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METERING GATES FOR PIPE DISTRIBUTION SYSTEMS

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INTRODUCTION

In 1947 the Bureau of Reclamation initiated a program for the development and standardization of water measurement devices. One purpose of this program was to evaluate the feasibility, flow characteristics, installation, and limitations, of various so-called "standard measuring devices."

This discussion concerns one of the standard devices, namely, the calibrated gate. The evaluation of the flow characteristics and limitations of this measuring device was made in the Hydraulic Laboratory of the Bureau of Reclamation at Denver, Colorado. The gate used in these studies was a metergate, the product of a Denver manufacturer. Valuable assistance and additional information on metergates were furnished by Colorado A&M College, Fort Collins, Colorado.

The simplicity of design and low maintenance cost has resulted in the extensive use of the metergate, both for measuring and regulating irrigation water. The metergate can be attached to corrugated pipe or to smooth pipe of concrete structure. When used as a measuring device, two 10-inch measuring wells, 2 feet or higher, are attached to the framework on the downstream side of the gate. One measuring well provides a means for recording the water surface upstream of the gate; the other well indicates the pressure head 1 foot downstream of the gate seat. The difference in water surface in the measuring wells plotted against the discharge gives the calibration curve for the metergate. Figure 1 shows a metergate with the gate leaf in full open position, the measuring wells, and a 2-foot section of corrugated pipe.

ANALYSIS

As a basis for evaluating the flow characteristics and limitations of the metergates, the following relationship was used:

$$Q = Cd \frac{\pi d^2}{4} \sqrt{2g \Delta H}$$

Where: Q = discharge, cfs
C_d = coefficient of discharge
d = nominal diameter of gate, feet
g = gravity, 32.2 ft/sec^2
ΔH = difference in water surface in measuring wells, feet

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From the initial analysis of the problem, it was concluded that the coefficient of discharge, C_d, would be influenced by the following variables which are defined in Figure 2: the upstream submergence, h; the gate opening, a; the nominal diameter of gate, d; the location of downstream measuring well, x, measured from the gate seat; and the mean velocity in the pipe, V. To facilitate the use of the variables, h, a, d, x, and V, they were translated into dimensionless parameters with this resulting relationship:

$$C_d = \phi(h/a,\ a/d,\ x/d,\ R_e)$$

The parameter, R_e, is the Reynolds number and is obtained from the following relationship:

$$R_e = \frac{Vd}{\nu}$$

V = mean velocity in the pipe, ft/sec

d = nominal diameter of gate, feet

ν = kinematic viscosity, ft^2/sec

The advantage of using R_e rather than V or Q was that the viscosity factor takes the temperature of the fluid into consideration, and R_e is a common parameter used to compare hydraulic data.

It was anticipated that the limitations of installation and operation for all sizes of metergates could be established with a satisfactory degree of accuracy by investigating the above parameters on a 12-inch metergate and applying the laws of similitude. However, early in the investigation it was found that the similitude relationships could not be applied because of dissimilarities in the gate assembly of the various sizes. Accordingly, a range of sizes--8-, 12-, 15-, and 24-inch metergates--were tested. These studies were supplemented by data on 18- and 48-inch metergates tested by Colorado A&M College.

The gate is manufactured in 14 sizes, ranging from 8 inches to 48 inches. It was felt that with the results of the six sizes tested, the characteristics of the other sizes could be determined by interpolation and extrapolation.

INVESTIGATION

The Upstream Submergence Limitation

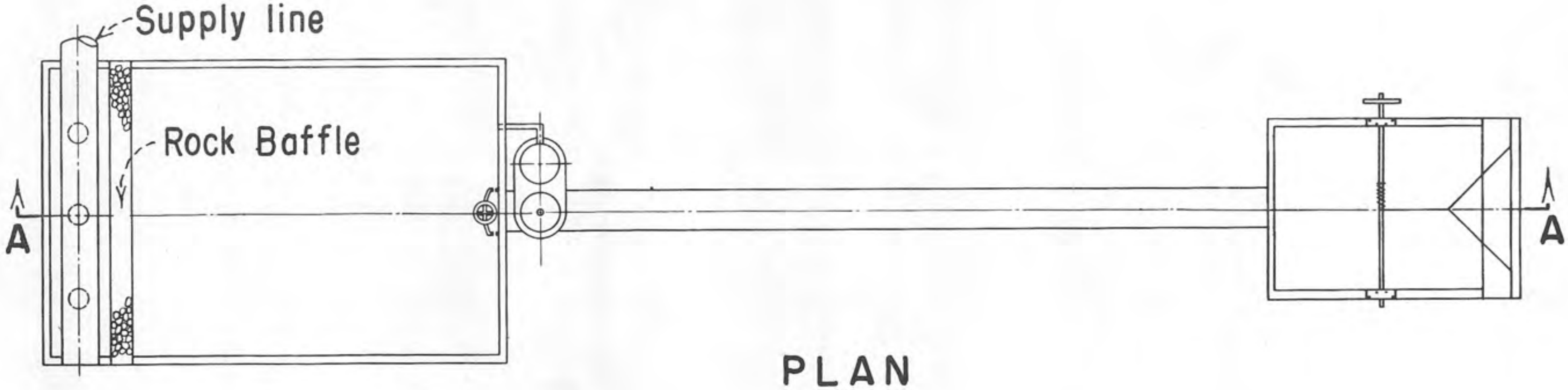
During the testing, logarithmic plots were made of discharge versus difference in head (ΔH) for the different sizes of gates at various openings. These plots gave straight lines for the higher values of ΔH; for small values of ΔH and h, as shown in Figure 3, the plots

