Control Effect of Flow through Perforated Inlet Diffuser in the Rectangular Settling Tanks. II. Experimental Investigations

By

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The experiments were carried out using a model inlet of the settling tank in order to confirm the theories derived in the previous paper¹⁾ and also to check the accuracy of the approximate method of calculation. Experiments were conducted for two types of inlet chamber, those in which the inlet conduits are parallel and perpendicular to the diffuser walls, respectively. The rate of distribution of flow along the diffuser walls was observed, and the results of the experiments are discussed in detail. The relative values of calculated flow distribution were compared to the observed values and found to be in good agreement, so that the control effect of flow through the inlet diffuser wall of a rectangular settling tank has been clarified, and the design criteria suggested by the theory have proved quite useful in the actual design of basins.

Furthermore, some discussions on the law of similitude for this model test are presented.

1. Introduction

With respect to flow in a settling tank or grit chamber, including the effect of a diffuser wall, and improvements in their hydraulic conditions, many researchers have sought to increase the volumetric efficiency of the basin by various kinds of tests with prototypes or models. Most of those previous experiments, however, were forced to adopt the tracer method to find the actual flow-down period of water fraction compared with the nominal detention period, due to the very low velocity of flow in the basin. Any tracer substance is, usually, introduced at the inlet zone of the basin and watched or analysed at the outlet only, so that the factors to be examined seem to have insignificant roles for the experimental purposes. Therefore, the decision to provide some form of an accessory device might prove to be a contribution to the designer's subject regardless of the fact that a number of experiments have already been performed for similar cases. It may due to the fact that most of the researchers adhered only to the

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regulation of flow in the sedimentation chamber that they did not attempt to clarify the significance or basic effect of every training device; in other words, they tried to improve directly the combined phenomena of inlet disturbances, diffusing action of accessory device, flow transition in the settling zone, and draw-off by outlet.

This series of papers will discuss the flow controlling mechanism of the diffuser and the velocity distribution along the diffuser wall in a rather restricted sense, for the above mentioned reasons. It is desirable to conduct such experiments to verify directly the results of analyses. The flow behaviour in the inlet chamber and the flow distribution along the diffuser wall are expected to show very delicate changes according to previous calculations¹⁾. Therefore, if the phenomenon in the test apparatus is affected by some unexpected factors, the actual influence of the diffuser wall may be difficult to detect, and consequently, the judgement as to the validity of the theory may become uncertain.

For the above reasons, a test inlet chamber without a settling zone was prepared and some other techniques were used in order to actualize the assumptions made in the theoretical calculation as faithfully as possible.

2. Experiments with a Rectangular Inlet Chamber and an Inlet Diffuser adjacent to the Side Wall of the Inlet Channel

As discussed in the previous paper¹⁾, if the inlet channel is parallel to the diffuser wall and its width is equal to that of the inlet chamber, the formulas²⁾ obtained for pressure flow in a uniform pipe with uniformly perforated outlet orifices will generally be directly applicable except for the narrow transition region which may exist near the entrance of the inlet channel. One of the writers has already verified the validity of this formula by laboratory tests and plant observations³⁾, so appropriately the theoretical formulas for flow in the inlet chamber will be accepted for the present case as representing the actual phenomenon well.

The test inlet chamber, 70 mm wide and 685 mm long with λ (the ratio of width to length of the chamber) 0.102, was constructed partitioning off a part of a polyvinyl-chloride tank, $700 \times 1{,}500 \times 150$ mm, by the diffuser wall. This experimental apparatus is illustrated schematically in Fig. 1 and is named "Apparatus I". As was assumed in the previous practical calculation, three longitudinal training walls were inserted in the connecting channel in order that the value of α_m (correction factor of the momentum of mean flow in the direction along the diffuser wall due to lateral velocity distribution) and σ (the ratio of velocity $(u)_{y=l}$ to mean velocity $U=\left(\int_0^l u\,dy\right)\Big/ l$, see Fig. 1) be nearly unity. 1,050 circular holes each of diameter 4.5 mm, were made at equal intervals of 10 mm along lines in both the vertical and horizontal directions, on the diffuser plate which was 685 mm long, 10 mm thick and about 150 mm high. The nominal opening ratio of the perforation e, is, therefore, 15.90%. Tap water is introduced to the chamber from the head tank at a constant rate of about 1,000 ml/sec and the water depth in the chamber was kept about at 7 cm by adjusting the control valve.

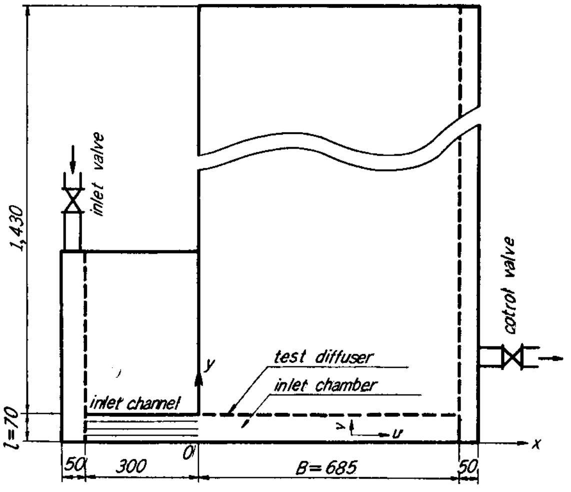


Fig. 1. Schema of test inlet chamber with an inlet diffuser adjacent to the side wall of inlet, Apparatus I.

