PAPER 189.

"A SILT SELECTIVE DISTRIBUTARY HEAD REGULATOR."

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A distributary head regulator is an important feature of the problem of distribution of supplies. It is, moreover, a necessary link between an earthen parent channel and an offtaking distributary. A distributary head is a regulator, a meter of supply, and a silt selective structure.

A distributary head was designed in the beginning simply as a regulator. It used to have a floor or a crest at bed level of a parent channel with gates to regulate supply. The distributaries were boosted with excessive silt charge and their discharge tables, based on gauges fixed in their head reaches, had to be occasionally revised.

To begin with, silt exclusion was the first to receive attention. A silt wall in the parent channel away from the gates was the first device tried in practice. It very soon proved to be an inefficient remedy.

Mr. Gibb did pioneer work in successful exclusion of silt (as described in Paper No. 28 of the Punjab Engineering Congress in 1916). Construction of a Gibb wall did meet with considerable success in some cases. (Work on similar lines by Mr. Elsden was also described in Paper No. 30 of the Punjab Engineering Congress in 1916.)

Mr. Woods described his work in Paper No. 29 of the Punjab Engineering Congress in 1916. It was provided to exclude silt by making the regulation overshot using rising cill gates. Metering of supply was arranged by making a head regulator to work as a free fall over the gates.

It was the first attempt to correlate the silt selective function of a distributary head regulator with the working of an offtaking channel. This device met with a little success only in a few cases. Later on Mr. Walton designed a useful rising gate on similar lines.

Mr. King developed a silt exclusive device, in the form of silt vanes (as described by him in Papers No. 41, 62, and 169 of the Punjab Engineering Congress). Gibb walls as used by their author on the Lower Chenab Canal, East Circle, were soon provided with R. C. slabs with a tunnel below it. This developed the design of the skimming platform as a device to exclude silt. Skimming platforms and silt vanes met with considerable success in some cases, but they

failed badly in cases, where supply in the parent channel was disturbed, before the platforms or the vanes could function.

Metering of supplies at the distributary head regulators was the last to receive attention. This was arranged in the form of open flumes as described by Mr. Crump in Irrigation Branch Paper No. 26 Class A.

Gibb's silt walls, Wood's rising gates, King's silt vanes, and Routh's skimming platforms were useful silt excluding devices. They served their purpose very well but they did not approach the ideal how much and where to exclude silt. It is the object of this paper to describe briefly a few experiments on distributary head regulators, which were carried out to investigate this phase of the problem.

Scope of the Experiments.

Experiments were carried out in two sets. The first set of experiments consisted of observations of existing distributary head regulators of various types on the Lower Jhelum Canal. There were six experiments in this set and were carried out on the following types of head regulators :

(1) Wood's rising cill gates. (Salam Distributary).

(2) Gibb regulator. (Fatehpur Distributary).

(3) Flume head regulator. (Mithalak Distributary).

(4) Regulator with a skimming platform. (Satghara Distributary).

(5) Silt selective head regulator. (Melay Distributary).

(6) Head regulator with a cantilever skimming platform. (Khunan Distributary).

In these experiments silt charges were measured by weight and the silt samples were analysed by means of sieves.

The second set of experiments was carried out on eight different models of a Silt Selective Head Regulator. In these models, the bed of the parent channel, the approach to crest, the floor in the approach chamber, and the sides of the approach chamber were glazed to visually examine the movements of silt particles. Silt charges were measured by weight in these observations and silt samples were analysed by the sedimentation method in the Irrigation Research Institute, Lahore. Some of the samples were also analysed by means of an optical siltometer in the Research Institute.

This paper deals in particular with the flume head regulator as used for the Mithalak distributary, Lower Jhelum Canal and as described by the author in Paper No.154 of the Punjab Engineering Congress, 1932. In the light of these experiments and actual experience of such

Distributary head regulators, this design was subjected to a few further modifications. The modified design is named in this paper "A Silt Selective Head Regulator."

Apparatus used in the first set of experiments.

Silt settling tanks of 10 cft. capacity were made with slight modification after the design of Mr. Kennedy as used by him in his experiments on the Sirhind Canal described in Irrigation Branch paper No. 9. The tank is designed as a funnel of galvanized iron capable of containing 10 cft. water with half foot of free board. Its design is given in plate No. 1. It is suitably strengthened by means of angle iron rings outside and flat iron straps. The diameter of the funnel is 3.0 feet. The diameter of the bottom of the funnel is 4 inches. A glass jar is clamped against a rubber washer to the bottom of the funnel. This arrangement is perfectly water-tight. A strong wire gauze screen is provided around the glass jar to protect it against any accidental breakage. An arrangement is provided to guide a ½ inch diameter flexible syphon tube exactly into the centre of the funnel from top to bottom so that the process of syphoning of clear water does not disturb silt on the sides of the funnel or in the jar. The funnel is placed on a four-legged stand so that the bottom of the jar is about 6 inches above ground level. The tank is calibrated to 10 cft. capacity, and a permanent mark is inscribed for the purpose. This arrangement has the additional advantage of portability, and provides visual examination of silt deposited in the jar.

Sludge collected in the glass jar was evaporated to dryness. The experience of the writer in drying silt samples in an open mortar pan shows that it is very difficult to regulate the fire. The fine silt in samples is oxidized at high temperature. It was, therefore, preferable to dry silt samples over a bath of boiling water.

The temperature of the silt did not rise to more than 100°C. which was sufficient to drive out all moisture in the silt and was well below the temperature which would oxidize the fine earth particles. A thermometer was used to see that the silt in all observations was heated to about 100°C.

The weighing of the silt samples was done by means of a sensitive chemical balance.

The dried silt samples were lightly ground by hand with a light wooden pestle. The classification of the silt samples was done by means of metallic sieves at Sargodha. The sieves used are given below

No. of meshes per inch ..	30	40	50	60	70	80	100	120	150
Diameter of hole in millimeter	.67	.5	.38	.32	.27	.23	.2	.15	.1

Procedure in the first set of Experiments.

One silt settling tank was put in at the head of a distributary, and the other near the cistern of the fall, downstream of the distributary head regulator. In fixing the tanks, care was taken that the tank was level, and that the legs of the stand were firmly secured to guard against unequal settlement. The tank at the distributary head was filled with water up to 10 cft. capacity by baling out water in kerosine oil tins from just below the hydraulic jump or the cistern downstream of a head regulator. It was assumed that water just downstream of a hydraulic jump or in the cistern was sufficiently churned up, and had a uniform grade and charge of silt for all practical purposes. Similarly, the silt settling tank, at the fall in the parent channel, was filled up to 10 cft. capacity by baling out water from the cistern of the fall. Water in the tanks in all observations was allowed to settle for six hours. The clear water in the cylindrical part of the tank was removed by means of a cock provided for this purpose. Then water in the conical part was syphoned off by means of half-inch diameter flexible pipe. The sides of the funnel were washed to remove the silt deposited on them. The water was again allowed to settle for six hours. The clear water was then syphoned off to about the middle of the jar, about three inches above the silt deposit in the jar. The lower portion of the cone was washed with a little clear water. The jar was then removed and closed with ground glass water-tight covers. New jars were put in and observations continued. In this way the observations could be taken daily. The samples were dried and weighed and classified.

Experiment No. 1 of the First set.

The First experiment was carried out on the head regulator of Mithalak Distributary. The design of this head regulator is given in Plate No. 2.

It is a flume regulator. The silt excluding device consists of a high crest sloping $\frac{1}{2}$ to 1 from the bed of the parent channel to the crest. The approach floor is at the same level as the crest of the flume. It has got an easy approach both upstream and downstream, on the sides up, to the beginning of the crest. The crest length is 2 H and is followed by a glacis.

The results of the experiments are given in Appendix 1. There are seven observations. The first two observations were carried out by pumping water from the hydraulic jump in the cases of Mithalak Distributary and from the cistern of the fall at R. D. 64,000 in the case of Northern Branch. Masonry tanks were especially constructed for these observations. The quantity of water pumped out was the same in each case. The remaining five observations were carried out by means of portable silt tanks of 10 cft. capacity as described before.

In spite of the fact that the depth on the crest was one-third of the depth in the parent channel, the head regulator took 92% silt by weight on the average in comparison with that in the parent channel. There are two bays of the head regulator. The downstream bay took more silt than the upstream bay. Sieve analysis showed that silt taken by the Mithalak Distributary was finer than that passing in the Northern Branch downstream of it.

As the crest was extended right up to the beginning of the approach at crest level, there was considerable draw-down at the entrance to the head. This tended to raise the silt conductive power to 92%, although it was taking very nearly surface water. It was suggested for high silt exclusion that the approach of the downstream bay needed further improvement, especially in curving the downstream wall on the lines of the middle pier. The channel is working satisfactorily with this silt conductive power of the head regulator, and it was, therefore, considered inadvisable to exclude more silt than that at present.

Second Experiment of the First set.

This experiment was carried out on the head regulator of the Fatehpur Distributary. The design of this head is given in Plate No. 2.

This head is an open flume and is provided with Gibb's groyne wall on lines of Mr. Elsden's suggestion described in paper No. 30 of the Punjab Engineering Congress 1916.

The waterway at the entrance to the chamber, enclosed by the groyne, is allowed considering the effective depth as two-third. A hole of three feet diameter is provided in the Gibb wall to escape the additional supply from the approach chamber. This hole is at the bed level of the parent channel. There is dry brick side pitching 30 feet long upstream of the head in the parent channel.

The velocity is increased on the sides on account of the presence of the side pitching. This reduces the difference between the side velocity and the mean velocity of the parent channel, as water approaches the head. This, again, increases the amplitude of the waves of cross flow of silt near the bed, from the middle of the channel towards the sides. Cross waves of silt, thus, miss the entrance of the head and are intercepted by the groyne wall.

Results of the experiment are given in Appendix 1. Silt taken by the head regulator is about 98.75% of the silt passing downstream of the fall at R. D. 64,000 Northern Branch, but the silt taken is somewhat finer than that in the Northern Branch. Mithalak Distributary is situated between the Fatehpur distributary head and the fall. Silt exclusion at the head regulator of Mithalak Distributary influences to some extent the results of this experiment.

It is concluded that the design of the Fatehpur distributary head is just a suitable design to give proportionate share of silt to an offtake.

Third Experiment of the First set.

This experiment was carried out on the Satghara Distributary head regulator taking off at R. D. 76,000 L, Northern Branch. The design of the head is given in Plate No. 3.

It is an open flume head regulator and is provided with a Gibb wall and a skimming platform. A circular groyne wall is provided with adjustable regulating shutters above the reinforced concrete platform. The depth on the platform is 1.5 feet against normal supply depth in the parent channel of 7.0 feet.

Shutters are adjusted in such a way that there is no draw-down at the nose of the groyne wall. A surface float in the parent channel put in line with the nose of the groyne wall comes straight to the nose. There is no disturbance in the supply approaching the approach chamber above the platform. There is further clarification of silt on the platform by escaping the supply straight below the shutters. In this case, the head has the maximum efficiency as a silt excluding device and the tunnel below the platform is never choked.

This experiment was carried out in two parts. The first part consists of three observations with shutters working, and the second part with the shutters down, as if the groyne wall above the platform was a solid wall. Results are given in Appendix 2. In these experiments the silt of the Northern Branch was measured at the fall at R. D. 64,000 Northern Branch and the silt in the distributary was measured from the hydraulic jump downstream of the head of the distributary.

Results of the first part of the experiment given in Appendix 2 show that the silt conduction of a head regulator with a skimming platform was as low as 72.9% by weight and that it took distinctly fine silt in comparison to silt in the parent channel upstream of it. Results of the second part show that even a skimming platform might fail to achieve high silt exclusion by its defective working.

The waterway at the entrance above the platform is an important factor controlling the entry of silt into the chamber enclosed by the groyne. From the following practical considerations it generally has to be more than that required

1. to suit the average supply conditions in the parent channel.
2. to allow for *rabi* and *kharif* supply levels in the parent channel.
3. to allow sufficient width between the pier and the toe of the sides so that the tunnel is not choked.

Supply of the distributary is limited to the authorised discharge at the meter flume downstream of it, and the excess supply turns round the nose of the groyne wall. This causes considerable draw-down, and disturbance near the nose of the groyne wall.

Surface floats from near the berm of parent channel do not even enter the approach chamber. Water approaching the head gets a twist, and there is produced a horizontal roller with axes parallel to the central line of the parent channel. Bottom muddy water of the parent channel thus enters the head and surface water escapes into the parent channel. The conduction of the head was, therefore, 89.7% in comparison to that in the parent channel. Bound eddies are produced just at the entrance of the tunnel, and work, rotating with their axes perpendicular to the bed, below the platform. Bound eddies cannot carry silt through the tunnel. When the tunnel gets choked to an appreciable extent, the efficiency of the head as a silt excluding device falls. In this case the head regulator is a poor silt excluding device and the tunnel below the platform tends to get choked.

Fourth Experiment of the First set.

This experiment was carried out on the head regulator of Salam Distributary taking off at R. D. 24,700L of Northern Branch, Lower Jhelum Canal. The design of this head is given in Plate No. 3.

It had a raised crest with a rising gate behind it after the design of Mr. Woods.

Results of this experiment are given in Appendix 2. Silt taken by the head regulator is 110.4% by weight on the average and sieve analysis shows that the distributary took at least as much coarse silt as that in the parent channel.

Although it took very nearly surface water of the parent channel, the silt conductive power of the head was very high. It was due to disturbance and eddies upstream of the gates caused by unsuitable approaches. Even coarse silt easily jumped over the vertical crest and the gates. Salam Distributary was, therefore, a bad silting channel. It was 18.0 feet wide with 1.0 foot depth for a discharge of 30 cusecs and had a slope of 1 in 2080. This experiment showed that in order to exclude silt it was not sufficient to take simply surface water from a parent channel, but also it was imperative to provide suitable approaches upstream, so that there was no disturbance upstream of the crest.

Fifth Experiment of the First set.

This experiment was carried out on the head regulator of the Melay Distributary taking off at R. D. 83,332R of the Southern Branch of the Lower Jhelum Canal. The design of the head is given in Plate No. 4.

It is this type of head regulator, that has been called a "Silt Selective Head Regulator" in this paper, A detailed description is given later on.

Results of this experiment are given in Appendix 3. The head regulator took 70.2% silt by weight in comparison with that in the parent channel downstream of it. It took a distinctly finer grade of silt in comparison to that in the parent channel.

Sixth Experiment of the First set.

This experiment was carried out on the head regulator of the Khunan Distributary taking off at R.D. 207,000 of the Northern Branch, Lower Jhelum Canal. The design of the head is given in Plate No. 4.

It is simply a flume regulator provided with a cantilevered skimming platform.

Results of this experiment are given in Appendix 3. The head took silt 72.4% by weight on the average in comparison to that in the parent channel. It is evident from the silt analysis by sieves that the silt taken by the head was distinctly finer than that passing in the parent channel.

Conclusions from the results of the First set of Experiments.

Experiment No. 1 shows that in this case the silt conductive power was as high as 92%. It is, therefore, concluded that a flume head regulator, after the design of the head of Mithalak Distributary is no good as an efficient silt excluding device. It is, no doubt, better than a head with rising cill gates having unsuitable approaches or an old type regulator with undershot regulation.

A regulator with a Gibb wall is a suitable device to give proportionate silt charge to an offtake, provided that the water-way at the entrance to the chamber enclosed by the groyne has been suitably selected.

A Gibb regulator modified into a skimming platform, a flume regulator with a cantilevered skimming platform, and a silt selective head regulator are suitable designs to serve as efficient silt excluders. Their silt selective power was found to be very nearly the same, at about 70% in comparison to the parent channel. No experiment was carried out on King's silt vanes but the author believes that this design was likely to have near about the same efficiency.

