PAPER No. 168.

SILT CONDUCTION BY IRRIGATION OUTLETS.

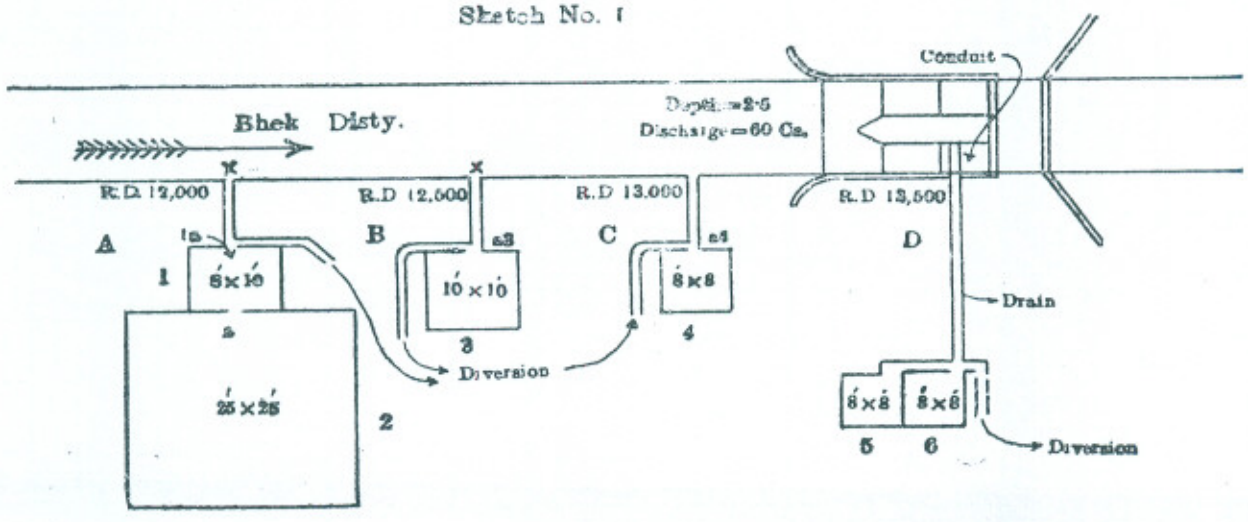
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The object of the author in writing this paper is to describe briefly a few experiments carried out to investigate the silt conducive power of certain types of irrigation outlets commonly used by the Punjab Irrigation Department for distribution of supplies. Outlets play a very important part in the successful working of irrigation channels. It is apparent that if they do not take their due share of silt charge carried in the parent channel, the silt charge of that channel will go on accumulating to an extent that the channel is unable to carry it forward. The channel will then silt up, and give rise to all the troubles consequent on such a state of affairs. Under these conditions the natural remedy would be to use outlets, which have comparatively a high power of conducting silt from the parent channel. The experiments were conducted, as described hereafter, to investigate the possibility of improving the silt conductive power of different outlets.

The Experimental Station.

The experiments were carried out at R. D. 12,000 of Bhek distributary, Lower Jhelum Canal. The arrangement of the Experimental Station is sketched below :—

Sketch No. 1



Three outlets were constructed at sites A, B, & C.

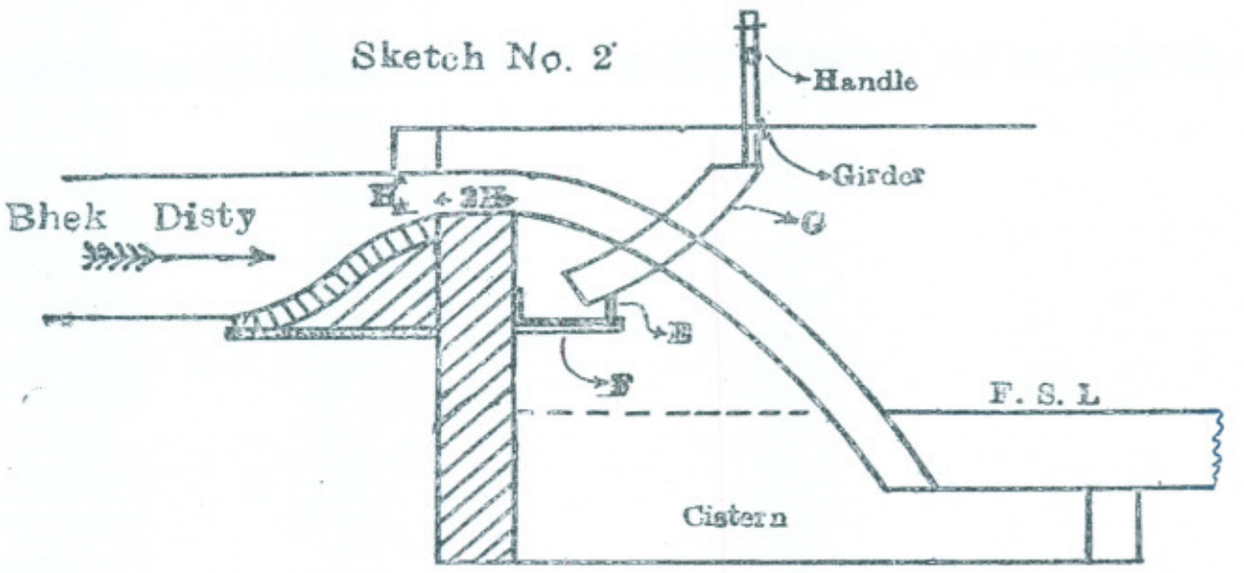
These outlets were connected with tank Nos. 1, 3 & 4, respectively.

To begin with, the outlet at A was built according to the modified design of A.P.M. set at 8-10th with depth on crest equal to 2·0 ft. At site B, it was built according to modified design of A.P.M. set at bed level with depth on crest equal to 2·5 ft. At site C, it was built

as an A.P.M. according to the type given in Appendix E, Irrigation Branch Paper No. 26 set at 6-10th with depth on crest equal to 1·5 ft. The width of all the three outlets was ·32 ft. A big tank No. 2 was provided at site A. Its primary object was to obtain a comparatively high degree of accuracy in the observations. At points a_1, a_2, a_3, and a_4 downstream of the diversions a watertight arrangement was made to regulate the water level downstream the outfall of the outlets by means of 0·1 ft. high karries. All those outlets were provided with chambers at site X shown in sketch No. 1 on the downstream side fitted with glazed side walls facing the distributary and up to the end of the crest of the outlets. The stream lines of silt laden water entering the outlet and those of the water running down the distributary could be visually examined through this glazed structure.

At site D 500 ft. downstream there is a 8·0 ft. fall in the distributary. It consists of two spans of 6·0 ft. each. The notched fall at this site was converted into a broad crested open flume, truncated to obtain the jet of water springing clear from the crest in a parabolic curve, as shown in the sketch below :—

Sketch No. 2



An iron conduit E, 1 ft. wide and 1 ft. deep was laid on brackets, F firmly secured in the drop-wall of the fall. The jet of water sprang clear of this arrangement. The conduit E was connected by means of a drain to the tanks No. 5 and 6, as shown in sketch No. 1. G in sketch No. 2 represents another U-shaped iron trough or spoon of 3″ width to intercept 3″ width of jet of water springing from the crest of the fall, and to direct the same into the conduit placed below. The design of the trough G was arrived at by trial and error to ensure that the jet of water falling in a parabola was calmly deflected into the conduit E connected with the Tanks Nos. 5 and 6, as shown in sketch No. 1.

Procedure in the Experiments.

All outlets were opened two to three hours before the observation and water was escaped, during this period through the diversions shown in sketch No. 1, in order to wash out any silt deposits in front of the outlets or in the outfall. All the six tanks had cement plastered sides and beds and were thoroughly cleansed before the observation.

The observation started at site D, where the silt charge in the supply of the distributary was measured. It was assumed that the silt charge in both the spans of the fall was similar and equal. The channel trough G was put in position in the middle of the span and diversion at site D was run for a few minutes till a steady flow was obtained. The diversion was then closed and tank No. 5 was filled up to a 3·0′ gauge. The supply to the tank was then cut off and diverted to the diversion. The channel trough G was then put in position 6 inches away from the right side wall of the span of the fall and tank No. 6 was filled up to gauge 1·5′. The channel trough G was lastly put in position 6 inches away from the left side wall of the span of the fall and the tank No. 6 was filled to gauge 3·0′. It was found that the tank No. 6 always contained 5 to 8 per cent. more silt than the tank No. 5. The average silt charge in the distributary was calculated by taking an average of the results of tanks Nos. 5 and 6.

The tanks at site C, B and A were then filled one after the other. The diversions were closed and the outlets run into the tanks in the modular conditions only.

The silt in water was allowed to settle in the tanks for 24 hours undisturbed. The tanks were covered with galvanized iron covers to protect them from storms. The clear water from the tanks was syphoned off, taking care that the silt deposited in the tanks was not disturbed. About 2 inches depth of water in the tanks and the residue were allowed to dry off in a couple of days. The dry silt was collected from the tanks and heated in iron pans to a temperature of about 100° C to drive out all moisture from it. The silt was then weighed and the results were tabulated as in Appendix II.

Silt Distribution in a Channel Section.

It was observed in course of other experiments (a description of which would be out of place for the purposes of this paper) that the silt charge in the channel varied with depth from top to bottom. The silt charge was low nearer the surface and high nearer the bed of the channel. Moreover the silt was finer near the surface and coarser near the bed. The silt charges were measured by weight; the author had not the means to grade them. It was, however, clearly observed through the glass gauge wells that both the silt charge and the silt grade increased from the surface to the bed of the channel.

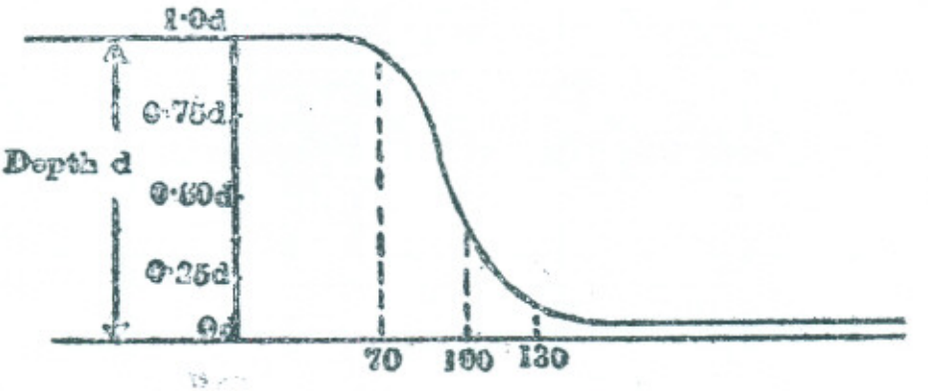
The explanation for this sort of distribution of silt is afforded by the forces keeping up the silt in suspension. Silt is supported in water by the vertical eddies produced on account of roughness of the bed. They work up against the depth of the channel. They are the strongest near the bed and relatively weaker as they approach the surface. It is natural to expect that they are capable of supporting a high silt charge near the bed and a comparatively light one near the surface.

Similarly silt is finer near the surface and coarser near the bed of the channel.

Silt conduction by outlets could, therefore, be greatly increased not only by weight but also in conducting comparatively coarser elements of silt by smoothly extracting highly silt charged water near the bed of the channel, by providing suitable approaches to the outlet and thus leaving behind not only low silt charge but also silt of comparatively finer grade.

It is very important that the approaches to an outlet should be designed in such a way that the entry of water would be smooth both in the bed and close to the outlet both upstream and downstream. Supposing the distribution of silt charge in a vertical plane of a channel was as sketched below :—

Sketch No. 3



Silt charge expressed as percentage.

If an outlet calmly takes water from the top half portion of the depth, the silt conduction would be less than proportionate, that is. cent per cent. If it could take in mostly the supply from below the quarter depth of the channel, the silt sucked in would be more than its due share and might be as much as 130°/₀. But if the approaches are not suitable, the entry of water is rough and disturbed and consequently the silt charge is churned up so much so that it gets evenly distributed from top to the bed of a channel. In such a case an outlet cannot draw more than cent per cent. silt even if it were set low and were fed from the water flowing near the bed of a channel. This has been the fate of

old orifice type outlets. The bed of the channel continued to silt up even to a level above the top of the opening of the outlets. This happened because water entered the outlets forming a vortex motion. The existence of a local pit upstream of such outlets lends support to such a theory. The swirls upstream of the outlets disturbed the distribution of silt charge so much that even though water was extracted from near the bed of the channel, the outlet could not draw more than its proportionate share of silt.

Keeping in view the abovementioned factors and taking the case of the A. P. M. outlets, which are commonly used for distribution of supplies, the design should provide the following essential factors for its success as a silt extracting device :—

1. The approach curve in bed of the channel to the outlet should be smooth.

2. The approach on the upstream and downstream side should be smooth so that there is no disturbance. There should be no corner to produce eddies.

3. The A. P. M. block should come up as much as possible towards the channel so that the high velocities generated under roof block exercise their effect in extracting water from near the bed of the channel.

4. The velocity of the filaments of water entering the outlet near the bed of the channel should be more than that of the top filaments, so that most of the supply taken up by the outlet is drawn from near the bed of the channel.

In order to provide for these improvements, a few changes in the design of projection of downstream wing, width of approach, approach curve on the U. S. side, approach curve in the bed and the glacis were introduced in the case of an A.P.M. type A as given in Plate I. These modifications are dealt with in the following paragraphs.

Position of wings.

The projection of the downstream wing or set back of the upstream wing is usually calculated allowing proportionate width for the discharge of the offtake calculated from the waterway allowed downstream of the outlet for the discharge downstream of it. It often happens that the section of a channel downstream of an outlet has no definite relation to the section of the channel upstream of it, where the outlet takes off fairly a big discharge, or when the slope changes in the parent channel downstream of it. The ideal approaches to the outlet will be, when water, as it reaches it from upstream, is divided proportionately. It is therefore desirable to calculate the projection of the downstream wing from the channel section upstream of the outlet and not from the downstream conditions.

The formula for the projection of downstream wing $w = \frac{q}{Q}\left(b + \frac{d}{2}\right)$ allows that the whole mass of water moves with the average velocity of the channel, but in practice the velocities in the middle of the channel

are higher, and those near the sides are lower than the average velocity of the channel. Water entering the outlet is moving slower than the average velocity of the channel. In order to make up the discharge of the outlet, greater width of the channel section is required than that if water were moving with average velocity. The ratio of the actual average velocities and the velocities near the sides at a distance of half a foot were worked out by actual observations at 15 sites for different reaches of the Mithalak and Sakesar distributaries. It was observed that this ratio varied from 2 to 1·15 from head to tail of the Mithalak distributary. This ratio appears as a constant in the formula of the projection of the downstream wing

$$w = C.\frac{q}{Q}\left(b + \frac{d}{2}\right)$$

The value of C can be lowered somewhat by putting a short length of dry brick pitching upstream of the outlet. It is recommended that the value of constant 'C' should be taken in the case of major distributaries as 2 in the head reach, 1·5 in the middle reach and 1·25 in the tail reach ; and 1·0 for small channels carrying discharges less than 10 cusecs.

The projection of the downstream wing of the outlet is a fixed obstruction. The kinetic energy of water impinging against it is converted into potential energy. Water jumps up vertically in impact and the potential energy takes the form of eddies rising up vertically, which have a great silt carrying capacity. Bottom silt is thus pushed up vertically in impact, but as soon as it is up the sloping face of the downstream wing wall of the outlet, it is free to move down into the channel. Thus the rolling bed silt, which ought to have gone in the outlet, is carried in the channel downstream in these eddies. It is therefore that an A. P. M. built with straight projection of the downstream wing and the face of downstream wing $\frac{1}{2}$ to 1 takes little share of the bottom coarse silt of the channel. These facts were examined through the plate glass projections in case of an A.P.M. built according to the design as per I.B. Paper No. 26 Appendix E.