In order to compare directly the calculated results with those of the experiments, it was necessary to measure the transversal velocity distribution exactly at the inner or outer side of the diffuser. The sectional mean value of the velocity through the diffuser section is $1{,}000/(68.5\times 7)\cong 2$ cm/sec for the present case, the magnitude of which is of the same order as for the prototype. Because such a low velocity is to be measured, previous researchers have often measured the distance which a dye or other tracer substance moved during some definite time interval. In case the tracer method is adopted, however, it must be noted that differences in density and molecular diffusion between the tracer and water fraction will affect the measurements. Furthermore, the longitudinal mixing or dispersion of dye or tracer cloud must be taken into account, and therefore the immediate effect of the flow controlling diffuser will be difficult to evaluate.

Thus, accurate measurement of a slow velocity of flow is, one of the important problems for further research, and in this case the resistance-type hot wire method(4) was adopted. This consists of a platinum pick-up held at the centre of a protecting cylinder, 40 mm in diameter and 70 mm long, and two galvanometers. In the experimental procedure, the pick-up is submerged in the steady velocity flow and is first charged with a faint current; the current is then increased by a definite amount, and the change of the current in the auxiliary circuit gives the required velocity when referred to a prepared calibration curve. If the pick-up is set very close to the diffuser wall, the measured velocity values might be rather scattered since even, slight change in the measuring position along the wall will affect the result due to the effect of the eddy currents which may occur near the wall by the jet action through the perforated orifice. Thus, in the present experiments, the controlled velocity at a constant distance downstream from the wall was measured, with one end of the protecting cylinder contacting the wall. Even under such circumstances, the effect of the jet flow through the orifice is still thought to influence the results since values two and three-times more than the calculated mean velocity were observed. The instrumental error including the calibration of this meter is inevitable, but the measured velocities change smoothly along the wall, so that, they are assumed to be proportional to the actual values at just the downstream side of the wall. Therefore, the relative values of flow distribution, r, can still be calculated using the individual and average values of the measured velocities.

Fig. 2 shows an example of the experimental results in comparison with

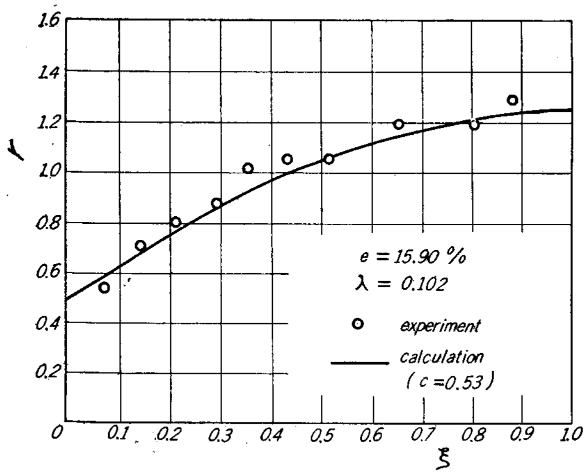


Fig. 2. Experimental result of relative distribution of flow for Apparatus I, compared with the calculated curve.

the theoretically calculated curve of r, with fairly good agreement when the discharge coefficient at the orifice, c, is taken as 0.53. Accordingly, in this case the effective opening ratio of the test diffuser wall, ce, is considered to be equal to $15.90 \times 0.53 \fallingdotseq 8.4\%$.

Although the flow behaviour in the same inlet chamber was observed by only dozing the dye, the regularity of the streamlines except for the region of small circulation near the corner $x=B$ and $y=0$ in Fig. 1 may be regarded as satisfactory for the assumption of linear change of (v/u) versus y.

3. Experiments with a rectangular Inlet Chamber and an Inlet Channel perpendicular to the Diffuser Wall

(1) Experimental Apparatus

Fig. 3 illustrates the test inlet chamber with an inlet channel perpendicular to the diffuser wall named "Apparatus II". The chamber is 600 mm long, 200 mm wide, about 70 mm deep and the width of the inlet channel is 200 mm, which has the same geometric proportion as the assumed numerical example calculated in the previous paper[5], w (the ratio of the chamber length to the inlet width) is 3 and λ 1/3. The flow introduced from the constant head tank is led to the chamber through the stilling basin and inlet channel.

