PAPER No. 176.

ON THE DESIGN OF AN A. P. M.

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The object of the Author in writing this paper is to describe briefly few experiments carried out to investigate the working of an A. P. M. ıdjustable Proportional Module). In 1928-29 a few distributaries on .e Lower Jhelum Canal were fitted with A. P. Ms. according to the :sign as given in Irrigation Branch Paper No. 26, Class A. It was und in the actual working of these channels that the co-efficient of scharge ' C ' in the formula $q = C B y\sqrt{h}$ for an A. P. M. and its actual odular limits did not agree in all cases with those given in the afore-entioned paper.

In the case of small channels carrying less than 20 cusecs, *e.g.*, Jani istributary, where the depth on crest for the outlets was low, *i.e.*, about 0 foot, and the outlets were relatively wide, the sum total of the out-t discharges according to the formula $q = 7{\cdot}3 B y\sqrt{h}$ plus absorption of .e channel was short of the actual discharge put in at the head by about) per cent. But in the case of major distributaries, for example Mithalak istributary, where the depths on the crest were high, *i.e.*, about 2·0 et, and the outlets were relatively narrow, the sum total of the outlet scharges in modular condition according to the formula $q = 7{\cdot}3 B y\sqrt{h}$ us absorption was more than the discharge actually put in at its head by)out $12\frac{1}{2}$ per cent.

The experiments were started in 1929 to investigate the variation the co-efficient of discharge of an Adjustable Proportional Module ıd to determine its minimum modular head under various conditions.

rocedure in Experiments.

These experiments were carried out at R. D. 12,000-R., Bhek Dis-ibutary, Lower Jhelum Canal. The description of the experimental ation has already been given in Paper No. 168, Punjab Engineering ongress, 1933. The discharges were calculated by tank measure-ıents. The water level in the outfall was regulated by means of 0·1)ot high karries. The karrie arrangement was designed as water-ght and placed sufficiently downstream of the hydraulic jump in the ıtfall. The observations were taken for every hissa rise of the water vel in the outfall, till the modular limit was passed. The results were ıbulated and are given in the Appendices.

Experiment No. 1.

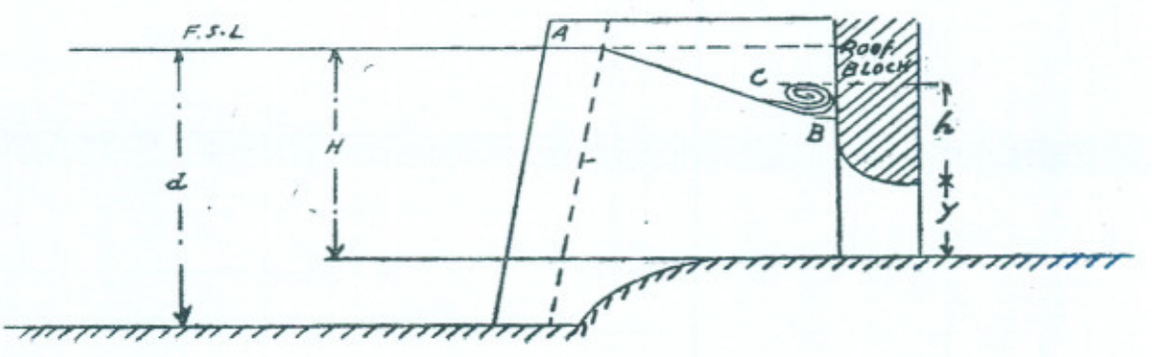
An A. P. M. set at 6/10th of the depth was constructed according t the design given in Irrigation Branch Paper No. 26, Class A. Th designed depth on the crest was 1·5 feet and the width of the outlet wa 0·32 foot. Nine pressure tubes were put in at the points shown i Plate No. 1. Point No. 1 represents the beginning of the A. P. M block and No. 3 the end of the A. P. M. block, where water leaves th orifice. Points Nos. 4 and 5 are on the level crest, downstream of th A. P. M. block. Point No. 6 represents the end of the level crest, tha is, the beginning of the glacis. Points Nos. 7 to 9 are on the glacis. Th tubes were bent round into the glazed chambers provided behind th downstream projecting wing of the outlet in the distributary.

Glass tubes of $\frac{1}{4}$ inch diameter were fitted vertically to the bra tubes of $\frac{1}{4}$ inch diameter in the chamber. The tubes are carefully fitte flush with the wooden crest and glacis exactly in the centre line of th outlet at all points. The pressure exerted by water passing through th outlet on the crest and the glacis were directly observed from the tub in the chambers.

Six sets of observations were taken as given in Appendix I. Twel observations were taken in each case for various water levels in the ou fall of the outlet. The width of the outlet was the same in all observa tions. The height of the opening was varied in every set of observatio and the approaches were modified for the changed discharge in eve case.

In Appendix I, Column No. 10, the figures ·15/·25 indicate that th water level in the pressure tube was fluctuating from 0·15 to ·25 foo In such a case, the pressure at Point No. 6 was not steady. Colum No. 15 in Appendix I gives the loss of head on entry from the distribu tary to the beginning of the A. P. M. block, through a long but narro length of approach usually provided by giving a curve with radius of 2 on the upstream side. The figure given below explains the point clearl

FIG No. 1



In the above sketch the water level drops from A to B. There is onstriction in the section, both on the sides and the bed. The pres-ure head is converted into velocity and the water level drops. Moreover, nergy is lost in friction through this narrow but long length of approach rom the distributary to the A. P. M. block. At the point B, the water evel again jumps up on impact with the roof block to level 'C.' The oint 'C' was in some cases considerably lower than the point 'A' nd the difference between these two points represented the loss of head t the entrance. There is no doubt that B C represents the velocity ead of the top filaments of water approaching the orifice and the velo-ity of the filaments near the approach curve in the bed will be somewhat ifferent. It was noticed through the glazed chambers provided down-tream of the projecting wing of the outlet in the channel that when here was a considerable draw, the top filaments were quicker than the laments near the approach curve in the beginning and had practically he same velocity as they approached the A. P. M. block. B C, therefore, epresented approximately the pressure head due to the average velocity f water approaching the A. P. M. block. This phenomenon has no-hing to do with the module, as it takes place before the orifice action tarts at the point B. The orifice of the A. P. M. is, therefore, ubject to the pressure head actually obtainable just upstream of the A. P. M. block at the point 'B' and not that theoretically obtained, onsidering the pond level in the parent channel. These conditions vere especially marked when the height of the opening was relatively igh and subsequently the outlet was narrow.

It is clear from the pressure observations, that when the working eads are high, the pressures at Point No. 3, the end of the A. P. M. block, re considerably less than the height of the opening, *i.e.*, the depth of he jet of water leaving the orifice. In such cases, the pressure head of vater leaving the orifice is less than 'Y' and the effective pressure on he orifice is therefore more than (H-Y).

The behaviour of the pressure at Point No. 6 at the end of level rest or the beginning of the glacis, is especially interesting. The pres-ure reads zero for a considerable range of water level in the outfall of the utlet, when the working heads are high. The roof block represents othing but a gradual restriction of the water-way, the pressure energy s converted into velocity as the water-way is reduced. The height of he opening is generally less than 0·5H and the critical conditions of low have passed below the A. P. M. block. The flow downstream of he roof block is below critical depth and is on a level floor. In such con-litions, water would flow either from below the critical depth to above he critical depth resulting in hydraulic jump, or at a continually in-reasing velocity. In the first case, the velocity head would be converted nto pressure head resulting in an increased depth as it recedes from the rifice block. The depth would increase to the critical depth of flow esulting in a hydraulic jump. In the second case, the pressure head vould go on decreasing and the velocity would increase as if below the rifice block. The former conditions are not attained, as the necessary

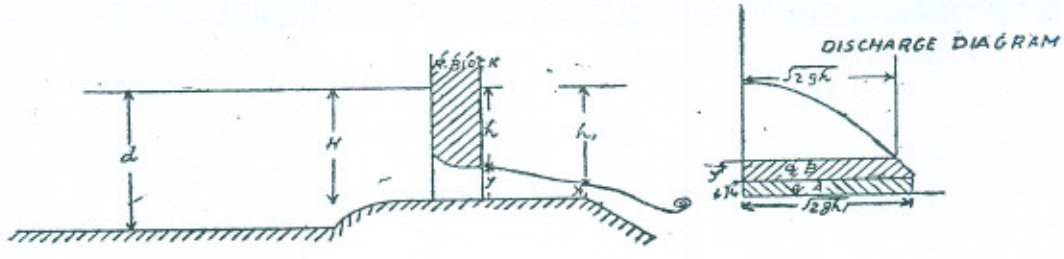
pressure or the depth required downstream of the hydraulic jump is no available when the working head is high and the water level in the out fall is low. Water moves under the second set of conditions. The dept of the water goes on decreasing up to the end of the level crest wher the complete aeration of the jet is established. The jet is already aerate on the top and the eddies are produced on the sides and at the bottom These conditions of flow continue so long as the hydraulic jump is on th glacis downstream of the end of the level crest. The flow on the leve crest downstream of the A. P. M. is in continuation of the flow unde the roof block in similar conditions, but the aeration of the jet is partiall attained at Point No. 3 but completely established at Point No. 6.

It is also clear from the pressure observations that, when the hydrauli jump comes on the level floor downstream of the A. P. M., the pressur at Point No. 6 rapidly rises and pressure at Point No. 3 is equal to Y o somewhat more than Y. The working head is reduced and the require depth in the outfall in the level floor is available to form a hydrauli jump on the level floor. The condition of flow is from below critica to critical depth resulting in a hydraulic jump on the level floor. In thi case 'Y,' depth downstream of A. P. M., exerts its full pressure on th floor as the water leaves the A. P. M. block. The effective pressure o the orifice is approximately equal to (H-Y). The A. P. M. works re markably well as a submerged orifice with a standing wave in this case so long as the hydraulic jump is on the level floor downstream of th A. P. M. block.

The discharge observations show the working of the A. P. M. i three different conditions depending upon the water level in the outfa or working head.

In the first case, when the hydraulic jump is on the glacis, the co efficient 'C' in the formula $q = C\,B\,y\sqrt{h}$ is more than 8·0, so that th co-efficient of discharge $c = \frac{C}{\sqrt{2g}}$ is more than unity. It is not therefore, a submerged orifice and the effective pressure on the outlet i something more than (H-Y). It will also be clear from the Colum No. 18 that it is not absolutely a freefall orifice, as the value of K i formula $q = K\,B\,(H^{\frac{3}{2}} - h^{\frac{3}{2}})$ fluctuates very much. The correct condi tion of flow in this case is shown in the figure below :—

FIG No 2



Let q be the discharge of the outlet. Let y_1 be the depth to which he water profile falls before it expands in the outfall so that $y > y_1$. The lischarge through the structure is shown in the diagram above and is nade up of two portions. Under these conditions, all the particles of vater which flow through the orifice below the elevation of the down-tream water surface at the end of the level floor have a velocity due o the difference of the elevation of the water surface upstream of the oof block and the water surface at the end of the level floor. They nake up the lower cross hatched rectangle.

$$q_A = C B \sqrt{2gh_1}\, y_1$$

Those particles which pass out of the orifice below the roof block t an elevation above the lower depth, y_1, have a velocity depending ıpon their elevation varying from $\sqrt{2gh}$ to $\sqrt{2gh_1}$. The total discharge hrough this upper section is shown in the discharge diagram by a shaded ›art of a parabola.

$$q_B = C B \tfrac{2}{3} \sqrt{2g}\, (h_1^{\frac{3}{2}} - h^{\frac{3}{2}})$$

The total discharge.

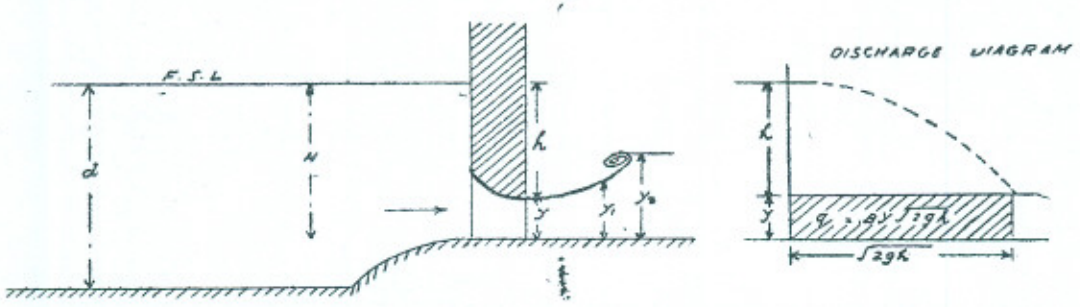
$$q = q_A + q_B$$

$$q = C B \sqrt{2g} \left\{ y_1 \sqrt{h_1} + \tfrac{2}{3} (h_1^{\frac{3}{2}} - h^{\frac{3}{2}}) \right\}$$

This explains why the value of C in the Column 17 of Appendix 1 was more than $\sqrt{2g}$ as used in formula $q = C B y \sqrt{h}$ The formula letermined above depends upon the depth of water actually run at the ;nd of the level crest, which could not be measured accurately, and, therefore, it was of little practical use.

In the second case when the hydraulic jump took place on the level loor, the condition of flow was as sketched below :—

FIG No. 3



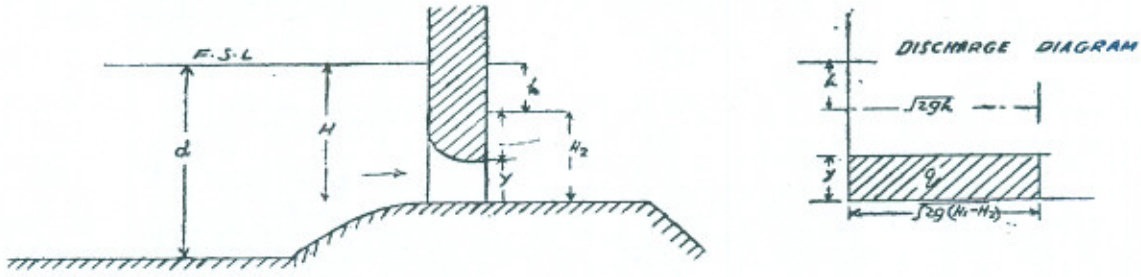
In this case $y_1 = y$ or $y_1 > y$. The discharge is represented by a ·ectangle as shown in the hatched portion above.

$$q = c \sqrt{2g}\, B\, y \sqrt{h} = C\, B\, y \sqrt{h}$$

The outlet is working as a submerged orifice with a hydraulic ump.

In the third case when the hydraulic jump does not take place downstream of the A. P. M. block the outlet is simply working as a drowned orifice. The condition of flow is sketched below :—

FIG No. 4



$$q = c\sqrt{2g}\ B\ y\ \sqrt{H_1 - H_2}$$
$$= C\sqrt{2g}\ B\ y\ \sqrt{h} \quad \text{where } H_1 - H_2 = h$$

It is also evident that the discharge of an A. P. M. is not independent of the water level in the outfall even though a hydraulic jump be formed. The discharge of an A. P. M. with a level crest equal to H downstream of the roof block depends upon the depth of water actually attained with high working heads at the end of the level floor. This could not be determined practically. Therefore, the design of the outfall of the A. P. M. requires to be changed to make its discharge independent of the water level in the outfall. Designs of the A. P. M. under the following two different conditions were tried :—

(*a*). No level floor downstream of the A. P. M. The glacis started from the A. P. M. block and followed approximately the profile of jet of water leaving the orifice in free fall conditions.

(*b*). Level floor throughout the length of outfall at the crest level of the A. P. M.

Second Experiment.

The experiment was carried out on three outlets constructed according to the design given in Plate No. 2 with no level floor downstream of the A. P. M. block, henceforth mentioned as type A. The modifications in the design are clearly explained in Paper No. 168, Punjab Engineering Congress, 1933. The width of the outlets was ·32 foot in each case. Outlet No. 1 had a depth on crest equal to 1·5 feet and was set at 6/10th. Outlet No. 2 had depth on the crest equal to 2·0 feet and was set at 8/10th. The third outlet had a depth on the crest equal to 2·5 feet and was set at bed level. The observations were taken for different values of the height of opening 'Y' and the approaches were modified every time the value of 'Y' was changed. The design of the roof block in these observations was kept the same as given in Irrigation Branch Paper No. 126.

