THESIS.

AN EXPERIMENTAL INVESTIGATION
OF A METHOD OF MEASURING THE VELOCITY OF WATER IN OPEN CHANNELS BY MEANS OF A MOVING VANE.

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Introductory.

In a pamphlet edited by the Technical Institute of Darmstadt entitled "Das Laboratorium fur Wasserkraftmaschinen der Grossh. Technischen Hochschule zu Darmstadt", mention is made of an apparatus used in that Institution for measuring the velocity of water in built-up channels. Details of the arrangement of the apparatus are not given, but it states that the principle consists in having a vane, which is placed in the channel, carried along by the water as the latter moves down the trough and observing the time taken by the vane in travelling a known distance.

After looking for some more information in the most recently published engineering books and papers without success, our attention was called to an article published in The Engineering News of July 4, 1912 in which a somewhat clearer description is given of a similar contrivance used in the Winnipeg Municipal Electric System, Dominion of Canada. The article reads: "On account of the desire to make a satisfactory test of the water turbines, a device was demanded for measuring the water passed, and for this purpose a measuring flume has been installed as an extension of the tail race of the spare unit. It is the intention to measure the velocity of the water passing thru this flume by observing the movement of a weighted vertical close-fitting diaphragm, suspended from a raft which is allowed to float with the current."

The author, W. G. Chace, goes on explaining how the time expended by the raft in moving between two fixed points was accurately recorded, which is practically the same method that we used in our experiments, that is, by making the moving vane break an electric circuit twice or three times as it passed by two or three wooden blocks, placed at a known distance apart alongside the channel.

The exact time at which the vane passed the electric contacts was recorded on a chronograph, as explained below.

Object of Thesis and Description of Apparatus.

The object of this Thesis is of ascertaining whether this method of measuring the velocity of water in artificial channels is as useful and practicable as any of the methods in ordinary use, like weirs and calibrated tanks for example, are for rapidly measuring the discharge.

Referring to the accompanying drawing, it is seen that our apparatus consisted mainly of a rectangular wooden trough one foot wide, one-foot-eight-inches high, and eighteen-feet nine-and-one-half inches long, supported on ~~five~~ six wooden horses. At one end of the trough there was a chamber into which the water from the City Mains was discharged and from which it moved trough the remaining length of the channel by passing first through two adjacent screens, the first being an ordinary wire screen, and the second a specially designed wooden screen, not shown in the drawing, in detail, but which consisted of a series of wooden planks four inches long, which tapered from one-half inch in the up stream side to a thin edge in the down stream side, with a clear distance of one-half inch between two consecutive planks.

At the other end we had a wooden block eight inches high over which the water discharged into a box made of galvanized iron, fixed to the trough, and connected to two calibrating tanks by means of a tube seven inches in diameter made of the same material as the box.

Two steel rails one-and-a-quarter inches by five-sixteenths of an inch in crossection, one grooved and the other plain, fixed on top of the sides of the channel served to guide the vane as it moved with the current.

The vane itself consisted of a sheet of aluminium eleven and five-eigths of an inch wide and twenty inches high weighted at the lower end, and suspended on an aluminium rod which in turn was connected to two pairs of brass wheels, one pair on each rail. These wheels had steel axes one-sixteenth of an inch in diameter in order to eliminate friction as much as possible, and its rims were cut down to about a width of one thirty-second of an inch.

The pair of wheels resting on the grooved rail carried a steel pointer which served to break the electric circuit as it passed by two or three wooden blocks fixed at a known distance on the sides of the trough.

These blocks were part of an electric circuit composed, as shown in Fig. 1., by three dry cells "C" connected in series to a chronograph "K", the two blocks (sometimes three blocks) "B", and a relay "R". The relay itself was also connected in series to a dry cell "P", and a chronometer "W".

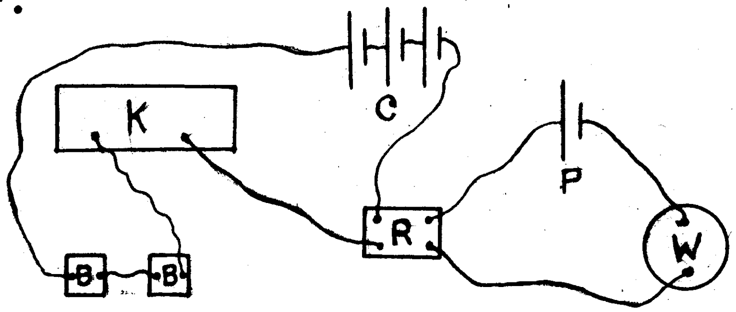


Fig. 1.

The chronometer broke the circuit every two seconds, and the exact instant it did so was recorded on the revolving drum of the chronograph by the pen resting upon it. Every time the vane passed the blocks "B" and thereby broke the circuit, a similar mark was recorded on the drum. Thus the exact time the vane took in moving from one block to the next was determined accurately.

A hook-gage was also installed on one side of the middle of the channel for determining the height of the water flowing and from it the average cross-section of the channel, as will be shown later.

Method of Procedure.

The first thing done was to accurately determine the average cross-section of the channel for the whole length of the run. The method employed was as follows: two wooden blocks of the width of the trough and fifteen inches high were placed in the channel, one at the beginning of the run and the other at the end. The space between the two blocks was filled with ordinary water which was in turn drawn out through a hole at the bottom of the trough, at regular intervals as read by the gage, and its weight determined. The process was carried on until all the water had been drawn out. The specific gravity of the water at that temperature was then determined by means of a Mohr-Westphal balance. By dividing the weights at each interval by the weight per cubic foot, the volume of the water at each instant was found; and in turn, by dividing this volume by the length between blocks the cross-section was determined. A table, shown on page 14 was then calculated from which the mean cross-section of the channel at different gage-heights was obtained by interpolation.

In order to check the values obtained by the above method, the average cross-sections at different gage-heights were also determined by carefully measuring by the aid of an "inside caliper". The results obtained are tabulated on page 15.

The tests proper were conducted in the following manner: the vane was made to travel by the flowing water from one end of the channel to the other at intervals of one or two minutes, as deemed necessary, the time taken in passing from one block to the next being recorded by the chronograph as already explained. Readings of the hook-gage were also taken at the same intervals.

