Report

of the

# FLUCTUATION STUDIES IN STILLING WELLS

# FOR

# ARMCO METERGATE MODEL NO. 101

By

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January 1951

CER47-52MLA13

CER 41-32 MLA 19 1 -

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prepared for

Armco Drainage and Metal Products, Inc.

Hardesty Division

Denver, Colorado

through

The Colorado Agricultural Research Foundation

January, 1951

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## Introduction

In order to save material, reduce the weight and simplify the use of the Armco Metergate Model 101, the Armco Drainage and Metal Products Co., Inc. contracted with the Colorado Agricultural Research Foundation to have the Hydraulics Laboratory of Colorado A and M College make tests to determine the possible use of 4-in. diameter stilling wells instead of the standard 10-in. wells. An additional change for the sake of convenience and accuracy of operation was the use of floats in the 4-in. wells instead of the usual measuring stick for determining the water-surface elevation. Previous tests which had been made to determine the feasibility of such a change demonstrated that the surge in the 4-in. well made the smaller well impractical and the additional storage in the 10-in. wells was necessary to hold the surging to the required minimum.

The criterion which was established prior to the beginning of the tests was that the surging in the 4-in. wells must not be greater than that in the 10-in. wells which have been established by the courts as satisfactory for use with the Metergate Model 101 as a water-measuring device.

## Analysis of the Problem

The probable reason for the smaller amount of surging in the 10-in. well than in the 4-in. well is the greater storage capacity of the 10-in. well so that it acts more like a surge chamber. In order to have the mean elevation of the water surface in the two wells the same for a given condition, it is necessary that the resistance to the surging flow be relatively the same for both inflow and outflow. In other words, the resistance to the inflow motion relative to the resistance to the outflow motion must be the same for both the 10-in. and 4-in. wells.

From the foregoing discussion, investigation falls into two separate problems; (a) comparison of the mean water-surface elevation in the two wells for a given condition of gate opening and discharge, and (b) reduction of the surge in the 4-in. well so that it is no more than that in the 10-in. well. A common method of reducing the degree of surging is the use of constrictions in the line which conducts the water in and out of the surge chamber. Therefore, this was proposed as the first method to be tested. At the same time, measurements were to be made of the mean water-surface elevation using both the 4-in. well with a constriction, and the 10-in. well without a constriction. Because of the possible clogging of the orifice which might result from sticks, leaves, and other debris lodging in the stilling well, the orifice was to be made as large as possible.

## Analysis of the Problem

Since the surging action is more or less random in nature, a statistical analysis of the surging in the two wells was believed to be a means of comparison -- the relative standard deviation being the measurement of comparison. The following section describes the experimental equipment and procedure utilized.

### Experimental Equipment and Procedure

In order to simulate as closely as possible conditions in the field, a special canal system was constructed as shown in Fig. 1. Water was supplied by the 14-in. pump to the head box from where it passed through a 6-in. rock baffle to distribute the flow uniformily across the channel downstream. From the channel (which had a bottom width of 4 ft. and 1 on 1 side slopes) the flow passed through the 18-in. metergate (this size being chosen as representative of those in use) which was recessed in the side of the channel as shown in the plan view of Fig. 1. Special care was taken to set the gate and construct the approach so that a standard gate setting was obtained. From the gate the water passed through 6 ft. of 18-in. corrugated pipe to the tail box in which the downstream depth of the flow could be controlled. After leaving the tail box, the flow returned to the sump for recirculation.

As shown in Fig. 1, the stilling wells were set according to the standards previously established -- one well connected to the head wall near the face of the gate and the other connected to the outlet pipe 1 ft. downstream from the face of the gate. Special fittings were used so that the 10-in. wells and the 4-in. wells could be interchanged without difficulty. Floats with a stem and pointer on them to facilitate accurate instantaneous readings of the water-surface elevation were used in each of the wells.

The testing procedure consisted of first zeroing the float gages in each well by filling the head box with water and shutting the intake valve and outlet pipe. The indicators on the floats were then adjusted to read the same on each tape for a given water-surface elevation.