The results of this experiment are given in Appendices II, III and V for outlets, with a depth on crest equal to 1·5, 2·0 and 2·5 feet. For the sake of brevity the actual readings of the tanks and the time are omitted, in Column No. 9 the value of K in formula $q = K\ B\ (H^{\frac{3}{2}} - h^{\frac{3}{2}})$ are worked out, and in the Column No. 8 the value of C in the formula $= C\ B\ y\sqrt{h}$ for the same observations are worked out. It will be noticed from these observations that up to a certain level in the outfall, the value of the co-efficient of discharge is fairly steady. Beyond this point, the value of the co-efficient drops rapidly and this point is called the modular limit for the observations.

The results of this experiment are plotted in Plate 3. There are three diagrams one for each depth on the crest of the outlet. Each diagram gives the value of 'K' in the formula $q = K\ B\ (H^{\frac{3}{2}} - h^{\frac{3}{2}})$ and that of 'C' in the formula $q = C\ B\ y\sqrt{h}$ for the same observations for the ratio h/H.

An examination of the observations in Appendices II, III and IV brings forth the following important points :—

(*a*). It was found in these observations that, due to modifications in the design of the upstream approach to the A. P. M. block, the loss of head in the entrance was eliminated. The actual depth on the crest just upstream of the roof block was the same as the pond level in the distributary.

(*b*). The variation in the value of 'C' in the formula $q = C\ B\ y\sqrt{h}$ in the three different sets of observations was far greater than that of 'K' in formula $q = K\ B\ (H^{\frac{3}{2}} - h^{\frac{3}{2}})$.

(*c*). The curve for the value of K has got a maximum value when the height of the opening is about ·45H and it drops somewhat, when the height of the opening is further reduced up to about y = ·35H. It rises again rather rapidly for values of 'y' lower than ·3H. The value of 'K' would be zero when the height of opening is zero, or h=H. This curve would thus have two maxima and two minima. Similarly the curve for 'C' would have two maxima and two minima. The explanation for the strange variation of the co-efficient of discharge is sought below :—

The co-efficient of discharge for an orifice is the product of the co-efficient of contraction at the *vena contracta* and the co-efficient of velocity. In the case of an A. P. M. no defined *vena contracta* is formed. The outlet runs full bore for all practical purposes within the usual range of its working for the height of its opening from 0·3H to 0·5H. The co-efficient of contraction should, therefore, be unity and the variation of the co-efficient of discharge should be due mainly to the co-efficient of velocity.

The co-efficient of velocity is the ratio of the actual velocity attaine through an orifice to the theoretical velocity which could be produce with the available head. This allows for the loss of head in the resistanc due to viscosity and friction. The friction in this case should be smal as the orifice consists of an iron block of only 1·0 foot length and shoul not affect the co-efficient of discharge to any marked extent.

But the actual observations show that there is considerable varia tion in the co-efficient of discharge as is clear from Plate 3. The co efficient of discharge is nothing but a measure of loss of energy in passin water from the upstream to the downstream of the iron block of th outlet. The energy is lost somewhere and the variation of this loss i considerable. An examination of the streamlines entering the A. P. M block from the glazed chamber showed that the streamlines bent dow upstream of the A. P. M. block, even though there was no loss of hea in entrance. The energy available in the form of static head upstrean of A. P. M. block was lost in bending of these streamlines. This los was variable depending on the inclination of streamlines as show below :—

FIG No 5



The co-efficient of discharge decreased for the same depth on th crest when the depression of the roof block was increased. Similarl the co-efficient of discharge decreased, when the depth on crest wa increased in the case of the outlets in this experiment.

(*d*). It may be noticed that the rate of reduction of the co-efficien decreased with the increase in the depth on crest. For different value of y, the co-efficient has again a tendency to rise when the value of y is les than ·3H. It appears that the energy due to increased pressure wa more in this case than the increase in friction due to increased velocity.

(*e*). The value of 'K' in formula $q = K B (H^{\frac{3}{2}} - h^{\frac{3}{2}})$ was con stant for all practical purposes for the range of y from 0·3H to 0·5H bu the value of 'C' in formula $q = C B \; y\sqrt{h}$ fluctuated very much for th above mentioned range of y as is evident from Plate 3.

(*f*). The variation of 'K' for the different values of the depth or the crest was regular but the variation of 'C' for different values of th depth on the crest was irregular.

It is, therefore, concluded from the above mentioned remarks tha the formula $q = K B (H^{\frac{3}{2}} - h^{\frac{3}{2}})$ for the modified design of type A was more suitable than the formula $q = C B y\sqrt{h}$.

A curve is drawn in Plate 4 showing the variation 'K' in formula $q = K B (H^{\frac{3}{2}} - h^{\frac{3}{2}})$ for different values of depth on the crest or Type A design. Three points on the curve were determined from the above experiments for H=1·5, H=2·0 and H=2·5 feet and the remaining points for higher values of 'H' were derived from the individual observations of outlets constructed according to this type by determining discharges of the outlets with portable calibrated iron flumes. From this curve it follows that the co-efficient drops rapidly to begin with and then the rate of fall decreases as the depth on crest increases.

Third Experiment.

It was noticed in the above experiment that there was a considerable variation in the value of 'K' with depth on the crest and also a rapid increase in the working heads required to work the A. P. M. in the modular condition. It has been explained that this variation was mostly due to the bending up of the streamline upstream of the roof block. For different depths on the crest, the design of the roof block of the A. P. M. as given in Irrigation Branch Paper No. 26 is the same. It is natural to expect that the streamlines have to bend more obliquely when the depth on the crest is increased. In this experiment the design of the roof block was changed with the depth on the crest. Different designs of the roof block were tried and the design finally adopted is given in Plate 5. The experiment was made on two outlets with H=2·0 feet and H=2·5 feet. The width was ·32 foot and the structural details of the outlets were the same as in the second experiment. The change in the design of roof block ensured a relatively smoother entry to the orifice with the increase in depth on the crest.

The results of the experiments are given in Appendices V and VI and are plotted in Plate 5. It will be noticed that there is considerable relative increase in the co-efficient of discharge and the modular limit has been considerably raised. The comparative effect is given below :—

'K' in formula $q = K B (H^{\frac{3}{2}} - h^{\frac{3}{2}})$ and 'K' for modified roof block.

		Standard roof block.	*Modified roof block.*
Size ..	.. H	yK	K
A ..	.. 1·5	4·7	..
B ..	.. 2·0	4·35	4·7
C ..	.. 2·5	4·1	4·5

The loss on entry in passing water through an A. P. M. block was thus reduced increasing thereby the efficiency of the outlet. Relatively low working heads were, therefore, required for the outlets fitted with the modified design of the roof block.

Fourth Experiment.

The experiment was carried out with the modified design of outlet "Type A" for different values of the width of the outlet. The depth on the crest was about 2·0 feet in each case and the width of the outlet was changed. The results of the observations are given in Appendix VI. It is clear from the observations, that the values of 'K' in the formula $q = K B (H^{\frac{3}{2}} - h^{\frac{3}{2}})$ in Appendix VI for width 0·5 foot are relatively higher than those previously obtained in the second experiment for width ·32 foot, when the depth on the crest was about the same.

In Appendix VII the values of 'K' for a width of ·2 foot are less than those obtained in the second experiment for the width ·32 foot.

The variation of 'K' with width of outlet for range of 'y' from 0·3H to 0·5H is

B=·2	B=·32	B=·5
K=4·10	5·35	4·60

Roughly speaking, with a width of ·5 foot the value of K is about 2 per cent. more and for width ·2 foot about 5 per cent. less than that for width of ·32 foot.

Fifth Experiment.

This experiment was carried out on two outlets with approaches modified Type A but the floor downstream of the outlet was made level throughout the length of the outfall at crest level. This design is referred to as Type B in the succeeding pages. The width of the outlet was ·5 foot. The results of the experiments for the outlet with a depth on the crest equal to about 2·0 feet are given in Appendices VIII and IX.

An examination of the results shows that the variation of 'C' is more regular than that of 'K.' The outlet is working very nearly as a submerged orifice with a hydraulic jump.

It is clear from these observations that the value of 'C' in the formula $q = C B y\sqrt{h}$ is not constant. It becomes smaller with increase in depth on the crest of the outlet. For H=1·5 it is about 7·5 and for H=2·0 it is 7·2 for the usual range of 'Y' from ·3H to ·5H.

No observations could be taken for different values of the width of the outlet in the case of Type B on account of the transfer of the Author from Sargodha Division, but the variation of 'C' on the lines of Type A is expected for different widths of the outlet.

It is concluded from this experiment that the formula of discharge $q = C B y\sqrt{h}$ is best suited for the Type B design of the A. P. M.

Modular Limits.

In these experiments the minimum modular head was considered to be the working head. The co-efficient of discharge tended to be constant for all practical purposes, if the working head was allowed more than the minimum modular head. The observations were taken by varying the water level in the outfall of the outlet, by ·1 foot by means of karries. The observations, therefore, show the minimum modular head correct only to within 0·1 foot.

It was observed that there were three stages in the conditions of the flow in the outfall for a particular setting of the roof block.

(*a*). A distinct hydraulic jump, when the co-efficient of discharge was the maximum and steady.

(*b*). A poor but regular standing wave giving a distinct bubbling noise. The co-efficient of discharge is variable, tending to approach the maximum observed in the first case.

(*c*). The outlet worked drowned with no bubbling and no standing wave. The co-efficient of discharge tended to increase somewhat as the working head was increased. The point where the condition (*b*) changed into the condition (*a*) represented the true modular limit in these observations.

Sizes and Gauges.

Let types of the outlets be designed by the depths on crest and the width of the outlet be the same as given in Irrigation Branch Paper No. 26. Class A.

Type A	depth on crest	..	..	1·5
do. B	do.	..	..	2·0
do. C	do.	..	..	2·5
do. D	do.	..	..	3·0
do. E	do.	..	..	3·5
do. F	do.	..	..	4·0

For the modified design of an A. P. M. Type A, a differential gauge has been designed for the outlet which gives the discharge of the outlet by direct reading in cusecs. It will also give the height of the opening and the depth on the crest by direct reading. The gauge is also designed to give the value of h_m, the minimum modular head in the designed conditions of the outlet. The gauge will be rigidly attached to the iron outlet and will be of universal use for the type and the size of the outlet to which it is attached.

Similarly for Type B, the gauge would be designed to give the velocity instead of discharge as at present. The gauge could also be made to read the height of the openings and the depth on crest. The minimum modular head could also be shown as in the Type A. The discharge could be calculated by multiplying the velocity read from the gauge and the area of the orifice.

Design of the A. P. M. in practice.

The size and setting of a roof block of the A. P. M. modified Type A for formula $q = K\ B\ (H^{\frac{3}{2}} - h^{\frac{3}{2}})$ could be determined easily from the Nomogram given in Plate 6. The instructions for its use are given on the Nomogram. A key diagram is also given to facilitate its use.

The design of the A. P. M. modified Type A could also easily be worked out by the help of the Table of power 3/2. The Nomogram would then serve as a useful and speedy check on the design.

In the case of A. P. M. modified Type B the Nomogram for the formula $q = C\ B\ y\sqrt{h}$ is given in Plate 7. The detailed instructions for its use are also given therein. A key diagram is also given in Plate 7 to facilitate the use of the Nomogram.

With a slide rule, the following alternative method for the design of A. P. M. modified Type B may be of interest. Fix H according to the setting of the outlet required. To determine the size of A. P. M., keep $h = y = H/2$ and calculate $B = \frac{q}{C\ y\ \sqrt{h}}$. A. P. M. size, having width of flume equal to this B or just higher than B to suit the standard width, will give the required width of the A. P. M.

Then calculate $a = \frac{q}{C\ B}$

$$Y\sqrt{h} = a \qquad \text{(A)}$$

$$h + y = H \qquad \text{(B)}$$

The solution for equations (A) and (B) is given by one setting of the slide rule.

Rule.

"*Set the reversed slide to 'a' on the D scale. The value of h and 'y' are given under the cursor on the A and C scales respectively.*"

This method is not only more accurate but also quicker than the Nomogram method.

Conclusions.

The A. P. M. is an orifice with a hydraulic jump downstream of the A. P. M. block. It is essentially a semi-module with its discharge variable with the full supply level in the parent channel. Its discharge should be independent of the water level in the outfall, so long as the hydraulic jump is formed in the outfall. It has been seen in these experiments that by adopting the design of the outfall as given in Irrigation Branch Paper No. 26, this object was only attained over a limited range when the hydraulic jump was on the level floor just downstream of the outfall. Hence it is concluded that the visual examination of the hydraulic

ımp just downstream of the A. P. M. is not a sufficient condition to stablish the working of the A. P. M. as a semi-module. The design f the outfall plays an important part and should be allowed for in the esign of the outlets.

It is also concluded, if the design of the A. P. M. is adopted as per 'ype A, the formula of discharge $q = K B (H^{\frac{3}{2}} - h^{\frac{3}{2}})$ fits the observa- ons better than the formula $q = C B y\sqrt{h}$.

Similarly if the design of the A. P. M. is adopted as per Type B, is better to use the formula of discharge $q = C B y\sqrt{h}$. In both cases ıe A. P. M. is a semi-module and the discharge is independent of the ater level in the outfall, so long as the hydraulic jump is formed in ıe outfall. In the first case it is very nearly a free-fall orifice and in the :cond case it is a submerged orifice with the hydraulic jump.

Moreover, it is pointed out that the formula $q = K B (H^{\frac{3}{2}} - h^{\frac{3}{2}})$ for 'ype A covers the full range of the setting of the roof block or ıe height of the opening, but the value of 'K' is variable for the ratio =h/H. When 'h' is zero, the A. P. M. is an open flume and the ılue of 'K' drops down to about 3·0 in all cases. It is, therefore, ɔncluded that the formula as used is only correctly applicable to the ınge of k from ·5 to ·7, *i.e.*, the height of opening from ·3H to·5H, when K' tends to be reasonably constant.

The formula $q = C B y\sqrt{h}$ for Type B does not even cover the ıll range of the variation of 'y' (height of the opening) for any parti- ılar setting of the crest. If 'h' is zero the discharge of the outlet :cording to the above formula is zero, which is incorrect as the discharge ould be about $q = 3{\cdot}0 B y^{\frac{3}{2}}$ as in an open flume.

The formula is of doubtful application when the value of 'y' is ore than 0·5H. Moreover, the value of 'C' tends to increase rapidly hen the height of the opening is less than ·3H. Hence it is concluded ıat the correct range of application of the formula $q = C B y\sqrt{h}$ for ype B should be when the height of opening 'y' is from ·3H to 0·5H.

The Author considers that the outlets should be set as low as possible the head reach of a channel, from the point of view of the silt conduc- ɔn by the outlets, when the available working heads permit.

Lastly, it is concluded that the minimum modular head for an A. P. M. not only variable for values of $k = \frac{h}{H}$ (ratio of the depression of the of block to the depth on the crest) but also varies with the depth on e crest of the outlet and its width. A. P. Ms. set lower than the 6/10th e found to require greater minimum modular heads than those given in e Irrigation Branch Paper No. 26 for the same value of 'K.'

