Report

of the

CALIBRATION OF ARMCO METERGATES MODEL NO. 101

By

Sol D. Resnick
Civil Engineering Section

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Colorado Agricultural Experiment Station

Fort Collins, Colorado

prepared for

Armco Drainage and Metal Products, Inc.

Hardesty Division

Denver, Colorado

through

The Colorado Agricultural Research Foundation

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FOREWORD

The studies described in this report were made during the period of March 1950 to January 1951 partially in the Hydraulics Laboratories of Colorado A & M College, Fort Collins, Colorado and partially in the Hydraulics Laboratory of the United States Bureau of Reclamation, Federal Center, Denver, Colorado. The calibration of the 48-in. and 18-in. metergates was authorized by a contract between the Colorado Agricultural Research Foundation of Colorado A & M College, through the Civil Engineering Section of the Experiment Station and the Armco Drainage and Metal Products, Inc., Hardesty Division of Denver, Colorado.

Mr. Ralph N. Tracy, Mr. H. M. Chadwick and Mr. Lance Hansen, engineers for Armco Drainage and Metal Products, Inc. inspected the installations of the metergates both before and during testing and discussed the results with Colorado A & M Laboratory staff members. Throughout the entire installing and calibrating of the metergates, consultations with and inspections by Mr. Tracy were maintained.

Mr. George E. Shafer, Chief Engineer, Armco Drainage and Metal Products, Inc., reviewed the preliminary report and made valuable suggestions toward producing a complete final calibration report.

Mr. James W. Ball and Mr. Joe B. Summers, Research and Geology Division, U. S. Bureau of Reclamation, Denver, Colorado, provided calibration data for the 12-in. and 8-in. metergates and were very cooperative in the assembly and analysis of the calibration data and in providing information for the report.

Laboratory staff engineers who contributed to the calibration studies were Mr. James R. Barton, who assisted in installing and testing the 48-in. and 18-in. metergates, and Mr. Chong H. Zee, who assisted in testing and assembly of the data for the preliminary and final reports.

The installing and testing of the 48-in. and 18-in. metergates, the assembly of the Colorado A & M College and U. S. Bureau of Reclamation calibration data, and the writing of the preliminary and final reports was directed by Prof. Sol D. Resnick under the general supervision of Prof. Maurice L. Albertson.

Prof. Thomas H. Evans is Dean of Engineering and Chairman of the Engineering Division of the Experiment Station, and Prof. Dean F. Peterson is Chief of the Civil Engineering Section of the Experiment Station.

Chapter II

INTRODUCTION

The Armco Metergate Model No. 101 is highly suitable as a control and standard measuring device when the calibration curves are based on accurate experimental data and the final accuracy desired is not greater than that permitted by the normal variation in gate castings and settings.

Previous experimental calibrations of the Armco Metergate Model No. 101 were made by the Fresno Irrigation District in 1928, tests being made on the 8-in., 10-in., 12-in., 14-in., 16-in., 18-in., 20-in., and 24-in. gates, with data for the other size gates being obtained by interpolation and extrapolation.

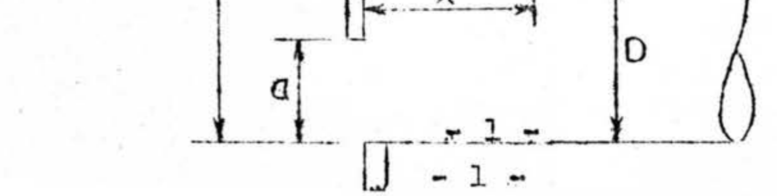
The Problem

Recently the manufacturers of the gate decided to calibrate the largest gate (48-in.) to eliminate the extrapolation and to recalibrate the smaller sizes at the same time. Therefore, the Armco Drainage and Metal Products, Inc., Hardesty Division, Denver, Colorado, engaged the Colorado Agricultural Research Foundation of Colorado A & M College in March 1950 to calibrate the 18-in. and 48-in. gates. Data obtained from the tests made by the College and experimental calibration data provided by the United States Bureau of Reclamation for the 8-in. and 12-in. gates, was analysed and used as the basis for a report presenting calibration curves for the 8-in., 10-in., 12-in., 14-in., 15-in., 16-in., 18-in., 20-in., 21-in., 24-in., 30-in., 36-in., 42-in., and 48-in. gates.

In order to facilitate testing procedure and to interpolate correctly to obtain discharge data for gates not tested, a complete theoretical analysis of the problem is essential.

Theoretical Analysis

The quantity of flow through an Armco Metergate is a function of the boundary geometry, the properties of the fluid, and the flow. The definition drawing gives the essential boundary



dimensions h, a, x, and D which affect the problem while the important fluid properties are the density ρ and the dynamic viscosity μ. The flow is described by the difference in pressure Δp upstream and downstream from the gate. If the six variables h, a, x, D, ρ, and μ are held constant, a given difference in well readings Δp should indicate a given discharge. The general function may be represented as

$$\phi\,(h, a, x, D, \rho, \mu, \Delta p, V) = 0 \qquad (1)$$

The foregoing variables may be rearranged through dimensional analysis into a group of dimensionless parameters to give the following equation:

$$\phi_1\,(h/a,\ a/D,\ x/D,\ \frac{\Delta h}{V^2/2g},\ Re) = 0 \qquad (2)$$

In these equations, V is the mean velocity in the outlet pipe, Δh is the difference in head in the stilling wells, and Re is the Reynolds number $\frac{VD}{\nu}$.

Eq. 2 may be rearranged to give

$$\frac{\Delta h}{V^2/2g} = \phi_2\,(h/a,\ a/D,\ x/D,\ Re) \qquad (3)$$

$$V = \phi_3\,(h/a,\ a/D,\ x/D,\ Re)\sqrt{2g\Delta h} \qquad (4)$$

By letting the term within the brackets equal the discharge coefficient C, the resulting equation is easily recognized as the equation for flow through an orifice.

$$V = C\sqrt{2g\Delta h} \qquad (5)$$

To compute Q, the continuity equation is used so that

$$Q = AV = AC\sqrt{2g\Delta h} \qquad (6)$$

where $$C = \phi_3\,(h/a,\ a/D,\ x/D,\ Re) \qquad (7)$$

If x/D is held constant,

$$C = \phi_4\,(h/a,\ a/D,\ Re) \qquad (8)$$

The final equation for determining Q in terms of Δh, therefore, is Eq. 6.

The equipment and procedure used for evaluating the foregoing functions are presented in the following chapter.

Chapter II

EQUIPMENT AND PROCEDURE FOR TESTING

The facilities of the laboratories selected for calibrating the Armco Metergate Model No. 101 included all of those necessary for complete testing and analysis. The 48-in. gate was tested at the Bellvue Laboratory, Colorado A & M College, where the large flows provided by the Cache la Poudre River were available. The 18-in. gate was tested in the Hydraulics Laboratory, Colorado A & M College, while the 8-in. and 12-in. gates were tested in the Hydraulics Laboratory of the U. S. Bureau of Reclamation, Denver, Colorado.

48-in. Metergate

The calibration tests on the 48-in. Armco Metergate were done by staff members of the Colorado A & M College. The installation for testing was located at the Bellvue Laboratory which is situated on the Cache la Poudre River about eight miles northwest of the College campus. Figs. 1, 2, 3, and 4 illustrate the experimental facilities used in the testing. During the spring runoff when the river is high, diversions of 100 cfs or more can be run through the 14-ft. wide concrete flume, but as the river recedes, the flow that can be diverted decreases. Tests on the high flows through the gate were run in late June when the maximum discharge was limited by experimental set-up to about 63 cfs.

Measurement of the discharge. All discharges were measured by a 15-ft rectangular sharp-crested weir at the end of the flume. The weir was calibrated at high flows by carefully performed current meter tests, while for discharges below 17 cfs the large weir was rated by use of a small 4-ft weir which had previously been calibrated volumetrically in the hydraulics laboratory on the campus. The tests for small discharges were made by Mr Carl Rohwer and Mr. Ralph Parshall.

The current meter measurements were made with a Price Current Meter which was rated in May 1950. A total of three measurements were made for discharges of approximately 60 cfs, 50 cfs, and 40 cfs. Measurements were made at 0.8 depth and 0.2 depth in each vertical section and vertical sections were taken every two feet across the 14-ft rectangular flume. The velocity across each section was fairly uniform. In determining the velocity at a point, sufficient time was taken so that minor variations resulting from turbulence were assumed to be averaged. Several measurements were repeated at each point to make sure that the independent measurements would check each other. In most cases the individual measurements checked within one percent. The current meter measurements invariably fell within one percent of the value determined by applying the Francis formula to the 15-ft weir. In fact, the calibration checked the Francis formula

$$Q = 3.33\, L \left[(H + h_v)^{3/2} - h_v^{3/2} \right]$$

so closely that a rating table based on this formula was used for all discharges above 20 cfs. For flows less than 20 cfs the rating table prepared by Parshall and Rohwer was used.

Measurement of the water surface elevations:- The water-surface elevations were measured at three points where the flow was essentially uniform. Each well was equipped with a Lory hook gage for determining the water-surface elevations. Two of these wells, Nos. 1 and 2, were installed about 10 ft upstream from the weir, one on each side of the flume for determining the head of the weir. By the use of a surveyor's level, the zero of each gage was found using the crest of the weir as a reference datum. Well No. 6, installed about 16 ft upstream from the metergate in the flume was referenced to the bottom invert of the gate by using the surveyor's level.

For high flows the maximum and minimum water-surface elevations in each well were read about four to six times during a run. Maximum and minimum water-surface elevations were determined by observing the water surface and following it with the hook gage so that when a maximum was reached the reading was recorded. The hook gage point was then made to follow the surface until a minimum was attained. This procedure was repeated four to six times during a run. For the low discharges the water-surface elevation was essentially constant, and only single readings were recorded about four to ten times during each run. When small variations were noticed, it was necessary to use more independent readings so that the average of the total number of readings approached the true average.

Measurement of the piezometric heads:- The three wells which measured the piezometric heads were located in zones of acceleration or in separation zones so that the water-surface elevation in the well represented a piezometric head and not an actual water surface. Since the water surface in a well fluctuated quite rapidly and sometimes varied over a range of one tenth of a foot, more readings were required to approach the correct average value. For high flows, as in the case of water-surface elevation determinations, the maximum and minimum elevations were measured for approximately four to six cycles of water surface fluctuation. The average values of the maximum and minimum in a well were averaged in turn to give the final water-surface elevation to be used in the calculations. For low flows 20 to 50 simultaneous readings were taken at each of the three wells and the water surface elevations were calculated so that one indicated the head at a point just upstream from the entrance to the pipe, one at a point on the pipe 12 in. from the entrance, and the other at a point of $x/D = 2/3$ or 2.67 ft. downstream from the entrance. The well at $x/D = 2/3$ was an experimental one while the one at 12 in. was the well actually used in the calibration of the gate.

It is believed that sufficient care was taken in the reading of the fluctuating water surfaces to assure a high degree of accuracy in the values of piezometric head determined.

18-in. Metergate

The calibration tests on the 18-in. Armco Metergate were also made by staff members of the Colorado A & M College. The installation for testing was located at the Hydraulics Laboratory, Colorado A & M College. Fig. 5 illustrates the experimental facilities used in the testing. Flows up to 8 cfs were provided by a 20 horsepower propeller-type pump through a 14-in. pipe.

Measurement of the Discharge:- All discharges were measured by a 10½-in. orifice plate which had been carefully calibrated in place several months prior to testing. The orifice calibration which was under the direct supervision of Dr. Maurice L. Albertson, utilized large volumetric tanks located below the floor level of the laboratory. This calibration duplicated the results to within one percent of a previous calibration conducted by Mr. Carl Rohwer and Mr. Maxwell Parshall in 1942. The range of calibration was from 1 cfs to 8 cfs, which included all the flows utilized in testing the 18-in. metergate hence none of the required metergate calibration data was based on extrapolated flow values.

Measurement of the piezometric heads:- The piezometric head difference, which indicated the flow through the orifice meter, was obtained by an average of 4 to 10 independent readings, the number depending on the amount of fluctuation, taken during each run with a water manometer.

Two wells were used to measure the piezometric head difference across the metergate opening. One well measured the head at a point just upstream from the entrance to the pipe and the other well measured the head at a point on the pipe 12-in. from the entrance. Since $x/D = 2/3$ is identical with $x = 12$ in. for the 18-in. metergate, the latter well was identical with the third experimental well, set in each case to measure the piezometric head at x/D = 2/3, used on the other sizes of metergates tested. By the use of a surveyor's level, the zero of each gage was found using the bottom invert of the gate as a reference datum.

Float indicators, which helped to damp the fluctuations, were used in the two wells for determining the water-surface elevations. For each test 20 to 100 readings, the number depending on the amount of fluctuation, were taken simultaneously at each well. The readings were spaced approximately two seconds apart.

12-in. and 8-in. Metergates

The calibration tests on the 12-in. and 8-in. Armco Metergates were supervised by Mr. James W. Ball and conducted by Mr. Joe B. Summers, Research and Geology Division, U. S. Bureau of Reclamation. The installation for testing was located at the Hydraulics Laboratory, which is under the direction of Mr. Harold M. Martin, U. S. Bureau of Reclamation, Federal Center, Denver, Colorado. Fig. 6 illustrates the experimental facilities used in the testing. Flows from 0.34 cfs to 7.27 cfs were provided by the laboratory pumping system.

Measurement of the Discharge:- The discharges were measured by 4 banks of calibrated Venturi meters, 4-in., 8-in., 10-in., and 12-in., located in the feeder line to the head box. The size of Venturi meter used was determined by the quantity of flow desired.

Measurement of the piezometric heads:- The piezometric head differences across the metergate openings were measured by piezometers in most cases, 10-in. wells being used occasionally for comparison purposes. While piezometers were tapped into the top of the pipe at many points, for both the 8-in. and 12-in. gates, one piezometer in each case indicated the head just upstream from the entrance to the pipe, one indicated the head at a point on the pipe 12-in. from the entrance, and a third experimental piezometer indicated the piezometric head at a point on the pipe of x/D = 2/3, or 0.667 ft. in the case of the 12-in. gate or 0.444 ft. in the case of the 8-in. gate downstream from the entrance. Fig. 6 shows a partial detail of the location of piezometer taps in the 8-in. installation.

The piezometers were connected to a central manometer bank which was scaled to 0.01 ft. of water; readings to the closest 0.005 ft. were easily estimated. Since fluctuations in the piezometers were damped to a large extent by carborundum disks set in the leads to the bank, approximately ten readings of each piezometer were considered sufficient to give an accurate test average.

Chapter III

PRESENTATION OF DATA

The experimental data, see Tables 1, 2, 3, and 4, were reduced to tabular form by graphical processes explained and illustrated in the following discussion. The graphs were made on logarithmic scales to provide a practical means of plotting the data which cover a wide range of values; furthermore, as shown by Eq. 6, it was anticipated that the locus of experimental points plotted in this manner would closely approximate a straight line.

The plotting of the experimental data for the 48-in., 18-in., 12-in., and 8-in. gates as discharge versus difference in head for various gate openings resulted in plots which were straight lines for relatively high values of Δh but which deviated from the straight line for the lower values of Δh, for example, see Fig. 7. Since it was necessary to interpolate for the intermediate gate openings and gate sizes to complete the tables, it was desirable to study the data to learn the causes of the deviation and the points of deviation. Therefore, (as suggested by the analysis in Chapter II) plots were made of the discharge coefficient C versus the relative head on the gate h/a with the relative gate opening a/D as the third variable, see Fig. 8. The relative location of the downstream well was kept at a constant value of x/D = 2/3. After careful examination of the data, it was concluded that for the 48-in., 18-in., 12-in., and 8-in. gates there was no consistent affect on variation of C because of variation in h/a. **Plots of C versus Re with** a/D as the third variable and x/D constant at 2/3 were made next for the 48-in., 18-in., 12-in., and 8-in. gates and the cause for the deviation at low discharges became apparent at once. With small head differences and corresponding relatively low values of Re, the discharge coefficient C increased as Re decreased for all gate openings for the 48-in. gate; increased for all but full gate openings, where C stayed constant for the 18-in. gate; increased for all gate openings below a/D = 0.9 where C stayed constant and then decreased for larger gate openings for the 12-in. gate; and C increased for all gate openings below a/D = 0.75 where C stayed constant and then decreased for larger gate openings for the 8-in. gate.

Since head differences for the well at x = 12-in. correlate well with head differences for x/D = 2/3, it was decided to plot C versus Re with A/D as the third variable based on head differences using the well at x = 12.in. Correlations between the 48-in., 18-in., 12-in., and 8-in. gates were consistent with varying a/D values.

From the above graphs a plot was made of C versus a/D for high values of Re, for constant C, and with gate size as the third variable, see Fig. 9. A second plot for high values of Re was made for C versus gate size with a/D as the third variable. This plot was utilized to adjust the curves in Fig. 9. The adjusted curves, which were used to obtain the constant coefficients of discharge C for metergate sizes not tested, fitted the experimental data except for a few cases where the adjusted curve values deviated slightly from the average test data.

To obtain the final plots from which tabular values could be computed, C was plotted against Re with a/D as the third variable, for the 48-in., 18-in., 12-in., and 8-in. metergates, Figs. 10, 18, 21, and 23. Points of constant C with minimum Re were connected as shown by broken lines in Figs. 10, 17, 21 and 23. From Fig. 9, C values were obtained and plotted on Figs. 10, 17, 21 and 23 for intermediate gate openings not tested. The remaining portion of each curve (low Re) was interpolated between the calibrated curves. Figs. 11, 12, 13, 14, 15, 16, 18, 19, 20 and 22 are final C versus Re plots obtained for the 42-in., 36-in., 30-in., 24-in., 21-in., 20-in., 16-in., 15-in., 14-in., and 10-in. metergates (which were not tested) by a series of interpolations: constant C values were obtained by interpolating between the adjusted calibrated curves for the 48-in., 18-in., 12-in., and 8-in. metergates as shown in Fig. 9; loci of constant C with minimum Re were obtained by interpolating between similar curves based on test data in Figs. 10, 17, 21 and 23; and the remaining portion of each curve (low Re) was easily obtained by interpolating between the portions (low Re) of the calibrated curves whose slopes were found to vary uniformly between gate sizes and gate openings.

