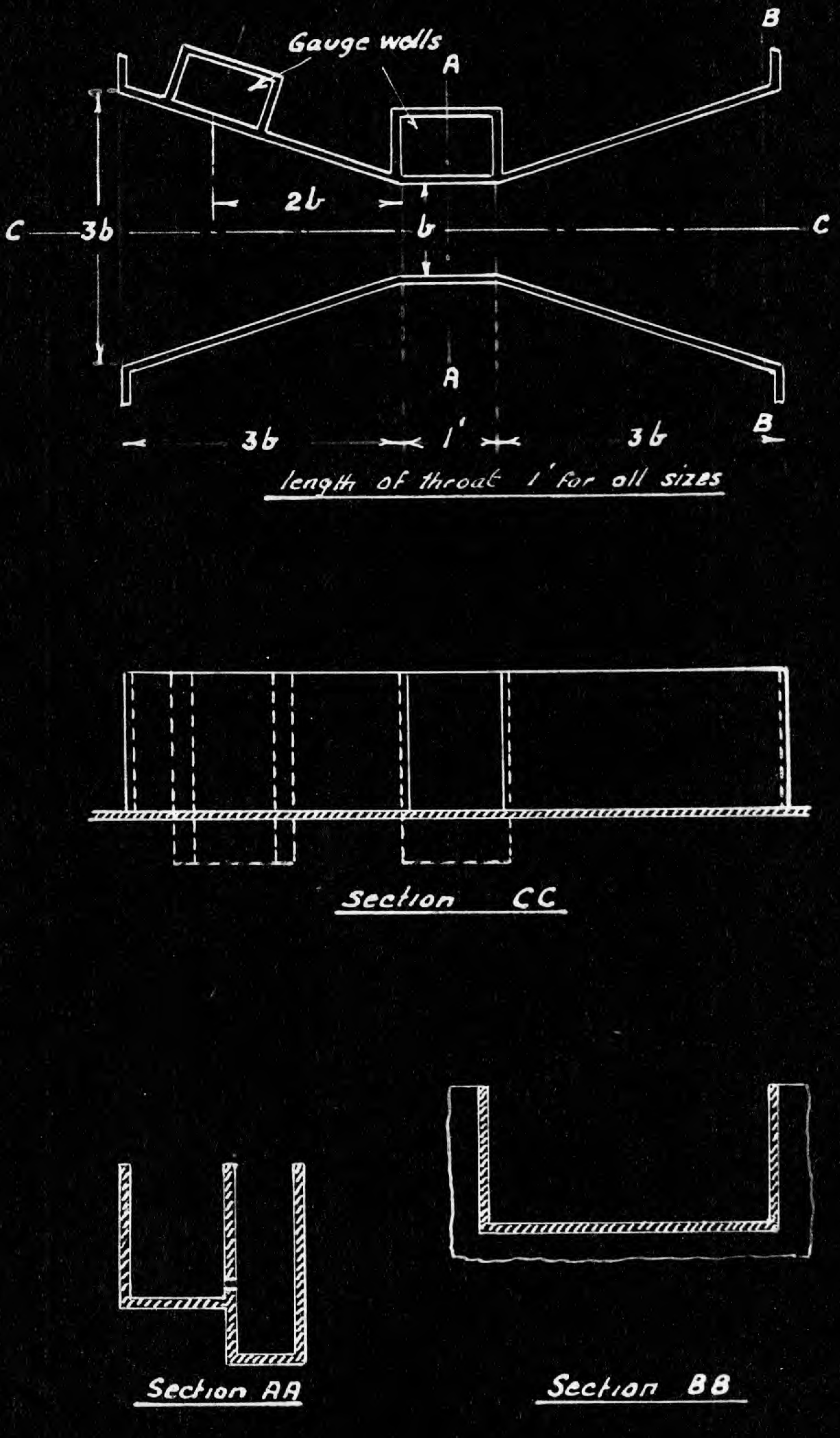


Fig 1 D

hold good for another size of the same type with some alterations in value of the coefficients allowing for such departure in size and material.

One gauge box has been arbitrarily located as shown in Figure (I)D at a distance of two thirds the length of the converging section i.e. twice the throat width from the upstream face of the throat. This position was chosen in order to avoid any possible influence due to contraction currents near the entrance to the converging section of the flume.

The throat gauge was located at the middle of the throat section where the drop in water was maximum (see ~~Appendix 6a~~). The zeros of both gauges were adjusted exactly at the elevation of the level floor of the flume.

Discharge curves for standard rectangular Venturi flumes (see Figure (I)D) are given in Mr Cone's Figures 2,3, and 4 for flumes, 1, 1.5 and 2 feet wide at the throat.

In Table I of this discussion (on blue print) discharges shown in Columns (4), (9) and (14) are read from the above mentioned discharge diagrams corresponding to given values of upper gauge readings i.e. upstream depths (d_1), and differences between upper and throat gauge readings (h) shown in Columns (1) and (2). Columns (3), (9) and (13) give the theoretical flows computed by the formula

$$Q \quad \frac{b_2 d_2 \sqrt{2gh}}{\sqrt{1-\left(\frac{b_2}{b_1}\cdot\frac{d_2}{d_1}\right)^2}} \qquad \text{(see formula 15 Appendix (3))}$$

in which, according to the standard proportion in Figure (1)D.

b_1 = width at upper gauge - $2\frac{1}{3}$ throat width

b_2 = throat width

$$\frac{b_2}{b_1} = \frac{3}{7}$$

$$\text{and } Q = \frac{b_2 d_2 \sqrt{2gh}}{\sqrt{1-\frac{9}{49}\left(\frac{d_2}{d_1}\right)^2}}$$

Columns (6), (11) and (16) give values of the coefficient of discharge (C) to be multiplied by the above formula to give the actual flow as indicated by the discharge diagrams. Values of flow in Columns (4), (9) and (14) are plotted as shown dotted (-----) in 3 corresponding diagrams in figures (2, 3, and 4)D

Vlaues of the coefficients of flow in Columns (6) (11) and (16) are also plotted against values of (h) for each value of d_1 in Figure (5) D and for each value of b_2 in Figure (6)D as shown in both Figures by the dotted curves (-----).

Mr R.L.Parshall in his paper on the Venturi flume stated that due to inadequate facilities it was not possible to carry the original investigations started by Mr V.M.Cone to the point most desirable from an irrigation standpoint. Subsequent tests were carried out under the supervision of Dr Schoder and the late Professor Tuner on large sized flumes These tests were meant to properly correlate all the tests previously made by Mr Cone and resulted in the discovery of various new characteristics of the flume.

The same standard type was used for tests on rectangular flumes. The floor was level and placed at the elevation of the grade of the channel. The length of the throat section was arbitrarily taken as 1 foot for the various sizes.

Gauge wells and position of upper and throat gauges were the same as previously mentioned in connection with Mr Cone's tests except that, due to switching of the current in the diverging section it was found necessary to observe the heads at identical points on each side of the flume. This is due to the effect of the side current explained by the writer on page......

A law of flow was established from experimental data for application to sizes up to 5 feet throat of the standard type (Figure 1D) viz.,

$$Q = \frac{C b_2 d_2 \sqrt{2gh}}{\sqrt{1 - \frac{9}{49}\left(\frac{d_2}{d_1}\right)^2}}$$

where the coefficietn of discharge C is given by :-

$$C = 0.9975 - 0.0175 b_2 + \frac{(h - 0.163 d_1^{\frac{1}{2}})^2}{\frac{8}{20 - b_2} \cdot d_1^2}$$

In Mr Parshall's paper the following notation is used instead of the writers notation:-

H_a	..	d_1	H_d	for	h

W for b_2 — H_b for d_2

In Table I, Columns (7), (12) and (17) are computed from the above formula for C and from these values of C and the theoretical flows in Columns (3), (8) and (13) Columns (5),(10) and (15) are computed, giving Mr Parshall's discharges corresponding to Mr Cone's for the same heads. Mr Parshall's discharges are plotted on diagrams of Figures (2, 3, and 4) D and are shown thus (—.—.—). Also Mr Parshall's coefficients of discharge are plotted on diagrams Figures (5, 6 and 7) D and are shown thus(—.—)

The discharge diagrams and the coefficients diagram Figure (7)D show that Cone's discharges were always less than Parshall's except in the case of the 1 foot throat flume. Even in this latter case, Cone's discharges and hence the coefficients tend to fall below Parshall's as the up stream depth decreases below 1.4 feet.

Figure (5) D shows that both Mr Cone's and Parshall's coefficients for a given upstream head decreases for larger size flumes.

Figure (6) D shows that for both Mr Cone's and Mr Parshall's the coefficients tend to have for each throat width a constant average for all values of d_1 between h = .05 ft to h = .2 ft and beyond h = about 0.2 ft, the coefficient for a given h and b_2 decrease as d increases.

As the results of Mr Cone's and Mr Parshall's tests considered separately agree in many features, the slight difference in actual values may be due to lack of facilities in carrying the first tests and also to less accuracy in the observation of heads. Also the original data of Mr Cone's tests were taken into account in establishing the above formula for C which can be taken as a final one established from two separate tests.

Diagram showing values of C in $Q = \dfrac{C b_2 d_2 \sqrt{2gh}}{\sqrt{1-\left(\frac{b_2}{b_1}\cdot\frac{d_2}{d_1}\right)^2}}$ from observations by { CONE - - - - - - - - ; PARSHALL —·—·— } for different values of d_1 and b_2 for Standard V. Flume in Fig (1)

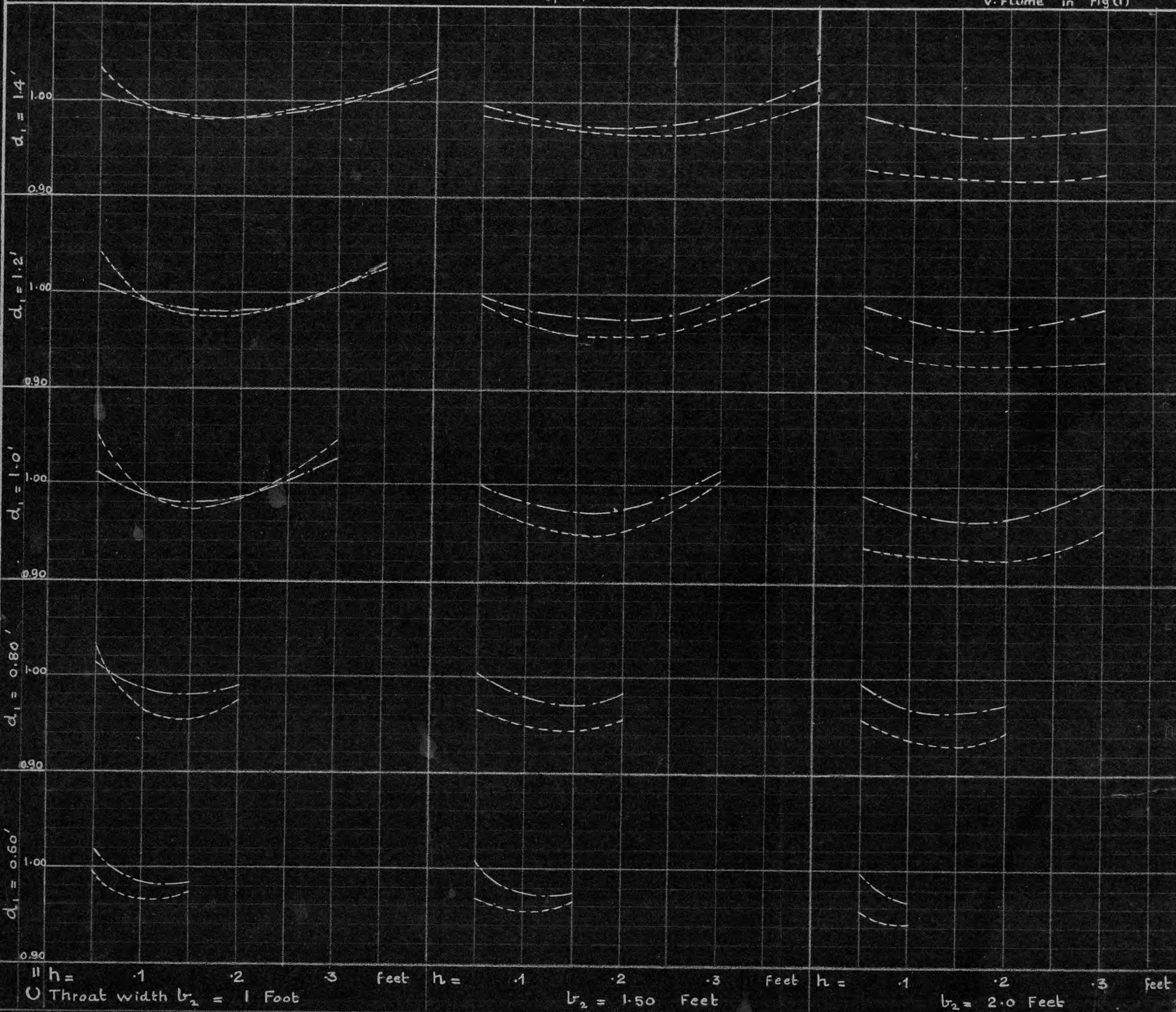
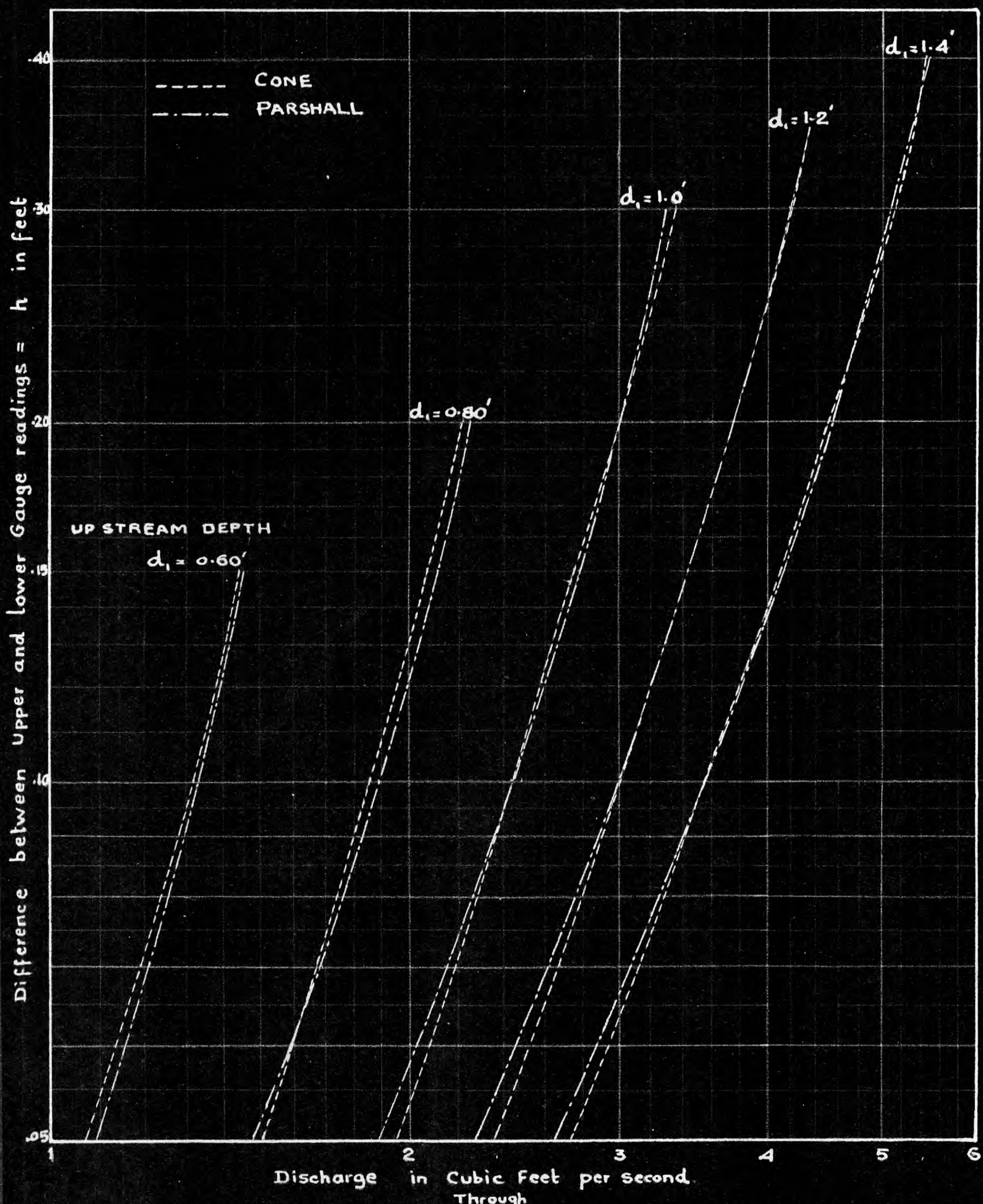


Fig (7) D Notations are as given in note in fig (5)

Table (1) Cone's and Parshall's discharges and Coefficients for same type of rectangular Venturi Flume for given values of d_1 and h

Upstream Depth	Difference of head.	Theoretical Flow $Q = \frac{b_2 d_2 \sqrt{2gh}}{\sqrt{1 - \frac{9}{49}\left(\frac{d_2}{d_1}\right)^2}}$			b_2 = 1 Foot				b_2 = 1.5 Feet				b_2 = 2 Feet			
					Discharge		Coefficient C		Discharge		Coefficient C		Discharge		Coefficient C	
d_1	h	$b_2=1'$	$b_2=1.5'$	$b_2=2'$	Cone's Diagram	Parshall's Formula	Cone	Parshall	Cone's Diagram	Parshall's Formula	Cone	Parshall	Cones Diagram	Parshall's Formula	Cone	Parshall
Feet	Feet	Cubic ft per sec.			cusecs				Cusecs				Cusecs			
0.60	0.05	1.072	1.610	2.144	1.070	1.092	0.998	1.019	1.560	1.625	0.968	1.009	2.050	2.135	0.957	0.997
	0.07	1.213	1.820	2.426	1.190	1.214	0.975	1.001	1.750	1.805	0.962	0.992	2.300	2.380	0.948	0.981
	0.10	1.354	2.030	2.708	1.320	1.334	0.968	0.985	1.940	1.980	0.956	0.976	2.650	2.615	0.943	0.967
	0.15	1.472	2.220	2.944	1.440	1.450	0.973	0.984	2.140	2.165	0.963	0.975	----	---		
0.80	0.05	1.462	2.210	2.924	1.510	1.483	1.033	1.014	2.130	2.220	0.963	1.004	2.800	2.900	0.958	0.993
	0.07	1.680	2.520	3.360	1.670	1.683	0.994	1.001	2.420	2.500	0.960	0.992	3.180	3.300	0.947	0.982
	0.10	1.915	2.870	3.830	1.850	1.894	0.963	0.988	2.730	2.810	0.950	0.979	3.580	3.710	0.935	0.969
	0.15	2.150	3.230	4.300	2.060	2.108	0.957	0.980	3.050	3.135	0.945	0.971	4.000	4.130	0.930	0.963
	0.20	2.268	3.400	4.536	2.210	2.250	0.974	0.991	3.250	3.338	0.957	0.982	4.280	4.415	0.943	0.972
1.00	0.05	1.864	2.795	3.728	1.960	1.885	1.052	1.011	2.730	2.800	0.980	1.001	3.500	3.695	0.938	0.991
	0.07	2.150	3.230	4.300	2.190	2.150	1.018	1.001	3.120	3.200	0.967	0.991	4.000	4.220	0.930	0.982
	0.10	2.465	3.700	4.930	2.440	2.440	0.990	0.989	3.550	3.628	0.960	0.980	4.580	4.780	0.928	0.971
	0.15	2.830	4.240	5.660	2.750	2.775	0.972	0.981	4.030	4.120	0.950	0.972	5.250	5.450	0.927	0.963
	0.20	3.050	4.570	6.100	3.000	3.000	0.983	0.983	4.350	4.450	0.952	0.974	5.620	5.890	0.922	0.966
	0.30	3.210	4.815	6.420	3.350	3.290	1.043	1.025	4.820	4.890	1.003	1.015	6.150	6.470	0.957	1.005
1.20	0.05	2.260	3.390	4.520	2.360	2.275	1.043	1.007	3.350	3.385	0.988	0.998	4.280	4.475	0.947	0.989
	0.07	2.620	3.930	5.240	2.680	2.620	1.022	1.000	3.850	3.890	0.980	0.990	4.910	5.140	0.937	0.981
	0.10	3.030	4.550	6.060	3.000	3.000	0.990	0.990	4.400	4.465	0.967	0.981	5.630	5.880	0.937	0.972
	0.15	3.510	5.270	7.020	3.430	3.440	0.978	0.981	5.050	5.130	0.958	0.973	6.500	6.770	0.927	0.964
	0.20	3.830	5.745	7.660	3.740	3.760	0.977	0.981	5.500	5.580	0.957	0.972	7.100	7.380	0.927	0.963
	0.30	4.165	6.230	8.330	4.200	4.180	1.005	1.004	6.100	6.200	0.978	0.995	7.750	8.220	0.930	0.986
	0.35	4.210	6.310	8.420	4.320	4.330	1.025	1.029	6.290	6.425	0.997	1.018	---	---	---	---
1.40	0.05	2.650	3.970	5.300	2.740	2.668	1.033	1.005	3.900	3.950	0.983	0.995	4.900	5.220	0.925	0.986
	0.07	3.085	4.625	6.170	3.120	3.080	1.012	0.998	4.530	4.580	0.980	0.989	5.700	6.050	0.924	0.980
	0.10	3.590	5.380	7.180	3.580	3.560	0.996	0.991	5.250	5.280	0.975	0.981	6.630	6.980	0.923	0.972
	0.15	4.190	6.280	8.380	4.110	4.120	0.980	0.982	6.100	6.120	0.970	0.973	7.730	8.080	0.922	0.965
	0.20	4.620	6.930	9.240	4.530	4.530	0.982	0.986	6.680	6.730	0.965	0.971	8.500	8.900	0.920	0.963
	0.30	5.120	7.680	10.240	5.120	5.090	1.000	0.994	7.450	7.570	0.970	0.985	9.500	10.000	0.928	0.976
	0.40	5.320	7.980	10.640	5.430	5.490	1.022	1.032	8.000	8.170	1.001	1.022	---	---		
(1)	(2)	(3)	(4)	(5)	(6)	(7) =(9)×(3)	(8) =(6)÷(3)	(9)	(10)	(11) =(13)×(4)	(12) =(10)÷(4)	(13)	(14)	(15) =(17)×(5)	(16) =(14)÷(5)	(17)

Fig 2 D Discharge curves for rectangular Venturi Flume

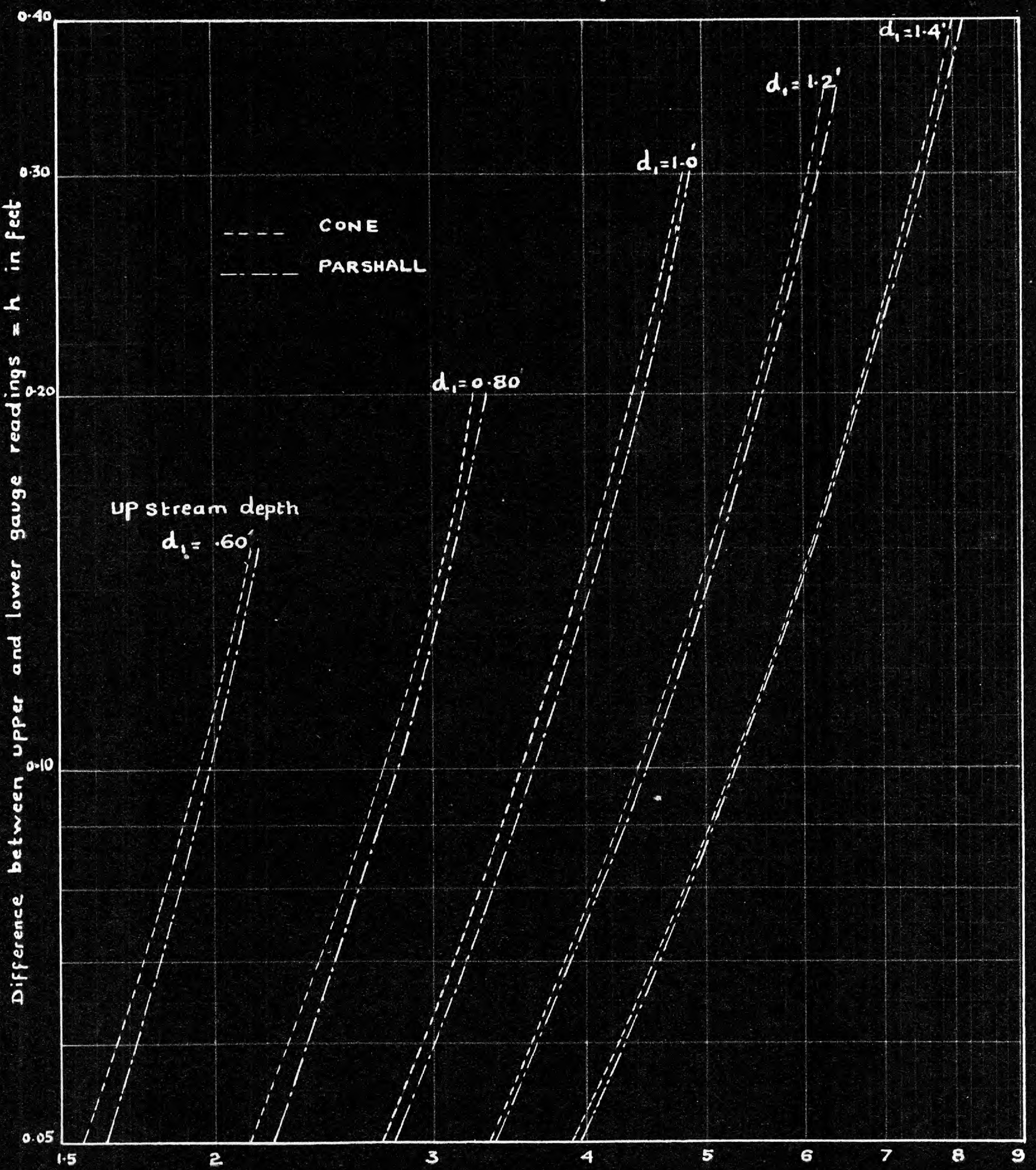


Through

Rectangular Venturi Flume, throat width = 1 Foot, $\frac{\text{width at upper gauge}}{\text{width at throat}} = 2\frac{1}{3}$