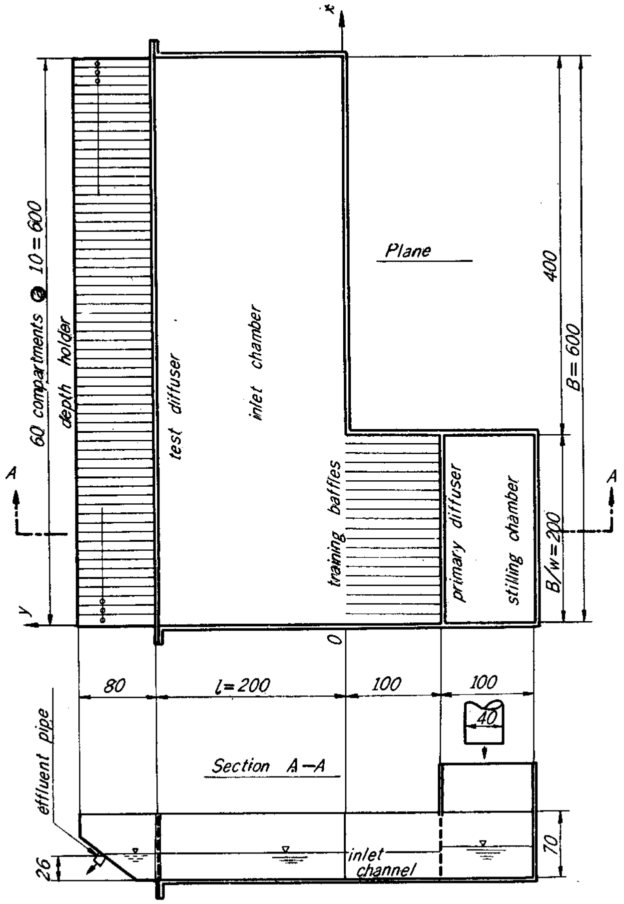


Fig. 3. Test inlet chamber with an inlet diffuser perpendicular to the inlet, Apparatus II.

At the connecting section between the stilling basin and inlet channel, a perforated primary diffuser wall was provided with about 7% total opening ratio with a number of 3 mm dia. holes spaced 10 mm apart in both the vertical and horizontal directions. In the inlet channel, 200 mm wide and 100 mm long, 19 parallel longitudinal training walls, length 100 mm, height 70 mm and thickness 0.2 mm, were arranged to distribute the inflow velocity uniformly with only a slight contraction of effective inlet width.

At the downstream end of the inlet chamber, the test diffuser wall of 600 mm effective length and 70 mm high was located, from which the effluent was discharged directly into the drain in order that the pressure distribution along the outer side of the diffuser be uniform in accordance with the simplifying theoretical considerations. If the opening ratio of the diffuser becomes larger than a definite value, however, the effluent water must be discharged in jet through all of the orifices increasing the total discharge, so that the water depth in the chamber maintains a larger value than the critical and the discharge coefficients of all orifices take almost equal values. Increase in total discharge has an important effect on the bottom friction and uneven water depth as will be shown later. Therefore, a brass-made depth holder was connected to the test diffuser wall, by means of which the orifices were submerged exactly as in the actual basin and the water depth in the chamber was held almost constant regardless of the variation of flow discharge. The low velocity anemometer, however, was not adequate to measure the velocity distribution at just the up or downstream sides of the wall since in this type of chamber those velocity values change more delicately than in the case of the parallel inlet channel. Consequently, it was decided that each vertical summation of the discharge along the wall, namely the discharge through any vertical series of orifices should be measured. The depth holder served well for this purpose. It is divided into 60 compartments by thin partition plates along the diffuser, each compartment is 10 mm wide and has a brass effluent pipe of 6 mm inner dia. and 10 mm length inclined 40° from the vertical. The flow through the diffuser orifices must not be influenced by the hydraulic conditions of the effluent pipe and even where the local controlled discharges through the diffuser differ from each other, those outflow conditions must be kept the same as possible. Accordingly, the effluent pipe must have large enough section to lower the friction, must be arranged so that the effluent may not cause partial flow, and also be held at the same level. In this way, once the depth holder is set horizontally, the local pressure at the downstream side of the diffuser can be kept almost constant.

The diffuser walls were made of polyvinyl-chloride sheets of 4 mm thickness. Although infinite combinations are considered between the hole diameter and spacing for a definite opening ratio, the local hydraulic effect in the settling zone due to the jet action of the orifice is out of consideration now, so the spacing of the holes was not changed during the experiments, i.e. horizontally 10 mm same as the partitioning pitch of depth holder and vertically 9 mm; however, various opening ratios were tested by changing the hole diameter. The arrangement of a greater number of smaller orifices would correspond to the theoretical assumption of uniform perforation and makes it easy to detect the expected changes of distribution rate, but its preparation is very troublesome. In fact, a small number of larger holes may result in erroneous drillings and lead to an unexpected distortion of the observed data. In the present experiments, a moderate arrangement of orifices was chosen as seen in Fig. 4. For the aid of present research, if the diffuser could possibly be made so as to produce an equal rate of flow from each effluent pipe of the depth holder, then the distribution rate of the orifice opening could be compared with the one which is theoretically computed. This experimental procedure is considered to be so difficult that in practice the discharge distribution along the uniformly perforated diffuser with comparatively small openings was measured and the experimental results were investigated in comparison with the curves obtained for the inversely proportional rate of calculated openings mentioned in the previous paper[6].