FIGURE 1

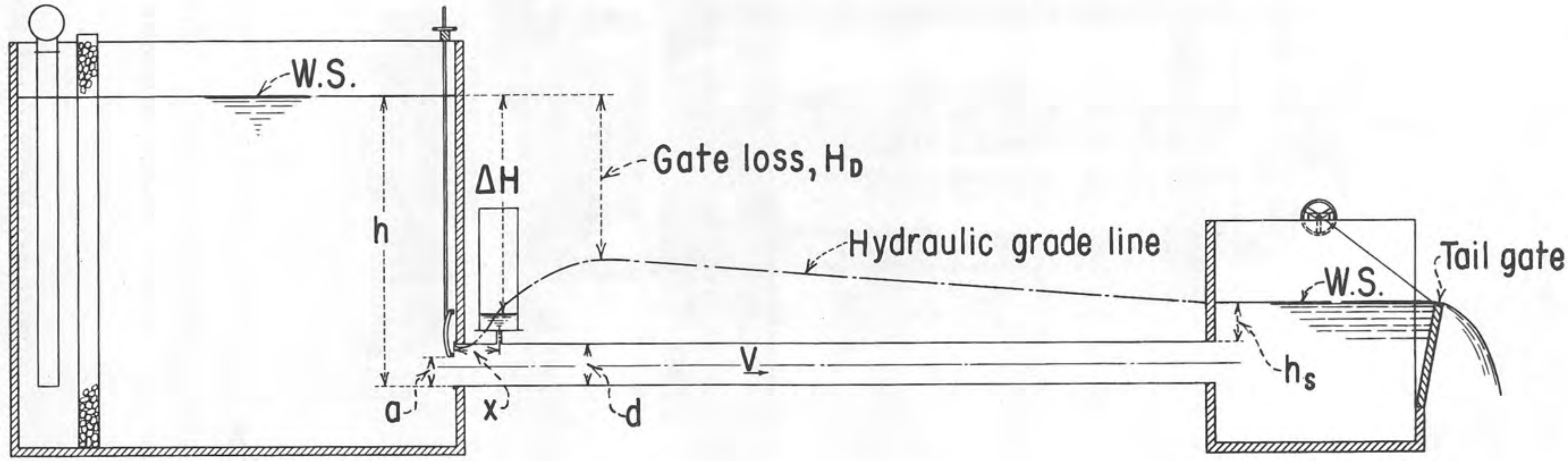
Metergate Studies

12-INCH ARMCO METERGATE MODEL NO. 101

FIGURE 2

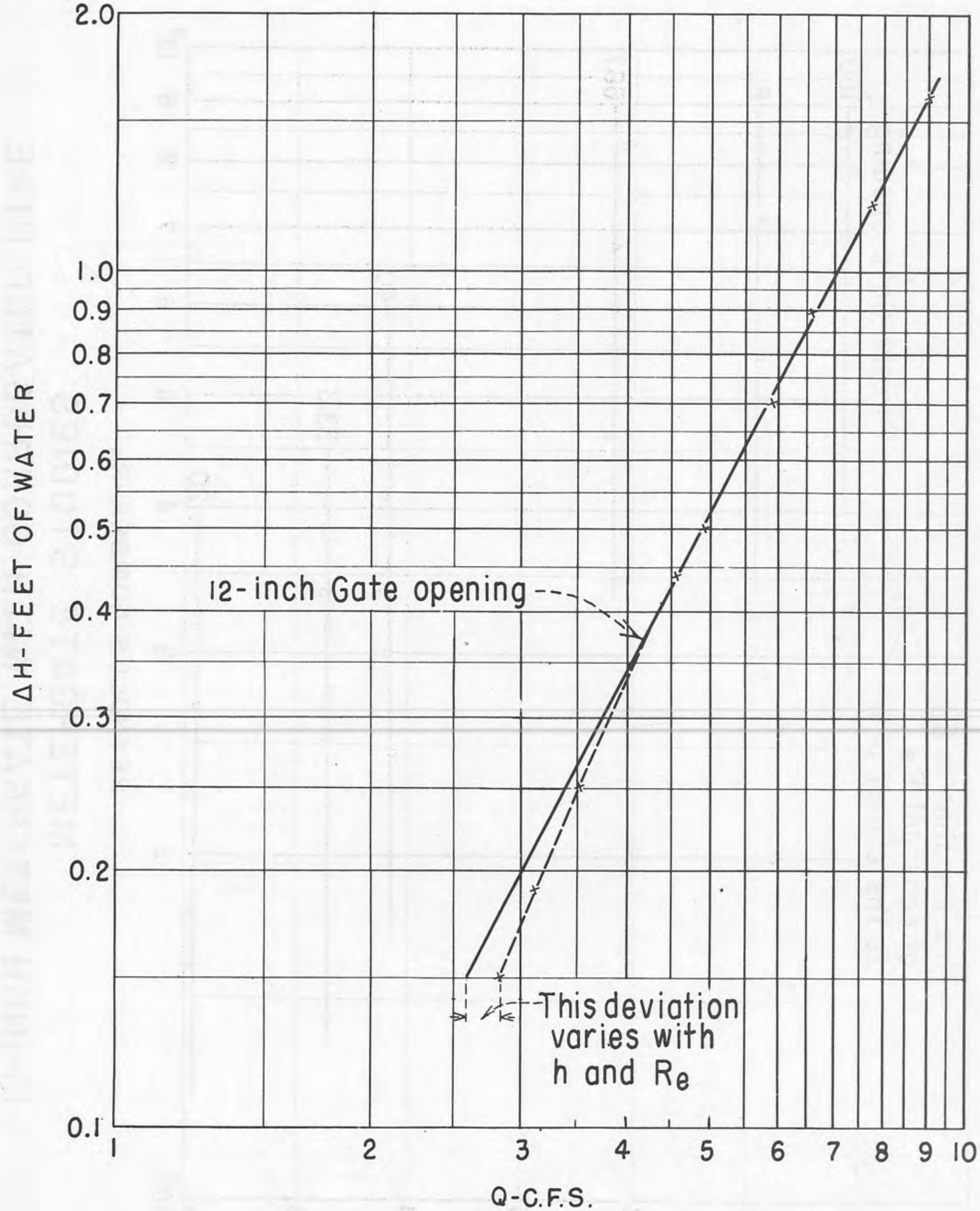