It is clear from experiment No. 3 part (B) and experiment No. 4, that any silt excluding device might fail, if the supply in the parent channel is disturbed, before it is taken by the head regulator. This disturbance may be caused by the rough sides or uneven bed of the parent channel. It may also be due to the presence of the structure of the silt excluder itself as in the case of experiment No. 3 part (B). Piers in the channel with silt excluding slab, and groyne walls are likely to be sufficient obstructions to cause adverse conditions unless counteracted by some such device as regulating shutters in the groyne wall tried in the case of Satghara Distributary.

It is clear from experiment No. 6 of the first set that a flume regulator with a cantilevered skimming platform is as efficient as a head with a skimming platform having a pier and a groyne wall. The former is simple in design and is free from the disturbing factors which affect the efficiency of the latter. The former saves the cost of the pier and the groyne wall. The former is, however, only suitable for an offtake, where a cantilever of 3 to 4.0 feet length will do.

A Silt Selective Head Regulator was a suitable design which could be made to have a high silt excluding efficiency as found in experiment No. 5. The efficiency depended on the velocity with which water entered the approach chamber. By suitably designing the entrance to the approaches the efficiency could be varied according to the requirements. It was thought desirable to investigate this design further by making models of this type under different conditions.

Procedure in the Experiments of the Second set.

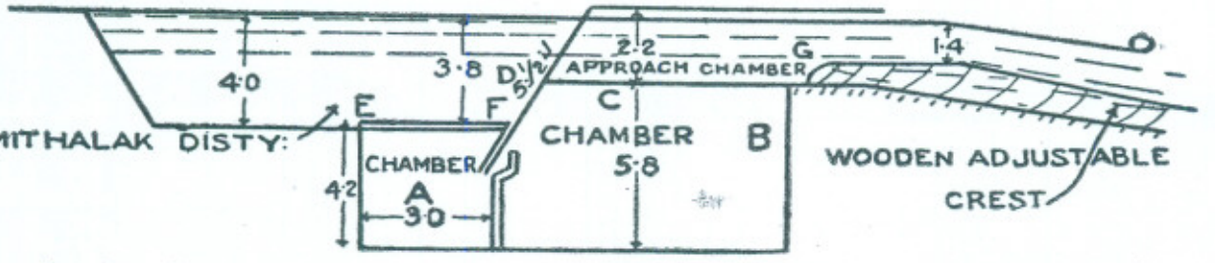
These experiments were carried out at R. D. 500R of Mithalak Distributary, Lower Jhelum Canal. Models of a silt selective head regulator were built in various conditions at this place. Water from models was taken through a diversion channel back to Northern Branch below the fall at R. D. 64,000 Northern Branch.

The procedure of sampling the water and of determining the silt content by weight was the same as described for the first set of experiments. Samples, in the case of the model, were taken from the hydraulic jump downstream of the model, and for the distributary they were taken from the hydraulic jump downstream of the head regulator of the Mithalak Distributary. In the case of the distributary, 10 cft. capacity of the sample was made up by taking alternate buckets of water from each bay of its head.

Samples were analysed by the mechanical method of sedimentation in pipettes in the Irrigation Research Institute, Lahore, and some of the samples were analysed by the optical siltometer, which alone gives the proper grading of silt.

Description of the Model.

A line diagram of the model is given below.



In the figure, chamber ' A ' is below the bed of the Mithalak Distributary. Chamber ' B ' is below the floor of the approach chamber of

the bed. The crest of the flume was arranged as shown in the figure. Width of the weir flume was 3.0 feet in all experiments. One could conveniently stand in chamber B and examine the stream lines rising up to the raised floor of the approach in slope ½ to 1, also from chamber A the stream lines deflected towards the head could be observed. Portions of the model EF, FD, CD, and CG were glazed for the visual examination of silt laden stream lines entering the head. At point F, a water-tight and adjustable expansion joint was provided.

Design of Model Head.

A typical design of a " Silt Selective Head Regulator " is given in Plate No. 5. The structure can be divided into three parts—approach chamber, regulator in the form of kurries, and weir flume. The approach chamber selects the silt. The supply is regulated upstream of the weir flume, which meters the supply.

Pitching upstream of the head in the parent channel on the side accelerates the side velocity, and it is further increased by the reduction of depth provided by raising of the bed of the parent channel in front of the head. The difference, between the mean velocity in the middle and the side velocity in the parent channel, is reduced. Water on the side simply sweeps straight along the head without any disturbance. Cross waves of silt near bed of the channel from the middle towards the sides, are cut off by this quick moving water in front of the head regulator. The floor of the approach is kept higher than bed of the parent channel and excludes bed silt of the parent channel according to requirements. The profile of the side, ½ : 1, is kept the same from bed of the parent channel to the floor of the approach chamber as the vertical wall is likely to cause disturbance. Smooth entry is provided into the chamber both upstream and downstream on sides. Water-way at the entrance to the approach chamber is the chief factor which controls the silt selective power of the head.

It is convenient to maintain the required supply level in the parent channel by regulation at the control point. A needle regulator is the most suitable device which interferes the least with silt carriage in the parent channel, and is easy and convenient to manipulate. However, if the distributary head regulator is designed according to the average supply level in the parent channel for want of a control point in it, regulation is provided as shown in the Plate No. 5 in the form of .2 foot kurries secured and locked in the grooves. In this case a straight length of at least 2H is required from the regulation kurries to the gauge hole of the meter flume. This distance will be increased according to disturbance caused by regulation by means of kurries.

The regulator is followed by a meter flume. The depth on crest of the flume is kept about 2/3 the depth in the approach chamber. It has got a length of crest equal to 2H and the distance of the gauge hole

from the beginning of the crest is 3H. The approach curve in the bed is laid with radius 2H. The crest is followed by a convenient glacis. Water to the gauge well is admitted through a single hole, the area of which is about 1/5000 of the area of the gauge well. The hole is provided in an iron plate secured flush with the wall and located an inch or two below crest level at a distance of 3H from the beginning of the crest.

First Experiment of the Second set.

This experiment was carried out on a flume regulator with raised crest ½ to 1 after the design of the Mithalak Distributary head regulator. Data of the structural details of the model is given in Appendix 5. A width of approach 8.1 feet was kept at the entrance. This was insufficient for a discharge of 28 cusecs of the offtake. This is a typical case when there is an excessive draw-down at the entrance of such regulators.

Surface floats were let off at distances of every multiple of 0.5 foot from the water edge on the side. Only 5 surface floats went into the offtake instead of 8 according to its share of surface water. Ping-pong balls were loaded and allowed to roll on bed of the parent channel upstream at the same distances as the surface floats, from corner of the bed and the side. Five bed floats jumped up into the offtake and were seen from behind the glazed crest wall.

Stream lines of water rising up the crest are shown in Plate No. 6 as visually examined while standing behind the ½ to 1 sloping raised crest. It was seen that there was a strong draw up along the crest.

Results of the analysis by weight given in Appendix 4 show that the model took 106.8% of the silt on the average in comparison to that in the parent channel upstream of it. Results of the grading of the silt samples also show that the model took coarser silt than that in the parent channel.

This experiment shows that very adverse conditions result by the provision of a restricted width of approach even though the crest may be high.

Second Experiment of the Second set.

The model was modified into a " Silt Selective Head Regulator " according to the data given in Appendix 5. In this experiment the depth in the approach chamber was 2.2 feet, and the depth on crest of the flume was 1.4 feet. The width of approach equal to 6·5 feet, was determined by trial and error so that there was a smooth entry at the entrance, and so that bottom water of the parent channel swept straight along the crest of the approach chamber. The radius of the downstream approach on the side was determined according to the required width of approach.

Five surface floats found their way into the model head, and no rolling ping-pong ball went up into it. Stream lines observed when standing behind the sloping crest of the approach chamber are shown in Plate No. 6. This shows that bottom water did not find its way to the model flume. The model head worked as an efficient silt excluder.

Results of analysis by weight of the silt samples as given in Appendix 4 clearly show that the silt taken by the model in this experiment was 80.6 on the average in comparison with that in the parent channel. This represents very nearly the ideal conditions when a "Silt Selective Head Regulator" works as an efficient silt excluder.

Third Experiment of the Second set.

This experiment was carried out on a " Silt Selective Head Regulator " under the same conditions as in the second experiment except that the width of approach was reduced to 5.0 feet instead of 6·5 feet. The circular curve of the downstream approach wall on the side was concentric with the upstream side approach curve.

Only four surface floats went into the model and four bed floats of loaded ping-pong balls jumped up into the model. Stream lines as observed by standing behind the ½ to 1 crest of the approach chamber are shown in Plate No. 6.

Results of the silt analysis by weight as given in Appendix 4 show that the model took 100.5% silt in comparison with that in the parent channel. The silt analysis both by the sedimentation method and the siltometer method shows, that the model took silt coarser than that in the parent channel. This experiment shows that with a draw at the entrance, induced velocities are set up and very adverse conditions are created which mar the efficiency of even a Silt Selective Head Regulator.

Fourth Experiment of the Second set.

This experiment was carried out on the same model as above but with $H=1.2$ and $H_a=2.2$ ft. The width of approach at the entrance was arranged so that there was no draw-down at the entrance to the approach chamber.

Four surface floats went into the model and no bed float found its way to the model flume head. The stream lines up the ½ to 1 crest to the approach chamber were observed as shown in Plate No. 6. They swept straight along the crest into the channel downstream with no tendency to rise into the model head.

The model head took 79.3% of silt by weight on the average in comparison with that in the parent channel. The silt taken by the model was distinctly finer than that in the parent channel as shown by analysis. This experiment very nearly represented the ideal conditions of working of a "Silt Selective Head Regulator."

Fifth Experiment of the Second set.

This experiment was carried out on a " Silt Selective Head Regulator " with H=1.0 and H_a =2.2 and width of approach 4.5 feet.

Only three surface floats went into the model, and two bed floats found their way into the approach chamber and entered the flume.

The condition of stream lines, observed rising up the crest is shown in Plate No. 6.

The silt taken by the model was about 83% in comparison with that in parent channel and it was somewhat finer than that in the parent channel.

Sixth Experiment of the Second set.

This experiment was carried out with the same model with H=1.0 and H_a =2.2 and with width of approach 6.0 feet.

Four surface floats went into the model head and no bed floats went up. The stream lines, as observed up the $\frac{1}{2}$ to 1 sloping crest to the approach chamber, are shown in Plate No. 6. There is reverse flow at the end.

The silt taken by the model was on the average 93.5% by weight and was somewhat finer than that in the parent channel.

This was the case of an excessive waterway at the entrance of the approach chamber. In this case, water from near the bed of the parent channel did not sweep up the crest but the model took a relatively high silt charge on account of the presence of eddies in front of the head. These eddies lifted up the silt of the parent channel from near its bed. Although no bed float went into the model yet the silt charge taken by the model was as high as 93.5% on account of vertical eddies caused by the reverse flow at the downstream of the entrance.

Seventh Experiment of the Second set.

The model in this experiment was modified and H_a was made equal to 1.8 feet and the depth on the crest of flume was kept at 1.2 feet. The width of approach to the chamber was kept 6.5 feet.

In this experiment four surface floats went into the model and no bed float rose up into the approach chamber. Stream lines as observed up the slope to the approach chamber, are shown in Plate No. 6. There was no draw-down or eddies at the entrance.

The silt taken by the model was 76.4% by weight and the model took distinctly finer silt in comparison with that in the parent channel. This very nearly represented the ideal working of a Silt Selective Head Regulator.

Eighth Experiment of the Second set.

This experiment was carried out under the same conditions as in the seventh experiment but the width of approach was reduced to 5.5 feet.

Four surface floats went into the model. Bed floats could not be seen as the water was very turbid in all the observations of this experiment. Stream lines, as observed in the experiment rising up the $\frac{1}{2}$ to 1 sloping crest to approach chamber, are shown in Plate No. 6.

The Model took silt by weight 100.4% of that in the parent channel. The silt taken was nearly as coarse as in the parent channel.

Discussion of the results of Second set of Experiments.

The experiments No. 2, 4 and 5 were carried out with H_a=2.2 feet and depths on the crest on the weir flume of 1.4 feet, 1.2 feet and 1.0 foot in the experiments respectively. The width of approach in experiments No. 2 and 4 was selected in such a way that the Silt Selective Head Regulator worked in the ideal conditions as shown in Plate No. 6. However, in experiment No. 5, the conditions were somewhat adverse. Silt conduction in these experiments is 80.6%, 79.3% and 82.9% respectively. The results of the fifth experiment are influenced by adverse circumstances and they are no doubt somewhat high. It is concluded that silt conductive power of a Silt Selective Head Regulator working under ideal conditions does not vary with its discharge of the offtake, so long as the depth in the approach chamber is not changed or, in other words, so long as the ratio of the depth in the approach chamber of a Silt Selective Head to the depth in front of it in the parent channel is not varied.

Ideal conditions of working mean that the width at the entrance to the approach chamber has been suitably selected, so that bottom water of the parent channel flows straight along the parent channel along the sloping $\frac{1}{2}$ to 1 crest and has no tendency to rise into the approach chamber. These conditions are available, when no rolling bed floats rise up into the approach chamber and the surface floats indicate neither draw-down at the entrance, nor eddies in front of the head.

Experiments Nos. 4 and 7 were carried out under almost the ideal conditions of working of a Silt Selective Head Regulator. The discharge of the offtake was the same but the depth in the approach chamber was different. In experiment No. 4 it was 2.2 feet and in the 7th experiment it was 1.8 feet. Silt conduction by weight in the first case was 81%, and was 75.4% in the latter case. Silt taken by the model was also finer in the 7th experiment in comparison to that in the 4th experiment. Under ideal conditions of working, the silt conduction varied with depth in the approach chamber. In other words, silt conduction

varied according to some power of the ratio of depth in the approach chamber to the depth in the parent channel in front of the head on the pitched floor.

Results of these experiments satisfy the following relation :—

$$P_1 = 100\left(\frac{H_a}{D}\right)^x \cdots\cdots\cdots\cdots (A).$$

where P_1=Silt conductive power of the head (expressed as percentage) in ideal conditions.

H_a=Depth in the approach chamber.

D=Depth in the parent channel opposite the head.

The value of index x in these observations is nearly $\frac{1}{3}$.

Experiments No. 3 and 8 were carried out with the width of approach less than that required. The velocity at the entrance was more than that under ideal conditions. The results in these experiment satisfy the following relation.

$$\frac{P}{P_1} = \left(\frac{V_a}{V_1}\right)^y \cdots\cdots$$

where P=Silt conductive power expressed as percentage.

P_1=Silt conductive power under ideal conditions.

V_a=Actual velocity at entrance to the approach chamber.

V_1=Velocity at entrance to the approach chamber under ideal conditions.

When the depth in the approach chamber is the same both in the ideal and the forced conditions,

$$\frac{V_a}{V_1} = \frac{W_1}{W_a}$$

hence $$\frac{P_a}{P_1} = \left(\frac{W_1}{W_a}\right)^y \cdots\cdots\cdots\cdots (B).$$

where W_1=Width of approach under ideal conditions.

W_a =Actual restricted width of approach.

The value of y in these experiments is very nearly unity.

In experiment No. 6 the width of the approach was excessive in comparison to that in experiment No. 5 carried out under the same conditions. The actual velocity at the entrance was less than the velocity under the ideal conditions of working. Silt conduction was raised from 83.0% to 93.5%.

$$\therefore \frac{P}{P_1} = \left(\frac{V_1}{V_a}\right)^z = \left(\frac{W_a}{W_1}\right)^z$$

There is only one observation of this type and the value of z works out to be about $\frac{1}{2}$.

In experiment No. 8, silt conduction is as high as 100.4%, while the restriction of water-way is not so much as to warrant such a high figure. It appears that the silt conduction of a head regulator tends to be proportionate when water in the parent channel is turbid and contains mostly fine silt in floods. Silt charge in the parent channel was about five times of that under the normal conditions at the beginning of these experiments. Moreover, it is a fact that the distributaries seldom silt up even with a high silt charge of fine silt during floods. The worst period for the distributary is generally from 15th September to 15th November. It was observed in the course of the experiments that normal silt charge was about an ounce in one cubic foot of water. It is concluded that the best period to carry silt conduction experiments on distributary head regulators or outlets is from 15th September to 15th November, or from 15th March to the end of April before the floods start.