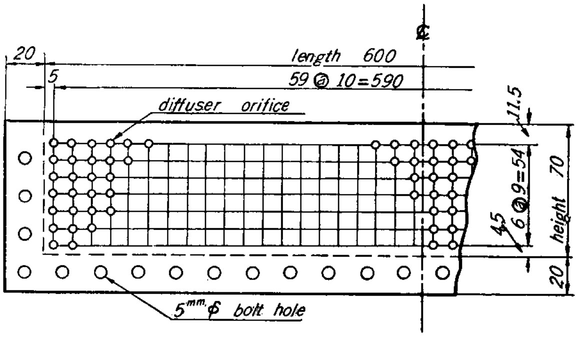


Fig. 4. Orifice arrangement in test diffuser of Apparatus II.

(2) Experimental Procedures

Graduated cylinders and stop-watches were used for the discharge measurements. The smaller dimensions of the test apparatus are considered more favourable for ease of operation. However, the installation may become erroneous especially for the depth holder effluent pipes. In order to eliminate these undesirable effects the primary calibration tests were carried out using a 1.8% opening rate diffuser with uniform 1.6 mm holes in the same arrangement as above. The increased head loss at the diffuser due to such small opening ratios is expected to produce a practically uniform distribution of flow as explained theoretically. Fig. 5 shows the calibrated examples in which 30 data were taken from the pair of effluent pipes to eliminate the effect due to irregularity of openings and the relative values of flow distribution r were calculated as the ratios of individual discharges to their average. The value of r varies between 0.81 and 1.15 as seen in Fig. 5. It can be realized from Fig. 5 that increasing the total discharge causes a rather even distribution of r because variation in the hydraulic condition of the effluent pipes becomes insignificant as compared with the head loss through the effluent pipe. The variation of r is similar for each case, and the results in Fig. 5 are generally recognized as illustrating the special characteristics of the depth holder. Furthermore, since the variation of r is rather irregular and fortunately, larger and smaller values are scattered alternately, the significant secondary flow hardly occurs. Consequently, each observed local values of the discharge through the test diffuser are corrected to the values corresponding to the uniform effluent condition by multiplying the reciprocals of r in Fig. 5 according to the location and magnitude of the total discharge.

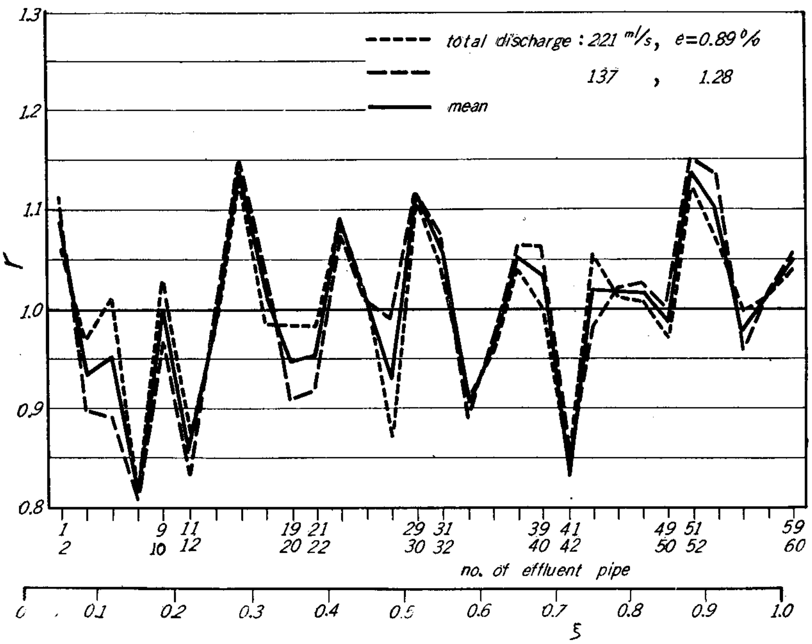


Fig. 5. Correction factor for the depth holder of Apparatus II.

(3) **Results and Discussion of Experiments**

The value of r, which signify the discharge distribution, are plotted in Fig. 6.

The diameters of diffuser orifices are 3.0 and 4.0 mm and the actual opening ratio varies with change in total discharge and the water depth in the chamber. In Fig. 6, the calculated curves of r for the cases $w=3$, $\lambda=1/3$ and the effective opening ratio $ce=5.96$ and 7.91% were reproduced from the previous paper.

