EFFICIENCY OF SELECTED SHAPES
OF GRIT CHAMBER TROUGHS

by

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I. INTRODUCTION

In a sewage treatment plant it is desirable to remove hard, gritty material such as sand and gravel from the sewage flow in order to save wear on pumping equipment, and to reduce the quantity of matter which must pass through the complete treatment process. Bar screens are used to remove large gravel or stones, but generally some form of grit chamber is used to remove smaller stones, sand and similar particles of high density and hardness.

It is not desirable, however, to remove all grit particles because in attempting to remove very small diameter particles certain decomposable organic constituents in the sewage would also be trapped. This decomposable matter, if dumped in the open without treatment along with the grit material, would pose a serious health problem. It is, therefore, desirable that a grit chamber have the ability of selective sedimentation in that it should trap coarse particles but pass fine particles. Most commonly a grit chamber is designed to trap a 0.2 mm diameter particle of specific gravity 2.65 but pass particles of smaller diameter.(3)

Many grit chambers are somewhat elaborate structures utilizing mechanical equipment, but in small plants where the flows are not great the grit chamber will in actuality be little more than a wide section of the pipeline where the velocity of flow is decreased to the point where the grit settles to the bottom and is trapped by a trough. This trough is then pumped clean at periodic intervals and the sand and grit is disposed of, generally by using it as a fill material.

At the present time there is no generally accepted method for the design of grit chamber troughs other than to provide sufficient capacity for the expected volume of grit including a suitable safety factor. These troughs usually are designed with sloping sides so that the grit will settle to a central point to be drawn off by a pipe or some type of screw mechanism, but there is no criteria now in use for the design of an overall shape that will trap the desired particles and pass the rest.

The objective of this investigation was to examine certain specific shapes of grit collection troughs to determine the efficiency of the sections for the selective collection of grit.

II. REVIEW OF LITERATURE

An investigation of the literature produced information which fell basically into two categories, sedimentation theory and grit chamber design. Literature on sedimentation theory dealt with the theory of settling of discrete particles or with the movement of bottom loads in streams, canals or chambers, and therefore, was not directly related to the subject being investigated.

H. M. Morris(5) studied flow over a depression in his development of relationships in quasi-smooth flow but was concerned only with very small square-shaped depressions. These depressions were too small to be analogous to the large troughs used in this investigation.

Articles dealing with grit chamber design invariably were concerned with developing the most efficient flow cross section rather than collection trough; and in every case a mechanically cleaned grit chamber was discussed rather than the simple collection trough which was the object of this investigation.

An indication of the problem, however, was given by Bramer and Hoak(1) who stated, "In practice, sedimentation basins are not often designed; they are sized on the basis of past experience." This would evidently apply to grit chambers as well as sedimentation basins since there is a great similarity in the two.

Metcalf and Eddy(4) again attested to the "rule of thumb" practices employed in trough design when they stated, "In some of the early trough and hopper bottoms the slopes were too flat for the grit to slide down them and there is some evidence that the inclination should be at least forty-five degrees." They indicate, therefore, that the hopper sides should be steep, but they provide no design criteria for a more definite slope.

The review of literature thus showed that very little work has been done on the design of non-mechanically cleaned grit chambers, leaving the subject open for investigation.

III. METHODS AND MATERIALS

The means by which datum was obtained in this investigation was the construction of a scale model grit chamber to obtain purely empirical values. The chamber was constructed of plywood and plastic according to the dimensions shown in Figure 1.

This investigation was confined to the comparison of three troughs as shown in Figure 2. The troughs were made of Plexiglass Acrylic Plastic so that particle movement in the trough could be readily observed. The remainder of the grit chamber was made of plywood utilizing wood screws, with waterproof glue being used as a sealant and to provide added strength. Wing nuts and bolts were used to connect the plastic sections to the plywood section, with Vaseline petroleum jelly being used to seal the joints. Petroleum jelly turned out to be an excellent sealing material since it was waterproof, clean, very workable, and never dries out. The plywood section of the chamber was painted with marine varnish to waterproof the surfaces and prevent warping.

Normally, a Parshall flume or a sedimentation tank would follow a grit chamber in actual usage, thereby controlling the depth in the chamber but since flow from the model had to be immediately channeled away a weir was used to control the height of the water surface and as a means of measuring the quantity of flow. The weir was placed at the end of a short stabilization section which followed the trough. The stabilization section was needed because if the weir were placed directly behind the trough, a large number of particles would hit the bottom of the weir and drop into the trough. The stabilization section provided a means for the particles which did not settle fast enough to be trapped by the trough to continue past and not be deflected downward.

The weir was rectangular with a piece of sheet metal tacked across the bottom edge to provide a sharp crest. Calibration of the weir was accomplished by passing a constant flow of water through the chamber and trapping and weighing that portion which passed in a measured time interval. By measuring the temperature of the water, and thereby knowing the density, the volume was easily determined; this divided by the time interval gave the quantity in cubic feet per second.

Two rulers were used to read the depth of flow, one located on the inside face of the weir measured the height of the weir crest above the bottom of the channel, and the other located about ten inches ahead of the weir on the wall of the channel measured the height of the water surface above the channel bottom. The difference in these two readings was plotted against the known quantity on log log graph paper. The calibration points are listed in Table 1 and plotted in Figure 3. The resulting graph was then used to determine quantities of flow during the various experiments by simply taking the difference of the two depths and reading the flow from the graph.

An approach channel was used to direct the water in the proper direction before it entered the chamber proper. The approach channel was made narrower than the chamber in order to maintain a velocity which would not permit grit to settle out before reaching the chamber. Water entered vertically downward at the upper end of the approach channel through a fire hose from a town water connection. Water passing over the weir was funneled directly into a floor drain to the sewer system.

Grit was introduced to the flow by use of a funnel with a rubber hose and clamp attached to the bottom. The funnel was suspended over the upper end of the approach channel and when the clamp on the hose was released the mixture of water and sand passed down into the flow at a nearly constant rate. Chasick and Burger(2) had experience in using sand in testing grit removal apparatus and they minimize the effect of the rate of sand feed. They stated, "The rate of feeding of sand, which varied from about two to ten pounds per minute, did not affect the efficiency of recovery."

Ordinary construction sand was used as grit during the entire investigation with a range of particle sizes being used. Grains of a uniform size were obtained by passing the raw sand through a series of standard sieves as indicated in Table 2.

A volumetric measurement was utilized in determining the amount of grit to be introduced to the flow entering the chamber. A water-sand mixture was used at all times to provide ease of handling and measuring. The water-sand mixture was poured into a 250 ml. graduated cylinder and the sand permitted to settle to the bottom. With a constant rotation of the cylinder on a table top the sand very quickly settled to a compact mass which would remain at a constant depth no matter how much additional rotation or vibration was employed. A water level of at least two inches above the sand surface in the graduated cylinder was maintained at all times to insure that all measurements were made in a subaqueous condition.

During a standard run a known volume of grit was placed in the funnel and the weir crest set at the desired height. A valve on the water main permitted control of the flow entering the approach channel. The quantity of flow was regulated with the valve until the desired depth in the chamber was obtained. Release of the clamp on the funnel permitted the mixture of sand and water to drop into the flow passing through the approach channel. Between two and ten minutes were required for the funnel to empty depending on what particle size was being used; the larger particle sizes flowed the fastest. For any one particle size, however, the rate of flow through the funnel was always the same.

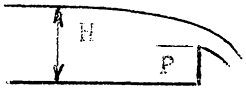
When all of the grit had been introduced to the flow the valve was closed, thus ceasing operation of the chamber. All of the grit which had settled out before reaching the trough was then swept down into the trough with a small paint brush to be removed and measured. Any grit which had passed the trough and settled in the stabilization section was not included in the measurement; in other words, the chamber and trough sections were considered as a unit in developing efficiencies and all grit settling in both were included in the measurement. The grit was then removed from the trough by siphoning with a plastic laboratory hose. The siphoning action was quite efficient and all of the grit was quickly and easily removed. After removal from the trough the mixture was poured into the graduated cylinder for final measurement.

At one point in the investigation a baffle was installed in the approach channel to prevent rippling, a problem which will be discussed later, but was unsuccessful. The baffle was four inches high and placed on the bottom of the approach channel about ten inches from the upper end. The baffle was somewhat useful at low flows but seemed to increase rippling at high flows and had to be removed.

TABLE I

Weir Calibration Data

Temperature of water - 23°C



Density of water at 23°C =
62.28 lbs./ft.^{3}

P ft.	H ft.	Trial	Weight lbs.	V Volume wt./62.28 cu. ft.	T Time seconds	Flow Rate V/T average cu.ft./sec.
0.10	0.225	1	500	8.028	157.5*	
0.10	0.225	2	500	8.028	137.9*	
0.10	0.225	3	500	8.028	131.9*	
0.10	0.225	4	500	8.028	129.6*	
0.10	0.225	5	500	8.028	128.9*	
0.10	0.225	6	500	8.028	127.4*	
0.10	0.225	7	500	8.028	129.0	
0.10	0.225	8	500	8.028	128.6	
0.10	0.225	9	500	8.028	129.4*	0.0623
0.10	0.208	1	400	6.423	133.5	
0.10	0.208	2	400	6.423	135.0	
0.10	0.208	3	400	6.423	135.9	
0.10	0.208	4	400	6.423	136.2	
0.10	0.208	5	400	6.423	137.3	0.0474
0.10	0.245	1	500	8.028	104.3*	
0.10	0.245	2	500	8.028	102.8*	
0.10	0.245	3	500	8.028	100.2	
0.10	0.245	4	500	8.028	100.9	0.0799
0.20	0.365	1	500	8.028	99.6*	
0.20	0.365	2	500	8.028	91.4*	
0.20	0.365	3	500	8.028	84.6*	
0.20	0.365	4	500	8.028	83.8*	
0.20	0.365	5	500	8.028	82.7	
0.20	0.365	6	500	8.028	82.5	0.0972
0.20	0.405	1	500	8.028	64.0*	
0.20	0.405	2	500	8.028	58.7*	
0.20	0.405	3	500	8.028	58.2	
0.20	0.405	4	500	8.028	57.4	0.1389

(continued)

TABLE I

Weir Calibration Data (continued)