Plate No. 7 gives the silt analysis of a few samples as analysed by the optical siltometer. This is the analysis of silt above .04 m.m. diameter, after the material below .04 m.m. diameter was separated by the sedimentation method. Sieve analysis does not go below .1 m.m. diameter, and the mechanical method only gives a very rough indication of the grade of silt. It is only the optical lever siltometer which gives the grade of the silt samples which is called the silt index of the samples. Analysis of both the distributary and the model sample in the same observation are plotted in the diagram in Plate No. 7. An examination of this diagram shows that the silt taken by the model was finer than that in the distributary when the silt conduction of the model was less than 100%.

Design of a Head with required silt conductive power.

Silt conductive power required for a head regulator depends upon the conditions in the parent channel and those which could be permitted in the offtaking channel as determined by the available slope, permissible C.V.R. and the ratio of bed to depth. This problem has been treated in detail by the author in a paper on " Design of Irrigation Channels" published by the Institution of Engineers, India, in 1934. An expression for this is given below as worked out in Appendix 1, Equation No. 5A of the said paper.

$$R = r_1^{\frac{1}{3}} \cdot r_2^{\frac{3}{5}} \cdot \lambda^{\frac{1}{6}}$$

where $R = \dfrac{\text{C.V.R in an offtake.}}{\text{C.V.R. in the parent channel.}}$

$r_1 = \dfrac{\text{Silt charge in an offtake.}}{\text{Silt charge in the parent channel.}}$

$=$ Silt conductive power of head.

$$r_2 = \frac{\text{Silt grade in an offtake.}}{\text{Silt grade in the parent channel.}}$$

$=$Silt Selective Power of the head with respect to its grade

$$\lambda = \frac{\text{Depth in the parent channel.}}{\text{Depth in the offtake.}}$$

The attempt to predict r_2 for a head regulator was not successful in these experiments for want of sufficient data of analysis of silt samples by the siltometer but the author considers that it is erring on the safe side to assume r_2 equal to r_1 (silt selective power by weight) till exhaustive research work is done in this respect. An examination of the plottings in Plate No. 7 shows that this assumption is very nearly borne out by the available data. The required silt conductive power of a head regulator could, therefore, be fixed by using the above expression and worked out from a Nomogram given in Plate No. 8.

The dimensions of the entrance of the approach chamber could be fixed from the formulae as worked out in this paper.

$$\frac{P}{P_1} = \left(\frac{W_1}{W}\right)^y$$

$$\text{or} \quad P = 100\left(\frac{H_a}{D}\right)^x \times \left(\frac{W_1}{W_a}\right)^y$$

$$= 100 \quad z_1^{\frac{1}{3}}.z_2$$

when P=Silt conductive power expressed as a percentage.

z_1=Ratio of depth in the approach chamber to the depth in the parent channel opposite on the pitched floor.

z_2=Ratio of width of approach under ideal conditions to that in the restricted condition.

A Nomogram is given in Plate No. 9 to work out the required depth in the approach chamber from the above expression. It is recommended that ideal conditions should be used as far as possible, as they are comparatively definite and can be verified by the bed; and the surface float observations after the construction of a head regulator.

Projection of the Downstream wing.

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

where S=Projection of the downstream wing or the set back of the upstream wing.

q=Discharge of the offtake.

Q=Discharge of the parent channel upstream.

b=Bed width of parent channel upstream.

d=Depth in the parent channel upstream.

Width of approach chamber under ideal conditions.

$$W=K\frac{S\times d}{Ha}$$

W=Width of approach.

S=Set back as determined above.

d=Depth in the parent channel upstream.

H_a=Depth in the approach chamber.

K=A factor.

K is a factor to allow for the difference in the velocity near the side and the average velocity of the parent channel. Its value is affected by the orientation of the head regulator of the offtake. The value of the factor K will be greater in a head regulator at right angles to the parent channel than that in an oblique one.

An expression for K covering the range of experiments and head regulators actually constructed under similar conditions is as given below :—

$$K=k \text{ Covers } \theta^{\frac{1}{2}} \times \text{ Covers } \phi^{\frac{1}{6}}$$

where k=a constant=2.0

$\theta = \text{Sin}^{-1}\frac{S}{W}$ =Inclination of the approach to the central line of the parent channel.

ϕ = Inclination of the offtake-head to the normal to the parent channel.

A Nomogram is given in Plate No. 9 to work out the value of K from the above expression. It would, however, be convenient to fix K in practice by observing the actual velocities in a channel by velocity rods at a distance of $\frac{S}{2}$ from the water edge. Determine then, the ratio of the average velocity of the channel to the side velocity and then correct for the inclination of the head regulators. It would be advisable to allow a somewhat liberal value of W and to restrict it afterwards, if necessary.

Conclusions.

Gibb's groyne walls, Wood's rising gates, Routh's skimming platforms and King's silt vanes comprised distinct improvements to solve the question of silt exclusion at the distributary head regulators.

However, none of the above mentioned devices could reach the ideal of silt exclusion. The Silt Selective Head Regulator described in this paper is as efficient a silt excluder as a successful head with a skimming platform. It not only saves the cost of the R. C. platform, the piers and the groyne wall, but also it is free from the adverse conditions which are usually set up on account of the very presence of this arrangement. Moreover, a " Silt Selective Head Regulator " is a simple and a suitable design to achieve the desired silt conductive power according to requirements. Successful distributary head regulators of this type were constructed on Lower Jhelum Canal in the cases of Salam distributary, Melay distributary, Wasuana minor and Tandlian minor following the design described in this paper.

It is not intended that the observations in this paper should be applied to Head Regulators of canals as the conditions of flow in a river are quite different from those in a canal flowing steadily in a uniform section.

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NOTATIONS FOR PLATE NO. 5.

Discharge in Canal U.S. of the offtake = Q
Depth in Canal .. .. = du
Bed width in canal .. .. = b
Discharge of the offtake .. .. = q
Bed width of the offtake .. = bo
Depth in the offtake .. .. = do
Depth on pitched floor in front of head = D=0.9d
Permissible silt conduction of the Head =P% } From Nomograms
Depth in Approach Chamber =Ha } Plate No. 8
Projection of the D.S. wing .. =q/Q (b+,d/2)
Width of approach .. .. $=W=K\frac{s \times d}{Ha}$
Radius of U/S side wall of approach chamber = R_1 =3Ha
Width of flume .. .. =B (Not less than W/2)
Depth on crest of flume .. .. $=H=(q/cB)^{2/3}$ (from 2/3 Ha to Ha)
Distance of gauge well hole from beginning of crest = 3 H
Length of Crest .. = 2 H

APPENDIX I.

EXPERIMENTS OF THE FIRST SET

No.	Date.	Northern Branch.										Mithalak Disty.										Silt Conduction considering N. B. as 100	Average.	Remarks.
		Silt in grams.	Percentage by weight.	Classifications of Silt with Sieves of Meshes.								Silt in grams.	Percentage by weight.	Classifications of silt with Sieves of Meshes.										
				40	50	60	70	80	100	120	Below 120			40	50	60	70	80	100	120	Below 120			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Experiment No. 1.																								
1	3-5-32	16,244.55	.107	.227	.197	.409	.810	2.767	2.735	13.195	76.59	17,919.85	.091	.16	.205	.415	.331	.736	.702	8.507	91.944	89.6%	..	Bay No. 1.
												14,883.75	.098	.700	.843	.429	.550	1.251	.965	5.855	91.993	..	..	.. 2.
2	10-5-32	22,623.3	.149	.560	.550	.620	.850	1.150	.785	15.870	79.675	19,845.0	.131	.12	.250	.460	.335	.610	.520	9.685	88.02	90.35%	..	.. 1.
												21,035.7	.139	.150	.310	.335	.187	.737	.329	3.46	94.521	..	..	.. 2.
3	4-6-32	286.679	.101	.120	.240	.262	.305	.220	1.055	11.70	83.188	267.77	.093	.13	.80	.89	.33	.197	.419	8.96	90.01	95.35%	91.8%	.. 1.
												281.86	.099	.250	.10	.117	.07	.0250	.300	6.92	91.992	..	..	.. 2.
4	11-6-32	217.728	.080	.367	.090	.540	.477	1.135	1.715	9.317	85.33	186.439	.065	.47	.250	.137	.117	.178	.345	6.140	92.78	90.19%	..	.. 1.
												206.345	.072	.130	.205	.80	.025	.190	.215	7.972	91.183	..	..	.. 2.
5	15-6-32	217.5	.076	.170	.100	.50	.155	.710	1.428	8.310	89.7	203.684	.071	.021	.090	.090	.091	.0302	.240	6.540	92.627	91.3%	..	.. 1.
												206.367	.073	.026	.082	.055	.052	.092	.119	2.602	96.702	..	..	.. 2.
6	19-6-32	203.96	.072	.08	.06	.46	.130	.700	3.815	9.895	84.85	178.370	.063	.030	.020	.020	.030	.050	.260	4.720	94.82	91.75%	..	.. 1.
												196.170	.069	.076	.082	.185	.070	.100	.920	6.040	92.434	..	..	.. 2.
7	26-6-32	327.150	.115	.135	.135	.307	.317	1.720	2.70	8.010	88.403	297.397	.104	.030	.045	.025	.020	.050	.117	2.400	97.293	92.07%	..	.. 1.
												295.08	.107	.010	.012	.030	.020	.035	.0215	2.15	97.493	..	..	.. 2.
	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Experiment No. 2.																								
1	10-6-32	252.450	.0880	1.0	.098	.1390	.142	.740	2.323	6.320	80.98	250.177	.088	.030	.070	.080	.020	.050	.214	.790	98.728	89.1%	..	
2	13-6-32	274.08	.096	.022	.094	.472	.092	.645	1.490	10.720	86.46	268.324	.094	.050	.050	.080	.070	.130	.320	1.806	97.423	97.0%	..	
3	17-6-32	230.250	.081	.070	.071	.500	.161	.120	2.970	9.310	85.79	230.169	.081	.100	.100	.194	.041	.218	.484	2.14	96.754	99.96%	98.75%	
4	21-6-32	202.20	.071	.220	.120	.552	.170	.770	.270	8.036	87.41	199.770	.070	.100	.080	.120	.022	.080	.32	2.92	96.248	98.8%	..	
5	28-6-32	273.855	.096	.060	.095	.340	.120	.620	2.420	8.320	88.043	269.747	.095	.038	.030	.155	.022	.135	.429	3.255	95.917	98.00%	..	

APPENDIX II.

EXPERIMENTS OF THE FIRST SET.

No.	Date.	Silt in grams.	Percentage by weight.	Classifications of Silt with Sieves of Meshes.								Silt in grams.	Percentage by weight.	Classifications of Silt with Sieves of Meshes.								Silt conduction considering N. B. as 100.	Average.	Remarks.
				40	50	60	70	80	100	120	Below 120			40	50	60	70	80	100	120	Below 120			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Experiment No. 2. Part (A.)																								
1	13-5-32	174.08	.096	.022	.472	.094	.092	.645	1.190	10.72	86.463	191.190	.067	.027	.05	.059	.025	.085	.169	2.98	97.615	72.69%		
2	17-6-32	220.250	.081	.071	.500	.071	.164	1.120	2.97	9.310	85.790	162.177	.057	.118	.122	.155	.050	.105	.285	2.185	96.980	70.43%	72.9%	
3	28-6-32	273.855	.096	.095	.340	.095	.122	.620	2.420	8.320	88.022	207.629	.080	.020	.03	.09	.070	.055	.020	3.231	96.125	75.80%		
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Experiment No. 3. Part (B.)																								
1	30-1-32	260.32	.092	.021	.020	.040	.698	1.235	2.38	5.226	92.37	237.98	.085	.027	.050	.039	.100	.185	.172	2.091	96.37	91.3%		
2	1-7-32	271.30	.096	.013	.070	.050	.532	1.323	2.916	5.296	91.80	257.31	.091	.023	.083	.023	.151	.093	.139	2.917	96.05	95.0%	89.7%	
3	2-7-32	308.72	.110	.031	.085	.020	.112	1.150	2.720	5.256	92.73	268.53	.095	.114	.093	.132	.035	.105	.150	2.441	96.92	87.1%		
4	4-7-32	387.15	.139	.026	.021	.030	.423	1.365	2.929	4.211	93 71	312.05	.110	.023	.032	.092	.124	.043	.101	1.785	97.80	85.2%		
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Experiment No. 4.																								
1	1-7-32	258.805	.091	.040	.089	.140	.022	.170	1.00	10.820	87.71	277.793	.095	.070	.050	.110	.015	.10	.300	8.51	90.812	105.1%	110.38%	
2	3-7-32	397.810	.119	.085	.097	.450	.045	.430	2.32	7.97	88.302	429.680	.144	.040	.050	.100	.020	.120	.650	8.80	90.220	108.0%		
3	5-7-32	208.795	.073	.040	.075	.392	.040	.425	1.75	5.32	91.738	236.167	.076	.060	.087	.105	.052	.135	.600	8.72	90.241	113.11%		
4	7-7-32	302.679	.106	.185	.079	.215	.060	.270	1.41	4.75	93.631	348.955	.123	.072	.40	.339	.045	.140	.645	7.902	90.714	115.3%		

APPENDIX III.

EXPERIMENTS OF THE FIRST SET.

