ENGINEERING LABORATORY DESIGN, INC.

BOX 278 • LAKE CITY, MINNESOTA 55041 • TELEPHONE 612-345-4515

HYDRAULIC DEMONSTRATION CHANNEL

Model A and Model B

Receiving and Unpacking Instructions

The channel will usually be shipped via motor carrier packed in a wooden crate. Any obvious damage to the crate or contents should be noted as exceptions on the delivery receipt. The unit should be unpacked immediately upon receipt and inspected for possible concealed damage. If damage is discovered, call the delivering carrier promptly and request a freight inspection. Insure that all packing materials are retained for inspection.

Accessory models will be packed in the plastic channel. Carefully unpack the models and compare them to the enclosed packing list and the purchase order. Please report any discrepancies promptly.

Installation and Maintenance

This hydraulic demonstration channel has been constructed with high quality materials and workmanship and will give many years of service if reasonable care is used in its operation. Time spent in familiarization with the equipment will be repaid in subsequent freedom from damage and necessity for repair or replacement of parts.

To permit a more compact shipping container, the channel is shipped with the headtank removed. A soft, construction grade caulking or silicone rubber should be applied to the flanges of the headtank. The unit is then positioned on the aluminum bars at the upstream end of the channel and fastened with the screws provided. Insure that the rubber headgate seals are properly oriented. On the Model B channel it will be necessary to make electrical connection to the headgate motor. Simply connect the seven color coded wires with the wire nuts provided in the junction box at the back of the headtank.

The reservoir should be filled with clean softened water approximately one-half full. The water in the reservoir should be changed periodically. An algicide may be required in some climates to prevent organic growth in the system.

The service cord should be connected to a grounded receptacle. 115V/single phase - 20 AMP service should be provided for domestic units.

The Plexiglas sides of the channel may be best cleaned by using a liquid detergent soap. Scratches may be removed by sanding with #400 wet or dry paper and then buffing with a cotton buffer and a polishing compound. Care should be used in this operation so as not to sand too deeply in a small area, or a distorted appearance may result.

Operation

Pump - After filling the reservoir and before starting the pump, air trapped in the pump casing should be released through the air vent provided. The pump is equipped with a mechanical seal and should not be run without water.

Tilting Mechanism - The slope adjustment is controlled by an electrically driven ball screw. On the Model A channel care should be exercised to prevent running the ball screw out of the nut. Limit the slope to a positive 15%. The Model B unit is equipped with limit switches which control the travel of the channel.

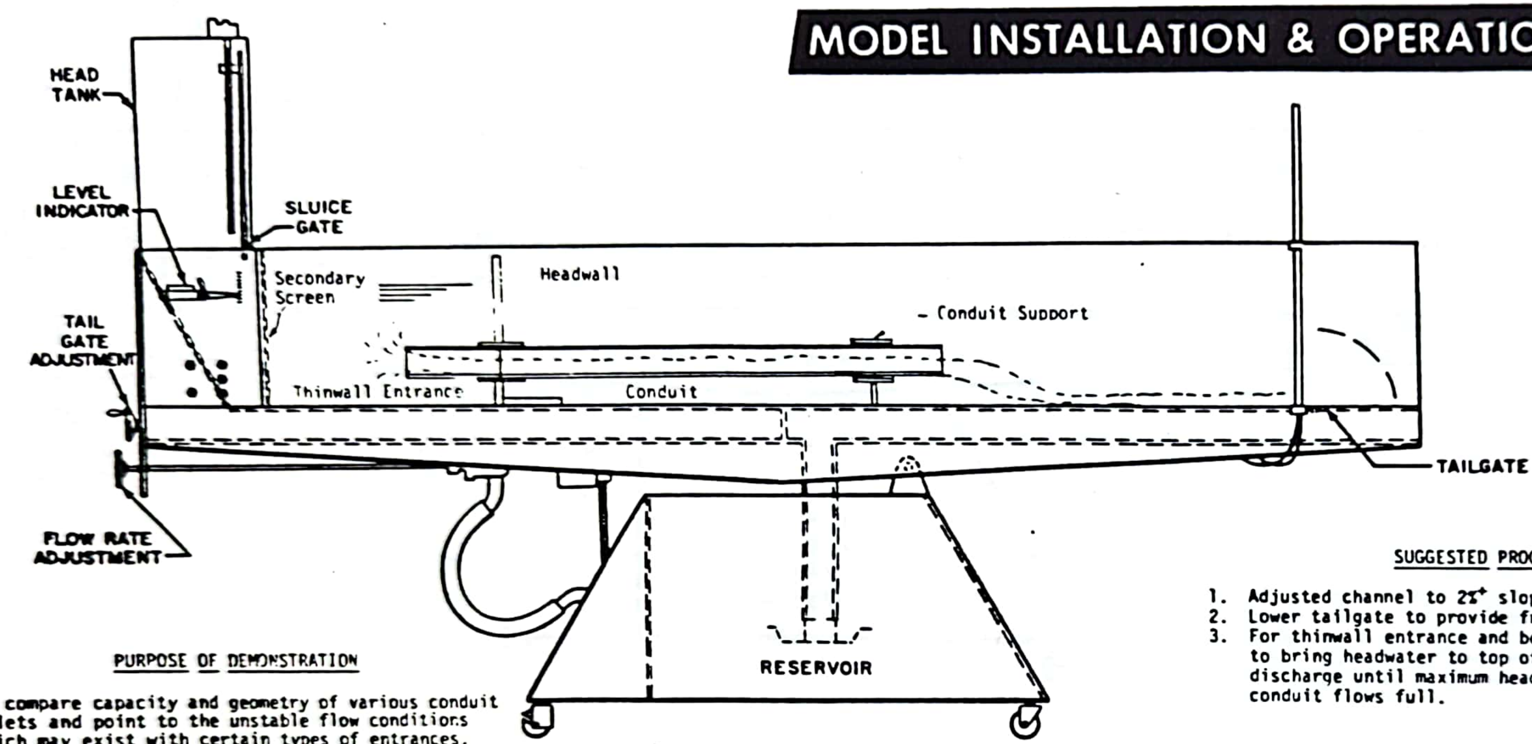
Flow Control - The rate of discharge can be controlled by the valve wheel located at the upstream end of the channel. This valve is a gate valve and the flow can be completely stopped without damage to the pump. When using only one pump on the Model B be sure to close the inoperative valve to prevent some flow from being returned to the reservoir.

Depth Control - The depth of flow in the channel is controlled by raising or lowering the tailgate at the downstream end of the channel. The Model A unit has a hand wheel for this purpose located at the upstream end of the channel. On the Model B the tailgate is electrically operated from a switch at the control panel. This unit is equipped with pre-set limit switches to control the travel of the tailgate. This gate is a two-piece unit and will automatically fold as it is lowered. However, it will be necessary to manually lower or raise the top leaf of the gate either to the fully collapsed or raised position.

Head Gate - The head gate on each unit is designed to provide an increased pressure head to be used with closed conduit models or with a partially open setting to develop higher velocity flows for demonstration of the hydraulic jump or other rapid flow phenomena. The Model A gate is manually controlled while the Model B has an electrically driven unit whose travel is controlled by pre-set limit switches. If objectionable leakage occurs when the gate is completely closed a soft rubber strip may be placed between the bottom of the gate and the channel floor. When this is done on the Model B gate extreme care should be used in lowering the gate, since the rubber strip is actually over-riding the lower limit setting.

Flow Measurement - The rate of flow in the channel can be determined by using the orifice meters fitted in the two individually valved supply pipes which are mounted below the Plexiglas channel. Higher flow rates can be measured with the large orifice in the 3" pipe. Low flow rates are measured using the smaller orifice in the 1½" pipe. The differential pressure across the orifice may be observed on the manometer located near the upstream end of the channel. A calibration chart relating the manometer deflection to the flow rate is furnished with each channel. To prevent errors in flow measurement insure that the valve controlling the supply pipe not in use is fully closed. The orifice to be measured by the manometer is selected with the small brass needle valves mounted on the bottom of the manometer. On Model B a third 3" pipe, orifice, valve and manometer are provided for the second pump.

MODEL INSTALLATION & OPERATION

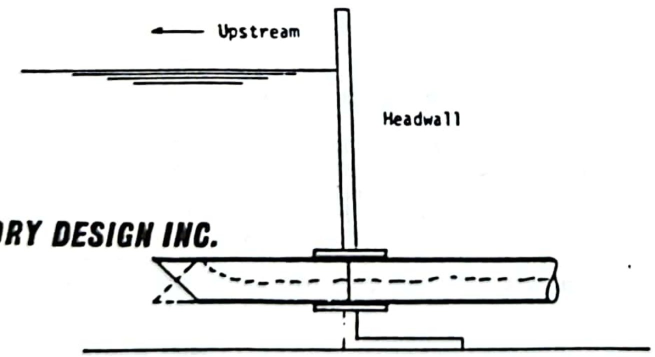


PURPOSE OF DEMONSTRATION

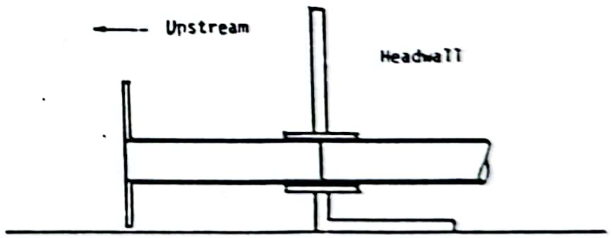
To compare capacity and geometry of various conduit inlets and point to the unstable flow conditions which may exist with certain types of entrances. The bevel and thin-walled tube (re-entrant orifice) locate the control at the entrance and retard the "priming" of the conduit until considerable head exists at the inlet.

