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HYDRAULIC CHARACTERISTICS OF SIMPLIFIED VENTURI METERS

by

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A THESIS

submitted to the

OREGON STATE COLLEGE

in partial fulfillment of
the requirements for the
degree of

MASTER OF SCIENCE

March 1942

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Preface

This thesis if the result of many tests conducted on four Stevens Simplified Venturi Meters at the Hydraulics Laboratory of Oregon State College. Two of the meters were furnished by Leupold-Vopel and Company of Portland, Oregon and to whom the author is thus indebted. Dr. J. C. Stevens, the designer of these meters, made many helpful suggestions during the testing and has encouraged the work in many ways.

The two small meters were owned by the Oregon State College, School of Agriculture and were made available for testing through the cooperation of Mr. M. R. Lewis and Mr. F. E. Price.

The author wishes to thank Dr. C. A. Mockmore, for giving so much of his time in helping to arrange these tests and in discussing the various problems presented.

Acknowledgement should also be made to the members of the Civil Engineering staff who cooperated in conducting the tests and also to all other persons who contributed in any way.

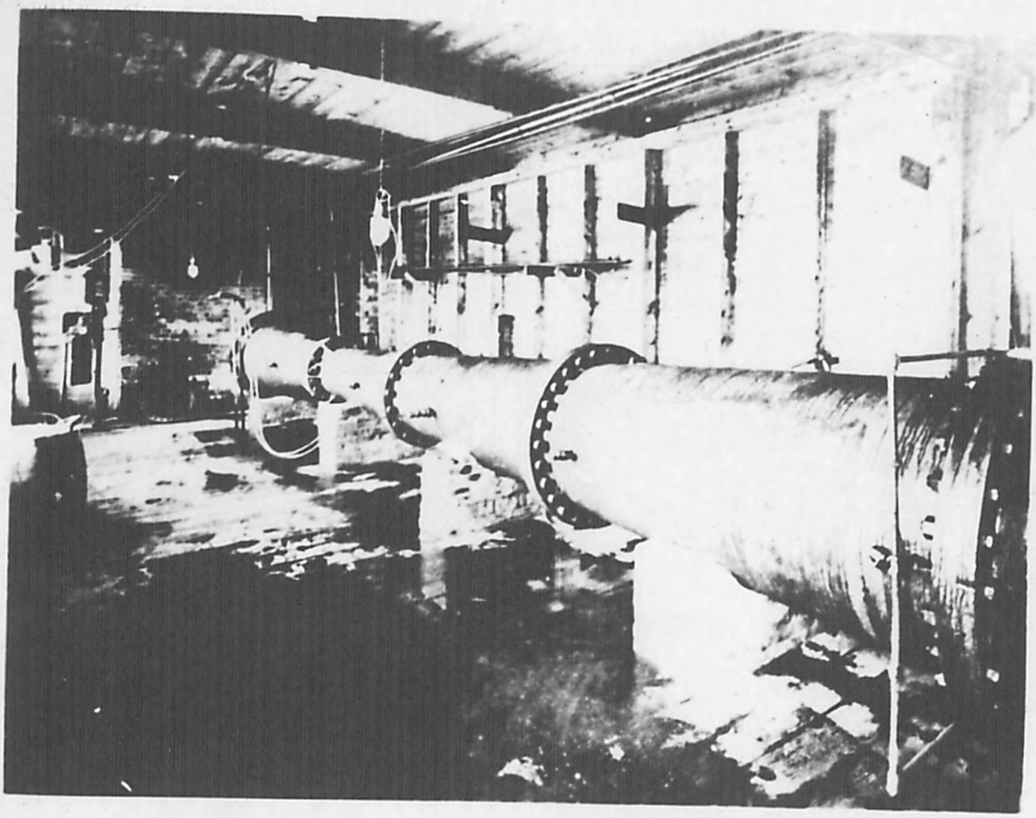

Fig. 1 36" x 16" Venturi Meter used [illegible] 1893, now in Alden Hydraulic Laboratory of the [illegible] technic Institute. [illegible]

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Illustrations

I Historical Review

I Historical Review

The art of measuring large quantities of water was greatly simplified when, in 1887, the late Clemens Herschel, M. Am. Soc. C.E., published the results of tests on a new type of water meter, which he had invented and named the Venturi meter. (8,9) An interesting sidelight is to note how this meter came to be named after the famous Italian scientist, Venturi. (11)

"Mr. Herschel experimented . . . . with what he named the Venturi water-meter. This name came about by accident. Venturi was an Italian experimenter, who lived in Paris during the French Revolution, and published an account of his experiments on expanding ajutages, in Paris, in 1797. He had observed that during this method of discharge suction was produced at the throat of the ajutage, and proposed to use suction as a pump to lift water. In course of time it became well known that these expanding ajutages increased the discharge otherwise obtained and they were used for various purposes, as for increasing the efficiency of hydraulic turbines.

"Mr. Herschel's invention consisted in producing such an expanding ajutage as part of a constriction in a pipe, and in imagining that and then demonstrating by experiment how the suction at the throat was a function of the velocity through the throat. When during the experiments, it became necessary to speak of the head at the throat, it became easier to pronounce and more euphonious, to speak of it and shout it as the 'head on the Venturi,' rather than 'head at the throat,' and thus came into being the name 'Venturi Meter.'

" 'One of the few, the immortal names
That were not born to die.' "

The meter was such a definite improvement over any previous type of measuring device that numerous installations were made during the next few years. It was used not only for metering water but for steam, gas, hot water, (1) oil and compressed air as well. In 1930 it was estimated there were approximately 40,000 Venturi meters in use throughout the world. (13)

Since the original tests, in 1887, by Mr. Herschel, many further experiments have been made. Some of these tests were made primarily to substantiate the accuracy of this type meter; (6) while others investigated the design and installation characteristics. Notable among the latter, were the tests made to determine the effect of installing a meter near a bend, pump, or similar location which might produce spiral or vortex motion in the water. (7,21) Most of the tests showed that erroneous coefficients are caused by such installations and therefore, proper precautions should be taken when installing a meter near any object which might cause such motions in the water.

It was originally thought that for the meter to be accurate, it should be made with definite and invariable lines; that the angle of convergence should be 10-1/2 degrees and that of divergence 2-1/2 degrees. This, however, has been proved to be false by many of the later tests. (4,16)

The last few years have seen changes not only in the angles of convergence and divergence of the throat, but in the general shape of the throat section as well. A meter with contraction in the vertical plane only, has been perfected for use in metering water which is carrying a large sediment load; the chance of sedimentation in the meter is thus eliminated. (17)

Lately the Germans have developed the meter shown in Fig. 2. They claim that there is less lost head in this shaped throat. (4) It is interesting to note that Mr. Herschel, in 1888, recommended using a similarly shaped meter (Fig. 3) but apparently never constructed one. (10)

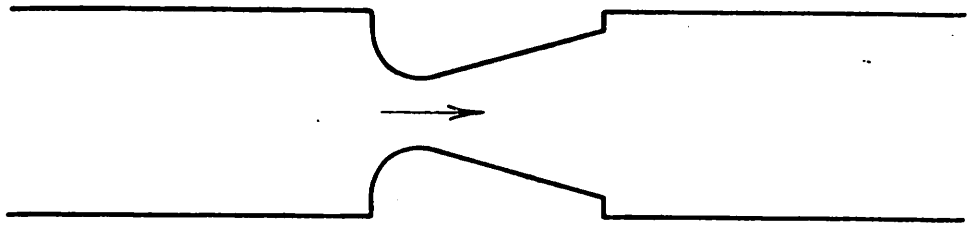


Fig. 2— Venturi Meter Developed by German Engineers

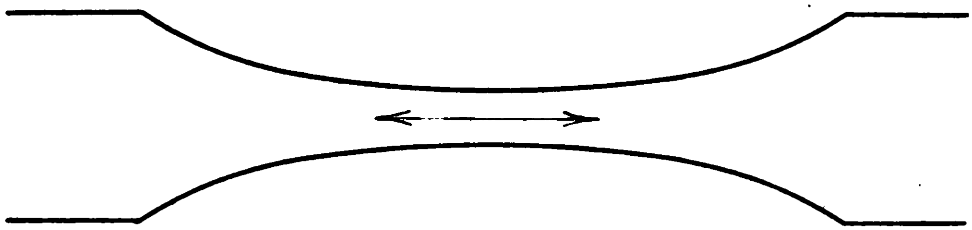


Fig. 3— Trumpet Shaped Venturi Meter Suggested by Herschel

To date, little effort has been made to produce a Venturi meter of good accuracy and at the same time of low cost, which could be used in the fields where an extremely accurate Venturi meter is not necessary. Pre-cast concrete meters have been designed and calibrated at the University of California and are used quite extensively in their irrigation projects. (5) The meter consists of two pre-cast concrete reducers with the insides specially shaped. This type is limited to construction from concrete only, as it is possible to shape the inside of the concrete pipe without a large additional expense, but it is not possible to do so with steel or cast iron. It was with the objective of developing a cheap yet accurate cast iron and steel Venturi meter, that Dr. J. C. Stevens, M. Am. Soc. C.E., suggested experimenting with a meter using standard pipe reducers for the converging and diverging sections.

Two 12"x8" meters of this type were designed and built by Dr. Stevens, one of cast iron and one of welded steel construction, and laboratory tests were made at the hydraulics laboratory at Oregon State College. Later two more meters, one a 4" x 3" and the other an 8" x 5" both of welded steel construction, were tested.

At the same time, Dr. Stevens was interested in seeing if it might be possible to install a standard gate valve in the throat section of a meter without materially affecting its hydraulic characteristics. Tests to determine this were conducted on the same meters. The data from these tests have been used to substantiate the following discussion.

II Theory

II Theory

The Venturi meter is an excellent, though simple, application of Bernoulli's theorem; therefore, any formula derived for a Venturi meter has this theorem as its basis. Though the several formulas that have been derived for the flow of water through a Venturi meter differ considerably in their final form, (18) in reality they differ only in the manner in which the energy losses are entered in the Bernoulli equation.

Standard Equation

The standard and probably the most widely used equation is the one in which the meter is considered as having no friction losses until after the Bernoulli equation has been solved, at which time a constant is introduced to take care of any and all losses. Referring to Fig. 4 the standard formula can be derived as follows:

Assuming that there is no friction loss, then Bernoulli's Equation will be

$$h_1 + \frac{V_1^2}{2g} = h_2 + \frac{V_2^2}{2g} \qquad \text{------------------------(1)}$$

by the equation of continuity

$$Q_t = V_1 A_1 = V_2 A_2 \qquad \text{------------------------(2)}$$

$$V_1 = V_2 \frac{A_2}{A_1}$$

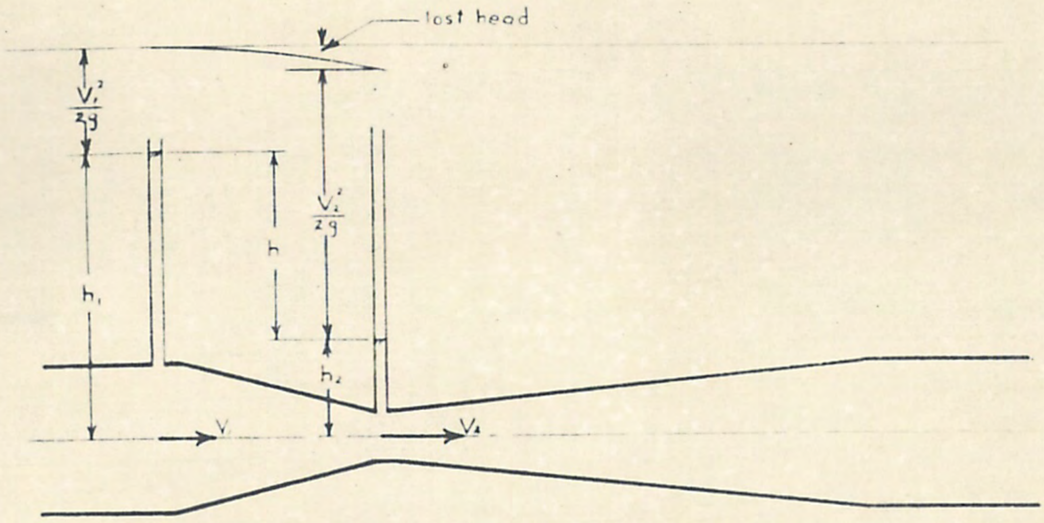


Fig. 4 — Venturi Meter

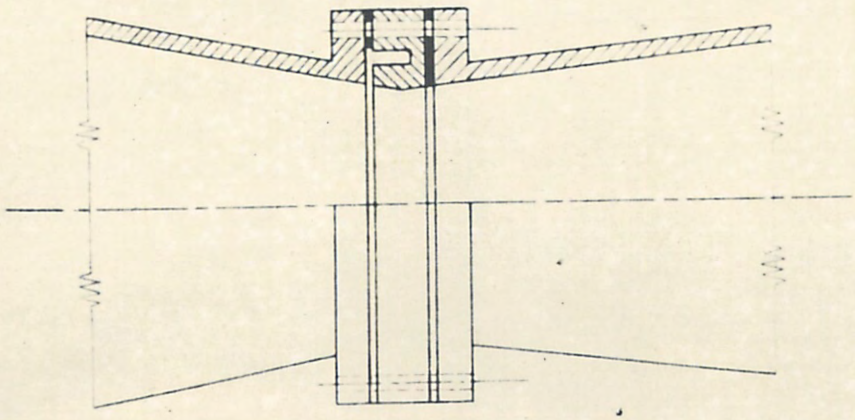


Fig. 5 — Annular Pressure Ring

but the actual rate of discharge will be

$$Q_a = C\ V_2 A_2$$

substituting in equation (1)

$$h_1 + \left(\frac{A_2}{A_1}\right)^2 \frac{V_2^2}{2g} = h_2 + \frac{V_2^2}{2g}$$

$$h_1 - h_2 = \frac{V_2^2}{2g} \left[1 - \left(\frac{A_2}{A_1}\right)^2\right]$$

Letting $h = h_1 - h_2$

$$V_2^2 = \frac{2\ gh}{1 - \left(\frac{A_2}{A_1}\right)^2}$$

$$V_2 = \sqrt{\frac{2\ gh}{1 - \left(\frac{A_2}{A_1}\right)^2}}$$

$$V_2 = \frac{A_1}{\sqrt{A_1^{\ 2} - A_2^{\ 2}}} \sqrt{2\ gh}$$

from equation (2)

$$Q_t = V_2\ A_2$$

$$Q_t = \frac{A_2 A_1}{\sqrt{A_1^2 - A_2^2}} \sqrt{2 gh}$$

but $Q_a = CV_2A_2$

therefore $$Q_a = \frac{CA_1 A_2}{\sqrt{A_1^{\ 2} - A_2^{\ 2}}} \sqrt{2 gh}$$

While this equation is derived on the false assumption that there is no lost head, it does give true results if the proper discharge coefficient, C, is to be had.

Submerged Nozzle Equation

Another formula with a more theoretically correct derivation can be derived by considering the meter as a submerged nozzle. In which case the coefficient of contraction is 1.00 and the lost head across the converging section of the meter (submerged nozzle) is

$$\frac{V_2^2}{2g}\left[\frac{1}{C_v^2} - 1\right] \quad (15).$$

Now setting up Bernoulli's Equation, it would read:

$$h_1 + \frac{V_1^2}{2g} = h_2 + \frac{V_2^2}{2g} + \frac{V_2^2}{2g}\left[\frac{1}{C_v^2} - 1\right] \text{------------------} (4)$$

by the equation of continuity

$$Q_t = V_1 A_1 = V_2 A_2$$

$$V_1 = V_2 \frac{A_2}{A_1}$$

substituting in equation (4)

$$h_1 + \left(\frac{A_2}{A_1}\right)^2 \frac{V_2^{\ 2}}{2g} = h_2 + \frac{1}{(C_v^{\ 2})} \quad \frac{V_2^{\ 2}}{2g}$$

$$h_1 - h_2 = \frac{V_2^2}{2g}\left[\frac{1}{(C_v)^2} - \left(\frac{A_2}{A_1}\right)^2\right]$$

again letting $h = h_1 - h_2$

$$V_2^{\ 2} = \frac{2gh}{\frac{1}{C_v^{\ 2}} - \frac{A_2}{A_1}^2}$$

$$V_2 = \sqrt{\frac{2\ gh}{\frac{1}{C_v^2} - \frac{A_2}{A_1}^2}}$$

but now $Q_a = V_2 A_2$

$$Q_a = A_2 \sqrt{\frac{2\ gh}{\frac{1}{C_v^2} - \frac{A_2}{A_1}^2}}$$

A close examination of equations (3) and (5) reveals that they both are of the form $A = KA_2 \ 2gh$ which is the constant that Herschel used in his original tests. (8) It is evident then, that the two constants C and C_v have a constant relation between each other. Therefore, for actual use one equation is as good as the other. In testing it was found that the C_v term was preferable, as the C_v values plotted closer together and therefore a definitely erroneous reading was easier to detect.

III Laboratory Equipment

III Laboratory Equipment

The tests were conducted in the Hydraulics Laboratory at Oregon State College during the Spring and Fall of 1941. The equipment layout was as shown diagrammatically in Fig. 6.

Pumps

The two Pelton centrifugal pumps were each capable of delivering approximately 1250 g.p.m. under a 75' head. The piping was so arranged that the pumps could be connected either in series or parallel. Under testing conditions a maximum discharge of about 3400 g.p.m. was obtained.

Vertical Tank

The vertical tank could be used as a pressure tank by allowing it to fill and then closing the air valves. This was done during the tests with the partially closed throat valves. During all other tests, the air valves remained open and the tank used only partially full, with the result that minor fluctuations caused by the pumps were absorbed in the tank.

Weighing Scales

The two sets of scales were manufactured by the Toledo Scale Company; each had a total capacity of 12,000

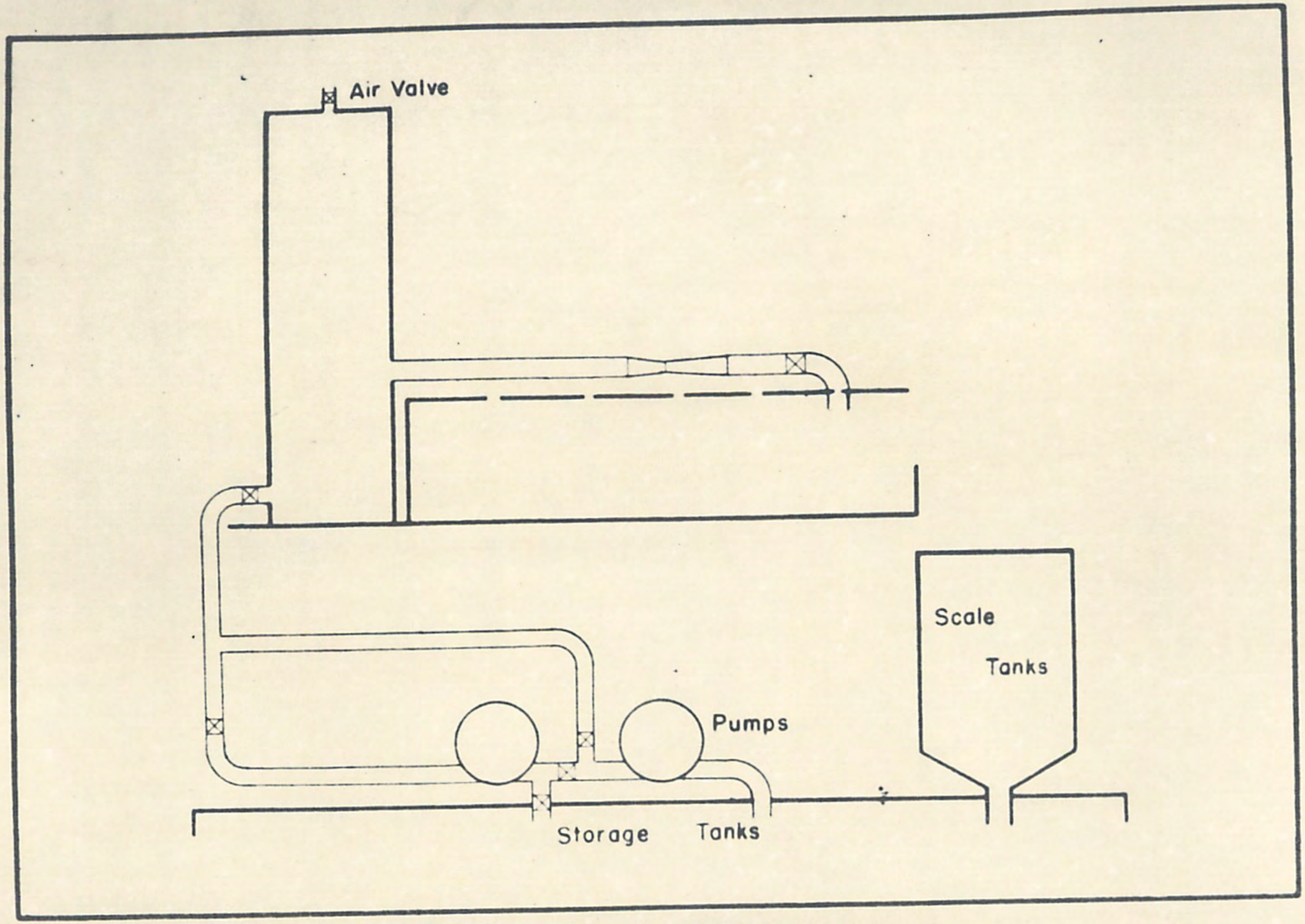


Fig. 6 — Laboratory Layout

pounds. They had been entirely reconditioned and calibrated just prior to these tests.

Entrance Pipe

The section of pipe, shown between the meter and the vertical tank, Fig. 6, was placed there to remove any spiral or vortex motions before the water entered the meter. A 10' length of entrance pipe was used during all runs on the 12" x 8" meters (runs 1 to 5 inclusive). Runs 6 and 7 on the 8" x 5" meter used a 14' entrance pipe; while Runs 8A to 8C inclusive used a 3' entrance pipe. Runs 9A to 9C on the 4" x 3" meter also used a 3' entrance pipe.

During the tests on the 12" x 8" meters, a set of vanes was placed in the entrance pipe to further insure a smooth flow. The tests on the 8" x 5" and 4" x 3" meters did not include such vanes as these meters had been installed previously to their tests and it was desired to rate them under similar conditions.

The valve shown on the discharge end of the meter was used to keep a positive pressure in the throat of the meter at all times.