If the face of the downstream wing were made vertical, the bottom silt stirred up in impact, could not escape but it is not advisible to make it vertical because it will restrict the waterway downstream of the outlet. The projection of the downstream wing is essential to allow for reduction in waterway according to the discharge of the offtaking outlet and to guide the due share of the supply and silt of the parent channel into the outlet. These defects, can, however, be removed in the design of an A.P.M. by giving a slight curvature in the projection of the downstream wing. Suitable curvature in the design of the downstream projected wing was determined by trial and error. This was determined by throwing an elastic ball in the stream which should after striking against any part of the downstream projected wing deflect towards the mouth of the outlet. A curvature of 1 in 5 ensured this. The radius of the curvature works out to be 2·6 times the projection of the downstream wing as given in Appendix I.

Approach curves.

The width of the approach should be equal to the projection of the downstream wing so that water enters the mouth of the outlet with the same velocity, as it approaches it. This serves to ensure that no induced velocities are set in before water enters the mouth of the outlet.

A radius of 2H for the upstream approach curve sets the A.P.M. block too much behind the mouth of the outlet, with the result that the A.P.M. is unable to exercise its full silt extracting power from the channel. If the A.P.M. be set lower than 6-10th the value of H increases and the A.P.M. block is set still behind.

For uniformity in design it is desirable to have a quadrant approach on the upstream side wall. This ensures smooth entry on the upstream side and eliminates a corner which would create eddies.

If the width of approach is the same as the width of the A.P.M., the length of approach is nil. The approach curve in the bed laid with a radius of 2H falls outside the upstream wing by 2/3 H for a setting of 6/10 depth and ·345 H for setting of 8/10th depth in the distributary as worked out in Appendix I. This represents the least limiting value of the distance of the A.P.M. block from the top end of the upstream wing at water level. This means setting the A. P. M. block unnecessarily back. It is, therefore, provided that the approach curve in the bed should be managed within $\frac{1}{2}$ to 1 slope of the face of the upstream wing.

The convex approach curve represents a sudden rise above the distributary bed which is naturally difficult for the rolling silt to jump over. It is, therefore, proposed that the approach curve in the bed should be concave to begin with and convex as it reaches the crest. The coarse bottom silt, when it once happens to have an easy entry in the mouth of the outlet, as proposed above, can easily be drawn over the convex part of the approach curve, as very high velocities are set in just upstream of the orifice. The design for the approach is worked out in Appendix I and the length of the approach curve in bed is limited to $d/2$. The radius of the concave part is 0·23 H and that of the convex part ·68 H when the setting is 8-10th depth.

It is proposed to do away with the level portion ·25 ft. just upstream of the A.P.M. as usually provided. It sets back the A.P.M. block unnecessarily by this amount. This will necessitate the construction of the face of the upstream wing wall, as vertical above water level.

Glacis downstream.

The level crest downstream of the A. P. M. tends to retard the velocity of the filaments of water passing near the crest of the outlet. If an orifice were discharging as a free fall, the velocity of filaments leaving near the floor of the outlet is actuated by the pressure head equal to depth on crest of the outlet and those near the top of the orifice by the

pressure head equal to depression of the top of the orifice. In order that an A.P.M. may draw the maximum silt, the filaments of water leaving near the crest should be quickest and should have a free exit. The glacis is provided to be circular up to a distance of ·4H and then sloping 1 in 5 for a distance of 2·5 ft. tangentially to this circle. The radius of this circle is worked out in Appendix I as 2H so that the circle passes through the point where the glacis starts tangentially 1 in 5 as if water had a free exit and traversed a parabolic path.

First set of observations.

The first set of experiments were carried out on three outlets. The first one was an A.P.M. as per design given in Irrigation Branch Paper No. 26 Appendix E set at 6-10th. Second one was according to the modified design of an A.P.M. type A as explained above set 8-10th. The third one represented the modified design of an A. P. M. type A set at bed level. The design of last two outlets is given in Plate No. I. The actual observations are given in table No. I Appendix II. Column No. 18 gives the ratio of the depression of the roof block to the depth on crest of the outlet, that is $k = \frac{h}{H}$. Observations were taken for various values of k as shown in column No. 18 and the approaches were modified every time the value of k was changed. Column Nos. 15, 16, and 17 give percentage silt conduction by the outlets considering the silt in distributary as 100. In Plate No. 2 the observations are plotted on a cross-section paper with values of k from col. No. 18 as the axis of X and the results from cols. 15, 16 and 17 as the axis of y. There is a separate curve for each outlet. An average line is drawn passing through the observations. In each case the silt conducive power of the outlet increases with the increase in the value of k, or in other words, the silt conducive power increases with reduction in the height of the opening of an A. P. M. Plate No. 3 gives a sketch of the stream lines as they were actually observed through plate glass approaches downstream of the outlet for the different outlets designed and constructed to give the same discharge.

Unfortunately a photographic impression could not be taken on account of dim light but the stream lines, as sketched therein, could be clearly seen and were checked and verified at the time by other engineers. The improvements in the silt entry to the outlets as obtained by the modifications in design of approaches are clearly shown in Plate No. 3.

The outlets built according to type A were in practice generally very successful. In the case of the Mithalak distributary, Lower Jhelum Canal, the outlets were remodelled into A. P. Ms. as per type given in Appendix E, Irrigation Branch Paper No. 26 in October 1928 and the channel was silt cleared according to the designed conditions in October 1929. In one season in summer 1930 the channel silted by about a foot downstream of every meter flume. In December 1930 the outlets were

remodelled according to the type A and set at 8-10th depth in the channel. The distributary scoured down gradually and within six months designed conditions were practically attained. There has been no silt trouble since then in the head reach 0-67000 of the Mithalak distributary where these outlets were tried.

Second set of observations.

The second set of observations was taken on three outlets. One of them was an A. P. M. set at 8-10th built according to the modified design type A with depression of the roof block=·6H. The second one was an open flume with crest at bed level built according to the design given in Appendix D, Irrigation Branch Paper No. 26, Class A. The third one was an open flume with crest at bed level built with modified approaches. The width of all the three outlets was ·32 ft. The design of open flume outlets is given in Plate No. 4. Five observations were taken in this case and are given in table No. 2 of Appendix II. Col. Nos. 15, 16 and 17 give the silt conducive power of the modified A.P.M. type A set at 8-10th open flume at bed level as per Appendix D, Irrigation Branch Paper No. 26, Class A, and open flume at bed level with modified approaches respectively. The figures therein denote the percentage silt conducive power considering the distributary silt as 100 in each observation. All these observations were taken under the same conditions of design. The variation in the results obtained is believed to be due to the variation in the grade of silt charge in the supply of the parent channel from time to time. It appeared that the silt conducive power or outlets having a low setting decreased with the decrease in the average grade of silt charge in the parent channel, in other words, when the average grade of the silt carried in the parent channel was low the difference between the silt charge carried near the surface and the bed of the parent channel was not much. When turbid water came containing mostly fine earth the silt conducive power of outlets set low tended to decrease and those set high tended to increase.

The departure of the results under similar conditions of flow of oultets as plotted in Plate No. 2 is also indicative of the effect of the quality of the silt charge carried in the parent channel.

Third set of observations.

It often happens that in some reaches of a channel very high working heads are available. Generally in such cases when the channels are in high embankment, the slopes in them are very flat. The Mithalak distributary in the Lower Jhelum Canal Circle had such conditions from R. D. 67,000 to 95,000. The working heads of the outlets are more than 3·0 ft. and the slope in the channel is only 1 in 5714. The watercourses in this reach have practically got no silt banks.

Under these circumstances the outlets could safely take silt considerably more than their share. It was tried to put the A. P. M. outlets below bed level and type design B was adopted as given in Plate No. 5

It was hoped to attain a higher silt conducive power of the outlets than obtained in type A of the design of the A. P. M. described before, because in case of the flat slopes in the channels the outlets of the type A did not completely cure the trouble of the silting up of the channels in this reach.

These experiments were carried out with an A.P.M. with modified approaches as per type B. The outlet was set at ·2 D below bed level. The A. P. M. block of the outlet was brought forward as far as the edge of the water line in the distributary. The projection of the downstream wall was kept zero at full supply level and $2w$ at bed level in the parent channel where "w" is the proportionate width of waterway calculated for the discharge of the outlet according to the formula $W = C \frac{q}{Q}(bu + \frac{d}{2})$ as given in Plate No. 5. The object was to entrap the bottom supply of the channel carrying high silt charge and high grade of silt and to permit free escapage of supply of parent channel near the surface. The width of approach is equal to B at full supply level and $(2w - B)$ at bed level in the parent channel so that the average width of approach is w.

The actual observations are given in table 3, Appendix II. First four observations were taken with height of the opening equal to 9 ft. The width of the outlet was ·2 ft. The depth on crest was 3·0 ft. and the outlet was set at 1·2 times the depth in the parent channel. The approaches were built for a discharge of 1·60 cusecs. The average silt conducing over for the outlet works out to be 128·9%. The variation in the results is attributed to the variation of the grade of the silt in the parent channel. When the silt charge in the parent channel was comparatively fine the silt conducive power of the outlet tended to decrease.

The approaches to this outlet were not changed and only the height of the opening was varied. Observations Nos. 5 and 6 were taken by making the height of the opening more than that with which the outlet was originally designed, that is, ·9 ft. The silt conducive power tended to decrease with the increase in the height of opening in observations Nos. 5 and 6. The discharge of the outlet increased with the height of the opening. The required width of approach at bed level increased with the increase in the discharge of the outlet. There was restricted entry of water into the outlet near the bed level of the channel. The increased discharge was made by the outlet by taking surface water from the channel. The forced entry of water into the outlet would also cause eddies in front of an outlet lifting up the coarse silt from near the bed of channel, which would escape into the channel downstream of the outlet. The results would probably have been better than those obtained, had the approaches been modified for the increased discharge of the outlet.

Observations Nos. 7 to 9 in table 3, Appendix II, were repeated with the same outlet, but the height of the opening was reduced in each case. The approaches to the outlet were not modified for the reduced

discharge. The silt conducive power of the outlet tended to decrease with the reduction in the height of the opening in these observations. The width of the approach to the outlet was provided for a higher discharge than that drawn by the outlet in these observations. The velocity of water as it entered the outlet from the parent channel decreased as the discharge of the outlet was reduced. It appeared the silt conducive power of the outlet was a function of the velocity with which the supply of water is drawn by the outlet from the parent channel from near its bed.

Fourth set of observations.

Some difficulty was experienced in the actual working of the outlets set very low as the high working heads required for such outlets were not available in all cases, when it was necessary to use outlets of high silt conducive power. The average working head for an irrigation outlet is generally one foot in Sargodha Division L. J. C. When the channel depth is more than 3·0 ft. the low setting of the outlet cannot be arranged to ensure their working in the modular conditions. The necessity of some other device was felt to increase the silt conducive power of outlets set high. The choice fell on the Bend outlet described by Khan Bahadur Sheikh Minhaj-ud-Din, Executive Engineer in the *Indian Engineering Magazine*, dated 13-2-1926. This set of observations was repeated with three outlets, modified design of A.P.M. type A set at 6-10th, Bend outlet set at 6-10th and modified design of A.P.M. type B set at bed level. The design for the first and the second is given in Plate No. 6 and that of the third in Plate No. 5. The observations are given in table 4 of Appendix II. The silt conducive power of the A.P.M. type B at bed level comes out to be 127·75% on the average. The bend outlet has the silt conducive power of 113·75% and A.P.M. modified type A draws about cent per cent silt as per col. No. 17, table 4, Appendix II. The last one takes just the proportionate share of silt.

Conclusions.

It is evident from the observations given in Appendix II that the silt conducive power of the outlets increases with the comparatively low setting of the outlets. The average silt conducive power of the A.P.M. outlets modified as per type A is 100%, 110% and 122% for their setting at 6-10th, 8-10th and at full depth of the channel. The A. P. M. outlets should be set as low as possible if the working heads permit. There is no doubt about it that the outlets set low will not draw proportionate share of the supply in the parent channel in case of fluctuations. The lowering of the crest beyond 6-10th simply makes the A. P. M. outlets sub-proportional. It ensures that a relatively greater share of extra supply put at the head will reach the tail. The author considers it rather an advantage when the channels are run only full supply or nil supply : the question of proportionate setting has little consideration.

It is clear from the comparison of the results given in column No. 15 in table 1 and column No. 17 in table 4 in Appendix II that an A.P.M. built with modified approaches as per type A has an advantage of about 7 or 8% over the A. P. M. built according to the design given in Appendix E. I. B. Paper No. 26, Class A. The improvement in the entry of the bed silt of the channel on account of improved approaches to the outlet are shown in Plate No. 3. This increase in the silt conducive power means a distinct advantage. The modification in the design of the approaches is, therefore, worth the trouble and labour.

A comparison of the results of the modified design of type B set at bed level in table 4 and the results of first four observations in table 3 for modified design of A.P.M., set at 1.2 times the depth in the channel shows that there is not much to choose between two outlets. It appears that the setting of the outlet below bed level does not exercise any additional advantage over those set at bed level when the parent channel is running full supply.

A small local pit is scoured down to the crest level just upstream of the outlet when its setting is below bed level. The outlets set in that position do cause a little scouring of the channel upstream only when the latter is running with small supplies, and the outlet is in a position to partake of that supply. A small cunette is scoured out depending upon the duration of the low supply and the setting of the outlet. Generally the effect does not extend beyond a chain. This cunette gets filled up with silt from the silt charge carried by the channel when full supply comes down. This is generally a negligible advantage and should have no bearing in the design.

The modifications in type design B of the A.P.M. outlets are rather drastic and not liked by the zemindars. The silt conducive power for an outlet set at bed level goes up to about 128°/₀ as is clear from col. Nos. 16, table 4, Appendix II. On the other hand, an A.P.M. set at bed level built according to design as per I. B. Paper 26 would have a silt conducive power of about 115°/₀ only. It would thus appear that the former type has an advantage over the latter by about 13°/₀. The adoption of this design of approach has however its limitations. It is only suitable for setting of outlets at bed level or below. It is probable that A.P.M. as per type B set at 6-10 might have a lower silt conducive power than an A.P.M. built according to the design in I. B. Paper No. 26.

Absorption in a distributary generally varies from 10 to 15 of its discharge. Water lost in absorption leaves its share of silt in the supply of the channel, which increases the silt charge carried in the water. If the outlets put in a channel have a silt conducive power of only cent per cent the proportion of silt charge in the channel supply will go on increasing proportionately to the water lost in absorption. In order that the silt charge in a channel should not vary appreciably from head to tail, outlets should have a silt conducive power of more than cent per cent.

An outlet having a silt conducive power of about 110% to 115% would, therefore, just provide means of equitable distribution of silt charge carried in a channel. Outlets built in the following conditions would produce the desired effect :—

1. A. P. M. set at 8/10th modified design type A.
2. A. P. M. set at 9/10th built as per design I. B. Paper 26.
3. Open flume set at bed level as per Appendix D., I. B. Paper No. 26.
4. Open flume set at 9/10th with modified approaches.
5. Bend outlet of K. B. Sh. Minhaj-ud-Din set at 6/10th.

The outlets having a silt conducive power of more than 110% give the cultivators more than the due share of silt. Where high working heads are available, the watercourses have good slopes and the silt is carried to the fields. In such cases it is preferable to use outlets of high silt conducive power. It will be a hardship to the cultivators to put outlets of high silt conducive power in place of those which are already diseased and are suffering from silt trouble. The cultivators are no doubt upset, when highly silt charged water is put into their watercourses. They tend to neglect them. The judicious selection of the type and setting of the A. P. M. outlets is very essential in each case for their successful working in modular conditions.