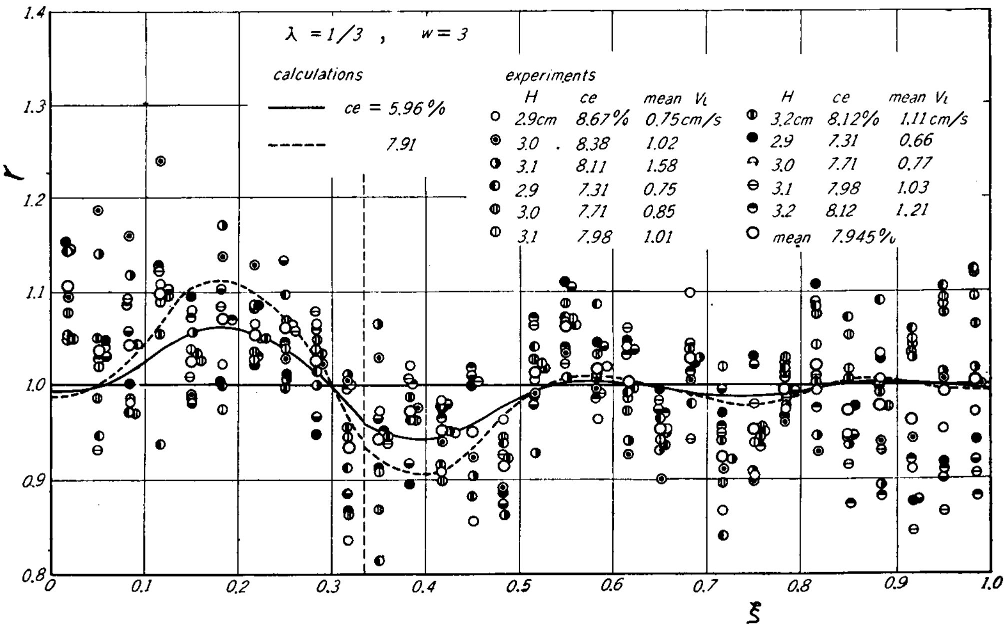


Fig. 6. Experimental results of the relative distribution of flow in Apparatus II, compared with the calculated curves.

The average value of ce in Fig. 6 is considered to exist in the range of 4.61 to 3.98% because the average e is 7.95% for the test diffusers and c is evaluated between 0.58 and 0.50 by the preliminary tests. Comparing the plotted experimental data and the theoretical curves, it is seen that the observed points spread a little wider but, in general, they are following the computed curves pretty well except for the neighbourhood of $\xi(=x/B)=0$. Such scattering of plotted data is thought due to the errors in the discharge measurement, the magnified effects of the correction factor $1/r$ in Fig. 5, and the slightly erroneous installations of the inlet chamber and depth holder which should be horizontal. Replacing the test diffuser wall required removal of the depth holder from the chamber, and the apparatus was reset very accurately every time, however, it was found from a number of preliminary tests that a slight inclination of the apparatus produced an unstable flow distribution especially in the region far from the inlet channel; in other words, if the side $\xi=1$ of the depth holder was set slightly higher or lower the value of r on this side showed a tendency to decrease or increase respectively. As explained numerically in the previous paper, the stability of the control effect of the diffuser seems to have a close relation to the Froude number in the inlet chamber. The minimum value of the absolute velocity appeared in the region near $\xi=1$ and corresponds to the wider scattered plottings near $\xi=1$ in Fig. 6.

In Fig. 6, the observed values of r near $\xi=0$ are larger than the calculated curves generally. This may be caused by the insufficiency of the approximate theoretical calculation, in which the location of the boundary between the regular and counter flow zones was assumed using the boundary conditions of the chamber regardless of the limit of the applicability of the theory of approximation concerning the value of $r_{f,0}$ (relative value of lateral velocity at $\xi=0$ on the boundary of the two zones). Therefore, it may readily be assumed that in the vicinity of $\xi=0$ the observed values of r are more reliable than the calculated.

Another series of tests was conducted to investigate the flow patterns in the inlet chamber. Methyl-orange solution was dozed into the stilling chamber as a tracer substance and its behaviour in the inlet chamber was observed in detail. Also, the movement of paper disks floating on the water surface were filmed. The co-existence of the regular flow zone and counter flow zone was recognized clearly especially in the distributing zone ($\xi=1/w \sim 1$) but the width of each zone were not constant and the value of φ (the width ratio of the counter flow zone to the chamber) was estimated to be about 0.2~0.25 near $\xi=1/w$ and about 0.4 near $\xi=1$.

