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SCIENTIFIC DISTRIBUTION OF CANAL WATER AND THE USE OF AUTO-ADJUSTING ORIFICE DISTRIBUTORS.

By Radha Krishna Khanna.

Preliminary.

During the last ten years increasing interest has been taken in the problems of scientific distribution of canal water, and although great advance has been made over the old methods of open cut and simple pipe or barrel outlets, so far, no standardized method of water distribution of general applicability has been devised. It is true that by far the largest number of channels in the province, having passed through a prolonged experimental stage of trial and error now enjoy settled conditions of flow and distribution ; but this is not the result of clearly defined methods of distribution ; and even now on the oldest established canals instances are not wanting of perpetually dry tails and uncontrolled flooding and drought in the middle reaches. Shortage trouble in the tail reaches of some channels is almost recognised as an inevitable evil from which there is no escape. Attempts are often made to improve conditions of tails by silt clearance and berm trimming of channels in the head reaches, but such remedies are very short lived, and shortage trouble in its chronic form reappears almost as soon as the work of improvements is completed. Flooding of channels by forcing extra supplies at heads, beside being generally not permissible, hardly ever fulfils its intended object of benefitting the tails ; so that confirmed cases of shortages can very seldom be successfully tackled with the existing means at our disposal. In the old days when irrigation was not so dense and competition for canal water not so keen, the crude device of ' Tatiling ' of outlets served as a rough means of giving temporary relief to tails ; but such interference in the flow of channels is out of date now ; and must be avoided even at the risk of permanently dry tails. We must therefore devise some form of distributors of canal water which will ensure automatic equitable distribution from head to tails of channels.

Problems of distribution :

According to the existing system of distribution of water on the basis of irrigable area, equitable distribution consists in supplying each tract of large or small area with water fixed in quantity and proportional to the area of land, when the channel is running with its authorized full supply discharge at head.

The difficulties of distribution are greatly simplified by observing he principle of rotational full supply running of distributing channels hen the main canals or branches are running with short supplies. Thus ring low supply periods of main canals or branches their offtaking

channels will take their authorized full supplies in turns rather than all run together with short supplies. If with authorized supply running in a distributing channel at its head its supply and supply levels at various points of its length remain steady and constant, and if also free falls were available from the distributing channel into the zamindari watercourses, the distribution of canal water would be a very simple matter indeed ; for in such a case we would only have to calculate the sizes of outlet pipes for their authorized discharges and constant working heads. Conditions under which water distribution has to be effected are very different from these and have presented extreme difficulties. River water in different seasons of the year brings down varying quantities of silt in suspension. When heavily silt laden water enters the distributing channels the velocities of flow are incapable of carrying along all the silt in suspension, some of which deposits in the bed and sides of channels. On the other hand, during clear water days, the flowing water picks up some silt from the bed and sides of channels during its passage through them, causing scour in the bed and sides. Thus with the same quantity of water entering at the head of a distributing channel its supply levels vary with its seasonal silting and scouring, with consequent variations in the discharges of its outlets. Nor is generally a clear fall available from a distributing channel into watercourses, with the result that supply levels of watercourses which are ever varying with the levels of land being irrigated at any particular time, affect the flow from the distributing channels into the watercourses in varying degrees.

To ensure authorized fixed discharges of outlets flowing from the distributing channels into the zamindari watercourses under all the varying conditions of supply levels in the feeding and the delivery channels has been the aim of those who have interested themselves in the problems of water distribution in the past few years. How far they have succeeded in achieving this objective will be seen from the following brief descriptions of existing devices for water distribution.

The old pipe or barrel outlet which only forms a passage of water from the feeding into the delivery channel, and is affected in its discharge by all the fluctuations in the supply levels of both, is quickly dying out, so it need not be considered here as an existing device for water distribution.

The next improved outlet is what is called the standing wave or the open flume outlet. When the command is not too low this flume outlet altogether eliminates the effect of water surface levels of the watercourse from the calculations of discharge through the outlet, which is a function of the depth of water over the crest of the flume and its width of opening. The claim made for this type of outlet is that if its crest is built 1-10th of the designed depth of water above its bed the variations of discharge through the flume due to small variations of supply on the channel will be proportional, *i. e.*, if the supply in the feeding channel goes up or down by certain percentage of its authorized supply, the outlet will draw the sar

percentage more or less than its authorized discharge. This claim is not tenable because in arriving at this it is assumed that all variations in the supply levels of the channel are due to increase or decrease in its supply ; whereas the actual fact is that the supply in any channel is supposed to remain constant, and it is the seasonal silt or scour which without any increase or decrease in the supply causes considerable variations in the supply levels. Moreover in a deep channel the width of opening of this typet of outlet becomes much too narrow to be desirable from considerations of construction and its maintenance in an unobstructed state. If the crest of the flume is built much above the bed of the channel to keep the width of opening sufficient, then the discharge passing through the outlet will be subject to heavy fluctuations with even slight variations in the supply levels of the channel, nor will the outlet draw its proper share of silt. Thus this outlet is not much use as a scientific distributor of water in the head reaches of channels. It has only one use, and that a very admirable one of effecting proportional distribution of fluctuating quantities of water generally reaching the tail reaches of irrigation channels.