PLAN

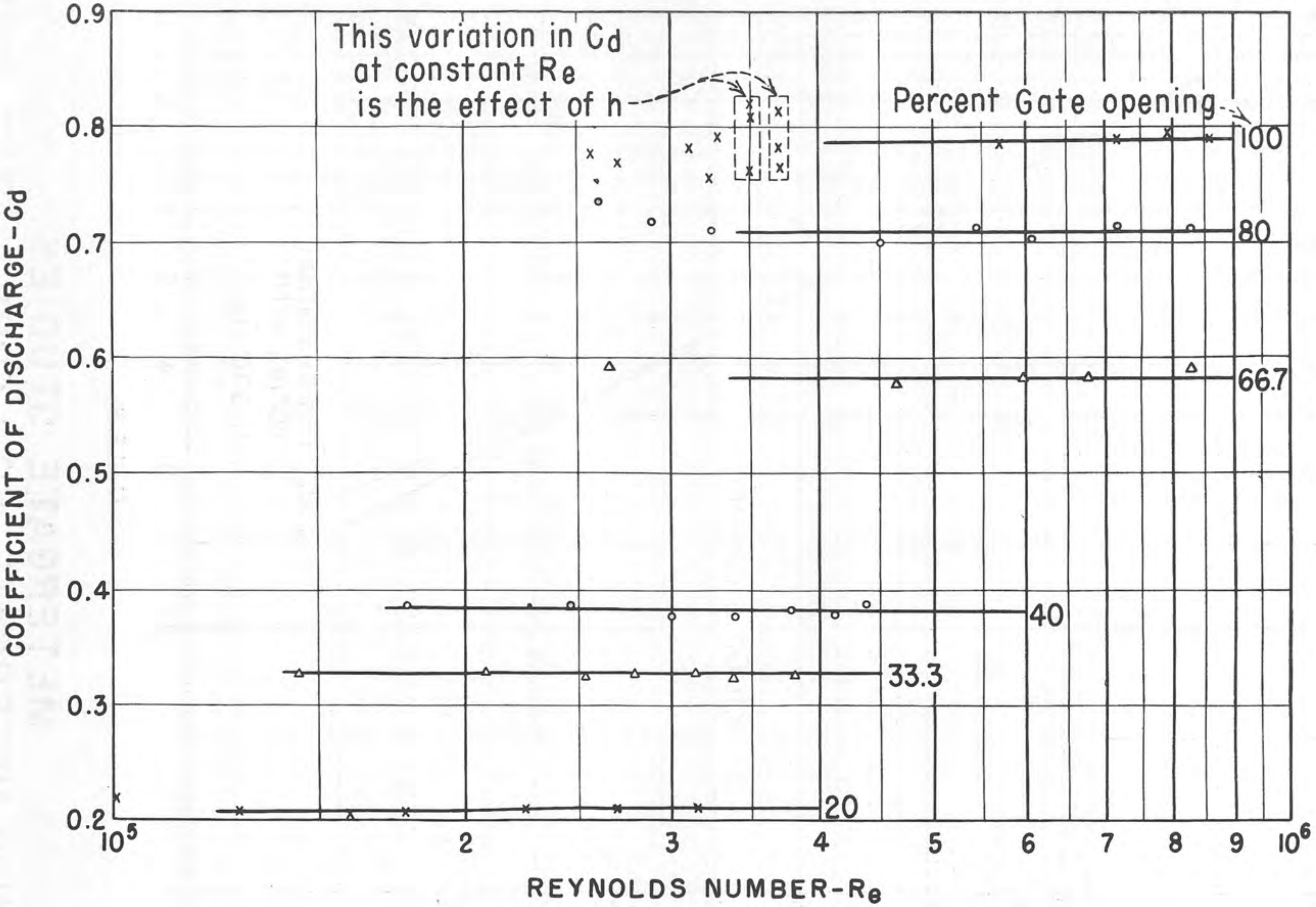


SECTION A-A

METERGATE STUDIES
LABORATORY INSTALLATION METERGATE TESTS



METERGATE STUDIES