The discharge per second was obtained by means of two calibrated tanks into which the water was carried from above. Each tank had a glass tube about one inch and a-half in diameter connected through the bottom , so that the differences in height of the water in the tank from one instant to the other could be read on a graduated scale placed alongside the tube. By means of these readings the discharge was read off a chart calculated for the purpose.

The amount of water running in the channel could be varied at will by opening or closing a valve connected to the tube leading from the pump, a Blake Pump, that lifted the water to the channel.

Before starting, the vane was introduced in the water and held in position by the frame, and the sheet of aluminium, or the vane proper, being able to swing freely with the rod on which it was suspended, was made to assume an inclined position by the water passing down the channel.

As the vane was released to start the run, it took about two feet to get started and run with the sheet of aluminium in a vertical position.

As the water level in the gage fluctuated considerably as the vane was moving, the entrance of the gage tube at the trough was plugged with loose cotton fibers thus obtaining a practically still level in the gage.

EXPLANATION OF TABLES.

In looking over the tables it will be found that each one is arranged in different fashion than the others, this being due mainly to a matter of convenience in reading and comparing results, as we used quite a variety of methods in conducting our experiments. As it is, we feel that some difficulty would be encountered in reading them intelligently without some explanation.

In "Observations #1" the method used was as follows: (1) The zero reading of tank #1 was taken and water then allowed to flow into it. (2) A reading was taken on an even minute and noted. (3) Zero reading of tank #2 was taken. (4) The water was shifted to tank #2 and the height of tha water in tank #1 was noted. (5) A reading of the tank #2 was taken on an even minute. And so on from one tank to the other.

The object of this method was to obtain a continuous record of the quantity of the water flowing. The total quantity up to any desired time may be obtained by simply adding up the numbers under the column marked "Discharge"

Example:- The quantity of water flowing from 3.06 to 3.15 is 90.1 + 237.8 = 327.9. The first two values are found under "Difference" and the last value under "Discharge". In the same way the total discharge from 3.15 to 3.19 is 327.9 + 133.6 = 461.5

Referring to "Tabulation of Results #1", we have in the first column the time read by the watch. The second column gives the number of seconds elapsed, as given by the chronograph, as the vane travelled from the first electric contact to the second. The third column gives the mean velocity of the vane in feet per second. The fourth, the discharge in cubic feet per second between two given watch times as taken from "Observations #1". The "Gage" column gives the readings of the hook gage in inches at each interval of time and the mean between two given watch times. The sixth column reads the mean area of cross-section of channel corresponding to the mean gage. The velocity of the water is given in the seventh column; and the last column gives the ratio of the velocity of the water to that of the vane.

The table "Observations #2" is self evident.

"Tabulation of Results #2" needs perhaps some explanation. During these tests three electric contact blocks were used instead of two only, in order to compare the velocity of the vane during the first part of the run to that of the second part. The second column gives: first, the time in seconds elapsed during the movement of the vane from block #1 to #2; second, corresponding time between #2 and #3; and third, the total time between #1 and #3. The third, fourth, and fifth columns give the velocities of the vane between blocks 1-2, 2-3, and 1-3, respectively. In the sixth column the average velocity of the water between two given times by the watch is found. The last column gives the ratio of the mean velocity of the water to that of the vane between blocks 1-3.

DISCUSSION OF RESULTS.

It is seen from the tables that almost invariably the velocity of the vane is greater than that of the water during a given time. This puzzled us at first since, having no records of any experiments similar to ours to have been conducted, we were naturally lead to believe that the reverse would be the case since the vane did not fit exactly to the cross-section of the channel, but had to be given a small clearance on account of "bumps" formed in the wood of the channel by the swelling that took place when it was first filled with water.

We had the channel perfectly levelled, but even if that had not been the case, the action of gravity would have affected both the velocity of the water and that of the vane, and so, there is no reason to believe this as a cause to the results obtained.

The possible accelerating effect of the "back-water" formed before the vane was released was investigated by letting the vane go into the water gradually and releasing it when it was in a vertical position, but this had no apparent effect on the velocity.

Since we had a wooden block at the end of the channel eight inches high over which the water flowed in the same fashion as over a weir, we thought that this might be the cause, for we could reasonably assume that the whole c cross-section of the water was flowing only at the beginning of the run, and gradually diminished to the cross-section flowing over the block. Accordingly we took the block down and ran the apparatus for about fifteen minutes. The results are shown on page 38. It is seen from them that the vane continues to travel with greater velocity than the water, as before.

Therefore it is safe to assume that this should be the case, but for what reasons we are only able to conjecture.

Taking this for granted we will now discuss the variation of the constant "K" (V/v). In "Observations #2" it is seen that the quantity of water discharged every two minutes varies from any other two-minute period considerably (about 5%). The vane was only run once every two minutes, and probably the variation of quantity during the scant ten seconds that the vane was running, was even more than 5%.

The main difficulty encountered, therefore, was with the unsteady flow of the water.

The plot shows that the velocities of vane and water are equal when v is about .35 f.p.s. As the velocity increases, the velocity of vane is more than that of the water. This may be due to the fact that the increase of friction on the sides of the channel retards the water there, and the vane moves at the higher speed of the water in the middle of the channel.

As the velocity decreases from .35 f.p.s. the vane moves slower than the water as it ought to be, due to the retarding forces of friction.

CONCLUSION.

In conclusion we may say that this method of measuring the velocity of water in artificial channels should prove satisfactory when the cross-section is constant thruout and a length of run of at least thirty feet is available. A stop watch should be sufficient to mark the time taken by the vane in passing between the two fixed points at a known distance apart.

After installing a flume and having decided on the apparatus to be used, the latter would have to be "calibrated", that is, to find the proper value of the constant "K" by which the observed velocity of the vane would have to be multiplied to obtain the true velocity of the water. In order to calibrate it, it is essential, for accurate results, to keep the discharge during one set of runs as nearly constant as is possible.

By a study of the tables and the accompanying plot we would expect a probable error of 2% in the velocity if the mean of five runs is used, provided the constant is obtained from our plot.