In order to provide a direct solution for obtaining tabular values from the final plots, a third grid system, which was based on the dimensionless parameter, $D^2 \Delta hg/\nu^2$, obtained by rearranging the variables in Eq. 1 through dimensional analysis, was added. In general, to find the discharge Q for a given head difference Δh, for a given size metergate, and a given gate opening, the following procedure can be utilized; solve the dimensionless parameter $D^2 \Delta hg/\nu^2$ by substituting the pipe diameter in ft. for D; the given head difference in ft. for Δh; 32.2 ft. per sec. per sec. for acceleration of gravity g; and 1.21×10^{-5} sq. ft. per sec., based on a temperature of 60°F selected as the average condition for the United States, for kinematic viscosity ν. With this value for $D^2 \Delta hg/\nu^2$, enter the figure which applies for the given gate size, and follow down the proper sloping line to the left until the curve representing the given gate opening is intersected. Finally, drop vertically down from this point, to read the value of Reynolds number Re from which either V or Q may be computed by the following equations:

Presentation of Data

$$R_e = \frac{VD}{\nu} = 0.826\times10^5\ VD$$

or

$$R_e = \frac{4}{\pi}\frac{Q}{\nu D} = 1.052\times10^5\ \frac{Q}{D}$$

From Fig. 10, utilizing the above method of computation, Table 5, Discharge Data for 48-in. Armco Motorgate was tabulated.

Chapter IV

DISCUSSION OF RESULTS

Although Eq. 8 included Reynolds number Re, it was believed at the outset that the influence of the relative head on the gate h/a was greater than the influence of Re and therefore the first analytical plot made, Fig. 8, was of discharge coefficient C versus h/a with the relative gate opening a/D as the third variable. However, close examination revealed a scattering of the points at low discharges demonstrating that some variable other than h/a was of paramount importance. Fig. 52 of Elementary Mechanics of Fluids, by Hunter Rouse, substantiates the foregoing conclusion in that the correspondingly smallest head on the orifice results in a deviation of 1.0% from the constant C of 0.61.

The second analytical plot, C versus Re with a/D as the third variable, resulted in no appreciable scatter of the data and yielded consistent trends demonstrating that Re was an important variable. This was substantiated by the fact that test data followed the same trend in spite of varying the relative head h/a on the gate for successive tests. Figs. 10, 17, 21 and 23 show these consistent gradual trends of C as Re decreases for all gate openings for the 48-in., 18-in., 12-in., and 8-in. metergate, the slopes varying consistently in all cases. The Reynolds number effect is due to the extent of development of the laminar sublayer at the entrance which in turn influences the separation point and the size and character of the separation zone downstream. The Reynolds number effect will vary with gate size having the greatest effect on the smaller size gates, since, while the radius of curvature of the leaf of the gate remains practically the same regardless of the size of the gate, the relative radius of curvature will become larger as the gate size becomes smaller.

Aside from possible variations in gate castings and settings, the discharge data, Table 5, obtained from Fig. 10 and the discharge data which can be obtained for the other size gates from Figs. 11 through 23, are accurate to within approximately ± 3%; however, the table is based on a water temperature of 60°F, which was assumed to be an average for the United States, and utilization of the tables with a deviation in water temperature of ± 20°F may cause an additional ± 1% error. Thus the data are accurate to ± 4% at the maximum deviation. This deviation may be found only under extreme conditions and under most conditions the maximum deviation will be only ± 2%.

Discussion of Results

For the 48-in. metergate a comparison of discharge data revealed that for relatively high discharges through the 2-in. gate opening, the Fresno curves read 28% high and for relatively high discharges through the 24-in. gate opening their curves read 18% low. Corresponding differences existed for other gate sizes.

Chapter V

CONCLUSIONS AND RECOMMENDATIONS

The calibration curves for the 48-in., 18-in., 12-in., and 8-in. metergates are based on accurate experimental data. While the remaining calibration curves for the 42-in., 36-in., 30-in., 24-in., 21-in., 16-in., 15-in., 14-in., and 10-in. metergates are based on interpolated data, the remarkably consistent relationships and trends between the curves based on test data indicates that the interpolated curves should be of an accuracy closely approaching the accuracy of the calibration curves based on test data.

The Armco Metergate Model No. 101 is highly suitable as a control and standard measuring device with utilization of the calibration curves, Figs. 10 through 23, if the final accuracy desired is not greater than that permitted by the normal variation in gate castings and settings.

As can be seen from Figs. 10, 17, 21 and 23, the portions of the C versus Re curves (high Re), which are horizontal or indicate a constant value of C, fit the test data very closely; hence, it is recommended that with a given metergate and for a required discharge the gate opening be regulated so that the operation takes place in the zone (high Re) to the right of the broken lines, Figs. 10 through 23, which connect points of constant C with minimum Re.

It is also recommended that the calibration data obtained from the above study be used for metergates whose settings do not vary greatly from the installations used in the testing program, see Figs. 4, 5 and 6.

Experimental Calibration Data for 48-in. Armco Metergate Model No. 101*

Opening of Gate	Q cfs	Δh in ft. x = 12"	Δh in ft. x/D = 2/3	h/a	C x/D = 2/3	Re	C x = 12"
48"	60.29	0.982	0.726	2.020	0.700	12.88×10^5	0.602
	49.98	0.674	0.514	1.880	0.690	10.67×10^5	0.601
	42.44	0.485	0.359	1.779	0.701	9.06×10^5	0.603
	33.76	0.304	0.212	1.696	0.725	7.19×10^5	0.606
	21.68	0.123	0.084	1.596	0.743	4.65×10^5	0.612
36"	58.26	1.078	1.037	2.688	0.566	12.43×10^5	0.556
	56.17	1.009	0.968	2.651	0.565	12.02×10^5	0.552
	39.02	0.496	0.467	2.349	0.566	8.35×10^5	0.549
	14.65	0.067	0.059	2.334	0.597	3.12×10^5	0.561
	14.28	0.063	0.054	2.050	0.608	3.04×10^5	0.564
	26.41	0.225	0.203	2.187	0.580	5.64×10^5	0.552
24"	53.05	1.498	1.532	4.047	0.424	11.33×10^5	0.430
	32.39	0.579	0.589	3.466	0.420	6.95×10^5	0.423

*Data from Colorado A & M College - 18 ft. corrugated pipe including 4 ft. riser

Experimental Calibration Data for 48-in. Armco Metergate Model No. 101

Opening of Gate	Q cfs	Δh in ft. x = 12"	Δh in ft. x/D = 2/3	h/a	C x/D = 2/3	Re	C x = 12"
24"	25.17	0.350	0.349	3.303	0.422	5.39×10^5	0.421
	15.82	0.137	0.140	3.562	0.419	3.38×10^5	0.424
	10.12	0.052	0.050	3.429	0.488	2.16×10^5	0.441
16"	43.07	1.933	1.956	6.100	0.305	9.20×10^5	0.307
	32.46	1.103	1.114	5.480	0.304	6.93×10^5	0.306
	21.43	0.479	0.482	4.970	0.314	4.59×10^5	0.307
	17.48	0.316	0.318	4.820	0.306	3.73×10^5	0.308
	8.05	0.063	0.061	5.100	0.322	1.72×10^5	0.317
8"	25.03	2.258	2.255	12.26	0.165	5.36×10^5	0.165
	15.27	0.810	0.810	10.13	0.168	3.26×10^5	0.168
	9.37	0.304	0.300	10.54	0.169	2.00×10^5	0.168
	5.78	0.113	0.114	10.21	0.170	1.24×10^5	0.170
	3.60	0.044	0.044	8.64	0.171	0.77×10^5	0.170
4"	12.22	2.107	2.105	23.85	0.0837	2.61×10^5	0.0834
	8.16	0.919	0.916	22.80	0.0846	1.75×10^5	0.0845
	5.12	0.355	0.354	20.25	0.0855	1.09×10^5	0.0850
	2.92	0.112	0.114	17.17	0.0861	0.623×10^5	0.0862

Table 1 (continued)

Experimental Calibration Data for 48-in. Armco Metergate Model No. 101

Opening of Gate	Q cfs	Δh in ft. x = 12"	Δh in ft. x/D = 2/3	h/a	C x/D = 2/3	Re	C x = 12"
2"	6.01	2.417	2.417	49.00	0.0384	1.29×10^5	0.0383
	4.98	1.629	1.630	44.20	0.0388	1.06×10^5	0.0387
	3.33	0.710	0.7095	37.75	0.0393	0.711×10^5	0.0391
	2.57	0.412	0.4135	35.05	0.0397	0.550×10^5	0.0397
	1.41	0.117	0.1175	31.40	0.0409	0.301×10^5	0.0409

Experimental Calibration Data for 18-in. Armco Metergate Model No. 101*

Opening of Gate	Q cfs	Δh in ft. x = 12"	Δh in ft. x/D = 2/3 **	h/a	C x/D = 2/3	Re	C x = 12" **
18"	8.01	0.570		2.020	0.749	5.91×10^5	
	6.96	0.406		1.862	0.768	5.13×10^5	
	6.24	0.315		1.750	0.784	4.61×10^5	
	6.23	0.311		1.744	0.789	4.60×10^5	
	5.84	0.281		1.697	0.779	4.31×10^5	
	5.15	0.212		1.602	0.787	3.81×10^5	
	4.46	0.171		1.842	0.764	3.30×10^5	
	3.78	0.126		1.590	0.749	2.78×10^5	
	2.25	0.046		1.380	0.742	1.66×10^5	
	[illegible]	0.038		2.210	0.749	1.53×10^5	
13 1/2"	2.14	0.054		[illegible]	0.653	1.59×10^5	
	2.10	[illegible]		[illegible]	0.655	1.55×10^5	
	2.02	0.048		2.980	0.651	1.49×10^5	

* Data from Colorado A & M College - 6 ft. corrugated pipe

** Since x/D = 2/3 is identical with x = 12", values are identical with values in corresponding column

Experimental Calibration Data for 18-in. Armco Metergate Model No. 101

Opening of Gate	Q cfs	Δh in ft. x = 12"	Δh in ft. x/D = 2/3 **	h/a	C x/D = 2/3	Re	C x = 12" **
9"	6.96	1.120		6.582	0.462	5.13×10^5	
	6.28	0.920		6.138	0.461	4.63×10^5	
	6.24	0.924		4.444	0.456	4.61×10^5	
	5.03	0.601		5.482	0.456	3.71×10^5	
	3.77	0.338		5.542	0.456	2.78×10^5	
	2.54	0.149		2.896	0.464	1.88×10^5	
	1.57	0.058		4.526	0.459	1.16×10^5	
3"	2.80	1.242		13.36	0.177	2.07×10^5	
	2.62	1.072		13.00	0.179	1.93×10^5	
	2.37	0.894		12.30	0.177	1.75×10^5	
	1.96	0.626		[illegible]	0.175	1.45×10^5	
	1.58	0.388		[illegible]	0.179	1.17×10^5	
	[illegible]	0.220		11.34	0.185	0.908×10^5	
	[illegible]	0.210		[illegible]	0.180	0.865×10^5	
	[illegible]	0.190		8.808	[illegible]	0.822×10^5	

** Since x/D = 2/3 is identical with x = 12", values are identical with values in corresponding column.

Experimental Calibration Data for 12-in. Armco Metergate Model No. 101*

Opening of Gate	Q cfs	Δh in ft. x = 12"	Δh in ft. x/D = 2/3	h/a	C x/D = 2/3	Re	C x = 12"
12"	7.27	2.13	2.28	4.23	0.764	8.80×10^5	0.788
	6.14	1.60	1.66	3.54	0.755	7.44×10^5	0.767
	5.08	1.06	1.19	2.87	0.739	6.16×10^5	0.780
	3.98	0.66	0.77	2.32	0.720	4.82×10^5	0.774
	3.85	0.59	0.60	2.14	0.789	4.66×10^5	0.793
	2.95	0.37	0.48	1.98	0.677	3.58×10^5	0.768
	2.31	0.25	0.28	1.75	0.694	2.81×10^5	0.732
	2.02	0.20	0.22	1.76	0.685	2.45×10^5	0.714
9"	4.64	1.16	1.39	4.12	0.624	5.62×10^5	0.682
	4.26	0.98	1.28	3.44	0.598	5.16×10^5	0.679
	3.64	0.72	0.85	3.07	0.627	4.41×10^5	0.679
	2.98	0.49	0.57	2.69	0.626	3.61×10^5	0.675
	2.12	0.24	0.29	2.35	0.625	2.57×10^5	0.686
	1.24	0.08	0.10	2.09	0.623	1.50×10^5	0.694
8"	4.23	1.18	1.21	4.02	0.610	5.13×10^5	0.616
	4.18	1.17	1.22	4.38	0.603	5.06×10^5	0.612
	3.14	0.67	0.69	3.29	0.603	3.80×10^5	0.608

* Data from U. S. Bureau of Reclamation - 2 ft. corrugated pipe, 18 ft. smooth pipe

Experimental Calibration Data for 12-in. Armco Metergate Model No. 101

Opening of Gate	Q cfs	Δh in ft. x = 12"	Δh in ft. x/D = 2/3	h/a	C x/D = 2/3	Re	C x = 12"
8"	2.73	0.48	0.50	2.98	0.613	3.31×10^5	0.625
	1.92	0.23	0.26	2.61	0.598	2.32×10^5	0.635
6"	2.63	0.74	0.76	4.70	0.478	3.19×10^5	0.486
	2.63	0.73	0.77	4.50	0.476	3.19×10^5	0.489
	2.16	0.50	0.53	4.00	0.470	2.61×10^5	0.484
	1.86	0.35	0.40	3.70	0.466	2.25×10^5	0.499
	1.55	0.24	0.29	3.50	0.456	1.88×10^5	0.502
4"	2.30	1.20	1.23	9.09	0.329	2.79×10^5	0.333
	1.52	0.48	0.59	6.90	0.314	1.84×10^5	0.348
	1.22	0.30	0.34	6.18	0.332	1.48×10^5	0.353
	0.76	0.11	0.11	5.16	0.360	0.920×10^5	0.363
2"	2.08	3.38	3.37	29.50	0.179	2.52×10^5	0.180
	1.43	1.63	1.67	19.80	0.176	1.73×10^5	0.178
	0.93	0.65	0.64	13.70	0.185	1.13×10^5	0.183
	0.72	0.36	0.46	11.50	0.169	0.873×10^5	0.191
	0.64	0.29	0.32	10.50	0.179	0.777×10^5	0.189
	0.51	0.19	0.18	9.12	0.191	0.620×10^5	0.186

Experimental Calibration Data for 8-in. Armco Metergate Model No. 101*

Opening of Gate	Q cfs	Δh in ft. x = 12"	Δh in ft. x/D = 2/3	h/a	C x/D = 2/3	Re	C x = 12"
8"	2.34	1.08	1.09	6.06	0.801	4.03×10^5	0.804
	2.31	1.02	1.05	5.76	0.805	4.00×10^5	0.817
	2.02	0.79	0.78	4.67	0.821	3.50×10^5	0.811
	1.82	0.66	0.68	4.56	0.791	3.16×10^5	0.800
	1.81	0.67	0.71-	4.09	0.768	3.15×10^5	0.789
	1.56	0.49	---	3.75	---	2.71×10^5	0.796
	1.52	0.48	0.48	3.16	0.784	2.64×10^5	0.782
	1.43	0.40	0.42	3.34	0.788	2.49×10^5	0.806
	1.42	0.40	0.41	4.85	0.792	2.47×10^5	0.802
	1.11	0.25	0.26	2.25	0.779	1.93×10^5	0.793
	1.10	0.24	0.24	4.62	0.803	1.91×10^5	0.803
	0.87	0.16	---	---	---	1.51×10^5	0.777
	0.81	0.14	---	---	---	1.41×10^5	0.772
	0.73	0.11	---	---	---	1.27×10^5	0.786
7"	2.24	1.00	---	6.51	---	3.89×10^5	0.800
	1.87	0.72	---	4.91	---	3.25×10^5	0.787

* Data from U. S. Bureau of Reclamation - 20 ft. corrugated pipe

Experimental Calibration Data for 8-in. Armco Metergate Model No. 101

Opening of Gate	Q cfs	Δh in ft. x = 12"	Δh in ft. x/D = 2/3	h/a	C x/D = 2/3	Re	C x = 12"
7"	1.70	0.59	---	4.20	---	2.95×10^5	0.790
	1.44	0.43	---	3.38	---	2.50×10^5	0.785
	1.19	0.31	---	2.72	---	2.06×10^5	0.763
	1.05	0.23	---	---	---	1.82×10^5	0.782
	0.97	0.19	---	2.12	---	1.68×10^5	0.795
	0.97	0.20	---	4.27	---	1.68×10^5	0.775
	0.87	0.17	---	---	---	1.51×10^5	0.754
	0.81	0.14	---	---	---	1.41×10^5	0.774
	0.81	0.14	---	---	---	1.41×10^5	0.774
	0.69	0.10	---	---	---	1.20×10^5	0.780
6"	2.14	1.10	1.36	7.48	0.653	3.72×10^5	0.726
	1.83	0.79	0.98	5.78	0.661	3.18×10^5	0.733
	1.65	0.65	0.80	3.02	0.663	2.87×10^5	0.729
	1.44	0.51	0.64	4.26	0.643	2.50×10^5	0.718
	1.20	0.38	0.48	3.52	0.622	2.08×10^5	0.693
	1.10	0.30	---	---	---	1.91×10^5	0.724
	0.97	0.22	0.27	3.58	0.664	1.69×10^5	0.737