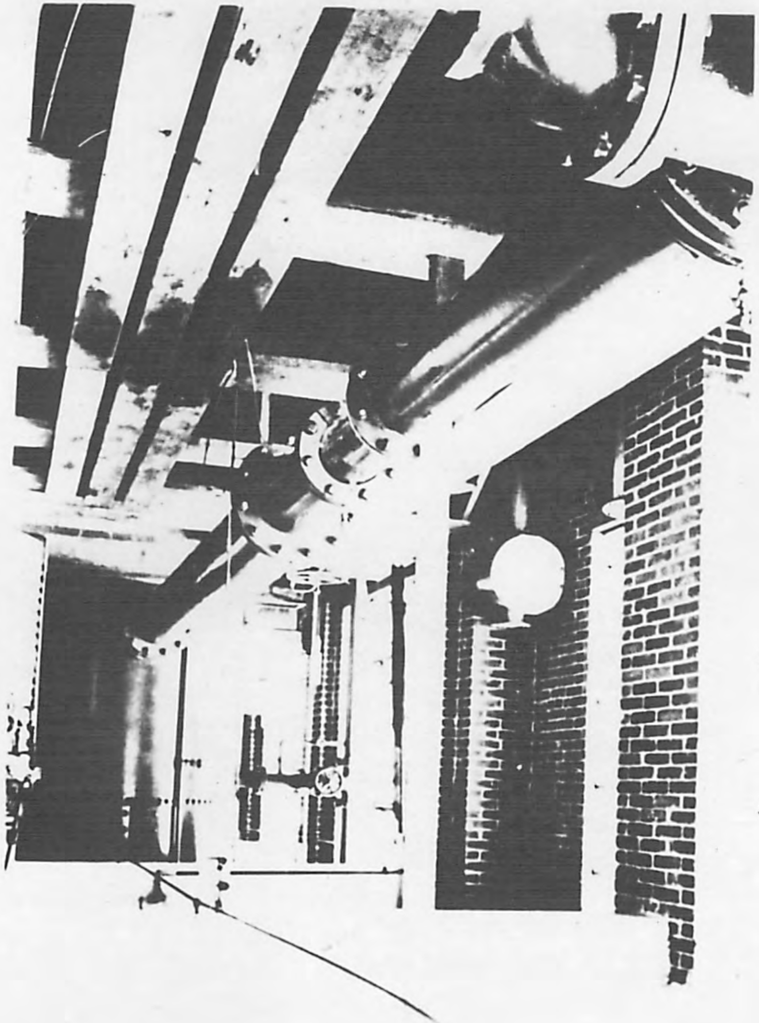
Venturi meters

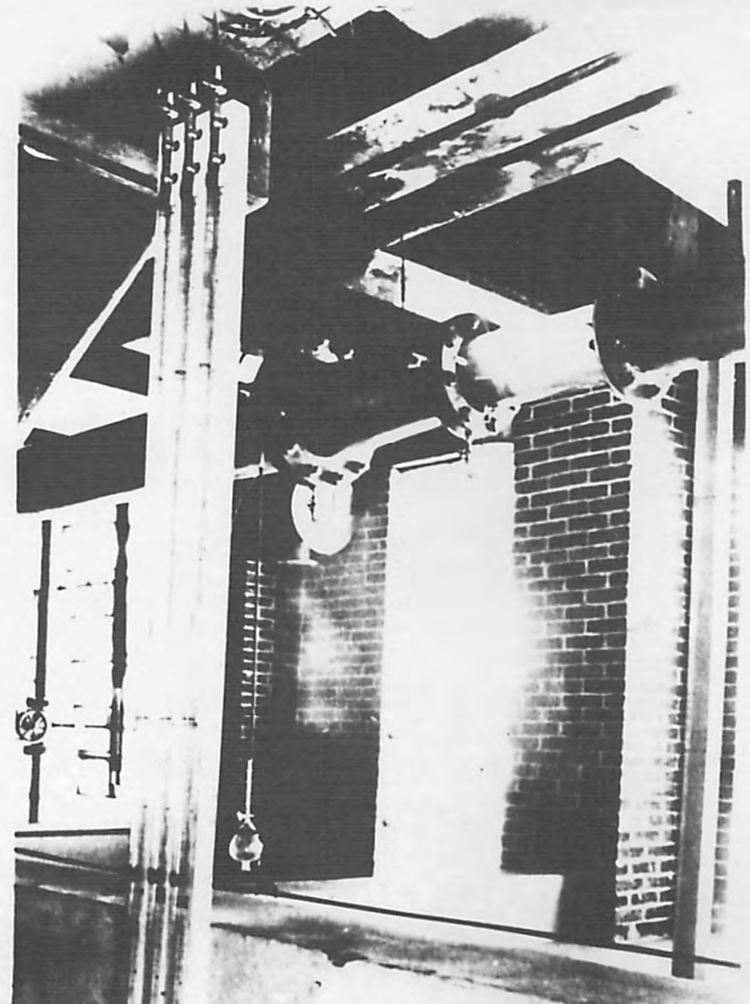
A Venturi meter is always composed of two separate parts. The pipe line portion being one, and the device for measuring the head at the entrance and throat sections, being the other. In these tests the pipe line portion was manufactured by Leupold, Volpel and Company and was of the Steven's Simplified type; while the head measuring devices were water piezometers.

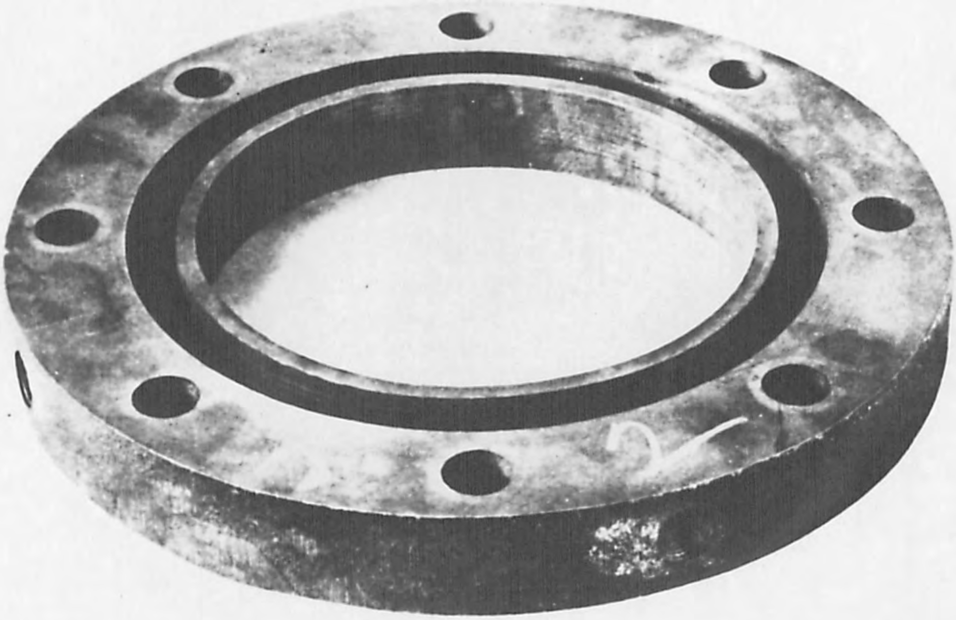
A Steven's Simplified Venturi meter consists of two standard pipe reducers and two annular pressure rings. The converging section generally being a standard short reducer, while the diverging section is a standard long reducer. The annular pressure rings, Fig. 9, were installed with their pressure face upstream, the opening being formed entirely around the ring by using the gasket, as shown in Fig. 5. For these experiments, a third ring was provided in order that the pressure at the discharge end could be recorded, the lost head across the meter thus being obtainable. The dimensions of the meters tested are given in Table 1.

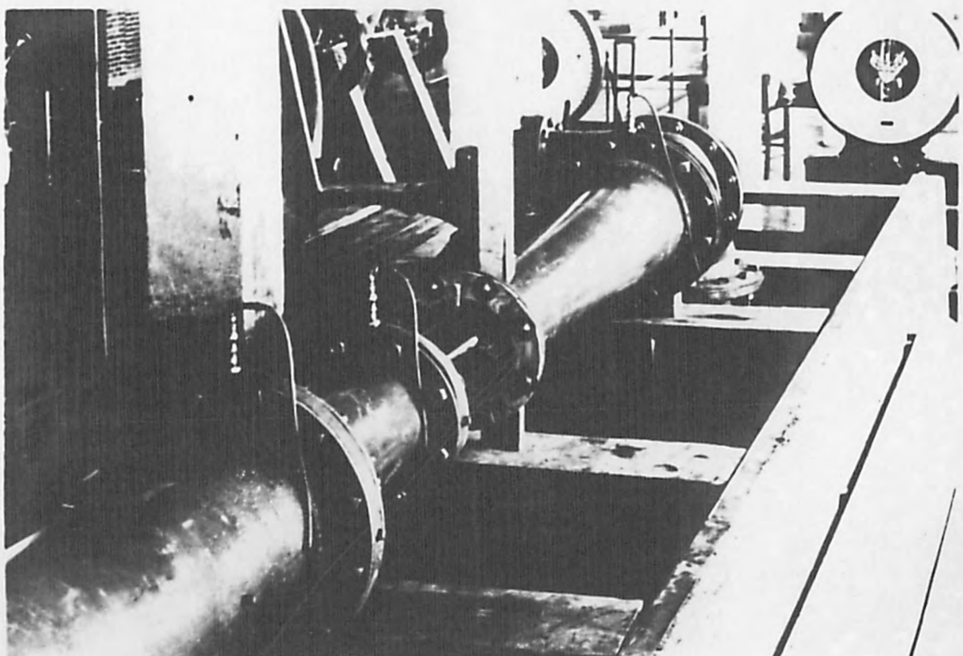
Peizometers

The water peizometers used were made of 16 mm glass tubing; the water heights were read from permanently mounted scales, which were divided to 0.01 of a foot. The 16 mm. glass tubing, however, was not large enough to still the columns sufficiently when 1/4" rubber tubing was used to connect the piezometers with the pressure rings, so that a dampening device was necessary. A very









efficient damper was devised by placing three inches of glass capillary tubing inside the 1/4" rubber tubing; a by-pass being provided to allow for the rapid changes in the head occuring when the discharge rate through the meter was changed. (Fig. 7)

Meter	Diameter of Pressure Rings in feet	Length of Converging Section	Angle of Convergence	Length of Diverging Section	Angle of Divergence	Ratio of Diameters	Length of Throat Inserts	Length of Inserted Valve
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	...	...
[illegible]	1.000 [illegible]	[illegible]	[illegible]	60"	[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		

IV Experimental Procedure

IV Experimental Procedure

Tests

The tests were conducted on four meters. Two of them, the 12" x 8" steel and 12" x 8" cast iron being new when tested; while the other two, the 8" x 5" steel and 4" x 3" steel, had been in use for approximately four months. The latter two meters were found to be so badly corroded that it was deemed advisable to thoroughly clean them before testing. They were therefore tested in a practically new condition. The individual test runs were as follows:

Run 1. 12" x 8" cast iron meter (as a standard meter)

Run 2. 12" x 8" welded steel meter (as a standard meter)

Run 3A. 12" x 8" welded steel meter, with a 1 ft. section of 8" pipe inserted in the throat.

Run 3B. Same as Run 3A plus an 8" gate valve. Valve downstream and fully open.

Run 3C. Same as Run 3B except valve 3/4 open.

Run 3D. Same as Run 3B except valve 1/2 open.

Run 3E. Same as Run 3B except valve 1/4 open.

Run 4A. 12" x 8" welded steel with a 2' section of 8" pipe inserted in the throat.

Run 4B. Same as Run 4A plus an 8" gate valve. Valve fully open.

Run 4C. Same as Run 4B except valve 3/4 open.

Run 4D. Same as Run 4B except valve 1/2 open.

Run 4E. Same as Run 4B except valve 1/4 open.

Run 5A. 12" x 8" welded steel with a 3' section of 8" pipe inserted in the throat.

Run 5B. Same as Run 5A plus an 8" gate valve. Valve fully open.

Run 5C. Same as Run 5B except valve 3/4 open.

Run 5D. Same as Run 5B except valve 1/2 open.

Run 5E. Same as Run 5B except valve 1/4 open.

Run 6. 8" x 5" welded steel meter with a 14' entrance pipe, assembled as a Standard meter.

Run 7. 8" x 5" welded steel meter with a 14' entrance pipe. A 2' length of 5" pipe and a 5" gate valve in throat. Valve fully open.

Run 8A. Same as Run 7 except for a 3' entrance pipe. (see page 23)

Run 8B. Same as Run 8A except valve 1/2 open.

Run 8C. Same as Run 8A except valve 1/4 open.

Run 9A. 4" x 3" welded steel meter with a 1' length of 3" pipe and a 3" gate valve in the throat section. Valve fully open.

Run 9B. Same as Run 9A except valve 1/2 open.

Run 9C. Same as Run 9A except valve 1/4 open.

The 12" x 8" meter tests were run purely for their experimental value, so that in setting the meters up an attempt was made to install them as ideally as the laboratory would permit. In these tests, a straight 10 ft. length of 12 in. pipe was placed between the meter and the vertical tank and, to further insure against any spiral motion of the water as it passed through the meters, a set of straightening vanes, 2 ft. in length, were placed in the upstream end of the 10 ft. entrance pipe.

The 8" x 5" and 4" x 3" meter tests were run mainly to find their characteristics under conditions approximating those of field use. There was not time to test the 4" x 3" meter in any other manner than service conditions. (Runs 9A, B, and C.) The 8" x 5" meter was tested, first of all, under service conditions which unfortunately were not too good, as the 3 ft. entrance pipe which was used was made by welding a piece of 8 in. O.D. pipe inside of a piece of 8 in. I.D. pipe. This caused a sudden enlargement only 0.54 of a ft. from the entrance pressure ring, which apparently formed a swirl in the water. It was felt at the time that these swirls so near the pressure ring were causing erroneous readings. Therefore, after completing the service condition tests, (Runs 8A, B, C.) a 14 ft. length of 8 in. pipe was substituted for the original entrance pipe. (Run 7) Later the valve and 2 ft. length of 5 in. pipe were removed from the throat of the meter and the meter coupled as an ordinary Venturi (Run 6), the 14 ft. entrance pipe being retained.

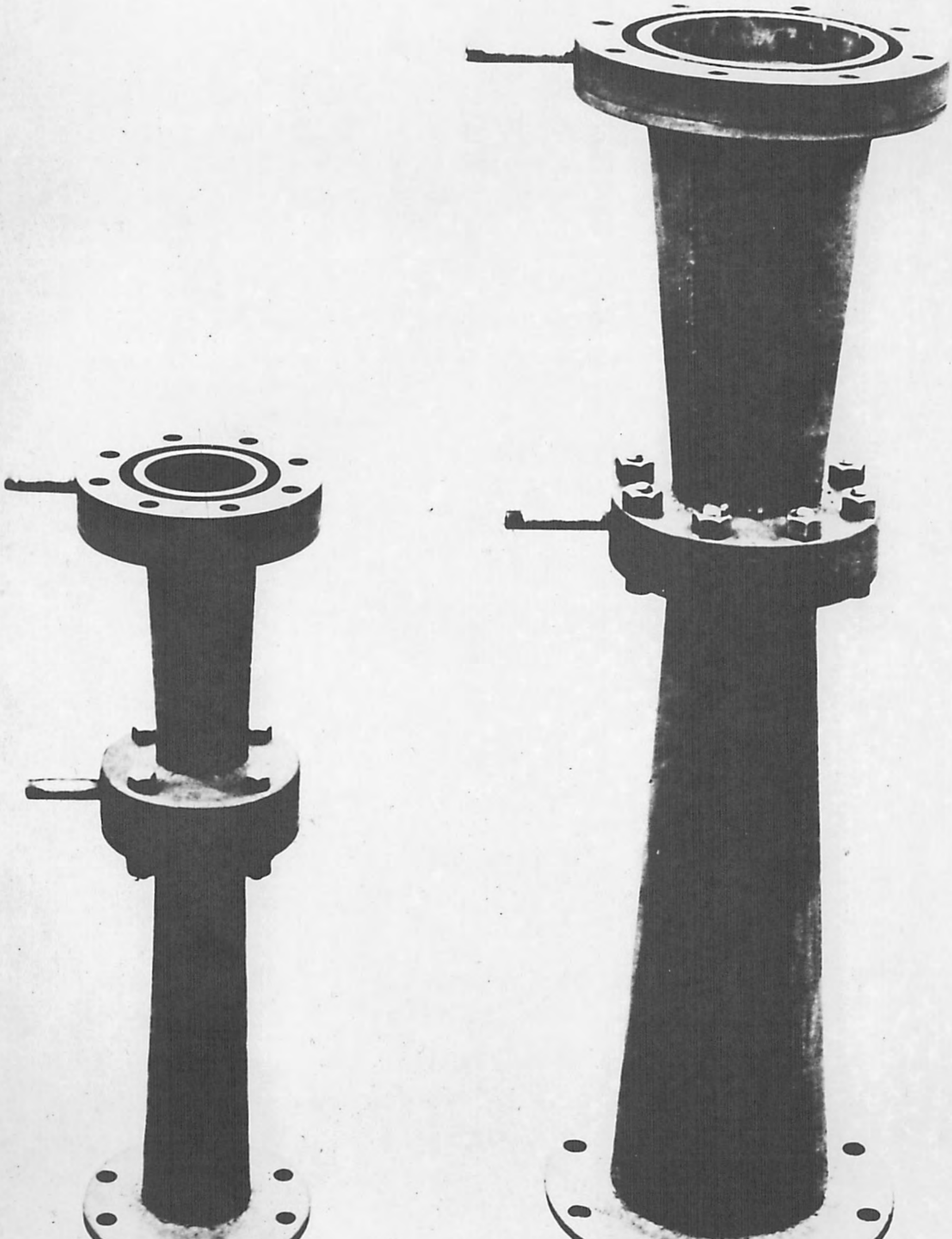


Fig. 11 4" x 3" and 8" x 5" Steel [illegible] Simplified Venturi Meter

Testing Procedure

The hydraulic characteristics of a Venturi meter are best determined by obtaining values of the meter coefficient and of the lost head for various rates of discharge. By solving either Equation 3 or 5, for its coefficient, it will be seen that by obtaining the values of Q and h in the laboratory, the coefficient can be computed. The values of Q were computed from the data obtained by timing with a stop watch the period necessary for a certain weight of water to flow into the scale tanks. It would have been possible to determine the rate of discharge by means of a weir; however, the accuracy of a weir is less than that of weighing tanks; therefore, the more accurate method was used.

The differential head and the lost head were determined by taking a number of piezometer readings simultaneously with the weighing period. The reading was taken at the bottom of the meniscus to the nearest 0.005 of a foot. Care was taken to read the entrance and throat piezometers at the same instant to insure a true differential head. The C_V quantity was computed immediately after each run, and the result plotted against Q. In this way, any definitely erroneous readings were discovered and rechecked. The readings found to be in error due to faulty operation were then struck out. This explains why the reading numbers are not continuous in the data tables of the Appendix B.

Under high heads, it was necessary to disconnect the exit piezometer and connect the tops of the entrance and throat piezometers together. This placed a compressed air column of the same pressure on top of each water column. While this did not allow a true head reading, it did allow a true differential head reading. This change-over made it possible to test larger rates of discharge when a partially closed throat valve was being used. However, the rubber tubing used for the piezometer connections could not withstand extremely high heads, therefore, the tests with partially closed valves were not made over the same range of discharges as in other tests. Low rates of discharge were not tested because the differential head could not be obtained with sufficient accuracy with the water piezometers.

While no use of it has been made in this discussion, the temperature of the water was taken after each reading and is given in the tables of Appendix B.

To insure correct results, the weighing scales were checked from time to time during these tests, as were the stop watches.

V Discussion of Results

V Discussion of Results

These tests were performed with two main objectives in mind. The first was to show if it is possible to obtain a Venturi meter of good accuracy and yet of low cost by combining two standard pipe reducers. The second was to determine if it might be possible to install a valve in the throat section of a meter without inducing materially harmful effects upon its characteristics. The results of these tests are shown by the curves in Fig. 13 and Appendix C. Four curves have been used for this purpose, being lost head, differential head, C_v and C vs. the rate of discharge, Q.

Meter Coefficients

It is sometimes desirable to have an average coefficient, especially where a mechanical recording device is used. The arithmetical mean coefficient has therefore been computed for each run and the results shown in Table II. This table also shows the maximum positive and negative percentage of error of the readings.

From the results obtained, it is apparent that the Steven's Simplified meter is only slightly inferior in hydraulic characteristics to any of the present standard machined Venturi meters. Fig. 12 shows a number of coefficient curves obtained by other experimenters on Simplex and Builder's Iron Foundry Venturi meters. (16) It will be noted

