UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

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HYDRAULIC MODEL STUDIES OF THE GRAND COULEE PUMPING PLANT INTAKE

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HYDRAULIC MACHINERY LABORATORY
REPORT NO. HM-3

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Denver, Colorado,
August 21, 1939

Bureau of Reclamation

Hydraulic Machinery Laboratory

Denver, Colorado
August 21, 1939

Laboratory Report No. HM-3
Grand Coulee Pumping Plant
Columbia Basin Project
Compiled by: F. Tessitor
Checked by: D. J. Hebert
Submitted by: G. J. Hornsby

Subject: Hydraulic model studies of the Grand Coulee pumping-plant intake

1. Introduction. The normal reservoir elevation at Grand Coulee Dam is 1288.0 and the minimum elevation is 1208.0, making a maximum draw-down of 80 feet. The maximum receiving canal elevation is 1585.0. Thus, the maximum head on the pumping plant will be 377 feet. The normal lift, however, will be from elevation 1288 to elevation 1585, or 297 feet. The pumps will be rated at 295 feet head with a delivery of 1,600 c.f.s. per pump. There will be twelve pumps in the plant, each constituting a separate unit with its own inlet and outlet conduits 14 feet and 12 feet in diameter, respectively.

The tests described in this report have to do only with the inlet conduit from the reservoir to the pump inlet flange. This includes the trashracks, the entrance through the gates, the conduit, and the elbow under the pump. While it is understood that the head losses in the various components of the inlet structure are important, it is believed that the velocity and the pressure distribution at the inlet flange of the pump are also important to the efficient performance of the unit as a whole. For this reason considerable attention was given to this point in the tests.

2. Summary. Hydraulic model studies on a scale of 1:17.3 were made of three types of elbows and two types of entrances in connection with the design of the intakes for Grand Coulee pumping plant.

It was found that from the standpoint of energy loss there is very little difference, for most practical purposes, among the three elbows and between the two entrances.

The total loss in the intake obtained by extrapolating model values to the prototype Reynolds' number is estimated to be $\frac{0.20\ V^2}{2g}$ where V is the mean velocity in the 14-foot diameter pipe. This total loss is made up approximately as follows: $\frac{0.10\ V^2}{2g}$ in the entrance, $\frac{0.04\ V^2}{2g}$ in the straight pipe, and $\frac{0.06\ V^2}{2g}$ in the elbow with its attached reducer.

From the standpoint of velocity distribution in the conduit, the circular entrance was slightly superior to the rectangular one. From the standpoint of distribution at the inlet flange of the pump, the vaned elbow was definitely superior to the two converging elbows.

3. Purpose of model studies. These studies were undertaken for the purpose of investigating the behavior of various elbows in the pumping plant intake line as proposed. By intake is meant the entire conduit from the forebay to the pump suction eye, including trashrack structure, entrance, straight conduit, and elbow. However, as the work progressed it was thought desirable to include studies of other types of entrances for comparative purposes.

Information was desired as to the hydraulic losses to be encountered with the several different installations, as well as the velocity distribution at several points in the intake system, particularly at the inlet flange of the pump.

4. Set-up and test procedure. In the test set-up, water is drawn from a forebay through the model of the intake by means of a vertical, single-suction, centrifugal pump. The pump discharges back into the forebay behind suitable baffles through a 6-inch diameter pipe fitted with an end cap orifice which is used to measure the discharge. For the different runs, the amount of flow was determined by adjusting the valve so that the height of a mercury column attached to the discharge orifice was set to a definite point. This setting of the mercury column was done visually, and, with reasonable care, could be set so that different runs at the same flow might vary ±0.025 inch in setting. The pump is not to be considered part of the model studies. A general view of the set-up is shown on plate A.

Upon consideration of the various factors involved, a model scale of 1 to 17.3 was chosen. The intake opening was made of wood and installed in such fashion that changes could be made easily. The rest of the intake from the entrance to the pump was made of pyralin to permit visual observation. Provision was made at suitable sections in this part of the intake for making the necessary physical measurements.

The test procedure consisted of measuring hydraulic losses and making velocity traverses. The losses were measured in the conventional manner, by installing piezometer rings and connecting these to open manometers. The velocity traverses were first obtained through the use of a spherical pitot tube known as the "Staukugel." This tube has five openings on the portion of the sphere facing the stream flow. The five openings are so placed that their readings permit computation of the velocity vector both as to direction and magnitude. How-

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In lieu of actual measurements of direction (except in one plane) visual observations were relied upon to study any abnormal conditions of flow within the conduit and elbows. The use of air and dye in the fluid flowing through the model showed up the objectionable characteristics and the desirable feature of the various set-ups tested. These observations have been relied upon to temper the various deductions drawn from the data.

5. Entrances tested. Two types of entrances were studied. One, which will hereafter be called the rectangular entrance, is the original design. This entrance is rectangular at the face of the dam and has a transition section to the circular portion of the intake conduit. The intake up to the elbow is on a slope of 10 degrees. The second entrance studied was a circular bellmouth entrance designed according to information obtained previously in the laboratory. This entrance is horizontal for a short distance and there turns by means of a 10-degree bend to meet the normal slope of the intake pipe. Other comparative features of these entrances may be obtained from the sketch on figures 1 and 2. The 10-degree slope of the conduit requires that the elbow turn the water 100 degrees instead of 90 degrees. This should be borne in mind when studying the results presented herein.

6. Elbows tested. Three types of elbows were tested. The first one, submitted by the design section, had a circular entrance which changed progressively to an elliptical section at the outflow end, the minor axis, which lies in the plane of the bend, becoming shorter and the major axis remaining constant. The sectional area and the radius of curvature change in such a manner that the product of the velocity times the radius remains constant. A transi-

tion section, changing from the elliptical to a circular section, was necessary between the elbow outflow and the pump inlet flange. This elbow will hereafter be referred to as the elliptical elbow.

The second elbow tested was a miter bend with a section containing vanes inserted at the intersection of the two segments. A rather sharp convergence was required between the elbow and the pump inlet flange to reduce the full intake diameter to that required at the pump. This elbow, which was designed in the laboratory, will hereafter be referred to as the vane elbow.

The third type tested was a constant radius elbow with a gradual convergence from the intake pipe up to the pump inlet flange. This elbow, which was submitted by the design section and modified slightly in the laboratory, will be referred to hereafter as the converging elbow. Photographs of the various elbows are shown on plate B.

An explanation of the choice of measurement sections would be appropriate here. The sections were located in such a manner that the hydraulic effects of the various parts of the intake could be observed. Section "D" was located immediately downstream from the entrance and section "C" immediately upstream from the beginning of the elbow. These two sections are common to all tests. The location of section "B" varied according to the elbow being tested, but, in general terms, it was located at the outflow end of the elbow proper. Section "A" was located as close to the pump impeller eye as physical limitations permitted.

During the progress of the test it was decided, on the basis of the promising results obtained from the vane elbow, to study the possibilities of decreasing the size of the whole pump intake. As this could be done very easily by use of the vane type of elbow, a 6-1/2-inch diameter intake was built of pyralin with a corresponding wooden bellmouth entrance. The same series of tests was conducted on this set-up as for the others.

An interesting deviation from the main program of tests consisted in investigating the effect on entrance loss of the various components of the trashrack structure. Piezometer readings were taken at section "D" for various discharges, with the complete installation in place. The next step consisted in removing portions of the trashrack and measuring the losses through the same range of flow. Next, the trashrack piers and bars were removed and the losses measured. This was carried through systematically until the rectangular entrance was clean with the face of the dam, as shown in plate C. These results are given in table 1.

Attention is called to the fact that all results given are for a condition of minimum reservoir elevation. This was used as the worst possible operating condition likely to occur. A check was made to see if the test results were influenced by suction head, but it was found not to have any measurable effect on the model results through a variation of about 18 inches (26 feet prototype). All subsequent tests were made with the minimum reservoir elevation.

7. Results. Since it was decided before completion of the model tests that the size of the intake conduit in the prototype would be 14 feet in diameter, the tests for the various elbows and entrances are compared on the basis of a convergance from 14 feet to 9.5 feet at the pump inlet flange.

A comparison of the velocity distributions for both types of entrances is shown in figure 3 in the dimensionless plot. It is apparent that the velocity distribution is more nearly symmetrical in the bellmouth entrance than in the rectangular one. It must be remembered that by bellmouth entrance is meant the bellmouth proper plus the 10-degree bend, because the measuring section is just downstream from the bend. The difference between the distribution of flow in the two entrances is quite small and even this small difference practically disappears before the elbow is reached.

In order better to predict the velocity distribution in the prototype, the model discharge was doubled. The distribution of velocity remained the same at the section tested (see dimensionless plot, sec. D, figure 3). For this increased discharge the velocity in the model was five feet per second. The velocity in the prototype will be 10 feet per second. Since the scale ratio is 17.3, the Reynolds' number in the prototype will be about 35 times that in the model. Therefore, the effects of friction will be relatively smaller in the prototype, with the result that the prototype will tend toward a more uniform distribution provided the distribution is symmetrical in the model. If, however, the distribution is not symmetrical, as in the case of the rectangular entrance, conditions are likely to be aggravated at higher Reynolds' numbers. The measurements were taken without the trashrack structure. It is believed that the trashracks and piers will be a stabilizing influence without affecting the flow pattern.

The losses in the two types of entrances are shown in table 2. The relative merits of the different set-ups tested may best be determined by keeping in mind the experimental error inherent in the individual values given. In obtaining the losses at the various sections, water manometers were used to read the pressures. These manometers were read with an accuracy of ±0.001 foot. The loss in head from the headwater to any section is obtained by subtracting the velocity head at that section from the difference in pressure as determined from the water manometer readings. Due to the possible variation in setting the flow, the velocity head may vary ±0.001 foot and the pressure readings from each manometer may also vary ±0.001 foot. The determination of loss would have an accuracy of ±0.003 foot (since two separate manometer readings are used in the determination). Expressed in percent of velocity head, the maximum variation would be of the order of magnitude of ±2.5 percent at the lowest model discharge. In general, the loss in the bellmouth entrance is lower than in the rectangular one when the gates are not in place. A comparison between the two entrances, with their respective gates in place, is given in table 1. In this case the bellmouth entrance is superior by from two to five percent of the velocity head. The loss, expressed in terms of velocity head, will be less in the prototype than in the model so that the values obtained in the model are on the safe side.

The loss in the trashrack structure was just barely perceptible in the model, being of the order of 0.005 foot at a velocity of 5 feet per second in the conduit. Since the velocity in the prototype is 10 feet per second, the loss will be of the order of 0.005 foot at a velocity of 5 feet per second in the conduit. Since the velocity in the prototype is 10 feet per second, the loss will be of the order of 0.03 foot, which is negligible. By far the most significant factor in the entrance losses was shown by the effect of the gate slots. A comparison of columns 4 and 5 in table 1 shows the effect of filling in the gate slots. As these tests were made with the rectangular entrance, the losses, of course, are applicable to that entrance only.

The values of K, in the formula for loss in the entrance, $h = \frac{KV^2}{2g}$, may safely be taken as 0.10 for the bellmouth and 0.12 for the rectangular entrance.

8. Elbows. A comparison of the three elbows, using the bellmouth entrance, is shown in figure 4. As pointed out previously, it was found that the type of entrance had a very minor effect on the flow in the elbows. Therefore a comparison on the basis of either entrance is valid.

From the standpoint of velocity distribution in the cross section immediately preceding the pump, the elbows in the order of their performance are vane elbow, converging elbow, and elliptical elbow. The converging and the elliptical elbows show their influence on velocity distribution in accordance with previous experimental work. There is an increase of velocity along the inner radius until the exit section is reached (section B). At this point there is separation with correspondingly lower velocity. The dimensionless plot of distribution on figure 4 brings out the severity of the separation in the elliptical elbow compared with the converging elbow. This tendency in the elliptical elbow is no doubt accentuated by the proportions of the transition section required.