Experimental Calibration Data for 8-in. Armco Metergate Model No. 101

Opening of Gate	Q cfs	Δh in ft. x = 12"	Δh in ft. x/D = 2/3	h/a	C x/D = 2/3	Re	C x = 12"
6"	0.97	0.22	0.28	3.02	0.656	1.69×10^5	0.737
	0.80	0.155	---	---	---	1.39×10^5	0.726
	0.80	0.155	---	---	---	1.39×10^5	0.726
	0.76	0.14	---	---	---	1.32×10^5	0.725
	0.69	0.12	---	---	---	1.20×10^5	0.712
5"	2.14	1.40	---	9.58	---	3.72×10^5	0.646
	1.78	0.96	---	7.18	---	3.09×10^5	0.650
	1.46	0.66	---	5.43	---	2.54×10^5	0.641
	1.16	0.41	---	4.01	---	2.02×10^5	0.646
	0.96	0.28	---	3.24	---	1.67×10^5	0.648
	0.85	0.21	---	2.78	---	1.48×10^5	0.663
	0.81	0.195	---	---	---	1.41×10^5	0.655
	0.76	0.17	---	---	---	1.32×10^5	0.658
	0.70	0.14	---	---	---	1.22×10^5	0.668
	0.63	0.11	---	---	---	1.09×10^5	0.678
	0.62	0.11	---	---	---	1.08×10^5	0.654
4"	1.99	1.79	2.12	13.05	0.490	3.46×10^5	0.531

Experimental Calibration Data for 8-in. Armco Metergate Model No. 101

Opening of Gate	Q cfs	Δh in ft. x = 12"	Δh in ft. x/D = 2/3	h/a	C x/D = 2/3	Re	C x = 12"
4"	1.73	1.36	1.60	10.59	0.490	3.01×10^5	0.530
	1.30	0.76	0.90	7.41	0.489	2.26×10^5	0.532
	1.15	0.58	0.69	6.36	0.496	2.00×10^5	0.539
	0.94	0.39	0.47	5.16	0.487	1.63×10^5	0.538
	0.89	0.35	---	---	---	1.55×10^5	0.537
	0.74	0.23	0.28	4.11	0.500	1.29×10^5	0.551
	0.73	0.23	---	---	---	1.27×10^5	0.544
	0.66	0.18	---	---	---	1.15×10^5	0.548
	0.57	0.13	---	---	---	0.990×10^5	0.556
	0.51	0.10	---	---	---	0.886×10^5	0.562
	0.51	0.10	---	---	---	0.886×10^5	0.562
3"	1.78	2.21	---	16.60	---	3.09×10^5	0.428
	1.15	0.90	---	8.68	---	2.00×10^5	0.433
	1.06	0.79	---	7.96	---	1.84×10^5	0.426
	0.91	0.58	---	6.56	---	1.58×10^5	0.426
	0.80	0.44	---	---	---	1.39×10^5	0.430
	0.69	0.33	---	---	---	1.20×10^5	0.429

Experimental Calibration Data for 8-in. Armco Metergate Model No. 101

Opening of Gate	Q cfs	Δh in ft. x = 12"	Δh in ft. x/D = 2/3	h/a	C x/D = 2/3	Re	C x = 12"
3"	0.65	0.27	---	---	---	1.13×10^5	0.447
	0.58	0.22	---	---	---	1.01×10^5	0.446
	0.53	0.18	---	---	---	0.921×10^5	0.453
	0.51	0.17	---	5.28	---	0.886×10^5	0.441
	0.46	0.13	---	---	---	0.802×10^5	0.456
	0.41	0.10	---	---	---	0.715×10^5	0.463
2"	0.97	1.32	1.48	16.86	0.284	1.68×10^5	0.302
	0.93	1.25	1.39	16.20	0.281	1.62×10^5	0.297
	0.89	1.23	1.37	16.02	0.271	1.55×10^5	0.287
	0.80	0.91	1.01	13.50	0.284	1.39×10^5	0.300
	0.66	0.62	0.69	11.10	0.284	1.15×10^5	0.300
	0.64	0.56	---	---	---	1.11×10^5	0.307
	0.62	0.55	0.61	10.44	0.284	1.08×10^5	0.299
	0.45	0.28	---	---	---	0.781×10^5	0.301
	0.42	0.24	0.27	12.90	0.288	0.730×10^5	0.306
	0.38	0.18	---	---	---	0.660×10^5	0.320
	0.34	0.14	0.16	6.78	0.304	0.590×10^5	0.325

Table 4 (continued)

Experimental Calibration Data for 8-in. Armco Metergate Model No. 101

Opening of Gate	Q cfs	Δh in ft x = 12"	Δh in ft. x/D = 2/3	h/a	C x/D = 2/3	Re	C x = 12"
2"	0.34	0.[illegible]4	0.16	10.98	0.304	0.590×10^5	0.325
	0.33	0.14	---	---	---	0.574×10^5	0.319
	0.28	0.10	---	---	---	0.486×10^5	0.325

Table 5

Discharge Data
48-in. Armco Metergate Model No. 101

Net Gate Opening Inches									
2	2½	3	3½	4	4½	5	5½	6	7
Discharge in Cubic Feet per Second									
1.19	1.51	1.85	2.21	2.52	2.84	3.15	3.45	3.75	4.34
1.32	1.69	2.06	2.47	2.80	3.16	3.50	3.83	4.18	4.84
1.43	1.87	2.25	2.70	3.06	3.44	3.83	4.19	4.55	5.29
1.54	2.00	2.43	2.91	3.29	3.70	4.13	4.50	4.90	5.70
1.65	2.12	2.59	3.10	3.52	3.95	4.40	4.80	5.24	6.09
1.75	2.24	2.74	3.29	3.72	4.20	4.66	5.08	5.56	6.4[illegible]
1.84	2.36	2.89	3.47	3.92	4.42	4.92	5.36	5.87	6.8[illegible]
1.93	2.48	3.02	3.63	4.11	4.64	5.16	5.62	6.14	7.1[illegible]
2.01	2.59	3.15	3.79	4.29	4.85	5.39	5.86	6.40	7.4[illegible]
2.09	2.69	3.27	3.94	4.45	5.05	5.60	6.10	6.66	7.7[illegible]
2.17	2.79	3.39	4.08	4.61	5.23	5.81	6.33	6.89	8.0[illegible]
2.24	2.88	3.51	4.22	4.77	5.40	6.02	6.56	7.12	8.2[illegible]
2.31	2.97	3.63	4.36	4.92	5.56	6.22	6.79	7.35	8.5[illegible]
2.38	3.06	3.74	4.49	5.07	5.71	6.40	7.00	7.58	8.8[illegible]
2.44	3.15	3.84	4.62	5.20	5.87	6.58	7.19	7.81	9.0[illegible]
2.51	3.24	3.94	4.74	5.33	6.01	6.76	7.36	8.03	9.3[illegible]
2.57	3.32	4.05	4.85	5.46	6.18	6.93	7.55	8.23	9.5[illegible]
2.68	3.47	4.23	5.07	5.73	6.48	7.24	7.92	8.63	10.0[illegible]
2.79	3.62	4.41	5.29	5.97	6.75	7.55	8.28	9.01	10.4[illegible]
2.90	3.76	4.59	5.51	6.20	7.02	7.86	8.62	9.38	10.9[illegible]

Table 5 (continued)

Net Gate Opening Inches									
2	2½	3	3½	4	4½	5	5½	6	7
Discharge in Cubic Feet per Second									
3.00	3.90	4.76	5.72	6.43	7.28	8.16	8.95	9.74	11.32
3.10	4.04	4.92	5.92	6.66	7.54	8.54	9.25	10.09	11.72
3.20	4.16	5.08	6.10	6.88	7.79	8.73	9.55	10.41	12.11
3.30	4.28	5.22	6.27	7.10	8.02	9.00	9.85	10.73	12.48
3.40	4.40	5.37	6.44	7.30	8.25	9.26	10.13	11.04	12.85
3.49	4.52	5.52	6.61	7.50	8.48	9.51	10.41	11.35	13.20
3.58	4.63	5.67	6.77	7.69	8.70	9.76	10.69	11.64	13.53
3.74	4.85	5.94	7.10	8.05	9.13	10.23	11.20	12.20	14.19
3.90	5.06	6.20	7.42	8.41	9.53	10.70	11.71	12.76	14.84
4.05	5.26	6.43	7.72	8.75	9.92	11.12	12.19	13.30	15.42
4.20	4.46	6.66	8.01	9.08	10.30	11.54	12.64	13.78	16.0[illegible]
4.35	5.65	6.89	8.29	9.40	10.65	11.95	13.10	14.26	16.56
4.50	5.83	7.10	8.56	9.70	11.00	12.34	13.52	14.72	17.1[illegible]
4.63	6.01	7.31	8.82	10.00	11.34	12.72	13.93	15.18	17.64
4.76	6.18	7.52	9.08	10.30	11.67	13.10	14.33	15.61	18.17

Table 5 (continued)

Discharge Data
48-in. Armco Metergate Model No. 101

Net Gate Opening Inches									
8	9	10	11	12	14	16	18	20	22
Discharge in Cubic Feet per Second									
4.93	5.48	6.05	6.56	7.12	8.06	9.00	9.88	10.78	11.73
5.48	6.11	6.73	7.30	7.88	8.98	10.00	10.94	12.00	12.98
5.98	6.67	7.33	7.96	8.58	9.79	10.91	11.98	13.14	14.22
6.44	7.20	7.90	8.55	9.25	10.57	11.79	12.92	14.20	15.34
6.90	7.66	8.43	9.08	9.89	11.28	12.60	13.82	15.18	16.42
7.32	8.12	8.95	9.61	10.49	11.98	13.37	14.67	16.10	17.40
7.70	8.56	9.44	10.12	11.05	12.63	14.10	15.47	16.96	18.34
8.05	8.97	9.90	10.62	11.60	13.24	14.78	16.21	17.80	19.23
8.40	9.37	10.33	11.10	12.11	13.83	15.43	16.93	18.60	20.10
8.75	9.76	10.76	11.55	12.60	14.40	16.06	17.62	19.34	20.95
9.10	10.13	11.18	11.98	13.08	14.92	16.67	18.29	20.07	21.71
9.42	10.49	11.56	12.40	13.53	15.44	17.26	18.93	20.79	22.45
9.73	10.83	11.94	12.81	13.98	15.94	17.82	19.57	21.47	23.19
0.03	11.17	12.31	13.20	14.41	16.44	18.37	20.16	22.13	23.92
0.32	11.49	12.66	13.59	14.83	16.92	18.90	20.74	22.78	24.62
0.61	11.80	13.00	13.96	15.23	17.40	19.41	21.31	23.39	25.30
0.88	12.10	13.34	14.32	15.62	17.88	19.91	21.85	23.99	25.95
1.40	12.70	14.00	15.01	16.40	18.73	20.90	22.93	25.19	27.23
1.90	13.26	14.61	15.70	17.13	19.54	21.83	23.96	26.29	28.42
2.40	13.81	15.20	16.32	17.83	20.35	22.72	24.94	27.38	29.60

Table 5 (continued)

Net Gate Opening Inches									
8	9	10	11	12	14	16	18	20	22
Discharge in Cubic Feet per Second									
2.87	14.32	15.78	16.93	18.50	21.10	23.58	25.85	28.40	30.70
3.32	14.82	16.34	17.53	19.14	21.85	24.40	26.76	29.38	31.80
3.75	15.31	16.88	18.13	19.77	22.60	25.20	27.65	30.33	32.80
4.18	15.79	17.40	18.67	20.38	23.30	26.00	28.51	31.27	33.80
4.60	16.24	17.90	19.21	20.97	23.95	26.75	29.34	32.19	34.80
5.00	16.68	18.39	19.73	21.56	24.60	27.47	30.13	33.07	35.75
5.38	17.11	18.87	20.24	22.11	25.22	28.18	30.90	33.93	36.65
6.13	17.95	19.79	21.23	23.19	26.46	29.53	32.41	35.60	38.45
6.85	18.77	20.68	22.19	24.22	27.65	30.86	33.84	37.15	40.20
7.53	19.51	21.52	23.08	25.20	28.75	32.12	35.24	38.65	41.80
8.20	20.25	22.33	23.96	26.16	29.85	33.35	36.60	40.15	43.40
8.84	20.96	23.13	24.80	27.08	30.95	34.50	37.90	41.60	44.95
9.45	21.64	23.87	25.61	27.95	31.95	35.65	39.10	42.95	46.40
0.05	22.31	24.60	26.40	28.81	32.90	36.75	40.30	44.25	47.80
0.64	22.97	25.32	27.18	29.66	33.84	37.80	41.50	45.55	49.20

Table 5 (continued)

Discharge Data
48-in. Armco Metergate Model No. 101

Net Gate Opening Inches								
24	26	28	30	34	38	42	46	48
Discharge in cubic Feet per Second								
2.46	13.23	13.92	14.72	15.82	17.00	17.20	17.67	17.78
3.81	14.70	15.55	16.32	17.57	18.75	19.10	19.59	19.78
5.16	16.12	17.05	17.85	19.20	20.30	21.00	21.48	21.68
6.37	17.42	18.42	19.23	20.72	21.84	22.63	23.24	23.38
7.50	18.63	19.70	20.60	22.10	23.33	24.15	24.78	24.98
8.57	19.76	20.89	21.83	23.40	24.67	25.60	26.21	26.36
9.57	20.85	22.02	23.05	24.65	26.00	26.95	27.63	27.74
20.52	21.85	23.10	24.15	25.87	27.28	28.30	29.00	29.12
21.42	22.82	24.13	25.20	27.02	28.50	29.65	30.35	30.50
22.30	23.77	25.13	26.25	28.14	29.67	30.90	31.53	31.65
23.15	24.67	26.09	27.25	29.20	30.80	32.07	32.69	32.81
23.96	25.52	26.98	28.18	30.20	31.85	33.17	33.85	33.93
24.75	26.36	27.85	29.10	31.20	32.90	34.27	34.98	35.05
25.52	27.18	28.70	30.00	32.20	33.93	35.32	36.05	36.17
26.25	27.95	29.53	30.87	33.11	34.90	36.36	37.06	37.20
26.97	28.71	30.34	31.72	34.01	35.88	37.34	38.07	38.20
27.65	29.45	31.14	32.57	34.88	36.80	38.30	39.08	39.20
29.01	30.88	32.65	34.15	36.60	38.57	40.20	41.00	41.16
30.32	32.25	34.10	35.67	38.20	40.30	41.97	42.78	42.98
31.55	33.60	35.50	37.10	39.75	41.95	43.68	44.55	44.70

Table 5 (continued

Jet Gate Opening Inches								
24	26	28	30	34	38	42	46	48
Discharge in cubic Feet per Second								
32.78	34.87	36.85	38.50	41.30	43.52	45.32	46.23	46.42
33.90	36.10	38.10	39.85	42.74	45.05	46.90	47.85	48.05
35.01	37.23	39.40	41.15	44.17	46.50	48.46	49.43	49.62
36.10	38.40	40.65	42.40	45.50	47.95	49.95	50.96	51.17
37.15	39.55	41.80	43.65	46.80	49.35	51.40	52.48	52.64
38.15	40.65	42.91	44.83	48.05	50.70	52.80	53.89	54.10
39.15	41.67	44.02	46.00	49.29	52.00	54.19	55.26	55.48
41.10	43.70	46.20	48.30	51.70	54.60	56.83	58.00	58.20
42.90	45.60	48.25	50.45	54.10	57.00	59.40	60.55	60.75
44.68	47.50	50.20	52.50	56.25	59.30	61.79	63.00	63.24
46.35	49.32	52.15	54.50	58.40	61.53	64.15	65.40	65.65
47.95	51.00	54.00	56.40	60.40	63.70	66.36	67.65	67.93
49.50	52.68	[illegible]	58.20	62.40	65.80	68.50	69.35	70.15
51.00	54.35	57.40	60.00	64.40	67.85	70.63	72.10	72.37
52.50	55.85	59.03	61.70	66.20	69.80	72.67	74.10	74.48

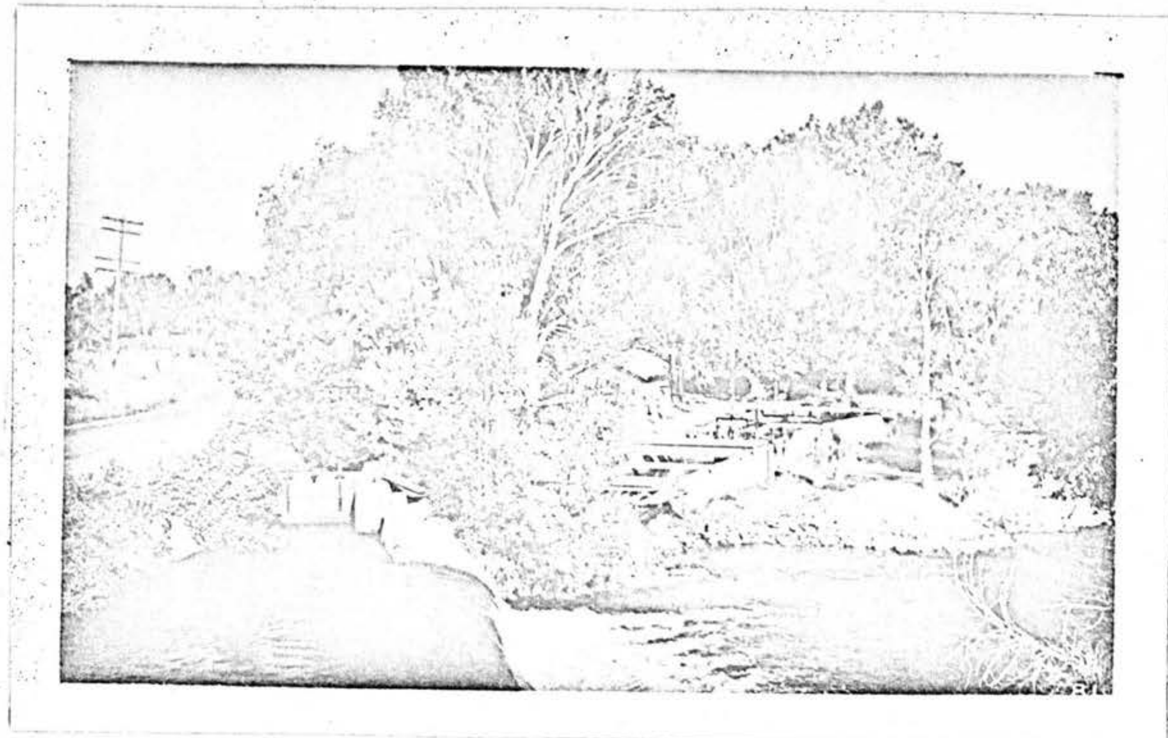


Fig. 1
General View of Laboratory on Cache La Poudre River
Flow from Diversion Works at Left through Flume to Calibrated Weir at Right
Calibration 48-in Armco Metergate Model No. 101
Colorado A & M College Hydraulics Laboratory, Bellvue, Colorado

