REPORT ON THE CALIBRATION OF

THE NEW MEXICO, WILLIAMS-TYPE METER

Prepared for

The State Engineer Office
New Mexico

Department of Civil Engineering

Colorado Agricultural and Mechanical College
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Introduction

Mr. Frank E. Irby, Mr. Charles B. Thompson, and Mr. James L. Williams visited the Hydraulics Laboratory at Colorado A and M College on 2 August, 1955 to discuss the possibility of calibrating a metering device which had been developed by Mr. Williams to measure directly the discharge from the outlet pipe of a pump. This discussion was held with Professor Maurice L. Albertson and Mr. Dasel E. Hallmark of the laboratory staff.

The New Mexico engineers pointed out that this system of measurement involved the use of Price current meters which are standard equipment for the field engineers, and that this equipment is considerably simplified as compared with carrying around completely separate equipment for measurement of discharge from wells. Furthermore, it was hoped that this system would provide measurements with a better combination of accuracy and simplicity or ease of measurement than found with other types of equipment for measuring the discharge from wells in the field.

Agreement was reached at this time that the calibration tests would be carried out under the general supervision of Professor Albertson, with one of the staff from the Civil Engineering Department of Colorado A and M College in immediate charge of the project. At least two members of the staff from the New Mexico State Engineer Office were scheduled to be on the job at all times.

The testing program took place from 3 August to 27 August, 1955. Mr. James L. Williams, Mr. James I. Wright and Mr. Donald E. Kienlen from the New Mexico State Engineer Office made the tests with Professor H. H. Schweizer of the Civil Engineering Department in immediate charge.

Testing Equipment

As may be seen in Fig. 1, the testing equipment consisted of an 8-in. pump and supply line to which was connected the various sizes of pipes representing the outlet pipe from a pump in the field. The Williams-type meter was fastened to the ends of these pipes which were tested at various lengths downstream from the last elbow. The elbows were placed immediately upstream from the outlet pipes to make the initial flow conditions as bad as possible.

The original design of the Williams meter included guide vanes upstream from the meter in order to orient the flow properly and to make the data more reproducible by eliminating surge fluctuations when measurement is made close to the elbows. The initial tests, however, indicated that certain minor modifications in the guide vanes were desirable. Therefore, the final design of the guide vanes was as sh in Fig. 2. The jacket placed on the outside of the pipe was sealed on the upstream end ~~yhr updytrem rnf~~ with a canvas sleeve. On the downstream end of the jacket were bolts and wing nuts to hold orifice plates on the end when needed to make the pipe flow full.

After the water discharged from the pipe, it could either be returned to the sump for re-circulation, or be dumped in a calibrated volumetric tank in order to determine precisely the rates of discharge.

Testing Procedure

The first step in testing was to place the small ring and guide vanes inside the outlet pipe and then to slip the jacket over the outside of the pipe -- clamping it in place against the inside ring to insure an exact and reproducible location. The purpose of the guide ring was to insure that: (a) the vanes were parallel to the centerline of the pin, (b) the axis of the cup meter was essentially vertical, and (c) the distance from the side wall to the cups was the same on each side. The guide vanes and ring were first installed inside the pipe, and then the current meter and jacket unit was installed.

In order to be sure that the discharge was reproducible, several runs were made at the same discharge by shutting off the pump and allowing the system to drain between tests. These tests were made at several discharges, and they demonstrated that the discharge was reproducible to within less than one per cent deviation from the average.

The problem with the original guide vanes was that a test was difficult to reproduce if the pump was shut off and the guide vanes removed and replaced. Therefore, considerable care was taken through numerous tests to be sure that the modified guide vanes would give reproducible results. These results were found to be within plus or minus two per cent of the average, which was determined from a number of points. In order to be certain that this reproducibility was not dependent upon certain individuals operating the equipment, three different persons were used both in mounting the meter and in observing the readings.

When the guide vanes and ring were not used, the jacket was placed by eye as nearly concentric with the pipe as possible to center the current meter inside the pipe.

Results

Figs. 3 to 10 show that in all cases the data could be represented by an average line from which the data seldom deviated even as much as two per cent. For a given physical arrangement, the revolutions per second (RPS) varied directly with the average velocity in the pipe, which permitted using a straight line through the origin and greatly simplified the determination of the rating curves.

Once the rating curves were tentatively determined in Figs. 3 to 10 for a given physical setup, the slope coefficient of each curve was determined in terms of feet per second per RPS, and plotted in Figs. 11 and 12. From these figures it may be seen that the slope coefficient varies continuously with both inside diameter of pipe and length of discharge pipe in diameters from the pump.

The variation of slope with length in diameters is approximately five per cent or less for each of the pipes with the exception of the 10 in. ID pipe for which the variation was nearly 20 per cent. For small values of pipe length the slope is small. With increasing pipe length, the slope increases until it reaches a maximum at about 6 diameters, after which it again decreases -- apparently approaching an asymptote at about 10 to 15 diameters. This variation is possibly caused by the irregular high-velocity jet issuing from the pipe bend (initial small slope coefficient), the spreading of this jet across the flow (slope reaching a maximum), and finally the development of the pattern of established flow wherein a core of higher velocity is developed due to boundary drag (slope coefficient again decreasing).