The error, using five-foot run is just about twice as much. In a given set of observations, the maximum deviation of "v" from tne mean in the case of a five-foot run is twice as much as that in a ten-foot run.

Computations of the Specific Gravity of Water used in Determination of Cross-section .

Temperature of Distilled Water = 21°.2 C

Temperature of Ordinary Water = 21°.2 C

Sp. Gr. by Mohr-Westphal Balance = 1.002

From Merriman's Tables:

Wt. of c. f. distilled water at 74°F = 62.269#

,, ,, ,, ordinary ,, ,, ,,

= 62.269x1.002=62.39#

Table giving Area of Cross-section at various Gage-Heights.

Distance between boards = 12.18 feet

Temperature of water = 74°F

Wt. of c. f. of water = 62.39#

Observ. Gage Rd.	Bal. Rd.	Diff.	Wt. of water corresponding to Gage Rd.	Area
7.406"	228.2#		939.7#	1.237
6.404	298.2	70.0	869.7	1.144
5.564	356.7	58.5	811.2	1.068
4.708	416.2	59.5	751.7	.989
3.493	506.0	89.8	661.9	.871
2.451	574.5	68.5	593.4	.781
1.914	608.2	33.7	559.7	.737
1.914	201.9			
	656.8	454.9	104.8	
	496.2			
	601.0	104.8	000.0	

By Interpolation:

3.000	.828
4.000	.920
5.000	1.016

Checking the Table of Cross-Sections by caliper measurements

	Heights of water.		
1st. section.	8.44"	8.33"	8.38"
2d. section	8.42	8.20	8.36
3d. section	8.32	8.32	8.36
4th. section	8.40	8.35	8.32
5th. section	8.32	8.22	8.19
6th. section	8.32	8.18	8.22
Sum	50.22"	49.66"	49.63"

Mean "h" = 8.32"   Gage Reading = 1.26"

h = 11"   Width = 1.005'   h = 0 to 8"   Width = 1.000'

1.005
1.005
1.010
1.010
5.035
5.000 Sum of the widths at bottom
10.035   Mean = 1.004'

Gage Reading	Height of Water	Mean Width	Mean "A"
1.26"	8.32"	1.000'	.693 sq.
3.00	10.06	1.000	.839
4.00	11.06	1.003	.924
5.00	12.06	1.005	1.010

OBSERVATIONS. #1.

Time	Tank 1. in.	Chart c.f.	Diff. c.f.	Disch. c.f.(total)	Chart c.f.	Tank 2. in.	D.p.s.
2.37	65.27	149.0					
			75.4				
	96.95	224.4					
			99.9	175.3	46.3	21.12	
2.42					146.2	63.10	.584
			95.8				
					242.0	103.30	
	3.97	3.0	215.2				
	94.32	218.2					
			155.3	466.3	50.0	22.70	
2.55					205.3	87.90	.598
			41.4				
					246.7	105.28	
	4.40	4.0	208.4	249.8			
3.02	91.91	212.4					.594
			17.2				
	99.12	229.6					
			124.0	141.2	34.8	16.35	
3.06					158.8	68.40	.588
			90.1				
					248.9	106.18	
	4.20	3.4	237.8	327.9			.607
3.15	103.99	241.2					
			1.6				
	104.70	242.8					
			132.0	133.6	17.8	9.20	
3.19					149.8	64.60	.557
			97.6				
					247.4	105.60	
	4.30	3.8	234.2	331.8			
3.28	102.70	238.0					.614
			3.8				
	104.30	241.8					
			173.8	177.6	13.5	7.40	
3.33					187.3	80.35	.592
			61.9				
					249.2	106.30	
	5.20	5.8	220.7	282.6			
3.41	97.75	226.5					.590
			12.5				
	103.10	239.0					
			165.7	178.2	15.6	8.30	
3.46					181.3	77.82	.594
			69.1				
					250.4	106.80	
	3.50	1.9	176.3	245.4			
3.53	77.50	178.2					.584
			60.2				
	102.80	238.4					
			225.7		11.6	6.60	
					237.3	101.30	
	5.40	6.4	112.7	398.6			
4.04	52.70	119.1					.605
			118.3				

Time	Tank 1. in.	Chart c.f.	Diff. c.f	Disch. c.f (total)	Chart. c.f	Tank 2. in.	D.p.s
	102.40	237.4					
			137.0	255.3	23.0	11.40	
4.11					160.0	18.90	.607
		~~[illegible]~~	84.4				
				244.4	104.30		
	4.20	3.4	218.6				
	95.90	222.0	121.6				
			121.6	424.6	25.60	12.80	
4.25					147.2	63.50	.505

TABULATION OF RESULTS. #1.

Length of run 11.16 feet   Two electric contacts

Time	Chron. secs.	"v"(vane) f.p.s.	Disch. c.f.p.s.	Gage in.	Mean "A" sq.ft.	$V=\frac{Q}{A}$ f.p.s.	$\frac{V}{v}$
2.43	19.10 s			5.077			
2.44	18.56			5.139			
2.46	18.22			5.064			
2.50	18.51			5.024			
	74.39			20.304			
Mean	18.60	.600	.598	5.076	1.023	.585	.975
2.56	18.15			5.075			
3.00	18.63			5.057			
3.01	18.12			5.112			
	54.90			15.244			
Mean	18.30	.610	.594	5.081	1.023	.579	.947
3.04	18.25			5.230			
3.05	18.16			5.092			
	32.41			10.322			
Mean	18.21	.612	.588	5.161	1.031	.569	.928
3.08	18.69			5.087			
3.09	18.30			5.199			
3.12	18.84			5.127			
3.14	18.98			49.40			
3.15	18.19			5.007			
	93.00			25.360			
Mean	18.60	.600	.607	5.072	1.023	.593	.987