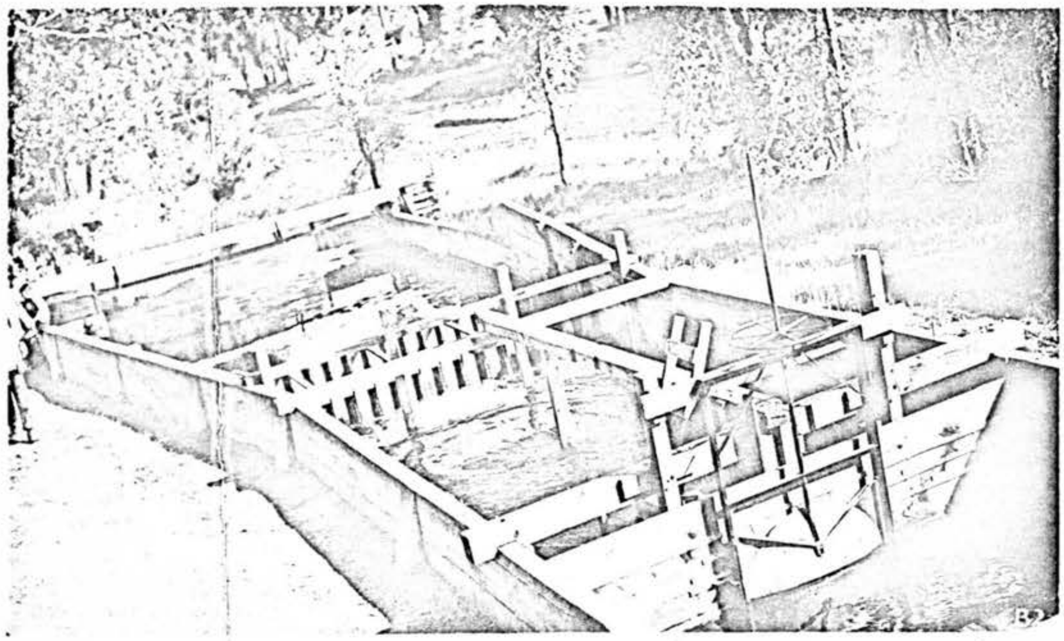


Fig. 2
Flow Patterns Downstream from Metergate to Calibrated Weir
Calibration 48-in Armco Metergate Model No. 101
Colorado A & M College Hydraulics Laboratory, Bellvue, Colorado

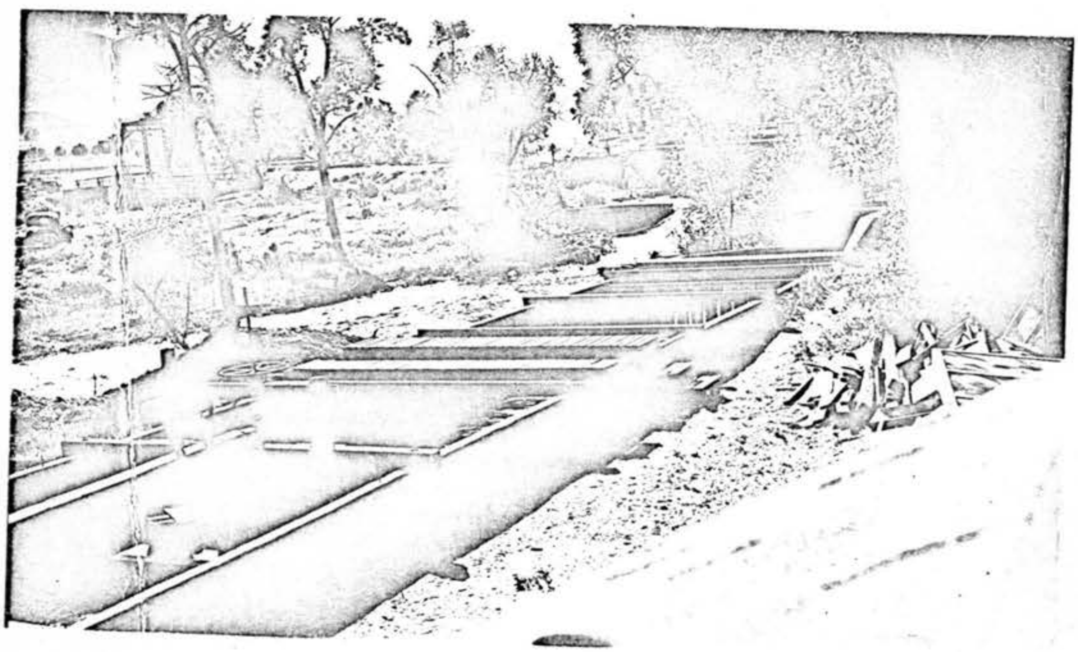
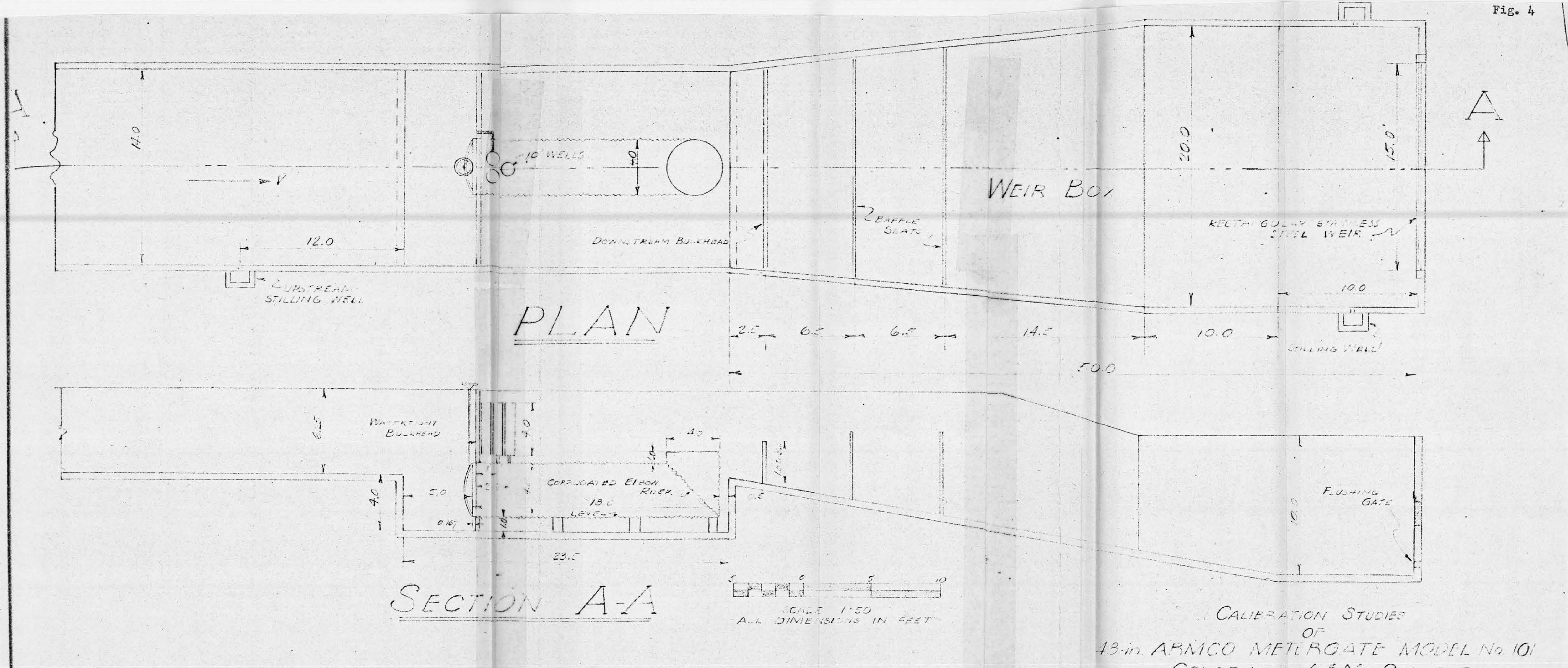
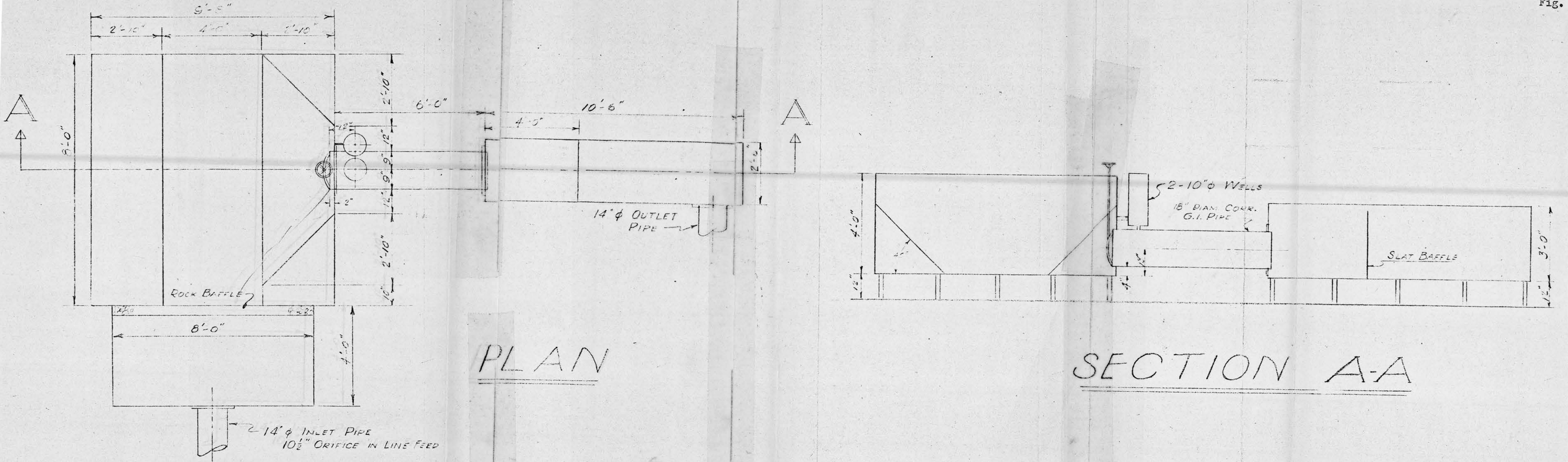


Fig. 3
Metergate and Flume Viewed from Downstream
Calibration 48-in Armco Metergate Model No. 101
Colorado A & M College Hydraulics Laboratory, Bellvue, Colorado

Fig. 4



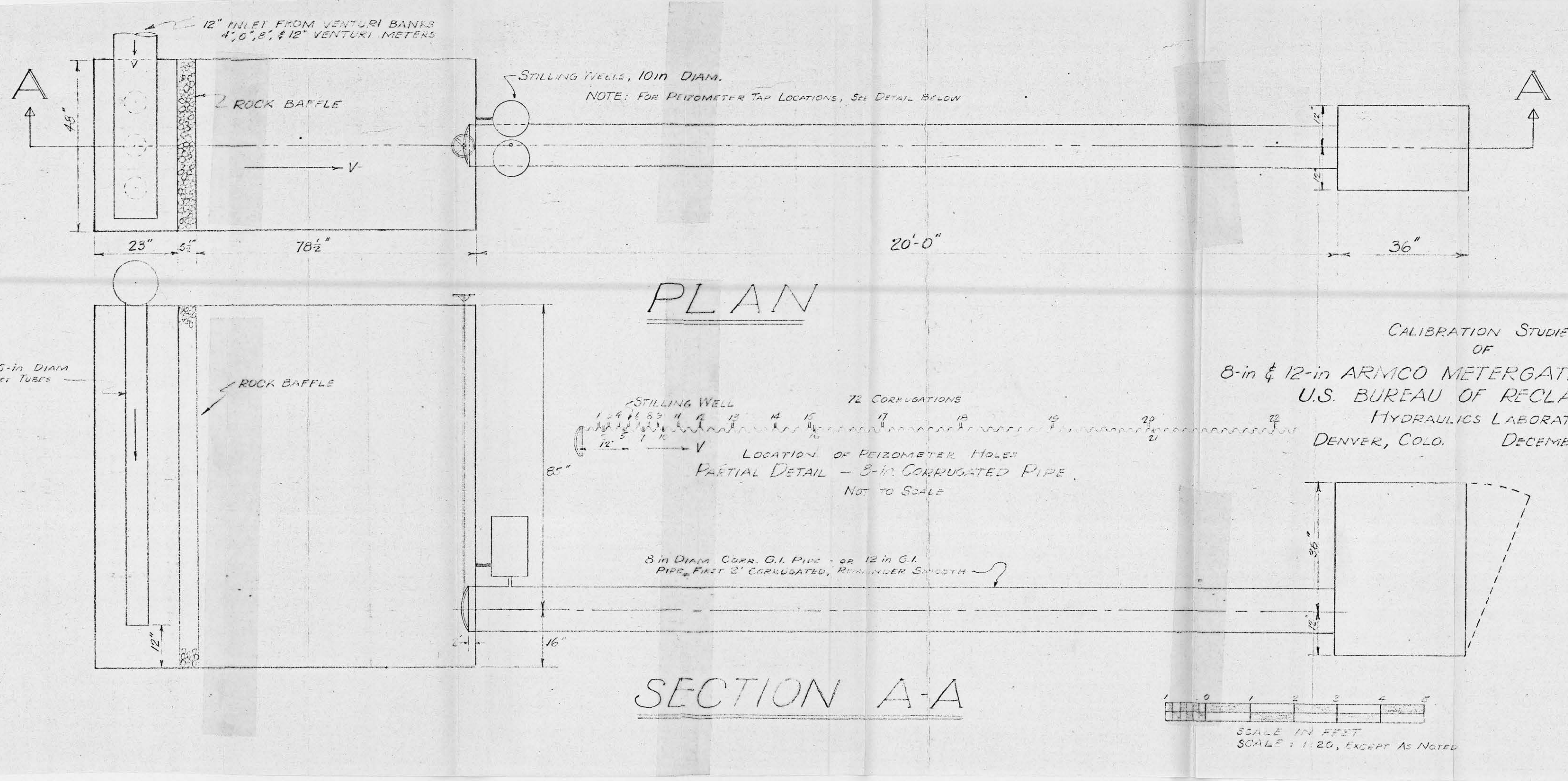
CALIBRATION STUDIES
OF
48-in. ARMCO METERGATE MODEL No. 101
COLORADO A & M COLLEGE
HYDRAULICS LABORATORY
FORT COLLINS, COLO. DECEMBER, 1950



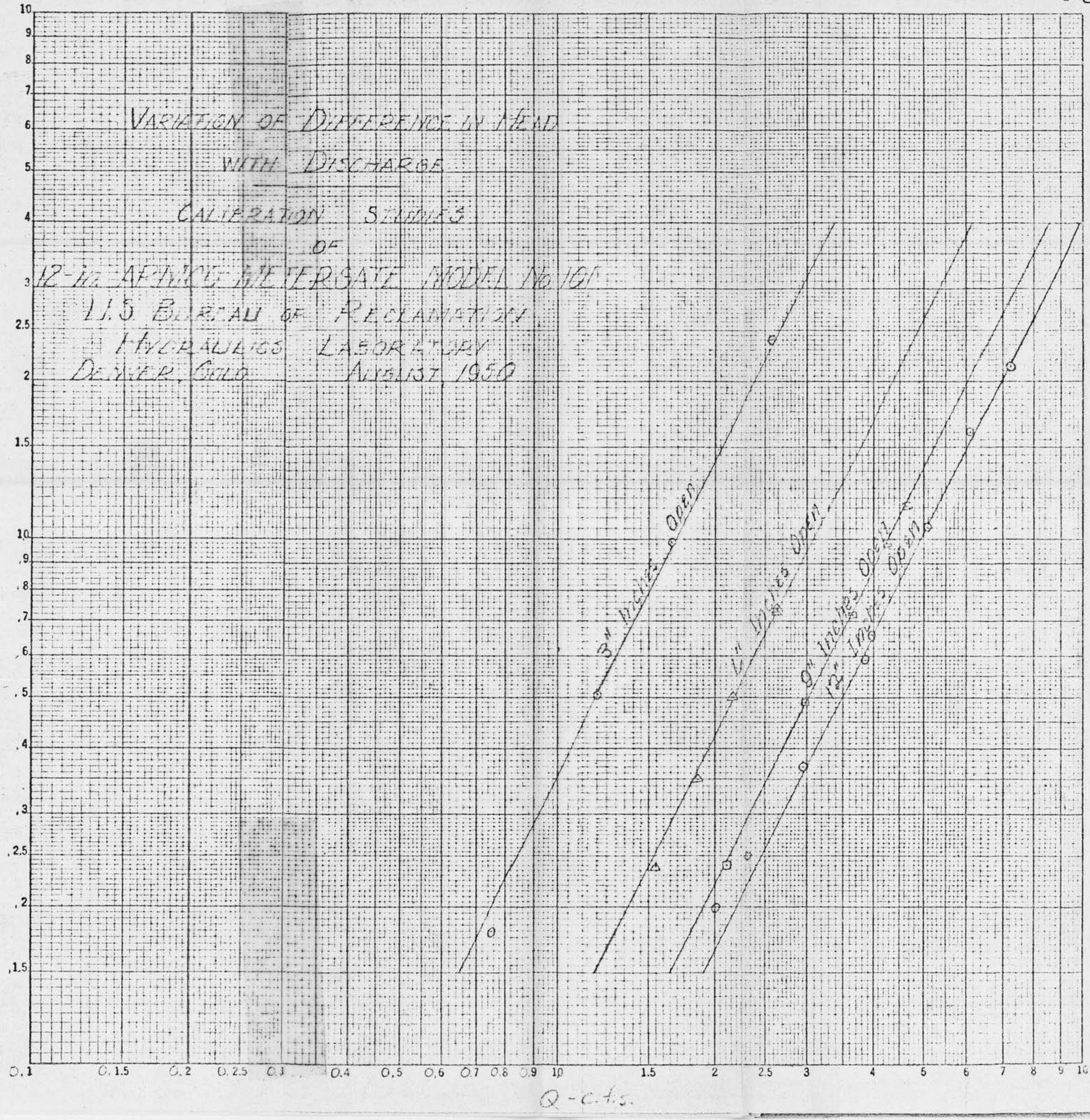
Calibration Studies
of
18-in. ARMCO Metergate; Model No. 101
Colorado A&M College
Hydraulics Laboratory
Fort Collins, Colo. December, 1950