15-INCH METERGATE WITH CORRUGATED PIPE



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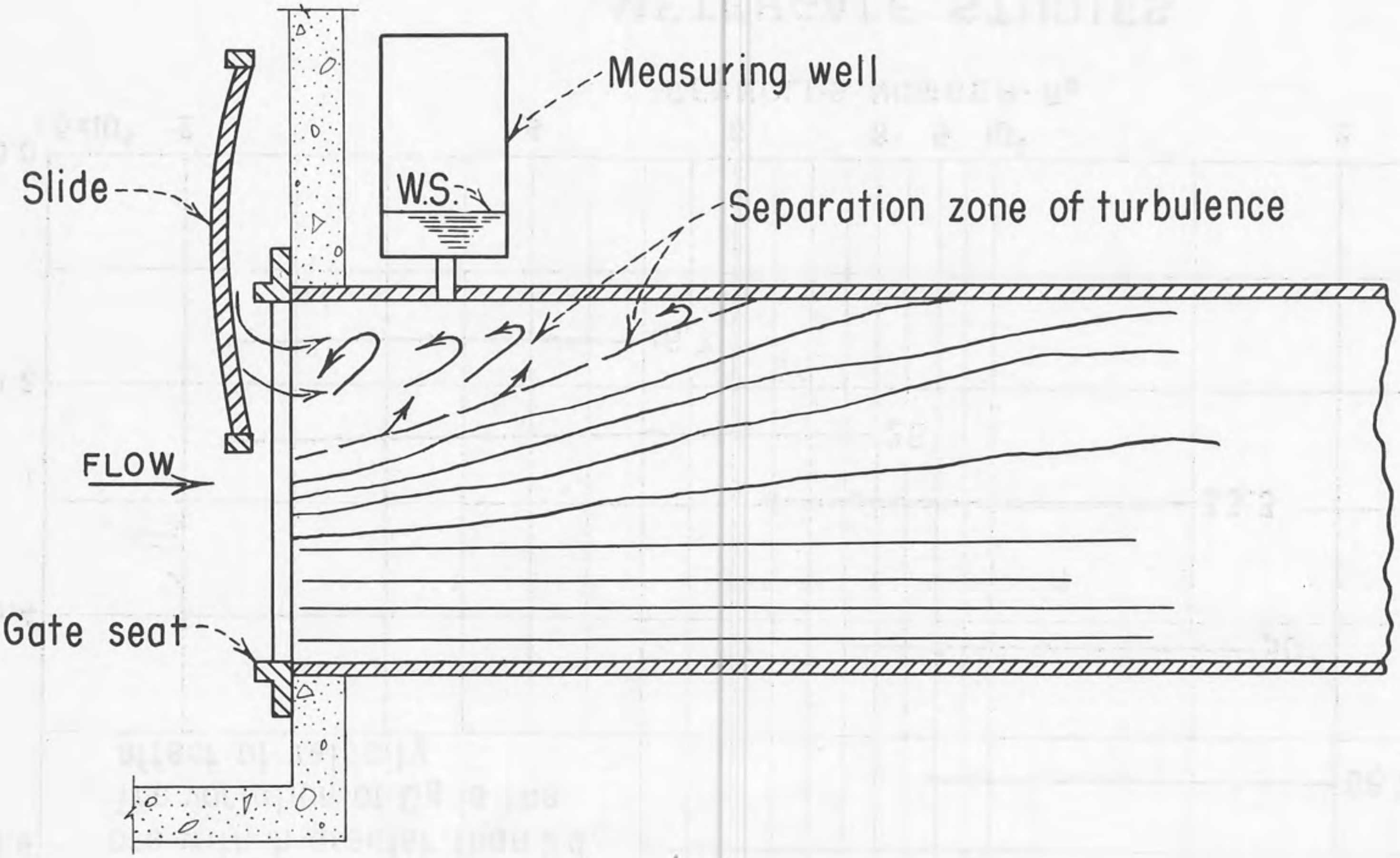
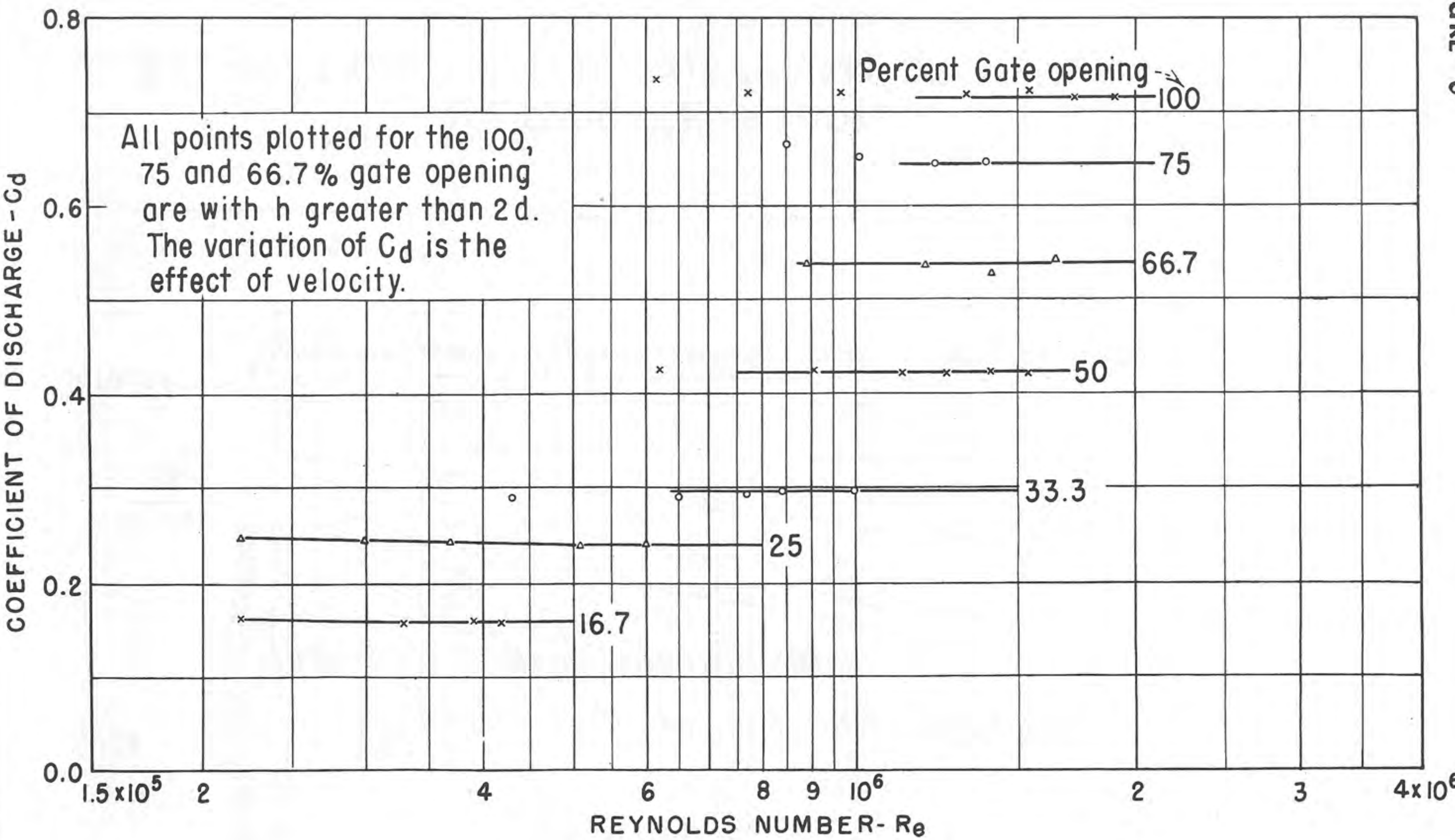


