UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

TESTS OF CREST-STAGE INTAKE SYSTEMS

By
John Friday

OPEN-FILE REPORT

JULY 1965

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TESTS OF CREST-STAGE GAGE INTAKE SYSTEMS

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By John Friday

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ABSTRACT

Many investigations have contributed to the development of an inexpensive gage that will accurately record a peak stage occurring on a stream. The accuracy of a crest-stage gage depends upon the amount of drawdown or pileup that occurs within the gage pipe when the intake system is subjected to stream velocities.

The Geological Survey tested a new concept of an intake system consisting of a series of intake holes spaced uniformly along the gage pipe. Two gages with different hole arrangements were tested with various combinations of intake holes open. Neither drawdown nor pileup was excessive for some of the combinations tested. Erratic results were obtained when the water surface was at or near an open set of intake holes.

Tests were also made on the familiar Columbus intake and on an intake used by the California district. These intakes, positioned at the lower end of a plain pipe, were found to be more accurate than the pipe-intake systems described. Although considerable variation in drawdown existed between several Columbus intakes, in most instances the drawdown became less when velocities approached 12 feet per second. This is believed to be the result of aeration of the water at the back of the gage at the higher velocities.

This investigation indicated that, of the intake systems tested, the Columbus-type intake provides the most accurate gage for determining peak stages of a stream where velocities of up to 12 feet per second may occur.

INTRODUCTION

Development of Crest-Stage Gage Intake Systems

Practically every problem in open-channel hydraulics involves the evaluation of water-surface elevations that result from a specific streamflow event. For floodflows, instantaneous peak stages must be known before analytical interpretations of the event can be made and related to a given problem. The Geological Survey has made extensive studies of the design and operation of an inexpensive crest-stage gage that will accurately record a peak stage occurring on a stream without requiring the use of costly water-stage recorders.

A crest-stage gage commonly used by the Geological Survey consists of a 2-inch-diameter vertical pipe equipped with a bottom intake that allows water to enter and leave the gage, and a venthole near the top of the pipe that maintains atmospheric pressure within the gage. A rod inside the gage rests on a datum pin of known elevation. When cork particles are placed in the gage, a rising stage will float the cork until a peak stage occurs. A falling stage will leave a line of cork particles on the rod, thereby marking the peak stage.

The major problem involved in the development of this gage has been the design of an intake that will provide a good agreement between the water surface of the stream and that recorded in the gage pipe. Previous tests on various intake systems indicate that a drawdown or pileup of water occurs inside the gage pipe, depending on the design of the intake, the direction of flow, and the water velocity at the gage. None of the intakes tested has proved to be completely satisfactory for all conditions of flow, but an intake referred to as a Columbus intake has been tested in velocities up to 8 feet per second and is considered adequate for most of the flow conditions normally experienced in the field (Carter and Gamble, 1963).

Purpose and Scope

The purpose of this investigation was (a) to define the drawdown or pileup characteristics of two gage pipes in which a system of intake holes were drilled, and (b) to increase the range of test velocities for the Columbus intake to 12 feet per second. The pipe intake systems were tested with various combinations of intake holes open and closed. The testing of any combination was discontinued if the results became worse than those found by Carter and Gamble in their testing of the standard Columbus intake. An intake used by the California District was also tested. For simplicity, the Columbus and California intakes are referred to as bottom intakes in this report.

Acknowledgments

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The author was assisted in the laboratory investigation by H. A. Ray, hydraulic engineer, (SW), Menlo Park, Calif.; G. L. Ducret, hydraulic engineer, (SW), Portland, Oreg.; L. B. Thompson, engineering aid, (SW), Portland, Oreg.; and personnel of the Corps of Engineers, Bonneville, Oreg.

This report was prepared under the general supervision of R. B. Sanderson, district engineer in charge of surface-water investigations in Oregon.

INSTRUMENTATION

This investigation was conducted in a current-meter calibrating flume at the Corps of Engineers Division Hydraulic Laboratory at Bonneville, Oreg. The flume is a concrete basin 230 feet long, 5 feet wide, and has a water depth of about 5.7 feet. An electrically powered carriage travels on rails set on each side of the basin and is designed to move at constant velocities of up to 18 feet per second. (See fig. 1.) The velocity of the carriage is determined by the time taken to travel a known distance after a constant velocity has been reached. The travel time is registered on an electrically controlled stopwatch read to a hundredth of a second, and the distance is determined by measuring between two darts that are electrically expelled near a graduated steel tape when the carriage stopwatch is started and stopped. The steel tape is attached near a rail for the carriage and extends the length of the flume.

The gage pipes were attached to a cross member near the center of the carriage and the drawdown or pileup was measured by one or more of the following methods:

1. Stick method. A stick is placed in the gage before the test run, cork is added to the gage after a constant velocity is reached, and the stick is removed before the velocity is interrupted. The distance between the cork line on the stick and the flume water surface is a measure of the drawdown or pileup that occurred during the constant-velocity period.