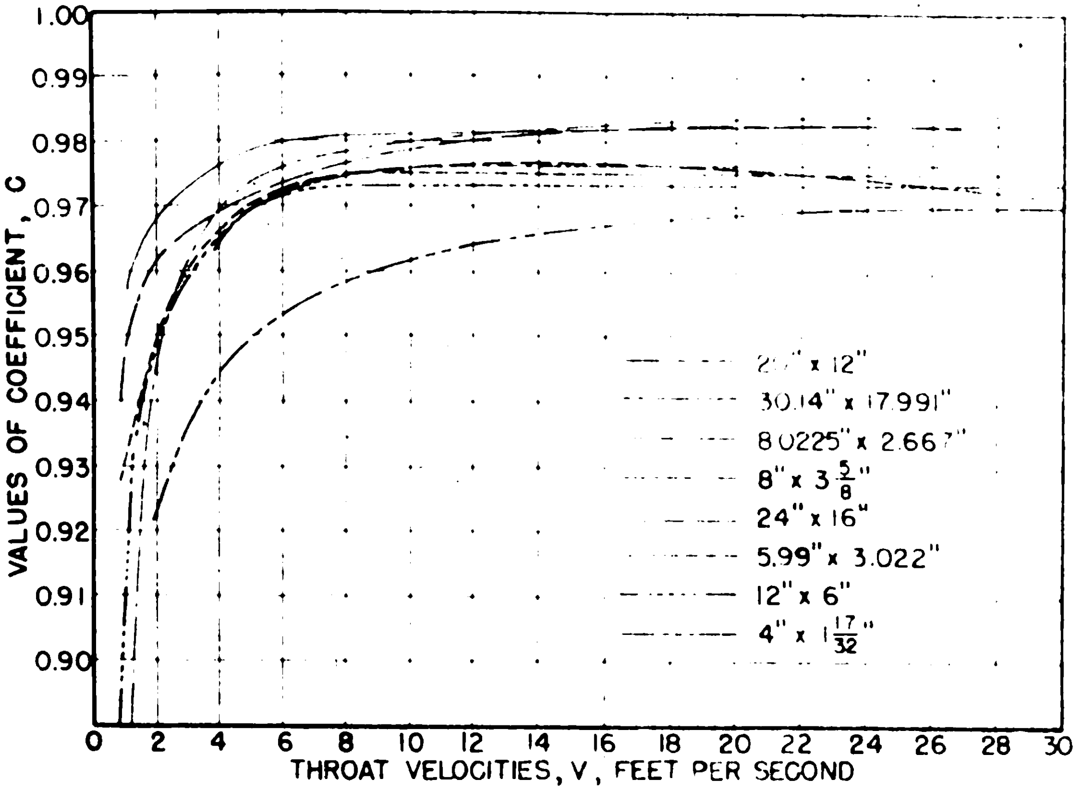


Fig. 12-Coefficients of Discharge for Standard Venturi Meters

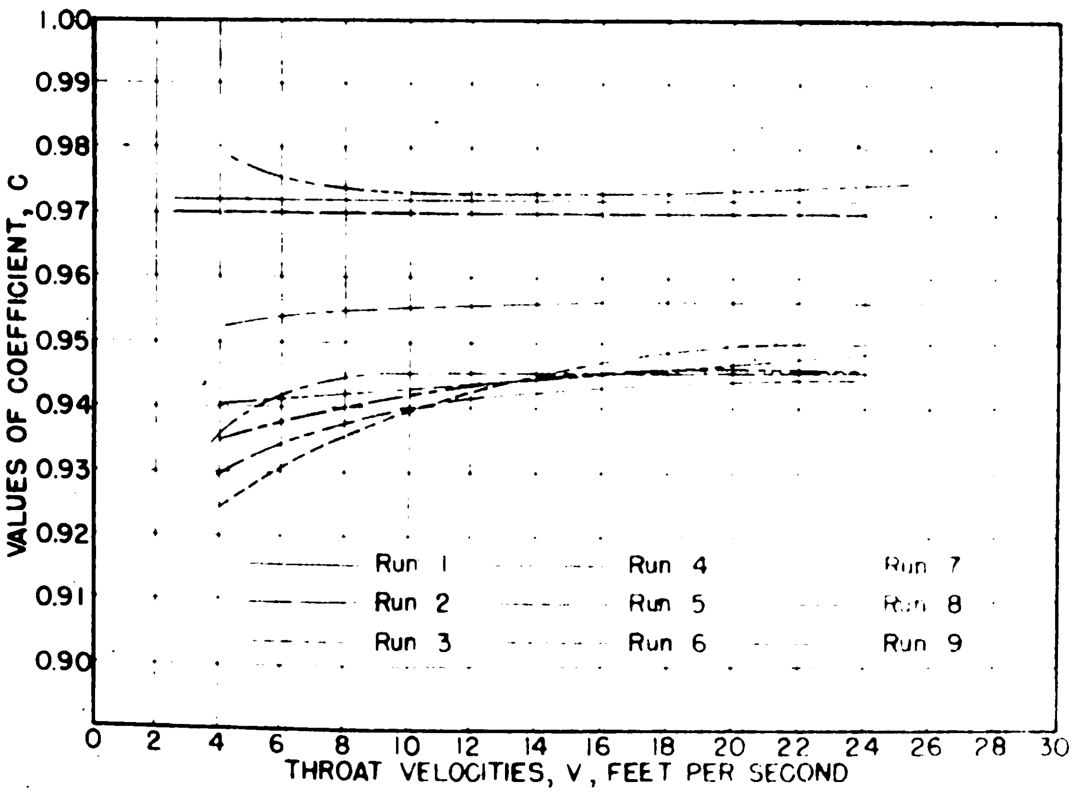


Fig. 13 Coefficients of Discharge for Simplified Venturi Meters

Table II

Run Number	Nominal Size	Average C_v	Average C	Maximum Positive Error	Maximum Negative Error	Lost Head $f = \frac{V^n}{a}$	
						a	n
1	[illegible]	0.977	0.972	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	0.975	0.970	[illegible]	1.07	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	0.940	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	171	[illegible]
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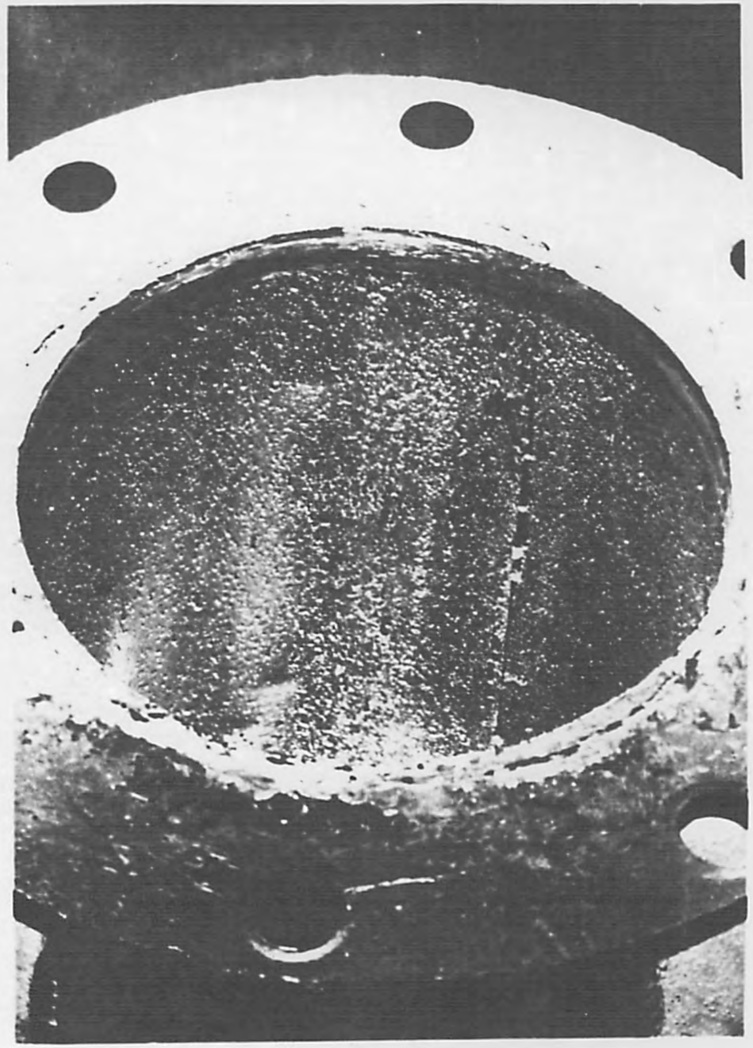
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.11	...	....
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	...	....
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	0.944	1.17	[illegible]	...	....
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	...	....
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	...	....
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	...	....
[illegible]	4x6	[illegible]	[illegible]	[illegible]	[illegible]	...	....
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	...	....
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	...	....
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	...	....
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	...	....
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	...	....

that for throat velocities above approximately seven ft./sec. the coefficients vary between 0.972 and 0.982 with the average about 0.976. Similar curves for the Steven's Simplified meter are shown in Fig. 13. Comparing the three runs which were made with the meters installed as Standard Venturi meters, with those of Fig. 12, it will be seen that they lie between 0.970 and 0.972, and thus are slightly lower than those for the standard meter. From this it would appear that the Simplified meter is less efficient (has a higher lost head). It is only natural to expect these meters to have slightly higher lost heads, as the standard meters has a smooth, turned brass throat, with all angles rounded; while the meters made from reducers are rougher (Fig. 14 and 15) and have definite angular bends. The lower efficiency, however, was found only in the steel meters, with the cast iron meter proving to have no larger lost head than that given for comparable standard meters. The surface roughness undoubtedly was the major factor in this respect, as the steel meters were visibly much rougher than the cast iron. The roughness of the steel meter was due partially to the welding which was evidently done by the electric arc process, as small beads of a character of those cast off by a hand controlled electrode were found over a considerable portion of the reducers.

Lost Head

An interesting comparison between the lost heads of the meters used in these tests and the standard meters can be obtained by figuring the equation of the lost head curve for each meter. This may be expressed in the form of $f = \frac{V^n}{a}$ where "f" is the lost head, "V" is the throat velocity, and "n" and "a" are constants for any meter. This formula has been computed for a large number of standard meters, with an average value of $f = \frac{V^{1.961}}{403}$ with a range in the "n" value from 1.67 to 2.14 and in the "a" value from 181 to 846. The "a" value generally is smaller for the very small meters, but above a 4 in. or 6 in. meter the value varies indiscriminately. The "n" value follows no rules whatsoever. The tests of the Simplified meters have lost head curves with "n" and "a" values, as shown in table II.

While the "n" values for the standard meters vary considerably, those in these tests strangely, in every case but one, were almost exactly the mean value for the standard type meters. Comparing "a" values of the tests against the average "a" value of 403, the cast iron meter with an "a" of 560, therefore has a smaller lost head than do most standard meters, while the two steel meters with values of 252 and 249 have lost heads of about 1.6 times that of the standard meter.

It should be pointed out here, that the accuracy of any Venturi meter is affected not only by the internal structure, but also by the manner in which the differential head is obtained. A distinction should always be made as to whether it is the meter accuracy or the head measuring device accuracy that is being determined. In these tests water piezometers, read by eye against a fixed scale, were used to determine the differential head. At low differential heads it was not possible to read the water levels accurately enough to obtain the same degree of accuracy in the final results as was obtainable at the higher differential heads. It will be noticed that due to this, in most runs, there is a wider spread of the coefficients at the low discharges.

Test runs, made with standard Venturi meters and using devices to read the differential heads with extreme accuracy (16) have shown that the meter coefficient commences to fall for velocities below about seven ft./sec. with a nearly uniform coefficient above this velocity. While the tests on the simplified meters were not conducted with sufficient accuracy to definitely show the falling off of the coefficient at low throat velocities, they do conclusively show that the coefficient remains nearly uniform throughout the entire range of flows tested.

Summary

These tests have thus proven that by coupling two standard pipe reducers together, a Venturi meter with the following characteristics can be had:

1. The coefficient should be about 0.970 or 0.972. This is slightly lower than that of present manufactured Venturi meters.
2. The lost head in meters made from cast iron reducers should be approximately equal that of the present standard meters, while that of a steel meter should be about 1-1/2 times as large.
3. The error in measurement, while depending upon the type of differential head measuring device, should not exceed ± 1.75%, as compared with ± 1% as guaranteed for present standard Venturi meters.

Throat Valve

In running the tests to determine if it would be possible to insert a valve in the throat section of the Venturi meter without greatly affecting its characteristics, the 12" x 8" steel meter was first used. Tests were run with insert sections of one, two and three foot lengths, both with and without a valve following them. Valve openings of fullyopen, three quarters open, one half and one quarter open were tried. These openings were found by measuring those proportions on the rising stem and do not represent area proportions. Later tests were run on the 8" x 5" and 4" x 3" steel meters but with only one length of insert.

The curves of C vs Q, as shown in Appendix C and Fig. 13, show that while the coefficient is lower than that for a straight Venturi meter, nevertheless, it remains nearly constant even with the valve three quarters closed. It is thus apparent that a valve may be placed in the throat of a Venturi meter, following a suitable section of straight pipe, without destroying its metering qualities.

No tests were run with only the valve inserted in the throat as it did not seem likely that the meter could function under this condition, as the eddies and swirls in front of the partially closed valve gate would likely be reflected upstream into the throat pressure ring. It may be possible though, that if a valve were needed for open and shut operation only, it could be placed directly following the throat pressure ring without an intervening straight section.

It is to be expected that the lost head across a meter with a valve inserted in the throat, would be greater than that across a regular meter. Table II shows this to be true, but the increase is not as large as one might think. Lost head figures are given only for the fully open valve condition, as the purpose of closing a valve is to increase the lost head for the purpose of decreasing the flow.

Sufficient tests were not run to determine if any definite length of pipe should be inserted ahead of the valve; however, experiments have shown that any obstruction or bend in a pipe or channel causes velocity and pressure changes which are reflected upstream. The distance upstream varying with the conduit and the cause. In orfice meters the recommendation is made that the upstream pressure connection be made from 1 to 2 diameters above the orfice plate; therefore, it seems reasonable to assume that a valve placed in the throat section of a Venturi meter should be at least one diameter or perhaps one and one half diameters below the pressure ring. Too long an intervening section would naturally cause an undue amount of lost head and should be guarded against.

By adding the value and the two foot section of pipe to the 8" x 5" meter, the lost head becomes about two and three quarters times greater than without this addition of fittings. This probably could be cut by using a shorter throat section.

While the coefficients tend to drop off for the small valve openings, this does not cause too large errors as the percentage of error figures in Table II show. Again, it must be stated, that the method of determining the differential head may be the cause of large errors and not the meter itself. A good example of this is the high positive error in Run 9 (Fig. 30). Here, the reading with the largest error has a small differential head and as low differential heads could not be read with great accuracy, the head measuring device may have been the cause of the error rather than the meter itself. Certainly it can be stated that a Venturi meter is no more accurate than is the device used to measure the differential head in calibrating the meter.

Accuracy

From the results of these tests it is apparent that a Venturi meter of good accuracy can be made by combining two standard pipe reducers along with suitable pressure outlets. While it cannot be claimed that they have an accuracy as high as the present standard makes of Venturi meters, their accuracy of ± 1.75% is good enough to allow their use in many instances.

Experiments have shown that, over a period of time, a Venturi meter becomes sufficiently corroded to cause a change in the coefficient. A Simplified meter can be removed and cleaned quite easily and therefore, over a period of years, its accuracy may be as good, if not better, than that of the present meters. The size and weight of a Standard meter makes removal and cleaning difficult.

In regards to accuracy, the following table shows the approximate relative accuracy and reliability of various previously used water measuring devices: (16)

	Percentage of Accuracy
Where the water is weighed	99.9
" " " " measured in tanks	99.9
" " " " by mechanically moving meters	99.0
" " " " by Venturi tube meters	99.0
" " " " by orfice meters	99.0
" " " " by pitot tube meters	97.5
" " " " by V-notch weir meters	97.0
" " " " by rectangular weir meters	96.5
" " " " by salt volocity method	90-98.5

The Simplified Venturi meter's relative error of about 1-3/4 % thus compares very favorably with other metering devices.

Advantages

It should be evident that the cost for meters of this type is much lower than for the present standard Venturi meters. This, plus the fact that a meter of this type can be made in any section of the country and therefore is readily available, is its major advantage.

There are many meter installations where accuracies of ± 1% are not essential and where a cheaper meter of nearly comparable accuracy would be just as desirable; the irrigation field being a notable example. Extensive use of this type meter could also be made by water works departments, especially by those in smaller towns where the present high cost prohibits their using many, if any, large meters.

The results of the tests made using a valve in the throat section of the meter, show that when an accuracy of around ±3% and a lost head of two, to three times as great as that through an ordinarily installed Venturi meter, is permissible, it would be possible to use such a set up. This type installation should be useful in work where the difference in cost, between a valve to fit the main pipe and one to fit the throat, would be important. It should also find application in the water works field where besides a lower cost of installation, it could be used to advantage on rate controllers where the smaller overall dimensions of a throat valve should make for ease of installation in the crowded filter galleries.

Besides the large factor of lower cost, the Simplified meter has several other advantages. For instance, the meters are usually of much shorter length. The length of the 12" x 8" Simplified cast iron meter was 3'9", while that of a present comparable standard meter would be about 9 ft. The 12" x 8" steel meter was 7'3" long, but as desirable a meter would have resulted if the 5 ft. diverging section was replaced with a 2 ft. section. This shortening of the diverging section has proved to result in a smaller overall lost head by several experiments. The German type meter (Fig. 2) confirms this fact as tests have shown it to have a much lower lost head than do comparable meters with long diverging sections. The shorter length of the Simplified meter should allow for easier installation and make the housing of a meter more convenient.

By placing the valve in the throat of a meter it is possible to have the rate control at the same place where the flow record is obtained. This should be of special advantage on projects where it is desirable to have the pumping unit, meter and control valve located in the same building. The desirability of having the valve and meter housed together and the advantage of being able to use a smaller and therefore cheaper control valve has been pointed out by irrigation engineers.

VI Conclusions

VI Conclusions

1. By combining two standard pipe reducers an accurate and readily available Venturi meter results.
2. A gate valve may be placed in the throat section of a Venturi meter with only minor effects to the hydraulic characteristics.

Part VII

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Appendix A

Installation Factors

Appendix A

Installation Factors

Materials to be Used

In installing any type of Venturi meter there are certain factors which must be kept in mind. One of these, is the selection of the material of which to construct the meter. There are several items besides the original cost which must be considered. While the steel meters have the advantage of having a lower first cost than the cast iron, they have several disadvantages.

The lost head, through the 12" x 8" steel meter tested, was twice that through the 12" x 8" cast iron meter. While this is the only comparison available, it is reasonable to assume that the ordinary welded steel pipe will usually have a greater relative roughness than will cast iron pipe and therefore, it should be expected that a steel meter will have the greater lost head. It has been previously pointed out that the steel meters tested were evidently welded with a hand controlled arc which greatly increased the roughness over that of the original steel plate. With the introduction of the newer machine welders, it may be possible that the steel meter will compare very favorably with that of the cast iron, in the item of lost head. The steel meter has the additional disadvantage that it must be maintained. Provisions must be made to allow for occasional removal of this meter in order that the water covered surfaces can be cleaned and repainted. The 8" x 5" and 4" x 3" meters tested were good examples of this point. Both of these meters had been in use for approximately four months, at the time of their removal and were found to be so badly corroded that cleaning was necessary before testing. Neither meter, however, had been painted before the original installation.

The steel meter is definitely much lighter in weight, and thus easier to install or dismantle than is a cast iron one, therefore, if shut downs or breaks in the line can be tolerated, some of the maintenance disadvantage is nullified.

Piezometer Connections

The piezometer take-off from the pressure ring should never be made at the top of the ring. A side take-off always being preferable. The reason for this is that any air in the pipeline hugs the top of the pipe with the result that air bubbles can enter the pressure line.

If any amount of silt is carried in the water being metered, a blow-off valve at the bottom of the pressure ring is helpful in ridding the ring of any silt which may collect in it. Care should always be taken to see that the lines from the pressure rings to the piezometers, or other recording devices, have no low or high spots in them.

In case they do, proper blow-offs should be provided.

Where water piezometers or differential manometers are used, some form of dampening device may have to be installed in order to insure the desired accuracy. In the case of water piezometers, this can be provided by using large stilling-well piezometer tubes or dampeners, as used in the test. A very neat type of dampener can be made by placing short, brass plugs, through which have been bored a small hole, into the pipe connecting the piezometer to the pressure ring. If the length of pipe into which the plugs are placed, is equiped with a union at both ends, it can be easily removed and plugs added or removed until the proper dampening is achieved. It must be noted, however, that all tubes must be dampened the same amount.

Installation

In installing a meter, care should be taken to avoid any set up that might cause a spiral movement of the water while passing through it. The chief causes of this being installation too near pumps, bends and sudden enlargements or contractions. It is thought that at least ten or twelve diameters of straight pipe should proceed a meter, where possible. Where this is impossible, or where the spiral movement still bothers, suitable straightening vanes can be used; the characteristics of the vanes being dependent upon the amount of straightening necessary.

Appendix B

Data Tables

TABLE 1

Reading	h		C_v	C	Lost head ft.	Temp. water °F
1	1.202	4.761	0.972	0.967	0.130	64.0
2	1.460	3.890	0.979	0.976	0.145	64.[illegible]
3	1.377	3.760	0.976	0.971	0.133	65.0
4	1.237	3.545	0.972	0.966	0.171	65.0
5	0.990	3.192	0.976	0.971	0.137	65.0
6	0.768	2.810	0.976	0.973	0.1[illegible]	[illegible]
7	0.693	2.660	0.979	0.976	0.10[illegible]	[illegible]
8	0.592	2.490	[illegible]	[illegible]	0.0[illegible]	[illegible]
9	0.597	2.480	0.977	0.972	0.078	[illegible]
11	0.472	2.239	0.9[illegible]	0.967	0.063	66.[illegible]
12	0.368	1.965	0.984	0.983	0.052	[illegible]
13	0.235	1.542	0.970	0.963	0.032	[illegible]
15	0.142	1.218	0.982	0.979	0.018	[illegible]
16	0.147	1.127	0.974	0.971	0.017	[illegible]
18	0.082	0.933	0.98[illegible]	0.989	0.01[illegible]	66.0
23	5.136	7.290	0.978	0.975	0.558	65.0
24	4.853	7.090	0.980	0.976	0.54[illegible]	65.0
26	4.352	6.680	0.974	0.971	0.515	65.0
27	3.941	6.360	0.975	0.971	0.470	65.0
28	3.557	5.980	0.967	0.961	0.418	66.0
29	3.207	5.810	0.985	0.983	0.397	6[illegible]
30	3.218	5.810	0.963	0.982	0.397	[illegible]
31	2.855	5.450	0.981	0.977	0.353	66.0
32	2.521	5.010	0.963	0.956	0.3[illegible]	66.[illegible]
33	2.505	5.075	0.975	0.972	0.310	66.0
34	2.155	4.633	0.964	0.956	0.262	66.0
35	2.137	4.670	0.973	0.968	0.257	66.0
39	1.758	4.310	0.986	0.985	0.230	66.0
40	1.613	4.050	0.972	0.966	0.208	[illegible]
41	1.453	3.815	0.966	0.960	0.180	66.[illegible]
42	1.405	3.770	0.969	0.964	0.165	66.[illegible]
43	0.990	3.193	0.977	0.973	0.130	66.[illegible]
44	5.318	7.350	0.972	0.966	0.615	66.0
45	4.[illegible]93	6.680	0.979	0.976	0.517	66.0
46	4.438	6.850	0.987	0.986	0.530	6[illegible]
47	4.450	6.730	0.972	0.967	0.527	6[illegible].5
48	4.542	6.910	0.985	0.983	0.540	6[illegible].5
49	4.508	6.820	0.978	0.974	0.545	6[illegible].5
50	4.140	6.510	0.974	0.970	0.500	67.0
51	[illegible].688	6.160	0.977	0.972	0.445	67.0
52	2.827	5.450	0.985	0.982	0.350	67.0
53	[illegible].822	5.380	0.974	0.970	0.305	67.0
54	3.068	5.640	0.977	0.972	0.380	67.0
55	[illegible]48	5.240	0.978	0.976	[illegible]	67.0
57	1.[illegible]90	4.[illegible]65	[illegible]	[illegible]1	[illegible]	[illegible].5
58	1.743	[illegible]50	[illegible]	[illegible]	[illegible]	67.5

DATA FOR RUN 1 (CON'T.)

Reading	h ft.	Q c.f.s.	C_v	C	Lost Head ft.	Temp. Water °F
61	1.315	3.790	0.977	0.977	0.175	67.5
62	1.295	3.660	0.979	0.974	0.170	68.0
63	1.083	3.340	0.977	0.973	0.143	68.0
64	0.835	2.925	0.974	0.970	0.108	68.0
65	0.478	2.225	0.979	0.976	0.067	68.0
66	0.320	1.800	0.970	0.965	0.047	68.0
67	0.360	1.927	0.977	0.974	0.052	68.0
68	0.247	1.603	0.981	0.977	0.033	68.0
71	0.218	1.496	0.975	0.972	0.033	68.0
72	1.862	4.355	0.972	0.968	0.232	68.0

DATA FOR RUN 2

Reading	h ft.	Q c.f.s.	C_v	C	Lost Head ft.	Temp. Water °F
1	6.070	7.350	0.970	0.964	1.598	63.0
2	6.103	7.420	0.975	0.970	1.601	63.0
3	4.972	6.680	0.973	0.967	1.298	63.0
4	5.355	6.970	0.977	0.973	1.401	63.0
5	4.502	6.360	0.974	0.968	1.197	63.0
6	4.505	6.360	0.973	0.968	1.187	63.0
7	3.967	5.980	0.975	0.970	1.060	63.0
8	3.685	5.810	0.981	0.978	0.992	63.0
9	3.683	5.760	0.975	0.969	0.995	63.0
10	3.392	5.525	0.974	0.969	0.932	63.0
13	2.943	5.170	0.978	0.974	0.803	64.0
15	2.557	4.800	0.974	0.969	0.702	64.0
16	2.252	4.505	0.974	0.970	0.618	64.0
17	2.250	4.570	0.979	0.984	0.620	64.0
18	1.838	4.047	0.970	0.964	0.510	64.0
19	1.962	4.195	0.972	0.967	0.540	64.5
20	1.722	3.950	0.977	0.973	0.478	65.0
21	1.808	4.048	0.977	0.972	0.464	64.0
23	1.587	3.817	0.982	0.979	0.457	64.5
24	1.583	3.817	0.983	0.981	0.451	64.5
28	1.235	3.340	0.975	0.970	0.325	65.0
29	1.110	3.148	0.971	0.965	0.304	65.0
31	0.830	2.745	0.977	0.974	0.225	65.0
32	0.720	2.548	0.974	0.970	0.195	65.0
33	0.610	2.340	0.972	0.968	0.167	65.5
34	0.488	2.083	0.971	0.963	0.128	65.5
35	0.492	2.100	0.975	0.968	0.133	65.5
36	0.370	1.834	0.978	0.974	0.100	65.5
37	0.300	1.645	0.975	0.970	0.278	66.0
38	0.270	1.571	0.980	0.976	0.070	66.0
39	0.270	1.562	0.976	0.971	0.072	66.0
42	0.090	0.905	0.979	0.975	0.025	65.5
43	0.112	0.997	0.969	0.962	0.037	65.5

DATA FOR RUN 2 (CON'T.)