METERGATE STUDIES
SEPARATION ZONE DOWNSTREAM OF METERGATE

FIGURE 5



METERGATE STUDIES
24-INCH METERGATE

indicated a variable deviation from a straight line. The effect was observed visually by noting the change in ΔH at a given flow when the tail gate setting was changed to raise or lower the hydraulic grade line, including the head box water surface. Although the flow remained constant, ΔH was different. This condition explains at least part of the deviation of the discharge curve from the straight line. In other words, the same discharge will be obtained at different values of ΔH by increasing or decreasing h, when the value of h is relatively small.

The equation of the curve on the graph shown in Figure 3 is:

$$Q = C_d \frac{\pi d^2}{4} \sqrt{2g \Delta H}$$

Any change in ΔH at a constant discharge must be the result of a variable C_d since there was no change in the pipe diameter, d, or the gravitational force, g.

As the value of h was increased in the critical region, the deviation from the straight line became smaller and was negligible when h was twice or more the diameter of the pipe. A plot of C_d versus R_e at the 100-percent gate opening shows the effect upon C_d of varying h at a constant value of R_e, Figure 4.

The Effect of Velocity Upon C_d

In the initial analysis, the assumption was made that the velocity of the flow would be one of the variables influencing C_d because the velocity would effect the separation zone shown in Figure 5. Since the downstream measuring well is located 1 foot from the gate seat, the value of ΔH is generally influenced by conditions within the separation zone. For simplicity of evaluation the mean velocity was chosen. This mean velocity is included in the dimensionless parameter, R_e, which was used in the study.