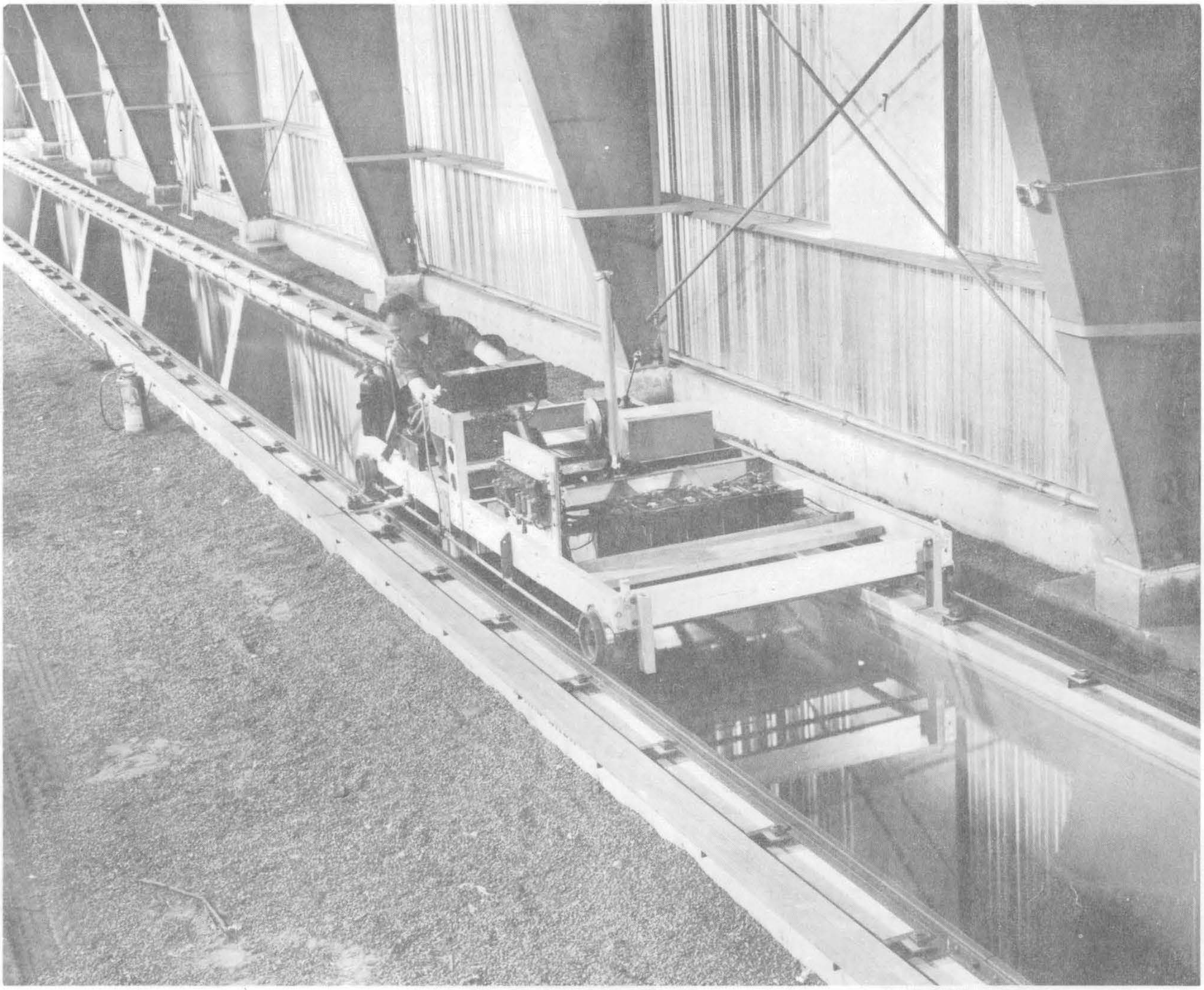


Figure 1. Photograph of carriage and testing flume.

2. Probe method. Cork is added to the gage prior to the test run. A probe is lowered and then withdrawn from the water surface during the constant-velocity period. A cork line is read directly on a steel tape attached to the probe. The probe consists of a 3/8-inch-diameter steel rod equipped with a sliding collar that fits into the top of the gage pipe. The collar centers the probe in the pipe and provides a positive datum stop when the probe is lowered beneath the water surface.