The vane elbow exhibits very different characteristics, and, since this type of elbow is just beginning to claim attention, some additional discussion is in order. This type of elbow has been used for some time in the aerodynamics laboratories for the purpose of turning air with a minimum distortion of velocity distribution. More recently it has been found by other investigators that by a careful and suitable design of the vanes this type of elbow can be made to give losses comparable to the best elbows of the conventional type. The design of the vanes in the elbow tested in the laboratory followed the suggestions proposed by Krober in technical memorandum No. 722 of the N.A.C.A. Nine thin vanes were installed with a shape approximating those proposed by Krober. More experimentation could be done in determining the most efficient type of vane, but it was felt that in this study it was not justified because of the relatively low velocities and correspondingly low losses.

The losses, as measured by means of piezometer rings, are shown in table 2. These are total losses from forebay to the measuring section indicated. The elliptical elbow shows an appreciably higher loss than the other two elbows. The vane and converging elbows show practically the same loss. The losses measured in this manner are dependent upon the velocity distribution and the curvature of the stream lines. Therefore, it was decided to evaluate the losses by integrating the pitot-tube measurements of total pressure. At any point the difference between the potential of the forebay and the total pressure is the loss in energy to this point. These energy losses are presented in figure 5. To get the average loss per pound of fluid, these losses are multiplied by the velocity, integrated over the cross section and then divided by the discharge. The losses obtained in this way differ materially from the losses obtained in the usual manner. The total loss per pound to section "A" for Q = 1.300 c.f.s. are as follows: Vane, 0.055 foot; elliptical, 0.046 foot; converging, 0.039 foot. Considering the fact that the probable error may be four or five percent, the three elbows show very close agreement.

In comparing these losses with the losses derived from the piezometer measurements, several differences may be noted. The loss in the elliptical elbow has been materially reduced. This reduction can be explained by referring to the velocity distribution. The distribution is distorted to such an extent that the piezometric pressure measured at the pipe wall will vary around the circumference. The average pressure is then more a function of the piezometer locations than of the actual mean pressure in the cross section. In the case of the converging elbow, the distribution is better; therefore the closer agreement obtained is to be expected. For the vane elbow the agreement should be very close, since the distribution of velocity is quite uniform both in magnitude and direction. There is a discrepancy in this case, and it is felt that more weight can be placed on the loss from the piezometer readings. Therefore the true loss in the vane elbow set-up will be in the neighborhood of 0.042 foot when the value in table 2 is corrected from Q = 1.426 c.f.s. to Q = 1.300 c.f.s. This adjustment brings the three elbows into even better agreement.

In summary, it can be stated that on the basis of energy loss, as determined by these tests, there is very little difference among the three elbows.

The change in the percentage loss with increasing discharge is shown in table 2. The percentage loss in the prototype will be somewhat less than in the model because of the higher Reynolds' number. On the other hand, if the relative roughness is greater in the prototype, the percentage loss will tend to be higher. The range of discharges in the model was not sufficiently wide to serve as a basis for extrapolation. A reasonable value for design purposes would be a loss coefficient of 0.20. The head loss from the forebay to the pump inlet would then be $\frac{0.20\ V^2}{2g}$ where V = velocity in the 14-foot diameter pipe. The magnitude of the loss would be 0.20 x 1.6 = 0.32 foot. This loss amounts to only 0.1 percent of the total pumping head and can be considered negligible.

9. <u>6-1/2-inch diameter intake model.</u> Since the results obtained with the vane elbow showed considerable promise, it was decided to construct an intake which had a constant diameter equal to that of the pump inlet. Because the vane elbow required only slightly more depth than the conduit diameter, it was possible to make the intake horizontal. The bellmouth was formed to approximately the same shape as the larger bellmouth entrance. The design of the elbow was changed so that there were only seven vanes as contrasted with nine vanes in the larger elbow. The velocity distributions at the various sections are shown on figure 6. The distribution is not as good as in the larger vane elbow. There is a breaking away of the flow at the inside of the miter. One reason for this is the smaller number of vanes and the corresponding larger passages. The drag induced by the vanes shows up very clearly in these tests; however, the variations in velocity caused by this drag are only of the order of four percent. The velocity distribution is not as satisfactory as that obtained in the larger vane elbow, and it serves to bring out the need

for more experimental study before a basis for design can be established.

The head loss from forebay to pump is higher than in the larger installation, due to higher velocities. The loss in the prototype, estimated by lowering the model values to take account of the higher Reynolds' number, is $\frac{0.30 V^2}{2g}$, where V = velocity in the 9.5-foot diameter pipe. The magnitude of this loss would be 0.30 x 7.94 = 2.4 feet, which is 0.75 percent of the total head.

10. Conclusions. Before drawing any definite conclusions, it is well to review first the particular factors involved in the problem and, second, those which are peculiar to the model set-up.

First, the elbows which turn the water through 100 degrees end a short distance from the eye of the pump impeller. The choice of diameters for the pump intake and the conduit makes it necessary to have a fairly sharp convergence between the elbow and the pump inlet flange.

Second, the pump used in the model study is not an homologous model pump and does not simulate the prototype. Therefore any effect of the laboratory pump on the model intake is peculiar to the model study and cannot be transferred to the prototype. This effect might be a distortion of the flow pattern as a result of unsymmetrical flow through the pump. On the other hand, the model pump may have a stabilizing effect. Whatever the effect, it would be small, and if secondary disturbances are neglected, this effect of the pump will be cancelled out in a comparative study.

Third, the losses determined in the model have an accuracy of ± 0.003 foot.

Bearing these factors in mind, the following conclusions are drawn from the model studies:

The bellmouth entrance is slightly better than the rectangular entrance from the standpoint of velocity distribution and loss of head. The difference in loss coefficient "K" is of the order of two to three percent in favor of the bellmouth design. The minimum entrance loss measured in the model was $\frac{0.10 V^2}{2g}$, where V is the velocity in the conduit. The loss in the prototype will be relatively smaller because of the higher value of Reynolds' number. A value of loss taken as $\frac{0.08 V^2}{2g}$ would be safe, considering the magnitude of the velocity head in the prototype. The losses in the trashrack structure were of the same order of magnitude as the observation error, so that no definite figures can be given for design data. The loss due to the gate slots is the greatest factor in the total loss in the rectangular entrance.

On the basis of head lost in passing through the elbow, there is very little difference among the three elbows. This is not surprising because in the usual installation of an elbow the major portion of the loss attributable to the elbow is developed in the downstream tangent, due to maldistribution of the velocity. In the problem of the pump intake, there is no downstream tangent, but there is the pump which may be affected by the velocity distribution.

From the standpoint of distribution, the vane elbow is definitely the best elbow, with the converging elbow next best. No attempt was made to find the magnitude and direction of the effect of the elbow on the performance of the pump. If this effect is appreciable, the vane elbow would appear to be the most desirable elbow. If the effect is negligible, the choice of elbow is merely one of cost. In other words, the elbow which can be built most economically is the most desirable one.

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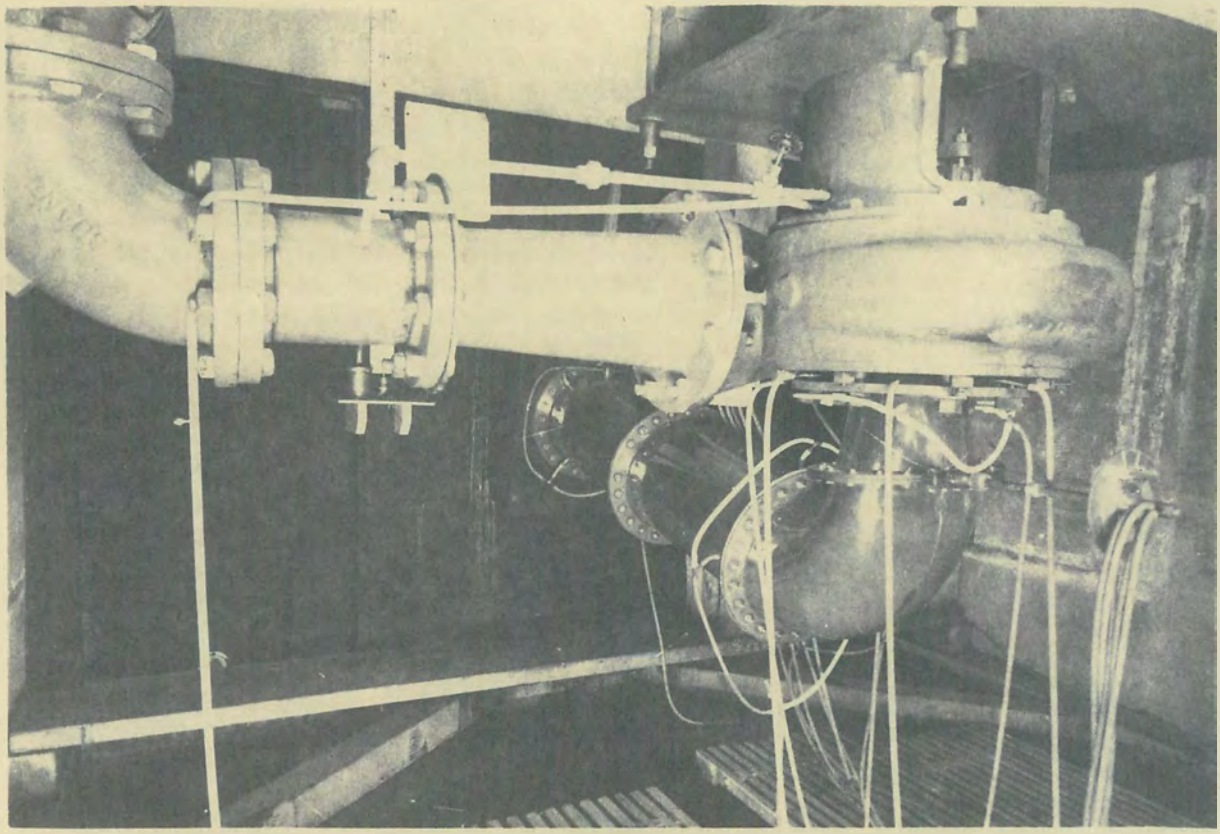
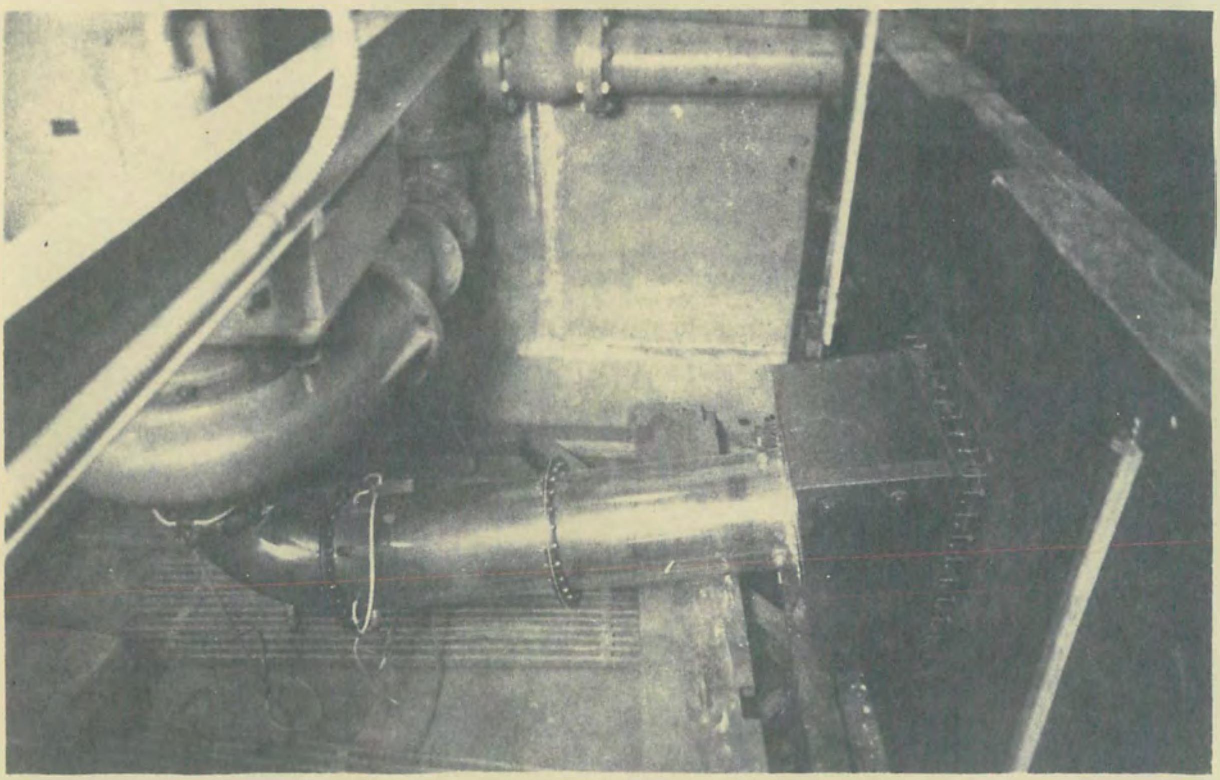
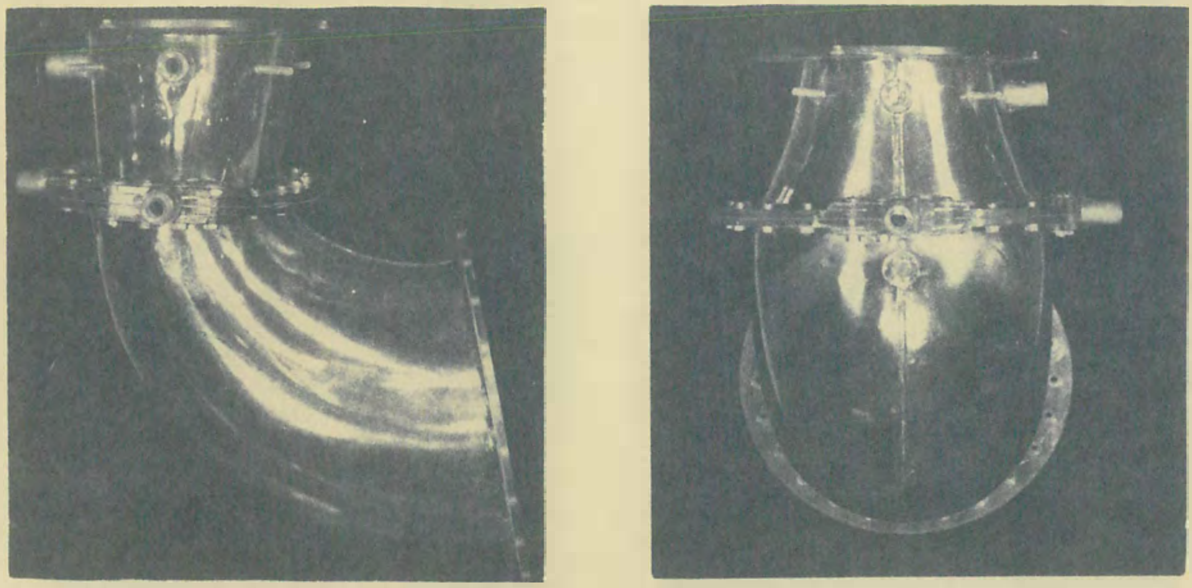
GENERAL VIEW OF SET-UP

