guarantee that sufficient water would be supplied to ensure maturing of crops in periods of shortages.

Opinions regarding the above method of assessment are sharply divided. Advocates of assessment on the volumatric basis argue that the method of assessment on acreage matured is open to the objection that the cultivator has no inducement to effect economy. On the contrary the experiment of sale on the volumatric basis has shown no tendency to economy of water. The economy of water rests with the man who waters the field and not with the proprietor and there is no evidence that the actual cultivator has been given any incentive to economise.

Under the present circumstances the method of assessment on acreage matured appears to be the best. It is more elastic. I put in a plea in my Paper on " Economics and Finances of Irrigation Projects " read on this platform in 1939 to make this method even more elastic than it is at present, and that is by making the system of charging water rates on a sliding scale basis. I have further studied this point. Mr. Madan of the Research Institute has extended the curves, I put in that Paper, at my request. These curves clearly indicate the necessity of making the water rates a certain percentage of the value of the crops raised per acre. When the prices of agricultural products are high and the margin of profit to the cultivators and land owners has considerably increased, Government is not in a position to charge higher water rates. The system only requires careful thought before it can be put into practice."

Mr. Kanwar Sain concluded by saying that he agreed with the authors that a module for general use had yet to be evolved and experiments were being carried out in the Irrigation Research Institute. These experiments shows that the value of the co-efficient of discharge in Mr. Crump's so-called A. P. M. with various combinations of B and Y under different working heads, *viz.*, 7·3 as originally taken by Mr. Crump was the best.

Mr. Abdul Rahman stated that the statements regarding the irrigation practice in the N. W. F. Province appearing on page 12, last subparagraph of paragraph 14, were incorrect, *i.e.*, " In some places, *e.g.*, North-west Frontier Province in India, the cultivator will not irrigate at night," and " In North-west Frontier Province, the water is allowed to run to waste." He stated that there was no wastage of water on the canals in the N. W. F. P. on which intensities of irrigation ranged from cent per cent to 140 per cent. He however pointed out that the Upper Swat canal, which was opened for irrigation in 1913, developed gradually and not at the same speed as the Lower Swat and the Kabul river canals. He went on to say that these three principal Government canals in the N. W. F. P. were equipped with over 85% of improved types of outlets, *viz.*, O.Fs. and O.S.Ms.

Mr. Kalha stated that the authors' recommendations regarding the selection of outlet types under various conditions were not the last word on the subject. He stated that the ideal conditions for running of a distributary were not actually attained in practice. These ideal conditions were not as stated by the authors. Regarding the running with full authorised supply of a channel, as postulated by Lacey's theory, the ideal conditions required a constant discharge flowing in an envelope made up of incoherent self borne alluvium and carrying a constant silt charge. He went on to say that there was no method evolved of delivering a constant silt charge to channels and this was causing all the difficulties in the design of outlets. He would like to know if the authors in their investigations had found any correlation between the 'f' adopted for channel design and the type of setting of the outlets to be fixed on it. He also pointed out that another important factor in the selection of outlets was the *haq* of the tail outlets for *nikal*. He suggested that it would be desirable if the outlets in the head reach were designed for proportionality, but with the approach improved as per Haigh's silt extracting outlets described on page 45 of the Paper. The crest of the outlet could then be fixed for whatever flexibility desired and the opening placed at bed level or even higher or lower as necessary for the extraction of the correct amount of silt that the particular watercourse could carry, and the 'f' of the channel design required.

He also pointed out that building of masonry profiles at suitable intervals in a watercourse to a grade of 0 2 per thousand would be a step in the wrong direction.

Mr. Khosla said that the Paper would be of immense use to the profession generally and to the young engineers in particular, as the latter rarely got opportunities to study types of outlets other than those few constructed on the channels in their charge. Mr. Khosla further remarked as follows :—

In para 18 of Chapter III, it was stated that for optimum conditions, the discharge of an outlet in cusecs should be five times of the area of the field it irrigated. Taking average discharge of an outlet as 1·5 cusecs, the area of the field works out to 0·3 of an acre. This theoretical value appeared to be on the high side. In the scheme of water requirements of crops carried out at Risalewala by the Agricultural Department, it had been determined that the economical size of a plot should be 1/8th acre, *i.e.*, each *Killa* should be divided into eight equal Kiaries.

The authors had advocated the use of pipe outlets in the first instance on new canals because the development of irrigation would be slow and frequent adjustments would be necessary. The trouble with these temporary outlets, however, was that once they were put in, the general tendency was to leave them there very much longer than was justified or desirable. This was evident from the face that out of a total of about 41,000 pipe outlets fitted on all the canals, more than 12,800 were still of the pipe or barrel type. The main objection to the building of permanent outlets in the first instance was that they did not draw their Full Supply discharge until F. S. Levels were attained, with the result that until the latter condition was obtained the tails got flooded. In case of crown waste area the installation of pipe outlets in the first instance would appear to be preferable, but in the case of proprietary areas the outlets should best be designed on the lines advocated by the authors for the Sutlej Valley non-perennial channels taking the normal supply as half of full supply.

Mr. M. D. Mithal, who, Mr. Khosla believed, was the pioneer in making a fresh approach to the design of outlets on the Sutlej Valley Canals, and who had carried out extensive remodelling in the Khanwah Division, had suggested an O. S. M. set at bed level and designed for normal supply conditions, with an open flume built alongside to make up the shortage above normal supply, with a view to prevent silting up of the parent channel. This type of outlet with slight modifications would be shortly tried on some channels of the S. V. P. The results obtained would be of value.

Mr. Haq Nawaz complained that after a remodelling scheme had been completed, it was generally found that the functioning of outlets was not generally watched to ensure that the outlets delivered their authorised discharges. He then went on to explain as to what steps they were taking in the Bahawalpur State to ensure the proper working of remodelled outlets. He said that red and blue gauges were fixed at each outlet to show any rise or fall in the full supply levels, so that steps could be taken promptly to remedy any serious defects. Gauges were also fixed in watercourses to indicate the highest water level in a watercourse at which the outlet would work modularly. Zamindars were asked not to silt clear their watercourses unnecessarily so long as the water level in the watercourse was below the mark and he advocated the use of such measures on all irrigation channels.

Dr. Bhandari in a written contribution pointed out that the authors had not mentioned in the paper the outlet known as Parshall flume, which he stated was in extensive use in America and Australia. Here he produced a drawing showing the section and plan of a typical Parshall flume. Dr. Bhandari went on to say that experiments had been carried out on Parshall flume, which showed certain variations from the results obtained by Mr. Parshall himself. Dr. Bhandari suggested a formula for an adjustable proportional module mentioned on page 38 of the paper. The formula in a simplified form is :—

$$q=\tfrac{1}{2}\,\delta_1\,B\,\sqrt{2gh}+\tfrac{1}{2}\,\delta_2\,B\,\sqrt{2gh}+\tfrac{2}{3}\,\sqrt{2g}B\left[H^{\frac{3}{2}}-h^{\frac{3}{2}}\right]$$

Mr. Bhandari, however, pointed out that there was a difficulty in using this formula which consisted in the actual measurement of δ_1 and δ_2 although their values could be calculated from various considerations of Reynolds Number of Turbulence, the size of the roughness grains of the material of the roof-block and the crest block.

In reply to the discussion, Mr. Mahbub expressed his gratification at the interest that the paper had evoked. He thanked the members who had participated in the discussion, and dealt briefly with the salient points touched by the various speakers.

The author thought that Mr. Montagu would be interested to know that the statement on page 1 of the Paper had been compiled from the figures supplied by the Executive Engineers of the Department on a recent request made to them for this information. Mr. Montagu had also referred to a new method of distribution of short supplies introduced on the W. J. C. by adopting a flexible period of rotation. Unfortunately Mr. Gupta was not there to give them the details of that method. Another method adopted on the S. V. canals was to use the storage capacity above the weirs in the river for damping fluctuations in supply.

The authors were grateful to Mr. Montagu for drawing attention to the two hydraulic phenomena which played such an important part in the design of all hydraulic structures, even outlets. His contribution filled in a gap in the study of the various types of outlets and his exposition of the critical section explained the varying co-efficients and indices determined emperically for different discharge formulae.

The authors had not advised a change in crest level in the inner flumes of the tail cluster to compensate for velocity of approach. All that was stated was that this was sometimes done. In fact, these were the official instructions on the subject. This would no doubt enable the inner flumes to draw excessive supplies when the full supply level fell below the designed level due to any cause.

A silt of 100% in the outlet implied the entire silt in the parent channel.

With regard to the suggestion made in the paper of using a straight flume in the Gibb's Outlet, it might be mentioned that Mr. Crump had shown in his analysis that under certain conditions the water surface level in a straight flume was more sensitive than at the outer wall in Gibb's Outlet, where the skimmers come into play. It was accordingly surmised that any surplus head could be consumed by having skimmers in a straight flume. Continuing, Mr. Mahbub said that he had since learnt that some experiments on the straight flume were carried out by Mr. Benson, but were not found successful. Anyhow, it was felt that some more experiments might usefully be done in this direction before finally discarding the idea.

Mr. Montagu had taken exception to the remarks made at the end of Appendix II. These remarks were no doubt applicable to only a certain set of conditions, *viz.*, when the outlet was set to the limit and the full working head available was being utilised. Under those conditions, a weir type was less sensitive than a pipe.

Mr. Ghafoor had contributed valuable information on outlet practice in the Bahawalpur State. The rigid flume module as devised by him promised to be a useful type, and it would be worthwhile carrying out further experiments in the Research Institute under varying heads to verify the results.

The use of roof blocks in all open flumes would seem to be a step in the right direction, but some further experiments were indicated to determine the best position and shape of the block, Mr. Mahbub mentioned that the idea of a roof block in an open flume was first introduced by Mr. Harvey in 1918.

It was interesting to note that pipe-cum-O. S Ms., the use of which had been advocated in the Paper, were being successfully used in the Bahawalpur State in large numbers. The advantage of having a uniformly low value of H in all flumes seemed somewhat doubtful, as there might be ample command on some outlets which might be availed of with advantage in a low setting. The roof block also would be more useful with a low setting.

Mr. Jesson had also mentioned that pipe-cum-open flumes, and pipe-cum-O. S. Ms., were used frequently in Bahawalpur, as O. S. Ms., could not be put in directly, due to the channels being deep and narrow. This ensured adequate silt draw.

With regard to the omission pointed out by Mr. Haigh of the Kent S. W. O. from the 33 different types described in the Paper, the authors regretted that in spite of a search they could not find the details of this outlet, and were, therefore, grateful to Mr. Haigh for the description he had so kindly furnished. It appeared, however, that this type was not likely to find any further use.

Mr. Haigh had also given the real reason for non-adjustability in his original S. M. M. O. which was not fully appreciated before. The point made by him regarding the desirability of having a clear indication as to whether the outlet in the field was taking its correct discharge, by having ledges at designed full supply level was important, and such indication should be given on all outlets. It was suggested that on the downstream side the highest level in the watercourse with which the outlet could work modularly might also be marked.

Mr. B. K. Kapur had stressed the advantages of pipe-cum-O. S. Ms., with which the authors were in full agreement. He advocated the conversion of open flumes and O. S. Ms., into Ghafoor's and Khanna's rigid modules where reclamation was being undertaken. This could usefully be done only after these outlets had been perfected and fully tested out.

Mr. R. K. Khanna desired that simplicity of design and ease of construction should also be added to the factors, indicated on page 71 of the paper, which should govern the selection of outlet types. These two factors were no doubt desirable, but were only of secondary importance. If an outlet of complex design but without moving parts could function with a low working head, and could give the necessary rigidity and immunity from tampering, it was to be preferred in spite of the complexity of design and some difficulty in construction.

Mr. Khanna had objected to the low-co-efficient of his outlet as determined by Mr. Kapur. Probably this low value of the co-efficient was due to the sucking effect of the chutes.

It had been clearly indicated in the paper that the rigid type of outlets designed by Messrs. Khanna and Ghafoor had only a limited use under certain specific conditions. Mr. Khanna had advocated the open flume type for use in the tail reaches of distributaries. It was, however, pointed out that this too had its limitations, and if not set at ·9 D, was not proportional.

Mr. Khanna had enquired the significance of the statement made in the paper that his and Mr. Ghafoor's outlets were in an experimental stage. All that was meant was that the number, size, spacing and slope of the chutes or vanes were still a matter of conjecture and required exact determination. Mr. Ghafoor had since worked out the various dimensions in terms of H, but these had yet to be verified.

Mr. Khanna had made some remarks with regard to the merits of his auto-adjusting orifice distributor. This outlet was not of much practical use, as it suffered from all the defects of outlets having moving parts as described in the paper.

Mr. Mahbub went on to say that the discussion raised by Mr. Khanna about the silting and scouring of channels being a function of hydraulic conditions, irrespective of the quality and quantity of the silt present in flowing water, was beyond the scope of this paper, and he did not, therefore, propose to dwell on the same. He added that on first principles, the silt brought in a channel must be disposed of by its off-takes, and unless off-takes were capable of doing so, the equalibrium must be disturbed.

With regard to Mr. Khanna's remarks regarding diverting the troubles on to the *zamindars* his attention was invited to the remarks at the bottom of page 67 of the Paper.

Mr. R. R. Handa had taken exception to the statement made in the Paper, that in some places in the N. W. F. P. the cultivator would not irrigate at night. K. B. Abdur Rahman had, however, indicated how this impression got about.

Mr. Handa had also suggested that the width between ledges, at full supply level, in tail clusters should be proportional to the designed B. This would, no doubt, be useful to ensure proportional distribution when the water level was higher than designed.

Mr. Thomas had suggested the use of a silt selective head in cases where the existing outlets did not draw their fair share of silt. This had already been referred to on page 67 of the Paper.

Mr. Sharma advocated the use of F. S. O. O. and S. S. O. O. for free fall and submerged semi-modules, instead of calling them O. S. Ms. This hair spliting, however, did not seem to be necessary.

He made useful observations on the hydraulics of open flumes and O. S. Ms., for which the authors were thankful. His remarks on the hydraulics of subordinates were rather interesting. These arguments could, however, hardly be justified in condemning any particular type of outlet, as such could easily be counteracted by a vigilant S. D. O. One might as well try to analyse the hydraulics of the buffalo which by sitting in a minor raised the full supply level, thus disturbing the conditions of flow both in the channel and through the outlet.

An accurate mathematical determination of the M. M. H. of a submerged O. S. M. was no doubt complex, as remarked by Mr. Sharma, but there hardly seemed any need of being lost in these complexities as accurate observations over an extensive range more than filled the needs of the practical engineer.

Sir William Roberts had remarked that moduling should not be undertaken irrespective of the command available. Mr. Mahbub assured him that this aspect was always considered when moduling channels and invited his attention to para 16 (*ii*), page 74, of the Paper, where it had been stated that the Scratchley type, which was non-modular, should be used where the working head available was insufficient for a module.

Mr. Edgecombe seemed to have misunderstood the remarks made by Mr. Gulhati when he introduced the Paper. All that was stated was that there were prejudices against the pipe and some other types which were not fully justified. Mr. Edgecombe's justification for the extensive use of pipes in the U. P. was interesting, as it was not fully realised that they had to deal with such low heads and small discharges.

Mr. Mithal had suggested that the water rate to be charged for canal water should equal the expense that a cultivator had to incur in providing water by well irrigation. Perhaps Mr. Mithal had forgotten that it would be necessary to raise our rates five or six times if this suggestion was accepted. Needless to add that if water rates were equal to those which a zamindar had to incur on well irrigation, he would not care two hoots about canal water and would be independent with his own wells.

So far as silt conduction by outlets was concerned, the outlets should be capable of disposing of the *entire* silt in a channel whether it was in suspension or rolling on the bed. This had been made abundantly clear in the Paper. It was for this reason that a pipe-cum-semi-module had been suggested for the non-perennial channels of the Sutlej Valley Canals. The velocity in the pipe should, of course, be sufficient to pick up the silt.

Mr. Mithal had referred to the remodelling carried out under the old orders on the Sutlej Valley Canals and considered that the method contained in this paper was similar to that followed in the past which was found to have failed. The main fault in the past practice was that outlets were set much too low and were designed for full supply conditions, without considering what would happen under normal supply conditions;

and, even if normal supply conditions were considered, they ignored the fact that whereas in normal supply, the water level in the wetercourses remained practically unchanged, the water level in the distributary fell by 0·3 D. As such, most of the outlets were found to work non-modularly in normal supply and the tails were flooded even with a low discharge running in the channel.

With regard to the proposal made by Mr. Mithal regarding the design of an O. S. M. set at bed level for normal supply conditions and building alongside it an open flume to make up the difference at full supply conditions, a detailed analysis of the working of combination of outlets had been made and it appeared that this suffered from the following very serious drawbacks :—

(1) The working head required for this type of outlet, when measured from the full supply level, worked out to ·6 of the full supply depth of a channel, as against ·4 for the types suggested in the Paper.

(2) Another drawback was that while the outlets would draw correct supply, both when normal supply and full supply were running, in the range between full supply and normal supply their draw off at one stage would be as much as 12% below the due share.

(3) The third drawback was that on account of the high-crested open flume, this combination of outlets was far more sensitive than the types suggested by the authors in the Paper. If the channel silted up by even 3 *hissas* and raised the full supply levels by the same amount, Mr. Mithal's outlet would draw 27% excess as compared with 11—17% in the types suggested by the authors.

It might be added for Mithal's information that the suggestions made in this paper for the types to be adopted on the non-perennial canals were based on the result of long conferences held between the Chief Engineer, the Superintending Engineers and Executive Engineers working on the Sutlej Valley Canals.

With regard to the Scratchley outlet, this no doubt suffered from many defects inherent in this type, but when the working head available was such that a semi-modular outlet could not be designed, the Scratchley type was the best in the field.

R. B. Kanwar Sain had drawn attention to the absorption in water-courses which introduced certain inequality in the distribution of water. This inequality was compensated to some extent while framing the warabandi by taking the *nikal* into account.

He had indicated, with the help of informative graphs, that a sliding system of assessment would be the best. With this the authors fully agreed, as had been expressed in this paper. This point was, however, not given a detailed consideration, as it was considered to be outside the real scope of the paper.

Mr. Kanwar Sain had indicated some perference for modules instead of semi-modules except at tail clusters and above control points. Some flexibility would, however, seem to be necessary in view of the special requirements of rotational running and temporary variations in the discharge at the head of channels.

K. B. Abdur Rahman had thrown interesting light on the irrigation conditions in the N. W. F. P. It was gratifying to note that as many as 85% outlets in this Province were modules.

Mr. Kalha had taken exception to the ideal conditions described in the paper, *viz.*, a constant supply and a constant water level. He considered these to be a constant discharge and a constant silt charge. Mr. Mahbub pointed out that a constant water level did also postulate a constant silt charge.

He wanted to know if there was any co-relation between the value of Lacey's 'f' and the setting of an outlet. This relationship was not of much consequence. The setting had to be such that the outlet drew, on an average, 110 to 115% of the quantity of silt in the parent channel, irrespective of the value of 'f'.

It had already been stated in the paper that the requirements of rotational running indicated outlets of high flexibility in the head reach. Mr. Kalha had advocated the use of proportional semi-modules fitted with a suitable silt extracting device in such cases. The objection to such a course would be that it would mean passing more silt than the water-courses on these outlets would be able to carry or in other words it would simply amount to diverting the silt trouble on to the *zamindars*.

The profiles recommended to be built in the main watercourses were to ensure a uniform slope and should be built corresponding to the slope desired in the watercourse so as to avoid the outlet becoming non-modular. This would vary with the command available and would not be ·2 per 1,000 in all cases.

R. B. A. N. Khosla threw some interesting light on the economical size of a field. With regard to his remarks about Mr. Mithal's modifications for outlets on the S. V. P., the speaker had given his views already. It would be interesting, however, to see how this outlet worked in actual practice.

Mr. Haq Nawaz Khan had given his experience as a *zamindars* and given a humourous touch to the discussion.

Dr. Bhandari in a written criticism gave details of 'Parshall Flume,' as used in America and Australia. This was just a modification of the open flume.

He had also given a new formula for discharge through an A. O. S. M., which was rather complicated, and involved several assumptions. The formula as advocated was good enough for all practical purposes, as the variation in discharge was found to be within 4%.

DISCUSSION

In introducing the paper Mr. Gulhati referred to a condemnation of pipe outlets made by a prominent officer of the Irrigation Branch in a paper presented to the Congress fifteen years earlier when the principle of the standing wave had been newly introduced in the design of outlets. This condemnation was in the following terms. "For the sake of fair distribution no new outlets should ever be built of barrel type. They are all of stupid type compared with standing wave outlets and lead to unfair distribution and puzzledom."

Continuing Mr. Gulhati stated that during the last fifteen years, different officers had sponsored different types of outlets and whenever any one had an opportunity to remodel one or more channels he put in his type which he considered superior to all other types whether known to him or not. And as any one type of outlets could not be suitable for all channels or even for different reaches of the same channel, this led to considerable remodelling which had to be undone soon after it was completed. This was one of the principal causes of cultivator's fear of remodelling which according to the speaker should be regarded as a welcome measure to improve the distribution of water.

Mr. Gulhati went on to say that during the previous fifty years a very considerable advance had been made in the design of outlets and various types had been evolved. In this paper an attempt had been made to collect details of the various types and to make a critical study of the working of these types with a view to determine the use that should be made of the different types of outlets.

He further stated that a number of terms, which were in common use, were being used loosely in connection with outlets. For instance, the term "A. P. M." which stood for adjustable proportional module actually represented an outlet which was neither proportional nor modular. The authors had therefore proposed a terminology which would help in keeping ideas clear.

The paper was mainly a study of the work done in the past but there was one aspect of the problem *viz.* the theory of flow over a field which had been examined in the paper from a new angle. This was contained in Appendix V, pages 94-98 of the paper. The results given in the table on page 98 of the paper were for one set of conditions only—when the depth of water was equal to 3″ and the absorption loss was $\frac{1}{2}''$ per hour. Other cases had since been worked out and the results were shown on plate 21.

Continuing Mr. Gulhati stated that he had nothing more to add except that, if there were any other types of outlets which had not been described in this paper, the authors would be grateful if they were brought to notice in the course of discussion. He particularly requested officers of provinces other than the Punjab, who were present, to give them the benefit of their advice on the subject and to acquaint those present with the practice regarding the design and working of outlets that was adopted in their provinces.