APPENDIX I.

FORMULAE AND CALCULATIONS.

Notation.

H = Depression of Orifice floor.
h = Depression of Orifice roof.
y = Height of Orifice.
B = Width of Orifice.
c = Coefficient of discharge.
C = Ratio of average velocity in the channel to the side velocity.
q = Discharge of module.
hm = Minimum head required to ensure module only.
hw = Available working head.
$k = \frac{h}{H} = \frac{\text{Depression of the Orifice roof.}}{\text{Depression of the Orifice floor.}}$
d = Full supply depth of the channel U. S.
b = Bed width of the channel U. S.
Q = Discharge of the Distributary U. S.
$s = \frac{H}{d}$ = Setting of the outlet.
R_a = Radius of approach curve in bed in convex part.
R = Radius of approach curve on U. S. Side.
R_p = Radius of projection of D. S. Wing.
R_o = Radius of outfall in Bed.
Rs = Radius of Expansion of the outfall walls.

Approach curve in Bed.—

The radius of approach curve in bed is recommended as 2 H in Irrigation Branch Paper No. 26, Appendix E. 4.

When the width of approach is equal to the width of the outlet, the length of approach is nil according to the formula :—

$$l = \sqrt{(4\,H - w + B)\,(w - B)}$$

A. P. M. Block would come forward within three inches of the water edge in distributary but in order to lay the approach curve in bed with the radius 2H, the A. P. M. Block has to be set back behind by the amount of the minimum limiting length of approach.

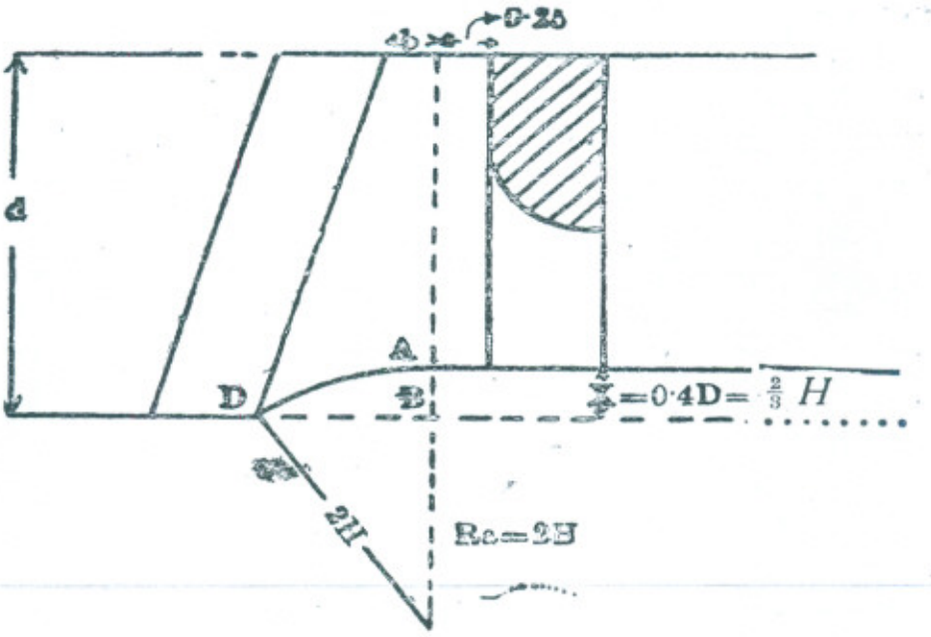
Let the outlet be set at $\frac{6}{10}$th and L be the minimum limiting length of the approach.

Geometrically.

$BD^2 = CD^2 - BC^2$

Let $BD = D$

$D^2 = R^2 - (R-x)^2$



$$D = \sqrt{(2H)^2 - (2H - 0{\cdot}4d)^2}$$

$$= \sqrt{(2H + 2H - \tfrac{2}{3}H)\ (2H - 2H) + \tfrac{2}{3}H)}$$

$$= \sqrt{(4H - \tfrac{2}{3}H)\ \tfrac{2}{3}H}$$

$$= \sqrt{\tfrac{10}{3}H.\ \tfrac{2}{3}H.} \qquad = \tfrac{2}{3}H\sqrt{5}$$

Considering that the U. S. face wall slopes $\frac{1}{2}$ to 1 and the approach curve in bed is laid with its extreme end at bed level in the line with the toe of the U. S. face wall.

But $H = \frac{6}{10}d$.

$$\therefore D = \tfrac{2}{3} \times \tfrac{6}{10} \times d \times \sqrt{5}$$

$$= \sqrt{\frac{2}{5}}d = {\cdot}895d$$

The minimum limiting length of approach

$$L = D - d/2 = {\cdot}895d - {\cdot}5d$$

$$= {\cdot}395d, \text{ say} = {\cdot}4d.$$

or $= {\cdot}4 \times \frac{10}{6}H. = {\cdot}66\ H$

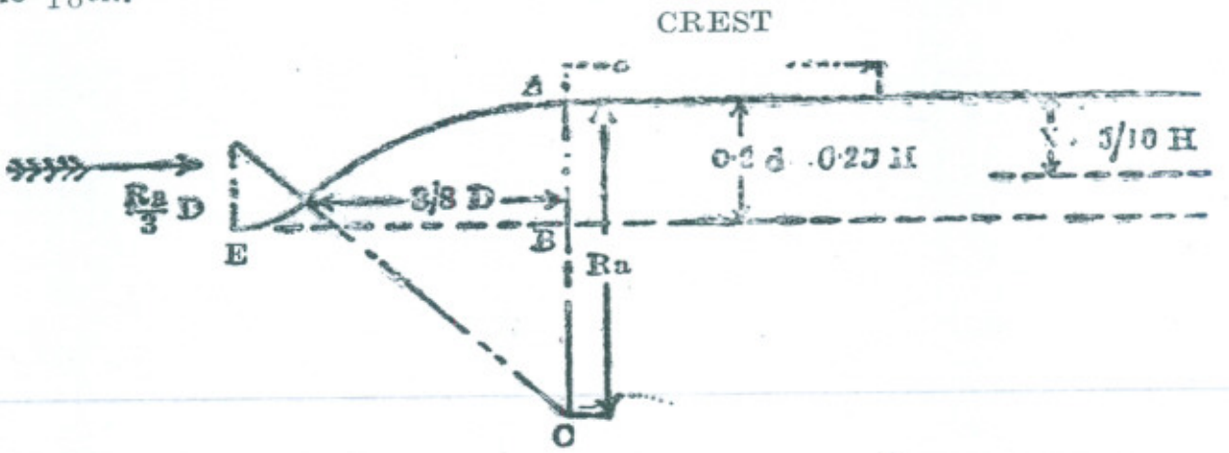
$$L = \tfrac{2}{3}H. \qquad \text{(A)}$$

When the outlet is set at $\frac{8}{10}$ the minimum limiting length of the approach works out :

$$L = {\cdot}345\ H. \qquad \text{(B)}$$

In order to avoid this unnecessary setting back of the A. P. M. Block, it is necessary that the approach curve in bed should be laid within $\frac{1}{2}$ to 1 slope of the U.S. face wall, in other words, the length of approach curve in bed should be ·5 *d*.

The proposed approach curve in bed is concave in the beginning for one-quarter length and convex at the end to the crest level. The radius of curve in bed is worked out below when the setting is $\frac{8}{10}$th.



$$BD^2 = (2R_a - x)\ x$$

$$(\tfrac{3}{8}\ d)^2 = (2R_a - \tfrac{3}{16}H)\ \tfrac{3}{16}H$$

$$(\tfrac{3}{64}\ H)^2 = (2\ R_a - \tfrac{3}{16}H)\ \tfrac{3}{16}\ H$$

$$\frac{225}{1024}\ H^2 = (2R_a - \frac{3}{16}\ H)\ \frac{3}{16}H$$

$$2\ R_a - \frac{3}{16}\ H = \frac{16}{3} \times \frac{225}{1024}\ H$$

$$= \tfrac{75}{64}\ H$$

$$2\ R_a = \frac{75+12}{64}\ H$$

$$R_a = \tfrac{87}{128}\ H = \cdot 68\ H \qquad (C)$$

The radius of the concave part

$$R = \frac{Ra}{3} = 0{\cdot}227\ H. \qquad (D)$$

Outfall Design.

Let *bw* be the width of the outfall or bed width of water course.

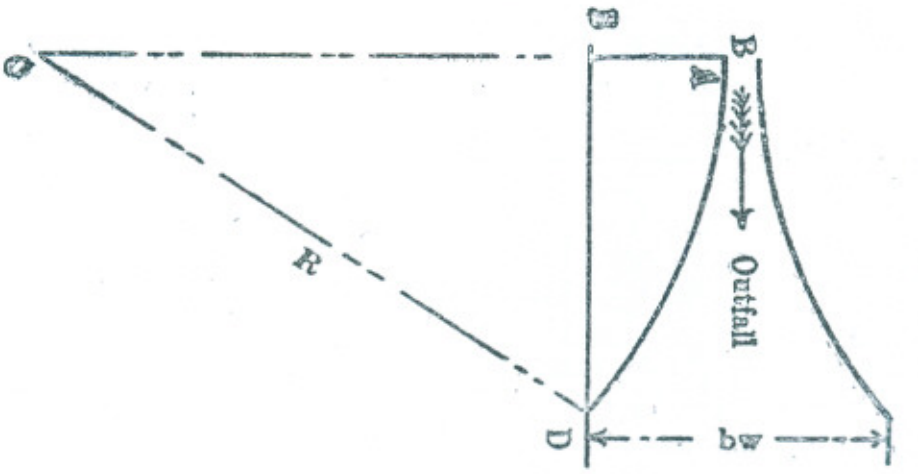
Let B be the width of the outlet.

Expansion on each side

$$E = AE = \frac{bw - B}{2}.$$

Let the expansion be 1 in 10 on the side.
Let R_s be the radius of the expansion of the walls of outfall.

Geometrically.



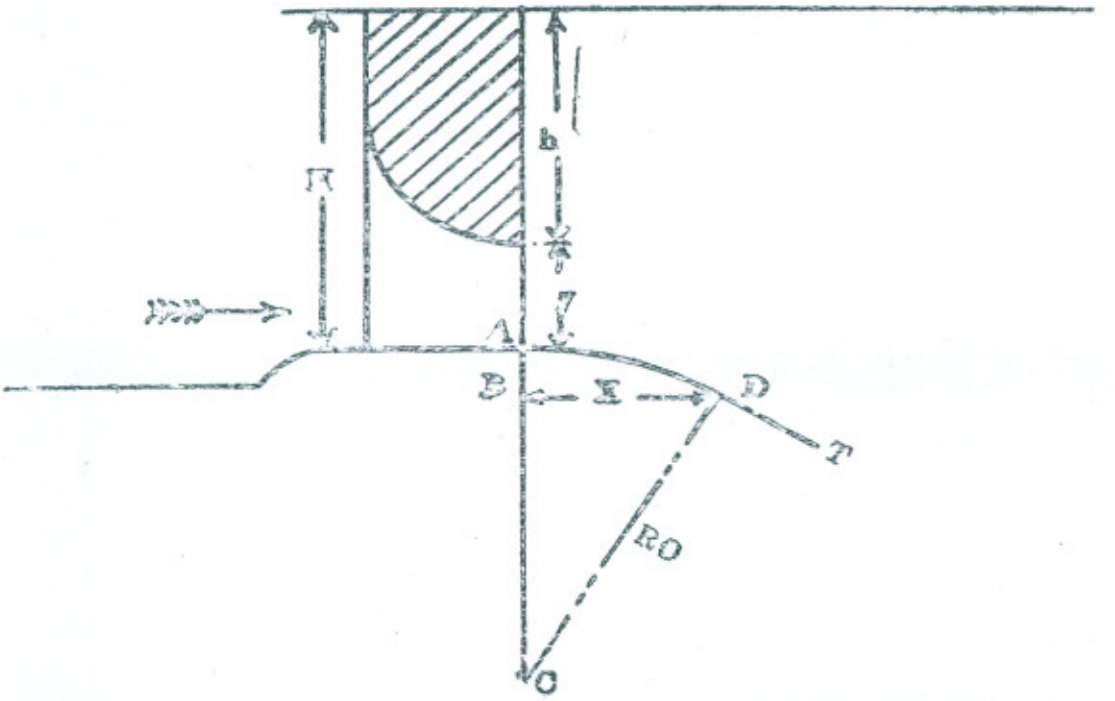
$AE\ (2\ R_s - AE) = DE^2$

But $DE = 10(AE)$

$AE\ (2\ R_s - AE) = 100\ AE^2$

$$2R_s - AE = 100\ AE$$
$$2R_s = 101\ AE$$
$$\text{or}\quad R_s = 50{\cdot}5\ \frac{(bw - B)}{2}$$
$$= 25{\cdot}25\ (bw - B)$$
$$= 50{\cdot}5\ E \qquad (E)$$

In order that the outlet may draw the maximum silt, the bottom filaments of water leaving the outlet should have a free exit. Any retardation in the velocity of these filaments directly affects the silt conduction of the coarse silt near the bed of the distributary.



The velocity of the filament of water travelling along the crest actuated by a Head of H ft.

$$V=\sqrt{2gH.}$$

Let t be the time in which a particle in this filament moves from A to D. Water along AD is moving with a velocity of V ft./sec. and is dropping under force of gravity. The drop in time t.

$$AB=s=\tfrac{1}{2}\ gt^2.$$

Let this drop be some fraction of H

$$s=kH$$

$$\therefore\ t=\sqrt{\frac{2\,k\,H}{g}}$$

But $x=BD=t.v$

$$=\sqrt{\frac{2kH}{g}}\qquad\sqrt{2gH}$$

$$\therefore\ x^2=\frac{2kH\times 2gH}{g}$$

$$=4kH^2 \qquad\qquad (I)$$

Let Ro be the radius of the outfall in bed downstream.

But **Geometrically**

$$x^2=(2R_o-s)\ s$$

Substituting for x and s

$$4\,kH^2=(2Ro-kH)\ kH$$

$$\therefore\ 2\ R_o-kH=4H$$

$$2\ R_o=4H\times kH=H\ (4\times k)$$

k is a small fraction and is negligible.

$$\therefore\ R_o=2H \qquad\qquad (F)$$

Let the curvature extend upto ·4H from the outlet

$$\therefore\ x=\cdot 4H$$

From equation (i)

$$k=\frac{x^2}{4H^2}=\frac{16\ H^2}{4H^2}=\cdot 04$$

Let i be the slope of the tangent T. D. at the end of curvature.

$$\therefore \qquad i \tan BCD = \frac{BD}{BC} = \frac{x}{Ro-s}$$

Substituting for x, R_o and s in terms of H

$$i = \frac{\cdot 4H}{2H-kH}$$

k is a small quantity and therefore negligible.

$$\therefore i = \frac{\cdot 4H}{2H} = \frac{1}{5} \qquad (G)$$

Therefore at the end of the curvature, it will be followed by a glacis 1 in 5.

Radius of projection of the downstream wing.

w=Projection of downstream wing

=BC

$\cdot 2w$=splay in distance w

Let R_p be radius of the projection of the downstream wing.

Geometrically.