	Silt in grams.	Per-centage by weight.	*Classifications of Silt with Sieves of Meshes.*										Silt in grams.	Per-centage by weight.	*Classifications of Silt with Sieves of Meshes*										Silt conduction considering N.B. as 100.	Average.	Remarks.
			30	40	50	60	70	80	100	120	150	Below 150			30	40	50	60	70	80	100	120	150	Below 150			
	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
														Experiment No. 5.													
32	446.90	.157	0	.01	.014	.026	02	.06	.360	4.509	..	94.8	294.58	.026	0	.002	.01	.015	.005	.05	.120	.77	..	99.028	65.9 %		
32	163 3	.057	0	.004	.02	.034	.02	.05	.150	1.92	..	97.992	118.65	.041	0	.002	.01	.01	.004	.06	.07	.30	..	99.544	72.6 %		
32	149.33	.052	0	.002	.01	.020	.61	.054	.220	2.72	..	96.964	91.90	.0339	0	0	.008	.012	.01	.06	.100	.42	..	99.590	61.5%	70.2%	
32	98.75	.034	0	.01	.02	.01	.02	.11	.309	1.45	..	98.05	79.8	.0274	0	0	.006	.03	.01	.06	.140	.680	..	99.071	80.8%		
	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
														Experiment No. 6 (A).													
3	503.927	.177	0	0	.001	.006	.004	.01	.02	.03	.05	99.879	400.196	.143	0	0	0	.001	.001	.002	.005	.01	.852	99.69	79.4%		
3	225.545	.083	0	.002	.005	.02	.009	.07	.307	.320	3.370	95.897	149.500	.0526	0	0	.002	.012	.008	.020	.040	.150	1.26	98.508	63.4%	73.1%	
3	268.52	.0876	0	.002	.011	.027	.011	.48	.397	.512	3.321	95.871	205.169	.0724	0	0	.002	.020	.008	.011	.029	.098	1.410	98.424	76.4%		
	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
														Experiment No. 6 (B).													
3	498.320	.176	0	0	.002	.007	.009	.012	.031	.032	2.88	97.625	392.850	.138	0	0	.001	.002	.001	.003	.006	.124	1.661	98.193	78.7%		
3	308.420	109	0	.003	.012	.220	.012	.052	.257	.412	2.505	96.724	217.723	.091	0	0	.003	.021	.012	.01	.034	.099	1.501	98.23	70.6%	72.7%	
	240. 730	.055	0	.003	.01	.024	.011	.069	.202	.320	3.538	95.732	165-241	.042	0	0	.002	.022	.007	.021	.052	.132	2.761	97.988	68.7 %		

No.	Date.	Mithalak Distributary.					
		Weight of silt in grams in Mithalak Distry.	*Mechanical Analysis.*				
			Percentage coarse sand above .2 m.m. in dia.	Percentage coarse sand .04 to .2 m.m. in dia.	Percentage silt .01 to .04 m.m. in dia.	Percentage fine silt .002 to .01 m.m. in dia.	Percentage clay
1	2	3	4	5	6	7	
		lb. oz.					
1	10-3-33	4—5	1.43	14.79	42.65	39.27	
2	11-3-33	1"—9"	1.28	12.57	29.18	51.53	
3	17-3-33	grams. 112.82	4.43	25.74	34.63	31.98	
4	18-3-33	106.82"	8.07	27.11	32.65	29.93	
5	19-3-33	109.95	8.74	27.54	31.05	27.95	
1	24-3-33	239.2	1.98	18.94	31.15	43.68	
2	25-3-33	147.72	3.94	29.02	36.20	28.18	
3	29-3-33	378.75	..	..	..	..	
1	31-3-33	159.60	..	..	..	..	
2	1-4-33	169.85	4.05	29.07	33.78	29.20	
3	7-4-33	745.169	..	..	..	..	
4	8-4-33	792.180	.69	9.94	31.53	51.98	
1	9-4-33	259.0	9.45	22.92	28.33	33.43	
2	10-4-33	216.15	..	..	..	..	
3	12-4-33	209.8	10.36	24.72	25.00	34.25	
1	25-4-33	612.223	1.31	12.53	32.28	49.93	
2	26-4-33	547.279	1.43	19.99	30.75	42.55	
3	27-4-33	413.792	2.42	21.91	40.05	30.49	
4	5-5-33	350.51	.82	19.49	37.10	40.40	
1	9-5-33	427.59	1.05	30.91	32.90	29.62	
2	10-5-33	492.57	1.13	30.00	31.40	34.92	
3	11-5-33	501.324	1.20	29.81	38.90	28.28	
4	12-5-33	399.30	0.53	33.73	20.65	32.88	
1	15-5-33	322.751	.63	20.36	42.33	31.33	
2	17-5-33	369.623	1.01	28.99	36.45	31.90	
3	18-5-33	400.222	1.17	30.63	35.65	30.33	
4	19-5-33	237.95	1.09	31.04	36.96	28.58	
1	21-5-33	892.513	3.54	28.69	36.05	31.08	
2	22-5-33	789.451	..	..	..	..	
3	23-5-33	923.315	1.63	30.62	36.75	28.28	
4	25-5-33	837.513	1.27	31.65	34.95	28.65	

APPENDIX IV.

EXPERIMENTS OF SECOND SET.

Date.	Mithalak Distributary.							Glass Model Head.								
	Weight of silt in grams in Mithalak Distty.	Mechanical Analysis.						Weight of silt in grams in Model Head.	Mechanical Analysis.						Percentage of Model silt to the Distty. silt by weight.	Average percentage silt conditions of the model in an experiment.	Remarks.
		Percentage coarse sand above .25 m.m. in dia.	Percentage coarse sand .04 to .25 m.m. in dia.	Percentage silt .01 to .04 m.m. in dia.	Percentage fine silt .002 to .01 m.m. in dia.	Percentage clay below .002 m.m. in dia.	Silt index of samples above .04 m.m. in dia. by siltometer.		Percentage coarse sand above .02 m.m. in dia.	Percentage coarse sand .01 to .25 m.m. in dia.	Percentage silt .01 to .04 m.m. in dia.	Percentage fine silt .002 to .01 m.m. in dia.	Percentage clay below .002 m.m. in dia.	Silt index of samples above .04 m.m. by siltometer.			
2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
								First Experiment.									
	lb. oz.							lb. oz.									
0-3-33	1—5	1.43	14.59	42.65	39.27	2.25		1—6	1.20	14.99	39.63	39.58	4.13	..	104.8 %		
1-3-33	1"—9"	1.28	12.57	29.18	51.53	5.00		1"—10"	.41	12.45	30.05	51.00	6.28	..	101.60 %		
	grams.							grams.									
7-3-33	112.82	4.43	25.74	34.63	31.98	3.50	11.68	122.95	11.64	35.36	29.53	21.33	2.33	12.72	109.0 %	106.8 %	
8-3-33	106.82"	8.07	27.11	32.65	29.83	2.58		115.325	10.26	37.02	27.28	23.03	2.88	..	107.96 %		
9-3-33	109.95	8.74	27.51	31.95	27.97	2.99		119.200	7.88	36.06	28.75	22.65	2.40	..	108.4 %		
								Second Experiment.									
14-3-33	239.2	1.98	18.94	31.15	43.68	3.79	..	184.16	2.78	26.88	24.25	42.97	3.13	..	80.0 %	80.6 %	
25-3-33	147.72	3.94	29.02	36.20	28.18	3.75	11.22	125.562	7.67	27.95	28.73	33.45	1.88	10.12	80.5 %		
29-3-33	378.75	..	..	..	..	..	..	307.923	1.31	28.59	28.80	38.50	3.53	..	81.3%		
								Third Experiment.									
31-3-33	159.60	..	..	..	..	..	..	167.40	1.97	30.46	32.07	34 35	2.53	..	105.0 %		
1-4-33	169.85	4.05	29.07	33.78	29.20	2.85	11.2	138.35	2.25	41.40	27.10	28.62	2.45	11.28	93.2 %	100.5 %	
7-4-33	745.169	..	..	..	..	..	..	739.600	.39	11.26	46.98	37.93	2.88	..	99.2 %		
8-4-33	792.180	.69	9.94	31.53	51.98	6.88	..	828.620	.23	10.78	26.28	56.53	5.13	..	104.6 %		
								Fourth Experiment.									
9-4-33	359.0	9.45	22.92	28.33	33.43	4.35	.	292.7	1.35	23.91	33.70	36.23	4.35	..	81.5 %		
10-4-33	216.15	..	..	..	..	..	..	167.5	..	..	..	..	..	..	78.5 %	79.3 %	
12-4-33	209.8	10.36	24.72	25.00	34.25	4.55	..	156.624	4.31	31.71	27.20	32.18	4.65	..	78.0 %		
								Fifth Experiment.									
25-4-33	612.223	1.31	12.53	32.28	49.93	3.50	..	491.615	2.51	18.10	32.30	42.50	2.70	..	80.3 %		
26-4-33	547.279	1.43	19.98	30.75	42.55	4.00	..	450.951	.99	19.90	33.32	39.17	4.00	..	82.04%	83.0 %	
27-4-33	413.792	2.42	21.91	40.05	30.49	3.20	10.3	347.171	.97	29.48	38.00	26.62	3.25	8.8	83.9 %		
5-5-33	350.51	.82	19.49	37.10	40.40	2.83	..	297.933	.41	19.25	34.33	39.80	2.87	..	85.0 %		
								Sixth Experiment.									
9-5-33	427.59	1.05	30.91	32.90	29.62	3.08	..	382.259	1.07	29.63	37.77	29.37	1.90	..	90.1 %		
10-5-33	492.57	1.13	30.00	31.40	34.92	2.55	7.96	466.422	1.10	30.00	31.40	34.92	2.55	7.08	94.7 %	93.7 %	
11-5-33	501.324	1.20	29.81	38.90	28.28	2.48	..	477.961	.48	33 80	39.10	25.05	2.88	..	95.3 %		
12-5-33	399.30	0.53	33.73	29.65	32.88	2.50	..	374.513	.68	28.11	44.25	25.85	1.89	..	93.8 %		
								Seventh Experiment.									
15-5-33	322.751	.63	20.36	42.33	31.33	5.68	..	237.691	1.66	31.51	36.38	27.43	2.38	..	73.7 %		
17-5-33	369.623	1.01	28.99	36.45	31.90	2.05	8.21	280.146	1.15	33.33	33.78	29.38	1.88	6.92	75.8 %		
18-5-33	400.222	1.17	30.63	35.65	30.33	1.78	.	303.268	.60	33.87	35.68	27.50	1.68	..	75.8 %	76.1 %	
19-5-33	237.95	1.09	31.04	36.95	28.58	2.13	..	180.601	.88	30.38	36.85	30.15	2.13	..	78.0 %		
								Eighth Experiment.									
21-5-33	892.513	3.53	26.83	36.05	31.08	1.58		893.405	.65	39.00	32.10	27.13	1.15	..	100.1 %	..	
22-5-33	789.451	..	..	..	..	..		797.346	.61	33.80	36.15	26.95	1.83	..	101.0 %	100.4 %	
23-5-33	923.315	1.63	30.62	36.75	28.28	1.98	8.03	929.708	3.01	32.85	33.23	28.68	1.73	9.62	100.7 %		
25-5-33	837.513	1.27	31.85	34.95	28.65	2.33		836.575			..	..	..	..	99.9 %		

APPENDIX V.

DATA FOR THE MODEL EXPERIMENT ON A SILT SELECTIVE HEAD REGULATOR.

Distributary.				Model.										
Bed U. S.	Depth U. S.	Discharge U. S. in cusecs.	Velocity.	H.	B.	H. a	W. A	V. a	Discharge in cusecs.	Surface Floats.	Bed Floats	Observed Silt conduction percentage.	Calculated Silt conduction percentage.	Remarks.
2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
18	4.0	170	2.125	2.2	3.0	2.2	8.12	1.6	28.5	5	5	106.8		
18	4.0	156	1.95	1.4	,,	2.2	6.5	1.05	15	5	*Nil.*	80.6	83	Ideal
18	4.0	156	1.95	1.4	,,	2.2	5.0	1.36	15	4	3	100.5	102.7	
18	4.0	153	1.91	1.2	,,	2.2	5.6	0.975	12	4	*Nil.*	79.3	83	Ideal
18	4.0	150	1.88	1.0	,,	2.2	4.5	0.91	9	3	2	83	83	Ideal
18	4.0	150	1.88	1.0	,,	2.2	6.0	0.672	9	4	*Nil.*	93.5	97	
18	4.0	153	1.91	1.2	,,	1.8	6.5	1.025	12	4	*Nil.*	76.4	77.5	Ideal
18	4.0	153	1.91	1.2	,,	1.8	5.5	1.2	12	4	Not observed.	100.4	91.5	

Note :–

H.–Depth on the crest of the Weir Flume.

B–Width of the Weir Flume.

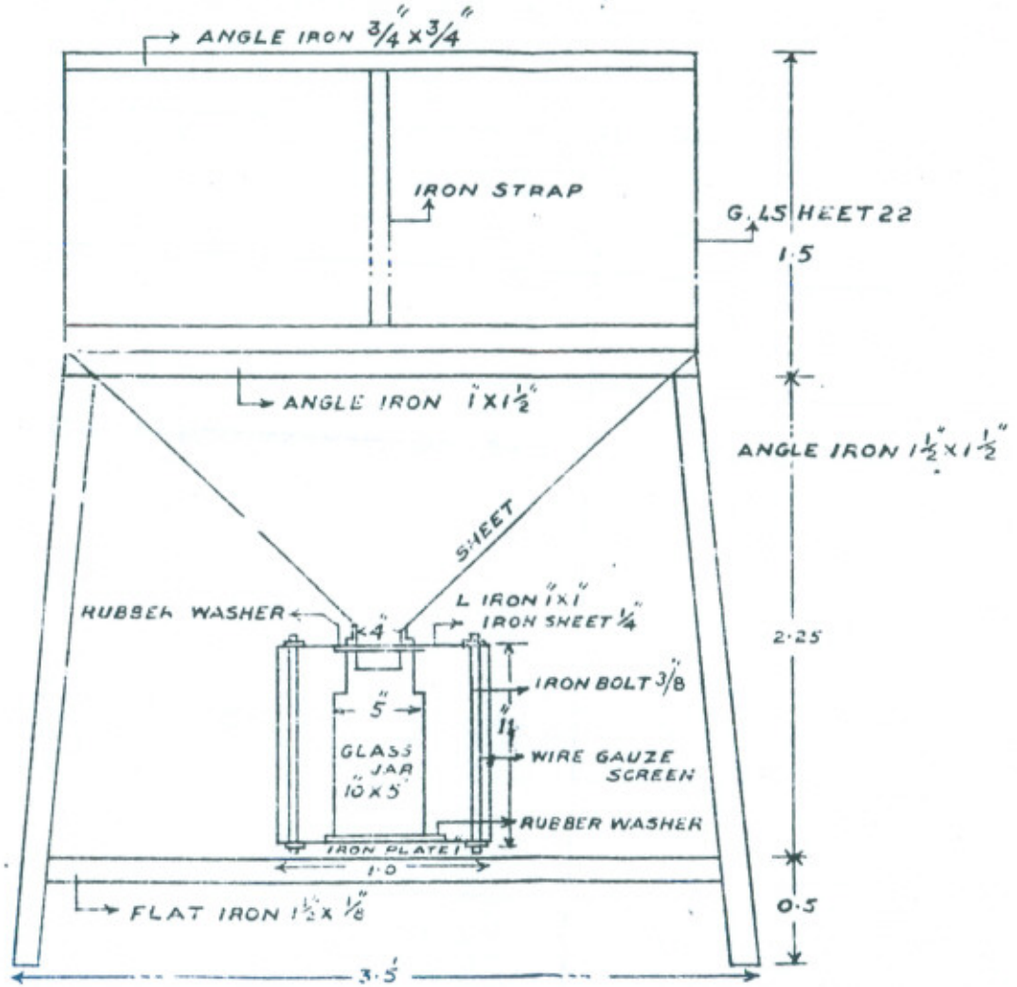
Ha–Depth in the approach chamber.

WA.–Width of Entrance of approach chamber.

Va–Velocity at Entrance of approach chamber.

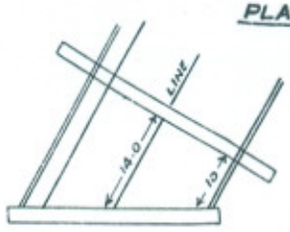
SILT SETTLING TANK
10 C.F.T. CAPACITY.

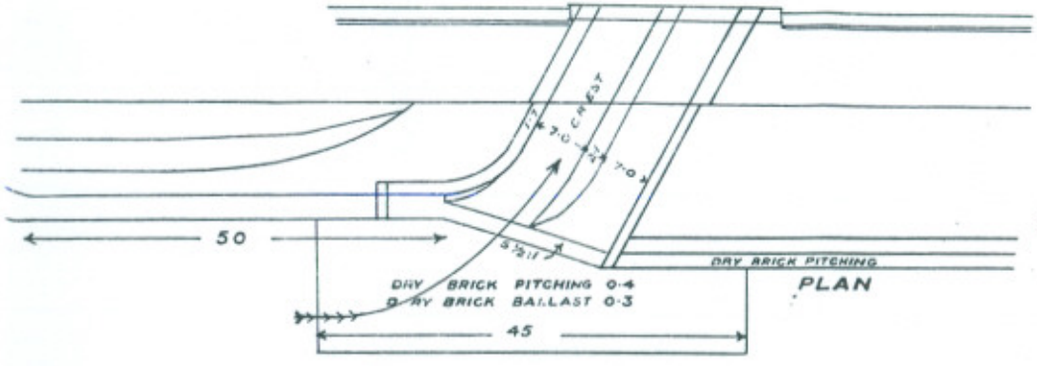
PLATE No 1
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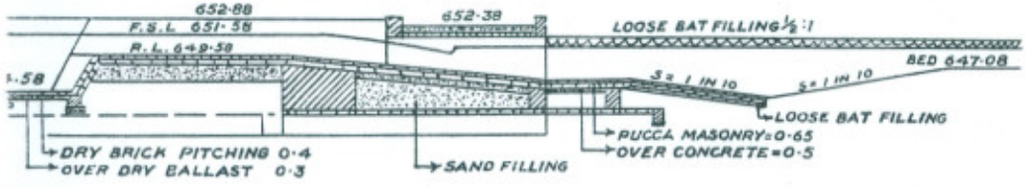
REGULATOR OF MITHALAK DISTRIBUTARY
KING R.D. 64000 OF NORTHERN BRANCH.