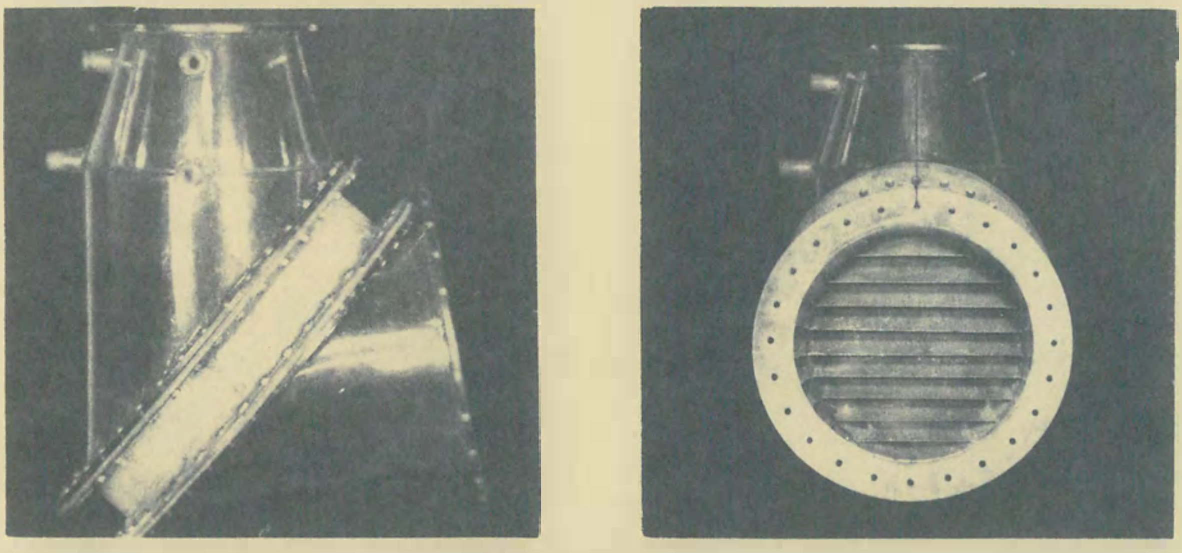




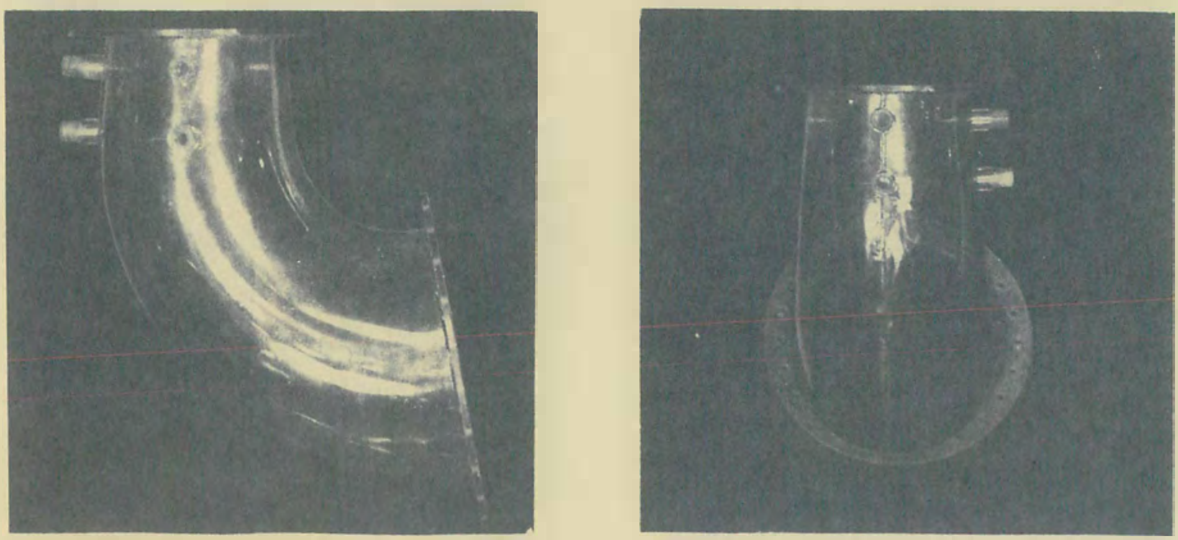
TYPES OF ELBOWS TESTED



Elliptical Elbow



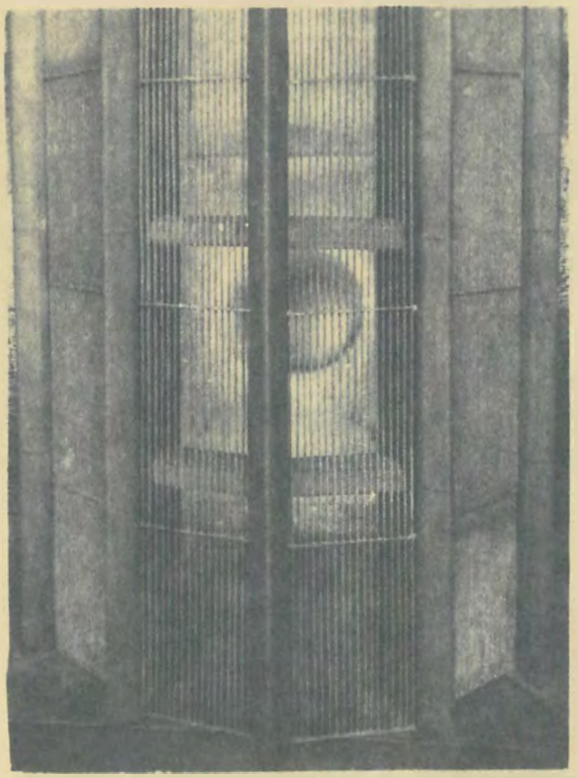
Vane Elbow



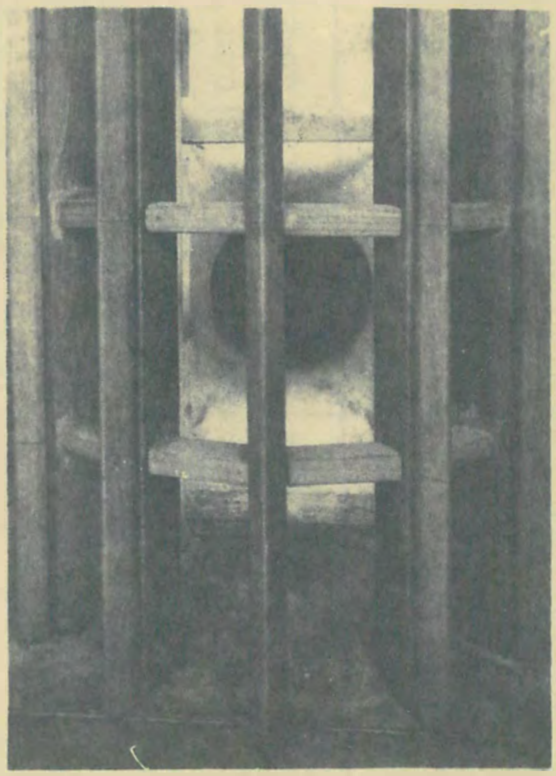
Converging Elbow

SOME STEPS IN THE PROGRESSIVE DISMANTLING OF THE TRASH RACK STRUCTURE FOR HEAD LOSS DETERMINATION

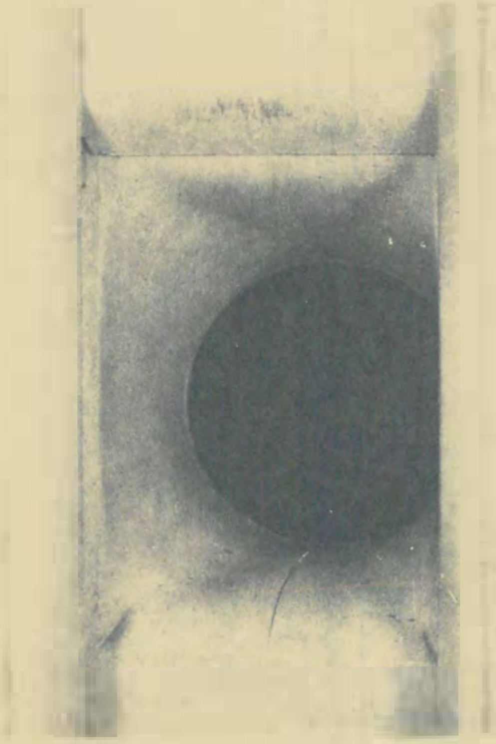
(Numbers correspond to columns on table 1)