The adjustable proportional module may roughly be defined as a combination of the orifice and the flume outlets. Its raised crest and the splayed downstream wing walls make its discharge free from the effects of variations in the water surface levels of the watercourse by producing a standing wave ; so its discharge is dependent on the supply levels of the feeding channel only. As in the case of the flume outlet it is claimed that if the head on the orifice of this type of outlet is kept .3 of the designed depth of the feeding channel then the discharge variations of the outlet will be proportional to the variations of supply in the feeding channel. This claim is based on the same assumption as was pointed out in the case of the flume outlet. The argument for proportionality in the flume and this type of outlet is arrived at like this :—

Q or supply running in the feeding channel .. $K_x x^m$

q or the discharge through the outlet .. $K_H H^n$

dQ/Q .. m. dx/x

dq/q .. n. dH/H

R or the ratio of variation of the discharge through the outlet to the variation of supply in the channel is

dq/q/dQ/Q or n. x/m. H

m for ordinary earthen channels is taken as 5/3

n for discharge through orifice is 1/2

R is therefore $\frac{1/2.\ x}{5/3.\ H}$ or $\frac{.3x}{H}$

Thus for unit proportionality [illegible] H equal to .3x or set the top of the orifice at .3x from the water surface of the channel. If now

any variations occur in the supply levels of the channel these affect the discharge through the orifice to a much greater extent than would be the case if the orifice were set lower down in depth, *i.e.* if the proportionality were kept as much below unit as possible. If the variations in the supply levels and consequently the working head of the orifice of the proportional module were .1x in either direction, which is a comparatively low figure for seasonal silting or scouring, then the working head of the orifice will vary from .4x to .2 x and the discharge of the outlet will vary from 20% more to about 20 % less than the authorized discharge, while the supply entering the head of the channel remained constant. This is the correct position of the proportional modules in a scheme for the scientific distribution of fixed supplies of the perennial channels. On the other hand the proportional module like the open flume outlet will be of great use in the proportional distribution of fluctuating supplies generally reaching the tail reaches of channels, and also for the proper distribution of the varying supplies of the inundation canals which are required to run from about two third supplies during short supply periods to about one and a half times their authorized supplies in the floods.

Another point which is urged in favour of this type of outlet is its easy adjustability. This advantage like its proportionality is more imaginary than real ; becuse carrying out frequent adjustments by the generally available agency of the subordinate staff is more easily said than done. And even if, after careful observations of the water surface levels of the distributary, the necessary adjustments were carried out, there is no guarantee that the channel will not soon change afterwards and thus all the advantage of adjustments will not be lost.

Two other types, the K. G. O., and the Harvey Stoddard improved outlets, when the minimum head for their modular working is available, give discharges unaffected by the supply levels of the watercourses but varying with changes in the supply levels of the feeding channel.

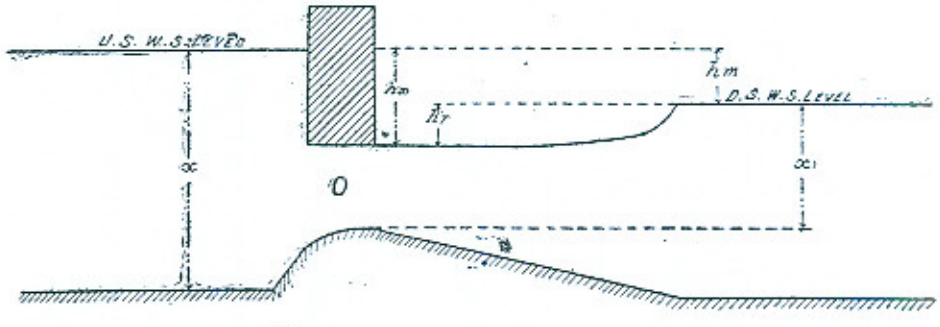
Two very serious drawbacks, beside its heavy initial and maintenance cost, have been urged against the K. G. O. viz. the excessive head required for its modular working, which inspite of rather ambitious claims of the makers is over 1/3 rd of the depth of supply in the feeding channel, and its extreme liability to interference by the zamindars who manage to draw greater than the rated discharge of the outlet by simply closing its air holes.

But inspite of these drawbacks the K. G. O. by reason of its low proportionality which is about ·37 with its normal setting of the centre of the orifice at ·8 of its full supply depth, and its consequent low sensitiveness to variations of supply levels in the feeding channel is perhaps an all round better outlet than [illegible] proportional office and standing wave type. The problem of distributi[illegible]erennial channels being the distribution of fixed quantiti[illegible]xed quantities, it is not quite clear how the unit prop[illegible]esults in wide variations of the discharges of outlets for comparatively small fluctuations in the supp

levels of the feeding channels, is intended to aid in the solution of the problem. The proportional outlets of any type built in the head reaches of channels are bound to cause extreme unsteadiness in the supplies reaching the tail reaches of channels ; so it is an unqualified disadvantage to build the proportional modules anywhere except in short lengths of the tail reaches where these will proportionately distribute the errors of regulations and distribution of the upper reaches. Taking the previous example of 1x variations in either direction in the supply levels of the feeding channel due to seasonal silting or scouring, the variations in the working head of a K. G. O. will be 12 % and in the discharge about 6% only against 20% variations of discharge of an adjustable proportional module. It is thus clear that the K. G. O. in proper working easily scores over the unit proportionality type as a scientific distributor of fixed supplies of the perennial channels.

The Harvey Stoddard improved outlet is essentially the same as the adjustable proportional module, except that it has not got the adjustability advantage, nor does it so much need it by reason of the comparatively lower setting of its orifice and conseqent lower sensitiveness to fluctuations in the supply levels of the feeding channels. The usefulness of this type of outlet as a scientific distributor of the fixed supplies of the perennial channels is increased by the lower setting of its oriffice ; but generally there is a very narrow field in this direction, because the lower setting of the orifice requires increased working head for the modular working of the outlet, and only a limited drop is in most cases available from the feeding into the delivery channel.