Mr. Montagu congratulated the Punjab Engineering Congress on the opportunity which the authors had presented, of adding such a valuable paper to the Congress proceedings. He remarked that the paper was an assembly of information from many sources and that its preparation involved a vast amount of search among old files, of mathematical analysis and of careful weighing of relative values. He added that the authors had performed a service of great value to the Irrigation Branch in the Punjab and to all the irrigation engineers the world over.

Mr. Montagu went on to say that although the paper had been prepared with meticulous care, as was apparent from the unusually small number of printers' errors to be found in the text, an inaccuracy in the table in paragraph 2 appeared. In this table it was given that there were no "pipe-cum-weir" outlets on the Lower Bari Doab Canal and that there were no "pipe-cum-weir" or "pipe-cum-O. S. M." outlets on the Western Jumna Canal. Mr. Montagu stated that he had constructed a small number of such outlets on the Lower Bari Doab Canal as Executive Engineer, Okara division, and on the Western Jumna Canal as Superintending Engineer.

The speaker further remarked as follows:—

In Chapter III, Para 6, the authors define the commonsense principles underlying the Engineers' outlook on the sources of Irrigation water. I wish that Governments and Legislatures would define for our guidance, a few clear legal principles respecting rights in water. Only so can constant disputes between states, towns and individual owners as to their respective claims, be avoided or settled in a reasonable manner. We should be grateful to the draftsmen of the Northern India Canal and Drainage Act, who laid it down as a principle that water is allotted to the land and not to an individual whether the land owner, the lessee or the cultivator.

In Chapter III, para 14, the authors have discussed the methods now employed in the Punjab to distribute short supplies. It is clearly better to run a channel at full supply or to close it, and this should be the aim of the controlling officers. Normally, the distributing channels of a canal or system are divided into "groups," each group corresponding roughly in capacity to the expected minimum supply during *rabi*. But this objective is not always attained. Supplies vary from day to day and from year to year and in consequence arrangements are always made to dispose of any balance or surplus left over after meeting the demand of the "group" entitled to first claim. But, on the older canals, the *rabi* available supply is frequently short of the discharge required to meet the first claim. In such cases, if the controlling officers adhere to a fixed period of rotation, many cultivators and even some channels may miss a turn altogether. The situation is aggravated when the total full supply capacity of groups is markedly different.

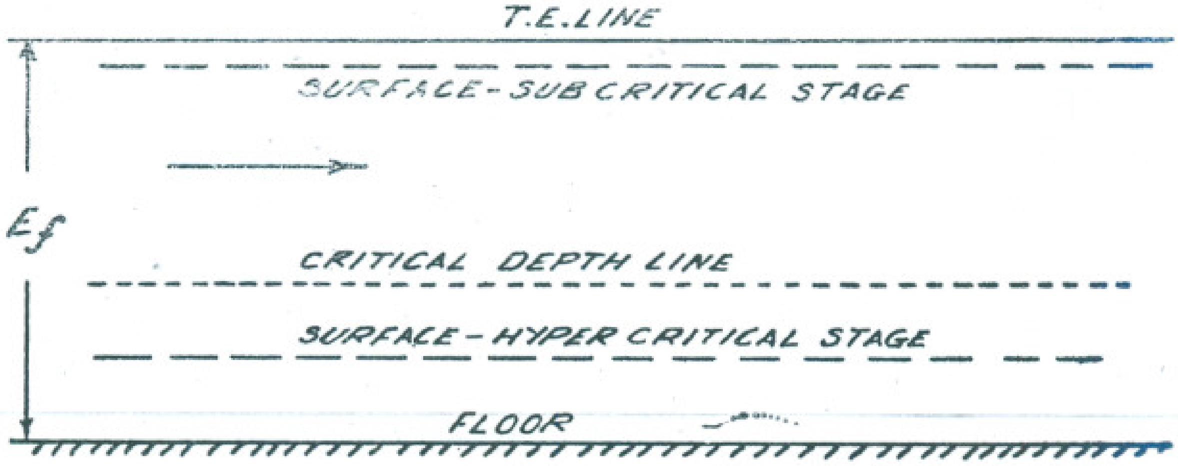
The solution adopted on the Western Jumna Canal was a flexible period of rotation, so adjusted that the same proportion of the full supply capacity of the group, was delivered to each group in turn. This system was due to the ingenuity of Mr. Radha Kishan Gupta, from whom I hope, we shall hear more on the subject.

In Chapter IV, at the end of para 3 (*iii*), the authors give a brief indication of the development of outlet installation. May I add to their remarks on this head, that I opposed the general use of the A. P. M. in all situations on a channel, as early as 1927-28. At that time I was in close touch with Mr. E. S. Crump to whom the Punjab Irrigation Branch owes so much. After consultation with him as to the nature of my problems and the proposed remedies, I installed a number of outlets now known as "pipe-cum-O. F." and "pipe-cum-O. S. M." both of which are development of the Harvey Stoddart combined semi-module. I have long been a supporter of this excellent form of outlet and strongly recommended its use, officially, as late as May 1942. In response to that recommendation, the Chief Engineers at that time replied with a flat refusal to include this excellent outlet in the list of approved types. Nevertheless, my Chief Engineer was good enough to say that if no other form of outlet was found suitable in a particular situation, special sanction might be given in individual cases. I may add that my Chief Engineer was soon tired of replying to my applications for specific sanction in individual cases and for a short time I received his general approval to insert these outlets where suitable. In consequence, I have actually fitted a number of minor heads with this type of semi-module. In proper situations, this type of outlet can be made extremely rigid, and it is, therefore, highly suitable for small minors taking off branches or main canals.

In sub-para (*iv*) of the same paragraph, the authors remark that "zemindars found it simple enough to close an outlet at its mouth" as being an adequate reason for discarding flap valves. In point of fact, I believe, that the cultivators themselves were responsible for discarding flap valves by the simple expedient of stealing them, whether of wood or iron. Nothing amuses a small boy, who is supposed to be looking after cattle, so much as to take a large stone and sit down near some outlet, bridge parapet, distance mark or other minor irrigation work, and solemnly pound it into fragments as a means of passing the time. The reduction in our patrol staff has reached the point where it is impossible to check these malevolent activities, and it is for consideration whether the damage done, and which must be repaired, exceeds in value the saving on our patrol staff.

I now desire to refer to Chapter V, para 4, wherein appears a statement that the maximum amount of slope to be given to pipes, should not exceed 1 in 12 (based on existing practice in the Western Jumna Canal). Let me say at once, I claim no sanctity for the maximum slope imposed. The executive engineers demanded guidance on the point, whereupon I met one of them at site and merely had a look at various slopes of a cast iron pipe lying in the trench in which it was to be installed. The slope of 1 in 12 was arbitrarily fixed by consent of the executive engineers concerned and I understand, has since been adhered to. I need hardly point out to the Congress that the raising of the exit end of a pipe outlet increases its flexibility and therefore should be reduced to the minimum.

Before proceeding further with my discussion of this paper, I must draw attention to two hydraulic principles. Hydraulic principles in general are applicable whatever be the situation whether to a syphon, a flume, a fall or an outlet.



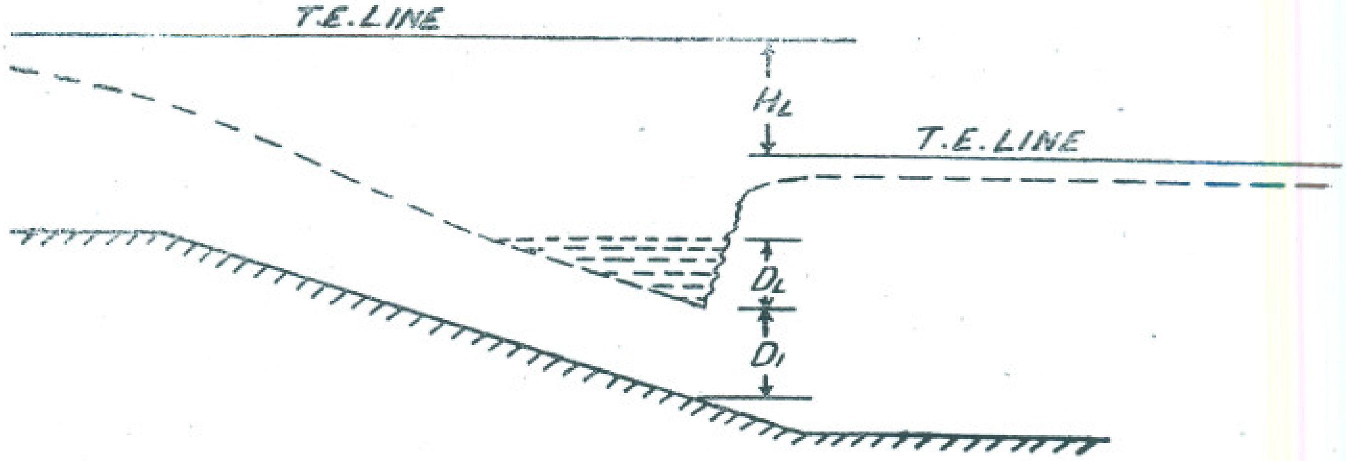
On the above sketch, I have shown the floor of a flume and the total energy line. There are two stages of flow to every value of E_f available, the sub-critical and hyper-critical. I draw these on the sketch. The value of the critical depth depends on the value of q alone. For a given discharge through this work the critical depth line may also be drawn in.

Imagine now that we have a roof which may be placed in this flume and depressed. If placed upon the "natural" water surface line in the sub-critical stage, there will be no pressure on the roof. If this roof is gradually depressed, the pressure thereon will increase until it reaches the D_c line. Here it will be a maximum. If further depressed, the pressure will fall until it reaches "natural" water surface line in the hyper-critical stage, at which point it will again be zero.

What happens if the roof be outside this range of positions is interesting theoretically, if not practically. In theory any position outside the range discussed leads to negative pressure. This can be attained, in certain conditions in the sub-critical stage, but in the hyper-critical stage, water in the syphon will be headed up.

If the minimum loss of head is desired, it is necessary to design the exit in such a way as to ensure that no standing wave shall occur. Full details of the process will be found in Central Board of Irrigation publication No. 6 entitled "Fluming."

The second hydraulic phenomenon is that which occurs when the hyper-critical stream is "loaded" or "blanketed" with a super-imposed load of water.



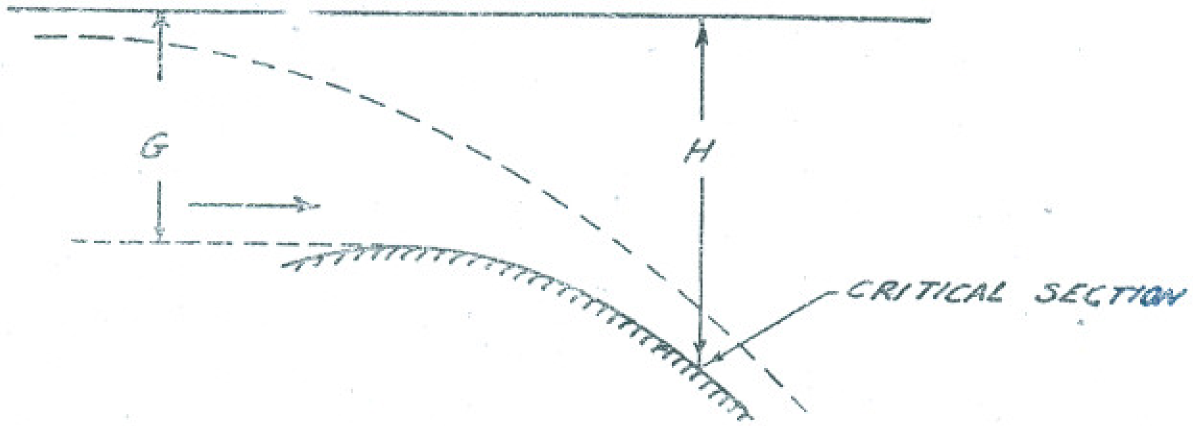
It is a fact that the hyper critical stream flowing under the theoretical load, will continue to descend a glacis with constant velocity and depth. The proof of this will be found in Central Board of Irrigation publication No. 7. Attention was first drawn to this phenomenon by Mr. T. Blench of the Punjab Irrigation Department.

These two hydraulic phenomena are examplified in certain outlets. The Kennedy gauge outlet and the Kirkpatric semi-module are both examples of the suppressed standing wave. By suppressing the standing wave, the minimum modular head is much reduced to the benefit of command. The wily cultivator has learnt this and by suitable positioning a piece of three ply, suppresses the standing wave in the open flume and Crump type orifices and increases his discharge.

The baffle type of outlet involves the second phenomenon referred to above, *e.g.*, Khannas and Ghafoors modules.

I am surprised to find that neither the originators of the various types of outlet nor the authors of this paper have discussed any of these outlets in terms of their hydraulic characteristics. I would earnestly suggest that the behaviour of these outlets should be re-examined with particular reference to the hydraulic phenomena referred to above.

Chapter V, para 8—The Harvey Outlet. The principal drawback to this outlet was the fact that with an increase in value of G the discharge was in excess of that given by the standard formula. These remarks also apply to the Jamrao type and to high efficiency over-flow weirs. For all these so-called "free fall" outlets it is essential that the position of the critical section should be known. The gauge zero should be set precisely at the level of the masonry bed at the critical section. Very little is known of the theory of curvature in flowing water, but unless the inlet is properly designed, the critical section may form outside the throat. If that is the case, then G becomes an arbitrary figure and not a real measure of the head acting at the critical section. This is illustrated by the figure



By properly designing the lip of a weir, the formula $4{\cdot}0\ G^{1.8}$ can be secured, where G is the height over the crest. What all this means is that critical section has shifted downstream and that the true value of H is very much larger. The theoretical formula $3{\cdot}0888\ H^{1.5}$ is rigid and any departure therefrom postulates a false measurement somewhere.

At the top of page 35 when discussing suitable positions for the open flume outlet, the authors refer to plate 20. The authors seem to advise a change in crest level to compensate for velocity of approach. May I record my own predilection for modifying the value of B to crest width. I prefer a uniform crest level for proportional dividers.

In para 9 of the same chapter, under the head (*ii*) (*c*) the authors quote various percentages of silt draw without intimating what 100 per cent is meant to be. A perusal of this and subsequent tables seems to indicate that 100 per cent is meant to be the same proportion of silt as in the present channel. I should be glad of the authors' confirmation.

Para 10 of the same chapter—The Jamrao type orifice module. I have but little to add to this excellent description and analysis beyond pointing out that the water between the baffles automatically applies the correct pressure to secure a "roof" which suppresses the standing wave and so improves the M M H for this outlet.

In para 14 of the same chapter, the authors discuss the "Pipe cum semi-module." It gives me great pleasure to learn of the authors' approval of this excellent outlet. I can but emphasize that if available command is poor, no known type of outlet can be rigid. This dual type of outlet is no exception. Its great advantages are its wide range of setting, its cheapness and freedom from hidden tampering.

After Mr. Crump's excellent analysis of the Gibb module, I was astonished to learn that he attempted to design a straight one. The Gibb module depends essentially on vortex flow and in trying to straighten the outlet trough, Mr. Crump destroyed its primary characteristic. To me, Mr. Crump's experiments would appear to be tests on a Skimmer vane type of outlet resembling that of Mr. Khanna or Mr. Ghafoor. All these three types depend on the characteristics of a loaded hyper-critical stream and a thorough understanding of the hydraulics of this condition is necessary before these outlets can attain perfection.

I would like to refer briefly to Chapter VI, para 11 (*v*). There is another entertaining theoretical limit to a cultivator's watercourse. Theoretically if the velocity in a watercourse of best discharging section falls below 0·882 feet per second, no silt can be carried. This limit is derivable from the Lacey formulae and affords an entertaining exercise.

In the same chapter, para 14, the authors list the objections to the use of temporary outlets on a new channel. I feel that in recording his views as per objection (*c*), Sir Thomas Ward must have given vent to irritation arising from experience. This is no place to discuss methods of remodelling, but I may be permitted to remark that the change over from temporary outlets whether wooden shoots, iron or concrete pipes, is a matter of remodelling and the initiative must come from the Superintending Engineer. My own somewhat limited experience of opening new areas to irrigation, leads me to the belief that temporary outlets with iron or concrete pipes are on the whole the best solution.

Of appendices, I wish only to refer to last few lines of Appendix II. There is here an assertion which, although true for the particular case considered, leaves a most misleading impression. For a free fall pipe outlet the discharge varies as $H^{\frac{1}{2}}$. For a weir the discharge various as $H^{\frac{3}{2}}$. I am just as correct and equallv misleading in stating that a pipe is the most rigid type. The truth is that the rigidity varies with the setting and the command, and each case must be examined in itself. The flexibility of a pipe outlet varies from a minimum at free fall conditions to a maximum when the H available is extremely small.

Lastly, I would like to add something to the summary of recommendations contained in para 16 of Chapter VI. In general, I find myself in entire agreement with the views expressed, but I cannot help but sound a note of warning in respect to silt draw-off. No matter how low the crest of a semi-module may be set in respect to the bed of the channel, the throat, that is the section at which the maximum velocity occurs, must necessarily be set well back from the channel bank. A well designed intake postulates some form of bell mouth and this in turn involves a low velocity at the precise point at which the water filaments leave the body of the parent channel. Low silt draw invariably accompanies conditions such as these. Much additional investigation is required into the relative silt draw-offs of various types of outlet. Until such time as an outlet, satisfactory in this as in all other characteristics, can be secured, I strongly advocate the use of the pipe cum semi-module in every possible situation. The advantages of this semi-module have already been stressed in the paper. To these I would add that in any bank of reasonable size, this outlet is economical. It may be a little more expensive in the small banks of small minors, but the additional cost is fully justified by its other excellencies.

Mr. Ghafoor after praising the paper for its general usefulness described the outlets which were being used in the Bahawalpur State as follows:—

Rigid Flume Module. Dimensions of plates as well as their spacing, inclination, etc., had been determined in terms of H, the depth on crest of the outlet (see plate No. 22), and it was a simple matter to design an outlet for any given value of H.

Since the publication of the note in 1941, he had been trying to devise some simple means of preventing the possibility of interference by zamindars. If the gap between the plates was blocked, the discharge in the outlet would increase. The best he had been able to get so far was to cover it with a cement concrete slab keeping a small window fitted with iron grating just over the plates for the purpose of inspection. This, he thought was good enough and the module could be safely used in this way.

Open flume roof block outlet. The outlet that was most commonly used in the Bahawalpur State was the open flume roof block outlet. It was devised by Mr. Ghafoor when he was sub-divisional officer on the Lower Chenab Canal. This outlet was largely used on the Lower Bari Doab Canal and in the Ferozepore Canals Circles. Mr. Bedford when he was Chief Engineer adopted the outlet as one of the standard outlets for use in the Irrigation Branch, although he limited its use to channels of depth 2·2 ft. or less. This limitation was wrong as was proved by further experiments by the speaker, which showed that the outlet was useful for any depth.

Mr. Ghafoor described the actual functioning of the outlet in the following terms :—

A square roof block is fixed in the ordinary open flume outlet at a distance H from the upstream end of the throat (see plate No. 23). When the roof block comes into action, there is a sudden drop in the discharge of the outlet amounting to about 5 %. To remove this hardship to the zamindar, the roof block is fixed slightly higher in actual practice, that is at ·7H above the crest instead of two-third H, at which the vena contracta occurs. The outlet thus draws about 5 % above its designed discharge just before the roof block comes into action. The moment the roof block comes into action, the discharge drops down exactly to the designed amount, and with further rise in the distributary, it slowly rises. The graph (plate No. 24) shows discharge in cusecs, and the height of water level above crest. The main curve shows the discharge in the open flume with a throat width of ·5ft. The other three curves are the discharge curves for outlets fitted with roof blocks for three different values of H, *viz.*, 1·0′, 1·25′ and 1·5′.

By actual experiments it has been determined that when the roof block is in action, the discharge formula of the outlet conforms very closely to the orifice formula $Q=CA\sqrt{h}$, h being measured from the upstream water level to the centre of the orifice and not to the soffit as in an A. P. M. (The dotted lines in graph show the discharge curves as per actual observations with 0·5′ wide flumes, and the firm lines those plotted by the orifice formula taking C=5 —— the firm and dotted lines almost coincide). In consequence of this larger value for *h* with the same exponent ½, it will be clear that it possesses a much lower flexibility than the A P. M., and this coupled with the fact that there is a definite set back in the discharge passing when the block first comes into action renders it a most rigid type of outlet.

The speaker went on to say that complaint of officers that the zamindars could increase their discharge by creating a bell-mouth approach just upstream of the roof block or by fixing a horizontal plate, was not of much importance as in actual practice the cultivators never resorted to such tactics. The speaker further remarked that Mr. Routh had informed him that the roof block was reported to be ineffective in case of free-fall outlets. On actual examination it was found that in every single case the failure was due to defective construction and that not a single outlet properly constructed was ever found to give unsatisfactory results. Mr. Ghafoor added that there was one very distinct advantage in this type of outlet which made it superior to any other type namely, the very high flexibility when the water level in the distributary was below the designed level, and very low flexibility when it exceeded the designed level. The high flexibility at low levels was of great importance for feeding the tails during periods of low supplies.

Regarding the design of the outlet, the speaker stated that the following six points should be kept in view while designing an open flume roof block outlet :—

(1) The roof block should be fixed at a distance equal to H from the upstream end of the throat where H is designed depth on the crest of the flume.

(2) The roof block should be fixed vertically at a height equal to ·7H above crest.

(3) The roof block should have square edges at the bottom unlike the curved bottom of the block of an A. P. M.

(4) Length of the throat should be equal to 2·5H or more, and in case of free-fall outlets, it should never be less than 3H.

(5) Downstreams plays may be anything so long as the length of the throat is not less than 3H. The flume may even be truncated at the downstream end of the throat.

(6) Minimum modular head required is 0·25H.

The speaker furthur remarked as follows :—

" On page 66 in paragraph (*d*), the authors say that rotational running indicates use of highly flexible outlets in the head reach of a channel. I would suggest putting it like this :—

" Rotational running indicates use of that outlet which will be highly flexible so long as the water level in the channel does not exceed the designed level and least flexible outlet when it exceeds the designed level."

"The open flume roof block outlet entirely fufils these two conditions. I have 45 moduled channels on the Sadiqia Canal alone, and I can confidently say that not a single tail of the moduled channels ever suffers even from a slight shortage now. I attribute this entirely to this type of outlet.