After zeroing the 10-in. wells, the discharge was varied about 5 times for each of the gate openings. The discharge was measured by the $10\frac{1}{2}$-in. orifice meter which had been calibrated volumetrically using the large measuring tank in the basement of the laboratory. For each discharge the value of $\Delta h$ was found as the difference in water-surface elevation between the upstream and downstream measuring wells. The upstream measurement was made by observing the fluctuations in the well over a period of time and estimating an average elevation. The fluctuations and mean water-surface elevation in the downstream well, however, were determined by one man reading the float gage at intervals of about two seconds with another man recording the readings. A series of 6 to 10 readings were recorded in this manner on 5-sec. to 15-sec. intervals until sufficient data had been obtained to give an accurate picture of the fluctuation pattern. If the variations seemed to be small only 40 readings were taken, but in some cases of large fluctuations as many as 100 readings were necessary. After each run additional measurements were made on the differential manometer connected to the orifice meter. The entire procedure required an average time of about 15 to 20 min. although initial runs sometimes required as much as 40 minutes to complete.

The 10-in. wells were then mounted on the 18-in. corrugated pipe in place of the 4-in. wells, and the same procedure was followed for each discharge.

## Analysis of the Data

In order first to determine whether the mean of the water-surface elevation in the 4-in. well was the same as that in the 10-in. well under the same conditions, care was taken to measure the discharge during each of the fluctuation determinations. The comparison is shown in Fig. 2 to be very good -- indicating that no consistent deviation exists from the 10-in. well. Because the results were considered to be satisfactory, no further consideration was given to this part of the problem.

Preliminary measurements were made with constrictions 1/4-in., 3/8-in., 1/2-in., and 5/8-in. diameter and with gate openings of 2-in., 4-in., 8-in., and 16-in. These measurements were then used to determine the particular areas requiring further study. For example, the data showed that the 1/4-in. diameter constriction and half gate opening caused a surge of approximately half that found with the 10-in. well. With the 3/8-in. constriction, the surge was about the same as with the 10-in. well except at moderate gate openings and high discharges under which conditions it was appreciably greater. The 1/2-in. and 5/8-in. constrictions, however, gave a damping action which was not appreciably better than no constriction at all.

As a result of the foregoing preliminary measurements and because a constriction as large as permissible was desired, the remainder of the experiments were devoted to a more detailed study of orifice-type constrictions 5/16-in. and 3/8-in. diameter. The results of these tests are tabulated in Table I and shown graphically in Figs. 3, 4, and 5.

In each of these figures the standard deviation of the surges in both the 4-in. well with 3/8-in. orifice constriction and the 10-in. well are plotted together. As shown in Fig. 3 the deviation for discharges less than 3 cfs with a small gate opening of 3 in. is 0.01 ft. or less. This means that about

70% of the time the fluctuation is less than 0.01 ft. above or below the mean water-surface elevation. The surges in the 4-in. well were about 50% greater than in the 10-in. well at a discharge of 1 cfs and about 15% greater at 3 cfs.

When the gate was approximately half open at 8 7/8 in., the standard deviation of the surges in the 10-in. well was increased (see Fig. 4) to about 0.02 ft. for a discharge of 7 cfs while the 4-in. well with the 3/8-in. orifice had surges approximately 45% greater than in the 10-in. well.

At full gate opening it was found (see Fig. 5) that the standard deviations of the surge was approximately the same for both the 10-in. and 4-in. wells -- being about 0.025 ft. for 8 cfs and about 0.003 ft. for 4 cfs.

The foregoing tests revealed that the 3/8-in. orifice constriction damped the surges so they were no greater than those in the 10-in. well when the gate was wide open. At low discharges and small gate openings, the surges were quite small regardless of the type of well. When the gate was half open, however, the surges were appreciably greater in the 4-in. well with the 3/8-in. orifice than in the 10-in. well. This probably resulted from the shape and location of the separation zone relative to the inlet to the stilling well and would no doubt have been different for gates of other sizes than 18-in.

In view of the foregoing data and observations, the half-gate opening was believed to be most critical for the 18-in. gate and therefore a smaller orifice of 5/16-in. was tested for this situation. Fig. 4 shows that the 5/16-in orifice damped the surges so that they were less than the surges in the 10-in. well except for low discharges where the surging was relatively small and unimportant.