This will be better understood from the following simple statement of the working of the combined orifice and standing wave outlets :—



In the accompanying sketch h_w is the head on the orifice or the head or column of water which imparts velocity to water going through the orifice O ; so that the discharge through the orifice is a function of this column of water and the area of the orifice. The jet of water coming out of the orifice with a certain velocity comes against the depth of water x_1 of the watercourse which tends to check this velocity. As this rushing is checked in its flow it tries to jump up, or in other words some of the ocity is re-converted into the head or column of water from which it s originally created. The extent of recoversion of the velocity depends

on the smoothness or gradualness with which the jet of water comes into contact with the column of water in the watercourse. An abrupt or rough contact results in eddying and disturbance with little or no re-conversion of velocity into static head ; whereas a smooth and gradual contact, resulting in the formation of a standing wave away from the mouth of the orifice, might lead to the re-conversion of 50% or more of the velocity into the equivalent head or column of water. This is called recovery of the head and is denoted by h_r on the sketch. When h^r represents the utmost amount of recovery possible under one set of conditions then the difference between h_w and h_r or the actual drop from the feeding channel into the watercourse denoted by h_m on the sketch is called the minimum modular head for that outlet.

If the drop from the feeding channel into the watercourse is less than the necessary h_w or the combined depth of water of the emerging jet, and h_r of the recovery head is less than the column x_1 of the water course the jet is pressed back towards the mouth of the orifice, the standing wave disappears, and as the watersurface of the watercourse is touching the mouth of the orifice at its lower end, the discharge of the outlet depends on the difference of levels of water in the feeeding channel and the watercourse, and is evidently liable to variations with fluctuations in either upstream or downstream levels. Thus for modular working of this type of outlet, *i.e.*, for independence of its discharge from fluctuations in the watersurface levels of the watercourse it is necessary that column x_1 of the watercourse should be less than the combined depth of the jet of water and h_r of the recovery head, or in other words h_m should be sufficient to satisfy the above requirement.

About 60 % of the head on the orifice h_w is all that is recoverable by bringing about a smooth contract between the emerging jet and the column of water x_1 of the watercourse ; so that the minimum drop h_m necessary for the modular working of this type of outlet is 40 % of h_w. If, therefore, the orifice is set very low h_w will necessarily be very large fraction of the depth x of the feeding channel, and consequently h_m which is 40 % of H_w will also be a very large percentage of the depth of water in the channel. For example for the unit proportionality setting of the orifice, or the setting of the top of the orifice at ·3 x below the watersurface level of the feeding channel, the minimum drop necessary for modular working of the outlet will only be 40 % of .3x or .12x only ; whereas with the setting of the top of orifice at ·8x below the watersurface level, which is necessary to lower the sensitiveness of the outlet to the normal value of a K. G. O. the minimum drop necessary for its modular working will be 40 % ·8x or ·32x ; or one foot drop for a supply channel of three feet depth. Thus for low sensitiveness for this type of outlet excessive drop is necessary for modularity.

From the foregoing brief mention of the more important types outlets in use in the province it will have been seen that whereas all improved outlets eliminate from their working the effects of variat. of supply levels in the delivery channel, none of them is independen

variations in the supply levels of the feeding channel. The unit proportionality outlets are extremely sensitive to fluctuations in the supply levels of the feeding channels, whereas the K. C. O. and the improved Harvey Stoddard outlets which achieve greater steadiness in their discharge require so much working head for their proper working that their adoption on a large scale is not possible.

We, therefore, want some type of distributor which will be immune in its working from the effects of fluctuations of supply levels both in the feeding and the delivery channels, and which will at the same time take its proper share of silt, and be simple in form and require a low working head for its modular working.

Some engineers will favour particular types of outlets for the simple reason that when such outlets were installed on certain channels the long-standing trouble at the tails ceased. The temporary ceasing of trouble after prolonged trial and error, although it may speak highly of the perseverance of the officers concerned against great odds, is no indication of the efficacy of the type of outlet used, unless it could be established that the feeding channels were getting only their authorized supplies at heads and that all the outlets got their correct discharges all the year round. In ordinary phraseology the trouble at a tail may have been considered to have ceased when some water began to go there where none went before. Themethods adopted for sending water to tail may have included the not uncommon unreasoning and drastic reductions of the upper outlets. It is, therefore, clear that some more tangible arguments, both theoretical and practical, about the efficacy of outlets as correct distributors of canal water are called for than the mere so-called ceasing of trouble at the tails, which may after all have been a temporary phase of the channel after fresh silt clearance and berm trimming.

Simplicity of construction, comparative freedom from chances of obstruction or interference by the zamindars, low cost and little or no maintenance or care, very low working head for its modular working, and above all its very easy adaptability for adjustment to give varying discharges and to take any required quantities of silt, are the distinguishing features of the 'Auto-adjusting orifice distributor' which I have devised for rendering accurate distribution of canal water entirely automatic.

The device consists of an ordinary pipe or barrel of masonry, cast iron, concrete or wood, with swinging-weight pockets built on the sides as shown in the accompanying sketch. Inside the barrel is a swinging vane rigidly fixed to a horizontal bar, on the other side of which and at the required particular angle with the direction of the vane are fixed two counterweight suspension rods. At the lower ends of the suspension rods are suspended two counterweights, calculated for the required discharge and the necessary range of workingheads over which the orifice is intended to give its fixed discharge. The horizontal bar, with the vane and suspension rods fixed to it, is capable of rotating freely between the two bearings which are fitted in the vertical walls of the barrel at a required distance below its roof.

With the rotation of the horizontal bar within its bearings, the vane swings inside the barrel, and the suspension rods and counterweights inside the counterweight pockets.

Now when this device is built at a distributary head or is used as an outlet on a channel, water passing through the barrel presses the vane with a force equal to the working head of water at the mouth of the orifice. The pressure of water acting on the vane exerts a turning moment on the horizontal bar, and as the weights are suspended from the horizontal bar by means of rig dly fixed rods, the weights move up as the vane is pressed down.