(See Fig 1 D for other proportions)

Fig 3 D Discharge curves for rectangular Venturi Flume

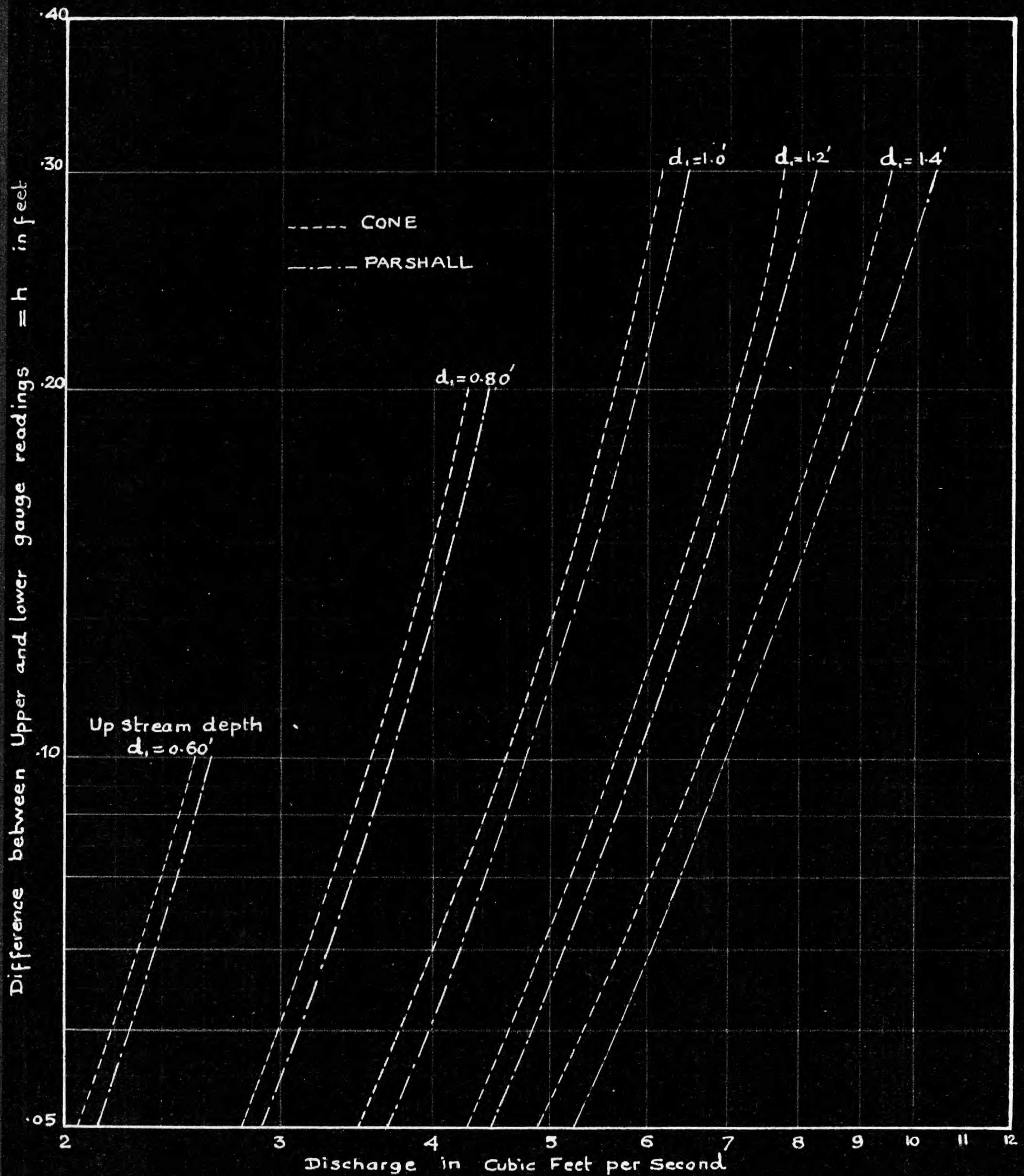


Discharge in Cubic Feet per Second through

Rectangular Venturi Flume, 1·5 Feet throat, $\frac{\text{Width at upper gauge}}{\text{Width at throat}} = 2\frac{1}{3}$

(See Fig 1 D for other proportions)

Fig (4)D Discharge curves for rectangular Venturi Flume

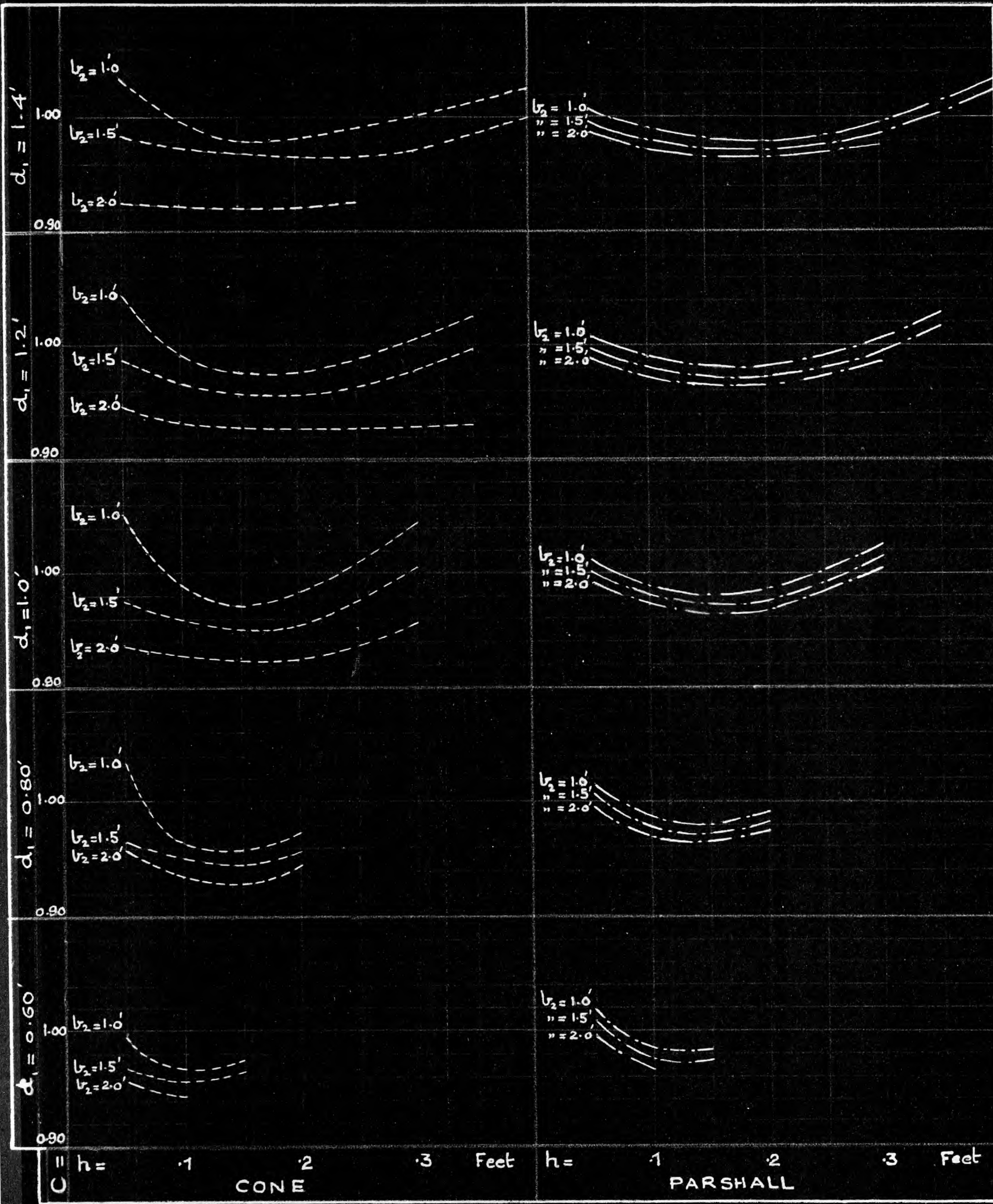


through

Rectangular Venturi Flume 2 Feet throat, $\frac{\text{Width at upper gauge}}{\text{Width at throat}} = 2\frac{1}{3}$

(See Fig 1D for other proportions)

Diagram showing variation of CONE'S and PARSHALL'S Coefficient C for three widths of Standard Venturi Flume (fig 1) with different values of d_1



Fig(5)D

d_1 = Upstream depth

d_2 = Depth in the throat

b_1 = width at upper gauge

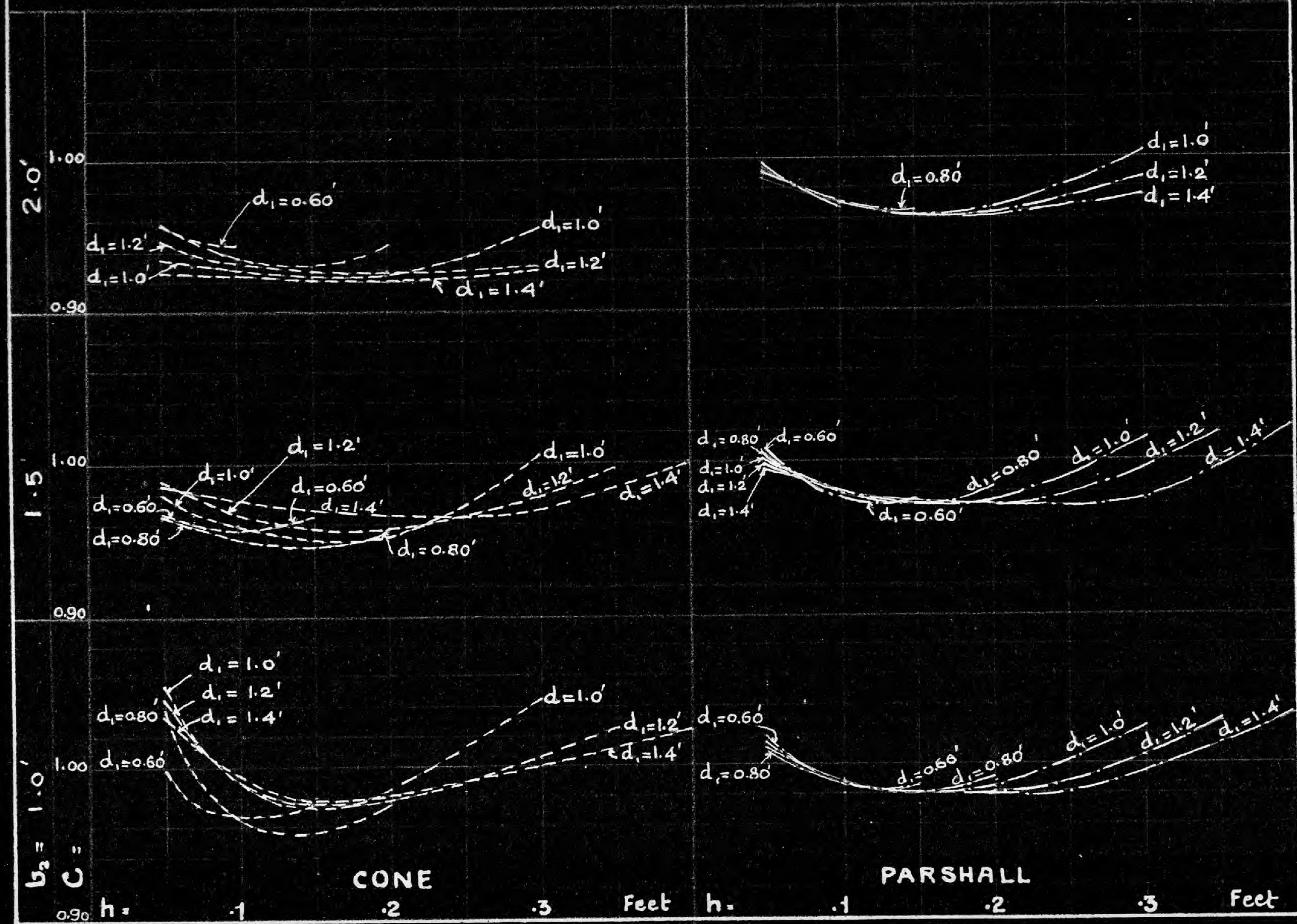
b_2 = " " throat "

$h = d_1 - d_2$

C = Coefficient of discharge in $Q = \dfrac{C\, b_2 d_2 \sqrt{2gh}}{\sqrt{1 - \left(\frac{b_2}{b_1} \cdot \frac{d_2}{d_1}\right)^2}}$

Fig (6) D

Diagram showing variation of C with d_1 for constant b_2 { CONE ------ PARSHALL —.—



II Mr E.W.Lane tests:-

1. Experimental Plant. (see Figure (8) D)

2. For the measurement of actual discharge a calibrated weir of the Cypoletti type was used. The head was measured 10' upstream of weir.

3. Float Gauges as shown in Figure (8) D were used for the detremination of levels. Hook gauges were also used.

4. Tests were made on

   1. Sharp and round edge contractions.
   2. Short flume with round entrance.
   3. Short flume with sharp entrance.
   4. Expanding flume with round entrance and expanding outlet.

Only the round entrance short and expanding flumes are discussed by the writer in this paper.

Each run of tests consisted of observation of discharge, depths above and below contraction and of water surface elevation at several stations spaced 0.25' along the flume.

(a) Short Flume (round entrance).

Water surface curves in Figure (9 D) were plotted by the writer from data given in Table 4 page 1165 of Mr Lane's paper.

The coefficients computed for points in the neighbourhood of the lowest point in the contraction are chosen by the writer (see Table (1)), because the theoretical discharges, computed by taking the depth just below the entrance as d in the equations of flow, are less than the actual values of flow and therefore give coefficients of discharge more than unity. Also the observation of depths inside the contraction near the maximum drop are the only ones comparable with cases and assumptions under which the given formulæ of flow were theoretically obtained. (See Appendix 3).

EXPERIMENTAL PLANT USED BY Mr E.W. LANE M. AM. SOC. C.E
IN TESTS ON FLOW OF WATER THROUGH CONTRACTIONS.

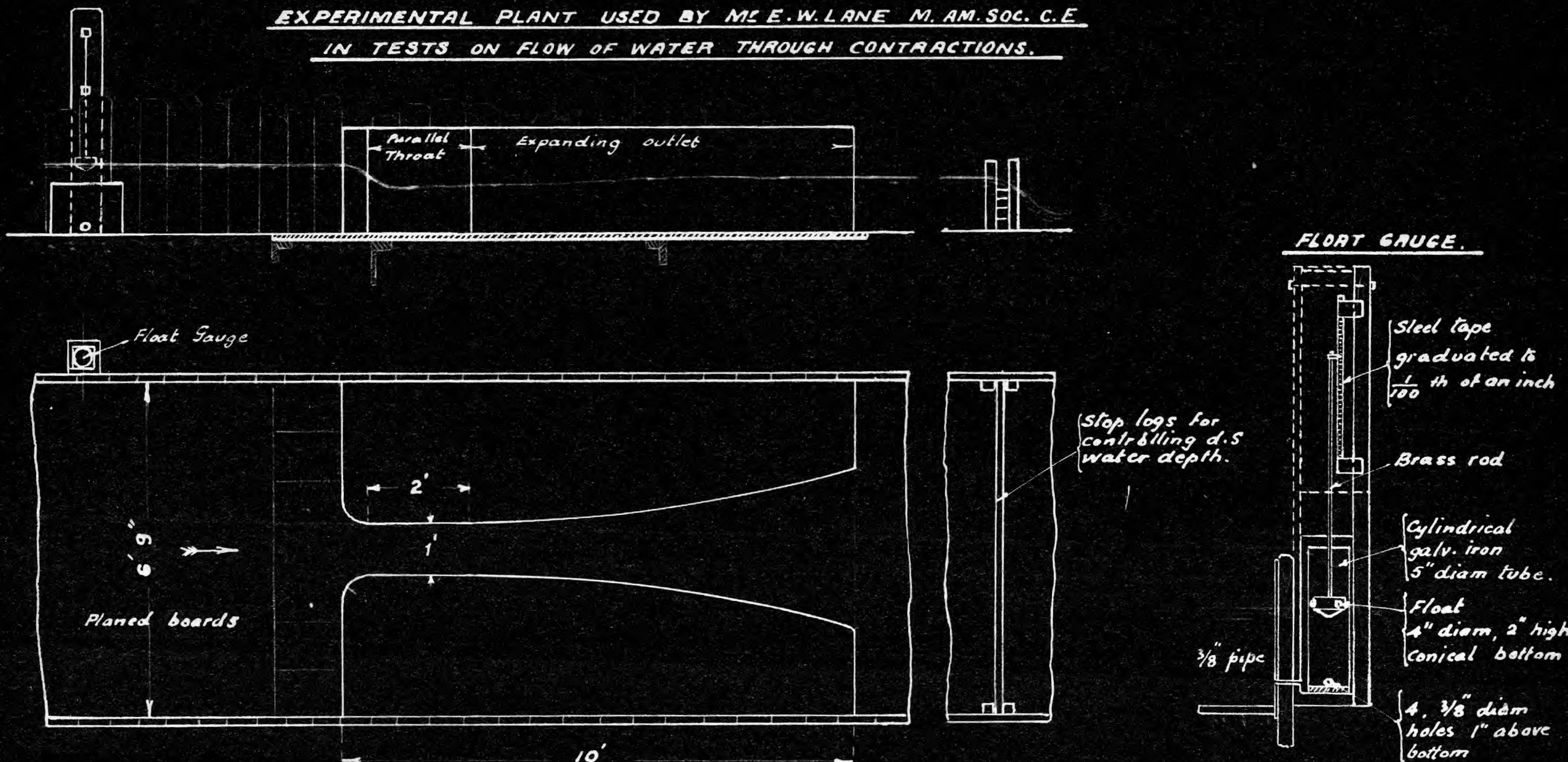


Fig (8) D

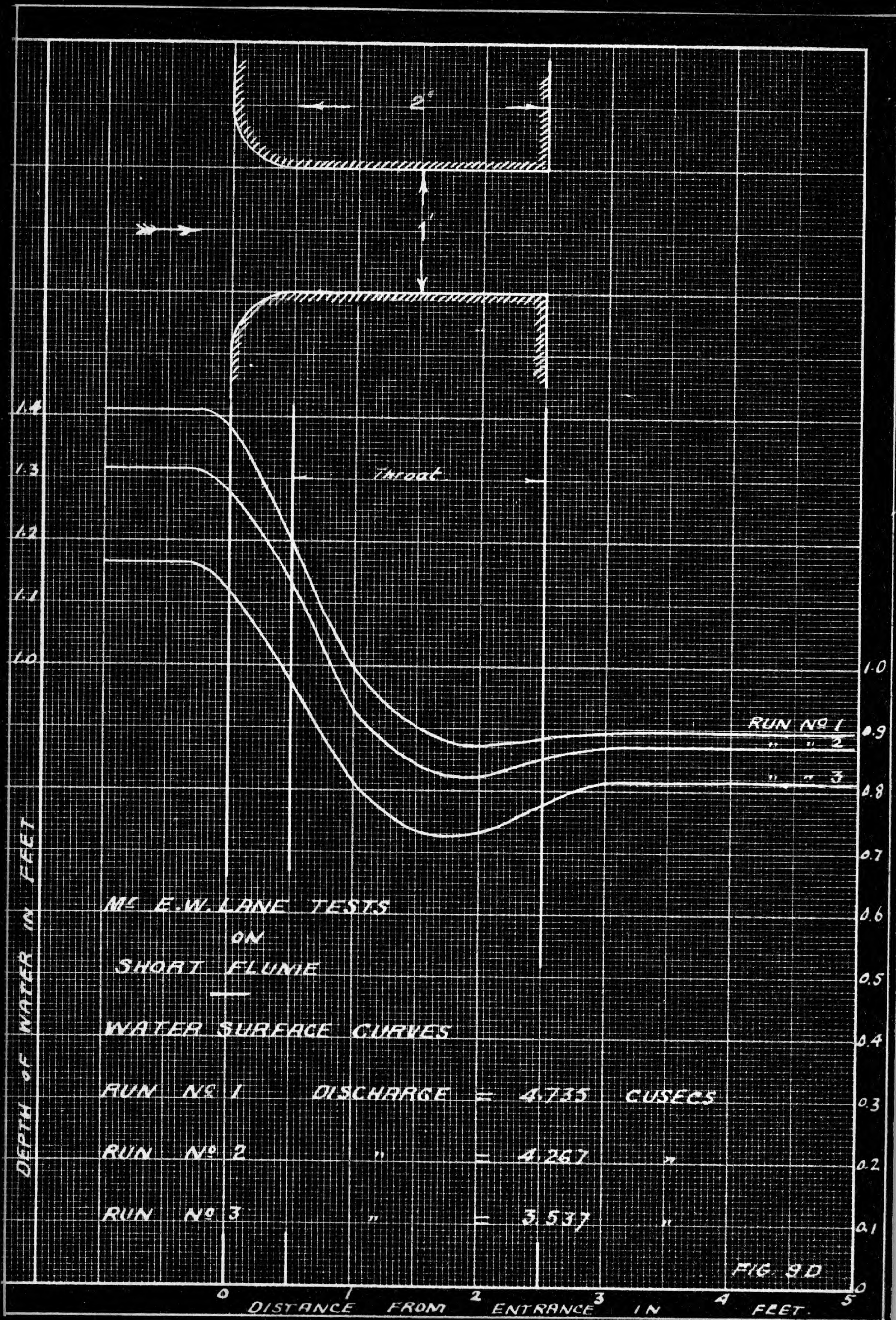

2'
1'
Throat
1.4
1.3
1.2
1.1
1.0
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
RUN No 1
" " 2
" " 3
DEPTH OF WATER IN FEET
Mr E.W. LANE TESTS
ON
SHORT FLUME
WATER SURFACE CURVES
RUN No 1 DISCHARGE = 4.735 CUSECS
RUN No 2 " = 4.267 "
RUN No 3 " = 3.537 "
0
1
2
3
4
5
DISTANCE FROM ENTRANCE IN FEET.

FIG. 9D

In the three runs as shown in Table 2 page.....
the least depth was practically 2/3 of the net head
The tail water depth is less than 2/3 H in runs 1 and 2
and little more than three.

By the nett head in this case is meant the original head H minus the loss of head or $\left(d + \frac{v^2}{2g}\right)$ It will also be noticed that due to this loss of head the depth inside the contraction which is about 2/3H or d_c is not in this case the depth that gives the maximum discharge with the given upstream head H. With or without a loss of head at entrance the downstream depth for maximum flow is two thirds of the upstream head H. When there is a loss of head, the depth of maximum discharge is higher than the critical depth inside a contraction.

The depth just below the flume was little higher than the depth inside the contraction. This was due to a stationary wave formed just beloe the outlet of the flume. Mr Lane's explained this phenomenon thus:- "This would indicate a slight recovery of head or change from velocity to elevation head of the water after leaving the flume. This seems to have been accomplished in a stationary wave which occurred at the lower end of the flume".

<u>Expanding Flume.</u>

The expanding flume experimented on by Mr Lane consisted of a round edged contraction followed by a divergent outlet. Dimensions are as shown in small sketch in Figure (10)D.

For each run, observations of levels from which values of C_{dA} and C_W† were computed, were taken at several positions along the flume in the same manner as in the case of short flumes.

The following table 3 page.... was recomputed from data given in Tables (6) to (10) in Mr Lane's paper pages 1166 - 7 - 8. Water surface curves are also shown in Fig (10) D

† C_{dA} & C_W are d'Aubuisson's & Weisbach's coefficients respectively.