The flow behaviours in the chamber are likely to show different characteristics

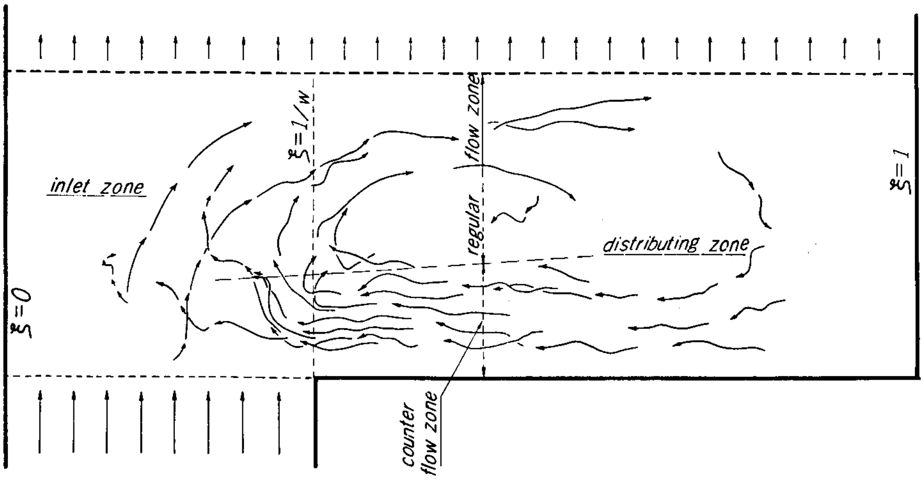
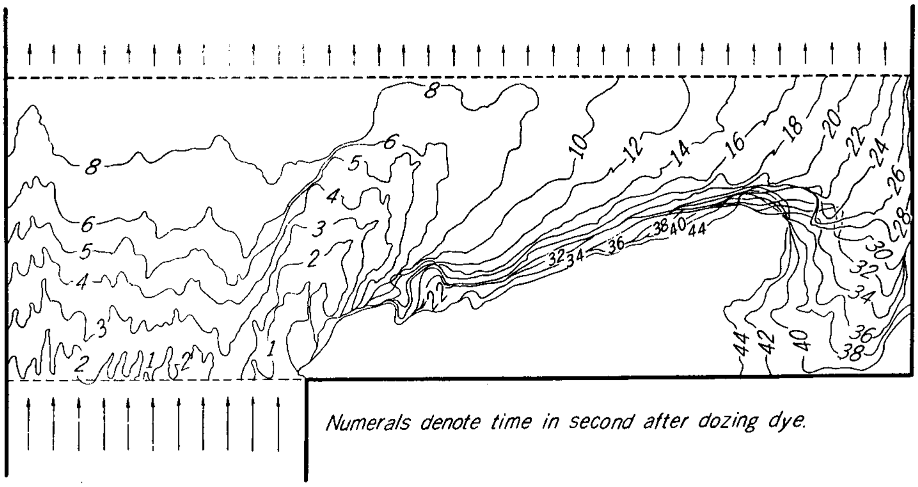


Fig. 7. Flow pattern in the surface layer.

according to the range of water depth in the chamber. Near the water surface, the flow circulates in simple form, as shown in Fig. 7, but almost stagnates in the midpart of the distributing zone. However, there appears significant counter flow in the inlet zone ($\xi=0\sim1/w$) and the float pieces flow back to the front of the inlet channel. At the condition of total discharge 136.91 ml/sec, depth in the chamber 3.0 cm and the opening ratio e, 2.01%, the back-flow velocity at the boundary of the inlet and distributing zones, $\xi=1/w$, was estimated to be 1.365 cm/sec in average from the movie film. Assuming that the water fraction takes the same velocity values over the total depth, the circulation ratio is calculated using the value of φ 0.25 as $(136.91+1.365\times3.0\times20.0\times0.25)/136.91=157.45/136.91=1.150$ which seems close to the value 1.188, obtained theoretically7).

For the flow at middle depth, the dye front was traced from the film as illustrated in Fig. 8. Although the dozing of dye was a little irregular, the flow introduced from the inlet channel flowed down the inlet zone almost evenly, then diffused to the distributing zone and flowed backwards. At this range of the depth, the appearance of counter flow in the inlet zone was not so remarkable as at the surface layer, whereas the local circulation of flow near $\xi=5/6$ appeared distinctly in accordance with the calculated result.



Numerals denote time in second after dozing dye.

Fig. 8. Flow pattern in the middle layer.

Next, to investigate the flow behaviour in the bottom range, methyl-orange powder was spread in the chamber. After the particles had settled, coloured traces were drawn by the bottom flow. Fig. 9 is a sketch of these traces, and seems to signify another small circulation in the region of $\xi=0.5\sim0.7$ as suggested by the calculation.

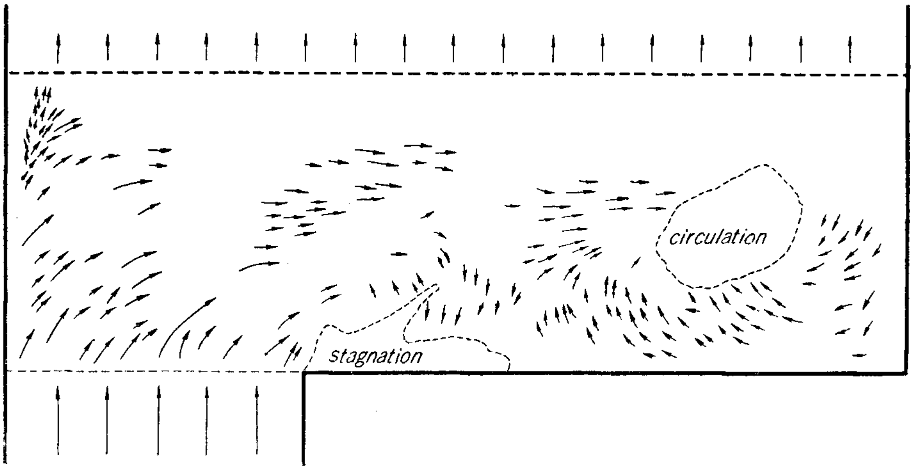


Fig. 9. Flow pattern in the bottom layer.