Reading	h ft.	Q c.f.s.	C_v	C	Lost Head ft.	Temp. Water °F
44	0.108	0.981	0.970	0.964	0.033	65.5
45	0.162	1.196	0.967	0.961	0.042	66.0
46	0.160	1.202	0.976	0.970	0.040	66.0
47	0.250	1.512	0.981	0.977	0.072	66.0
48	0.250	1.506	0.978	0.973	0.068	66.0
49	0.349	1.765	0.971	0.965	0.098	66.0
50	0.348	1.766	0.973	0.968	0.100	66.0
51	0.448	2.023	0.980	0.976	0.123	66.0
52	0.615	2.357	0.975	0.971	0.187	66.0
54	0.922	2.867	0.971	0.965	0.255	66.0
55	1.025	3.035	0.973	0.968	0.295	65.5
56	1.157	3.242	0.977	0.975	0.327	65.5
57	1.247	3.367	0.978	0.974	0.345	66.0
59	1.373	3.530	0.977	0.973	0.380	66.0
61	1.482	3.640	0.972	0.966	0.415	66.0
62	1.563	3.780	0.980	0.977	0.448	66.0
63	1.640	3.815	0.968	0.963	0.453	66.0
64	1.633	3.831	0.974	0.968	0.457	66.0
66	1.703	3.910	0.973	0.968	0.473	66.0
67	1.778	4.046	0.983	0.980	0.503	66.0
68	1.786	3.986	0.970	0.963	0.513	66.0
69	4.077	6.070	0.975	0.971	1.122	66.0
70	4.450	6.360	0.978	0.975	1.208	66.0
71	4.958	6.680	0.974	0.969	1.282	66.0
72	5.573	7.091	0.975	0.971	1.468	66.0
73	2.890	5.103	0.974	0.970	0.763	66.5
75	3.240	5.380	0.971	0.966	0.880	66.5
76	3.237	5.380	0.971	0.966	0.882	66.5
77	2.458	4.715	0.976	0.959	0.675	66.5
78	1.963	4.219	0.977	0.973	0.542	66.5
79	2.232	4.450	0.969	0.962	0.627	67.0
80	2.203	4.450	0.973	0.968	0.608	67.0

DATA FOR RUN 3 - A

1	1.130	3.091	0.951	0.940	0.328	65.0
2	0.995	2.899	0.949	0.939	0.295	65.0
3	0.918	2.779	0.947	0.937	0.268	65.0
4	0.830	2.634	0.946	0.935	0.238	65.0
5	0.757	2.488	0.937	0.925	0.220	65.0
6	0.760	2.515	0.944	0.932	0.217	66.0
7	0.270	1.512	0.950	0.940	0.082	66.0
8	0.307	1.602	0.946	0.934	0.093	66.0
9	0.362	1.757	0.953	0.943	0.105	66.0
10	0.580	2.200	0.945	0.932	0.173	66.0
11	0.410	1.838	0.940	0.927	0.122	66.0

DATA FOR RUN 3 - A (CON'T.)

Reading	h ft.	Q c.f.s.	C_v	C	Lost Head ft.	Temp Water ^oF
12	0.402	1.829	0.944	0.932	0.118	65.0
14	0.218	1.338	0.938	0.925	0.070	65.0
15	0.107	0.941	0.941	0.930	0.037	65.0
16	0.140	1.082	0.946	0.935	0.047	65.0
17	0.195	1.280	0.947	0.937	0.060	63.0
18	1.168	3.160	0.954	0.944	0.345	64.0
19	1.513	3.600	0.955	0.946	0.445	64.5
20	1.710	3.841	0.958	0.949	0.498	64.5
21	1.712	3.752	0.939	0.927	0.495	64.5
22	1.887	4.039	0.958	0.951	0.537	64.5
23	1.887	4.005	0.951	0.942	0.547	64.5
24	2.237	4.380	0.955	0.946	0.642	65.0
25	2.253	4.330	0.944	0.932	0.655	65.0
26	2.748	4.850	0.951	0.939	0.790	65.0
27	2.977	5.040	0.952	0.945	0.860	65.0
28	3.155	5.240	0.960	0.952	0.900	65.0
29	3.165	5.250	0.962	0.954	0.900	65.0
30	3.420	5.415	0.955	0.945	0.980	65.0
31	3.627	5.600	0.959	0.950	1.057	65.0
32	6.633	7.560	0.957	0.948	1.677	65.0
33	5.750	7.025	0.957	0.946	1.633	65.0
34	5.182	6.790	0.963	0.954	1.502	65.0
35	5.168	6.680	0.950	0.940	1.488	65.0
36	4.885	6.460	0.954	0.944	1.368	65.0
37	4.505	6.210	0.955	0.945	1.258	65.5
38	4.145	5.890	0.946	0.935	1.198	66.0
39	3.958	5.800	0.953	0.942	1.098	66.0
40	4.015	5.850	0.953	0.944	1.128	66.0
41	4.490	6.160	0.950	0.938	1.303	66.0
42	3.966	5.845	0.958	0.949	1.142	66.0
43	3.217	5.200	0.947	0.937	0.925	66.0
44	2.633	4.727	0.951	0.941	0.770	66.0
45	2.473	4.550	0.947	0.934	0.700	66.0
46	2.070	4.183	0.949	0.938	0.582	66.0
47	1.137	3.070	0.942	0.930	0.317	66.0
48	1.332	3.360	0.951	0.941	0.377	66.0

DATA FOR RUN 3 - B

Reading	h ft.	Q c.f.s.	C_v	C	Lost Head ft.	Temp Water ^oF
1	1.227	3.243	0.955	0.946	0.452	66.0
2	6.375	7.420	0.958	0.949	2.433	66.0
4	6.032	7.220	0.959	0.950	2.277	66.0
7	5.617	6.965	0.959	0.950	2.095	66.5
9	4.892	6.510	0.959	0.951	1.840	66.5
10	4.342	6.115	0.957	0.948	1.618	66.5
11	3.997	5.845	0.954	0.944	1.495	66.5

DATA FOR RUN 3 - B (CON'T.)

Reading	h ft.	Q c.f.s.	C_v	C	Lost Head ft.	Temp. Water ^oF
13	3.543	5.488	0.951	0.943	1.238	66.5
14	3.373	5.359	0.953	0.943	1.168	67.0
15	3.108	5.150	0.954	0.944	1.180	67.0
16	2.887	4.960	0.953	0.943	1.088	67.0
17	2.665	4.800	0.958	0.950	1.010	67.0
19	2.290	4.390	0.948	0.938	0.868	67.5
20	2.242	4.330	0.945	0.934	0.862	67.5
21	2.210	4.340	0.953	0.942	0.828	67.5
22	2.208	4.380	0.960	0.951	0.832	67.5
23	2.140	4.260	0.951	0.941	0.790	67.5
25	1.922	4.055	0.955	0.945	0.741	67.0
27	1.883	3.975	0.947	0.936	0.718	67.0
29	1.672	3.815	0.961	0.953	0.625	67.5
30	1.485	3.560	0.954	0.944	0.568	67.5
31	1.228	3.238	0.954	0.944	0.467	67.5
32	1.223	3.230	0.953	0.944	0.458	67.5
33	1.350	3.424	0.960	0.952	0.500	67.5
34	1.210	3.160	0.941	0.928	0.437	67.5
35	1.163	3.153	0.955	0.945	0.370	67.5
36	0.812	2.618	0.945	0.939	0.378	67.0
37	0.812	2.610	0.946	0.936	0.305	67.0
38	1.105	3.064	0.951	0.941	0.415	67.5
39	1.107	3.040	0.945	0.934	0.415	67.0
40	1.053	2.957	0.943	0.931	0.393	67.0
41	0.827	2.643	0.950	0.938	0.353	67.0
42	0.725	2.456	0.944	0.931	0.278	67.0
43	0.638	2.300	0.941	0.932	0.245	67.0
44	0.505	2.050	0.944	0.931	0.195	67.0
45	0.408	1.834	0.939	0.927	0.153	67.0
46	0.320	1.630	0.943	0.931	0.120	67.0
48	0.370	1.776	0.953	0.944	0.143	66.0
49	0.277	1.531	0.950	0.940	0.107	66.0
50	0.243	1.408	0.936	0.923	0.099	66.0
51	0.242	1.413	0.940	0.928	0.100	66.0
52	0.200	1.272	0.933	0.920	0.082	66.0
53	0.200	1.273	0.933	0.920	0.082	66.0
54	0.155	1.128	0.938	0.926	0.065	66.0
55	0.130	1.023	0.930	0.916	0.055	66.0
56	0.128	1.015	0.930	0.916	0.053	66.0
59	1.033	3.000	0.961	0.954	0.395	66.5

DATA FOR RUN 5 - C

Reading	h ft.	Q c.f.s.	C_v	C	Lost Head ft.	Temp. Water °F
1	6.297	7.350	0.956	0.946		66.0
2	6.392	7.090	0.954	0.944		66.0
3	5.710	7.025	0.959	0.949		66.0
5	5.672	6.900	0.955	0.944		66.5
6	4.777	6.410	0.953	0.948		66.5
7	5.112	6.630	0.962	0.955		67.0
8	4.672	6.115	0.954	0.945		67.0
9	4.740	6.410	0.959	0.950		67.0
10	4.235	6.070	0.961	0.953		67.0
11	3.833	5.720	0.955	0.943		67.0
12	4.023	5.935	0.965	0.956		67.0
14	3.993	5.390	0.960	0.952		67.5
15	3.528	5.430	0.954	0.942		67.5
17	3.193	5.270	0.961	0.953		68.0
18	2.993	5.100	0.961	0.952		68.0
19	2.895	5.010	0.959	0.951		68.0
20	2.850	4.915	0.951	0.940		68.0
21	2.790	4.915	0.959	0.951		68.0
22	2.447	4.605	0.955	0.953		68.0
23	2.035	4.170	0.954	0.945		68.0
24	1.528	4.227	0.948	0.937		
25	2.343	4.[illegible]15	0.951	0.952		68.0
27	1.803	3.348	0.958	0.950		68.0
29	1.523	3.310	0.955	0.946		68.0
30	1.545	3.410	0.958	0.950		68.0
31	1.532	3.312	0.959	0.949		68.5
32	1.613	3.725	0.956	0.946		68.5
33	1.435	3.360	0.954	0.944		68.5
35	1.510	3.315	0.954	0.944		69.0
36	1.357	3.130	0.950	0.940		68.5
37	1.013	2.923	0.949	0.938		68.5
38	0.820	2.510	0.945	0.931		68.5
39	0.825	2.518	0.945	0.931		68.5
40	0.530	2.295	0.946	0.934		69.0
41	0.527	2.103	0.947	0.936		69.0
42	0.415	1.870	0.949	0.938		69.0
43	0.367	1.746	0.944	0.931		69.0
44	0.310	1.613	0.943	0.940		69.0
45	0.310	1.593	0.945	0.934		69.0
46	0.275	1.505	0.939	0.927		69.0
47	0.237	1.395	0.939	0.926		69.0
49	0.205	1.2985	0.936	0.922		69.0
50	0.170	1.173	0.936	0.923		69.0
51	0.145	1.030	0.931	0.913		69.0
52	0.120	0.938	0.934	0.92[illegible]		68.5

[illegible] RUN 5 - D

Reading	h ft.	Q c.f.s.	C_v	C	Lost Head ft.	Temp. Water °F
2	[illegible]	[illegible].770	[illegible]	[illegible]		[illegible]
3	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
[illegible]	2.[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
[illegible]	1.[illegible]	[illegible].150	[illegible]	[illegible]		[illegible]
7	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
10	1.[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
11	[illegible]	[illegible]	[illegible]	[illegible]		69.0
[illegible]	1.173	[illegible]	[illegible]	[illegible]		[illegible]
13	1.1[illegible]	[illegible].147	0.946	[illegible]		[illegible]
14	1.137	[illegible]	[illegible]	[illegible]		[illegible]
15	.173	[illegible].172	0.954	[illegible]		70.0
[illegible]	1.050	[illegible]	[illegible]	[illegible]		70.0
17	[illegible]	[illegible]	[illegible]	[illegible]		70.0
[illegible]	1.[illegible]	[illegible].270	[illegible]	[illegible]		70.0
19	1.[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
20	1.[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
21	1.[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
[illegible]	1.200	[illegible]	[illegible]	[illegible]		[illegible]
23	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
[illegible]	0.7[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
27	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
30	0.417	[illegible]	[illegible]	[illegible]		[illegible]
[illegible]	[illegible]	1.7[illegible]	[illegible]	[illegible]		
33	[illegible]	1.742	[illegible]	[illegible]		[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
[illegible]	[illegible].183	[illegible]	[illegible]	[illegible]		[illegible]
[illegible]	0.133	[illegible]	[illegible]	[illegible]		[illegible]
40	0.150	1.11[illegible]	[illegible]	[illegible]		[illegible]
41	[illegible].153	1.114	[illegible]	[illegible]		[illegible]
42	0.1[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
[illegible]	1.[illegible]	3.[illegible]	[illegible]	[illegible]		[illegible]
70	1.[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
71	1.7[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
[illegible]	1.[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
73	1.[illegible]	[illegible]	[illegible]	[illegible]		[illegible]

DATA FOR R.L. 3 - D ([illegible])

Reading	h ft.	Q c.f.s.	C_v	C	Loss Head ft.	Temp. Water °F
74	2.080	4.140	0.939	0.927		68.5
76	2.077	4.140	0.940	0.928		68.5
77	[illegible]5	4.235	0.940	0.928		68.5
78	2.320	4.400	0.9[illegible]	0.935		[illegible].5
79.	2.323	[illegible].465	[illegible]	0.946		69.0
80	2.692	4.755	0.947	0.937		69.0
84	3.310	[illegible]	[illegible]	0.951		69.5
85	[illegible]	[illegible]	[illegible]	0.943		70.0
86	3.368	5.765	[illegible]	.947		70.0
88	3.570	5.535	0.962	0.954		70.0
89	4.157	6.025	0.962	0.955		69.5
90	4.678	6.330	0.955	0.946		70.0
91	4.865	6.435	0.959	0.950		70.0
92	3.980	5.325	0.953	0.943		70.0
93	4.103	[illegible]	0.961	0.954		70.0
95	3.520	5.460	0.943	0.930		
96	3.573	5.470	0.946	.933		70.5
98	3.470	5.470	0.957	0.943		70.5
99	3.2[illegible]	[illegible].270	.95[illegible]	[illegible]		71.0
101	2.[illegible]73	[illegible].070	[illegible]	0.950		71.0
102	2.913	[illegible]	0.951	0.945		71.0
103	2.397	4.[illegible]	0.942	0.932		71.0
104	2.57[illegible]	4.570	0.950	0.940		71.[illegible]
105	2.555	4.770	0.953	0.943		71.5

DATA FOR RUN 3 - E

Reading	h ft.	Q c.f.s.	C_v	C	Lost Head ft.	Temp. Water °F
2	0.137	1.052	0.932	0.919		70.0
3	0.137	1.054	0.933	0.920		70.0
5	0.150	1.111	0.939	0.927		70.0
6	0.205	1.286	0.932	0.917		70.0
7	0.182	1.215	0.934	0.920		70.0
8	0.242	1.411	0.939	0.926		70.0
9	0.337	1.652	0.933	0.920		70.0
10	0.407	1.806	0.929	0.915		70.0
11	0.438	1.880	0.932	0.922		70.0
13	0.482	[illegible]	0.951	0.941		70.0
14	0.542	2.110	0.939	0.926		70.0
15	0.637	2.208	0.942	0.931		70.0
16	0.693	2.383	0.939	0.926		70.0
17	0.718	2.417	0.935	0.922		70.0
18	0.780	2.543	0.942	0.930		70.0
19	0.730	2.535	0.940	0.927		67.5
20	0.845	2.670	0.949	0.939		[illegible]
21	0.908	2.745	0.943	0.931		68.0
22	0.950	2.836	0.950	0.940		68.0
23	1.000	[illegible]	0.948	0.937		68.0
24	1.053	2.938	0.951	0.941		68.0
25	1.093	3.022	0.945	0.934		68.0
26	1.130	[illegible]	0.947	0.936		68.5
27	1.053	[illegible]	0.952	0.942		
28	1.220	3.223	0.953	0.943		69.0
29	1.295	3.322	0.955	0.943		69.0
30	1.378	3.447	0.955	0.946		69.0
31	1.392	3.432	0.361	0.953		69.0
32	1.412	3.528	0.953	0.950		69.5
33	1.493	3.568	0.954	0.945		[illegible]
34	1.528	3.623	0.957	0.948		69.5
35	1.548	3.640	0.954	0.946		70.0

DATA FOR RUN 4 - A

Reading	h ft.	Q c.f.s.	C_v	C	Lost Head ft.	Temp. Water °F
1	0.110	0.973	0.956	0.948	0.033	56.0
2	0.150	1.124	0.948	0.938	0.045	56.0
3	0.223	1.358	0.941	0.929	0.067	56.0
4	0.220	1.355	0.945	0.934	0.070	56.5
5	0.218	1.350	0.946	0.934	0.055	56.5
6	0.307	1.610	0.949	0.939	0.095	57.0
7	0.410	1.853	0.943	0.938	0.098	57.0
8	0.500	2.050	0.948	0.937	0.150	57.0
9	0.590	2.234	0.950	0.940	0.178	57.0
10	0.690	2.420	0.951	0.941	0.210	57.0
11	0.837	2.698	0.961	0.953	0.255	57.0
12	0.840	2.651	0.946	0.935	0.248	57.0
13	0.932	2.850	0.962	0.954	0.270	57.5
14	0.928	2.835	0.959	0.951	0.270	57.5
15	1.035	2.967	0.952	0.942	0.302	57.5
16	1.128	3.110	0.955	0.946	0.328	57.5
17	1.213	3.222	0.955	0.945	0.350	57.5
18	1.322	3.380	0.958	0.950	0.375	57.5
19	1.415	3.485	0.955	0.945	0.398	57.5
20	1.513	3.640	0.964	0.956	0.442	57.5
23	1.607	3.725	0.958	0.950	0.453	57.5
24	1.730	3.841	0.954	0.944	0.488	58.0
25	6.613	7.625	0.965	0.958	1.880	58.0
26	6.297	7.350	0.956	0.946	1.762	58.0
27	5.948	7.120	0.953	0.942	1.667	59.0
28	5.635	7.025	0.964	0.957	1.570	59.0
29	5.645	7.025	0.963	0.955	1.597	59.0
30	5.423	6.875	0.961	0.954	1.508	59.0
32	4.550	6.260	0.954	0.948	1.283	59.5
33	4.215	6.065	0.963	0.954	1.183	60.0
34	3.832	5.780	0.962	0.954	1.085	60.0
35	3.570	5.525	0.954	0.944	1.010	60.0
36	3.283	5.340	0.960	0.952	0.910	60.0
37	2.873	4.900	0.945	0.934	0.813	60.0
38	2.865	4.975	0.958	0.950	0.795	60.0
39	3.077	5.120	0.953	0.943	0.858	60.0
40	4.015	5.935	0.964	0.957	1.112	60.0
41	4.705	6.410	0.962	0.955	1.302	60.5
43	2.673	4.740	0.947	0.936	0.750	60.5
44	2.422	4.575	0.958	0.950	0.700	61.0
45	2.237	4.375	0.955	0.946	0.638	61.0
46	1.995	4.180	0.964	0.956	0.583	61.0
47	2.003	4.098	0.946	0.934	0.575	61.0
48	1.997	4.160	0.959	0.951	0.585	61.0
49	1.840	3.965	0.954	0.944	0.533	61.5

DATA FOR RUN 4 - [illegible]

Reading	h ft.	Q c.f.s.	C_v	C	Lost Head ft.	Temp. Water °F
2	1.916	4.087	0.962	0.954	0.702	62.0
4	1.760	3.918	0.962	0.952	0.618	62.5
5	1.670	3.333	0.965	0.958	0.608	62.5
6	1.533	3.640	0.959	0.950	0.540	63.0
7	1.402	3.483	0.959	0.950	0.503	63.0
10	1.152	3.045	0.930	0.917	0.452	63.0
11	1.140	3.070	0.941	0.928	0.430	63.0
12	1.055	3.010	0.955	0.946	0.400	63.0
13	0.927	2.810	0.955	0.945	0.352	63.0
14	0.820	2.653	0.956	0.946	0.312	63.0
15	0.638	2.442	0.959	0.951	0.268	63.0
16	0.612	2.276	0.950	0.940	0.240	63.0
17	0.540	2.164	0.960	0.952	0.217	63.0
18	0.497	2.055	0.949	0.940	0.193	63.0
19	0.483	2.018	0.949	0.938	0.188	63.0
20	0.485	2.023	0.949	0.939	0.187	63.0
21	0.405	1.869	0.958	0.949	0.160	63.0
22	0.305	1.602	0.948	0.937	0.120	63.0
24	0.155	1.148	0.953	0.942	0.062	63.0
25	0.110	0.967	0.951	0.942	0.045	63.5
26	0.150	1.151	0.949	0.938	0.065	63.5
27	0.250	1.454	0.956	0.939	0.100	63.5
28	0.428	1.920	0.957	0.948	0.173	63.5
30	0.642	2.622	0.947	0.937	0.247	63.0
31	1.130	3.140	0.962	0.954	0.440	64.0
32	1.233	3.223	0.948	0.938	0.473	64.0
33	1.470	3.552	0.956	0.945	0.565	64.0
34	1.813	3.927	0.952	0.942	0.698	64.0
35	2.257	4.425	0.960	0.952	0.863	64.0
36	2.423	4.590	0.960	0.953	0.933	64.0
37	2.503	.643	0.948	0.937	0.973	64.0
38	2.568	4.643	0.947	0.936	0.960	64.0
39	2.728	4.797	0.949	0.938	1.020	64.0
40	2.903	5.005	0.957	0.949	1.033	64.0
41	3.073	5.100	0.949	0.939	1.153	64.0
42	3.320	5.325	0.954	0.944	1.247	64.0
43	3.513	5.395	0.942	0.930	1.310	65.0
44	3.505	5.525	0.961	0.953	1.298	65.0
45	3.885	5.640	0.953	0.950	1.373	65.0
46	3.918	5.785	0.954	0.944	1.552	65.0
47	4.222	6.045	0.959	0.951	1.570	65.0
48	4.330	6.115	0.954	0.944	1.[illegible]0	65.0
49	4.495	6.185	0.952	0.942	1.693	65.5
50	4.740	6.410	.959	0.951	1.792	65.5
51	4.913	6.460	0.951	0.942	1.857	65.5

DATA FOR RUN 4 - B (CON'T.)

Reading	h ft.	Q c.f.s.	C_v	C	Lost Head ft.	Temp. Water °F
52	5.042	6.540	0.951	0.941	1.923	65.5
53	5.287	6.320	0.965	0.958	1.993	65.5
54	5.275	6.790	0.963	0.955	1.998	65.5
55	5.415	6.875	0.963	0.955	2.038	65.5
56	5.610	7.025	0.965	0.958	2.098	66.0
57	6.370	7.435	0.965	0.958	2.447	67.0
58	6.357	7.350	0.951	0.942	2.381	67.0
59	6.080	7.280	0.962	0.954	2.332	68.0
60	5.790	7.060	0.956	0.947	2.237	68.0
61	2.313	4.450	0.955	0.945	0.882	68.0
62	2.250	4.365	0.953	0.940	0.850	68.0
63	1.725	3.823	0.951	0.940	0.638	68.0
64	2.033	4.130	0.946	0.934	0.778	68.0
65	2.028	4.172	0.956	0.946	0.730	68.0

DATA FOR RUN 4 - C

Reading	h ft.	Q c.f.s.	C_v	C	Lost Head ft.	Temp. Water °F
3	0.483	1.970	0.930	0.917	0.510	68.0
4	0.693	2.405	0.945	0.934	0.748	68.0
5	0.705	2.435	0.943	0.937	0.762	68.0
6	0.632	2.375	0.951	0.941	0.682	68.0
7	0.532	2.085	0.937	0.924	0.560	68.0
8	0.525	2.030	0.940	0.928	0.555	68.0
9	0.443	1.912	0.941	0.928	0.470	68.0
10	0.862	2.[illegible]0	0.947	0.937	0.927	68.0
11	0.958	2.820	0.943	0.932	1.025	68.0
12	0.948	2.824	0.949	0.937	1.018	68.0
13	1.065	3.013	0.953	0.943	1.165	68.0
14	1.142	3.121	0.954	0.944	1.243	68.0
15	1.135	3.130	0.958	0.949	1.257	67.5
16	0.970	2.860	0.949	0.939	1.053	67.5
17	0.760	2.528	0.947	0.937	0.830	67.5
18	0.553	2.153	0.946	0.935	0.607	67.5
19	0.440	1.903	0.939	0.927	0.472	67.5
20	0.896	2.783	0.958	0.950	1.171	67.5
21	1.125	3.117	0.958	0.950	1.242	67.5
22	1.253	3.270	0.954	0.944	1.370	68.0
23	1.368	3.410	0.952	0.942	1.505	68.0
25	1.493	3.560	0.951	0.943	1.620	68.0
26	1.167	3.113	0.944	0.932	1.290	68.0
27	1.010	2.923	0.951	0.940	1.113	68.0
28	0.812	2.600	0.944	0.933	0.830	68.0
29	0.400	1.833	0.947	0.936	0.435	68.0
30	0.312	1.606	0.947	0.929	0.363	68.0

DATA FOR RUN 4 - C (CON'T.)