APPENDI

PRESSURE AND DISCHARGE OBSERVATIONS FOR AN A. P. M

FIRS

S

B = ·32 y = ·3

Serial No.	Depth on Crest.	Working Head.	Drowning Ratio.	*Pressure in pipes Nos.* 1	2	3	4	5	6
1	2	3	4	5	6	7	8	9	10
1	1·44	1·34	·07	1·10	·71	·19	·33	·32	Nil
2	1·44	1·24	·13	1·10	·71	·20	·34	·31	,,
3	1·44	1·14	·20	1·09	·71	·20	·31	·31	,,
4	1·44	1·04	·27	1·11	·72	·27	·33	·32	,,
5	1·44	·99	·32	1·11	·72	.40	·32	·32	,,
6	1·44	·86	·40	1·11	·71	·55	·34	·34	0/·25
7	1·44	·73	·47	1·12	·72	·35	·35	·40	·45
8	1·44	·69	·52	1·20	·90	·70	·60	·64	·58
9	1·44	·59	·59	1·25	1·00	·90	·90	·87	·67
10	1·44	·35	·66	1·30	1·10	1·00	1·00	·98	·82
11	1·44	·44	·70	1·32	1·20	1·10	1·10	1·10	·95
12	1·44	·37	·74	1·37	1·24	1·12	1·16	1·16	1·10
13	1·44	·32	·77	1·38	1·30	1·19	1·21	1·21	1·16

B = ·32 y = ·4

1	1·44	1·34	·07	1·00	·65	·28	·43	·37	Nil
2	1·44	1·24	·13	1·01	·68	·29	·43	·38	,,
3	1·44	1·14	·20	1·01	·68	·35	·44	·39	,,
4	1·44	1·06	·26	1·00	·72	·41	·44	·38	,,
5	1·44	·94	·34	1·02	·72	·44	·44	·40	,,
6	1·44	·84	·41	1·02	·72	·50	·44	·42	0/0·5
7	1·44	·74	·48	1·02	·73	·68	·45	·42	·25/·3
8	1·44	·64	·55	1·03	·74	·74	·45	·45	·44
9	1·44	·59	·59	1·10	·86	·87	·75	·76	·68
10	1·42	·47	·66	1·16	1·00	·96	·85	·86	·72
11	1·42	·42	·70	1·25	1·13	1·03	1·00	1·00	·85
12	1·42	·37	·74	1·28	1·18	1·13	1·12	1·12	·98
13	1·42	·32	·77	1·33	1·25	1·21	1·22	1·22	1·14
14	1·42	·22	·84	1·36	1·30	1·26	1·25	1·26	1·19

S PER IB.. PAPER No. 26, CLASS A, APPENDIX E.

XPERIMENT.

o. 1.

H = 1·5

s below.								
7	8	9	Discharge.	Loss of Head.	Effective H.	Co-efficient C in $q = C B y \sqrt{h}$	Co-efficient K in $q = K B (H^{\frac{3}{2}} - h^{\frac{3}{2}})$	
11	12	13	14	15	16	17	18	19
·14	·14	·07	·82	·01	1·43	8·08	5·06	
·16	·15	·12	·82	·02	1·42	8·11	5·08	
·19	·19	·20	·82	·02	1·42	8·10	5·08	
·24	·25	·31	·82	·02	1·42	8·08	5·06	
·36	·41	·40	·81	·02	1·42	8·05	5·05	
·30	·53	·55	·81	·02	1·42	8·02	5·03	Least Modular Limit.
·64	·65	·65	·78	Nil	1·44	7·67	4·78	
·77	·77	·78	·72	,,	1·44	7·10	4·41	
·87	·87	·88	·62	,,	1·44	6·16	3·85	
·99	·99	1·00	·56	,,	1·44	5·50	3·43	
1·10	1·09	1·11	·50	,,	1·44	4·90	3·06	
1·15	1·16	1·16	·45	,,	1·44	4·50	2·79	
1·21	1·20	1·21	·14	,,	1·44	4·09	2·56	

Set No. 2.

A = 1·5

·18	·16	·10	1·02	·02	1·42	7·93	4·84	
·18	·18	·10	1·02	·02	1·42	7·95	4·85	
·21	·18	·17	1·02	·02	1·42	7·95	4·85	
·22	·23	·24	1·02	·01	1·43	7·87	4·80	
·32	·32	·40	1·02	·01	1·43	7·90	4·81	
·40	·42	·48	1·03	·01	1·43	8·00	4·88	
·55	·55	·58	1·01	·01	1·43	7·85	4·77	Least Modular Limit.
·67	·68	·68	·99	·01	1·43	7·70	4·67	
·86	·83	·87	·96	·01	1·43	7·50	4·54	
·90	·91	·92	·83	Nil	1·42	6·50	3·97	
1·00	1·00	1·01	·69	Nil	1·42	5·43	3·28	
1·12	1·12	1·14	·60	,,	1·42	4·73	2·86	
1·22	1·21	1·22	·52	,,	1·42	4·00	2·47	
1·25	1·24	1·25	·44	,,	1·42	3·47	2·10	

APPENDI

Serial No.	Depth on Crest.	Working Head.	Drowning Ratio.	*Pressure in pipes Nos.* 1	2	3	4	5	6
1	2	3	4	5	6	7	8	9	10
		B = ·32				Y = ·5			
1	1·42	1·42	·00	1·00	·75	·22	·53	·43	Nil
2	1·42	1·32	·07	1·00	·74	·22	·53	·44	,,
3	1·42	1·22	·14	1·00	·74	·23	·52	·43	,,
4	1·42	1·12	·21	1·01	·74	·25	·51	·40	,,
5	1·42	1·04	·26	1·00	·74	·35	·50	·42	,,
6	1·42	·94	·33	1·00	·74	·46	·53	·45	,,
7	1·42	·84	·40	1·00	·74	·58	·53	·45	0/·1
8	1·42	·80	·43	1·00	·76	·65	·50	·45	.05/.2
9	1·42	·72	·50	1·00	·73	·68	·48	·45	·20/·2
10	1·42	·62	·56	1·01	·75	·85	·55	·60	·55
11	1·42	·90	·63	1·22	·91	1·03	·83	·80	·65
12	1·42	·42	·70	1·18	1·03	1·08	·97	·97	·75
13	1·42	·37	·74	1·18	1·05	1·15	1·08	1·07	·97
14	1·42	·32	·77	1·31	1·21	1·15	1·14	1·13	1·05
15	1·42	·22	·84	1·36	1·27	1·26	1·27	1·26	1·17
		B = ·32			Y = ·6				
1	1·42	1·32	·07	·98	·81	·27	·60	·48	Nil
2	1·42	1·22	·14	1·00	·81	·32	·59	·49	,,
3	1·42	1·12	·21	1·00	·80	·32	·60	·50	,,
4	1·42	1·02	·28	1·00	·83	·40	·60	·49	,,
5	1·42	·92	·35	1·00	·82	·55	·61	·50	0/·05
6	1·42	·82	·42	1·00	·82	·63	·61	·52	·05/·25
7	1·42	·71	·50	1·01	·82	·72	·62	·53	·15/·25
8	1·42	·61	·57	1·01	·84	·85	·65	·62	·45/·35
9	1·42	·52	·63	1·10	·98	·99	·84	·82	·70
10	1·42	·42	·70	1·17	1·03	1·03	·98	·93	·75
11	1·42	·35	·75	1·27	1·25	1·23	1·03	1·19	·95
12	1·42	·27	·80	1·20	1·24	1·20	1·20	1·19	1·06
13	1·42	·22	·89	1·34	1·29	1·28	1·24	1·27	1·20

–continued.

below.								
7	8	9	Discharge.	Loss of Head.	Effective H.	Co-efficient C in $q = CBy\sqrt{h}$	Co-efficient K in $q = KB(H^{\frac{3}{2}} - h^{\frac{3}{2}})$	
11	12	13	14	15	16	17	18	19
	Set No. 3.						H = 1·5	
22	·23	·14	1·18	·03	1·39	7·83	4·63	S. W. F. Yes.
20	·23	·17	1·18	·03	1·39	7·85	4·62	
16	·21	·15	1·18	·03	1·39	7·84	4·62	
20	·23	·19	1·17	·03	1·39	7·80	4·60	
23	·25	·27	1·18	·03	1·39	7·82	4·62	
30	·35	·45	1·17	·03	1·39	7·80	4·60	
35/·45	·55	·48	1·17	·03	1·39	7·80	4·60	
40/·50	·55	·62	1·10	·03	1·39	7·30	4·30	
55	·64	·70	1·13	·03	1·39	7·36	4·40	
75	·85	·90	1·13	·02	1·40	7·41	4·41	
90	·95	·96	1·06	·01	1·41	7·00	4·14	
97	·97	·97	·97	·01	1·41	6·36	3·80	Least Modular Limit.
07	1·08	1·07	·77	·01	1·41	5·01	3·40	
15	1·16	1·16	·69	Nil	1·42	4·56	2·70	No Standing Wave.
27	1·27	1·27	·52	,,	1·42	3·45	2·05	
	Set No. 4.						H = 1·5	
23	·27	·21	1·33	.06	1·36	8·00	4·53	No standing wave formed.
23	·27	·21	1·33	·07	1·35	8 00	4·52	
26	·31	·27	1·32	·08	1·34	8·03	4·53	Standing Wave formed.
29	·35	·37	1·32	·08	1·34	8·02	4·52	
40	·50	·55	1·32	·08	1·34	8·00	4·51	
45	·55	·60	1·33	·08	1·34	8·06	4·55	
55/·65	·60/·70	·70	1·25	·08	1·34	7·60	4·28	
73	·80	·84	1·23	·08	1·34	7·51	4·23	
96	·95	·98	1·23	·05	1·37	7·40	4·18	
01	1·03	1·05	1·24	·03	1·39	7·31	4·16	
10	1·13	1·15	1·11	·01	1·41	6·48	3·70	Least Modular Limit. No Standing Wave.
20	1·02	1·20	·82	·01	1·41	4·80	2·74	
27	1·25	1·27	·65	·01	1·41	3·80	2·17	

APPEND

Serial No.	Depth on Crest.	Working Head.	Drowning Ratio.	*Pressure in pipes N*					
				1	2	3	4	5	6
1	2	3	4	5	6	7	8	9	10
	B = ·32			Y = ·71					
1	1·42	1·32	·07	1·06	·90	·31	·68	·55	Nil
2	1·42	1·22	·14	1·06	·90	·32	·68	·55	,,
3	1·42	1·12	·21	1·06	·90	·35	·67	·53	,,
4	1·42	1·02	·28	1·06	·90	·44	·67	·54	,,
5	1·42	·92	·35	1·06	·88	·52	·66	·52	·02
6	1·42	·82	·42	1·06	·90	·62	·68	·46	·05/
7	1·43	·73	·49	1·06	·90	·65	·71	·60	·15/
8	1·43	·61	·57	1·07	·90	·70	·72	·61	·35
9	1·44	·52	·64	1·06	·90	·84	·75	·74	·55
10	1·44	·42	·71	1·06	·96	·98	·88	·85	·75
11	1·44	·36	·76	1·20	1·08	1·08	1·08	1·08	·85
12	1·44	·29	·81	1·30	1·20	1·15	1·15	1·15	1·05
13	1·44	·24	·83	1·35	1·25	1·25	1·20	1·15	1·24
14	1·44	·19	·87	1·40	1·35	1·30	1·28	1·20	1·28
	B = ·32			Y = ·8					
1	1·43	1·28	·10	1·05	·97	·41	·77	·60	Nil
2	1·43	1·18	·17	1·05	·96	·38	·77	·60	,,
3	1·43	1·08	·24	1·06	·97	·47	·77	·61	,,
4	1·43	·98	·31	1·06	·97	·48	·77	·62	,,
5	1·43	·91	·36	1·07	·97	·52	·78	·63	·06
6	1·43	·82	·43	1·06	·97	·63	·79	·65	·10/
7	1·43	·71	·50	1·07	·98	·73	·79	·69	·32
8	1·43	·60	·58	1·07	·99	·81	·82	·71	·40/
9	1·43	·53	·63	1·07	1·00	·88	·83	·79	·62
10	1·43	·43	·70	1·11	1·05	1·00	·90	·90	·81
11	1·43	·33	·76	1·22	1·16	1·09	1·08	1·08	1·00
12	1·43	0·24	·83	1·23	1·25	1·17	1·20	1·20	1·13
13	1·43	·18	·87	1·36	1·34	1·25	1·28	1·29	1·25
14	1·43	·13	·90	1·42	1·40	1·36	1·37	1·36	1·32

—continued.

s below.								
7	8	9	Discharge.	Loss of Head.	Effective H.	Co-efficient C in $q = C\ B\ y\sqrt{h}$	Co-efficient K in $q = K\ B\ (H^{\frac{3}{2}} - h^{\frac{3}{2}})$	
11	12	13	14	15	16	17	18	19
			Set No. 5.					H = 1·5
·28	·30	·25	1·47	·10	1·32	8·30	4·42	
·30	·30	·25	1·47	·10	1·32	8·30	4·42	
·29	·30	·26	1·46	·10	1·32	8·28	4·41	
·31	·35	·37	1·46	·10	1·32	8·26	4·40	
·37	·44	·50	1·47	·10	1·32	8·30	4·42	
·48/·55	·55	·52	1·47	·10	1·32	8·30	4·42	S. W. F. Yes.
·57	·60	·62	1·47	·10	1·33	8·31	4·40	
·65	·71	·72	1·43	·10	1·33	8·09	4·28	
·83	·85	·83	1·42	·08	1·36	8·06	4·20	
·95	·98	·96	1·32	·09	1·35	7·74	3·91	
1·05	1·05	1·05	1·25	·08	1·36	7·10	3·77	
1·15	1·15	1·15	1·03	Nil	1·44	5·38	2·91	Least Modular Limit.
1·23	1·23	1·23	·72	,,	1·44	3·81	2·06	
1·27	1·28	1·28	·70	,,	1·44	3·65	2·06	
			Set No. 6.					H = 1·5
·30	·32	·26	1·55	·12	1·31	8·50	4·28	
·30	·32	·24	1·55	·12	1·31	8·48	4·27	
·32	·33	·29	1·55	·12	1·31	8·50	4·28	
·36	·36	·38	1·55	·12	1·31	8·49	4·28	
·42	·42	·46	1·54	·12	1·31	8·47	4·26	
·54	·52	·54	1·53	·12	1·31	8·41	4·23	S. W. F. Yes.
·60	·62	·64	1·52	·12	1·31	8·37	4·21	
·72	·73	·75	1·50	·12	1·31	8·22	4·13	
·84	·86	·88	1·48	·12	1·31	8·12	4·08	
·02	1·01	1·03	1·42	·12	1·31	7·80	3·89	
1·11	1·12	1·12	1·23	·08	1·35	6·50	3·18	
·21	1·20	1·21	1·05	·04	1·39	5·34	2·71	Least Modular Limit.
1·28	1·29	1·29	·83	·01	1·42	4·16	2·16	
·36	1·37	1·37	·61	Nil	1·43	3·00	1·57	

APPENDIX II.

DISCHARGE OBSERVATION FOR A. P. M. MODIFIED TYPE A.

2ND EXPERIMENT PART I.

Set No. 1.

Y = ·73

B ·32

Serial No.	Working Head.	H on Crest.	Loss of Head in Entry.	Effective H	Drowning Ratio.	Discharge.	Value of C in formula $q = C B y \sqrt{h}$	Value of K in formula $q = K B (H^{\frac{3}{2}} - h^{\frac{3}{2}})$	
1	2	3	4	5	6	7	8	9	
1	0·07	1·50	Nil	1·50	·95	·47	2·33	1·28	
2	0·12	1·50	Nil	1·50	·92	·66	3·23	1·77	
3	0·17	1·50	Nil	1·50	·88	·80	3·93	2·16	
4	0·23	1·50	Nil	1·50	·84	·96	4·73	2·60	
5	0·29	1·50	Nil	1·50	·80	1·14	5·31	3·07	
6	0·34	1·50	Nil	1·50	·77	1·40	6·87	3·79	
7	0·40	1·50	·01	1·49	·73	1·61	7·93	4·37	
8	0·50	1·50	·01	1·49	·66	1·76	8·66	4·77	Least Modular Limit.
9	0·60	1·51	·02	1·49	·60	1·76	8·65	4·76	
10	0·70	1·51	·02	1·49	·53	1·76	8·68	4·78	
11	0·80	1·51	·02	1·49	·46	1·76	8·68	4·78	
12	0·89	1·51	·02	1·49	·40	1·76	8·68	4·78	
13	0·99	1·51	·02	1·49	·33	1·75	8·63	4·75	
14	1·10	1·51	·02	1·49	·26	1·75	8·62	4·74	
15	1·20	1·51	·02	1·49	·19	1·76	8·64	4·76	
16	1·30	1·51	·02	1·49	·12	1·75	8·63	4·75	

Set No. 2.