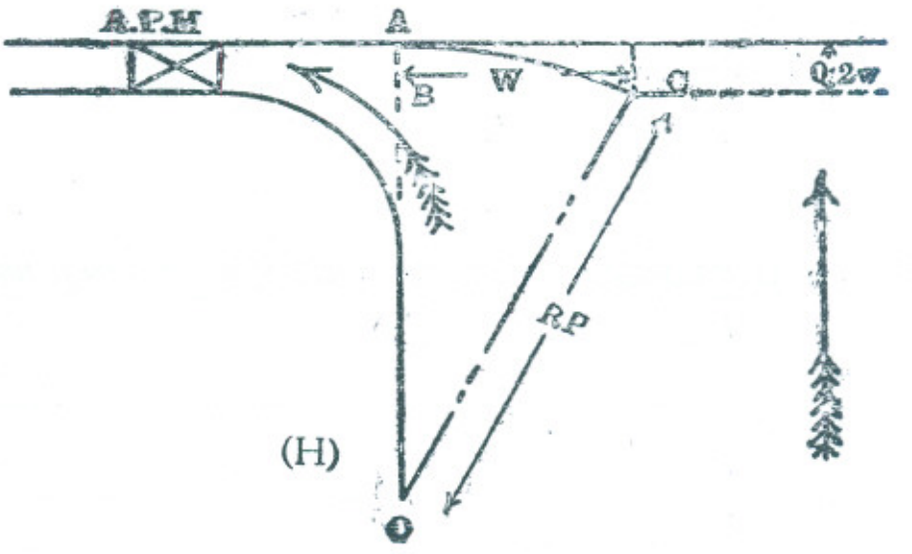
$$AB\,(2R_p - AB) = BC^2$$

$$\cdot 2\,w\,(2R_p - \cdot 2w) = w^2$$

$$2R_p - \cdot 2\,w = 5w$$

$$2R_p = 5w + \cdot 2\,w = 5\cdot 2\,w$$

$$\therefore R_p = 2\cdot 6\,w$$



(H)

TABLE No. I. APPENDIX II.

Statement showing silt drawn by different types of outlets Semi-modules (A.P. Modules).

Serial No.	Date.	Distributary Silt.			A. P.M. as per I. B Paper 26 at 6/10th			Silt conducive Outlet at 8/10th Type A.			Silt conducive outlet at bed level Type A.			Percentage of silt drawn by outlet.			Value of $K = \frac{h}{H}$
		Volume of water.	Silt.	Percentage by weight.	Volume of water.	Silt.	Percentage by weight.	Volume of water.	Silt.	Percentage by weight.	Volume of water.	Silt.	Percentage by weight.	A.P.M. I.B. Paper 26 at 6/10th.	Silt conducive at 8/10 type A.	Silt conducive at bed level TypeA.	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
		Cft.	Lbs. oz.		Cft.	Lbs. oz.		Cft.	Lbs. oz.		Cft.	Lbs. oz.					
1	16-5-31	228·8	29–0	·202	160·8	18-44	·182	96	13–5	·222	110	16–10	·241	90·0	110.0	119.7	Same discharge
2	15-5-31	238·4	26–1	·1715	168·0	16–3½	·158	95	11–3	·187	116	15–2¾	·209	92·0	109·0	122	·6
3	20-6-31	238·4	22–10	·152	144·0	12–14	·143	1151·1	121–9¼	·169	147·3	17–7⅝	·19	94·0	111·0	125	·7
4	30-6-31	191·7	18–6	·1536	155·2	13–9	·14	1081·25	115–0	·172	160·8	19–5⅛	.192	91·2	112·0	125	·75
5	9-7-31	188·48	34–14	·295	162·4	27–5	·269	748·8	154–0	·33	145·7	34–0	·373	91·2	112·0	126.5	·8
6	13-8-31	182·0	37–13	·331	157·0	30–6½	·31	784·0	170–8	·35	151·81	36–11¾	·387	93·6	105·7	117.0	Same discharge
7	21-8-31	393·6	86–0	·35	143·2	28–7⅛	·318	1222	285–10¼	·374	164·2	43–1⅛	·42	91.0	107·0	120	·5
8	27-8-31	391·7	40–6	·165	159·2	14–10	·147	1272·2	142–4	·179	179·5	21–7¼	·191	89.0	108·5	116	·4
9	3-9-31	371·0	32–8	·14	145·6	12–0	·1316	1343·0	126–12½	·151	133·4	14–3½	·171	94·0	108·0	122	·6
10	13-9-31	380·8	43–5	·182	156·8	16–15	·173	1201·2	150–2½	·200	133·7	18–9¾	·223	95·0	110·0	123	·7
11	18-9-31	382.2	35–0	·150	147·2	13–1	·1425	1052·1	112–6¾	·171	112·9	13–5	·189	95·0	114·0	125	·8

K. R. SHARMA,
ASSISTANT ENGINEER,
Mithalak Sub-Division, Sargodha.

TABLE No. 2 APPENDIX II.

Statement showing silt drawn by different types of open flume outlets.

Serial No.	Date.	*Distributary Silt.*			*Open flume outlet at bed level according to Mr. Crump's design.*			*Modified A. P. M. type A at 8/10th No. 2.*			*Open flume outlet at bed level Modified design 3.*			*Percentage of silt drawn by outlets.*		
		Volume of water.	Silt.	Percentage by weight.	Volume of water.	Silt.	Percentage by weight.	Volume of water.	Silt.	Percentage by weight.	Volume of water.	Silt.	Percentage by weight.	No. 1.	No. 2.	No. 3.
12	2-10-31	228·8	29-0	·203	168	22–15	·219	1081·25	150–3¾	·222	113·828	16-10¼	·234	108	110	115
13	8-10-31	371·0	27–13	·12	165·29	13–10½	·132	1343	111-10	·133	·10	15–15¼	·140	110	111	116.6
14	15-10-31	381·4	42–14¼	·18	163·62	19–13½	·1937	1210	149–12	·198	136·08	17–12	·2087	108	110	116
15	21-10-31	380·5	35–10¾	·15	164·46	16–5	·1587	1231·2	121–9	·158	142·18	15–8¾	·175	106	112	116.6
16	28-10-31	371·84	37–2	·16	137·74	14–5	·166	1393·75	152–7	·175	227·656	26–4	·1854	104	109	115

K. R. SHARMA,

ASSISTANT ENGINEER,

Sargodha Division, L. J. Canal.

TABLE No. 3. APPENDIX II.

Silt drawn by A. P. M. Modified Type B set ·2d below bed.

Serial No.	Date.	*Distributary Silt.*			*Silt drawn by outlet ·2d below bed level.*			Percentage of silt drawn by outlet.	
		Volume of water.	Weight of silt.	Percentage by weight.	Volume of water.	Weight of Silt.	Percentage of water.		
			Lbs. oz.						
1	1-5-32	196·8	18-11	·152	$\frac{Y=·9}{12·7}$	15–5½	·200	131·6 %	
2	10-5-32	185·6	15–11	·135	124·767	13–13	·1755	130 %	
3	25-5-32	179·2	11–5	·101	121·666	9–13	·129	128 %	Average 128·9 %
4	1-6-32	180·48	11–6	·099	123·734	9–10¼	·1247	126 %	
5	9-6-32	188·8	12–5¾	·102	$\frac{Y=1·20}{126·83}$	9–11	·1224	120 %	
6	15-6-32	191·36	10–14½	·089	$\frac{Y=1·5}{127·868}$	8–2¾	·1023	115 %	
7	21-6-32	185·8	12-12¼	·11	$\frac{Y=·8}{112·362}$	9–10½	·1375	125 %	
8	28-6-32	188·8	11–7	·097	$\frac{Y=7}{111·328}$	8–1½	·1164	120 %	
9	4-7-32	180·48	11–13½	·105	$\frac{Y=·6}{113·396}$	8-12½	·1239	118 %	

K. R. SHARMA,
ASSISTANT ENGINEER,
Sargodha Division, L. J. C.

TABLE No. 4. APPENDIX II.

Statement showing silt drawn by different types of Outlets.

Serial No.	Date.	*Distributary Silt.*			*Bend Outlet.*			*A.P.M. at Bed level Modified design Type B.H.=2·5, Y=0·4H.*			*A.P.M. outlet at 6/10th Modified approaches, Type A.H.=1·5, Y=.4 H.*			*Percentage of silt-drawn by outlets considering distributary Silt as 100.*		
		Volume of water.	Silt in Lbs.	Percentage by weight.	Volume of water.	Silt in Lbs.	Percentage by weight.	Volume of water.	Silt in Lbs.	Percentage by weight.	Volume of water.	Silt in Lbs.	Percentage by weights	Bed outlet.	Outlet at Bed level.	Outlet at 6/10th.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
			Lbs.		Cft.	Lbs. oz.		Cft.	Lbs.oz.		Cft.	Lbs. oz.				
1	22-8-30	183·68	23	·20	800	118	·236	125	20–5	·26	160.8	19·14	·198	118	130	99
2	4-9-32	170·2	8–15½	·08	781·25	42–15½	·088	127	8–1	·1016	168	8–7¾	·0808	110	127	101
3	19-9-32	182·4	11–6½	·10	812·5	57–6	·113	122	9–13	·129	162·4	10–2	·10	113	129	100
4	26-9-32	179·84	14–9¾	·13	762·5	70–8½	·148	119	12–1	·1625	152	12–1½	·1274	114	125	98
												AVERAGE		113·57	127·75	99·5

K. R. SHARMA.
ASSISTANT ENGINEER,
Sargodha Division L. J. Canal.

NOTATION FOR OPEN FLUMES. PLATE 4.
MODIFIED TYPE.

bw Bed width of channel u/s of outlet
d Depth " " " " "
Q Discharge " " " " "
bd Bedwidth " " d/s " "
q Discharge of outlet
H Depth on crest

$B = \frac{q}{C H^{3/2}}$ Width of outlet

$\frac{2}{3} K$ Depth of control section where $K = \left(\frac{q}{3{\cdot}09\ B}\right)^{2/3}$

$2K$ Length of crest
$1.5K$ Minimum working head
$b.w$ Actual working head

$w = \frac{q}{6}\left(bw + \frac{d}{2}\right)$ Set back of u/s wing and width of approach

Minimum set back = ·5′

$S = w - B$ Splay of u/s side wall
$2\text{-}5s$ Radius of splay on side
$2s$ Length of approach curve on side
$2{\cdot}6w$ Radius of curvature in projected wing
$25{\cdot}25\ (bw\text{-}B)$ Radius of outfall

STANDARD TYPE.

b Bedwidth
d F. S. depth of channel below outlet
Q Discharge
q Discharge of outlet
H F. S. depth on crest of outlet

$B = \frac{q}{3 H^{3/2}}$ = Width of flume at waist

$w = q/Q\left(B + \frac{d}{2}\right)$ = Width of mouth of approach

= Set back of u/s wing

l Length of approach curve $= \sqrt{(w\text{-}b)\ (4H - w + B)}$
L Length of outfall

$R = \frac{q\text{-}B}{4} + \frac{L2}{q\text{-}B}$ = Radius of outfall

NOTATION FOR A.P.M. PLATES 1, 5 and 6.

bw Bedwidth in channel u/s of outlet

d Depth of „ „ „ „ „

Q Discharge „ „ „ „ „

bd Bedwidth „ „ „ D/s „

q Discharge of outlet

H Depth on crest

w Depression of roof block of A.P.M.

B width of throat of A. P. M.

$w\text{-}h=y$ Height „ „

hm Minimum working head

hw Actual „ „

$w=C\frac{q}{Q}\left(bw+\frac{d}{2}\right)$ Width of waterway for an outlet of discharge

w Projection of the d/s wing at bed level

$\frac{bw}{2}+\frac{d}{2}+s$ Distane of A. P. M. block from centre line u/s

L Length of outfall

25·25 $(bw\text{-}B)$ Radius of outfall wings

2·6 w. Radius of curvature on d/s projection

S=w—B „ „ splay on u/s side wall

$$C=\frac{\text{Average Velocity in channel u/s}}{\text{Velocity near the side u/s}}$$

=2·0 per head reach in major distributary

1·5 „ middle „ „ „ „

1·25 „ tail „ „ „ „

1·0 „ channels below 10 cusecs

FOR MODIFIED A.P.M. TYPE B. PLATE 1.

5·2 $(2w-B)$=Radius of curvature of projected wing at bed level.

DISCUSSION.

Mr. K. R. Sharma in introducing his paper said that the paper dealt with a few field observations carried out to determine the silt conductive power of A. P. M. and open flume outlets under different conditions. He further said that it was not extended to any new outlet.

A few changes in the approaches to those outlets were attempted and the results of the actual use of those outlets in practice and tests carried out showed that those changes improved the silt conduction of the outlets.

The results showed that the silt conductive power of the outlets improved with their low setting. The outlets would be set low as far as the working head permit. The tests showed that the setting of the outlets below bed level do not prove of any substantial advantage over those set at bed level.

It had been brought out that it was not enough that the outlets should draw proportionate share of silt from a channel but that it should extract its due share of silt charge from the parent channel. The due share of silt drawn by an outlet would be from 110 to 115 p.c. of the silt charge in the parent channel in order to make up for the silt left in the parent channel by water lost in absorption.

Lastly it was visualised that if the silt charge of the parent channel were lessened and its grade reduced, by use of outlets of high silt conductive power, the channel could then be run nonsilting ; thus the effect of silt conduction by outlets on the regime of a channel was an important factor and should be allowed for in the design of the channels.

Mr. Kanwar Sain said that every canal engineer knew it well that the power of outlets at different sites of a channel to draw off silt varied enormously.

Going along a channel one was struck forcibly by the fact that while some watercourses had absolutely no silt on their banks, others had very high heaps on both sides. Silt heaps as high as fifteen feet existed on several watercourses on U. B. D. C. and L. C. C.

The question had several times arisen in his mind why had this inequitable distribution of silt which certainly meant a recurring expense to the share-holders not been made the subject of a detailed investigation just as had the equitable distribution of water.

The outlets should be able to take their 'Due Share of Silt', has naturally been emphasised in the past as well as by Mr. Sharma in his paper under discussion.

The point was what was the ' Due Share ' of a certain outlets ? Should each outlet be made to draw the same percentage of silt that the parent channel was carrying ?

In the past obviously this is what was attempted by the canal engineers. Those outlets which had a good command never

accumulated much silt, while others with poor command were choked up and continuous silt clearance for years had produced silt mountains on their banks.

Fed up by the difficulties of clearing silt in such cases, they think it more expedient to request for a change of site for the outlet, only to shift the acute trouble perhaps to the next generation.

It would be realized that some of the small holders might easily if in the neighbourhood of the watercourse, have all their land covered over by silt.

The only remedy was to give a watercourse only as much silt as it could easily digest. It might be possible to give extra silt to some other outlets, irrigating low lands. The critic might point out that in that manner in certain cases it may not be possible to dispose off all the silt that might come in the channel. The reply would be that measures should be taken to bring in as much silt as could be disposed of in that manner. That might involve some remedial measures at the head regulators of canals. And if that day was yet far off no one should be afraid of the consequences of his own actions and he must put up with occasional silt clearances. That would be more equitable than making only some of the cultivators suffer to the advantage of others.

Mr. Sharma's paper was a clear advance in that direction. If we were capable of sending known and predetermined quantities of silt down any offtake, the day was not far off, when the silt problem might be satisfactorily solved.

On one point, he had found it difficult to agree with the author, when he declared that any outlet set below the bed level would not draw more silt than if it were set at the bed level of the parent channel. When the K. G. O.s were installed at approximately bed levels in place of pipes which were at that time below the bed level, it was commonly said that K. G. O.s caused silting up in the channel and would not draw sufficient silt.

Fifteen years later those very K. G. O.s were complained of by the cultivators that they were drawing too much silt. The cause was that the bed of the distributary had risen and was higher than the bottom of the K. G. O.s.