Time	Chron. sec.	"v"(vane) f.p.s.	Disch. c.f.p.s.	Gage in.	Mean "A" sq.ft.	$V = \frac{Q}{A}$ f.p.s.	$\frac{V}{v}$
3.16	19.15			4.964			
3.17	18.71			5.043			
3.19	19.10			5.045			
	5 .96			15.051			
Mean	18.99	.587	.557	5.017	1.018	.548	.933
3.20	18.70			5.040			
3.21	18.24			5.130			
	3 .94			10.170			
Mean	18.47	.605	.614	5.085	1.024	.599	.988
3.31	18.54			5.190			
3.33	18.34			5.098			
3.34	18.30			5.095			
3.35	18.48			5.037			
3.38	19.10			5.057			
	92.76			25.477			
Mean	18.55	.602	.591	5.095	1.025	.577	.958
3.44	18.50			5.105			
3.45	18.60			5.107			
3.46	18.26			5.068			
	55.36			15.280			
Mean	18.45	.605	.594	5.093	1.025	.578	.955

Time	Chron. sec.	"v"(vane) f.p.s.	Disch. c.f.p.s.	Gage in.	Mean "A" sq.ft.	$V=\frac{Q}{A}$ f.p.s.	$\frac{V}{V}$
3.47	18.40			5.105			
3.48	18.66			5.072			
3.50	19.38			5.084			
3.52	18.73			5.029			
3.53	18.66			5.052			
	93.83			25.342			
Mean	18.77	.595	.584	5.068	1.022	.570	.958
3.54	18.66			5.043			
3.55	18.52			4.984			
3.57	18.54			5.017			
3.58	18.91			5.038			
3.59	18.80			5.105			
4.00	18.16			5.147			
4.01	19.12			5.147			
4.02	18.81			5.082			
4.03	18.85			5.093			
4.04	18.21			5.070			
4.05	18.31			5.096			
4.07	18.60			5.156			
4.08	18.40			5.052			
4.10	18.32			5.126			
4.11	18.06			5.123			
	278.27			76.279			
Mean	18.55	.601	.606	5.085	1.024	.592	.985

OBSERVATIONS. #2.

Time	Tank l. in.	Chart c.f.	Disch. c.f.	Gage in.	Area sq.ft.	Vel. f.p.s
2.15	38.6	85.4		3.220		
2.17	46.6	104.6	19.2			
2.19	54.7	123.8	19.2	3.221		
2.21	62.6	142.6	18.8			
2.23	70.7	162.0	19.4	3.220		
2.25	78.6	180.8	18.8			
2.27	86.3	199.0	18.2	3.220		
2.29	94.2	217.9	18.9			
2.31	102.0	236.4	18.5	3.221		
			151.0			
		Mean	18.88	3.221	.848	.185
2.35	14.0	26.8				
2.37	21.9.	45.7	18.9	3.221		
2.39	29.9	64.7	19.0			
2.41	37.9	83.8	19.1	3.221		
2.43	45.7	102.4	18.6			
2.45	53.7	121.4	19.0	3.221		
2.47	61.6	140.2	18.8			
2.49	69.4	158.8	18.6	3.221		
2.51	77.5	178.2	19.4			
2.53	85.1	196.2	18.0	3.221		
			169.4			
		Mean	18.82	3.221	.848	.185

Time	Tank l. in.	Chart c.f.	Disch. c.f.	Gage in.	Area sq.ft.	Vel. f.p.s.
2.58	11.7	21.4		3.221		
3.00	19.6	40.2	18.8			
3.02	28.0	60.1	19.9			
3.04	35.9	79.0	18.9	3.221		
3.0	43.5	97.2	18.2			
3.08	51.4	116.0	18.8	3.221		
3.10	59.1	134.2	18.2			
3.12	67.0	153.1	18.9	3.221		
		Mean	18.80	3.221	.848	.185
3.35	24.0	50.6				
3.37	42.6	95.0	44.4	4.267		
3.39	61.4	139.8	44.8			
3.41	80.0	184.1	44.3	4.266		
3.43	99.8	231.2	47.1(?)			
		Mean	44.50	4.267	.946	.392
3.46	13.1	24.6		4.256		
3.48	32.1	70.0	45.4			
3.50	50.9	114.8	44.8	4.256		
3.32	70.2	160.8	46.0	4.238		
3.54	89.5	206.7	45.9	4.238		
3.5	103.6	240.2	33.5(?)	4.238		
		Mean	45.52	4.245	.944	.402

Time	Tank l. in.	Chart c.f.	Disch. c.f.	Gage in.	Area sq.ft.	Vel. f.p.s
3.58	9.7	16.6				
4.00	28.6	61.6	45.0			
4.02	48.0	108.0	46.4	4.254		
4.04	67.5	154.3	46.3	4.260		
4.06	86.5	199.6	45.3	4.260		
4.08	105.9	245.6	46.0	4.260		
		Mean	45.80	4.259	.945	.404
4.10	12.4	23.0		4.262		
4.12	31.8	69.2	46.2	4.262		
4.14	51.6	116.4	47.2	4.284		
4.16	70.8	162.2	45.8	4.284		
4.18	90.2	208.4	46.2	4.284		
		Mean	46.35	4.274	.946	.408
4.22	12.2	22.6		4.284		
4.24	31.6	68.7	46.1	4.284		
4.26	51.0	115.0	46.3	4.284		
4.28	70.3	161.0	46.0	4.284		
4.30	90.0	207.9	46.9	4.284		
		Mean	46.34	4.284	.948	.407

Time	Tank l. in.	Chart c.f.	Disch. c.f.	Gage in.	Area sq.ft.	Vel. f.p.s
5.25	7.0	10.2				
5.28	37.5	82.8	72.6(?)	4.325		
5.30	60.5	137.6	54.8	4.325		
5.32	80.0	184.1	46.5	4.325		
5.34	99.8	231.2	47.1	4.325		
		Mean	49.47	4.325	.951	.433
5.36	13.8	26.4				
5.38	33.7	73.8	47.4	4.306		
5.40	53.3	120.3	46.5	4.309		
5.42	73.4	168.4	48.1	4.309		
5.44	93.5	216.2	47.8	4.309		
		Mean	47.45	4.309	.950	.416
5.46	4.1	3.2		4.309		
5.48	21.5	44.7	41.5	4.309		
5.50	41.0	89.0	44.3	4.310		
5.52	60.2	136.9	47.9	4.310		
5.54	80.1	184.3	47.4	4.310		
5.56	99.9	231.4	47.1	4.310		
		Mean	45.64	4.310	.950	.400