As the weights move out from the vertically hanging position they exert increasing turning effort on the bar in the opposite direction to that of the pressure on the vane, so that at any particular moment the vane and the counterweights rest in a position in which their respective turning moments balance each other. With increasing working head the free end of the vane is pressed lower, and cuts off area of opening of orifice to the required amount.

I have designed and experimented with orifices to give constant discharges for ranges of 1-4, 1-6, and 1-10 of working heads ; the lower limit of the range being any suitable unit, and the upper limit its given numerical multiple. Thus an outlet of 1-4 range could be designed to give constant discharge from ·5 to 2 ft. or 1 ft. to 4 ft. working heads and so on. The calculations and design of the orifice are very simple and will be understood from the following diagrams. Figures 1, 2 and 3 represent the shapes of the vanes and the action of the area adjusting mechanism of the distributors of the above three ranges, whereas the figures 1_a, 2_a, and 3_a are the curves of areas of the three ranges ; the black line curves being the reciprocals of square roots to show the areas of orifice required to give constant discharges at varying working heads ; and the dotted line curves being the areas of orifices actually obtained from calculations of the designed distributors.

The turning moment of the pressure on the vane about the rotating horizontal bar varies as the working head on it varies, and the turning moment of the weights varies as the horizontal projection between the pivot point and the centre of suspension of the weights ; so that equal horizontal divisions between the lowest and the highest positions of the weights represent the positions of equilibrium of the adjusting mechanism at equal intervals of working heads. On the three figures 1, 2, and 3 positions of equilibrium of the adjusting mechanism at unit intervals of working heads are shown. The length of the vane depends on the required maximum reduction in the area of opening of the orifice, and the counterweights are calculated by equating the turning moments of the counterweights and the pressure on the vane about the pivot point in any position of equilibrium ; allowance being, of course, made for the effect of buoyancy of water on the counterweights.

It will be observed that for constant discharge the area of the orifice is required to vary inversely as the square root of the working head, whereas in a rectangular orifice, the section I have adopted, the variations of the area due to the turning of a flat rectangular vane about a fixed horizontal pivet will be as the sines of angles turned, and both these variations do not follow the same law. The variations of area of the orifice due to the turning of the vane could be made to agree approximately with the required inverse square root variations either by changing the section of the orifice from the rectangular, or by setting the vane and the rods at suitable angles, turning the ends of the vane as shown in the figures, fixing the position of the horizontal pivot at a suitable distance below the top of the orifice, and by giving suitable side clearance between the vane and the vertical walls of the orifice. I have adopted the latter method to conform the actual variations of area to the required amounts, in order to retain the simple rectangular shape of the orifice, and to avoid complicated calculations.

The actual curves of areas of orifice for varying working heads obtained by the above device of setting the vane and the rods at suitable angles, etc., closely follow the required inverse square root curves except in the beginning of the range, when the actual area of opening of the orifice is 80% to 90% against the required 100 %. But the actual discharge is more than 80 % or 90 % of the required discharge, because owing to friction the vane is not pressed down sufficiently at low working heads, and consequently the area of opening and the discharge is more than the calculated figure. Moreover this discrepency does not much matter, because we can accept the orifice to begin to give correct discharge at a little more than the minimum range of its working heads ; *e.g.*, for an orifice designed for ·5 to 2 ft. we may accept it to be correct from ·6 to 2 ft. and so on.

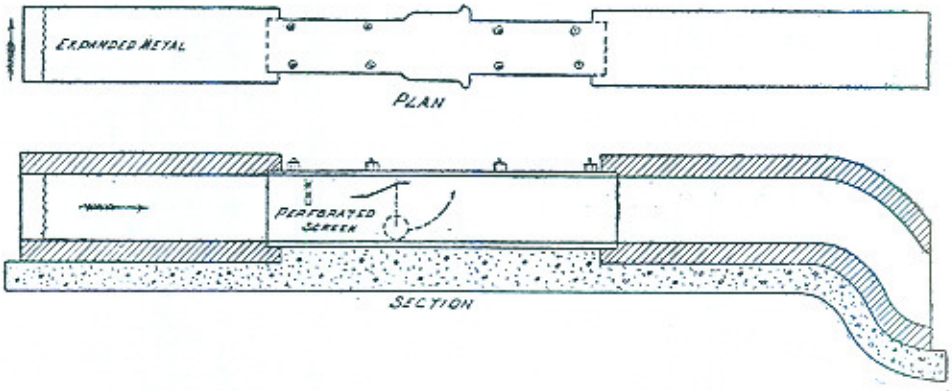
The weights of the mechanism of the orifice of 1-10 range have been calculated so that the total reduction of the orifice takes place between 1-7·5 units of working heads after which the area of the orifice remains steady. As the working head increases, less and less reduction in the area of the orifice per unit increase of working head is necessary to keep constant discharge. This fact has been taken advantage of in designing the large range orifice by effecting the total reduction of area between 1-7·5 units of working heads, in order to keep the curve of areas close to the required inverse square root curve.

The theory and design of the orifice distributor have been explained above. For the practical installation of this orifice as an outlet it is suggested that castings two to three feet long and fitted with the vane and counterweights be built in the middle of the banks of channels, the remaining portion of the barrel being built in masonry as per sketch given below. The adjusting mechanism being in this way six or seven feet away from either ends of the outlets, and being also hidden from view when the channel is dry, will not be at the disposal of zamindars for unauthorized interference. To prevent the possibility of the vane being

pushed up from the downstream end, the masonry end of the barrel is given a curved shape as shown in the sketch. No advantage can be derived by pushing the vane from the upstream side so the upstream end of the masonry barrel is kept straight.