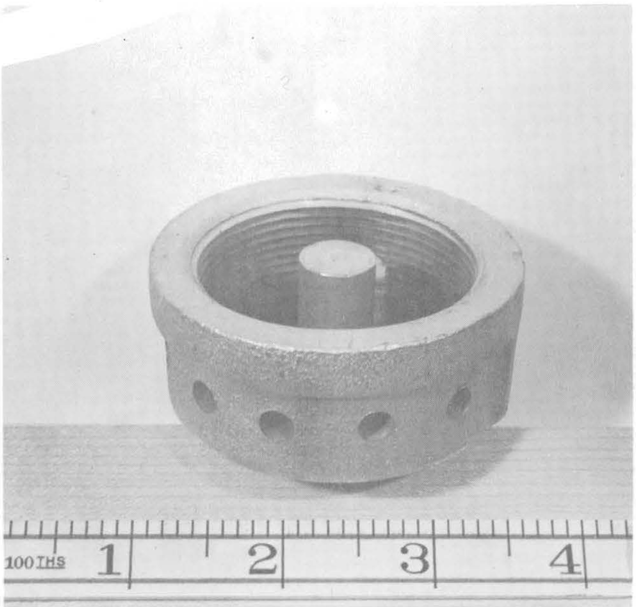
3. Float method. A plastic float, supporting a length of ¼-inch-diameter wood dowel, is inserted in a gage pipe. A graduated steel tape at the upper end of the dowel projects above the top of the pipe and is read by means of an indicator attached to the pipe. Continuous water-surface movement is read directly from the tape.

All these methods provided a reliable means of measuring the draw-down and pileup measured in these tests. Agreement between the methods was usually excellent.

TESTING PROCEDURE

The testing sequence of this investigation began with the pipe intake systems, when 17 combinations of open and closed intakes were tested in velocities of from 2 to 8 feet per second. Columbus bottom intakes (fig. 2) were attached to pipes A and B (fig. 3) and positioned 4.5 feet below the water surface. The probe method was used for most of the tests made on these intakes. This method made it possible to get two independent readings during the slower velocity runs. An aluminum rod was placed in the gage rather than the wooden stick normally in that position under field conditions. Some combinations of open and closed intakes were designed to simulate field conditions when ice or silt obstruct the bottom intake. Pipe A was also tested with the water surface at and near an intake on the pipe.

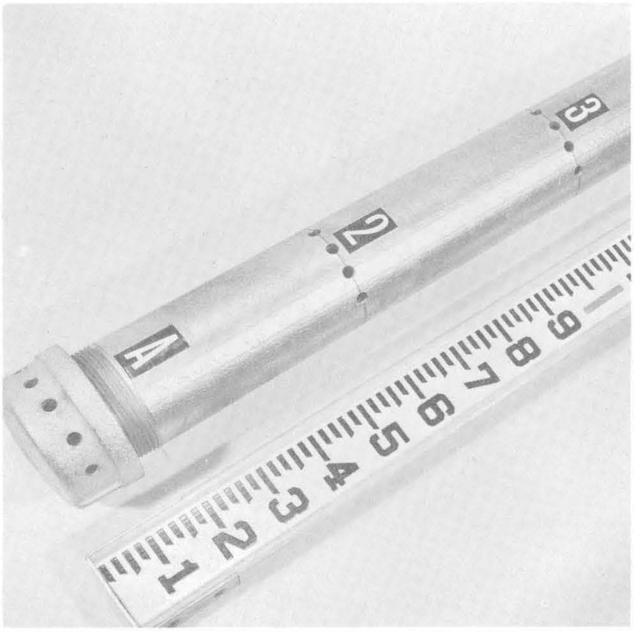
The Columbus bottom intakes were tested in velocities of from 2 to 12 feet per second with the intakes mounted on a plain pipe and positioned 2.0 feet below the water surface. All three methods of measuring drawdown or pileup were used for these tests. The California bottom intake (fig. 2) was also mounted on a plain pipe and positioned 2.0 feet below the water surface. This intake was tested in erect and inverted positions in velocities of from 2 to 10 feet per second.



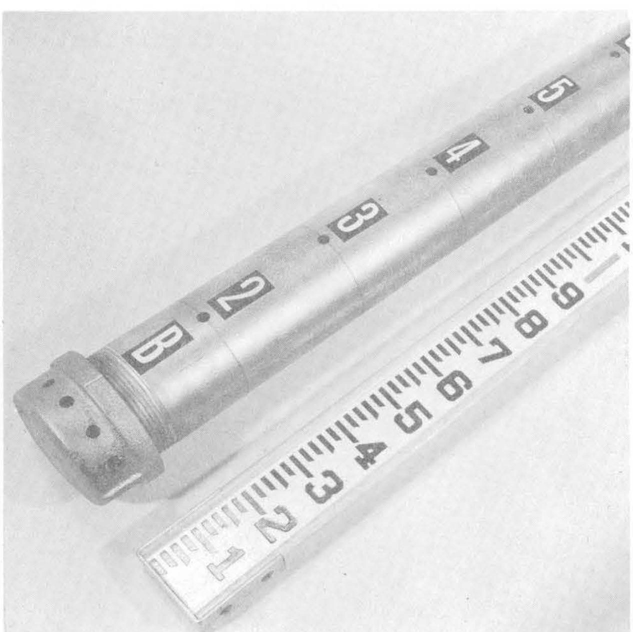
A Columbus intake consists of a standard 2-inch galvanized iron pipe cap equipped with a 3/4-inch datum pin welded to the center of the cap and cut off flush with the top of the cap. The intake holes consist of (a), five $\frac{1}{4}$-inch holes drilled in the face of the cap and spaced 30° apart with respect to the longitudinal axis of the gage pipe and (b), one $\frac{1}{4}$-inch hole drilled in the back of the cap.