Time	Tank l. in.	Chart c.f.	Disch. c.f.	Gage in.	Area sq.ft.	Vel. f.p.s.
5.58	12.7	23.6		4.294		
6.00	32.6	71.2	47.6	4.294		
6.02	52.6	118.8	47.6	4.294		
6.04	72.2	165.5	46.7	4.294		
6.06	92.3	213.4	47.9	4.294		
		Mean	47.45	4.294	.948	.417
6.10	11.7	21.3		4.294		
6.12	31.5	68.5	47.2	4.294		
6.14	51.3	115.8	47.3	4.294		
6.16	71.1	163.0	47.2	4.294		
6.18	89.9	207.6	44.6(?)	4.294		
6.23	20.8	43.0		4.294		
6.25	40.6	90.2	47.2	4.294		
		Mean	46.70	4.294	.948	.410
8.04	10.1	17.5		4.974		
8.06	43.2	96.4	78.9	5.050		
8.08	75.7	173.9	77.5	5.035		
8.12	13.5	25.6		5.124		
8.14	46.5	104.3	78.7	5.156		
8.16	79.5	183.0	78.7	5.170		
~~8.17~~	~~96.0~~	~~122.2-~~	~~39.2(?)~~			
		Mean	78.7	5.100	1.025	.637

Time	Tank l. in.	Chart c.f.	Disch. c.f.	Gage in.	Area sq.ft.	Vel. f.p.s.
8.19	20.6	42.6		5.200		
8.21	53.2	120.2	77.6	5.215		
8.23	86.3	199.0	78.8	5.215		
8.24	103.1	239.0	40.0	5.215		
		Mean	78.80	5.216	1.036	.633
8.26	10.4	18.3		5.225		
8.28	43.7	97.6	79.3	5.244		
8.30	76.7	176.3	78.7	5.264		
8.31	94.2	218.0	41.7(?)	5.244		
		Mean	79.0	5.244	1.038	.635

TABULATION OF RESULTS. #2

Three blocks used

Distance block #1 to #2=5.187 feet
,, ,, #2 to #3=5.990 feet
Total distance (1-3) = 11.177 feet

Time	Time of run secs.	"v" 1-2	"v" 2-3	"v" 1-3	Q/A f.p.s.	V/v
2.15	29.07	.179				
	32.08		.187			
	61.15			.182		
2.17	34.05	.152				
	35.65		.168			
	69.70			.160		
2.19	29.50	.176				
	33.19		.181			
	62.69			.178		
2.21	30.07	.173				
	34.48		.174			
	64.55			.173		
2.23	30.41	.171				
	34.66		.173			
	65.07			.172		
2.25	28.07	.185				
	34.52		.174			
	62.59			.178		

Time	Time of run secs.	"v" 1-2	"v" 2-3	"v" 1-3	$\frac{Q}{A}$ f.p.s.	$\frac{V}{v}$
2.29	28.96	.179				
	30.50		.194			
	59.46			.188		
2.31	29.71	.174				
	30.54		.196			
	60.25			.185		
	Sum	1.388	1.445	1.416		
	Mean	.174	.181	.177	.185	1.04

Time	Time of run secs.	"v" 1-2	"v" 2-3	"v" 1-3	Q/A f.p.s.	V/v
2.45	29.58	.175				
	33.20		.180			
	62.78			.178		
2.46	29.74	.175				
	35.10		.171			
	64.84			.172		
2.48	29.16	.178				
	33.91		.177			
	63.07			.177		
2.50	30.14	.172				
	32.55		.184			
	62.69			.178		
2.52	30.40	.170				
	34.60		.173			
	65.00			.172		
		.870	.714	.877		
	Mean	.174	.177	.175	.185	1.06
2.54	32.00	.162				
	35.00		.171			
	57.00			.196		
2.56	27.15	.191				
	32.10		.186			
	59.25			.188		
2.58	26.92	.193				
	33.44		.179			
	60.36			.185		
3.01	30.14	.172				
	33.08		.177			
	63.22			.176		
		.718	.713	.745		
	Mean	.180	.178	.186	.185	.995

Time	Time of run secs.	"v" 1-2	"v" 2-3	"v" 1-3 f.p.s.	$\frac{Q}{A}$	$\frac{V}{v}$
3.3	13.82	.375				
	15.ol		.398			
	28.83			.394		
3.37	11.45	.453				
	16.77		.357			
	28.22			.395		
3.38	13.30	.390				
	14.40		.416			
	27.70			.402		
3.39	11.17	.465				
	16.40		.365			
	27.57			.405		
3.40	12.24	.424				
	15.76		.380			
	28.70			.399		
3.41	14.80	.350				
	13.40		.447			
	28.20			.396		
3.42	13.47	.386				
	15.48	.388				
	28.95			.386		
3.43	11.95	.434				
	19.70		.304			
	31.65			.352		
		3.277	3.055	3.129		
	Mean	.410	.382	.391	.392	1.00

Time	Time of run secs.	"v" 1-2	"v" 2-3	"v" 1-3	$\frac{Q}{A}$ f.p.s.	$\frac{V}{v}$
3.44	14.70	.353				
	13.30		.450			
	28.00			.398		
3.45	14.30	.363				
	13.25		.452			
	27.50			.405		
3.46	12.70	.408				
	14.65		.408			
	27.35			.407		
3.48	13.84	.374				
	13.77		.435			
	27.61			.404		
3.49	14.68	.354				
	13.26		.452			
	27.94			.400		
3.50	12.17	.427				
	14.36		.417			
	26.53			.420		
3.51	11.39	.456				
	15.30		.392			
	26.69			.415		
3.57	26.70			.417		
		2.735	3.006	3.266		
	Mean	.391	.429	.408	.402	.986