SUGGESTED PROCEDURE

1. Adjusted channel to 2%+ slope.
2. Lower tailgate to provide free overfall.
3. For thinwall entrance and bevel inlet adjust flow to bring headwater to top of inlet, then increase discharge until maximum head is reached or until conduit flows full.



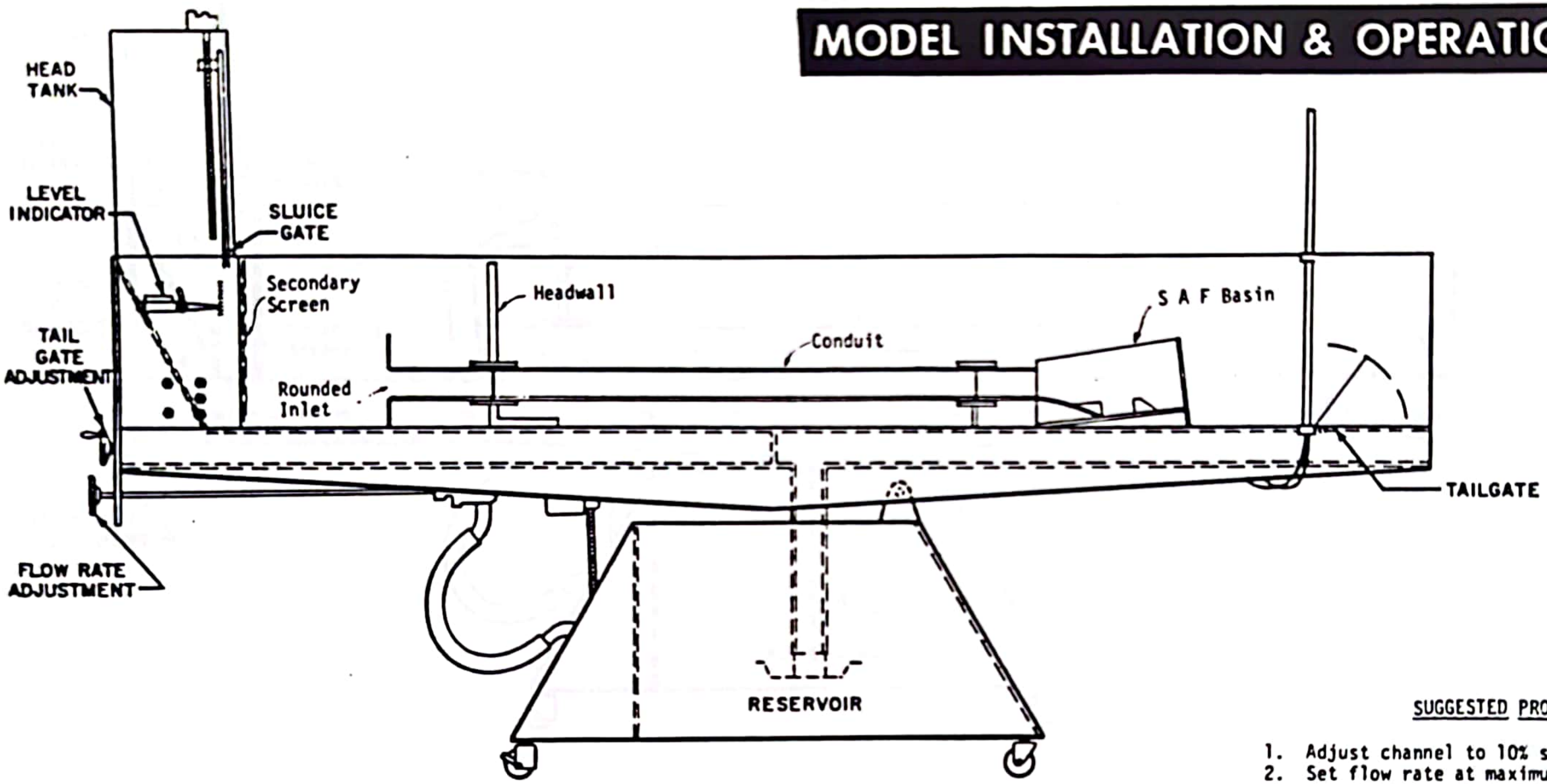
Bevel Down - Open channel flow in conduit
Bevel Up - Full pipe flow in conduit



Rounded Entrance
Square Edge Entrance

PIPE ENTRANCES

MODEL INSTALLATION & OPERATION



SUGGESTED PROCEDURE

1. Adjust channel to 10% slope.
2. Set flow rate at maximum for type of inlet used.
3. Start demonstration with tail gate in down position to show action with insufficient tailwater depth. Slowly increase tailwater until proper action is obtained and jump is contained within the structure.
4. Discharge may be increased or decreased to illustrate effectiveness of this structure to varying conditions.

NOTE: Any inlet section may be used in combination with the SAF basin.

PURPOSE OF DEMONSTRATION

To show the improved flow conditions and cost savings that can be obtained by using properly designed energy dissipation outlet structures in the conveying of high energy flows from reservoirs to downstream channels either natural or artificial. This type of structure offers good protection to erodible streambeds. It should be emphasized that many varieties and combinations of stilling blocks may be used.

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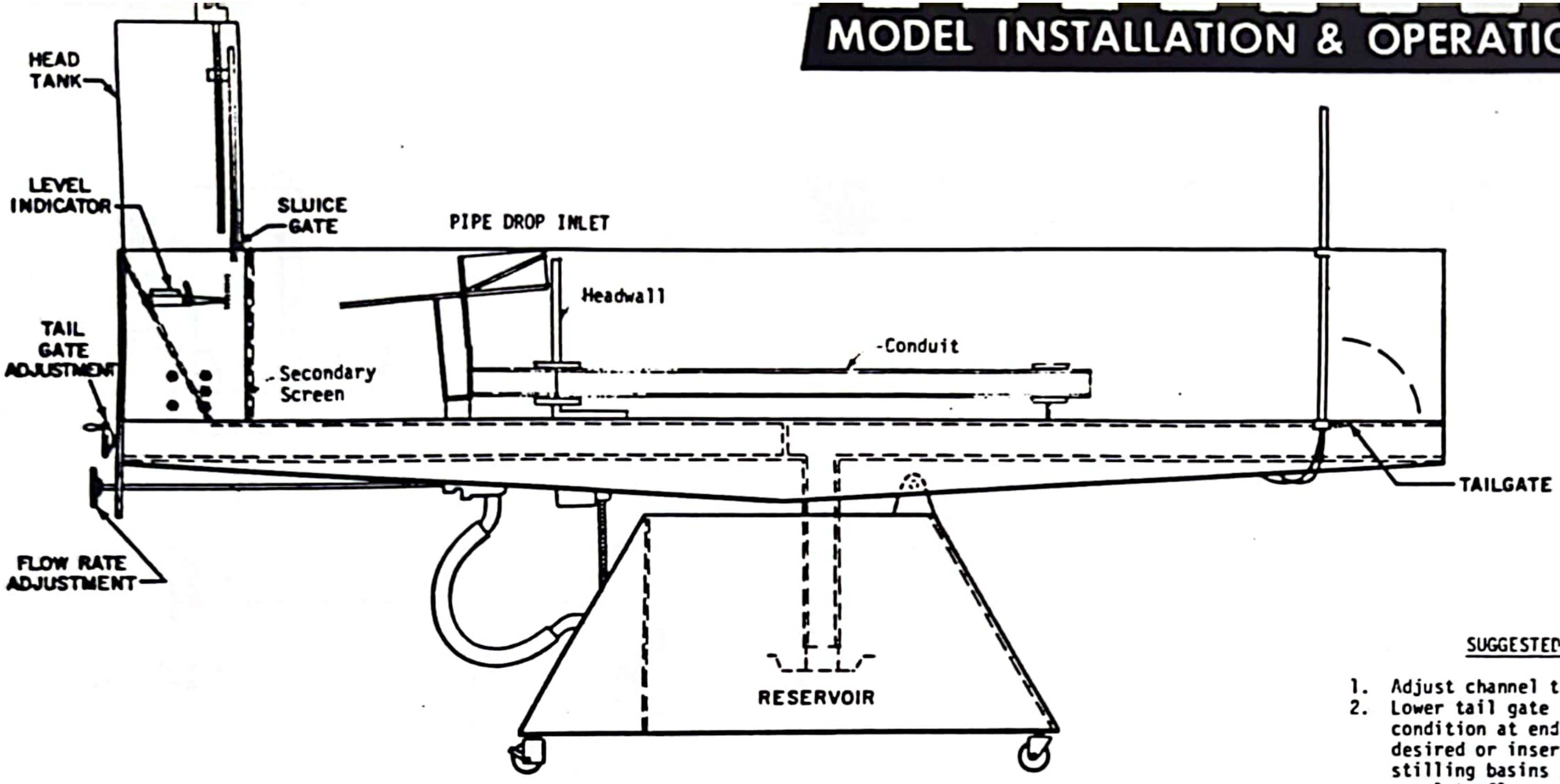
S A F STILLING BASIN

MODEL INSTALLATION & OPERATION



PURPOSE OF DEMONSTRATION

This inlet is a typical outflow structure to be used in a reservoir. The sloped face represents a 1:3 side slope of the reservoir fill. The vertical and longitudinal vertical walls prevent vortex formation. As discharge begins weir flow exists, followed by a period of orifice flow, and finally as sufficient head is available, the system is filled and full pipe flow is accomplished. In the zone between orifice and pipe flow periods of "slug" flow occur in which the tube alternately flows as an open channel and then with short lengths of full pipe flow. The head-discharge relationship of this structure makes it an excellent flow "limiter."

SUGGESTED PROCEDURE

1. Adjust channel to 10% slope.
2. Lower tail gate to allow free-out condition at end of conduit if desired or insert either of the stilling basins to portray a complete flow conveying system.
3. Begin with small discharge to illustrate weir flow, then slowly increase to obtain orifice and full pipe flow.

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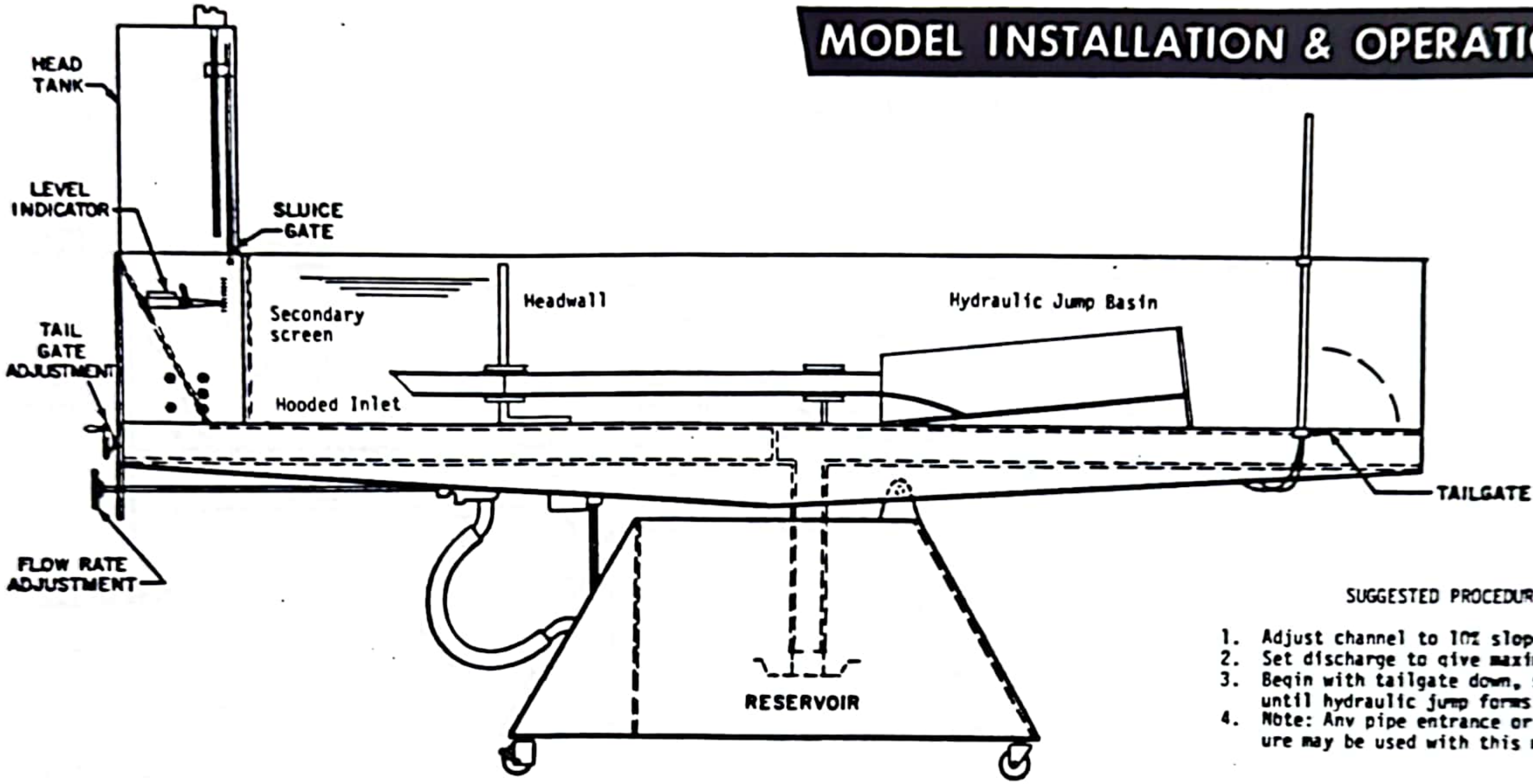
PIPE DROP INLET

MODEL INSTALLATION & OPERATION



SUGGESTED PROCEDURE

1. Adjust channel to 10% slope
2. Set discharge to give maximum flow
3. Begin with tailgate down, slowly raise until hydraulic jump forms in basin
4. Note: Any pipe entrance or inlet structure may be used with this model.

PURPOSE OF DEMONSTRATION

To show use of a stilling basin lacking energy dissipating devices. Energy reduction is obtained soley through the means of the hydraulic jump. Location of the jump is unstable and dependant completely on the height of the tailwater. Note the long length of basin required for proper performance.

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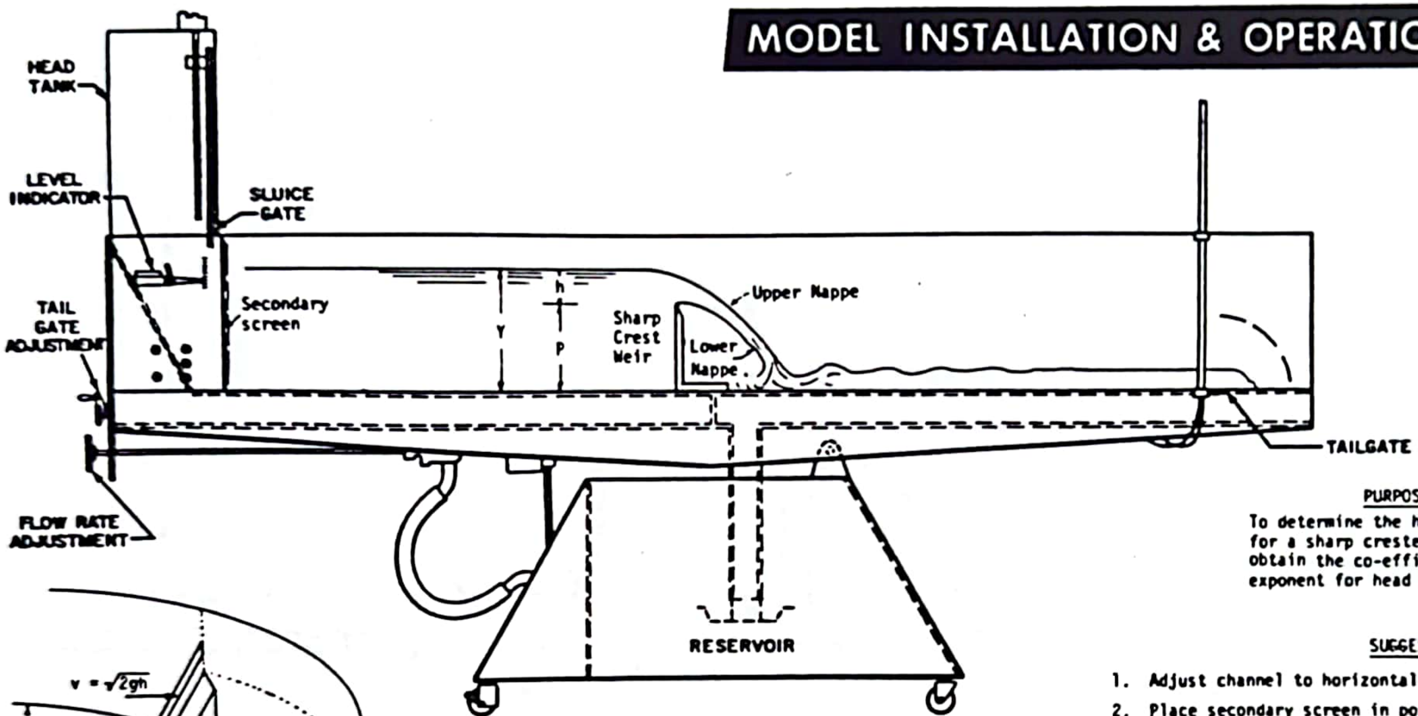
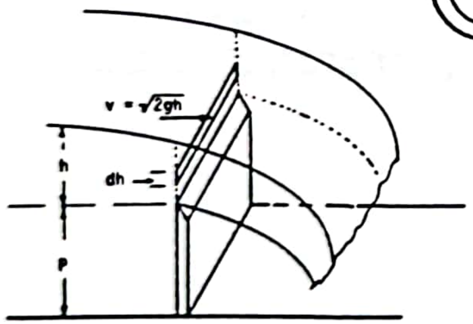
HYDRAULIC JUMP BASIN

MODEL INSTALLATION & OPERATION





For discharge through orifice of height dh and length L

$$dQ = c_d\sqrt{2gh}\ L\ dh$$

Integrating from 0 to H

$$Q = 2/3\ C_d\sqrt{2g}\ L\ H^{3/2}$$

From previous experimenters Kindsvater and Carter summarized the data to suggest the basic equation

$$Q = C_e L_e H_e^{3/2}$$

where $C_d = 3.22 + 0.40\ H/P$ cfs

and $L_e = L - 0.003$

$H_e = H + 0.003$

PURPOSE OF CALIBRATION

To determine the head-discharge relationship for a sharp crested suppressed weir and obtain the co-efficient of discharge and the exponent for head factor.

SUGGESTED PROCEDURE

1. Adjust channel to horizontal position.
2. Place secondary screen in position and raise head gate to highest limit.
3. Insert weir and fasten to bottom at mid-point.
4. Determine elevation of weir crest by point gage or other measuring device.
5. Start pump and adjust discharge to obtain minimum discharge over weir consistent with full areation of the nappe.
6. Measure elevation of the water surface at such a distance upstream as to be out of the drawdown area.
7. Record head on the weir and manometer reading on the supply orifice meter.
8. Increase discharge and repeat Step 7 and repeat as necessary to define the head-discharge curve.
9. Plot results on semi-log paper and determine discharge co-efficients and head term exponent.

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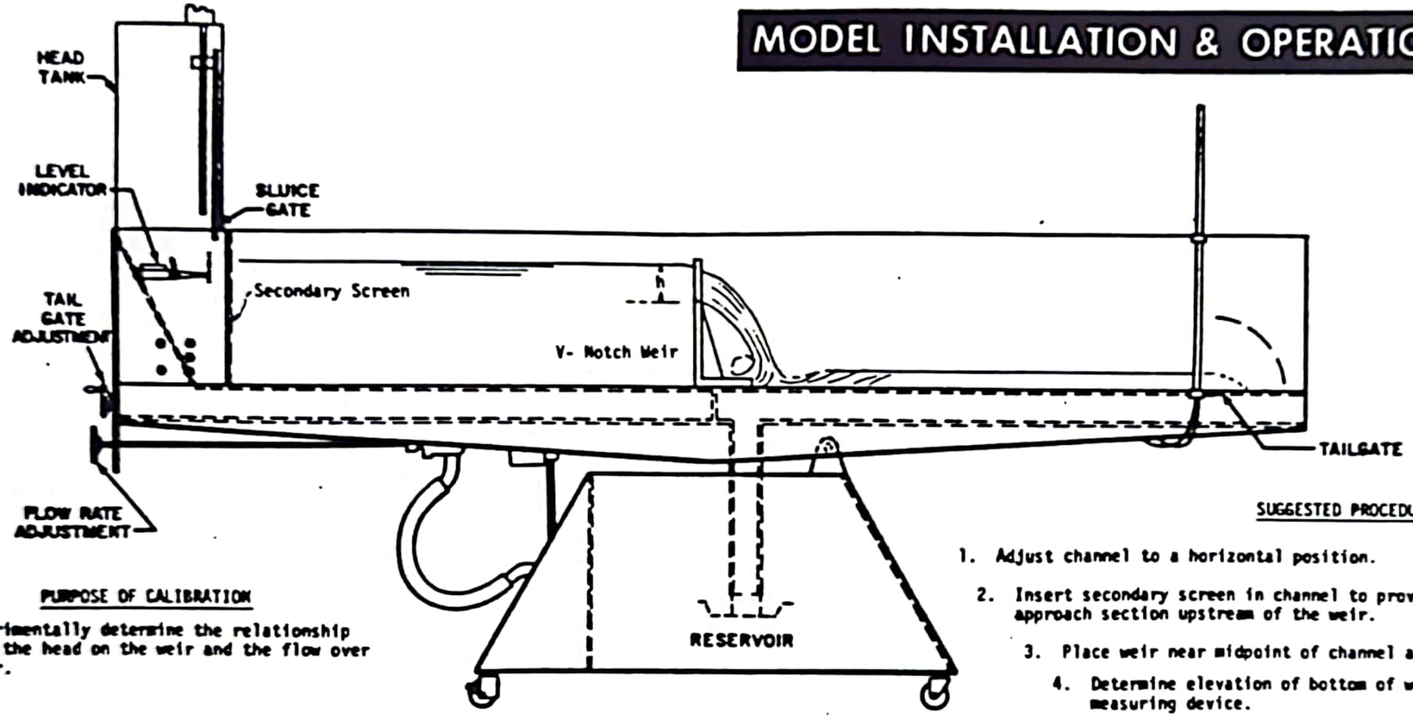
STRAIGHT WEIR

MODEL INSTALLATION & OPERATION

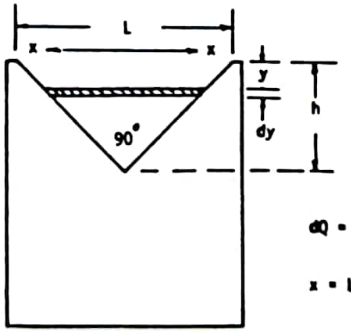


PURPOSE OF CALIBRATION

To experimentally determine the relationship between the head on the weir and the flow over the weir.

SUGGESTED PROCEDURE

1. Adjust channel to a horizontal position.
2. Insert secondary screen in channel to provide uniform velocities in the approach section upstream of the weir.
3. Place weir near midpoint of channel and fasten to bottom.
4. Determine elevation of bottom of weir notch by point gage or other measuring device.
5. Start pump and adjust discharge to obtain the minimum flow over the weir consistent with full areation of the nappe.
6. Measure elevation of the water surface at such a distance upstream as to be out of the drawdown area.
7. Record head on weir and manometer reading on channel supply orifice meter.
8. Increase discharge and repeat Step 7 to obtain as many points as desired to define the head discharge curve.
9. Plot results on semi-log paper to determine the exponent and discharge coefficient.



$$dQ = C_d \, x \sqrt{2gy} \; dy$$

$$x = L \left(\frac{h-y}{h} \right) = 2(h-y)\tan \theta/2$$

$$Q = 8/15 \; C_d \sqrt{2g} \tan \theta/2 \;\; h^{5/2}$$

$$Q = 2.5 \, h^{5/2} \quad \text{cfs}$$

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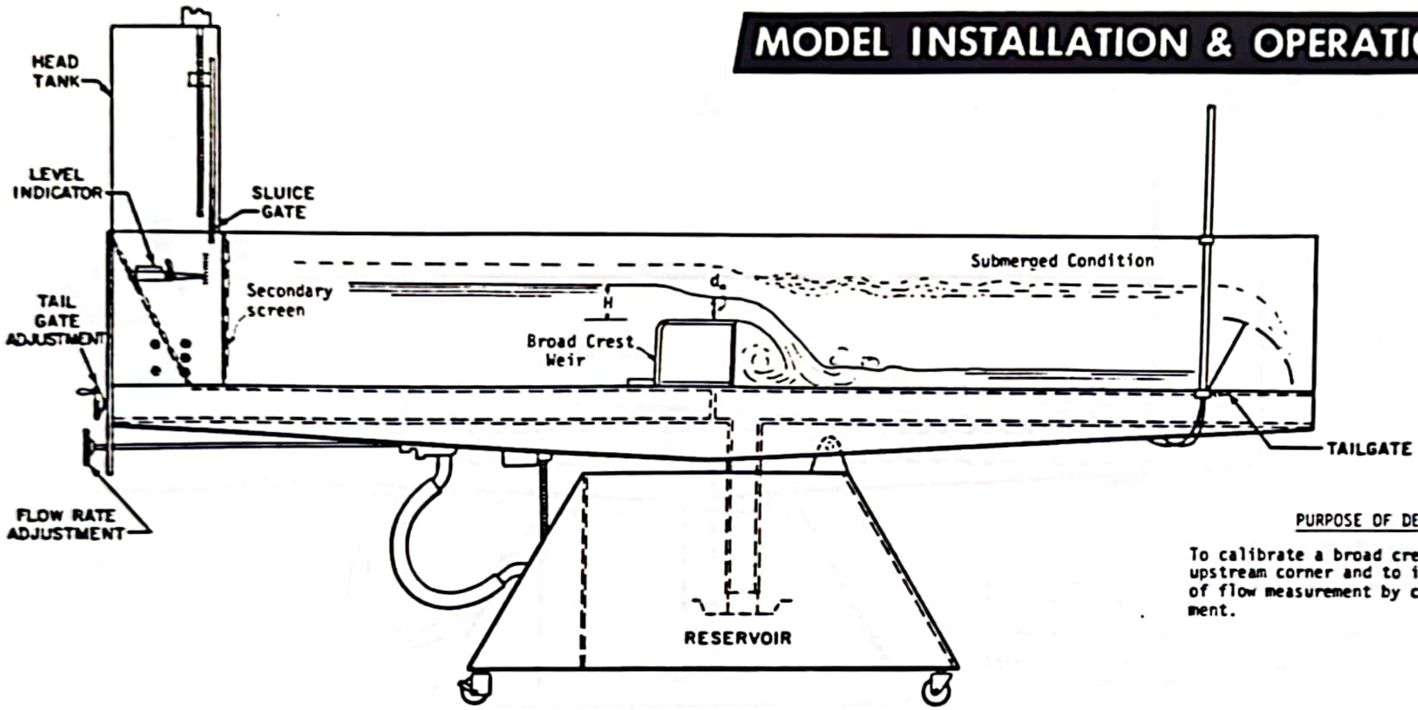
V-NOTCH WEIR

MODEL INSTALLATION & OPERATION



PURPOSE OF DEMONSTRATION

To calibrate a broad crest weir with rounded upstream corner and to illustrate the principle of flow measurement by critical depth measurement.

SUGGESTED PROCEDURE

1. Adjust channel to horizontal slope.
2. Attach model to channel bed, placing secondary screen at channel upstream end. Head gate should be raised to upper limit.
3. Calibrate weir by recording both H and D terms and also manometer reading of supply orifice. Enough readings should be made to define the head discharge curve.
4. Raise tail water to submerge the weir.
5. Observe the effect of submergence on the upstream level and also its effect on the discharge. At what point does the weir cease to have "free" discharge?

Discharge over a Broad Crested Weir

$$Q = 3.087\ LH^{3/2} = 5.67\ LD^{3/2}\ \text{cfs}$$

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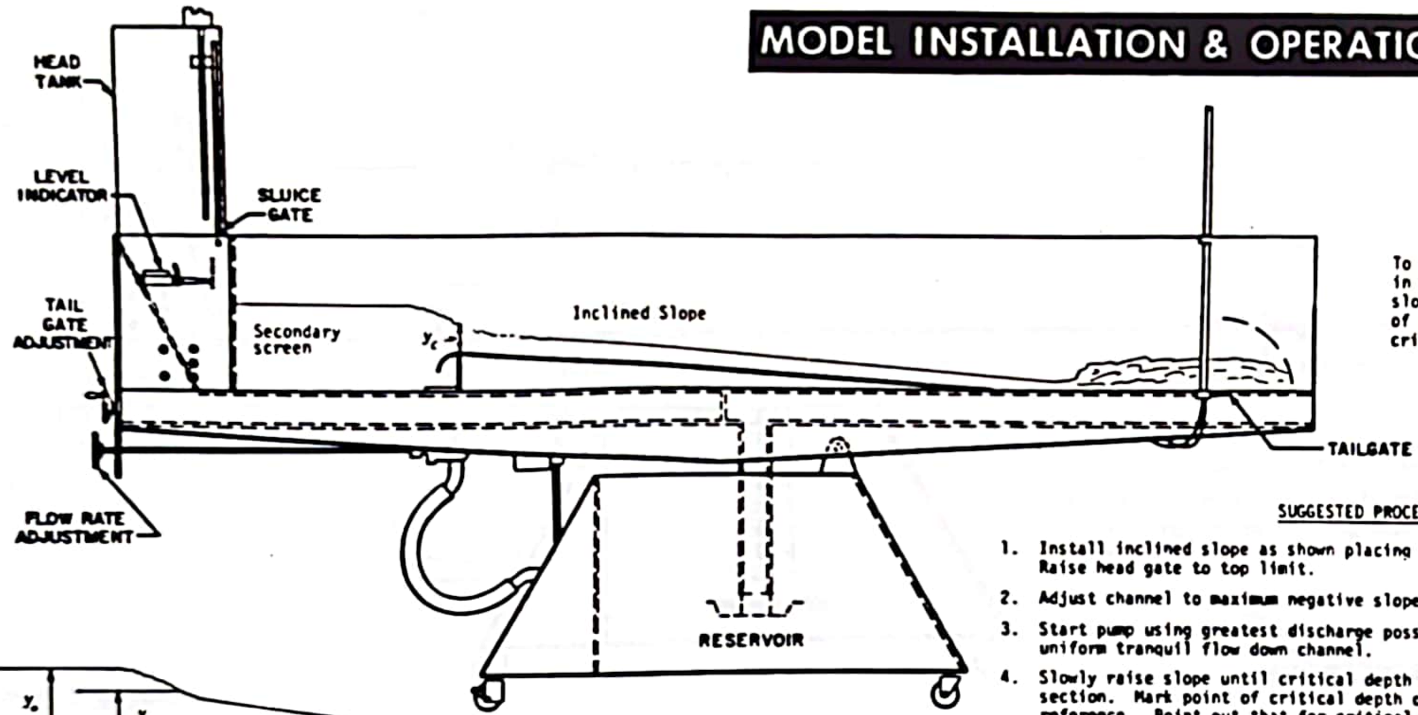
BROAD CREST WEIR

MODEL INSTALLATION & OPERATION

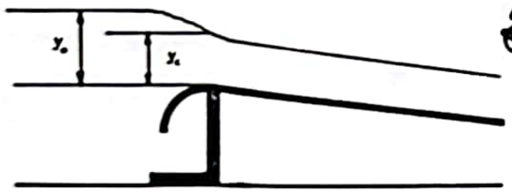


PURPOSE OF DEMONSTRATION

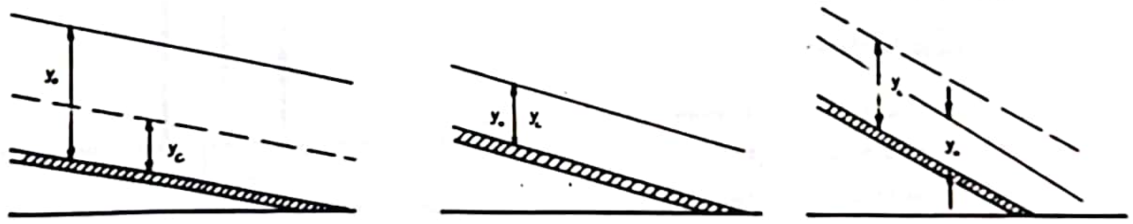
To illustrate types of varied flow in open channels. The inclined slope is used to provide a point of control in the establishment of critical depth.

SUGGESTED PROCEDURE

1. Install inclined slope as shown placing secondary screen at headgate. Raise head gate to top limit.
2. Adjust channel to maximum negative slope.
3. Start pump using greatest discharge possible. Adjust tailgate to give uniform tranquil flow down channel.
4. Slowly raise slope until critical depth is obtained over the entrance section. Mark point of critical depth on channel side wall for later reference. Point out that for critical slope the velocity down the slope is uniform with no acceleration or deceleration. When critical flow occurs show that waves caused by surface disturbances do not travel upstream.
5. Increase slope further to show accelerated flow down slope. An hydraulic jump may be formed at the lower end of the slope by adjusting the level of the tailwater.
6 Show how to determine the Froude number and its use.



Critical Depth



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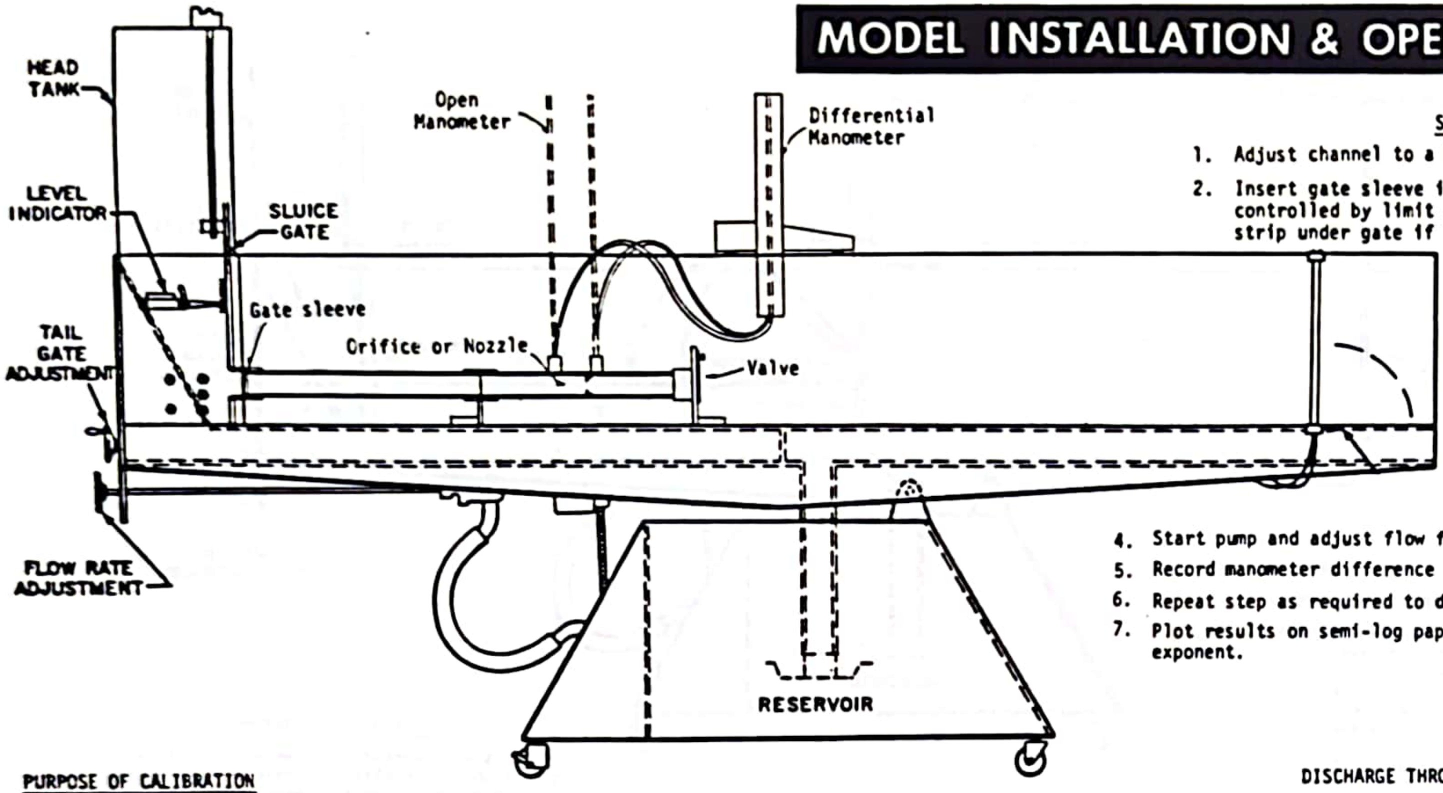
INCLINED SLOPE

MODEL INSTALLATION & OPERATION



SUGGESTED PROCEDURE

1. Adjust channel to a horizontal position.
2. Insert gate sleeve in headgate and lower to bottom limit. (Travel controlled by limit switch on Model B.) Place thin soft rubber strip under gate if leakage is excessive.
3. Assemble orifice or flow nozzle unit with straight conduit length as indicated. Attach open manometer tubes or differential gage as desired. Use valve unit on downstream end when necessary to raise pressure level.
4. Start pump and adjust flow for minimum deflection of the manometer.
5. Record manometer difference and also reading of supply orifice manometer.
6. Repeat step as required to define discharge curve.
7. Plot results on semi-log paper to determine discharge coefficient and exponent.

PURPOSE OF CALIBRATION

To determine the pressure differential-discharge relation of the orifice in comparison to the flow nozzle.

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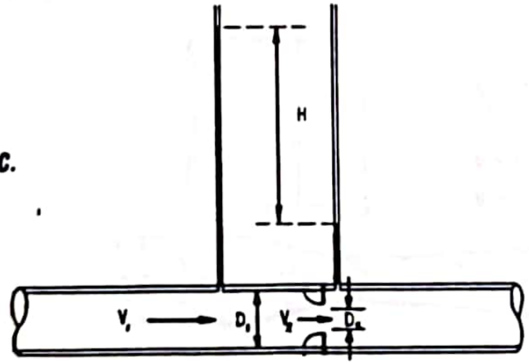


DISCHARGE THROUGH A PIPE ORIFICE

$$Q = \frac{C_v C_c A_2}{\sqrt{1 - C_c^2 \left(\frac{D_2}{D_1}\right)^4}} \sqrt{2g\Delta h}$$

For a given orifice the above can be expressed

$$Q = C_d A_2 \sqrt{2g\Delta h} \quad \text{cfs}$$

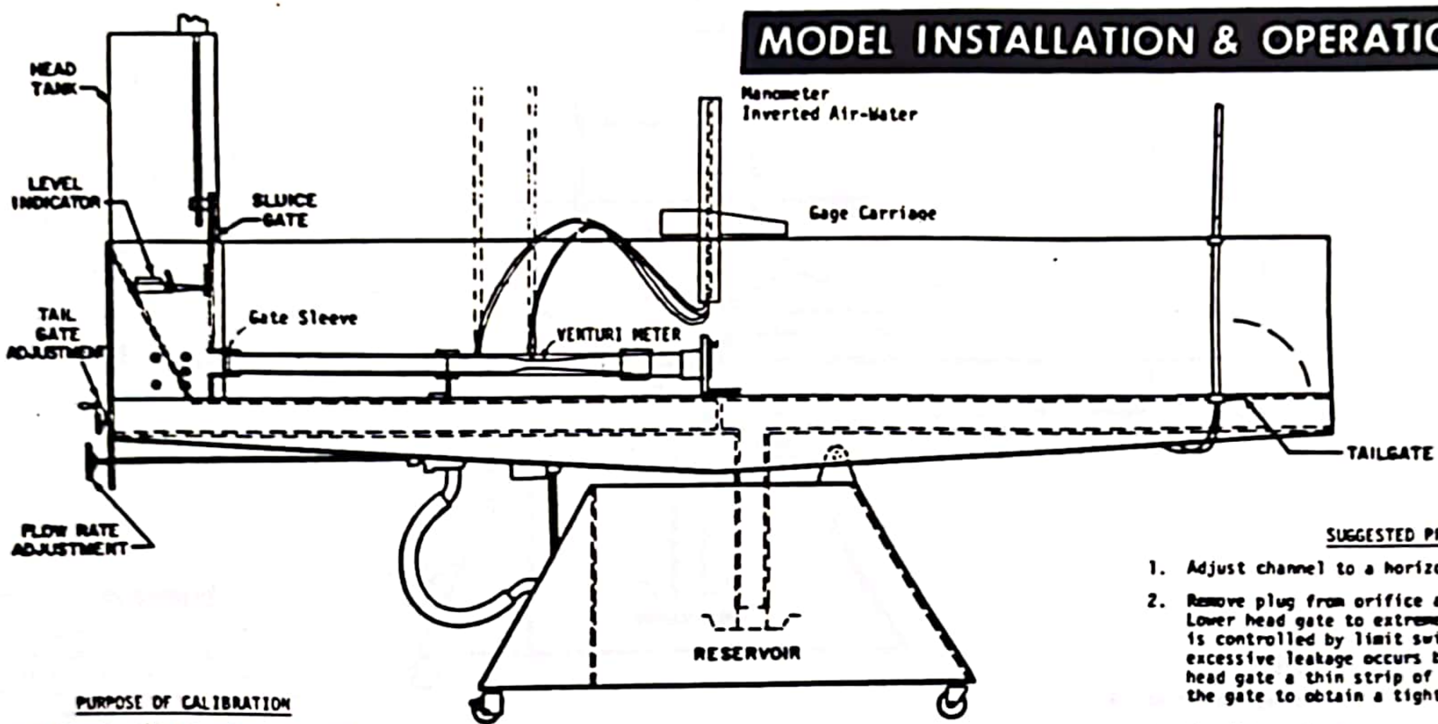
where C_d = Coefficient of discharge

A_2 = Area of Orifice

Δh = Change in head

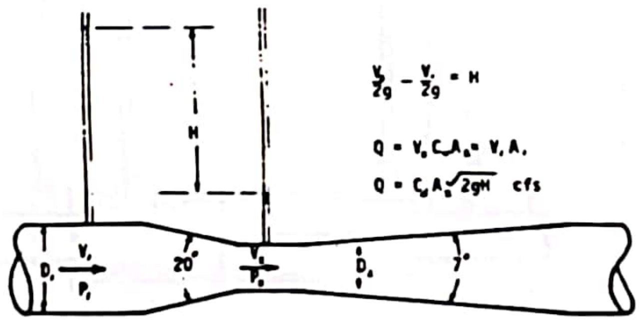
ORIFICE and FLOW NOZZLE

MODEL INSTALLATION & OPERATION



PURPOSE OF CALIBRATION

To determine the relation between the discharge and the pressure differential developed between the upstream section and the throat of the meter. The meter is a direct application of the Bernoulli equation.



$$\frac{V_a}{2g} - \frac{V_1}{2g} = H$$

$$Q = V_a C_c A_a = V_1 A_1$$

$$Q = C_d A_a \sqrt{2gH} \text{ cfs}$$

SUGGESTED PROCEDURE

1. Adjust channel to a horizontal slope.
2. Remove plug from orifice and insert gate sleeve. Lower head gate to extreme lower position. (This is controlled by limit switches on the Model B.) If excessive leakage occurs between the bottom of the head gate a thin strip of soft rubber may be used under the gate to obtain a tighter seal.
3. Assemble Venturi Meter and sections of straight conduit as shown in sketch.
4. Install plastic manometer tubes or connect to differential manometer as indicated. If open manometer is used it will be necessary to use the butterfly valve unit to increase the pressure level downstream of the meter. The butterfly valve unit is available for purchase if this was not furnished as a specified accessory.
5. Start pump and regulate discharge to give the minimum flow through the system.
6. Record the difference of pressure through meter and also note manometer deflection of channel supply meter.
7. Repeat Step 6 as required to give the number of points necessary to define the discharge curve.
8. Plot results on semi-log paper to determine the coefficient and exponent.

VENTURI METER

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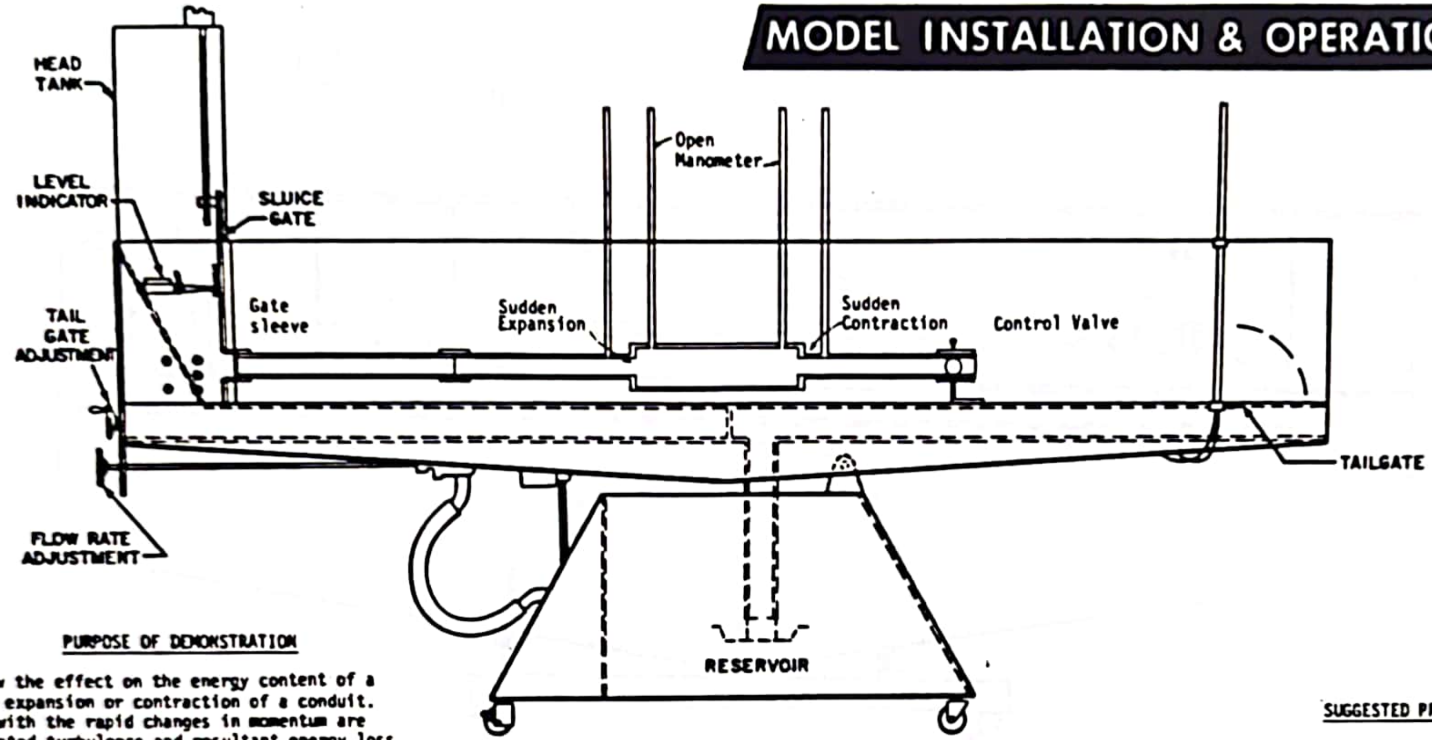
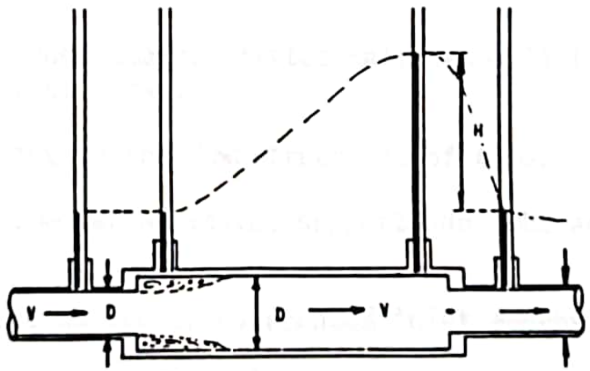
MODEL INSTALLATION & OPERATION



PURPOSE OF DEMONSTRATION

To show the effect on the energy content of a sudden expansion or contraction of a conduit. Along with the rapid changes in momentum are associated turbulence and resultant energy loss in the separation zone.



SUGGESTED PROCEDURE

1. Adjust channel to horizontal slope.
2. Insert gate sleeve in head gate and lower gate to channel floor using thin rubber strip under gate if leakage is excessive.
3. Assemble contracted section and straight conduit as shown, using a control valve on downstream end to raise pressure level.
4. Start pump and regulate discharge to significant change in pressure levels in the open manometers.
5. Note rise in pressure from first upstream manometer to third manometer and drop from third to fourth manometer.

SUDDEN CONTRACTION AND EXPANSION

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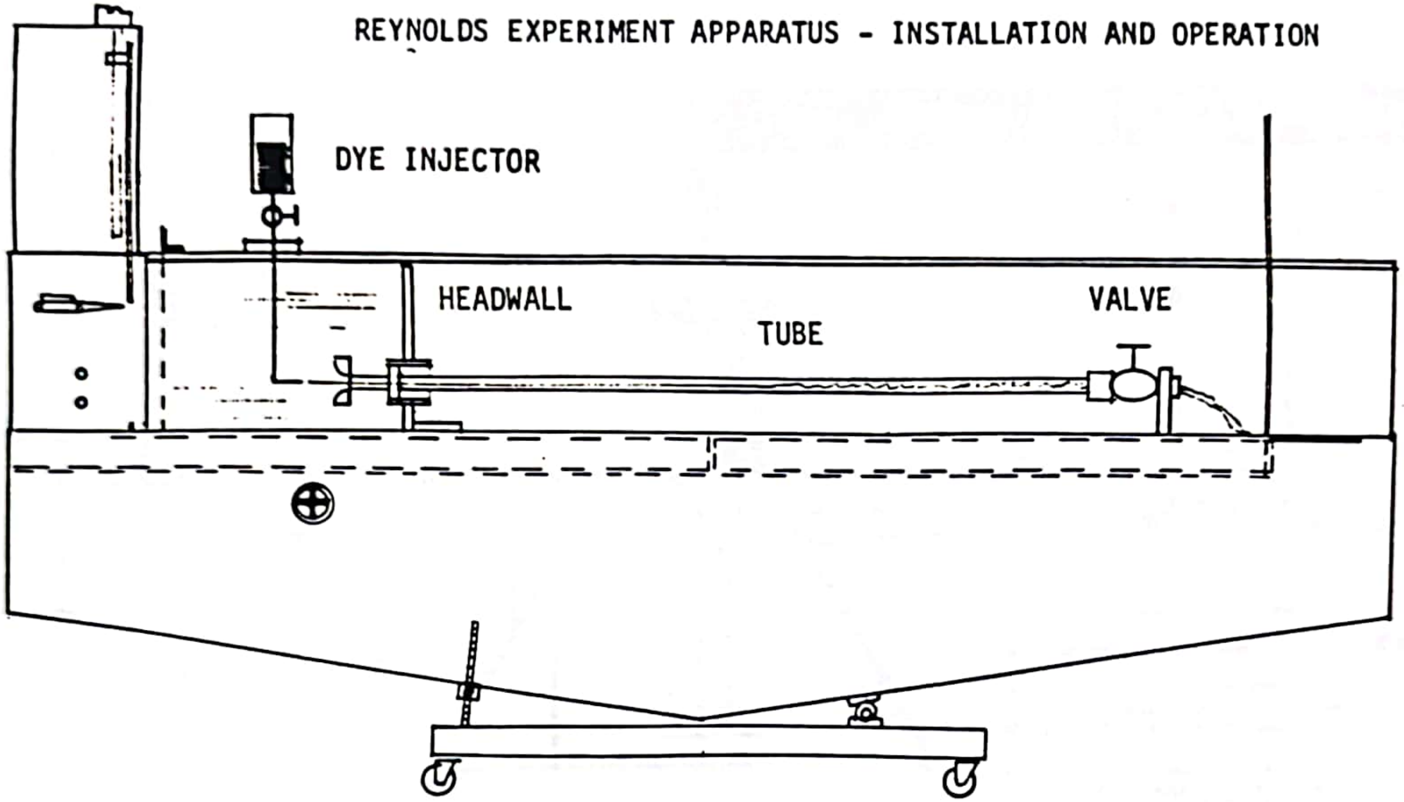
REYNOLDS EXPERIMENT APPARATUS - INSTALLATION AND OPERATION



1. Level the channel.

2. Insert long tube with round adapter fitted into headwall (from pipe flow set) and locate in upstream end of channel as shown.

3. Fit the valve and support to the downstream end of tube.

4. Assemble dye reservoir, metering valve, support and tube as shown. Fasten to channel rail with small C - clamps.

5. Adjust dye injector tube to center on rounded inlet approximately 2" upstream.

6. Start pump and adjust flow control valve and tube outlet valve to establish steady flow.

7. Fill dye reservoir with vegatable dye and adjust valve to produce visible dye stream.

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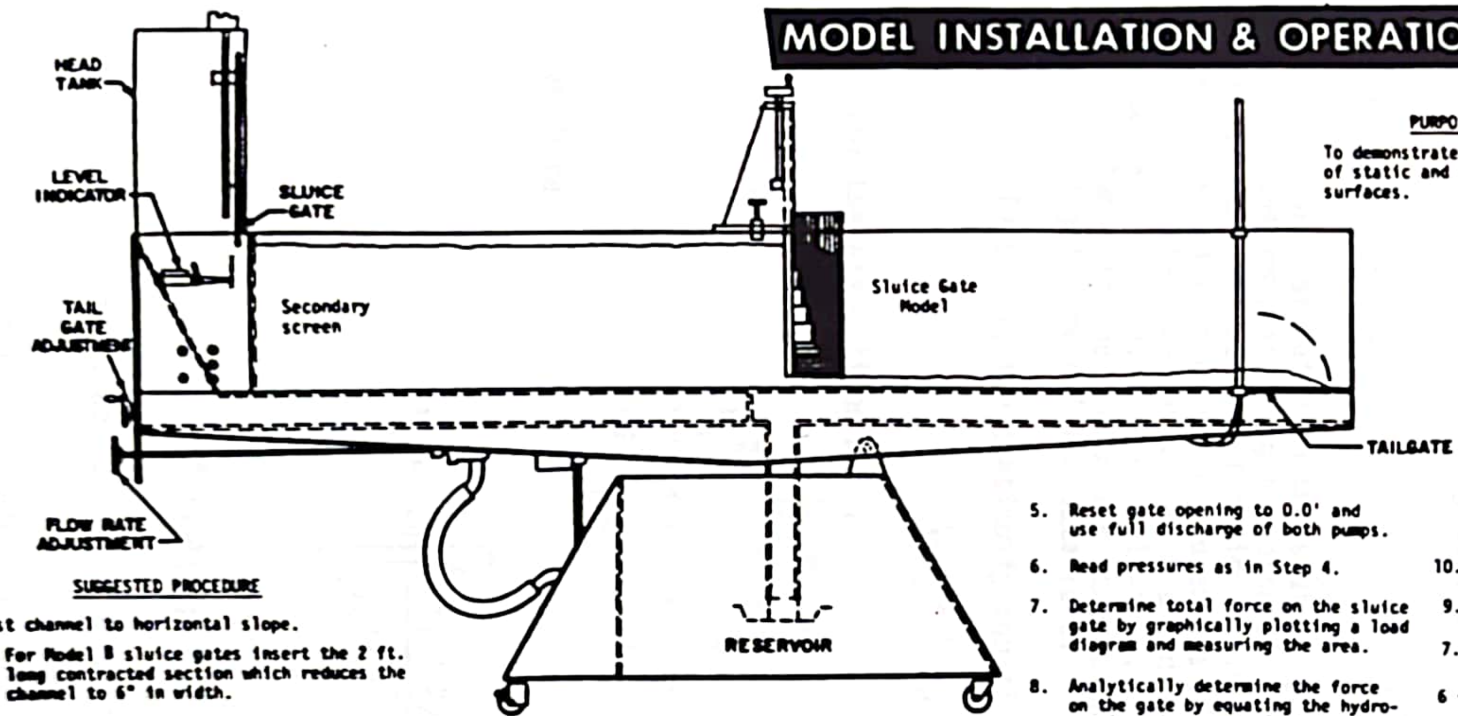
MODEL INSTALLATION & OPERATION



PURPOSE OF DEMONSTRATION

To demonstrate methods used in the determination of static and dynamic forces acting on submerged surfaces.

SUGGESTED PROCEDURE

1. Adjust channel to horizontal slope.

   1a. For Model B sluice gates insert the 2 ft. long contracted section which reduces the channel to 6" in width.

2. Place model in channel as shown using C clamps to fasten base to channel side rails.

3. Set gate opening to approximately 0.0 ft. to utilize full discharge of one pump. (Obtain rate of flow from supply orifice meter.)

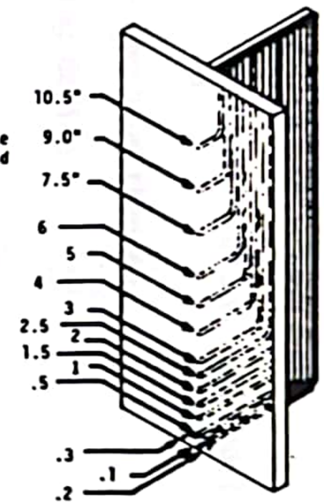
4. Read pressures on the gate face by observing height of water column in the individual manometer tubes.

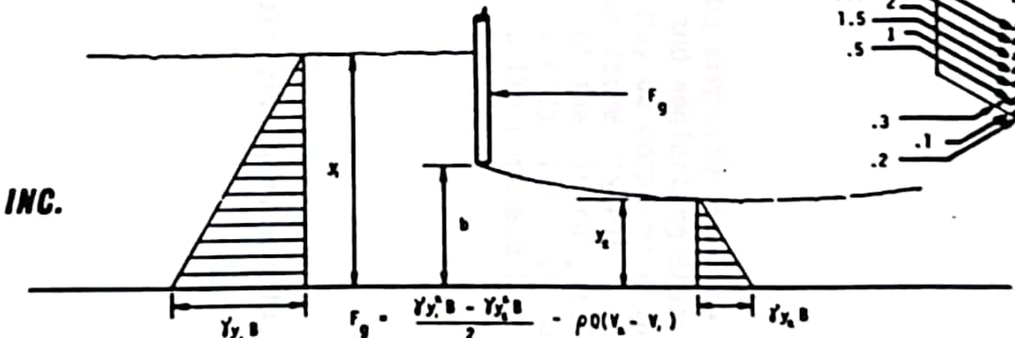
5. Reset gate opening to 0.0' and use full discharge of both pumps.

6. Read pressures as in Step 4.

7. Determine total force on the sluice gate by graphically plotting a load diagram and measuring the area.

8. Analytically determine the force on the gate by equating the hydrostatic and momentum forces on each side of the sluice gate. (See equation.)





$$F_g = \frac{\gamma y_1^2 B - \gamma y_2^2 B}{2} - \rho Q(V_2 - V_1)$$

where $y_2 = C_c b$ and $Q = V_1 y_1 B = V_2 y_2 B$

B = Width of channel

SLUICE GATE

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SLUICE GATE

The sluice gate may be installed in either the Model A or the Model B channel. It may be used

I. To illustrate the momentum theorem

II. As a flow-measuring device

I. Momentum Theorem

The force of water on the sluice gate may be computed from the momentum theorem, assuming one-dimensional flow and neglecting shear along the channel bed and the side walls. This may be compared with the force obtained from direct measurements of the pressure distribution on the sluice gate. Depths upstream and downstream of the sluice gate, the sluice gate opening, the channel width, and the heights of the various water columns in the piezometer tubes connected to the upstream face of the sluice gate are all the data required.

From Figure 1, the continuity equation is

$$V_1 y_1 = V_2 y_2$$

For the assumptions mentioned above, the Bernoulli equation is valid. For a zero bed slope,

$$\frac{V_1^2}{2g} + y_1 = \frac{V_2^2}{2g} + y_2$$

From these

$$V_1 = 2g\left[\left(\frac{y_1 - y_2}{(y_1/y_2)^2 - 1}\right)\right]^{1/2} \qquad \text{ft/sec}$$

and

$$V_2 = V_1 (y_1/y_2) \qquad \text{ft/sec}$$

The momentum theorem, based on the above assumptions, is

$$B\gamma y_1^2/2 - B\gamma y_2^2/2 - F_g = V_1 y_1 B\rho(V_2 - V_1)$$

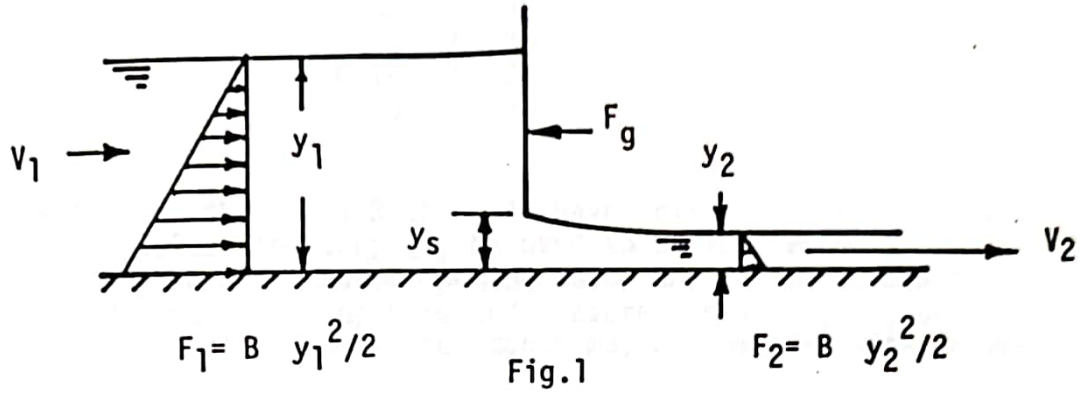

Fig.1

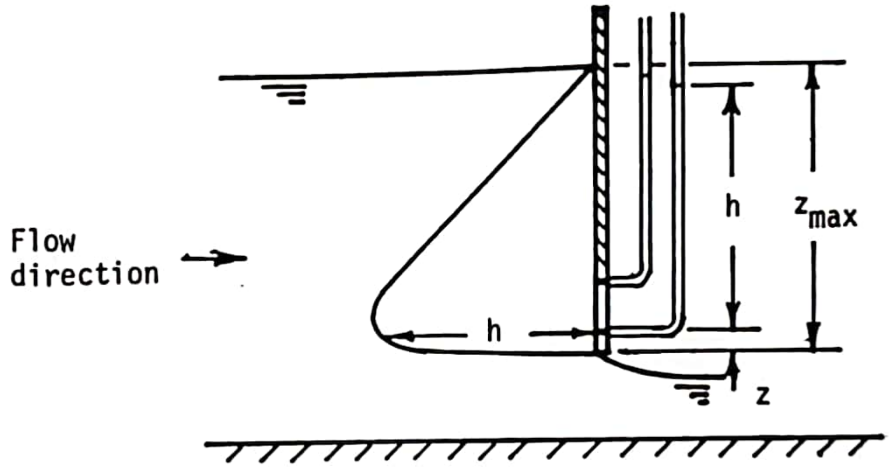

Fig.2

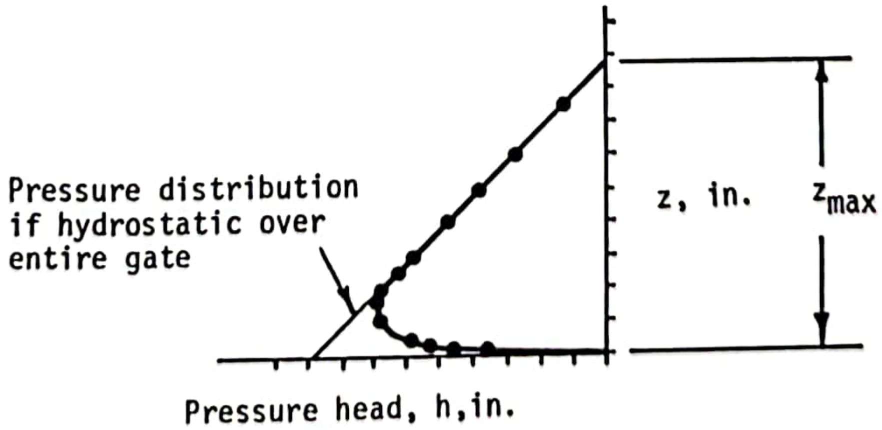

Fig. 3

y_s/y_1	K
0.0	0.611
0.05	0.599
0.10	0.588
0.15	0.578
0.20	0.568

Both the Model A and the Model B channels have orifices in the supply ducts. If these are calibrated they may be used to calibrate the sluice gate. Some channels have a discharge opening below the tailgate, and flow may then be diverted through the opening and measured in a weighing or volumetric tank. Values of K from measurements may be compared with values listed above.