The results of these studies are shown on Figure 6. As stated on the figure, the value of h was held greater than 2d, thus eliminating any influence of the upstream submergence. By varying R_e in the lower range the deviation of C_d was apparent. At high values of R_e or discharge, the curve is a straight line since any factors effecting C_d are small. The deviation of C_d attributable to R_e is also included on Figure 3.

The Influence of Corrugated Pipe on C_d

The effect of pipe corrugation upon C_d is indicated in Figure 7. These curves of C_d versus percent gate opening were based upon plots made of C_d versus R_e similar to the plot shown in Figure 6, at Reynolds numbers where the value of C_d was constant. This constant value of C_d is beyond the critical zone where the influence by h (upstream submergence) and R_e is negligible. The effect of the pipe corrugations was evident between 40 to 90 percent of the gate opening. The effect upon C_d can be explained by the fact that the zone of separation is influenced in shape and character by the pipe roughness, thus influencing ΔH from which C_d is obtained. Below the 40-percent gate opening the separation zone covers a much longer portion of the pipe, and the pressure in the vicinity of the measuring tap was relatively constant. Above the 90-percent opening the influence of the shape of the gate frame (angle iron, etc.) of the metergate upon the contraction region immediately downstream is apparently more dominant than the corrugations of the pipe.

The Influence of Approach Design on C_d

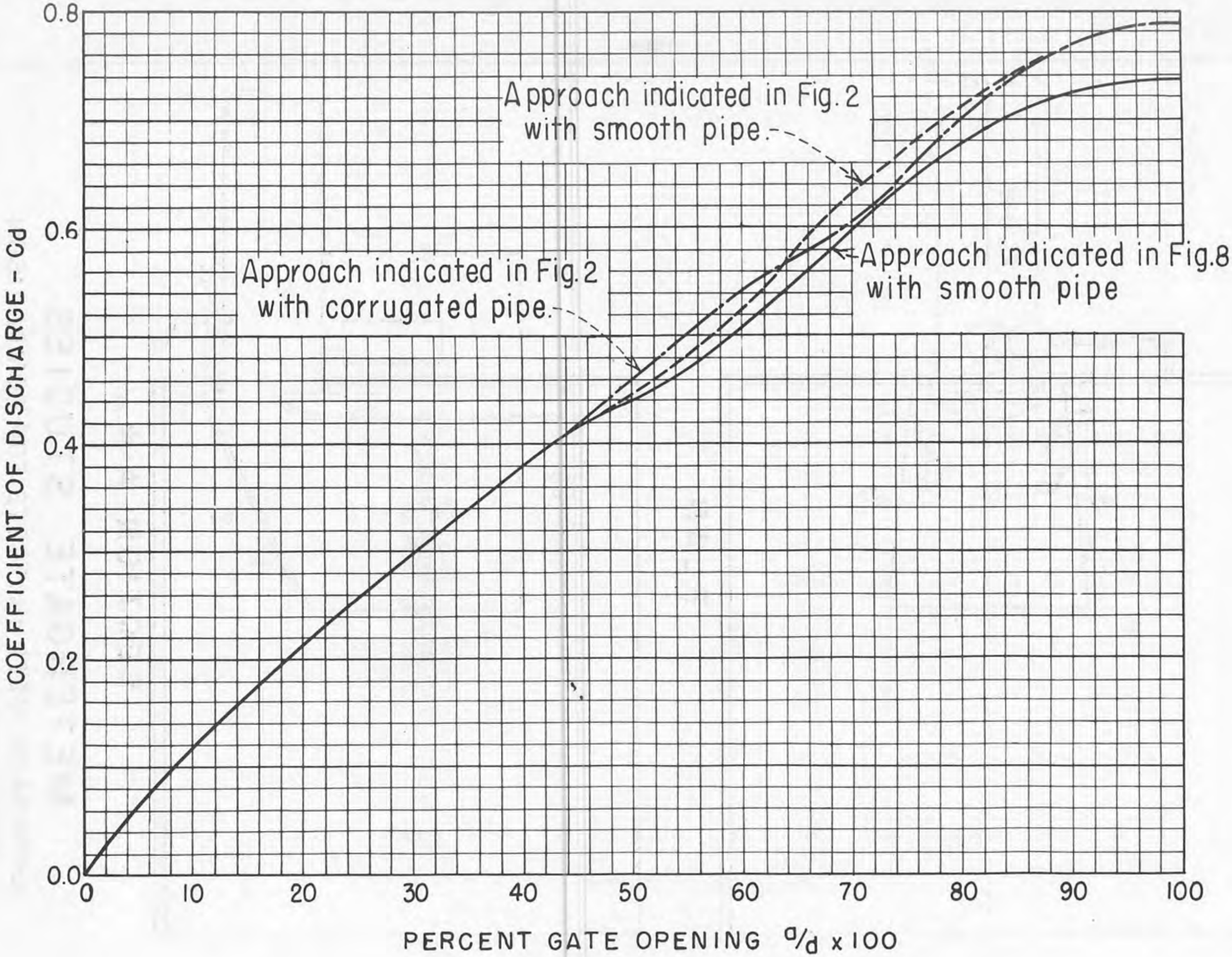
Since it was expected that some variation in C_d might be attributed to the approach conditions, a test was made on one of the most common approach designs and compared to the unconfined entrance of Figure 2. The approach design shown in Figure 8 was used for this purpose. The effect of this approach on C_d as compared to that of the unconfined entrance is shown on Figure 7. This is a result of changes in the streamlines approaching the gate entrance which influences the zone of separation.