Time	Time of run secs.	"v" 1-2	"v" 2-3	"v" 1-3	$\frac{Q}{A}$ f.p.s.	$\frac{V}{v}$
4.02	12.90					
	15.20					
	28.10			.397		
4.04	11.85					
	15.45					
	27.30			.407		
4.05	11.64					
	15.12					
	26.76			.417		
4.06	13.63					
	13.05					
	26.68			.417		
4.08	11.75					
	14.96					
	26.71			.417		
				2.055		
			Mean	.411	.404	.983
4.09	11.43	.453				
	15.97		.375			
	27.40			.407		
4.11	13.60	.381				
	13.57		.432			
	27.17			.411		
4.12	12.09	.429				
	14.61		.410			
	26.70			.418		
4.13	11.35	.457				
	15.69		.382			
	27.04			.413		

Time	Time of run secs.	"v" 1-2	"v" 2-3	"v" 1-3	$\frac{Q}{A}$ f.p.s.	$\frac{V}{v}$
4.14	13.30	.390				
	16.08		.373			
	29.38			.380		
4.16	12.38	.420				
	15.00		.399			
	27.38			.407		
4.17	11.30	.458				
	15.55		.385			
	26.85			.415		
		2.988	2.756	2.851		
	Mean	.427	.394	.407	.408	1.00
4.19	12.90					
	16.20					
	29.10			.384		
4.22	12.29					
	15.16					
	27.45			.407		
4.23	11.13					
	15.60					
	26.73			.417		
4.24	13.50					
	14.48					
	27.98			.399		
4.25	14.20					
	14.55					
	28.75			.388		
4.27	11.49					
	15.61					
	27.10			.412		

Time	Time of run secs.	"v" 1-2	"v" 2-3	"v" 1-3	$\frac{Q}{A}$ f.p.s.	$\frac{V}{v}$
4.28	13.60					
	13.66					
	27.26			.409		
4.29	11.80					
	15.10					
	26.90			.415		
4.30	13.50					
	14.60					
	27.60			.404		
		Mean		.404	.407	1.01
5.25	14.77	.352				
	16.83		.356			
	31.60			.353		
5.26	14.45	.359				
	16.50		.363			
	30.95			.360		
5.29	10.64	.487				
	12.60		.475			
	23.24			.479		
5.32	11.01	.471				
	13.09		.458			
	24.10			.463		
5.33	12.40	.418				
	14.16		.424			
	26.56			.420		
5.34	12.51	.414				
	14.16		.478			
	26.67			.418		
		2.501	2.554	2.493		
	Mean	.417	.426	.416	.433	1.04

Time	Time of run secs.	"v" 1-3	"V" f.p.s.	V/v
5.35	26.71	.418		
5.38	26.17	.427		
5.39	26.86	.415		
5.40	26.16	.427		
5.42	26.30	.424		
5.43	26.10	.427		
5.44	26.40	.423		
		2.961		
	Mean	.423	.416	.983
5.45	26.10	.427		
5.46	26.11	.427		
5.48	26.30	.424		
5.50	27.80	.401		
5.52	26.28	.424		
5.53	26.35	.423		
5.54	26.58	.420		
5.55	26.09	.427		
5.56	26.25	.425		
		4.218		
	Mean	.422	.400	.948
5.58	26.30	.424		
6.01	26.00	.429		
6.02	26.45	.422		
6.03	26.30	.424		
6.04	26.80	.416		
		2.115		
	Mean	.423	.417	.986
6.08	26.67	.428		
6.09	26.75	.417		
6.10	26.40	.422		
6.12	26.00	.429		
6.13	26.00	.429		
6.14	26.53	.421		
6.15	26.63	.417		
6.20	26.98	.414		
6.22	26.90	.415		
6.24	26.50	.421		
		4.213		
	Mean	.421	.410	.974

Time	Time of run secs.	"v" 1-3	"V" f.p.s.	V - v
8.04	17.50	.637		
8.05	17.71	.630		
8.06	17.21	.648		
8.07	12.28	.646		
8.08	17.31	.645		
8.09	17.00	.656		
8.11	17.46	.640		
8.12	17.05	.655		
8.13	17.27	.646		
8.14	17.30	.645		
8.15	17.10	.653		
8.16	16.80	.664		
8.17	17.50	.657		
		8.422		
	Mean	.648	.637	.983
8.18	17.20	.648		
8.19	17.15	.651		
8.20	17.00	.657		
8.21	17.60	.634		
8.22	17.99	.657		
		3.243		
	Mean	.649	.633	.976
8.25	17.05	.655		
8.27	16.80	.664		
8.32	16.86	.663		
		1.982		
	Mean	.661	.635	.961

OBSERVATIONS #3.

Two blocks used at a distance apart of 11.3 feet.