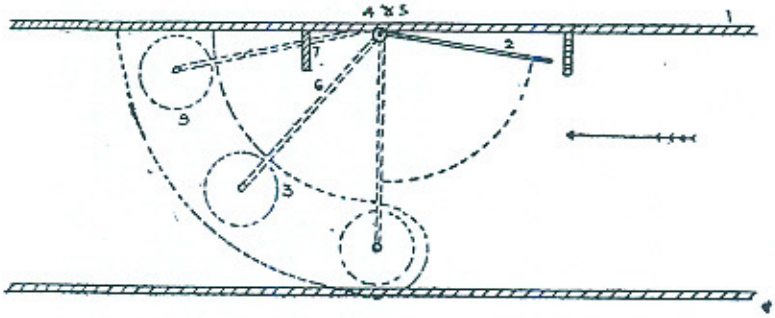
It is important to keep out large jungle from the orifice, and for this purpose a piece of expanded metal is built in front of the opening. The upstream end of the opening is built with a slight curvature as shown in the sketch, to prevent jungle accumulating in front of it.

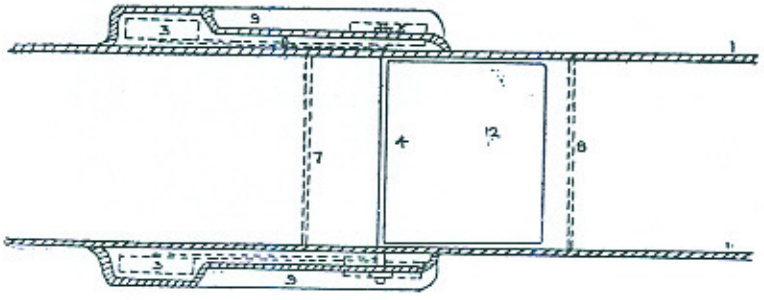
The roof of the casting is detachable to permit access to the orifice adjusting mechanism for readjusting its weights to increase or decrease its discharge if necessary without dismantling the whole outlet.

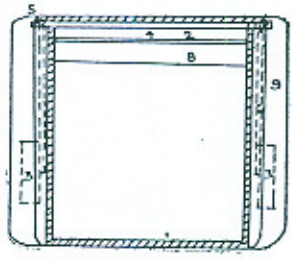


From the above description of the construction and design of the outlet it is clear that there is practically nothing in its mechanism which could go wrong or be interfered with. For distributing fixed supplies of the perennial channels it would constitute a positive advance over the present methods. The inevitable errors of rough discharge tables of channels will be eliminated ; the gauge reader terror will disappear ; and the ever present menace of remodelling and reduction of outlets will no more make the lives of zamindars perpetually miserable. The simple and unpretentious design of the device will, I believe, be its recommendations ; and I hope a fair trial will be given to it by installing it on a number of channels and nothing results.

SKETCH DRAWING
OF
AUTO-ADJUSTING ORIFICE DISTRIBUTOR







1. PIPE OR BARREL.
2. SWIMING VANE.
3. COUNTER WEIGHT.
4. HORIZONTAL BAR.
5. BEARINGS.
6. COUNTER-WEIGHT SUSPENSION RODS.
7 & 8. VANE PROTECTION STRIPS SWIMING WEIGHT POCKET.

