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CONTROL STRUCTURES IN STRATIFIED FLOWS

by

D. R. F. HARLEMAN and Y. GODA

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PREPARED FOR
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INTRODUCTION

During the past decade the Tennessee Valley Authority has designed and built several structures for the purpose of withdrawing cold bottom water from thermally stratified reservoirs. The cold water is used to supply condenser water for steam-generated power plants. During the summer months the primary flows in the Tennessee River system are controlled by releases from upstream storage dams through low level turbine intakes. The cold water, discharged by the turbines, forms a density underflow in the downstream river and reservoirs which may be from 10 to 15°F colder than the overlying surface water (Ref. 1, 2, 3).

The intake structures in the form of submerged sluice gates are known as "skimmer walls". The water in the condenser water channel downstream of the gate is homogeneous and has a specific gravity equal to the lower, colder water in the intake channel upstream of the gate. The colder water is caused to flow through a vertical opening at the bottom of the gate by virtue of a head differential across the wall. The problem is to determine the maximum discharge of the colder water through the gate without inducing a steady state withdrawal from the warmer layer upstream of the gate. A basic experimental and analytical investigation of this problem was conducted in the Hydrodynamics Laboratory of the Department of Civil Engineering at the request of TVA in the spring and summer of 1954 (Ref. 4) as part of a continuing program of research in stratified flow (Ref. 5, 6). The flow configuration is shown schematically in Figure 1. While the information obtained from this study has proved to be a valid basis for design of skimmer walls of the type shown in Figure 1, questions have been raised in regard to the relative efficiency of other possible geometrical configurations.

The proposed Bull Run steam power plant of the TVA is to be located at mile 48 on the Clinch River in the backwater of the Melton Hill Dam (under construction). After completion of Melton Hill, the normal depth of water in the Clinch River at this point will be approximately 20 feet. The Bull Run condenser water intake will be approximately 32 miles downstream from Norris Dam which is the source of cold water during the summer period of thermal stratification in Melton Hill reservoir. In the absence of the Bull Run plant the normal "plunge point" for the cold water in the reservoir would probably be in the vicinity of the Bull Run site. It is estimated that condenser water requirements will cause diversion of most of the river flow for sizeable periods of time. The heated water is to be returned to the river approximately one mile below the intake structure. This addition of heat will result in a reinforcement of the reservoir stratification and will probably move the cold water "plunge point" upstream. Due to the topography, the maximum length of an intake structure is approximately 400 feet. Because of the relatively small depth of the colder layer (probably of the order of 15 feet), the question arose as to whether a horizontal bottom intake opening of width (a) as shown in

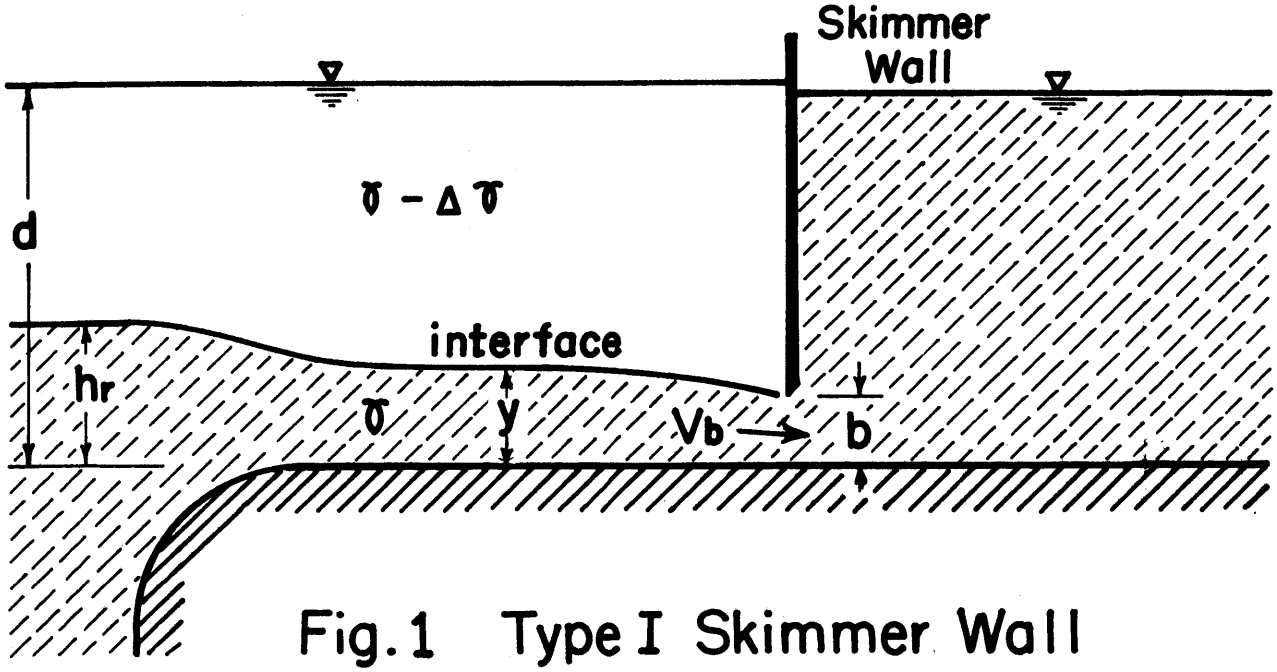


Fig. 1 Type I Skimmer Wall with Vertical Intake

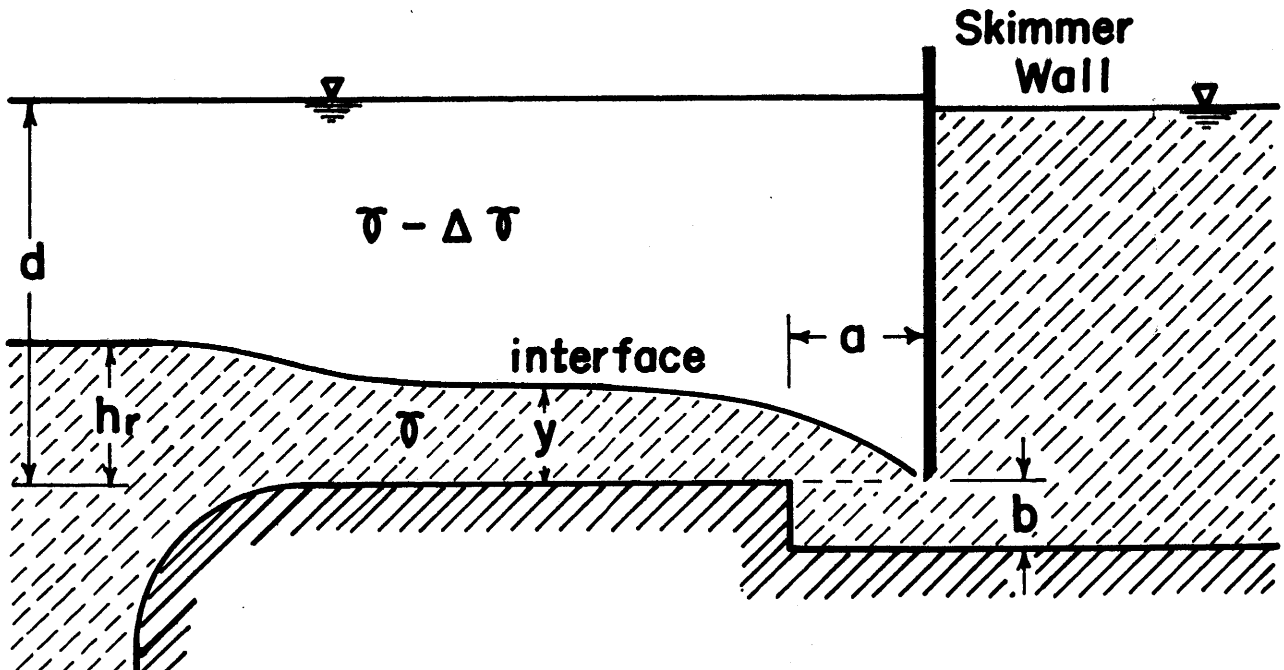


Fig. 2 Type II Skimmer Wall with Bottom Intake

Figure 2 (Type II) might be more efficient than a vertical opening of height (b) as shown in Figure 1 (Type I). In the horizontal intake skimmer wall the lip of the skimmer wall is essentially at the elevation of the river bed. This configuration requires the excavation of a bottom step of height (b) in order for the fluid to pass through the horizontal opening (a) and flow under the gate into the condenser water channel.