PLATE No 2
189

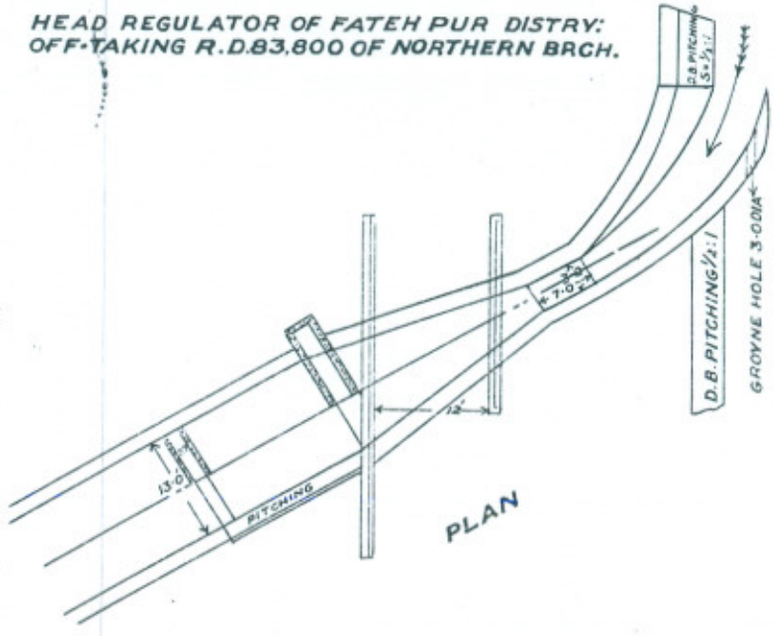


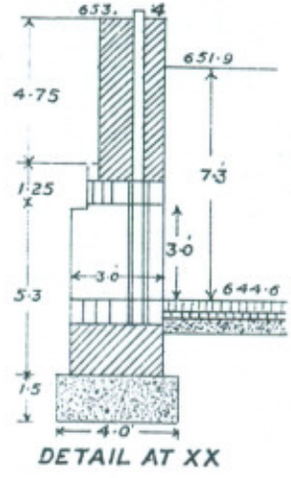


LONGITUDINAL SECTION

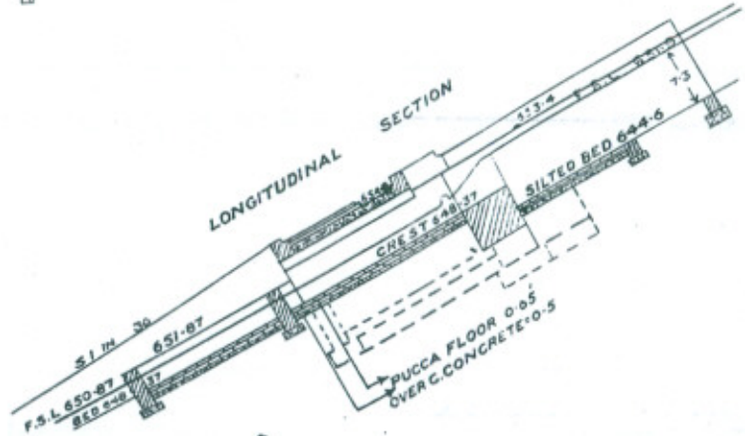


HEAD REGULATOR OF FATEH PUR DISTRY:
OFF-TAKING R.D.83,800 OF NORTHERN BRCH.



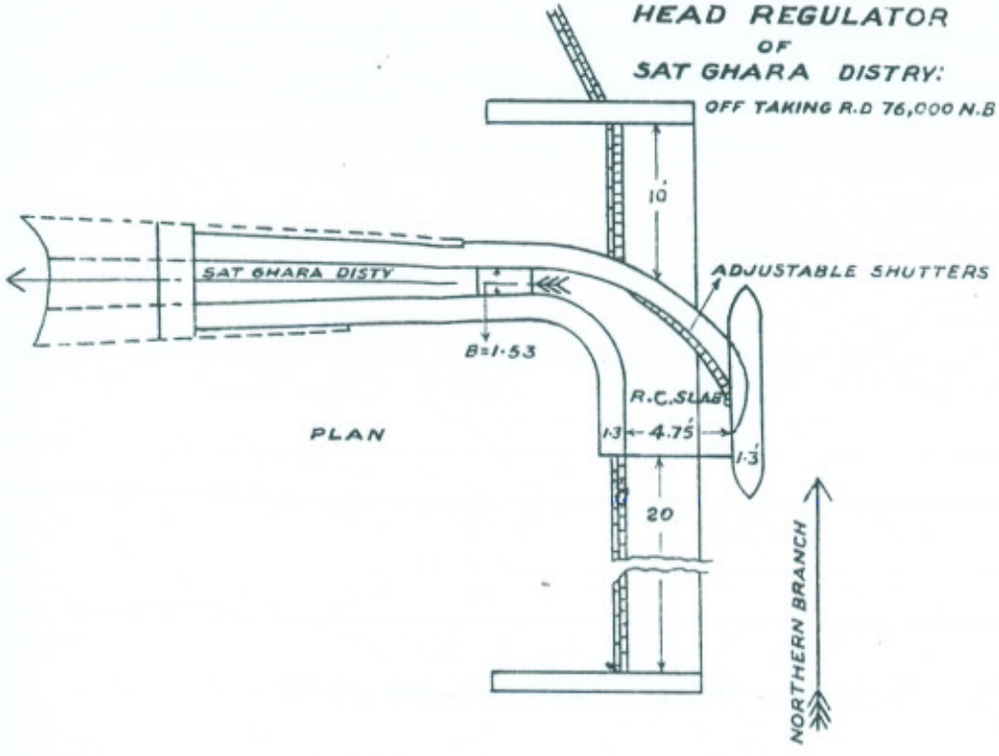


DETAIL AT XX

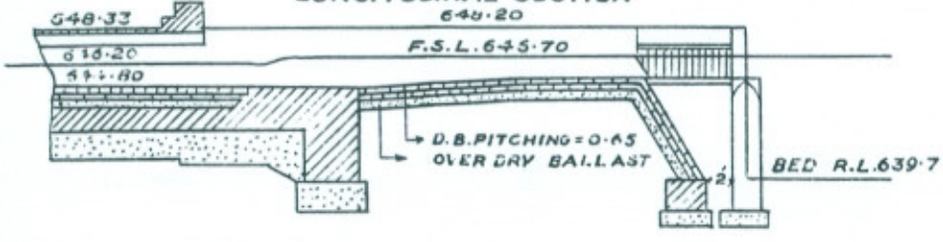


HEAD REGULATOR OF SAT GHARA DISTRY:

OFF TAKING R.D 76,000 N.B



LONGITUDINAL SECTION



HEAD REGULATOR OF SALAM DISTY:

OFF TAKING R.D. 24000 NORTHERN BRCH:

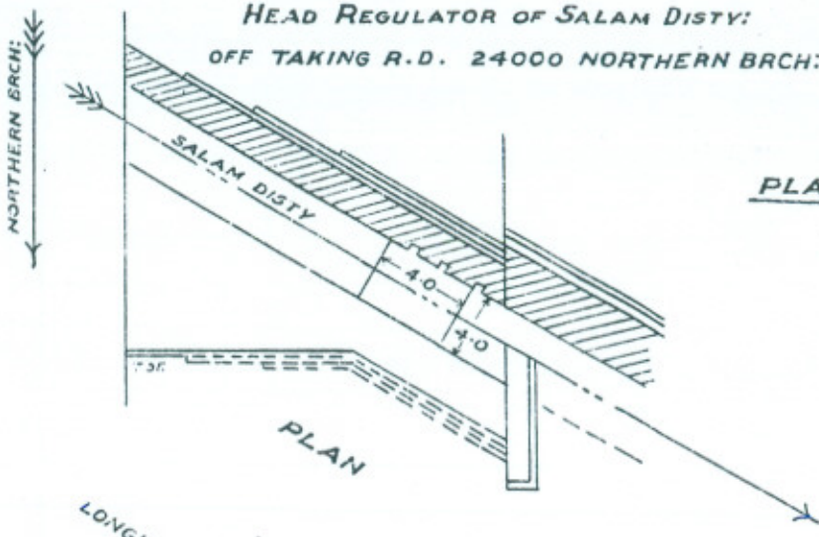
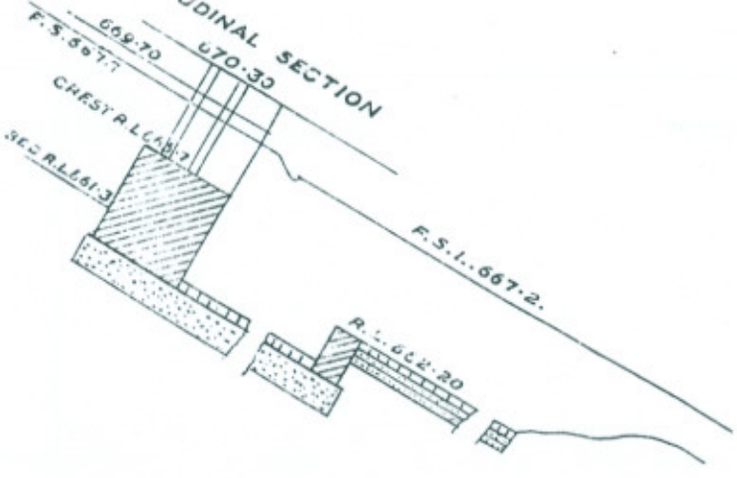
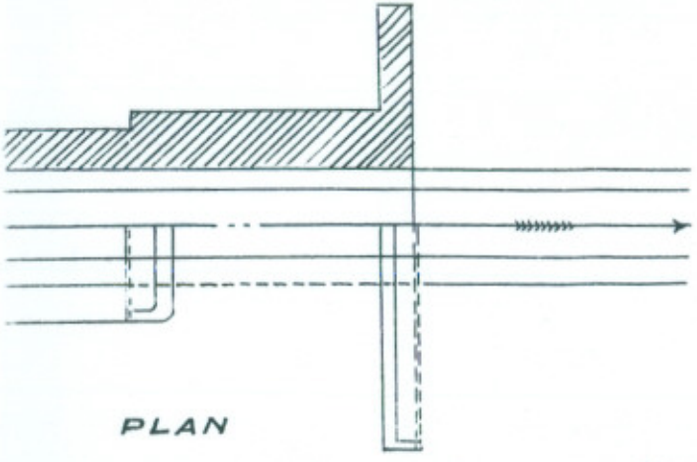


PLATE No 3
189

LONGITUDINAL SECTION



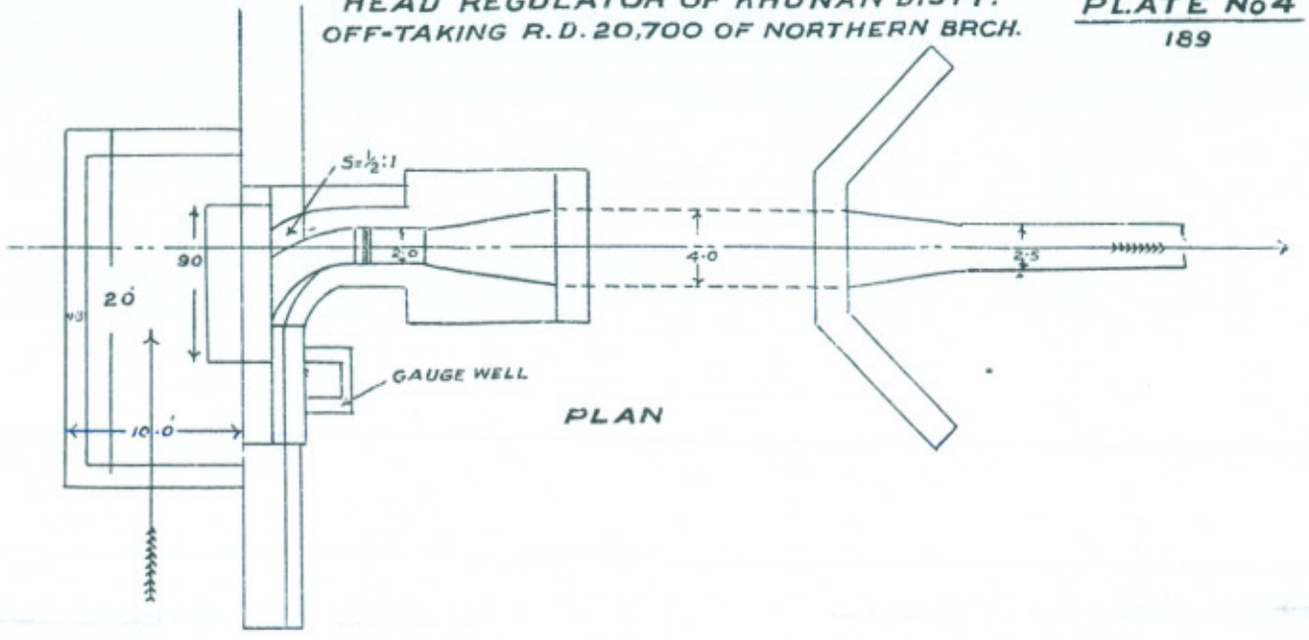
'AD REGULATOR OF MELAY DISTRY:
TAKING R.D. 83,332 OF SOUTHERN BRANCH.



PLAN

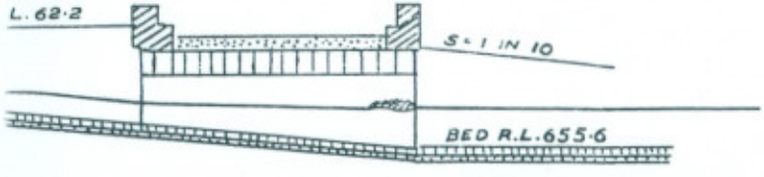
HEAD REGULATOR OF KHUNAN DISTY:
OFF-TAKING R.D. 20,700 OF NORTHERN BRCH.