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ASSISTANT ENGINEER
MUZAFFARGARH CANAL DIVISION

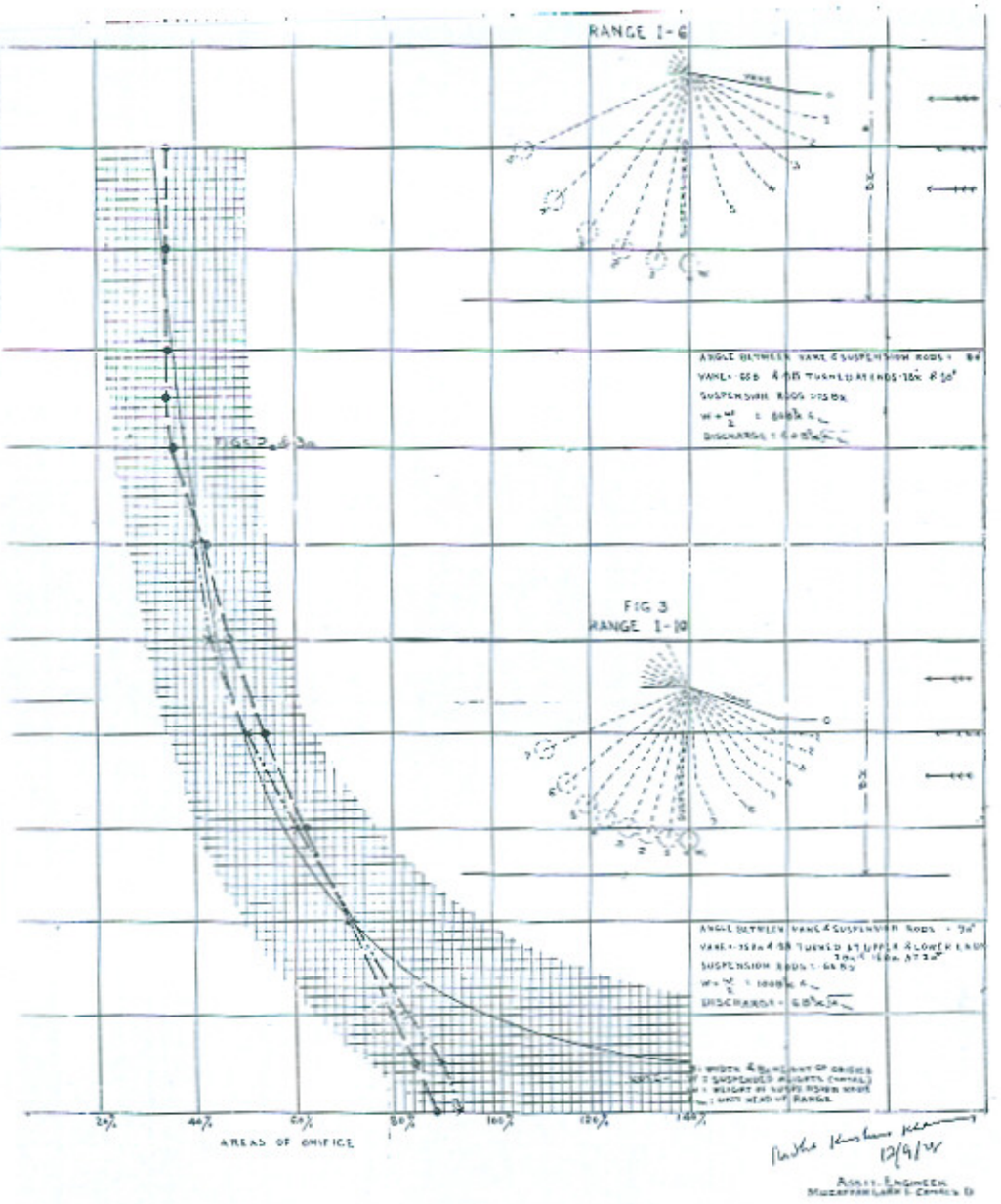
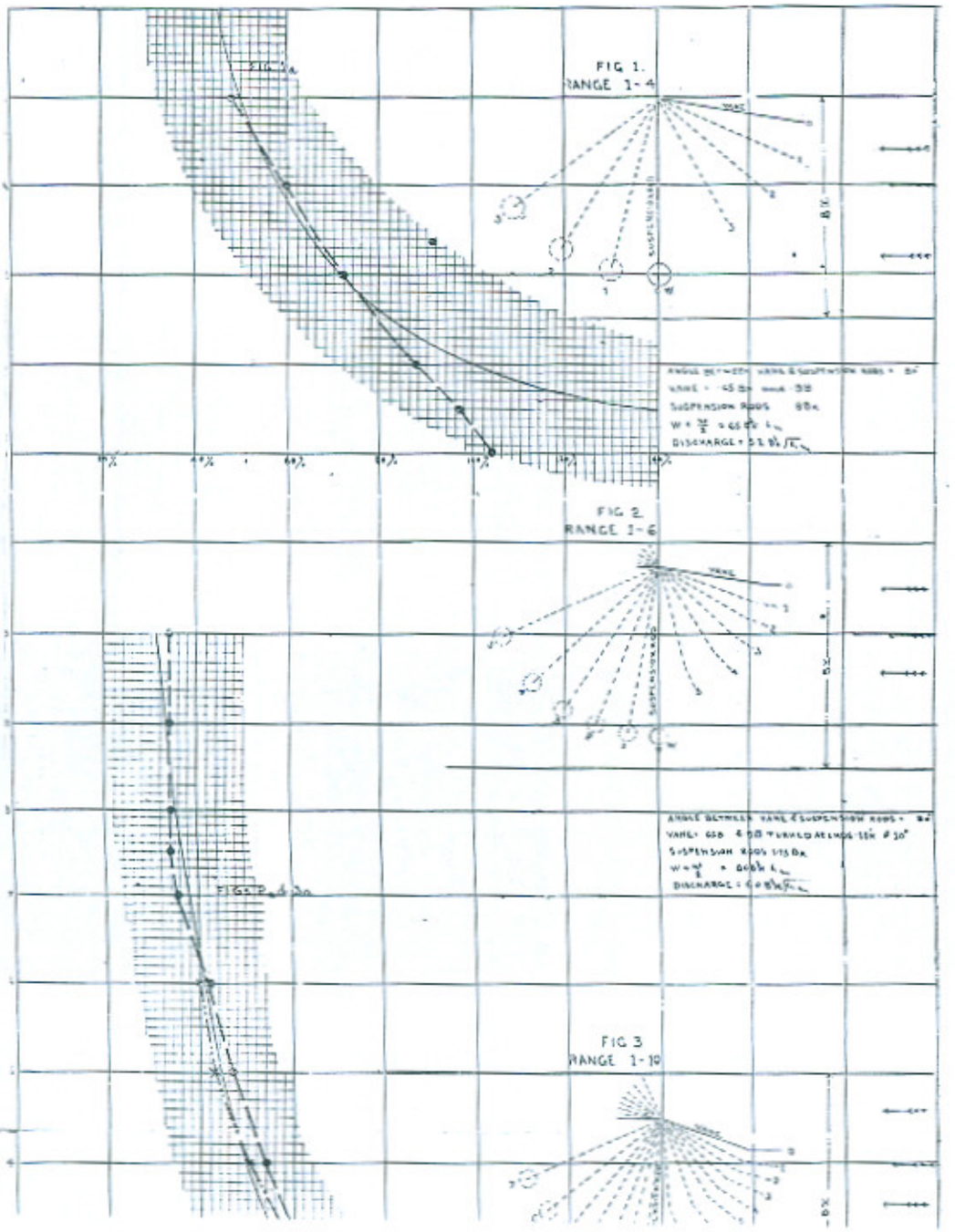


FIG 3

DIAGRAMS & FORMULAE FOR AUTO-ADJUSTING ORIFICE DISTRIBUTORS



DISCUSSION.

MR. RADHA KRISHNA KHANNA, in introducing his paper, said that his paper perhaps lacked a detailed description of the device and he, therefore, exhibited models and diagrams which he described. Some might doubt the ability of the simple flap hanging from the roof of the orifice to fulfil the function claimed for it, but a demonstration of the working of the device had been given by the speaker to Engineers at Bahawalnagar.

Others would question the necessity of a constant discharge distributor on perennial channels. This school of thought holds that the errors of regulation in channels cannot be avoided, resulting in varying supplies entering the heads of distributaries and minors, and in view of this they regard exact proportionality as a cure for all difficulties in water distribution. It would be difficult to convince such people that the unit proportionality or any proportionality idea was incompatible with the requirements of even distribution of water from head to tail on channels.