Because the 5/16-in. orifice constriction was adequate for damping the surges under the critical condition of half gate opening, the assumption was made that it would be equally effective for other gate openings and therefore further tests were not necessary.

## Conclusions

1. The mean water-surface elevation in the 4-in. stilling well is the same as in the 10-in. well -- all other factors remaining constant.

2. Although the 3/8-in. orifice constriction damps the surges in the 4-in. stilling well so that they are approximately the same as those in the 10-in. well for large and small gate openings, the intermediate gate openings require an orifice 5/16-in. diameter to damp the surges satisfactorily.

## Recommendations

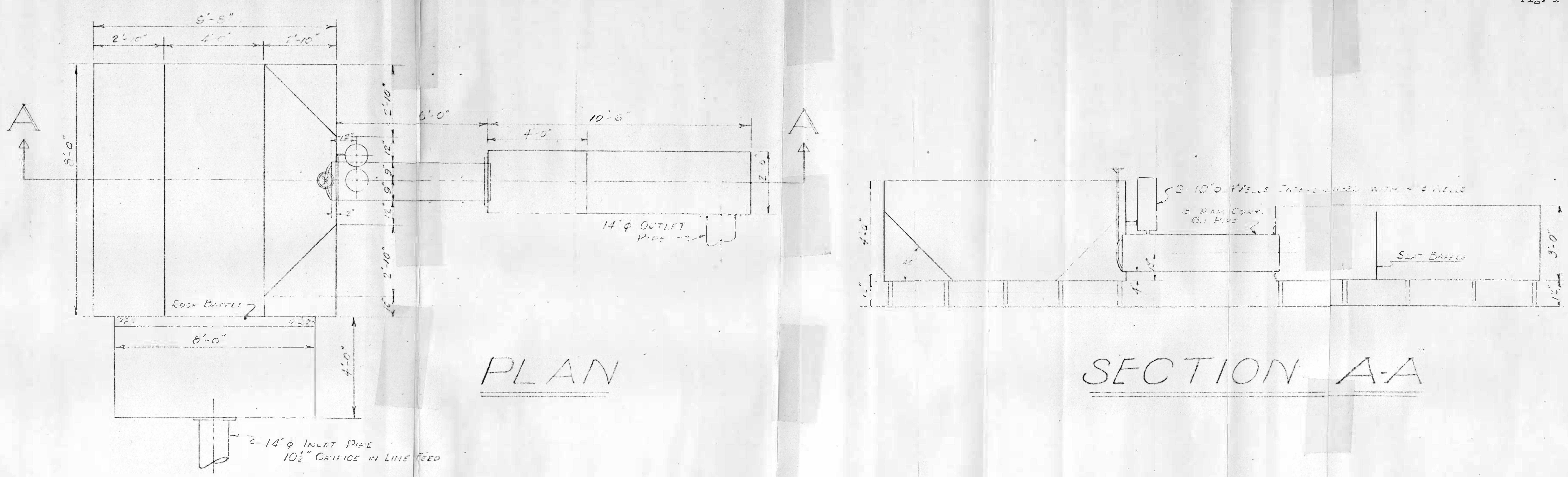
1. Because of the heavy surging found at intermediate gate openings, the 5/16-in. orifice should be used throughout.

2. In order to determine whether plugging of the orifice and sticking of the float are problems likely to be encountered, special field installations and tests over a period of time are necessary.