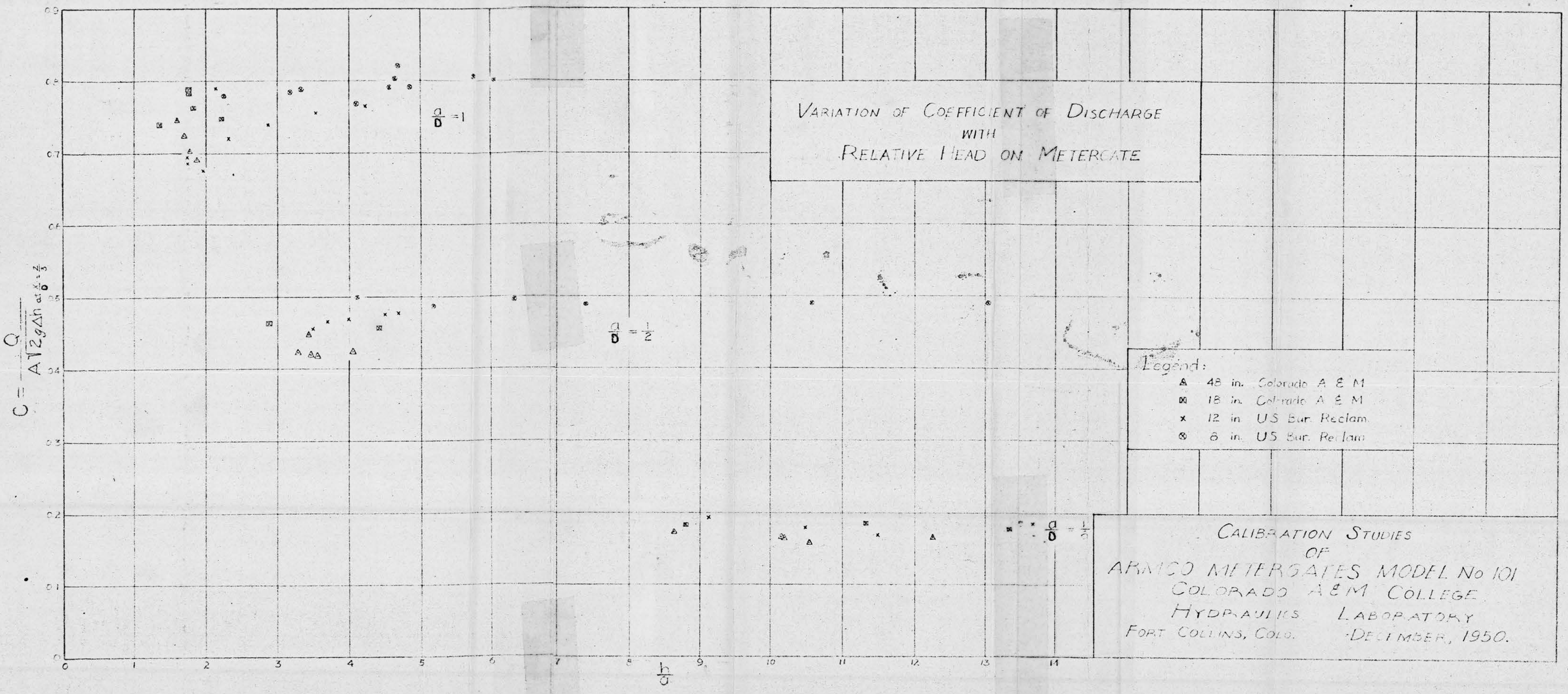
Scale in Feet

Scale: 1"=30"



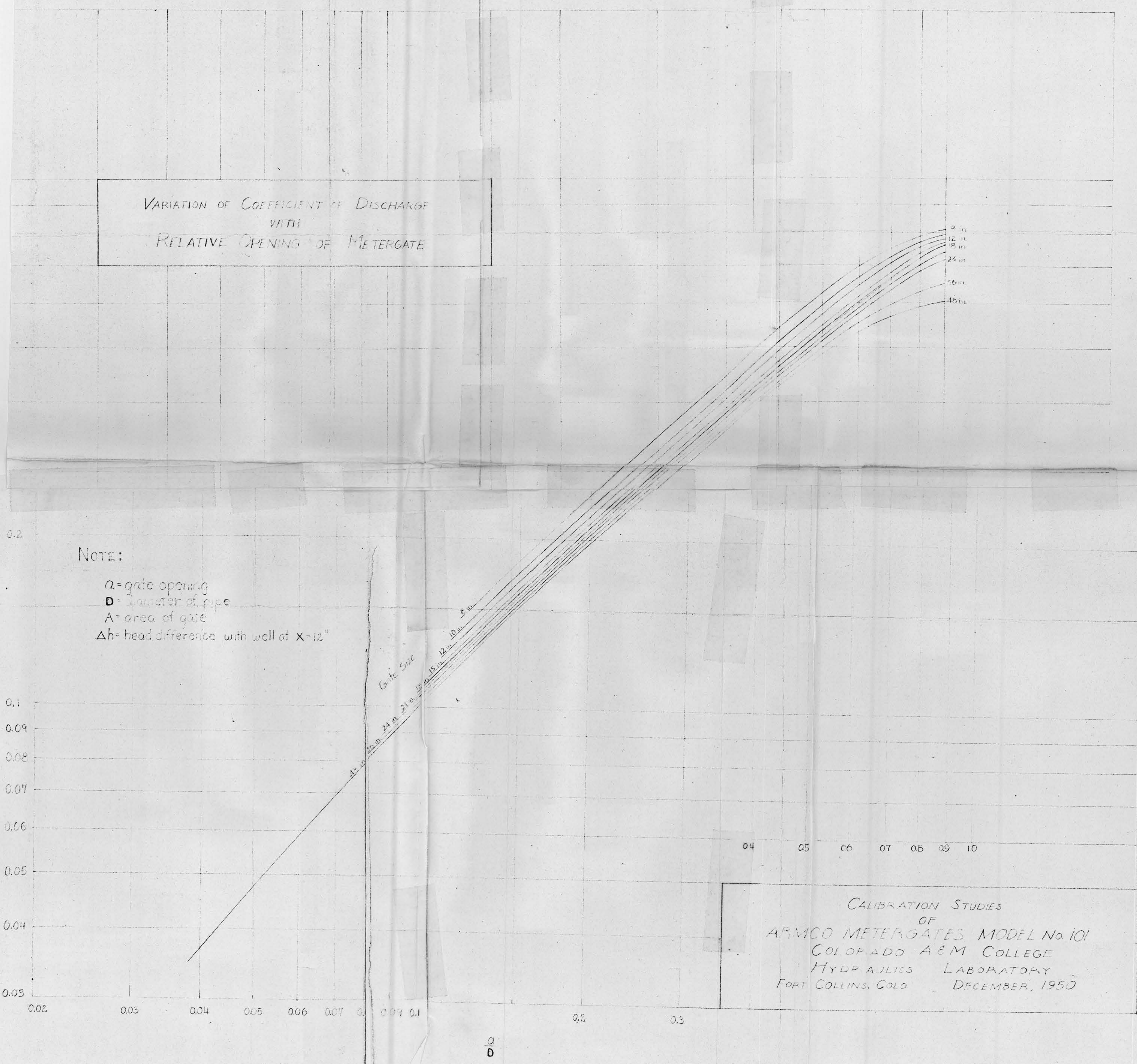
CALIBRATION STUDIES
OF
8-in & 12-in ARMCO METERGATE, MODEL No. 101
U.S. BUREAU OF RECLAMATION
HYDRAULICS LABORATORY
DENVER, COLO. DECEMBER, 1950


VARIATION OF DIFFERENCE IN HEAD
WITH DISCHARGE
CALIBRATION STUDIES
OF
12-in. ARMCO METERGATE MODEL No. 101
U.S. BUREAU OF RECLAMATION
HYDRAULICS LABORATORY
DENVER, COLO. AUGUST, 1950
3" inches open
6" inches open
9" inches open
12" inches open
Δh - Feet at x = 12 in.
Q - c.f.s.

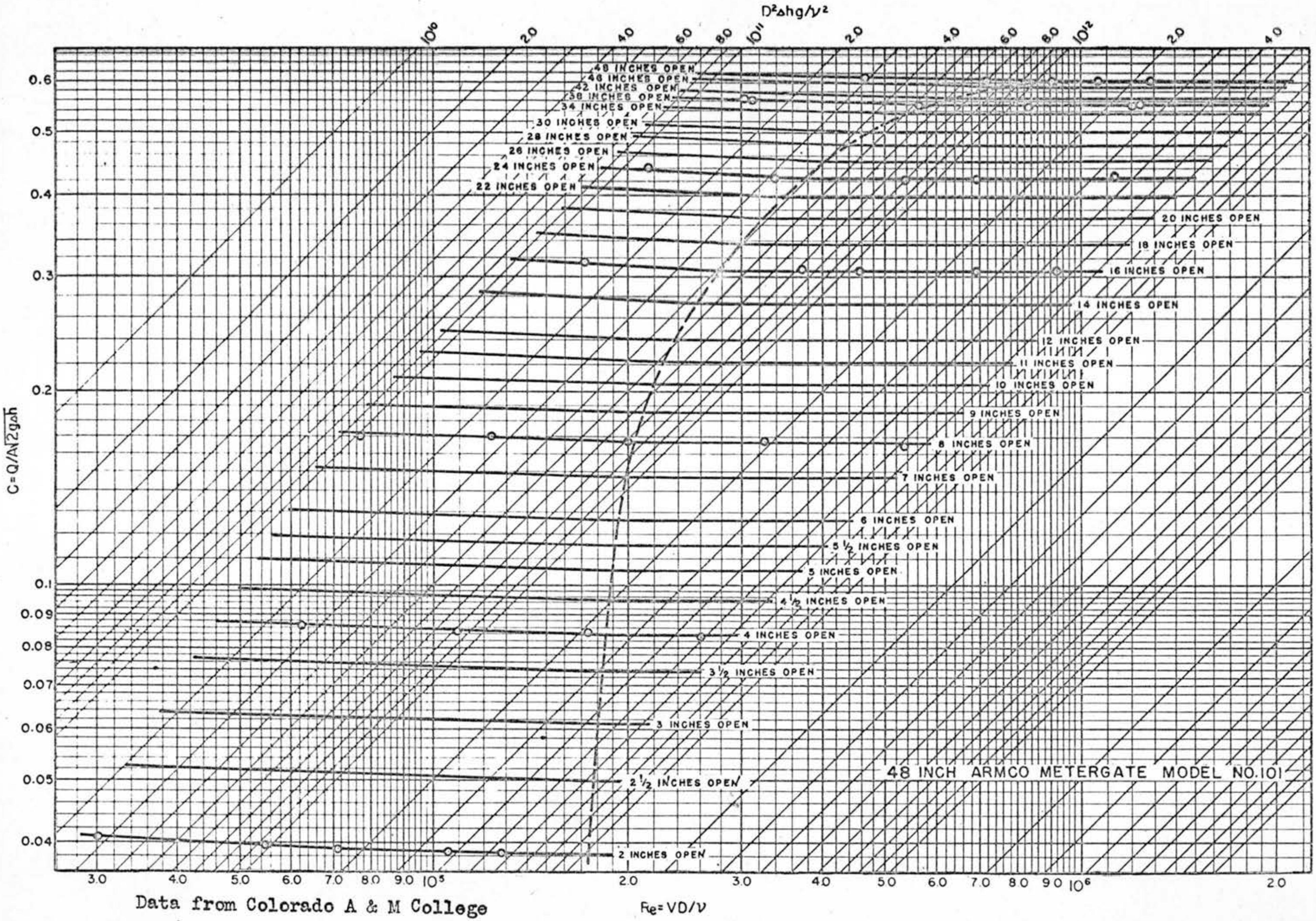


CALIBRATION STUDIES
OF
ARMCO METERGATES MODEL No 101
COLORADO A & M COLLEGE
HYDRAULICS LABORATORY
FORT COLLINS, COLO. DECEMBER, 1950.

Fig. 9

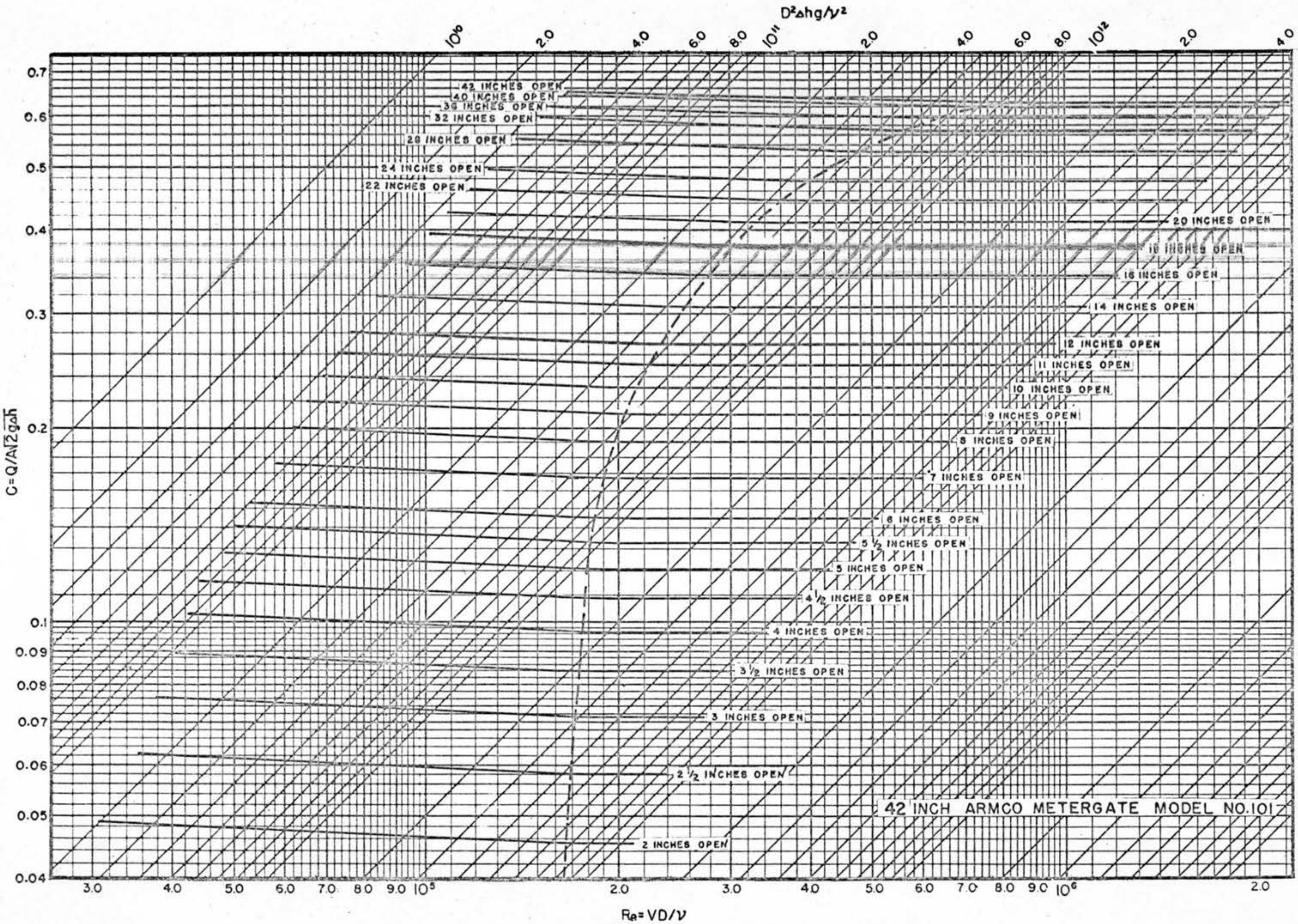


VARIATION OF COEFFICIENT OF DISCHARGE
WITH
RELATIVE OPENING OF METERGATE
NOTE:
a = gate opening
D = diameter of pipe
A = area of gate
Δh = head difference with well at X = 12"
C = Q / A√2gΔh
Gate Size
24 in
21 in
15 in
15 in
12 in
10 in
8 in
12 in
18 in
24 in
48 in
a/D
0.2
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.03
0.04
0.05
0.06
0.07
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
CALIBRATION STUDIES
OF
ARMCO METERGATES MODEL No. 101
COLORADO A & M COLLEGE
HYDRAULICS LABORATORY
FORT COLLINS, COLO
DECEMBER, 1950



Data from Colorado A & M College

Fig. 10



D²Δhg/ν²
10¹⁰
2.0
4.0
6.0
8.0
10¹¹
2.0
4.0
6.0
8.0
10¹²
2.0
4.0
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.09
0.08
0.07
0.06
0.05
0.04
C=Q/A√2gΔh
42 INCHES OPEN
40 INCHES OPEN
36 INCHES OPEN
32 INCHES OPEN
28 INCHES OPEN
24 INCHES OPEN
22 INCHES OPEN
20 INCHES OPEN
18 INCHES OPEN
16 INCHES OPEN
14 INCHES OPEN
12 INCHES OPEN
11 INCHES OPEN
10 INCHES OPEN
9 INCHES OPEN
8 INCHES OPEN
7 INCHES OPEN
6 INCHES OPEN
5 1/2 INCHES OPEN
5 INCHES OPEN
4 1/2 INCHES OPEN
4 INCHES OPEN
3 1/2 INCHES OPEN
3 INCHES OPEN
2 1/2 INCHES OPEN
2 INCHES OPEN
42 INCH ARMCO METERGATE MODEL NO.101
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10⁵
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10⁶
2.0
Re=VD/ν