A California intake consists of a 2-inch galvanized cast-iron coupling equipped with a 2-inch square-head pipe plug. A 3/8-inch diameter datum pin is below the intake holes when the intake is in an erect position. This intake can be inverted by reversing the position of the plug and rotating the unit 180°. The intake holes are identical to those described for the Columbus intake.

Figure 2. Photograph and description of Columbus and California bottom intakes.



Pipe A consists of a standard 2-inch galvanized iron pipe equipped with a Columbus-type bottom intake. The gage pipe has a system of intake holes spaced 0.5 ft apart which are identical to those described for the Columbus intake. The intake systems are numbered from one to nine beginning with the bottom intake.



Pipe B consists of a standard 2-inch galvanized iron pipe equipped with a Columbus-type bottom intake. The gage pipe has a system of single $\frac{1}{4}$-inch diameter intake holes spaced 0.25 ft apart drilled in the face and in the back of the pipe. The intake systems are numbered from one to seventeen, beginning with the bottom intake.

Figure 3. Photograph and description of pipe intake systems A and B.

The float method was used for some of the tests made on Columbus and pipe B intake systems. A record of spot observations was made while the carriage was moving at constant velocity. This was accomplished by relaying, by radio, tape-gage readings made at 2-second intervals. These readings are the basis for the continuous curves shown in figure 4.

A series number was assigned to the test runs made for each intake or intake system. Table 1 is a summary of all test runs made in this investigation, but does not necessarily indicate the order of the actual testing.

Prior to each series, a reference point (or base reading) was established when the water surface within the gage was referred to either the datum pin or the top of the gage, depending upon which method for measuring drawdown or pileup was to be used. All measurements of water-surface movement were determined from this reference point.

All test runs were made in same direction down the flume. Because of the water turbulence following the faster velocity runs, considerable time was spent waiting for this turbulence to subside. Surging action was less than 0.05 foot prior to each test run.