The extremely small value of slope for the 10 in. pipe at 3 diameters is probably a peculiarity of the pipe bends upstream. Furthermore, the guide vanes are perhaps relatively too short to straighten the flow adequately in a short distance. Therefore, it is recommended that this curve not be used for pipe lengths less than 4 diameters. As seen in both Fig. 11 and Fig. 12, the curves are a systematical family for lengths greater than 4 diameters for the 10 in. pipe and for 3 diameters for the other pipes.

When the pipes are longer than 9 diameters the slope seems to be approaching an asymptote -- which is to be expected as the flow pattern (velocity and turbulence distribution across the pipe) approaches equilibrium.

Fig. 12 shows the variation which occurs with changing pipe diameters. This variation is due in some measure to the fact that the guide vanes and rings were not geometrically proportioned from one pipe size to another. Therefore, strictly speaking, the curves for the pipes rated with vanes are not continuous between changes in pipe sizes (broken lines), and interpolation in these areas may result in some error, perhaps as much as 3 or 4 per cent.

Pipes 5.68 in., 6.06 in., 6.47 in., and 7.07 in. in diameter were tested without guide vanes for pipe lengths of 6 to 11 diameters. In addition, the 7.07-in. pipe was tested for 3.5 diameters, and the 6.47-in. pipe for 16 diameters to determine the slope coefficient for extremes in pipe lengths. Except for the 6.06-in. pipe, the data were consistent between trials and form a reasonable family of curves, so they are considered to be quite accurate despite the abnormally poor entrance conditions due to the two elbows upstream. The data for the 6.06-in. pipe are inconsistent, and if used, would give results obviously incompatible with the data for the other pipe sizes. Despite this fact, however, the error involved in drawing the curve for the 6.06-in. pipe as a part of the family of other sizes is less than 3 per cent. The expected error for the curves of the other pipe sizes having lengths between 6 and 11 diameters and for interpolation between these curves, is one per cent or less.

The tests show that for pipe sizes varying from 5 in. to 7 in. without guide vanes, the discharge pipe should be at least 6 diameters long. Beyond about 15 diameters the slope coefficient may be treated as a constant. Because insufficient tests were made for lengths less than 6 and greater than 11 diameters, the expected error in extrapolating to 4 or 15 is $1\frac{1}{2}$ per cent. Interpolation between these extrapolated curves will give results that are accurate within two per cent.

Recommended Use of Data

In view of the foregoing, it is recommended that:

1) When guide vanes are used, the curves of Fig. 11 be used from 3 diameters to 10 diameters to determine the slope coefficient for pipe diameters of 7.07 in. ID, 8.13 in. ID, and 8.84 in. ID; and the curve for 10.02 in. ID be used from 4 diameters to 10 diameters.
2) For pipe sizes of 5.68 in. ID, 6.06 in. ID, 6.47 in. ID, and 7.07 in. ID without guide vanes, the curves of Fig. 11 should be used

from 6 diameters to 11 diameters, to determine the slope coefficient. For lengths greater than 11 diameters the slope coefficient decreases somewhat wrom that for 11 diameters and should follow parallel to the curve for 6.47 in. ID.

3) Extrapolation may be made along curves in Fig. 11 with accurate results. However, extrapolation along the curves in Fig. 12 should be made with caution, particularly in the region of the broken lines.

4) To prevent flow distortion upstream from the orifice plates, and to prevent back pressures which might reduce the discharge, the orifice place to be used is the largest one that will force the discharge pipe to flow full. From the practical viewpoint of pressure against the orifice, two men were unable to place an orifice plate sufficiently small to cause more than approximately two per cent reduction in discharge.

Accuracy

The overall accuracy of the Williams-type meter is within plus or minus two per cent within the range of conditions stipulated under "RecommendeedUse of Data)" This accuracy applies to all pipe sizes from 5.68 in. to 10.02 in. inside diameter.

TABLES

The tables include:

Table I -- Raw and Computed Data necessary to obtain the velocity in feet per second and the corresponding RPS of the current meter. These data were used to plot Figs. 3 to 10. The scale readings were obtained from the float gage in the volumetric calibration tank, the time in seconds from a stop-watch, and the revolutions (Rev) from the current meter. Two trials were made for each test to check the accuracy and reproducibility of the data.

Table II --Summary of Slope Coefficients, obtained from the slopes of the straight lines in Figs. 3 to 10.

TABLE II

SUMMARY OF SLOPE COEFFICIENTS

Pipe Size in.	Length in Diameters	Slope Coefficient ft/sec/RPS	Remarks
5.68	6	1.684	No vanes or ring
"	8.5	1.626	"
"	11	1.572	"
6.06	6	1.642	"
"	11	1.616	"
6.47	6	1.70	"
"	11	1.61	"
"	16	1.58	"
7.07	3.5	1.862	"
"	6	1.712	"
"	8	1.68	"
"	10.7	1.644	"
7.07	3.5	1.832	With vanes and ring
"	6	1.852	"
"	8	1.768	"
"	10.7	1.778	"
8.13	3	1.960	"
"	5.5	1.990	"
"	8	1.936	"
8.84	3	1.872	"
"	6	1.952	"
"	9	1.872	"
"	9	1.840	"
10.02	3	1.672	"
"	4.5	1.980	"
"	6	2.026	"
"	9	1.894	".