Pipe-cum-truncated flume roof block. The speaker remarked that in the case of deep channels with wide banks this type was one of the best outlets and had been used by him on Fatteh distributary carrying a discharge of about 400 cusces with very satisfactory results. Here the speaker produced a diagram showing the details of the outlet. He further stated that he kept the crests of the truncated flumes of all outlets in a reach in a line parallel to the water surface line of the channel, *i. e.*, at the same depth below the water surface line. The advantage of such an arrangement was obvious in that it ensured equitable distribution of water when the channel was being raised. Another advantage of this arrangement was that by keeping the crest fairly high say, 1·5ft. only below the full supply level, the tails gained very considerably in time factor. The main objections to a high setting of the outlets are :—

(1) Low silt induction. This is entirely eliminated in this type by depressing the upstream end of the pipe to any extent according to the amount of silt induction required, and

(2) An outlet with a high setting is bound to be highly flexible. The roof block in the flume removes this defect. The shallow truncated flume was of additional advantage, as it used very little working head, besides making the structure very cheap.

Pipe outlets with sockets. The outlets which were used on the Bahawalpur State canals in the beginning were Hume pipe outlets all of 15″ diameter with sockets of the required diameter fitted at the mouth. Sockets were made of iron pipe about 6″ long with cement mortar inside the hume pipe at the upstream end. Such outlets were fitted to keep down costs when making frequent alterations in sizes of all outlets, which was so necessary in case of new channels during the period of development. Extensive experiments had been carried out to find out the co-efficients of discharge with different ranges of diameter of pipes and sockets.

Widening tail clusters above full supply level. The speaker pointed out that in widening the upper portion of an open flume he had always found it best to make it proportional to the designed width of the flume so that the tail chaks got the benefit of the excess proportionately. This was of great importance when the difference between the widths of the various flumes of the cluster was great.

Mr. Jesson remarked that generally speaking the full supply depth of distributaries and minors on the Panjnad Canals of the Bahawalpur

State was considerable, and much greater than on distributaries in the Punjab. That was due to the fineness of the silt.

Consequently an A. P. M. with its crest at designed bed level of the channel was unsuitable, as the available working head was insufficient to make the outlet moduler.

Mr. Jesson further remarked that moduling in the perennial area of of the Panjnad Canal was only started last year, and the type of outlet that had been adopted was shown on the board.

Generally speaking they aimed at the working head of not less than 0·5′ between the channel and the well, so as to give a velocity at the mouth of the 4 f/s which was probably about the minimum velocity for silt induction.

In some cases where the working head available was considerable the velocity could be increased by increasing the working head between the channel and the well.

The design of the A. P. M. outlet was based on Sharma's experiment on the Upper Jhelum Canal, but a cast iron A. P. M. was not used.

The roof block was made of cement concrete and only the curved portion was cast iron.

The cost also consisted of a separate cast iron piece.

Those cost iron pieces prevented tempering with the outlets.

The roof block could be adjusted as shown on the board.

Recently due to difficulty in obtaining hume pipes only one pipe of the correct size without a socket was fitted in the face wall, and the remainder of the length was a brick culvert.

Mr. Jesson also remarked that where the total working head was less than say 1′ open flume outlet must be adopted. It would be noticed that the size of the well was small, which meant that there was a certain amount of surging in front of the module, but he doubted if that effected the discharge to any great extent.

When the working head was considerable, and the outlet could draw off more than its share of the silt in the channel the mouth of the outlet was set below bed level. In some cases the speaker had been able to set it as much as 1′ below designed bed level.

Unfortunately very few outlets had been constructed up to date, but those that had been completed were working quite satisfactorily.

If any members of the Congress would like to correspond with the speaker about that type of outlet he would be delighted to reply to their querries.

After congratulating the authors on producing a Paper which was likely to become a standard work on the subject, Mr. Haigh pointed out that in spite of the length of the paper it did not seem to be quite exhaustive as he could find no reference in it, for instance, to a type of outlet which was used in moderate numbers at one time, *i.e.*, the Kent Standing Wave outlet.

The Kent outlet was of the semi modular orifice type in which the orifice was bell-mouthed. The lower part of the orifice and the throat of the flume were modelled in one iron casting, while the upper part of the orifice, also a casting, was adjustable. This outlet was quite satisfactory though expensive and not readily obtainable.

The speaker said that he had been interested in outlet design for a very long time, chiefly because he had the privilege of working under Mr. Crump at the time he was engaged on the development of the A. P. M.

The speaker remarked that he would like to say something about the question of bell-mouthed orifice *versus* approved flume in the A. O. S. M.

Crump's original approach flume was designed to ensure that each outlet should take its share of silt along with its water. To this end it was arranged to take a complete vertical section of water in the parent channel from surface to bed, and it was anticipated that as the orifice was set back some distance from the entrance to the flume, the setting of the outlet would have little effect on the silt draw.

Whether the A. P. M. took its fair share of silt or not, it actually took a much smaller share than the bed level orifice it generally replaced with the consequence that channel regime was affected with resultant loss of command. Variation of the setting was in practice found to have some effect on silt draw, but it was quite obvious that this effect must be largely neutralized by the approach flume. Consequently when he had attempted to design an outlet in the Karnal Division in 1935 he had omitted this flume and brought the orifice forward in direct contact with the parent channel.

In the original S. M. M. O. the orifice had been found in precast concrete blocks and the authors had suggested that the proposed substitution of an adjustable C. I. orifice was due to the lack of adjustability of the original design. This was not so, as the concrete blocks were so cheap that to replace them was little more expensive than adjusting an A. P. M. There were two reasons for the change. Concrete can be tampered with if the zamindar is sufficiently determined and while this was not very likely to occur with the peaceable zamindars of Karnal, it quite probably would in Lyallpur. Secondly, the manufacture of the concrete blocks was complicated and it was much simpler for the average departmental officer to be able to obtain the cast iron orifice ready made than to have to manufacture the concrete blocks.

He had always thought that the success of the C. I. A. P. M. as compared to the equally efficient Balmer Lawrie sheet iron type and the Kent S. W. O. had been largely due to its ready availability.

Another point he would like to touch on is the desirability of having clear indication, as to whether the outlet in the field is taking its correct discharge. In the design of the S. M. M. O. he had embodied broad ledges at designed distributary F. S. level both upstream and downstream with the result that it was possible to see at once when passing an outlet whether distributing level was correct and approximately what was the working head. He had also left the outlet uncovered so that it was possible to see the standing wave and know whether the outlet was working modularly or not. In practice it was found that these observations could be made in the case of moderate sized channels even for outlets on the opposite bank.

He thought this a very great advantage.

Mr. B. K. Kapur remarked that he had found that the silt induction of outlets had a fundamental bearing on channel regime, as channels fitted with pipe outlets set at or below bed level rarely suffered from silt trouble, and thus engineers must keep in view the silt drawing capacities of the types of outlets which they propose to instal on channels. Under similar conditions a channel fitted with outlets of high silt drawing capacity could work to a flatter slope than one fitted with outlets of low silt drawing capacity. He was of opinion that most of the silting trouble except in small lengths of head reaches of channels, was due to faulty design of outlets rather than faulty design of channels. The speaker strongly advocated a more extensive use of the pipe-cum-O. S. M. type of outlet with a view to increase the silt draw, wherever the working heads available were ample while in other situations a judicious selection between an O. S. M. and the open flume was to be made.

The speaker went on to say that in 1925 the late Khan Bahadur Sheikh Minhajuddin carried out a series of experiments on different types of outlets on the Bhatinda distributary for the purpose of comparing their silt drawing capacity. He was associated with the actual execution of those experiments and it was found that the silt drawing capacity of the various types depended mostly on the velocity of flow into the outlet. Thus even a small amount of bell mouthing appreciably reduced silt draw and it was on account of this that O. S. Ms having large areas and consequently low velocities at the entrance, drew less than their fair share of silt even if fixed at or below bed level.

The speaker mentioned the great utility of constant discharge outlets on channels on which there was a seasonal variation in the water surface levels either due to silting or running extra supplies for reclamation.

Mr. R. K. Khanna remarked as follows :—

In Chapter VI, the authors have laid down the principal considerations which should govern the selection of outlet types. These considerations are :—

(*a*) The maximum rigidity possible with the working head available.

(*b*) Silt conduction.

(*c*) Immunity from tampering.

(*d*) Ease of adjustment.

(*e*) Cost.

To these might be added 'Simplicity of Design' and 'ease of construction.'

Mr. Khanna went on to say that for the head reaches of channels where good working heads were usually available orifice semi mo dules or Crump's A. P. Ms. fitted with the speaker's chutes would be most appropriate. For the lower reaches of channels Crump's open flumes were the best under all conditions.

The speaker added that the authors of the Paper had referred to certain experiments carried out by Mr. B. K. Kapur on his O. S. M. type of rigid module. The value of co-efficient for this type of outlet was supposed to be 6·0 against 7·3 for the simple O. S. M. The speaker remarked that there was obviously some mistake in observations or calculations, but even if the co-efficient was found to be lower than that of an O. S. M. it would not in any way detract from the usefulness of the outlet.

The speaker further remarked that the authors had described his and Mr. Ghafoor's outlets as being in the experimental stage, which he considered was not quite correct. Regarding the speaker's auto-adjusting orifice distributor described in the paper, he remarked that with this device in use at the head of an offtaking channel, the discharge tables could be dispensed with and that if any alteration in discharges had to be made, these could be effected by simply adjusting the weights.

Mr. Khanna went on to say that barrel or simple orifice outlets should be avoided as a rule, because unless there be free fall working outlets, these outlets must cause progressive silting up of the watercourse in the head reach even with large working heads. That he maintained that the silting and scouring of channels was a function of hydraulic conditions irrespective of the qualities and quantities of silt present in suspension in flowing water and as such the silt conduction of outlets could not affect the silting or scouring tendencies of channels. Even if the arguments about silt conduction were right, it would be wrong to divert our troubles to the poor *zamindars* by introducing more silt into their watercourses.

Mr. R. R. Handa pointed out that on the Sirhind Canal there was in vogue a system of *mirabs*, who were local men living in the village and their function was to run a *warabandi* where it had been sanctioned under Section 68 of the Canal Act or had been framed by the Village Community themselves.

Mr. Handa further pointed out that it was not a fact that in the North-west Frontier Province the cultivators would not irrigate at night. The cultivators did cultivate at night time also. It was not practicable to shut down all the canal system at night.

Mr. A. R. Thomas after congratulating the authors on their detailed and valuable contribution to the literature of irrigation engineering, said that it was apparent that a solution for the silting of distributaries was to increase the silt drawing capacity of the outlets. Mention had been made of designs of outlet which would draw a high proportion of silt, but unless outlets were to be rebuilt on a large scale the problem of existing channels which were silting, remained. There appeared to be scope for a single silt *selective* head which could be added to existing outlets.

Mr. K. R. Sharma observed as follows :—

On page 37, statement that " there is no level crest " in narrow open flume outlets is not correct. The length of crest was ·5 ft. in all cases. On page 67, while quoting his silt conduction experiments it is stated that a pipe fixed at bed level is also considered to draw an equivalent amount of silt charge (110 to 112%). This sentence should conclude by including " provided no vortex is formed at the entry in the parent channel."

The orifice type outlets falling in the category of semimodules should be further divided in three categories. It is misleading to call them all as O. S. M.

(*i*) Freefall semi-module orifice outlets (F. S. O.)

(*a*) K. G. O. (*b*) Jamrao type.

(*ii*) Submerged semi-module orifice outlet (S. S. O. O.)

(*a*) Crump. A. P. M. (*b*) Sharma's improved A. P. M.

(*iii*) *Combined type.*

Harvey Stoddard improved outlets which is a combination of orifice and weir type.

If any name is to be assigned to speaker's improvements of the A P.M. it should be S.S.O.O.

Mr. Sharma pointed out that the discharge of all outlets depended upon the the behaviour and properties of the control section and said that the constancy of discharge depended upon the control section which was defined by the parallelism of stream line in the critical flow. The parallelism of stream lines connoted two things :—

(*i*) The velocity throughout the depth is the same.

(*ii*) The pressure on the floor is equal to depth.

The horizontal length of crest equal to 2H was the essential feature of design to attain parallelism and eliminate the variation of the co-efficient. Any disturbance of the control section resulted in reduction of the discharge.

Mr. Sharma then described the various methods which caused fouling of the control section.

He then stated that the hydraulics of A.P.M. a submerged semi-module, was much more complicated than that of the open flume because the control section was a fixed point at the end of the roof block. He showed that with the value of Y between ·25H and ·5H, the co-efficient of discharge C in the formula $q = C\,B\,Y\sqrt{b}$ was far from being constant. Here he produced figures showing relationship between $\frac{B}{Y}$ to C. He went on to discuss the effect on Ca, *i. e.*, co-efficient of sectional area of vertical starvation and horizontal starvation and the effect on Cb *i. e.*, co-efficient of velocity of excessive length of approach and unsuitable approaches.

Mr. Sharma concluded by pointing out that the hydraulics of the minimum modular limits of the A. P. M. was cumbersome and lengthy because there were four kinds of losses which constituted it and added that the reduction in M. M. H. of S. S. O. O. was possible by adding a suitably designed surge chamber as experimented and published in his paper No. 237 Punjab Engineering Congress, which showed that the reduction was 33 %.

Sir William Roberts observed that such valuable papers enabled the Congress to have a preponderating influence on Government policy regarding distribution of water. He further stated that no mention had been made of 'loss of head' and that it was common knowledge that many fields took twice as long to irrigate as others owing to inefficient head. Loss of head may be a determining factor in deciding modularity of tail reaches. It should be considered seriously where there was risk for even 10 % of the area being affected as the ultimate result would be loss of efficiency.

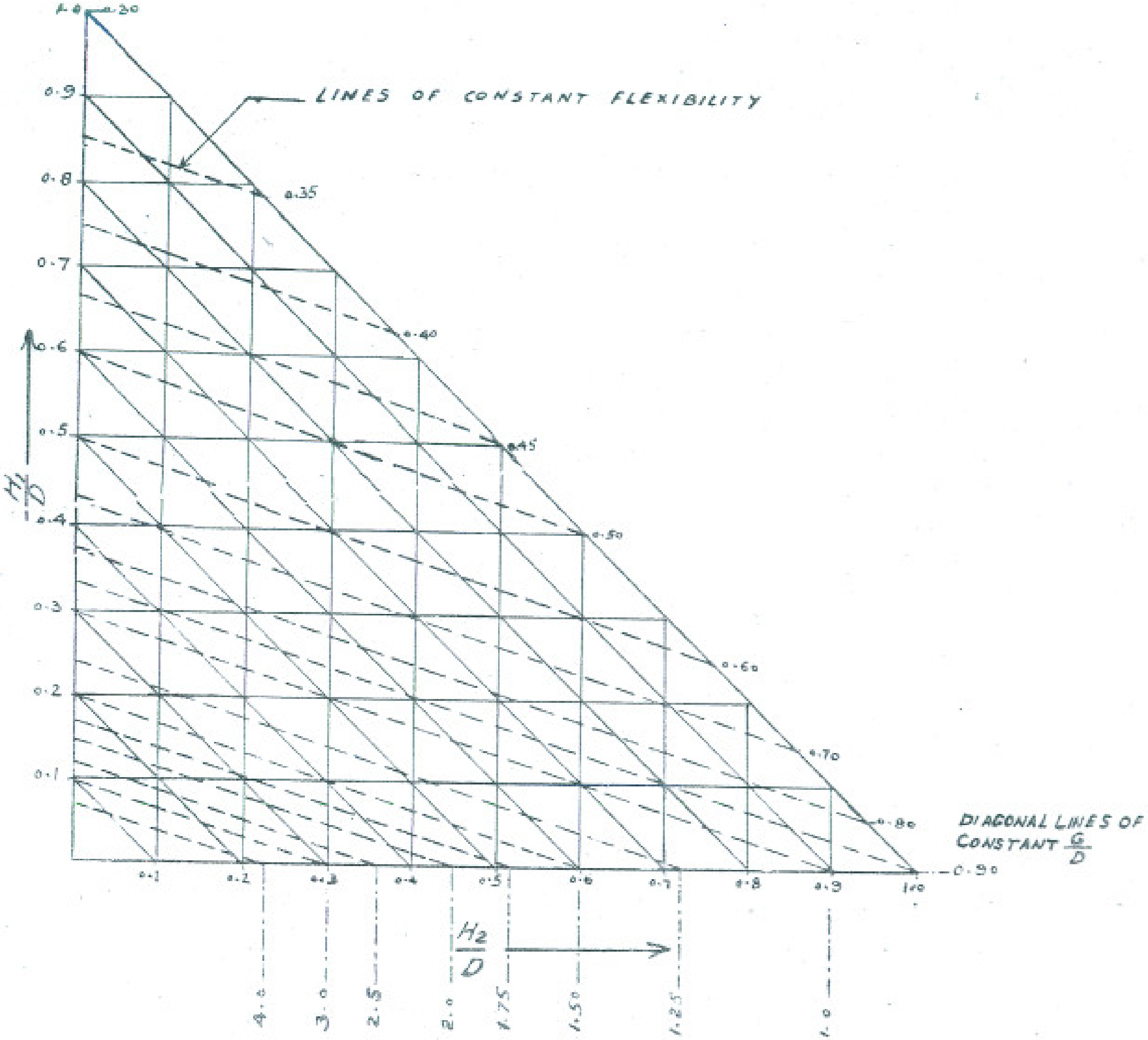
He expected that this aspect would be dealt with in the final Paper that would be published.

Mr. Edgecombe remarked that in U. P. pipe outlets were still being used on all channels with the exception of the tube-well system, where water was delivered through the underground pipe system.

The speaker stated that the retention of pipe outlets was not due to any apathy on the part of the U. P. Engineers but was the direct result of the major policy of preventing waterlogging, with the result that U. P. was free from this evil. The speaker added that when the Ganges Canal was constructed approximately one hundered years ago, it was laid down that in all irrigation projects strict attention should be given to the prevention of waterlogging with the result that in U. P. there was no waterlogging.

Moreover, the speaker added, that the ancient methods of irrigation by open wells and natural tanks had not been replaced by canal irrigation in U. P. as for as possible. In furthering this long term policy, it was considered that the best channel was one on which the irrigation was 15 % lift. Thus the working heads of outlets were small. This fact coupled with the smallness of the agricultural holdings in U. P. resulted in outlets of small discharges. This was reflected in the far greater mileage of minor channels than in the Punjab.

Thus in U. P. the engineer had to deal with small heads and small discharges, conditions which suited pipe outlets.

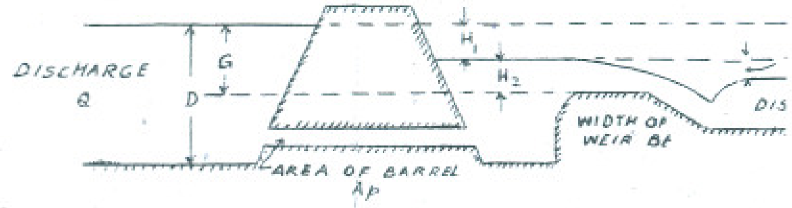


FLEXIBILITY DIAGRA

FOR

ORIFICE, WEIR & HARVEY-STODDARD OU

FLEXIBILITY $F = \frac{D}{\frac{10}{3} H_1 + \frac{10}{9} H_2}$ DISCHARGE q



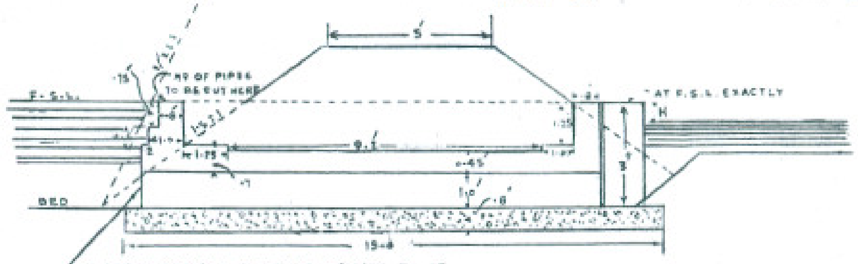
PUNJAB E

1:

IN FLAP
PES OUTLET

PLATE No. 6.
PAPER No 264

FIG: 15.

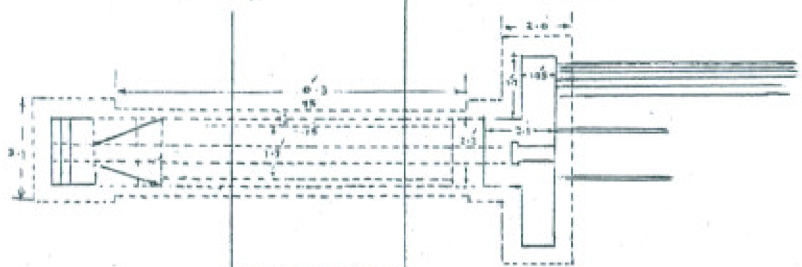


FRONT BRICK & FLOOR AT ORIFICE TO BE IN CEMENT AND TO EXACT DIAMENSIONS OR A STONE WITH EXACT ORIFICE CUT IN IT MAY BE USED.

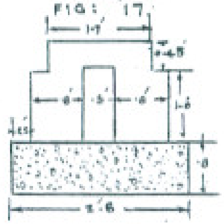
TYPE OUTLET

SCALE 1/50

FIG: 16.



CROSS SECTION
SCALE 1/25
FIG: 17.



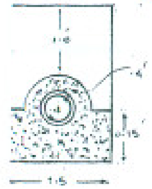
PUNJAB ENGINEERING C(
1944

SD: R. G. KENNEDY
SE. W. J. CANAL.

ON FOR 1 PIPE OUTLET

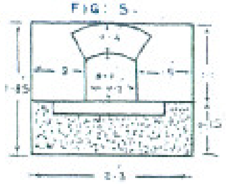
FIG: 4.

SCALE 1/25



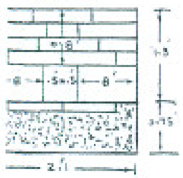
SECTION FOR 1 PIPE CULVERT

FIG: 5.



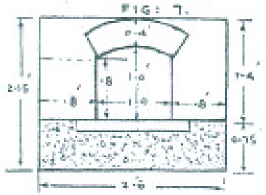
TION FOR 2 PIPES OUTLET

FIG: 6.



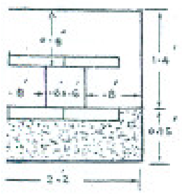
SECTION FOR 2 & 3 PIPES CULVERT

FIG: 7.