Y = ·60

B = ·32

1	0·06	1·50	Nil	1·50	·96	·35	1·96	1·15	
2	0·13	1·50	..	1·50	·91	·54	2·91	1·72	
3	0·19	1·50	..	1·50	·87	·66	3·66	2·12	
4	0·25	1·50	..	1·50	·83	·80	4·42	2·56	
5	0·32	1·50	..	1·50	·78	·93	5·15	2·98	
6	0·39	1·50	..	1·50	·74	1·16	6·39	3·70	
7	0·40	1·50	..	1·50	·69	1·35	7·43	4·30	
8	0·55	1·50	..	1·50	·63	1·48	8·07	4·70	
9	0·65	1·50	..	1·50	·56	1·48	8·13	4·71	Least Modular Limit.
10	0·75	1·50	..	1·50	·50	1·47	8·10	4·69	
11	0·85	1·50	..	1·50	·43	1·48	8·15	4·72	
12	0·95	1·50	..	1·50	·36	1·47	8·12	4·70	
13	1·05	1·50	..	1·50	·30	1·48	8·12	4·70	
14	1·15	1·50	..	1·50	·23	1·48	8·15	4·72	
15	1·24	1·50	..	1·50	·17	1·47	8·10	4·69	
16	1·35	1·50	..	1·50	·10	1·47	8·07	4·68	
17	1·45	1·50	..	1·50		1·48	8·15	4·72	

APPENDIX II.—*concld.*

Set No. 3.

Y = ·50

B = ·32

Serial No.	Working Head.	H. on Crest.	Loss of Head in Entry.	Effective H.	Drowning Ratio.	Discharge.	Value of C in formula $q = C B y \sqrt{h}$	Value of K in formula $q = K B (H^{\frac{3}{2}} - h^{\frac{3}{2}})$	
1	2	3	4	5	6	7	8	9	
1	0·06	1·50	Nil	1·50	·96	·29	1·81	1·08	
2	0·13	1·50	Nil	1·50	·91	·45	2·81	1·68	
3	0·20	1·50	Nil	1·50	·86	·56	3·52	2·10	
4	0·27	1·50	Nil	1·50	·82	·68	4·27	2.55	
5	0·34	1·51	Nil	1·51	·77	·79	4·93	2·95	
6	0·43	1·51	Nil	1·51	·71	·97	6·04	3·61	
7	0·49	1·51	..	1·51	·67	1·17	7·31	4·37	
8	0·58	1·51	..	1·51	·61	1·25	7·80	4·66	Least Modular Limit.
9	0·67	1·51	..	1·51	·55	1·25	7·80	4·66	
10	0·76	1·51	..	1·51	·50	1·25	7·81	4·67	
11	0·87	1·51	..	1·51	·42	1·25	7·83	4·68	
12	0·96	1·50	..	1·50	·36	1·24	7·79	4·65	
13	1·06	1·50	..	1·50	·29	1·24	7·77	4·64	
14	1·15	1·50	..	1·50	·23	1·24	7·79	4·65	
15	1·25	1·50	..	1·50	·16	1·24	7·79	4·65	
16	1·35	1·50	..	1·50	·10	1·24	7·79	4·65	

Set No. 4.

Y = ·15

B = ·32

1	·08	1·52	Nil	1·52	·94	·10	1·95	1·27	
2	·17	1·52	Nil	1·52	·88	·12	2·22	1·44	
3	·22	1·52	..	1·52	·85	·13	2·39	1·55	
4	·29	1·51	Nil	1·51	·80	·25	4·58	2·97	
5	·37	1·51	Nil	1·51	·75	·32	5·85	3·80	
6	·50	1·52	..	1·52	·67	·36	6·42	4·17	
7	·60	1·52	..	1·52	·60	·38	6·90	4·48	
8	·67	1·52	..	1·52	·56	·41	7·30	4·74	Least Modular Limit.
9	·79	1·52	..	1·52	·48	·44	7·83	5·09	
10	·87	1·52	..	1·52	·42	·43	7·83	5·08	
11	1·06	1·52	..	1·52	·30	·43	7·81	5·07	
12	1·16	1·51	..	1·51	·23	·44	7·85	5·09	
13	1·26	1·51	..	1·51	·17	·43	7·82	5·07	
14	1·36	1·51	.	1·51	1·05	·44	7·85	5·10	
15	1·43	1·51	Nil	1·51	·06	·44	7·86	5·10	
16	1·45	1·51	Nil	1·51	·04	·44	7·85	5·09	

APPENDIX III.

DISCHARGE OBSERVATIONS FOR A.P.M. MODIFIED TYPE A.

EXPERIMENT No. 2, PART II.

Set No. 1.

Y = 1·0

B = ·32

Serial No.	Working Head.	H. on Crest.	Loss of head in entry.	Effective H.	Drowning Ratio.	Discharge.	Value of C in Formula $q = CBy\sqrt{h}$.	Value of K in Formula $q = KB(H^{\frac{3}{2}} - h^{\frac{3}{2}})$	
1	2	3	4	5	6	7	8	9	10
1	·04	1·99	Nil	1·99	·98	·48	1·54	0·84	
2	·13	1·99	Nil	1·99	·93	·80	2·53	1·39	
3	·18	1·99	..	1·99	·91	1·12	3·54	1·93	
4	·25	1·99	..	1·99	·87	1·43	4·49	2·45	
5	·32	1·99	..	1·99	·83	1·74	5·48	2·99	
6	·40	1·99	..	1·99	·79	1·90	5·96	3·25	
7	·48	1·99	..	1·99	·79	2·16	6·78	3·71	Least Modular Limit.
8	·54	1·98	..	1·98	·72	2·50	7·85	4·28	
9	·62	1·98	..	1·98	·68	2·60	8·13	4·44	
10	·71	1·98	..	1·98	·64	2·60	8·14	4·45	
11	·80	1·99	..	1·99	·59	2·60	8·12	4·43	
12	·89	1·99	..	1·99	·55	2·63	8·18	4·47	
13	1·00	1·99	..	1·99	·49	2·62	8·15	4·46	
14	1·09	1·99	..	1·99	·45	2·63	8·18	4·48	
15	1·22	1·99	..	1·99	·38	2·61	8·11	4·41	
16	1·32	1·99	..	1·99	·33	2·62	8·15	4·46	

Set No. 2.

Y = ·8

B = ·32

1	·05	2·00	Nil	2·00	·97	·40	1·45	0·84	
2	·08	2·00	..	2·00	·96	·76	2·74	1·59	
3	·11	2·00	..	2·00	·94	1·01	3·59	2·09	
4	·20	2·00	..	2·00	·90	1·15	4·08	2·38	
5	·28	2·00	..	2·00	·86	1·28	4·56	2·66	
6	·37	2·00	..	2·00	·81	1·41	5·00	2·92	
7	·47	2·00	..	2·00	·76	1·54	5·47	3·19	
8	·54	2·00	..	2·00	·73	1·65	5·85	3·41	
9	·63	2·00	..	2·00	·68	1·86	6·62	3·86	
10	·71	2·00	..	2·00	·64	2·14	7·61	4·42	
11	·78	2·00	..	2·00	·61	2·13	7·58	4·41	
12	·88	2·00	..	2·00	·56	2·13	7·56	4·40	
13	·98	2·00	..	2·00	·51	2·14	7·58	4·42	
14	1·09	2·00	..	2·00	·45	2·12	7·54	4·39	
15	1·19	2·00	..	2·00	·40	2·12	7·54	4·39	

APPENDIX III.—*concld.*

Set No. 3.

Y = ·59
B = ·32

Serial No.	Working Head.	H on Crest.	Loss of head in entry.	Effective H.	Drowning Ratio.	Discharge.	Value of C in Formula $q = CBy\sqrt{h}$.	Value of K in Formula. $q = KB(H^{\frac{3}{2}} - h^{\frac{3}{2}})$	
1	2	3	4	5	6	7	8	9	10
1	0·20	1·99	Nil	1·99	·89	·54	2·41	1·49	
2	0·30	1·99	..	1·99	·85	·73	3·27	1·99	
3	0·40	1·99	..	1·99	·79	·83	3·75	2·28	
4	0·46	1·99	..	1·99	·76	·94	4·23	2·56	
5	·55	1·99	..	1·99	·72	1·03	4·65	2·82	
6	·60	1·99	..	1·99	·69	1·13	5·08	3·09	
7	·65	1·99	..	1·99	·67	1·21	5·45	3·31	
8	·73	2·00	..	2·00	·63	1·45	6·46	3·93	Least Modular Limit.
9	·78	2·00	..	2·00	·59	1·56	7·00	4·24	
10	·90	2·00	..	2·00	·55	1·60	7·16	4·35	
11	1·00	2·01	..	2·01	·50	1·60	7·14	4·34	
12	1·10	2·01	..	2·01	·45	1·60	7·14	4·34	
13	1·20	2·00	..	2·00	·40	1·58	7·08	4·30	
14	1·30	2·00	..	2·00	·35	1·60	7·16	4·35	
15	1·40	2·00	..	2·00	·30	1·58	7·08	4·30	
16	1·50	1·99	..	1·99	·24	1·58	7·10	4·31	

Set No. 4.

Y = ·5
B = ·32

1	·07	2·00	..	2·00	·96	·27	1·42	·88	
2	·11	2·00	..	2·00	·94	·35	1·82	1·13	
3	·18	2·00	..	2·00	·91	·54	2·79	1·72	
4	·25	2·00	..	2·00	·87	·72	3·70	2·28	
5	·33	2·00	..	2·00	·83	·81	4·16	2·57	
6	·42	2·00	..	2·00	·79	1·04	5·34	3·30	
7	·51	2·00	..	2·00	·74	1·24	6·33	3·91	
8	·60	2·00	..	2·00	·70	1·27	6·48	4·00	
9	·68	2·00	..	2·00	·66	1·30	6·63	4·10	Least Modular Limit.
10	·78	2·00	..	2·00	·61	1·34	6·84	4·23	
11	·85	2·00	..	2·00	·57	1·39	7·11	4·40	
12	·95	2·00	..	2·00	·52	1·39	7·10	4·39	
13	1·05	2·00	..	2·00	·47	1·40	7·15	4·42	
14	1·16	1·99	..	1·99	·41	1·39	7·14	4·40	
15	1·26	1·99	..	1·99	·36	1·40	7·17	4·42	
16	1·36	1·99	..	1·99	·31	1·38	7·15	4·41	

APPENDIX IV.

DISCHARGE OBSERVATIONS FOR A. P. M. TYPE A (STANDARD ROOF BLOCK).

EXPERIMENT No. 2, PART II.

Y = 1·0 **Set No. 1.** B = ·32

Serial No.	Working Head.	H on Crest.	Loss of head in entry.	Effective H.	Drowning Ratio.	Discharge.	Value of C. in Formula $q = C B y \sqrt{h}$	Value of K. in Formula $q = KB(H^{\frac{3}{2}} - h^{\frac{1}{2}})$	
1	2	3	4	5	6	7	8	9	
1	·02	2·50	..	2·50	·99	0·84	2·15	1·24	
2	·11	2·50	..	2·50	·95	1·35	3·46	1·99	
3	·24	2·50	..	2·50	·90	1·92	4·93	2·84	
4	·38	2·47	..	2·47	·84	1·95	5·44	3·00	
5	·53	2·50	..	2·50	·78	2·23	5·72	3·30	
6	·69	2·48	..	2·48	·72	2·32	5·95	3·45	Least Modular Limit.
7	·85	2·45	..	2·45	·65	2·40	6·26	3·60	
8	·94	2·50	..	2·50	·62	2·26	6·57	3·78	
9	1·08	2·49	..	2·49	·56	2·62	6·72	3·85	
10	1·20	2·50	..	2·50	·52	2·75	7·05	4·06	
11	1·39	2·48	..	2·48	·55	2·73	7·00	4·05	
12	1·49	2·45	..	2·45	·39	2·71	7·05	4·02	
13	1·59	2·50	..	2·50	·32	2·75	7·05	4·06	

Y = ·80 **Set No. 2.** B = ·32

1	·02	2·50	..	2·50	·99	·70	2·12	1·26	
2	·16	2·50	..	2·50	·93	1·23	3·70	2·20	
3	·25	2·50	..	2·50	·90	1·47	4·42	2·50	
4	·37	2·50	..	2·50	·85	1·67	5·03	2·85	
5	·46	2·50	..	2·50	·81	1·73	5·21	2·95	
6	·53	2·50	..	2·50	·78	1·82	5·48	3·10	
7	·69	2·50	..	2·50	·72	1·93	5·81	3·30	
8	·85	2·50	..	2·50	·66	2·01	6·05	3·42	Least Modular Limit.
9	·92	2·50	..	2·50	·63	2·14	6·44	4·65	
10	1·04	2·50	..	2·50	·60	2·23	6·71	3·80	
11	1·10	2·50	..	2·50	·56	2·35	7·07	4·01	
12	1·20	2·50	..	2·50	·52	2·34	7·07	4·00	
13	1·30	2·50	..	2·50	·48	2·35	7·07	4·02	
14	1·40	2·50	..	2·50	·44	2·40	7·22	4·07	
15	1.50	2·50	..	2·50	·40	2·37	7·13	4·05	
16	1.60	2·50	..	2·50	·36	2·37	7·13	4·05	

APPENDIX IV—*contd.*

Y = ·51 **Set No. 3.** B = ·32

Serial No.	Working Head.	H. on Crest.	Loss of head in entry.	Effective H.	Drowning Ratio.	Discharge.	Value of C in Formula $q = C\,By\sqrt{h}$	Value of K in Formula $q = K\,B\,(H^{\frac{3}{2}} - h^{\frac{3}{2}})$	
1	2	3	4	5	6	7	8	9	
1	·03	2·50	..	2·50	·98	·24	1·40	·89	
2	·07	2·50	..	2·50	·97	·35	2·04	1·30	
3	·11	2·50	..	2·50	·90	·46	2·71	1·70	
4	·18	2·50	..	2·50	·92	·55	3·21	2·04	
5	·24	2·50	..	2·50	·90	·62	3·58	2·28	
6	·33	2·50	..	2·50	·86	·73	4·21	2·68	
7	·38	2·50	..	2·50	·84	·82	4·14	2·65	
8	·45	2·50	..	2·50	·82	·80	4·59	2·92	
9	·54	2·50	..	2·50	·78	·85	4·89	3·11	
10	·63	2·50	..	2·50	·74	·87	5·00	3·19	
11	·72	2·50	..	2·50	·71	·89	5·14	3·27	Least Modular Limit.
12	·81	2·50	..	2·50	·67	·90	5·17	3·29	
13	·90	2·50	..	2·50	·64	·93	5·37	3·41	
14	·98	2·50	..	2·50	·60	·96	5·54	3·52	
15	1·07	2·50	..	2·50	·57	·99	5·71	3·63	
16	1·16	2·50	..	2·50	·53	1·01	5·80	3·69	
17	1·25	2·50	..	2·50	·50	1·05	6·03	3·83	
18	1·36	2·50	..	2·50	·47	1·12	6·44	4·10	
19	1·38	2·50	..	2·50	·44	1·12	6·45	4·11	
20	1·48	2·50	..	2·50	·40	1·11	6·43	4·09	
21	1·59	2·50	..	2·50	·36	1·12	6·47	4·12	
	Y = ·51				**Set No. 4.**			B = ·32	
1	·02	2·51	..	2·51	·99	·24	1·06	·66	
2	·06	2·51	..	2·51	·97	·35	1·54	1·26	
3	·11	2·51	..	2·51	·95	·46	2·02		
4	·17	2·51	..	2·51	·93	·55	2·42	1·50	
5	·24	2·51	..	2·51	·90	·63	2·75	1·70	
6	·32	2·51	..	2·51	·87	·70	3·05	1·90	
7	·38	2·50	..	2·50	·84	·75	3·26	2·04	
8	·45	2·50	..	2·50	·92	·81	3·51	2·09	
9	·53	2·50	..	2·50	·78	·87	3·80	2·39	
10	·61	2·50	..	2·50	·75	·92	4·01	2·52	
11	·69	2·50	..	2·50	·72	·97	4·21	2·64	Least Modular Limit.
12	·77	2·50	..	2·50	·69	1·03	4·47	2·81	
13	·85	2·50	..	2·50	·66	1·09	4·74	2·97	
14	·94	2·50	..	2·50	·62	1·13	4·93	3·09	
15	1·03	2·50	..	2·50	·58	1·16	5·08	3·18	
16	1·12	2·50	..	2·50	·55	1·22	5·33	3·34	
17	1·20	2·50	..	2·50	·51	1·27	5·54	3·47	
18	1·30	2·50	..	2·50	·48	1·35	5·90	3·70	
19	1·38	2·50	..	2·50	·44	1·43	6·32	3·90	
20	1·49	2·55	..	2·55	·41	1·48	6·48	4·01	
21	1·59	2·54	..	2·54	·37	1·48	6·49	4·00	
22	1·69	2·54	..	2·54	·23	1·42	6·47	3·99	
23	1·79	2·54	..	2·54	·29	1·48	5·49	4·00	