Fig. 11

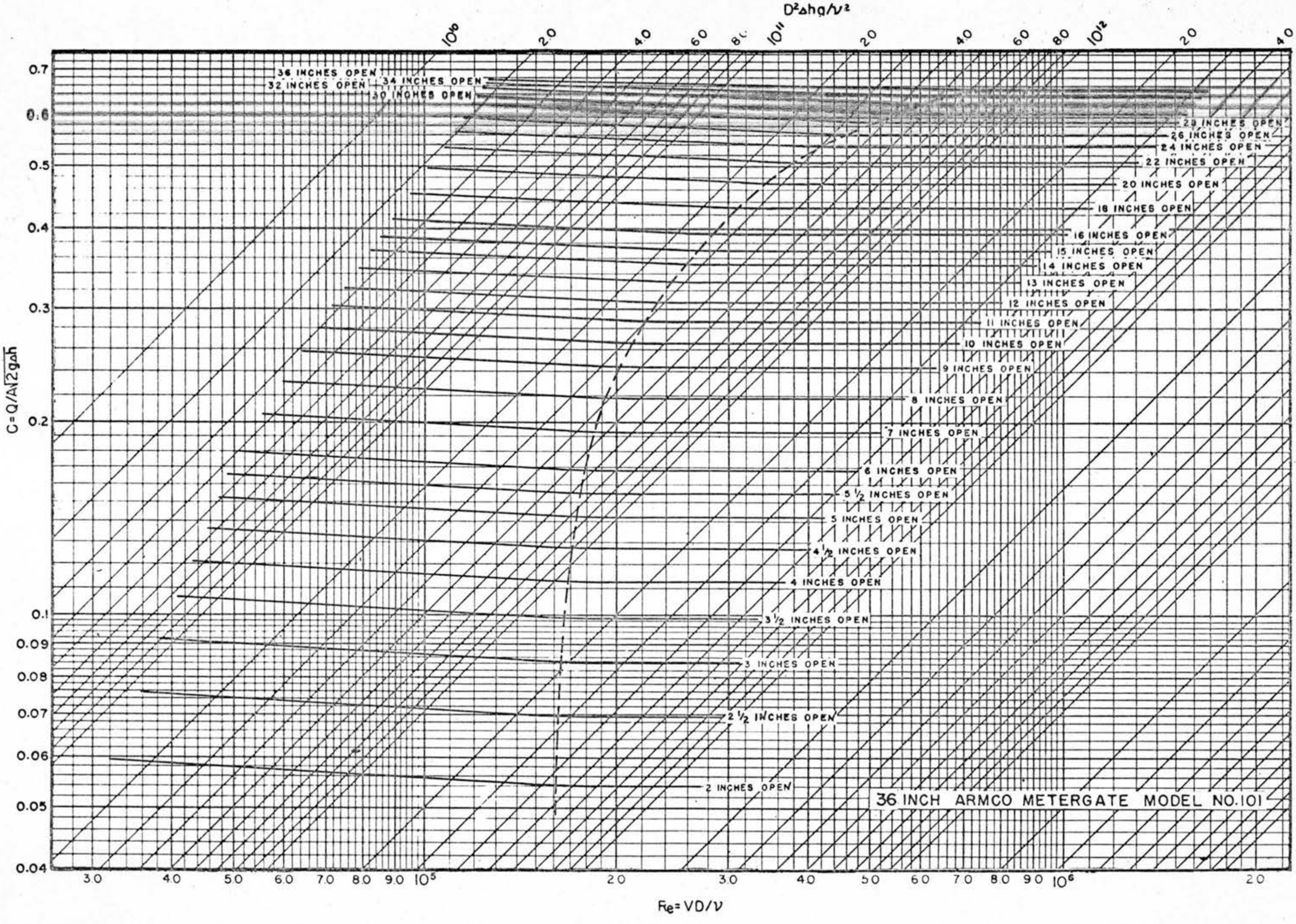

D²Δhg/ν²
36 INCHES OPEN
34 INCHES OPEN
32 INCHES OPEN
30 INCHES OPEN
28 INCHES OPEN
26 INCHES OPEN
24 INCHES OPEN
22 INCHES OPEN
20 INCHES OPEN
18 INCHES OPEN
16 INCHES OPEN
15 INCHES OPEN
14 INCHES OPEN
13 INCHES OPEN
12 INCHES OPEN
11 INCHES OPEN
10 INCHES OPEN
9 INCHES OPEN
8 INCHES OPEN
7 INCHES OPEN
6 INCHES OPEN
5 1/2 INCHES OPEN
5 INCHES OPEN
4 1/2 INCHES OPEN
4 INCHES OPEN
3 1/2 INCHES OPEN
3 INCHES OPEN
2 1/2 INCHES OPEN
2 INCHES OPEN
C=Q/A√2gΔh
Re=VD/ν
36 INCH ARMCO METERGATE MODEL NO.101

Fig. 12

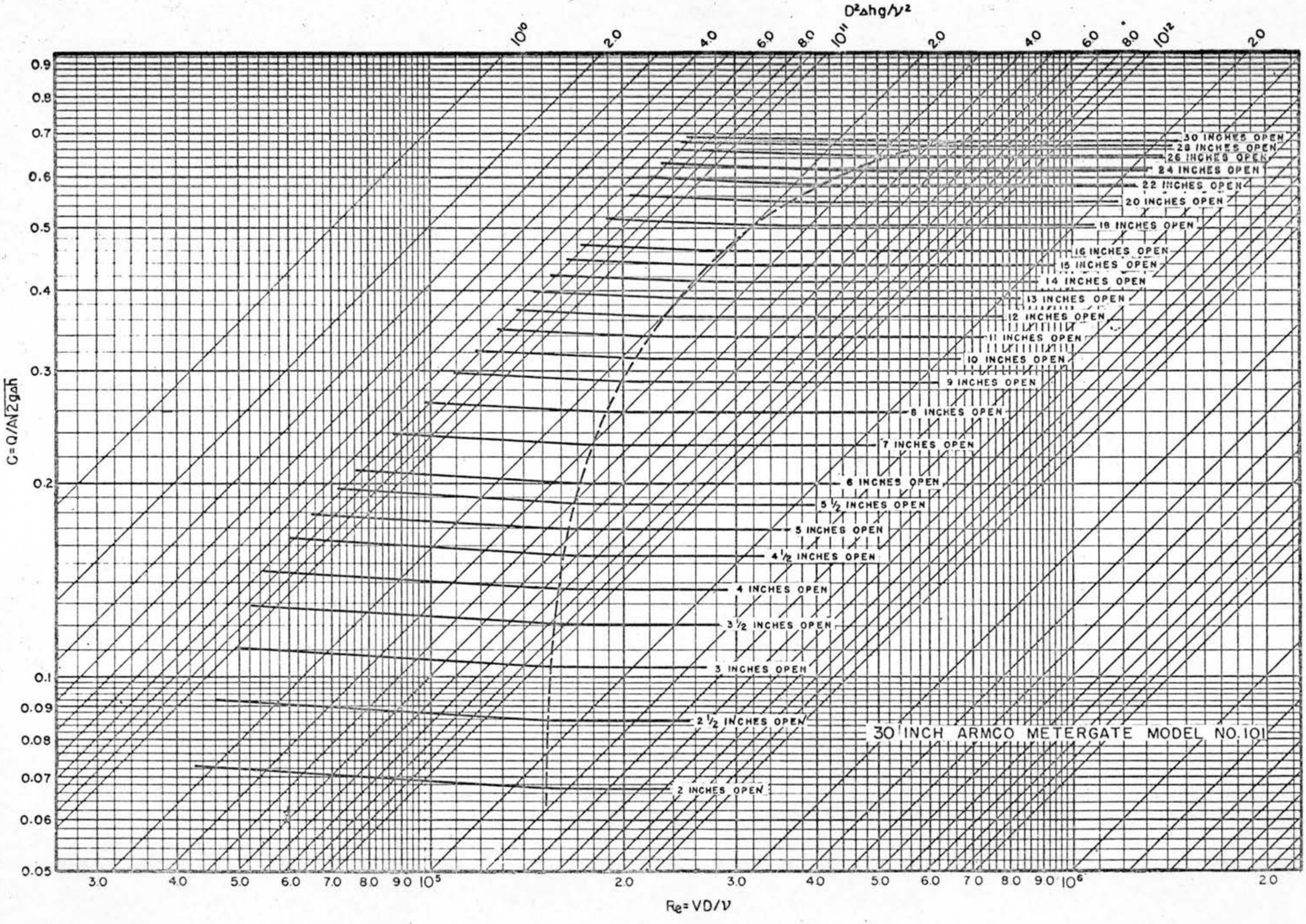

$D^2 \Delta hg/\nu^2$
$C = Q/A\sqrt{2g\Delta h}$
$R_e = VD/\nu$
30 INCHES OPEN
28 INCHES OPEN
26 INCHES OPEN
24 INCHES OPEN
22 INCHES OPEN
20 INCHES OPEN
18 INCHES OPEN
16 INCHES OPEN
15 INCHES OPEN
14 INCHES OPEN
13 INCHES OPEN
12 INCHES OPEN
11 INCHES OPEN
10 INCHES OPEN
9 INCHES OPEN
8 INCHES OPEN
7 INCHES OPEN
6 INCHES OPEN
5 1/2 INCHES OPEN
5 INCHES OPEN
4 1/2 INCHES OPEN
4 INCHES OPEN
3 1/2 INCHES OPEN
3 INCHES OPEN
2 1/2 INCHES OPEN
2 INCHES OPEN
30 INCH ARMCO METERGATE MODEL NO.101

Fig. 13

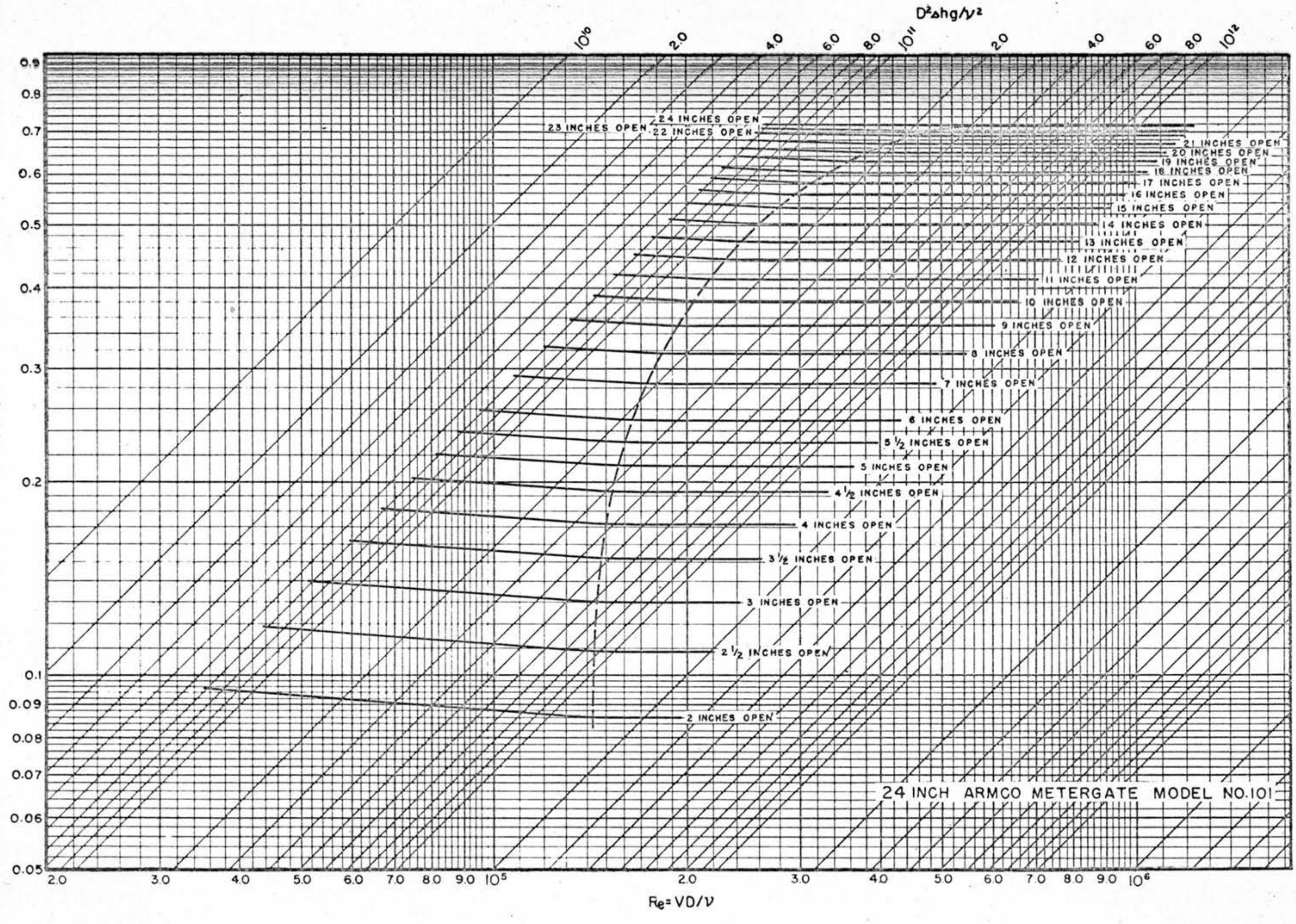
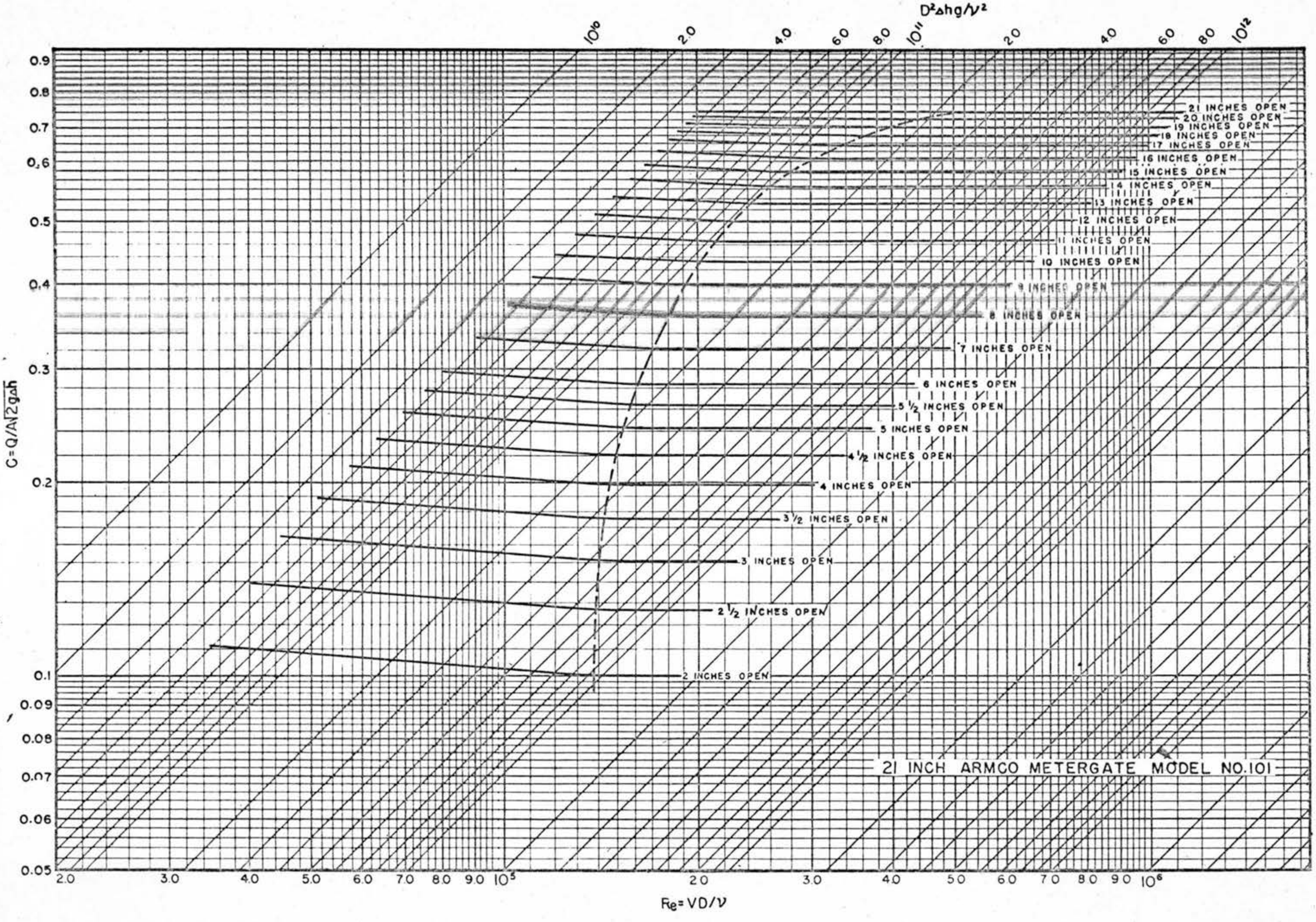

D²Δhg/ν²
10¹⁰
2.0
4.0
6.0
8.0
10¹¹
2.0
4.0
6.0
8.0
10¹²
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.09
0.08
0.07
0.06
0.05
24 INCHES OPEN
23 INCHES OPEN
22 INCHES OPEN
21 INCHES OPEN
20 INCHES OPEN
19 INCHES OPEN
18 INCHES OPEN
17 INCHES OPEN
16 INCHES OPEN
15 INCHES OPEN
14 INCHES OPEN
13 INCHES OPEN
12 INCHES OPEN
11 INCHES OPEN
10 INCHES OPEN
9 INCHES OPEN
8 INCHES OPEN
7 INCHES OPEN
6 INCHES OPEN
5 1/2 INCHES OPEN
5 INCHES OPEN
4 1/2 INCHES OPEN
4 INCHES OPEN
3 1/2 INCHES OPEN
3 INCHES OPEN
2 1/2 INCHES OPEN
2 INCHES OPEN
24 INCH ARMCO METERGATE MODEL NO.101
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10⁵
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10⁶
Re= VD/ν