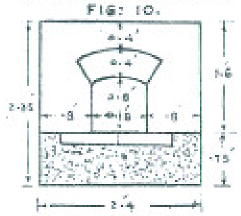
C: FOR 3 PIPES OUTLET

FIG: 8.



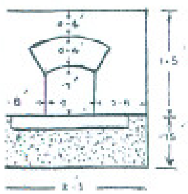
SECTION FOR 5 PIPES OUTLET OR CULVERT

FIG: 10.



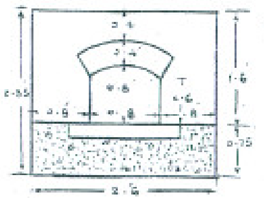
CTION FOR 4 PIPES TLET OR CULVERT

FIG: 9.



SECTION FOR 6 PIPES OUTLET OR CULVERT

FIG: 11.



ENLARGED SEC: OF OUTLET

SCALE 1/10

FIG: 14.

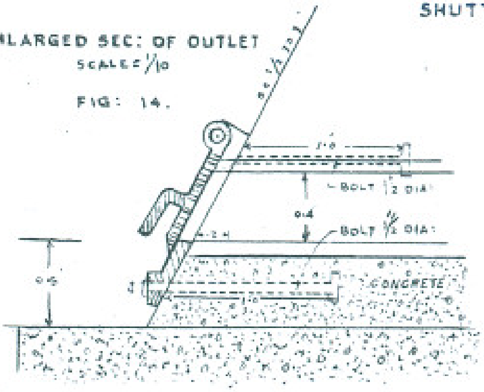
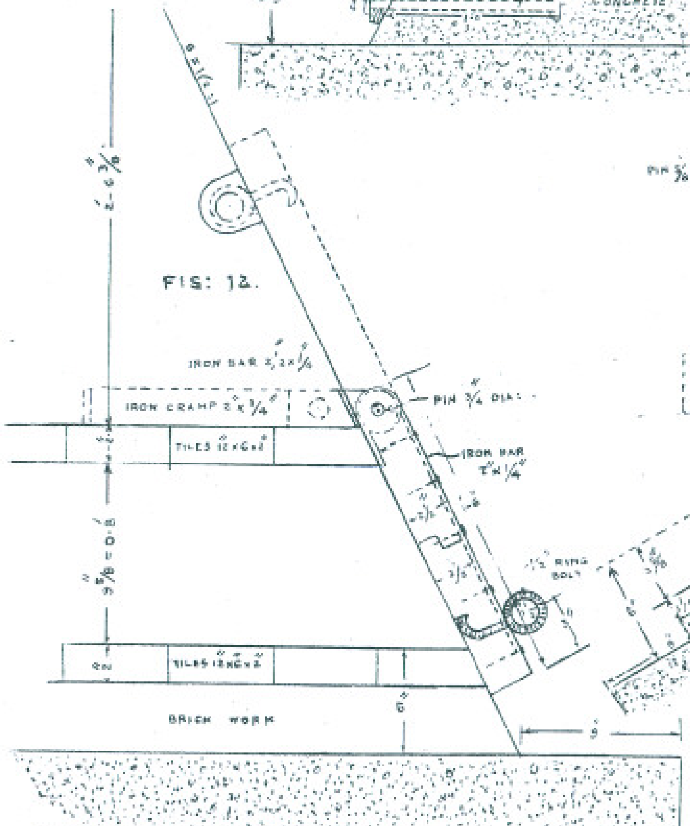


FIG: 12.



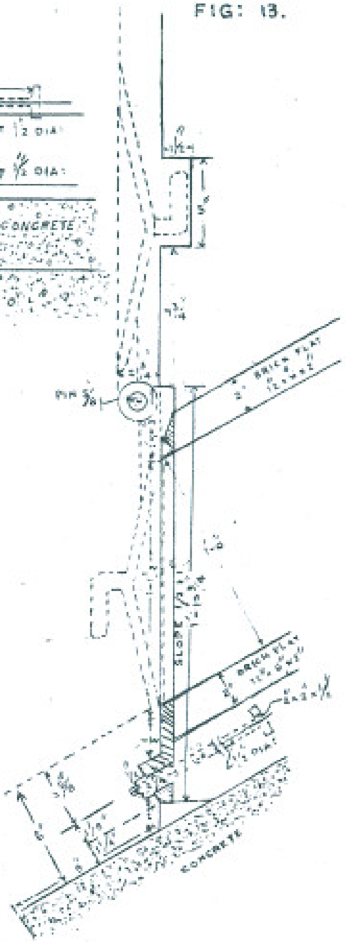
WOODEN FLAP SHUTTER FOR 5 PIPES OUTLET

SCALE 6" = 1 FOOT.

SEC: OF CAST IRON FLAP SHUTTER FOR 8 PIPES OUTLET

SCALE 6" = 1 FT.

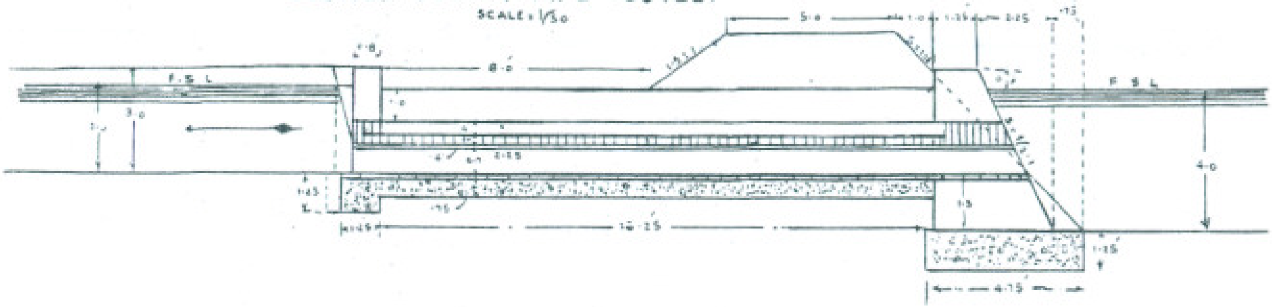
FIG: 13.



SECTION FOR 4 PIPE OUTLET

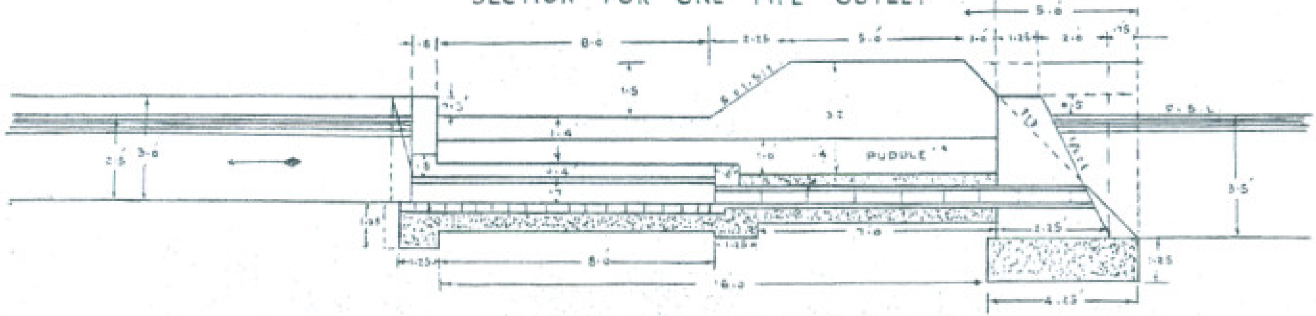
SCALE = 1/50

FIG: 1.



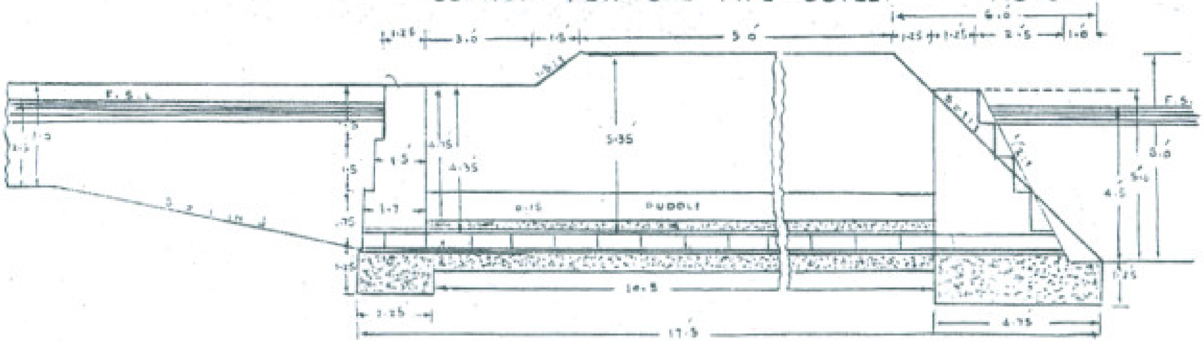
SECTION FOR ONE PIPE OUTLET

FIG: 2.



SECTION FOR ONE PIPE OUTLET

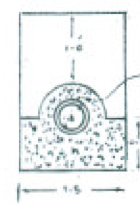
FIG: 3.



SECTION FOR 1 PIPE OUTLET

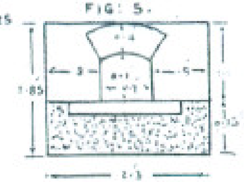
FIG: 4.

SCALE = 1/25



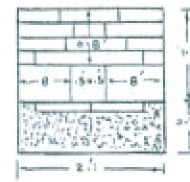
SECTION FOR 1 PIPE CULVERT

FIG: 5.



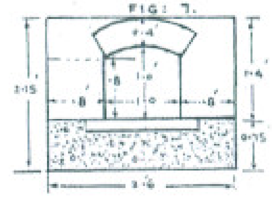
SECTION FOR 2 PIPES OUTLET

FIG: 6.



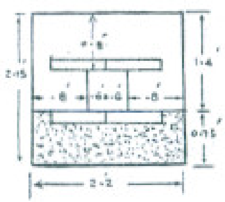
SECTION FOR 2 & 3 PIPES CULVERT

FIG: 7.



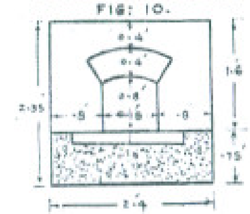
SEC: FOR 3 PIPES OUTLET

FIG: 8.



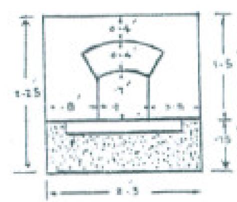
SECTION FOR 5 PIPES OUTLET OR CULVERT

FIG: 10.



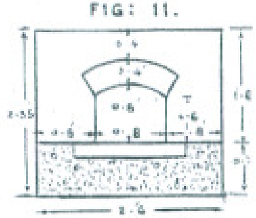
SECTION FOR 4 PIPES OUTLET OR CULVERT

FIG: 9.



SECTION FOR 6 PIPE OUTLET OR CULVERT

FIG: 11.



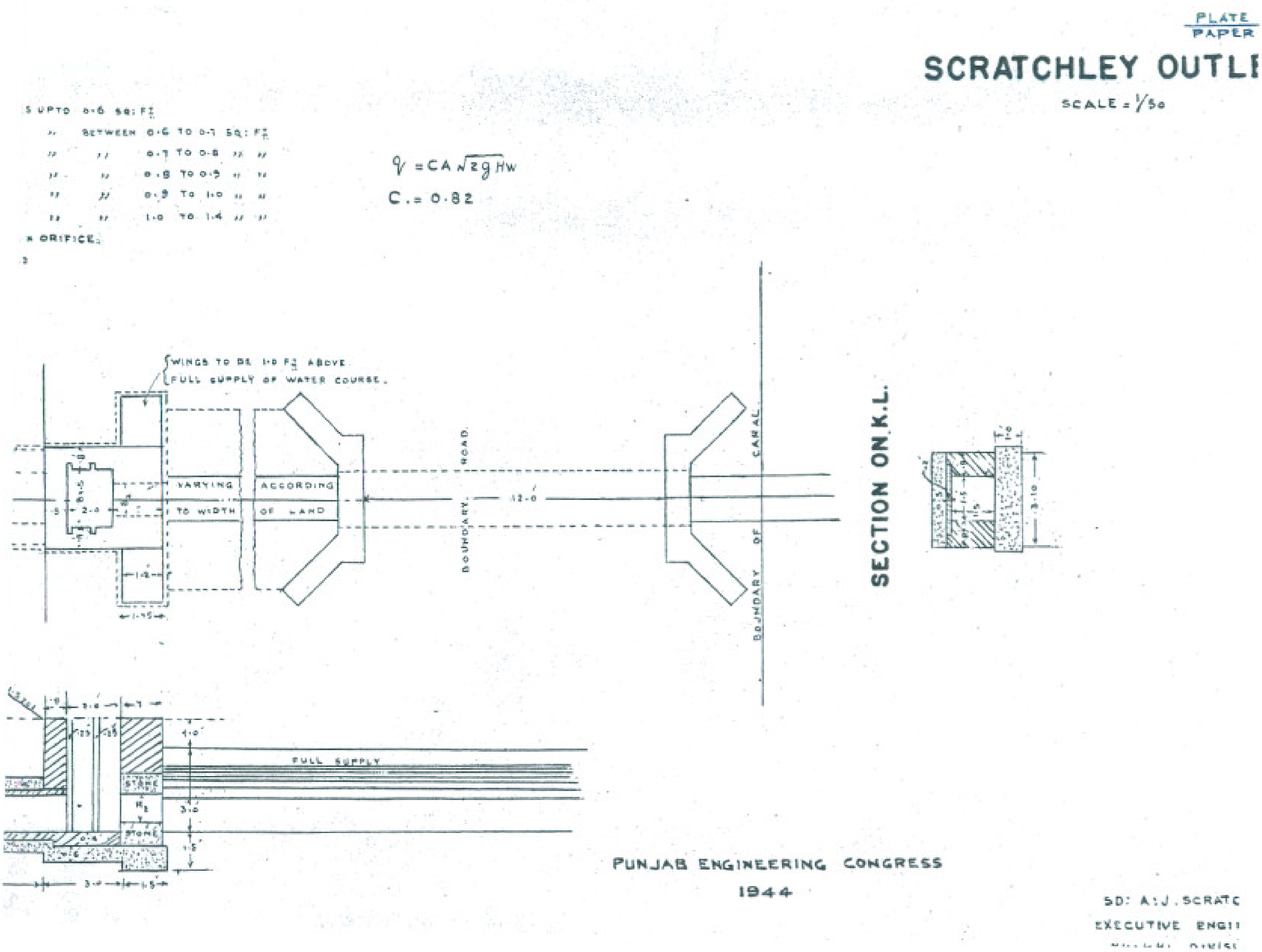


PLATE
PAPER
SCRATCHLEY OUTLI
SCALE = 1/50
S UPTO 0·6 SQ: FT.
" BETWEEN 0·6 TO 0·7 SQ: FT.
" " 0·7 TO 0·8 " "
" " 0·8 TO 0·9 " "
" " 0·9 TO 1·0 " "
" " 1·0 TO 1·4 " "
K ORIFICE.
$q = CA\sqrt{2gHw}$
C. = 0·82
WINGS TO BE 1·0 FT. ABOVE
FULL SUPPLY OF WATER COURSE.
VARYING
ACCORDING
TO WIDTH
OF LAND
BOUNDARY ROAD
12·0
BOUNDARY OF CANAL
SECTION ON K.L.
3·10
FULL SUPPLY
STONE
STONE
PUNJAB ENGINEERING CONGRESS
1944
SD: A.J. SCRATC
EXECUTIVE ENGI

ILL OUTLET
ND 3 FT. F.S. DEPTH

30

CACH AREA

RAJBAHA.

WILL BE $\frac{d}{4}$ BELOW

ALWAYS BUT
E CILL WILL

ORIFICE	T.
0·4 PIPE	1·2
0·5 x 0·5	1·2
0·5 x 0·6	1·2
0·6 x 0·6	1·2
0·6 x 0·7	1·2
0·7 x 0·7	1·2
0·7 x 0·8	1·2
0·8 x 0·8	1·2
0·9 x 0·8	1·5
0·9 x 0·9	1·5
0·9 x 1·0	1·8
1·0 x 1·0	1·5
1·1 x 1·0	1·5
1·2 x 1·0	1·6
1·3 x 1·0	1·6
1·4 x 1·0	1·6
1·5 x 1·0	1·6
1·5 x 1·1	1·6
1·5 x 1·2	2·15
1·5 x 1·3	2·15
1·5 x 1·4	2·15

B. H.

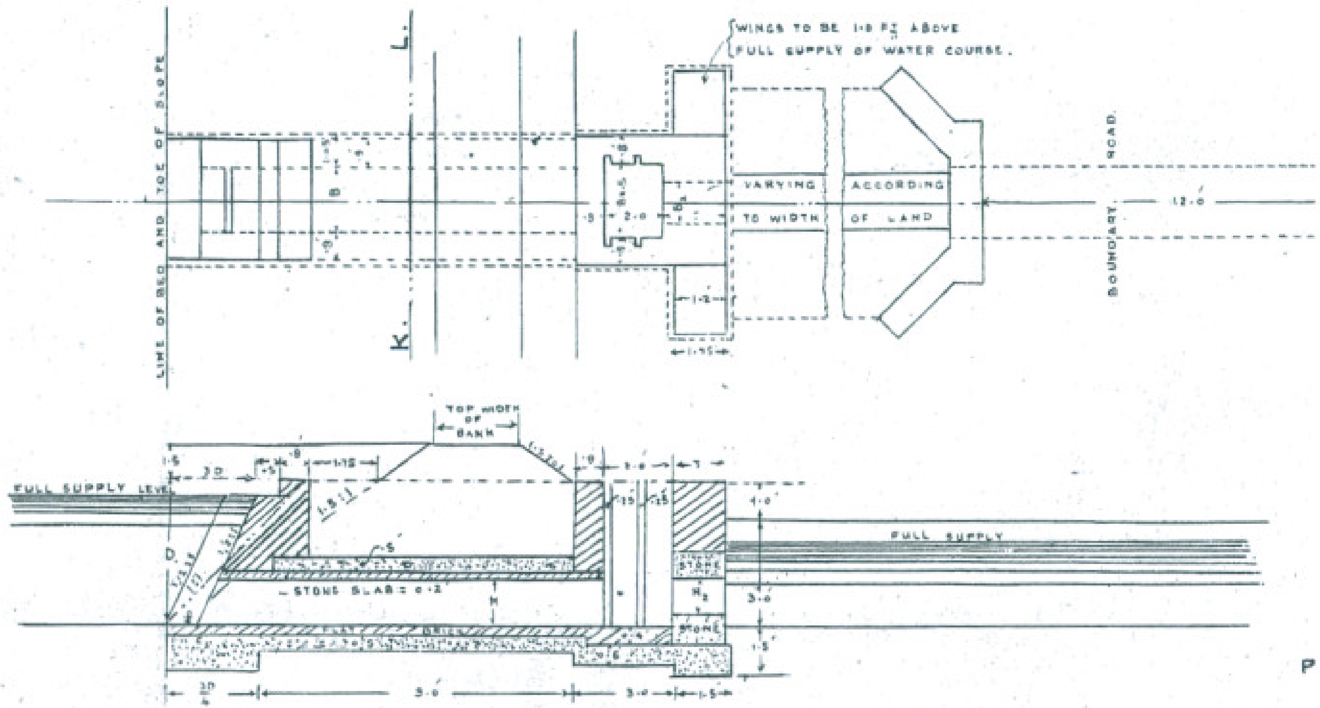
BARREL OF OUTLET TO BE 1·0 x 1·0 FOR ALL ORIFICES UPTO 0·6 SQ: FT.
" " " " " 1·2 x 1·0 " " " " BETWEEN 0·6 TO 0·7 SQ: FT.
" " " " " 1·4 x 1·0 " " " " " 0·7 TO 0·8 " "
" " " " " 1·5 x 1·0 " " " " " 0·8 TO 0·9 " "
" " " " " 1·5 x 1·25 " " " " " 0·9 TO 1·0 " "
" " " " " 1·5 x 1·5 " " " " " 1·0 TO 1·4 " "

FOR LARGER SIZE MAKE BARREL 5/3 x ORIFICE.

T. TO BE NEVER LESS THAN 1½ OR MORE THAN 3 TIMES H_2
H. TO BE NEVER MORE THAN, B.

$$q = CA\sqrt{2gHw}$$

C. = 0·82

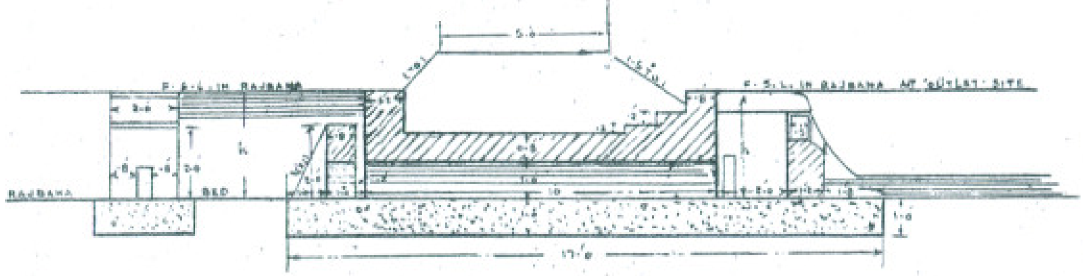


KENNEDY'S CILL OUTLET

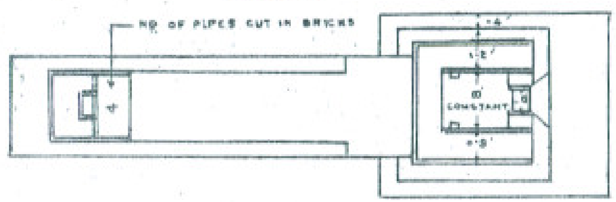
DRAWN FOR 4 PIPES AND 3 FT. F.S. DEP.