In order to convince such dissentients of the truth of the speaker's assertions he could not do better than refer them to the various causes of regime changes in channels mentioned by Mr. Crump in his very valuable paper on the moduling of irrigation channels. The advantages of the constant discharge distributor over the proportional type would be evident from the fact that after fitting constant discharge distributors, all the various causes of regime changes can be ignored with confidence that such changes would not affect proper distribution one way or the other.

Shortage in the tail reaches of channels presented difficulties which were really incapable of a permanent solution so long as the department did not get rid of the idea of proportionality of water distribution in the head reaches.

Constant discharge distributors would have yet another important advantage on the Sutlej Valley Canals, where shortages during the winter months were bound to occur and rotational restrictions would be stringent. On these canals constant discharge distributors would be indispensable.

L. BHIM SEN said on page 76 and 77 the writer says that the outlets have been designed independently of the supply level in the watercourse, but none of them is designed to be independent of the variation of the supply level in the parent channel. In this connection he appears to have ignored the well-known Gibb Module. The discharge of this Module is independent of the supply levels both in the parent channel and in the watercourse within all practical range of variation. Gibbs Module is much simpler, compact and immune from tampering than the proposed device.

This device appears to be after the well-known design of Kennedy's Gate Module and there is no difference in principle between the two. The counterbalance weights in the case of Kennedy's gate move on roller wheels on an inclined track and are above the water and hence any source of error due to buoyancy as indicated by the writer at bottom line of page 78 is eliminated and the bearings being above water are free from any possible corrosion. Even these gate modules, however, enclosed in rooms and under supervision were not very successful and have been mostly replaced.

From experience in a division which contains all sorts of outlets, it can be said that very few types are immune from tampering at the hands of zamindars. The proposed device which depends for its working on counterbalance weights offers less prospect of immunity than the types in use. Gibb's Module is a fool proof outlet and nothing short of that will be a success in practice as a rigid or positive module. Shahkot Distributary in the Upper Gugera Division is 30 miles long and is fitted along with Gibb's Module, and as far as rigidity of modules is concerned is working very satisfactorily. Authorised discharge at head is giving authorised discharge at tail.

Mr. Lacey remarked that had the title of the paper been "A new positive module with moving parts" it would have made it more easy to criticise the Author's paper without entering into the somewhat vexed question as to the place of modules, and semi modules both of the orifice and flume type in a scientifically designed distribution system. Mr. Lindley had already discussed the pros and cons of the subject in a very able paper presented to the Congress. and so far as he was aware little had been added to that branch of the subject since its publication. Whatever personal view was held as to the precise applicability of a given type of module to a given situation the general concensus of opinion was that a use could be found for any of the three types of modules in a well designed system and that none should be used without discrimination.

The Author was to be congratulated on producing a simple form of positive module that functioned with a reasonable amount of accuracy. It had, however, the disadvantage of moving parts and was, therefore, more likely to give trouble than the Gibb's which had no moving parts and had now been further developed by Mr. Inglis in Bombay. The Author's brief description of existing devices for water distribution was in his opinion too brief to do them justice and he, therefore, advocated a reference to Mr. Lindley's paper if fuller information was desired.

Mr. Bihari Lal Uppal endorsed the usefulness of a constant discharge outlet but considered that the Author's design did not achieve his object particularly at the beginning of the range.

This was not surprising in view of the fact that the device does not secure an orifice area correctly proportional to the inverse of the square root of H.

However, the Author's calculations showed that by using the side clearance the discharge remains fairly constant except at the beginning of the range.

In spite of its defects, however, he considered that the outlet would be useful where constant discharge is wanted.

But the writer in his examination and criticisms of existing types tries to show that they are inferior to his device, the exclusive use of which he advocates provided constant supplies are received at the heads of channels. He thus starts with the assumption that with constant discharge at the head of the channel, the supply levels will vary with seasonal silting and scouring. How far such variations in supply levels of a channel will actually take place, the writer has failed to establish. In the speaker's opinion with constant discharge running at the head of a distributary and with control points suitably distributed along its length there would be no appreciable variations in the supply levels of a channel.

The Author's outlet would thus only be useful on a channel which is getting *fixed discharge at head*. But on such a channel with the existence of control points there can be practically no variation in supply levels, and, if any occurs the utility of the outlet vanishes.

The writer admits that his outlet is unsuitable for installation on an inundation canal, where supplies may have to vary from 50 per cent. to 150 per cent. of the authorised discharge. If the postulated fixed discharge is exceeded, the auto-adjusting outlet will be unable to take anything more than its designed discharge with the result that the tail will be flooded. If, however, discharge at head is defective with upper outlets will take their full share, the tail will get all the shortage.

Even when the channel is taking constant discharge, cases will not be wanting when on account of slack demand, the zamindars will close some of the outlets with the inevitable result that excessive supply will go down to the tail and may damage the tail reach so seriously that it may not be possible to repair it during the season without destroying the crops.

Thus it is apparent that the installation of this autoconstant discharge outlet on a channel throughout its length will cause more harm than good.

On the other hand, the use of the Open Flume Outlet, with a proportionate setting specially, on the tail reaches of a channel is fully established by this time and it cannot be denied that in many cases with the provision of flumes or control points in a distributary, the trouble of short supply at the tail has entirely vanished.

Thus overlooking the defective calculations already pointed out and admitting that the outlet can be made perfect by further finer calculations the Auto-adjusting Outlet can be useful only in odd places such as :—

(*i*) in a branch canal subject to variations in supply,

(*ii*) above a stop dam or a regulator in the parent channel, where heading up may be necessary to feed an offtaking channel.