Some Installation Limitations

The tests on the several gate sizes disclosed an important limitation, namely that of providing ample outlet submergence, h_s, Figure 2, for the differential heads ΔH at which the metergates were expected to operate. The outlet submergence must be sufficient to provide a measurable water surface in the downstream measuring well, and 6 inches above the top inside surface of the pipe was arbitrarily selected for the minimum pressure head in this study. To meet this condition, it was determined that the value of h_s must be at least 1 foot for a maximum ΔH of 18 inches.

A study was made to determine any effects of offsetting the measuring well tap, which is located 1 foot downstream of the gate seat. This procedure is desirable sometimes for construction purposes. This test disclosed that there was an error in discharge of as much as 3 percent if the tap is offset 3-1/2 inches from the vertical center line. The manufacturers' rating tables are based on pressures obtained on the top at the vertical center line.

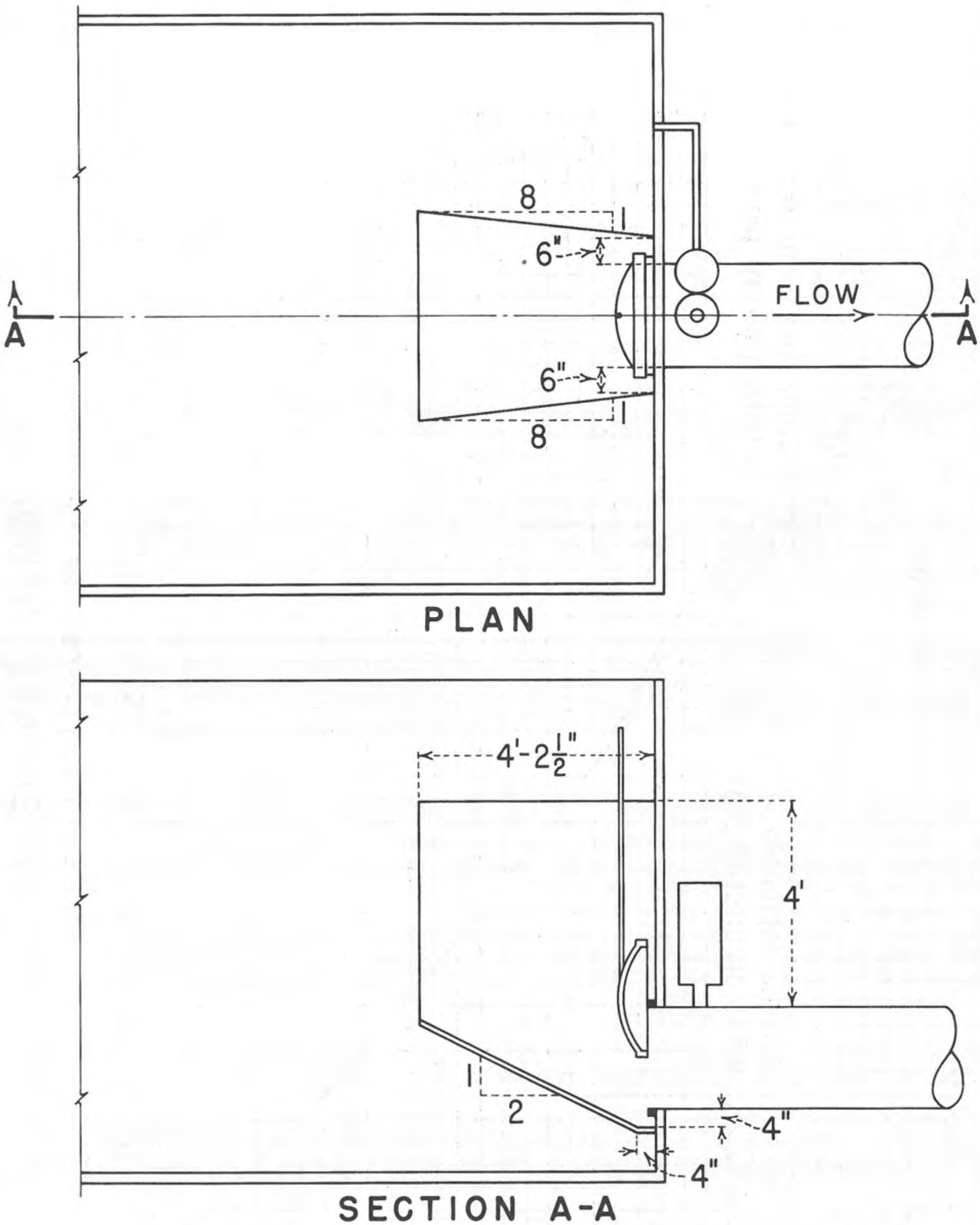
For all tests performed on the gates the pressure distribution in the pipe downstream was recorded to determine the necessary length of pipe downstream from the metergate to give uniform velocity distribution. The importance of this test was to make certain that an installation will have sufficient pipe length to minimize erosion at the outlet and to prevent sweeping the water out of the downstream measuring well at partial gate openings. Based on these tests, a length of six diameters should be used as a criterion.