SCALE = 1/80

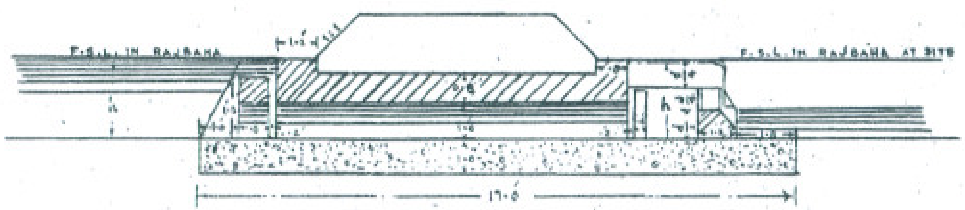
AS NEAR RAJBAHA HEAD

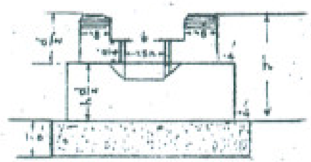


PLAN



AS NEAR RAJBAHA TAIL





5-2" TO 8 PIPE AND 6-2 FOR 8 TO 12 PIPES

IN ABOVE: n = NUMBER OF PIPES IN THE OUTLET OF 0·256 EACH AREA
h = FULL SUPPLY DEPTH IN RAJBAHA AT ANY POINT
d = FULL SUPPLY DEPTH IN RAJBAHA AT HEAD OF RAJBAHA.

THE OUTER CILL LEVEL OF ANY OUTLET FOR EACH RAJBAHA WILL BE $\frac{d}{2}$ BELOW THE FULL SUPPLY LEVEL AT THAT POINT.

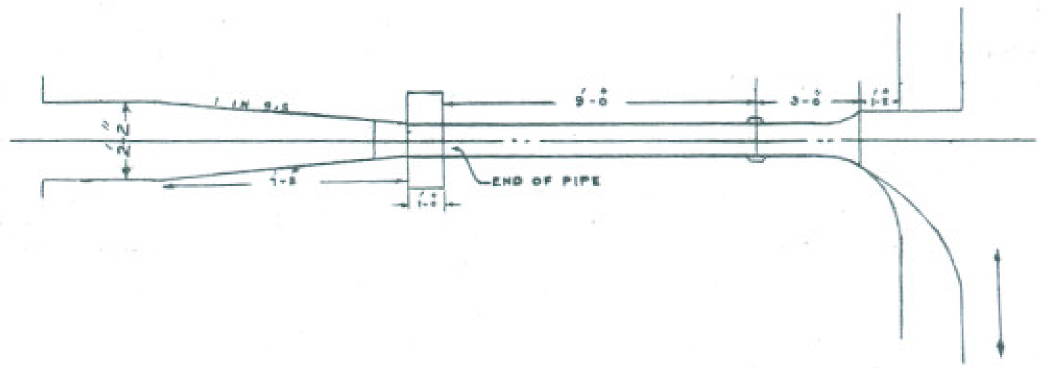
THEN HEIGHT OF CILL ABOVE BED WILL THEREFORE BE $(h - \frac{d}{2})$ ALWAYS BUT NEAR THE TAIL WHERE $\frac{d}{2}$ IS GREATER THAN h THE CILL WILL BE AT BED LEVEL.

PLATE No 4
PAPER No 26.

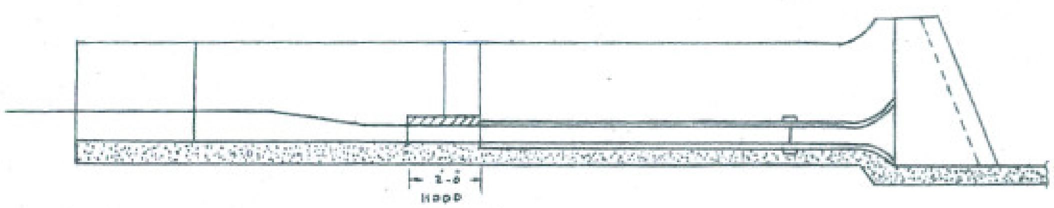
STANDING WAVE PIPE OUTLET WITH DOWN STREAM HOOD

SCALE = 1/50

PLAN



L. SECTION



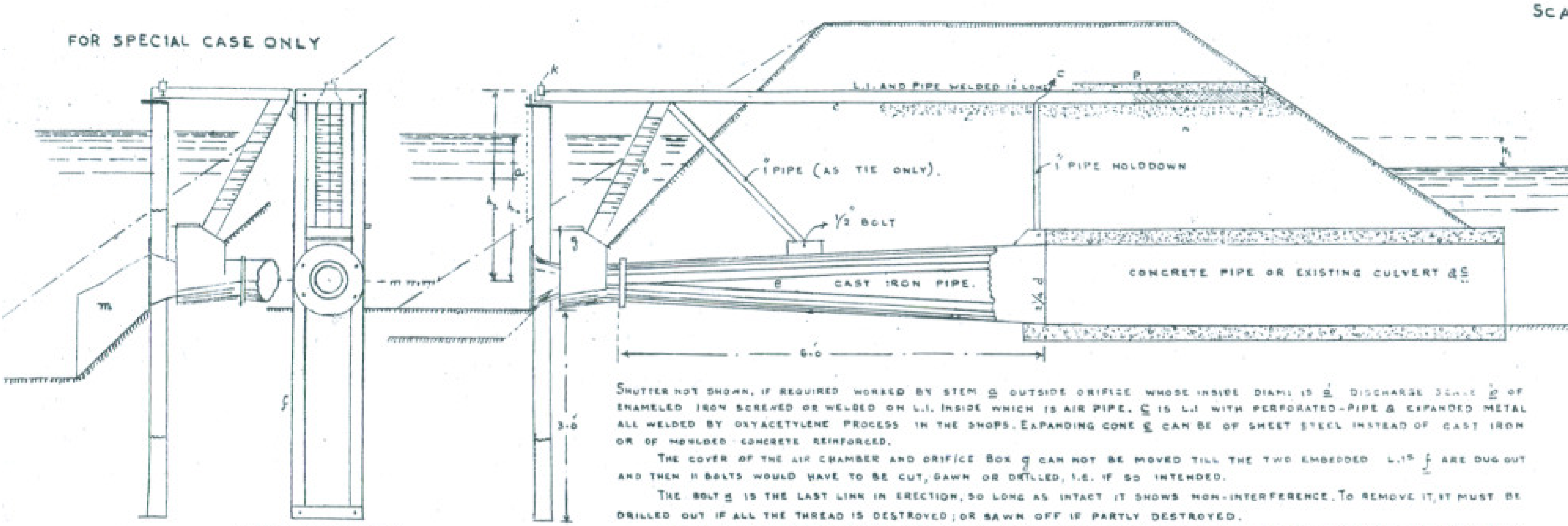
SD: C. E. INGLIS D/ 14.4.28
SUPERINTENDING ENGINEER
IRRIGATION DEVELOPMENT & RESEARCH CIRCLE.

PUNJAB ENGINEERING CONGRESS

KENNEDYS GAUGE MODIFIED AND TAMP

SCALE: 1/20

FOR SPECIAL CASE ONLY



FRONT ELEVATION

THE SPECIAL BELL-MOUTH m IS FOR CASES WHERE THE COMBINATION OF POOR HEAD DEEP CHANNEL AND HEAVY BED SILT EXISTS.

SHUTTER NOT SHOWN, IF REQUIRED WORKED BY STEM a OUTSIDE ORIFICE WHOSE INSIDE DIAM. IS d. DISCHARGE SCALE b OF ENAMELED IRON SCREWED OR WELDED ON L.I. INSIDE WHICH IS AIR PIPE. C IS L.I WITH PERFORATED-PIPE & EXPANDED METAL ALL WELDED BY OXYACETYLENE PROCESS IN THE SHOPS. EXPANDING CONE e CAN BE OF SHEET STEEL INSTEAD OF CAST IRON OR OF MOULDED CONCRETE REINFORCED.

THE COVER OF THE AIR CHAMBER AND ORIFICE BOX g CAN NOT BE MOVED TILL THE TWO EMBEDDED L.I.S f ARE DUG OUT AND THEN H BOLTS WOULD HAVE TO BE CUT, SAWN OR DRILLED, I.E. IF SO INTENDED.

THE BOLT k IS THE LAST LINK IN ERECTION, SO LONG AS INTACT IT SHOWS NON-INTERFERENCE. TO REMOVE IT, IT MUST BE DRILLED OUT IF ALL THE THREAD IS DESTROYED; OR SAWN OFF IF PARTLY DESTROYED.

ALL AIR HOLES QUITE PROTECTED, AND IN g BARBED WIRE PREVENTS INTERFERENCE FROM BELOW. C IS LAID ON DRY BALLAST, AIR ADMITTED ITS WHOLE LENGTH, AND AT n EXPANDED METAL WOUND ROUND AND ROUND AND WELDED ON. P IS A THIN LAYER OF ASPHALT POURED OVER THE BALLAST TO KEEP OUT EARTH, OR A ONE INCH LAYER OF CEMENT CONCRETE ABOUT 3'-0 × 3'-0 AREA MAY BE MADE IN SITU WITH EXPANDED METAL REINFORCEMENT ANCHORED TO THE L.I. C. THE BREAKAGE OF OUTER VISIBLE EDGE OF P WOULD SHOW TAMPERING.

STODDARD HARVEY IMPROVED IRRIGATION OUTLET

SCALE 1/50

PLATE NO. 6
PAPER NO. 264

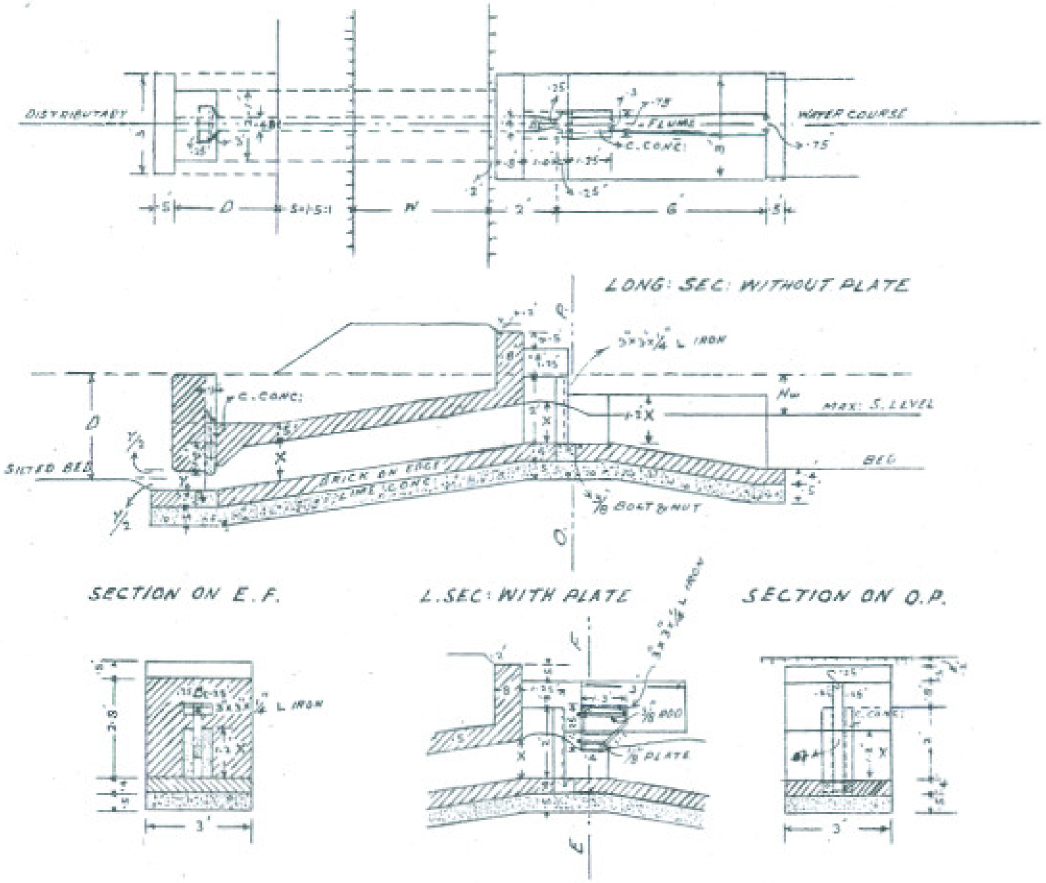


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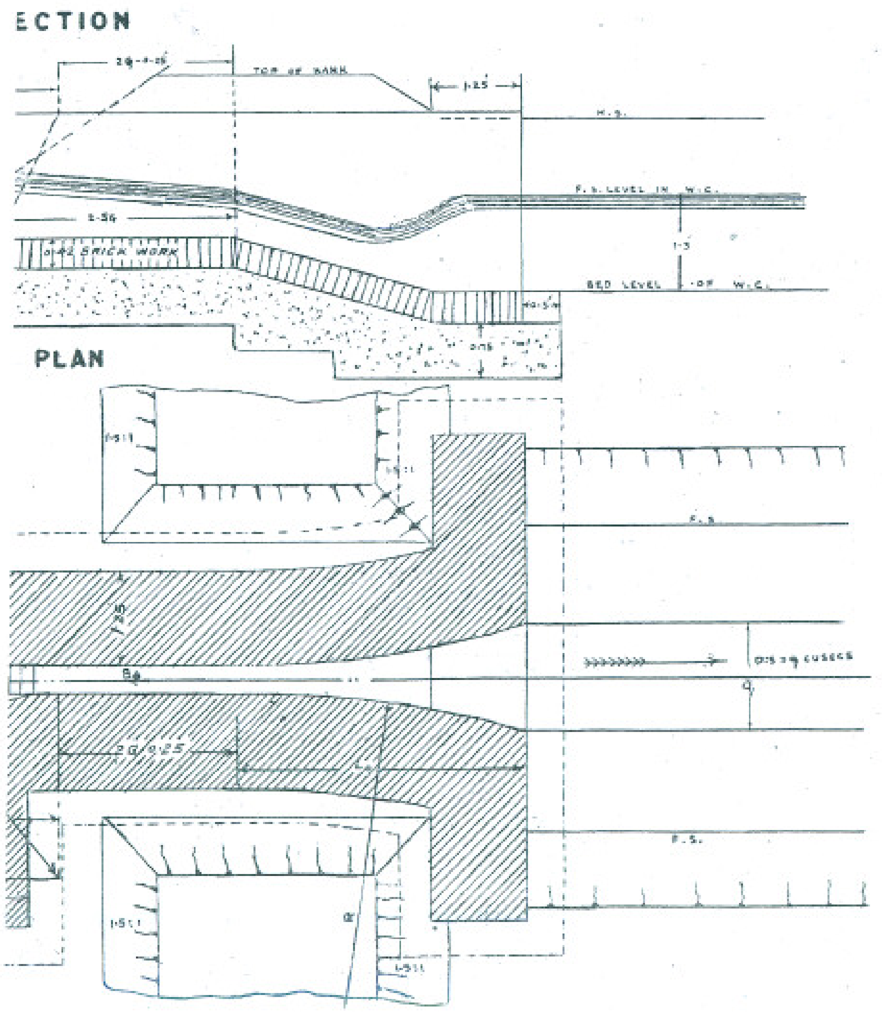
PLATE No 7
PAPER No 264

CRUMPS OPEN FLUME OUTLET

SCALE = 1/20



B = BED WIDTH. } OF CHANNEL
D = F.S. DEPTH. } BELOW OUTLET
Q = DISCHARGE }

q = DISCHARGE OF OUTLET

G = F.S. DEPTH ON CREST OF OUTLET

$B_t = \frac{q}{3H^{3/2}}$ = WIDTH OF FLUME AT WAIST.

$W = q/Q\,(B + D/2)$ = WIDTH OF MOUTH OF APPROACH = SET BACK OF UPSTREAM WING.

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

L = LENGTH OF OUTFALL

$R = \frac{W-B_t}{4} + \frac{L^2}{W-B_t}$ = RADIUS OF OUTFALL.

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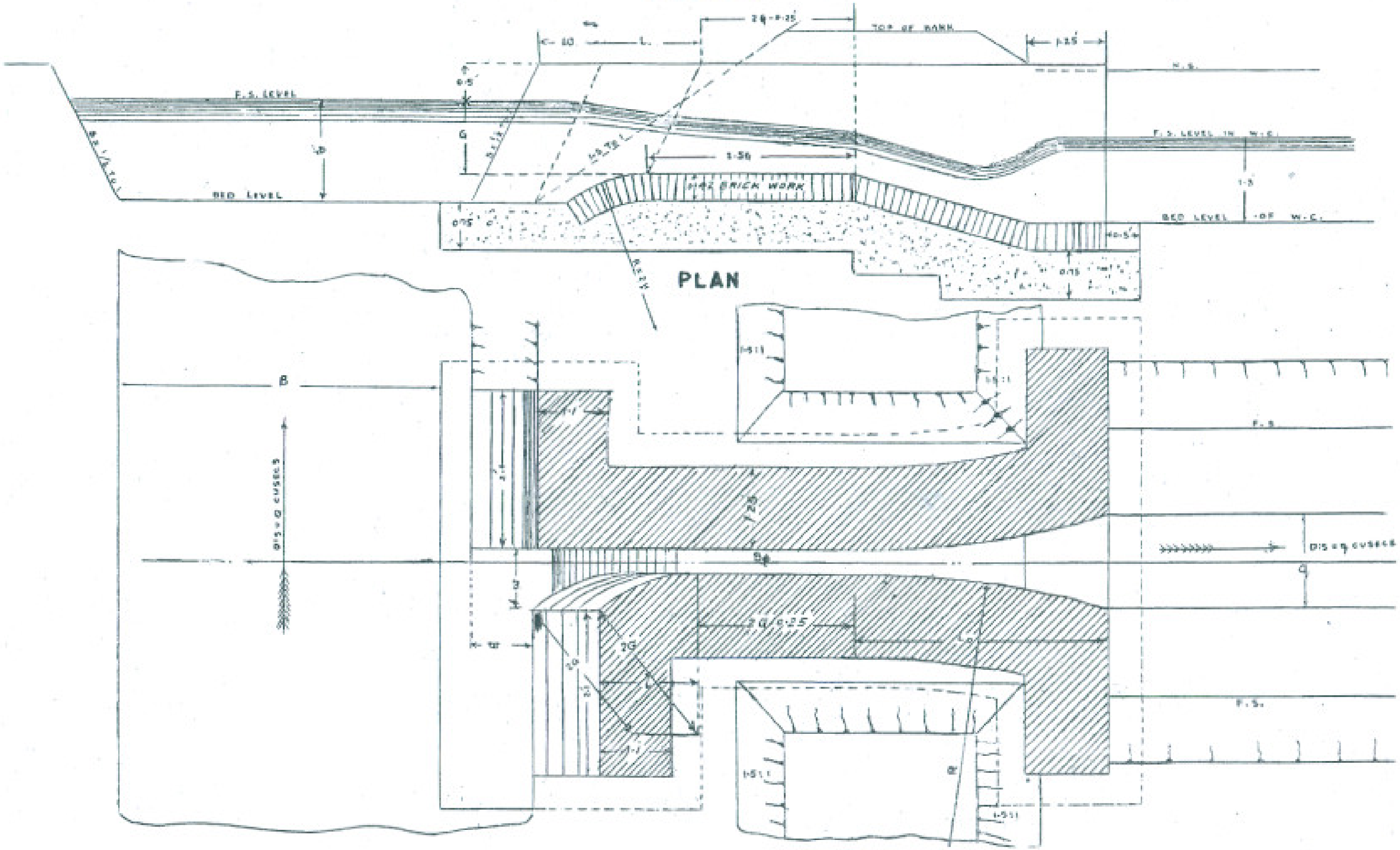
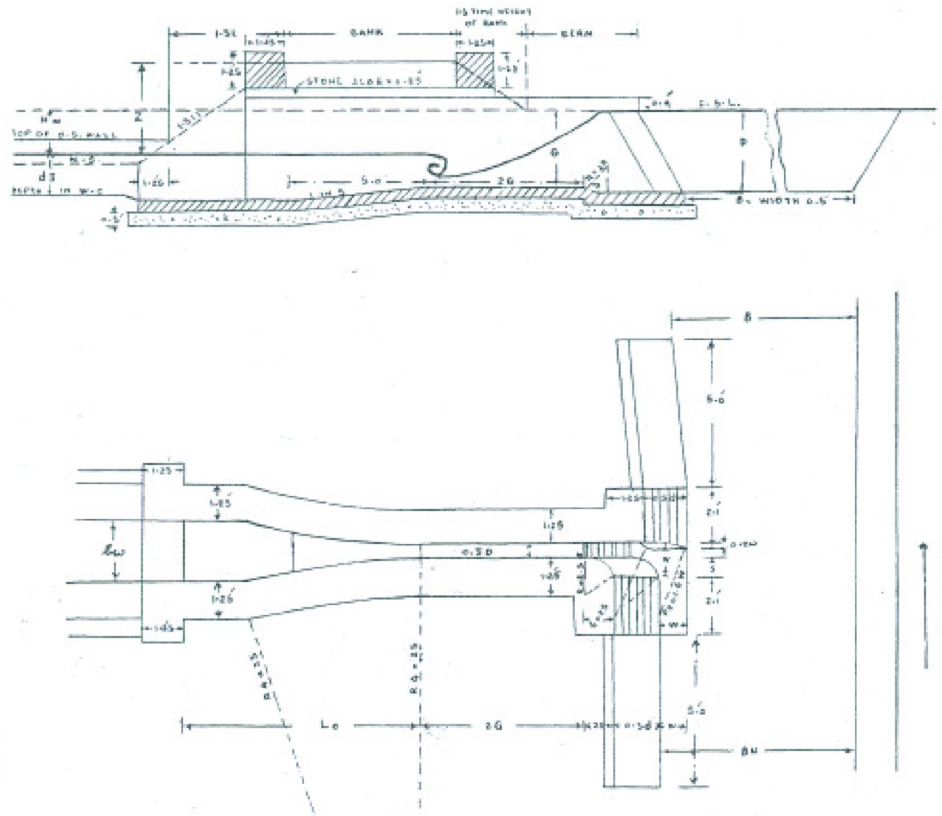
SECTION



TOP OF BANK
N.S.
F.S. LEVEL
F.S. LEVEL IN W.C.
BED LEVEL
BED LEVEL OF W.C.
BRICK WORK
PLAN
B
F.S.
F.S.



SHARMAS IMPROVED WEIR FLUME

SCALE - 1/50

WIDTH IN CHANNEL U/S OF OUTLET ....

DEPTH " " " " " ....

DISCHARGE " " " " ....

BED WIDTH IN CHANNEL D/S OF OUTLET ....

DISCHARGE OF THE OUTLET ....

SETTING OF THE OUTLET ....

DEPTH ON CREST ....