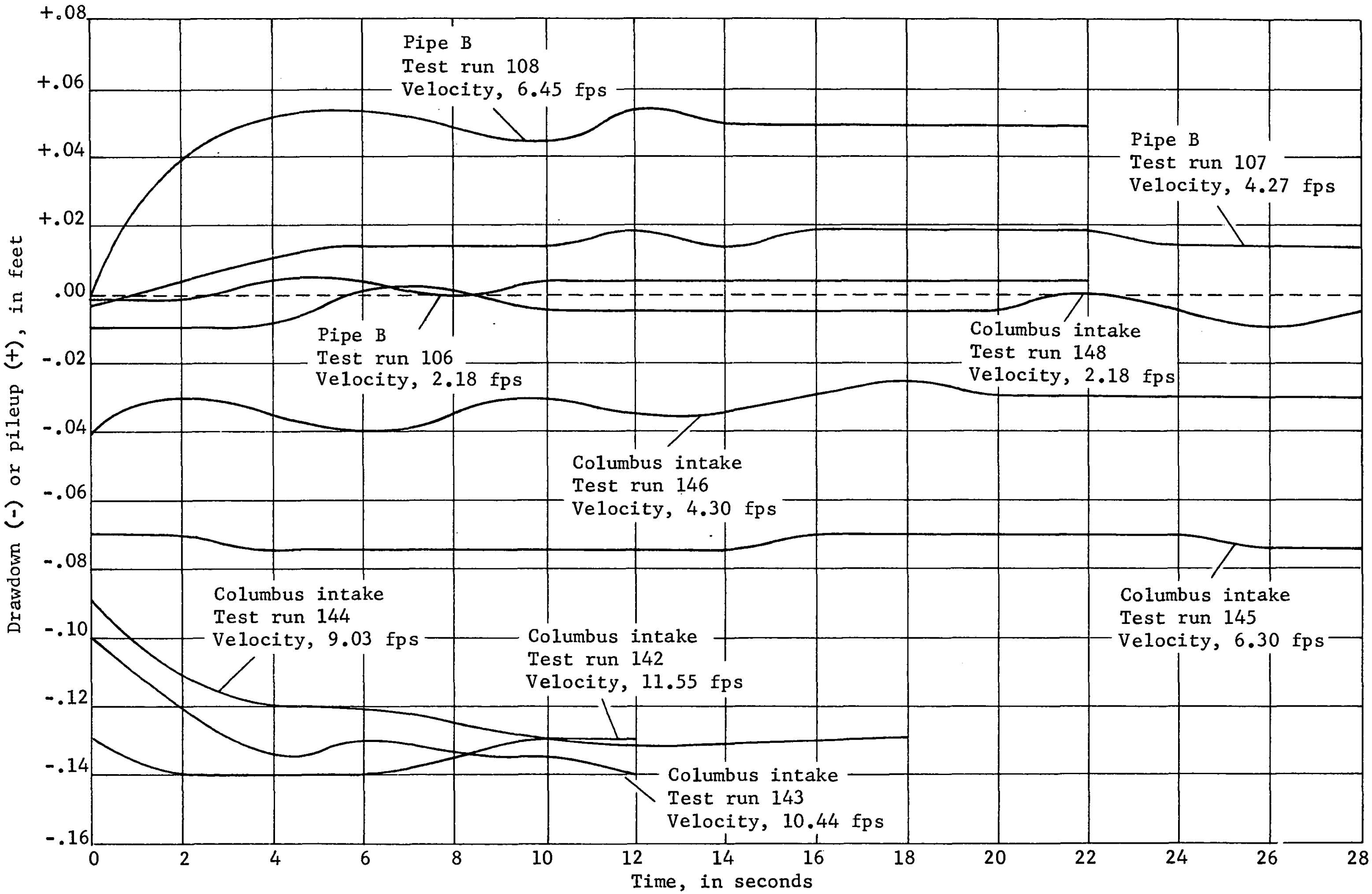


Figure 4. Continuous record of drawdown and pileup occurring during various test runs.

TEST RESULTS

Figures 5 to 9 show the results obtained for the intake systems tested in this investigation. Pictures of pipes A and B are included for easier reference to the relative location of open and closed intakes.

Pipe A

Pipe A was tested in a series in which the lower combinations of intakes were opened first. The test results shown in figure 5 indicated similar drawdown trends until the fourth series, when intake 5 was opened. In that series, four test runs were made at a velocity of about 6.5 feet per second, and the results ranged from 0.04 foot drawdown to 0.01 foot pileup. All subsequent tests of this gage gave the same unstable results at 6.5 feet per second. This instability is shown as a shaded area in figure 6. It should be noted that in all these series at least one test run was made at a velocity of about 8 feet per second and resulted in the maximum drawdown for each series.