Table 1

EXPERIMENTAL FLUCTUATION DATA FOR 18-IN. ARMCO METERGATE

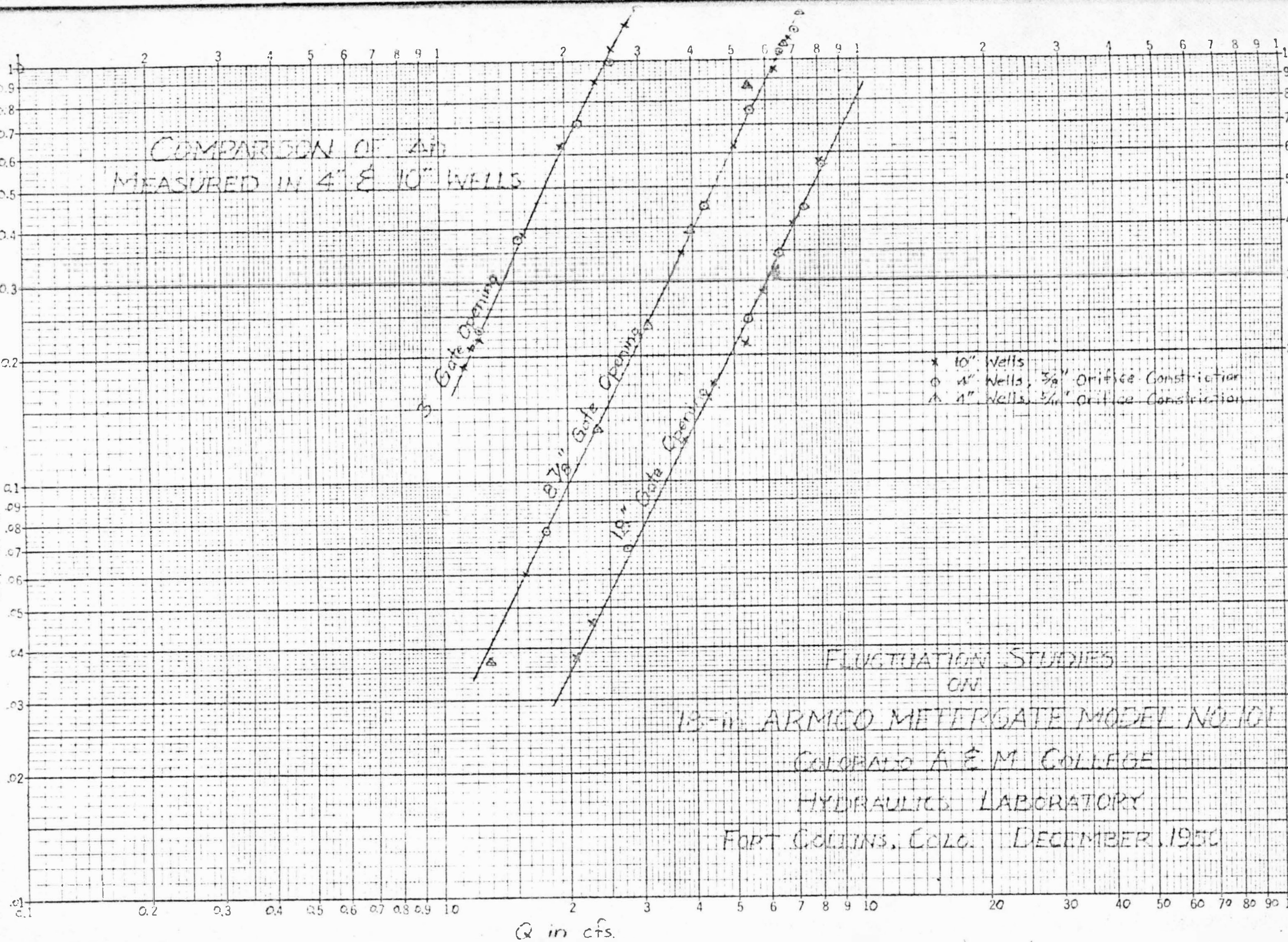
| Orifice Size in inches | Well Size in inches | Gate Opening in inches | Differential Head in feet $\Delta h$ | Standard Deviation $\sigma$ in feet | Relative Deviation $\frac{\sigma}{\Delta h}$ | Discharge Q in cfs |
|---|---|---|---|---|---|---|
| None | 10 | 18 | 0.212 | 0.0053 | 0.0260 | 5.15 |
| " | " | " | 0.570 | 0.0242 | 0.0425 | 8.01 |
| " | " | " | 0.406 | 0.0134 | 0.0330 | 6.96 |
| " | " | " | 0.281 | 0.0092 | 0.0328 | 5.84 |
| " | " | " | 0.126 | 0.0028 | 0.0222 | 3.78 |
| " | " | 8 7/8 | 0.060 | 0.0013 | 0.0217 | 1.57 |
| " | " | " | 0.349 | 0.0037 | 0.0106 | 3.77 |
| " | " | " | 1.14 | 0.0088 | 0.0077 | 6.96 |
| " | " | " | 0.620 | 0.0061 | 0.0098 | 5.03 |
| " | " | " | 0.946 | 0.0160 | 0.0170 | 6.28 |
| " | " | 3 | 1.072 | 0.0062 | 0.0058 | 2.62 |
| " | " | " | 0.894 | 0.0061 | 0.0068 | 2.37 |
| " | " | " | 0.626 | 0.0046 | 0.0074 | 1.96 |
| " | " | " | 0.388 | 0.0020 | 0.0052 | 1.58 |
| " | " | " | 0.210 | 0.0015 | 0.0071 | 1.17 |
| 3/8 | 4 | 18 | 0.561 | 0.0218 | 0.0389 | 8.09 |