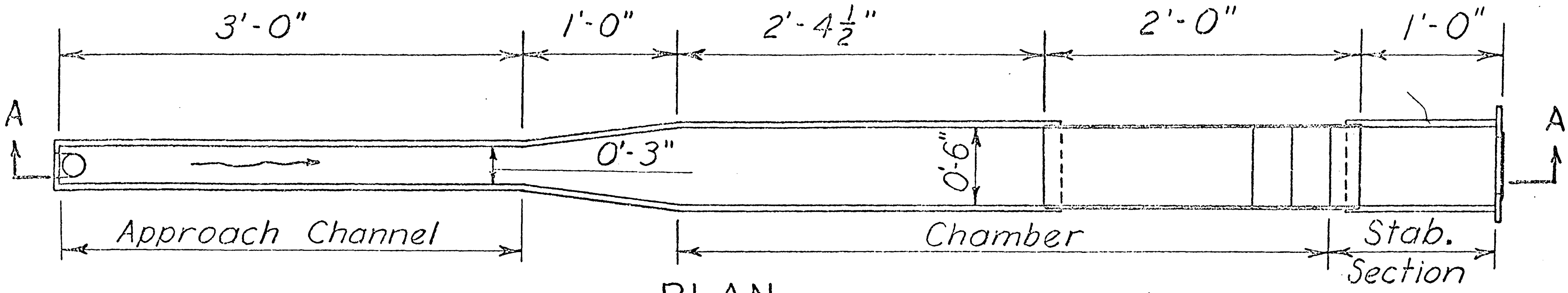
P ft.	H ft.	Trial	Weight lbs.	V Volume wt./62.28 cu.ft.	T Time seconds	Flow Rate V/T average cu.ft./sec.
0.20	0.350	1	500	8.028	92.7*	
0.20	0.350	2	500	8.028	94.3	
0.20	0.350	3	500	8.028	95.5	
0.20	0.350	4	500	8.028	95.8	
0.20	0.350	5	500	8.028	94.7	0.0844
0.20	0.319	1	500	8.028	139.5	
0.20	0.319	2	500	8.028	140.4	
0.20	0.319	3	500	8.028	142.5	
0.20	0.319	4	500	8.028	162.7*	
0.20	0.319	5	500	8.028	140.2	0.0571
0.20	0.281	1	200	3.211	118.5*	
0.20	0.281	2	200	3.211	93.5*	
0.20	0.281	3	200	3.211	98.4	
0.20	0.281	4	200	3.211	100.6	
0.20	0.281	5	200	3.211	109.8*	
0.20	0.281	6	200	3.211	102.4	
0.20	0.281	7	200	3.211	97.9	
0.20	0.281	8	200	3.211	103.6	0.0319
0.20	0.380	1	500	8.028	81.6*	
0.20	0.380	2	500	8.028	78.3*	
0.20	0.380	3	500	8.028	76.2*	
0.20	0.380	4	500	8.028	75.3*	
0.20	0.380	5	500	8.028	73.4*	
0.20	0.380	6	500	8.028	73.0	
0.20	0.380	7	500	8.028	73.0	0.110

*Values not used in computing T average

TABLE II

List of Sieves Used to Obtain Grit Particles

U. S. Sieve Number	Diameter of Particle Passing Sieve, millimeters	Average Diameter of Particle Obtained millimeters
20	0.840	0.72
30	0.590	
40	0.420	0.36
50	0.297	
60	0.250	0.20
100	0.149	
120	0.125	0.10
200	0.074	



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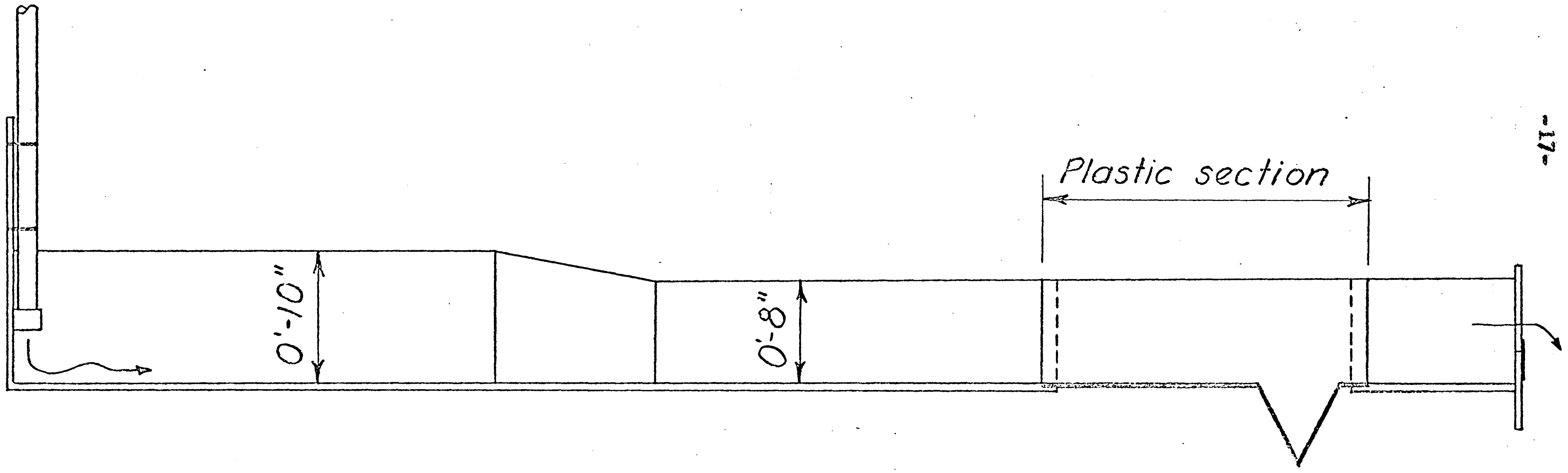


SECTION A

Figure 1: Sketch of apparatus

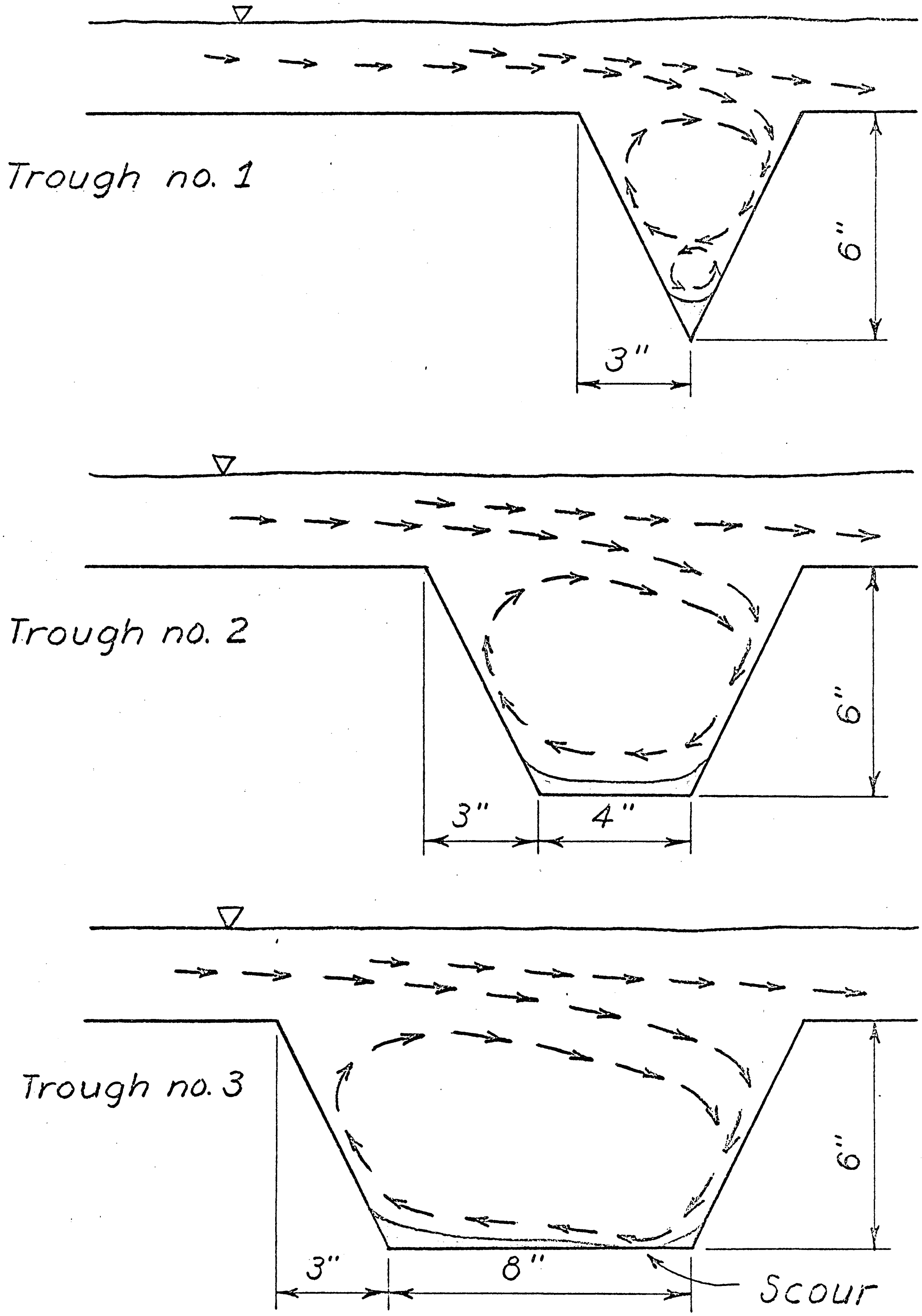


Figure 2: Trough dimensions and typical particle flow patterns

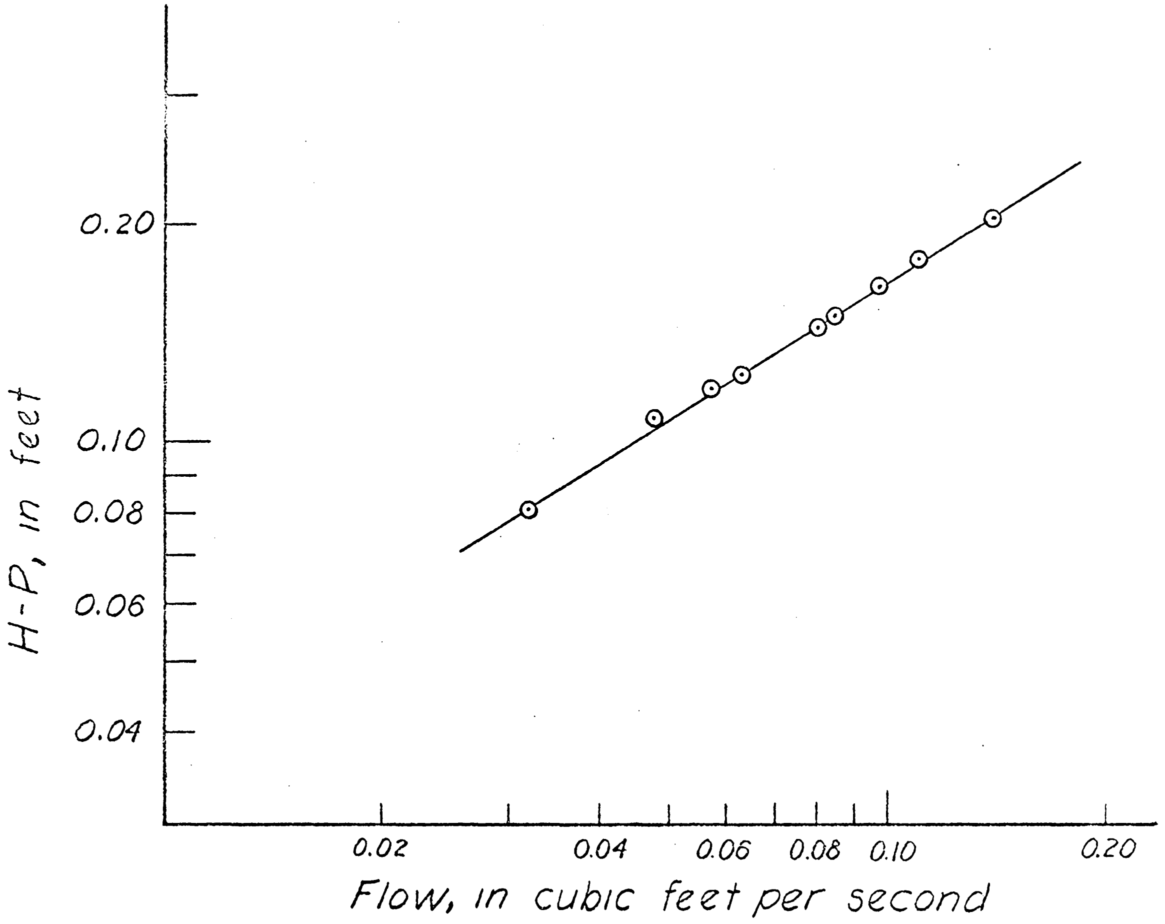


Figure 3 : Weir calibration curve

IV. RESULTS

The investigation was divided into four experiments which were run according to the method described in Section III --- Methods and Materials, the difference being that a different sand particle size was used for each experiment.