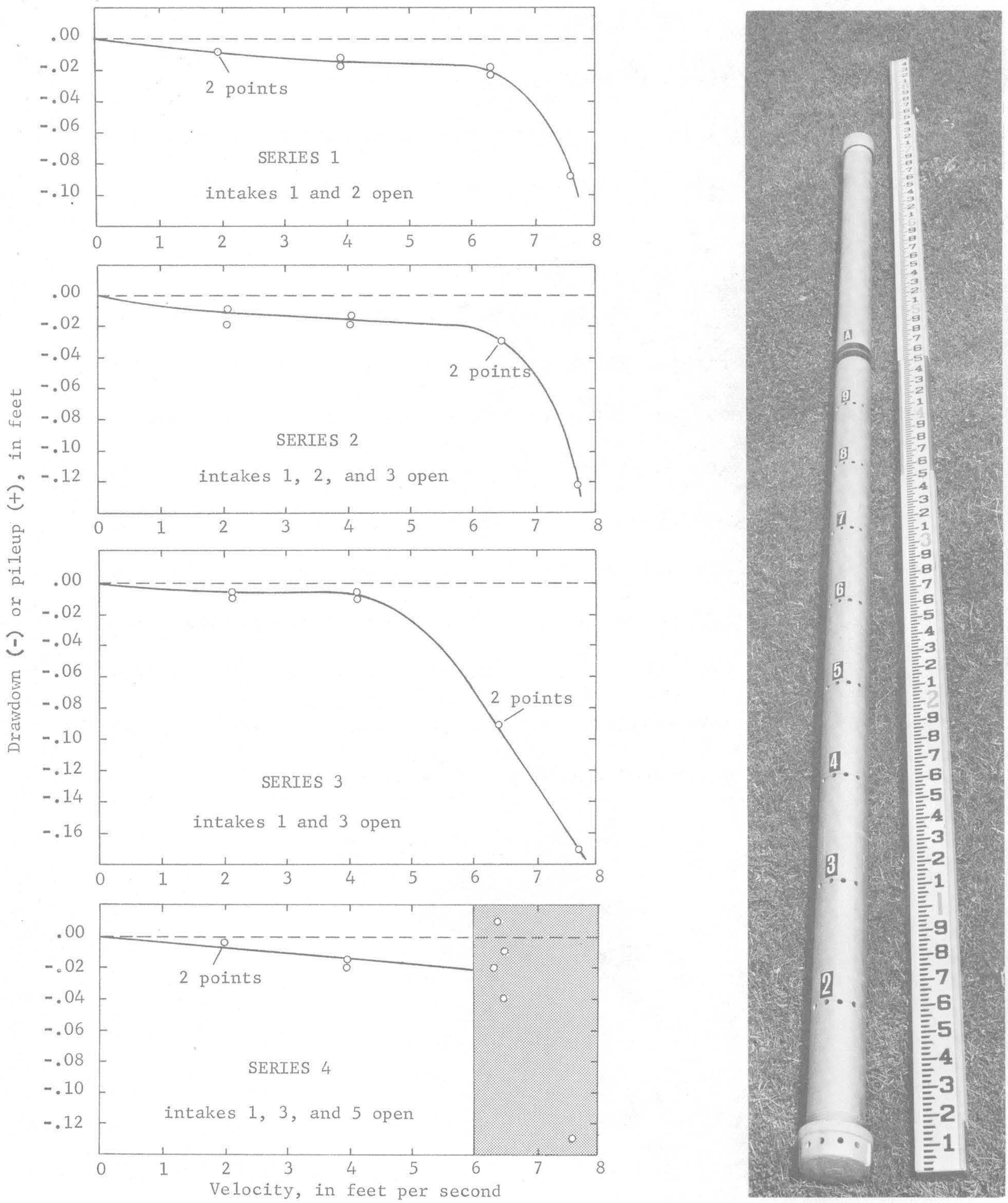


Figure 5. Photograph of pipe A and graphs showing results of tests made when various combinations of intakes were open.