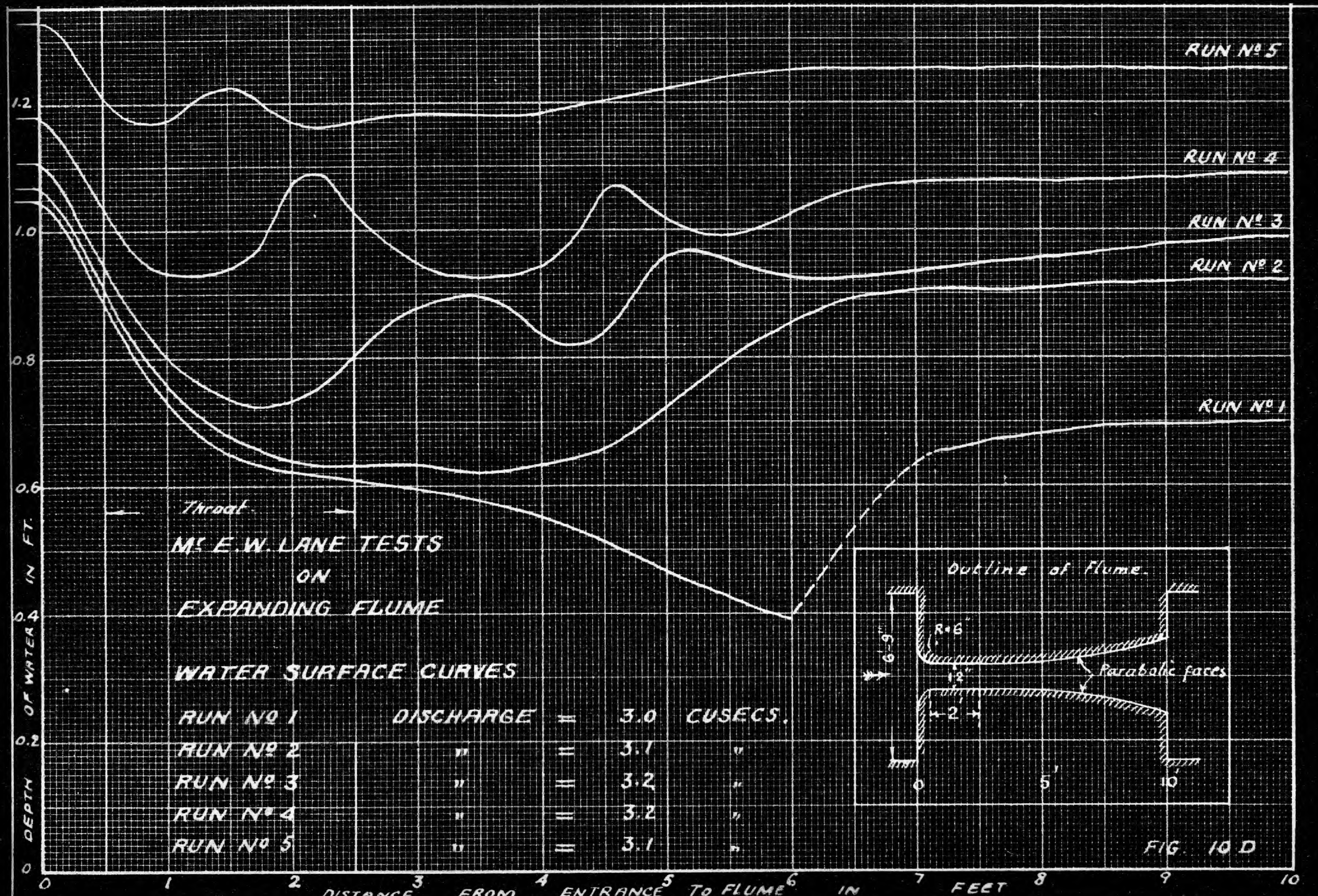

RUN Nº 5
RUN Nº 4
RUN Nº 3
RUN Nº 2
RUN Nº 1
1.2
1.0
0.8
0.6
0.4
0.2
0
DEPTH OF WATER IN FT.
Throat
Mr. E.W. LANE TESTS
ON
EXPANDING FLUME
WATER SURFACE CURVES
RUN Nº 1 DISCHARGE = 3.0 CUSECS.
RUN Nº 2 " = 3.1 "
RUN Nº 3 " = 3.2 "
RUN Nº 4 " = 3.2 "
RUN Nº 5 " = 3.1 "
Outline of Flume.
R=6"
6'-9"
1'2"
2'
Parabolic faces
0
5'
10'
0 1 2 3 4 5 6 7 8 9 10
DISTANCE FROM ENTRANCE TO FLUME IN FEET
FIG. 10 D

Table (2)

The following Table (2) was computed by the writer from data given in Table No.4 page 1165 in Mr Lane's paper.

d_1	d_2	d_3	h $d_1 - d_2$	d_1-d_3	Q_a	Q_t	C
←---	Feet			--→	←-- cusecs →		
1.410	0.884	0.895	0.526	0.515	4.735	5.10	0.928
1.317	0.829	0.829	0.488	0.459	4.267	4.59	0.930
1.164	0.730	0.738	0.434	0.730	3.537	3.85	0.917

TABLE (3) Computed from data given in Table 6 page 1166 in Mr Lane's paper.

d_1	d_2	d_3	h $d_1 - d_2$	d_1-d_3	Q_a	Q_t	C
←----	Feet			----→	←- cusecs →		
1.050	0.608	0.700	0.442	0.350	3.000	3.290	0.913
1.080	0.638	0.921	0.442	0.159	3.100	3.390	0.915
1.110	0.724	0.991	0.386	0.119	3.200	3.590	0.891
1.180	0.922	1.087	0.258	0.093	3.200	3.810	0.840
1.320	1.163	1.253	0.157	0.067	3.100	3.740	0.828

~~Figure 10 D.~~

In the original tables the discharge was observed to vary slightly for each observation along the flume. The writer, however, took the mean discharge instead of the variable ones. This will not make any appreciable difference.

In calculating the value of C the writer took only into consideration the depth at the lowest point inside the throat. This is usually followed by a surface wave which gives an erroneous value of the mean if taken into account. See page.... on the effect of surface waves inside the throat of flumes.

IV. P.S.Wilson and C.A.Wright in (1920) experimented on two designs of rectangular venturi flumes. Each flume had a throat width of 8" inches equal to 1/3 width of channel. The length of the converging part was three times the throat width and that of the diverging part was ten times the throat width Figure (11)D. The throat length of the first flume was 24 inches and that of the second was 8 inches.

The flumes were built of tongued and grooved dressed cypress with the grain horizontal. The channel was reinforced concrete.

Discharges were measured in a 400 cubic ft capacity measuring tank.

Every 2 feet along the canal a pair of opposite 1 inch pipe openings were built into the concrete. These entered the sides of the canal normally and horizontally with inverts level with the floor.

The gauge boxes consisted of 6 inch iron pipes with cylindrical copper floats provided with radial fins.

In order to vary the depth in the flume while keeping the discharge constant, adjustable system of pickets was arranged at the bottom of the canal to back up the water to the desired extent. This was done to avoid unequal distribution which would have been caused by an ordinary gate or weir.

Each run consisted of a single tank measurement of discharge and a reading of each gauge. The average of three or more similar runs was termed "set" and tabulated for computation and plotting.

The coefficients of discharge were computed from the same formula 15 taking $\frac{b_2}{b_1} = \frac{1}{3}$

Values of Q for given values of h and d_1 are plotted by the writer on a logarithmic sheet Figures (12)D and (13)D only few observations or sets corresponding to values of d_1 as near as possible to the round values 1.0, 1.5, 1.8, 2, 2.2 and 2.4 feet were chosen and plotted from both the tables of the 8" X 8" throat flume Figure (12) D and 8"X 24"† throat flume Figure (13)D. The points on the diagrams are joined by straight lines and when possible by approximate curves. Curves showing the theoretical flow with C = 1 in formula are also plotted on each diagram. Figure (12) D shows that the results for the 8" X 8" throat for upstream depths above 1.8 feet and differences of head of less than .10 feet were unreliable, not only, as is stated in the original report because of the peculiar phenomenon of the decrease in h with increase in Q but also as can be seen from the diagram, because of the considerable deviation from the theoretical curves giving irregularly varying values of C much greater than unity. It was mentioned in the report on these tests that " this variation was entirely due to the presence of waves of various types superimposed on the otherwise natural surface of the water flowing through the throat, these existing on account of the tendency under some conditions for the tail water to run back into the throat". This tendency seems to be

† See foot note in next page.

checked by the increase in velocity when the difference in head h is increased.‡

Figures (13) D and (14) D show that at low values h with the throat length three times the width, the variation in C is not so irregular as in the case of the 8" X 8" throat because in the case of the 8" X 24" throat the gauge openings in the throat were three times as far from the downstream end of the throat as in the 8" X 8" one and therefore the gauge readings were not so badly affected by the waves in the divergence.

In Figure (14) D part of diagrams (12) D and (13) D for values of h above 0.1 is plotted to double the scale. It shows that for both lengths of the throat the variation in C is regular above h = 0.1 and that points of the 8" X 8" throat and approximate curves joining them are closer to theoretical curves where C = 1

In Figure (15) D, values of C are plotted against values of h for the two throat lengths. In each case the value of d_1 (to the nearest second decimal) are also written near each point. By joining equal values of d_1 by approximate curves it is observed by the writer that the variation in c with d_1 is very much similar to that shown by Cone's and Parshall's curves in Figure (5) D. It can be also seen that the mean curve passing through all the points is much flatter in the case of the 24" throat than in the case of the 8" one.

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† See pages (453-4) Vol.85 Engineering News Record.

‡ See page on "Effect of surface curves inside the throat of a Venturi Flume".

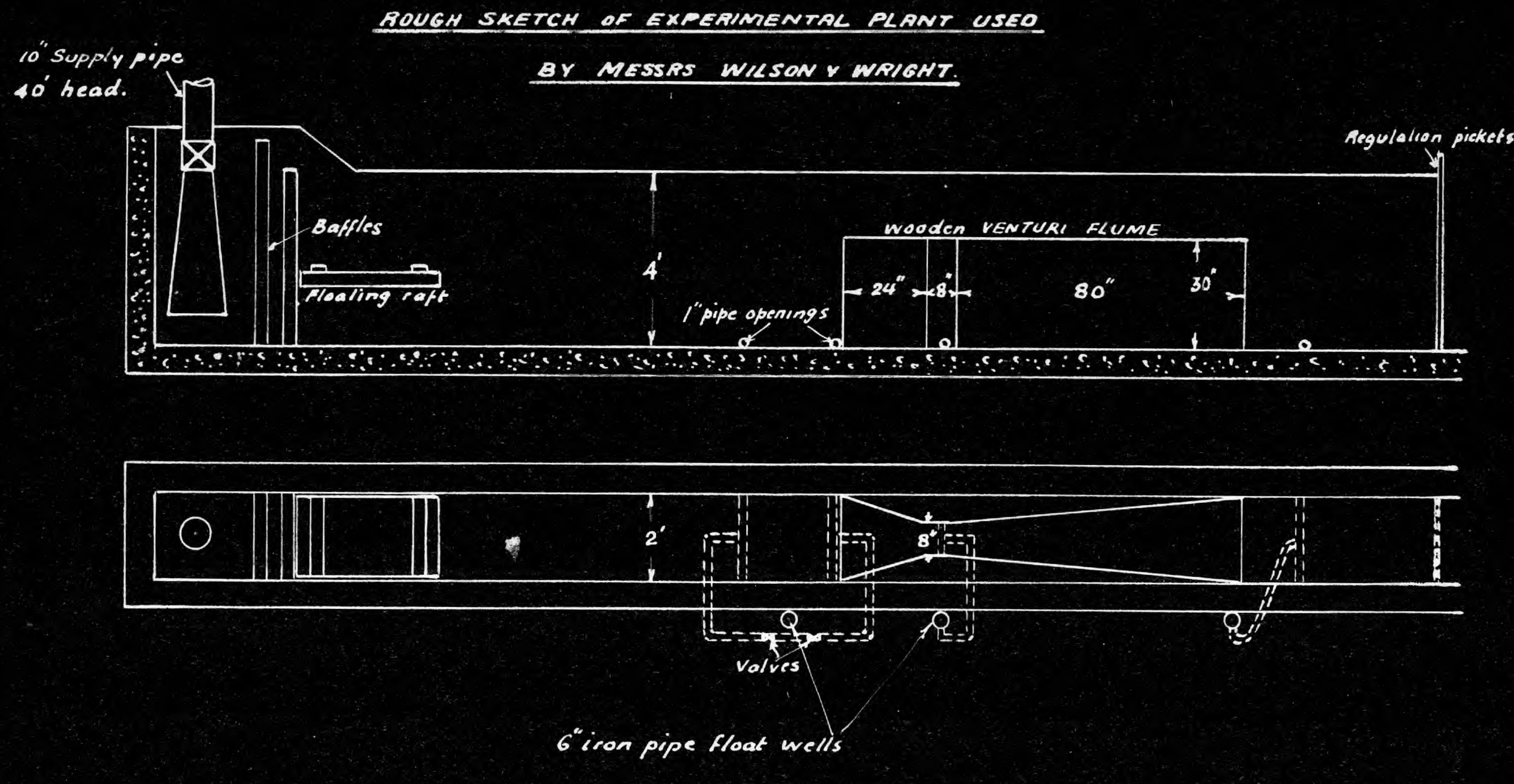

ROUGH SKETCH OF EXPERIMENTAL PLANT USED
BY MESSRS WILSON & WRIGHT.
10" Supply pipe
40' head.
Regulation pickets
Baffles
Floating raft
4'
WOODEN VENTURI FLUME
24"
8"
80"
30"
1" pipe openings
2'
8"
Valves
6" iron pipe float wells

Fig (II) D

Part of Fig (9) & (10) for h above 0.10' plotted to double the scale

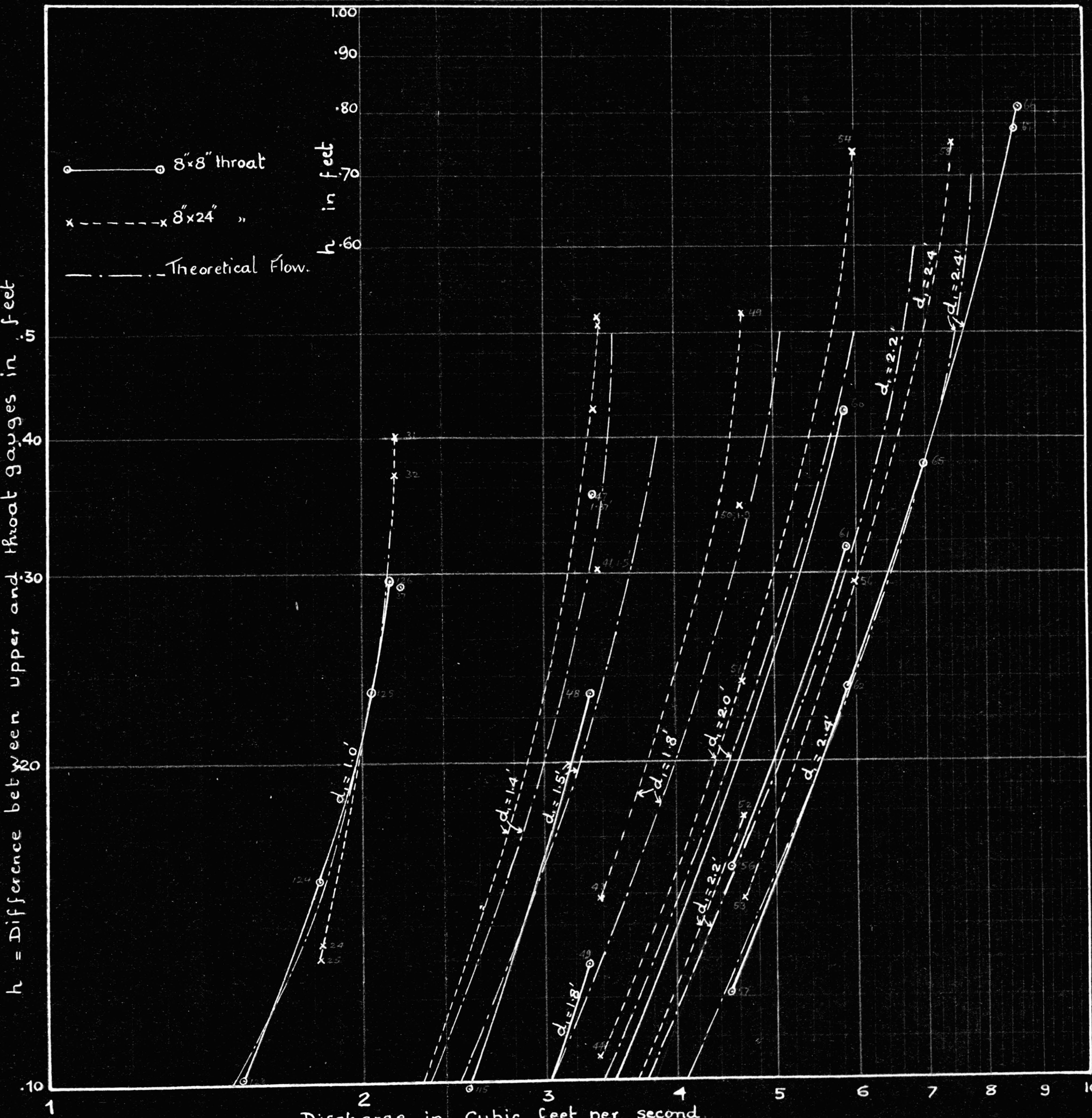


Fig (14) D

The number written near each point is the No. of the set in the original tables.
A second number near few points indicates the approximate value of d_1 in feet.

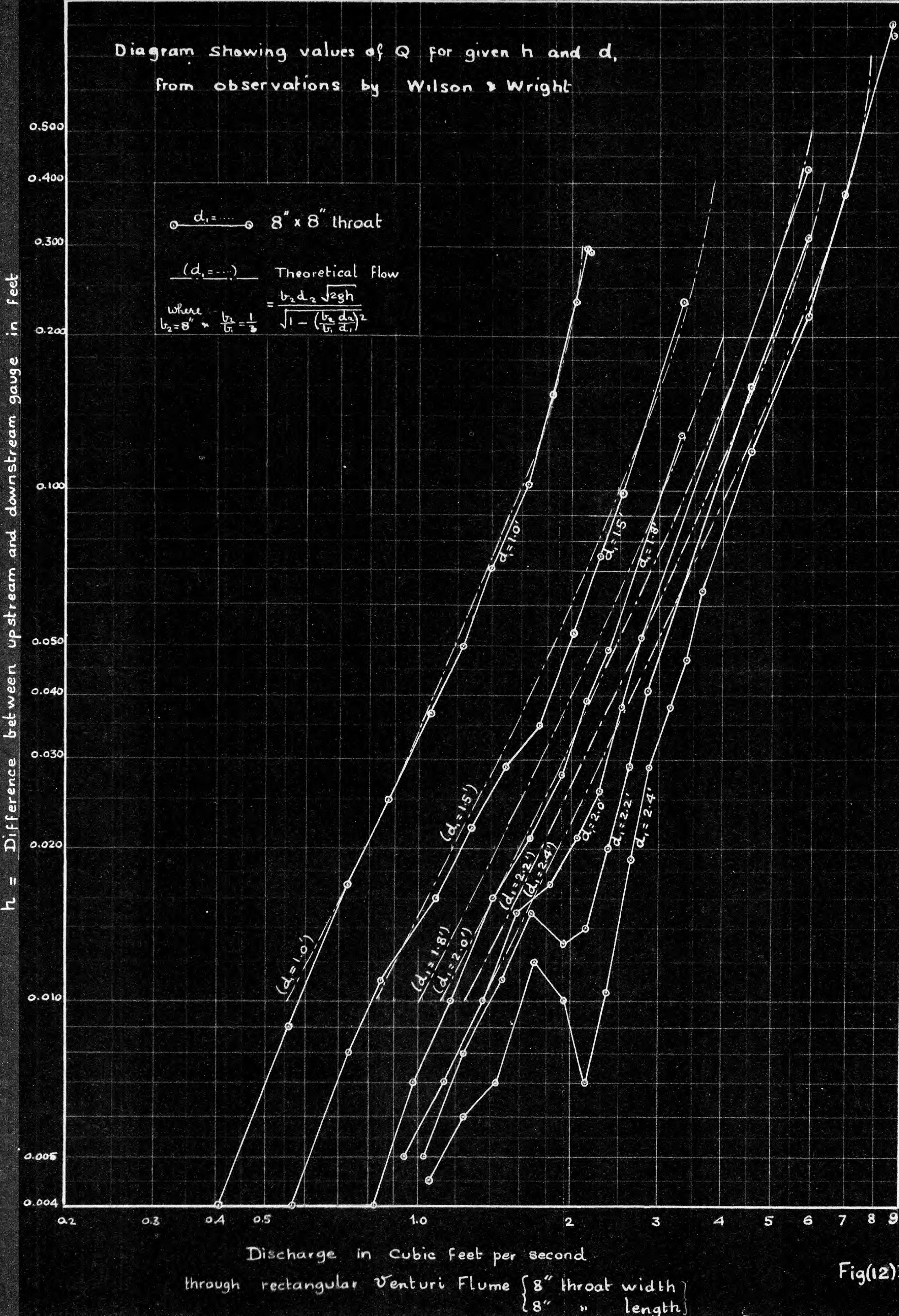
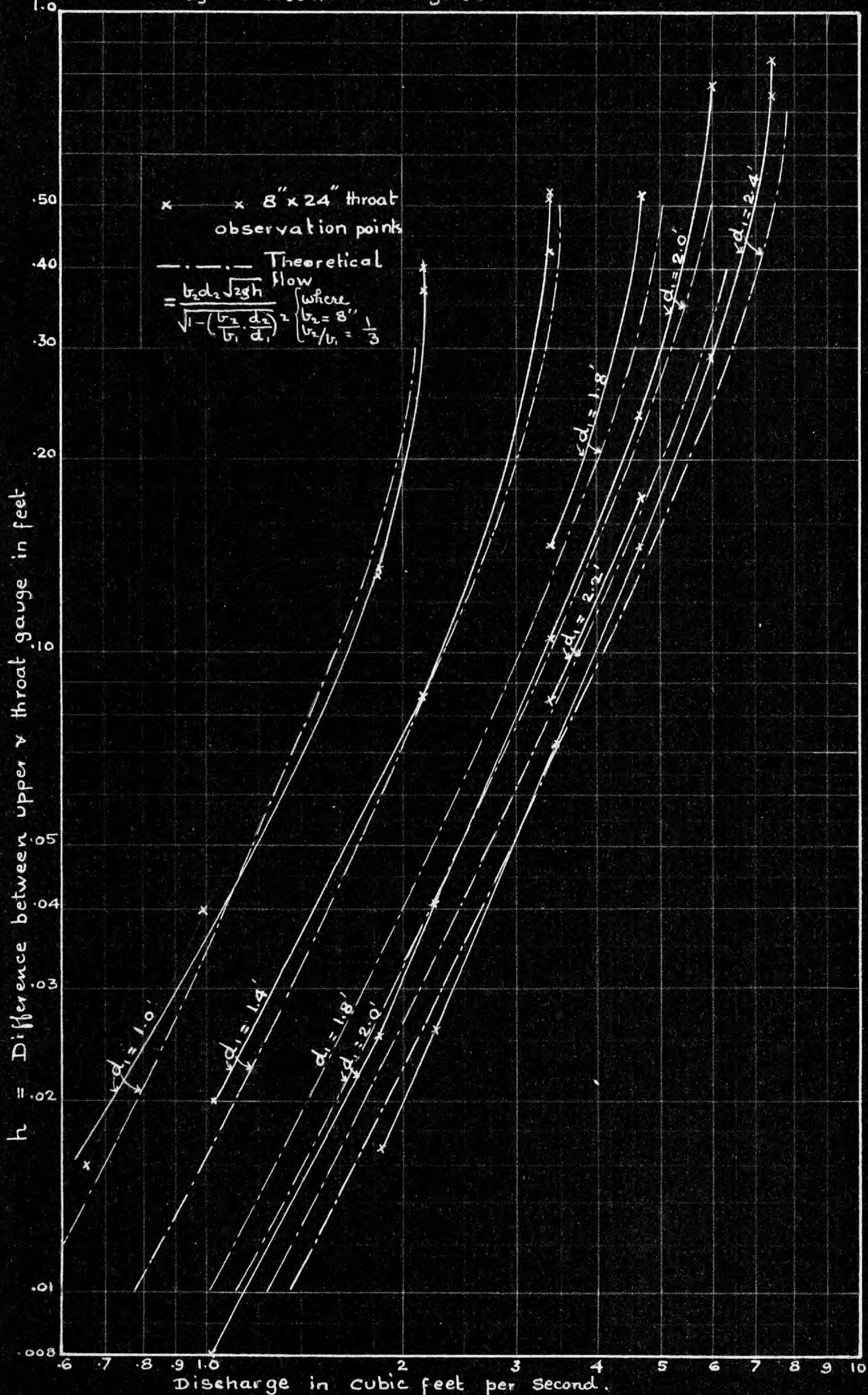


Diagram showing values of Q for given h and d,
from observations by Wilson & Wright
8" x 8" throat
Theoretical flow
$= \frac{b_2 d_2 \sqrt{2gh}}{\sqrt{1-\left(\frac{b_2}{b_1}\frac{d_2}{d_1}\right)^2}}$
where $b_2 = 8"$ & $\frac{b_2}{b_1} = \frac{1}{3}$
$d_1 = 1.0'$
$d_1 = 1.5'$
$d_1 = 1.8'$
$d_1 = 2.0'$
$d_1 = 2.2'$
$d_1 = 2.4'$
$(d_1 = 1.0')$
$(d_1 = 1.5')$
$(d_1 = 1.8')$
$(d_1 = 2.0')$
$(d_1 = 2.2')$
$(d_1 = 2.4')$
h = Difference between upstream and downstream gauge in feet
0.500
0.400
0.300
0.200
0.100
0.050
0.040
0.030
0.020
0.010
0.005
0.004
0.2
0.3
0.4
0.5
1.0
2
3
4
5
6
7
8
9
Discharge in Cubic feet per second
through rectangular Venturi Flume { 8" throat width, 8" " length }

Fig(12)I

Diagram showing values of Q for given value of h and d_1 from observations by Wilson & Wright.



Rectangular Venturi Flume 8" throat width
24" " length.