The preliminary experiments employed sand grain sizes of 0.72 and 0.36 mm. The results of these experiments, presented in Tables III and IV, showed 100 percent removal after several test runs. Experimentation was shifted to smaller sand sizes upon evidence that the experimental unit was not performing the function of selective sedimentation.

The results of Experiment III, where a 0.2 mm grain size was used, are given in tabular form in Tables V, VI and VII and plotted in Figure 4. The results of Experiment IV, where a 0.1 mm grain size was used, are given in tabular form in Tables VIII, IX and X and plotted in Figure 5.

Data points were obtained within the widest range of velocities which were practical for each experiment. At lower velocities nearly all the grit would settle out in the chamber before reaching the trough, and at high velocities ripples would form on the water surface that made it difficult to read the depth in the chamber.

These ripples occurred during the weir calibration runs, however, and did not seem to have any marked effect upon the results, as can be seen in Figure 3 in which nearly all points plot on a straight line.

The patterns of particle flow which were observed in the troughs are shown in Figure 2. The troughs are numbered 1, 2 and 3, a notation which is used throughout this work.

A double vortex formed in Trough 1 as shown in Figure 2, the smaller vortex rotating at a faster rate than the larger one. The small vortex did not appear to produce any scouring effect upon the collected grit beneath it. In Trough 2 the grit collected in the corners, as shown in Figure 2, and in a thin layer across the bottom. Only Trough 3 showed clear evidence of scouring action, however, it did not appear that the scoured particles were driven up into the flow of the vortex but were simply pushed to a new position on the bottom nearer to the opposite wall. In all three troughs it appeared thay any particle which hit the sides or bottom did not re-enter the flow pattern.

In general the grit was caught in the trough in two ways. First, a certain amount of grit which settled out just before reaching the trough would be pushed along the bottom by the flow to the edge of the trough and slide down. Only a small percentage would be picked up at the edge and carried into the vortex. Secondly, a certain portion of the grit would strike the opposite wall and slide down to the bottom. Grit seemed to collect in the bottom of Troughs 2 and 3 in approximately equal amounts at both ends, indicating that the two trapping mechanisms just described were each responsible for nearly the same amount of grit being trapped by the trough.

The curves in Figure 4 compare velocity with the percent of grit which passed the trough. Three weir height settings were selected to be used for comparison, 0.05 feet, 0.10 feet, and 0.15 feet. As can be seen the 0.05 feet curve predominantly appeared to the left, the 0.10 feet curve next, and the 0.15 feet curve to the right in relation to each other. The 0.05 feet curves have a characteristically steeper slope, followed by the 0.10 feet curves, with the 0.15 feet curves starting out very steep but quickly leveling off. These characteristics are not nearly so prominent in Figure 5 which plots the results of Experiment IV in which a small grain size of 0.1 mm was used. In Experiment IV a wider divergence of data points made the construction of a reasonable line through the points more difficult.

Table XI gives the results of Experiment IVR, a repeat of one series in Experiment IV. It was felt that since sand for any one run during the investigation was obtained by using sand which was trapped in the previous run plus some extra sieved sand for makeup, that possibly the sand was not constant in its nature from one run to the next. In Experiment IV, for example, the average grain size used was 0.1 mm but actually varied from 0.074 mm to 0.125 mm. It was felt that a possible error was being introduced in that the smaller particles were probably being removed more than the larger particles in the range. When the sand was then retrieved to be used again the average size could possibly have been higher than the 0.1 mm being assumed.

For the repeat series a large quantity of raw sand was run through the grit chamber at the highest velocity which was to be used. The sand retrieved was then set aside as a source of supply for makeup sand to be used in the repeat series. This should have provided a more constant grit supply and have had the effect of increasing the average diameter. The results, however, did not show a significant change from data obtained previously and, in fact, varied both higher and lower indicating no trend one way or the other. The results obtained from the repeat series are plotted in Figure 6 which also presents the previous results.

Figure 7 is a bar graph which gives the percent capture of sand for the three troughs under equal conditions of weir height, velocity, and particle size. One relatively high velocity and one relatively low velocity were chosen for comparison. The percent passing values plotted in the bar graphs were taken from the graphs in Figures 4 and 5.

An effort to compare the variables effecting grit scour with the percentages of grit passing the unit during the experiments is shown in Figures 8, 9, and 10, for weir settings of 0.05 feet, 0.10 feet, and 0.15 feet, respectively. In these figures the percent grit passing the trough is plotted against the three variables, Reynolds number (N_R), Froude number (N_F), and the depth in the chamber (H), which were thought to effect scour. The depth variable was divided by the width of the channel in order to create a dimensionless parameter to correspond to the Reynolds and Froude numbers. As can be seen in Figures 8, 9, and 10, the curves are very nearly straight lines, indicating a linear variation of the selected variables with percent passing or performance.

Figures 8, 9, and 10 also give an indication of the order of importance of the three variables in that the variable which is effective over the widest range of values can be expected to have the most prominent total effect. In other words, the parameter which varies the most can be expected to have the greatest effect on performance. The Reynolds number can be seen to show the greatest range of variation, with the Froude number next, and the depth parameter last.

TABLE III

Results of Experiment I - Trough 1

Particle size 0.72 mm

P ft.	H ft.	velocity ft./sec.	grit added ml	grit trapped ml	percent passing
0.10	0.225	0.570	133.5	133.5	-
0.10	0.280	0.803	134.0	134.0	-
0.10	0.300	0.900	135.0	135.0	-
		Experiment discontinued			

TABLE IV

Results of Experiment II - Trough 3

Particle size 0.36 mm

P ft.	H ft.	velocity ft./sec.	grit added ml.	grit trapped ml	percent passing
0.05	0.15	0.587	176.0	176.0	-
0.05	0.17	0.695	175.0	175.0	-
0.10	0.28	0.803	175.0	175.0	1.0
		Experiment discontinued			

TABLE V

Results of Experiment III - Trough 1

Particle size 0.2 mm

P ft.	H ft.	velocity ft./sec.	Reynolds number N_R	Froude number N_F	grit added ml.	grit trapped ml.	percent passing
0.05	0.13	0.492	0.633×10^4	0.0578	132.0	131.0	0.8
0.05	0.15	0.587	0.871×10^4	0.0713	131.0	128.0	2.3
0.05	0.17	0.695	1.169×10^4	0.0882	128.0	119.0	7.0
0.10	0.20	0.440	0.870×10^4	0.0301	130.0	127.0	2.3
0.10	0.22	0.535	1.164×10^4	0.0404	127.0	121.0	4.7
0.10	0.24	0.625	1.484×10^4	0.0505	121.0	109.0	9.9
0.10	0.26	0.715	1.839×10^4	0.0611	153.0	124.0	19.0
0.10	0.26	0.715	1.839×10^4	0.0611	154.0	131.0	14.9
0.10	0.28	0.803	2.224×10^4	0.0715	142.0	113.0	20.4
0.10	0.28	0.803	2.224×10^4	0.0715	142.0	105.0	26.1
0.15	0.27	0.437	1.167×10^4	0.0220	146.0	144.0	1.4
0.15	0.29	0.524	1.503×10^4	0.0294	144.0	140.0	2.8
0.15	0.31	0.606	1.858×10^4	0.0368	140.0	129.0	7.9
0.15	0.335	0.716	2.372×10^4	0.0475	129.0	97.0	24.8

TABLE VI

Results of Experiment III - Trough 2

Particle size 0.2 mm

P ft.	H ft.	velocity ft./sec.	Reynolds number N_R	Froude number N_F	grit added ml.	grit trapped ml.	percent passing
0.05	0.13	0.492	0.633×10^4	0.0578	170.0	170.0	---
0.05	0.15	0.587	0.871×10^4	0.0713	170.0	164.0	3.5
0.05	0.17	0.695	1.169×10^4	0.0882	164.0	152.0	7.3
0.10	0.20	0.492	0.870×10^4	0.0301	154.0	153.0	0.6
0.10	0.22	0.535	1.164×10^4	0.0404	153.0	145.0	5.2
0.10	0.24	0.625	1.484×10^4	0.0505	145.0	126.0	13.1
0.10	0.26	0.715	1.839×10^4	0.0611	148.0	126.0	14.9
0.10	0.28	0.803	2.224×10^4	0.0715	126.0	96.0	23.6
0.15	0.27	0.437	1.167×10^4	0.0220	146.0	143.0	2.1
0.15	0.29	0.524	1.503×10^4	0.0294	143.0	139.0	2.8
0.15	0.31	0.606	1.858×10^4	0.0368	139.0	129.0	7.2
0.15	0.33	0.682	2.226×10^4	0.9438	129.0	100.0	22.5

TABLE VII

Results of Experiment III - Trough 3

Particle size 0.2 mm

P ft.	H ft.	velocity ft./sec.	Reynolds number N_R	Froude number N_F	grit added ml.	grit trapped ml.	percent passing
0.05	0.13	0.492	0.633×10^4	0.0578	164.0	161.0	1.8
0.05	0.15	0.587	0.871×10^4	0.0713	141.0	136.0	3.5
0.05	0.17	0.695	1.169×10^4	0.0882	136.0	128.0	5.9
0.10	0.20	0.440	0.870×10^4	0.0301	164.0	164.0	-
0.10	0.22	0.535	1.164×10^4	0.0404	175.0	169.0	4.0
0.10	0.24	0.625	1.484×10^4	0.0505	169.0	150.0	11.2
0.10	0.26	0.715	1.839×10^4	0.0611	150.0	130.0	13.3
0.10	0.28	0.803	2.224×10^4	0.0715	130.0	106.0	18.5
0.15	0.27	0.437	1.167×10^4	0.0220	152.0	147.0	3.3
0.15	0.29	0.524	1.503×10^4	0.0294	147.0	142.0	3.4
0.15	0.31	0.606	1.858×10^4	0.0368	140.0	124.0	11.4
0.15	0.33	0.682	2.226×10^4	0.0438	124.0	78.0	37.1