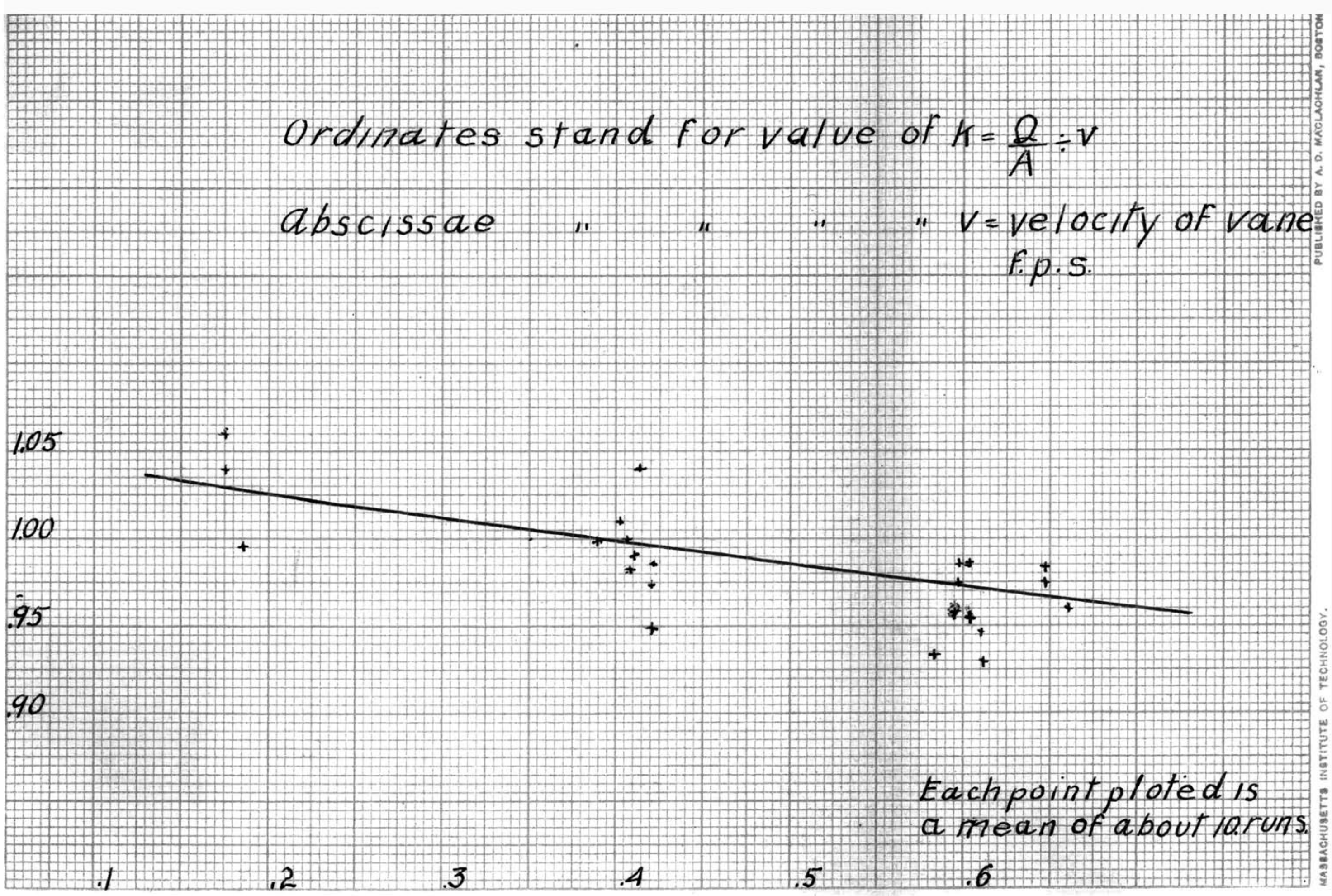
No "weir" at end of channel.

Tank	Time	Scale of tank in.	Chart c.f.	Disch. c.f.	Gage in.	"A" sq.ft.	"V" f.p.s.
1.	3.29	3.7	2.3		1.72	.732	1.170
	3.31	46.8	105.0	102.7			
2.	3.31	4.1	5.6		1.71	.731	1.174
	3.33	47.3	108.6	103.0			
1.	3.33	3.4	1.6				
	3.35	45.4	101.7	100.1	1.70	.730	1.152
2.	3.35	4.9	7.5				
	3.37	48.4	11.2	103.7	1.69	.729	1.184
1.	3.37	3.7	2.3				
	3.39	46.0	103.1	100.8	1.69	.729	1.150
2.	3.39	48.4	111.2				
	3.41	91.2	213.2	102.0	1.69	.729	1.165
1.	3.41	4.7	4.7				
	3.43	47.0	105.5	100.8	1.68	.728	1.150
2.	3.43	5.0	7.8				
	3.45	47.8	109.8	102.0	1.68	.728	1.167
							9.312
					Mean		1.164

TABULATION OF RESULTS #3.

Time	Time of run secs.	"v" f.p.s.	"V" f.p.s.	V / v
3.28	8.89			
3.29	8.90			
3.30	8.90			
3.31	9.40			
3.32	9.30			
3.33	9.38			
3.34	9.50			
3.35	9.32			
3.36	8.67			
3.37	9.35			
3.38	9.15			
3.39	9.39			
3.40	9.00			
3.41	9.48			
3.42	9.32			
3.43	8.83			
Mean	9.174	1.23	1.164	.947

P L A T E S .