Fig (13) D

Diagram showing variation of C with h in Wilson and Wright tests

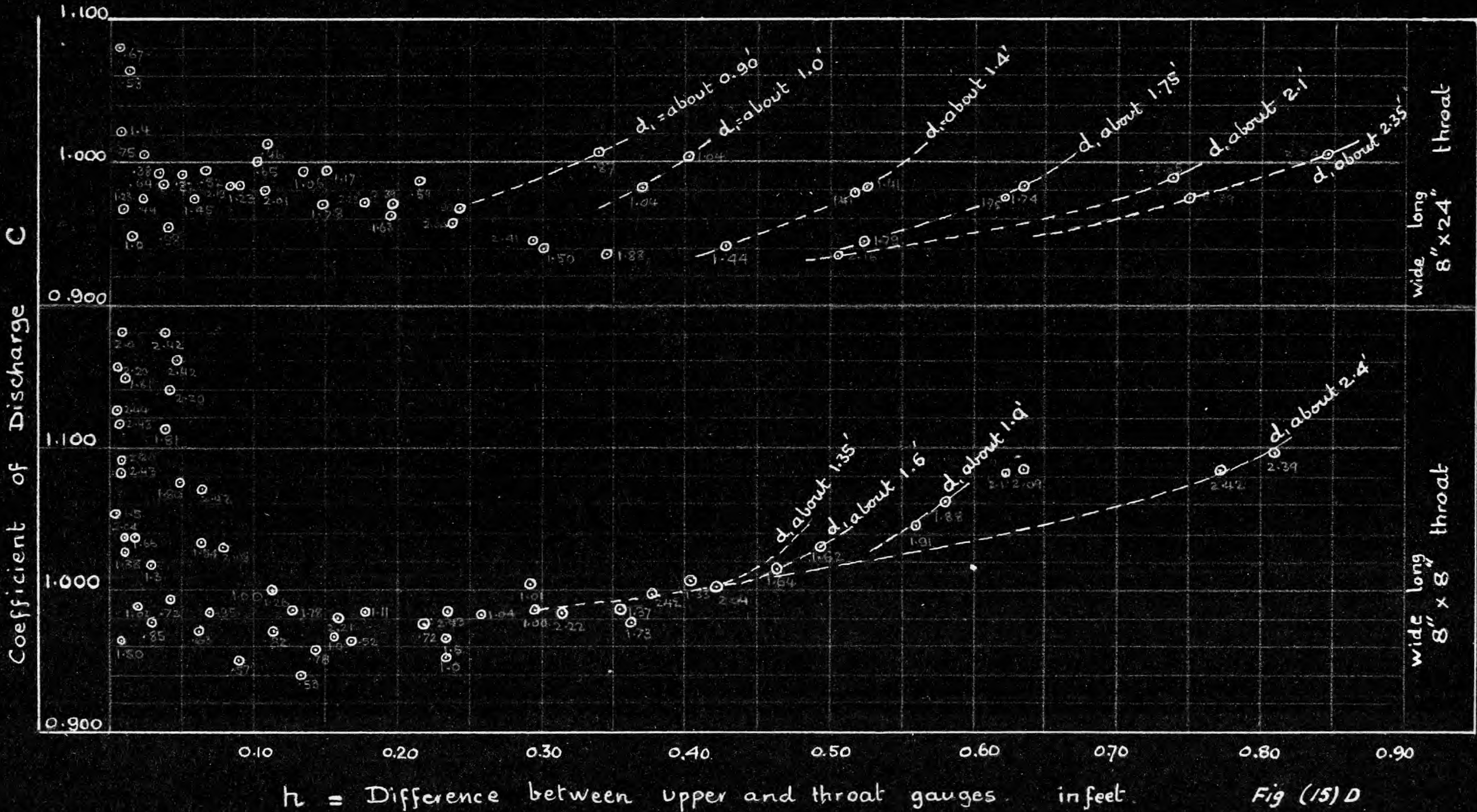


Fig (15) D

The experiments by Professor Alexander Jameson were made in a 44 ft long X 14½ inches deep wooden tilting flume at King's College, London. The flume was set to a gradient of 1:528. The water was supplied through a 4 inch pipe by means of a 4 inch centrifugal pump. Along the supply pipe there was a venturi meter calibrated by direct measurement in a sump (450 gallons capacity). The meter constant was 0.980.

The discharge entered the flume through a stilling tank with baffles. The depth was regulated by means of a weir at the lower end of the flume.

Figure (16) D shows the design of the venturi flume used. The depths were measured by pipes recessed in the bed of the flume with small holes in the top at about 1.5 inches centres, leading to vertical glass gauges outside the flume reading to .001 ft. One gauge was at the entry to the converging section, another was at the entry to the throatand only in certain tests there was a third gauge at the end of the divergence. Each set was the average of 4 to 9 readings. The formula used for the computation of flow through the flume was

$$Q = A_2 \sqrt{2g\,(H_1 - d_2)}$$

in which the notation is simply altered to correspond with the writer's on page .

For the application of this formula that does not include the main width of channel (b_1), the velocity of approach v_1 must be known. However, if b_1 is known, it will be more direct to write the same formula in the form of No.15 (see Appendix (3).

In the following tables 4(on blue print) Columns (1),(2),(3),(4),(6) and (8) are taken from Table (1) page 5 in the original paper. The remaining columns are computed by the writer.

In the computation of the theoretical discharge

In the original paper d_1 is noted by H, $d_1 + \frac{v_1^2}{2g}$ by H' and d_2 by h.

formula (15) was used taking b_1 = 1.218 feet b_2 = 0.594 ft as shown in Figure (16) D.

Values of C in column (9) are plotted on a logarithmic sheet as shown in Figure (20) D against values of h in Column (5). The line joining the points gives a relation C = 1.04 h thus making the general formula of flow for the special flume in Figure (16) D

$$Q = \frac{1.04\, b_2 d_2 \sqrt{2g}\, h^{.52}}{\sqrt{1 - \left(\frac{b_2}{b_1} \cdot \frac{d_2}{d_1}\right)^2}}$$

between h = 0.03 to h = 0.2.

In Table 4 set 1 it will be noticed that the drop h was very small and the depth inside the contraction was well above the critical value. According to section (d) Appendix (9) the water surface curve in the expansion followed the high stage (see Appendix (5)) and a water depth .003 ft less than the original was restored. (see Figure (18) D).

In set II the drop was almost exactly one thrid of the total energy head H_1 and according to section (d) Appendix (9) firstly the theoretical discharge was the maximum possible which equals 3.085 b_2 $H_1^{3/2}$ as shown by the agreement of Columns (7) and (14). Secondly the depth inside the contraction is the critical value (see Appendix (6)), and according to Section (d) Appendix (9) the water surface curve followed the low stage as shown in Figure (18)D.

In set III the observed values of d are a little more than (d_c = .667 H) as in II but it will be noticed that not only the theoretical flow was very nearly the maximum flow but also the water surface curve in the expansion followed the low stage because had it followed the high stage a hydraulic jump wouldnot have been possible (See Section (d) Appendix (9)). This proves that, according to theory the water surface must have dropped below the critical value i.e. dropped .007 feet just downstream the throat gauge which is quite possible.

PROF. A. JAMESONS TESTS.

Rough plan of Venturi Flume tested and water surface curves for different sets.

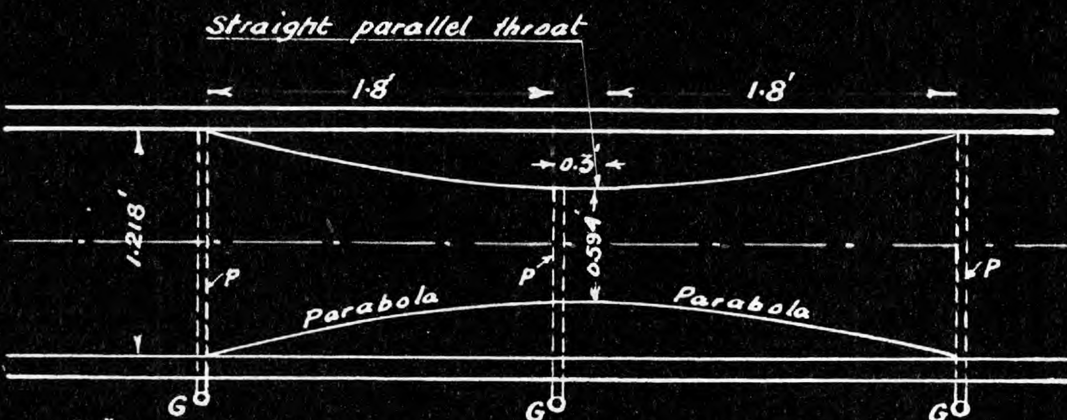


Fig (16) D

"P" Pipes embedded in floor with holes $1\frac{1}{2}$" apart

"G" Piezometer tube gauges.

The Venturi flume is made of parabolic arcs of wood.

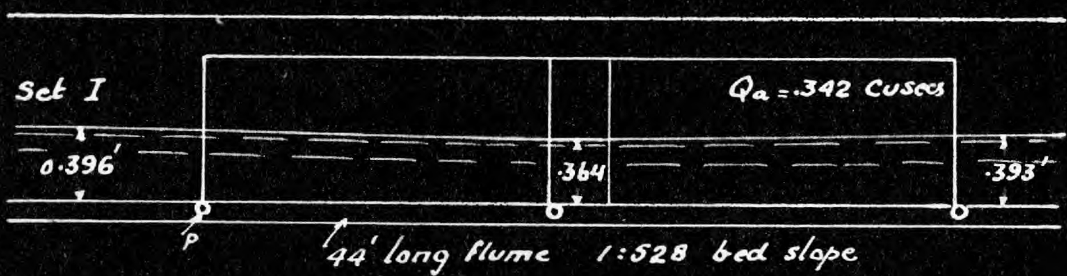


Fig (17) D

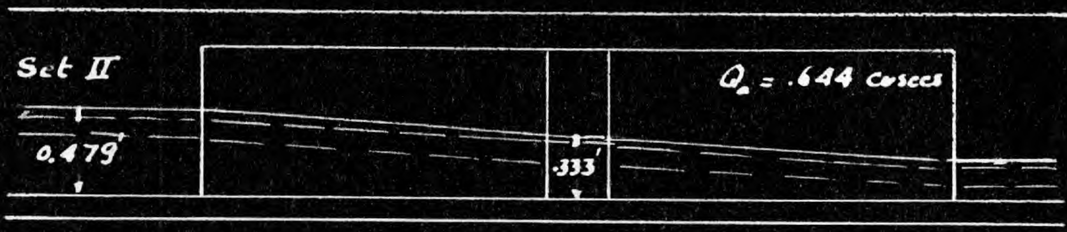


Fig (18) D

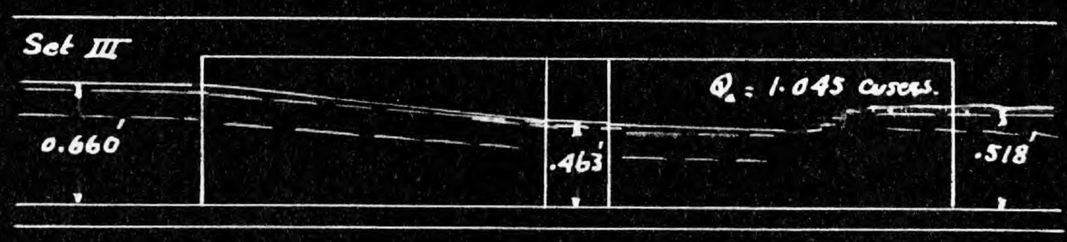


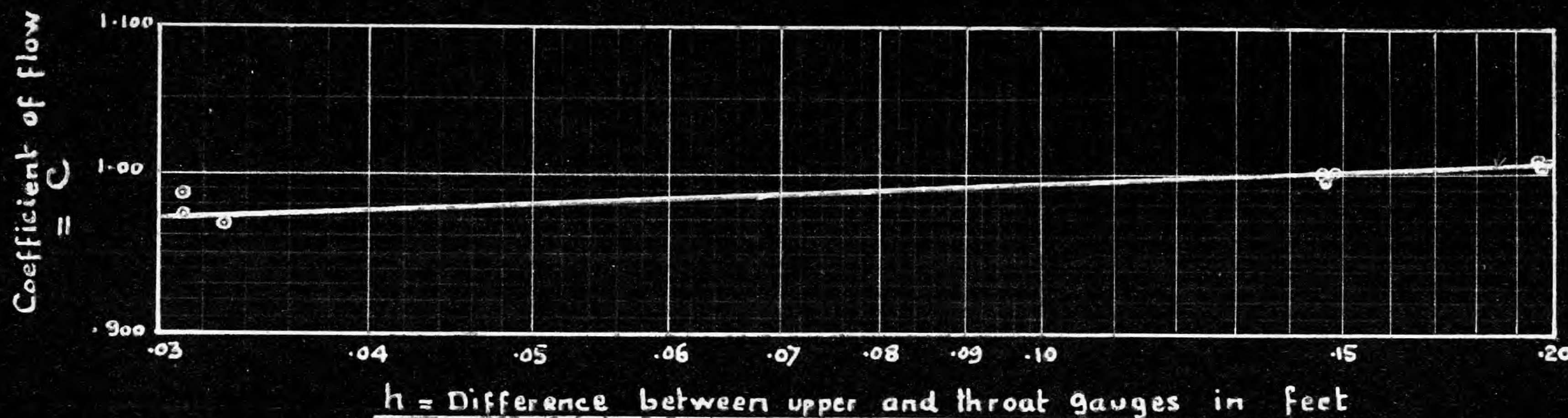
Fig (19) D

Table (4) computed from data obtained from Prof. A Jameson's test results.

Set No.	Test No.	Depth at entry $= d_1$	Depth in throat $= d_2$	Drop in throat $= h = d_1 - d_2$	Depth at end of expansion $= d_3$	Theoretical Discharge $= \frac{b_2 d_2 \sqrt{2gh}}{\sqrt{1-\left(\frac{b_2}{b_1}\cdot\frac{d_2}{d_1}\right)^2}}$	Actual discharge by Venturi Meter	Coefficient of Discharge $= \frac{\text{actual } Q}{\text{Theor. } Q}$	Actual velocity of approach $= v_1$	$\frac{v_1^2}{2g}$	$H_1 = d_1 + \frac{v_1^2}{2g}$	$\frac{d_2}{H_1}$	Max. flow $= 3.085 b_2 H_1^{3/2}$
		Feet				Cusecs			Ft/sec	Feet			Cusecs.
I	4	0.386	0.363	0.033		0.351	0.339	0.966	0.703	.00772	0.404	0.898	
	5	0.395	0.364	0.031	0.392	0.341	0.337	0.988	0.701	.00766	0.403	0.902	
	6	0.386	0.365	0.031	0.393	0.353	0.343	0.972	0.710	.00786	0.404	0.903	
II	1	0.479	0.333	0.146		0.643	0.644	1.000	1.103	.01900	0.498	0.668	0.644
	2	0.481	0.333	0.148		0.647	0.647	1.000	1.103	.01900	0.500	0.667	0.647
	3	0.478	0.331	0.147		0.642	0.640	0.997	1.097	.01875	0.497	0.667	0.642
III	7	0.658	0.461	0.197	0.517	1.035	1.037	1.002	1.293	.02610	0.684	0.674	1.035
	8	0.659	0.463	0.196	0.517	1.036	1.045	1.009	1.303	.02650	0.686	0.675	1.040
	9	0.662	0.464	0.198	0.520	1.045	1.052	1.006	1.304	.02650	0.689	0.674	1.045
①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩	⑪	⑫	⑬	⑭

Diagram showing values of C in formula $Q = \frac{C b_2 d_2 \sqrt{2gh}}{\sqrt{1 - \left(\frac{b_2}{b_1}\frac{d_2}{d_1}\right)^2}}$

plotted against h in Prof A. Jameson's Tests.



The curve is a straight line giving $C = 1.04\, h^{.02}$

Fig (20) D

APPENDIX I.

DERIVATION OF GENERAL FORMULA OF FLOW OF WATER IN OPEN CHANNELS.

In Figure 1 let b c be a stream tube of small cross-sectional area δa in a steady stream of cross-sectional area A.

The centre line of the tube intersects the planes (1) and (2) in b and c

At section (1)

$\frac{p_1}{w}$ = depth of b below water surface.

z_1 = height of b above datum plane.

$\frac{p_2}{w}$ = depth of c below water surface.

z_2 = height of c above datum plane.

h = drop of water level from section (1) to (2)

δl = distance between sections (1) and (2)

h_f = head lost in friction in tube from b to c

H_f = total head lost in friction from section (1) to section (2)

Applying Bernoullis Theorem to points b and c

we get :- $$\frac{P_1}{w} + \frac{V_1^2}{2g} + z_1 = \frac{P_2}{w} + \frac{V_2^2}{2g} + z_2 + h_f \quad \text{--------- (1)}$$

Summing up for all the tubes forming the whole stream we get :-

$$\Sigma\left(\frac{P_1}{w} + \frac{V_1^2}{2g} + z_1\right) = \Sigma\left(\frac{P_2}{w} + \frac{V_2^2}{2g} + z_2\right) + \Sigma h_f$$

or $$\Sigma\left(\frac{P_2}{w} + z_1 - \frac{P_2}{w} - z_2\right) = \Sigma \frac{V_2^2 - V_1^2}{2g} + H_{f_1} \quad \text{----- (2)}$$

But $$\frac{P_1}{w} + z_1 - \frac{P_2}{w} - z_2 = h$$

$\therefore$ From (2) $$\Sigma h = \Sigma \frac{V_2^2 - V_1^2}{2g} + H_f \quad \text{--------- (3)}$$

As h is the same for all the tubes and v_1 and v_2 can be approximately taken as the mean of velocities at section (1) and (2) respectively, we can put

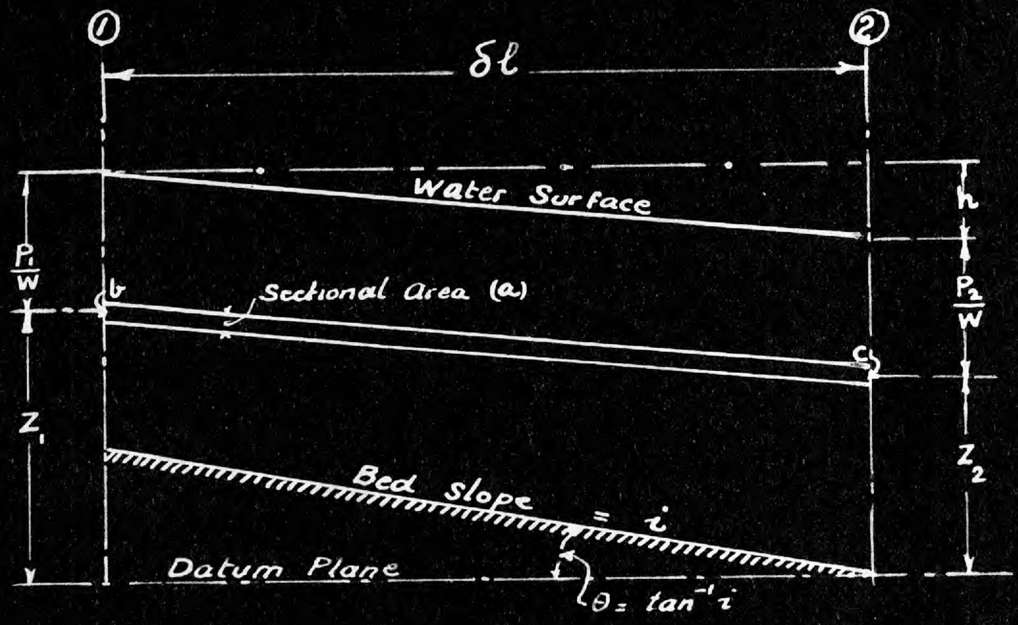


Fig 1

P_1 = Pressure at b in lbs per square ft.

P_2 = " " c " " " " "

W = Weight of water in lbs per cubic ft.

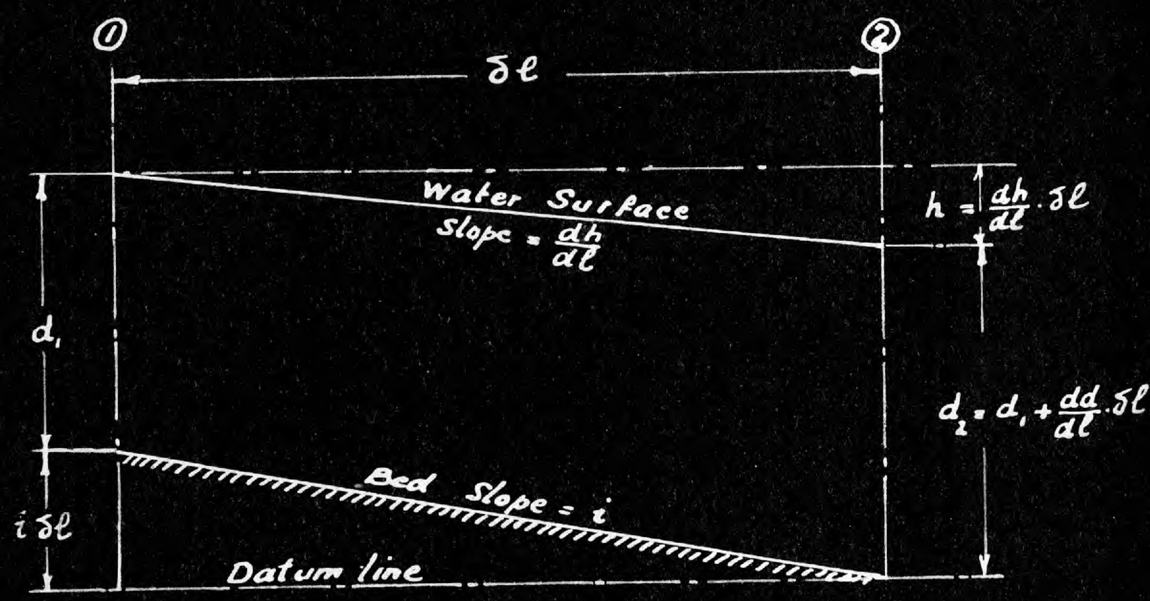


Fig (2)

$$\Sigma h = Ah \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

$$\text{and } \Sigma \frac{V_2^2 - V_1^2}{2g} = A\left(\frac{V_2^2 - V_1^2}{2g}\right) \quad \ldots\ldots\ldots\ldots (5)$$

Let P be the wetted perimeter of channel section, v be either the mean velocity or the root of the mean of the squares of velocities between section (1) and (2), and f be the coefficient of roughness of section.

$$\text{Then} \quad H_f = \frac{fv^2}{2g} \cdot P.\delta l \quad \ldots \quad (6)$$

Also assuming $v_1 = v$

and $v_2 = v + \frac{dv}{dl}.\delta l$

$$\text{we get} \quad \frac{V_2^2 - V_1^2}{2g} = \frac{v\frac{dv}{dl}.\delta l}{g} \quad \ldots \quad (7)$$

(neglecting small quantities of the second order)

Substituting from (4),(5),(6) and (7) in (3) we get

$$Ah = A\,\frac{v\frac{dv}{dl}.\delta l}{g} + \frac{fv^2}{2g}.P.\delta l \ldots \quad (8)$$

Putting $h = \frac{dh}{dl}.\delta l$ in (8) and then dividing by $A\delta l$ we get

$$\frac{dh}{dl} = \frac{v}{g}.\frac{dv}{dl} + \frac{fv^2}{2g}.\frac{P}{A} \quad \ldots \quad (9)$$

In Figure 2

d_1 = depth of water in section (1)

d_2 = „ „ „ (2)

i = slope of bed

$$\text{and} \quad d_1 + i\delta l = \frac{dh}{dl}.\delta l + d_2$$

$$\therefore \quad d_1 + i\delta l = \frac{dh}{dl}.\delta l + d_1 + \frac{dd}{dl}.\delta l$$

$$\text{or} \quad i = \frac{dh}{dl} + \frac{dd}{dl}.\delta l$$

$$\text{From which} \quad i = \frac{dh}{dl} + \frac{dd}{dl}$$

or

Substituting in (9) we obtain

$$i - \frac{dd}{dl} = \frac{v}{g}.\frac{dv}{dl} + \frac{fv^2}{2g}.\frac{P}{A} \ldots \quad (10)$$

Equation (10) is the fundamental equation of flow at any section.

APPENDIX (2).

RELATION BETWEEN DEPTHS AND VELOCITIES OF FLOW IN MAIN CHANNEL AND IN CONTRACTED SECTION.

The effect of a side contraction at any section in a channel on a flowing stream is generally an increase in the original normal depth just above the contraction, followed by a drop below that depth inside the contraction. The depth above the contraction and the drop will depend upon the flow and the ratio of contraction. The tail level may be below, the same or above the level in contraction. The first two cases are generally accompanied by a hydraulic jump to be discussed later. In the third case the tail water depth will differ from the upstream depth by an amount depending upon the amount of drop in the throat or in other words upon the velocity inside the throat. This difference between the upstream and tail level is known as the loss of head.
Generally speaking, alterations in the shape of water surface curve above, inside, and below contraction vary with the original conditions of flow and with the nature of the contraction. As a general rule, the velocity inside the contraction increases and the depth decreases. Exceptions to this rule will be discussed later.