Mr. Mithal stated that having received the paper only yesterday he could not got through it very carefully and he had made only a few notes. On page 233 the author mentioned, Condition II, that the approach on the upstream and downstream side should be simple and that there was no disturbance. Looking at Plate I, it appears that Mr. Sharma puts an obstruction on the downstream side of the outlet which was a copy of Paper No. 26 of Mr. Crump and the silt induction wall. The speaker said that he did not know how the author could reconcile this with the opposite statement. Then about these experiments regarding silt, the speaker carried out a few experiments at 65,000 of Habri Distributary on the Western Jumna Canal in 1924. He found in some cases that similar

outlets under similar conditions gave more deposit of silt in some places than in others on the same channel. He could not explain this and he would ask the author if he had made acquaintance with similar phenomena. On page 232, lines 10 and 11, the author advocated unlimited increase in silt drawn by outlets. If the author unfortunately succeeded in his attempt then the cultivator will have to clear his watercourses every third day and it would ultimately result in the decrease of irrigation and the speaker did not think that the aim was to decrease the irrigation.

Mr. Colyer speaking on Mr. Sharma's paper stated that, on page 7 the author advised a quadrant-approach. He said that his experience of quadrant-approaches was that they were so long that they were inclined to cause interference at the actual throat, and thus to reduce the discharge, as the jet shot across the throat and prevented smooth parallel-sided entry. He was not qualified to say definitely whether this affected the discharge, but he rather thought it did. The speaker considered that for smooth entry a flatter curve for a shorter length was better than a sharp curvature with a whole quadrant. Another point was about silting of watercourses. The zamindars usually tried to force water on to 100 p. c. of the area of a *Chak*, including high portions, regardless of the fact that only a smaller percentage was intended to be irrigated, with the result that the watercourses silted up, and drowned the outlets. Unfortunately this was, in practice, a much more potent factor in causing silt-deposit and unsatisfactory working of outlets and distributaries, than the exact design of the outlet, and it was really the ultimate determining factor of the silting trouble, which even the 'perfect outlet' could not overcome, and for which there appeared to be no remedy, short of absolute and rigid exclusion of even small areas for which ample command was not available.

Mr. Handa said that besides the hydraulic considerations of the channel, there were other factors which interfered with the working of channels, resulting in silt deposits. These were :—

(1) Attempt of the zamindars to irrigate uncommanded areas, by heading up supply in the watercourses. This was clear when during a tour, one came across certain watercourses which had very high silt banks, while others had not. In due course these watercourses threw back silt into the channel.

There seemed no remedy in case of proprietary areas to prevent zamindars from irrigating such high lands by heading up. In case of crown waste lands, however, it was the duty of the Irrigation Engineer to be on the look-out that the Civil Department did not allot or sell such uncommanded lands.

(2) Silt thrown by interested irrigators in the bed of the channels, in order to raise full supply and thereby to increase the discharge of the outlets. This was more or less an organized attempt to counteract

the effect of remodelling or researches of diligent officers, like Mr. K. R. Sharma, who deserved congratulations on his attempt and their results.

The remedy against this import of silt into the channel by non-hydraulic agencies, as adopted by Mr. Handa during his duties, had been as below :—

(*a*) For Open Flumes Reduce "B" to suit increased "H."

(*b*) For A. P. M.'s reduce, "Y."

Silt clearance would naturally in such cases be inaffective, as, as soon as it was done and the channel was re-opened, it would again be thrown into it.

Hydraulic Surveys often baffled the officers, as they spent time in devising means for eradicating the trouble by spending money, sometimes huge, while the causes of trouble really were found as below :—

(1) the Y.'s of A. P. M.'s were actually bigger than designed, through the connivance of some agency,

(2) the floors of bridges were higher than the designed bed. The possession of the old level books by the subordinates doing Hydraulic Survey was a constant menace to the correctness of the Survey.

When the defects like (1) above existed, no amount of remodelling would help. The remedy was putting in A. P. M.'s not of iron (adjustable), but of cement concrete moulded into shape as one whole. These latter could not easily be tampered with.

Further a layman could not mould it himself without detection and further because it could be checked by Sub-Divisional Officer before it was fitted in.

Experience showed that even though a new cement concrete A. P. M. was required, the cost of readjustment did not compare unfavourably with the cost in adjusting a steel A. P. M. Instances were on record, stating that in certain cases, the bolts in adjustable outlets were left loose and the Y.'s could thus be adjusted by the irrigator at will, without rendering him open to *tawan*.

On the Upper Bari Doab Canal cement concrete A. P. M.'s had been used with very great success.

Mr. Handa drew the attention to these sides of the question also, instead of the hydraulic discussions only.

Mr. Montagu, speaking on Mr. Sharma's paper, pointed out that the preceding speakers had stated certain hard facts—troubles which those in charge of the actual distribution of water knew were due to the cultivators and as such could not be overcome by the design of any particular outlet, no matter how ingenious, no matter to what extent proportional or the range of modularity.

Mr. Crump's so called "adjustable proportional module "was particularly susceptible to interference by the zamindar. Apart from this practical drawback, it suffered from a theoretical disadvantage unless inserted with the greatest discretion,—a discretion seldom found in the design offices of divisions.

Owing to the high crest necessary to secure "proportionality," the outlet always failed to draw its fair charge of silt. The remedy was boldly to throw over any attempt to secure proportionality and go for modularity, by lowering the crest of the outlet. The speaker personally, looked upon proportionality as a delusion and a snare, except in the solitary case of proportional dividers of the open flume type, inserted occasionally in a channel.

In support of his contention that the Crump "A. P. M." caused silting the speaker mentioned the case of a channel in the Montgomery Division of the Lower Bari Doab Canal. This channel had been fitted with the Crump type "A.P.M." from head to tail (a system Mr. Crump would be the first to deprecate). Upon opening the channel, water was fairly well distributed and the correct supply reached the tail within a reasonable percentage of designed. Within four months, the supply to the last quarter of the channel had been reduced to a trickle by reason of the excessive silting which had taken place in the head reaches, the consequent overdraft of the upper outlets combined with reduction in supply rendered necessary by the raising of the full supply level.

The speaker then went on to invite the attention of those present to a very old type of outlet, which in the absence of any accepted name, he termed the "diaphragm-*cum*-weir." The advantages were great: (*a*) a high degree of immunity from interference due to the certainty of early detection ; (*b*) accuracy of rating ; (*c*) a large range of modularity could be insured by careful design ; (*d*) low consumption of head ; (*e*) cheapness when in heavy channel banks ; (*f*) swift determination of the actual discharge.

The speaker sketched the outlet on the blackboard. It consisted of a barrel so designed that the velocity of discharge precluded silting in ordinary conditions ; a steel diaphragm in which a hole was cut ; the variation of this diaphragm permitted a variation in authorised full supply discharge. At the water-course end of this barrel was a small cistern, from which the discharge issued over a small "long-crested" weir. A scale attached to, or a mark engraved on, the wall of the cistern indicated the authorised level of the water over the cill and could be checked at a glance.

The speaker had inserted numerous outlets of this type but had not yet been faced with conditions under which the results were less satisfactory than any other kind of outlet. No outlet met all conditions, but the diaphragm-*cum*-weir type appeared to be the most generally suitable. Combined with occasional proportional dividers at minor offtakes and large outlets, together with Crump's "adjustable semi-modules" (*i.e.*, the A. P. M. with a low crest), at the extreme tails and open tail

clusters, very fair and stable distribution was possible. In conclusion, the speaker ventured to repeat a warning so often uttered and seldom heard. The distribution of water was a business without finality and continual watching and adjustment was necessary if a constant supply (within reasonable limits) was to be maintained at all offtakes in a channel.

Mr. S.L. Malhotra, speaking on Mr. Sharma's paper, referred him to a note by Mr. Murphy on orifice semi-module outlets, which were A. P. M.s differing from the same in having a setting of 9/10. The speaker had designed some outlets on the S. V. P. on the principles laid down by Mr. Murphy. These O. S. M. outlets were used in the head reaches of distributaries with depths over 30′ and had two distinct advantages over Crump's A. P. M., *viz.*, low flexibility represented by $r=\frac{1}{3(l-k)}$ and adequate silt conducting power. There was no silt trouble on the channels on which these were used and the condition of tails was quite satisfactory. In uniformity with the O. S. M. outlets, the open flumes in the tail reaches of the channels had also a setting of 9/10 and were thus well suited for these reaches in having high flexibility and good silt conducting power.

Referring to Mr. Handa's remarks regarding interference by zamindars of open flume outlets by illegal heading up in channels, the speaker referred to the ingenious design by Mr. Routh on the L.B.D.C. providing open flumes with rectangular roof-blocks 21″ down stream of the upstream end of the throat and 7/8″ above the water line with designed level in the channel. This made the water-curve touch the block at a heading up of over one *hissa* above designed level and reduced the discharge of the outlet below permissible even, by rendering the flume into an orifice. The discharge did not rise to permissible till after a heading up of ·25′. There is thus no temptation for the zamindars to tamper with the channel regime by illegal *chhaps*, as any such action tends to deprive them even of their *haq* supply.

Mr. Wilson, speaking on Mr. Sharma's paper said that his paper was most interesting and his modifications seemed to be a considerable improvement as far as increasing the silt conduction of module outlets was concerned. The author recommends a setting of 8/10ths instead of the standard setting of 6/10ths of the channel depth. It was generally recognised that the standard A. P. M. with the latter setting did not draw its full share of silt and the ordinary A. P. M. in many cases failed on this account. On page 13 the author recommended his modified A. P. M. set at 8/10ths or a standard A. P. M. set at 9/10ths, but none of his recommended types except the bend outlet were proportional modules and all required undue working head.

The standard A. P. M. set at 6/10ths was a perfect outlet as far as proportionality and equitable distribution was concerned but failed in some cases on the silt question. The author in his modifications had improved the silt conductivity, but in Appendix 2 Table IV he showed

that his modified A.P.M. set at 6/10ths drew cent. per cent. silt and it was suggested that in most cases this design would be satisfactory with regard to silt draw, proportionality and working head.

Proportionality was a great advantage and in putting the outlet crest lower than 6/10ths of the depth this advantage was lost and a greater working head was required ; therefore the crest should not be lowered except as a last resource. What was required, it was suggested, was a further modification of the approaches of an A. P. M. with a crest at 6/10ths having complete proportionality, a low working head, and adequate silt draw.

The speaker suggested that this could be done and proceeded to illustrate methods by a series of sketches. The principles illustrated may be summed up as follows :—

1. Advancing the lower half of the downstream wing wall.

2. Advancing the downstream wing wall twice the normal amount at the bottom, gradually changing to no advance at the water surface.

3. A greater advance at the bottom reducing to no advance at the level of the bottom of the roof block.

4. A diaphragm at the face of the wing walls to cut off all top water.

Mr. Sharma thanked the members who had taken part in his paper's discussion and met the points raised by various speakers. Agreeing with Mr. Kanwar Sain he remarked that the silt should be controlled at the head regulators of the channels. In fact it would be a great improvement if the silt was regulated there. He thought that 6/10th outlets would work the channels more satisfactorily. Referring to his remarks that outlets set below bed levels should be more advantageous than at the bed level, the author said that observations made by him generally showed no marked increase and he did not consider therefore it was of any advantage.

Referring to Mr. Mithal's remarks about the contradictory statements made in para. 2 on page 233 that approaches upstream and downstream should be smooth, so that there was no obstruction, he explained that if these were made straight there would be obstruction. On the contrary, the speaker had said at the end of the paper that where the water courses were bad the output should be judicially selected, so that the watercourses were not given any additional silt discharge.

With reference to Mr. Colyer's remarks, the author replied that he agreed with him that if the approach had covered a big radius, then there was a tendency for the water to go out. He further agreed with Mr. Colyer that the uncommanded lands were generally the source of troubles.

Referring to Mr. Wilson's remarks that for the sake of proportionality, the outlets should not be lowered too much, the speaker expressed his own personal opinion that proportionality was of little account. If the channels silted up, the proportionality goes away. For the sake of working heads, outlets had to be kept sometimes high.

CORRESPONDENCE.

Mr. Wilson in correspondence stated that owing to the late delivery of the advance copy of the Paper he had only time to run through it quickly and hence failed to notice that outlet Type B, if set at 6/10 of the depth was more or less in accordance with his idea of an ideal outlet. However, figures of silt conductivity of outlet Type B were only given for a setting at bed level and at 0·2 *d* below bed level, both of which shew that the silt conductivity was far in excess of what was normally required. Comparing Type A at bed level (Table 1) with Type B at bed level (Table 4) it would be seen that Type B drew 6 p.c. more silt than Type A when the outlets were approaching the maximum limit of conductivity and 14 p.c. more than the bend outlet (Table 4). Now Type A at 6/10 setting (Table 4) drew on the average 99·5 p.c. hence it was reasonable to suppose that Type B at 6/10 setting would draw about 110 p.c. This was in accordance with the author's ideas of necessary silt conductivity and in the writer's opinion was ample. If this deduction was correct then an outlet similar to Type B set at 6/10 was an ideal outlet having (1) Ample silt conductivity (2), Complete proportionality and (3) Comparatively low minimum working head.

His only criticism of outlet Type B as designed by the Author was that in bringing the roof block and throat so close to the parent channel, the silt conductivity might be increased by the roof block acting as a cut off to top water, but when set at 6/10 the sharp rise of the crest would be nearly equally effective as a cut off to bottom water ; also with the best of design there was bound to be a slight swirl at entry between wing walls and with the throat so close to this disturbance the co-efficient of discharge was likely to be upset and had a tendency to be variable.

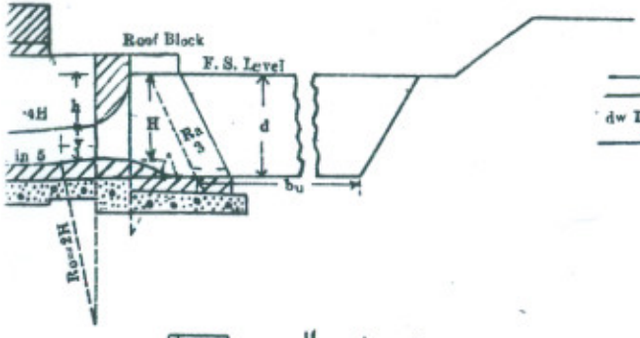
Personally he would much prefer an outlet designed as per Irrigation Branch Paper No. 26 with wing walls modified according to the author's Type B, and in order to avoid the cut off of bottom water, built with a flattened slope to the crest. If such an outlet failed to give sufficient silt draw, it would still be possible to make a cut off to top water, either by a heavy masonry diaphragm close to the parent channel or else by starting the side slope of the downstream wing wall below full supply level thus creating a slight outward draw of top water. *i. e.*, there would be a slight flow from the outlet to the parent channel near the water surface.

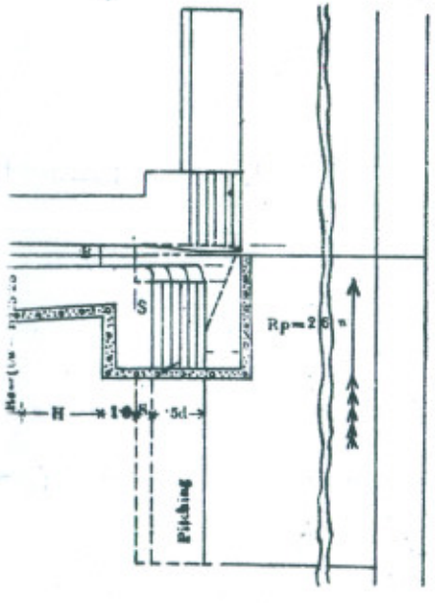
The method of measuring the silt charge adopted by the author appeared quite suitable for experimental outlets, but had the disadvantage of being somewhat expensive and restricted the experiments to one particular channel. The silt charge could be measured equally accurately from a few bottle samples taken from the standing wave of a fall in the parent channel and again from the standing wave of the outlet concerned. This method made it possible to modify existing outlets under a large variety of conditions and also made it possible to compare the grade of silt both in the distributary and in the watercourse.