APPENDIX IV—*concld.*

Y = ·248 **Set No. 5.** B = ·32

Serial No.	Working Head.	H on Crest.	Loss of head in entry.	Effective H.	Drowning Ratio.	Discharge.	Value of C in Formula $q = C\,By\sqrt{h}$	Value of K in Formula $q = K\,B(H^{\frac{3}{2}} - h^{\frac{3}{2}})$.	
1	2	3	4	5	6	7	8	9	
1	·03	2·48	..	2·48	·98	·12	1·05	·56	
2	·08	2·48	..	2·48	·96	·17	1·48	·86	
3	·13	2·48	..	2·48	·94	·22	1·88	1·10	
4	·20	2·48	..	2.48	·91	·27	2·32	1·35	
5	·27	2·48	..	2·48	·89	·32	2·77	1·61	
6	·35	2·48	..	2·48	·85	·37	3·16	1·84	
7	·43	2·48	..	2·48	·82	·42	3·60	2·10	
8	·52	2·48	..	2·48	·78	·47	4·05	2·36	
9	·61	2·48	..	2·48	·74	·52	4·46	2·60	
10	·70	2·48	..	2·48	·71	·57	4·85	2·83	
11	·80	2·48	..	2·48	6·77	·63	5·35	3·12	Least Modular Limit.
12	·91	2·48	..	2·48	6·33	·67	5·71	3·33	
13	1·01	2·48	..	2·48	5·92	·71	5·94	3·46	
14	1·12	2·48	..	2·48	5·48	·71	6·03	3·52	
15	1·22	2·48	..	2·48	5·08	·72	6·16	3·59	
16	1·29	2·48	..	2.48	4·75	·73	6·22	3·63	
17	1·38	2·48	..	2·48	·44	·95	6·43	3·75	
18	1·54	2·48	..	2·48	·40	·85	7·28	4·25	
19	1·58	2·48	..	2·48	·36	·85	7·27	4·24	
20	1·68	2·48	..	2·48	·33	.85	7·28	4·25	
21	1·79	2·48	..	2·48	·27	·85	7·28	4·24	

APPENDIX V.

8/10TH DISCHARGE OBSERVATIONS FOR A. P. M. TYPE A (MODIFIED ROOF BLOCK).

EXPERIMENT No. 3.

Y = 1·02 — **Set No. 1.** — B = ·32

Serial No.	Working Head.	H on Crest.	Loss of head in entry.	Effective H.	Drowning Ratio.	Discharge.	Value of C in Formula $q = CBy\sqrt{h}$	Value of K in Formula $q = KB\,(H^{\frac{3}{2}} - h^{\frac{3}{2}})$	
1	2	3	4	5	6	7	8	9	
1	·03	1·98	..	1·98	·98	·49	1·56	·85	
2	·07	1·98	..	1·98	·96	·72	2·29	1·25	
3	·11	1·98	..	1·98	·94	1·10	3·48	1·90	
4	·16	1·97	..	1·97	·91	1·39	4·43	2·41	
5	·22	1·97	..	1·97	·88	1·65	5·24	2·85	
6	·28	1·96	..	1·96	·85	1·77	5·67	3·08	
7	·35	1·96	..	1·96	·82	2·14	6·82	3·71	
8	·43	1·96	..	1·96	·78	2·45	7·82	4·25	
9	·49	1·99	..	1·99	·75	2·75	8·66	4·78	
10	·59	1·98	..	1·98	·70	2·79	8·84	4·81	Least
11	·70	1·98	..	1·98	·64	2·76	8·74	4·76	Modular
12	·80	1·98	..	1·98	·59	2·76	8·73	4·75	Limit.
13	·90	1·99	..	1·99	1·99	2·79	8·77	4·78	
14	·99	1·99	..	1·99	1·99	2·78	8·74	4·76	
15	1·09	1·99	..	1·99	1·99	2·78	8·75	4·77	
16	1·09	1·98	..	1·98	1·98	2·76	8·73	4·75	
17	1·28	1·98	..	1·98	1·98	2·76	8·74	4·77	
18	1·38	1·97	..	1·97	1·97	2·75	8·74	4·75	
19	1·49	1·97	..	1·97	1·97	2·76	8·79	4·78	
20	1·60	1·97	..	1·97	1·97	2·76	8·76	4·76	
21	1·70	1·98	..	1·98	1·97	2·76	8·73	4·75	
	Y = ·75				**Set No. 2.**			B = ·32	
1	·04	1·98	..	1·98	0·98	0·34	1·25	·75	
2	·07	1·98	..	1·98	0·96	0·47	1·79	1·04	
3	·11	1·98	..	1·98	0·94	0·75	2·84	1·65	
4	·16	1·98	..	1·98	0·92	0·95	3·60	2·09	
5	·22	2·00	..	2·00	0·89	1·12	4·60	2·46	
6	·30	2·00	..	2·00	0·85	1·24	5·09	2·72	
7	·38	2·00	..	2·00	·81	1·41	5·76	3·08	
8	·46	2·00	..	2·00	·77	1·61	6·60	3·53	
9	·52	2·00	..	2·00	·74	1·90	7·76	4·15	
10	·60	2·00	..	2·00	·70	2·15	8·80	4·70	Least
11	·70	2·00	..	2·00	·65	2·15	8·78	4·69	Modular
12	·80	2·00	..	2·00	·60	2·16	8·82	4·71	Limit.
13	·90	1·99	..	1·99	·54	2·15	8·88	4·72	
14	1·00	1·99	..	1·99	·49	2·14	8·85	4·70	
15	1·10	1·98	..	1·98	·44	2·14	8·81	4·71	
16	1·20	1·98	..	1·98	·39	2·13	8·06	4·68	
17	1·31	2·00	..	2·00	·34	2·16	8·83	4·72	
18	1·41	2·00	..	2·00	·29	2·16	8·82	4·71	
19	1·52	2·00	..	2·00	·24	2·16	8·83	4·72	
20	1·62	1·99	..	1·99	·18	2·16	8·92	4·74	
21	1·73	1·98	..	1·98	·12	2·13	8·10	4·70	

APPENDIX V—*contd.*

Y = ·60 **Set No. 3.** B = ·32.

Serial No.	Working Head.	H. on Crest.	Loss of head in entry.	Effective H.	Drowning Ratio.	Discharge.	Value of C. in Formula $q = CBy\sqrt{h}$	Value of K in Formula $q = KB(H^{\frac{3}{2}} - h^{\frac{3}{2}})$	
1	2	3	4	5	6	7	8	9	
1	0·07	1·96	..	1·96	·96	·27	1·24	·75	
2	·11	1·96	..	1·96	·94	·38	1·73	1·05	
3	·18	1·98	..	1·98	·90	·54	2·43	1·46	
4	·25	1·98	..	1·98	·87	·72	3·22	1·91	
5	·33	1·98	..	1·98	·83	·81	3·62	2·19	
6	·41	1·97	..	1·97	·79	1·04	4·65	2·81	
7	·50	1·99	..	1·99	·74	1·24	5·48	3·32	
8	·59	1·99	..	1·99	·70	1·38	6·13	3·71	
9	·67	1·99	..	1·99	·66	1·59	7·03	4·26	Leastl
10	·75	1·98	..	1·98	·62	1·72	7·66	4·62	Modular
11	·85	1·98	..	1·98	·57	1·72	7·68	4·63	Limit
12	·95	2·00	..	2·00	·52	1·72	7·59	4·60	
13	1·05	2·00	..	2·00	·47	1·73	7·66	4·63	
14	1·16	2·00	..	2·00	·42	1·72	7·62	4·61	
15	1·26	2·00	..	2·00	·37	1·71	7·88	4·59	
16	1·36	1·98	..	1·98	·31	1·72	7·68	4·63	
17	1·46	1·98	..	1·98	·26	1·72	7·66	4·62	
18	1·56	1·98	..	1·98	·21	1·72	7·68	4·63	
19	1·67	1·99	..	1·99	·16	1·72	7·63	4·62	

Set No. 4.

Y = 1·25 and B = ·32

1	0·02	2·50	..	2·50	·99	·81	1·82	1·99	
2	0·05	2·50	..	2·50	·87	1·23	2·77	1·99	
3	0·09	2·50	..	2·50	·96	1·62	3·68	1·51	
4	0·14	2·50	..	2·50	·94	1·86	4·19	1·99	
5	0·19	2·50	..	2·50	·92	1·97	4·42	2·28	
6	0·25	2·50	..	2·50	·90	2·30	5·18	2·41	
7	0·32	2·50	..	2·50	·87	2·52	5·65	2·82	
8	0·40	2·50	..	2·50	·84	2·71	6·09	3·09	Least
9	0·47	2·50	..	2·50	·81	1·96	6·65	3·31	Modular
10	0·54	2·48	..	2·48	·78	3·32	7·54	3·61	Limit.
11	0·61	2·48	..	2·48	·75	3·58	8·14	4·08	
12	0·70	2·49	..	2·49	·71	3·70	8·32	4·41	
13	0·80	2·49	..	2·49	·67	3·70	8·32	4·55	
14	0·92	2·49	..	2·49	·63	3·71	8·34	4·56	
15	1·03	2·50	..	2·50	·58	3·71	8·33	4·54	
16	1·15	2·50	..	2·50	·54	3·70	8·32	4·53	
17	1·28	2·50	..	2·50	·48	3·72	8·36	4·55	

APPENDIX V—*concld.*

Y=1·0 **Set No. 5.** B= ·32

Serial No.	Working Head.	H. on Crest.	Loss of head in entry.	Effective H.	Drowning Ratio.	Discharge.	Value of C in formula $q=CBy\sqrt{h}$.	Value of K in Formula $q=KB\,(H^{\frac{3}{2}}-h^{\frac{3}{2}})$	
1	2	3	4	5	6	7	8	9	
1	0·03	2·50	..	2·50	·98	·56	1·45	0·84	
2	·07	2·50	..	2·50	·97	·73	1·86	1·08	
3	·10	2·50	..	2·50	·96	·79	2·04	1·18	
4	·14	2·50	..	2·50	·94	·90	2·30	1·32	
5	·19	2·50	..	2·50	·92	·99	2·51	1·47	
6	·24	2·50	..	2·50	·90	1·08	2·78	1·61	
7	·29	2·50	..	2·50	·88	1·30	3·33	1·93	
8	·35	2·50	..	2·50	·86	1·45	3·71	2·15	
9	·41	2·50	..	2·50	·83	1·70	3·34	2·51	
10	·48	2·50	..	2·50	·80	1·86	4·75	2·75	
11	·55	2·50	..	2·50	·78	2·06	5·26	3·04	Least Modular Limit.
12	·63	2·50	..	2·50	·74	0·20	5·61	3·25	
13	·71	2·50	..	2·50	·71	2·51	6·41	3·71	
14	·79	2·50	..	2·50	·68	2·92	7·47	4·32	
15	·88	2·50	..	2·50	·68	3·04	7·78	4·50	
16	·98	2·50	..	2·50	·60	3·05	7·79	4·51	
17	1·09	2·50	..	2·50	·56	3·03	7·75	4·48	
18	1·20	2·50	..	2·50	·50	3·05	7·79	4·51	
19	1·30	2·50	..	2·50	·40	3·04	7·76	4·49	
20	1·40	2·50	..	2·50	·40	3·08	7·78	4·50	

Set No. 6.

Y= ·75 and B= ·32

1	·04	2·50	..	2·50	·98	·34	1·10	·66	
2	0·08	2·50	..	2·50	·96	·50	1·59	·96	
3	·12	2·50	..	2·50	·95	·60	1·90	1·15	
4	·16	2·50	..	2·50	·93	·68	2·16	1·31	
5	·21	2·50	..	2·50	·91	·78	2·47	1·50	
6	·26	2·50	..	2·50	·89	·88	2·80	1·70	
7	·33	2·50	..	2·50	·86	·99	3·15	1·91	
8	·40	2·48	..	2·48	·83	1·06	3·39	2·05	
9	·48	2·48	..	2·48	·80	1·17	3·71	2·25	
10	·56	2·48	..	2·48	·77	1·26	4·02	2·43	
11	·64	2·48	..	2·48	·74	1·38	4·39	2·66	Least Modular Limit.
12	·71	2·48	..	2·48	·71	1·49	4·72	2·88	
13	·78	2·48	..	2·48	·68	1·63	5·16	2·12	
14	·85	2·48	..	2·48	·65	1·74	5·52	2·35	
15	·93	2·48	..	2·48	·62	1·89	6·00	3·63	
16	1·00	2·50	..	2·50	·60	2·27	7·16	4·34	
17	1·08	2·50	..	2·50	·56	2·33	7·35	4·45	
18	1·18	2·50	..	2·50	·52	2·33	7·37	4·46	
19	1·28	2·50	..	2·50	·48	2·33	7·37	4·46	
20	1·28	2·50	..	2·50	·44	2·33	7·35	4·45	
21	1·28	2·50	..	2·50	·40	2·34	7·38	4·47	

APPENDIX VI.

DISCHARGE OBSERVATIONS FOR A.P.M. TYPE A (STANDARD ROOF BLOCK).

EXPERIMENT 4 FOR DIFFERENT WIDTHS, PART I.

Set No. 1.

Y = ·5 B = ·2

Serial No.	Working Head.	H on Crest.	Loss of head in entry.	Effective H.	Drowning Ratio.	Discharge.	Value of C in Formula $q = CBy\sqrt{h}$	Value of K in Formula $q = KB\,(H^{\frac{3}{2}} - h^{\frac{3}{2}})$	
1	2	3	4	5	6	7	8	9	
1	1·52	1·84	..	1·84	·17	·82	7·10	4·35	
2	1·42	1·84	..	1·84	·22	·81	7·05	4·32	
3	1·22	1·84	..	1·84	·33	·81	7·02	4·30	
4	1·14	1·84	..	1·84	·36	·81	7·04	4·31	
5	1·04	1·84	..	1·84	·43	·82	7·08	4·34	Least Modular Limit.
6	·94	1·84	..	1·84	·50	·51	7·05	4·32	
7	·86	1·84	..	1·84	·53	·78	6·78	4·15	
8	·77	1·84	..	1·84	·58	·73	6·34	3·87	
9	·67	1·84	..	1·84	·63	·67	5·79	3·54	
10	·59	1·84	..	1·84	·67	·68	5·87	3·59	

Set No. 2.

Y = ·6 B = ·2

1	..	1·90	..	1·90	·23	·96	7·06	4·25	
2	..	1·90	..	1·90	·28	·96	7·05	4·24	
3	..	1·90	..	1·90	·34	·96	7·08	4·26	
4	..	1·90	..	1·90	·40	·95	7·01	4·22	
5	..	1·90	..	1·90	·48	·96	7·05	4·24	Least Modular Limit.
6	..	1·90	..	1·90	·53	·91	6·66	4·01	
7	..	1·90	..	1·90	·57	·86	6·30	3·78	
8	..	1·90	..	1·90	·63	·77	5·70	3·42	
9	..	1·90	..	1·90	·68	·75	5·50	3·30	
10	..	1·90	..	1·90	·72	·70	5·10	3·09	

APPENDIX VI.—*concld.*

Set No. 3.