Fig. 14



D²Δhg/ν²
10¹⁰
2.0
4.0
60
80
10¹¹
2.0
4.0
60
80
10¹²
21 INCHES OPEN
20 INCHES OPEN
19 INCHES OPEN
18 INCHES OPEN
17 INCHES OPEN
16 INCHES OPEN
15 INCHES OPEN
14 INCHES OPEN
13 INCHES OPEN
12 INCHES OPEN
11 INCHES OPEN
10 INCHES OPEN
9 INCHES OPEN
8 INCHES OPEN
7 INCHES OPEN
6 INCHES OPEN
5 1/2 INCHES OPEN
5 INCHES OPEN
4 1/2 INCHES OPEN
4 INCHES OPEN
3 1/2 INCHES OPEN
3 INCHES OPEN
2 1/2 INCHES OPEN
2 INCHES OPEN
C=Q/A√2gΔh
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.09
0.08
0.07
0.06
0.05
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10⁵
2.0
3.0
4.0
50
60
70
80
90
10⁶
Re=VD/ν
21 INCH ARMCO METERGATE MODEL NO.101

Fig. 15

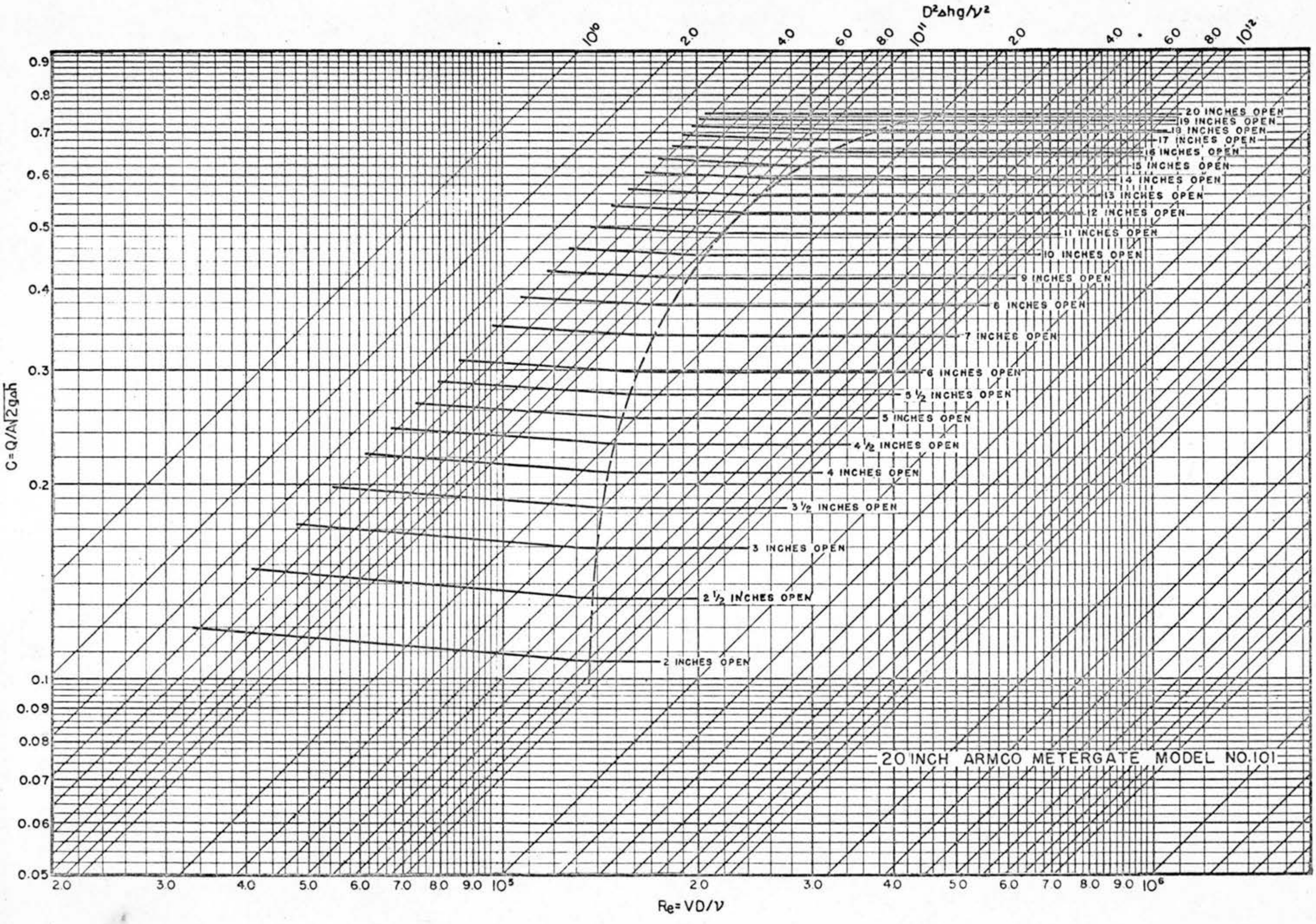
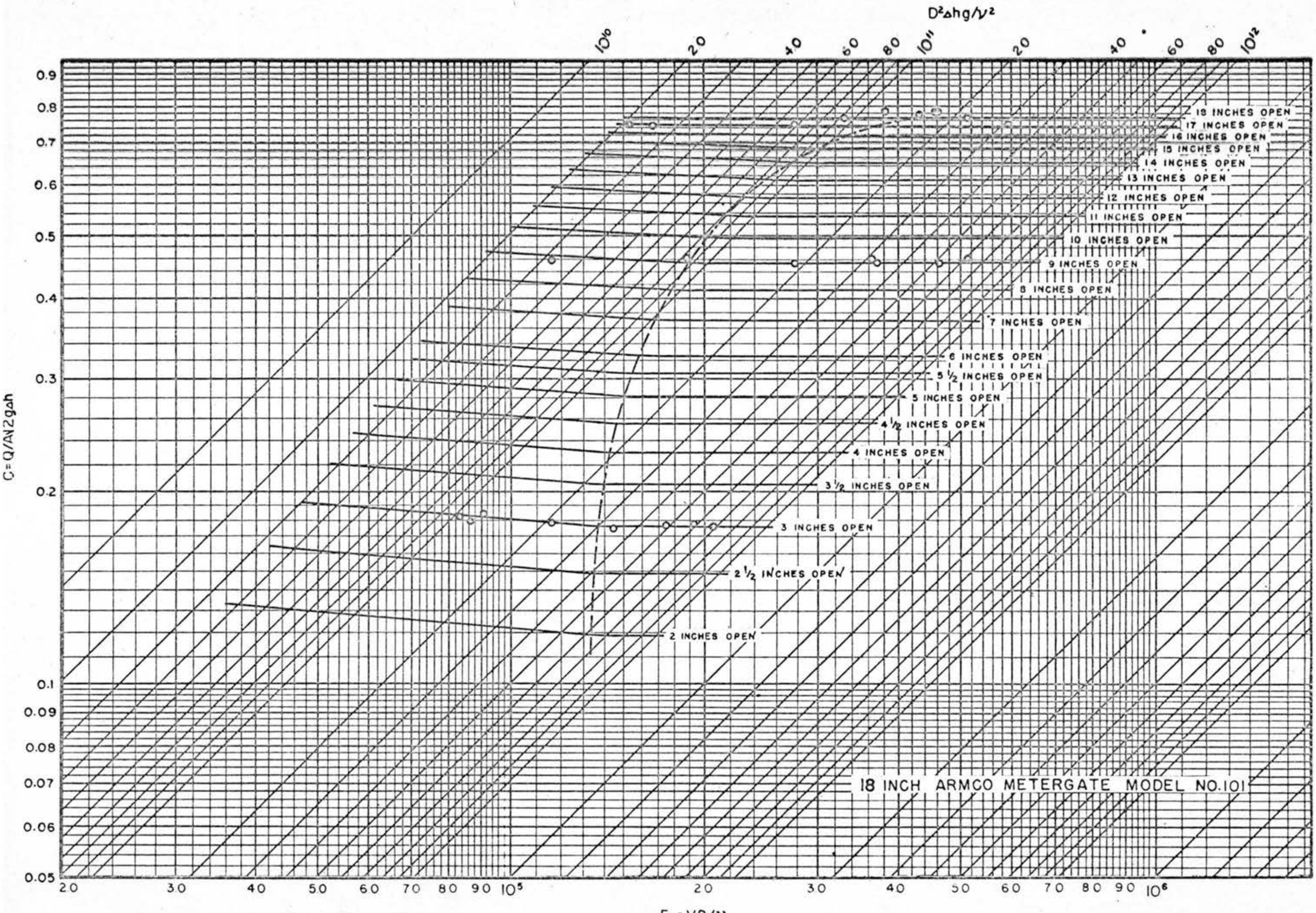
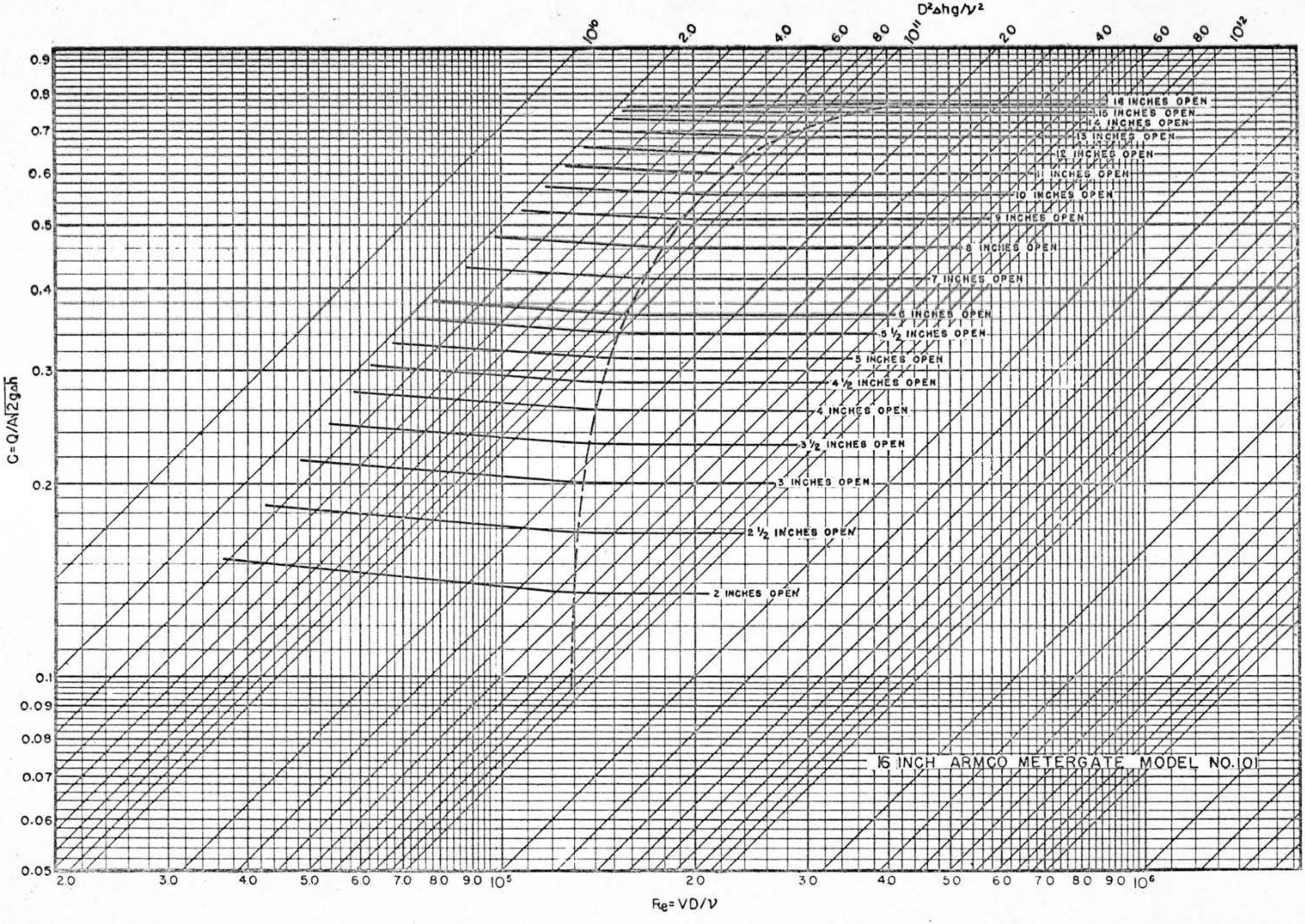

D²Δhg/ν²
C=Q/A√2gΔh
Re=VD/ν
20 INCHES OPEN
19 INCHES OPEN
18 INCHES OPEN
17 INCHES OPEN
16 INCHES OPEN
15 INCHES OPEN
14 INCHES OPEN
13 INCHES OPEN
12 INCHES OPEN
11 INCHES OPEN
10 INCHES OPEN
9 INCHES OPEN
8 INCHES OPEN
7 INCHES OPEN
6 INCHES OPEN
5 1/2 INCHES OPEN
5 INCHES OPEN
4 1/2 INCHES OPEN
4 INCHES OPEN
3 1/2 INCHES OPEN
3 INCHES OPEN
2 1/2 INCHES OPEN
2 INCHES OPEN
20 INCH ARMCO METERGATE MODEL NO.101