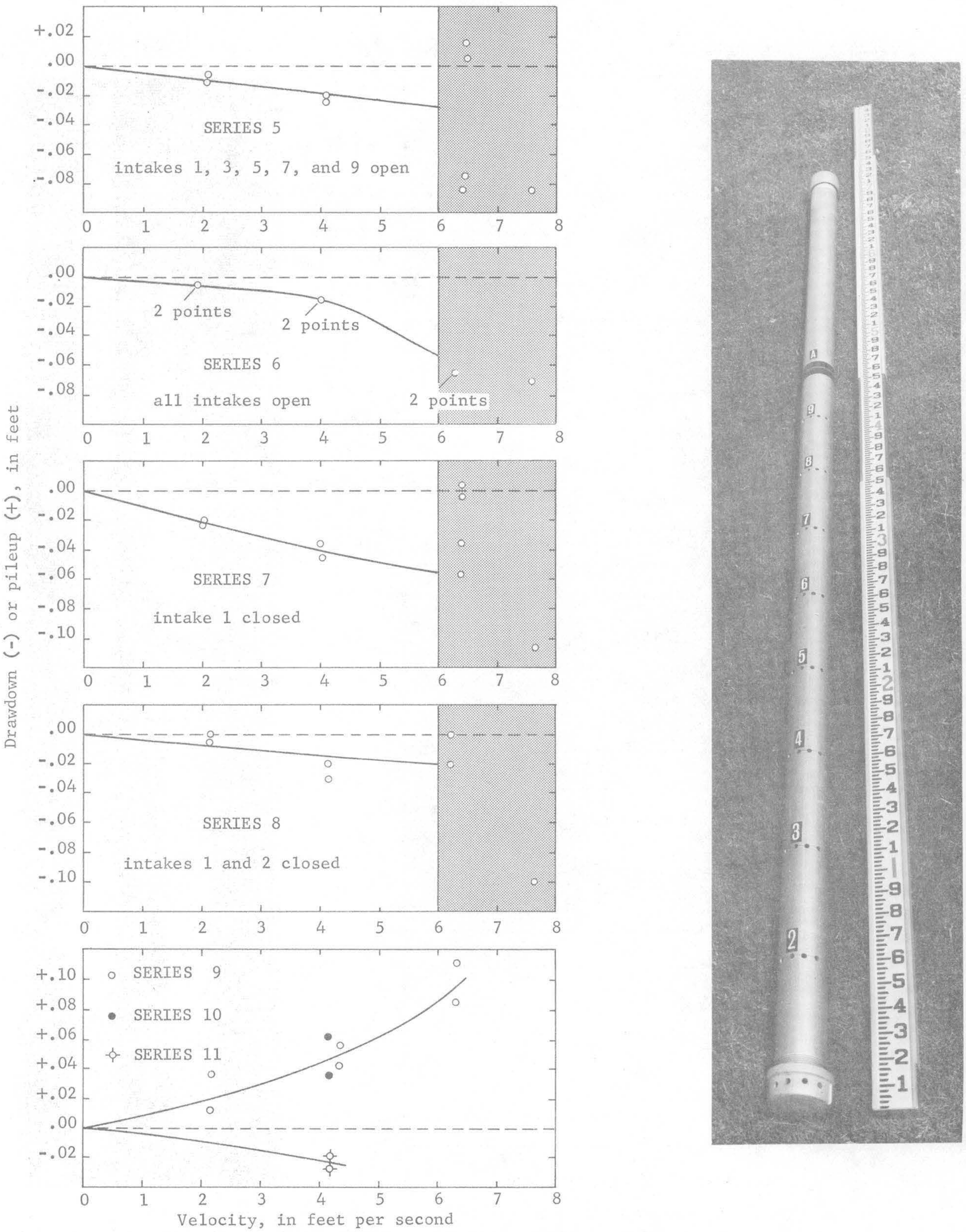
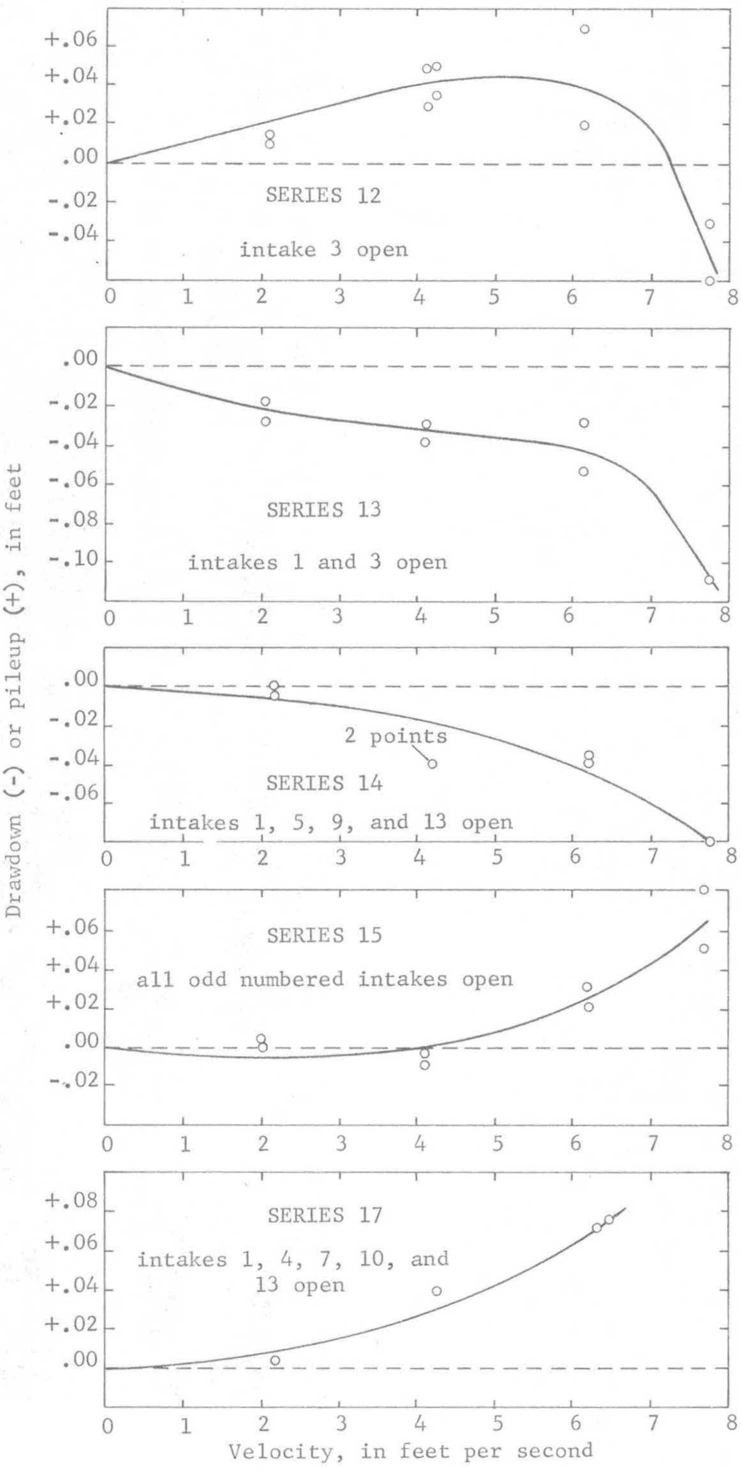


Figure 6. Photograph of pipe A and graphs showing results of tests made when various combinations of intakes were open