Reading	h ft.	Q c.f.s.	C_v	C	Lost Head ft.	Temp. Water °F
31	0.243	1.435	0.951	0.941	0.267	68.0
32	0.205	1.311	0.946	0.935	0.227	68.0
33	0.153	1.138	0.950	0.941	0.173	68.0
35	1.560	3.640	0.952	0.942	1.708	68.0
36	1.642	3.725	0.950	0.939	1.803	68.0
37	1.735	3.850	0.955	0.945	1.913	68.0
38	1.925	4.048	0.952	0.943	2.113	68.0
39	6.303	7.281	0.948	0.937	7.060	67.0
40	6.312	7.320	0.951	0.941	7.050	67.0
41	6.197	7.281	0.955	0.946	6.940	67.0
42	6.092	7.185	0.951	0.940	6.822	67.0
43	5.775	7.025	0.954	0.944	6.472	67.0
45	5.233	6.680	0.953	0.944	5.863	67.0
46	5.088	6.570	0.951	0.940	5.675	67.5
47	4.850	6.460	0.957	0.948	5.397	68.0
48	4.563	6.210	0.950	0.939	5.055	68.0
49	4.377	6.090	0.950	0.940	4.801	68.5
50	4.150	5.980	0.957	0.946	4.632	68.5
51	3.943	5.782	0.951	0.941	4.313	69.0
52	3.638	5.600	0.958	0.948	3.985	69.0
54	3.118	5.185	0.957	0.949	3.417	
55	2.900	4.978	0.954	0.944	3.235	69.0
56	2.723	4.810	0.951	0.942	2.932	69.0
57	2.528	4.645	0.953	0.944	2.735	69.0
58	2.322	4.462	0.956	0.946	2.522	69.0
60	2.047	4.160	0.949	0.939	2.123	69.5

DATA FOR RUN 4 - D

Reading	h ft.	Q c.f.s.	C_v	C	Lost Head ft.	Temp. Water °F
2	1.873	3.907	0.953	0.944		69.0
3	1.725	3.805	0.947	0.936		69.0
4	1.723	3.850	0.957	0.947		69.0
5	1.693	3.805	0.954	0.946		68.5
6	1.600	3.718	0.958	0.950		68.5
7	1.467	3.558	0.953	0.944		68.5
8	1.413	3.482	0.954	0.945		69.0
10	1.313	3.338	0.951	0.942		69.0
11	1.163	3.153	0.954	0.944		69.0
12	1.028	2.965	0.952	0.942		69.0
13	0.915	2.795	0.954	0.945		69.0
14	0.823	2.618	0.944	0.933		69.0
15	0.722	2.465	0.948	0.938		69.0
16	0.612	2.257	0.944	0.937		69.0
17	0.635	2.315	0.954	0.939		69.0
18	0.532	2.124	0.951	0.937		69.0
19	0.430	1.890	0.942	0.942		69.0
20	0.370	1.750	0.946	0.934		69.0
21	0.288	1.543	0.941	0.931		69.0
22	0.218	1.355	0.949	0.938		69.0
23	0.145	1.118	0.958	0.948		69.0
24	0.111	0.943	0.933	0.920		69.0
25	2.073	4.213	0.956	0.946		64.2
26	2.437	4.575	0.956	0.947		64.2
27	2.600	4.657	0.944	0.934		64.0
28	2.630	4.730	0.949	0.938		64.0
29	2.810	4.855	0.946	0.936		64.0
30	2.808	4.915	0.956	0.947		64.0
31	2.983	5.040	0.953	0.943		64.0
32	3.138	5.170	0.952	0.943		64.0
34	3.422	5.415	0.955	0.946		65.0
35	3.535	5.450	0.947	0.936		65.0
36	3.538	5.485	0.953	0.943		65.0
37	3.728	5.640	0.953	0.944		65.0
39	4.150	5.940	0.951	0.942		65.5
40	4.282	6.070	0.953	0.948		65.5
41	4.460	6.165	0.953	0.944		65.5
42	4.638	6.210	0.944	0.932		66.0
43	4.648	6.250	0.949	0.939		66.0
45	4.928	6.515	0.956	0.949		66.0
46	5.035	6.590	0.958	0.950		66.0

DATA FOR RUN 4 - E

Reading	h ft.	Q c.f.s.	C_v	C	Lost Head ft.	Temp. Water °F
2	0.778	2.543	0.943	0.932		66.0
3	0.827	2.604	0.937	0.925		66.0
4	0.863	2.680	0.945	0.933		66.0
5	0.938	2.790	0.943	0.931		66.0
6	1.202	3.160	0.943	0.932		66.0
7	1.200	3.203	0.954	0.945		66.0
8	1.173	3.140	0.946	0.935		66.0
9	1.175	3.117	0.941	0.930		66.0
11	1.072	3.000	0.947	0.936		66.0
12	1.057	2.990	0.949	0.939		66.0
13	1.025	2.930	0.946	0.935		66.0
14	0.910	2.752	0.944	0.933		66.0
15	0.703	2.438	0.950	0.940		66.0
17	0.525	2.075	0.938	0.925		66.5
18	0.503	2.043	0.938	0.927		66.5
19	0.455	1.954	0.938	0.926		66.5
20	0.430	1.875	0.937	0.924		66.5
21	0.422	1.850	0.933	0.921		66.5
24	1.200	3.204	0.955	0.945		61.0
25	1.353	3.409	0.956	0.947		61.0
26	1.503	3.569	0.950	0.940		61.0
29	1.678	3.770	0.950	0.940		61.5
30	1.648	3.710	0.945	0.933		61.5

DATA FOR RUN 5 - A

Reading	h ft.	Q c.f.s.	C_v	C	Lost Head ft.	Temp. Water °F
3	0.302	1.602	0.957	0.942	0.097	
4	0.305	1.602	0.948	0.937	0.083	59.0
8	0.172	1.193	0.945	0.933	0.056	59.5
18	0.101	0.934	0.958	0.949	0.028	
19	0.100	0.930	0.959	0.950	0.029	
23	0.104	0.931	0.944	0.932	0.030	59.0
25	0.112	1.017	0.961			59.0
28	0.296	1.571	0.944	0.933	0.09	59.0
29	0.350	1.737	0.957	0.949	1.10	59.0
30	0.353	1.723	0.948	0.937	0.103	59.0
31	0.365	1.755	0.949	0.939	0.109	
32	0.367	1.755	0.947	0.936	0.102	
33	0.410	1.873	0.955	0.946	0.119	
34	0.415	1.868	0.947	0.952	0.128	
35	2.176	4.272	0.946	0.936	0.548	59.0
36	2.138	4.275	0.944	0.932	0.360	
37	1.935	4.030	0.947	0.936	0.398	59.0
38	1.934	4.030	0.947	0.936	0.495	
39	1.679	3.793	0.955	0.946	0.437	60.0
40	1.707	3.793	0.948	0.938	0.436	

DATA FOR RUN 5 - A (CON'T.)

Reading	h ft.	Q c.f.s.	C_v	C	Lost Head ft.	Temp. Water °F
41	1.217	3.205	0.949	0.938	0.307	60.0
42	1.208	3.173	0.944	0.932	0.324	
44	0.931	2.848	0.962	0.954	0.237	60.0
45	0.901	2.750	0.947	0.936	0.243	
46	0.896	2.740	0.946	0.935	0.241	60.0
47	0.481	2.010	0.943	0.937	0.192	
48	0.497	2.023	0.942	0.930	0.174	60.0
49	0.615	2.297	0.950	0.947	0.162	
50	0.609	2.273	0.951	0.940	0.158	
53	0.478	2.022	0.954	0.944	0.110	60.0
54	0.482	2.022	0.951	0.941	0.122	60.5
55	0.642	2.321	0.946	0.935	0.154	60.5
56	0.642	2.321	0.946	0.935	0.171	60.5
57	0.903	2.776	0.953	0.944	0.235	60.5
58	0.901	2.750	0.947	0.936	0.238	60.5
59	1.057	2.967	0.945	0.932	0.269	60.0
60	1.053	2.930	0.950	0.939	0.273	60.0
61	1.193	3.153	0.943	0.931	0.315	61.0
62	1.195	3.173	0.948	0.933	0.312	61.0
63	1.224	3.205	0.946	0.935	0.320	60.5
64	1.227	3.220	0.948	0.938	0.321	60.5
65	1.275	3.270	0.947	0.936	0.327	60.5
66	1.273	3.270	0.949	0.936	0.330	60.5
67	5.261	6.305	0.943	0.931	1.287	61.0
69	4.825	6.330	0.949	0.939	1.193	61.0
73	2.910	4.930	0.944	0.932	0.725	61.2
74	2.924	4.970	0.949	0.944	0.729	61.2
76	2.486	4.577	0.949	0.938	0.618	61.5
77	1.650	3.77	0.957	0.948	0.411	62.0
78	1.647	3.725	0.949	0.937	0.410	62.0
79	2.300	4.420	0.951	0.941	0.597	62.5
80	2.313	4.420	0.949	0.940	0.593	62.5
82	2.231	4.300	0.949	0.939	0.571	62.5
83	2.154	4.273	0.950	0.941	0.554	6[illegible].0
84	2.150	4.245	0.946	0.935	0.548	6[illegible].0
91	1.044	2.980	0.952	0.942	0.262	60.0
92	1.412	3.513	0.955	0.946	0.392	59.0
94	2.172	4.250	0.944	0.932	0.553	5[illegible].0
95	2.219	4.330	0.954	0.939	0.547	[illegible]
96	2.929	4.960	0.947	0.936	0.738	5[illegible].0
98	3.448	5.360	0.944	0.932	0.853	59.0
101	4.467	6.180	0.952	0.942	1.113	56.0
102	4.207	5.980	0.951	0.942	1.038	56.0
103	4.330	6.385	0.949	0.939	1.225	56.0
104	4.638	6.310	0.951	0.941	1.165	57.5

DATA FOR RUN 5 - A (CON'T.)

Reading	h ft.	Q c.f.s.	C_v	C	Lost Head ft.	Temp. Water °F
105	3.810	5.660	0.948	0.936	0.958	58.0
106	3.605	5.490	0.945	0.934	0.392	58.0
107	3.030	5.070	0.951	0.941	0.753	58.0
109	0.633	2.413	0.955	0.944	0.172	58.5
110	0.835	2.540	0.944	0.933	0.215	58.5

DATA FOR RUN 5 - B

Reading	h ft.	Q c.f.s.	C_v	C	Lost Head ft.	Temp. Water °F
1	1.818	3.946	0.955	0.945	0.710	64.0
2	1.797	3.900	0.950	0.940	0.705	65.0
3	1.715	3.860	0.960	0.952	0.685	65.0
4	1.485	3.560	0.954	0.945	0.559	65.0
5	1.241	3.250	0.952	0.943	0.471	65.0
6	1.403	3.430	0.946			
8	1.322	3.383	0.959	0.952	0.500	65.5
9	0.956	2.860	0.955	0.945	0.365	66.0
11	1.119	3.080	0.951	0.940	0.418	66.0
12	0.923	2.835	0.961	0.953	0.360	66.0
13	0.913	2.788	0.952	0.943	0.348	66.0
14	0.817	2.625	0.949	0.939	0.314	66.0
15	0.682	2.399	0.949	0.939	0.255	66.0
16	0.631	2.304	0.948	0.938	0.252	66.0
17	0.578	2.195	0.944	0.933	0.228	66.0
18	0.565	2.173	0.946	0.935	0.225	66.0
19	0.542	2.141	0.950	0.940	0.217	66.0
20	0.430	1.914	0.953	0.943	0.160	66.0
21	0.265	1.500	0.951	0.942	0.106	66.5
22	0.630	2.318	0.954	0.944	0.250	67.0
23	0.447	1.953	0.954	0.944	0.1717	67.0
24	0.450	1.953	0.951	0.941	0.180	67.0
25	0.410	1.880	0.957	0.949	0.160	67.0
26	0.320	1.638	0.946	0.935	0.130	67.0
27	0.230	1.408	0.957	0.949	0.090	67.0
28	0.203	1.312	0.950	0.941	0.083	67.0
29	0.170	1.197	0.949	0.938	0.070	67.5
30	0.132	1.067	0.957	0.949	0.053	67.5
31	6.223	7.280	0.953	0.943	2.460	67.5
33	5.733	6.965	0.950	0.940	2.240	67.5
34	5.230	6.620	0.946	0.935	2.032	68.0
35	5.023	6.540	0.952	0.942	1.948	68.0
36	4.643	6.320	0.956	0.948	1.800	68.0
37	4.105	5.960	0.959	0.951	1.572	68.0
38	3.765	5.620	0.947	0.936	1.457	68.0
40	5.538	6.905	0.953	0.944	2.222	68.0

DATA FOR RUN 5 - F (CON'T.)

Reading	h ft.	Q c.f.s.	C_v	C	Lost Head ft.	Temp. Water °F
41	5.385	6.790	0.955	0.946	2.122	68.0
42	5.148	6.620	0.953	0.942	2.030	68.0
43	4.933	6.515	0.961	0.952	1.937	68.5
44	4.623	6.310	0.957	0.948	1.780	68.5
45	4.402	6.120	0.951	0.942	1.708	68.5
46	4.225	6.000	0.953	0.943	1.622	69.0
47	4.160	5.935	0.950	0.940	1.562	69.0
48	3.867	5.720	0.950	0.940	1.490	69.0
50	3.603	5.545	0.953	0.943	1.388	69.0
51	3.450	5.380	0.946	0.936	1.333	70.0
52	3.430	5.415	0.954	0.944	1.323	70.0
53	3.225	5.235	0.951	0.942	1.242	70.5
54	3.052	5.040	0.943	0.932	1.187	70.5
55	3.043	5.085	0.951	0.942	1.185	70.5
56	2.798	4.885	0.953	0.943	1.090	70.5
57	2.602	4.670	0.946	0.936	1.012	70.5
58	2.350	4.450	0.948	0.938	0.895	71.0
59	2.182	4.318	0.954	0.945	0.852	71.0
60	2.082	4.208	0.951	0.942	0.723	71.0
61	1.835	3.945	0.951	0.941	0.710	71.0

DATA FOR RUN 5 - C.

Reading	h ft.	Q c.f.s.	C_v	C	Lost Head ft.	Temp. Water °F
1	0.230	1.395	0.950	0.940	0.245	70.5
2	0.148	1.118	0.946	0.939	0.153	70.5
3	0.110	0.967	0.951	0.942	0.115	70.5
4	0.172	1.190	0.940	0.926	0.183	71.0
5	0.170	1.191	0.945	0.933	0.182	71.0
6	0.310	1.635	0.957	0.949	0.330	71.0
7	0.367	1.772	0.955	0.945	0.388	71.0
8	0.415	1.876	0.951	0.941	0.420	71.0
9	0.483	2.033	0.954	0.945	0.512	71:0
10	0.575	2.189	0.944	0.932	0.598	71.0
11	0.565	2.195	0.953	0.943	0.588	71.0
12	0.650	2.335	0.946	0.936	0.683	71.0
13	0.723	2.492	0.956	0.947	0.752	71.0
14	0.803	2.610	0.951	0.941	0.845	71.0
15	0.900	2.800	0.962	0.953	0.945	71.0
16	0.985	2.922	0.960	0.951	1.032	71.0
18	1.095	3.023	0.945	0.933	1.142	71.0
19	1.220	3.218	0.951	0.941	1.273	71.5
20	1.345	3.395	0.955	0.946	1.400	71.5
21	1.473	3.539	0.951	0.942	1.543	71.5
22	1.575	3.710	0.963	0.955	1.643	71.5
23	1.680	3.825	0.961	0.954	1.758	71.5

DATA FOR RUN 5 - C (CON'T.)

Reading	h ft.	Q c.f.s.	C_v	C	Lost Head ft.	Temp. Water °F
24	1.732	3.880	0.961	0.952	1.823	71.5
25	1.751	3.351	0.950	0.940	1.368	71.5
26	1.607	3.691	0.951	0.940	1.598	72.0
27	1.838	3.947	0.950	0.940	1.838	72.0
28	2.033	4.172	0.955	0.945	2.042	72.0
29	2.200	4.330	0.953	0.943	2.212	72.0
30	2.423	4.578	0.959	0.950	2.455	72.0
31	2.622	4.700	0.948	0.938	2.765	72.0
32	2.667	4.975	0.957	0.949	3.032	72.0
33	2.740	4.858	0.956	0.943	2.903	72.0
34	3.073	5.170	0.961	0.952	3.260	72.5
35	3.322	5.325	0.954	0.944	3.503	72.5
36	3.533	5.505	0.956	0.946	3.755	72.5
37	3.733	5.680	0.959	0.950	3.965	72.5
38	4.032	5.890	0.956	0.950	4.382	72.5
39	4.303	6.070	0.954	0.945	4.595	73.0
40	4.515	6.260	0.960	0.952	4.825	73.0
42	4.682	6.235	0.949	0.938	5.042	73.0
43	4.860	6.410	0.949	0.939	5.215	73.0
44	5.075	6.520	0.958	0.950	5.545	73.0
45	5.313	6.760	0.956	0.948	5.773	73.0
47	5.392	6.790	0.954	0.945	5.805	73.5
48	5.718	7.060	0.962	0.954	6.138	74.0
49	5.882	7.090	0.954	0.944	6.287	74.0
50	5.927	7.135	0.962	0.954	6.320	74.0

DATA FOR RUN 5 - D

Reading	h	Q	C_v	C	Lost Head	Temp. Water
1	1.667	3.780	0.955	0.946		70.5
2	1.643	3.727	0.949	.939		70.5
3	1.575	3.650	0.950	0.940		70.5
4	1.733	3.800	0.944	0.933		70.5
5	1.640	3.700	0.945	0.934		70.5
6	1.628	3.710	0.949	0.939		70.5
7	1.500	3.560	0.949	0.939		70.5
8	1.278	3.270	0.945	0.934		70.5
9	1.178	3.166	0.952	0.943		70.5
10	1.062	2.978	0.945	0.934		70.5
11	0.930	2.800	0.949	0.939		71.0
12	0.762	2.535	0.949	0.939		71.0
13	0.677	2.380	0.946	0.935		71.0
14	0.617	2.280	0.949	0.937		71.0
15	0.590	2.212	0.943	0.931		71.0
16	0.552	2.170	0.954	0.944		71.0
17	0.530	2.125	0.953	0.943		71.0
18	0.522	2.103	0.950	0.940		71.0
19	0.500	2.053	0.949	0.938		71.0

DATA FOR [illegible] 5 - D (CONT.)

Reading	h ft.	Q c.f.s.	C_v	C	Lost Head ft.	Temp. Water °F
20	0.377	1.770	0.943	0.932		71.0
21	0.[illegible]35	1.553	0.949	0.940		71.0
22	0.[illegible]40	1.412	0.943	0.[illegible]31		71.0
23	0.[illegible]12	1.324	0.[illegible]41	0.[illegible]		71.0
26	4.[illegible]67	6.460	0.955	0.946		70.0
28	4.745	6.360	0.953	0.944		71.0
30	4.4[illegible]2	[illegible].160	0.954	0.944		71.5
31	[illegible].102	[illegible].000	0.956	0.946		71.5
33	3.[illegible]02	5.720	0.953	0.[illegible]48		72.0
34	3.588	5.[illegible]25	0.952	0.944		72.0
35	3.37[illegible]	5.540	0.949	0.939		72.0
36	3.207	[illegible].240	0.954	0.946		7[illegible].0
37	2.948	4.[illegible]90	0.949	0.939		
38	[illegible].353	4.[illegible]85	0.944	0.[illegible]33		7[illegible].5
39	[illegible].[illegible]67	4.945	0.953	0.94		7[illegible].5
40	[illegible].728	4.[illegible]	0.953	0.949		72.5
41	[illegible].[illegible]13	[illegible].723	0.954	0.9[illegible]		7[illegible].0
42	2.482	[illegible].[illegible]05	0.[illegible]54	0.944		73.0
43	2.350	4.[illegible]50	0.94[illegible]	0.937		73.0
44	[illegible].222	4.573	0.[illegible]57	0.94[illegible]		73.0
45	[illegible].073	[illegible].150	0.944	0.93[illegible]		73.0
46	1.[illegible]0	[illegible].100	0.949	0.93[illegible]		73.0
47	1.345	3.[illegible]08	0.[illegible]41	0.[illegible]29		7[illegible].5
48	1.[illegible]50	[illegible]	0.94[illegible]	0.[illegible]3[illegible]		
49	0.432	1.[illegible]05	0.946	0.935		72.0
50	0.345	1.[illegible]	0.94[illegible]	0.93[illegible]		72.0
51	0.270	1.[illegible]07	0.943	[illegible].[illegible]37		72.5
52	0.[illegible]13	1.342	0.949	0.939		72.5
53	0.160	1.146	0.933	0.[illegible]23		[illegible]
54	0.137	1.05[illegible]	0.936	[illegible].923		7[illegible].5
55	0.135	1.056	0.941	0.923		7[illegible].5

DATA FOR [illegible] 5 - E

Reading	h ft.	Q c.f.s.	C_v	C	Lost Head ft.	Temp. Water °F
1	0.[illegible]35	[illegible].726	0.947	0.[illegible]36		7[illegible]
2	0.[illegible]23	[illegible].[illegible]13	0.94[illegible]	0.932		7[illegible].5
3	0.[illegible]20	[illegible].510	0.[illegible]43	0.932		7[illegible].5
4	0.[illegible]12	[illegible].[illegible]34	0.[illegible]39	0.927		7[illegible].5
5	0.107	0.921	0.925	0.[illegible]10		71.[illegible]
6	0.1[illegible]	1.135	0.927	0.[illegible]11		71.[illegible]
8	0.193	1.[illegible]	0.[illegible]9	0.[illegible]13		71.5
9	0.[illegible]	[illegible].[illegible]7	0.[illegible]32	[illegible]		71.5
10	0.300	[illegible].[illegible]	0.937	[illegible]		7[illegible]
11	0.347	1.[illegible]73	[illegible]	[illegible]		7[illegible].5
12	0.3[illegible]	1.7[illegible]	0.[illegible]39	[illegible]		71.5
13	0.457	[illegible].[illegible]1[illegible]	[illegible].930	0.[illegible]15		71.5

Reading	h ft.	Q c.f.s.	C_v	C	Lost Head ft.	Temp. Water °F
14	0.503	2.023	0.936	0.921		71.5
15	0.540	2.103	0.937	0.924		71.5
16	0.592	2.200	0.937	0.925		71.5
17	0.675	2.300	0.940	0.926		71.5
18	0.730	2.447	0.937	0.925		71.5
19	0.810	2.510	0.947	0.937		71.5
20	0.895	2.735	0.945	0.934		71.5
21	0.950	2.827	0.947	0.937		71.5
22	1.003	2.870	0.935	0.929		71.5
23	1.030	2.912	0.939	0.927		70.0
24	1.033	2.933	0.944	0.933		70.5
25	1.052	2.912	0.932	0.918		70.5
26	1.043	2.946	0.941	0.929		71.0

DATA FOR RUN 6

Reading	h ft.	Q c.f.s.	C_v	C	Lost Head ft.	Temp. Water °F
4	1.742	1.517	0.977	0.974	0.493	67.5
5	2.055	1.680	0.969	0.964	0.590	67.5
8	2.537	1.817	0.971	0.966	0.633	67.5
9	3.193	2.032	0.969	0.964	0.858	68.0
10	3.635	2.150	0.972	0.969	0.960	67.0
11	3.955	2.263	0.971	0.967	1.072	66.0
12	4.430	2.400	0.970	0.966	1.200	66.0
14	4.615	2.363	0.969	0.965	1.168	67.5
15	4.815	2.510	0.974	0.970	1.300	67.5
16	5.357	2.606	0.980	0.977	1.442	68.0
17	5.335	2.655	0.977	0.973	1.437	68.0
18	5.665	2.745	0.980	0.976	1.530	68.0
19	6.038	2.790	0.967	0.962	1.635	68.0
20	6.417	2.895	0.972	0.968	1.730	68.0
23	7.623	3.173	0.983	0.980	2.033	68.0
24	8.082	3.290	0.983	0.980	2.193	68.0
25	8.605	3.390	0.981	0.979	2.367	68.0
26	9.233	3.490	0.974	0.970	2.520	68.0
27	9.590	3.570	0.979	0.976	2.650	68.0
28	10.257	3.675	0.975	0.972	2.863	68.0
29	11.130	3.843	0.979	0.975	3.095	68.0
30	1.675	1.463	0.974	0.970	0.457	68.0
31	1.460	1.368	0.965	0.959	0.383	68.5
33	1.273	1.302	0.979	0.976	0.353	68.5
34	1.103	1.202	0.972	0.970	0.302	68.5
35	0.987	1.141	0.977	0.973	0.285	68.5
36	0.817	1.043	0.981	0.978	0.222	68.5
37	0.585	0.8845	0.982	0.980	0.163	68.5
38	0.428	0.757	0.983	0.980	0.122	68.5
39	0.268	0.599	0.982	0.980	0.078	68.5

DATA FOR RUN 6 (CON'T.)