PLATE No 4
189

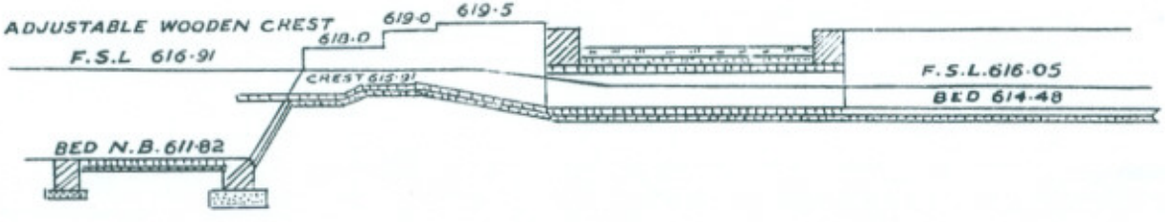


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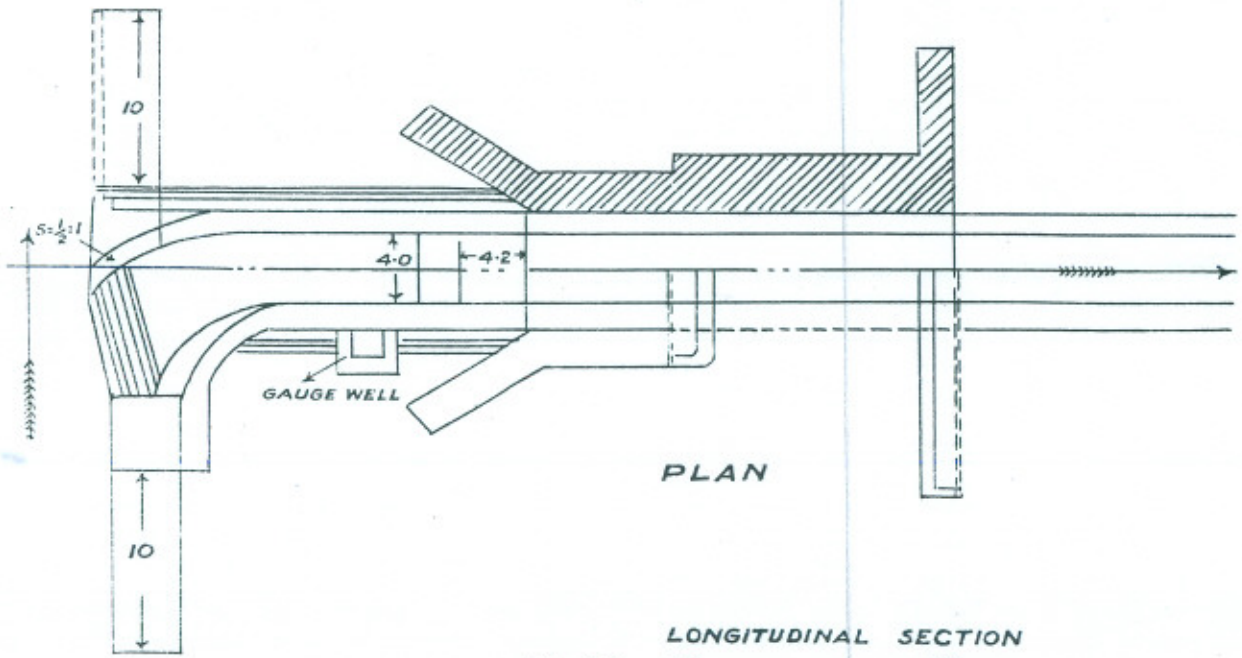
LONGITUDINAL SECTION



LONGITUDINAL SECTION

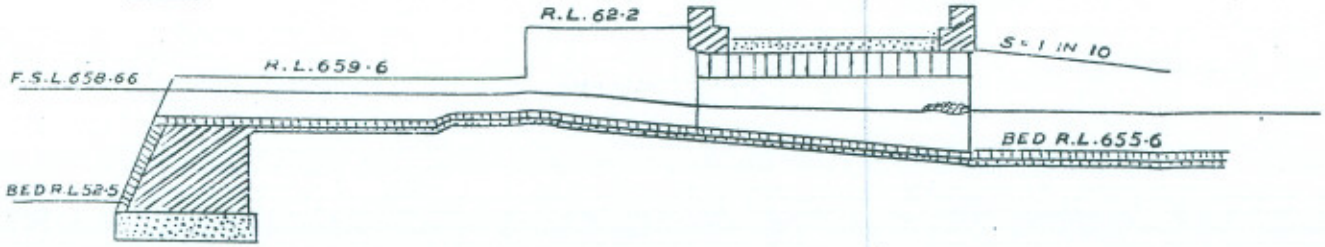


HEAD REGULATOR OF MELAY DISTRY:
OFF-TAKING R.D. 83,332 OF SOUTHERN BRANCH.

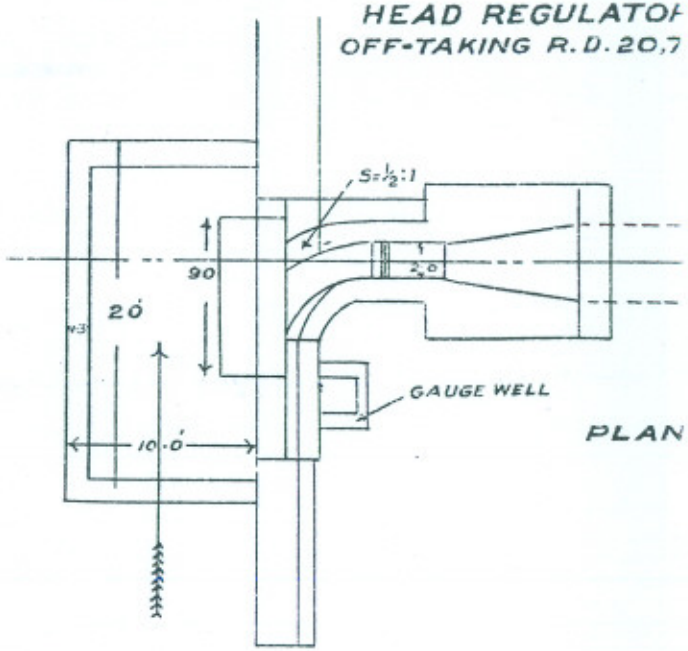


PLAN

LONGITUDINAL SECTION

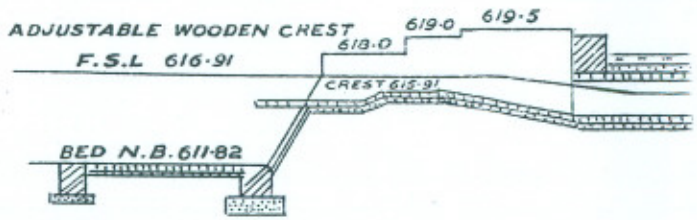


HEAD REGULATOR
OFF-TAKING R.D. 20,7



PLAN

LONGITUDI



SILT SELECTIVE HEAD REGULATOR.

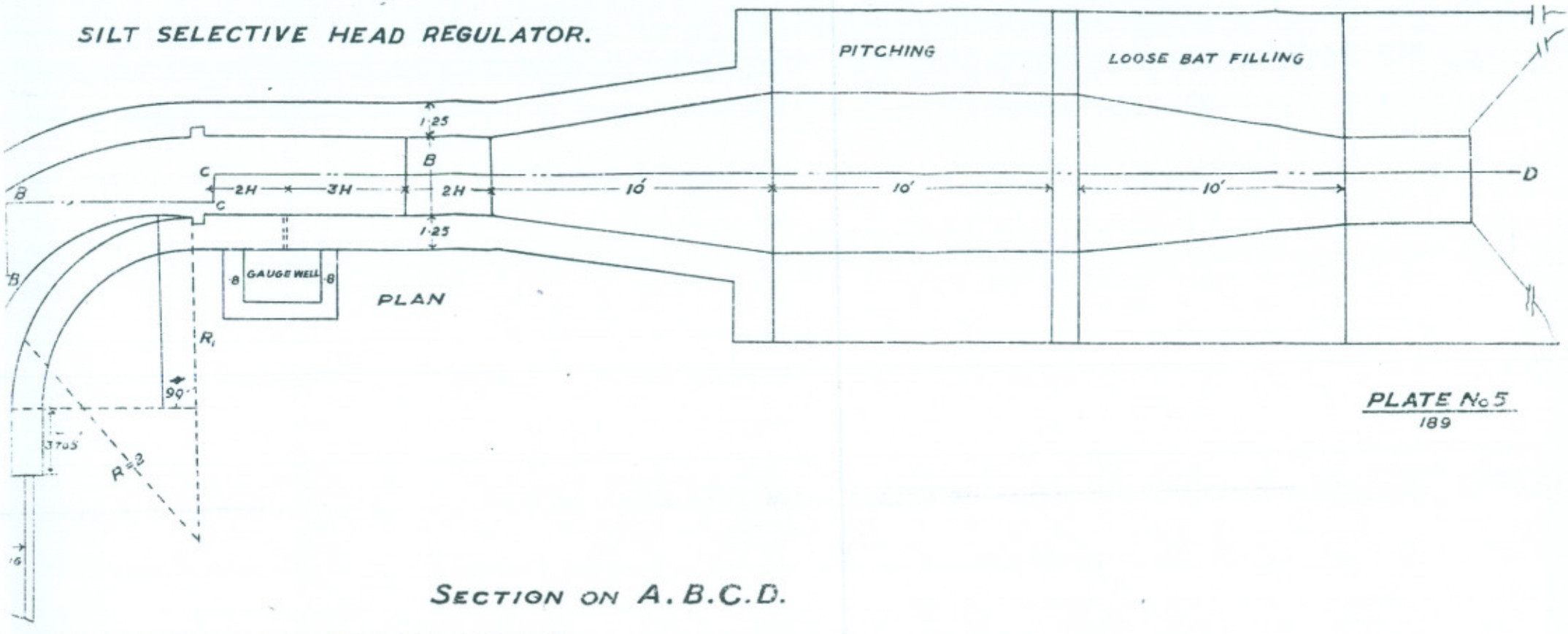
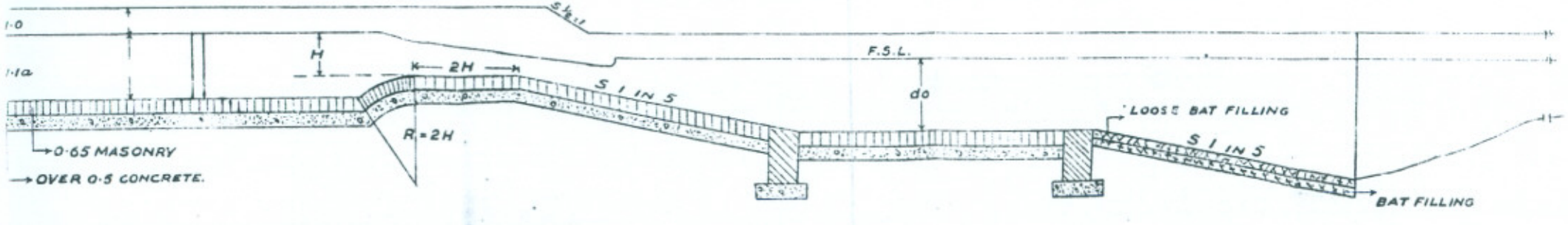
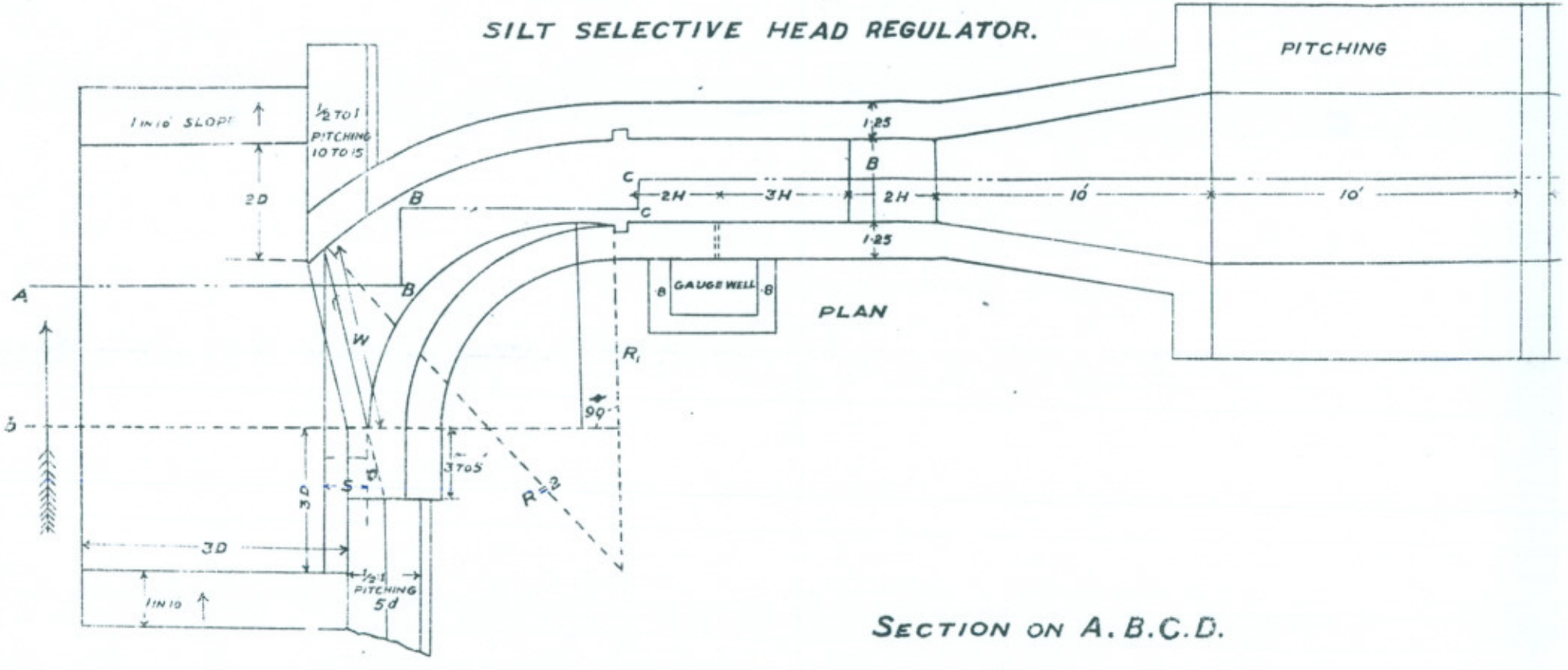


PLATE No 5
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SECTION ON A.B.C.D.



SILT SELECTIVE HEAD REGULATOR.



SECTION ON A.B.C.D.

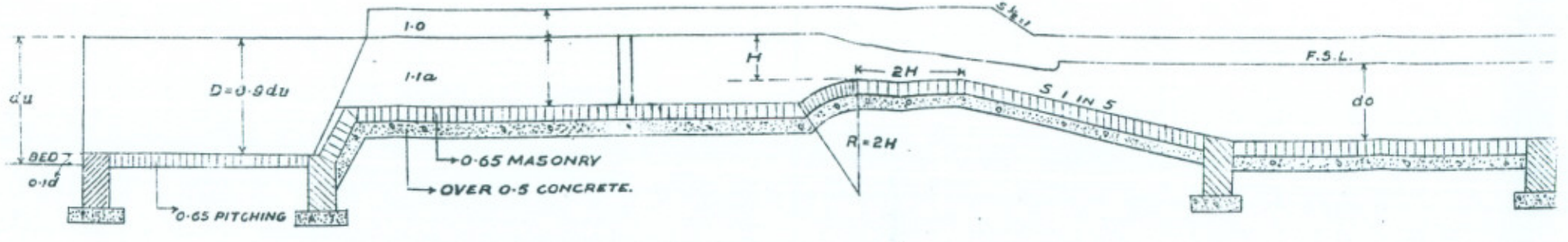
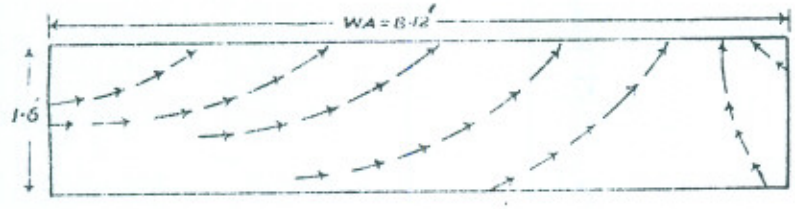


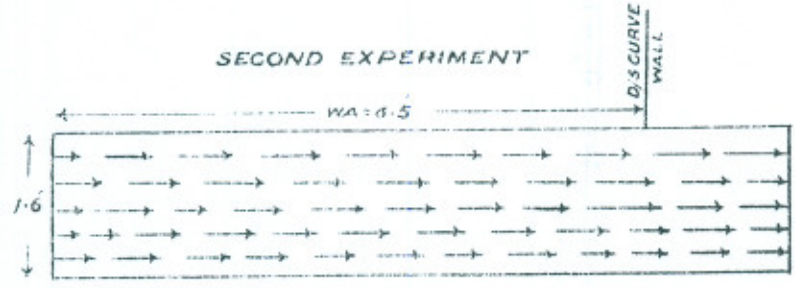
PLATE No 6
189

SKETCH OF STREAM LINES
FOR
EXPERIMENTAL GLASS HEAD REGULATOR
AT SATGHARA.