TABLE VIII

Results of Experiment IV - Trough 1

Particle size 0.1 mm

P ft.	H ft.	velocity ft./sec.	Reynolds number N_R	Froude number N_F	grit added ml.	grit trapped ml.	percent passing
0.05	0.11	0.396	0.431×10^4	0.0443	128.0	116.0	9.4
0.05	0.12	0.417	0.495×10^4	0.0450	135.0	88.0	34.8
0.05	0.12	0.417	0.495×10^4	0.0450	134.0	108.0	19.4
0.05	0.13	0.492	0.633×10^4	0.0578	127.0	103.0	18.9
0.05	0.13	0.492	0.633×10^4	0.0578	126.0	102.0	19.0
0.15	0.14	0.536	0.742×10^4	0.0637	131.0	88.0	32.8
0.05	0.15	0.587	0.871×10^4	0.0713	143.0	86.0	39.9
0.10	0.19	0.395	0.742×10^4	0.0255	129.0	110.0	14.7
0.10	0.20	0.440	0.870×10^4	0.0301	135.0	107.0	20.7
0.10	0.21	0.490	1.018×10^4	0.0355	137.0	93.0	32.1
0.10	0.22	0.535	1.164×10^4	0.0404	125.0	80.0	36.0
0.10	0.23	0.587	1.335×10^4	0.0465	122.0	62.0	49.2
0.15	0.26	0.396	1.018×10^4	0.0187	128.0	105.0	18.0
0.15	0.27	0.437	1.167×10^4	0.0220	133.0	99.0	25.6
0.15	0.28	0.482	1.335×10^4	0.0258	130.0	90.0	30.8
0.15	0.29	0.524	1.503×10^4	0.0294	132.0	82.0	37.9

TABLE IX

Results of Experiment IV - Trough 2

Particle size 0.1 mm

P ft.	H ft.	velocity ft./sec.	Reynolds number N_R	Froude number N_F	grit added ml.	grit trapped ml.	percent passing
0.05	0.11	0.396	0.431×10^4	0.0443	130.0	120.0	7.7
0.05	0.12	0.417	0.495×10^4	0.0450	134.0	108.0	19.5
0.05	0.12	0.417	0.495×10^4	0.0450	138.0	97.0	29.7
0.05	0.125	0.448	0.554×10^4	0.0499	130.0	106.0	18.5
0.05	0.13	0.492	0.633×10^4	0.0578	142.0	108.0	23.9
0.05	0.14	0.536	0.742×10^4	0.0637	137.0	101.0	26.3
0.05	0.15	0.587	0.871×10^4	0.0713	144.0	88.0	38.9
0.10	0.19	0.395	0.742×10^4	0.0255	119.0	103.0	13.4
0.10	0.20	0.440	0.870×10^4	0.0301	132.0	107.0	18.9
0.10	0.21	0.490	0.018×10^4	0.0355	136.0	87.0	28.7
0.10	0.22	0.535	0.164×10^4	0.0404	130.0	79.0	39.2
0.10	0.23	0.587	1.335×10^4	0.0465	125.0	61.0	51.2
0.15	0.26	0.396	1.018×10^4	0.0187	133.0	111.0	16.5
0.15	0.27	0.437	1.167×10^4	0.0220	131.0	103.0	21.4
0.15	0.28	0.482	1.335×10^4	0.0258	136.0	98.0	27.9
0.15	0.29	0.524	1.503×10^4	0.0299	136.0	81.0	40.4

TABLE X

Results of Experiment IV - Trough 3

Particle size 0.1 mm

P ft.	H ft.	velocity ft./sec.	Reynolds number N_R	Froude number N_F	grit added ml.	grit trapped ml.	percent passing
0.05	0.12	0.417	0.495×10^4	0.0450	135.0	109.0	19.0
0.05	0.13	0.492	0.633×10^4	0.0578	138.0	98.0	29.0
0.05	0.13	0.492	0.633×10^4	0.0578	128.0	98.0	23.4
0.05	0.14	0.536	0.742×10^4	0.0637	131.0	93.0	29.0
0.05	0.145	0.566	0.812×10^4	0.0686	136.0	97.0	28.7
0.05	0.15	0.587	0.871×10^4	0.0713	156.0	88.0	43.6
0.10	0.20	0.440	0.870×10^4	0.0301	164.0	123.0	25.0
0.10	0.21	0.490	1.018×10^4	0.0355	123.0	86.0	30.0
0.10	0.22	0.535	1.164×10^4	0.0404	129.0	88.0	31.8
0.10	0.225	0.560	1.246×10^4	0.0433	133.0	77.0	42.1
0.10	0.23	0.587	1.335×10^4	0.0465	144.0	70.0	51.4
0.10	0.24	0.625	1.503×10^4	0.0505	132.0	57.0	56.8
0.15	0.27	0.437	1.167×10^4	0.0220	130.0	104.0	20.0
0.15	0.28	0.482	1.335×10^4	0.0258	132.0	99.0	25.0
0.15	0.29	0.524	1.503×10^4	0.0294	130.0	83.0	36.2
0.15	0.30	0.567	1.682×10^4	0.0333	142.0	77.0	45.8

TABLE XI

Results of Experiment IVR - Trough 1

Repeat of Experiment IV Using Washed Sand Makeup

Particle size 0.1 mm

P ft.	H ft.	velocity ft./sec.	grit added ml.	grit trapped ml.	percent passing
0.10	0.19	0.395	130.0	110.0	15.4
0.10	0.20	0.440	136.0	104.0	23.5
0.10	0.21	0.490	137.0	97.0	29.2
0.10	0.22	0.535	125.0	77.0	38.4
0.10	0.23	0.587	122.0	64.0	47.5

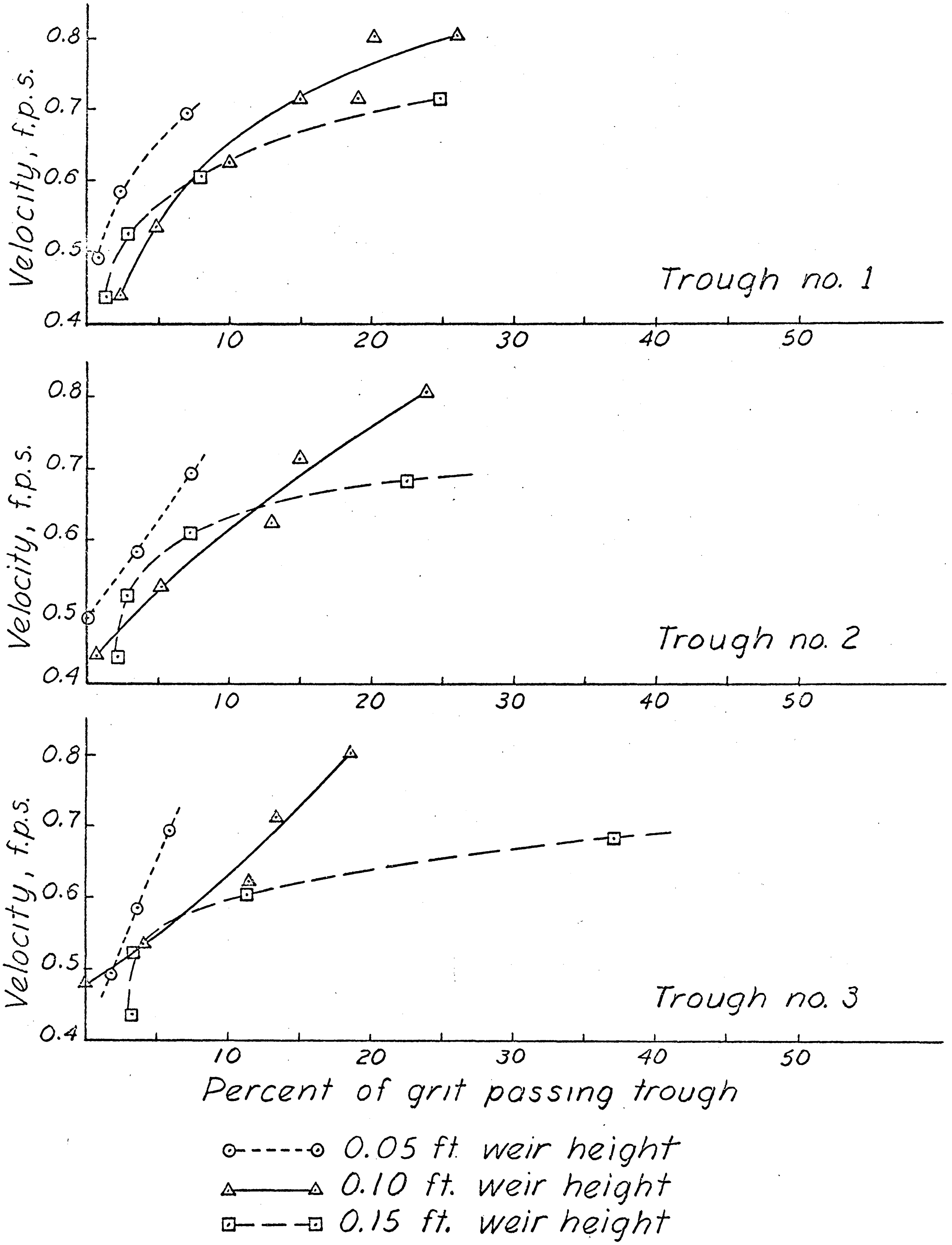


Figure 4: Velocity vs. percent grit passing trough for Experiment III, 0.2mm.