| " | " | " | 0.443 | 0.0116 | 0.0268 | 7.39 |
| " | " | " | 0.344 | 0.0115 | 0.0334 | 6.40 |
| " | " | " | 0.344 | 0.0152 | 0.0438 | 6.40 |
| " | " | " | 0.242 | 0.0072 | 0.0298 | 5.40 |
| " | " | " | 0.069 | 0.0011 | 0.0160 | 2.76 |
| " | " | 8 7/8 | 1.190 | 0.0301 | 0.0253 | 7.05 |
| " | " | " | 1.043 | 0.0159 | 0.0152 | 6.52 |
| " | " | " | 1.043 | 0.0191 | 0.0183 | 6.52 |
| " | " | " | 0.757 | 0.0117 | 0.0154 | 5.49 |
| " | " | " | 0.445 | 0.0076 | 0.0171 | 4.26 |
| " | " | " | 0.076 | 0.0020 | 0.0263 | 1.77 |
| " | " | 3 | 1.420 | 0.0111 | 0.0078 | 2.91 |
| " | " | " | 0.999 | 0.0057 | 0.0057 | 2.44 |
| " | " | " | 0.701 | 0.0047 | 0.0067 | 2.05 |
| " | " | " | 0.378 | 0.0032 | 0.0085 | 1.48 |
| " | " | " | 0.231 | 0.0025 | 0.0108 | 1.18 |
| 5/16 | " | 8 7/8 | 1.348 | 0.0145 | 0.0108 | 7.37 |
| " | " | " | 1.348 | 0.0192 | 0.0142 | 7.37 |
| " | " | " | 0.870 | 0.0068 | 0.0078 | 5.42 |
| " | " | " | 1.086 | 0.0169 | 0.0156 | 6.64 |
| " | " | " | 0.391 | 0.0059 | 0.0151 | 3.97 |
| " | " | " | 0.037 | 0.0016 | 0.0433 | 1.29 |
| " | " | " | 0.133 | 0.0028 | 0.0210 | 2.36 |
| " | " | " | 0.237 | 0.0035 | 0.0148 | 3.11 |