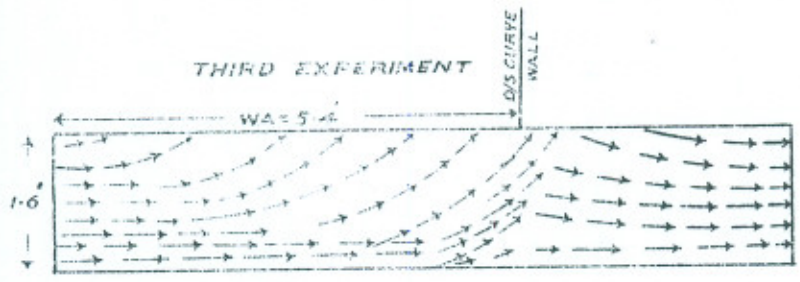
SECOND SET OF EXPERIMENTS.



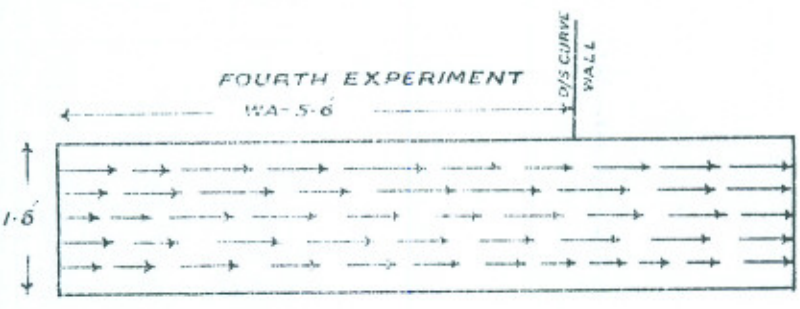
SECOND EXPERIMENT



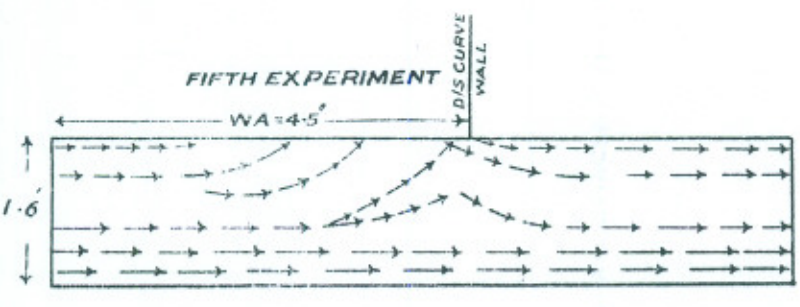
THIRD EXPERIMENT



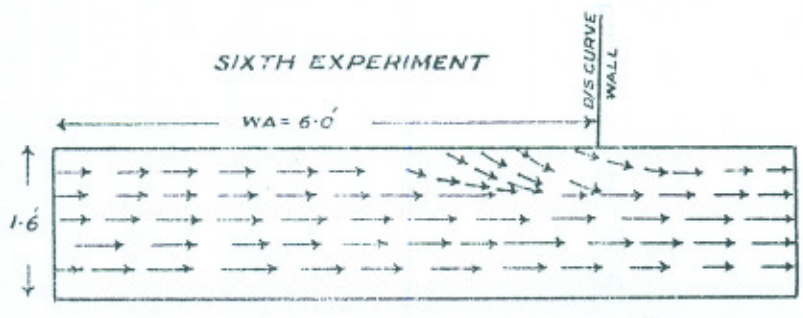
FOURTH EXPERIMENT



FIFTH EXPERIMENT

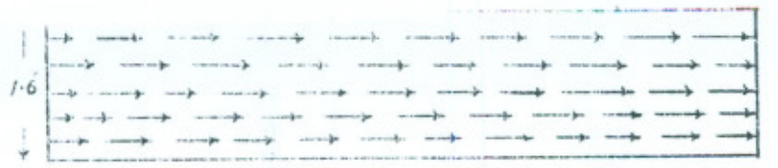


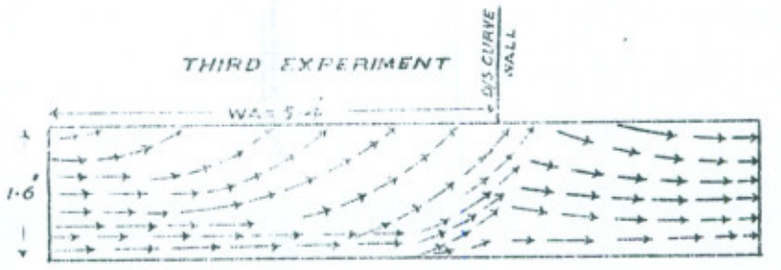
SIXTH EXPERIMENT

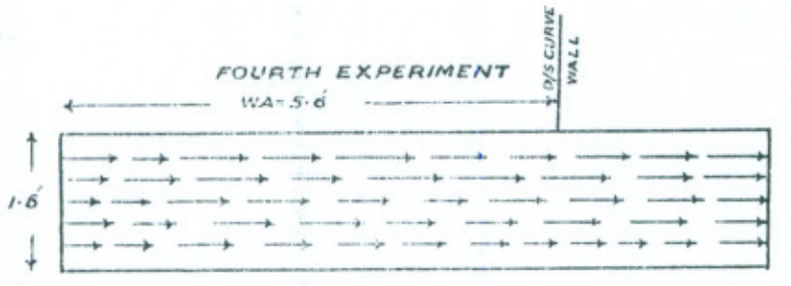


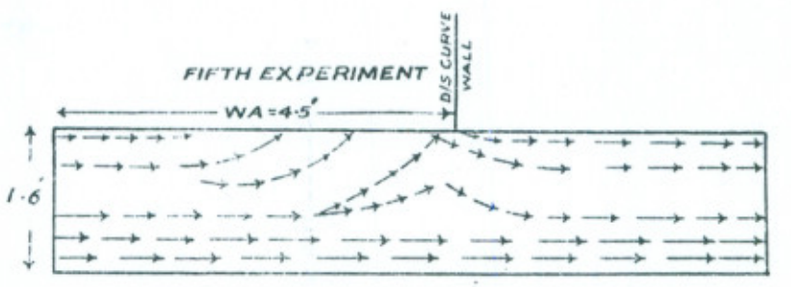
SEVENTH EXPERIMENT

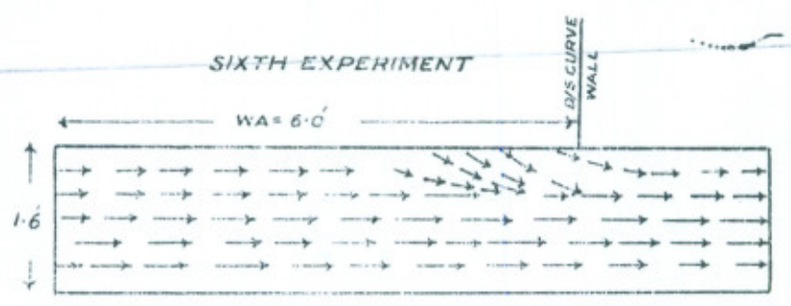
S CURVE WALL

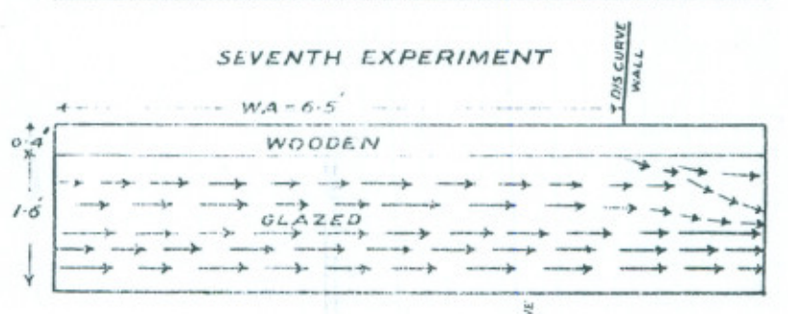

1·6'

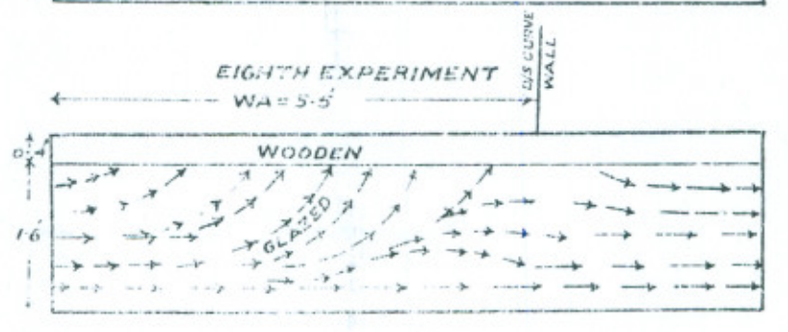

THIRD EXPERIMENT
D/S CURVE WALL
WA = 5·4'
1·6'


FOURTH EXPERIMENT
D/S CURVE WALL
WA = 5·6'
1·6'


FIFTH EXPERIMENT
D/S CURVE WALL
WA = 4·5'
1·6'


SIXTH EXPERIMENT
D/S CURVE WALL
WA = 6·0'
1·6'


SEVENTH EXPERIMENT
D/S CURVE WALL
WA = 6·5'
0·4'
WOODEN
1·6'
GLAZED


EIGHTH EXPERIMENT
D/S CURVE WALL
WA = 5·5'
0·4'
WOODEN
1·6'
GLAZED

SILT DISTRIBUTION CURVES IN MODEL EXPERIMENTS.

PLATE No 7

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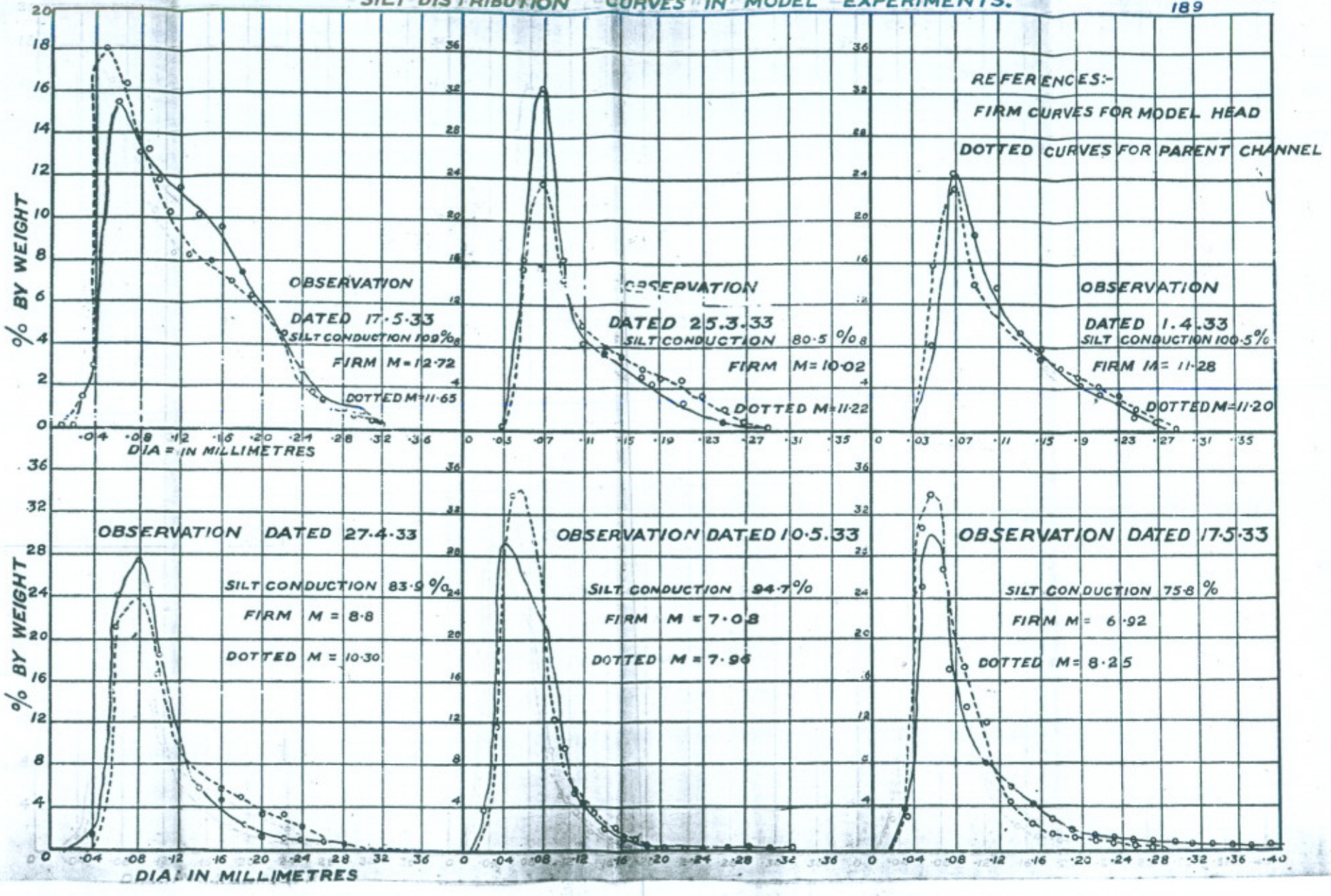


PLATE No 8

189

NOMOGRAM TO DETERMINE SILT SELECTIVE POWER OF A HEAD.



MIDDLE HORIZONTAL

$R = r_1^{1/3} \cdot r_2^{3} \cdot \lambda^{1/6}$ WHERE

R = RATIO OF CRITICAL VELOCITY RATIO D/S OF THE HEAD OF AN OFF-TAKE TO THAT IN THE PARENT CHANNEL

r_1 = RATIO OF SILT CHARGE D/S OF THE HEAD OF AN OFF-TAKE TO THAT IN THE PARENT CHANNEL. (SILT SELECTIVE POWER)

r_2 = RATIO OF SILT GRADE D/S OF THE HEAD OF AN OFF TAKE TO THAT IN THE PARENT CHANNEL.

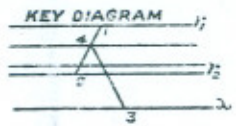
λ = RATIO OF DEPTH IN THE PARENT CHANNEL TO THAT D/S OF THE HEAD OF AN OFF-TAKE.



INSTRUCTIONS.

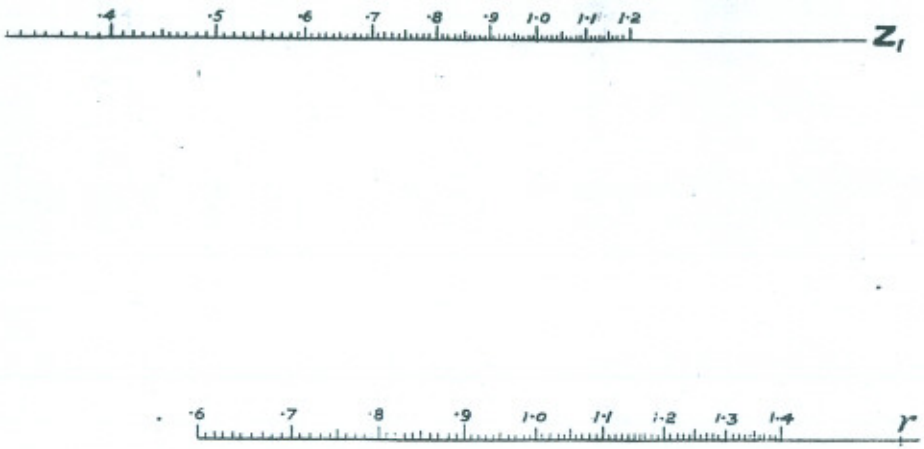
JOIN r_1 & r_2 CUTTING ON THE INTERSECTION OF THE MID-HORIZONTAL. JOIN THIS INTERSECTION WITH λ & R.