It appeared to the writer hardly fair or necessary to force an undue quantity of silt on the zamindars in the head reach of distributaries if it was found possible to give every outlet only slightly more than its net quantitative share of silt and to make outlets draw silt of a heavier grade than the average in the parent channel. He saw no reason why a very near approach to this ideal should not be attained by carrying out a number of experiments on a variety of modifications to existing outlets the cost of which would be negligible.

VE OUTLET TYPE A

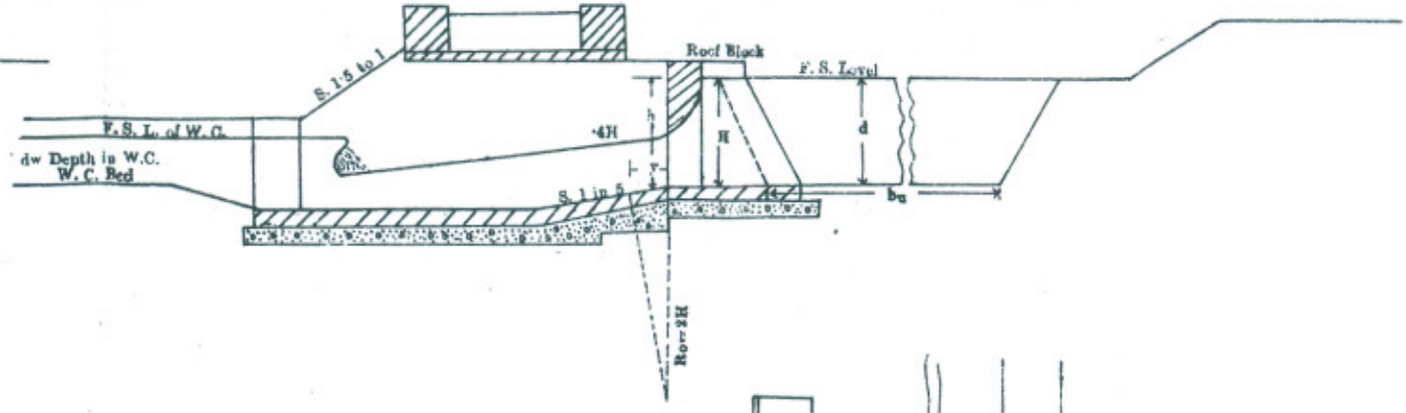
AT 8/10 TH

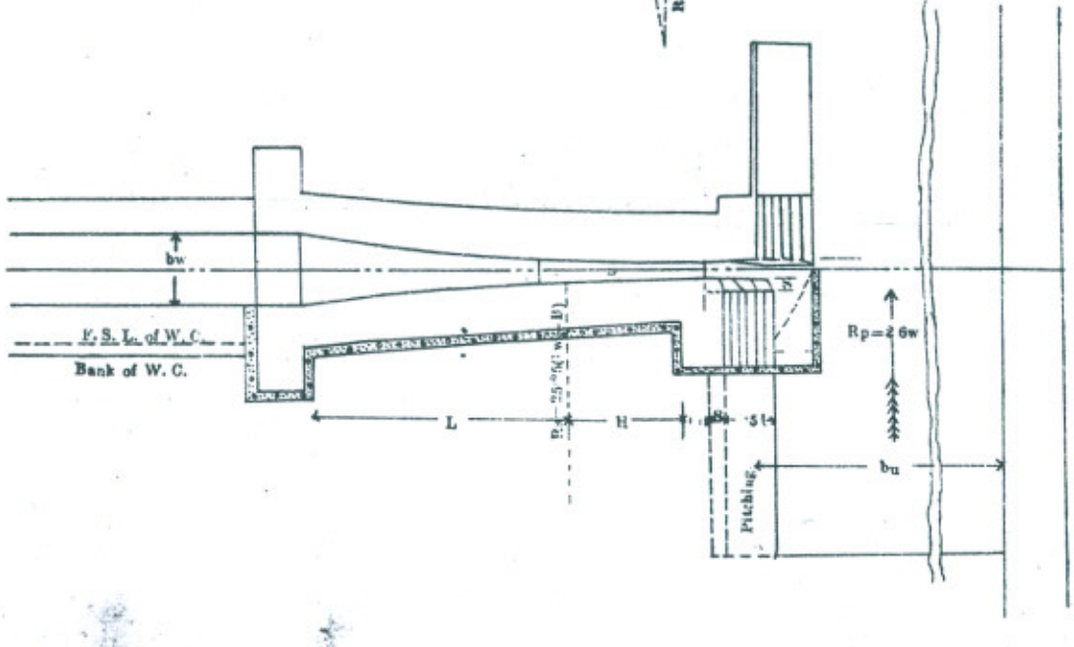




SILT CONDUCTIVE OUTLET TYPE A

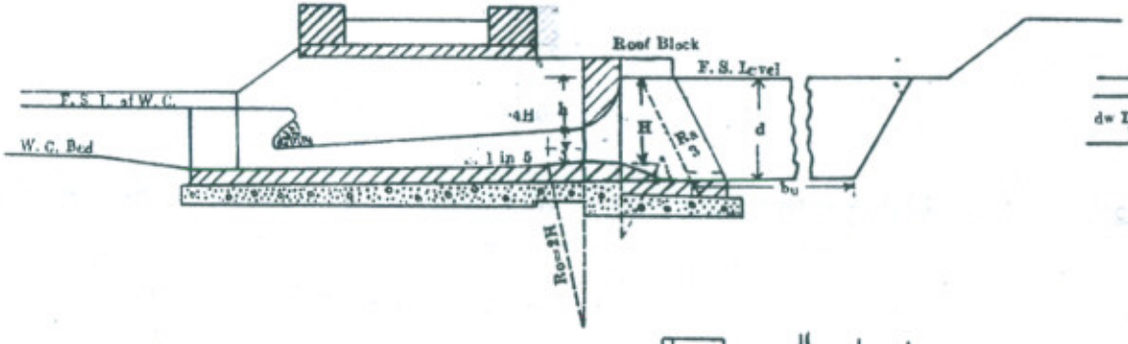
SET AT BED LEVEL

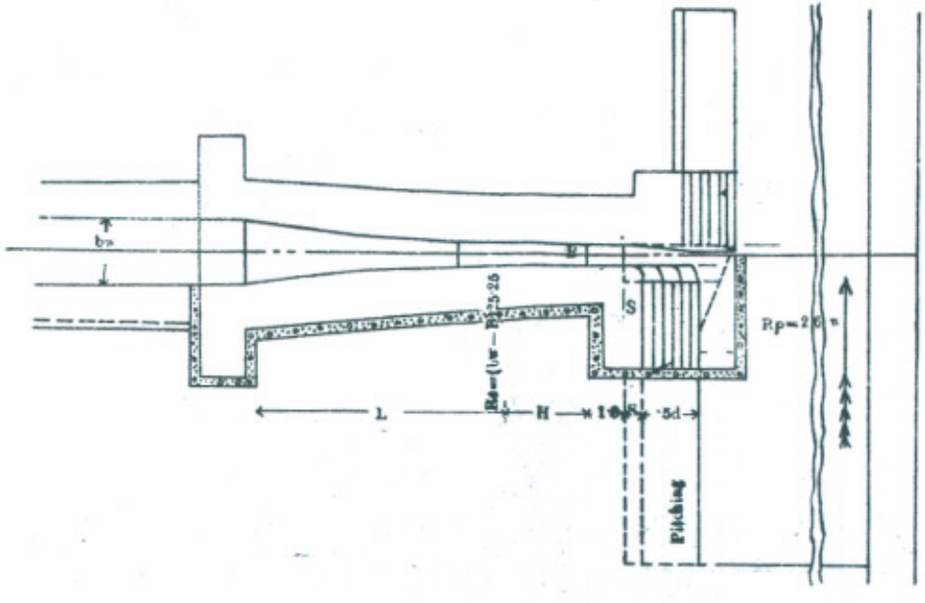




SILT CONDUCTIVE OUTLET TYPE A

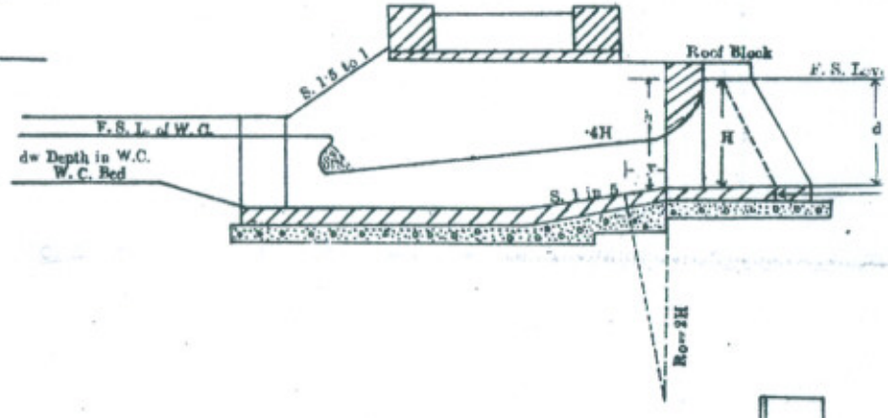
SET AT 8/10 TH

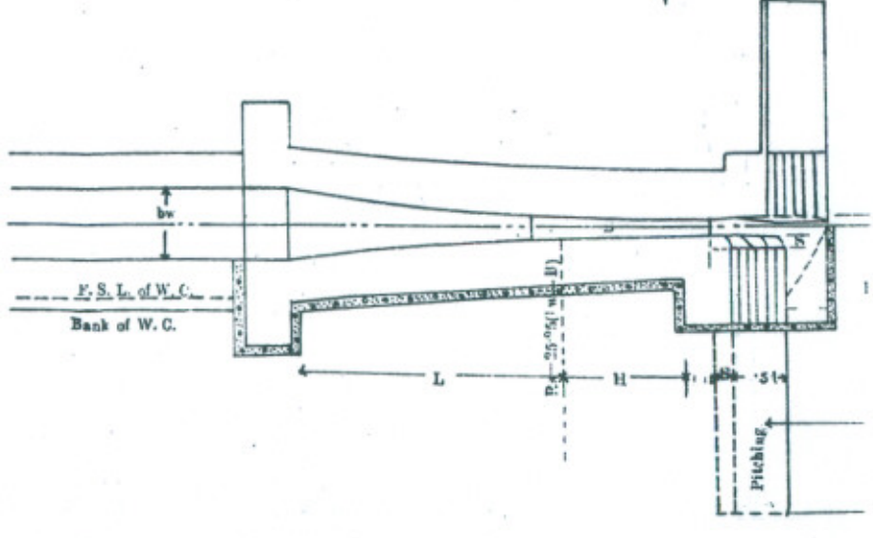




SILT CONDUCTIVE OUTLET TYPE A

SET AT BED LEVEL





SILT CONDUCTION BY WEIGHT

PLATE II

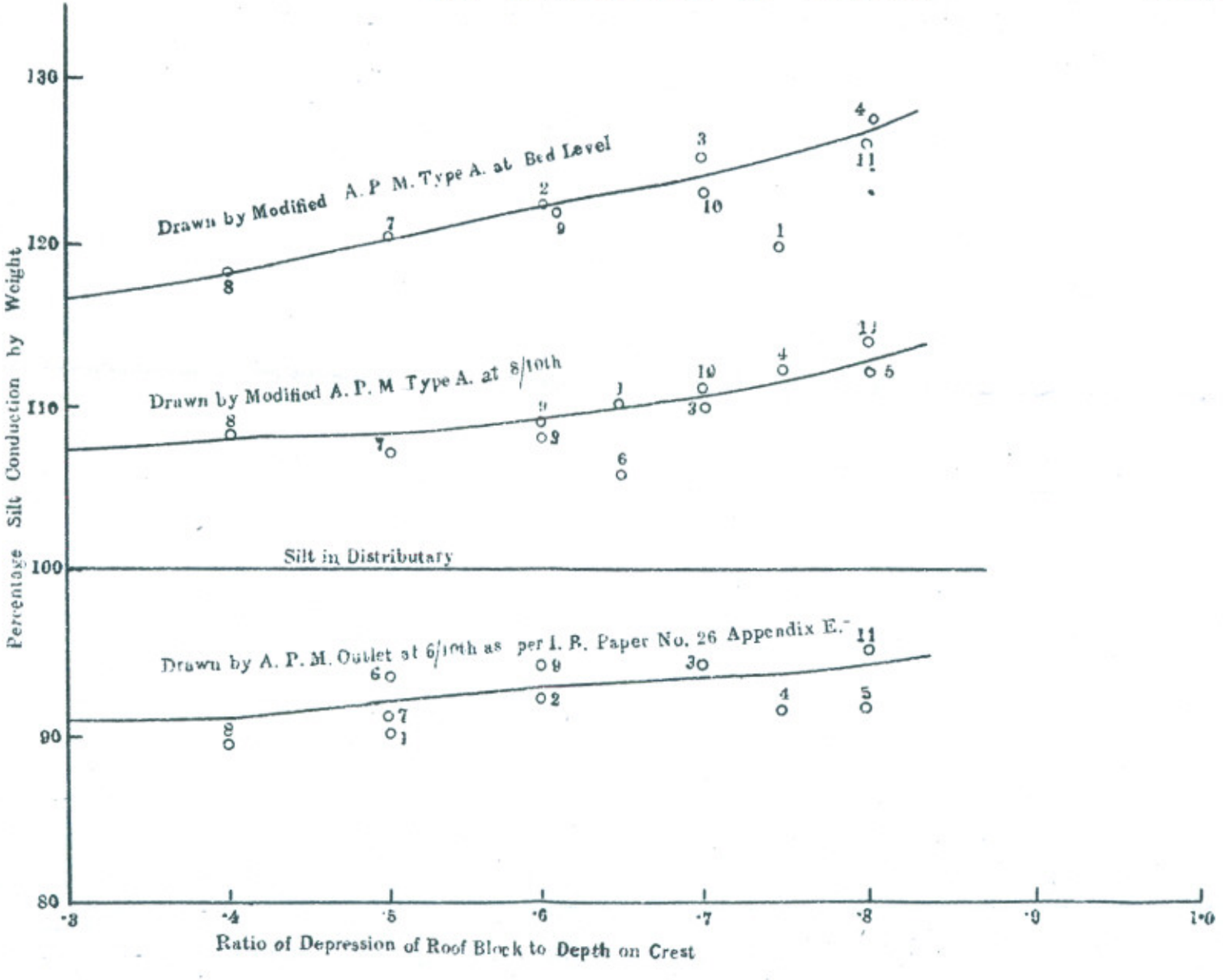
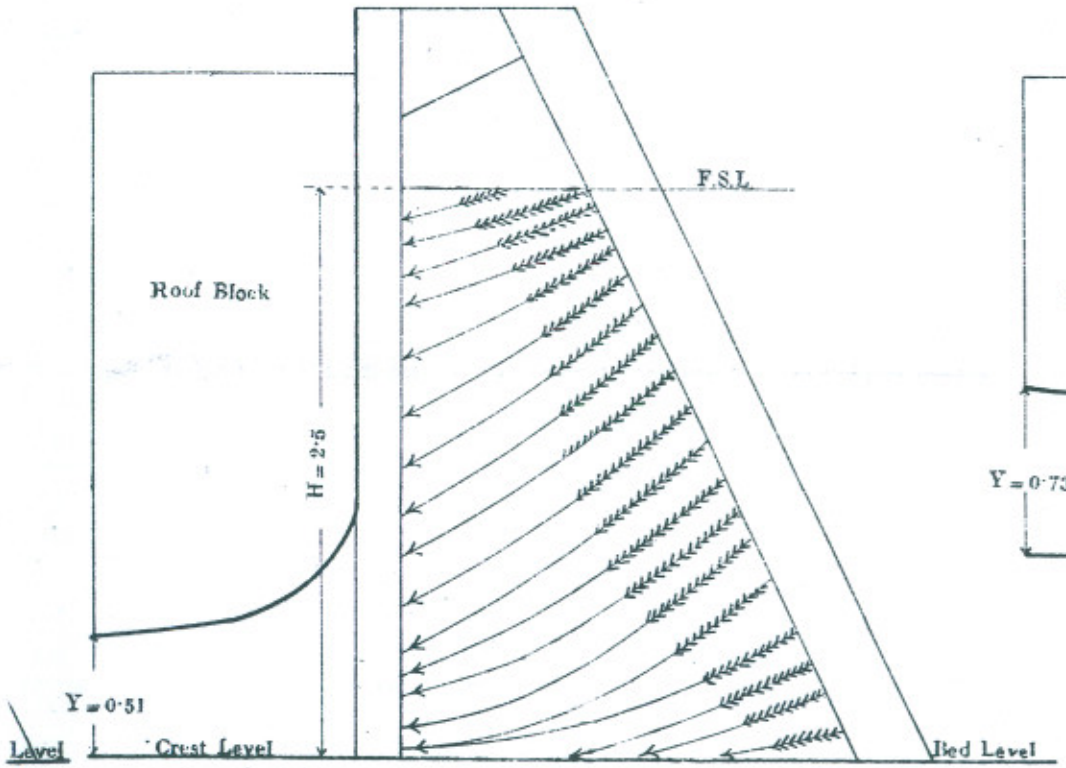