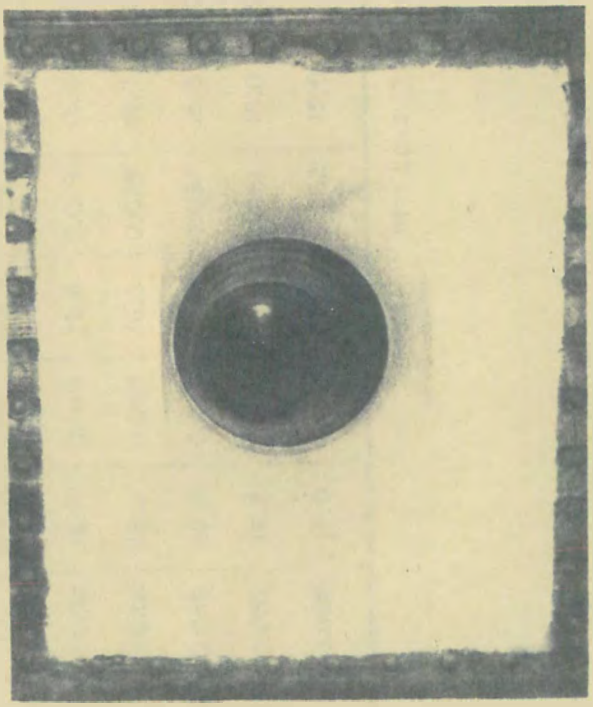
1. Fully Installed



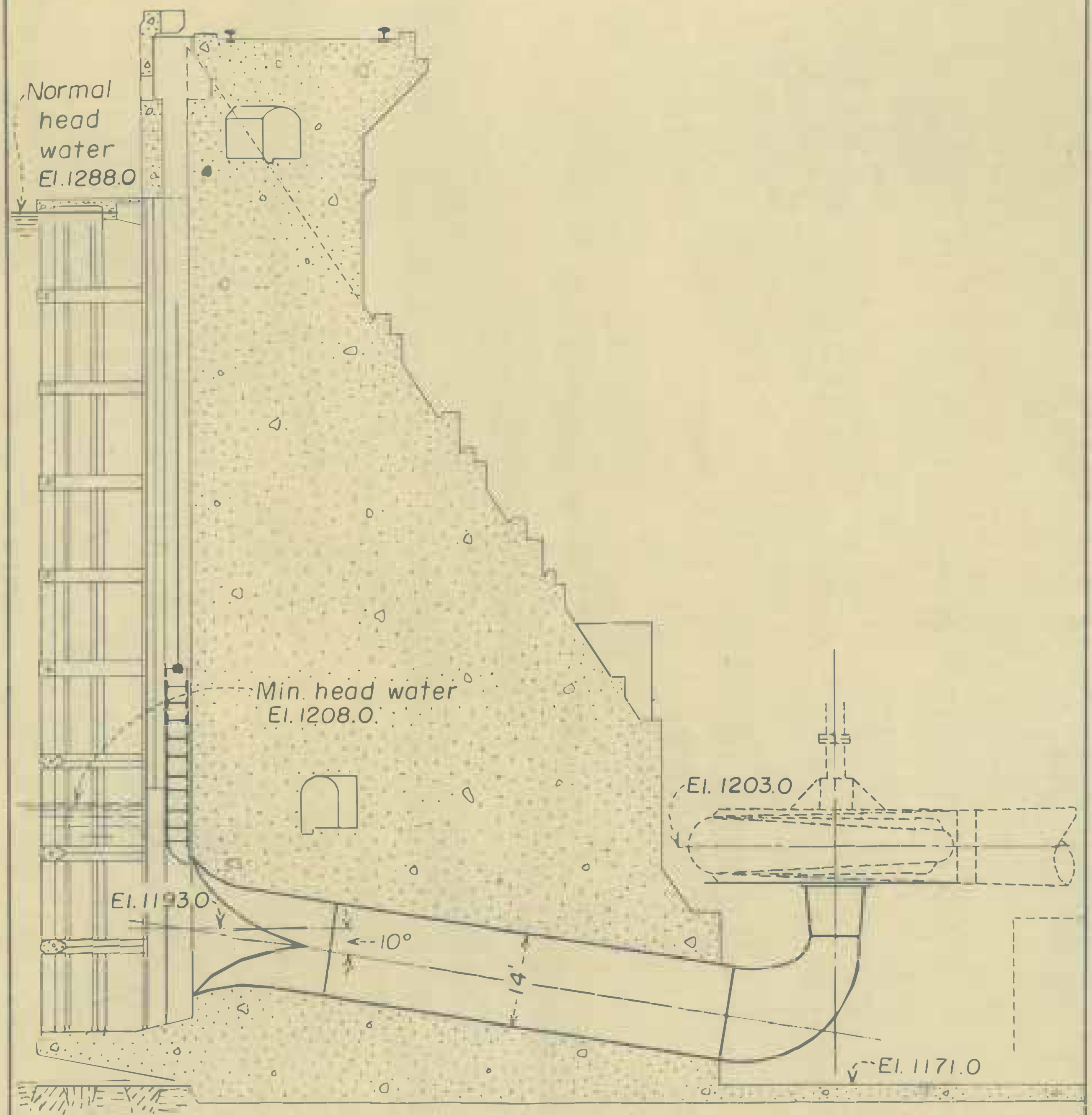
2. Trash Racks Removed



3. Trash Racks, Piers, and Ribs Removed



6. Completely Dismantled.



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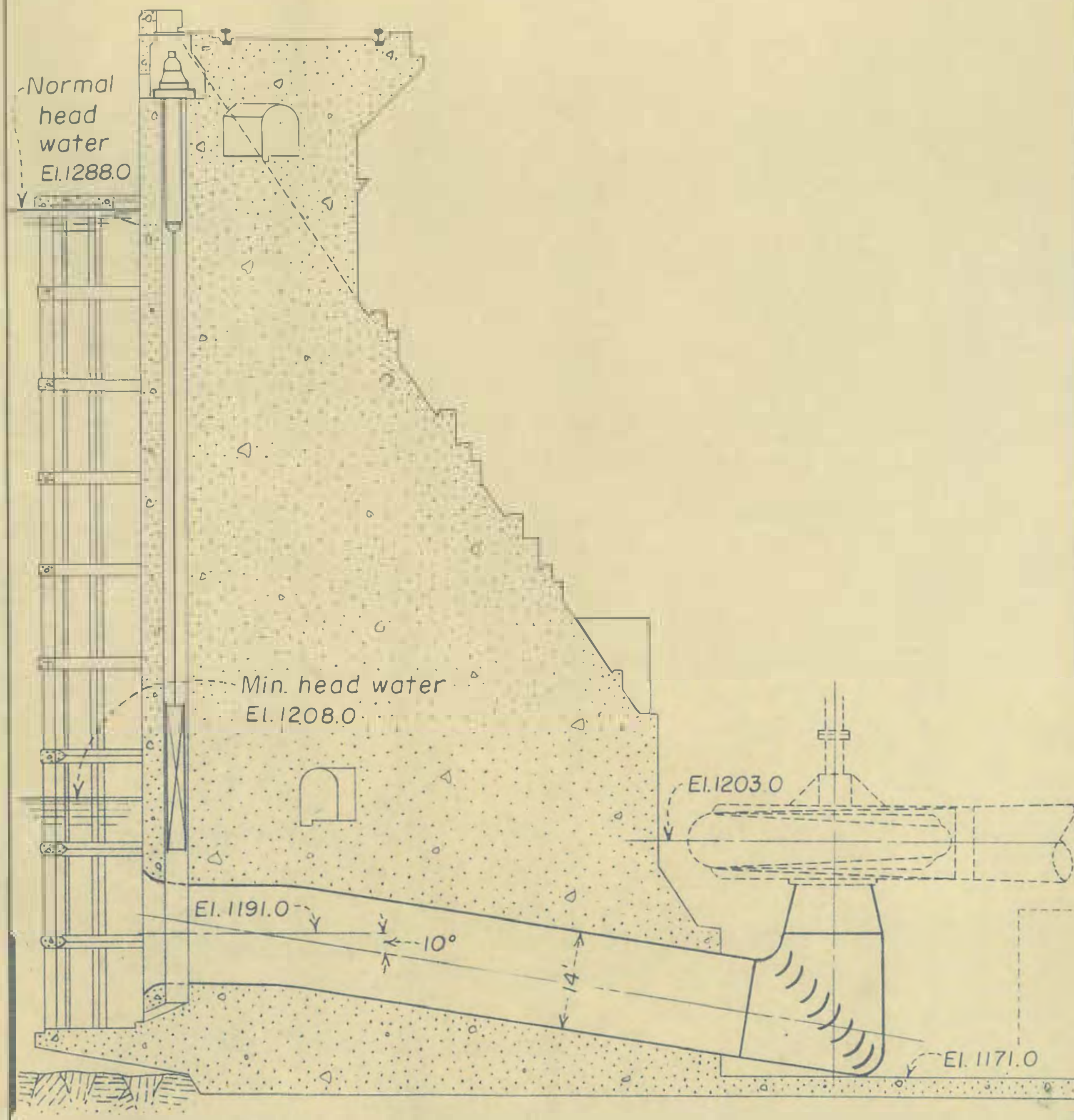
COLUMBIA BASIN PROJECT-WASHINGTON

GRAND COULEE PUMPING PLANT
MODEL STUDIES OF INTAKE
TYPICAL SECTION OF RECTANGULAR ENTRANCE TESTED WITH ELLIPTICAL ELBOW

DRAWN. F.T. SUBMITTED.
TRACED. E.M.W.-H.S. RECOMMENDED.
CHECKED. D.J.H. APPROVED.
DENVER, COLO - MAY 18, 1939 | 222-D-4112



UNITED STATES
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GRAND COULEE PUMPING PLANT
MODEL STUDIES OF INTAKE

TYPICAL SECTION OF BELL-MOUTH ENTRANCE
TESTED WITH VANE ELBOW

DRAWN .. F.T. ..... SUBMITTED.
TRACED. E.M.W.-H.S. RECOMMENDED
CHECKED .. D.J.H. .... APPROVED.....

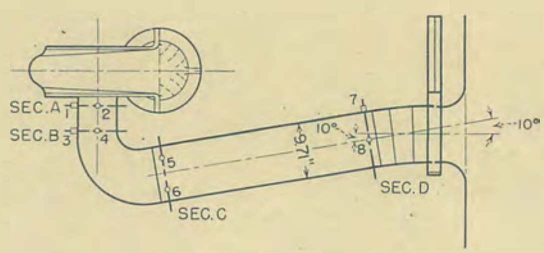
DENVER, COLO. MAY 18, 1939 | 222-D-4113

TABLE 2

PIEZOMETER MEASUREMENTS OF LOSSES 'h_f' IN FEET OF WATER

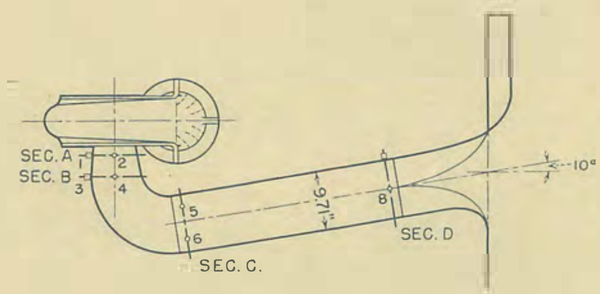
DISCHARGE c.f.s.	SECTION-A						SECTION-C						SECTION-D					
	ELL. ELBOW		VANE ELBOW		CONV. ELBOW		ELL. ELBOW		VANE ELBOW		CONV. ELBOW		ELL. ELBOW		VANE ELBOW		CONV. ELBOW	
	h_f	%V.H.*	h_f	%V.H.*	h_f	%V.H.*	h_f	%V.H.*	h_f	%V.H.*	h_f	%V.H.*	h_f	%V.H.*	h_f	%V.H.*	h_f	%V.H.*
BELL-MOUTH ENTRANCE																		
1.426	.104	86.7	.045	37.5	.042	35.0	.030	25.0	.027	22.5	.027	22.5	.020	16.7	.020	16.7	.018	15.0
1.697	.141	83.0	.062	36.5	.063	37.1	.041	24.1	.038	22.3	.038	22.3	.030	17.6	.025	14.7	.026	15.3
2.016	.184	77.0	.075	31.4	.076	31.8	.055	23.0	.047	19.7	.050	20.9	.040	16.7	.032	13.4	.036	15.1
2.400	.247	72.9	.100	29.5	.095	28.0	.073	21.5	.066	19.5	.069	20.3	.055	16.2	.047	13.9	.052	15.3
2.603	.270	67.5	.114	28.5	.102	25.5	.083	20.7	.075	18.7	.077	19.2	.065	16.2	.054	13.5	.054	13.5
RECTANGULAR-TRANSITION ENTRANCE																		
1.426	.100	83.3	.045	37.5	.044	36.7	.030	25.0	.027	22.5	.030	25.0	.025	20.8	.025	20.8	.027	22.5
1.697	.131	77.0	.054	31.8	.059	34.9	.039	23.0	.038	22.3	.038	22.3	.030	17.6	.034	20.0	.033	19.4
2.016	.165	69.0	.082	34.3	.079	33.0	.054	21.3	.051	21.3	.056	23.4	.040	16.7	.044	18.4	.048	20.1
2.400	.220	64.9	.102	30.1	.097	28.6	.068	20.0	.071	20.9	.074	21.8	.053	15.6	.056	16.5	.059	17.4
2.603	.246	61.5	.115	28.7	.115	28.7	.081	20.2	.078	19.5	.084	21.0	.064	16.0	.063	15.8	.068	17.0

* Percent of velocity head at Section C



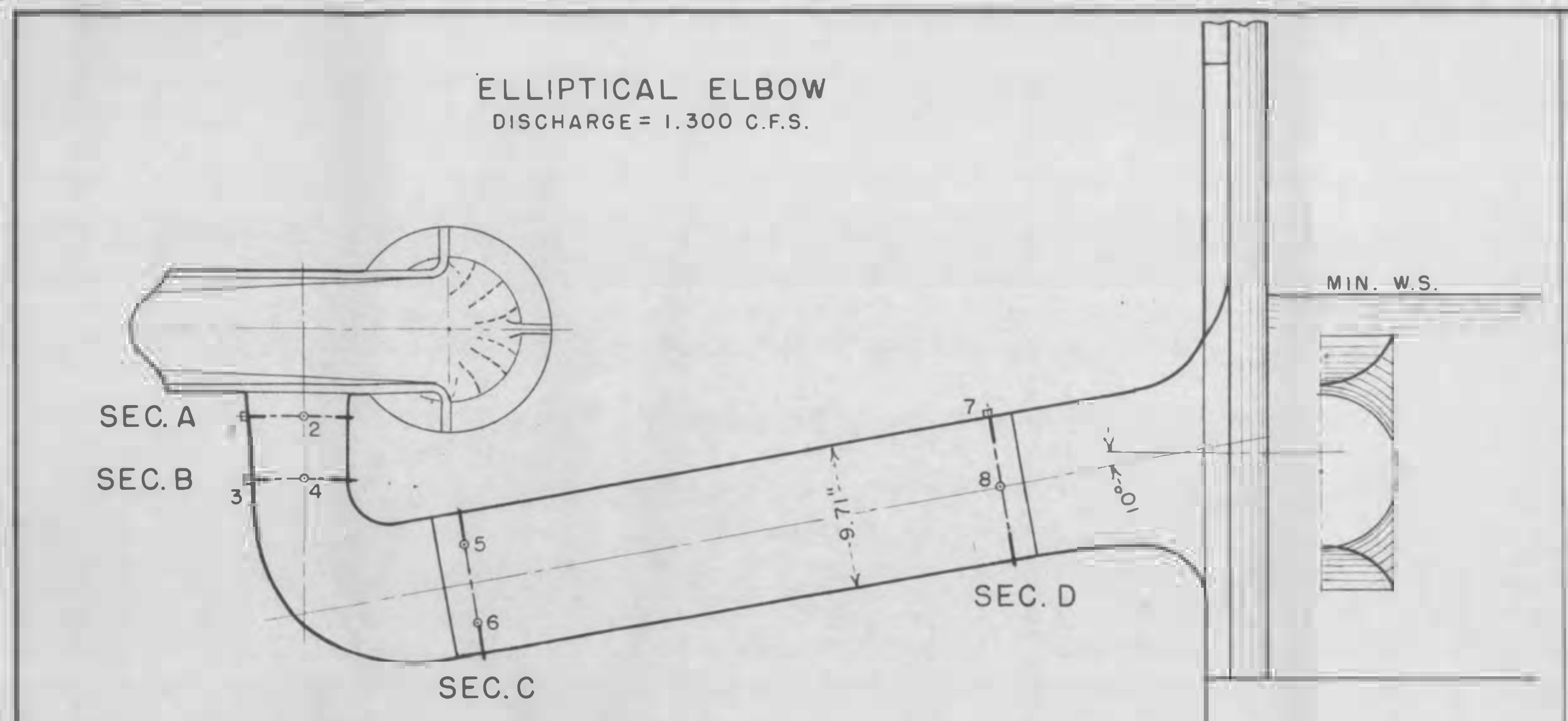
BELL-MOUTH ENTRANCE

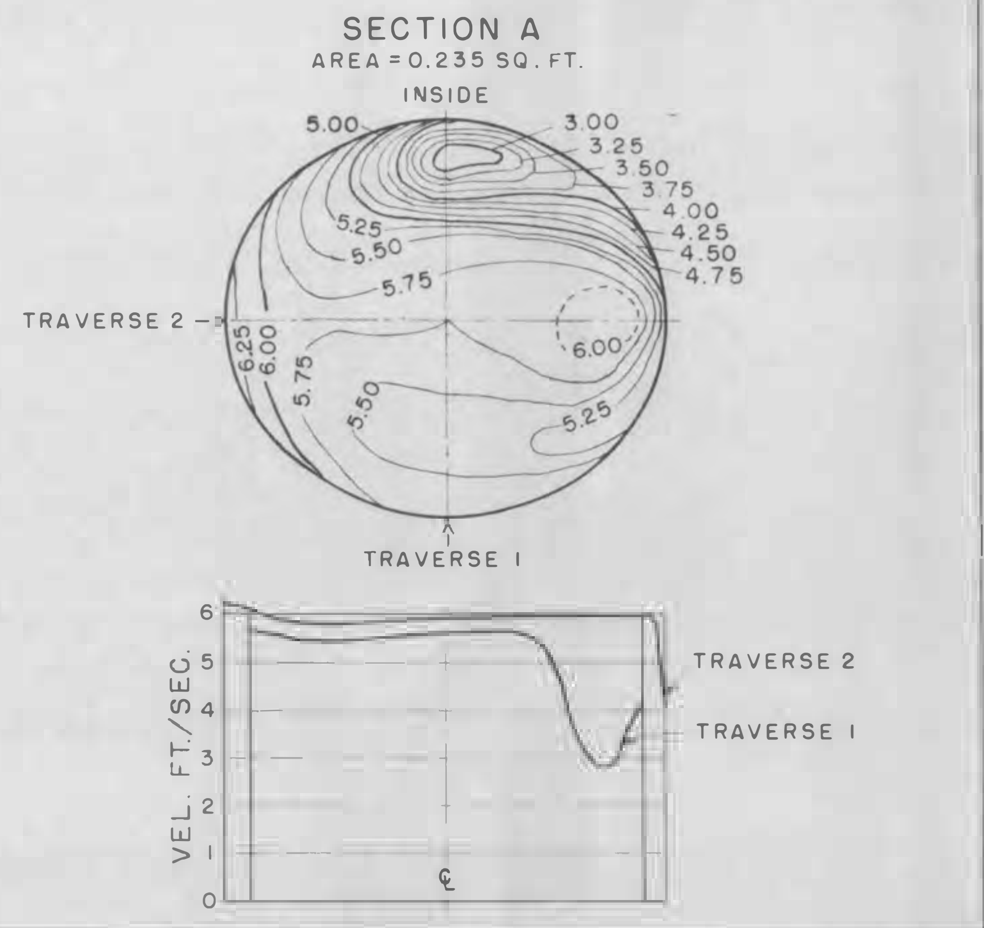
SKETCHES SHOWING LOCATION OF SECTIONS

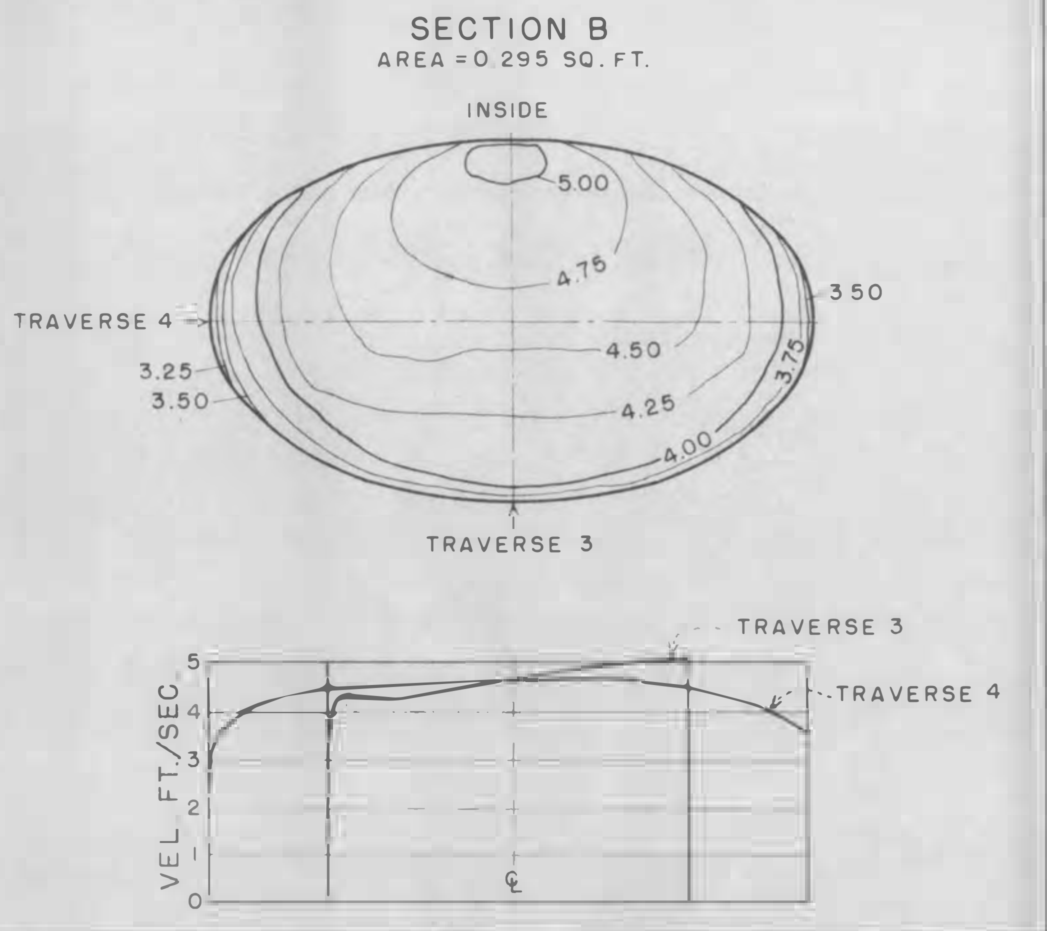


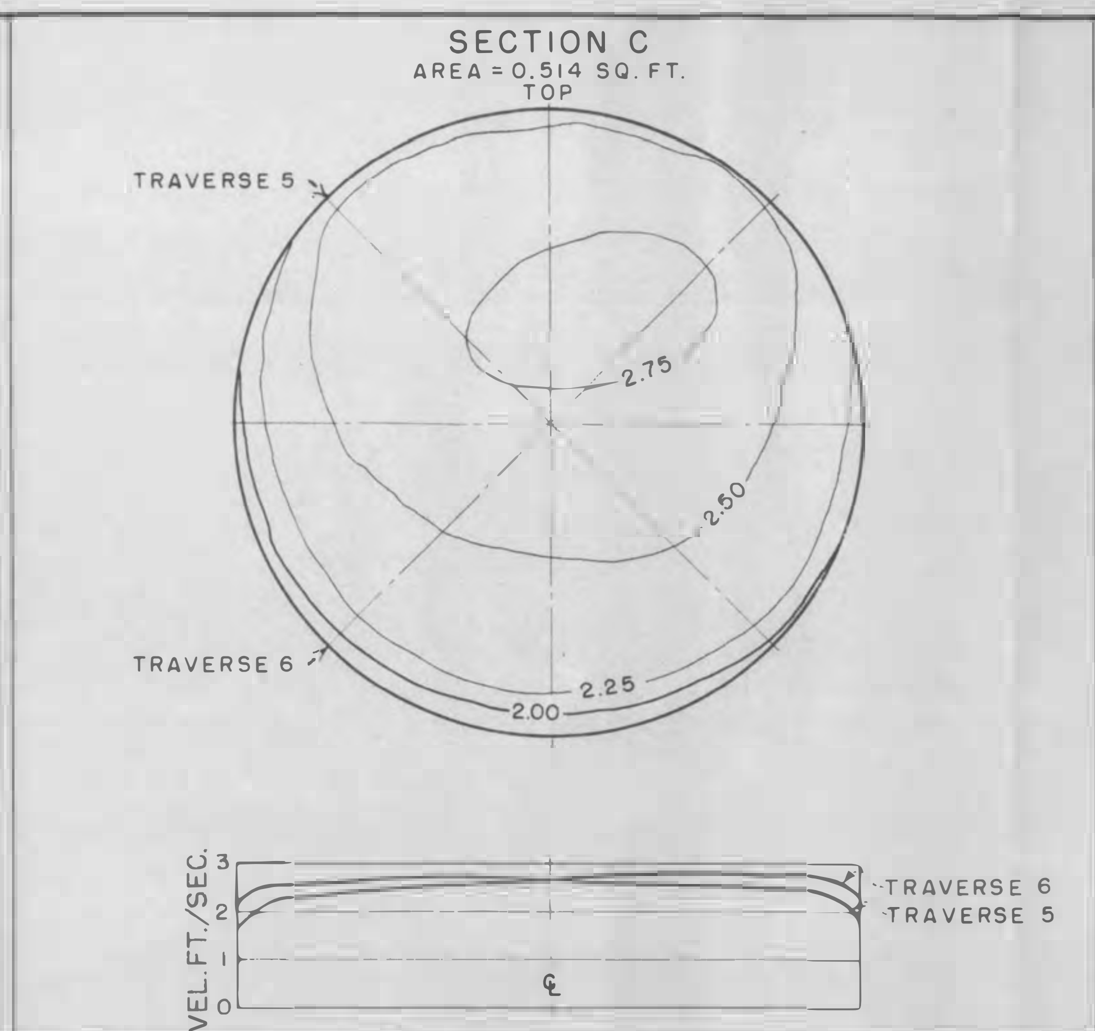
RECTANGULAR ENTRANCE

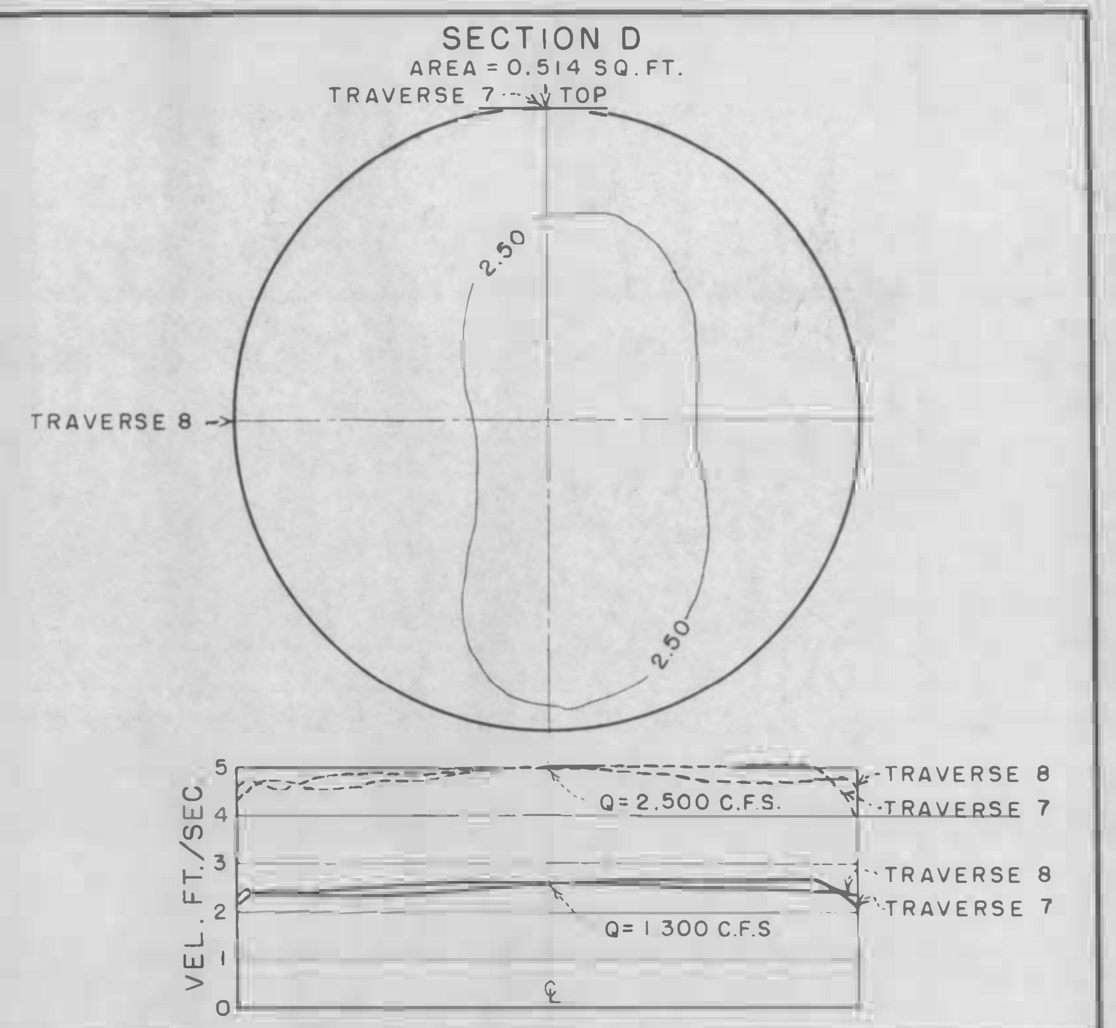
TABLE 2

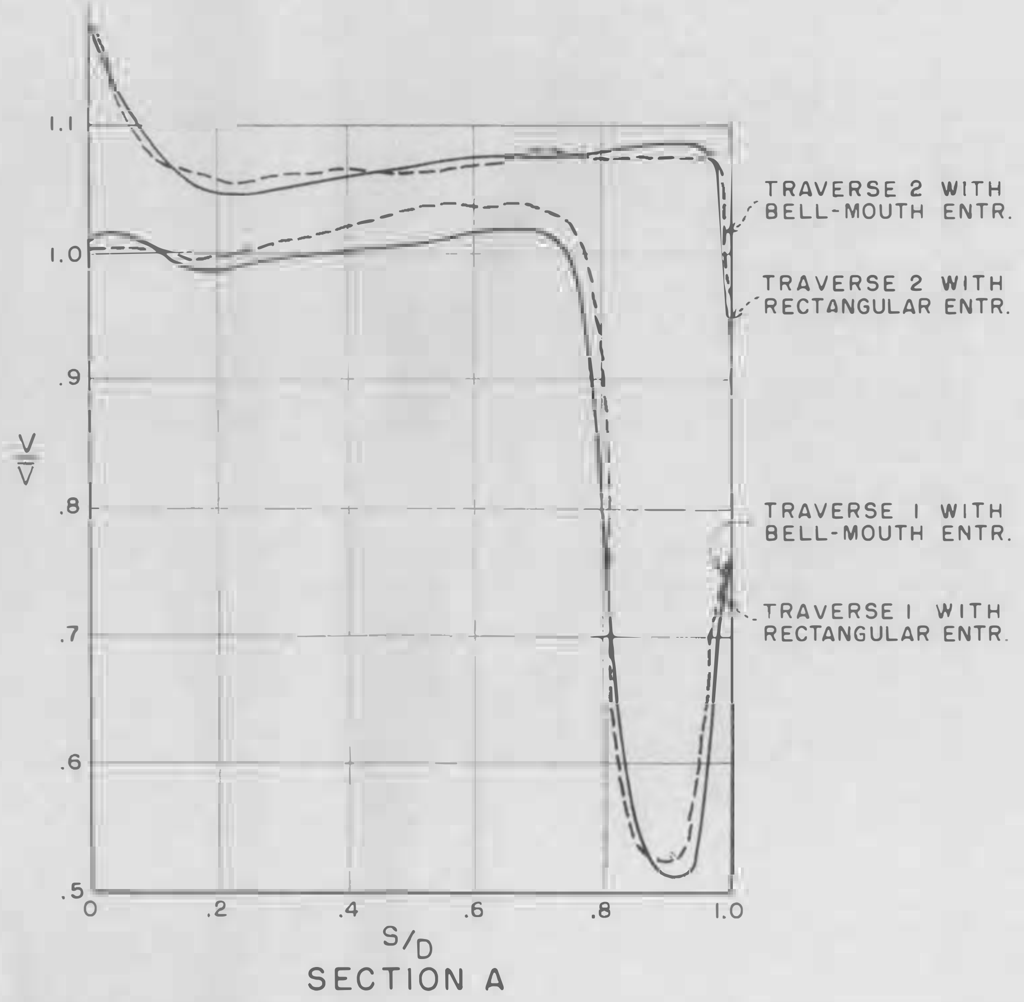


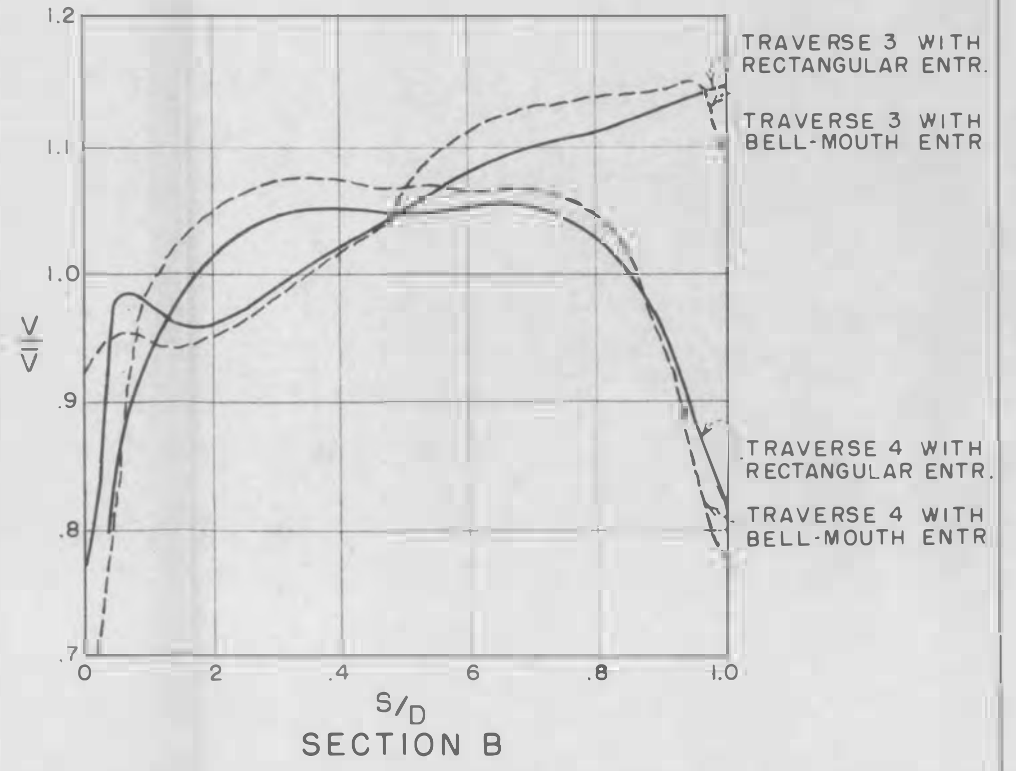


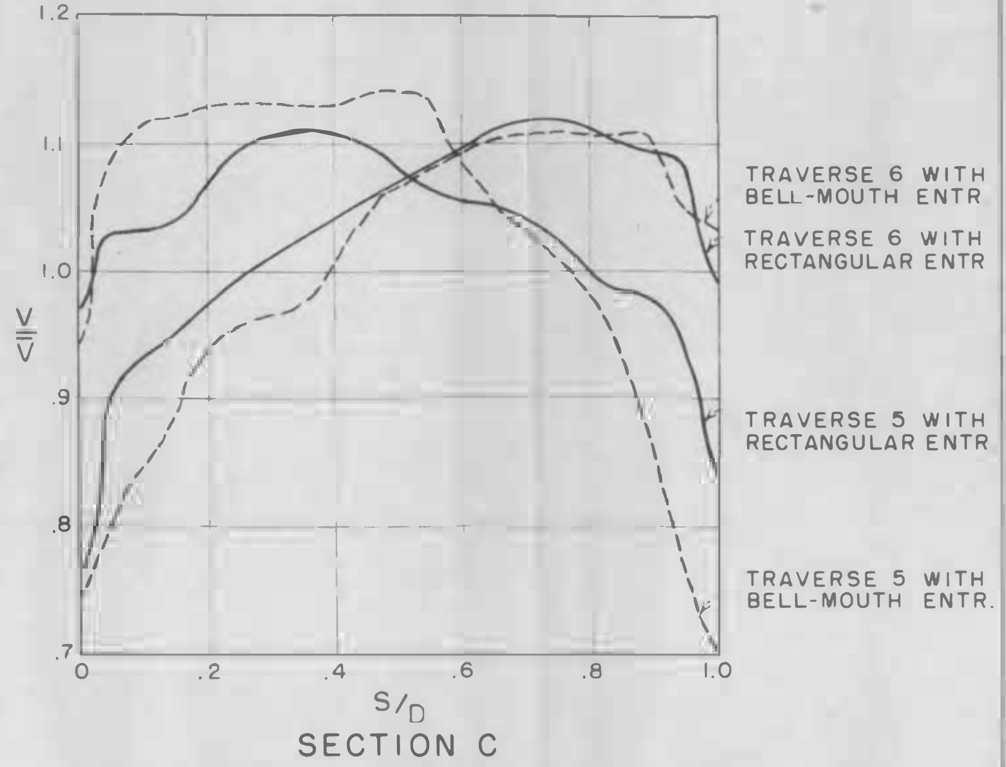


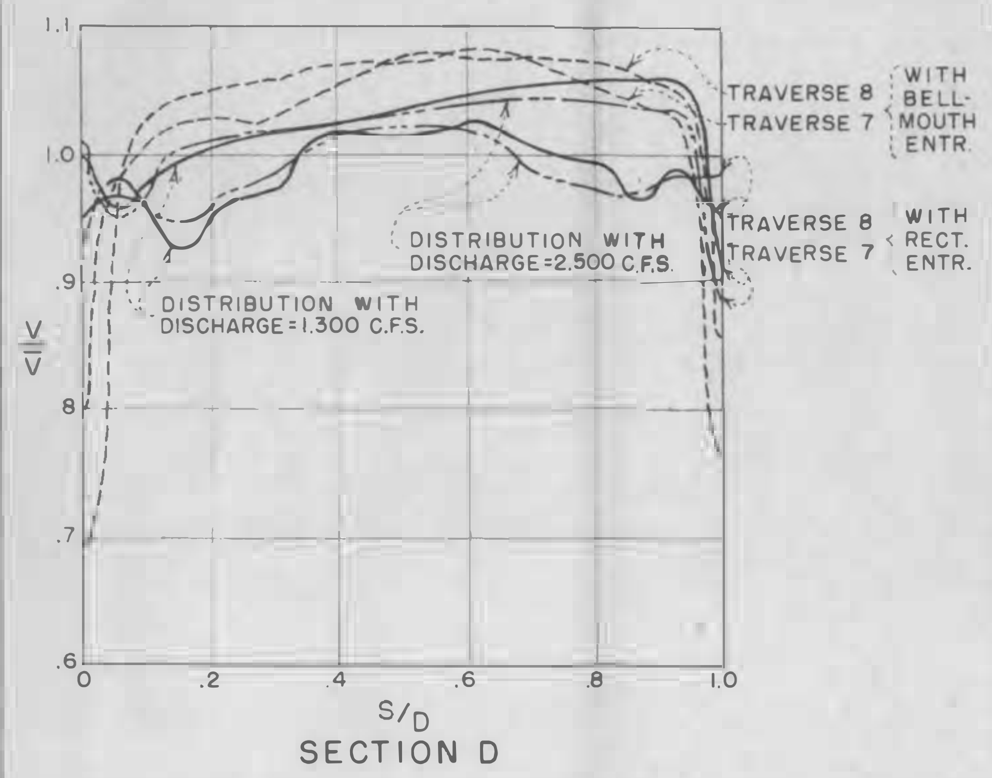












NOTES

The curves shown in this section are the graphical presentation of the various velocity traverses similar to those above, except that the plotting is non-dimensional.