KEY DIAGRAM





NOMOGRAM TO DETERMINE DEPTH IN APPROACH CHAMBER.



$100\,Z_1^{1/3} \cdot 1/Z_2$ WHERE Z_2 IS LESS THAN UNITY

$60 = Z_1^{1/3} \cdot 1/Z_2$

$Z_1^{1/3} \cdot 1/Z_2$ WHERE γ_1 = RATIO OF SILT CHARGE TAKEN BY THE OFFTAKE TO THAT IN THE PARENT CHANNEL.

$\frac{HA}{D}$ = RATIO OF DEPTH IN APPROACH CHAMBER TO THE DEPTH IN FRONT OF HEAD ON PITCHED FLOOR

$\frac{WA}{W1}$ = RATIO OF ACTUAL WIDTH OF APPROACH TO THAT REQUIRED IN THE IDEAL CONDITION.

$= 100 Z_1^{1/3} \cdot Z_2^{1/2}$ · WHERE Z_2 IS MORE THAN UNITY.



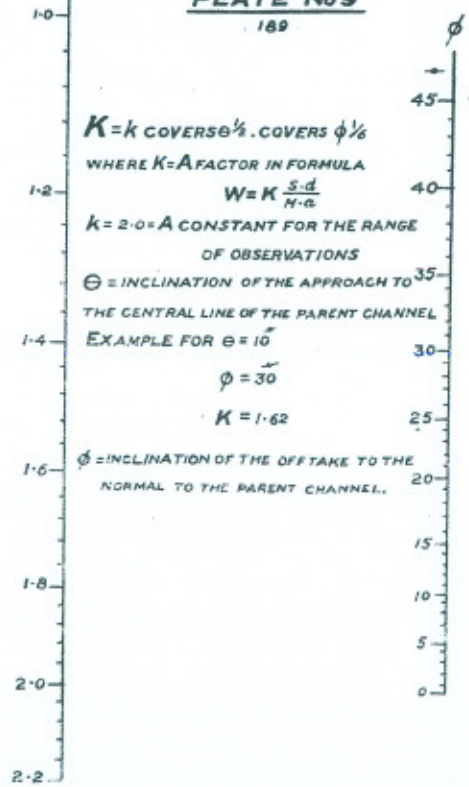
$3/100 = \gamma_1 = Z_1^{1/3} \cdot Z_2^{1/2}$



K NOMOGRAM TO DETERMINE K

PLATE No 9

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$K = k$ COVERSE $\theta^{1/3}$. COVERS $\phi^{1/6}$

WHERE K = A FACTOR IN FORMULA

$W = K \frac{S \cdot d}{M \cdot a}$

$k = 2{\cdot}0$ = A CONSTANT FOR THE RANGE OF OBSERVATIONS

Θ = INCLINATION OF THE APPROACH TO THE CENTRAL LINE OF THE PARENT CHANNEL

EXAMPLE FOR $\Theta = 10°$

$\phi = 30°$

$K = 1{\cdot}62$

ϕ = INCLINATION OF THE OFF TAKE TO THE NORMAL TO THE PARENT CHANNEL.

DISCUSSION.

Mr. **K. R. Sharma** in introducing his paper said that he had made an attempt in the paper to bring forward the three important functions of a distributary head regulator. It was a regulator, a meter of supply and a silt selective structure. A silt selective head regulator as described in the paper comprised all the three requirements at the right place. The silt selecting device as incorporated in this design was very simple. The silt selection depended only on the design of the approach chamber. This design was free from the encumbrances such as a skimming platform, silt vanes, Gibb walls, etc.

Simple formulae, as stated on page 43 of the paper, had been worked from the experiments described therein, which enabled one to design a head regulator of a distributary with the required silt conductive power. It had been shown by actual experiments that a silt selective distributary head regulator was as efficient a silt excluding device as a head with a skimming platform. However it had the great advantage that one could design it to take or exclude silt according to the requirements.

The author expressed great pleasure in claiming his paper as the last link to complete the great work of Mr. R. G. Kennedy. This work started with humble beginnings with paper No. 154 of the Punjab Engineering Congress, 1932, named " Remodelling of Mithalak Distributary ", which described one of the twenty-two channels treated on the same lines. These channels were remodelled to sections according to Kennedy's theory. They invariably ran satisfactorily non-silting, except as influenced by the silt conduction of outlets and distributary head regulators. The second attempt to perfect the theory of silt carriage and distribution in channels was described in paper No. 168 of the Punjab Engineering Congress of 1933, namely, " Silt conduction by Irrigation outlets." This paper supplied the last link in describing the silt conduction by distributary head regulators. However the most important work which linked all of these three papers did not find a place in the Proceedings of the Punjab Engineering Congress, but was published last year in the Proceedings of the Institution of Engineers, India, namely, " Design of Irrigation Channels ". All of these four papers are but one subject and therefore inter-connecting formulae as evolved in the last mentioned paper on to the basis of Kennedy's theory are stated below :—

$$(a)\quad r_1 = \left\{ \frac{Q_1 - 1/100\,(p_1 q_1 + p_2 q_2 + p_3 q_3 + \text{——})}{Q_1 - (A + q_1 + q_2 + q_3 + \text{——————})} \right\}$$

$$(b)\quad r_2 = \left\{ \frac{Q_1 - 1/100^3\,(p_1^3 q_1 + p_2^3 q_2 + p_3^3 q_3 + \text{—})}{Q_1 - (A + q_1 + q_2 + q_3 + \text{——————})} \right\}^{1/2}$$

$$(c)\quad R = r_1^{1/3} \cdot r_2^{\cdot 3} \cdot r_3^{\cdot 1}$$

where Q_1 = Discharge in a channel in the beginning of a reach.
A = Absorption in cusecs in Q reach.

P_1, P_2, P_3 = Silt conductive powers of outlets or offtakes in a reach as percentage.

Q_1, Q_2, Q_3 = Discharge in cusecs of outlets or offtake in a reach.

R = Ratio of C. V. R. at the end of a reach to that at its beginning.

r_1 = Ratio of silt charge by weight at the end of a reach to that at its beginning.

r_2 = Ratio of silt grade at end of a reach to that at its beginning.

r_3 = Ratio of discharge at the beginning of a reach to that at its end.

What Mr. Kennedy expressed in words in his paper regarding the effect of outlets, offtake head regulators and absorption, had been put in the mathematical form. The question of selection of V_0 was no longer a guess work in adopting the silt conductive powers of outlets and distributary head regulators as determined experimentally and as described in the above mentioned paper. This was distinctly a step forward in solving the problem of silt transportation, as even in Lacey's most important work, the selection of 'f' was nothing but a big guess work as described by Mr. Blench in paper No. 187 of the Punjab Engineering Congress.

Lastly the author remarked that it was a paper not on silt exclusion but on silt selection according to what the off-take could carry forward with the available slope, without silting.

Mr. **R. K. Khanna** said that Mr. Sharma's ideal of a distributary head regulator apparently was that it should not pass any silt into the distributary or the off-taking channel. As the attainment of the ideal was impossible, without perhaps the installation of a double filter at the head of every distributary or minor head, Mr. Sharma had greatly lowered his conception of a perfect distributary head and would feel quite content with his ideal " Silt Selective Head Regulator ", of the seventh experiment of the second set.

To the minds uninitiated in the mysteries of different kinds of motion of water, the super scientific analysis by Mr. Sharma of the behaviour of flow under different conditions of his experiments must be all Greek and Latin. Even the comparatively simple observations of Mr. Sharma at the end of pages 33 and 35 were far beyond common understanding.

In the ordinary conception Mr. Sharma's all experiments excepting one on the regulation with the rising sill gates were carried out on open flume regulators, and apparently in spite of the different silt conductive powers of the regulators as discovered by Mr. Sharma, all the channels worked satisfactorily. Salam distributary was a bad silting channel. But if Mr. Sharma had not been wholly absorbed in his silt analysis, he would have seen that the dimensions and slope of the channel and

not the silt conducting power of the head regulator, were responsible for its silting tendency. If instead of 18 ft. bed width, and 1 in 2080 slope of flow for a 30-cusec channel, the distributary was redesigned to about 10 ft. bed width and about 1 in 3500 slope of flow, with a reasonable drop from the parent into the offtaking channel, then Mr. Sharma would have found out, perhaps great to his surprise, that irrespective of the silt conductive powers of different types of head regulators, any open flume with a proper glacis at its downstream end, would have given him a satisfactory non-silting channel. He would also have discovered that all the minute specifications of his ideal regulator, including the bed pitching, the pacca platform, the length and slope of the approach channel, and the exact location of the gauge well and its hole were all redundant. Any but a super-scientific mind would see that pitching the bed of a 7 ft. deep main branch could not possibly have any effect on the silt conductive power of a regulator, stuck up high above the bed. And once water had entered the approach channel of a flume regulator, the exact radius of curvature of the approach channel and the location of the gaugewell, would not make any difference to the mysterious silt conductivity of the regulator.

People seemed to have strange notions about the functions of silt in flowing water. The one aim of recent, so-called, scientific research on hydraulics had been to eliminate all silt from the flowing water. Luckily the forces of nature did not tamely submit to the aggressive and unreasonable attempts of man to interfere with the free play of those forces. As far as one could see all silt excluding devices had failed to exclude silt from flowing water. But still man in his anxiety to derive consolation from his labour, imagined different shapes of eddies and waves created by his inventions, all tending to eliminate or reduce harmful silts. The ideal silt selective head regulator of Mr. Sharma was apparently the creation of some such flight of imagination.

Pandit **Khushi Ram Erry** congratulated Mr. Sharma on producing a novel design of what he called a silt selective head regulator.

He did not know how the olympian gods would like this design. But speaking as a sub-divisional officer he could say that it would only add one more stunt to the already too numerous silt-exclusive devices, thus making confusion worse confounded.

The design was certainly very complicated and expensive. In fact it would be inadvisable to design the head on these lines, unless one agreed with the author's theories on the design of channels, which he was afraid, had not so far received as great an appreciation as the author thought they deserved.

The author had tried to prove the superority of this type of head regulator over other silt excluding designs from the results of certain model experiments carried out by himself. Model experiments might

be all right, but what about actual working of the channels on the Lower Jhelum Canal, which as stated by the author had such head regulators. After all the proof of the pudding is in the eating. As far as he remembered Mr. Sharma had left Lower Jhelum Circle about 3 years ago. Therefore the silt selective regulators had had ample time to prove their worth. Had they actually done so? It was surprising that the author made no mention of their actual working in his paper. He asked Mr. Sharma to state if any silt clearance was found necessary on any of those channels after remodelling of their head regulators. If so, the speaker requested him to state the amount of money spent on each of these channels, on silt clearance under special estimates, as well as on silt removal during bed clearance, charged to annual maintenance and repairs.

A comparison of expenditure incurred on silt and bed clearance and other measures adopted to maintain the regime of channels fitted with silt selective Heads, with similar expenditure on other channels without such head regulators would give a true measure of the efficiency of this new design.

Mr. **M. D. Mithal** stated that Mr. Sharma deserved to be praised for the labour spent on the experiments he had carried out. He asked if all this experimental work was necessary. Was silt selection essential at all?

Great emphasis had been laid on reducing the silt content of an offtaking minor and any success in that direction was considered as a praiseworthy act. But this success increased the silt content in the portion of distributary downstream of this minor and if high silt content was considered objectionable it should not be allowed to decrease in one and increase in the other.

Mr. Mithal's view was that it was the churning and eddies caused by abrupt curves in stream lines which caused silting and not the silt content.

The aim should be that water on all the four sides must be 'stream lines' to enable to carry its silt without dropping. The attempts so far had been to give it only lateral stream lining with an abrupt base and top and therefore the result had been no better.

The author did not mention the effect of the type of the Head he advocated on the channel, as it was not the silt content that mattered so much as the eddies that caused it to drop. For the purposes of discussion he would take a standing wave to be an eddy.

Mr. Mithal referred to the churning of the milk that caused the butter to separate. Butter is in much finer suspension than silt and the effect of churning on silt could therefore be easily imagined.

Mr. Mithal advocated the necessity of proportional distribution with the least possible rippling and the water would carry its silt as the cohesion between water and silt particles should be taken into consideration. Moreover it was only seldom that the water was saturated with silt.

To support his argument he quoted the case of Masudpur distributary of the Western Jamna Canal.

The Masudpur distributary was a hundred cusecs channel at the tail of the Hansi Branch. Its head till February 1933 was 2 bays of 7′ with raised crest.

In February 1933 it was remodelled with the crest at about 6″ below the bed of the parent and about 3′ below the bed of minor. The bed went down by about 2′ near the head and no silt clearance had been done till then in the head reach.

None of the experiments of the author ran counter to this view.

Mr. Mithal gave a note of warning about spending money in pulling down and rebuilding works again and again and calling them 'experiments.'

Because of the hard times, Mr. Mithal suggested that it was time to make an attempt at standardization in the Irrigation Branch instead of allowing all sorts of designs to be tried. Enough data had been collected and some intelligent men should be appointed to frame rules for remodelling so that money would be more economically employed than at present. Some engineers were prepared to spend as far as Rs. 500 a cusec on remodelling while with a little forethought the remodelling might not cost more than Rs. 60.

Mr. **C. C. Inglis**, in a written communication stated that silt exclusion at offtakes depended on the proper control of curvature of flow in the parent channel. Nature's way of doing this is concave bend, which causes the bottom water containing the bed silt to flow across towards the convex bank, the relatively clear top water flowing straight on into the off-taking channel. There was a demonstration model at the Khadakvasla Hydro-dynamic Research Station near Poona which demonstrated the remarkable way in which silt could be controlled by curvature.

There are four main types of curvature controlling devices :—

(*i*) *Divide walls* which should not have any holes in them except for intermittent scouring, where required.
These created still* pond conditions, and hence flicked out bed water.

(*ii*) *Converging side*, which creates the same conditions as a concave curve, causing the bed water to move away from the side of the channel towards midstream.

* T. P. 52. G of B. P.W.D. "Factors affecting exclusion of bed silt from canals taking off from alluvial rivers."

(*iii*) *King's Vanes*, which prevent cross flow of bed water.

(*iv*) *Skimming devices—silt-ejectors*, etc.

Type (*i*) is especially useful at the Heads of canals which is the best place to exclude bed silt. This works well in canals also, but is fairly expensive. They can be designed to work well at all depths. This is the same idea as Gibb's though developed independently. If gates or undersluices are provided, these should be kept closed, when the offtaking channels are open ; and should only be opened as a temporary measure, the offtaking channels being kept closed.

Type (*ii*) was probably first used in the U. P. It was, however, developed independently in Sind.*

It is effective because it causes curvature of flow, the bed water being deflected towards midstream. Where maximum silt exclusion is required, the contraction should be upstream and not at the offtake.

(*iii*) King's vanes, when properly designed, are effective provided conditions are fairly uniform and flow axial. They are not desirable where conditions vary.

(*iv*) Having little experience of skimming devices and ejectors he would only say that it appeared that ejectors required less water to get rid of the same quantity of silt than any alternative device except desilting basins ; but that they were very sensitive and hence required very close supervision where conditions varied. Ample head must also be available to prevent the tunnels becoming clogged and a good fall downstream, to enable the silt to be carried away.

The Author's design was based on (*ii*) ; but was also related to (*iv*) and was therefore sensitive to small changes. It had the merit of being cheap, compact and easy to modify to draw more or less silt ; but where maximum silt exclusion was desirable, Type (*ii*) was better.

The Author had assumed that silt from water from the turbulence below a standing wave flume gave average results. This might be so with fine silts ; but was not the case† with coarse silts, which were carried along the bed.

The **Author** in reply to the discussion and correspondence said that Mr. Khanna's remarks were not in conformity with the views expressed in the paper. It was made clear in the opening remarks on the

* Bombay P. W. D. T. P. 26. "Report on model of a group of regulators at Oderolal, Rohri Canal, Sind."

† 1934-35 Annual Report of the Irrigation Research Division, Bombay.