These different flow behaviours in the surface, middle and bottom ranges may naturally be due to the fact that the actual flow is not two-dimensional but influenced by the different magnitude of the viscosity forces in the vertical direction. Throughout the total depth, it can be concluded, however, that the calculated result obtained before explains satisfactorily the actual flow behaviour as well as the control effect of the diffuser in the distributing zone. So far as the inlet zone is concerned, the calculated values of r_f are supposed to vary so much that the flow in this zone seems more uniform actually.

In the previous paper, a changing rate of the opening area e^* along the diffuser was proposed using an approximate calculation. In order to ascertain whether or not the uniform distribution of flow is attained by adopting the proposed e^*, an additional test was conducted. For this purpose, a test diffuser of the following dimensions was used: the value of e^* at $\xi=0$ was 12.00% and the assumed discharge coefficient, c, was 0.5, ce^* at $\xi=0$ was 6.00%. From this, ce^* at each section was calculated and their average value along the wall became 5.96%. The distribution of ce^* was converted to that of e^* as illustrated by the real line in Fig. 10, then transformed to the stepwise change of e^* as the broken line of the same figure, which was obtained by the combination of 5~7 holes of different diameters, 1.6, 1.9, 2.5, 3.0 and 3.1 mm, with a constant horizontal spacing of 10 mm. These holes were located vertically in the range of 3.0 cm water depth. The plot in Fig. 10 is a typical experimental result, in which, r should be nearly unity. These local undulations may be the result of over-corrections of $1/r$ in Fig. 5 due to the irregularity of the depth holder effluent pipes. It will be easily understood from these plots that near $\xi=0$ the calculated

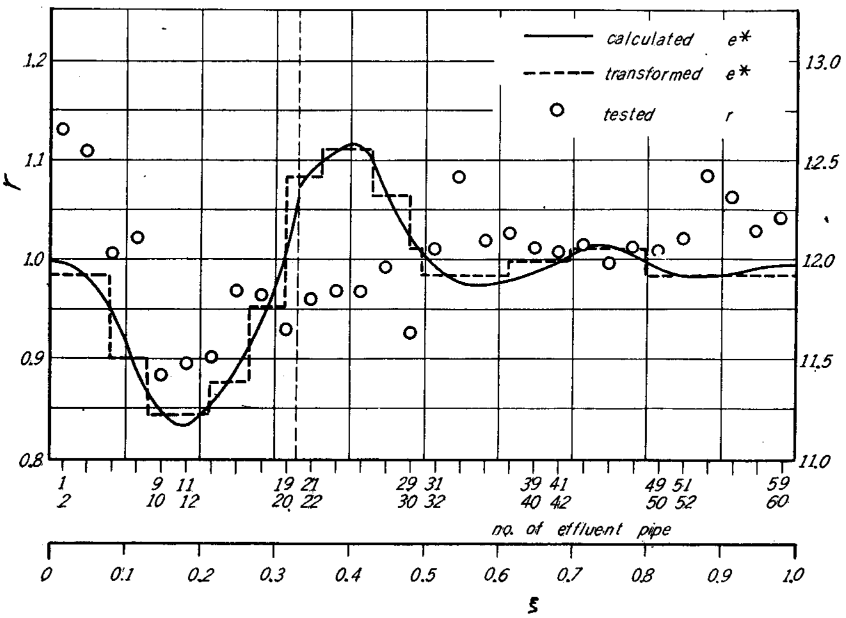


Fig. 10. Experimental result on the relative distribution of flow in Apparatus II with varying opening ratio of the diffuser.

value of e^* must be reduced, and must be increased slightly in the midpart of the inlet zone. These results also well confirmed the results of Fig. 6 and the above considerations.

4. Some Considerations of the Hydraulic Similitude in the Model Test

In most cases of similar study, a pilot plant or hydraulic model is adopted to study the effects of flow controlling devices or to improve the flow characteristics of the settling tank, expecting easier operation and freely changeable conditions. It is a wellknown fact that appropriate laws of similitude must be introduced for the phenomenal correlation between the model and the prototype. In general, two different laws of similitude—Froude's law and Reynolds' law—are applied to the hydraulic models, the former concerns such cases where gravity force overcomes the influences due to viscosity or surface tension, and the latter, where gravity and surface tension are of little importance compared with viscosity. It is impossible to build up a model which satisfies both Froude and Reynolds similarity laws unless the scale of the model is 1:1. Therefore, any investigation is required for each case to know which law should take the priority.

In the present problem, the flow behaviour in the inlet chamber and the subsequent phenomenon in the vicinity of the diffuser wall must be similar between the model and prototype, and the representative dimensionless factor r, or r_f, must be a definite value for given values of e, c, α_m, σ, λ and w, inasmuch as the derived theory is valid assuming the fluid viscosity negligible. Therefore, when changes in c, α_m and σ can be neglected, the model is required only to satisfy the condition of geometric similarity to the prototype for the corresponding linear dimensions and there are no limitations on the applied flow rate. When the discharge coefficient c through the diffuser orifice is supposed to vary with the model scale, the effective opening ratio ce should be taken equal to the prototype, and also the values of α_m and σ. In the present study, which is analysing the flow characteristic in the chamber two-dimensionally and the control effect through the diffuser one-dimensionally, the model requires geometric similitude only, and the scale for depth seems rather insignificant.