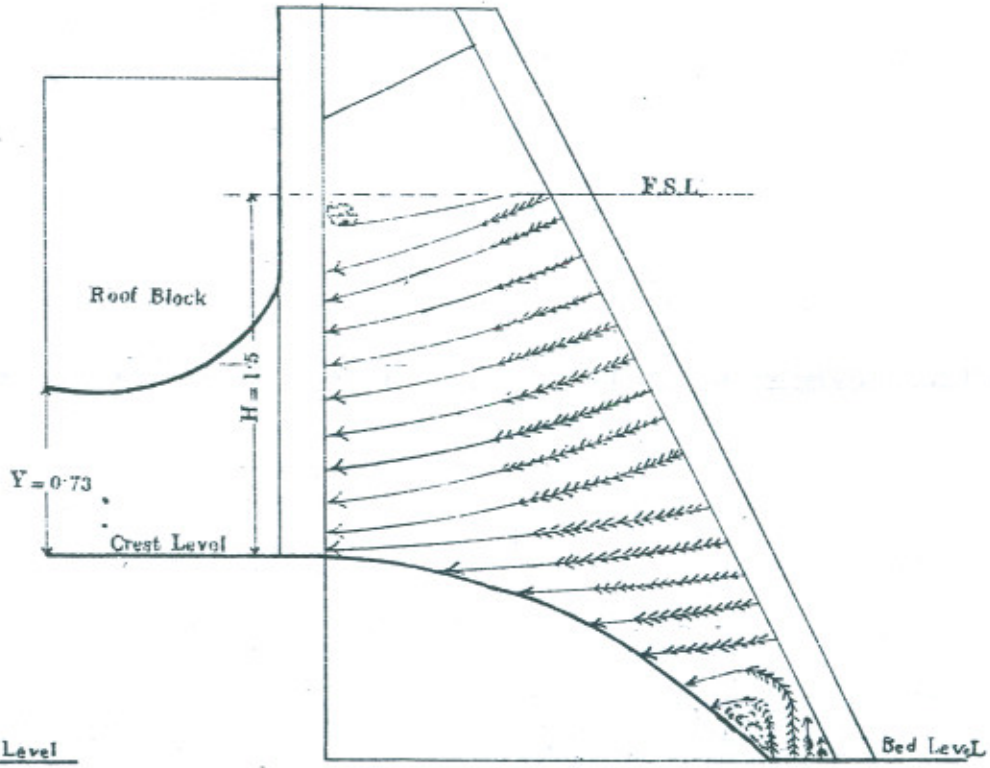
PLATE III

STREAM LINES ENTERING OUTLET

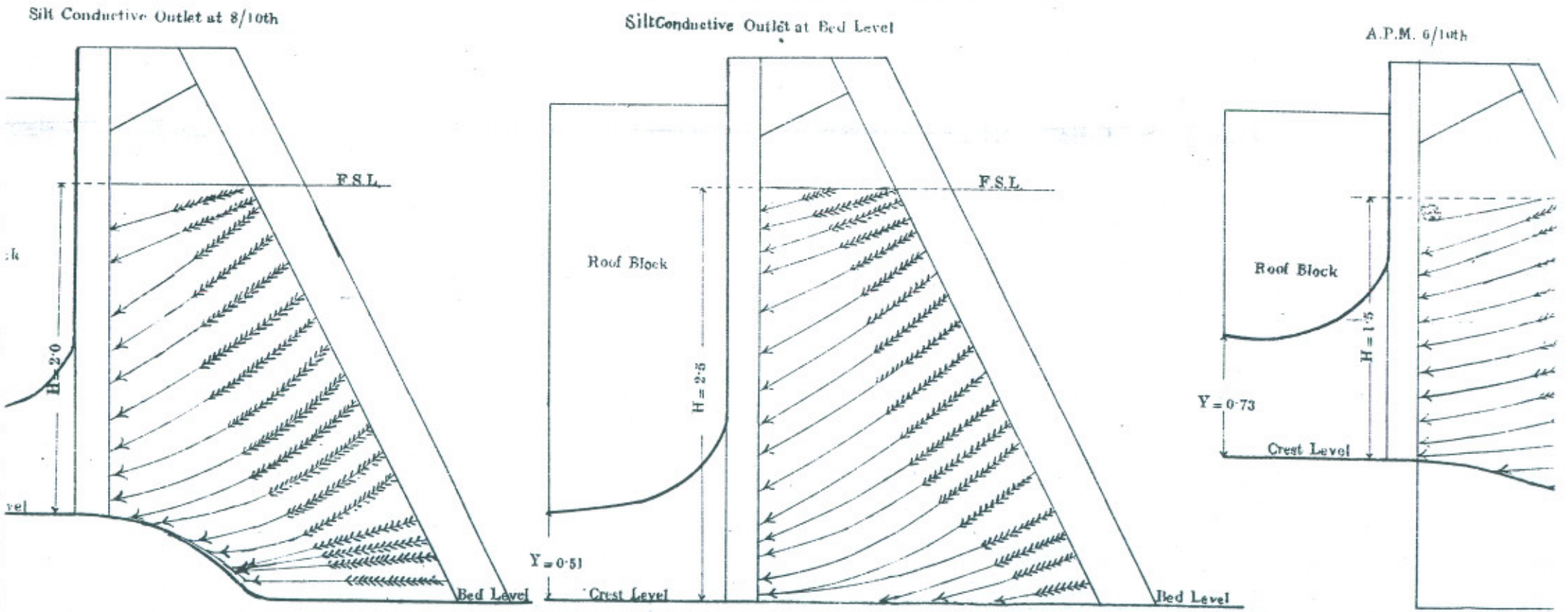
Silt Conductive Outlet at Bed Level



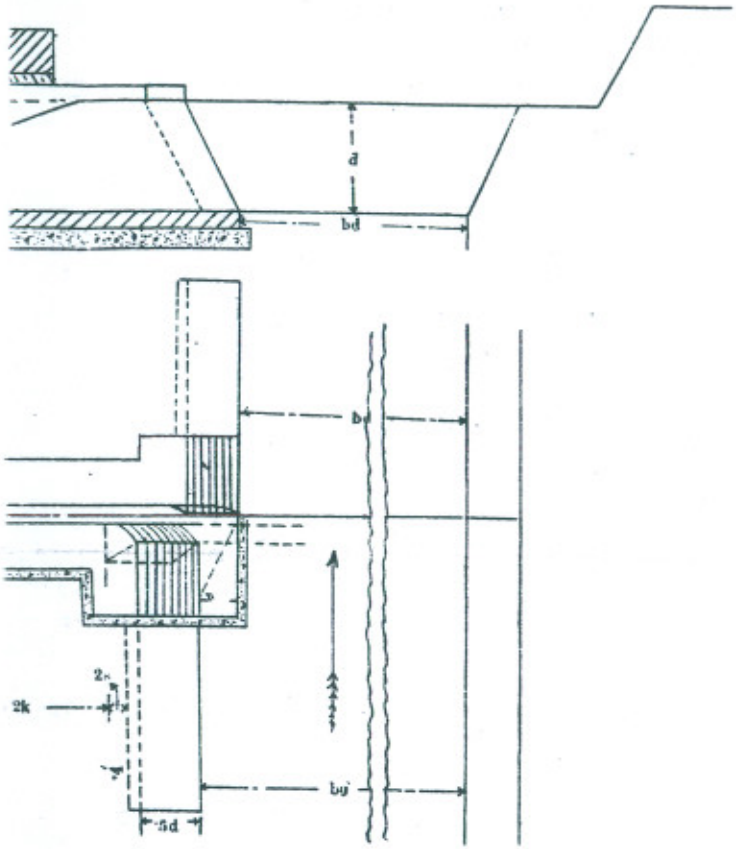
A.P.M. 6/10th



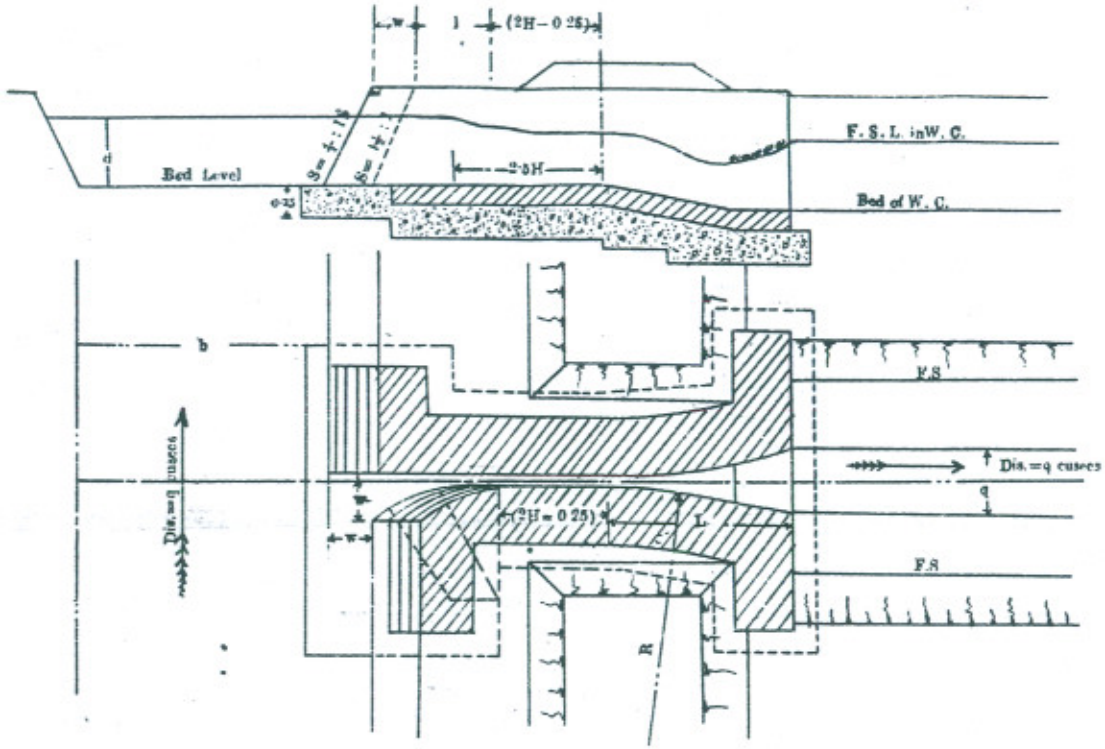
STREAM LINES ENTERING OUTLET



: OUTLET
AT BED LEVEL

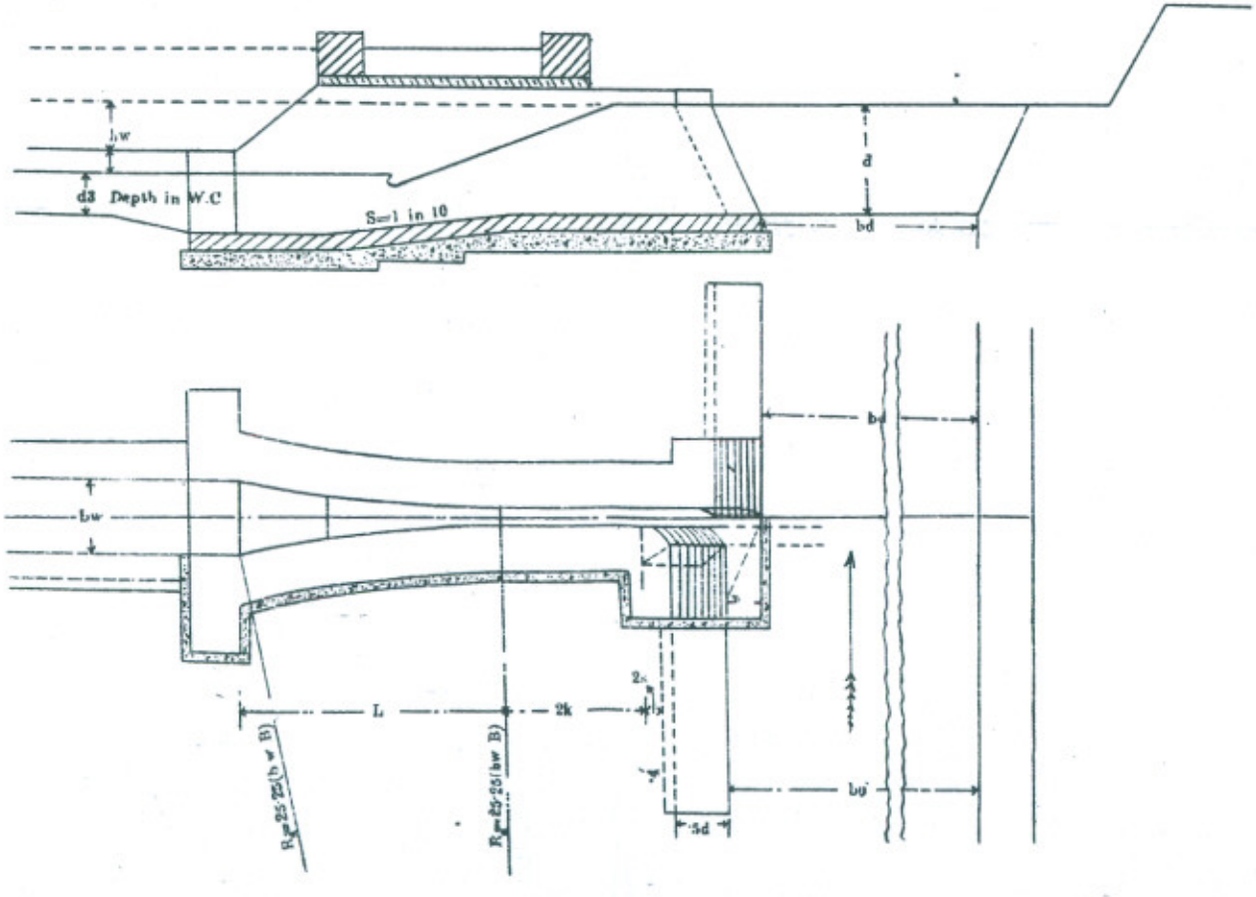


FLUME OUTLET
SET AT BED LEVEL AS IN I.B. PAPER NO. 26



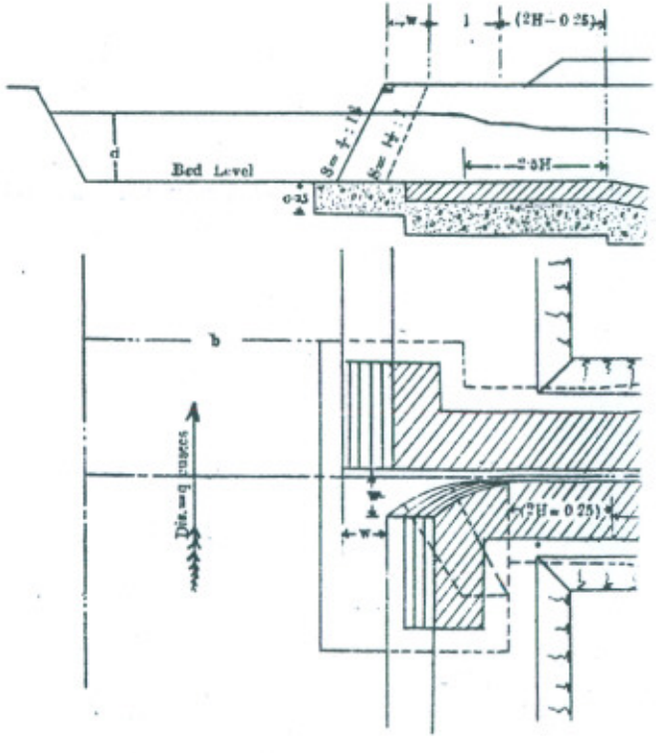
OPEN FLUME OUTLET

MODIFIED DESIGN AT BED LEVEL



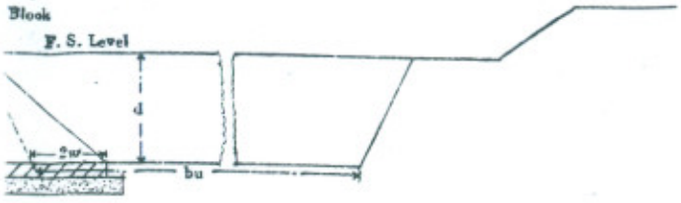
FLUME OUTLE

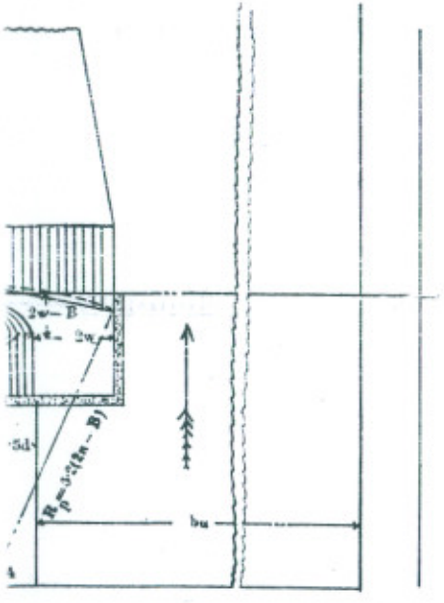