Reading	h ft.	Q c.f.s.	C_v	C	Lost Head ft.	Temp. Water °F
40	2.375	1.773	0.978	0.975	0.638	68.0
41	2.282	1.745	0.981	0.978	0.613	68.0
42	2.533	1.838	0.981	0.979	0.685	68.0
43	2.955	1.974	0.976	0.974	0.812	68.0
44	3.435	2.120	0.972	0.969	0.933	68.0
45	3.942	2.272	0.973	0.970	2.063	68.0
46	4.452	2.412	0.972	0.968	1.210	68.0
47	5.233	2.628	0.976	0.973	1.422	68.0
48	5.465	2.670	0.972	0.968	1.483	68.0
49	5.360	2.772	0.974	0.970		69.0
50	7.678	3.123	0.977	0.973	2.010	69.0
51	7.960	3.244	0.977	0.974	2.177	
52	0.732	0.980	0.973	0.970	0.268	69.0
53	0.508	0.824	0.982	0.978	0.143	69.0

DATA FOR RUN 7

Reading	h ft.	Q c.f.s.	C_v	C	Lost Head ft.	Temp. Water °F
1	1.795	1.510	0.961	0.954	1.232	66.5
2	2.638	1.829	0.960	0.954	1.740	67.0
3	2.750	1.875	0.964	0.958	1.733	66.5
4	3.232	2.053	0.965	0.959	2.148	66.5
6	3.610	2.130	0.957	0.952	2.328	67.0
7	2.247	1.683	0.958	0.951	1.492	67.0
8	3.995	2.258	0.962	0.956	2.627	67.0
9	5.108	2.535	0.957	0.950	3.343	67.0
10	5.525	2.636	0.957	0.950	3.642	67.5
11	6.050	2.754	0.956	0.946	3.945	67.5
12	6.622	2.900	0.961	0.955	4.305	67.5
13	7.258	3.020	0.957	0.950	4.752	67.5
14	7.802	3.135	0.957	0.951	5.113	67.5
15	8.368	3.244	0.957	0.950	5.498	68.0
16	8.942	3.390	0.965	0.960	5.962	68.0
17	9.415	3.454	0.959	0.953	6.2[illegible]0	68.0
18	9.910	3.578	0.968	0.963	6.505	68.0
19	10.432	3.685	0.971	0.966	6.857	68.0
20	10.910	3.725	0.961	0.956	7.212	68.0
21	10.865	3.710	0.959	0.954	7.178	68.0
22	11.568	3.822	0.959	0.952	7.[illegible]0	68.0
23	1.390	1.331	0.962	0.957	0.905	68.0
24	1.240	1.255	0.961	0.954		68.0
25	1.020	1.132	0.956	0.949	0.658	68.0
26	0.805	1.017	0.965	0.961	0.515	68.0
27	0.640	0.903	0.962	0.956	0.413	68.0
28	0.492	0.7935	0.964	0.958	0.317	68.0
29	0.338	0.6625	0.970	0.965	0.225	68.0
30	0.213	0.531	0.978	0.974	0.150	68.0
31	0.220	0.534	0.969	0.964	0.150	68.0

[illegible] - A

Reading	H	Q	C_v	C	Lost Head ft.	Temp. Water
1	2.107	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2	2.115	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3	[illegible]	[illegible]	[illegible]	[illegible]	1.150	[illegible]
4	[illegible]	[illegible]	0.942	[illegible]	1.150	[illegible]
5	1.375	[illegible]	[illegible]	0.936	[illegible]	
6	[illegible]	[illegible]	0.950	[illegible]	[illegible]	
7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
8	[illegible]	[illegible]	0.951	0.944	[illegible]	[illegible]
9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
13	[illegible]	0.917	0.950	0.943	[illegible]	[illegible]
14	[illegible]	2.150	0.951	[illegible]	[illegible]	[illegible]
15	[illegible]	[illegible]	0.945	0.941	[illegible]	[illegible]
16	[illegible]	[illegible]	0.950	[illegible]	[illegible]	[illegible]
17	[illegible]	[illegible]	0.948	[illegible]	[illegible]	[illegible]
18	[illegible]	[illegible]	[illegible]	0.945	[illegible]	[illegible]
19	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
20	[illegible]	[illegible]	0.956	0.949	[illegible]	64.0
21	[illegible]	[illegible]	0.944	0.937		[illegible]
22	10.752	[illegible]	0.955	[illegible]		[illegible]
23	[illegible]	3.400	0.954	[illegible]		[illegible]
24	[illegible]	[illegible]	0.958	[illegible]		[illegible]
25	[illegible]	[illegible]	0.959	0.953		[illegible]
26	[illegible]	[illegible]	0.950	0.954		[illegible]
27	1.032	1.127	0.948	0.940	[illegible]	[illegible]
28	0.508	0.734	0.951	0.943	0.327	[illegible]
29	0.375	[illegible]	0.950	[illegible]	0.235	[illegible]
30	[illegible]	[illegible]	[illegible]	[illegible]	0.200	[illegible]
31	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
32	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
33	[illegible]	[illegible]	[illegible]	0.942		[illegible]
34	[illegible]	[illegible]	[illegible]	0.952		[illegible]

DATA FOR RUN 8 - F

Reading	h ft.	Q c.f.s.	C_v	C	Lost Head ft.	Temp. Water °F.
2	0.343	0.307	0.953	0.945		66.5
3	0.547	0.322	0.919	0.940		66.0
4	.725	0.357	0.941	0.932		66.0
5	0.703	0.383	0.955	0.943		66.5
8	0.210	0.5116	0.953	0.946		
9	0.295	.601	0.946	0.936		66.0
10	0.3[illegible]3	0.673	0.9[illegible]	0.947		66.0
11	0.937	1.100	0.948	0.936		66.0
12	1.147	1.193	0.951	0.944		66.0
13	1.293	1.257	0.948	0.936		66.0
14	1.300	1.275	0.954	.947		
15	1.347	1.335	0.915	0.933		66.0
16	1.733	1.457	0.951	0.942		66.0
17	2.055	1.590	0.943	0.939		66.0
18	2.227	1.[illegible]55	0.954	0.946		66.0
19	2.555	1.817	0.950	0.943		66.5
20	3.117	1.974	0.954	0.947		66.5
21	3.542	2.030	0.946	0.937		66.5
22	3.843	2.112	0.958	0.951		66.5
23	3.900	2.210	0.955	0.943		66.5
24	4.233	2.320	0.957	0.950		66.5
25	4.572	2.390	0.955	0.947		66.5
26	5.003	2.470	0.944	0.936		66.5
27	4.9[illegible]3	2.495	0.954	0.946		66.5
28	5.443	2.620	0.957	0.951		
29	5.737	2.690	0.954	0.947		67.0
30	6.053	2.725	0.954	0.938		67.0
31	6.238	2.795	0.954	0.946		
32	7.073	2.990	0.959	0.952		

DATA FOR RUN 8 - C

1	0.192	0.435	0.946	0.938		66.0
4	0.493	0.784	0.949	0.941		67.0
6	0.727	0.954	0.955	0.947		66.5
7	0.805	0.997	0.949	0.941		67.0
8	0.893	1.054	0.953	0.944		67.0
9	0.943	1.030	0.947	0.940		67.0

DATA FOR RUN 9 - A

Reading	h ft.	Q c.f.s.	C_v	C	Lost Head ft.	Temp. Water °F
1	1.914	0.853	0.963	0.946		60.0
2	3.436	0.878	0.960	0.943		60.5
3	2.807	0.796	0.963	0.946		60.5
4	0.750	0.413	0.973	0.961		61.0
8	2.743	0.787	0.962	0.945		62.5
10	1.909	0.853	0.959	0.941		62.5
11	0.871	0.442	0.960	0.941		63.0
13	0.522	0.340	0.956	0.937		63.0
15	0.530	0.347	0.964	0.943		63.5
16	3.636	0.907	0.963	0.947		63.5
17	5.360	1.094	0.959	0.940		63.5
19	0.582	0.3575	0.954	0.932		64.5
20	0.376	0.2880	0.955	0.936		64.5
21	0.244	0.2327	0.956	0.937		64.5
22	0.191	0.2053	0.956	0.935		65.0

DATA FOR RUN 9 - B

Reading	h ft.	Q c.f.s.	C_v	C	Lost Head ft.	Temp. Water °F
1	0.407	0.305	0.967	0.951		61.0
2	0.662	0.387	0.963	0.946		61.0
3	0.760	0.4155	0.964	0.948		60.5
4	0.890	0.450	0.965	0.950		61.0
5	1.443	0.571	0.963	0.945		61.0
6	1.699	0.627	0.970	0.958		60.5
7	1.846	0.653	0.970	0.957		61.0
9	2.338	0.733	0.968	0.954		61.0
10	2.663	0.769	0.957	0.938		61.0
11	2.838	0.797	0.959	0.942		61.0
12	3.012	0.814	0.954	0.934		61.0
13	3.241	0.850	0.958	0.940		61.0
14	0.310	0.2636	0.960	0.942		62.0

DATA FOR RUN 9 - C

Reading	h ft.	Q c.f.s.	C_v	C	Lost Head ft.	Temp. Water °F
1	0.130	0.1688	0.953	0.933		62.0
2	0.082	0.130	0.933	0.904		62.5
3	0.133	0.1748	0.968	0.952		63.0
4	0.239	0.2235	0.937	0.911		63.0
5	0.231	0.224	0.950	0.927		63.0

Appendix B

Graphs of Results

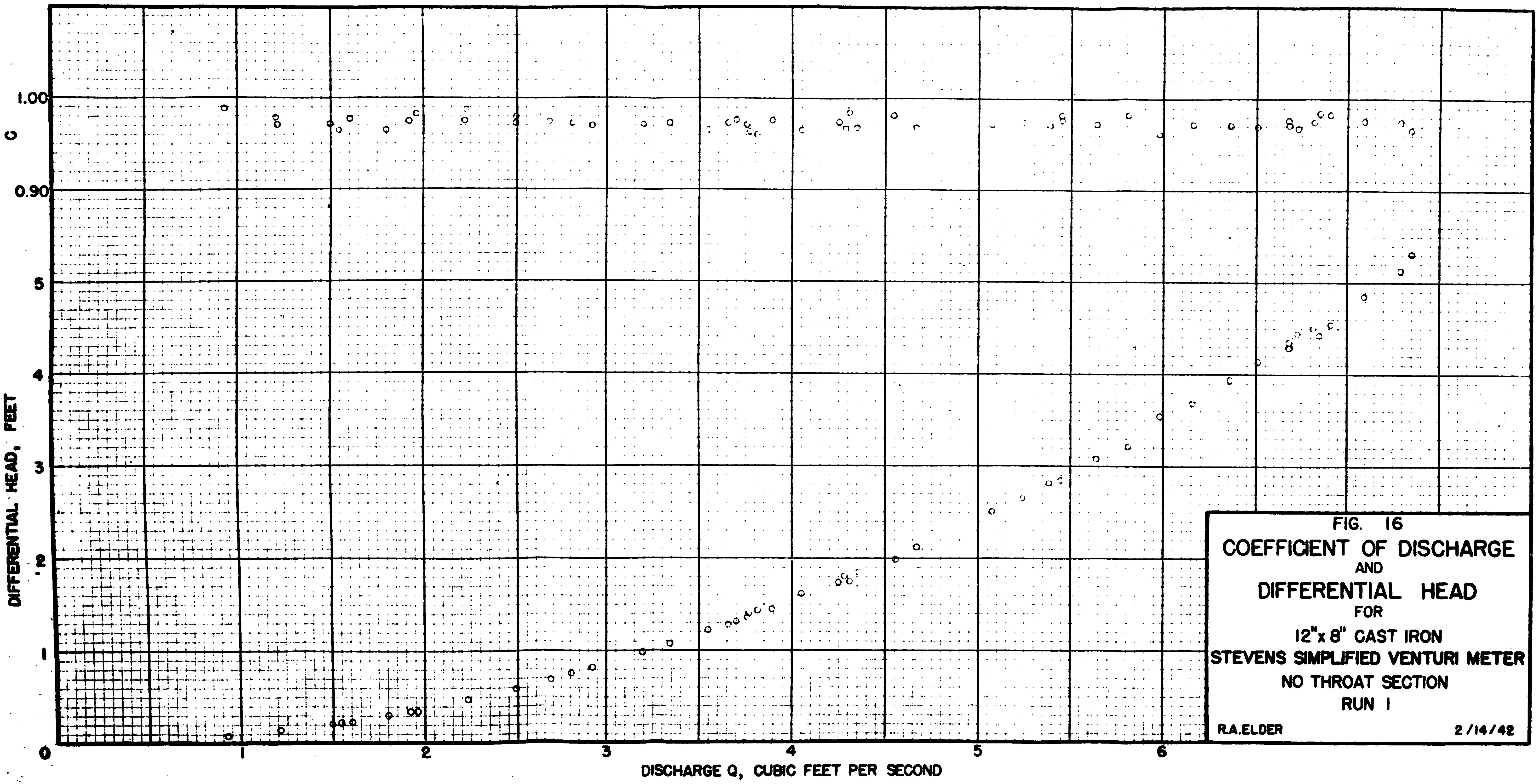


FIG. 16
COEFFICIENT OF DISCHARGE
AND
DIFFERENTIAL HEAD
FOR
12"x 8" CAST IRON
STEVENS SIMPLIFIED VENTURI METER
NO THROAT SECTION
RUN I

R.A.ELDER 2/14/42

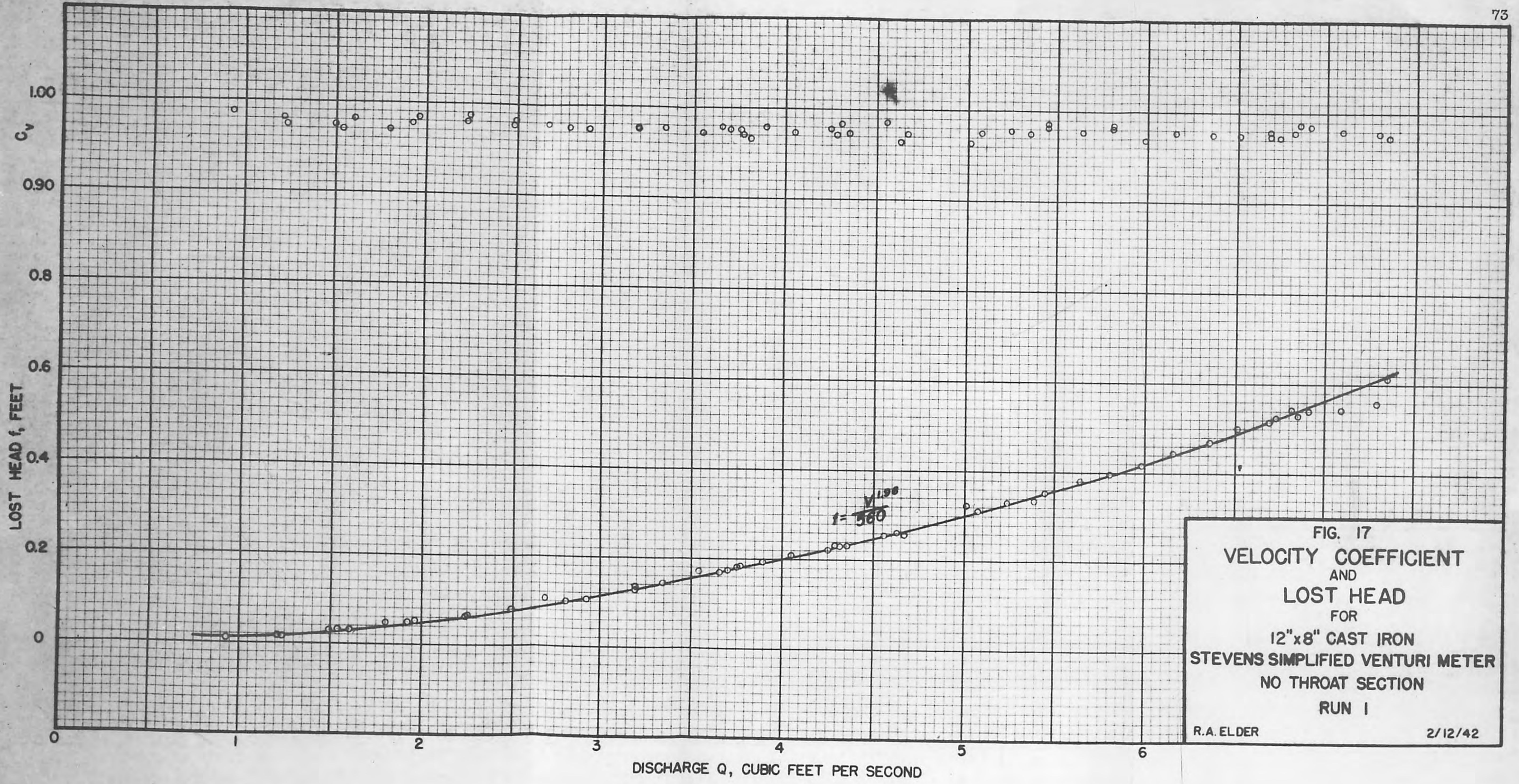


FIG. 17
VELOCITY COEFFICIENT
AND
LOST HEAD
FOR
12"x8" CAST IRON
STEVENS SIMPLIFIED VENTURI METER
NO THROAT SECTION
RUN 1

R.A. ELDER 2/12/42

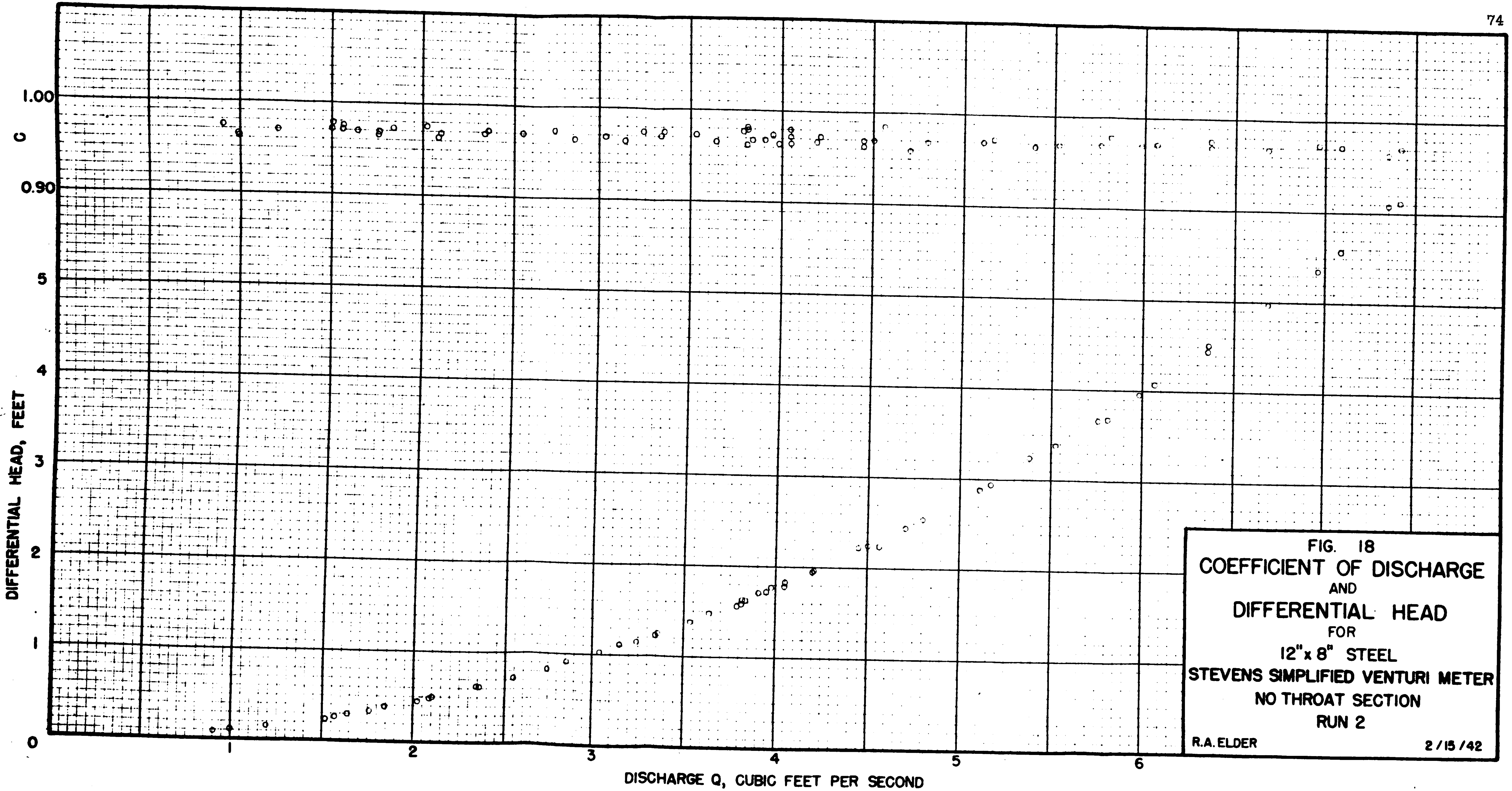


FIG. 18
COEFFICIENT OF DISCHARGE
AND
DIFFERENTIAL HEAD
FOR
12" x 8" STEEL
STEVENS SIMPLIFIED VENTURI METER
NO THROAT SECTION
RUN 2