Fluctuation 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"



COMPARISON OF Δh
MEASURED IN 4" & 10" WELLS
Gate Opening
7/8" Gate Opening
½" Gate Opening
10" Wells
4" Wells, 3/8" Orifice Constriction
4" Wells, 5/16" Orifice Constriction
FLUCTUATION STUDIES
ON
18-in. ARMCO METERGATE MODEL NO. 101
COLORADO A & M COLLEGE
HYDRAULICS LABORATORY
FORT COLLINS, COLO. DECEMBER, 1950
Δh in ft.
Q in cfs.


Fig. 2

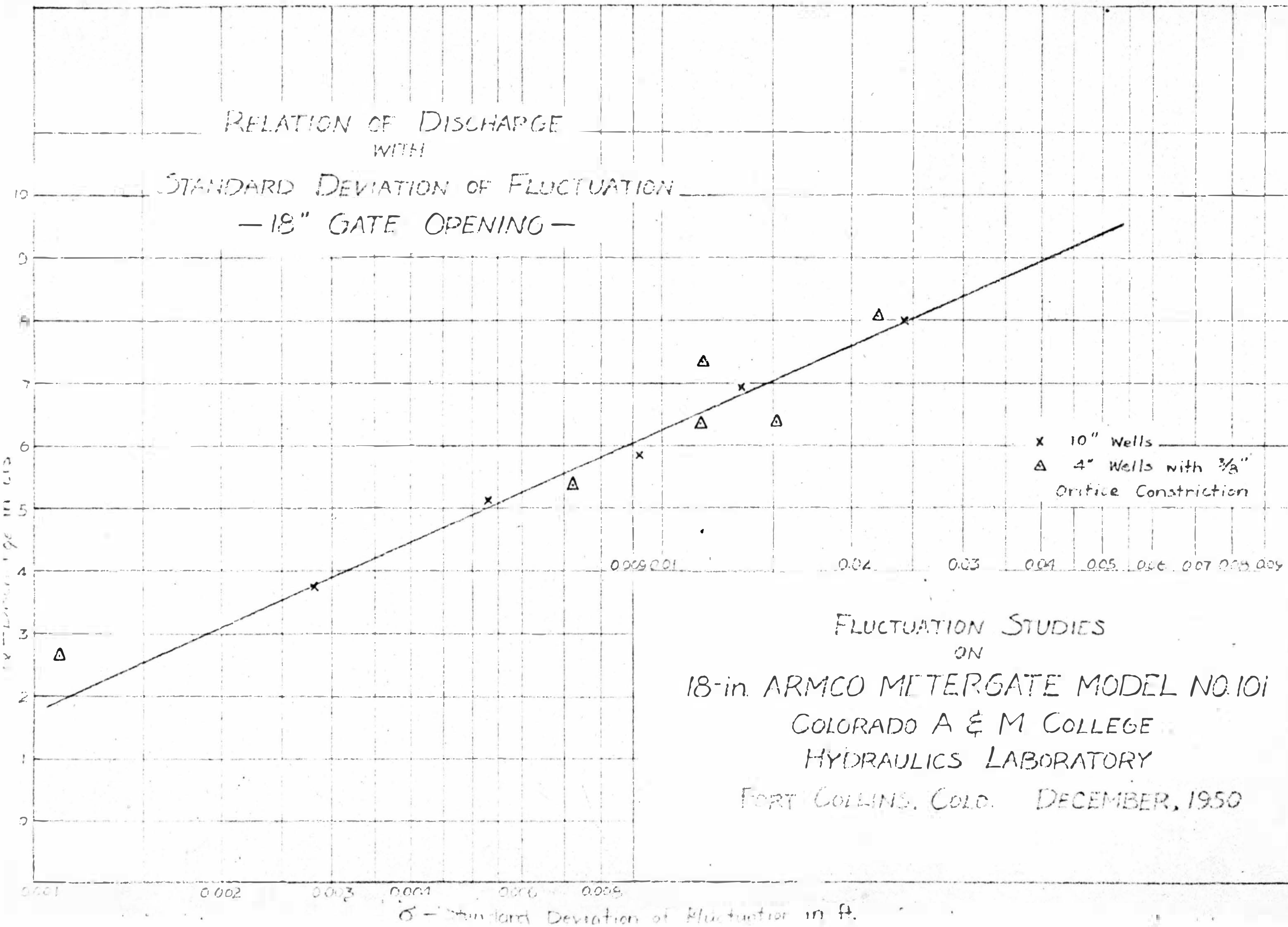
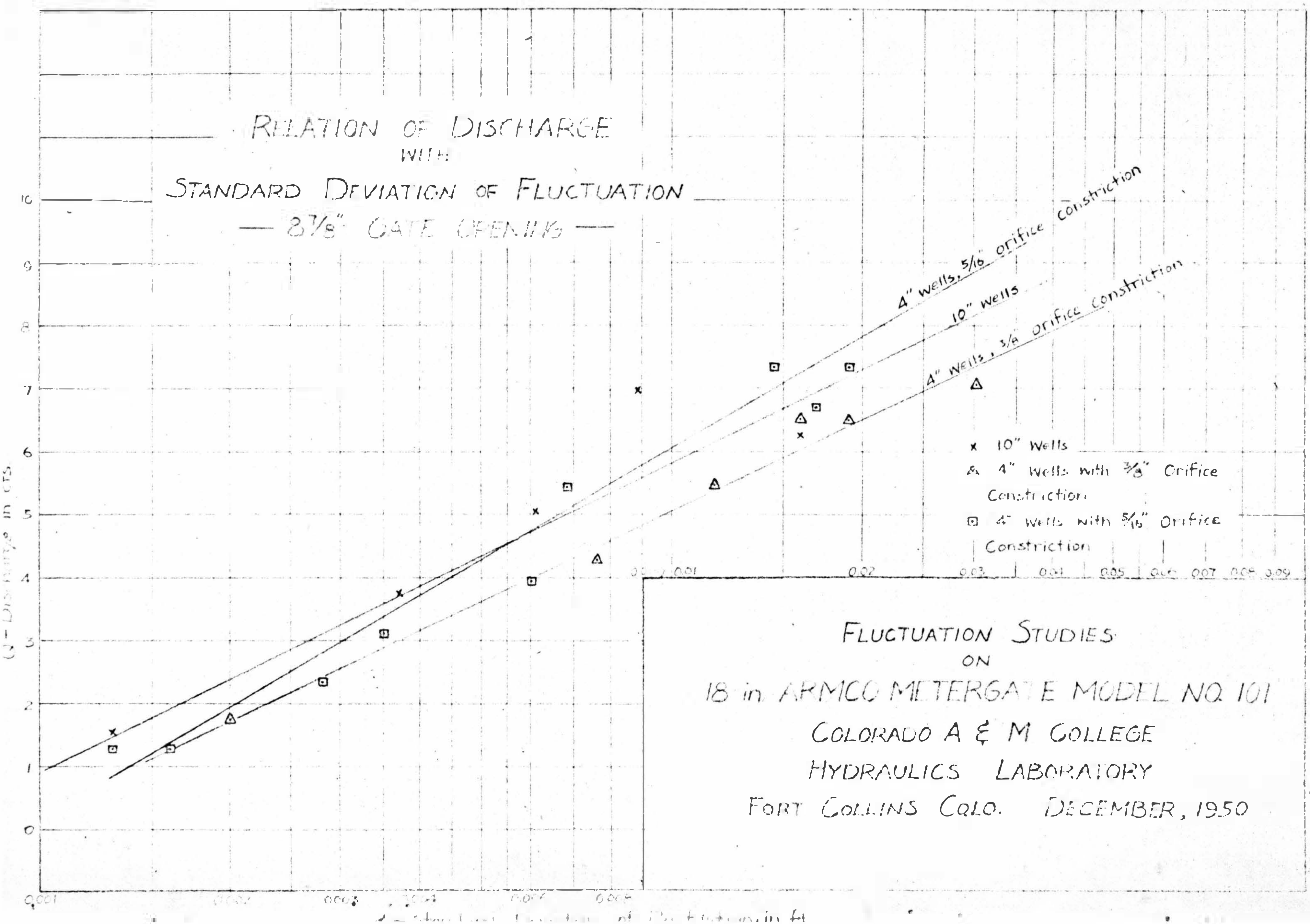