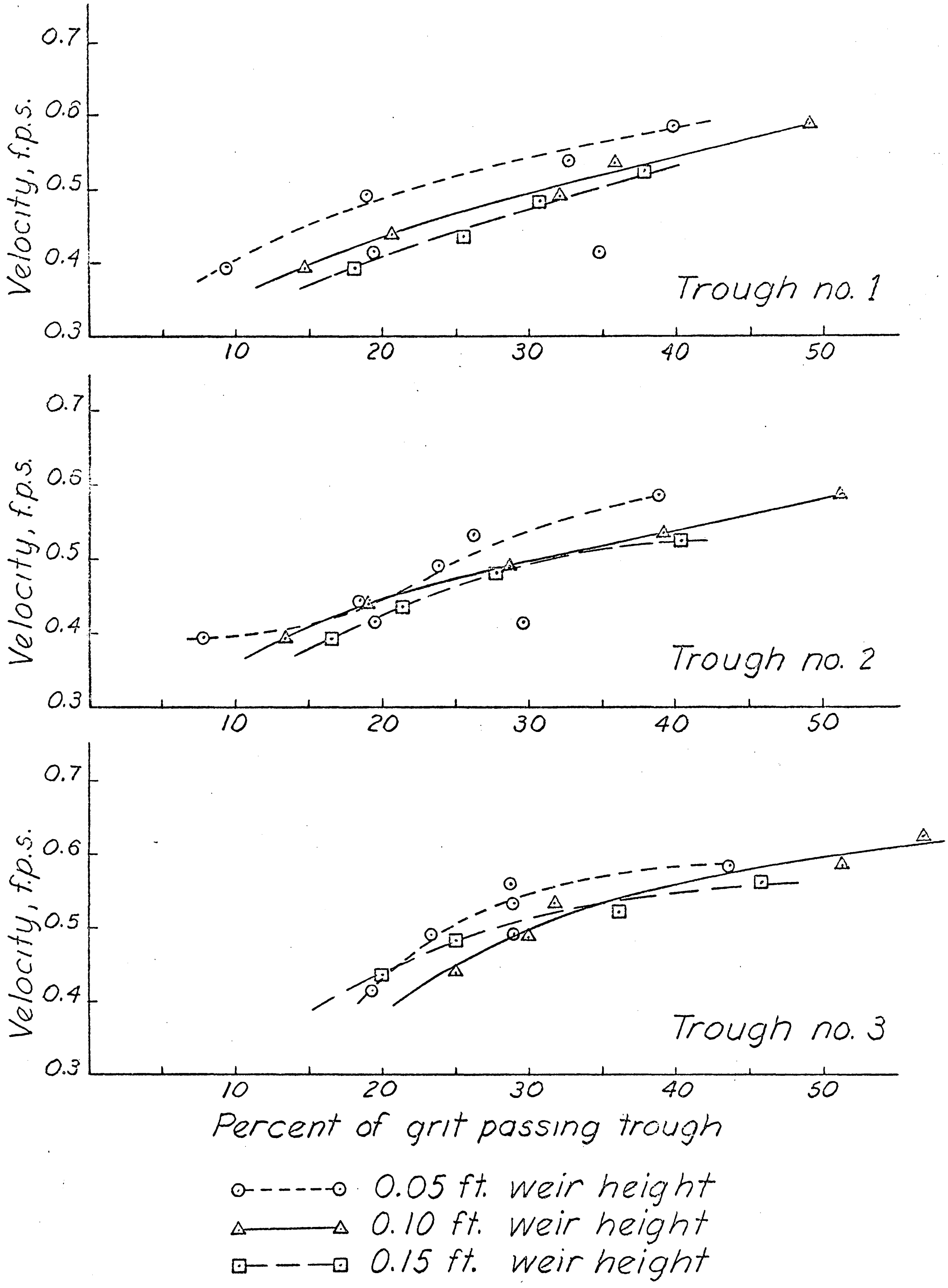


Figure 5: Velocity vs. percent grit passing trough for Experiment IV, 0.1 mm.

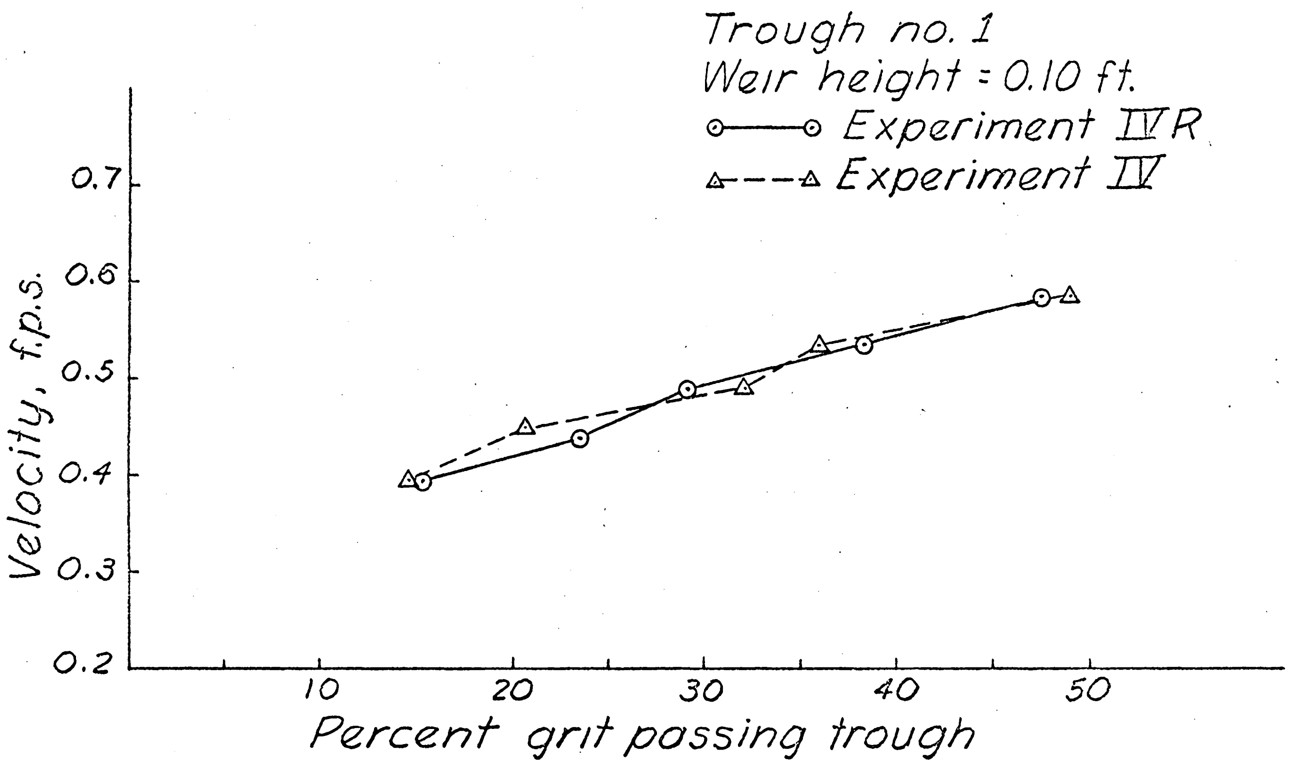
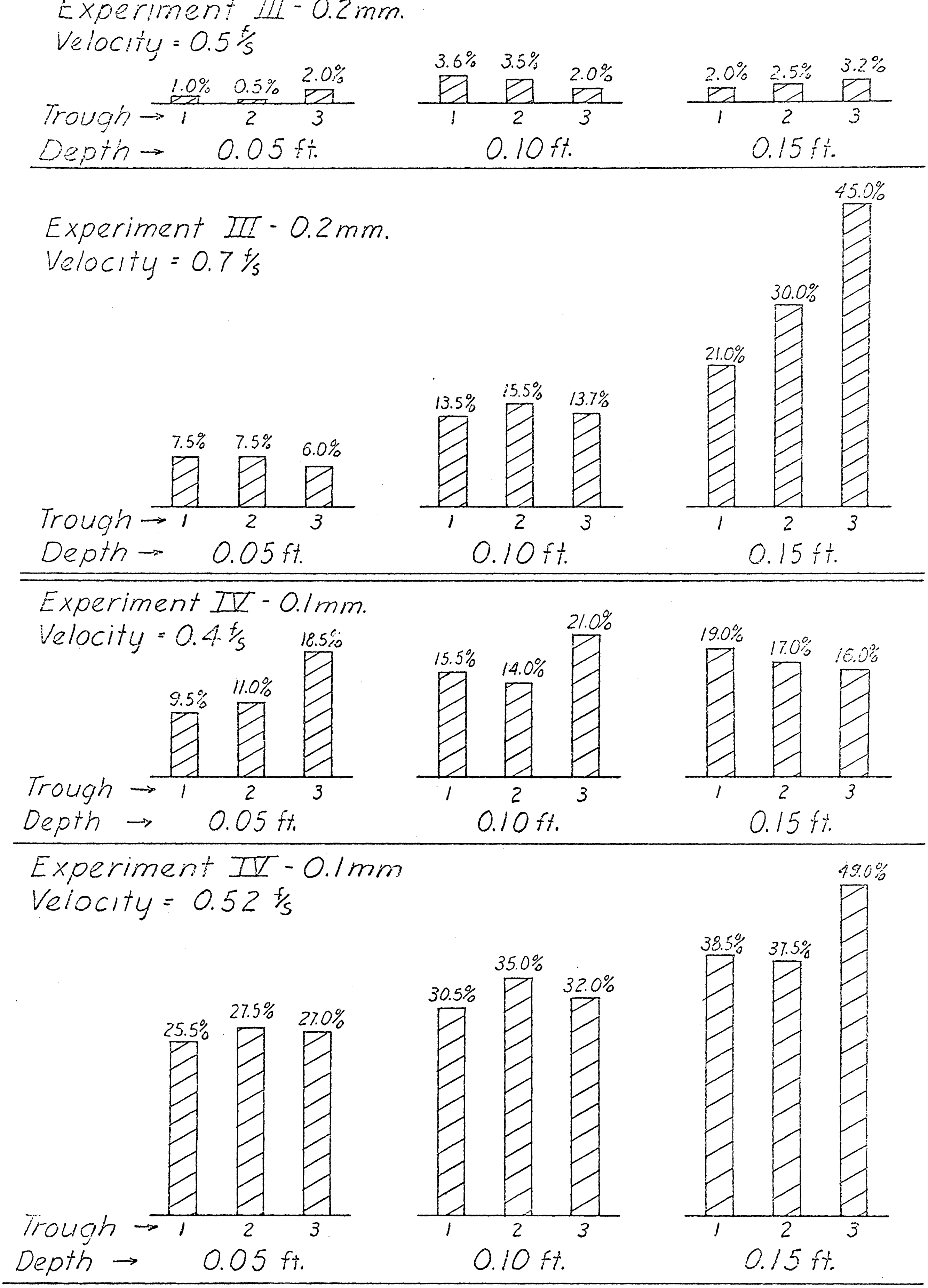