R.A. ELDER 2/15/42

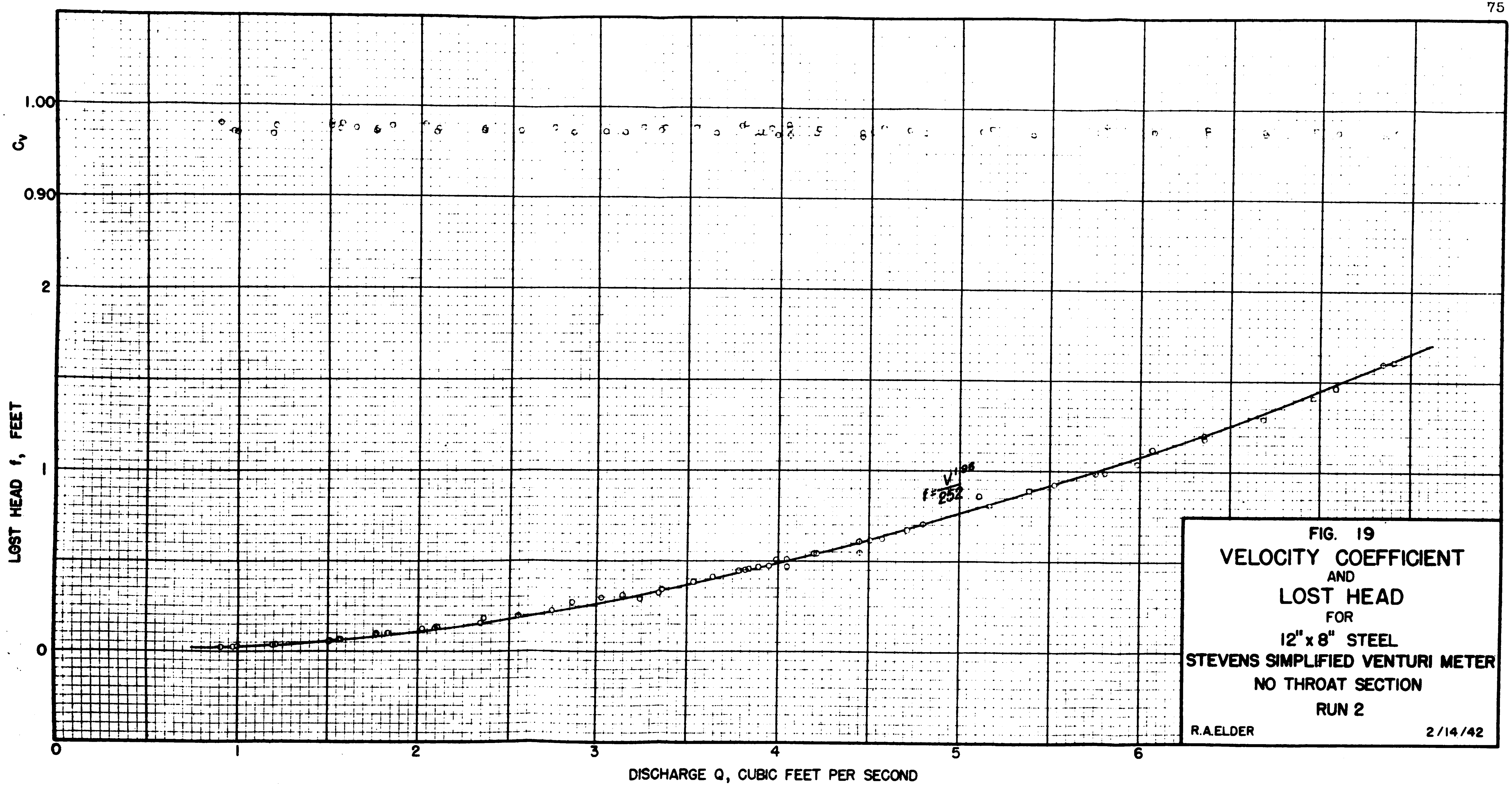


FIG. 19
VELOCITY COEFFICIENT
AND
LOST HEAD
FOR
12" x 8" STEEL
STEVENS SIMPLIFIED VENTURI METER
NO THROAT SECTION
RUN 2

R.A.ELDER 2/14/42

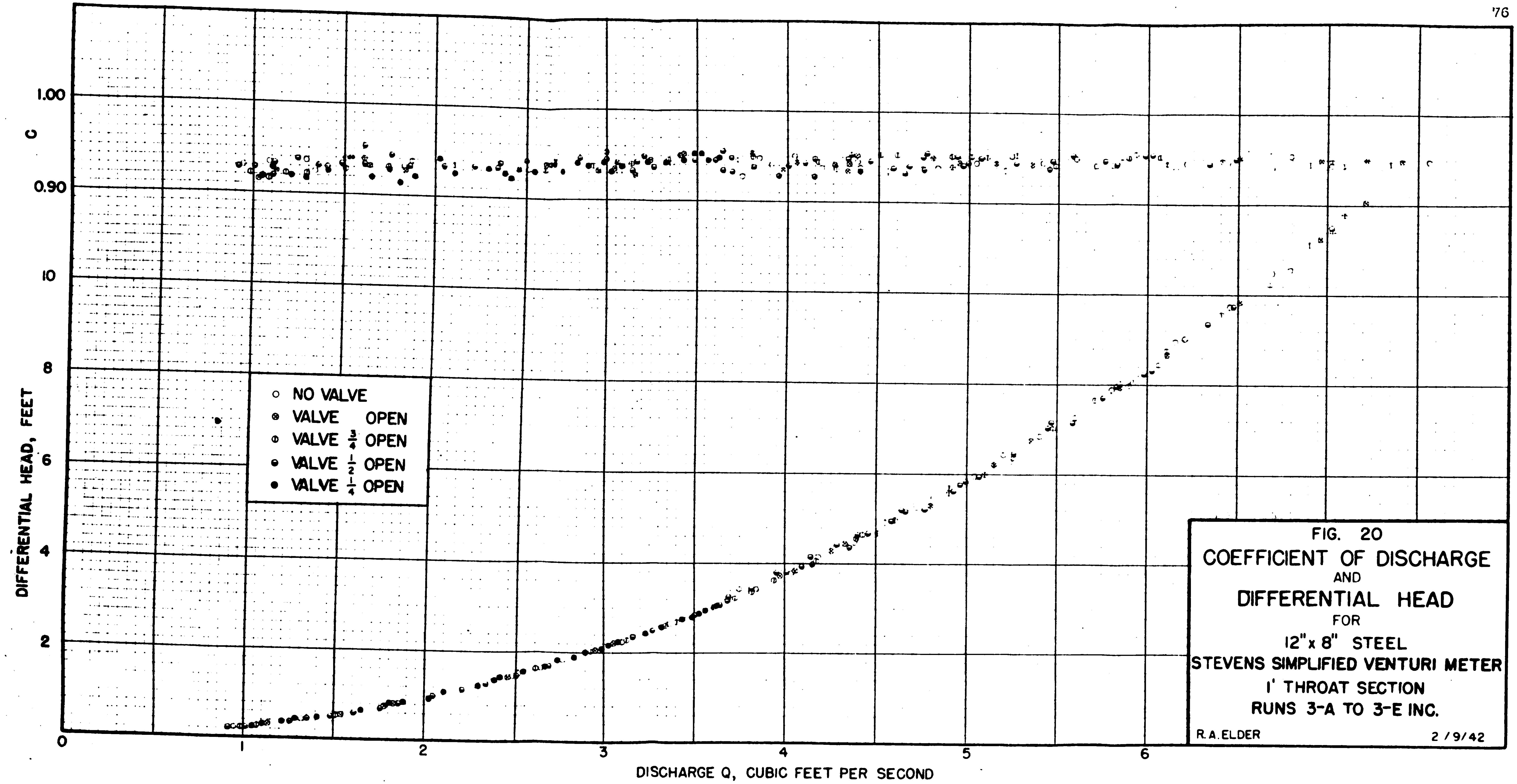


FIG. 20
COEFFICIENT OF DISCHARGE
AND
DIFFERENTIAL HEAD
FOR
12" x 8" STEEL
STEVENS SIMPLIFIED VENTURI METER
1' THROAT SECTION
RUNS 3-A TO 3-E INC.

R. A. ELDER 2/9/42

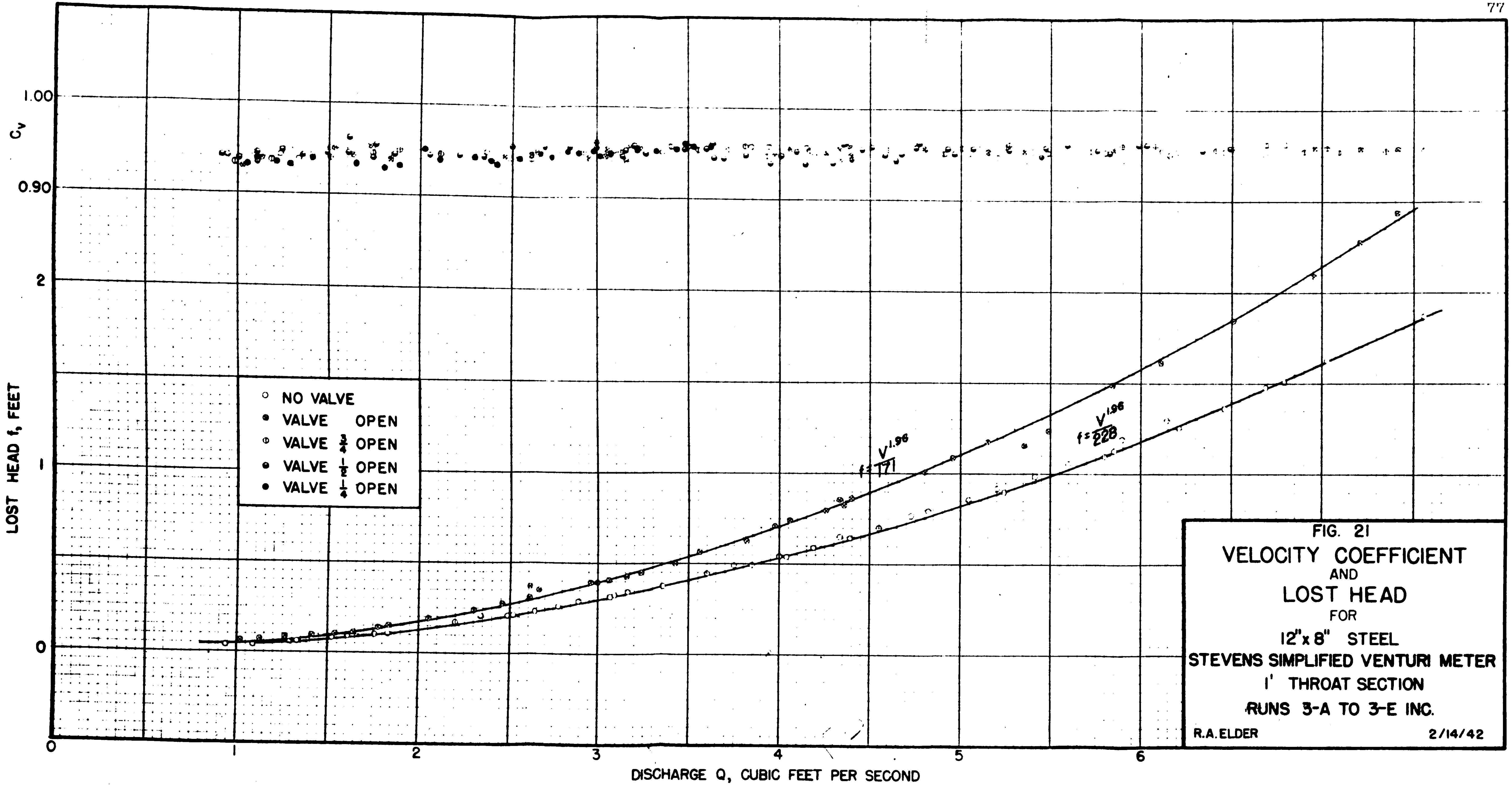


FIG. 21
VELOCITY COEFFICIENT
AND
LOST HEAD
FOR
12" x 8" STEEL
STEVENS SIMPLIFIED VENTURI METER
1' THROAT SECTION
RUNS 3-A TO 3-E INC.

R.A. ELDER 2/14/42

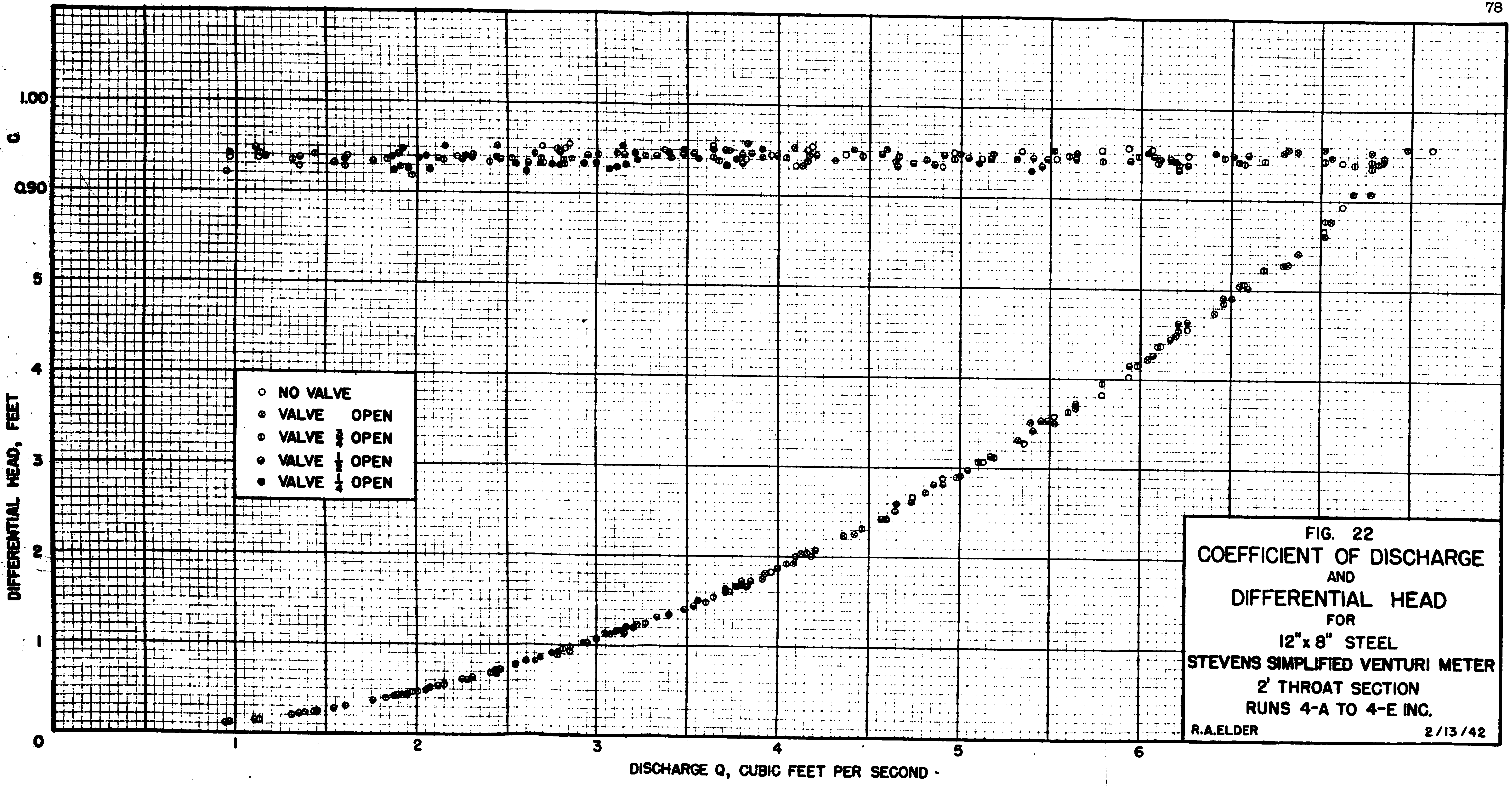


FIG. 22
COEFFICIENT OF DISCHARGE
AND
DIFFERENTIAL HEAD
FOR
12"x 8" STEEL
STEVENS SIMPLIFIED VENTURI METER
2' THROAT SECTION
RUNS 4-A TO 4-E INC.
R.A.ELDER 2/13/42

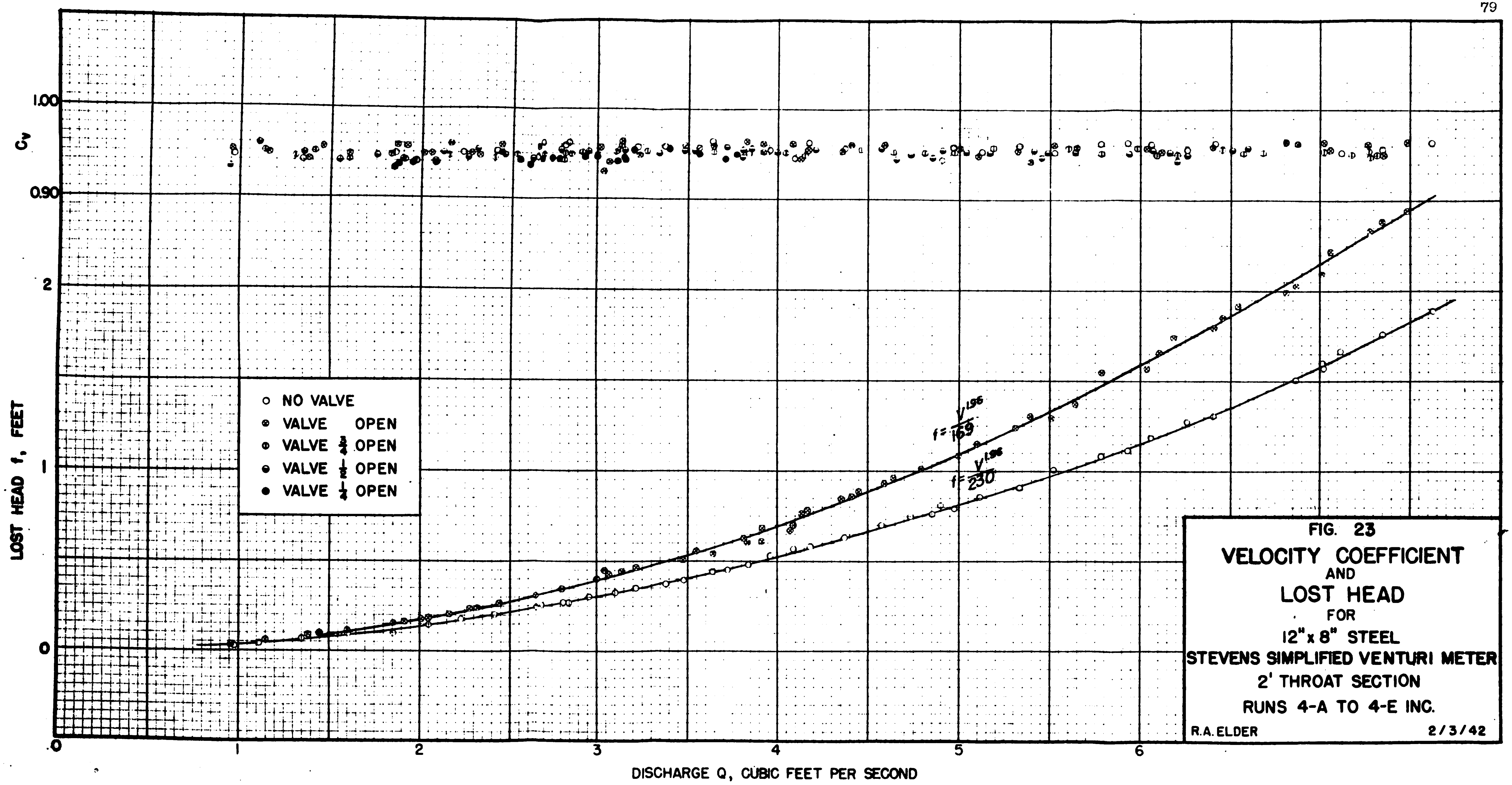
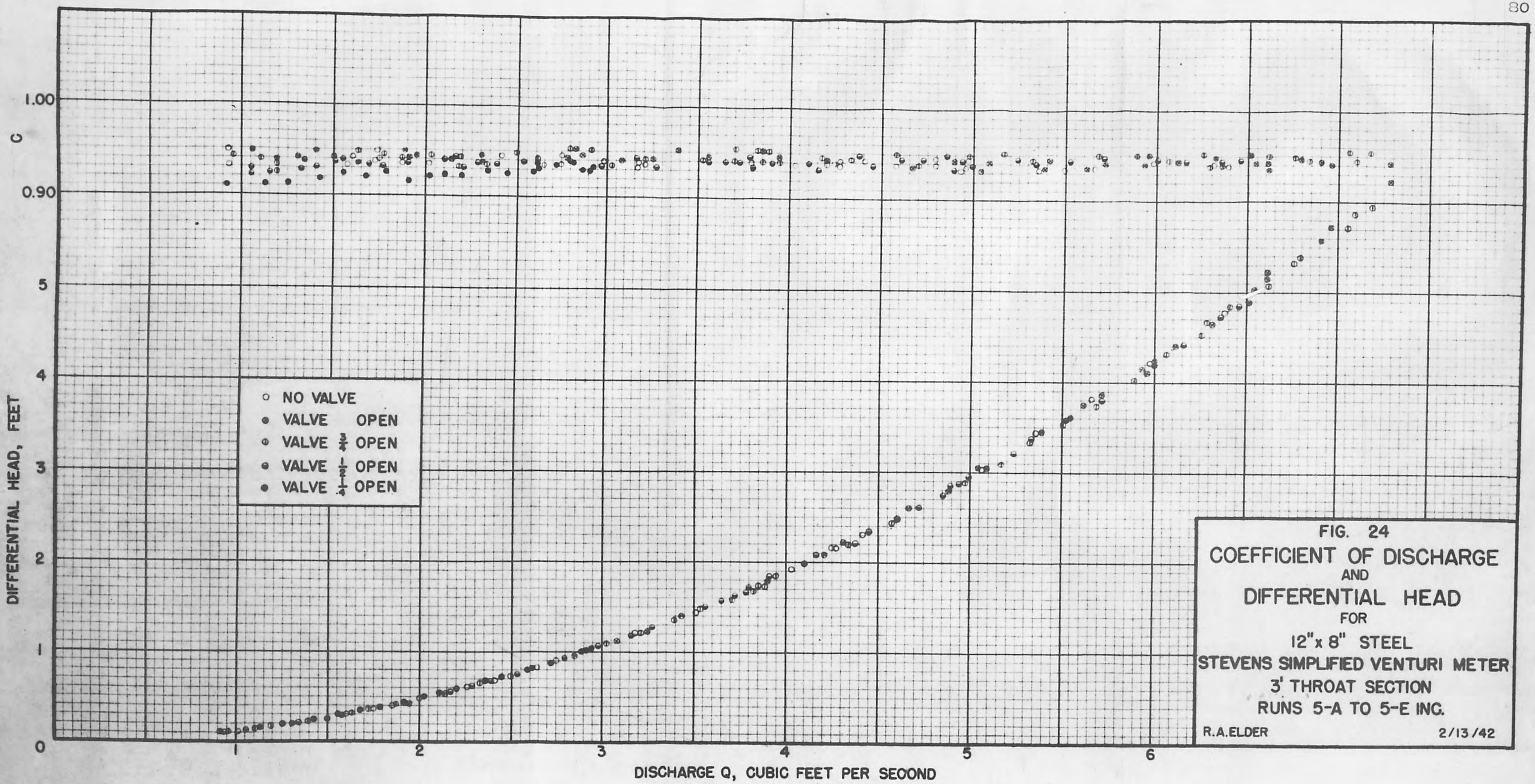


FIG. 23
VELOCITY COEFFICIENT
AND
LOST HEAD
FOR
12" x 8" STEEL
STEVENS SIMPLIFIED VENTURI METER
2' THROAT SECTION
RUNS 4-A TO 4-E INC.