The speaker considered that the outlet was far from being simple in construction and as the writer had not so far got the outlet produced on commercial lines he could have no idea of the actual cost.

The writer also claims that his device cannot be obstructed or interfered with by the zamindars, but it is hard to imagine that it will be so immune from interference. On the other hand, it is apparent that if any interference takes place either in pushing the vane up or alterations to the counterbalance weights, it will not be easy to detect it.

MR. COLYER said that the last time he saw a Kennedy Gate Outlet was in 1904 (speaking from memory). It was practically the same as the one presented now and the former had not come into use, there was no likelihood of this outlet coming into, use as it was not an improvement on the Kennedy's.

He went on to say that the whole question is whether a fixed or a proportional module is required. Opinion was divided into various schools of thought as the practice in various provinces was different.

In the Punjab channels are run full supply which does not need a rigid module. There are in all rivers and in all canals periodic variations of supply which are beyond control and for this reason he personally was an advocate of the proportional module similar to the A. P. M.

MR. NICHOLSON said he did not approve of the application of devices such as Mr. Khanna's channels from head to tail. He considered that in any case the Gibb's Module, the Open Flume Outlet, the K. G. O. and the A. P. M. were pereferable to Mr. Khanna's invention.

He also said that the name of the outlet as given in the paper is too long and unwieldy.

He wanted to know what was the minimum working head of the outlet and added that in his opinion Gibb's Module gave the least 'minimum working head' of any type.

He also referred to the moving parts of the model and said that they were by no means easy to operate and simple as was claimed in the paper.

MR. KHANNA replying to the discussion said that the mere fact that he has given a longish name to the outlet was no argument against the device itself. Before replying to the individual criticisms he would like to dispel the wrong impression of certain members who thought that he had advocated constant discharge outlets to be fitted on the channels from head to tail. He had clearly stated in paragraph 1 on page 173 of the paper that the unit proportionality flumes were admirably suited for the distribution of supplies in the tail reaches of channels. This applied equally to the tail reaches of distributaries, canals and branches, in the head reaches of which constant discharge outlets were fitted. He said that the main object of his discussing at length in his paper the various types of existing outlets was to remove the wrong impression from the minds of people that the unit proportionality, or

any proportionality theory, other than the constant discharge distribution principle was suitable as a basic principle for the scientific distribution of the fixed supplies of the perennial channels.

As to individual criticisms, Mr. Bhim Sain had said that the Gibb's module was a simpler, better and more compact type of outlet, and that these were working successfully on the Shahkot distributary in its thirty miles length, so much so that if 2 extra cusecs were put in at its head these reached the tail. And yet he said the constant discharge outlets were generally not adopted because the proportional outlets were better. Mr. Khanna said that at the time of writing the paper he was not aware that any type of constant discharge outlets were existing on any channel in the province, but if so, and if they were better or simpler than his device they should be adopted. Personally he thought that since the Gibb's Outlet had not been adopted for so many years there must be something wrong with it. For instance it may not capable of carrying silt or it may require excessive working head for its modular working. As regards simplicity and freedom from being tampered with by the zamindars Mr. Khanna said he did not know anything about Gibb's outlet but his module with a flap hanging from the roof of an orifice was simple enough and with the orifice adjusting mechanism situated in the middle of a 10 or 12 feet wide bank and the bent downstream end of the orifice it was very unlikely to be tampered with. It had been suggested that the outlet was similar to the well known Kennedy gate module. This he denied. The Kennedy gate involved mathematically calculated curved grooves about the calculations of which no body knew anything. This fact was deplored by Mr. Lindley in his paper on water distribution. In the present module the vane was hung from the roof and the counterweights swung freely; so that it was not a copy of the Kennedy module gate.

Mr. Bhim Sen also said that the buoyancy of water acting on the counterweights introduced an error into the working of the outlet. This was wrong because the buoyancy had been provided for in calculating the counterweights.

Mr. Behari Lal said that the idea of a constant discharge outlet was commendable but he has questioned the suitability of this design. He is doubtful if the device is accurate over its full range; he suspects inaccuracies resulting from the side clearance, he says it is unsuitable for inundation canals owing to its complicated construction and states that its cheapness has not been established. The inaccuracies in the beginning of the range are more theoretical than real because as has been stated in the paper on account of friction the vane does not respond to the pressure fully in the beginning of the range with the result that the area of orifice opening is more than the calculated figure, and so the discharge remains constant from the very beginning of the range. This was demonstrated by him at Bahawalnagar where a tank nearly 3 feet deep was emptied by means of this outlet at an absolutely constant rate of

discharge. The side clearance had been provided for in the calculations of the size of the outlet. He agreed that the outlet was not suitable for inundation canals. As regards its simplicity and cheapness there was nothing complicated in the device and a small casting of the outlet could not cost more than 10 or 12 rupees. Of course the control arrangement was to be made of cast iron the rest of the outlets being built of ordinary masonry.

Mr. Lacy had objected to the title of the paper and did not follow to whom the menace referred to by the writer of the paper applied. The menace was of course to the peace of mind of the zamindars who are always in fear of their outlets being reduced in size in the frequent remodellings which now take place to send water to the tails.

Mr. Colyer thinks that the A. P. M. is a stream-lined adjustable outlet the setting of which can be varied at will. As has been stated in the paper there is a very narrow limit to the lower setting of the A. P. M. type of outlet, and a very heavy price in the shape of increased working head has to be paid for the low setting of these outlets. Unlimited command is not always available so the type is not suitable for the constant discharge distribution of water.

Mr. Nicholson also objects to the name of the outlet, and also raises an important consideration as to the minimum working head required for the modular working of the outlet. As can be easily understood no more working head is required than for the passage of water through an ordinary orifice. The vane comes into action only when there is excessive working head and so really no extra working head is required for this outlet. A simple working part like the one fitted to this module should not be a serious objection.