SET AT BED LEVEL AS IN I.B. P/



A.P.M TYPE B

L

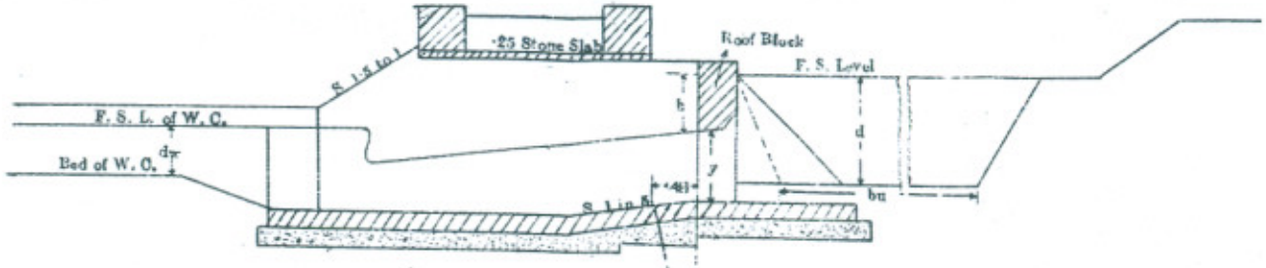


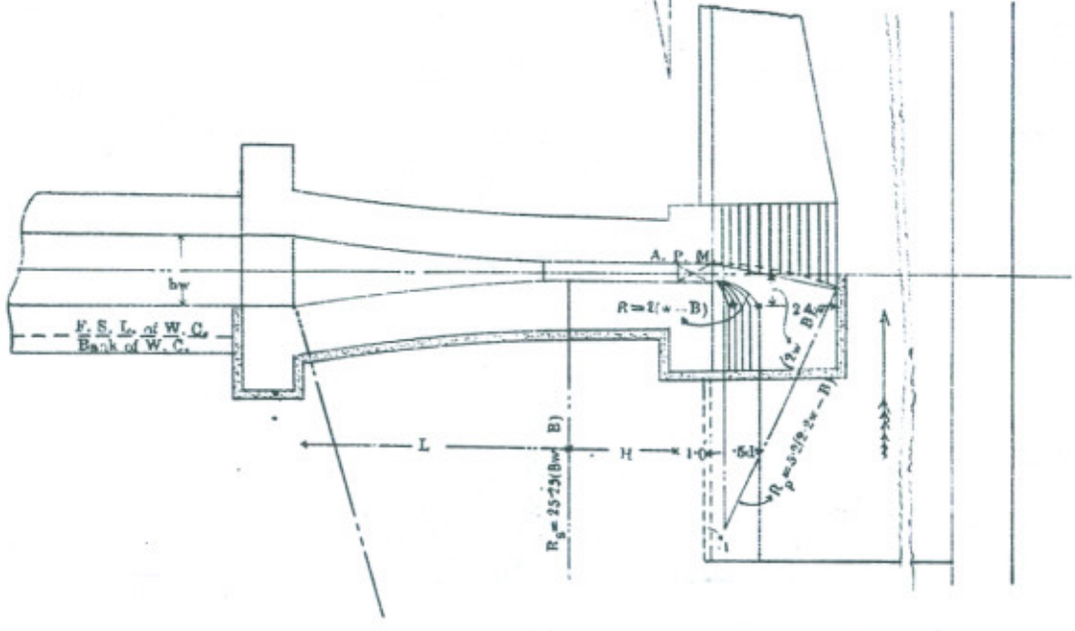


MODIFIED DESIGN OF A.P.M TYPE B

SET AT ·2 D BELOW BED LEVEL

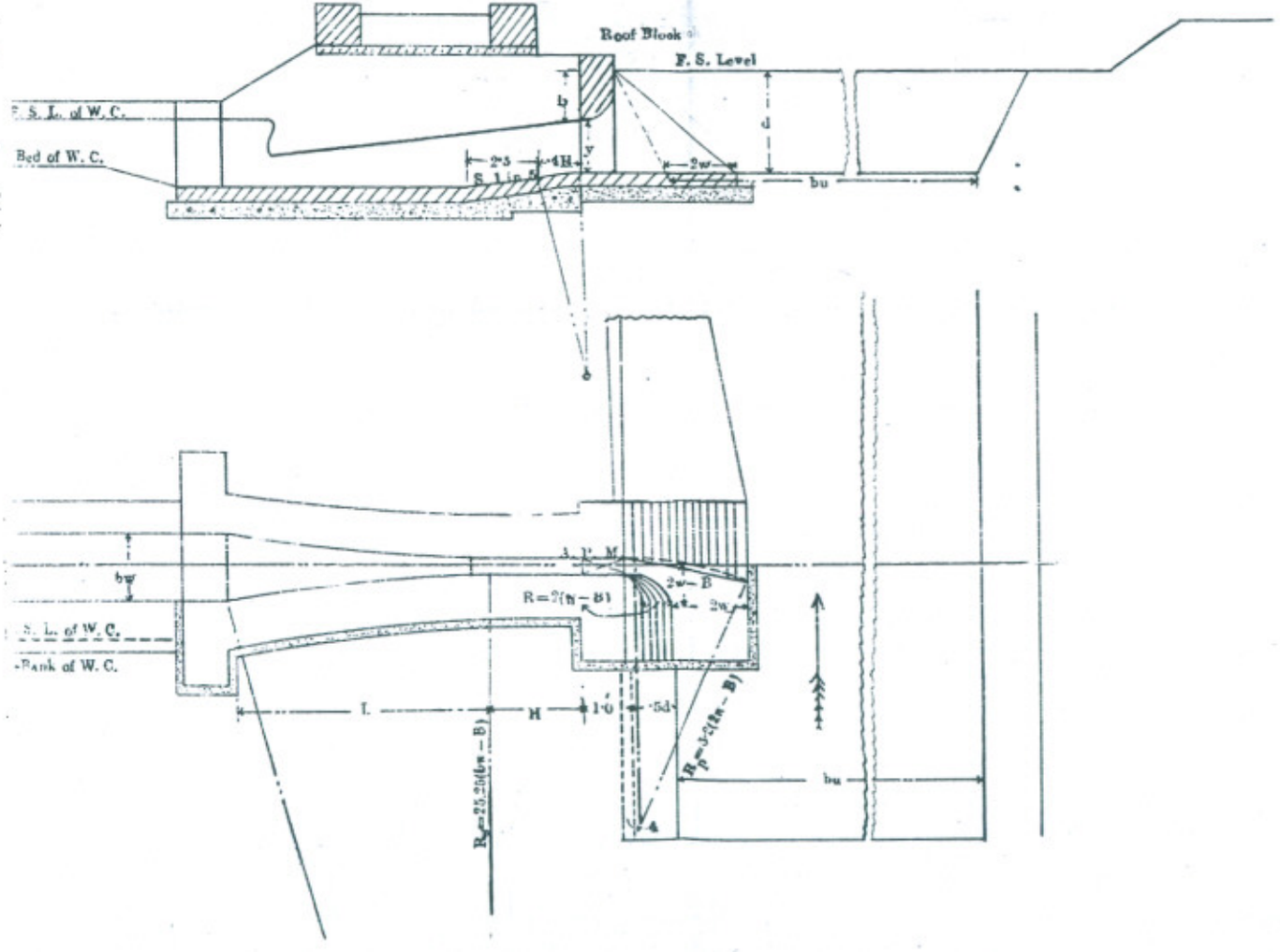
PLATE V.





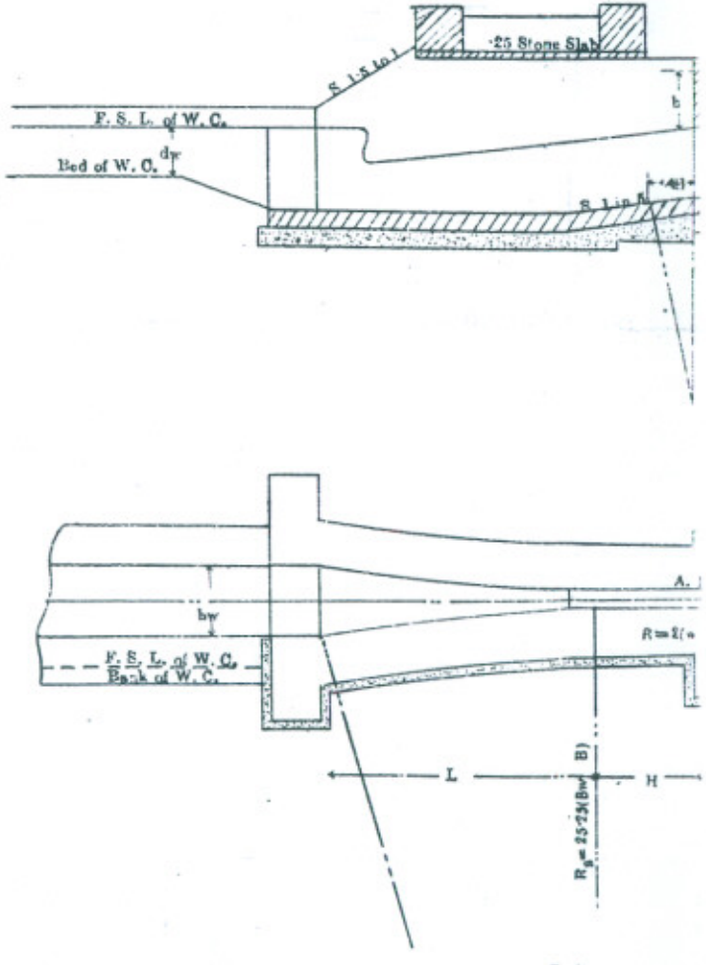
MODIFIED DESIGN OF A.P.M TYPE B

SET AT BED LEVEL



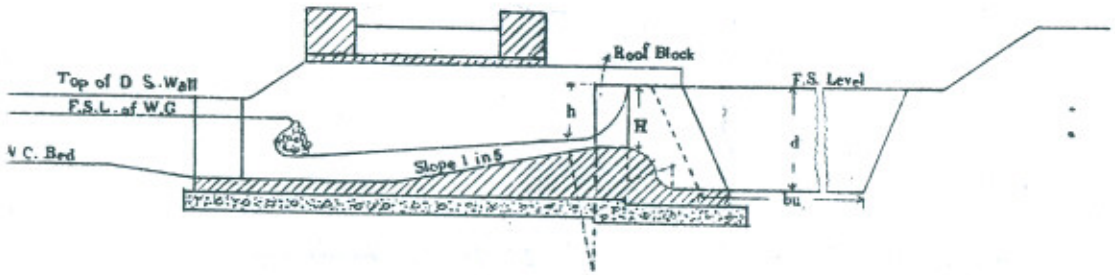
MODIFIED DESIGN OF A.P

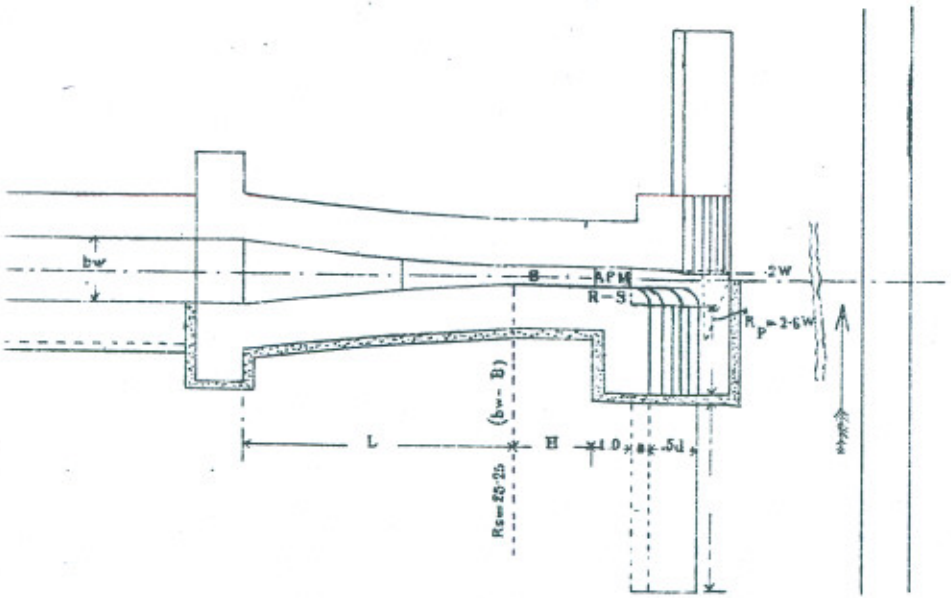
SET AT ·2 D BELOW BED LE



MODIFIED A.P.M. TYPE A

SET AT 6/10TH





BEND OUTLET

SET AT 6/10TH

PLATE VI:

