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EVALUATION STUDY OF THE PENDVANE FLOW METER

by

A. R. Robinson

Prepared through the cooperation of the
Applied Research Company, the Colorado Agricultural
Experiment Station and the Agricultural Research Service,
Soil and Water Conservation Research Division, Northern Plains Branch.

Colorado State University
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INTRODUCTION

The Pendvane flow meter has been calibrated for a range of operating conditions both in the hydraulics laboratory at Colorado State University and through a field trial. Three meters were tested all of which were made for a 2-foot-wide rectangular section. Each of the meters was a production model furnished by the Applied Research Company, 1340 Glenarm Place, Denver, Colorado.

The Pendvane meter is a vane type measuring device for open channels which was developed over a period of years both by Mr. Ralph L. Parshall and by personnel of the Applied Research Company. The development of the meter was inspired by need for a simple, direct reading device which would give a reasonable accuracy and would operate at practically no loss at head. Disadvantages of most presently used devices are that a considerable loss of head is usually required for correct operation and that, for most, a reading of depth must be converted to flow by use of tables or charts. In many cases it has been found that these two items limit the use of the devices. Another great need is for a device that will work under conditions of very low velocities and submerged conditions. Most of the existing devices will not operate at all under these conditions. It has been advanced that the Pendvane meter operates very successfully for this condition and that its action is not affected by variation of approach velocity or by any downstream condition.

The Pendvane flow meter has been developed so that vanes of different shapes are available for measurements of flow in different cross-sections. The given vane must be suspended in a section of defined shape and size. Sections which are being recommended are 6 feet in length with the meter being mounted approximately at the half-way point. These measuring sections may be either trapezoidal or rectangular but must conform to the shape for which the meter was developed and calibrated. The vane shape was determined so that, for a constant flow, the meter should indicate the same flow if the velocity is high and the depth shallow or for greater depths and slower velocities. The shape of the vane is such that the force is integrated so for a constant discharge the same flow is indicated for a range of velocities and depths.

The indicating device in the head of the meter consists of a liquid-filled tube mounted opposite a calibrated scale in the head of the instrument. This head has a curvature which has been predetermined in the laboratory. In the liquid-filled tube is a small air bubble which moves along the curved tube depending on the deflection of the vane. The amount of flow is then indicated on the scale opposite the bubble in the tube. This scale can be marked in cubic feet per second, gallons per minute, or any prescribed unit of discharge.

A meter being used in a trapezoidal section is shown as Fig. 1. A field installation with a flow of water through the section is shown as Fig. 2.

The use of pendulum flow meters has been reported by Thysse[1]. In this case truncated cones were used to determine velocities at sea and in rivers. For velocities in the range of 2.5 to 6.0 feet per second, the

[1]Observations of the velocity of flow by means of the force exerted on a solid object (Impact flow meters), by J. Thysse, Commission Des Mesures Hydrauliques, Rapport 15, Delft, Netherlands.

meters were accurate to 5 to 10 per cent. For velocities lower than 2.5 feet per second the error increased. The accuracy of this method was stated to be not less than 5 per cent under favorable conditions increasing to 10 per cent or more deviation under unfavorable conditions.

DESCRIPTION OF TESTS

Most of the tests were made in a 2-foot wide, glass wall, testing flume which is part of the permanent equipment in the hydraulics laboratory at Colorado State University. This flume was used by Mr. Parshall for much of the early development work of the vane meter. For these tests the flow meter was installed at a point which gave approximately a 15-foot length of unobstructed channel immediately upstream. The meters were installed very carefully in the manner prescribed by the developers. This included the clearance of the tip from the floor and the meter being level and exactly at right angles to the direction of flow. In order to determine the effect of the approach velocity profile on the operation of the meter, a lattice baffle was installed 8 feet upstream from the measuring section for some of the tests. This baffle consisted of 1-inch x 1-inch strips of lumber having openings 1-3/8 inches square. In effect this broke up the establishment of a normal velocity profile so that this variation in profile could be studied.

For these tests the discharge was determined using precalibrated orifice plates in the discharge line from the pump. Flows up to about 5 cfs were used with the depth of flow for a given discharge being varied using an adjustable tailgate. Usually, for a constant discharge, five depths of flow and the corresponding velocities were used.

For the field tests an existing concrete box on a farm lateral which was 2 feet wide and 2 feet deep was used. The meter was installed 3 feet from the upstream end of the section. This box was located approximately 150 feet downstream from the head gate on the lateral. This head gate was used to regulate the amount of flow into the section. The meter was installed very carefully according to the prescribed instructions.

Immediately downstream from the meter section was installed a 1 foot Parshall measuring flume. This flume was a commercial one and the assembled dimensions were set very accurately. The flume was installed correctly and during operation, measurements of depth were made very carefully. In order to insure that submergence of the flume was not a factor during the test period, depths of flow at the point for determining submergence effect were also taken. With these measurements it was determined that submergence was not a factor during the flume operation so that the free-flow-discharge relationship was used throughout the testing. An adjustable tailgate was used in the ditch immediately downstream from the Pendvane meter section to vary the depth of flow through the section for a given discharge.

PRESENTATION AND EVALUATION OF DATA

For the operation of the meter, zones A and B have been specified by the manufacturer. Zone A is the recommended range of operation with greater accuracy being specified in this range than zone B which also covers a usable range of operation. Actually these zones limit the range of velocities with those in zone B being higher than zone A. Depths lower than specified for zone B would necessarily mean much higher velocities and are therefore not in a recommended zone of operation. These operation zones have been shown on Figs. 3, 4, 5, and 6 which summarize the results of all the tests.

For the laboratory tests shown in Figs. 3, 4, and 5, relatively constant discharges of 1, 2, 3, 4, and 5 cfs were used. For each discharge the depth was varied in the 2-foot-wide section so that both the A and B zone of operation were included. For this comparison a ratio of the discharge as indicated by the vane meter and that determined from the orifice in the pump-discharge line was used for a comparison. A ratio of

1.0 would indicate that the two determinations were the same. If the ratio was 0.9, then the vane discharge was 10 per cent lower than that from the orifice meter. Conversely for a ratio of 1.10 the vane discharge was 10 per cent higher than that from the orifice meter. The normal section indicated in Figs. 3, 4, and 5 was that with the 2 glass wall flume with 15 feet of unobstructive approach. The second condition shown in Figs. 3 and 4 was with the baffle installed 8 feet upstream from the vane meter section.

Considering first only those tests in the laboratory flume for the A zone and the normal flume section, it is noted that for flows of 1 to 3 cfs, the Pendvane meter indicated discharges that were always equal to or higher than those from the orifice meters. For the higher flows the Pendvane meter gave discharges that were both lower and greater than that by the orifice method. For each meter the general trends were very similar. For the three lower flows with the normal section, it is noted that the vane meter over-registered the flow by as much as 9 or 10 per cent at the intermediate depths. However, the average range of this variation was in the order of 5 per cent. As an example, with meter A-3 for a flow of 2 cfs the ratio varied from 1.000 to 1.052 for the A zone. Considering the two higher flows under this condition, it is noted that there is a much wider variation in the determined discharges. Here the trends are almost identical between the three meters and the ratios vary from less than one to greater than one. For 4 cfs at the shallower depth this ratio is about .94, whereas at depths nearer 1.7 feet it varies from 1.045 to 1.068. In this range the overall variation is between 8 and 12 per cent for this condition.

The foregoing condition is one which would not normally be found in the field. This is due to the long section with uniform side walls which would facilitate the development of a thick boundary layer and a velocity profile which would probably not be representative of the field situation. For the more usual condition baffles were installed 8 feet upstream from the measuring point. In a sense this would simulate a rough boundary and changing from one section to another in that turbulence would be introduced. The effect of this condition on the operation of the meters is illustrated in Figs. 3 and 4. In general, an entirely different relationship was found than with the previous condition illustrating that the approach velocity does exert a considerable influence on the operation of the meter. Particularly this will be true for the different distribution of velocity. For discharges in the range of 1 and 2 cfs the vane meter over-registered by a factor varying from 1.00 to about 1.05. In one case, for the A-2 meter and 2 cfs, this variation was from .996 to 1.083 for the A zone. For 3 and 4 cfs, ratios varying from .96 to over 1.11 were noted giving a maximum variation from the indicated discharge by orifice meter of from 10 to 13 per cent. For the highest flow (5 cfs) under this condition, the vane meter always over-registered to a maximum ratio of about 1.08.

In general, the laboratory tests made in the B zone of operation show a wider range in deviation of vane discharge from the independent method. Differences up to + 12 per cent for the lower flows and - 13 per cent at the higher flows were observed.

The results of observations on the meter operation under field conditions are shown in Fig. 6. The effect over a range of depths for each of four different discharge ranges are shown. For flows of 1.5 and 3.5 cfs the vane meter gave discharges which were both less than and greater than those determined by Parshall flume. At an intermediate flow of 2.5 cfs the vane meter gave flows that were always larger and at 4.5 cfs, always smaller than those from the Parshall flume determination. This amounted to a total variation of about 8 per cent for the lowest flow and 4 per cent for the others. All these tests were within the A zone of operation. Considering only the lowest and highest ratios results in an overall expected accuracy of about $\pm$ 5 per cent for a total range of 10 per cent.

Another method of comparison of discharge as determined by an independent method from that of the Pendvane meter is shown in Figs. 7, 8, and 9. This gives the comparison of the discharge as determined by the Pendvane meter and that of the independent method of orifice or Parshall flume. If the two determinations were the same, then a 1 to 1 relationship given by the heavier line would be determined. For flows in the A zone of operation the deviations are generally within ± 5 per cent although there are several points which fall between the + 5 and + 10 per cent lines. In general, for the B zone of operation the points fall between the 5 and 10 per cent deviation lines on both the positive and negative sides. No significant differences were noted between the deviation of points for either the normal flume section or the one in which baffles were installed upstream from the meter.

Field tests comparing the discharge of the Pendvane meter with that of an accurately installed Parshall flume is given in Fig. 9. Here the deviations are near ± 5 per cent as a maximum with most of the points falling within ± 4 per cent accuracy. These points represent carefully observed data where, in many cases, duplicate observations were made.

DISCUSSION OF RESULTS

From the results of tests which have been presented it is evident that approach conditions and the resulting approach velocities do have some influence on the accuracy of the flow meter. With the long, smooth-walled section a wider deviation of results were noted than under the other conditions. With this condition a large range in velocity would be expected in the vertical section. This might range from twice the average velocity near the surface to one-half near the bottom.

For the case of the lattice baffle installed upstream from the measuring point in the laboratory flume, the velocities in a center line profile would be more nearly the same. This would also be true for the field measuring section primarily because the measurements are made immediately downstream from a section of converging flow. Recent tests concerned with measuring flumes gave almost constant velocities in vertical as well as horizontal profiles when measured in parallel walled sections immediately downstream from a convergence. For these reasons, the latter two conditions should be representative of the field situation and were used to determine relative accuracy of the device. Table I summarizes the results of tests under these conditions.

In general, an accuracy of about ± 5 per cent could be expected from the Pendvane meter based on the results of these tests. At intermediate depths for a constant flow the accuracy is better, usually being in the range of 0 to ± 5 per cent. The largest deviations in the A zone (-5.8 to +11.5 per cent) were usually at the lower depths and corresponding higher velocities.

Table I Pendvane Meter Evaluation

Discharge Range(cfs)	Depth of Flow(ft) With Zone	Meter Deviation Percent	Depth of Flow(ft) With Zone	Meter Deviation Percent
	Meter A-1		Meter A-2	
1	0.58 B	+ 5.6	0.57 B	+ 6.3
	.83 A	+ 3.4	.88 A	+ 5.2
	1.18 A	+ 4.7	1.19 A	∓ 1.0
	1.60 A	+ 4.4	1.60 A	+ 0.1
	1.97 A	+ 5.0	1.98 A	+ 4.3
2	.56 B	+ 8.8	.55 B	+11.7
	.84 A	+ 0.6	.82 A	- 2.9
	1.13 A	+ 3.9	1.13 A	+ 8.4
	1.49 A	+ 1.1	1.54 A	+ 2.2
	1.92 A	+ 4.4	1.95 A	- 0.4
3	.87 A	+ 6.1	.88 A	+ 4.0
	1.16 A	+ 5.2	1.19 A	+11.6
	1.50 A	- 0.7	1.51 A	+ 5.5
	1.69 A	0.0	1.70 A	0.0
	1.96 A	- 3.6	1.98 A	+ 1.1
4	1.14 A	+ 5.8	1.20 A	+10.9
	1.36 A	+ 7.7	1.39 A	+11.5
	1.57 A	+ 1.0	1.61 A	+ 4.1
	1.75 A	- 4.0	1.77 A	+ 1.3
	1.98 A	- 2.1	1.95 A	- 2.9
5	1.50 AB	+ 3.8	1.46 A	+ 7.7
	1.68 AB	- 0.8	1.66 A	+ 2.1
	1.83 AB	+ 0.6	1.82 A	+ 2.5
	1.93 AB	+ 2.6	1.96 A	+ 3.8

Table I Pendvane Meter Evaluation (Cont.)

Discharge Range(cfs)	Depth of Flow(ft) With Zone	Meter Deviation Percent
	Meter A-3	
1.5	.71 AB	+ 5.2
	.85 A	+ 5.3
	1.02 A	+ 2.1
	1.29 A	- 3.9
	1.42 A	- 3.6
2.5	.90 A	+ 3.8
	.98 A	+ 5.2
	1.07 A	+ 5.2
	1.18 A	+ 1.8
	1.32 A	+ 1.0
3.5	1.12 A	+ 1.7
	1.23 A	0.0
	1.29 A	0.0
	1.46 A	- 2.2
	1.53 A	- 2.3
4.5	1.37 A	- 5.8
	1.47 A	- 4.3
	1.52 A	- 3.3
	1.58 A	- 2.1

ACKNOWLEDGMENT

The study of the Pendvane flow meter was made possible through the cooperation of the Applied Research Company, the Colorado Agricultural Experiment Station and the Agricultural Research Service, Soil and Water Conservation Research Division, Northern Plains Branch. Meters for the study were furnished by the Applied Research Company and the tests and evaluations were made as a public service by the Experiment Station and Agricultural Research Service.

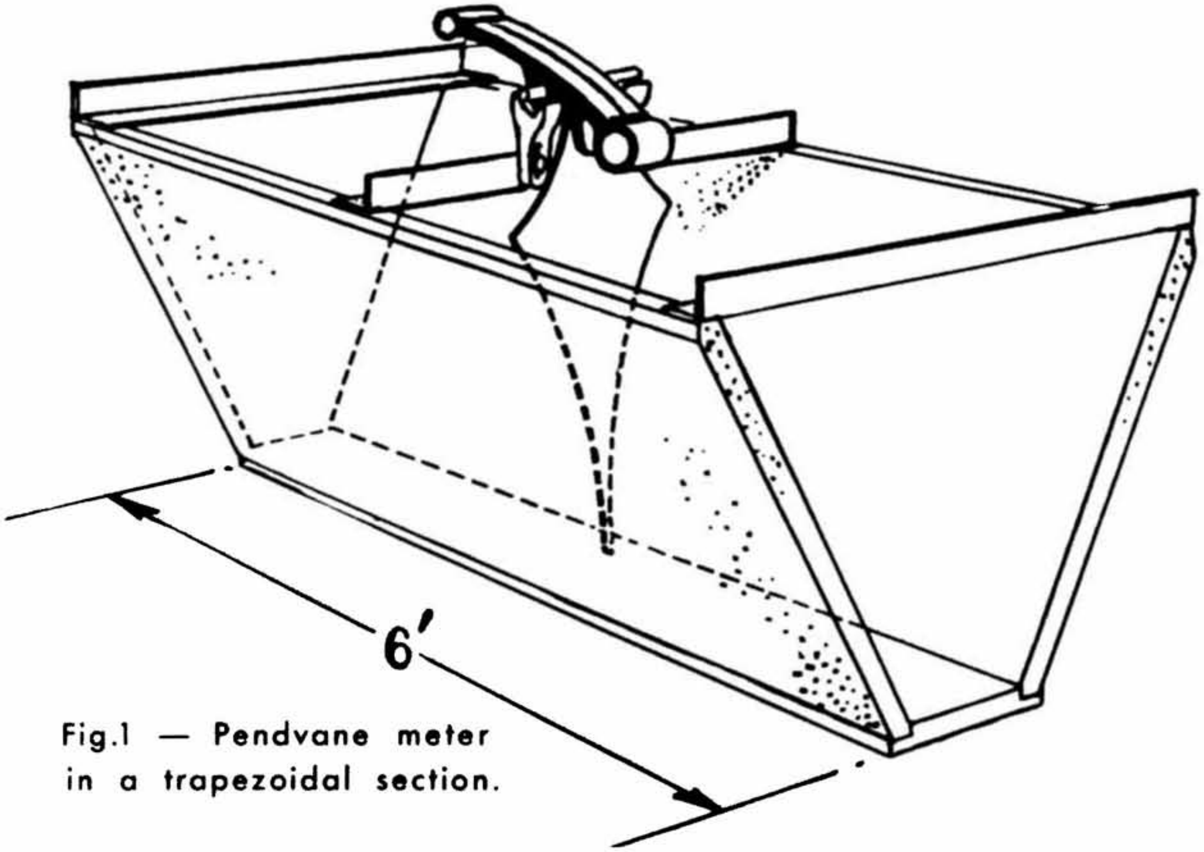

Fig.1 — Pendvane meter in a trapezoidal section.

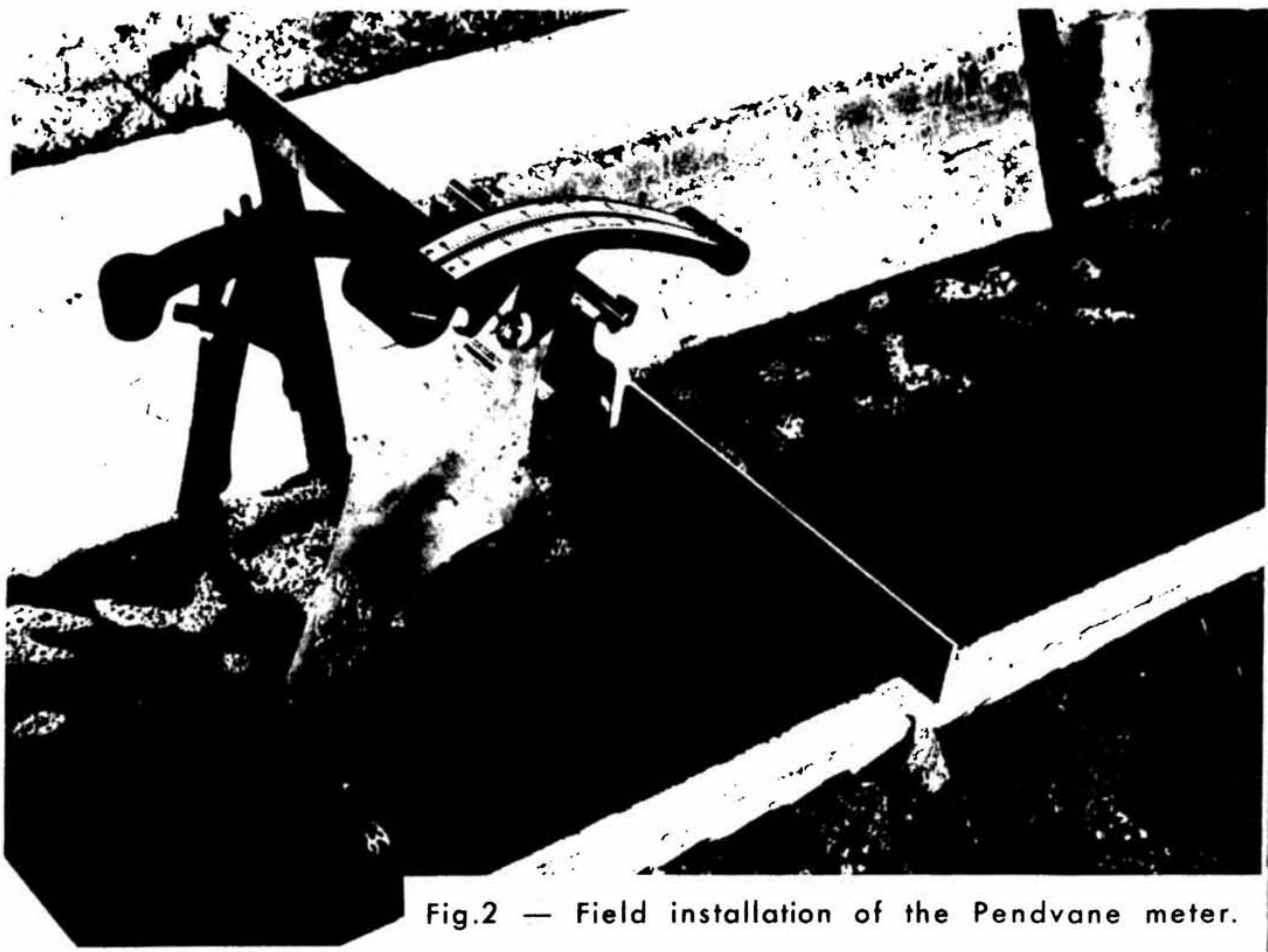

Fig.2 — Field installation of the Pendvane meter.

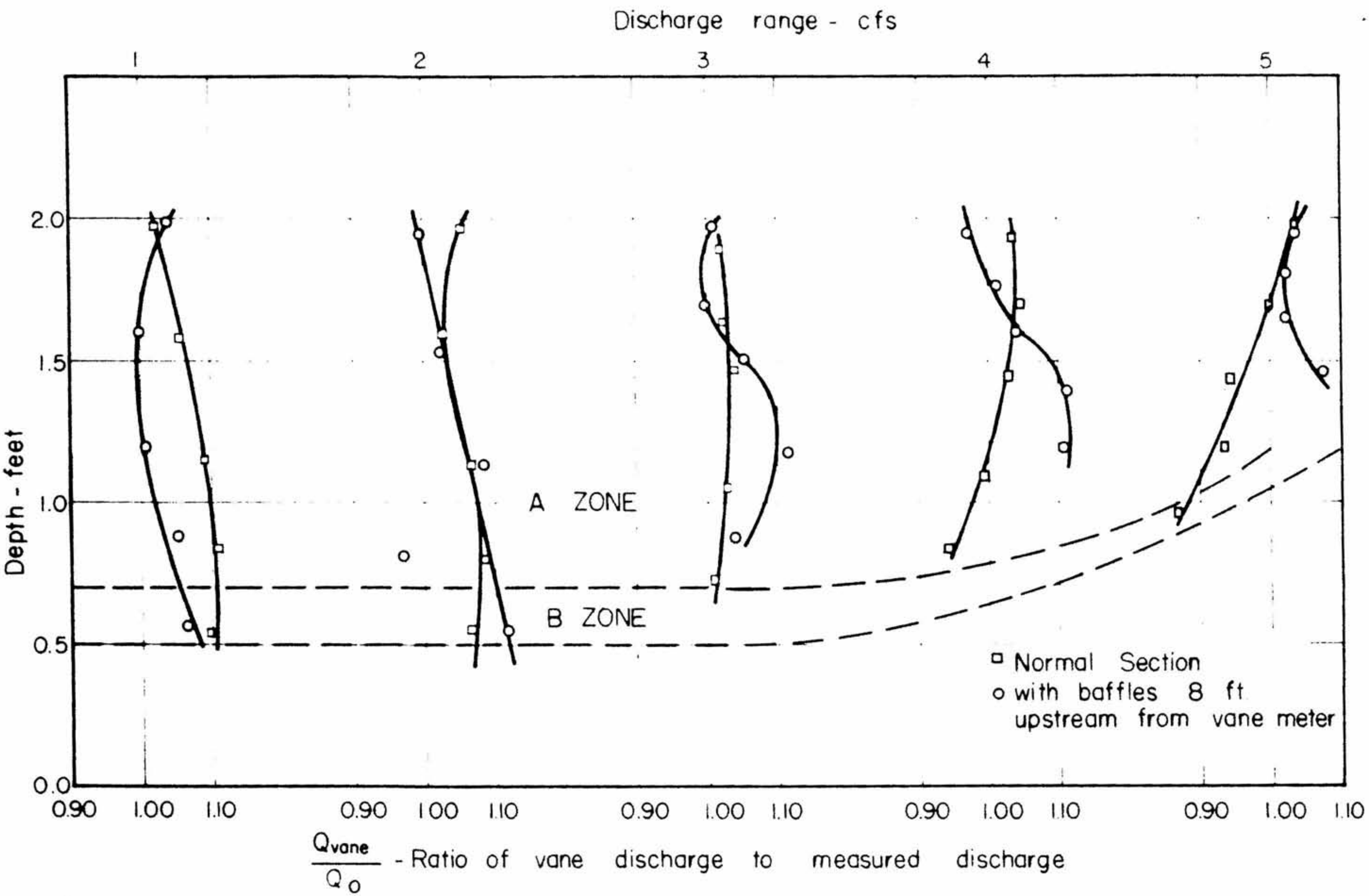

Fig. 4 Tests of Pendvane meter No. 24R24L A-2 in 24" wide channel

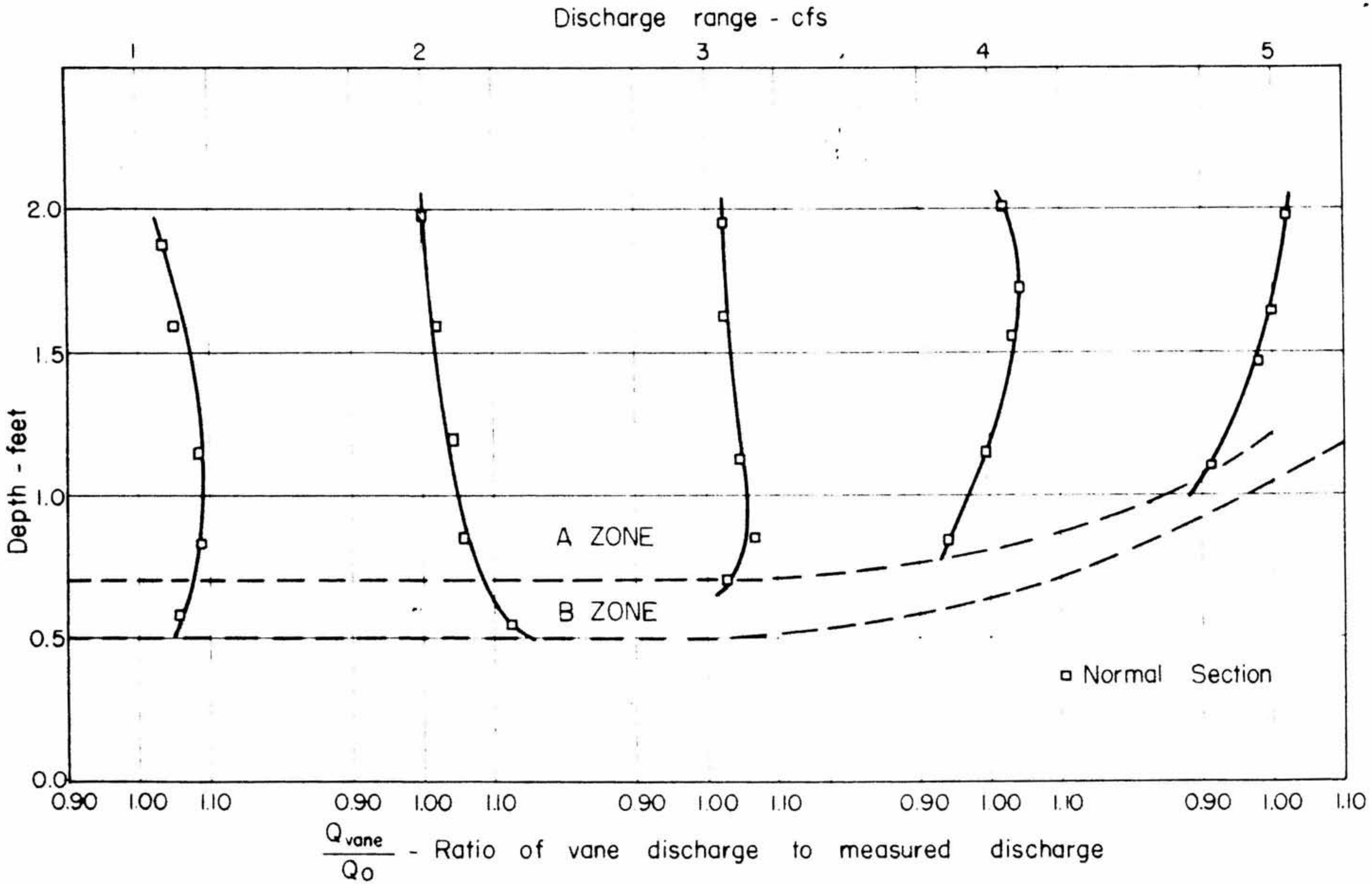

Fig. 5 Tests of Pendvane meter No. 24R24L A-3 in 24" wide channel

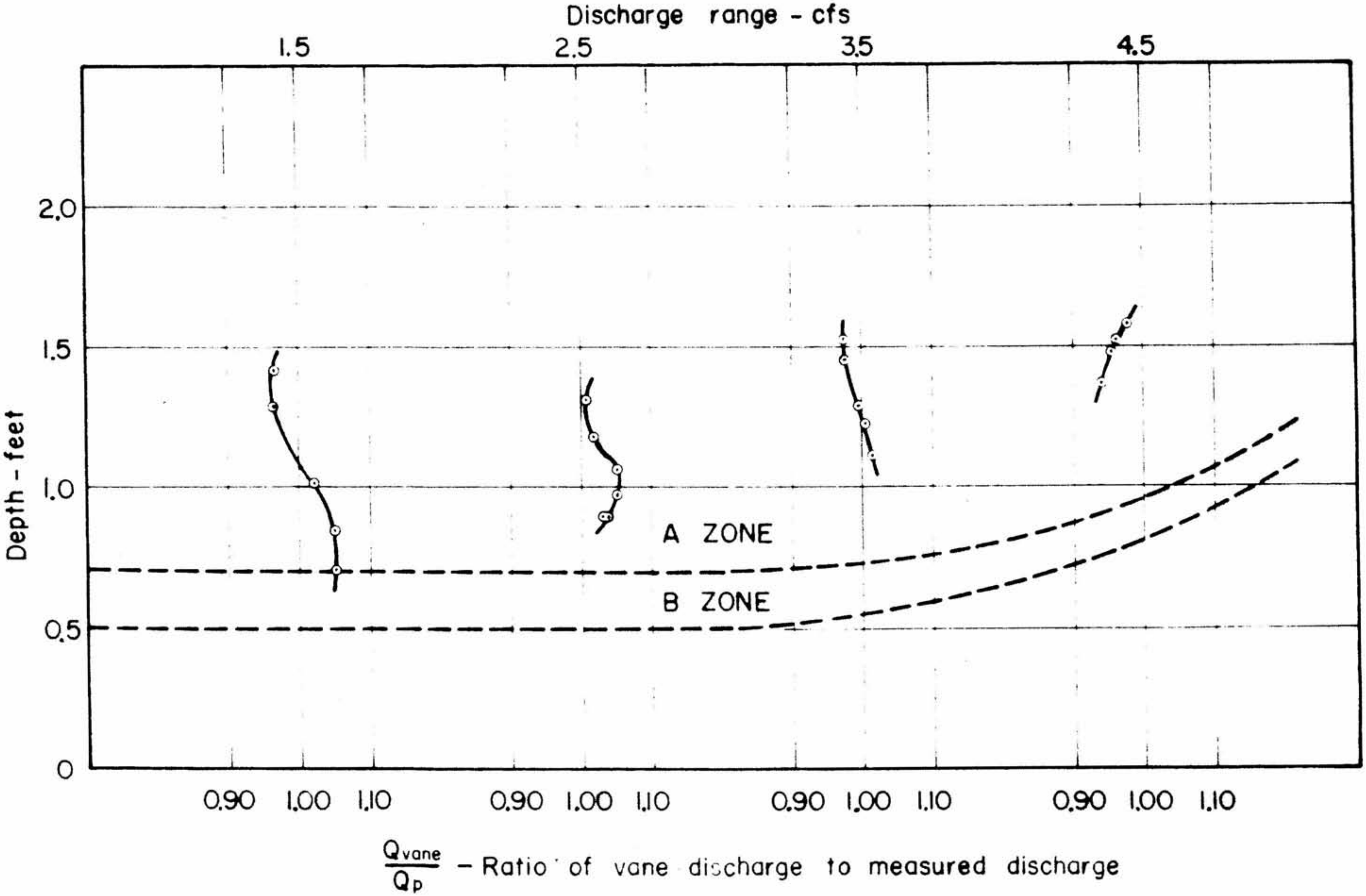

Fig. 6 Field Tests of Pendvane Meter No. 24R24L A-3

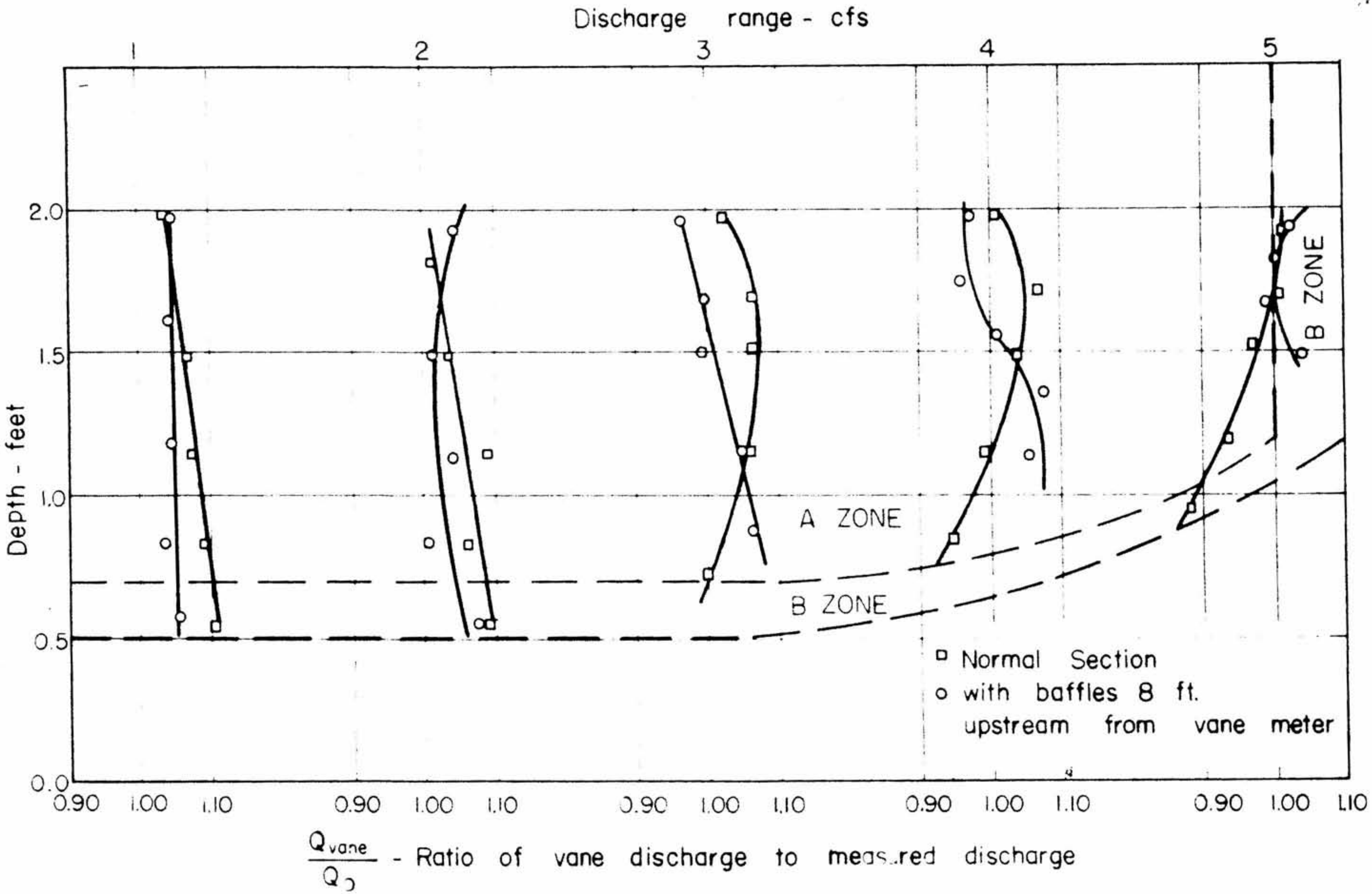

Fig. 3 Tests of Pendvane meter No. 24R24L A-I in 24" wide channel

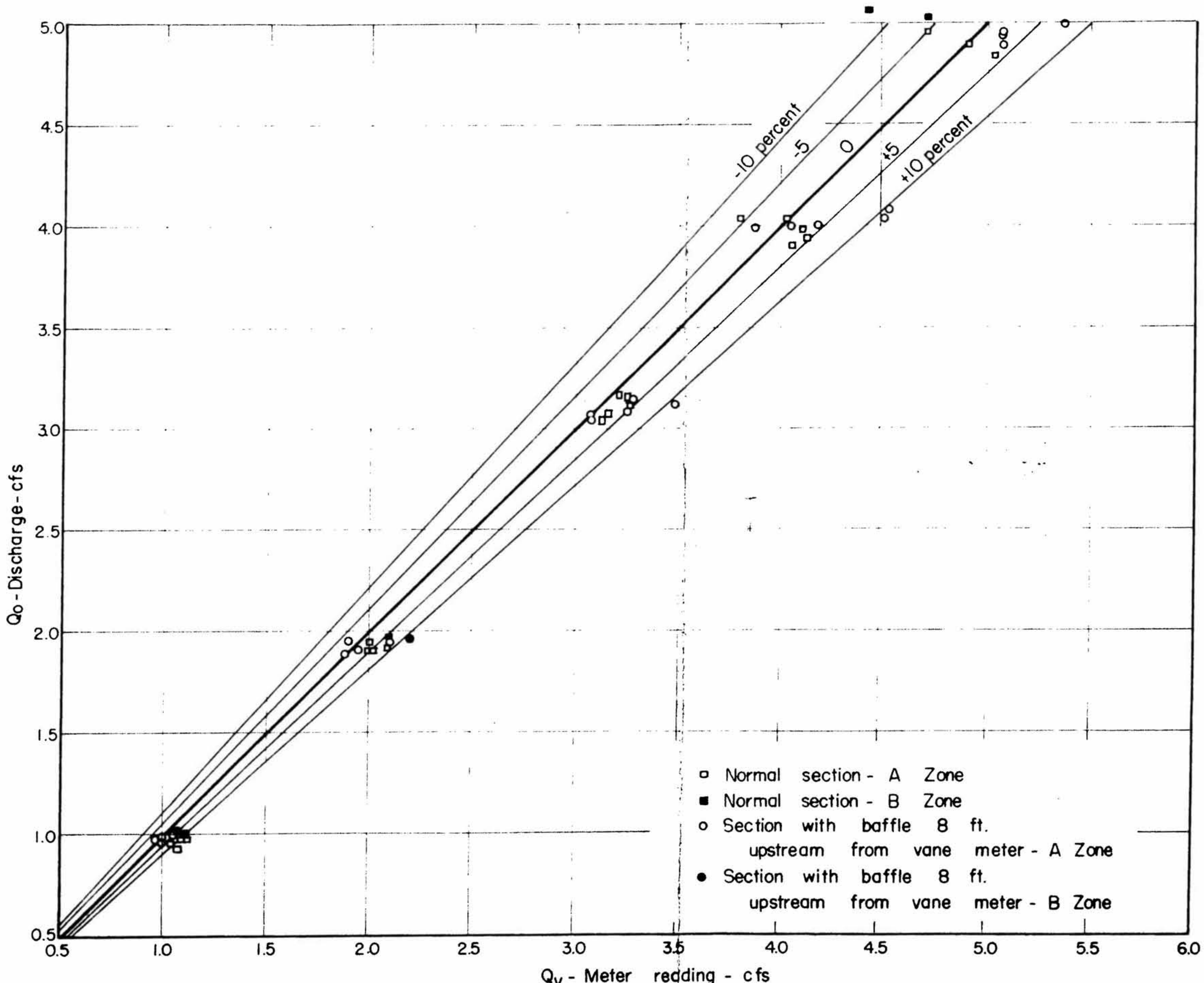

Fig. 8 Tests of Pendvane meter No. 24R24L A-2 in 24" wide channel

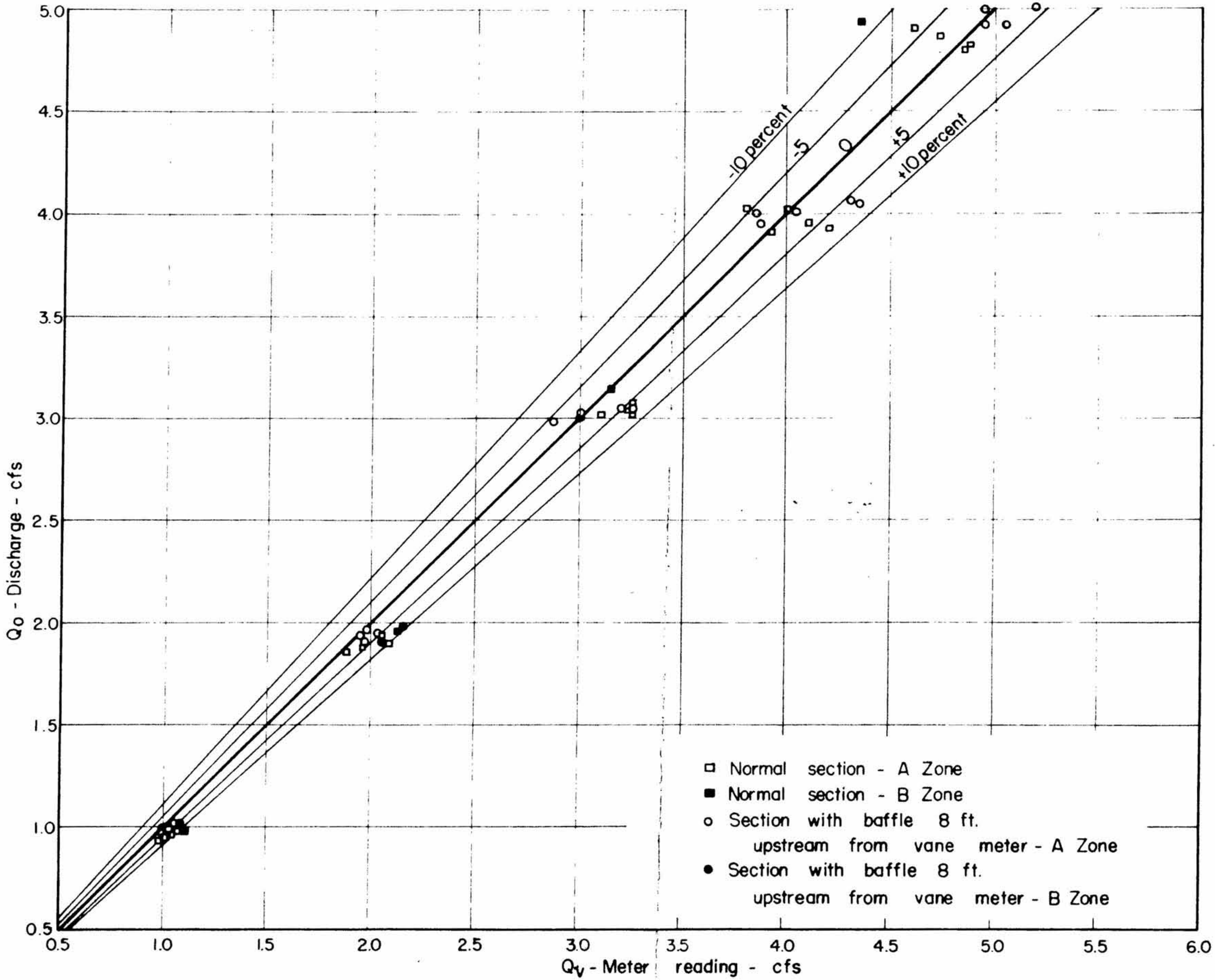

Fig. 7 Tests of Pendvane meter No. 24R24L A-1 in 24" wide channel

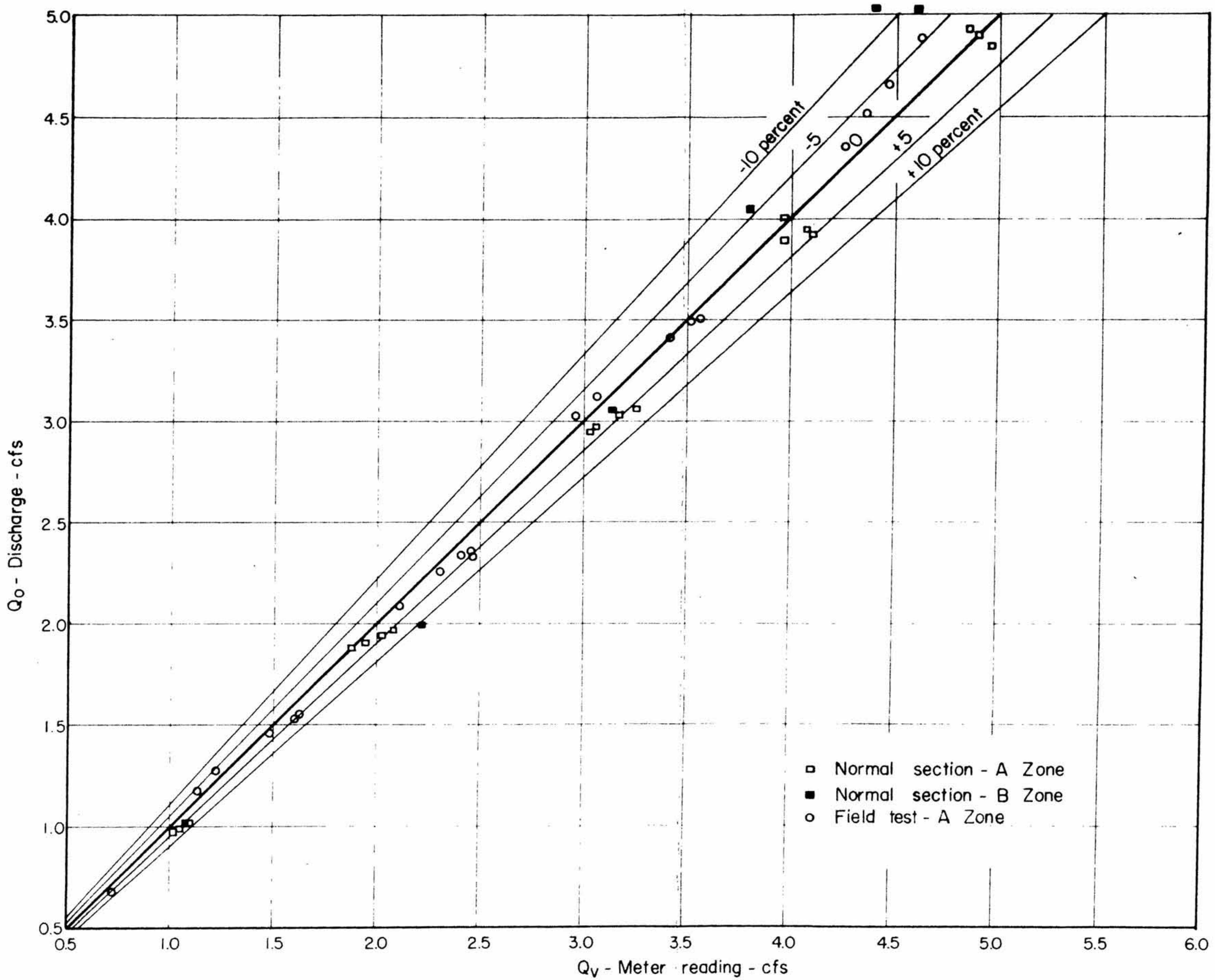

Fig. 9 Tests of Pendvane meter No. 24R24L A-3 in 24" wide channel

SCHUSTER

PENDVANE

FLOWMETER

INSTRUCTIONS FOR INSTALLATION & OPERATION

THE APPLIED RESEARCH CO.

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PENDVANE FLOWMETER
INSTRUCTIONS FOR INSTALLATION AND OPERATION

CANAL SHAPE

Each model of the PENDVANE Flowmeter is designed and calibrated for operation in a lined section of canal having a specific size and shape. At the point of installation the canal must have a permanent, unvarying cross-section for a length of at least six feet. The cross-section must conform with the dimensions shown in Table I for the applicable model number; any appreciable variation from those dimensions will decrease the accuracy of the meter.

INSTALLATION OF LINER

The canal liner can be made of any durable material, such as concrete or wood, that will provide continuous, smooth, flat surfaces for the sides and bottom. Cross member "B" (see Figure B and C) from which the meter is suspended can be of any reasonably inflexible material, but must be not more than 2 inches square; a structural steel angle is recommended.

Prefabricated lightweight concrete channel liners manufactured by The Applied Research Company provide easily assembled, permanent installations. The liner is precast in three pieces, a bottom and two side slabs. When assembled and held in position by the metal cross members, it conforms to the dimensions required for accurate operation of the meter.

The steps for assembly of the precast liner are:

1. Shape a six-foot length of unlined ditch to provide a space slightly larger than the outside dimensions shown in Table I for the model number of your PENDVANE. Provide a smooth, firm surface to support the bottom slab in the position indicated on Figure B.

2. Place the bottom slab level across the width, and sloped in the direction of flow.

3. Place one side slab in approximate position, with smooth slab face on water side. Use blocks if necessary to provide temporary support.

4. Move second slab to approximate position. Then connect the slabs at the top by bolting on the end angle members "A" (see Figure B). Leave bolts slightly loose.

5. Install the bracket support angle "B", making sure that the upstanding leg is downstream and the spacing between angles "A" and "B" are as shown in Figure B. Leave bolts slightly loose.

6. Level the liner across the channel using a carpenter's level along angle "B". Backfill with the liner in this position. Thoroughly tamp backfill material.

7. Shape the ditch for a distance of twice the maximum water depth both upstream and downstream from the ends of the liner to provide reasonably smooth transitions between the unlined ditch and the inside faces of the side slabs of the canal liner.

8. Tighten all of the bolts for the steel cross members to a snug position.

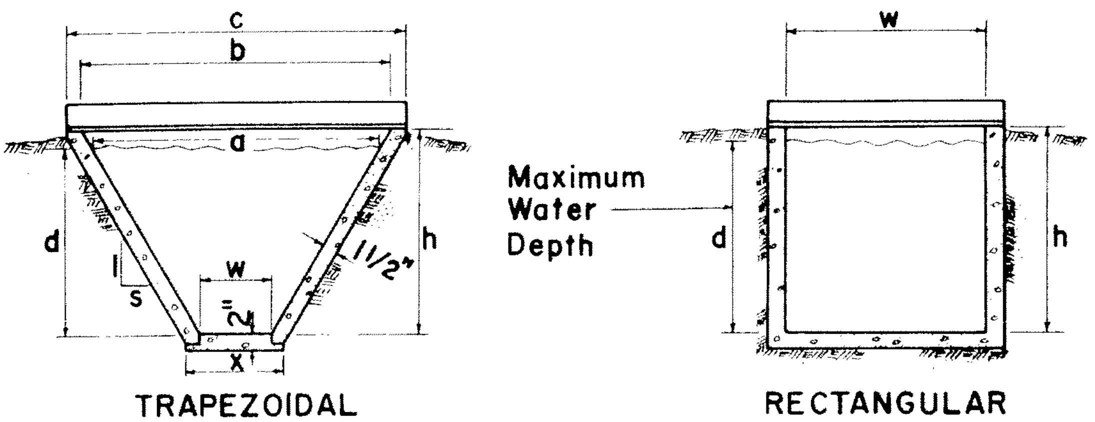


FIGURE A

MODEL NO.	Dimensions of Liner - Inches							
	w	s	d	h	a	b	c	x	e
6 A 12	6	1/2:1	12	[illegible]	18	[illegible]	21-1/8	9	14
6 B 12	6	1:1	12	[illegible]	30	32	[illegible]	9	14
12 B 12	12	1:1	12	[illegible]	36	38	42-1/4	15	14
6 A 24	6	1/2:1	24	26	30	32	34-1/8	9	27
12 A 24	12	1/2:1	24	26	36	38	40-1/8	15	27
12 B 24	12	1:1	24	26	60	64	[illegible]	15	27
24 B 24	24	1:1	24	[illegible]	72	76	[illegible]	27	27
[illegible] A 36	[illegible]	1/2:1	36	41	[illegible]	[illegible]	[illegible]	12	[illegible]
12 A 36	12	1/2:1	36	41	[illegible]	[illegible]	[illegible]	[illegible]	42
18 A 36	18	1/2:1	36	41	[illegible]	[illegible]	[illegible]	[illegible]	42
18 B 36	18	1:1	36	41	[illegible]	[illegible]	[illegible]	[illegible]	42
24 B 36	24	1:1	36	41	96	100	[illegible]	[illegible]	[illegible]
6 R 12	6	Vert.	12	13					14
12 R 12	12	Vert.	12	[illegible]					14
12 R 18	[illegible]	Vert.	18	[illegible]					[illegible]
18 R 18	18	Vert.	18	[illegible]					[illegible]
24 R 18	24	Vert.	18	[illegible]					[illegible]
24 R 24 L	24	Vert.	24	26					27
24 R 24 H	24	Vert.	24	36					[illegible]
30 R 24	30	Vert.	24	[illegible]					[illegible]
36 R 24	36	Vert.	24	36					[illegible]
48 R 24	48	Vert.	24	[illegible]					27
30 R 30	30	Vert.	30	33-1/2					[illegible]
36 R 30	36	Vert.	30	33-1/2					34-1/2
48 R 30	48	Vert.	30	33-1/2					34-1/2
60 R 30	60	Vert.	30	33-1/2					[illegible]
36 R 36	36	Vert.	36	41					[illegible]
42 R 36	42	Vert.	36	41					[illegible]
60 R 36	60	Vert.	36	[illegible]					[illegible]
72 R 36	72	Vert.	36	[illegible]					[illegible]

TABLE I

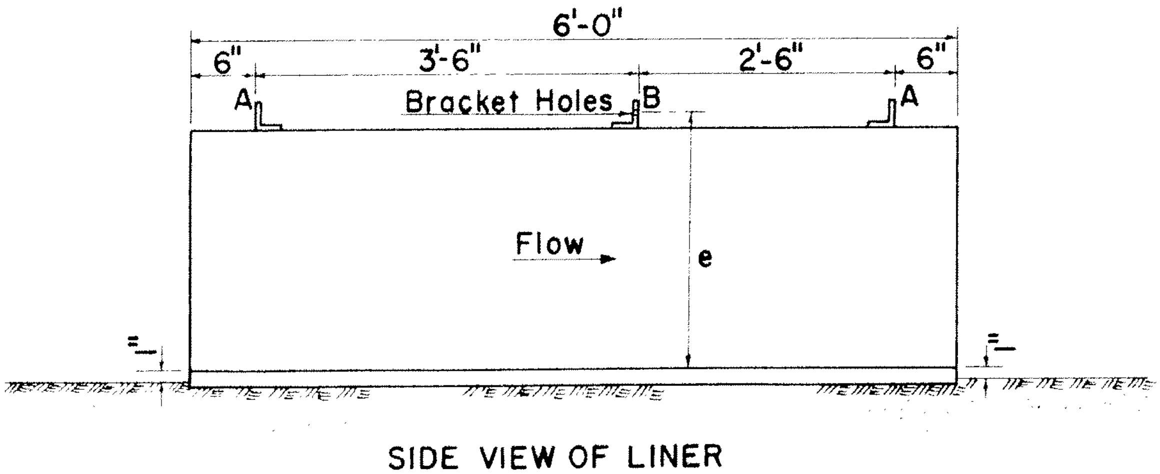


FIGURE B

INSTALLATION OF METER

1. Mount the bracket on cross member "B" as shown in Figure C, placing the smooth face of the bracket against the angle cross member.

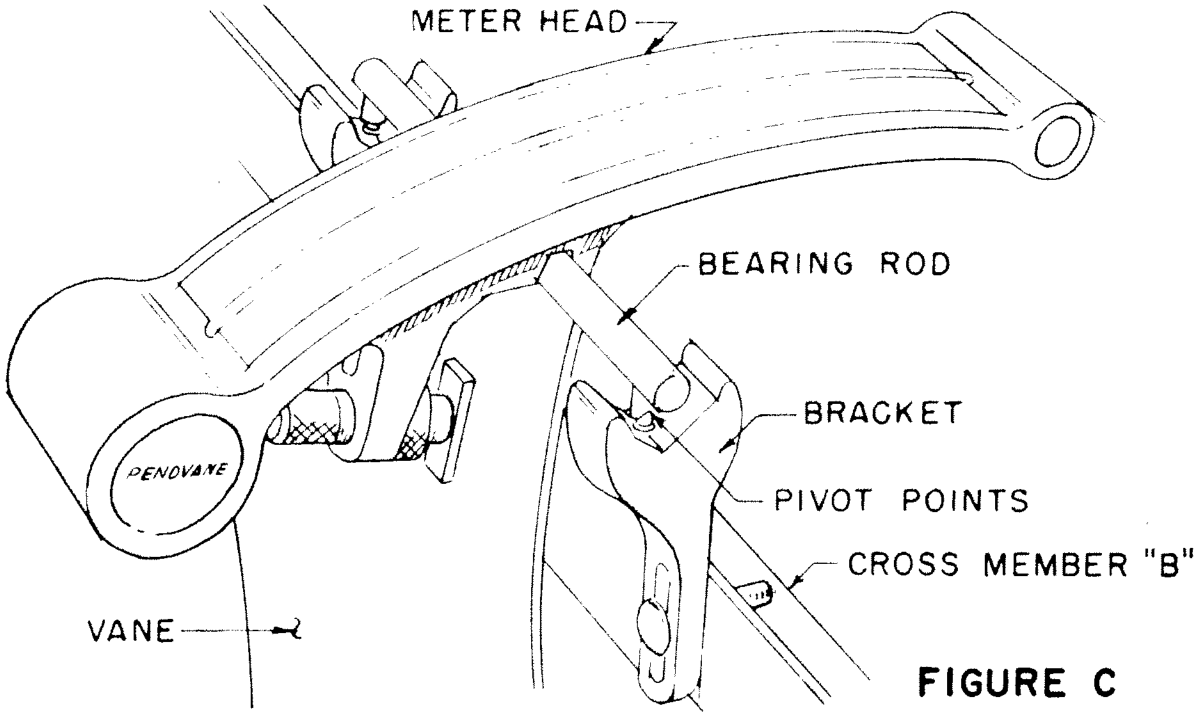


FIGURE C

2. Place the vane on the bracket with the name plate facing downstream. Make sure that the socket bearings in the bearing rod of the vane are resting on the pivot points in the bracket.

3. Adjust the position of the bracket so that the tip of the vane is directly above the centerline of the bottom slab and so that the top of the bearing rod of the vane is exactly the distance above the surface of the bottom slab shown in Table II. Tighten bracket bolts.

Meter Model Number	Top of Bearing Rod to Surface of Bottom Slab - Inches	Meter Model Number	Top of Bearing Rod to Surface of Bottom Slab - Inches
6A12	15-9/16	18R18	23-1/16
6B12	15-9/16	24R18	23-1/16
12B12	15-9/16	24R24L	30-9/16
6A24	30-9/16	24R24H	30-9/16
12A24	30-9/16	30R24	30-9/16
12B24	30-9/16	36R24	30-9/16
24B24	30-9/16	48R24	30-9/16
9A36	45-9/16	30R30	38-1/16
12A36	45-9/16	36R30	38-1/16
18A36	45-9/16	48R30	38-1/16
18B36	45-9/16	60R30	38-1/16
24B36	45-9/16	36R36	45-9/16
6R12	15-9/16	48R36	45-9/16
12R12	15-9/16	60R36	45-9/16
12R18	23-1/16	72R36	45-9/16

TABLE II

4. Remove the meter head from its case and place it upon the bearing rod of the vane as shown in Figure C. DO NOT LOOSEN THE LOCK RING ON THE ADJUSTING SCREW. When the meter head is in the correct position, the magnet located in the adjustment screw should be near the center of the metal rectangle on the vane. The meter head will then be locked magnetically in position.

5. Check the zero adjustment by moving the vane so that the center of the bubble is directly opposite the zero line on the scales. Release the vane and allow it to swing slightly. If the bubble remains in position, the factory adjustment has not been disturbed and no further adjustment is necessary. If the bubble moves away from the zero position, see instructions for ADJUSTMENT OF THE PENDVANE FLOWMETER.

OPERATION

The PENDVANE Flowmeter is ready to operate as soon as installation is complete and the zero reading is checked. Field calibration is not required because operation of the meter is largely independent of field conditions. Such conditions as pipe flow discharging directly into the liner should be avoided. Best accuracy is achieved where ditch flow is reasonably normal. Also, for greatest accuracy the depth of water should be within the range shown as Zone "A" in Figure D (attached inside the back cover of these instructions). In most ditches, normal operation will result in combinations of depth and velocity that will fall within the Recommended Range of Operation. If this is not the case in your ditch, the additional depth can be provided by narrowing the ditch at a point about twice the maximum water depth downstream from the liner. Do not raise the water depth by raising the bottom of the ditch because this will result in an accumulation of mud in the liner. For occasional situations when Zone "A" conditions are not attainable, readings taken within the limits of Zone "B" may be acceptable. Typical variation in accuracy is shown on Figure E (attached inside the back cover of these instructions).

The quantity of water flowing in the ditch is determined by reading the position of the center of the bubble on either of the two scales. The flow of water in a canal is not uniform but consists of a series of small surges. Because of the accuracy of the PENDVANE these small surges are indicated by the bubble. Experience has proven that an average of the high and low reading will give an accurate determination of the average discharge.

ADJUSTMENT OF THE PENDVANE FLOWMETER

The PENDVANE Flowmeter is factory adjusted and ready for operation when packed for shipment. It is shipped in a carton designed to protect the meter. However, distortion of either the vane or meter head resulting from a severe shock after removal from the carton could necessitate a zeroing adjustment. Also, placing the meter head on end or upside down for any prolonged period could change the size of the bubble to an extent that would require adjustment of the bubble size.

CHECKING ADJUSTMENTS

The zero adjustment can be checked by placing the meter on a bracket in a dry canal or on a bench-mounted bracket. With the vane at rest, the center of the bubble should be in a direct line with the zero marks on the scales. The bubble will seek this position naturally, but the viscosity of the fluid and the shape of the tube near the zero mark are such that movement of the bubble to its final position is very slow. The time required for checking can be shortened by moving the vane as required to place the bubble in the zero position, releasing the vane and allowing it to swing slightly. If the bubble moves away from the zero position, an adjustment is necessary.

The size of the bubble does not change the accuracy of the PENDVANE, but reading is difficult if the bubble is too large or too small. At 70 degrees Fahrenheit, the bubble should be about 3/16 of an inch long. It will be smaller at higher temperatures and larger at lower temperatures. If the bubble becomes longer than 3/8-inch when cold or too small to read easily when hot, an adjustment should be made.

ADJUSTMENT TO ZERO

TO ADJUST THE BUBBLE TO ZERO POSITION loosen the lock ring on the adjustment screw (see Figure F) and turn the screw slowly in the direction required to move the bubble to a zero reading. Several attempts may be necessary because tightening the lock ring will change the position of the bubble.

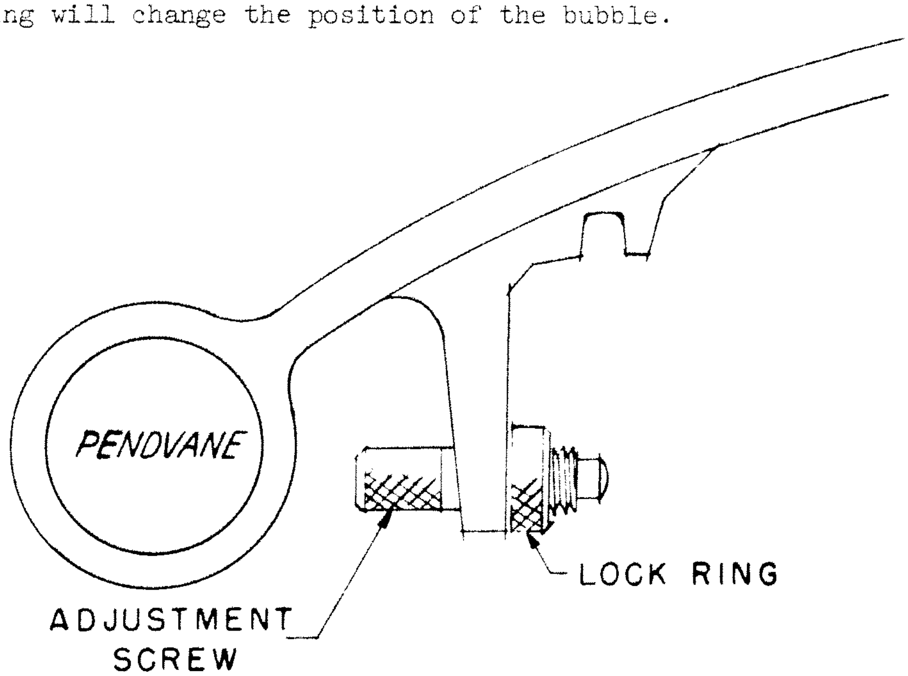
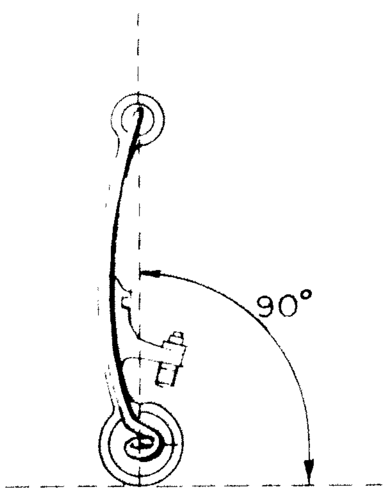


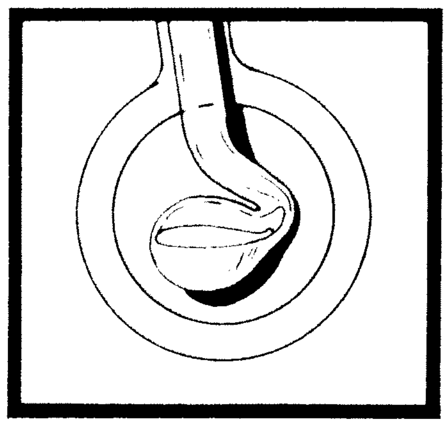
FIGURE F

ADJUSTMENT OF BUBBLE SIZE

If the bubble is too small, allow the meter head to become as warm as possible by placing it in a horizontal position in direct sunlight or near some heat source. Then place the meter head in the position shown in Figure G at a location where it can cool. Contraction of the liquid due to cooling will draw air from the air reservoir into the tube and enlarge the bubble. The time required is dependent upon the difference between the temperature of the heated meter head and the temperature of the cooling area.

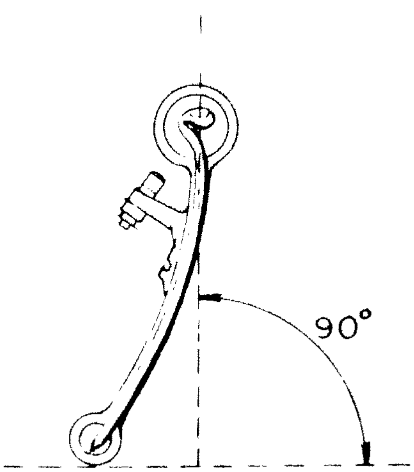
If the bubble is too large the adjustment process is reversed. First cool the meter head in a horizontal position and then place it in the sun or near a heat source in the position shown in Figure H. The expansion of the fluid due to warming will force some of the air from the bubble into the air reservoir. Time requirements are the same as for increasing the bubble size.

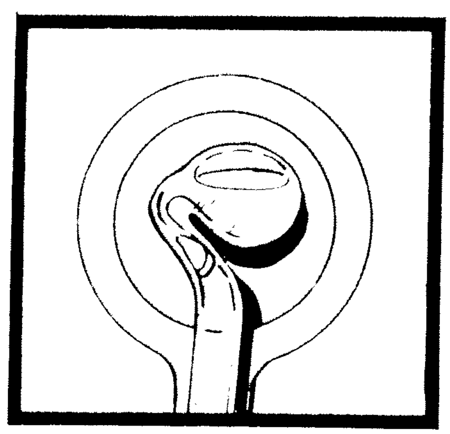




Enlargement showing air from reservoir being drawn into tube.

FIGURE G





Enlargement showing bubble being forced into reservoir.

FIGURE H