Fig. 16



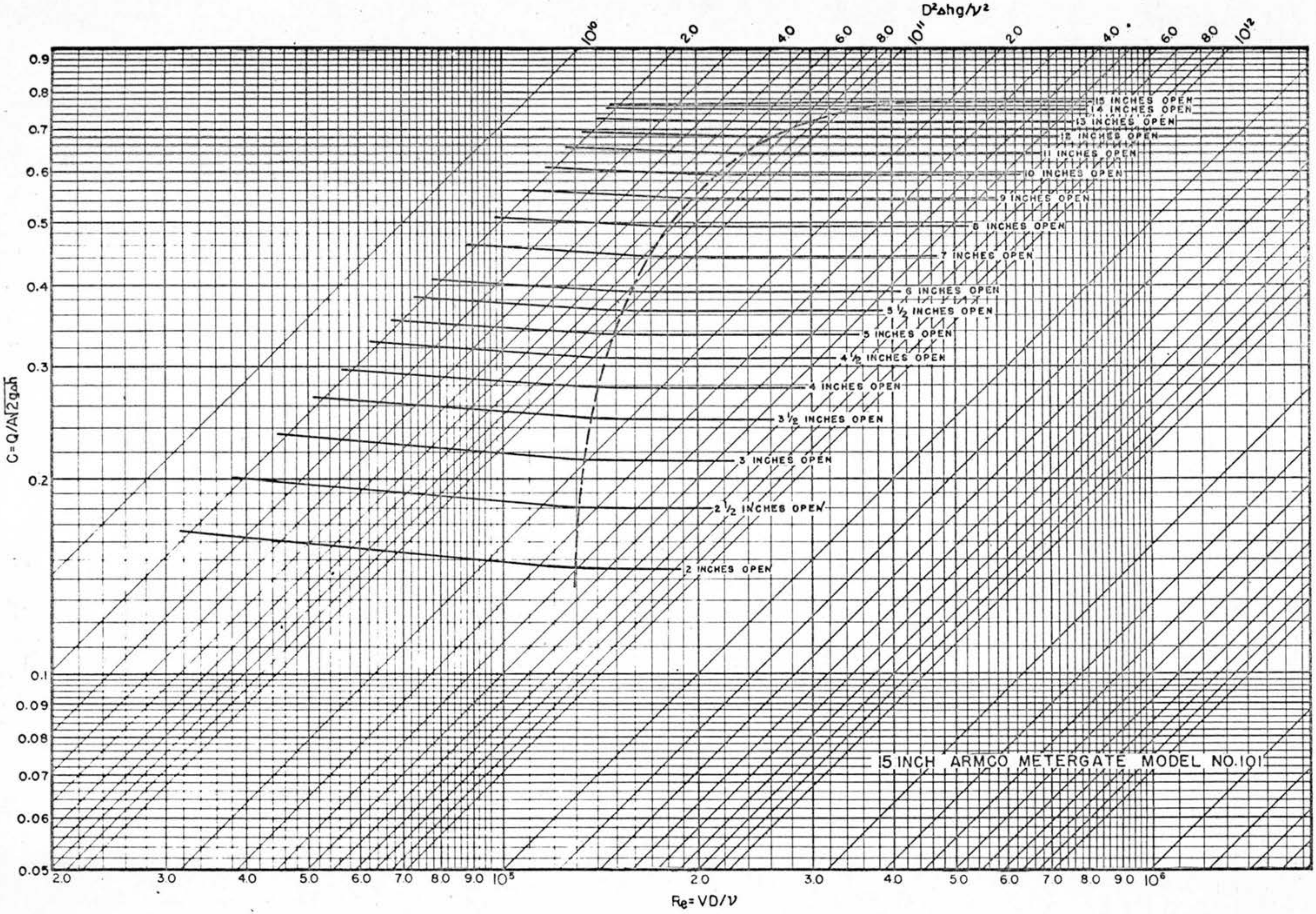
Data from Colorado A & M College

Fig. 17



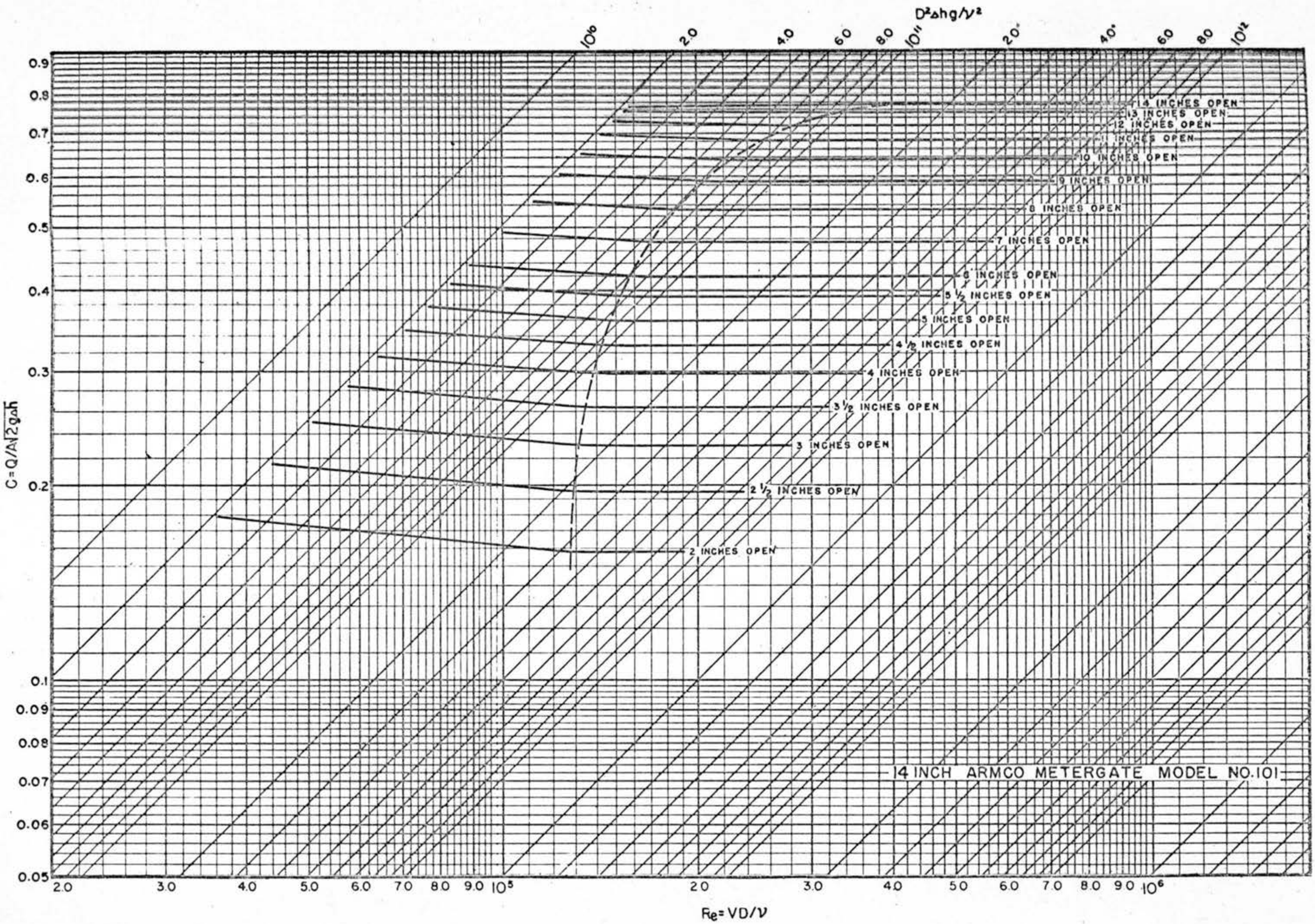
$D^2 \Delta h g / \nu^2$
10^{10}
2.0
4.0
6.0
8.0
10^{11}
2.0
4.0
6.0
8.0
10^{12}
16 INCHES OPEN
15 INCHES OPEN
14 INCHES OPEN
13 INCHES OPEN
12 INCHES OPEN
11 INCHES OPEN
10 INCHES OPEN
9 INCHES OPEN
8 INCHES OPEN
7 INCHES OPEN
6 INCHES OPEN
5 1/2 INCHES OPEN
5 INCHES OPEN
4 1/2 INCHES OPEN
4 INCHES OPEN
3 1/2 INCHES OPEN
3 INCHES OPEN
2 1/2 INCHES OPEN
2 INCHES OPEN
16 INCH ARMCO METERGATE MODEL NO. 101
$C = Q/A\sqrt{2g\Delta h}$
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.09
0.08
0.07
0.06
0.05
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10^5
2.0
3.0
4.0
50
60
70
80
90
10^6
$R_e = VD/\nu$

Fig. 18



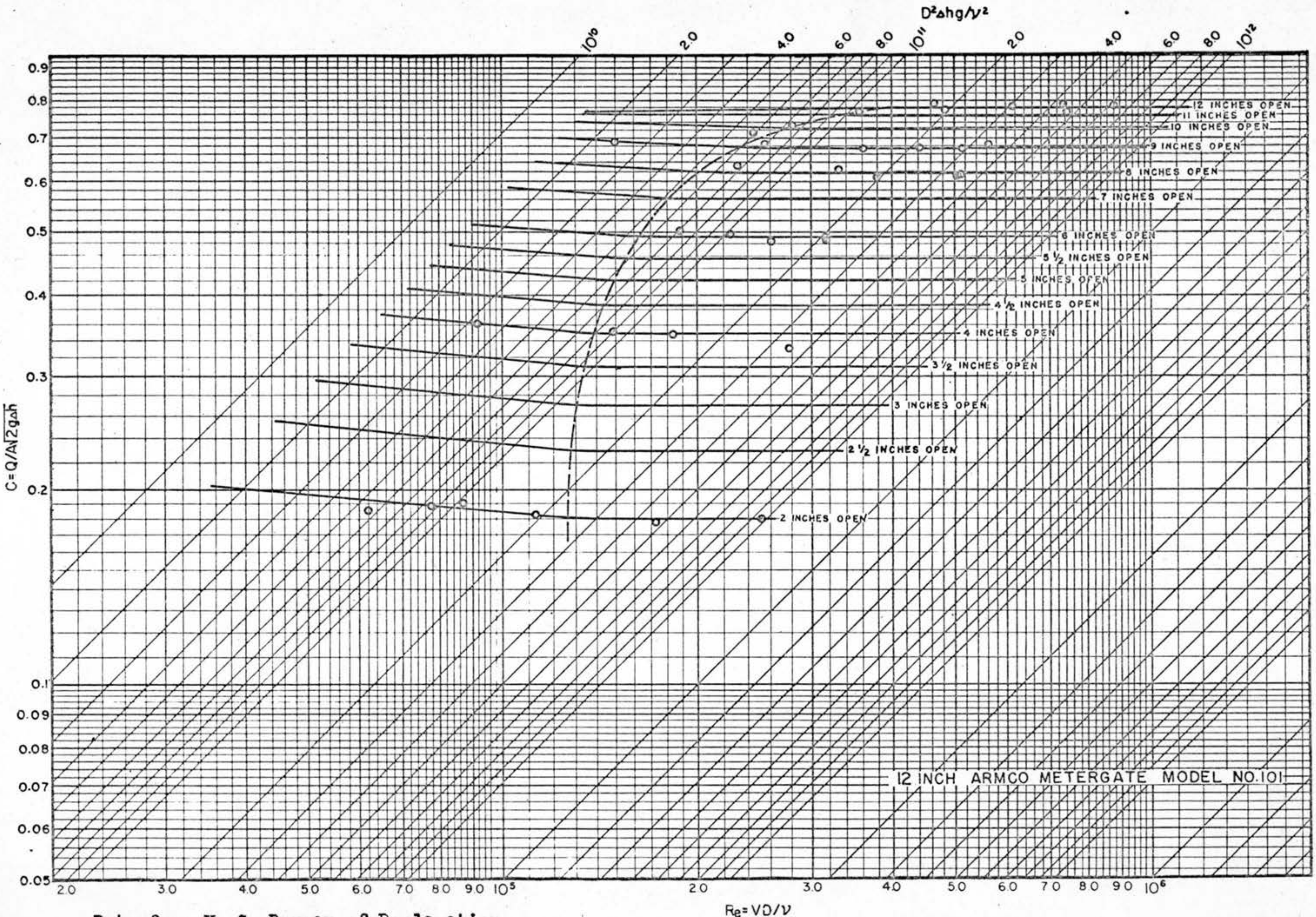
D²Δhg/ν²
10¹⁰
2.0
4.0
6.0
8.0
10¹¹
2.0
4.0
6.0
8.0
10¹²
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.09
0.08
0.07
0.06
0.05
C=Q/A√2gΔh
15 INCHES OPEN
14 INCHES OPEN
13 INCHES OPEN
12 INCHES OPEN
11 INCHES OPEN
10 INCHES OPEN
9 INCHES OPEN
8 INCHES OPEN
7 INCHES OPEN
6 INCHES OPEN
5 1/2 INCHES OPEN
5 INCHES OPEN
4 1/2 INCHES OPEN
4 INCHES OPEN
3 1/2 INCHES OPEN
3 INCHES OPEN
2 1/2 INCHES OPEN
2 INCHES OPEN
15 INCH ARMCO METERGATE MODEL NO.101
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10⁵
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10⁶
Re=VD/ν

Fig. 19



D²Δhg/ν²
10¹⁰
2.0
4.0
6.0
8.0
10¹¹
2.0
4.0
6.0
8.0
10¹²
C=Q/A√2gΔh
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.09
0.08
0.07
0.06
0.05
14 INCHES OPEN
13 INCHES OPEN
12 INCHES OPEN
11 INCHES OPEN
10 INCHES OPEN
9 INCHES OPEN
8 INCHES OPEN
7 INCHES OPEN
6 INCHES OPEN
5 1/2 INCHES OPEN
5 INCHES OPEN
4 1/2 INCHES OPEN
4 INCHES OPEN
3 1/2 INCHES OPEN
3 INCHES OPEN
2 1/2 INCHES OPEN
2 INCHES OPEN
14 INCH ARMCO METERGATE MODEL NO.101
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10⁵
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10⁶
Re=VD/ν

Fig. 20



Data from U. S. Bureau of Reclamation

Fig. 21

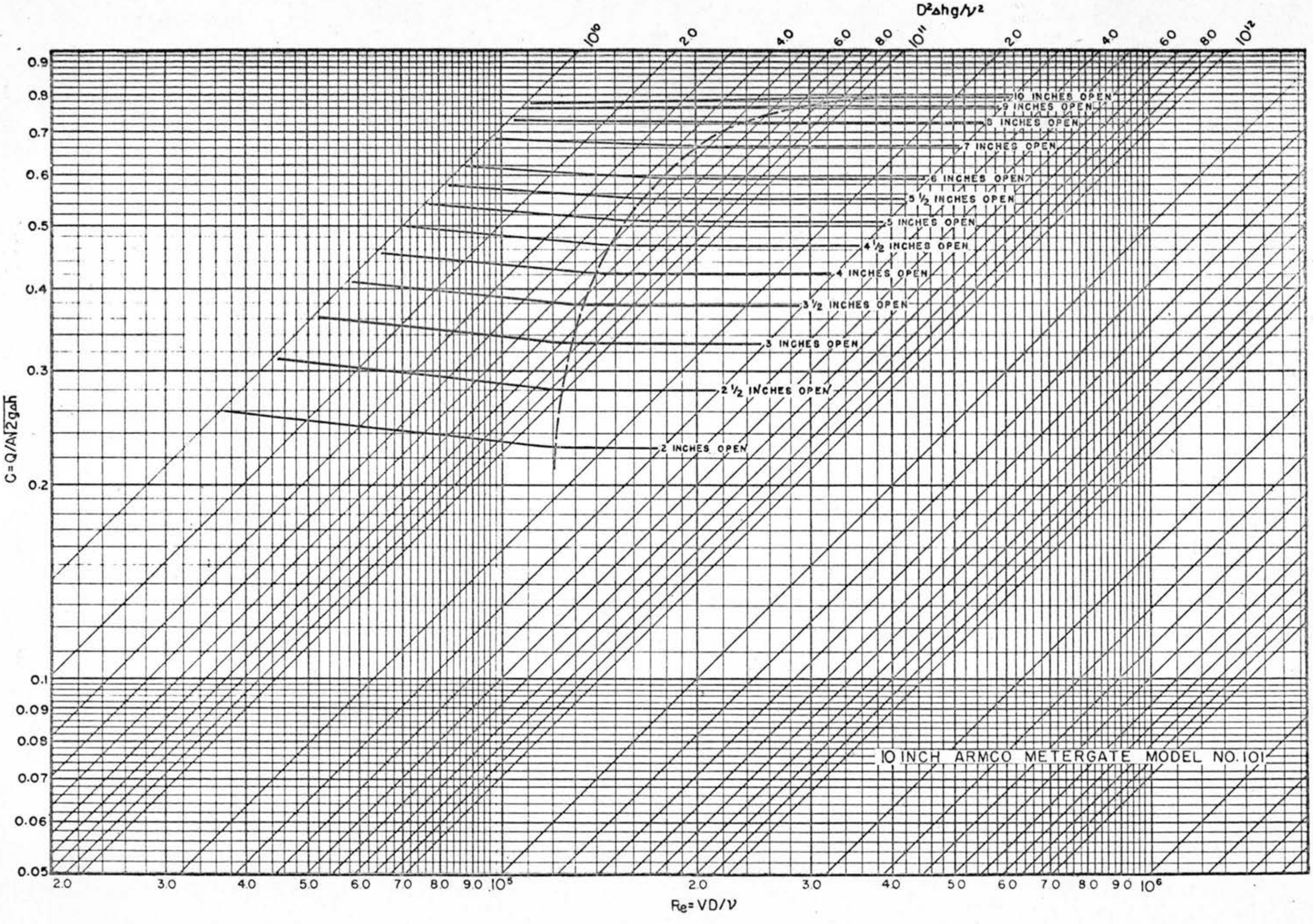
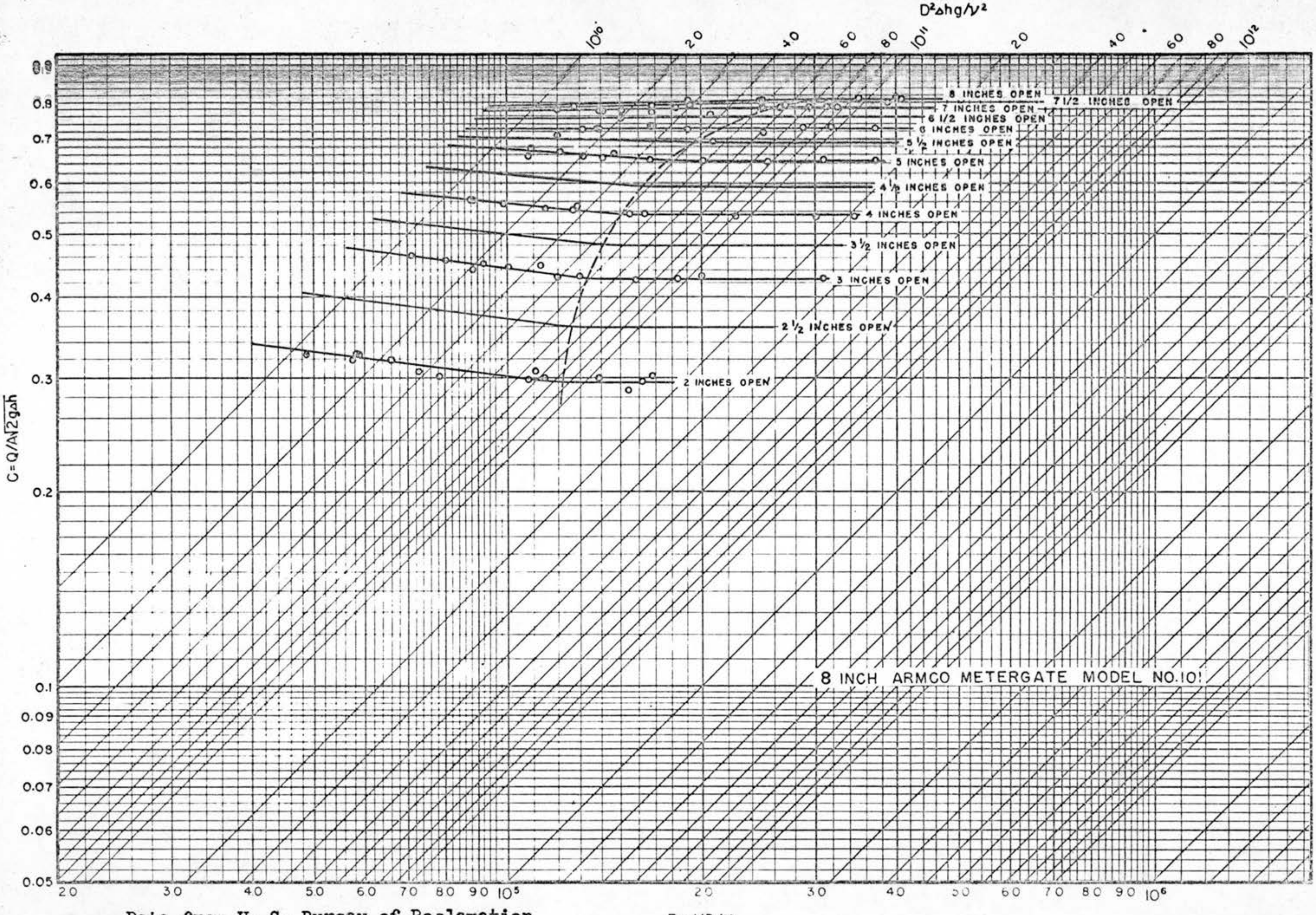

D²Δhg/ν²
10¹⁰ 2.0 4.0 6.0 8.0 10¹¹ 2.0 4.0 6.0 8.0 10¹²
10 INCHES OPEN
9 INCHES OPEN
8 INCHES OPEN
7 INCHES OPEN
6 INCHES OPEN
5 1/2 INCHES OPEN
5 INCHES OPEN
4 1/2 INCHES OPEN
4 INCHES OPEN
3 1/2 INCHES OPEN
3 INCHES OPEN
2 1/2 INCHES OPEN
2 INCHES OPEN
C=Q/A√2gΔh
0.9 0.8 0.7 0.6 0.5 0.4 0.3 0.2 0.1 0.09 0.08 0.07 0.06 0.05
10 INCH ARMCO METERGATE MODEL NO.101
2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0 10⁵ 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0 10⁶
Re=VD/ν

Fig. 22



Data from U. S. Bureau of Reclamation

Fig. 23