Y= ·8 B= ·2

Serial No.	Working Head.	H on Crest.	Loss of head in entry.	Effective H.	Drowning Ratio.	Discharge.	Value of C in Formula $q=CBY\sqrt{h}$.	Value of K in Formula $q=KB\,(H^{\frac{3}{2}}-h,^{\frac{3}{2}})$	
1	2	3	4	5	6	7	8	9	
1	1·28	1·86	..	1·86	·31	1·21	7·42	4·19	
2	1·18	1·86	..	1·86	·36	1·21	7·43	4·20	
3	·98	1·86	..	1·86	·47	1·22	7·46	4·22	
4	·89	1·86	..	1·86	·52	1·21	7·45	4·21	
5	·79	1·86	..	1·86	·57	1·21	7·44	4·20	Least
6	·69	1·86	..	1·86	·63	1·18	7·23	4·08	Modular
7	·61	1·86	..	1·86	·67	1·00	6·17	3·49	Limit.
8	·54	1·86	..	1·86	·71	·92	5·67	3·20	
9	·44	1·86	..	1·86	·76	·85	5·24	2·95	
10	·33	1·86	..	1·86	·82	·75	4·63	2·51	

Set No. 4.

Y=1·0 B= 2.

1	1·53	1·85	..	1·85	·17	1·42	7·74	4·12	
2	1·43	1·85	..	1·85	·22	1·43	7·76	4·13	
3	1·37	1·85	..	1·85	·26	1·43	7·80	4·15	
4	1·27	1·85	..	1·85	·31	1·43	7·76	4·13	
5	1·14	1·84	..	1·84	·26	1·42	7·78	4·13	
6	1·04	1·84	..	1·84	·43	1·42	7·74	4·11	
7	·99	1·86	..	1·86	·46	1·42	7·65	4·08	Least
8	·88	1·86	..	1·86	·52	1·41	7·64	4·07	Modular
9	·79	1·88	..	1·88	·58	1·42	7·60	4·06	Limit.
10	·68	1·88	..	1·88	·63	1·42	7·56	4·05	
11	·59	1·88	..	1·88	·68	1·37	7·33	3·92	
12	·51	1·89	..	1·89	·73	1·15	6·10	3·20	
13	·41	1·89	..	1·89	·78	1·00	5·32	2·86	
14	·34	1·88	..	1·88	·80	·91	4·86	2·60	

APPENDIX VII.

DISCHARGE OBSERVATIONS FOR A. P. M. TYPE A. (STANDARD ROOF BLOCK).

EXPERIMENT No. 4 FOR DIFFERENT WIDTHS PART II.

Y = ·3 **Set No. I.** B = ·5

Serial No.	Working Head.	H. on Crest.	Loss of head in entry.	Effective H.	Drowning Ratio.	Discharge.	Value of C in formula $q = C B y \sqrt{h}$	Value of K in Formula $q = K B (H^{\frac{3}{2}} - h^{\frac{3}{2}})$	
1	2	3	4	5	6	7	8	9	
1	1·63	1·85	..	1·85	·11	1·39	7·49	4·77	
2	1·58	1·85	..	1·85	·14	1·39	7·48	4·76	
3	1·56	1·86	..	1·86	·16	1·39	7·46	4·75	
4	1·51	1·86	..	1·86	·18	1·40	7·52	4·77	
5	1·46	1·86	..	1·86	·21	1·41	7·52	4·76	
6	1·36	1·86	..	1·86	·26	1·39	7·45	4·74	Least
7	1·26	1·86	..	1·86	·32	1·38	7·40	4·71	Modular
8	1·18	1·88	..	1·88	·37	1·39	7·38	4·70	Limit.
9	1·06	1·88	..	1·88	·43	1·39	7·38	4·70	
10	·93	1·88	..	1·88	·50	1·36	7·26	4·62	
11	·88	1·88	..	1·88	·53	1·18	6·30	4·00	
12	·83	1·88	..	1·88	·56	1·12	6·00	3·80	
13	·76	1·88	..	1·88	·60	1·00	5·32	3·38	
	Y = ·4				**Set No. 2.**			B = ·5	
1	1·57	1·84	..	1·84	·14	1·80	7·52	4·70	
2	1·54	1·84	..	1·84	·16	1·81	7·55	4·72	
3	1·44	1·84	..	1·84	·21	1·80	7·53	4·71	
4	1·34	1·84	..	1·84	·27	1·80	7·52	4·70	
5	1·27	1·84	..	1·84	·30	1·81	7·57	4·73	Least
6	1·17	1·84	..	1·84	·36	1·80	7·50	4·69	Modular
7	1·07	1·84	..	1·84	·41	1·80	7·53	4·70	Limit.
8	·99	1·84	..	1·84	·46	1·80	7·54	4·71	
9	·89	1·84	..	1·84	·51	1·80	7·52	4·70	
10	·76	1·84	..	1·84	·58	1·74	7·27	4·55	
11	·69	1·84	..	1·84	·62	1·25	5·25	3·28	
	Y = ·5				**Set No. 3.**			B = ·5	
1	1·53	1·84	..	1·84	·16	2·18	7·53	4·61	
2	1·46	1·84	..	1·84	·20	2·20	7·60	4·66	
3	1·44	1·84	..	1·84	·21	2·19	7·57	4·63	
4	1·36	1·84	..	1·84	·26	2·20	7·60	4·66	
5	1·26	1·84	..	1·84	·31	2·18	7·53	4·61	
6	1·16	1·84	..	1·84	·37	2·19	7·58	4·64	Least
7	1·12	1·84	..	1·84	·39	2·23	7·71	4·70	Modular
8	1·02	1·84	..	1·84	·44	2·20	7·60	4·66	Limit.
9	·92	1·84	..	1·84	·50	2·16	7·49	4·58	
10	·82	1·84	..	1·84	·55	2·19	7·58	4·64	
11	·70	1·84	..	1·84	·62	2·11	7·32	4·48	
12	·66	1·84	..	1·84	·64	1·85	6·42	3·97	
13	·60	1·84	..	1·84	·67	1·69	5·86	3·58	

APPENDIX VII—*concld.*

Y = ·6 **Set No. 4.** B = ·6

Serial No.	Working Head.	H. on Crest.	Loss of head in entry.	Effective H.	Drowning Ratio.	Discharge.	Value of C. in Fromula $q = CB y\sqrt{h}$	Value of K in Formula $q = K B (H^{\frac{3}{2}} - h^{\frac{3}{2}})$	
1	2	3	4	5	6	7	8	9	
1	1·33	1·85	..	1·85	·28	2·54	7·59	4·55	
2	1·23	1·85	..	1·85	·33	2·55	7·60	4·56	
3	1·13	1·85	..	1·85	·38	2·56	7·63	4·58	
4	1·07	1·85	..	1·85	·42	2·56	7·65	4·59	
5	·97	1·85	..	1·85	·47	2·52	7·53	4·51	
6	·90	1·85	..	1·85	·51	2·52	7·54	4·51	Least Modular Limit.
7	·82	1·85	..	1·85	·55	2·50	7·46	4·48	
8	·72	1·85	..	1·85	·61	2·50	7·46	4·47	
9	·62	1·85	..	1·85	·66	2·26	6·73	4·04	
10	·58	1·85	..	1·85	·68	1·98	5·90	3·54	
11	·53	1·85	..	1·85	·71	1·82	5·42	3·25	
12	·48	1·85	..	1·85	·74	1·53	4·56	2·73	

Y = ·7 **Set No. 5.** B = ·5

1	1·49	1·86	..	1·86	·20	2·89	7·68	4·50	
2	1·38	1·86	..	1·86	·25	2·89	7·67	4·49	
3	1·30	1·86	..	1·86	·30	2·90	7·70	4·51	
4	1·24	1·86	..	1·86	·33	2·87	7·63	4·47	
5	1·16	1·86	..	1·86	·36	2·86	7·60	4·45	
6	1·06	1·86	..	1·86	·43	2·88	7·66	4·48	
7	·92	1·80	..	1·80	·58	2·81	7·68	4·47	Least Modular Limit.
8	·82	1·80	..	1·80	·54	2·82	7·70	4·47	
9	·75	1·80	..	1·80	·58	2·81	7.68	4·46	
10	·65	1·80	..	1·80	·63	2·80	7·66	4·45	
11	·54	1·80	..	1·80	·70	2·68	7·31	4·26	
12	·50	1·80	..	1·80	·72	2·38	6·48	3·77	

APPENDIX VIII.

DISCHARGE OBSERVATIONS FOR A.P.M. TYPE B (STANDARD ROOF BLOCK).

EXPERIMENT No. 5, PART I.

y = ·3 **Set No. 1.** B = ·5

Serial No.	Working Head.	H on Crest.	Loss of head in entry.	Effective H.	Drowning Ratio.	Discharge.	Value of C in Formula $q=CBy\sqrt{h}$	Value of K in formula $q=KB\,(H^{\frac{3}{2}}-h^{\frac{3}{2}})$	
1	2	3	4	5	6	7	8	9	
1	·96	1·46	..	1·46	·34	1·22	7·60	4·77	Least Modul Limit.
2	·86	1·46	..	1·46	·41	1·22	7·57	4·74	
3	·71	1·46	..	1·46	·51	1·22	7·57	4·75	
4	·61	1·46	..	1·46	·58	1·22	7·59	4·76	
5	·51	1·46	..	1·46	·65	1·14	7·09	4·45	
6	·45	1·46	..	1·46	·69	·96	6·00	3·70	
7	·34	1·46	..	1·46	·76	·82	5·08	3·18	
	y = ·4				**Set No. 2.**			B = ·5	
	1·36	1·46	..	1·46	·06	1·55	7·53	4·61	Least Modul Limit.
2	·86	1·46	..	1·46	·41	1·55	7·54	4·62	
3	·66	1·46	..	1·46	·54	1·55	7·55	4·62	
4	·56	1·46	..	1·46	·61	1·54	7·50	4·60	
5	·46	1·46	..	1·46	·68	1·54	7·50	4·59	
6	·39	1·46	..	1·46	·73	1·22	5·96	3·65	
7	·30	1·46	..	1·46	·80	1·03	5·00	3·06	
	y = ·5				**Set No. 3.**			B = ·5	
1	1·36	1·46	..	1·46	·06	1·84	7·53	4·48	Least Modul Limit.
2	·96	1·46	..	1·46	·34	1·83	7·51	4·46	
3	·66	1·46	..	1·46	·54	1·84	7·52	4·47	
4	·56	1·46	..	1·46	·61	1·83	7·50	4·46	
5	·46	1·46	..	1·46	·68	1·83	7·49	4·45	
6	·36	1·46	..	1·46	·75	1·59	6·51	3·87	
7	·31	1·46	..	1·46	·78	1·29	5·30	3·15	
	y = ·6				**Set No. 4.**			B = ·5	
1	1·31	1·46	..	1·46	·10	2·08	7·50	4·31	Least Modul Limit.
2	·86	1·46	..	1·46	·41	2·08	7·50	4·31	
3	·66	1·46	..	1·46	·54	2·08	7·51	4·32	
4	·56	1·46	..	1·46	·61	2·08	7·50	4·31	
5	·46	1·46	..	1·46	·68	2·08	7·50	4·32	
6	·36	1·46	..	1·46	·75	2·08	7·50	4·31	
7	·29	1·46	..	1·46	·80	1·64	5·90	3·39	
8	·21	1·46	..	1·46	·85	1·23	4·44	2·51	

APPENDIX IX.

DISCHARGE OBSERVATIONS FOR A. P. M. TYPE B. (STANDARD ROOF BLOCK.)

EXPERIMENT NO. 5, PART II.

Y = ·4 **Set No. 1.** B = ·5

Serial No.	Working Head.	H. on Crest.	Loss of head in entry.	Effective H.	Drowning Ratio.	Discharge.	Value of C in Formula $q = C B y \sqrt{h}$	Value of K in Formula $q = KB (H^{\frac{3}{2}} - h^{\frac{3}{2}})$	
1	2	3	4	5	6	7	8	9	
1	1·74	1·84	Nil	1·84	·05	1·77	7·40	4·62	
2	1·64	1·84	,,	1·84	·10	1·78	7·41	4·64	
3	1·54	1·84	,,	1·84	·16	1·77	7·40	4·62	
4	1·44	1·84	..	1·84	·21	1·77	7·39	4·62	
5	1·34	1·84	..	1·84	·27	1·77	7·40	4·62	Least Modular Limit.
6	1·01	1·82	..	1·82	·44	1·76	7·40	4·62	
7	·87	1·82	..	1·82	·52	1·76	7·41	4·62	
8	·77	1·82	..	1·82	·57	1·76	7·40	4·62	
9	·72	1·82	..	1·82	·60	1·75	7·38	4·61	
10	·57	1·82	..	1·82	·68	1·65	6·93	4·33	

Y = ·5 **Set No. 2.** B = ·5

1	1·78	1·86	..	1·86	·04	2·11	7·24	4·43	
2	1·66	1·84	..	1·84	·09	2·09	7·25	4·43	
3	1·60	1·85	Nil	1·85	·13	2·10	7·24	4·43	
4	1·53	1·85	,,	1·85	·17	2·10	7·25	4·44	
5	1·25	1·85	,,	1·85	·32	2·10	7·24	4·43	
6	·97	1·85	..	1·85	·47	2·10	7·24	4·44	Least Modular Limit.
7	·87	1·85	..	1·85	·53	2·10	7·25	4·44	
8	·72	1·84	..	1·84	·60	2·05	7·12	4·36	
9	0·65	1·85	..	1·85	·64	2·04	7·05	4·32	
10	·54	1·84	..	1·84	·70	1·87	6·48	3·96	
11	·46	1·84	..	1·84	·75	1·62	5·60	3·43	

APPENDIX IX—*concld.*

Y = ·6 **Set No. 3.** B = ·5

Serial No.	Working Head.	H. on Crest.	Loss of head in entry.	Effective H.	Drowning Ratio.	Discharge.	Value of C in Formula $q = C B y \sqrt{h}$.	Value of K in Formula $q = K B (H^{\frac{3}{2}} - h^{\frac{3}{2}})$	
1	2	3	4	5	6	7	8	9	
1	1·64	1·84	Nil	1·84	·10	2·40	7·20	4·31	}
2	1·44	1·84	,,	1·84	·21	2·40	7·20	4·31	
3	1·22	1·84	,,	1·84	·33	2·40	7·20	4·31	
4	1·04	1·84	..	1·84	·43	2·40	7·21	4·31	
5	·91	1·81	..	1·81	·50	2·37	7·20	4·30	
6	·79	1·81	..	1·81	·56	2·37	7·20	4·30	Least Modular Limit.
7	·69	1·81	..	1·81	·61	2·37	7·21	4·31	
8	·59	1·81	..	1·81	·67	2·37	7·20	4·30	
9	·46	1·81	..	1·81	·74	2·32	7·05	4·21	
10	·41	1·81	..	1·81	·77	2·24	6·81	4·07	
11	·36	1·81	..	1·81	·80	1·81	5·51	3·29	
12	·29	1·81	..	1·81	·84	1·28	3·88	2·31	}

Y = ·8. **Set No. 4.** B = ·5

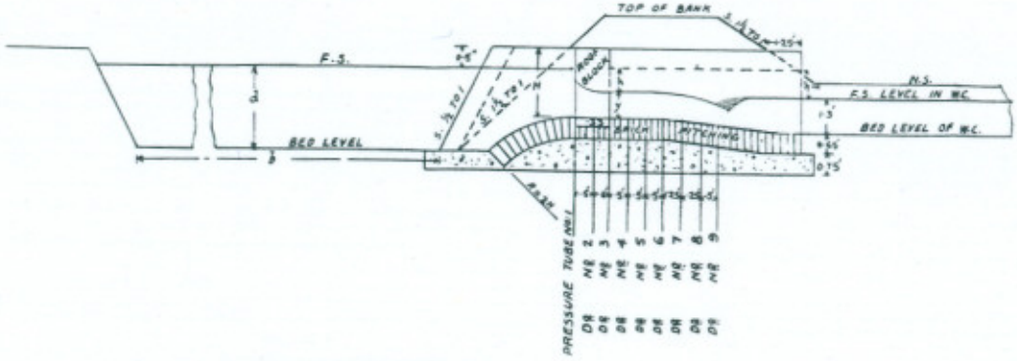
1	1·60	1·80	Nil	1·80	·11	2·88	7·20	4·07	}
2	1·55	1·80	,,	1·80	·14	2·88	7·20	4·07	
3	1·52	1·82	,,	1·82	·16	2·90	7·20	4·08	
4	1·12	1·82	..	1·82	·38	2·90	7·20	4·08	
5	1·02	1·82	..	1·82	·44	2·91	7·20	4·08	
6	·92	1·82	..	1·82	·50	2·90	7·20	4·08	Least Modular Limit.
7	·82	1·82	..	1·82	·55	2·90	7·19	4·08	
8	·72	1·82	..	1·82	·60	2·91	7·20	4·08	
9	·62	1·82	..	1·82	·65	2·90	7·20	4·08	
10	·55	1·82	Nil	1·82	·70	2·62	6·50	3·68	
11	·50	1·82	,,	1·82	·72	2·12	5·28	2·99	}

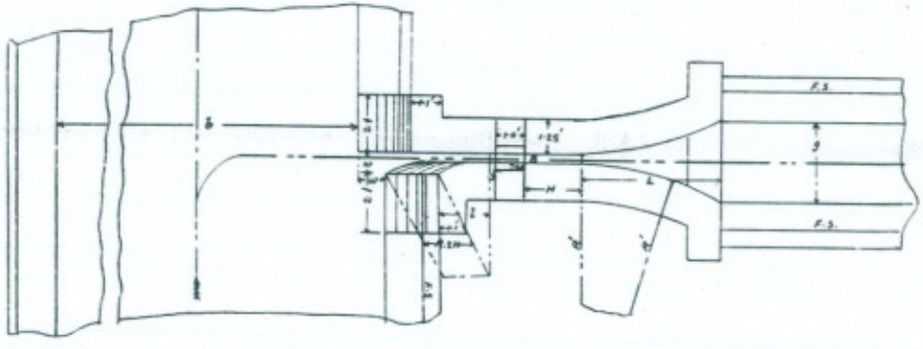
PLATE No 1.