Figure 6: Comparison of repeat series with original series



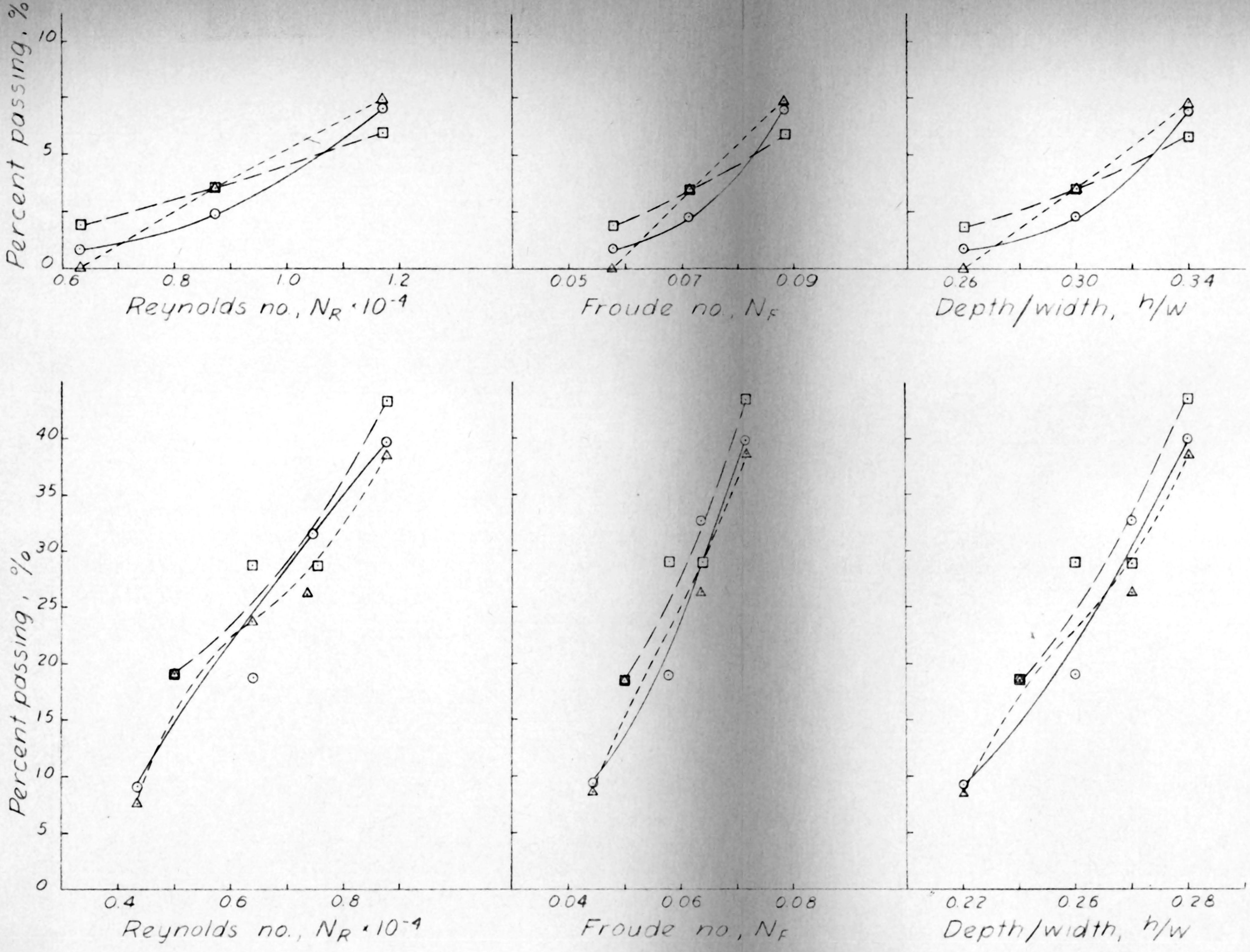
Experiment III - 0.2mm.
Velocity = 0.5 f/s

Experiment III - 0.2mm.
Velocity = 0.7 f/s

Experiment IV - 0.1mm.
Velocity = 0.4 f/s

Experiment IV - 0.1mm
Velocity = 0.52 f/s

Figure 7 : Bar graph comparisons of percent grit passing trough for Troughs 1, 2, & 3, under identical conditions.



Upper graphs = 0.2 mm part. size
Lower graphs = 0.1 mm part. size

Figure 8: Percent passing vs. selected variables for 0.05 ft. weir setting

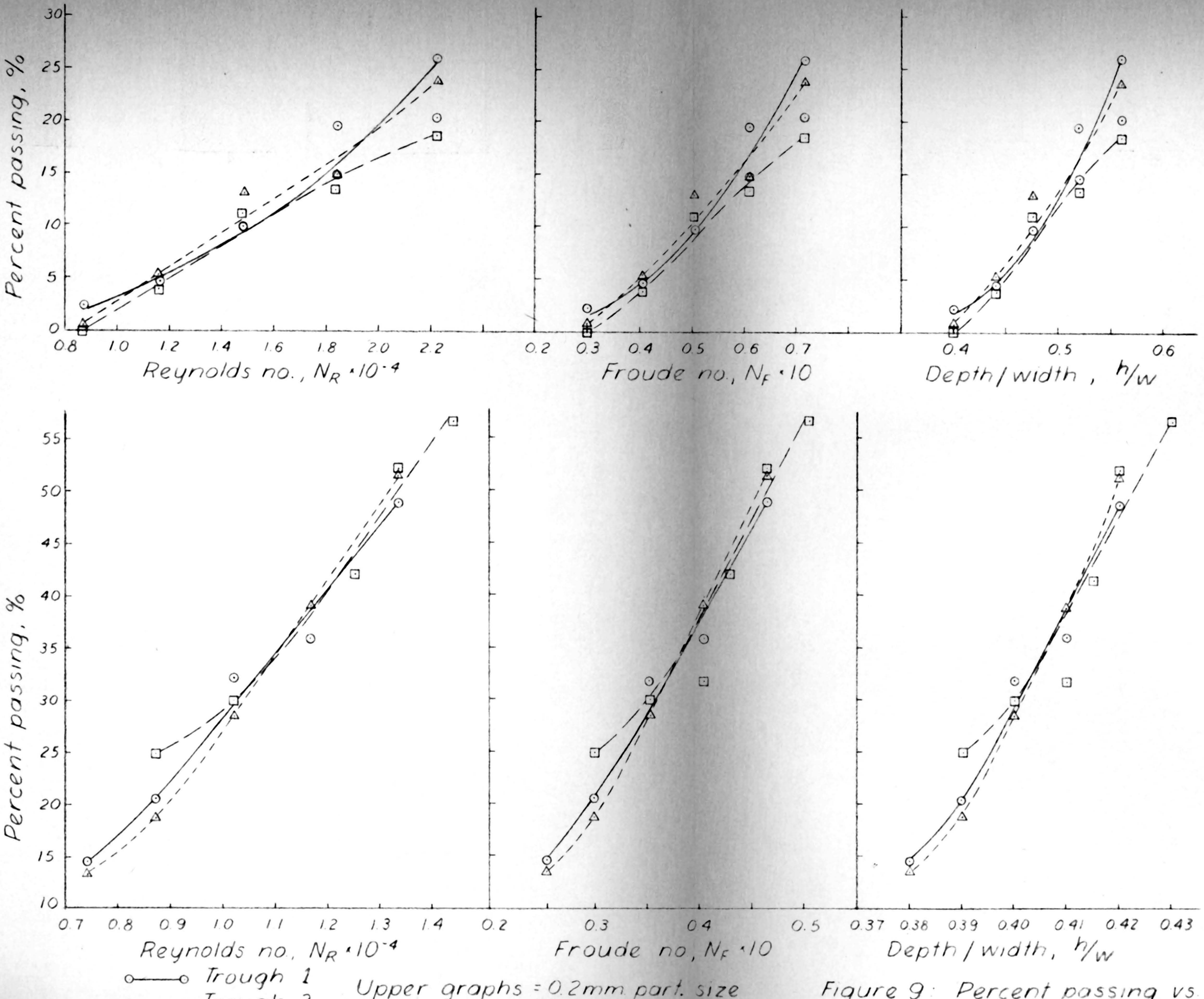


Figure 9: Percent passing vs. selected variables for 0.10 ft. weir setting

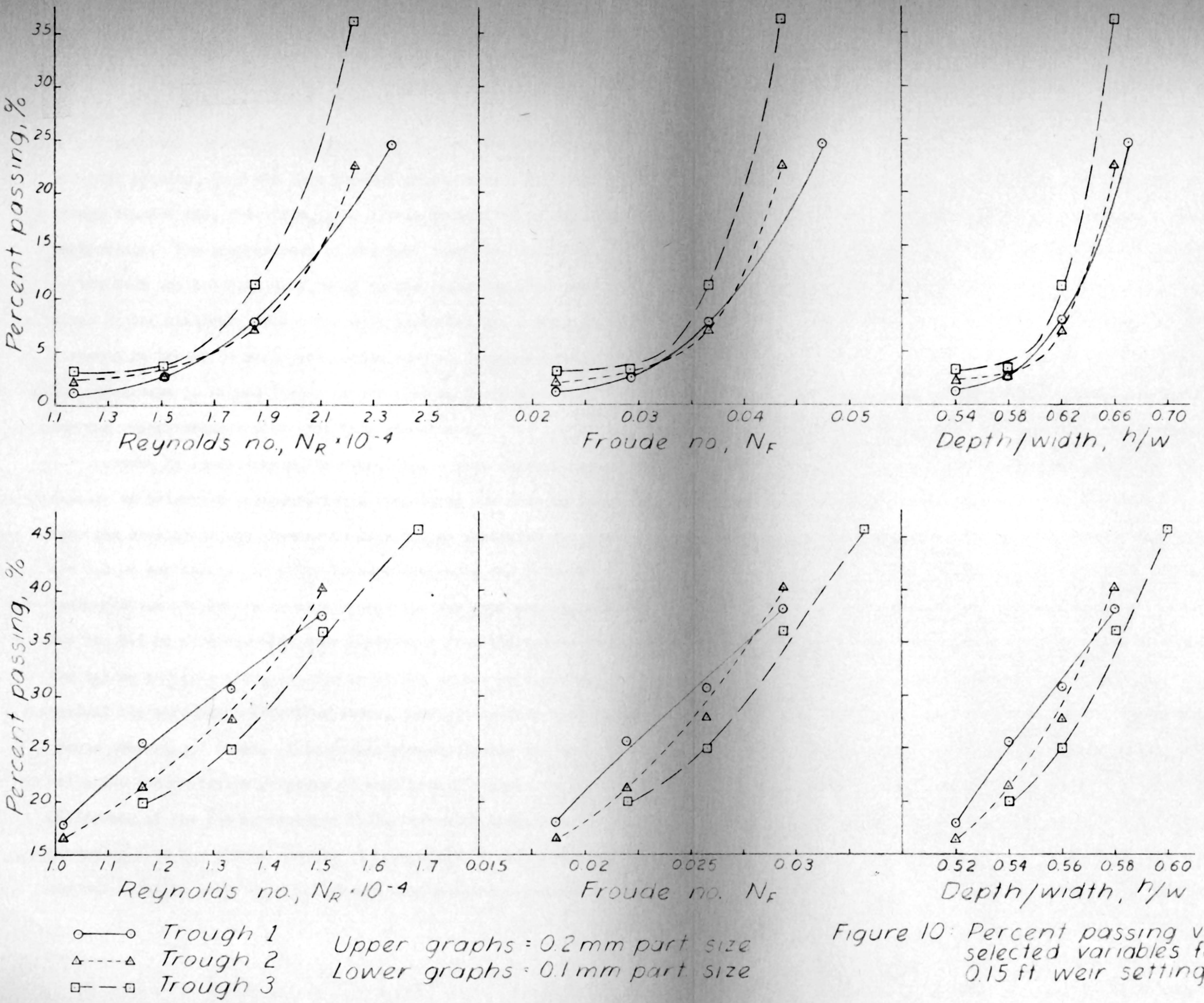


Figure 10: Percent passing vs. selected variables for 0.15 ft weir setting

V. DISCUSSION OF RESULTS

The curves plotted in Figures 4 and 5, for velocity versus per cent passing, show the same general configuration for each trough studied and, therefore, give little indication of relative performance. The predominance of the 0.05 feet weir height curve to the left and the 0.15 feet curve to the right was expected since at the shallower depths the grit particles had a shorter distance to travel to reach the bottom than at deeper depths. The bar graphs in Figure 7 also do not give an indication that any one trough trapped more grit than the others.