APPENDIX (3)

RELATION BETWEEN THE DISCHARGE AND DEPTHS d_1 AND d_2

Taking for simple illustration a smooth channel with horizontal bed and rectangular section in the main channel and in contraction as in Figure (3), then equation (1) Appendix (1) becomes

$$\frac{P_1}{w} + \frac{V_1^2}{2g} = \frac{P_2}{w} + \frac{V_2^2}{2g} \qquad (11)$$

Taking v_1 and v_2 as the mean velocities at sections (1) and (2) we can apply equation (11) to points A and B on the bed figure 3

As before, $\frac{P_1}{w} = d_1$ = depth of A below water surface

$\frac{P_2}{w} = d_2$ = ,, ,, B ,, ,, ,,

$$\therefore d_1 + \frac{V_1^2}{2g} = d_2 + \frac{V_2^2}{2g} \qquad (12)$$

$$\text{or} \quad \frac{V_2^2}{2g} - \frac{V_1^2}{2g} = d_1 - d_2 = h \qquad \text{(Fig.3).....(13)}$$

Let width of main channel = b_1

and ,, ,, contracted section = b_2

Then the discharge $Q = b_1 d_1 v_1 = b_2 d_2 v_2$ .....(13a)

$$\therefore \frac{V_1^2}{2g} = \frac{V_2^2}{2g}\left(\frac{b_2 d_2}{b_1 d_1}\right)^2$$

substituting in equation (13) we get

$$\frac{V_2^2}{2g}\left[1 \mp \left(\frac{b_2 d_2}{b_1 d_1}\right)^2\right] = d_1 - d_2 = h \qquad .....(13b)$$

and substituting from (13b) for V_2 in (13a) we get:-

$$Q = \frac{b_2 d_2 \sqrt{2gh}}{\sqrt{1 - \left(\frac{b_2 d_2}{b_1 d_1}\right)^2}} \qquad .....(14)$$

The following cases are based on the above formula (14)

(a) Due to the effect of contraction in a suddenly reduced section, Eytlwein introduced a coefficient C_E and put

$$Q = b_1 d_1 v_1 = c_E b_2 d_2 v_2$$

and thus equation (14) became.

$$Q = \frac{b_2 d_2 \sqrt{2gh}}{\sqrt{1 - c_E^2 \left(\frac{b_2 d_2}{b_1 d_1}\right)^2}} \qquad ....(14a)$$

(b) If the reduction in section is gradual through convergent side walls as in Figure (5), then C_E can be dropped and formula (14) can be used. Still in this case a coefficient of flow to suit the special contraction and

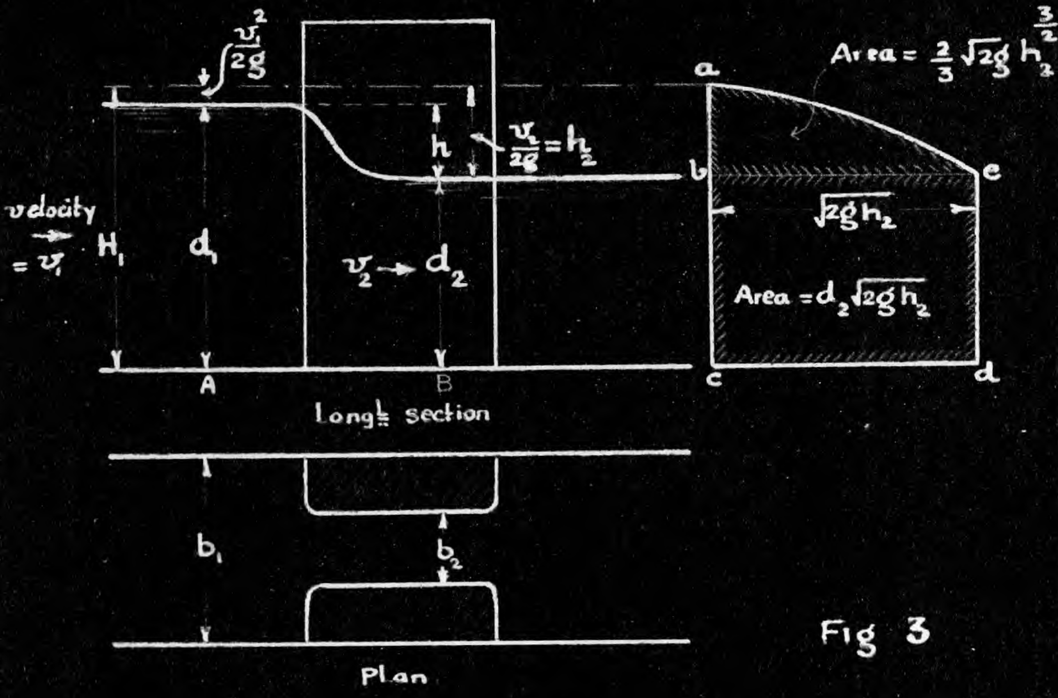

Area = $\frac{2}{3}\sqrt{2g}\,h_2^{\frac{3}{2}}$
$\frac{v_1^2}{2g}$
a
h
$\frac{v_2^2}{2g} = h_2$
b
e
velocity $= v_1$
H_1
d_1
$v_2 \rightarrow d_2$
$\sqrt{2gh_2}$
Area $= d_2\sqrt{2gh_2}$
A
B
c
d
Long^{l} section
b_1
b_2
Plan

Fig 3

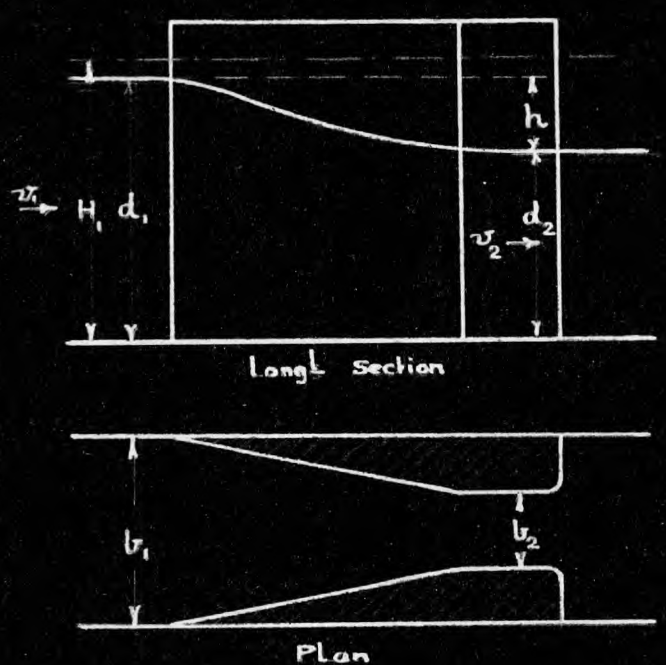

h
v_1
H_1
d_1
d_2
v_2
Long^{l} Section
b_1
b_2
Plan

Fig 4

roughness of flume may be required and we get

$$Q = \frac{C b_2 d_2 \sqrt{2gh}}{\sqrt{1 - \left(\frac{b_2 d_2}{b_1 d_1}\right)^2}} \qquad \text{..........(15)}$$

(c) The problem can be also treated as that of a submerged weir with the crest flush with the bed of the channel.

Referring to Figure (3) and applying equation (12)

$$\frac{V_2^2}{2g} = d_1 + \frac{V_1^2}{2g} - d_2$$

$$\therefore V_2 = \sqrt{2g}\sqrt{d_1 + \frac{V_1^2}{2g} - d_2}$$

and $$Q = b_2 d_2 \sqrt{2g}\sqrt{d_1 + \frac{V_1^2}{2g} - d_2} \qquad \text{...........(16)}$$

Applying a coefficient of discharge C_{dA} we obtain d'Aubuisson's formula :-

$$Q = C_{dA}\, b_2 d_2 \sqrt{2g\left[\left(d_1 + \frac{V_1^2}{2g}\right) - d_2\right]} \qquad \text{...........(16a)}$$

Denoting $(d_1 - d_2)$ by h

and $(d_1 - d_2) + \frac{V_1^2}{2g}$ by h_2 the last equation can be written $Q = C_{dA}\, b_2 d_2 \sqrt{2gh_2}$ ....(16b)

The value of Q per unit width of contracted section according for formula (16) is represented graphically by the shaded area (b c d e) Figure (3).

(d) Weisbach added to the theoretical flow from formula (16), the flow in the top part above d treated separately as in the case of a weir with head above the crest $= h_2$

This makes the discharge Q per unit width of contracted section equal to the total shaded area represented by (a c d e) Figure 3

Applying a coefficient of discharge C_w we get the formula for the total flow according to Weisbach :-

$$= C_w\left[\frac{2}{3}\sqrt{2g}\, h_2^{3/2} + \sqrt{2g}\, d_2 h_2^{1/2}\right] \qquad \text{............(17)}$$

(e) If the drop in water level in passing through a long contraction takes place in two stages i.e. the total drop inside the contraction is h_2 and after leaving the

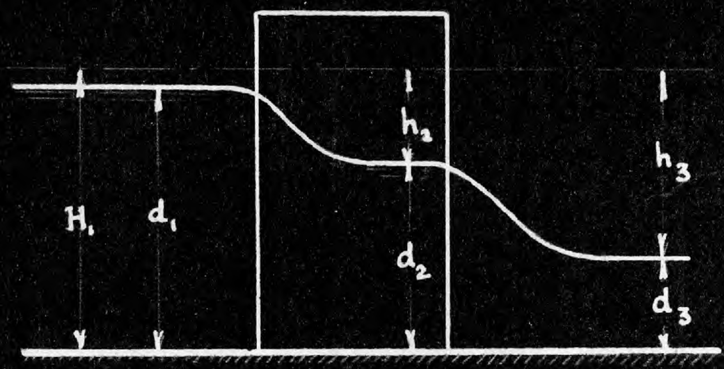


Fig 5

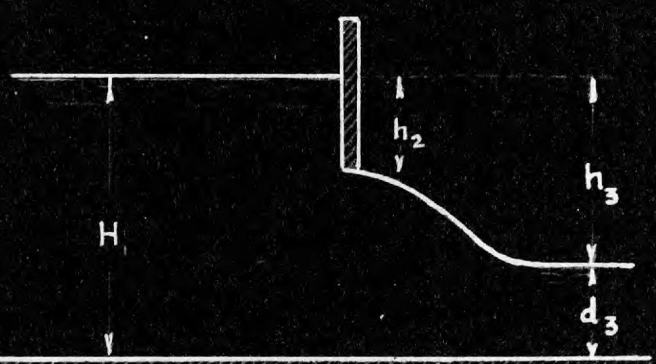
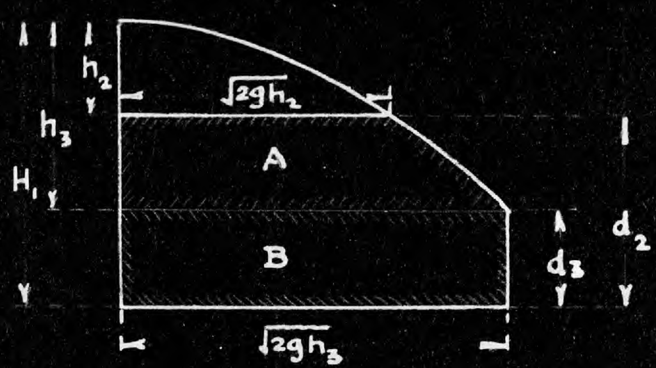


Fig 6



$$\text{Area A} = Q_A = \frac{2}{3}\sqrt{2g}\left[h_3^{3/2} - h_2^{3/2}\right]$$

$$\text{Area B} = Q_B = d_3\sqrt{2gh_3}$$

Fig 7

contraction is h_3 as in Figure 5 then as will be explained in the following Appendix (4) the depth d_2 is the depth in contraction corresponding to the maximum discharge under a head H_1 and that d_2 remains unchanged and equal to $\frac{2}{3} H_1$ so long as d_3 is less than d_2 $\left[H_1 = d_1 + \frac{V_1^2}{2g}\right]$

In this case $h_2 = \frac{d_2}{2} = \frac{H_1}{3}$

and from equation (16b)

$$Q = C b_2 d_2 \sqrt{2g\,h_2} = C b_2 \sqrt{2g} \cdot \frac{2}{3} H_1 \sqrt{\frac{H_1}{3}}$$

$$= 3.085\, c\, b_2 H_1^{3/2} \quad \text{in foot second units.}$$

APPENDIX (4).

DEPTH OF MAXIMUM DISCHARGE.

At any section in an open flume, let

H = depth + velocity head $= d + \frac{v^2}{2g}$

In a smooth horizontal flume of constant section and sectional area H will be constant at all sections along the flume and the value of v and therefore the discharge Q depends upon d. The question is now to find the value of d that gives maximum Q for a given value of H

We have $H = d + \frac{v^2}{2g}$

$$= d + \frac{Q^2}{A^2 2g} \quad \text{(where A = sectional area)}$$

$$\therefore Q = A\sqrt{2g}\sqrt{H-d}$$

and $$\frac{dQ}{dd} = \sqrt{2g}\left[\sqrt{H-d}\cdot\frac{dA}{dd} - \frac{A}{2\sqrt{H-d}}\right]$$

$$= \sqrt{2g}\,\frac{2\frac{dA}{dd}(H-d) - A}{2\sqrt{H-d}}$$

If the top width = W ft

we get $W\, dd = dA$

$$\frac{dA}{dd} = W$$

and $$\frac{dQ}{dd} = \sqrt{2g}\,\frac{2W(H-d) - A}{2\sqrt{H-d}}$$

For Q to be a maximum $\frac{dQ}{dd} = 0$

or $2W(H-d) = A$

or $H - d = \frac{A}{2W}$

or $\qquad d = H - \frac{A}{2W}$ ....(19)

In a restangular section $\quad A = Wd$

and d for max discharge $\quad = H - \frac{d}{2}$

i.e. d ,, ,, $\quad = \frac{2}{3} H$ ....(20)

and $A = \frac{2}{3} W H$

Thus giving maximum discharge

$$Q_{max} = W \sqrt{2g} \cdot \frac{2}{3} H \sqrt{\frac{H}{3}}$$

$$= 3.085\, W H^{3/2}$$ (in feet see units)(20a)

In this case $\quad V = \sqrt{2g(H-d)}$

$$= \sqrt{2g(\tfrac{3}{2}d - d)}$$

$$= \sqrt{gd}$$

From the above we conclude that if the water depth below a contraction with a round entrance as in Figure (3) or a gradual convergent entrance as in Figure (4) in less than the depth for maximum flow as given by equation (20) corresponding to a given upstream head H then the depth inside the contraction will adjust itself to that depth of maximum flow which is, in other words, the least depth to allow the flow in the main channel to pass through the contraction. There will be in this case another drop to the tail water level just below the contraction. If the depth of tail water is equal to the depth for maximum discharge or 2/3 H, the depth inside the contraction will be the same as the tail water depth. If the tail water level is above H then the depth inside the contraction will be say y feet lower than the tail water level such that Drop at entrance in feet - y= loss of head through contraction in feet.

APPENDIX (5).

ALTERNATIVE DEPTHS OR ALTERNATIVE STAGES OF FLOW.

From the formula
$$d + \frac{V^2}{2g} = H$$
$$d + \frac{Q^2}{A^2 2g} = H$$

and in the rectangular section of width b, $A = b\,d$

$$\therefore\ d + \frac{Q^2}{b^2 d^2 2g} = H \quad \text{or} \quad d^3 + \frac{Q^2}{2g b^2} - Hd^2 = 0 \ \ldots\ldots\ldots\ (21)$$

Equation (21) is a cubic equation in d and for a constant head H and discharge Q and width b we can obtain three values of d of which one value is negative or impossible. The other two are the two possible depths of the water under the given conditions. The lower value of d is called the "low stage depth" and the higher value is called the "high stage depth".

Taking a constant value of H equal say 9 ft and b = 10 ft we can plot from the following table a curve as in Figure (8) showing variation of Q with d. The table is calculated from equation (21)

d	=	1	2	3	4	5	6	7	8	9
Hd^2	=	9	36	81	144	225	324	441	576	
d^3	=	1	8	27	64	125	216	343	512	
	=	8	28	54	80	100	108	98	64	
Q	=	226.5	423	588	716	800	832	793	642	

Taking a constant value of Q say 800 cubic feet per second a similar curve showing the relation between d and H can be plotted from the following table as shown in Figure (8)

Taking b = 10 feet as before,

we get $\frac{Q^2}{2gb^2} = \frac{800 \times 800}{2 \times 32 \times 100} = 100$

$\therefore$ from (21)

$$d - Hd^2 + 100 = 0$$

Curves Showing relation between d & H for Constant Q & b
and " d & Q " " H & b
in the equation $d^3 - Hd^2 + \frac{Q^2}{2gb^2} = 0$ for rectangular section
Q = discharge in cubic feet per sec. , d = depth in feet , H = Energy head $\left(d + \frac{v^2}{2g}\right)$ b = width in feet

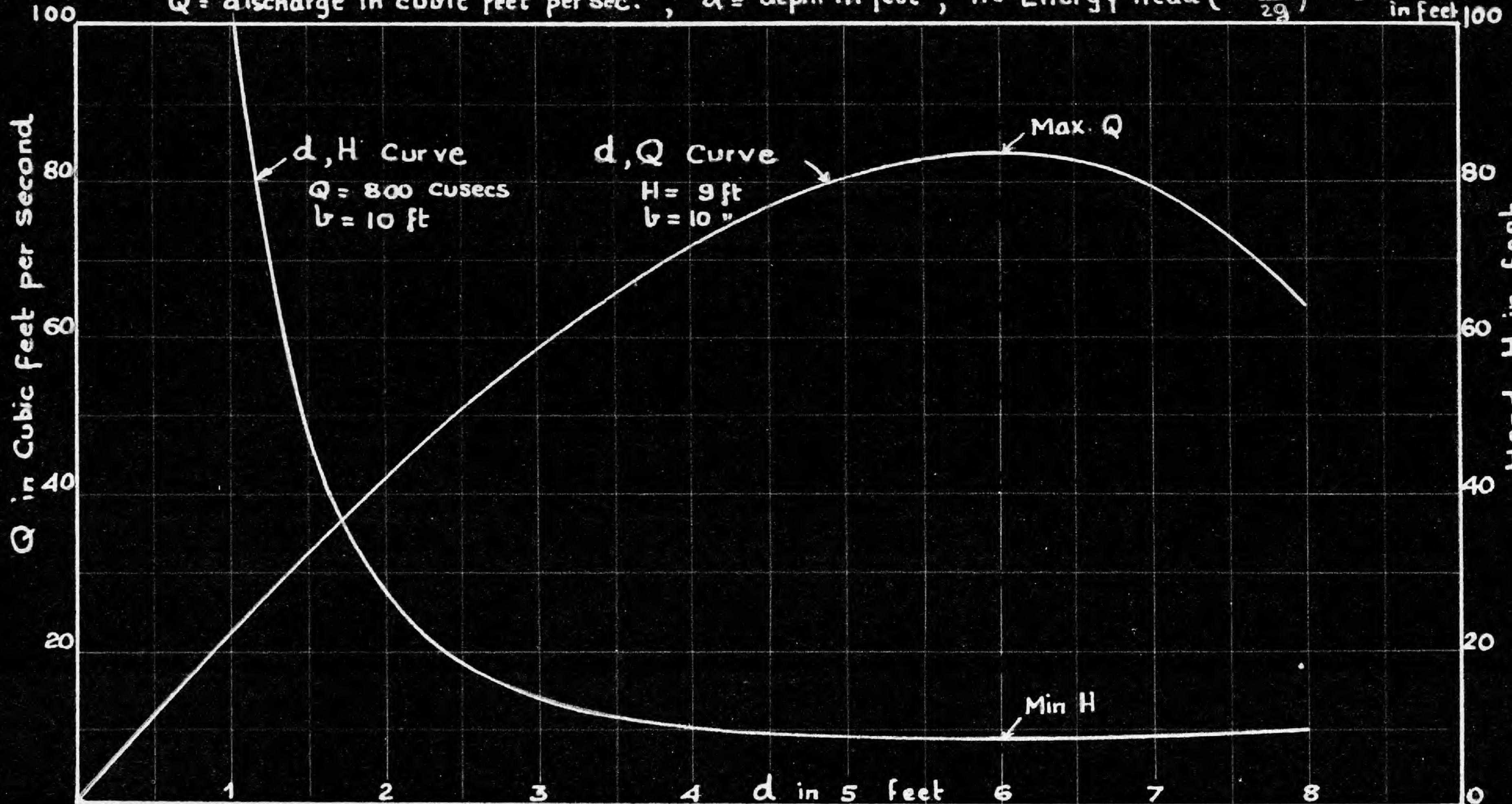


Fig 8

d in feet =	1	1.5	2	3	4	5	6	7	8
d =	1	3.37	8	27	64	125	216	348	512
Hd = d 100 =	101	103.37	108	127	164	225	316	443	612
d =	1	2.25	4	9	16	25	36	49	64
H =	101	46	27	14.1	10.25	9	8.78	9.05	9.58

It is clear from equation (21) and the curves in Figure (8) that the depth that gives the maximum value of Q for a given H gives the minimum value of H for a given Q. Also from the d Q curve we notice that for any discharge there are two possible depths of flow which are already known as the low stage and high stage depths except for the case of maximum possible flow when there is only one value of d. Similarly from the A H curve we notice that for any H there is a low stage and a high stage depth except for the least possible H when there is only one value of d. This one value of d corresponding to maximum flow (when H and b are constants) is known as the critical depth. When the water inside a contraction is flowing at the critical depth then below the contraction, depending upon the depth of tail water, it may fall below this critical depth or rise above it. The first case is the low stage flow and as it is always accompanied by a rapid fall and increase in velocity it is called "torrential flow". The second case is the high stage flow and although it is generally accompanied by eddies yet for the rise in level and the check in the velocity of flow ~~yet~~ it can be comparatively called "calm flow".

APPENDIX (6).

CRITICAL DEPTH.

This depth already mentioned in previous Appendix can be duduced in a more general way as follows:-

From the equation $d + \frac{Q^2}{2gA^2} = H$

$$\frac{dH}{dd} = 1 - \frac{2\frac{dA}{dd}}{A^3} \cdot \frac{Q^2}{2g}$$

Also at any section, if W = top width of water surface

$$dA = W dd \quad \text{and} \quad \frac{dA}{dd} = W$$

i.e. H is a minimum when $\frac{Q^2}{g} = \frac{A^3}{W}$

or when $\frac{A^2v^2}{g} = \frac{A^3}{W}$

i.e. $\frac{v^2}{g} = \frac{A}{W}$

and for a rectangular section in which A = wd we get under this condition of minimum H

$$\frac{v^2}{g} = \frac{Wd}{W} = d$$

$$\text{ie} \quad v = \sqrt{gd}$$

which is the same conclusion arrived at in finding the depth for maximum flow.

The value of d that makes H minimum for a given discharge is called "the critical depth" and will be denoted by "d_c".

APPENDIX (7).

GRAPHICAL ILLUSTRATIONS.

The results obtained in Appendices (5) and (6) can also be clearly seen from the graphical illustration in the diagram in Figure (9) which gives the relation between the variables d, Q, H and b in formula (21)
$(d^3 - Hd^2 + \frac{Q^2}{2gb^2} = 0)$
The following is a brief explanation of the use of the above mentioned diagram :-

This diagram can be used to determine any of the four variables d, Q, H or b when the other three are given.

1. If we are given d, b and H and required to find Q

Assume d = 2.78 feet

H = 3 "

b = 2 "

The vertical line through d = 2.78 on the bottom scale intersects the curve for H = 3 at the point C_2.

A horizontal line through C_2 meets the vertical through b = 2 feet at e which falls on the curve for Q = 20 cubic feet per second giving the required flow.

2. If Q, b and d are given and H is required

If b = 2 feet

Q = 20 cubic feet per second

d = 2.78 feet.

A vertical line through b = 2 feet on the top scale meets the curve for Q = 20 cubic feet per second in e and the horizontal through e meets the vertical through d = 2.78 feet at C_2 on the curve of H = 3 feet.

3. The other two cases for finding b and d are treated on the same lines remembering that a vertical through a value for d is produced to meet the H curve and a vertical through a value of b is produced to meet the Q

curves. Inversely, and intersection on the H curve is projected vertically downwards to give a corresponding value of d and an intersection on the Q curves is projected upwards to give a corresponding value of b on the b scale.

(a) GRAPHICAL DETERMINATION OF DEPTH OF MAXIMUM FLOW:-

Given b and H, to find d that gives the maximum flow.

If b = 1.5 feet

and H = 3 feet

Applying the previous methods we see that the higher the point c is for any value of d and H the higher is the point e or the value of Q for a given value of b. Therefore the value of d below the highest point of the H curve gives the highest possible position for e and therefore the maximum corresponding Q.

From the diagram, for H = 3 feet, a projection of the top point c on the d scale gives d = 2 feet = 2/3 H as proved in Appendix (4) (equation (20)).

The horizontal through c meets the vertical through b = 1.5 feet at e' giving the maximum flow about 24 cubic feet per second.

By calculation from equation (20a)

$$Q = 3.085 \ b H^{3/2}$$
$$= 3.085 \times 1.5 \times 3$$
$$= 3.085 \times 1.5 \times 5.2 = 24 \text{ cubic ft.per.sec}$$

(b) GRAPHICAL DETERMINATION OF ALTERNATIVE DEPTHS.

If we are given :-

b = 2 feet

Q = 20 cubic feet per second.

H = 3 feet

then a vertical through b = 2 feet meets the curve for Q = 20 in e and the horizontal through e meets the curve for H = 3 feet in two points c_1 and c_2 giving the two possible values of d which are d = .85 feet ("low stage")

and d = 2.78 ,, ("high stage)

(c) GRAPHICAL DETERMINATION OF "CRITICAL DEPTH".

Given b and Q to find the value d_c that gives maximum H

If b = 2 feet

and Q = 20 cubic feet per sec.

it can be seen from the diagram that the maximum points of the H curves lie all on a straight line A B C shown dotted on the diagram. This line can be divided as shown to give points of intersection with intermediate H curve.

The vertical through b = 2 feet meets the curve of Q = 20 cubic feet per sec in e.

The horizontal through e meets the line A B C† in f corresponding to H = 2.18 feet and d = 1.46 feet = 2/3 H

The horizontal line through e cannot meet the H curves in a lower value for H than 2.18 feet and thus the corresponding depth of 1.46 feet is the critical depth required.

In this case.

Area of section = 2 x 1.46 = 2.92 square feet

velocity $\frac{20}{2.92}$ = 6.85 ft per second

and from $v = \sqrt{g d_c}$

$v = \sqrt{32 \times 1.46}$ = 6.85 ft.per second.

From the previous results of Appendices (4),(5), and (6) we can deduce the general conditions of flow inside a contraction, when the depth inside the contraction = d_c = 2/3H as follows :-

1. The discharge is the max possible for the given value of H.
2. The velocity of flow inside the contraction $v = \sqrt{g d_c}$

   i.e. the depth is twice the velocity head.
3. The value of H is the minimum possible for passing the maximum flow.

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† For note see following page.