V = Actual measured velocity at the point.
$\bar{V}$ = Mean velocity across section from $\bar{V} = \frac{Q}{A}$.
D = Total distance across given traverse.
S = Distance from initial point of traverse to point of measurement.

Iso-velocity lines for the various sections are plotted at intervals of 0.25 ft per sec.
All values given are actual model values.

DEPARTMENT OF THE INTERIOR
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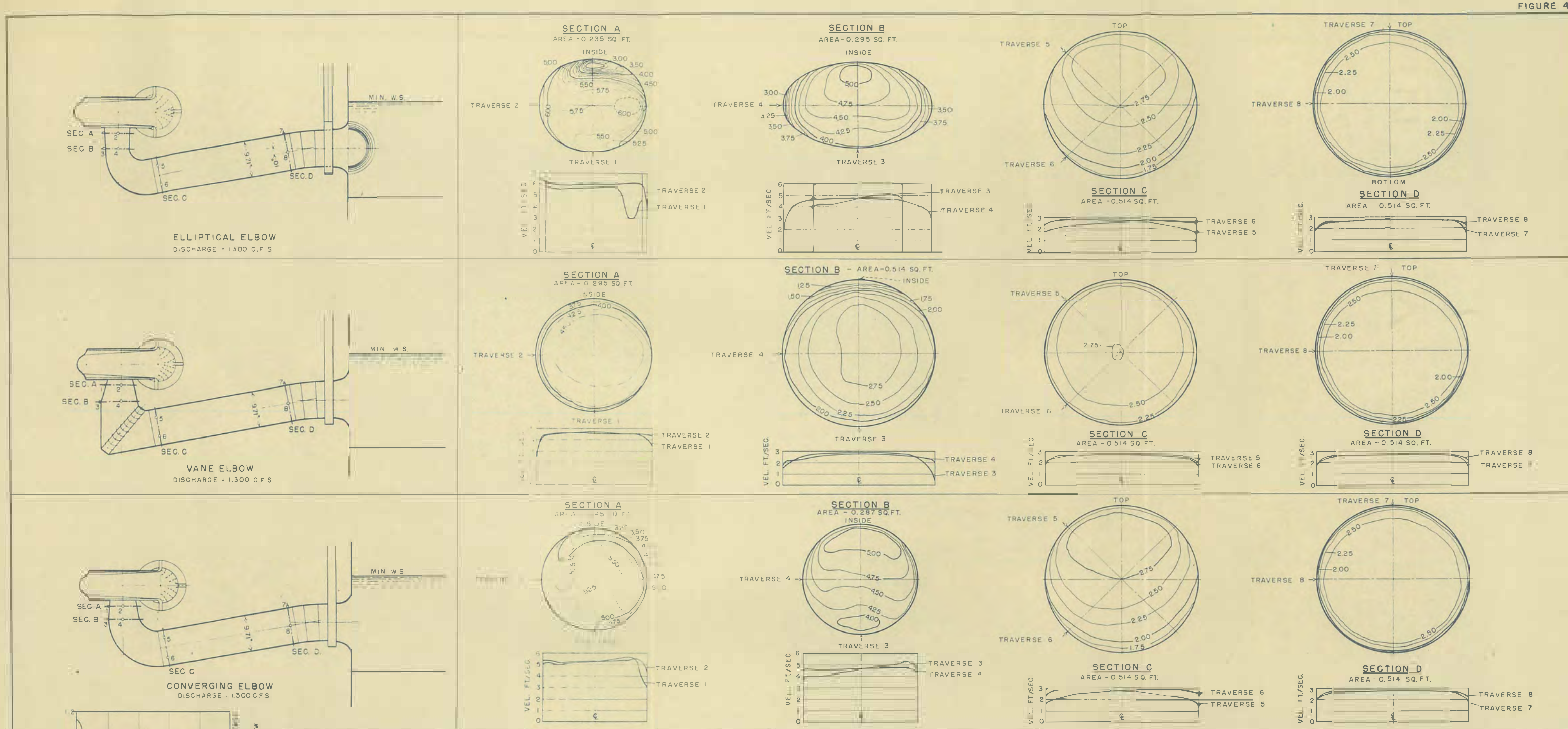
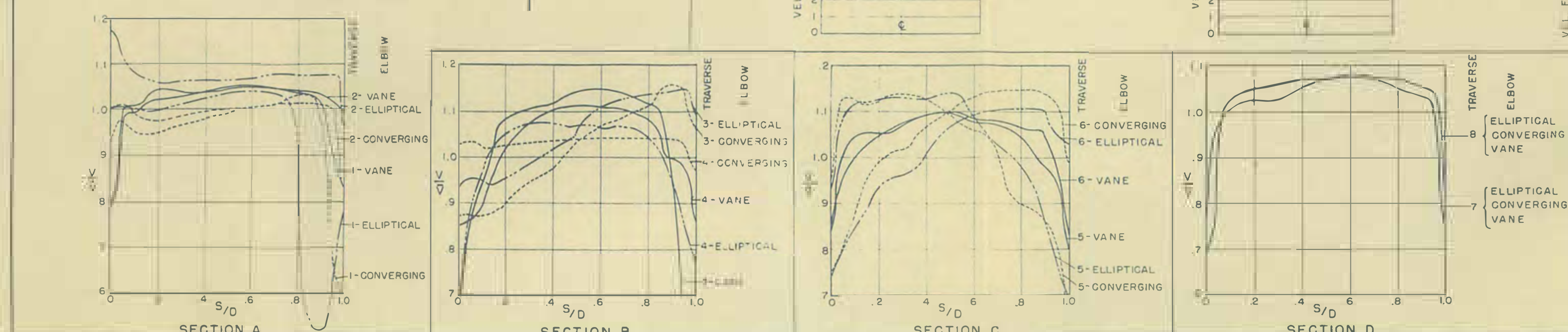
GRAND COULEE PUMPING PLANT
MODEL STUDIES OF INTAKE
MODEL SCALE 1:17.3
VELOCITY DISTRIBUTIONS WITH ELLIPTICAL ELBOW AND RECTANGULAR ENTRANCE