RELATION OF DISCHARGE
WITH
STANDARD DEVIATION OF FLUCTUATION
— 18" GATE OPENING —
x 10" Wells
Δ 4" Wells with 3/8" Orifice Constriction
FLUCTUATION STUDIES
ON
18-in. ARMCO METERGATE MODEL NO. 101
COLORADO A & M COLLEGE
HYDRAULICS LABORATORY
FORT COLLINS, COLO. DECEMBER, 1950
σ — Standard Deviation of Fluctuation in ft.

Fig. 3



RELATION OF DISCHARGE
WITH
STANDARD DEVIATION OF FLUCTUATION
— 8 7/8" GATE OPENING —
4" wells, 5/16" orifice constriction
10" wells
4" wells, 3/8" orifice constriction
× 10" Wells
△ 4" Wells with 3/8" Orifice Construction
⊡ 4" Wells with 5/16" Orifice Construction
FLUCTUATION STUDIES
ON
18 in. ARMCO METERGATE MODEL NO. 101
COLORADO A & M COLLEGE
HYDRAULICS LABORATORY
FORT COLLINS COLO. DECEMBER, 1950


Fig. 4

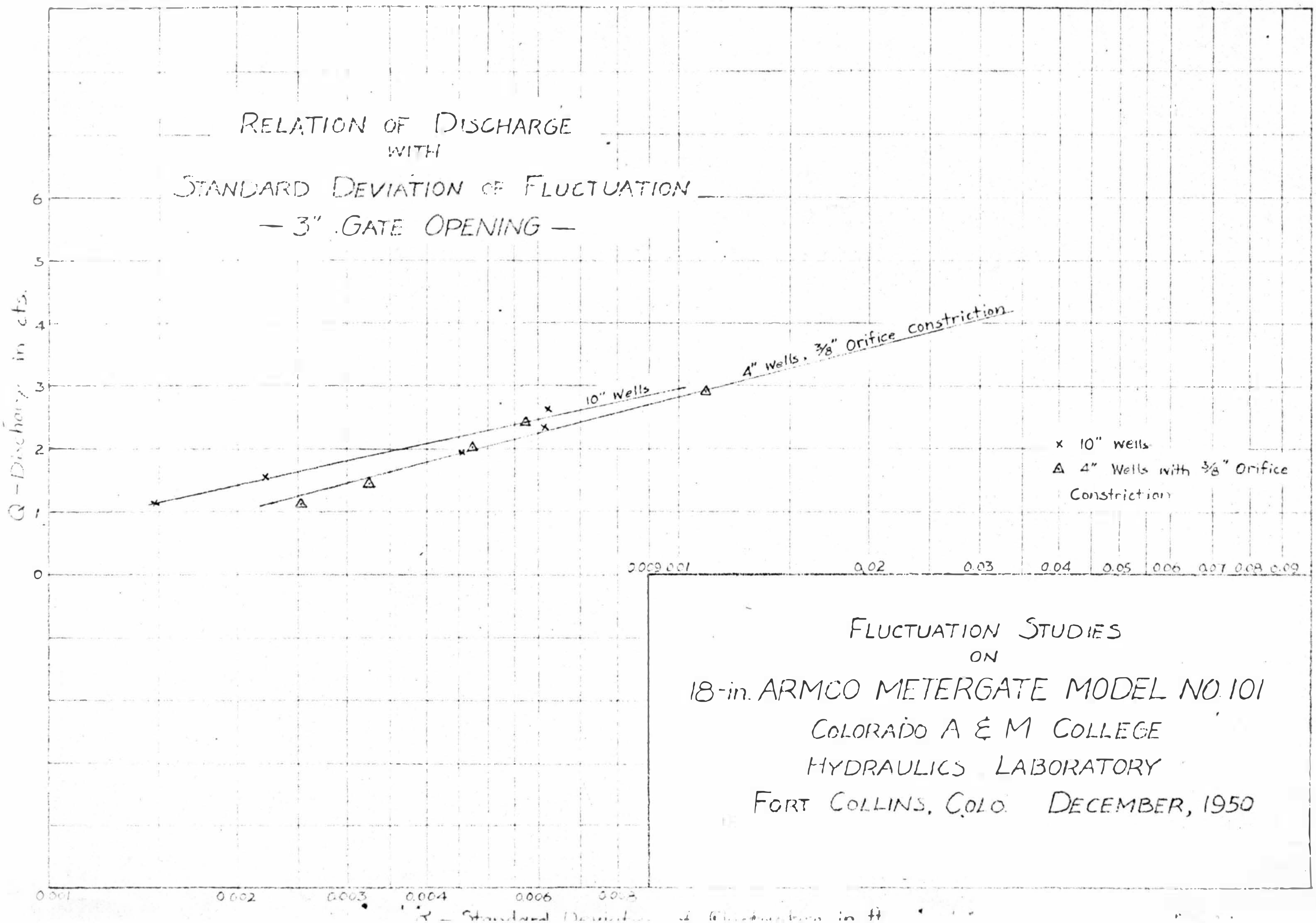

RELATION OF DISCHARGE
WITH
STANDARD DEVIATION OF FLUCTUATION
— 3" GATE OPENING —
Q - Discharge in cfs
0
1
2
3
4
5
6
10" Wells
4" Wells, 3/8" Orifice constriction
× 10" Wells
Δ 4" Wells with 3/8" Orifice Constriction
0.001
0.002
0.003
0.004
0.006
0.008
0.009 0.01
0.02
0.03
0.04
0.05
0.06
0.07 0.08 0.09
FLUCTUATION STUDIES
ON
18-in. ARMCO METERGATE MODEL NO. 101
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Fig. 5