Because it is desirable, however, that a grit chamber have the ability of selective sedimentation a comparison was made to indicate the ability of the chamber to trap 0.2 mm particles and pass the 0.1 mm particles. In order to best determine the selective sedimentation properties of each trough the per cent passing values for the 0.2 mm particle size were subtracted from the values for the 0.1 mm particle size, and the resulting values were plotted against the parameters effecting scour, namely, Reynolds number, Froude number, and depth. This analysis most clearly evidenced the selective sedimentation property of each trough because taking the difference of the two percentages indicated which trough was operating over the widest range. A trough with a wide range at any one velocity would have a high per cent passing for small particles coupled with a low per cent passing for large particles.

A fair comparison could not be made, however, unless the three troughs were compared under identical scour conditions. In order to accomplish this it was necessary to select a particle size and determine the corresponding scour velocity for each weir setting. A particle size of 0.15 mm, an average of the two particle sizes actually used, was selected and the Shields equation (1) was used to determine the particle diameter which would be scoured by all of the velocities which were recorded during the experiments

$$(1) \qquad V_o = \sqrt{\frac{8k}{f} g\ (s-1)d}$$

V_o - scour velocity

k - constant for coarse sand, 0.04

f - friction factor from Moody curves using sand diameter as absolute roughness and $4R_H$ as equivalent diameter

s - specific gravity of particle, 2.74, determined by ASTM test, designation D854-58

d - diameter of particle

Once these particle diameters were obtained they were plotted against their respective scour velocities for each weir setting in Figure 11. The plot in Figure 11 enabled a scour velocity to be read for the chosen 0.15 mm particle diameter for each weir setting. The scour velocity thus obtained was used in Figures 4 and 5 to read an actual per cent passing value at that velocity. The differences in the percentages of the two particle sizes taken from Figures 4 and 5 are plotted against the selected scour parameters in Figure 12.

Figure 12 shows that the difference in per cent passing is greatest for Trough 2 at the extremes of the range and nearly equal for all three troughs at the midpoint of the range. This indicated that Trough 2 had a high capture of large particles along with a low capture of small particles in comparison to the other troughs. Therefore, the ability of selective sedimentation appeared to be greatest in Trough 2.

An attempt was also made to determine a prediction equation which would describe the phenomena occurring in the chamber. There were four variables which were felt would enter into a development of a prediction equation, Reynolds number, Froude number, depth, and per cent passing. Since four variables are very difficult to work with in a dimensional analysis one was chosen to be eliminated. As stated previously, Figures 8, 9 and 10 showed that the depth variable was last in order of importance, so it was neglected in the analysis.

The three remaining variables were plotted in Figures 13 and 14 in an effort to determine how the parameters combined, in addition or in multiplication. The Reynolds number was plotted against per cent passing and the Froude number indicated at each resulting point. An interpolation between the varying values of Froude numbers was then performed to produce two series of points for two constant values of Froude number. If the two resulting constant Froude number lines were parallel, then the remaining two variables would be known to combine in addition. If they were parallel when plotted in a logarithmic plot, they would have been known to combine in multiplication.

Figure 13 shows that the constant Froude number points have no semblence of order about them for the 0.2 mm particle size. A rough logarithmic plot did not bring about any improvement.

In Figure 14, however, the points produced two constant Froude number lines which were closely parallel. This gave evidence that the parameters would combine in addition, but an attempt was not made to produce a prediction equation because the results in Figure 13 were contradictory and, therefore, a general equation could not be evolved.

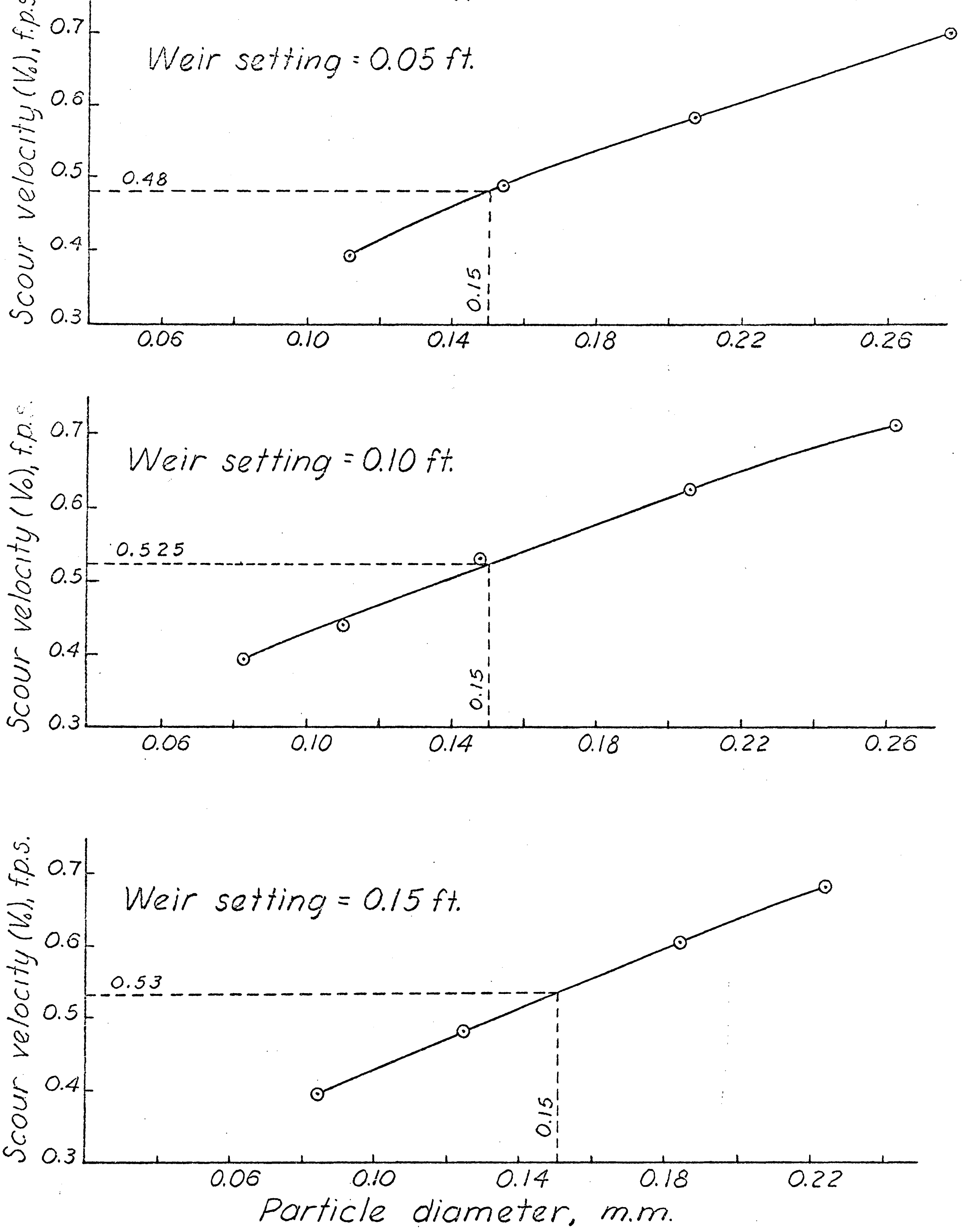


Figure 11: Scour velocity vs. particle diameter

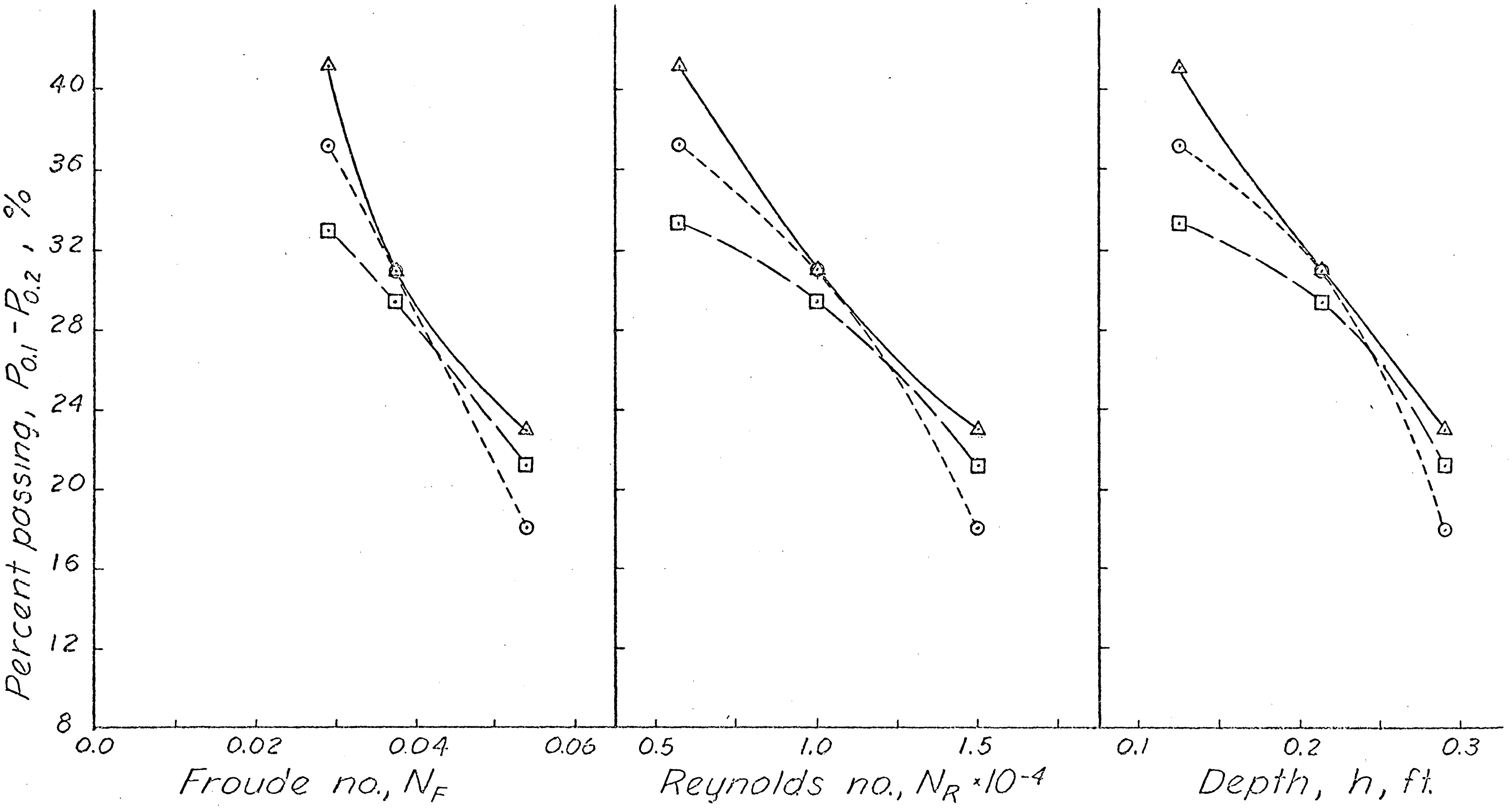


Figure 12: Difference in percent passing for 0.1 & 0.2 mm. particles vs. selected variables