R.A. ELDER 2/3/42



1.00
0.90
C
5
4
3
2
1
0
DIFFERENTIAL HEAD, FEET
1
2
3
4
5
6
DISCHARGE Q, CUBIC FEET PER SECOND
NO VALVE
VALVE OPEN
VALVE ¾ OPEN
VALVE ½ OPEN
VALVE ¼ OPEN
FIG. 24
COEFFICIENT OF DISCHARGE
AND
DIFFERENTIAL HEAD
FOR
12"x 8" STEEL
STEVENS SIMPLIFIED VENTURI METER
3' THROAT SECTION
RUNS 5-A TO 5-E INC.
R.A.ELDER
2/13/42

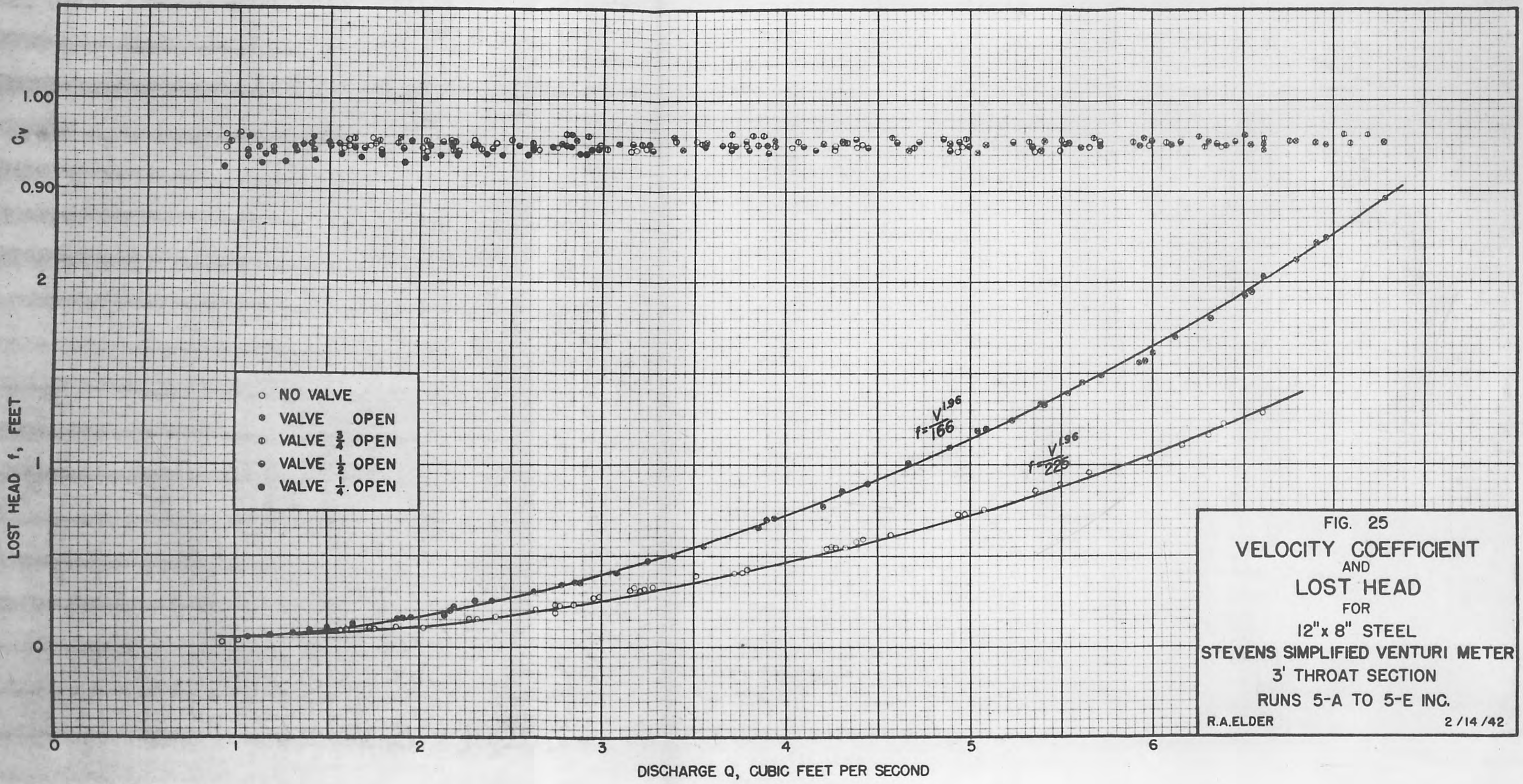


FIG. 25
VELOCITY COEFFICIENT
AND
LOST HEAD
FOR
12" x 8" STEEL
STEVENS SIMPLIFIED VENTURI METER
3' THROAT SECTION
RUNS 5-A TO 5-E INC.

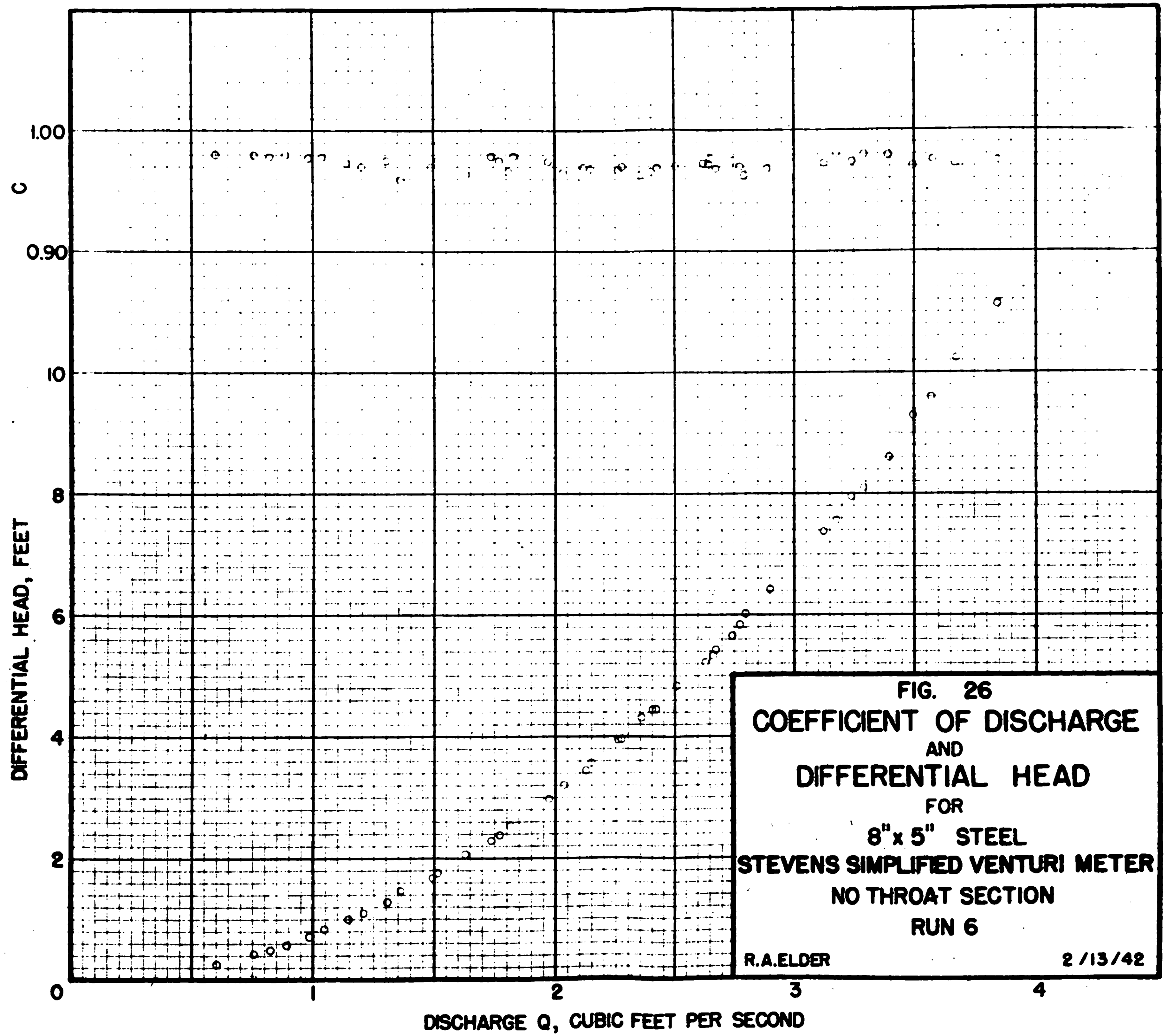


FIG. 26
COEFFICIENT OF DISCHARGE
AND
DIFFERENTIAL HEAD
FOR
8" x 5" STEEL
STEVENS SIMPLIFIED VENTURI METER
NO THROAT SECTION
RUN 6

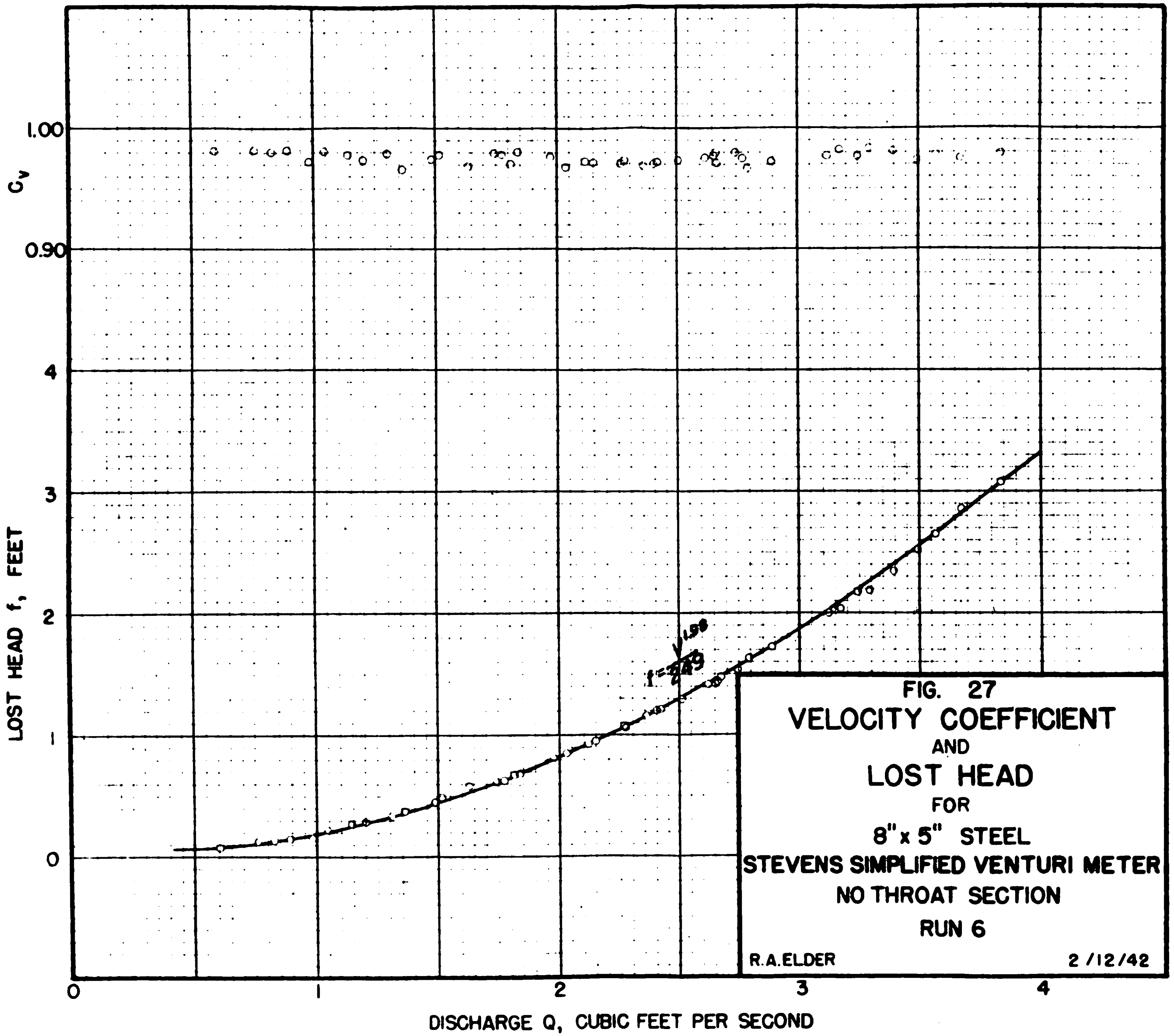


FIG. 27
VELOCITY COEFFICIENT
AND
LOST HEAD
FOR
8" x 5" STEEL
STEVENS SIMPLIFIED VENTURI METER
NO THROAT SECTION
RUN 6

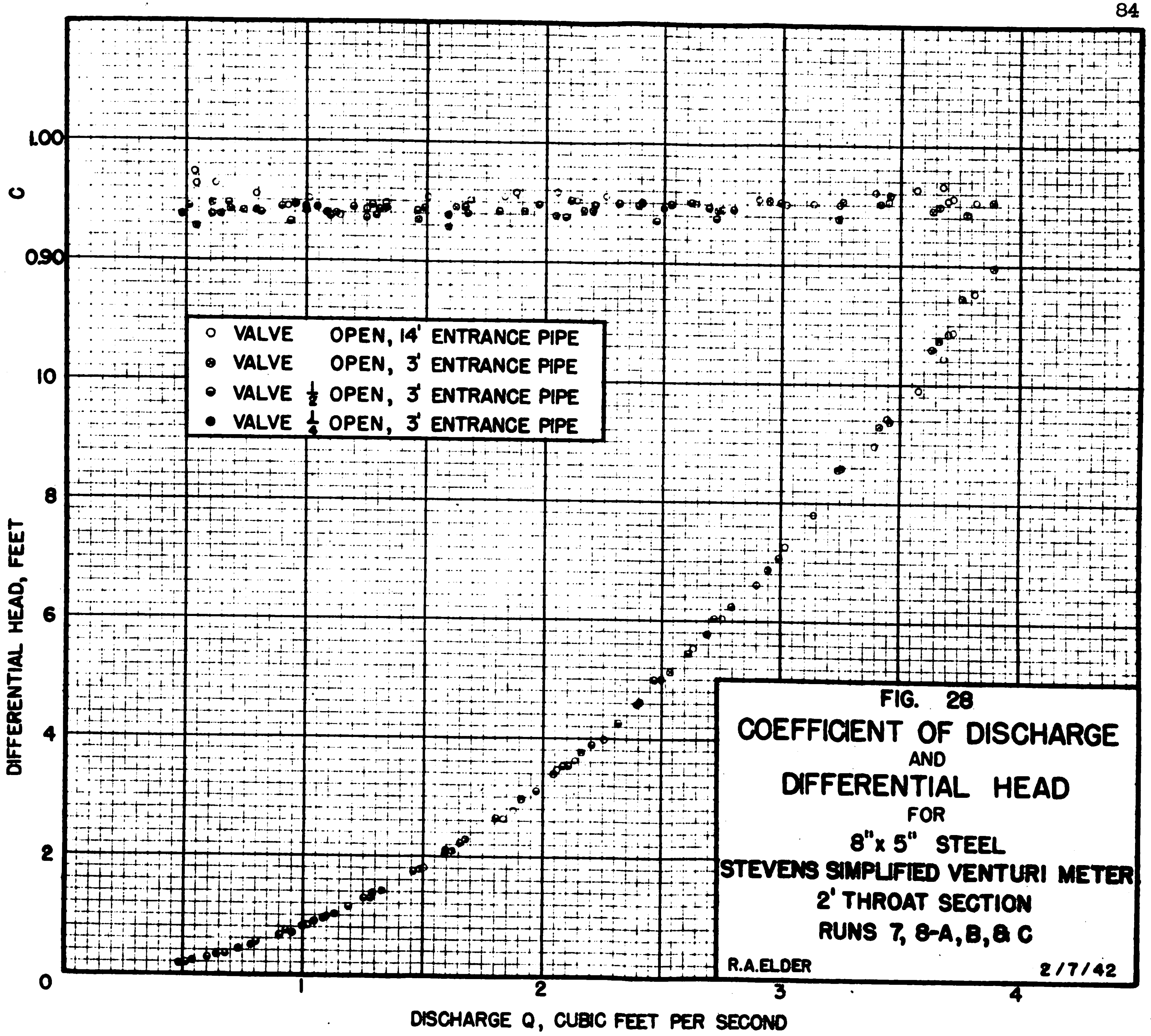


FIG. 28
COEFFICIENT OF DISCHARGE
AND
DIFFERENTIAL HEAD
FOR
8" x 5" STEEL
STEVENS SIMPLIFIED VENTURI METER
2' THROAT SECTION
RUNS 7, 8-A, B, & C

R.A. ELDER 2/7/42

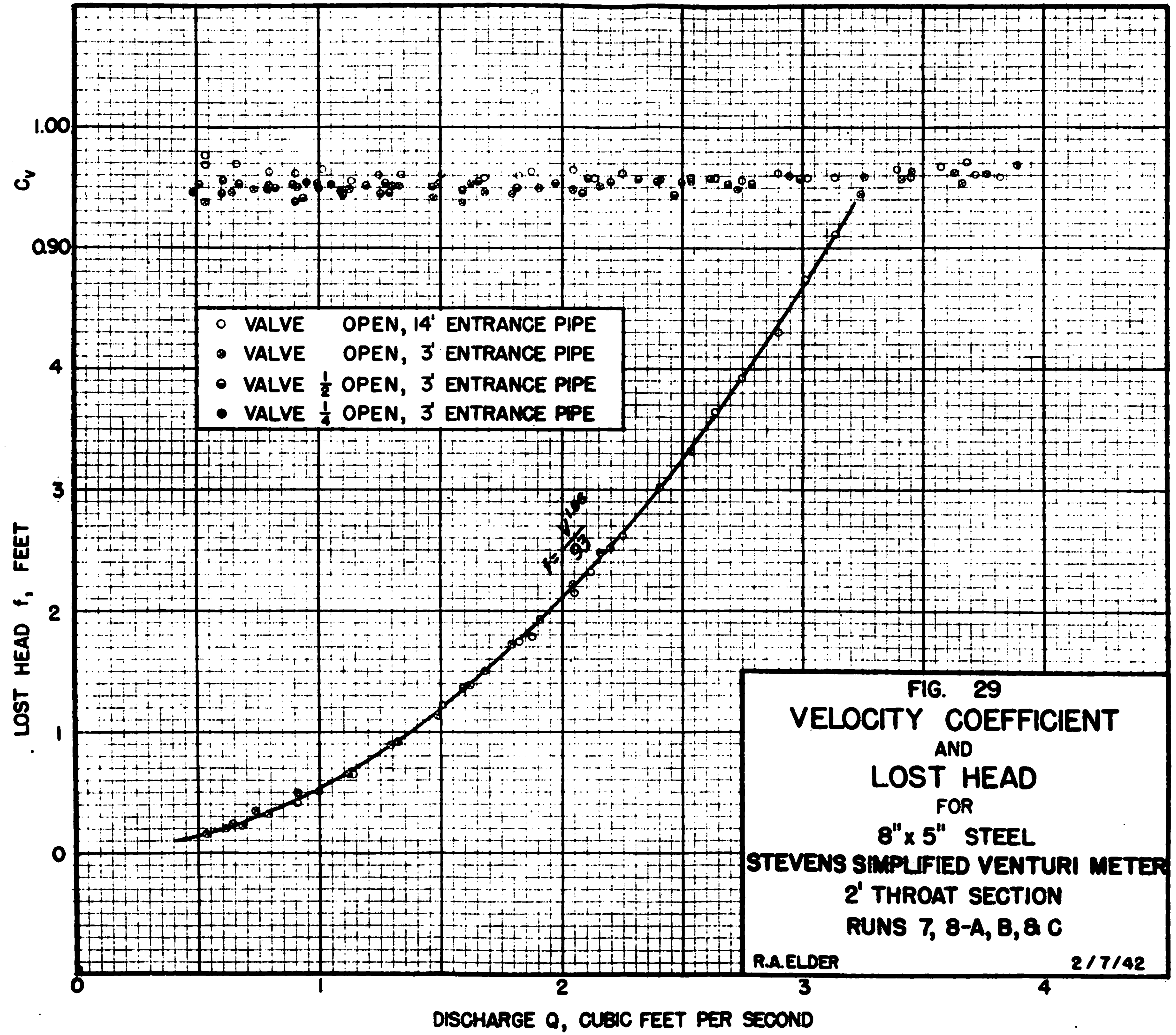


FIG. 29
VELOCITY COEFFICIENT
AND
LOST HEAD
FOR
8" x 5" STEEL
STEVENS SIMPLIFIED VENTURI METER
2' THROAT SECTION
RUNS 7, 8-A, B, & C

R.A. ELDER 2/7/42

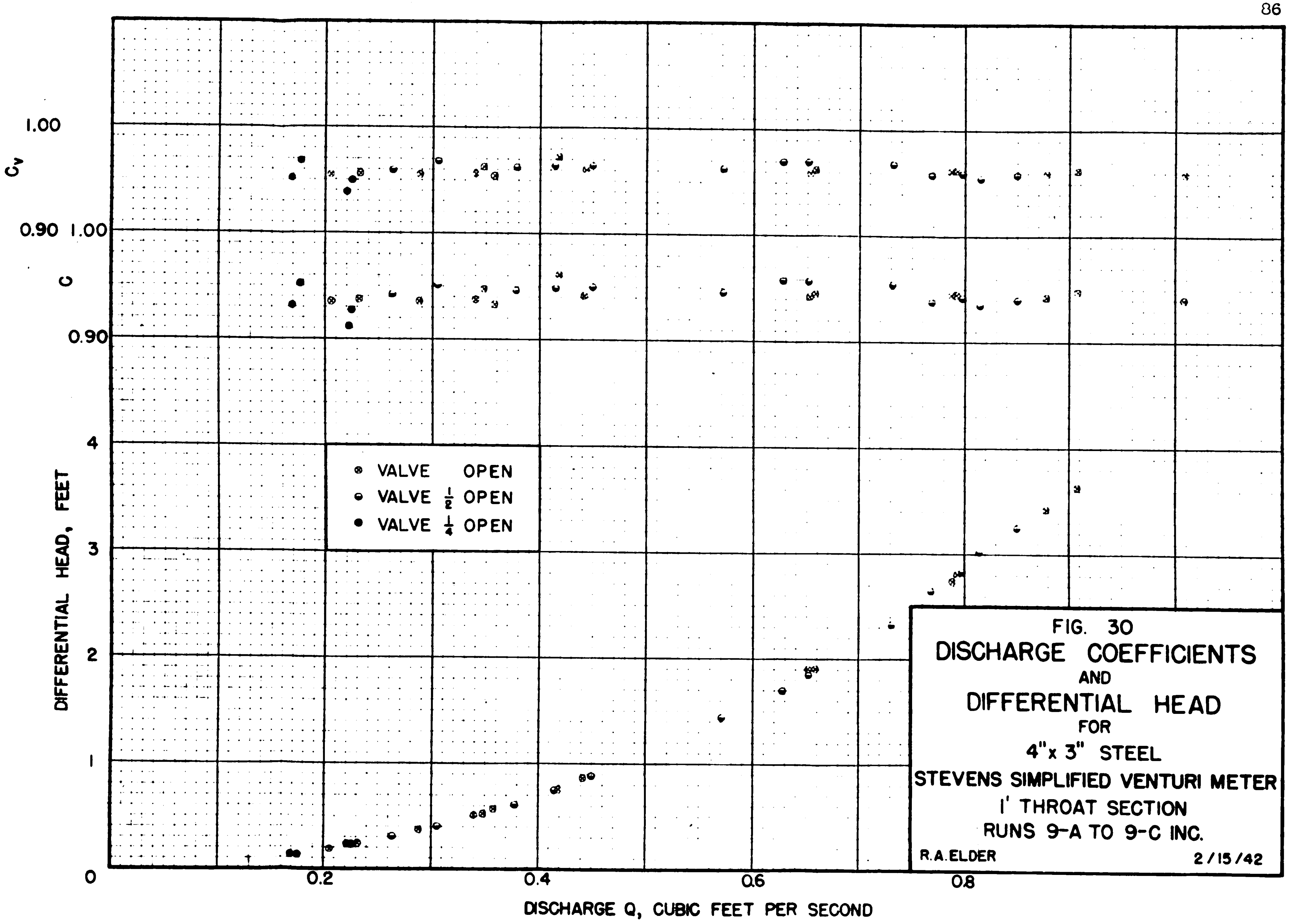


FIG. 30
DISCHARGE COEFFICIENTS
AND
DIFFERENTIAL HEAD
FOR
4"x 3" STEEL
STEVENS SIMPLIFIED VENTURI METER
1' THROAT SECTION
RUNS 9-A TO 9-C INC.
R.A. ELDER 2/15/42