If Froude's law is applied in addition to the condition of geometric similitude, Y, the difference in pressure head between the inlet chamber and the downstream side of the diffuser wall, or the difference of water level between the chamber and the downstream side, should also be scaled down to the model scale.

The influence of fluid viscosity may be evaluated by the head loss due to the bottom friction. To actualize the same control effect in the model diffuser as in the prototype, the ratio of local rate of friction loss to the changing rate of Y along the model diffuser must correspond to that in the prototype. Then upon certain mathematical treatments, the following relationship is introduced:

$$\frac{H_m}{H}=\frac{B_m}{B}\frac{\lambda_{fm}}{\lambda_f},$$

in which, H denotes the water depth in the real inlet chamber, B the length of the chamber signifying the representative linear dimension and λ_f the resistance coefficient due to bottom friction, and the suffix 'm' means the value in the model chamber. If Froude's law is accepted as dominant, the Reynolds' number of flow in the model chamber would be less than the one in the prototype, so the value of λ_{fm} may be greater than λ_f. Consequently, the scale of the depth, H_m/H should be larger than the value of B_m/B. In the actual chamber, however, the effect of bottom friction is extremely small in comparison with the local variation of water depth caused by the velocity change, so that the above relationship becomes unimportant and the applied total discharge can be chosen rather arbitrarily for this reason.

The amount of discharge applied to the model will be limited in another way. As assumed in the theoretical calculation, the local change of Y along the diffuser is very small. For instance, if the length, width and water depth of the chamber is taken to be 15, 5 and 4 m respectively and the width of the inlet channel is 5 m, calculation shows that even the difference of the maximum and minimum values of Y along the diffuser does not exceed 1/11,400 of the mean depth at the mean diffusing velocity of 1.0 cm/sec (51,840 m^3/day). In the model chamber, therefore, the above ratio should be taken sufficiently small, so that the applied rate of flow in the chamber is restricted with respect to the value of the water depth. In the present experiments, H_m is about 3.0 cm, and if the above limitation is reduced to the ratio 1/100 from the order of 1/10,000, the total discharge becomes less than about 170 ml/sec. Most of the experiments involved in Fig. 6 satisfy this condition.

In the present investigation, Reynolds number seems to have no direct relation to the flow distribution caused by the diffuser, but Reynolds number at the diffuser orifice may rule the characteristics of flow in the settling chamber in relation with the spacings and diameters of the holes. Mau(8) concluded that the Reynolds number at the diffuser was more important than that in the basin part in terms of basin performance, whereas the Froude number at the inlet had little concern. It was verified in this research, however, that the Froude number of the inlet chamber is of great importance since it controls both the stability of flow in the inlet chamber and the characteristics of flow diffusion through the diffuser.

5. Summary

In this paper, the results of detailed experiments on the two typical cases of inlet, with the inlet channels parallel and perpendicular to the diffuser walls, were introduced and proved to be in good agreement with the theoretical calculations in the previous paper(1). The above descriptions may be summarized as follows.

First, for the experiments on the test inlet chamber with the channel perpendicular to the basin axis:—

(i) the resistance type hot-wire anemometer was used to measure the velocity distribution of the controlled flow through the diffuser with allowable accuracy.

(ii) The relative rate of flow distribution along the wall when plotted follows well the calculated curve when the discharge coefficients of the 4.5 mm diameter orifices, on the wall of 10 mm thickness, are taken as 0.53.

Next, for the experiments on the test chamber with an inlet channel parallel to the basin axis:—

(iii) the test apparatus was constructed without an adjoining settling chamber by using a depth holder, so that the required, immediate flow controlling effect of the diffuser wall might be investigated. Unfortunately however, some irregularities due to the depth holder arrangement required correction of the observed data.

(iv) Although the data was scattered because of sensitivity of flow to the errors in the installation of the chamber, moderate experimental values verified well the delicate changes in relative flow distribution suggested by the theoretical calculations.

(v) In the narrow region in front of the inlet channel, the experimental results deviate slightly from the calculated, for reasons which were discussed in connection with the approximate calculations of the theory.

(vi) Movie film analyses were used to study the flow patterns in the chamber. In the surface, middle and bottom layers different types of flow patterns were observed. However, the overall flow pattern substantiated the existence of a circulation of flow as predicted by calculation.

From the considerations of hydraulic similitude for the model test:—

(vii) a geometrically similar model is sufficient for investigating the direct control effect of the diffuser only, but the applied rate of flow must be limited to keep the water depth in the chamber uniform.

(viii) The Froude number in the chamber generally rules the stability of the flow controlling effect through the diffuser, and the Reynolds number at the diffuser orifice may relate to the general flow characteristics in the settling chamber and the disturbing effects of the jet flow through the orifices.

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