DRAWN F.T. SUBMITTED
TRACED C.I.H. RECOMMENDED
CHECKED D.J.H. APPROVED
DENVER, COLO.-FEB. 7, 1939 222-D-4114





NOTES

The curves shown in this section are the graphical presentation of the various velocity traverses similar to those above, except that the plotting is non-dimensional.

V = Actual measured velocity at the point.

$\bar{V}$ = Mean velocity across section from $\bar{V} = \frac{Q}{A}$

D = Total distance across given traverse.

S = Distance from entrance to point of measurement.

Iso-velocity lines for the various sections are plotted at intervals of 0.25 feet per second

All values given are actual model values.

DEPARTMENT OF THE INTERIOR
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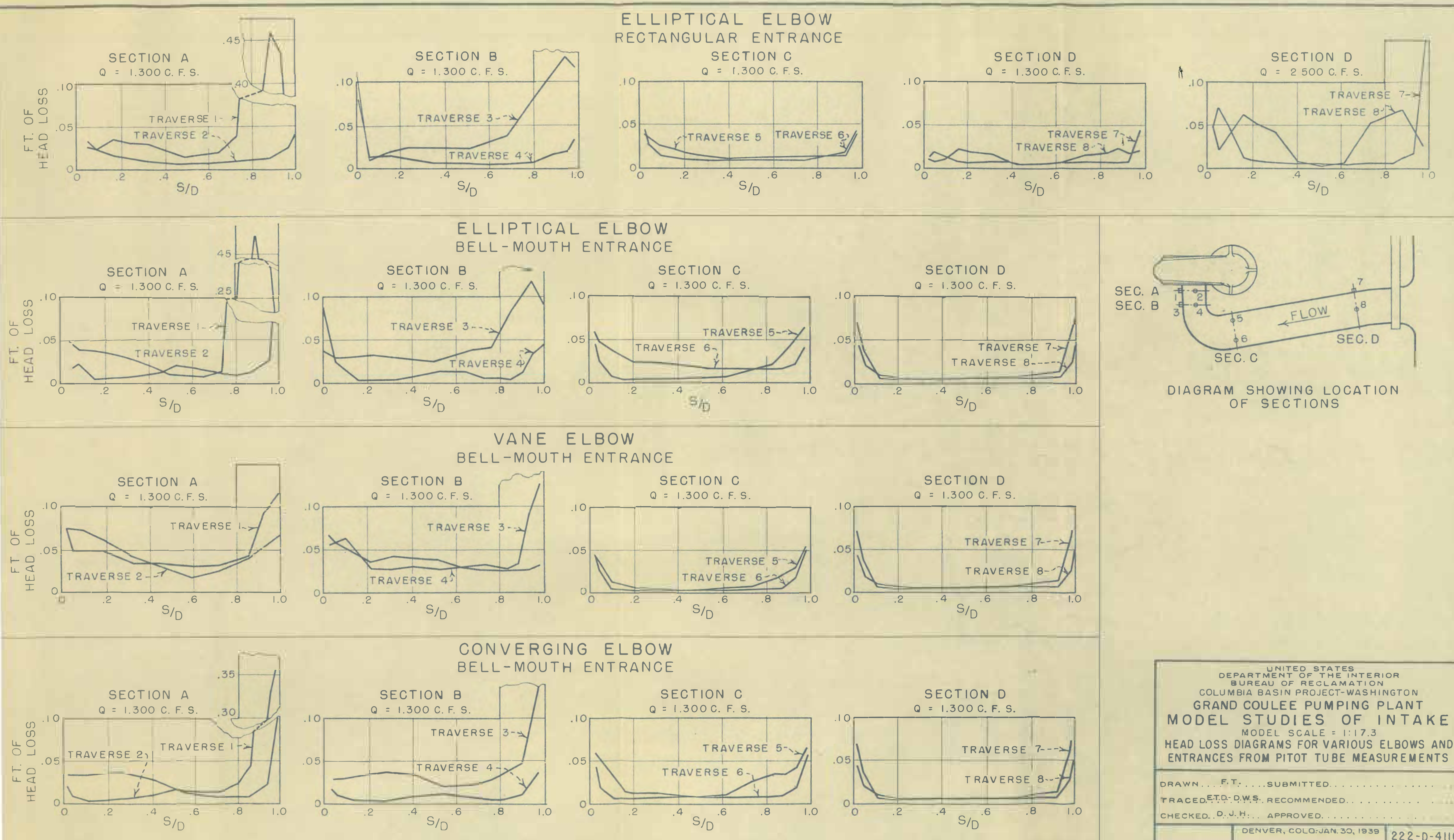
GRAND COULEE PUMPING PLANT

MODEL STUDIES OF INTAKE

MODEL SCALE = 1:17.3

VELOCITY DISTRIBUTIONS WITH VARIOUS ELBOWS AND BELL-MOUTH ENTRANCE

DRAWN F.T.	SUBMITTED
TRACED E.F.J. D.R.S.	RECOMMENDED
CHECKED D.J.H.	APPROVED
DENVER, COLORADO JANUARY 24, 1939	222-D-4115



UNITED STATES
DEPARTMENT OF THE INTERIOR
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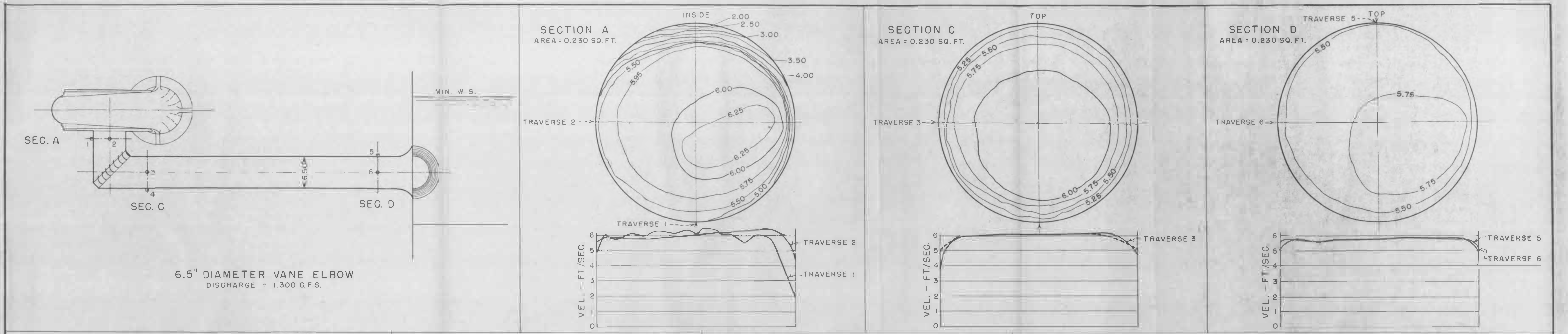
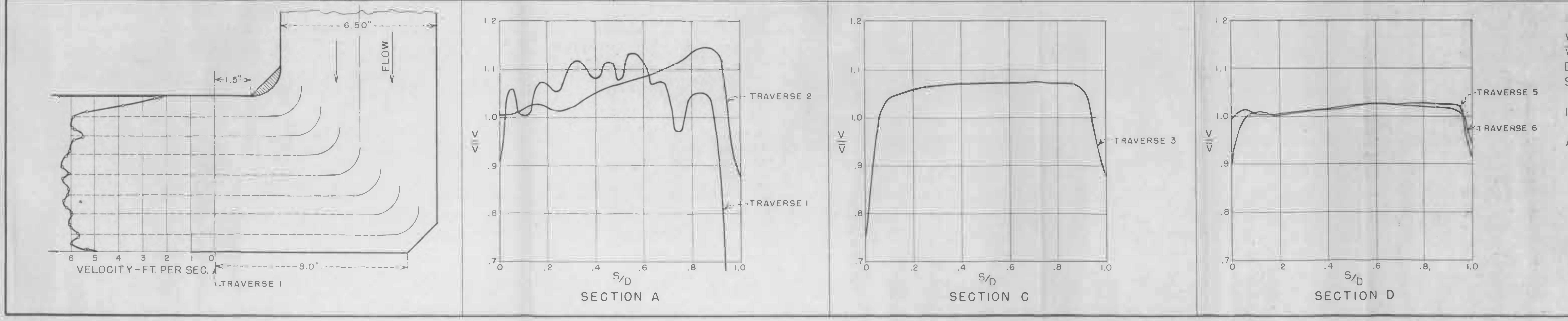
COLUMBIA BASIN PROJECT-WASHINGTON
GRAND COULEE PUMPING PLANT
MODEL STUDIES OF INTAKE
MODEL SCALE = 1:17.3
HEAD LOSS DIAGRAMS FOR VARIOUS ELBOWS AND ENTRANCES FROM PITOT TUBE MEASUREMENTS

DRAWN F.T. SUBMITTED
TRACED E.T.D.-D.W.S. RECOMMENDED
CHECKED D.J.H. APPROVED

DENVER, COLO. JAN. 30, 1939 — 222-D-4116





NOTES

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$\overline{V}$ = Mean velocity across section from $\overline{V} = \frac{Q}{A}$.
D = Total distance across given traverse.
S = Distance from initial point of traverse to point of measurement.
Iso-velocity lines for the various sections are plotted at intervals of 0.25 ft. per sec.
All values given are actual model values.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
COLUMBIA BASIN PROJECT - WASHINGTON

GRAND COULEE PUMPING PLANT
MODEL STUDIES OF INTAKE
MODEL SCALE = 1:17.3
VELOCITY DISTRIBUTION WITH 6.5" DIA. VANE ELBOW AND BELL-MOUTH ENTRANCE

DRAWN... F.T. ..... SUBMITTED ....
TRACED. F.T.-D.-D.W.S. RECOMMENDED ....
CHECKED... D.J.H. .... APPROVED ....

DENVER, COLO. - JAN. 30, 1939 | 222-D-4117