METERGATE STUDIES
15-INCH METERGATE

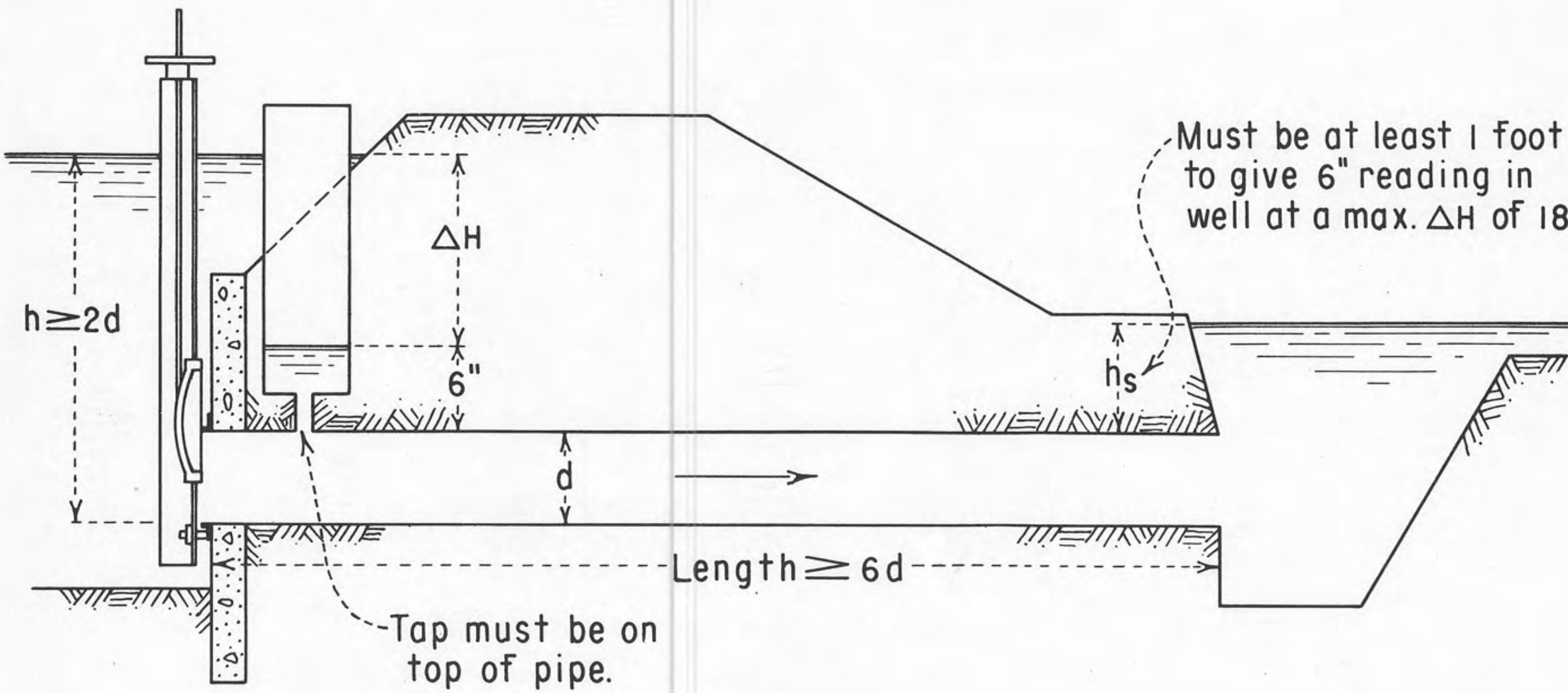
FIGURE

FIGURE 8



METERGATE STUDIES

APPROACH USED IN TESTS FOR COMPARISON WITH UNCONFINED ENTRANCE FIGURE 2.



METERGATE STUDIES

INSTALLATION LIMITATIONS

FIGURE 9

CONCLUSIONS

Most of the flow characteristics and limitations of metergates described in this paper are satisfied by proper installation, Figure 9. These include a value of h (upstream submergence) greater than 2d, ample outlet submergence, h_s; measuring well tap on the top of the pipe at the vertical center line; and a minimum pipe length of six diameters. The effect of velocity upon C_d has been considered in the new rating tables prepared by the manufacturer in 1951. These tables have compensated for the effect of pipe corrugations since a mean value of C_d between smooth and corrugated pipe was used in their preparation. For a more accurate measurement of discharge, it is recommended that the approach conditions are similar to those of the unconfined entrance on Figure 2.

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