WIDTH OF THE OUTLET ....

LENGTH OF CREST ....

MINIMUM MODULAR HEAD ....

ACTUAL WORKING HEAD ....

SET BACK OF U/S WING } WB ....
WIDTH OF APPROACH }

SPLAY OF U/S SIDE WALL ....

RADIUS OF SPLAY ON SIDE ....

LENGTH OF APPROACH CURVE ON SIDE ....

RADIUS OF CURVATURE OF D/S PROJECTED WING ....

RISE OF CREST ABOVE DISTY: BED U/S ....

RADIUS OF CURVATURE OF APPROACH CURVE IN BED ....

LENGTH OF OUTFALL ....

RADIUS OF CURVATURE OF OUTFALL ....

DISTANCE OF BEGINING OF CREST FROM C.LINE OF DISTY: U/S ....

WIDTH OF WATER COURSE bw = ---- { 0 TO 1 CUSEC = 1.5 FEET; 1 TO 2 CUSECS = 2.0 FEET; ABOVE 2 CUSECS = 2.5 FEE

K .... = AVERAGE VELOCITY IN CHANN / VELOCITY NEAR THE SIDE.

= 2 FOR HEAD REACHES IN MA

= 1.5 FOR MIDDLE REACH

= 1.25 FOR TAIL REACH

= 1.0 FOR ... NNELS BELOW

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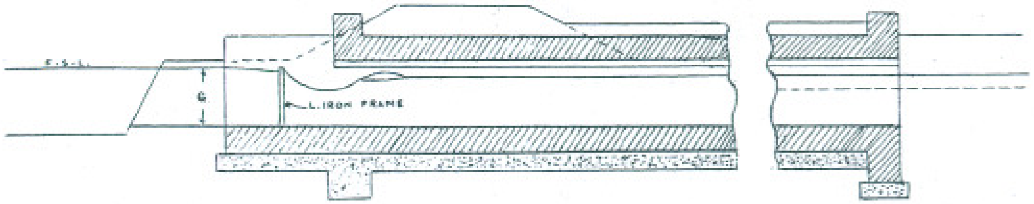
PLATE No. 9

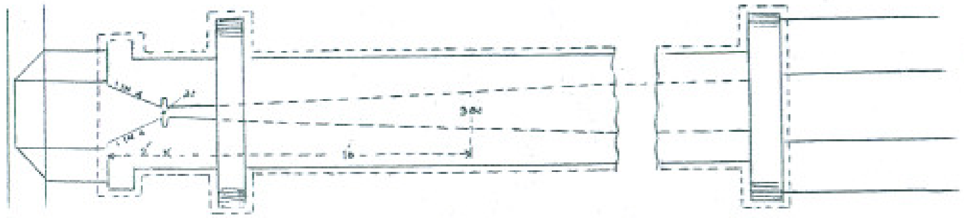
PAPER No. 264

KIRKPATRICK OPEN FLUME SEMI MODULE

SCALE : 1/50



LONGITUDINAL SECTION



PLAN

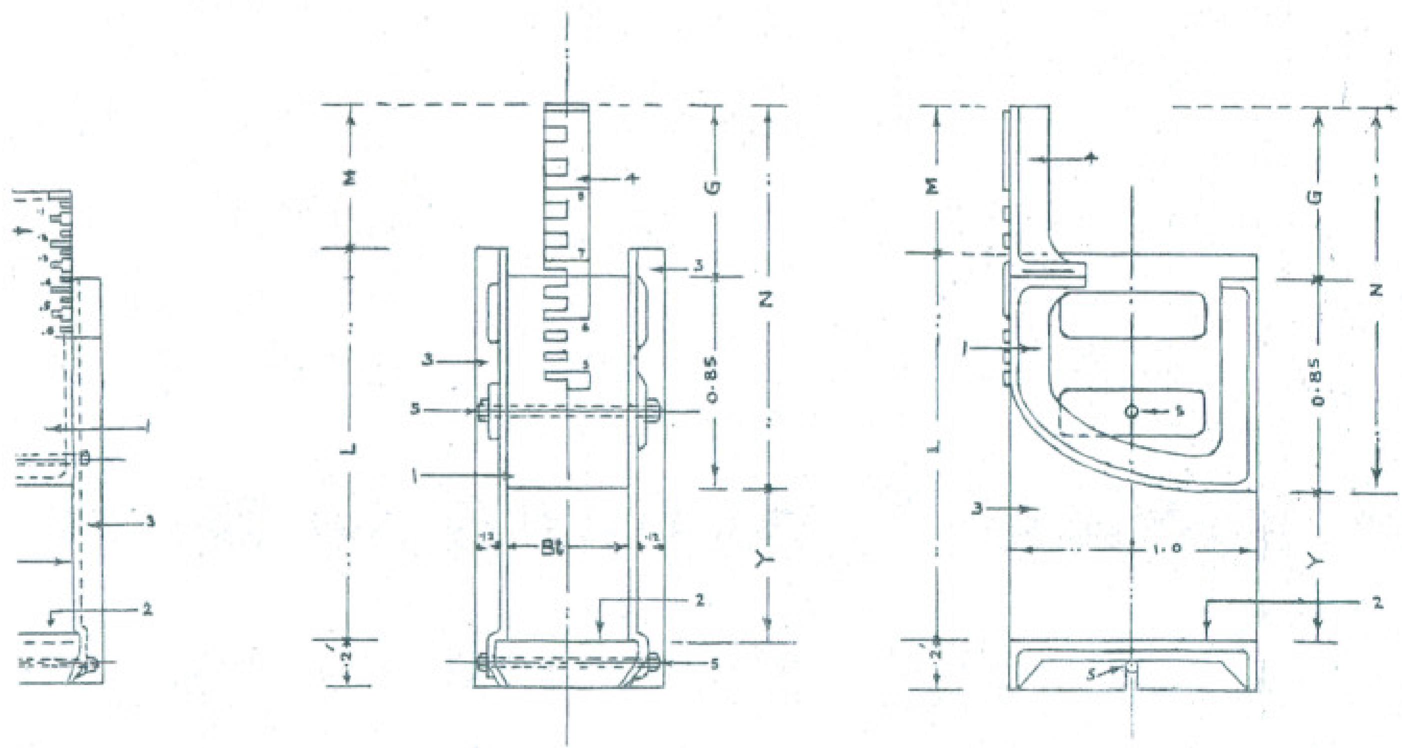
PUNJAB ENGINEERING CONGRESS

1944

BLOCK

PAPER No. 264

ORDINARY TYPE ROOF BLOCK
FOR A.P.M.



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CRUMPS
ADJUSTABLE PROPORTIONAL MODULE.

B = BED WIDTH, D = F.S. DEPTH, Q = DISCHARGE } OF CHANNEL BELOW OUTLET

q = DISCHARGE OF OUTLET

G = DEPTH OF FLOOR OF OUTLET BELOW W.S

Y = HEIGHT OF ORIFICE

$Bt = \frac{q}{7.85\,Y\sqrt{Hs}}$ = WIDTH OF OPENING { Hs = HEAD ABOVE TOP OF ORIFICE; Hw = WORKING HEAD OF OUTLET

$W = \frac{q}{Q}\left(B + \frac{D}{2}\right)$ = WIDTH AT MOUTH OF APPROACH

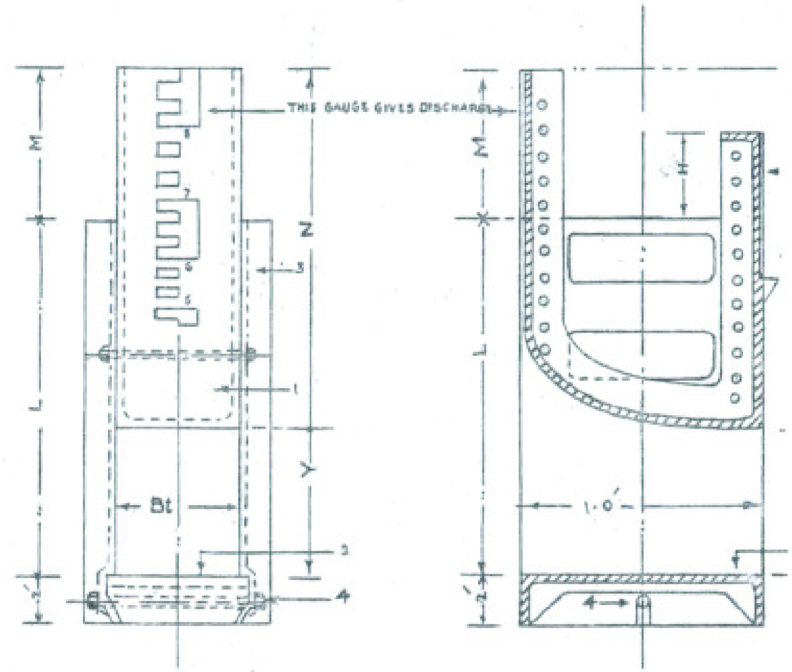
Z = LENGTH OF APPROACH CURVE = $\sqrt{(W-Bt)(4G-W+Bt)}$ SET BACK OF U/S WINGS.

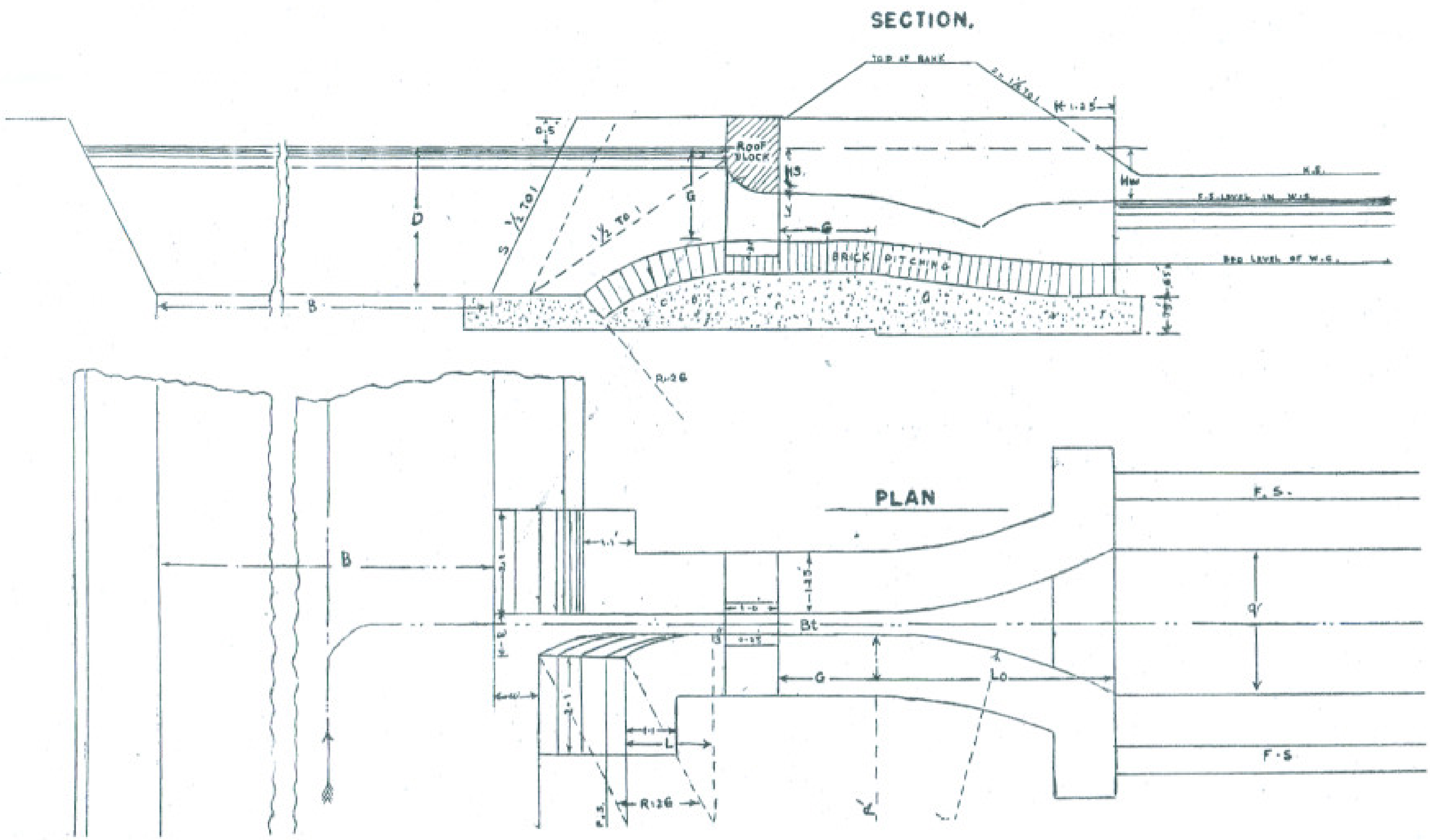
L = LENGTH OF OUTFALL

R = 2G = RADIUS OF APPROACH CURVE

$R' = \frac{Y-Bt}{4} + \frac{L^2}{(Y-Bt)}$ = RADIUS OF OUTFALL

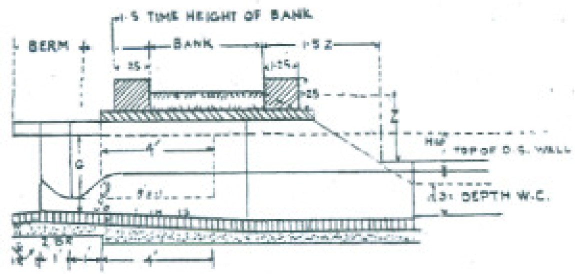
HT OF SIDE PLATE = NEAREST MULTIPLE OF 3 INCHES IN EXCESS OF H.O.S.

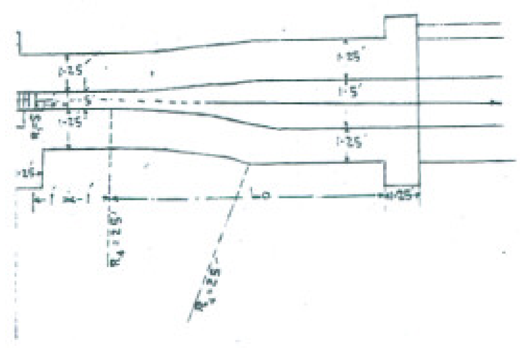



SECTION.
TOP OF BANK
ROOF BLOCK
BRICK PITCHING
H.S.
F.S. LEVEL IN W.C.
BED LEVEL OF W.C.
Hw
D
G
B
PLAN
F.S.
F.S.
Bt
G
Lo
L
B

MPROVED O.S.M. OUTLET

SCALE = 1/50





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 OF CHANNEL D.S. OF OUTLET .... B
DISCHARGE OF OUTLET .... q
SETTING .... δ
DEPTH ON CREST = H .... δD
WIDTH OF O.S.M. .... B_t
DEPRESSION OF ROOF BLOCK .... H_s
HEIGHT OF OPENING .... Y
$q = C B_t Y \sqrt{H_s}$
MINIMUM MODULAR HEAD (FROM DIAGRAM) .... H_m
ACTUAL WORKING HEAD .... H_w
SET BACK OF U.S. WING / WIDTH OF APPROACH $\Big\} = W = K \frac{q}{Q}\left(B_u + \frac{D}{2}\right)$
SPLAY OF U.S. SIDE WALL = S .... $W - B_t$
RADIUS OF SPLAY ON SIDE = R .... S
LENGTH OF APPROACH CURVE ON SIDE .... S
RADIUS OF CURVATURE OF D.S. PROJECTED WING, $R_2 = 2.6W$ .... $2.6W$
DISTANCE OF THE BACK OF O.S.M. WHERE 'Y' AND 'G' ARE MEASURED FROM THE CENTRAL LINE OF U.S. CHANNEL
$= \frac{B_u}{2} + \frac{d_2}{2}\ S + 1.5$
$\text{OR} = \frac{B_u}{2} + 2.23\ R + 1.5$
R = RISE OF APPROACH CURVE IN BED ABOVE DISTRIBUTARY BED
U.S. $= (1-\delta)D + 0.1$
RADIUS OF CONVEX PART OF APPROACH CURVE IN BED, $R_3 = 2R$
RADIUS OF CONCAVE PART OF APPROACH CURVE IN BED = R
LENGTH OF OUTFALL .... L_o
RADIUS OF CURVATURE OF OUTFALL .... $R_4 = 25$
HEIGHT OF Hm REDUCING DEVICE $- y_o = Y + 0.05$ WHERE $Y > 0.8$, $y_o =$ .... $1.1Y$

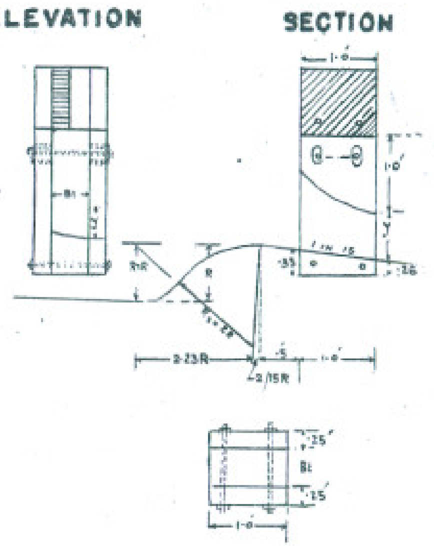
WIDTH OF W.C. $= \begin{cases} 0 \text{ TO } 1.0 \text{ CUSECS} = 1.5 \text{ FEET} \\ 1 \text{ TO } 2.0 \text{ CUSECS} = 2.0 \text{ FEET} \\ \text{ABOVE } 2.0 \text{ CUSECS} = 2.5 \text{ FEET} \end{cases}$

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

K = 2·0' FOR HEAD REACHES OF MAJOR DISTY:
= 1·5' FOR MIDDLE REACHES IN MAJOR DISTY:
= 1·25 FOR TAIL REACHES IN MAJOR DISTY:
= 1·0' FOR CHANNELS BELOW 10 CUSECS

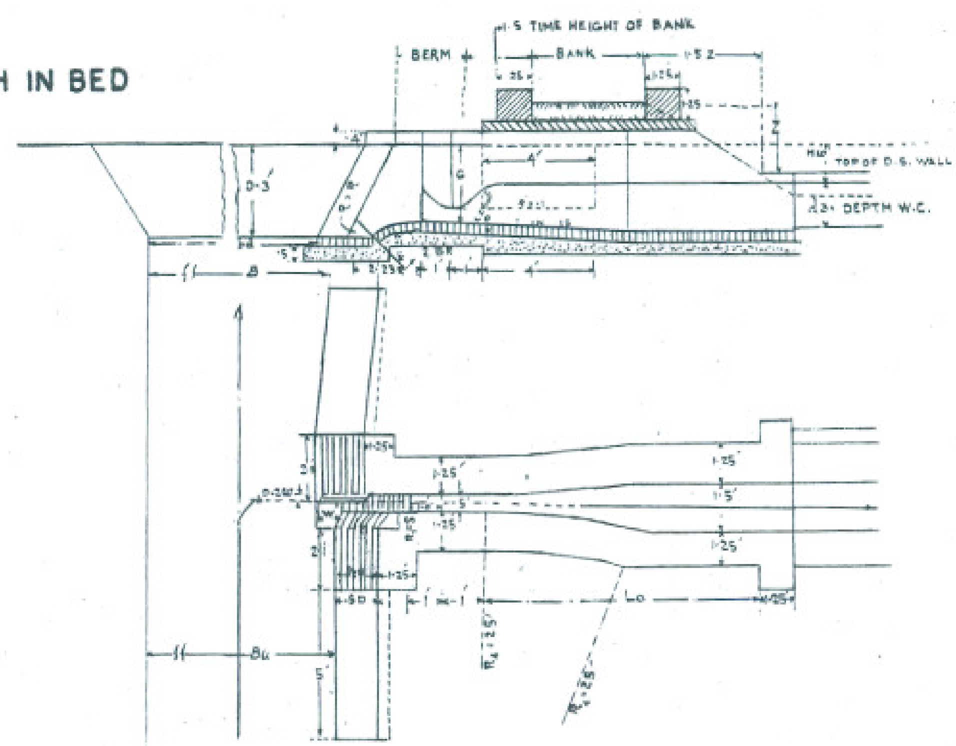
DETAIL OF ROOF BLOCK & APPROACH IN BED

SCALE = 1/20



SHARMAS IMPROVED O.S.M. OUTLET

SCALE = 1/50

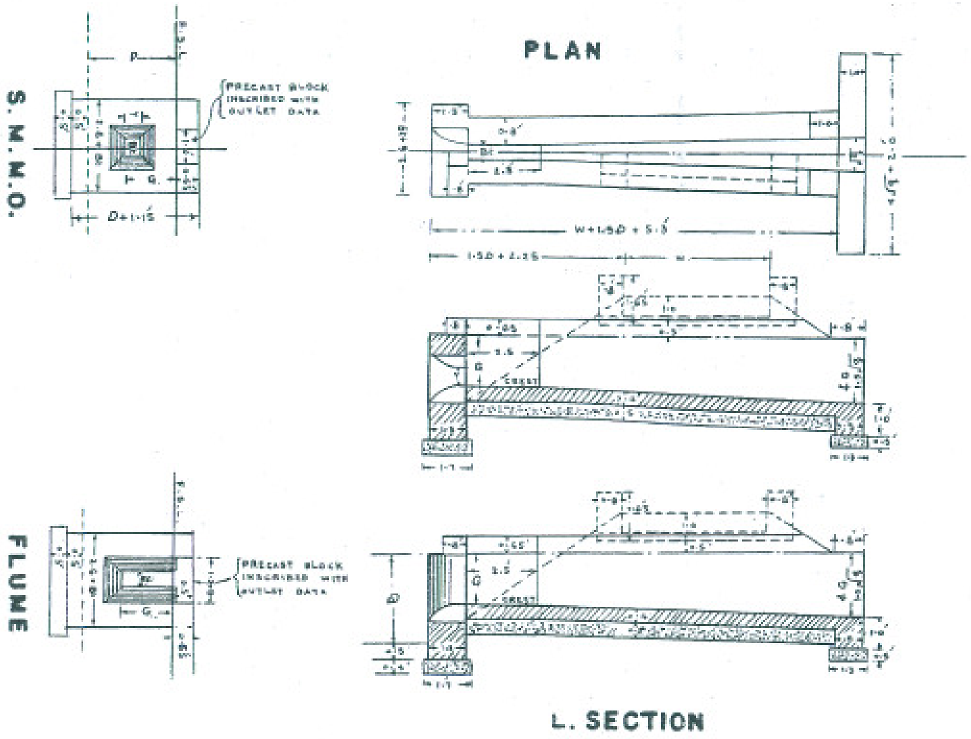


HAIGH'S SEMMODULAR

AND

FLUME OUT

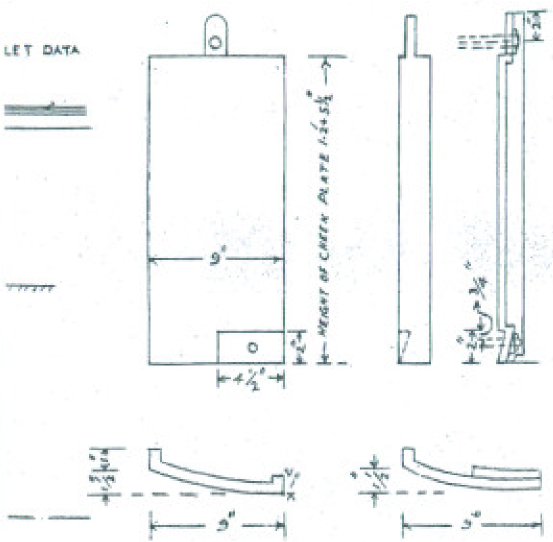
SCALE: 1/50



PU

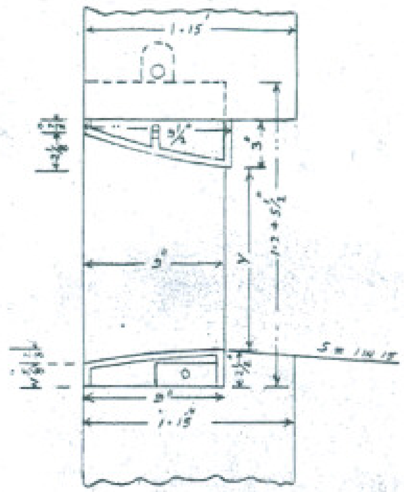
HAIGH'S
JUSTABLE BELL MOUTH ORIFICE

SCALE = 1/25



DETAILS OF CHEEK PLATE

SCALE = 6" = 1 FT:

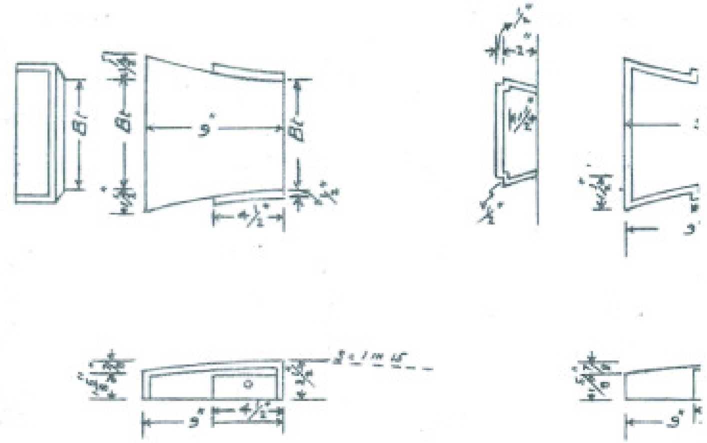


DETAILED SECTION

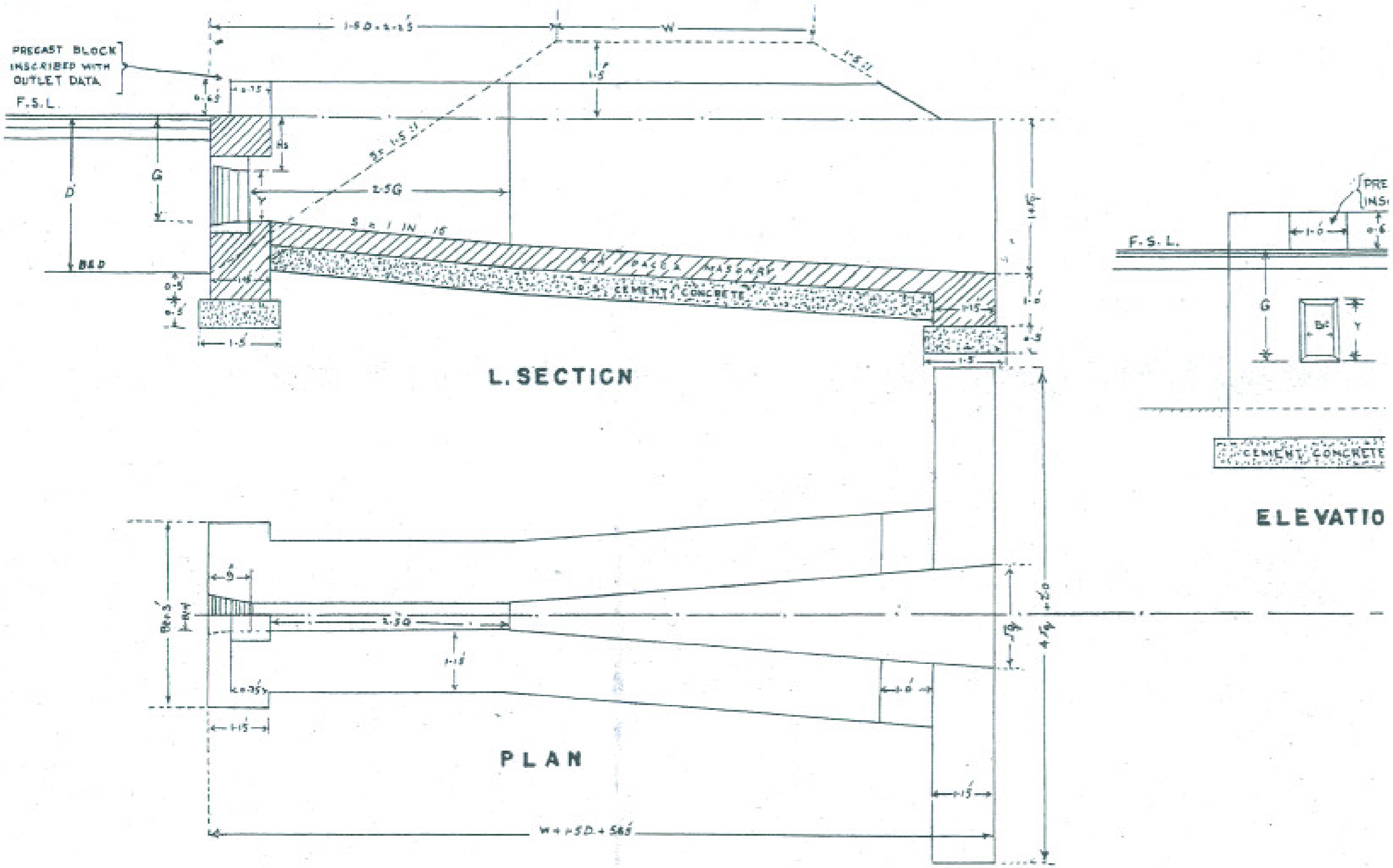
SCALE = 6" = 1 FT:

DETAIL OF BED PLATE

SCALE = 6" = 1 FT:

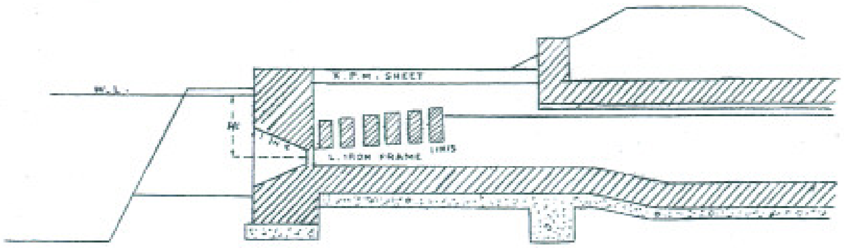


PUNJAB

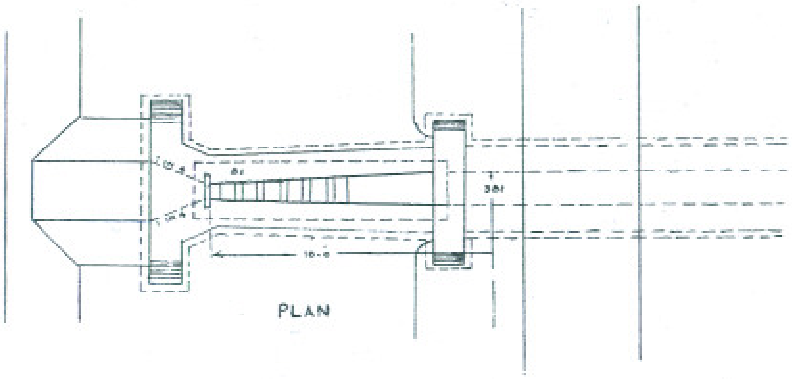

PRECAST BLOCK INSCRIBED WITH OUTLET DATA
F.S.L.
BED
2.5G
S = 1 IN 15
CEMENT CONCRETE
L. SECTION
PLAN
ELEVATIO

KIRKPATRICK JAMRAO TYPE ORIFICE SEMI-MODULE

SCALE: 1/50



LONGITUDINAL SECTION



PLAN

SIZE OF MODULE	M.M.H WITH 6 BAFFLES	M.M.H WITH 9 BAFFLES
8"	HC/4·1	HC/4·8
7"	HC/4·0	HC/4·7
6"	HC/3·9	HC/4·6
5"	HC/3·7	HC/4·5
4"	HC/3·5	HC/4·4
3"	HC/3·3	HC/4·3

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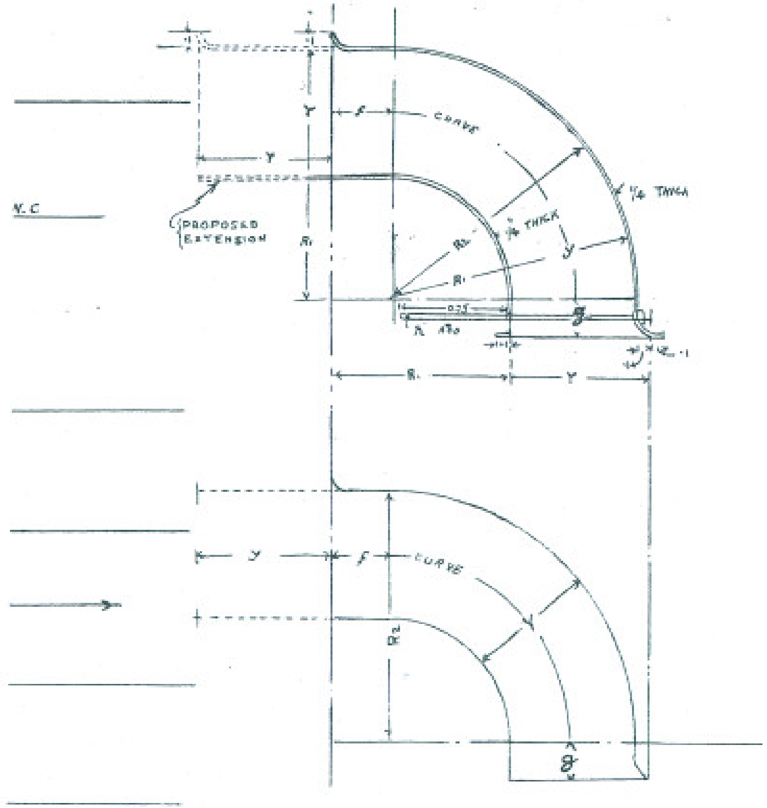
BEND OUTLET

SCALE = 1/25

ELEVATION

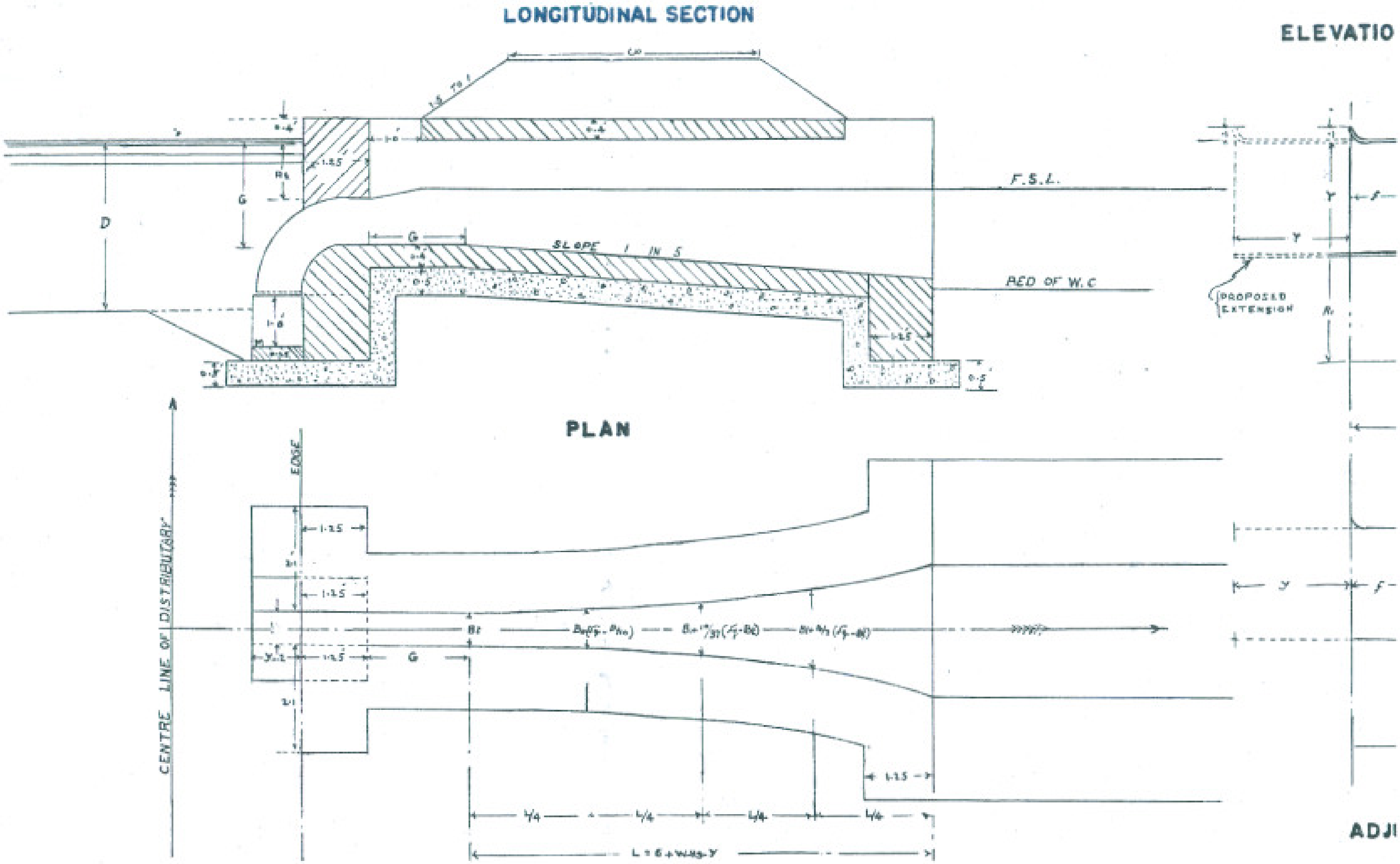


ADJUSTABLE PLATE P

SCALE = 1/16

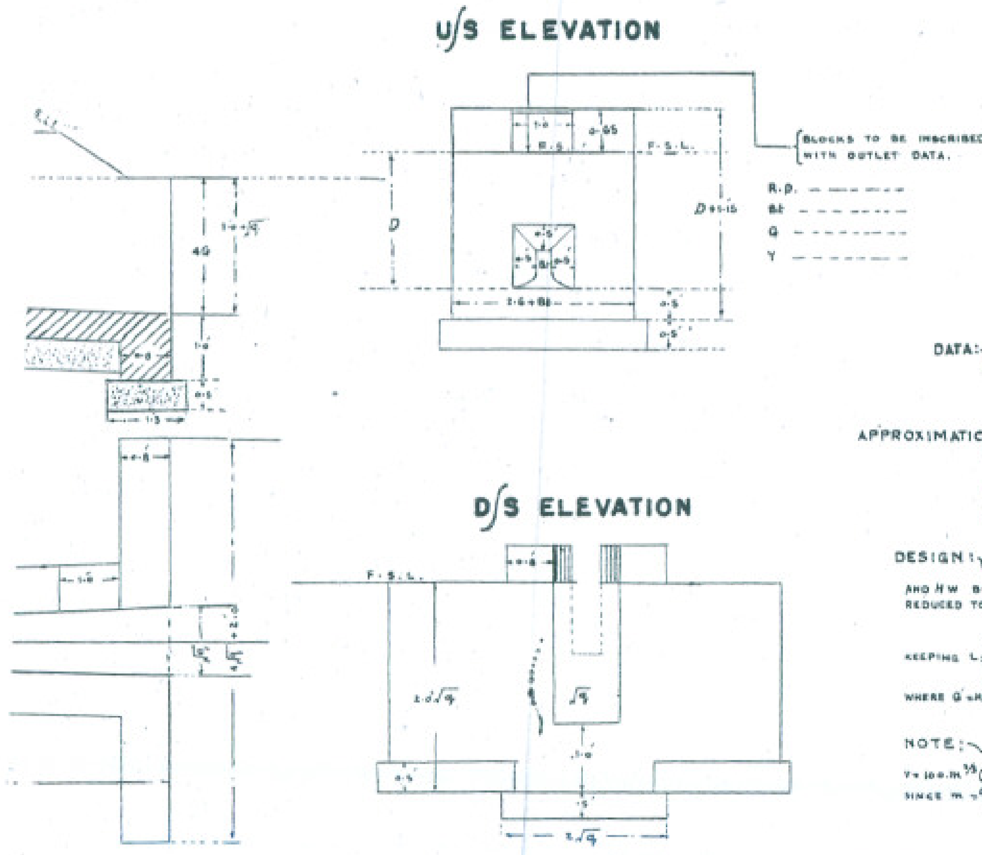
DETAIL OF DESIGN

SIZE NUMBER	Y	Z	e	R_1	$R_2 = R_1 + y$	$f = 1.25 - R_1$	$g = 2 - R_1$	B MAXIMUM
1	0.80	2.30	0.75	1.15	1.35	0.10	0.35	0.60
2	0.60	1.80	0.85	1.15	1.75	0.10	0.05	0.70
3	0.60	1.50	0.25	0.90	1.50	0.35	0.00	0.70
4	0.50	1.10	0.90	0.60	1.10	0.65	0.00	0.75
5	0.40	1.80	0.90	1.15	1.55	0.10	0.25	0.75


LONGITUDINAL SECTION
ELEVATIO
F.S.L.
SLOPE 1 IN 5
BED OF W.C
PROPOSED EXTENSION
PLAN
EDGE
CENTRE LINE OF DISTRIBUTARY
L = 6 + W.45 - Y
ADJ

HAIGH'S
SILT EXTRACTING OUTLET

SCALE = 1/25



DESIGN OF SILT EXTRACTING OUTLET.

DATA:-

D = DISTRIBUTARY FULL SUPPLY DEPTH

q = OUTLET DISCHARGE

Hw = AVAILABLE WORKING HEAD.

APPROXIMATION:-

(1). TAKE Bt (WIDTH OF ORIFICE) = $\sqrt{q/10}$ AND Hl (LOSS OF HEAD IN APPROACH FLUME) = 4K

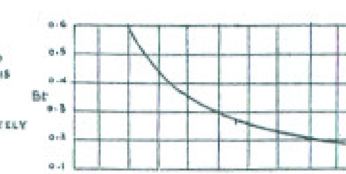
(2). K IS OBTAINED FROM THE CURVE BELOW.

(3) Hw (WORKING HEAD FOR ORIFICE) IS THEN Hw - Hl

DESIGN:- NOW DESIGN THE ORIFICE AS AN O.S.M. FOR q, D AND Hw BUT KEEP Bt = 0·8Y FOR WHICH THE O.S.M. FORMULA IS REDUCED TO $q = 5.85 Y^2 \sqrt{Hs}$

(4) Hl = K.L.Hs MAY NOW BE CALCULATED ACCURATELY KEEPING L = 3(D-G) WHERE G = Hs + Y + Hl (Hl FROM (1)).

(5) THE CREST LEVEL IS NOW FIXED AS F.S.L - G WHERE G = Hs + Y + Hl WITH Hl AS OBTAINED FROM (4)



NOTE:- LOSS OF HEAD IN APPROACH FLUME IS CALCULATED FROM MANNING $V = 100 \cdot m^{2/3} \left(\frac{Hl}{L}\right)^{1/2}$ OR $Hl = K.L.Hs$ WHERE $K = \frac{0.01}{8 Y + ...}$ SINCE $m = Y^{0·8}/3$ AND $V = 5/8 \sqrt{2 g Hs}$

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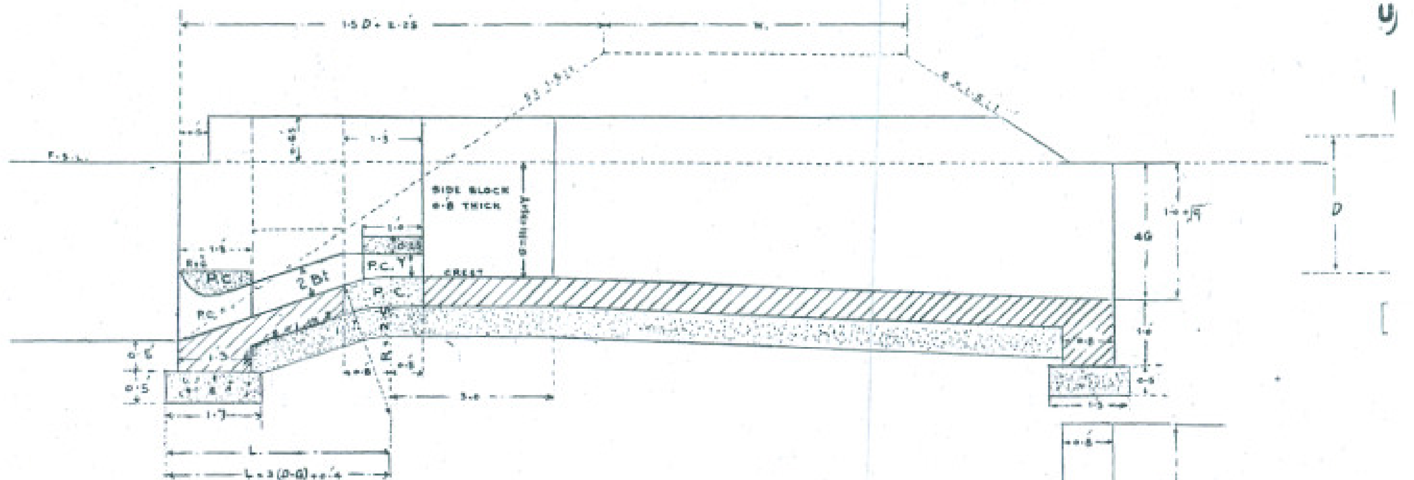
LONGITUDINAL SECTION



PLAN.