TYPE DESIGN
OF
ADJUSTABLE PROPORTIONAL MODULE

SCALE = 1/50

AS PER APPENDIX E OF I.B. PAPER No 26.





b = BED WIDTH
d = F.S. DEPTH } OF CHANNEL BELOW OUTLET.
Q = DISCHARGE

q = DISCHARGE OF OUTLET. y = HEIGHT OF ORIFICE.

H = DEPTH OF FLOOR OF OUTLET BELOW W.S.

$B = \frac{q}{1.3 \times y\sqrt{h}}$ WIDTH OF OPENING { h = HEAD ABOVE TOP OF ORIFICE. h_m = WORKING HEAD OF OUTLET.

$W = \frac{q}{4}(\frac{b}{2} + \frac{d}{2})$ = WIDTH AT MOUTH OF APPROACH = SET BACK OF U/S WINGS.

l = LENGTH OF APPROACH CURVE $= \sqrt{(W-B)(4H-W+B)}$

L = LENGTH OF OUTFALL.

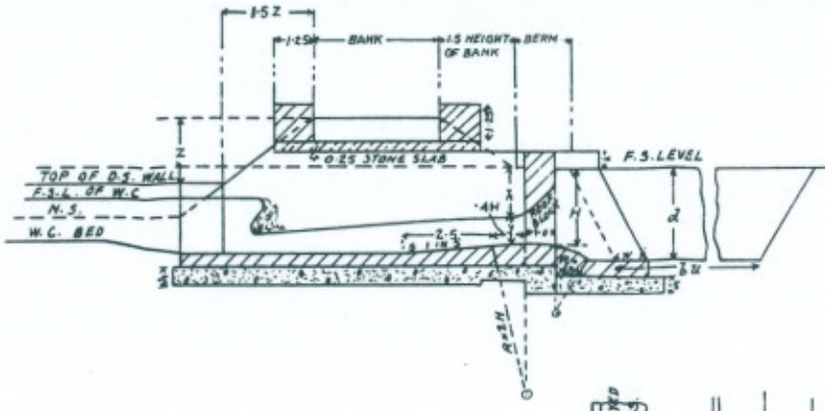
$R = 2H$ = RADIUS OF APPROACH CURVE.

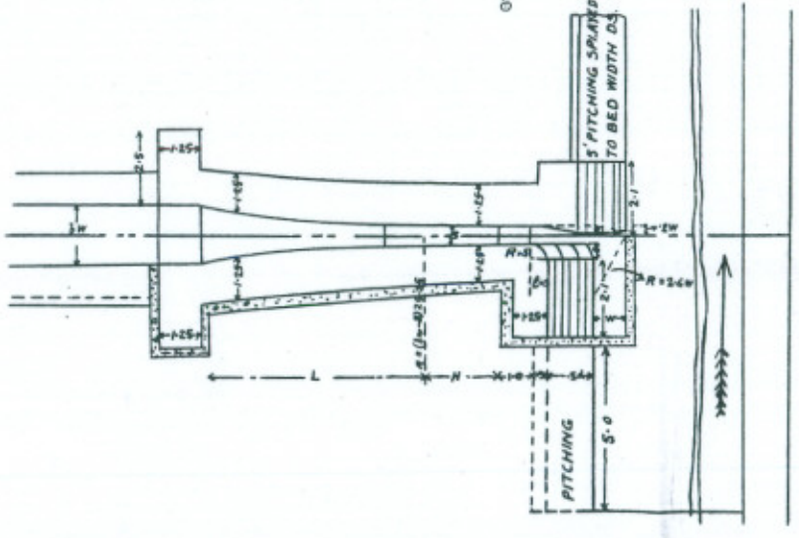
$R' = \frac{q-B}{4} + \frac{L^2}{4-B}$ = RADIUS OF OUTFALL.

HEIGHT OF SIDE PLATE = NEAREST MULTIPLE OF 3" IN EXCESS OF $H + 0.5$.

TYPE DESIGN OF SILT CONDUCIVE OUTLET TYPE A
SET AT 8/10 TH.

PLATE No. 2.





BED WIDTH IN CHANNEL U.S. OF OUTLET $= b_u$.
DEPTH IN CHANNEL U.S. OF OUTLET $= d$.
DISCHARGE IN CHANNEL U.S. OF OUTLET $= Q$.
BED WIDTH IN CHANNEL D.S. OF OUTLET $= b_d$.
DISCHARGE OF OUTLET $= q$.
DEPTH ON CREST $H = \cdot 8\,d$
DEPRESSION OF ROOF BLOCK $= h$.
WIDTH OF A.P.M. $= B$.

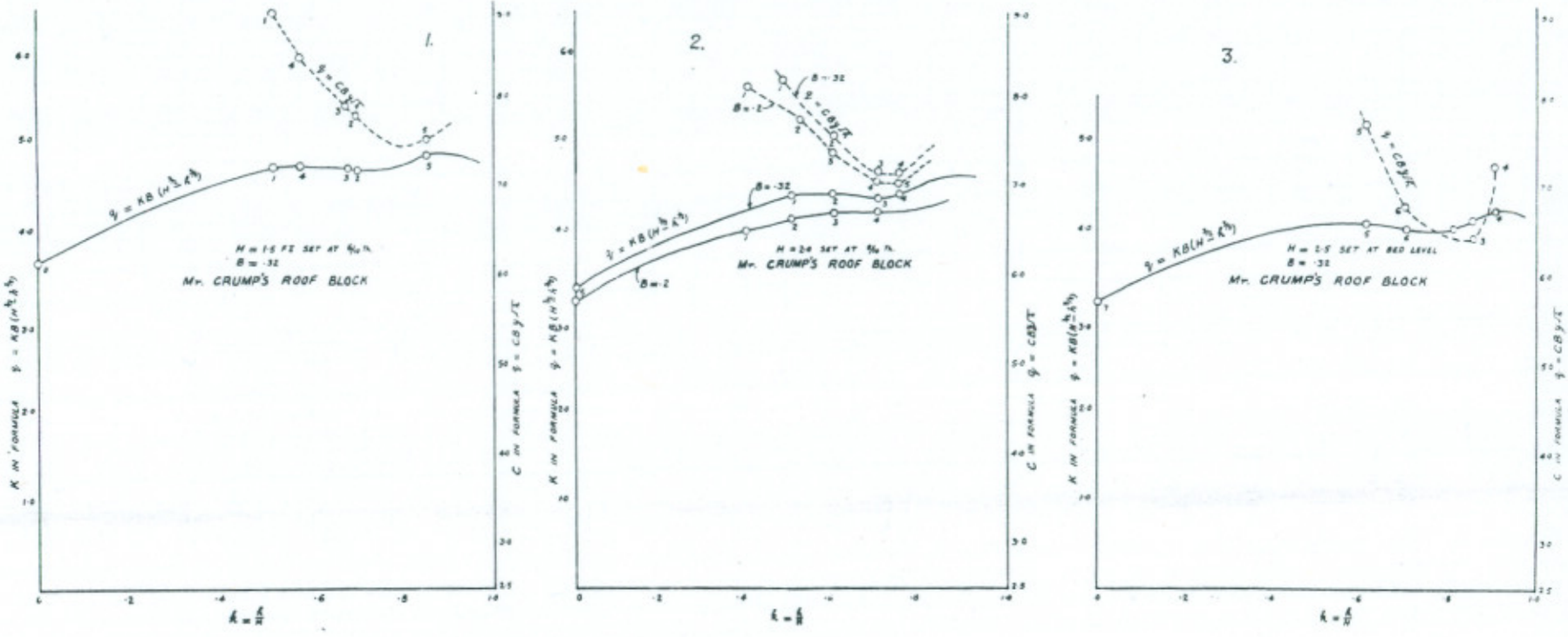
$$q = KB\left(H^{3/2} - h^{3/2}\right)$$
$$h = \left(H^{3/2} - \frac{q}{KB}\right)^{2/3}$$

HEIGHT OF OPENING $= H - h = y$
MINIMUM WORKING HEAD $= h_m$.
ACTUAL WORKING HEAD $= h_w$.
PROPORTIONATE WIDTH OF WATER WAY FOR OUTLET DISCHARGE $= W = C\,q^{3/5}(b_d + d/2)$
WIDTH OF APPROACH $= W$
SPLAY OF U.S. SIDE WALL $= S = (W - B)$
RADIUS OF SPLAY ON SIDE $= S$
DISTANCE OF A.P.M BLOCK FROM CENTRAL LINE U.S. $= b_u/2 + d/2 + S$
LENGTH OF APPROACH CURVE ON SIDE $= l = S$.
LENGTH OF OUTFALL $= l$.
RADIUS OF OUTFALL $= (b_W - B)\ 25{\cdot}25$
RADIUS OF CURVATURE ON D.S. PROJECTED WING $= 2{\cdot}6W$.
WIDTH OF WATER COURSE
- 0 TO 1 CUSEC $= 1{\cdot}5$ FT.
- 1 TO 2 CUSECS $= 2{\cdot}0$ FT.
- ABOVE 2 CUSECS $= 2{\cdot}5$ FT.

$C = \dfrac{\text{AVERAGE VELOCITY IN CHANNEL U.S.}}{\text{VELOCITY NEAR THE SIDE U.S.}}$

$C = 2{\cdot}0$ FOR HEAD REACH IN MAJOR DISTY.
$= 1{\cdot}5$ FOR MIDDLE REACH IN MAJOR DISTY.
$= 1{\cdot}25$ FOR TAIL REACH IN MAJOR DISTY.
$= 1{\cdot}0$ CHANNELS BELOW 10 CUSECS.

MODIFIED DESIGN OF A.P.M.
VARIATION OF COEFFICIENT.



VARIATION OF K WITH H

B = 32 FT. RANGE OF Y FROM ·3H TO ·5H

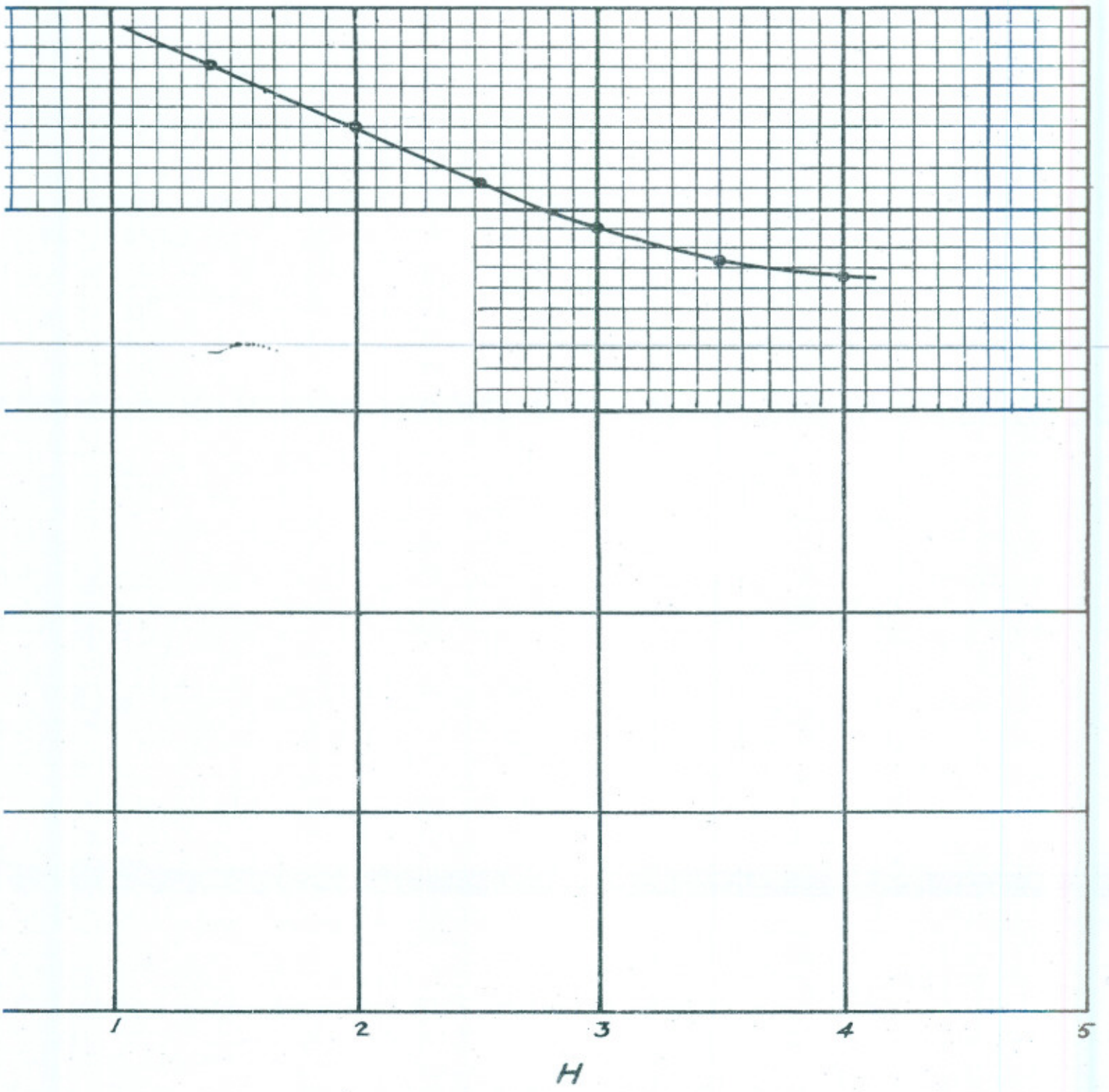
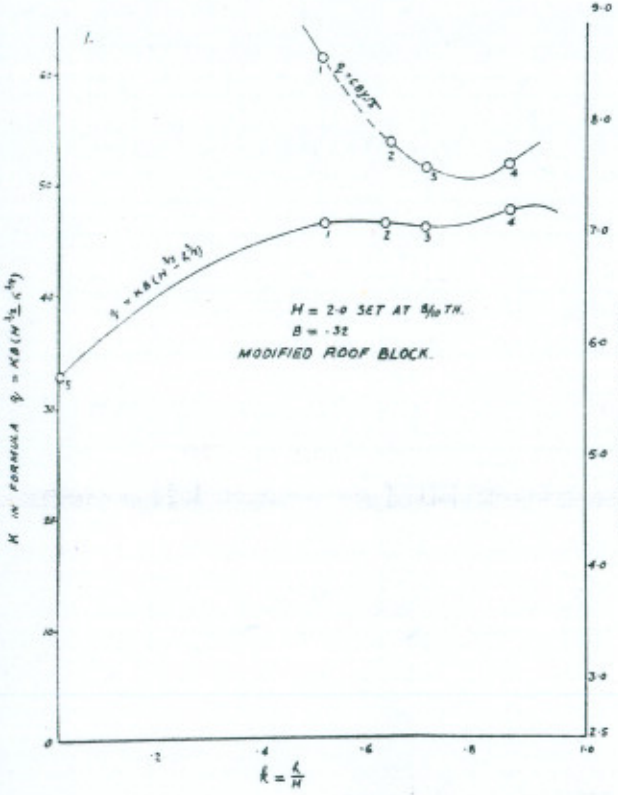
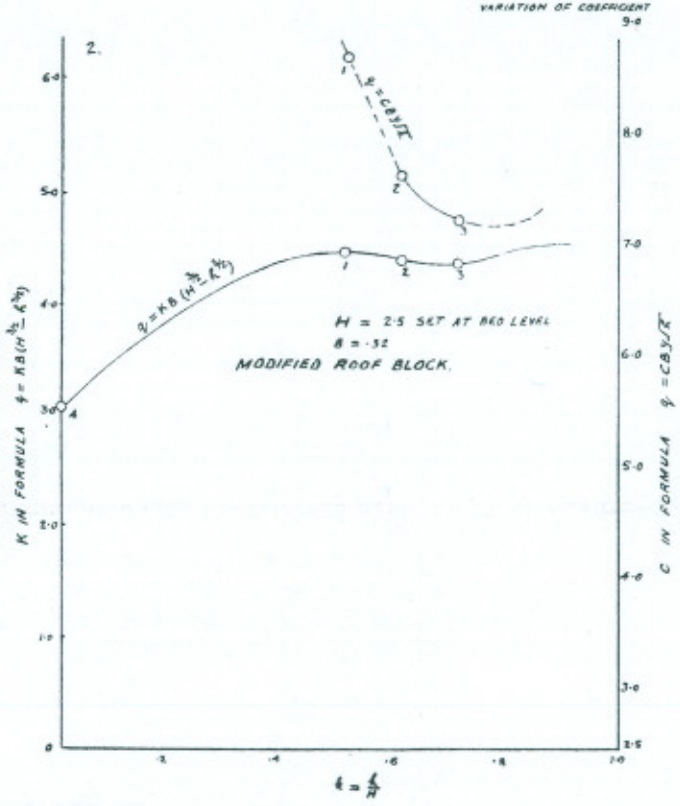


Plate No. 5.