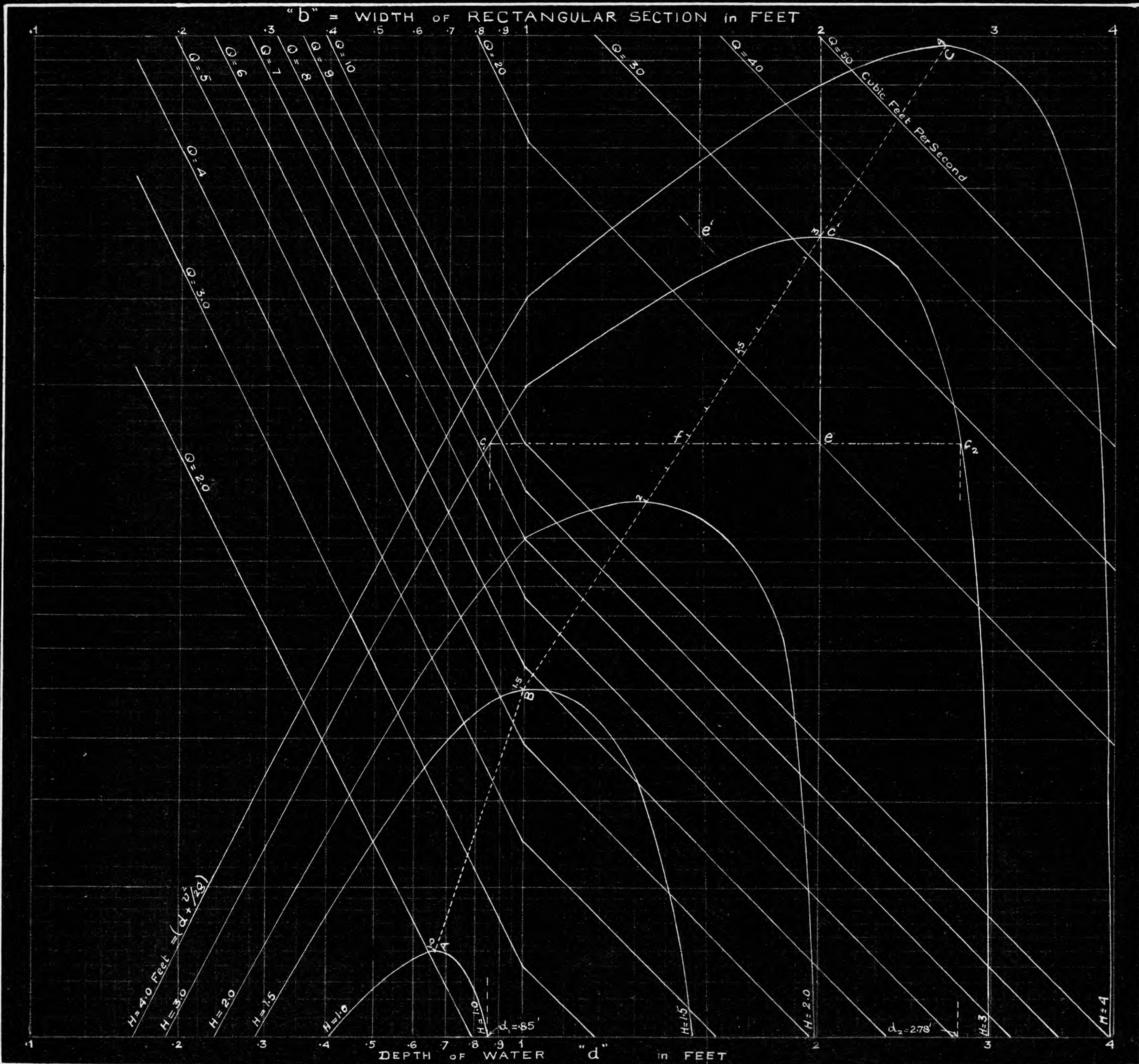

FIG. 9 DIAGRAM SHOWING RELATION BETWEEN THE VARIABLES "d" "Q" "H" and "b" IN THE EQUATION $d^3 - Hd^2 + \frac{Q^2}{2gb^2} = 0$

- d = Depth of rectangular Section in Feet.
- H = " " Energy Gradient = $d + v^2/2g$ in Feet
- Q = Discharge in Cubic Feet per Second.
- b = Bed Width in Feet.

4. The curve of water surface downstream the point where $d = d_c$ can follow two different courses. This is because, at a short distance downstream this point we have two possible depths of flow which are (as in Appendix (5))the alternative depths and therefore the water surface curve may either follow the high stage depths or the low stage ones.

If the width of the restangular flume is gradually increasing downstream the point where the depth equals d_c , then by consulting the diagram in Figure (9) it will be seen that in such a case the high stage depths will increase as the width increases and the low stage depths will decrease as the width increases.

If H = 3 and Q = 20 cubic feet per second then as b increases, the horizontal line c_1 c_2 moves downwards giving smaller values for d_1 and higher values for d_2 . Both d_1 and d_2 start from a common value $d_c = 2$ when $b = 1.25$ feet as shown on the diagram.

A P P E N D I X (8).

CONDITIONS OF FLOW IN A VENTURI FLUME.

A good illustration of the different conditions of flow in a flume of this shape is given by Mr S.H.Woodward, M.Amer.Soc.C.E. in his report on "Theory of the Hydraulic JUMP AND back water curves"

The example chosen is a smooth horizontal flume in which the depth is varied in such a way that the water surface curve is a straight line.

A similar example is worked out by the writer in detail using nearly the same data.

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† (previous page) On account of the change in scale A B C in diagram is in two parts each having a different slope but they actually represent one line on a one scale diagram.

See Miami Conservancy Tech.,Report Part III page

(a) Let discharge entering the flume = 2000 cubic ft/sec.

,, H = d at entrance = 40 ft

,, Water depth ,, ,, = 2 ft

Length of flume = 90 ft.

The water surface curve is required to slope upwards along a straight line up to a depth of say 38 ft. Two separate curves similar to those in Figure (9) are plotted in Figure (10) for H = 40 ft and Q = 2000 cubic ft per second.

Depths at intervals along the flume were found as shown on small figure on the sheet of Figure (10).

Corresponding values of b are found in the manner explained on diagram in Figure (9)

The values of b thus found and tabulated were plotted as shown in figure giving the required shape of the flume.

It is interesting to note also that the minimum value of b occurs at the point where the depth is equal to $d_c = \frac{2}{3} H$ = 26.7 feet. This is methematically proved as follows:-

$\because$ Q is constant

$\therefore$ $b_1 d_1 v_1$ at entrance = b v d at any section

and $v = \dfrac{b_1 \ v_1 \ d_1}{bd}$

then $\dfrac{v^2}{2g} + d = \dfrac{b_1^2 v_1^2 d_1^2}{2g\, b^2 d^2} + d = H$

$\therefore \dfrac{b_1^2 \ v_1^2 \ d_1^2}{2g \ b^2 d^2} = H - d$

let $\dfrac{v_1^2 \ b_1^2 \ d_1^2}{2g} = A$

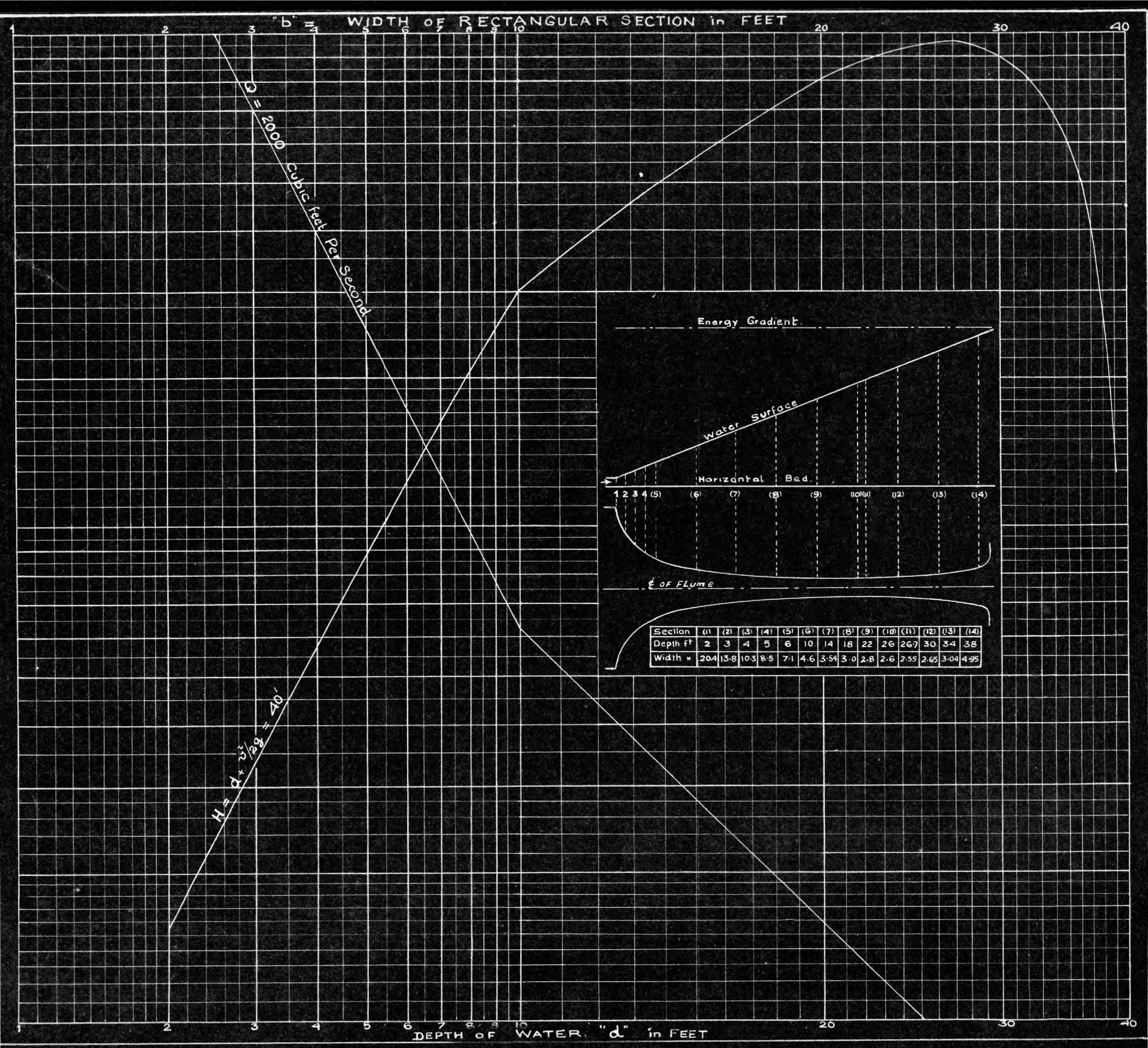
$\therefore \dfrac{A}{b^2 d^2} = H - d$

or $b^2 = \dfrac{A}{d^2 (H - d)}$

From the above relation, the width b is a minimum when $d^2 (H - d)$ is a maximum.

let $d^2 (H - d) = y$

$\dfrac{dy}{dd} = 3d^2 - 2Hd$ which = 0 when d = 2/3 H = d_c



Section	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Depth ft	2	3	4	5	6	10	14	18	22	26	26·7	30	34	38
Width "	20·4	13·8	10·3	8·5	7·1	4·6	3·54	3·0	2·8	2·6	2·55	2·65	3·04	4·95

Fig 10 Diagram as Fig 9 For Q = 2000 Cubic ft per Sec and H = 40'

i.e. the width is minimum when the depth reaches its critical value for the given H. Beyond this value the width increases again as shown in figure

If the flume discharges into a reservoir where the depth of water = 40 ft the theoretical value of B is infinity.

From the above it is clear that the flow can be reversed from the high level to the low level i.e. from the reservoir where d= 40ft to the channel where d = 2 ft and b = 20.4feet keeping the same shape of the flume and water surface curve.

Also we conclude that for the same value of H any other shape of flume with the same minimum width will cause the water surface to follow a special corresponding rising or falling curve.

Considering flow from left to right and then from right to left in the above mentioned flume, the following table (1) shows the different conditions of flow which are of a great importance in dealing with water surface levels through a "Venturi Flume".

TABLE (1)

	Depth at entrance.	Shape of flume below entrance	Water surface slope.
1.	Below critical(d_c)	Convergent	Upwards
2.	Above ,,	Divergent	,,
3.	,, ,,	Convergent	Downwards
4.	Below ,,	Divergent	,,

(b) EFFECT OF FRICTION.

Friction is the only factor that would cause a slight alteration in the above theoretical results. The effect of slope of bed in a short flume is quite negligible.

As the effect of friction is nearly the same as raising the bed of a smooth flume, the following illustration also given by Mr Woodward in the same report throws light on the question.

If instead of varying the bed width of the flume as before we keep the width constant and raise the bed in order to make the water surface slope upwards as in Figure (11), then considering two points A and B and applying Bernoullis Theorem we get :-

$$\frac{V_1^2}{2g} + d_1 = \frac{V^2}{2g} + d + h$$

When the velocity is high at the beginning the difference between the velocity heads $\frac{V_1^2}{2g}$ and $\frac{V^2}{2g}$ is sufficient to raise the water to a height h

$$\text{i.e. } \frac{V_1^2}{2g} - \frac{V^2}{2g} = h \quad \text{very nearly}$$

$$\text{and} \quad d = d_1 \quad \text{,,} \quad \text{,,}$$

i.e. the water depth changes very slightly and the bed is raised nearly parallel to the water surface. This condition changes gradually until a certain point is reached when the depth varies at the same rate as the water surface level. This point, where the bed is horizontal is found as follows:-

$$h = \frac{V_1^2}{2g} + d_1 - \frac{V^2}{2g} - d$$

$$= \frac{V_1^2}{2g} + d_1 - \frac{V^2}{2g} - \frac{V_1 d_1}{V}$$

let $v_1 \; d_1 = k$

Then $h = H - \frac{V^2}{2g} - \frac{K}{V}$

and $\frac{dh}{dv} = -2\frac{V}{2g} + \frac{K}{V^2} = -\frac{V}{g} + \frac{K}{V^2}$

from which $\frac{dh}{dv} = 0$ when $\frac{v}{g} = \frac{k}{v}$

i.e. $\frac{v}{g} = \frac{v_1 \; d_1}{v^2} = \frac{v \; d}{v^2} = \frac{d}{v}$

or when $v^2 = gd$ or $v = \sqrt{gd}$

i.e. when the water depth $= d_c$

Beyond this critical point the bed slopes downwards while the water surface continues to rise until it reaches its maximum elevation $H = \frac{V_1^2}{2g} + d$, ft above datum plane.

Also in this case, if the bed is raised following another curve of the same maximum ordinate the water surface will follow a corresponding rising curve. As the flow can be reversed from high to low level without altering the shape of the bed the following tabulated general conclusions can be deduced:-

TABLE (2).

	Depth at entrance.	Slope of bed below entrance.	Water surface slope.
1.	Below critical	Upwards	Upwards at a greater rate than bed.
2.	Above ,,	Downwards	Upwards
3.	,, ,,	Upwards	Downwards
4.	Below ,,	Downwards	Downwards at a greater rate than bed.

Combining the effect of friction as that of an upward bed slopw in cases 1 and 3 of previous table (2) with the results in table (1) we obtain the following results in table (3) for a rough flume.

TABLE (3).

	Depth at entrance.	Shape of flume below entrance.	Water surface slope	Effect of friction on water surface slope.
1.	Below critical	Convergent	Upwards ----	Increases the slope.
2.	Above ,,	Divergent	,, ----	Decreases the slope.
3.	,, ,,	Convergent	Downwards--	Increases the slope.
4.	Below ,,	Divergent	,, ----	Decreases the slope.

APPENDIX (9).

HYDRAULIC JUMP.

When a sheet of water in a shallow stream moving with a high velocity passes into a stage of low velocity and a greater depth, the abrupt rise of water from the low level to the high level takes place steadily in one position forming a standing wave. The phenomenon is generally known as the "hydraulic jump". This can be observed when water with a high velocity flows out of a flume or a bottom sluice of a dam and strikes against the water flowing with a lower velocity in the main channel downstream

As this jump is likely to happen after water leaves a contraction such as the contracted section of a Venturi Flume it is necessary to study:-

1. The conditions under which it occurs.
2. The loss of energy resulting from it.
3. The means of its control.

1. (a) The hydraulic jump generally occurs when a stream running at a depth below the critical value and with a velocity higher than the critical value is suddenly checked and the velocity reduced by internal impact.

It does not seem in agreement with Bernoulli's Theorem that water flowing in a smooth restangular channel with a level bottom can change suddenly to a different depth. In the following theorem it is proved by the consideration of impact that such a change can take place from a depth below the critical to depth above the critical.

(b) THEORY OF THE HYDRAULIC JUMP.

The mathematical theory of the hydraulic jump was first worked out by Belanger in 1838. It was also given in an article on Hydrodynamics by W.C.Unwin in the ninth edition

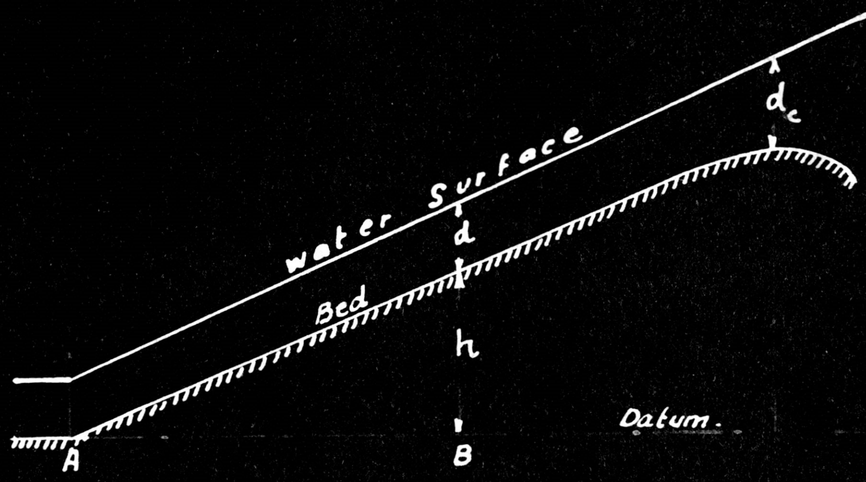


Fig 11

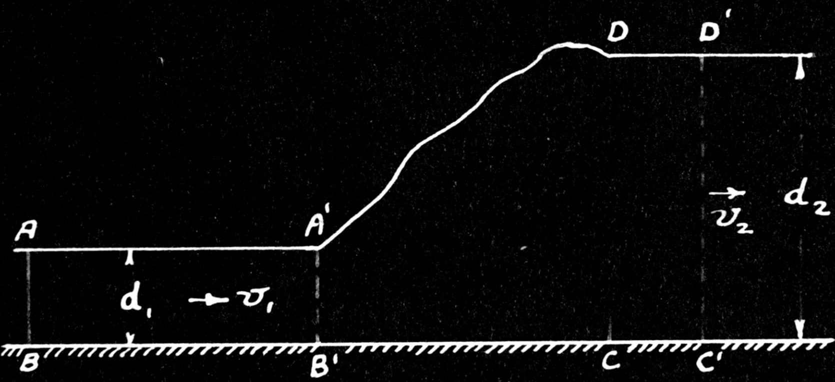


Fig 12

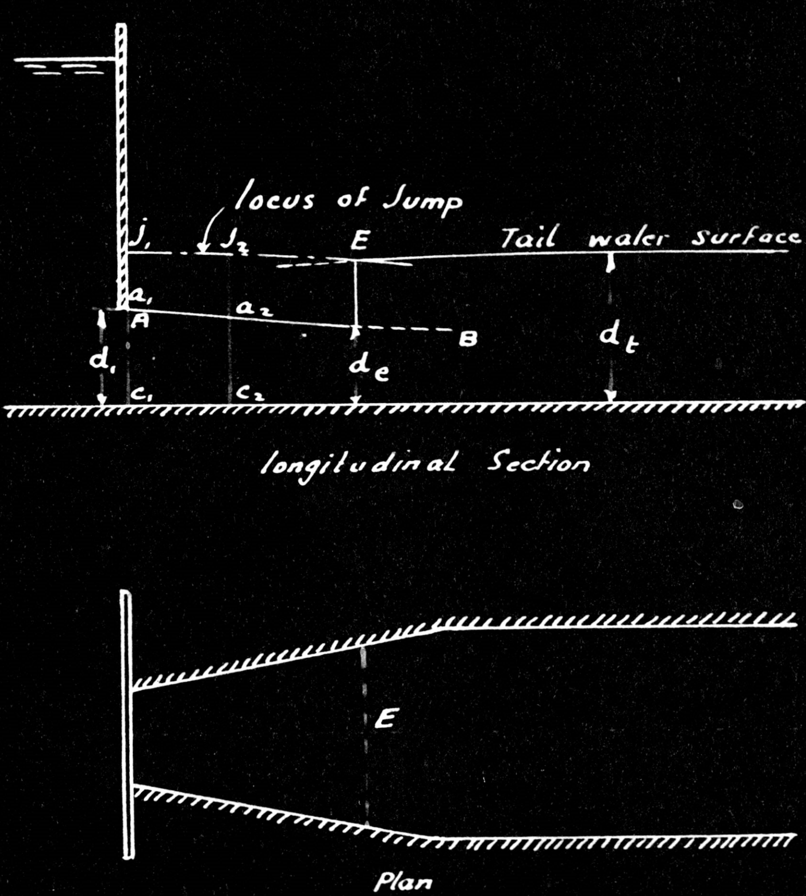


Fig 13

of the Encylopedia Britanica about 1880 and in the article by A.H.Gibson entitled "The Formation of standing waves in an open stream". ϕ

Let A B C D Figure (12) be a mass of water moving through a hydraulic jump in a rectangular channel and let it move in a short interval of time to the position A B C D.

Let d_1 = depth of water at entrance through jump in ft.

d_2 = ,, ,, leaving jump in ft.

v_1 = velocity unstream the jump in ft/second.

v_2 = velocity downstream ,, ,, ,,

Q = Discharge in cubic ft per second

Considering unit width of channel we get

$v_1 d_1 = v_2 d_2 = q$ = discharge per unit width and mass of water flowing per second per unit width $\frac{wq}{g}$ where w = weight of one cubic ft of water in lbs.

Change of momentum per second. $= \frac{wq}{g}(v_1 - v_2)$

but $v_2 = \frac{v_1 d_1}{d_2}$

Change of momentum per second $= \frac{wq}{g}\left(v_1 - \frac{v_1 d_1}{d_2}\right)$

$$= \frac{wqv_1}{gd_2}(d_2 - d_1)$$

Static pressure acting on plane AB $= \frac{wd_1^2}{2}$ per unit width

,, ,, ,, ,, DC $= \frac{wd_2^2}{2}$,, ,,

As the difference in pressure is equal to the change of momentum in one second we get :-

$$\frac{wqv_1}{gd_2}(d_2 - d_1) = \frac{w}{2}(d_2^2 - d_1^2)$$

$$\therefore \frac{qv_1}{gd_2}(d_2 - d_1) = \frac{d_2^2 - d_1^2}{2}$$

$$\text{or } \frac{qv}{gd_2} = \frac{d_2 + d_1}{2}$$

$$\therefore d_2^2 + d_2 d_1 = \frac{2qv_1}{g} = \frac{2v_1^2 d_1}{g} \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

ϕ/ See paper No.4081 Minutes of Proceedings of the Institution of Civil Engineers Vol.CXCVII. Session 1913-14. Part III.

from which

$$d_2 = -\frac{d_1}{2} + \sqrt{\frac{d_1^2}{4} + \frac{2v_1^2 d_1}{g}} \qquad \text{................(2)}$$

giving the value of d_2 corresponding to a given value of d_1 and v_1

Substituting $\frac{q}{d_1}$ for v_1 in (1) we get

$$d_2^2 + d_2 d_1 = \frac{2q^2}{g d_1}$$

$$\therefore \frac{d_2^2 d_1 + d_2 d_1^2}{2} = \frac{q^2}{g} = \frac{d_2 d_1 (d_2 + d_1)}{2} \qquad \text{................(3)}$$

The critical depth

$$d_c = \frac{V_c^2}{g} = \frac{q^2}{d_c^2 g}$$

$$\therefore \frac{q^2}{g} = d_c^3$$

Substituting in (3) we get

$$\frac{d_2 d_1 (d_2 + d_1)}{2} = d_c^3 \qquad \text{................(4)}$$

(c) From equation (4) we draw the following conclusions :-

Case 1.

If $d_1 = d_c$

$d_2 \; d_c \; (d_2 + d_c) = 2d_c^3$

or $d_2 \; (d_2 + d_c) = 2d_c^2$

i.e. $d_2 = d_c$

Case 2.

If d_1 is $< d_c$

d_2 is $> d_c$

Case 3.

If d_1 is $> d_c$

d_2 is $< d_c$ which is impossible because there is no physical phenomenon to explain the possibility of the reversal of jump.

Therefore the hydraulic jump is only possible in Case 2 i.e. from a depth below the critical to a depth above the critical.

APPENDIX (10).

EFFECT OF TAIL WATER LEVEL ON THE CONDITION OF FLOW IN THE EXPANDING FLUME BELOW A CONTRACTION.

(1) When the depth in contraction is above the critical depth, the theoretical water surface curve in the flume downstream will be the high stage one as explained in Section (d) of Appendix (9).

Let this stage curve A B Figure 16 intersect the plane P Q at the bottom of the expanding flume at the point "B".

If the tail water level is higher or lower than "B" there can be neither a rise through a jump nor a drop from the curve A B″ to the tail water (see case 3 Section (c) Appendix (9)). Therefore the water surface in the flume will simply adjust itself to coincide with the level of tail water and the discharge through the contraction in such a case will thus depend upon the tail water level i.e. with a constant head above the contraction, the discharge increases as the tail water level drops until the latter reaches the level of critical depth inside the contraction. If the discharge is constant, the upstream head will alter with the tail water to give a constant flow.

(2) When the depth in contraction = critical value. In this case if the critical depth is reached say at D Figure (16), then an infinitismal drop in the water surface below D will cause the water surface in the flume below to slope downwards, following the low stage curve (A B in Figure (13) according to case 4 in Table (1) Appendix (8). Also an infinitismal rise above D will cause the water surface in the flume to slope upwards following curve A″ B″ (high stage) according to case 2 Table (1) Appendix (8).

Therefore when the depth inside the contraction $= d_c$ the two curves D A B and D A″ B″ are possible.

Let the curve D A B and D A" B" meet the plane P.Q. at the bottom of the flume in B and B" respectively as in Figure (16).

(a) If the tail water level is below B, the water surface curve in the flume will follow the curve A B and there will be a drop at B to the tail water level as in Figure (16 a)

(b) If the tail level is between B and B" the condition will be similar to the case discussed in Section (d) Appendix (9) and thus the water surface in the flume will follow the curve A B and then rises through a hydraulic jump at the point corresponding to E (in Figure (13)) as shown in Figure (16) (b).

(c) As the tail water level rises above B the point (E) where the jump occurs moves backwards or upstream until the tail water level reaches B" when the point E coincides with D and according to case i Section C Appendix (9), as $d = d_c$ there will be no jump and the water surface curve in the flume will just follow the high stage curve D A B" Figure(16c)

(d) If the tail water level is higher than B", a jump from D B" is impossible and the depth at D will thus be raised [Figure (16d)] if the head upstream the contraction is constant and the case will be similar to that of Section (1) in this Appendix.

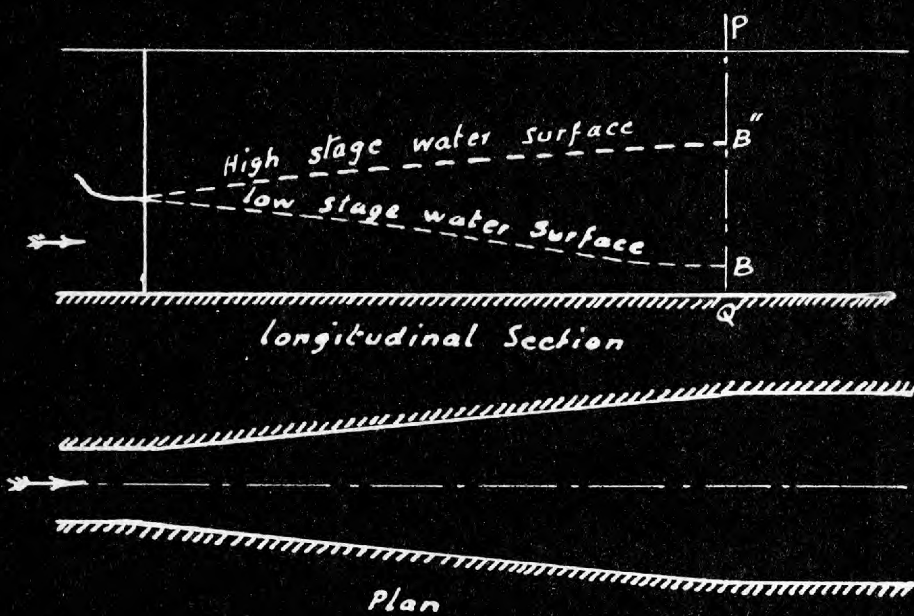


Fig 14

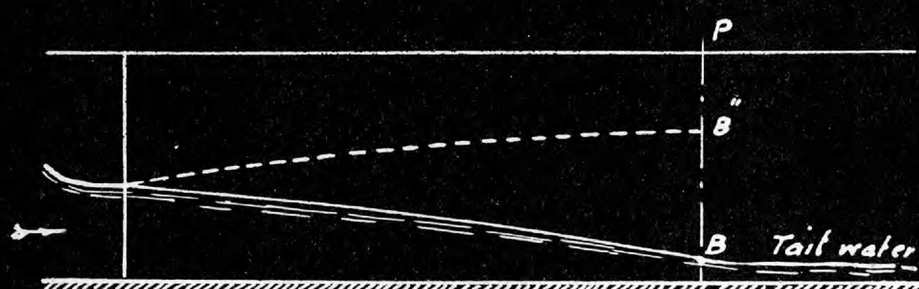


Fig 14a

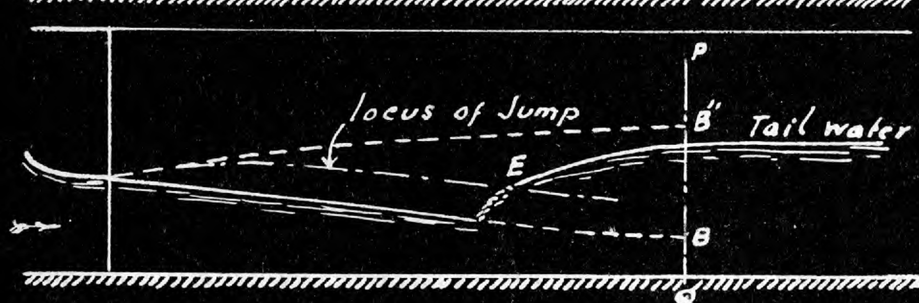


Fig 14b

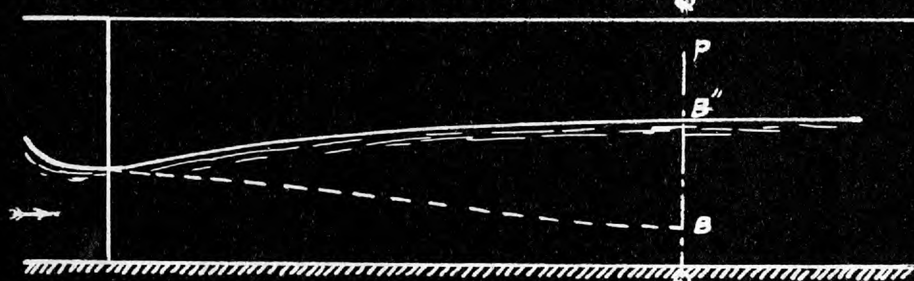


Fig 14c

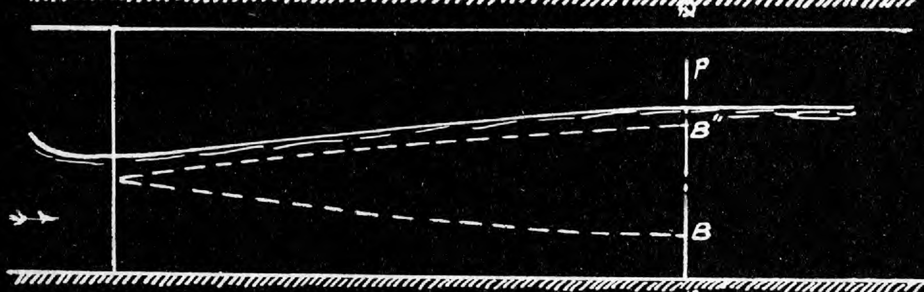


Fig 14d

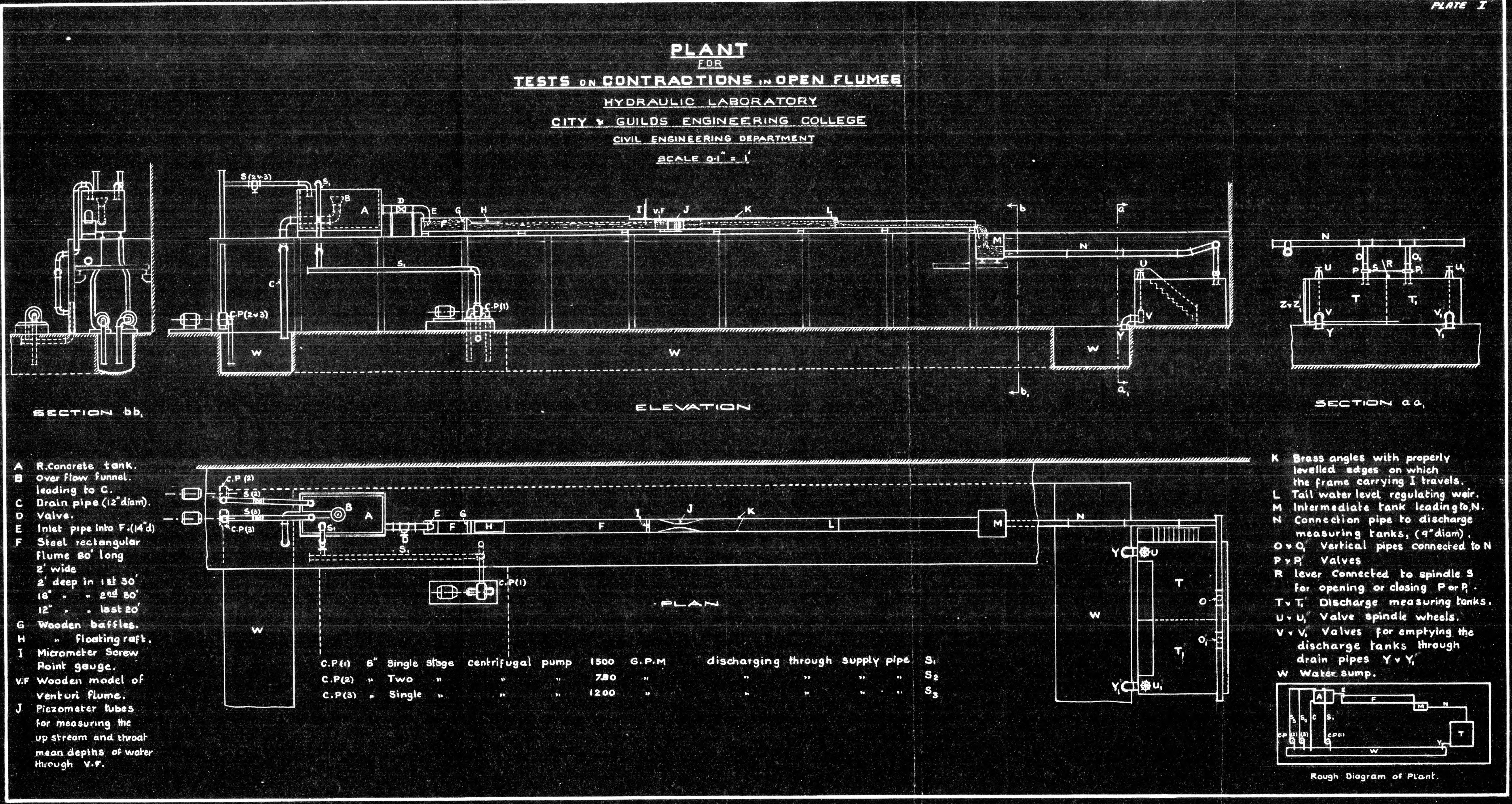
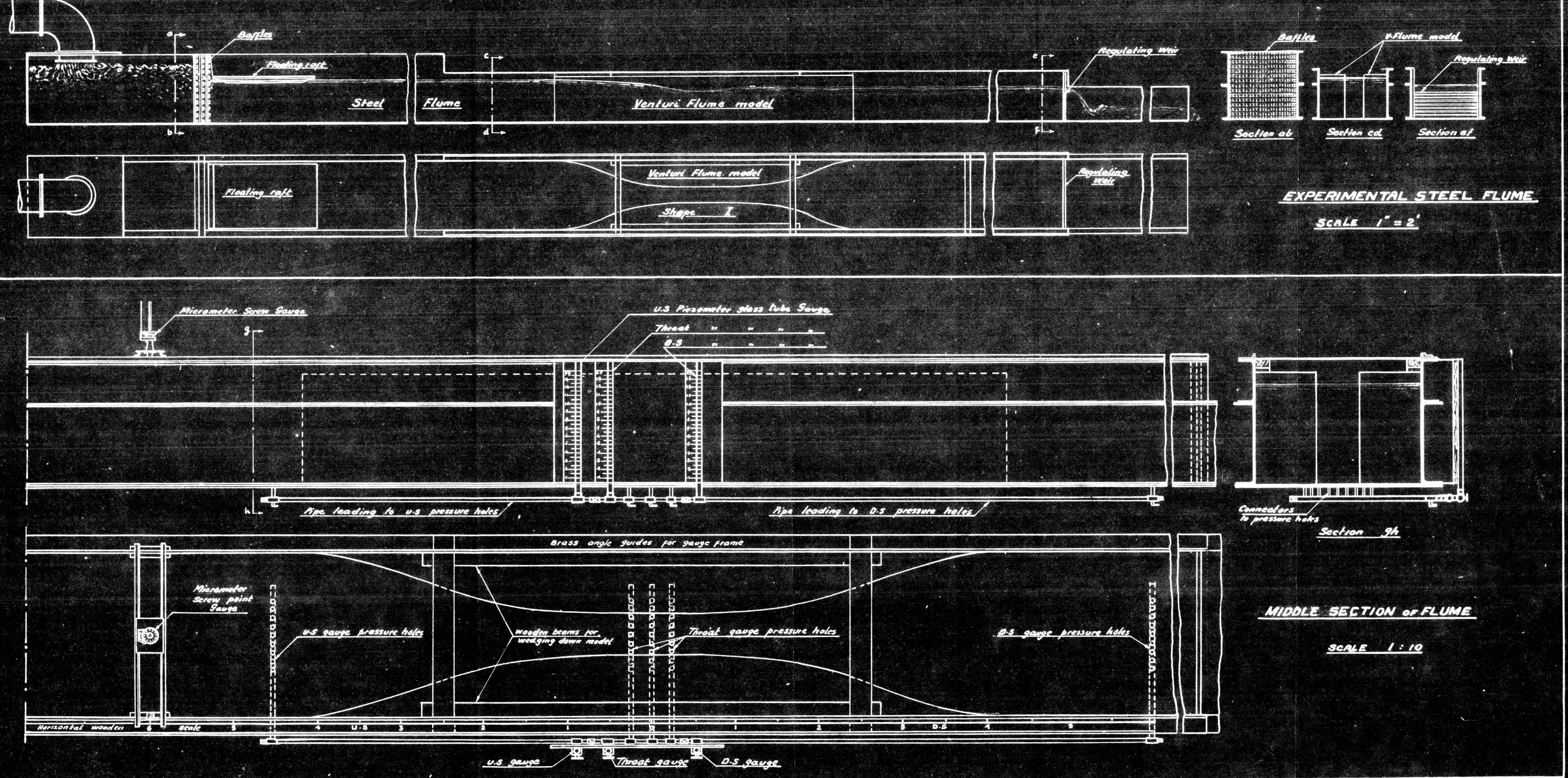


PLATE I
PLANT
FOR
TESTS ON CONTRACTIONS IN OPEN FLUMES
HYDRAULIC LABORATORY
CITY & GUILDS ENGINEERING COLLEGE
CIVIL ENGINEERING DEPARTMENT
SCALE 0·1" = 1'
SECTION bb,
ELEVATION
SECTION aa,
PLAN
A R.Concrete tank.
B Over flow funnel. leading to C.
C Drain pipe (12" diam).
D Valve.
E Inlet pipe into F. (14" d)
F Steel rectangular flume 80' long 2' wide 2' deep in 1st 30' 18" " " 2nd 30' 12" " " last 20'
G Wooden baffles.
H " Floating raft.
I Micrometer Screw Point gauge.
V.F Wooden model of Venturi flume.
J Piezometer tubes for measuring the up stream and throat mean depths of water through V.F.
K Brass angles with properly levelled edges on which the frame carrying I travels.
L Tail water level regulating weir.
M Intermediate tank leading to N.
N Connection pipe to discharge measuring tanks, (9" diam).
O & O, Vertical pipes connected to N
P & P, Valves
R lever connected to spindle S for opening or closing P or P,.
T & T, Discharge measuring tanks.
U & U, Valve spindle wheels.
V & V, Valves for emptying the discharge tanks through drain pipes Y & Y,
W Water sump.
C.P(1) 6" Single stage centrifugal pump 1500 G.P.M discharging through supply pipe S1
C.P(2) " Two " " " 750 " " " " " S2
C.P(3) " Single " " " 1200 " " " " " S3
Rough Diagram of Plant.

PLATE II


Baffles
Floating raft
Steel
Flume
Venturi Flume model
Regulating Weir
Baffles
V-Flume model
Regulating Weir
Section ab
Section cd
Section ef
Floating raft
Venturi Flume model
Shape I
Regulating Weir
EXPERIMENTAL STEEL FLUME
SCALE 1" = 2'
Micrometer Screw Gauge
U.S Piezometer glass tube Gauge
Throat " " " "
D.S " " " "
Pipe leading to u.s pressure holes
Pipe leading to D.S pressure holes
Connectors to pressure holes
Section gh
Brass angle guides for gauge frame
Micrometer Screw point Gauge
U.S gauge pressure holes
Wooden beams for wedging down model
Throat gauge pressure holes
D.S gauge pressure holes
MIDDLE SECTION of FLUME
SCALE 1 : 10
Horizontal wooden scale
U.S
D.S
U.S gauge
Throat gauge
D.S gauge

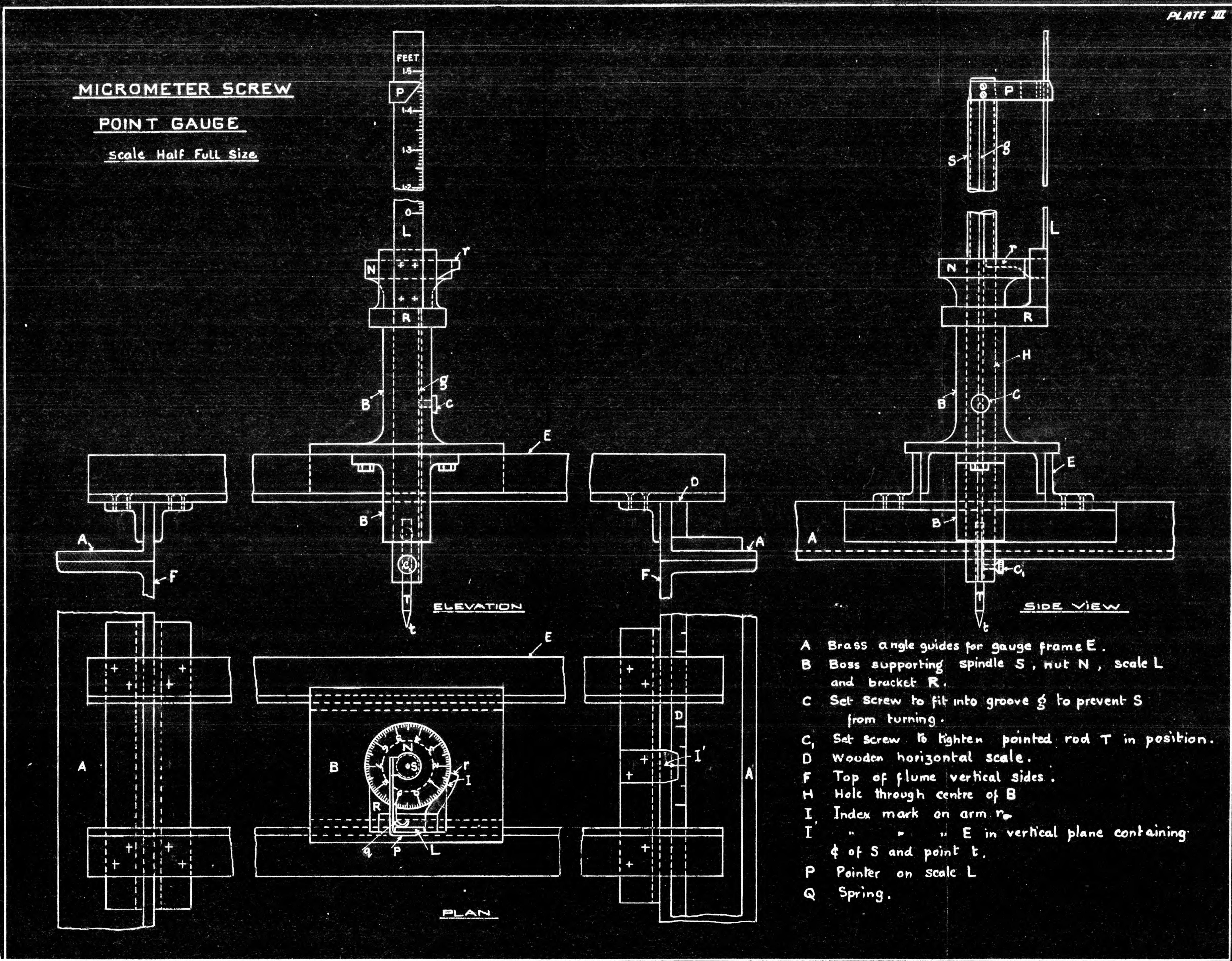
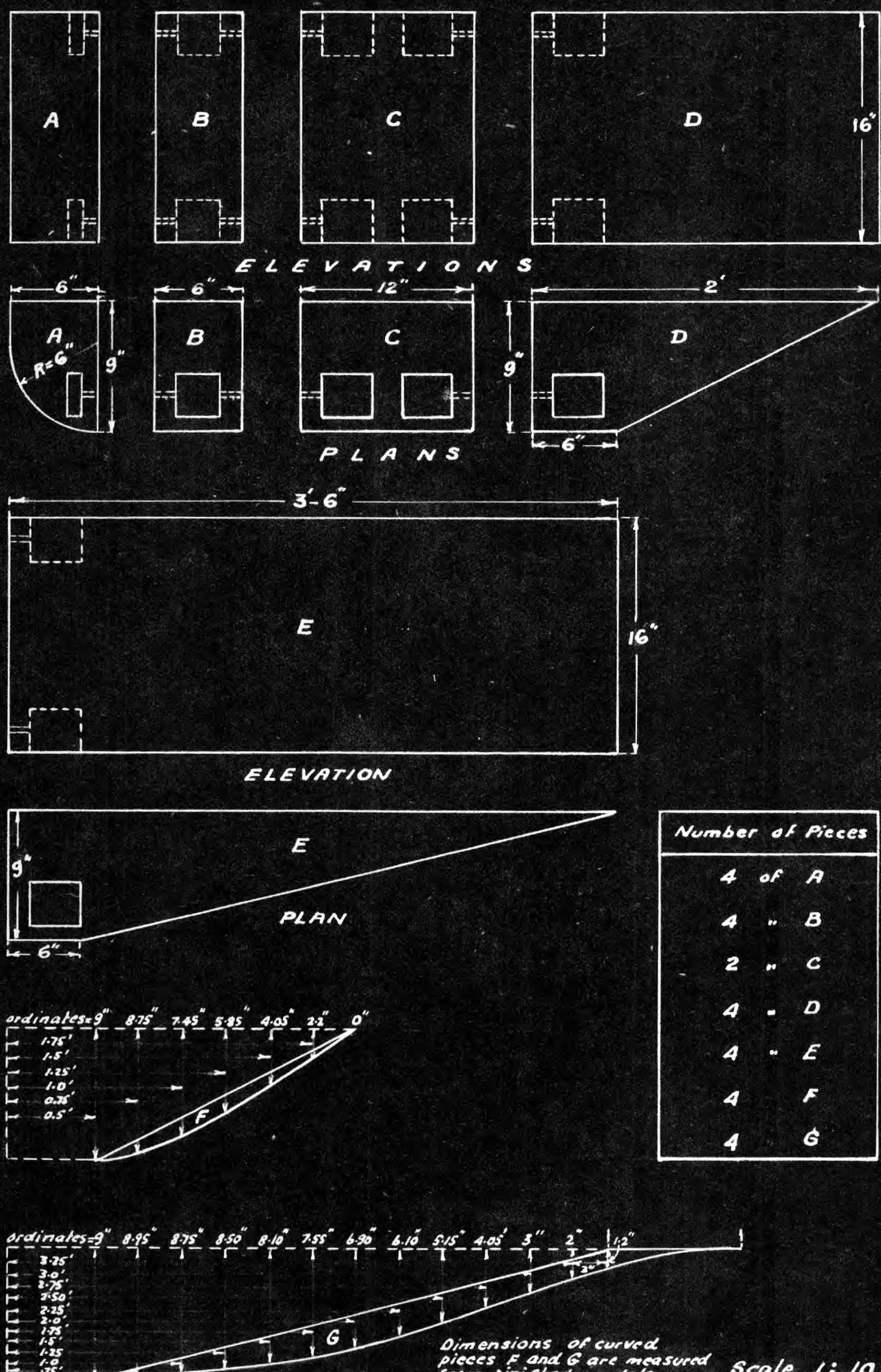


PLATE III
MICROMETER SCREW
POINT GAUGE
Scale Half Full Size
FEET
1.5
1.4
1.3
1.2
0
P
L
N
R
r
g
C
B
E
D
A
F
T
t
C₁
S
H
I
I'
Q
ELEVATION
SIDE VIEW
PLAN
A Brass angle guides for gauge frame E.
B Boss supporting spindle S, nut N, scale L and bracket R.
C Set screw to fit into groove g to prevent S from turning.
C₁ Set screw to tighten pointed rod T in position.
D Wooden horizontal scale.
F Top of flume vertical sides.
H Hole through centre of B
I Index mark on arm r.
I' " " " E in vertical plane containing ¢ of S and point t.
P Pointer on scale L
Q Spring.

SEPARATE BLOCKS MADE FOR BUILDING UP DIFFERENT SHAPES OF MODELS.

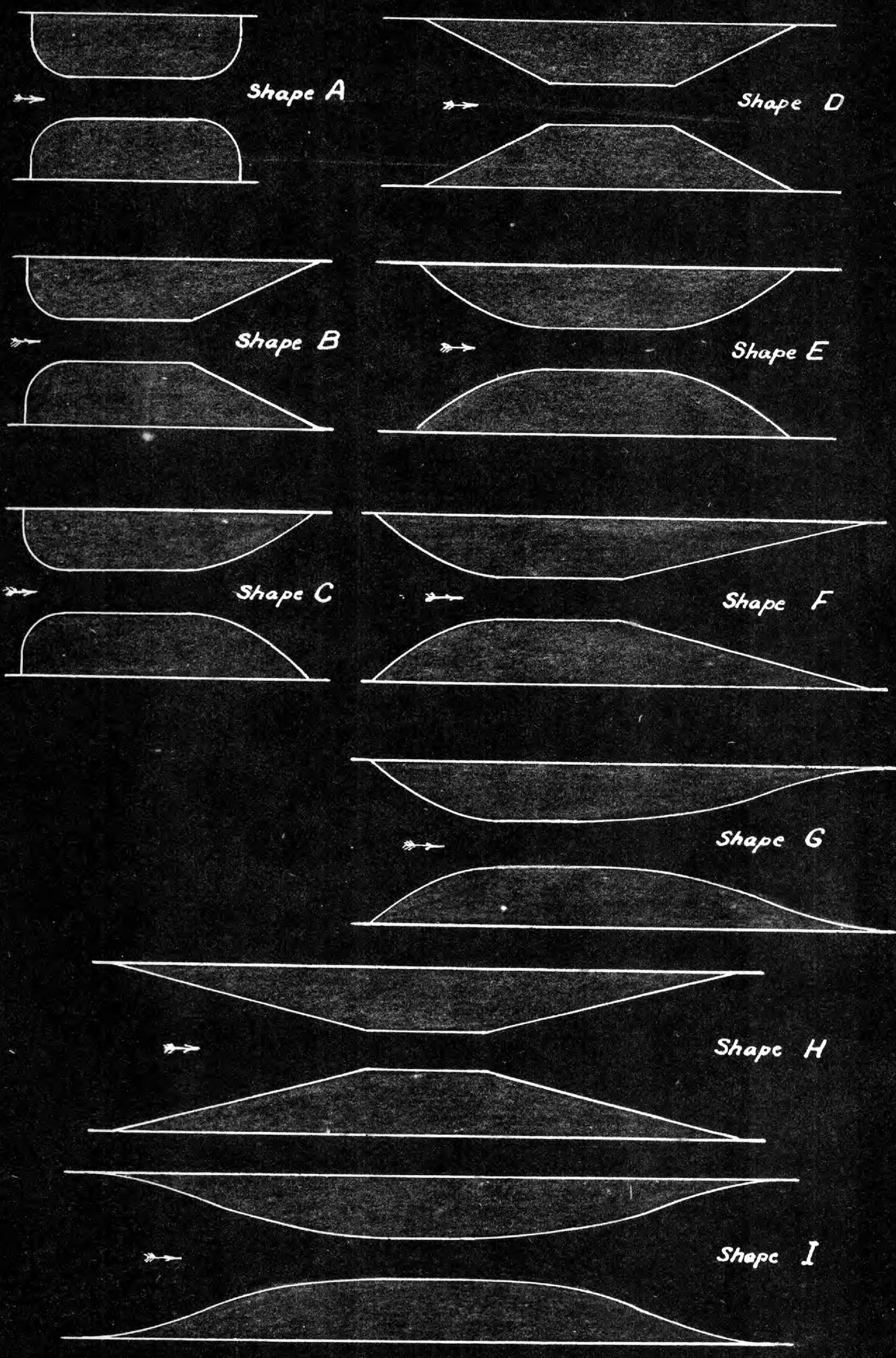


Number of Pieces		
4	of	A
4	"	B
2	"	C
4	"	D
4	"	E
4		F
4		G

Dimensions of curved pieces F and G are measured from finished models

Scale 1: 10

SHAPES OF FLUME MODELS TESTED



N.B. letters indicate different shapes of models and do not refer to letters of different pieces on plate.

PLATE VI

DIAGRAM GIVING VALUES OF Q IN CUSECS FOR A GIVEN THROAT DROP ($d_1 - d_2 = h$) AND U.S DEPTH d_1 IN THE EQUATION $Q = \frac{b_2 d_2 \sqrt{2gh}}{\sqrt{1-\left(\frac{b_2}{b_1}\cdot\frac{d_2}{d_1}\right)^2}}$ WHEN CHANNEL WIDTH $b_1 = 2'$ AND THROAT WIDTH $b_2 = 6''$

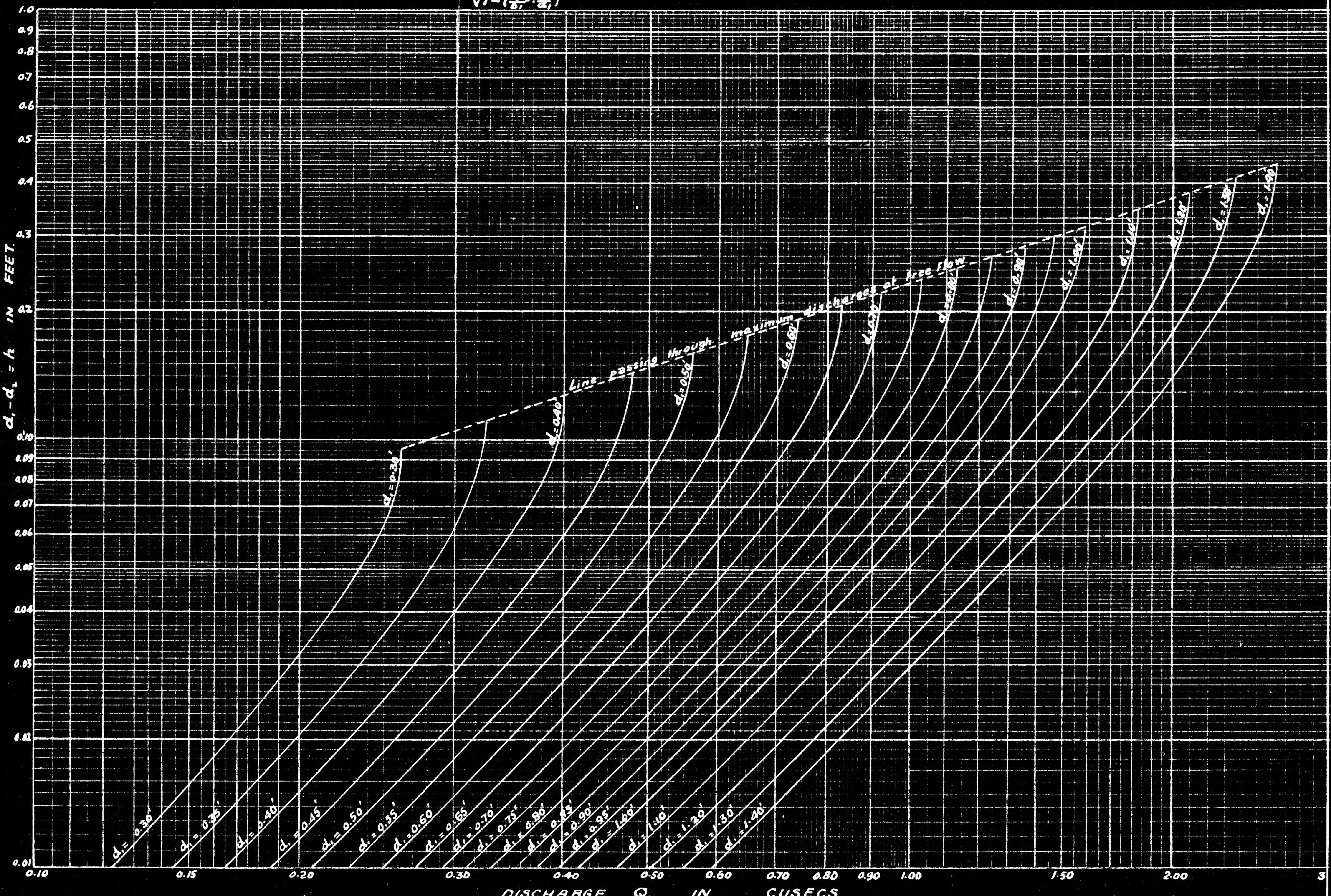
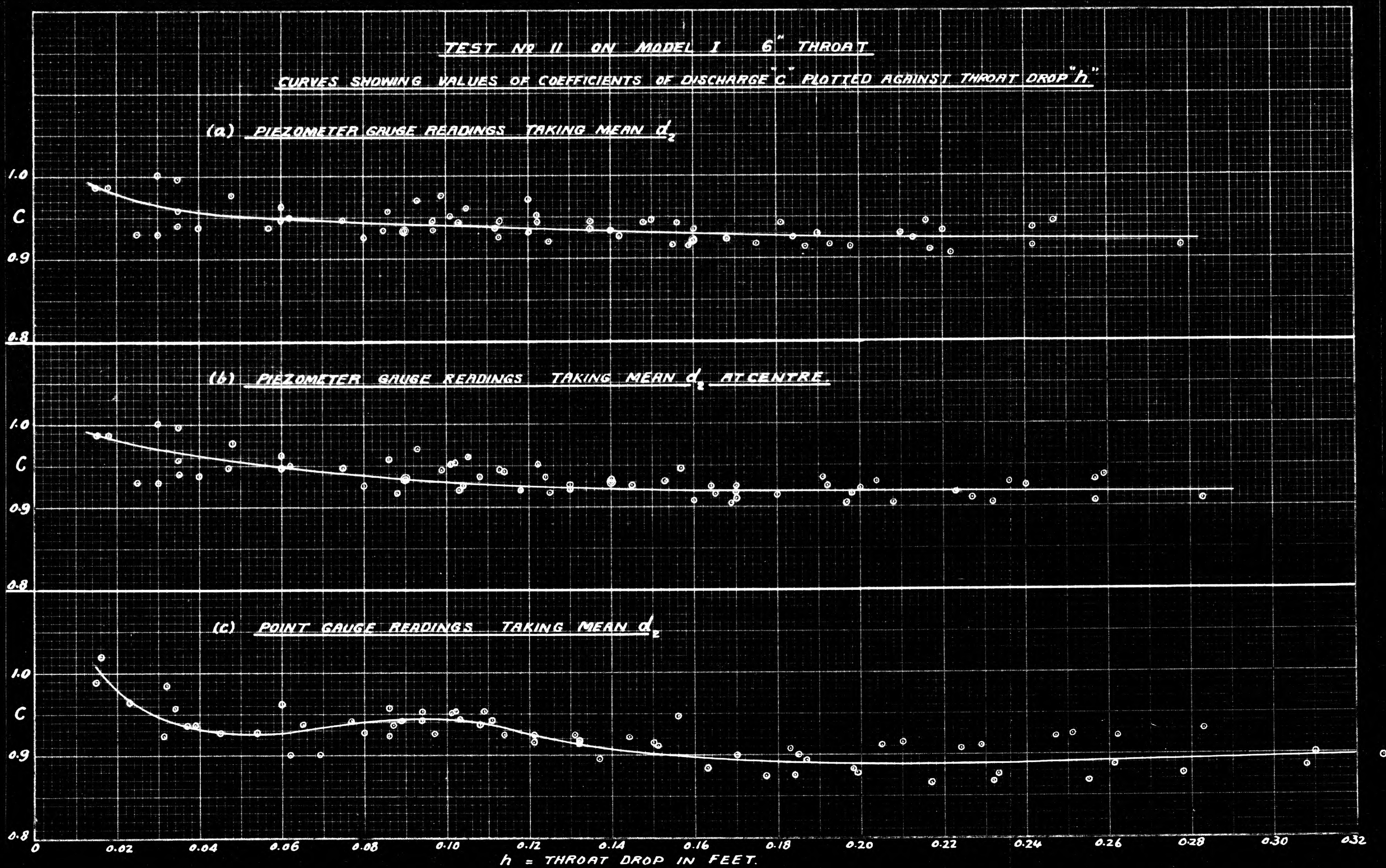
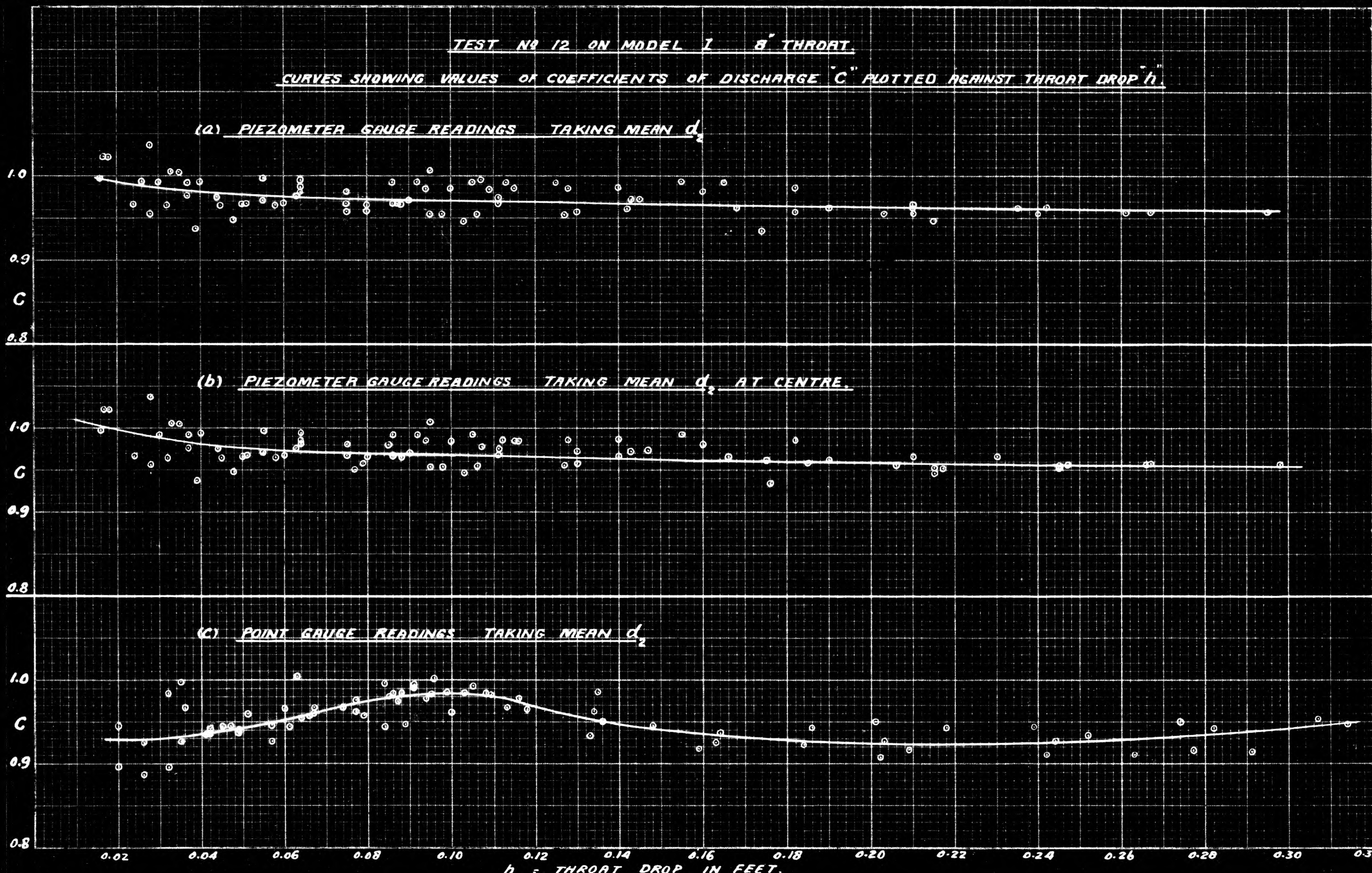


PLATE VIII


TEST No 11 ON MODEL I 6" THROAT
CURVES SHOWING VALUES OF COEFFICIENTS OF DISCHARGE "C" PLOTTED AGAINST THROAT DROP "h"
(a) PIEZOMETER GAUGE READINGS TAKING MEAN d2
(b) PIEZOMETER GAUGE READINGS TAKING MEAN d2 AT CENTRE
(c) POINT GAUGE READINGS TAKING MEAN d2
C
1.0
0.9
0.8
0
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18
0.20
0.22
0.24
0.26
0.28
0.30
0.32
h = THROAT DROP IN FEET.


TEST No 12 ON MODEL I 8" THROAT.
CURVES SHOWING VALUES OF COEFFICIENTS OF DISCHARGE "C" PLOTTED AGAINST THROAT DROP "h".
(a) PIEZOMETER GAUGE READINGS TAKING MEAN d2
(b) PIEZOMETER GAUGE READINGS TAKING MEAN d2 AT CENTRE.
(c) POINT GAUGE READINGS TAKING MEAN d2
1.0
0.9
0.8
C
0.02 0.04 0.06 0.08 0.10 0.12 0.14 0.16 0.18 0.20 0.22 0.24 0.26 0.28 0.30 0.32
h = THROAT DROP IN FEET.

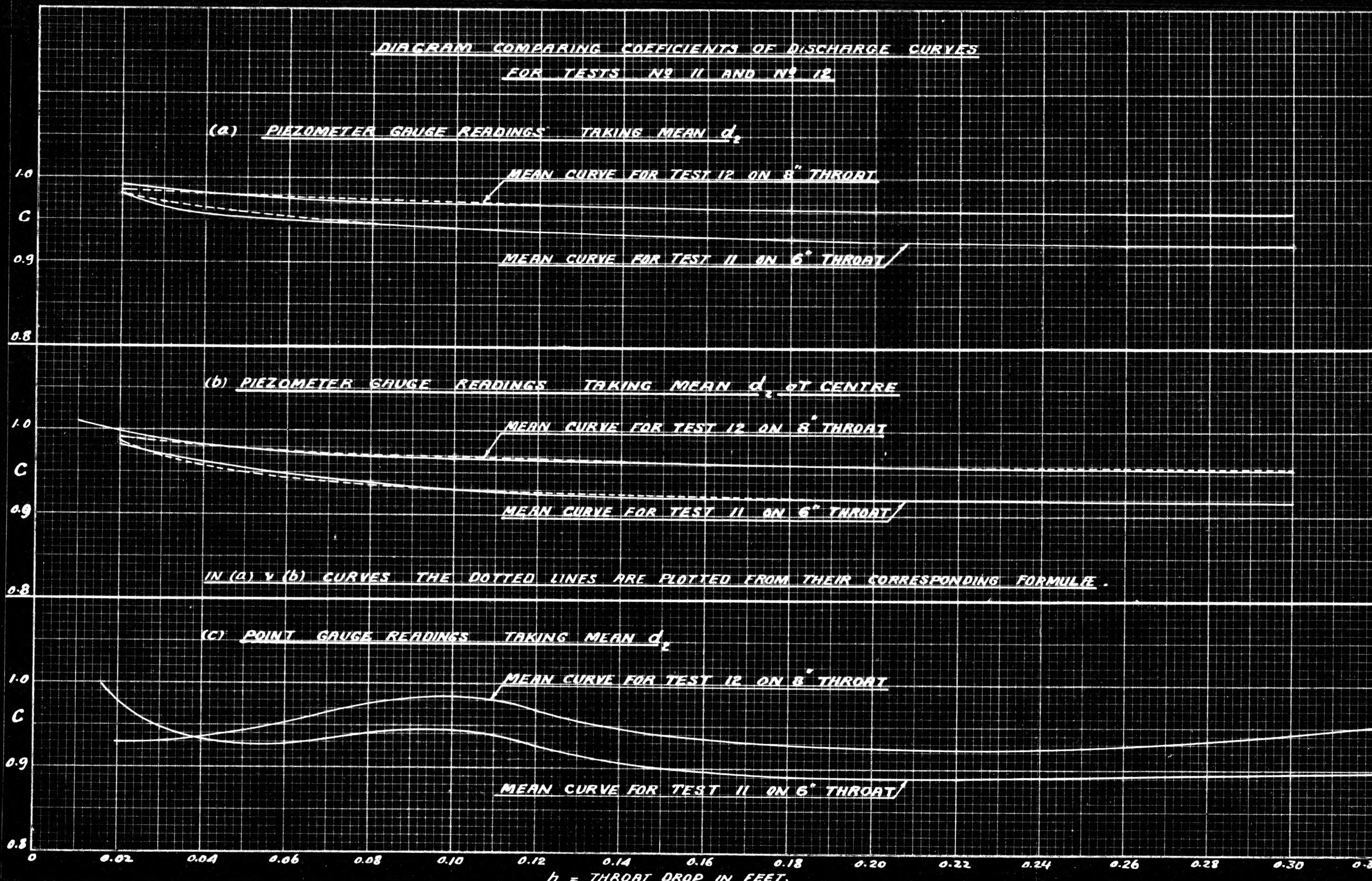


DIAGRAM COMPARING COEFICIENTS OF DISCHARGE CURVES
FOR TESTS Nº 11 AND Nº 12
(a) PIEZOMETER GAUGE READINGS TAKING MEAN d2
MEAN CURVE FOR TEST 12 ON 8" THROAT
MEAN CURVE FOR TEST 11 ON 6" THROAT
(b) PIEZOMETER GAUGE READINGS TAKING MEAN d2 AT CENTRE
MEAN CURVE FOR TEST 12 ON 8" THROAT
MEAN CURVE FOR TEST 11 ON 6" THROAT
IN (a) & (b) CURVES THE DOTTED LINES ARE PLOTTED FROM THEIR CORRESPONDING FORMULÆ.
(c) POINT GAUGE READINGS TAKING MEAN d2
MEAN CURVE FOR TEST 12 ON 8" THROAT
MEAN CURVE FOR TEST 11 ON 6" THROAT
1.0
C
0.9
0.8
0
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18
0.20
0.22
0.24
0.26
0.28
0.30
0.32
h = THROAT DROP IN FEET.

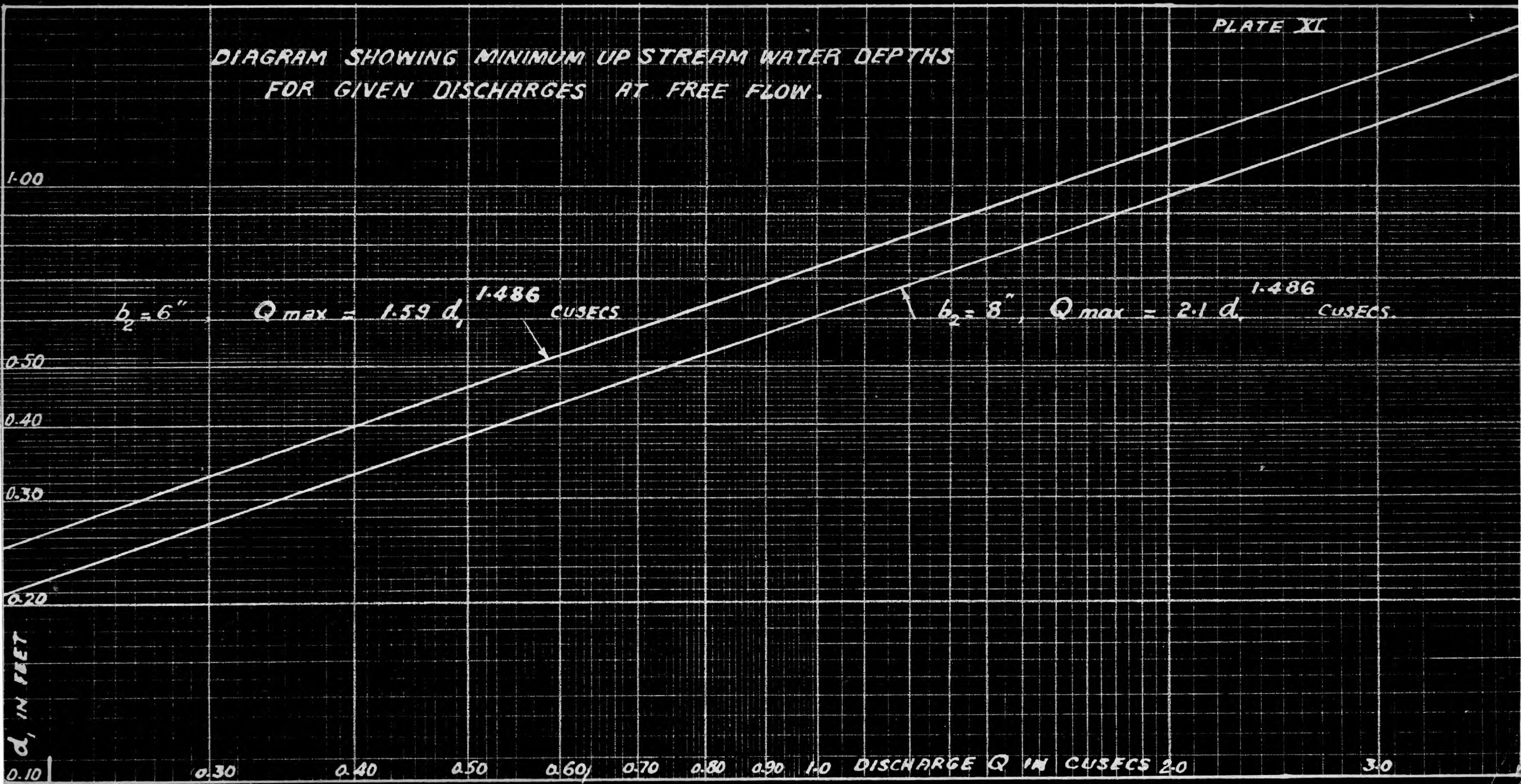


PLATE XI
DIAGRAM SHOWING MINIMUM UP STREAM WATER DEPTHS FOR GIVEN DISCHARGES AT FREE FLOW.
$b_2 = 6''$, $Q_{max} = 1.59\, d_1^{1.486}$ CUSECS
$b_2 = 8''$, $Q_{max} = 2.1\, d_1^{1.486}$ CUSECS.
1.00
0.50
0.40
0.30
0.20
0.10
d_1 IN FEET
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.0
DISCHARGE Q IN CUSECS
2.0
3.0