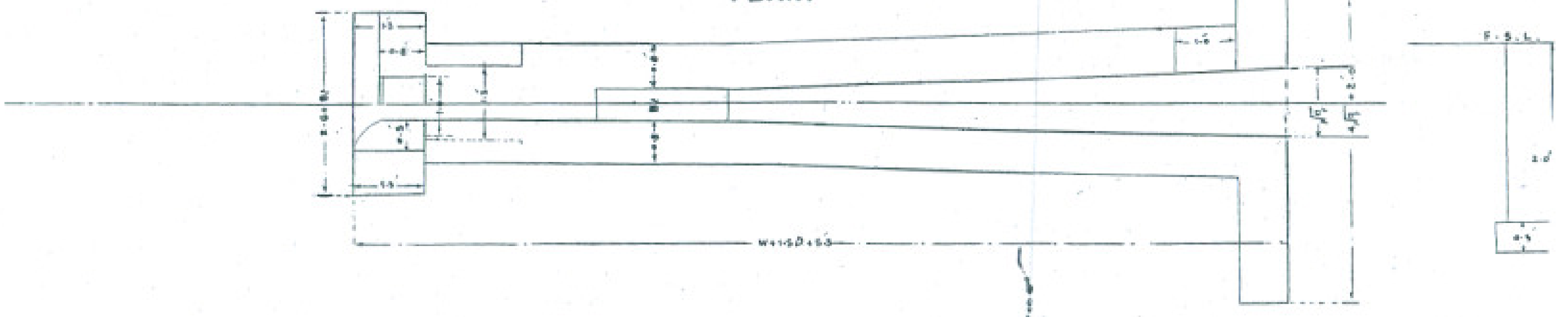


PLATE No. 17
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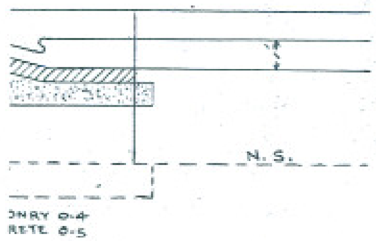
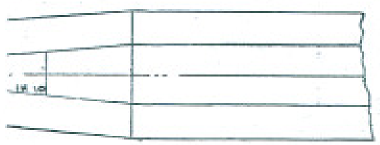
-CUM-O. F.

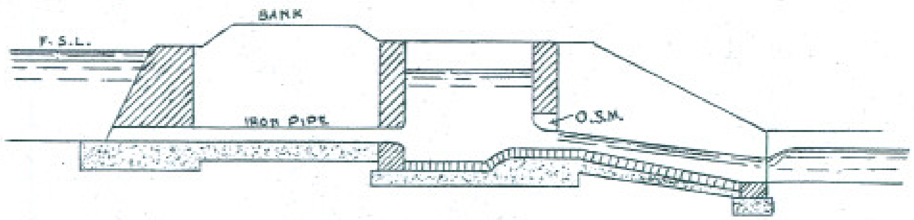
SCALE = 1/80





. RADII OF CURVATURE ARE EQUAL TO 2G

PIPE-CUM-O. S. M.



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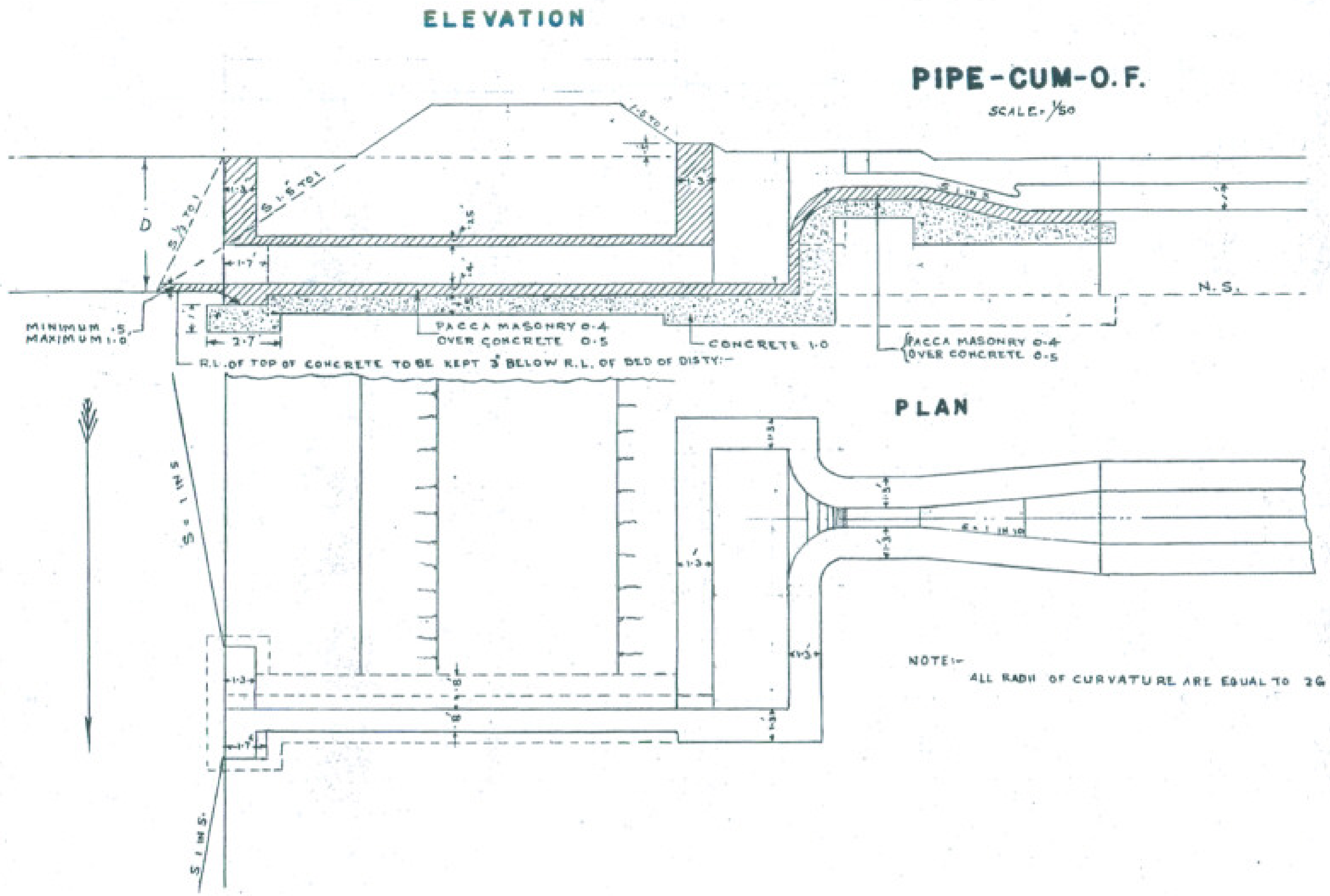
PIPE-CUM-O.F.

SCALE 1/50



NOTE:-
ALL RADII OF CURVATURE ARE EQUAL TO 2G

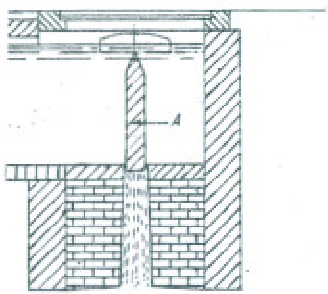
PLATE No. 18
PAPER No 264

EUROPEAN MODULES

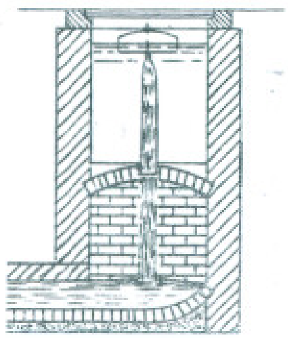
USED ON HENARES CANAL

2nd CANAL

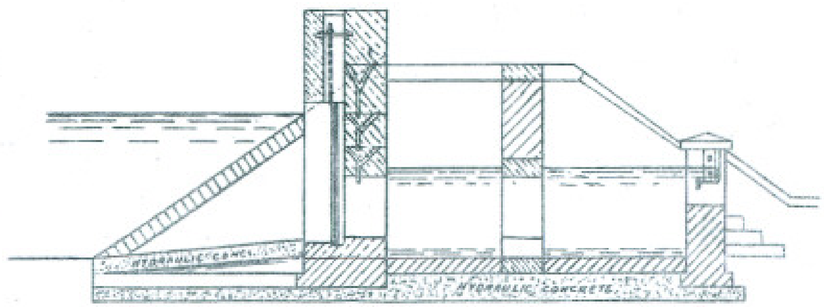
ECTION



CROSS SECTION

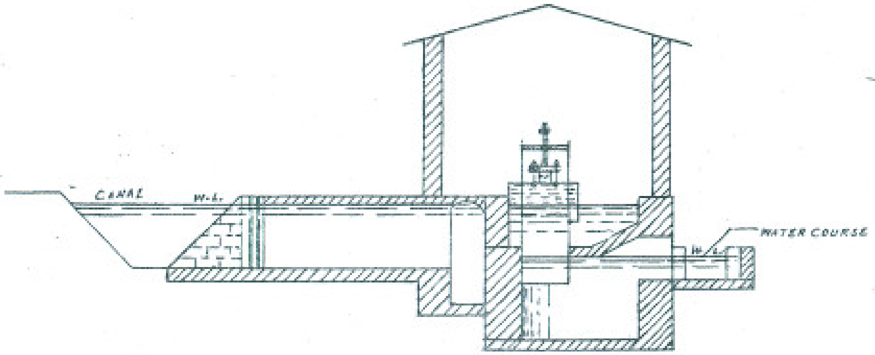


LONG: SECTION

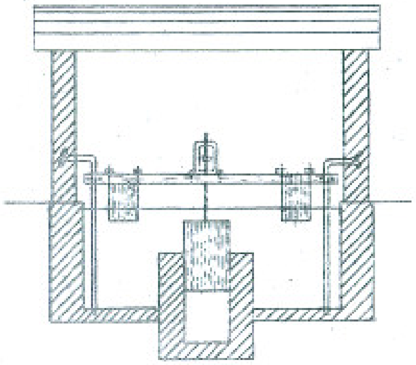


USED ON MARSEILLES CANAL

LONG: SECTION

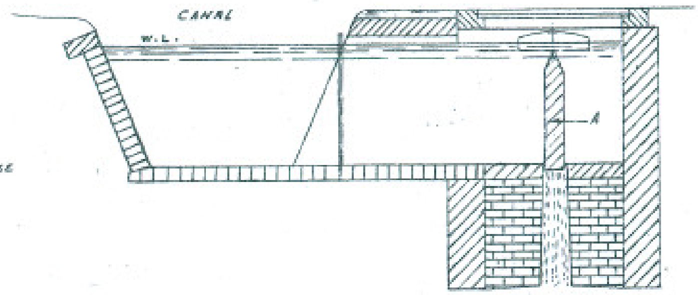


CROSS SECTION

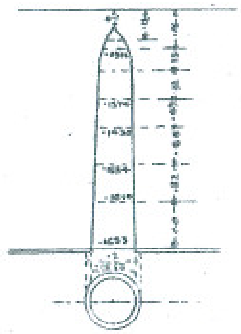


USED ON ISABELLA 2ND CANAL

LONG: SECTION



DETAIL OF A



CROSS SECTION

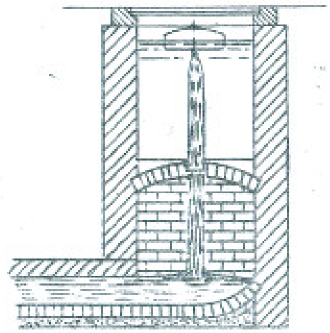
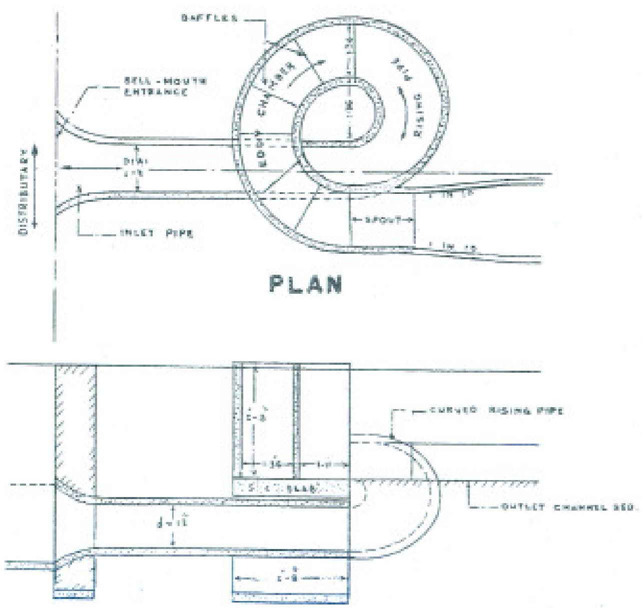


PLATE No 19.
PAPER No 254

GIBB'S MODULE

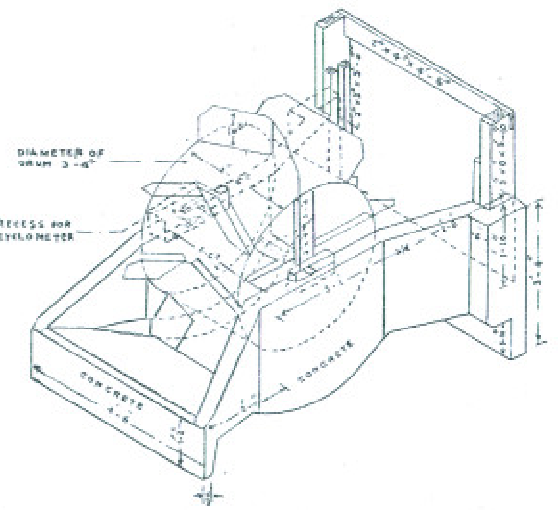
SCALE 1" = 3 FEET



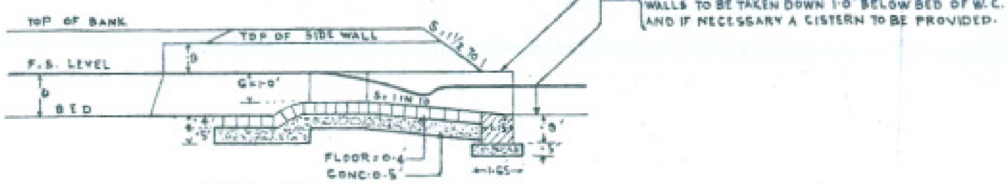
PLAN

L. SECTION

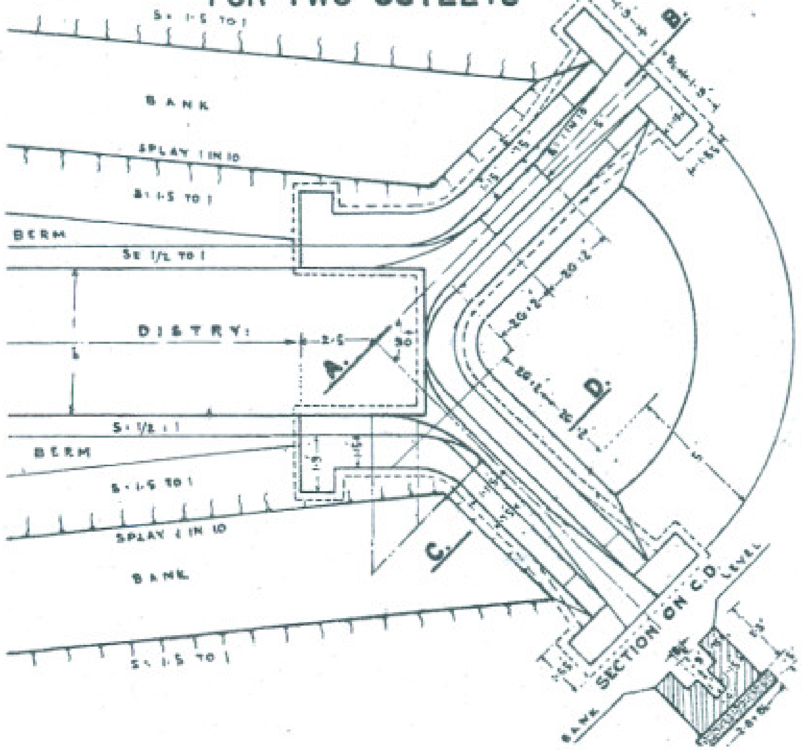
DETHRIDGE METER



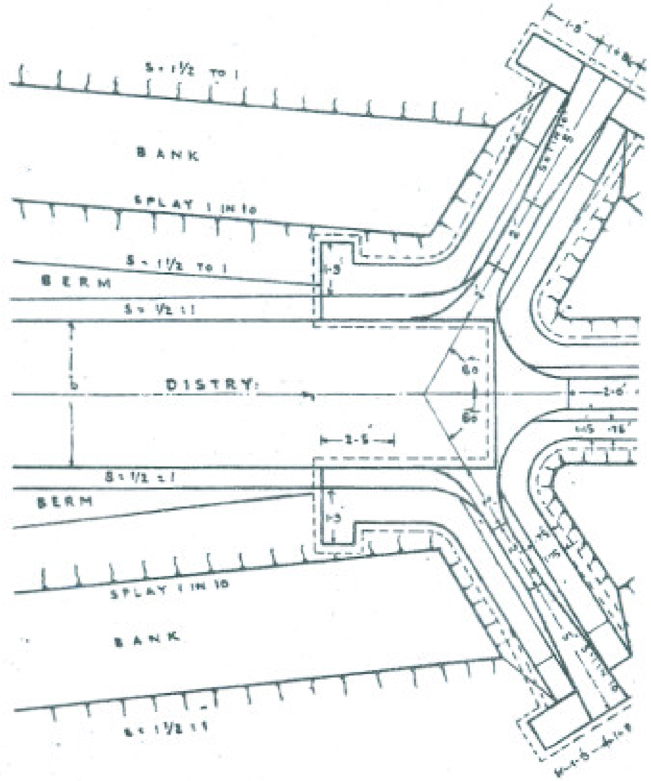
SECTION ON A.B.



FOR TWO OUTLETS



FOR THREE OUTLET



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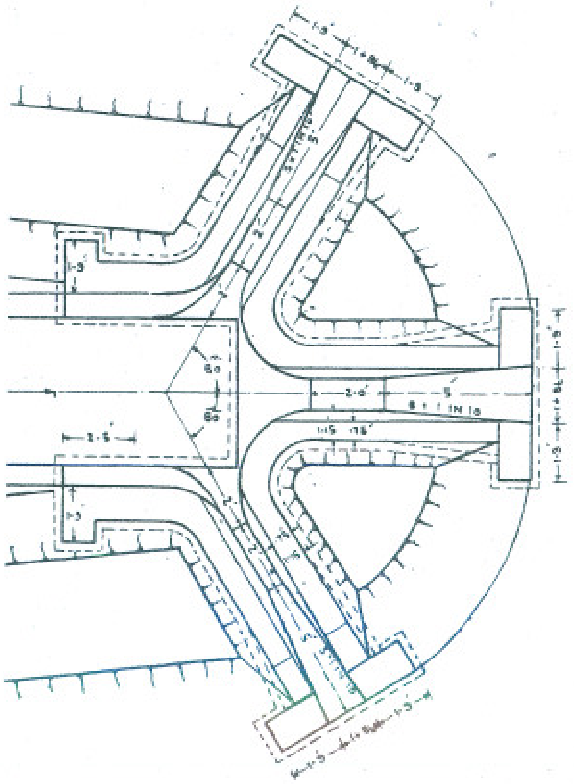
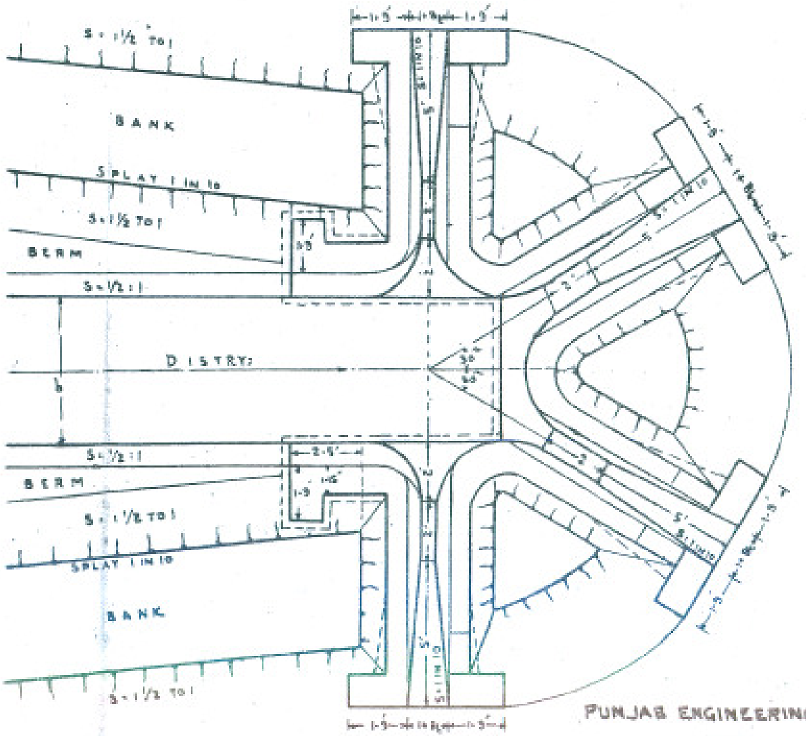
TAIL CLUSTERS.

FOR THREE OUTLETS



FOR FOUR OUTLETS



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