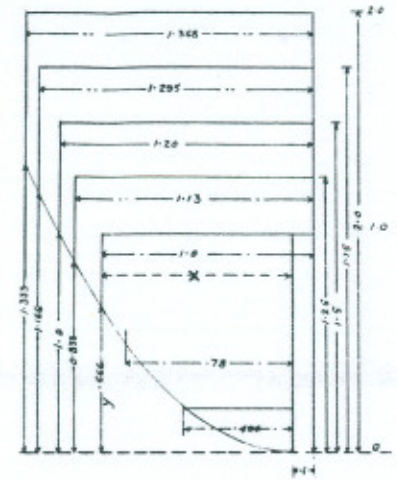
MODIFIED DESIGN OF A.P.M.

VARIATION OF COEFFICIENT





MODIFIED DESIGN OF ROOF BLOCK



$x = K\sqrt{y}$

$9 = K\sqrt{60}$

$K = 9 - \sqrt{60} = 1.026$

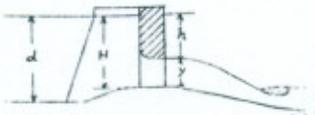
y	x
0·1	= 0·35
0·2	= 0·494
0·3	= 0·604
0·4	= 0·697
0·5	= 0·78
0·6	= 0·854
0·66	= 0·90
0·70	= 0·923
0·80	= 0·985
0·833	= 1·032
0·9	= 1·046
1·0	= 1·103
1·1	= 1·157
1·17	= 1·193
1·20	= 1·207
1·30	= 1·258
1·33	= 1·273

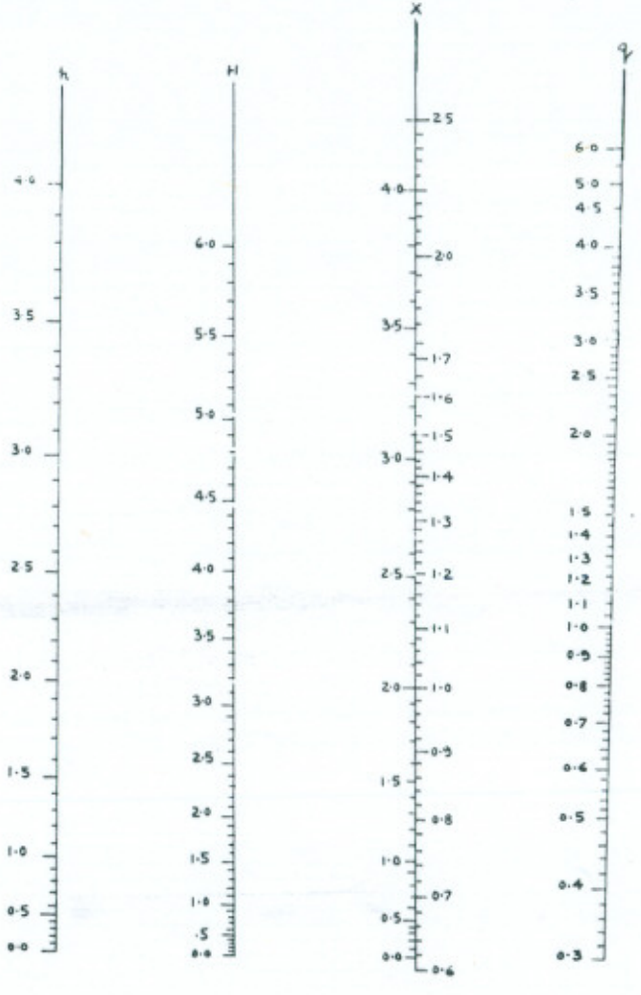
ADJUSTABLE PROPORTIONAL MODULE
NOMOGRAM FOR DISCHARGE FORMULAE

PLATE No 6

$q = K\,B\,(H^{3/2} - h^{3/2})$ WHERE

q = DISCHARGE OF OUTLET
K = COEFFICIENT
B = WIDTH OF OUTLET
H = DEPRESSION OF CREST LEVEL
h = DEPRESSION OF ROOF BLOCK
$Y = H - h$





INSTRUCTIONS

(a) TO FIND SIZE No.
FIX H FROM SETTING OF THE A.P.M, KEEP $h = \frac{H}{3}$. JOIN h WITH H AND READ X ON THE LEFT. THEN READ X ON THE RIGHT. JOIN q AND K CUTTING THE MID VERTICAL. JOIN X ON THE RIGHT AND THE ABOVE INTERSECTION ON THE MID VERTICAL AND PRODUCE IT TO B SCALE AND CHOOSE THE SIZE No THE NEXT ABOVE.

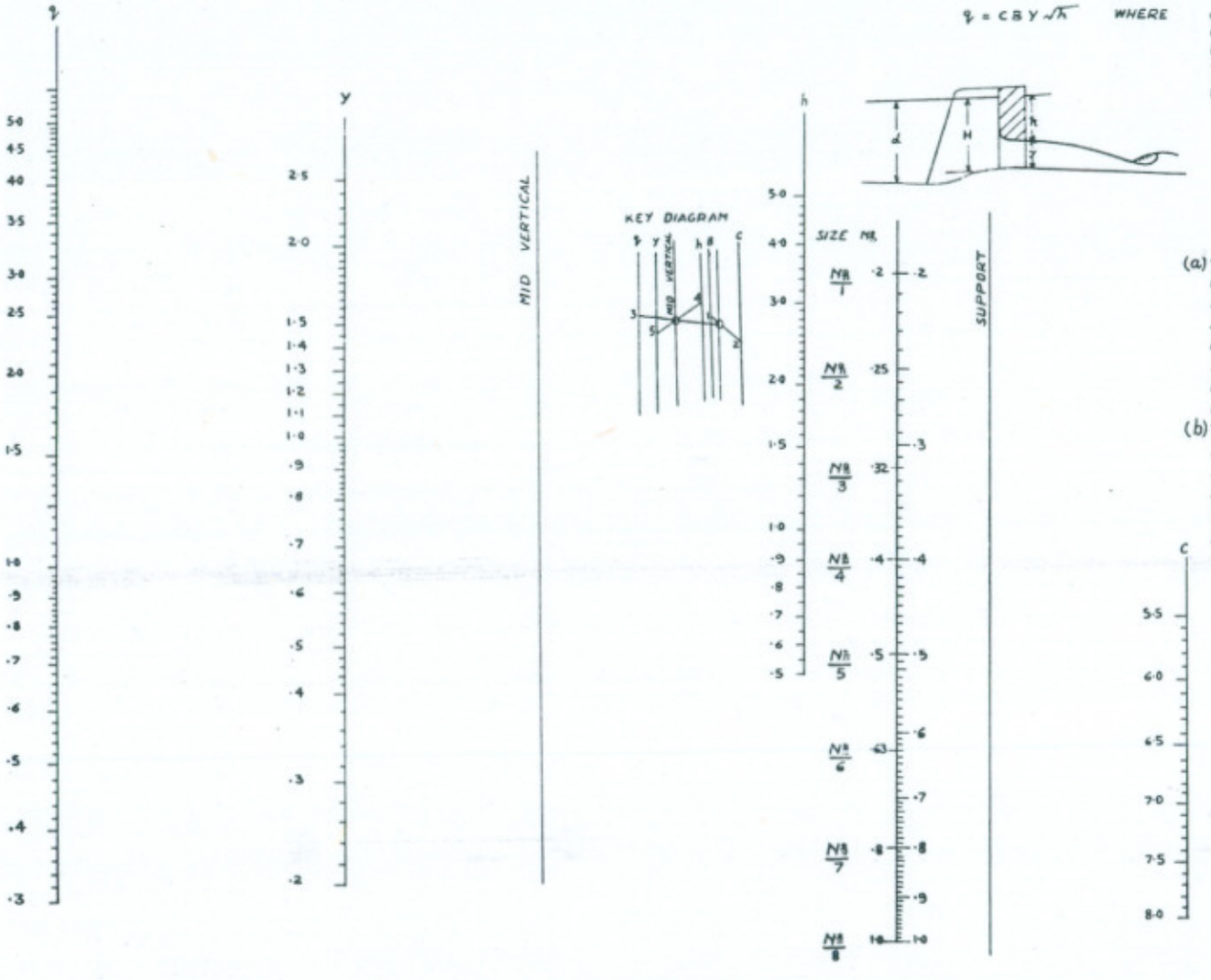
(b) TO FIND SETTING VIZ. h AND Y. JOIN q AND K INTERSECTING THE MID VERTICAL. JOIN SIZE No WITH THE ABOVE INTERSECTION AND PRODUCE IT TO X ON THE RIGHT SIDE. THEN READ X ON THE LEFT SIDE. JOIN X ON LEFT SIDE WITH H AND PRODUCE IT TO READ h.

ADJUSTABLE PROPORTIONAL MODULE
NOMOGRAM FOR DISCHARGE FORMULAE

PLATE No. 7

$q = CBY\sqrt{h}$ WHERE

q = DISCHARGE OF OUTLET
C = COEFFICIENT
B = WIDTH OF OUTLET
h = DEPRESSION OF ROOF BLOCK
Y = HEIGHT OF OPENING = H-h
H = DEPTH ON CREST



INSTRUCTIONS

(a) TO FIND SIZE No.
KEEP $Y = h = \frac{H}{2}$. JOIN Y AND h AND GET AN INTERSECTION ON MID VERTICAL
JOIN q AND THE ABOVE INTERSECTION AND PRODUCE IT TO CUT THE SUPPORT
JOIN C AND THE POINT ON SUPPORT AND PRODUCE IT TO B SCALE. KEEP SIZE No. NEXT JUST BELOW.

(b) TO FIND SETTING VIZ h AND Y
JOIN B AND C CUTTING THE SUPPORT.
JOIN q AND THE INTERSECTION ON THE SUPPORT CUTTING THE MID VERTICAL SAY AT POINT P. SWING STRAIGHT EDGE ABOUT THIS POINT P AND FIND h AND Y SO THAT $h + Y = H$

DISCUSSION.

MR. SHARMA in introducing his paper said that this paper was the result of observations on experimental outlets for over four years. The first experiment dealt with the A. P. M. It was shown that the A. P. M. works in three stages depending upon the position of the hydraulic jump. It was more or less a free fall orifice when the hydraulic jump was on the glacis. It worked as a submerged orifice with a hydraulic jump when the hydraulic jump was on the level crest downstream of the A. P. M. blocks. Lastly, it worked as a drowned orifice where there was no hydraulic jump.

The second experiment gave the variation of the coefficient of discharge with the depth on crest.

The third experiment was an attempt to increase the coefficient of discharge and to raise the modular limit by modifying the design of the roof block.

The fourth experiment was a return to the Harvey-Stoddart outlet with a level floor downstream of the orifice. The Author said that he could not finish the work on this type of outlet.

The Author pointed out the following corrections in the paper :—

On page 103, capital C printed in the three equations should be small c.

In Plate 4, it was ·32 feet width instead of 32 feet.

L. ISHAR DAS said he concurred with the Author that the standard approach curves for the A. P. M. were unsatisfactory but he considered they ought to depend on the depth of a channel. He was as much averse to Mr. Crump's roof block as he was to the Author's on theoretical grounds, and considered that the introduction of a curve below the roof block had decreased the efficacy of the A. P. M.

MR. S. D. KHANGAR said that he wished to touch on just a few points.

The Author stated that " it was also evident that the discharge of an A. P. M. was not independent of the water level in the outfall even though a hydraulic jump be found. The discharge of an A. P. M. with a level crest equal to H downstream of the roof block depended upon the depth of water actually attained with high working heads at the end of the level floor."

The statement was not borne out by Author's own experiments Thus in experiment No. 1, Set No. 1, the discharge remained constant as the working head changes from 1·34′ to 0·86′. In Set No. 2, it was constant for a range of 1·34′ to 0·74′, and so on for other sets. It was constant as long as a good standing wave formed. He did not think that the formula for discharge worked out by the Author was correct.

Again Appendices I, II, III, IV, VI and VII showed that the coefficient C in the formula $Q = C B Y \sqrt{h}$ varied from 6·44 to 8·65. He had occasion to check with a wooden or tin flume the actual discharge of over 80 A. P. M's. Those included both standard as well as the Author's modified type A. H. varied from 1·5 to 3·6. The standing wave formed in all positions, *i.e.*, on glacis or crest. He did not find those large variations. It was found that 7·3 was a good average, the variation being 4 to 5 per cent. plus or minus as H, B, or $\frac{Y}{H}$ altered. Any variation greater than that could be directly traced to the defects in the construction of the outlet. Thus it was found that the A. P. M. block was not always of the correct size.

A. 0·2, A. P. M. was anything from 0·19 to 0·21 wide. The construction of the parallel throat below the A. P. M. had an important effect. If its width was less than the width of A. P. M. block, or its crest was uneven, or bricks were projecting on the sides or mortar was not cleared from the throat, the discharge was reduced. Similarly when the length of parallel flume was more than H below the block, the coefficient was effected. Leaking outlets gave a higher coefficient. Bad construction of upstream approaches also effected the coefficient. When those defects were removed the coefficient came to about 7·3.

THE AUTHOR replying to the discussion said, with reference to the remarks of Mr. Ishar Das, that the speaker carried a wrong impression, as the Author did not mean that Mr. Crump's design of the A. P. M. as a submerged orifice was wrong but it was only shown by these experiments that it had certain limitations, depending upon the F. S. L. in the watercourse, which could be overcome by making the floor in the outfall level throughout.

The formula for the modified design of the Author was never meant to be also true for a submerged orifice. The variation of the coefficient of the discharge for the shape of the orifice and the depression was admitted and could not be helped as found in these experiments.

Replying to the remarks of Mr. S. D. Khangar the Author said that it was true that the Table I of Appendix I with a low value of Y did not show the three stages in the working of an A. P. M. but the remaining Tables of Appendix I with high values of Y clearly showed them.

Appendix I for the usual range of Y's from ·30 H to ·50 H clearly shows the three stages.