Ordinates stand for value of k = Q/A ÷ v
Abscissae " " " " v = velocity of vane f.p.s.
1.05
1.00
.95
.90
.1
.2
.3
.4
.5
.6
Each point ploted is a mean of about 10 runs.
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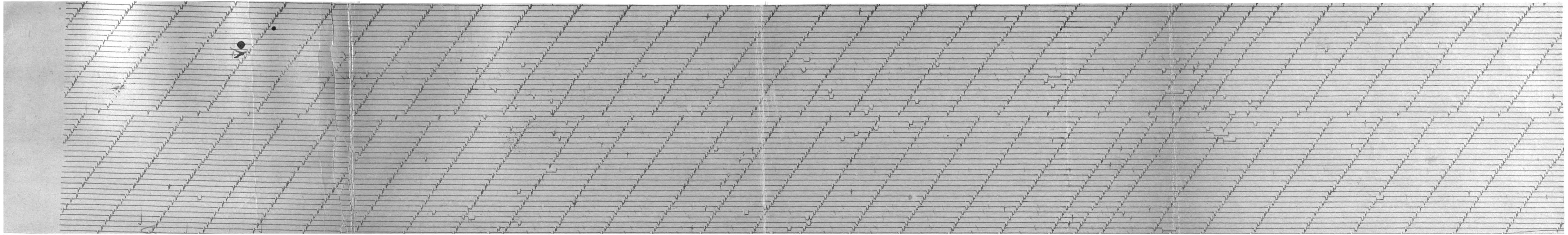
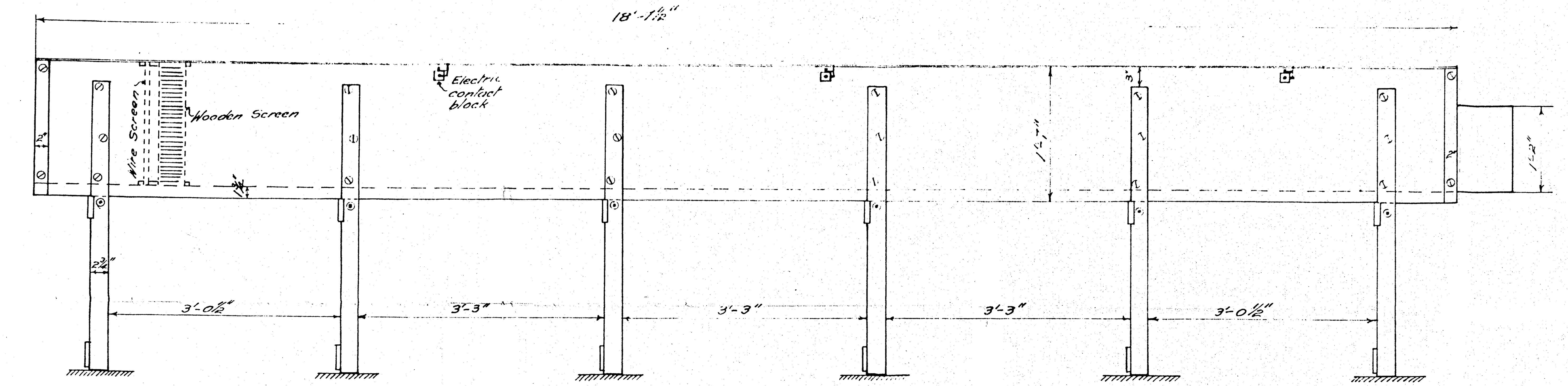
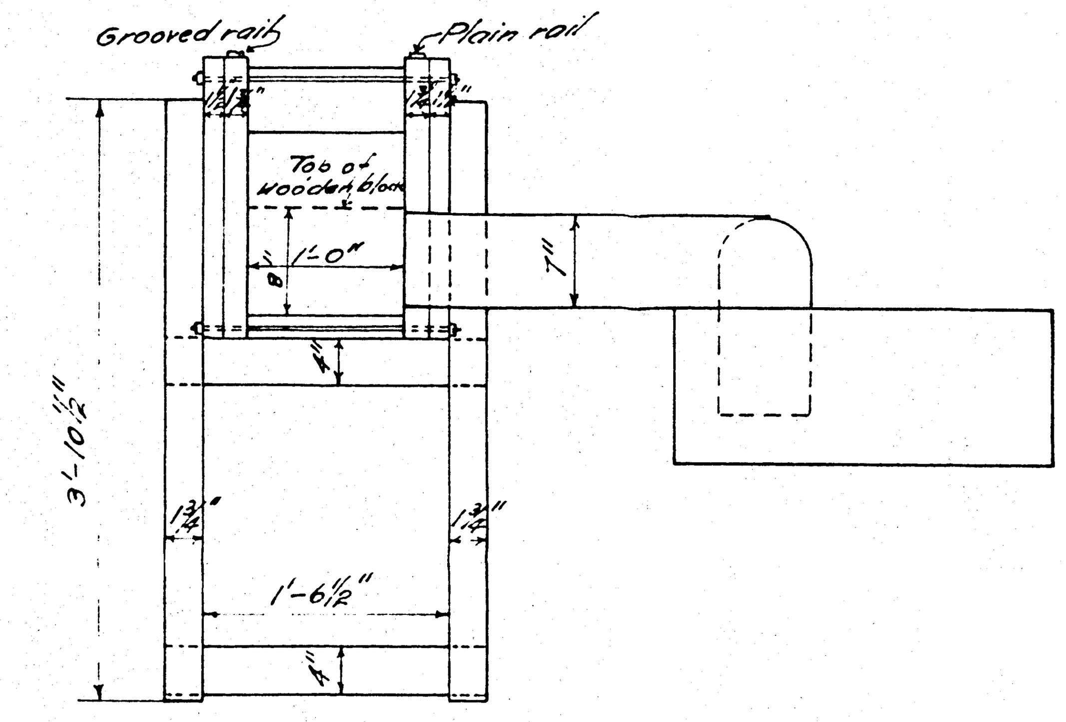
SAMPLE OF CHRONOGRAPH RECORD.

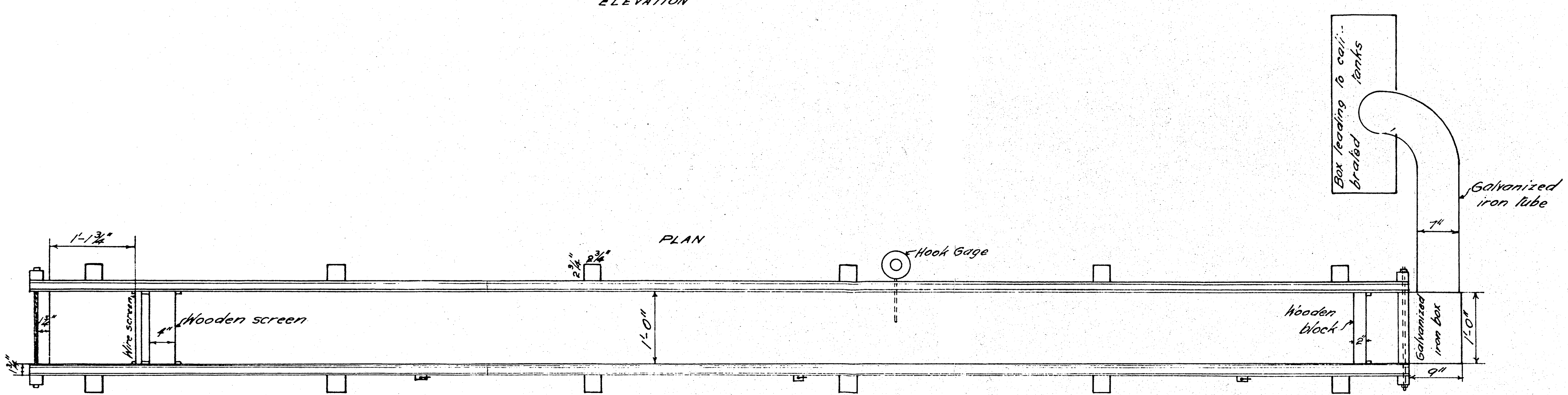




ELEVATION



SIDE VIEW



PLAN

SHOWING DETAILS OF TROUGH AND MOVING VANE

Scale of Trough: 1"=1' May, 1914

E Garza A. Gongora

DETAILS OF MOVING VANE

TRUE SIZE