In order to have an accurate comparison for the two skimmer wall configurations, the experiments on the two types of walls were conducted using the same quantitative basis for the determination of the discharge at incipient drawdown. The drawdown discharge criterion for the 1954 tests was essentially a visual one; hence, the tests on the type I structure were repeated. In addition, it was desired to obtain quantitative information on the magnitude of the energy loss across the skimmer wall.

The experiments were conducted in the M. I. T. Hydrodynamics Laboratory using salt water and fresh water to simulate the prototype density differences due to thermal effects. For laboratory purposes and reproducibility of results a sharp interface between the two layers is obtained. It is recognized that in the field such a sharp interface is not possible; however, equivalent interfacial heights may be determined by using the depth at which the vertical density gradient is a maximum.

EXPERIMENTAL EQUIPMENT AND PROCEDURE

Apparatus

The experiments were carried out in a parallel-glass-wall flume (4.5 in. wide, 18 in. high, and 8 ft. long) with an entrance reservoir (18 in. square and 36 in. high) at one end. Figure 3 shows the arrangement of the experimental equipment. The other end of the flume was connected to the suction side of a pump which returned the water to the reservoir. A mixing tank (52 gal.) for salt water was also connected to the suction side of the circulating pump so that the pump could be used to fill the flume with salt water.

The transition section from the reservoir to the flume consisted of three cylindrical quadrants: two with vertical axes and radii of 5.75 in., and one with a horizontal axis and a radius of 5.5 in. A false bottom of lucite plate was set in the flume in order to permit construction of the type II skimmer wall. The false bottom (3 in. above the flume floor) was adopted as a datum level and the downstream end of this section (13.7 in. from the end of the transition section) was used as a datum point.

The adjustable sluice gate was made of lucite plate strengthened with aluminum angles. For the type I case, the sluice gate was located at the datum point with an opening of 1.5 in. For the type II case, the gate was set 1.5 and 3.0 in. downstream of the datum point at the height of the datum level and the vertical opening was also 1.5 in.

Instrumentation

The measured quantities were the discharge, the height of the reservoir interface between the fresh and the salt water, and the density difference between the fresh and the salt water. The discharge was measured by means of a small venturi-meter (inner diameters of 0.79 and 0.59 in.) inserted in the pipeline between the pump and the reservoir and connected to an air-water manometer. The height of the interface was measured with a point-gage located 2.5 in. from the outer side of the reservoir.

The density difference was calculated from the specific gravities of the fresh and the salt water samples. The samples were taken through a siphon into a cylinder and a hydrometer (range of 0.995 - 1.055 with a division of 0.0005) was used to measure the specific gravities. A thermometer was also used to measure the temperatures of the samples and the water in the flume and reservoir.

In addition to the above instruments, a dye-injector was used to make streamlines visible. It consisted of a hypodemic syringe and a long stainless tubing attached to a point-gage near the gate.

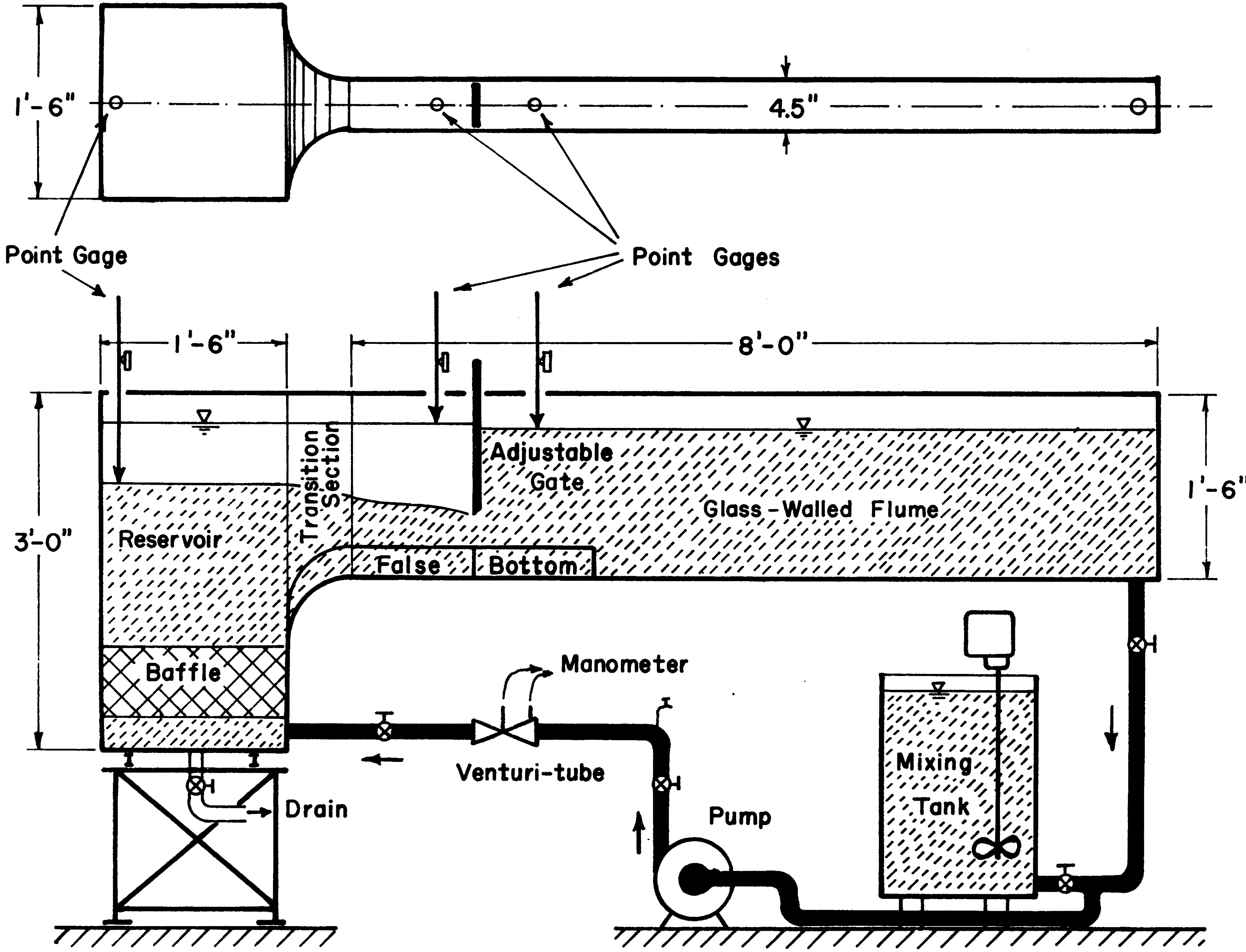


Fig. 3 Experimental Equipment

For the study of the head difference across the sluice gate, two hook-gages were set on either side of the gate. One hook-gage was 4.1 in. upstream of the gate, and the other was 6.3 in. downstream of the gate. Readings of two gages were calibrated for a common datum level with homogeneous water at rest.

Filling Process

The experiment was started by filling the reservoir and flume with salt water to a predetermined height such that the interface between the fresh and the salt water came to a given height after introduction of the fresh water. The skimmer wall was fixed at a given position before the filling process was begun.

The temperature of the fresh water was adjusted to that of the salt water. It was then poured slowly onto a floating board in the reservoir through a siphon until the fresh water surface was about 12 in. above the datum plane. To avoid mixing of the fresh and the salt water the introduction of the fresh water on top of the salt water took from 2 to 3 hours.

CRITERION FOR INCIPIENT DRAWDOWN

After completion of the filling process the interface upstream of the skimmer wall is horizontal and equal to h_r above the datum. As the discharge valve on the pump is progressively opened, the interface in the approach channel upstream of the wall is depressed. For any given flow rate (as long as there is no withdrawal from the upper layer) the interface elevation in the reservoir (h_r) remains constant with time. As the discharge increases, there is a tendency for the formation of a wedge of intermediate density fluid upstream of the wall. This separation wedge tends to obscure the visual indication of incipient drawdown of the upper layer. The separation wedge is removed by increasing the discharge well beyond the point of incipient drawdown. This causes the interface to drop below the lip of the skimmer wall and a simultaneous withdrawal from both upper and lower layers is obtained. Below the skimmer wall the two layers become well mixed, the interfacial height (h_r) in the reservoir immediately starts to rise and the density difference decreases slightly due to the entrainment of the upper layer water.

An example of the interface elevation as a function of time, after the increase of discharge necessary to cause drawdown, is shown in Figure 4 for the type I skimmer wall. Note that, while the discharge is held constant, the rate of interfacial rise is a continuously decreasing function of time. Thus, for the initial interface height (2.1 in.), the discharge (8.4 in^3/sec.) is greater than the discharge for incipient drawdown, however, as the interface rises, this discharge becomes the incipient drawdown discharge at some interfacial height which is to be determined by specifying a criterion for drawdown.

The criterion which has been adopted is as follows: The discharge at incipient drawdown (Q_d) is that discharge at which not more than two percent of the total flow under the skimmer wall causes from the upper layer water upstream of the wall. Hence,

$$Q_f = 0.02\ Q_d \qquad (1)$$

where Q_f is the discharge from the upper layer. If A_f is the horizontal area of the reservoir and skimmer wall approach channel,

$$Q_f = A_f \frac{dh_r}{dt} \qquad (2)$$

which relates the discharge from the upper layer to the time rate of change of h_r.

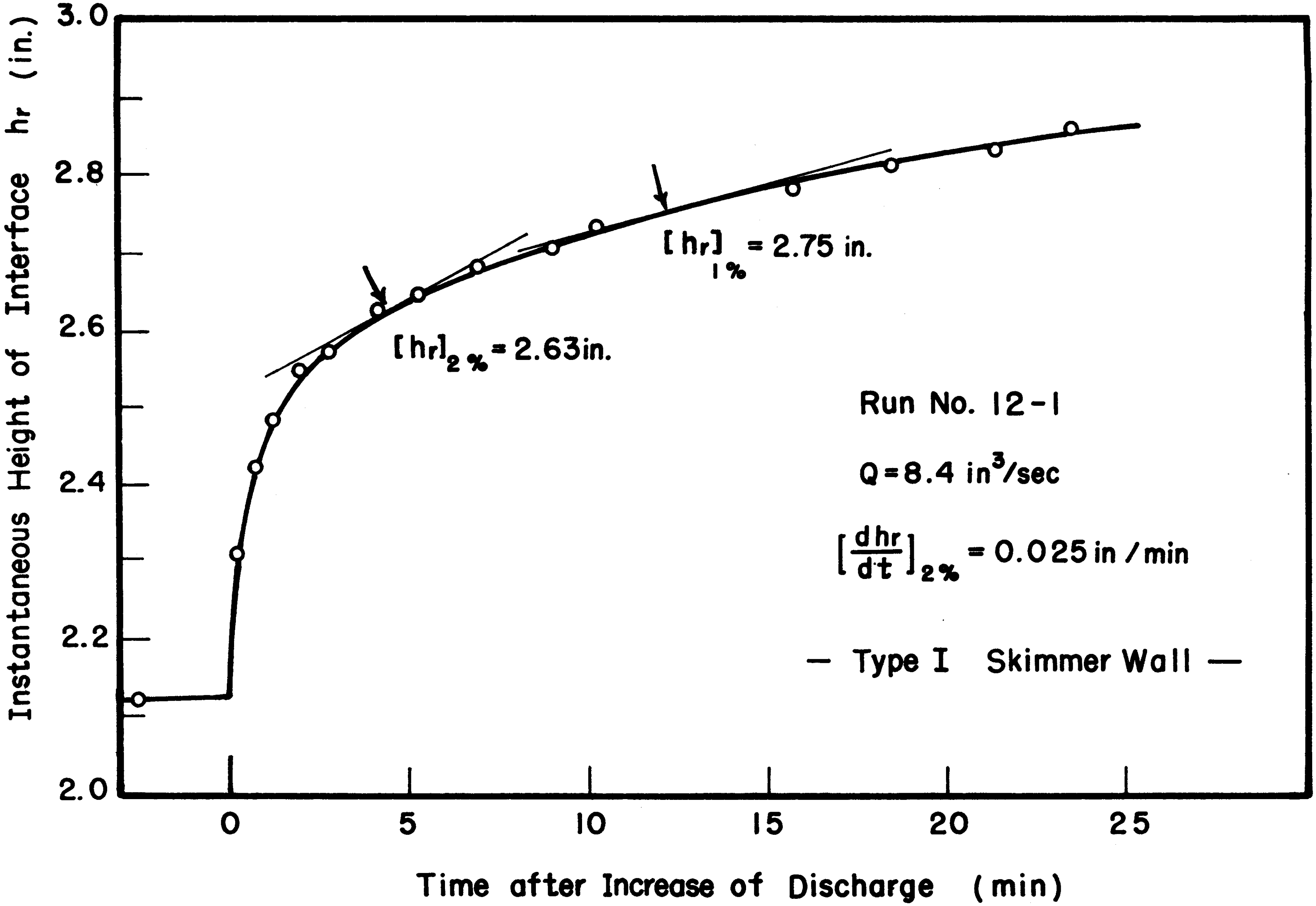


Fig. 4 Rising Interface after Increase of Discharge

Therefore from equations (1) and (2):

$$\left[\frac{dh_r}{dt}\right]_{2\%} = \frac{0.02\ Q_d}{A_f} \qquad (3)$$

For example, in Figure 4, if Q_d = 8.4 in³/sec. and since A_f = 400 in²

$$\left[\frac{dh_r}{dt}\right]_{2\%} = .00042 \text{ in/sec or } .025 \text{ in/min.}$$

From the computed slope, the value of h_r can be determined graphically as shown in Figure 4 (h_r = 2.63 in.). The interfacial height on the basis of a one percent withdrawal from the upper layer is also shown for comparison (h_r = 2.75 in.). In either case the method of defining incipient drawdown seems to give consistent and reproducible results which can be used as a basis for comparison of the two types of skimmer wall structures.

THEORETICAL CONSIDERATIONS

Critical Discharge in a Stratified Fluid

Consider the flow shown in Figure 1 in which only the lower layer fluid is in motion with a mean velocity V. Neglecting friction, curvature effects and velocities in the inlet section, the one-dimensional energy equation for the lower layer is as follows:

$$\frac{(\gamma - \Delta\gamma)(d - h_r)}{\gamma} + h_r = \frac{(\gamma - \Delta\gamma)(d - y)}{\gamma} + y + \frac{V^2}{2g} \qquad (4)$$

Expanding and simplifying:

$$h_r = y + \frac{V^2}{2g\ \Delta\gamma/\gamma} \qquad (5)$$

The flow rate is

$$Q = VBy \qquad (6)$$

where B is the flume width, hence,

$$Q^2 = 2g \frac{\Delta\gamma}{\gamma} B^2 y^2 (h_r - y) \qquad (7)$$

For a given h_r the maximum flow rate is obtained by differentiating Q with respect to y and equating to zero. The critical depth obtained in this manner is,

$$y_c = \frac{2}{3} h_r \qquad (8)$$

and from equation (7), the critical discharge is,

$$Q_c = B \sqrt{g \frac{\Delta\gamma}{\gamma} \left(\frac{2}{3} h_r\right)^3} \qquad (9)$$

This equation reduces to the familiar critical discharge equation for free surface flow when $\Delta\gamma = \gamma$, hence, when the specific weight of the upper layer fluid $(\gamma - \Delta\gamma)$ is zero.

For a given width and density difference the critical discharge of the lower layer depends only on the height of the interface in the reservoir (h_r). Regardless of the position or opening of the skimmer wall, the flow of the lower layer cannot exceed the critical discharge defined by equation (9). If the discharge through the skimmer wall exceeds the critical flow in the lower layer, there must be a drawdown of the interface and a discharge from the upper layer.

For large gate openings (relative to h_r) drawdown may also occur before critical flow is reached in the lower layer of the approach channel, if the depth y in the approach channel is equal to or less than the opening b. Again neglecting friction and curvature effects, this condition is given by equation (5) with y = b, thus,

$$h_r = b + \frac{V_d^2}{2g\,\Delta\gamma/\gamma} \tag{10}$$

The flow rate for the drawdown condition is

$$Q_d = V_d\,B\,b \tag{11}$$

hence,

$$\frac{h_r}{b} = 1 + \frac{Q_d^2}{B^2 2g \frac{\Delta\gamma}{\gamma} b^3} \tag{12}$$

Dividing and multiplying the last term by Q_c as given by equation (9), the following form is obtained:

$$\frac{Q_d}{Q_c} = 2.6\sqrt{\frac{h_r/b - 1}{(h_r/b)^3}} \tag{13}$$

If $h_r/b = 3/2$, $\frac{Q_d}{Q_c} = 1.0$ which is the condition for critical flow in the approach channel. Thus, the elementary theory predicts a functional dependence of the ratio of drawdown discharge to critical discharge on h_r/b of the form shown in Figure 5.

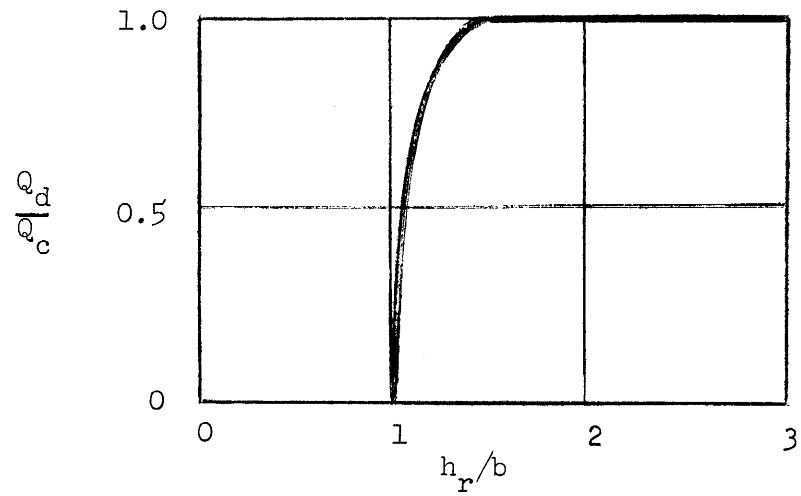


Fig. 5 Ratio of drawdown discharge to critical discharge as a function of h_r/b

Frictional effects, non-uniform velocity distribution and flow curvations may be expected to modify the results given by equation (13). A detailed analysis of these effects are given in Ref. 4.

Head Loss across Skimmer Wall

With the notation shown in Figure 6, the one-dimensional energy equation may be written between the reservoir and the contracted section of the jet downstream of the skimmer wall, neglecting losses,

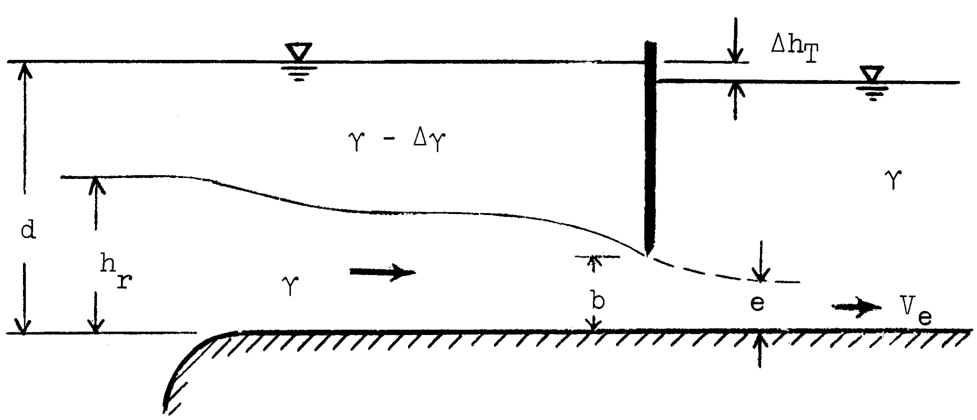


Fig. 6 Definition Sketch for Head Loss across Skimmer Wall

$$\frac{(\gamma - \Delta\gamma)(d - h_r)}{\gamma} + h_r = \frac{V_e^2}{2g} + (d - \Delta h_T) \qquad (14)$$

The head loss caused by the skimmer wall is equal to the kinetic energy of the flow at the contracted section since it is assumed that this velocity will be dissipated in the condenser water channel below the wall:

$$h_{loss} = \frac{V_e^2}{2g} \qquad (15)$$

Substituting equation (15) into equation (14), the following expression is obtained:

$$h_{loss} = \Delta h_T - \frac{\Delta\gamma}{\gamma} (d - h_r) \qquad (16)$$

The head loss is less than the measured water surface elevation difference because even if the system is at rest, there is an elevation difference due to the unequal densities on either side of the gate.

EXPERIMENTAL RESULTS - DRAWDOWN DISCHARGE

Tables I and II give the summary of the experimental runs and data for 1% drawdown and 2% drawdown conditions. Fifteen drawdown conditions were observed for the type I skimmer wall and eighteen for the type II wall. The interface heights ranged from 1.8 to 7.7 in. The gate opening was kept at 1.5 in. throughout the experiments; hence, the ratio of the interface height to the gate opening varied from 1.2 to 5.1. The density difference varied from 0.0020 to 0.0034, corresponding to a density difference caused by a temperature differential between 15 and 30 degrees (F) for fresh water. Mean velocities across the gate opening were between 0.38 and 6.0 in./sec.

Figure 7 shows a sequence of three photographs for both the type I and type II skimmer walls indicating conditions (a) prior to drawdown (b) at incipient drawdown and (c) with flow from both upper and lower layers passing under the wall.

The experimental data for the relation between drawdown discharge Q_d/Q_c and h_r/b is shown in Figure 8 for the type I skimmer wall.

In general the results are in accord with the analysis shown in Figure 5, although the numerical results are modified by curvature effects and other factors neglected in the theoretical study. Figure 8 clearly shows that the optimum range of gate openings is between h_r/b of 2.5 and 4.0. In this range the 2% drawdown discharge reaches ninety percent of the critical discharge, hence,

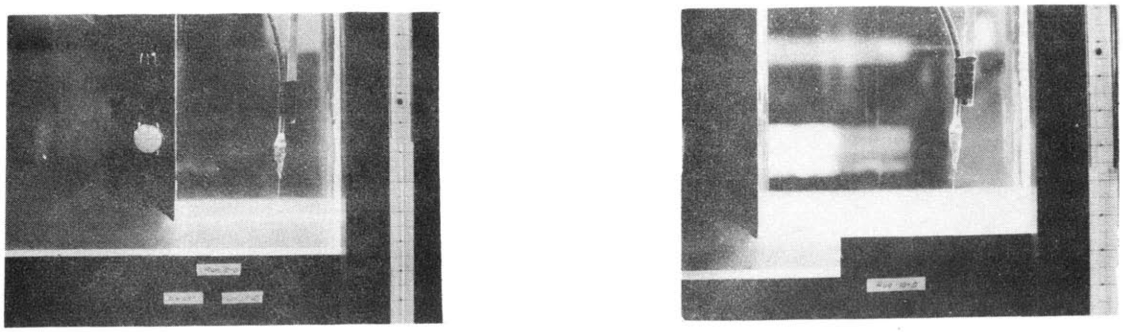
$$Q_d = .90B\sqrt{g\,\frac{\Delta\gamma}{\gamma}\left(\frac{2}{3}h_r\right)^3} \qquad (17)$$

and the design discharge for the skimmer wall is independent of the opening b within the range stated above. If h_r/b is less than 2.5, the gate opening is too large and drawdown tends to occur before critical flow is reached. If, on the other hand, the value of h_r/b is greater than 4, there is a reduction in the efficiency of the structure. This is probably due to increased curvature effects as the opening (b) becomes small in relation to h_r.

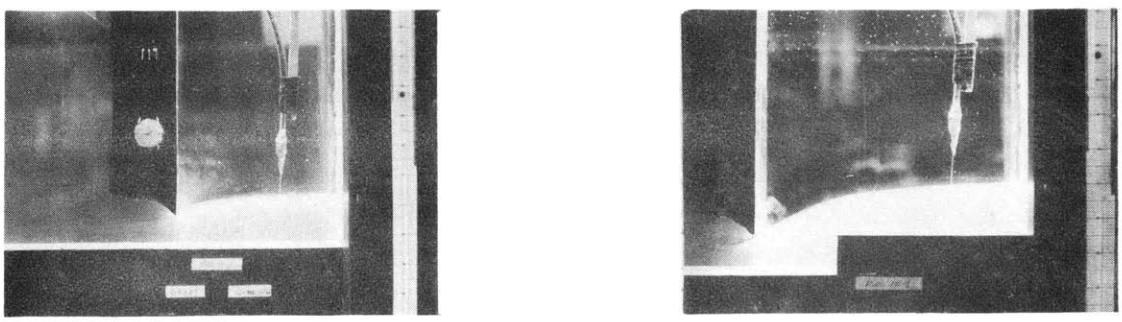
The experimental data for the type II skimmer wall is shown in Figure 9. In this configuration the lip of the skimmer wall is set to coincide with the elevation of the stream bed. The depth of excavation (b) can therefore be greater or less than h_r. The ratio h_r/b approaches zero as a lower limit rather than unity as in the type I case. The optimum range of h_r/b is between 2.5 and 3.5 and the drawdown discharge is slightly less than ninety percent of the critical discharge. The design discharge for the type II wall is therefore also given by equation (17). A twofold variation in the horizontal location of the wall does not appreciably affect the results.

It is apparent that there is no advantage in the type II wall in comparison with the type I wall. Hence, an excavation of the river bottom in the vicinity of the skimmer wall cannot be justified. The lower layer flow becomes critical at the step and any variation in the downstream location of the skimmer wall (either in distance (a) or opening b) cannot influence the approach flow. The type II gate may in certain positions interfere with the supercritical nappe of the underflow and cause appreciable mixing with the upper layer.

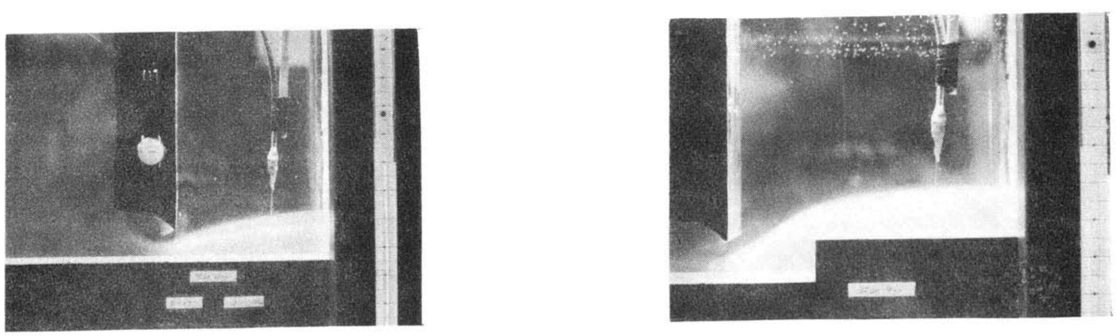
Type I   Type II



(a) Prior to drawdown



(b) Incipient drawdown



(c) Flow from both layers

Fig. 7 Increasing Discharge under Skimmer Wall

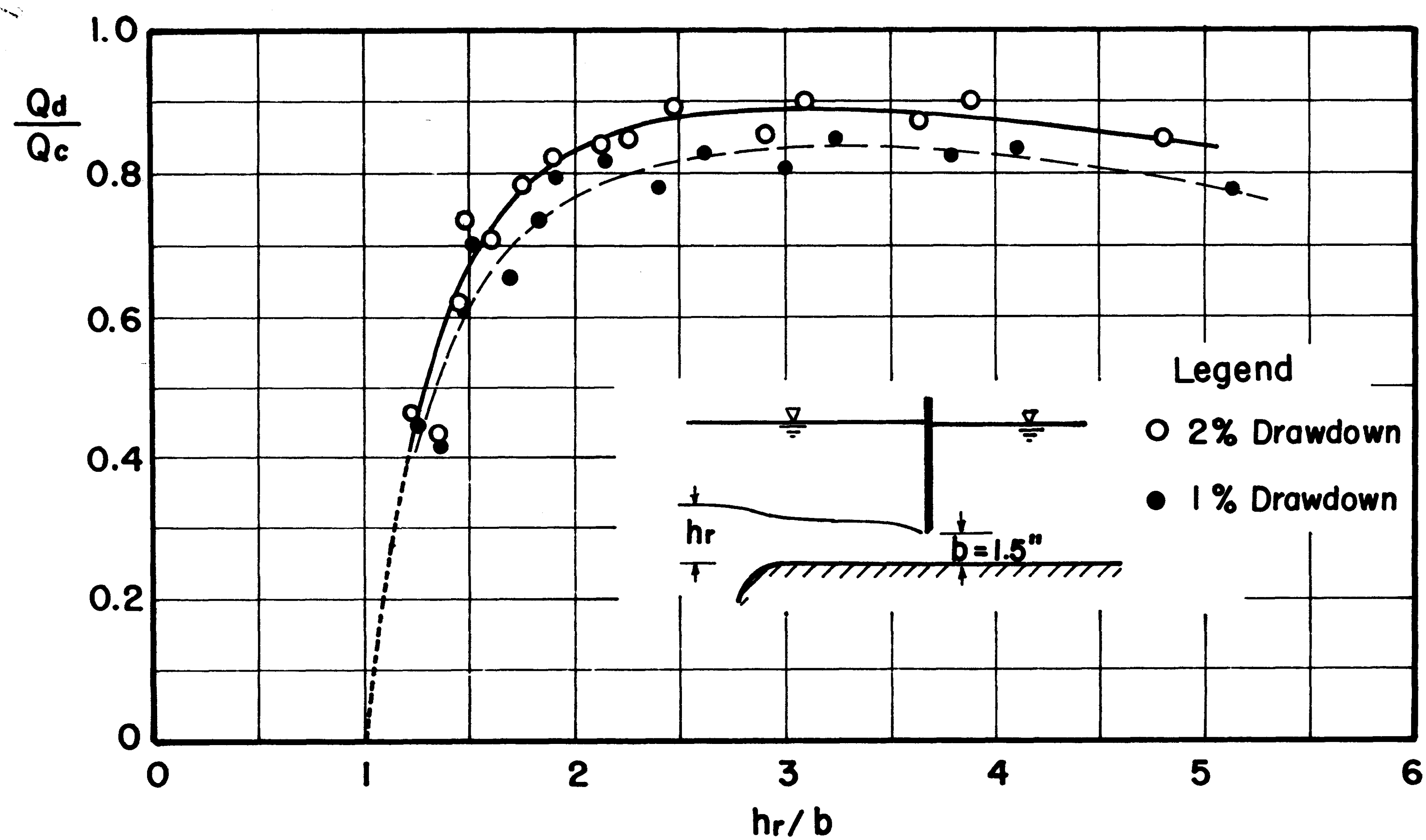


Fig. 8 Ratio of Drawdown Discharge Q_d to Critical Discharge Q_c — Type I —

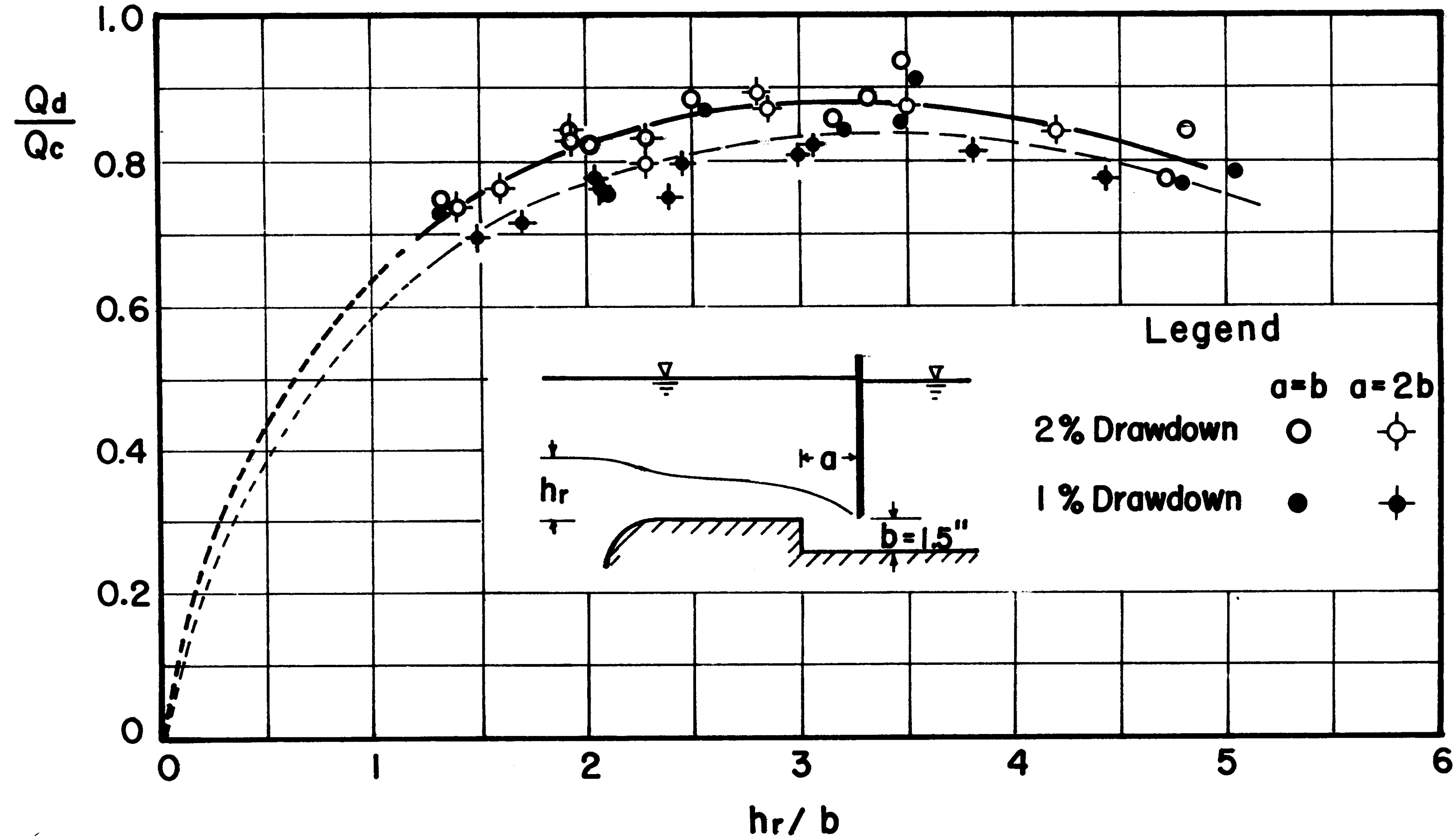


Fig. 9 Ratio of Drawdown Discharge Q_d to Critical Discharge Q_c —Type II—

EXPERIMENTAL RESULTS - HEAD LOSS AT SKIMMER WALL

Table III is a summary of the experimental runs and data on head loss across the type I skimmer wall. Head differentials across the skimmer wall were measured in six runs with a homogeneous flow (no interface) and in five runs with the stratified system. In the latter case the measurements were made near the condition of incipient drawdown.

In order to calculate the head loss from equation (15) the contraction coefficient downstream of the skimmer wall was measured by means of dye streamlines as shown in Figure 10. Using the notation of Figure 6,

$$C_c = \frac{e}{b}$$

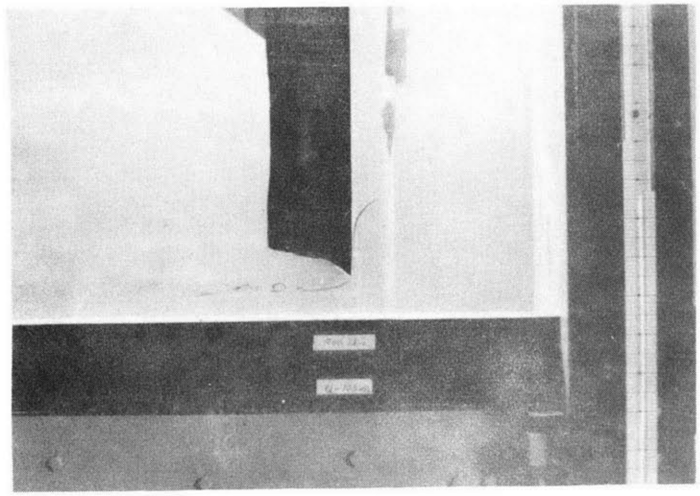
and the experimental values for C_c are shown in Figure 11. There is an increase in the contraction coefficient with increasing values of b/h_r.

Since,

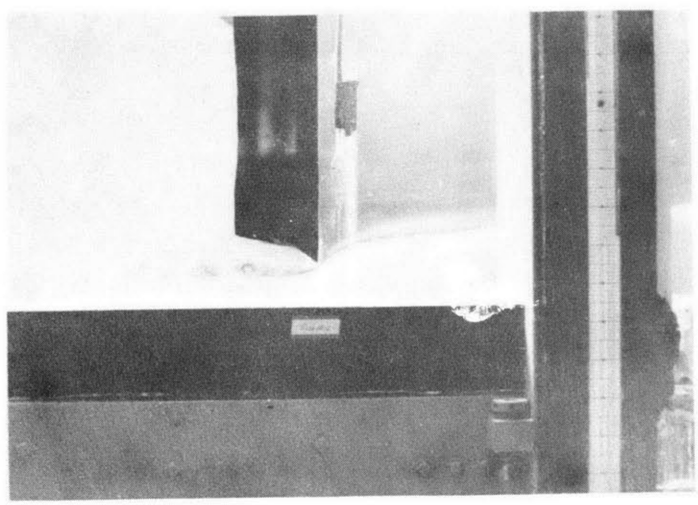
$$V_e = \frac{Q}{B\,C_c\,b}$$

the velocity head was computed for each run as given in Table III.

Equation (16), which is based on the measured elevation difference across the skimmer wall can also be used to compute head loss. A comparison of the two methods is shown in Figure 12. For the highest flow rates the head loss computed from equation (16) is about thirty percent higher than that given by the velocity head at the contracted section. Both methods are subject to experimental error. The values of V_e are subject to inaccuracies in the measurement of the contraction coefficient and in addition the kinetic energy correction factor has been assumed equal to unity whereas it is probably at least ten percent higher. The head loss, based on the measured differential, is too high by an unknown amount equal to the energy loss between the reservoir and the skimmer wall which was neglected in deriving equation (16).



Homogeneous Flow



Stratified Flow

Fig. 10 Dye Streamlines used to measure Contraction Coefficient

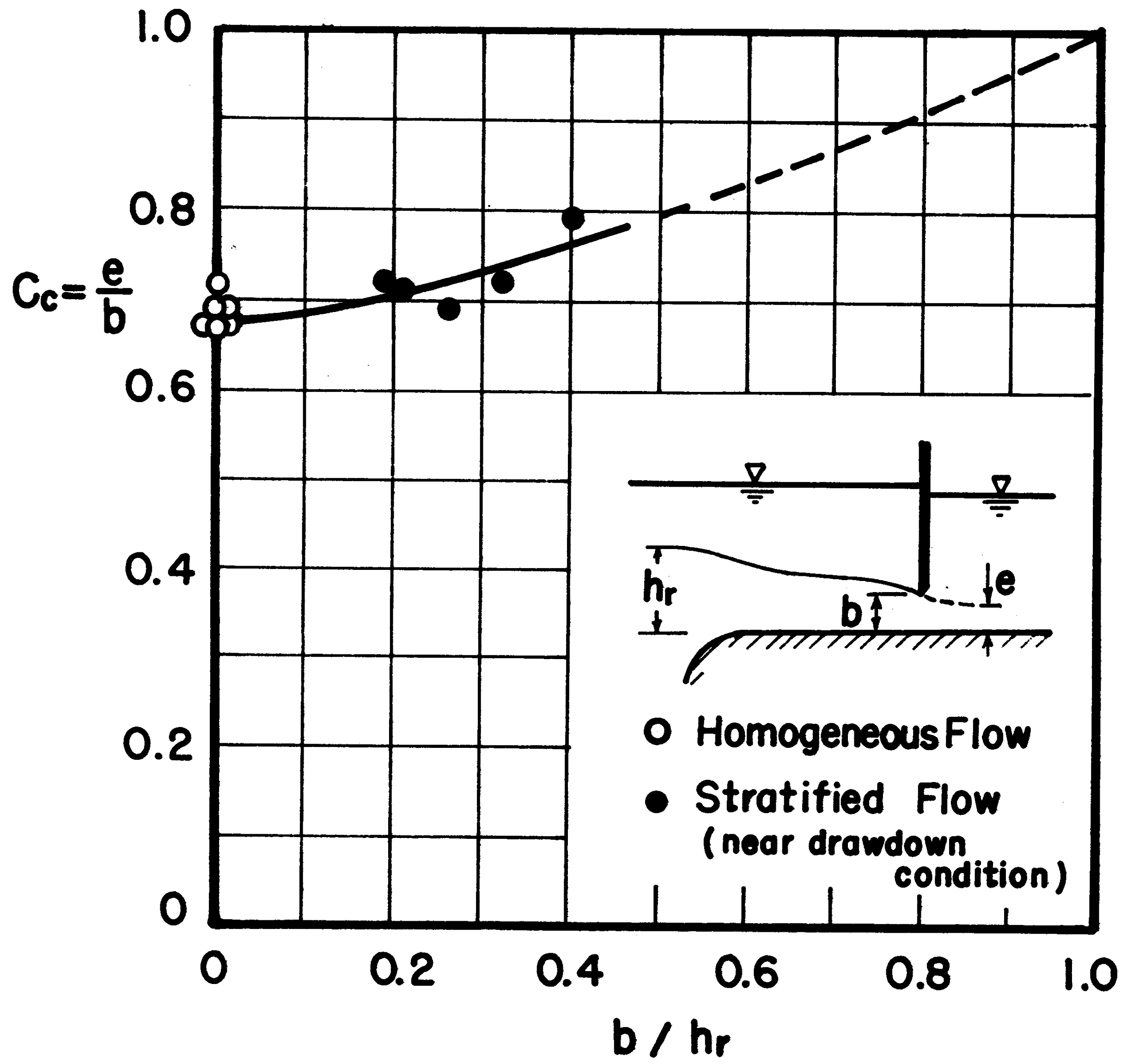


Fig. 11 Contraction Coefficient for Homogeneous & Stratified Flows

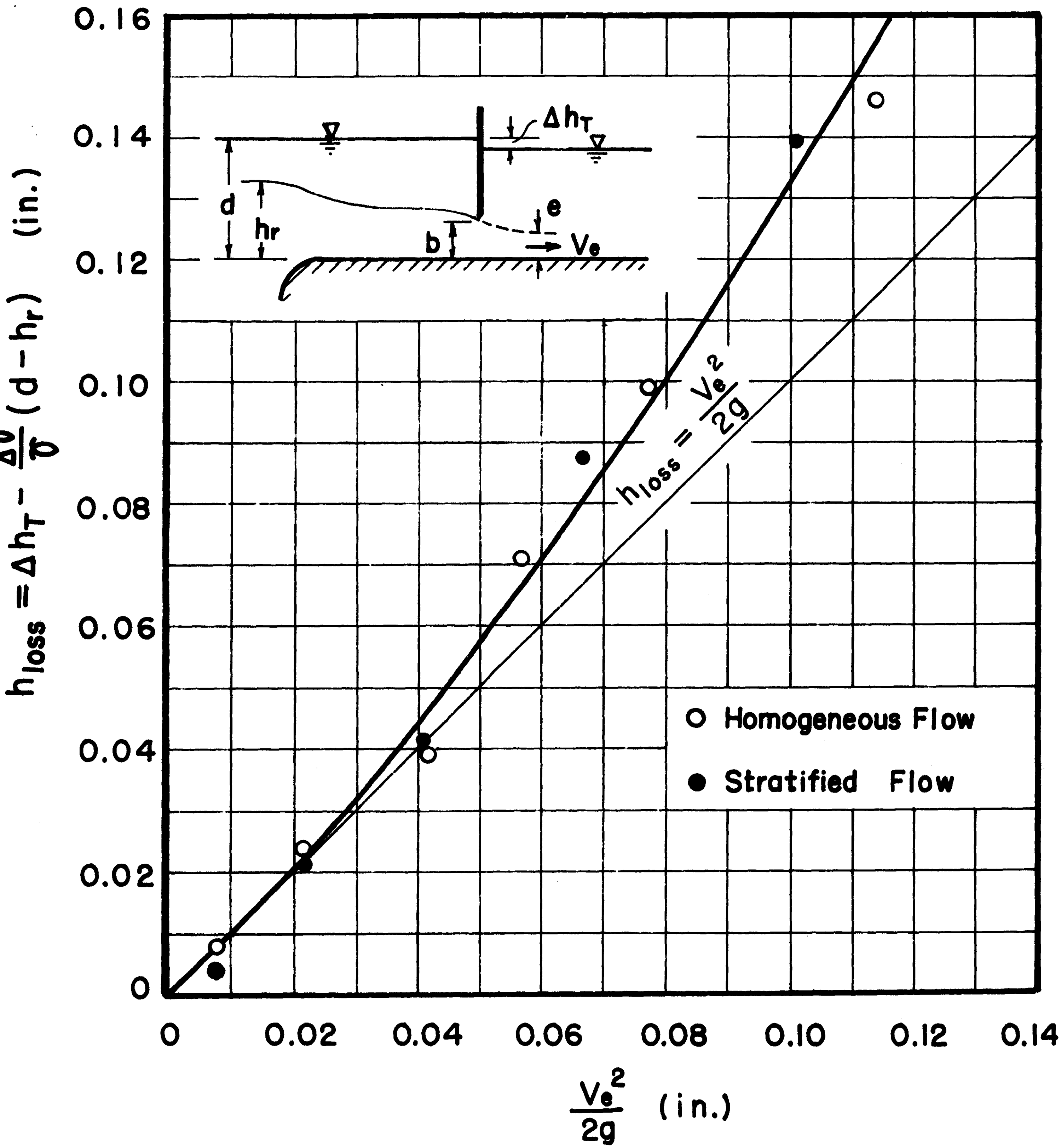


Fig. 12 Measured Head Loss vs. Velocity Head $V_e^2/2g$

SUMMARY AND CONCLUSIONS

1. The type I skimmer wall with a vertical intake is most efficient when operated at comparatively small bottom intake openings (b) in comparison with the stagnation interfacial height (h_r). The maximum discharge of the lower layer fluid without drawdown of the upper layer is approximately ninety percent of the theoretical maximum when h_r/b is between 2.5 and 4.0.

2. The type II skimmer wall having a horizontal bottom intake has a maximum efficiency slightly less than the type I wall for the same interfacial height (h_r) and density difference. The position of the gate is such that it intercepts the nappe of the lower layer fluid and causes more mixing with the upper layer fluid than the type I wall. This fact coupled with the greater expense for channel bottom excavation for the type II wall does not justify its use.

3. A method of calculating the head loss caused by a skimmer wall is presented. The head loss increases as the intake opening (b) is decreased, however, the skimmer wall is more efficient at smaller openings if the interfacial elevation (h_r) is a variable or difficult to define. The smallness of the opening must be balanced against the increased head for the condenser water pumps.

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TABLE I

Drawdown Discharge, Type I Skimmer Wall (b = 1.5 in.)

Run No.	Drawdown Discharge	Density Difference	1% Drawdown Condition Interface Height	Relative Height	Relative Discharge	2% Drawdown Condition Interface Height	Relative Height	Relative Discharge
	Q_d(in³/sec)	$\Delta\gamma/\gamma$	h_r(in.)	h_r/b	Q_d/Q_c	h_r(in.)	h_r/b	Q_d/Q_c
11-1	3.2	.0031	2.04	1.36	.41	2.03	1.36	.42
11-2	5.2	.0031	2.18	1.45	.61	2.16	1.44	.62
11-3	7.0	.0031	2.55	1.70	.66	2.41	1.61	.71
11-4	10.2	.0030	2.87	1.91	.79	2.85	1.90	.82
11-5	12.1	.0030	3.22	2.15	.82	3.14	2.10	.84
11-6	16.6	.0030	3.93	2.62	.82	3.72	2.48	.89
11-7	23.0	.0029	4.86	3.24	.85	4.65	3.10	.90
11-8	31.7	.0028	6.15	4.10	.83	5.83	3.89	.90
12-1	8.4	.0029	2.75	1.84	.73	2.63	1.75	.78
12-2	13.5	.0029	3.60	2.40	.78	3.40	2.26	.85
12-3	19.7	.0029	4.51	3.01	.81	4.36	2.91	.85
12-4	27.3	.0028	5.68	3.79	.82	5.40	3.63	.87
12-5	40.1	.0027	7.70	5.14	.77	7.20	4.80	.85
12-6	2.6	.0023	1.88	1.26	.44	1.83	1.23	.46
12-7	5.8	.0023	2.28	1.52	.70	2.21	1.48	.73

TABLE II

Drawdown Discharge, Type II Skimmer Wall (b = 1.5 in.)

Run No.	Horizontal Opening	Density Difference	Drawdown Discharge	1% Drawdown Condition: Interface Height	1% Drawdown Condition: Relative Height	1% Drawdown Condition: Relative Discharge	2% Drawdown Condition: Interface Height	2% Drawdown Condition: Relative Height	2% Drawdown Condition: Relative Discharge
	a (in.)	$\Delta\gamma/\gamma$	Q_d(in³/sec)	h_r(in.)	h_r/b	Q_d/Q_c	h_r (in.)	h_r/b	Q_d/Q_c
3-10	1.5	.0022	24.6	5.31	3.54	.91	5.20	3.47	.94
4-5	1.5	.0022	4.5	1.97	1.31	.74	1.96	1.30	.75
5-4	1.5	.0023	9.6	3.18	2.10	.76	3.01	2.01	.82
6-4	1.5	.0020	21.1	5.17	3.47	.85	5.03	3.36	.88
7-2	1.5	.0021	31.6	7.15	4.78	.77	7.07	4.72	.78
8-1	1.5	.0020	13.6	3.81	2.54	.87	3.75	2.50	.88
8-2	1.5	.0023	20.0	4.80	3.20	.84	4.73	3.16	.86
8-3	1.5	.0022	35.9	7.54	5.03	.79	7.23	4.82	.84
9-1	3.0	.0034	8.0	2.54	1.69	.72	2.44	1.63	.76
9-2	3.0	.0033	11.3	3.10	2.07	.76	2.93	1.96	.83
9-3	3.0	.0032	15.0	3.68	2.45	.80	3.58	2.29	.83
9-4	3.0	.0031	21.1	4.59	3.06	.82	4.41	2.84	.87
9-5	3.0	.0030	27.1	5.71	3.81	.81	5.25	3.50	.87
10-1	3.0	.0028	5.7	2.19	1.46	.70	2.12	1.41	.74
10-2	3.0	.0028	10.3	3.05	2.03	.78	2.89	1.93	.84
10-3	3.0	.0028	12.3	3.53	2.36	.75	3.41	2.27	.79
10-4	3.0	.0027	19.0	4.47	2.99	.81	4.20	2.80	.89
10-5	3.0	.0026	32.3	6.65	4.44	.78	6.30	4.20	.84

TABLE III

Head Loss Across Skimmer Wall (b = 1.41 in, d = 12 in.)

Run No.	Height of Interface h_r (in.)	Contracted Depth e (in.)	Discharge Q (in^3/sec)	Δh_T (in.)	Velocity Head at Cont. Sect. $\frac{V_e^2}{2g}$ (in.)	Density Difference $\Delta\gamma/\gamma$	Contraction Coefficient $C_c = \frac{e}{b}$	Relative Opening b/h_r
13-1	-	.98	10.5	0.008	.007	-	.69	-
13-2	-	.95	17.3	0.024	.021	-	.67	-
13-3	-	.95	24.1	0.039	.041	-	.67	-
13-4	-	1.02	28.3	0.071	.049	-	.72	-
13-5	-	.97	33.0	0.099	.074	-	.69	-
13-6	-	.95	40.0	0.146	.114	-	.67	-
14-1	3.53	1.12	12.2	0.024	.007	.0024	.79	.40
14-2	4.43	1.02	18.6	0.039	.021	.0025	.72	.32
14-3	5.33	.98	25.4	0.059	.043	.0026	.69	.26
14-4	6.76	1.00	32.3	0.098	.067	.0023	.71	.21
14-5	7.50	1.01	40.4	0.150	.100	.0022	.72	.19