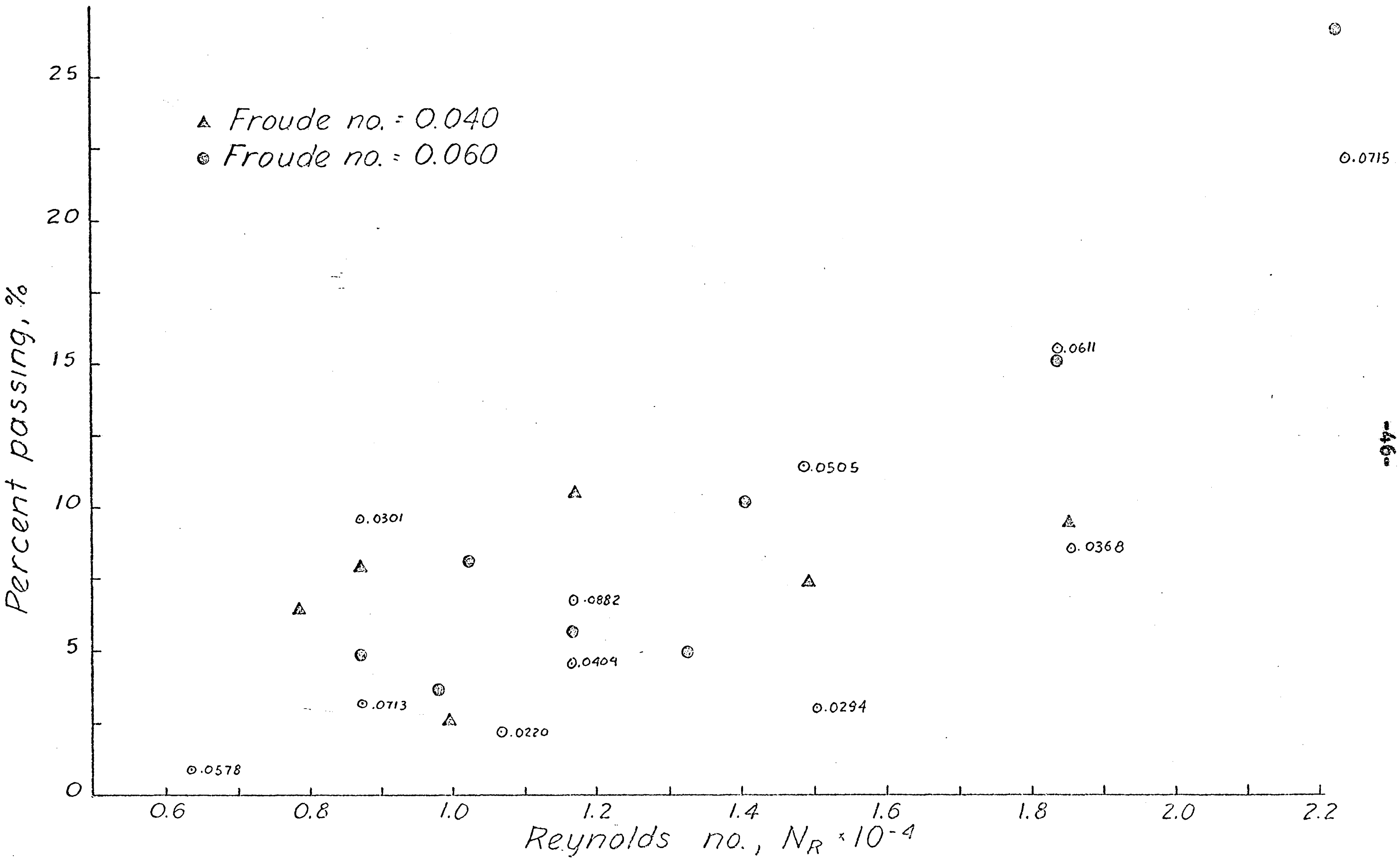


Figure 13: Percent passing vs. Reynolds no. at constant Froude no. for 0.2 mm. particle size

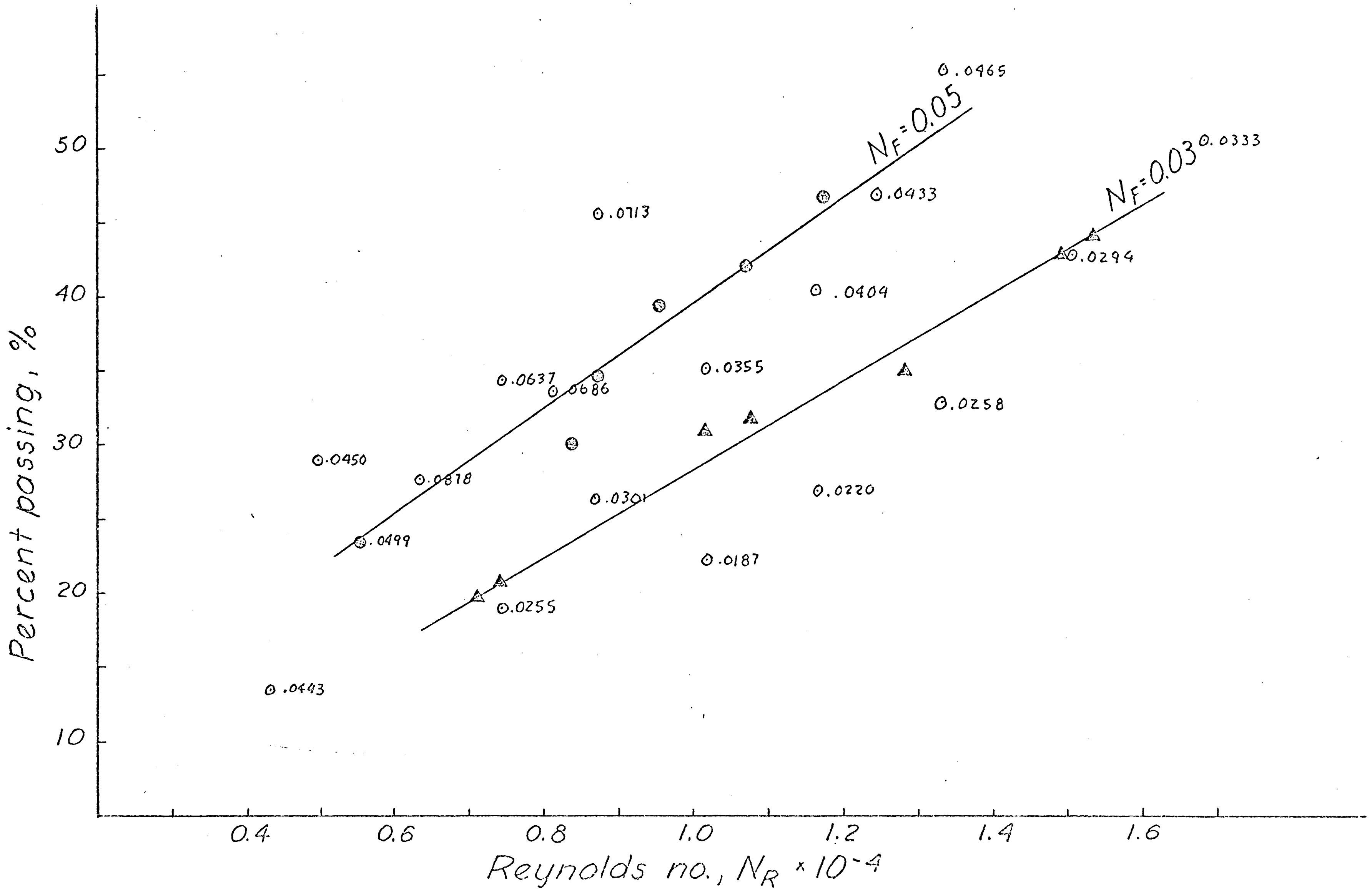


Figure 14: Percent passing vs. Reynolds no. at constant Froude no. for 0.1 mm. particle size

VI. CONCLUSIONS

This investigation led to the following conclusions:

1. A modification of the apparatus to lengthen the approach channel and reduce rippling would produce better results in the higher velocity ranges.

2. Additional data is required in order to formulate a relationship between the parameters affecting grit capture.

3. Trough 2 was relatively more efficient for the selective capture of the grit particles used.

VIII. SUMMARY

The object of this investigation was to determine the efficiency of three selected shapes of grit chamber troughs for the selective capture of grit.

A model grit chamber was constructed of wood with three plastic, interchangeable trough sections. Water from a town main was run through the apparatus at various depths and velocities, with sand of specific particle sizes being added to the flow as it entered the model. Ordinary construction sand was used after being run through a series of sieves to obtain the desired particle sizes. The three troughs were of the same general shape but with three different bottom lengths.

After all the grit had been added to the flow the process was halted, and all the grit which did not pass the trough was removed and measured. This measurement when compared with the known amount of grit which was added gave a percentage capture of grit for each run.

The study showed that Trough 2, the medium length trough, was the most effective for the selective capture of grit.

An attempt was made to formulate an equation relating the variables affecting grit removal, but the data proved to be contradictory.

VIII. ACKNOWLEDGEMENTS

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ABSTRACT

Efficiency of Selected Shapes of Grit Chamber Troughs

Grit is usually removed from sewage flow just prior to treatment by some type of grit chamber, often little more than a wide channel with a depressed trough to trap the grit. Three shapes of grit chamber troughs were studied in a model to determine which was the most efficient for the selective capture of grit. The model was constructed of wood, with plastic, interchangeable troughs, and was six inches wide by about ten feet long, including a three foot approach channel to the chamber. The three troughs were six inches deep with 2:1 side slopes and differed, therefore, only in bottom length. Trough 1 tapered to a point, Trough 2 had a four inch bottom length, and Trough 3 had an eight inch bottom length.

Water from a town main was run through the apparatus at velocities varying from 0.4 to 0.8 fps and depths from 0.1 to 0.33 feet. Grit was added, as the flow entered the approach channel, through a funnel. Ordinary construction sand was used as grit after being sieved to obtain 0.1 and 0.2 mm diameter particles. When all the grit had been added the flow was stopped and all grit which had not passed the trough was removed and measured. This measurement when compared with the known amount of grit which was added produced a value of per cent grit passing

the trough for each run.

Trough 2, the medium length trough, was found to be relatively most efficient for the selective capture of grit.