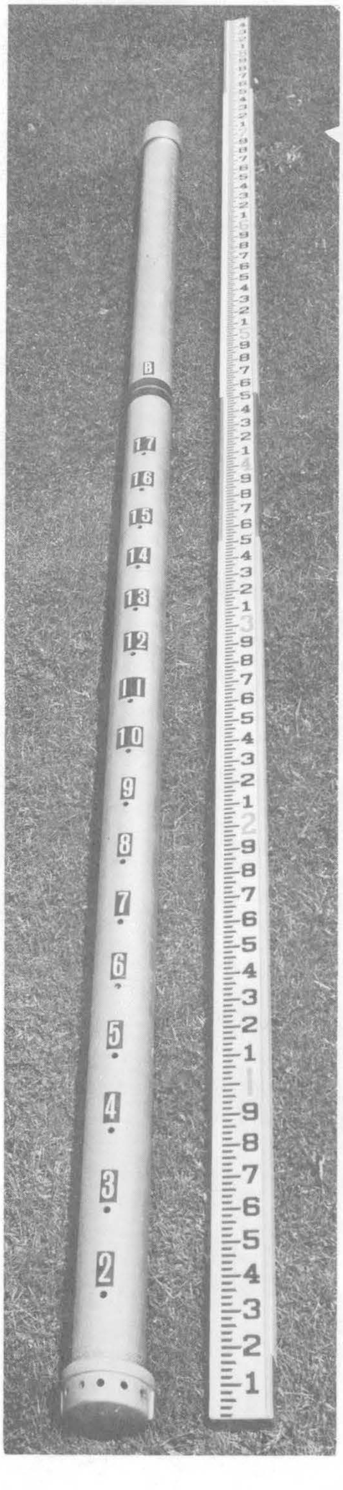


Figure 7. Photograph of pipe B and graphs showing results of tests made when various combinations of intakes were open.

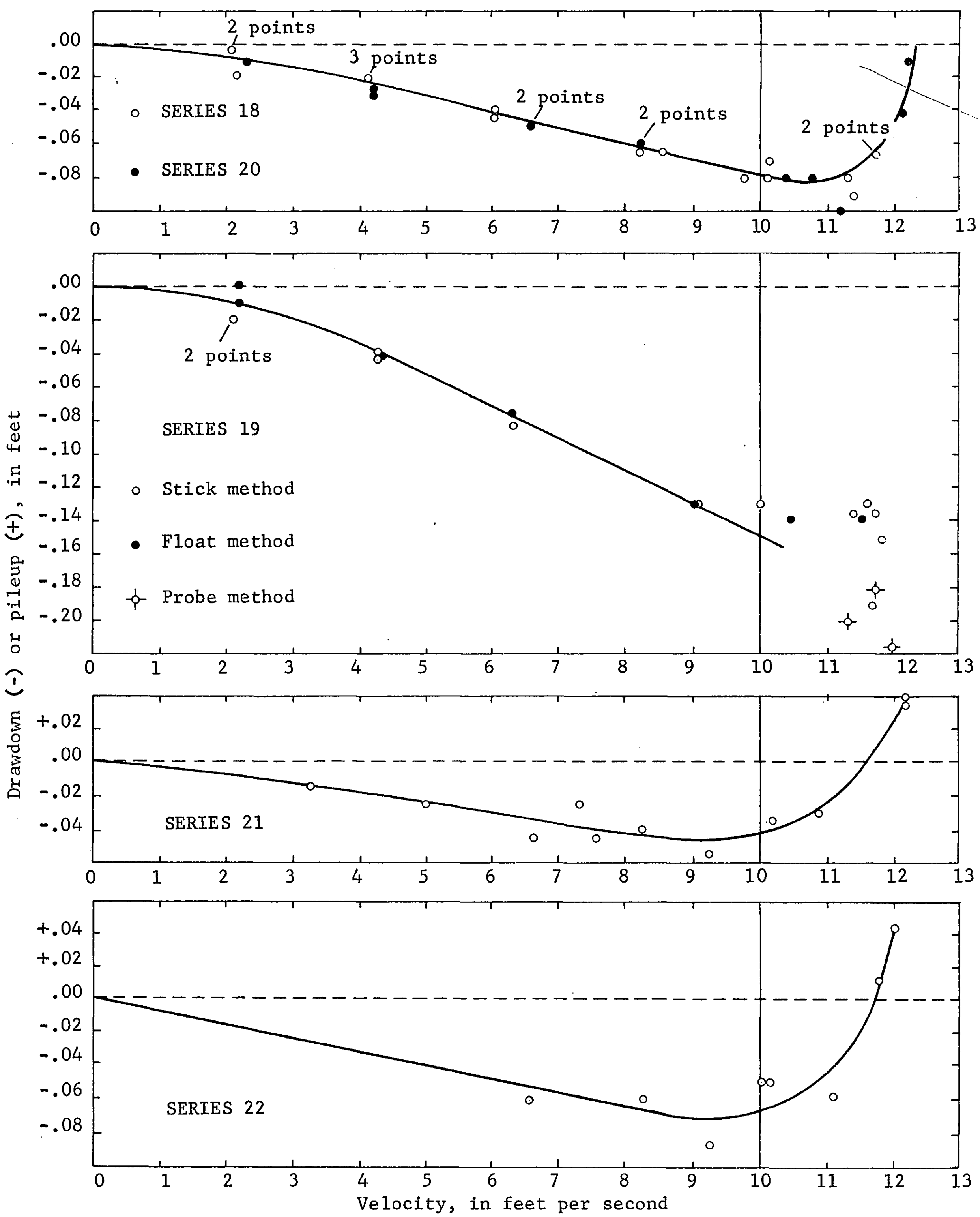


Figure 8. Test results of Columbus bottom intakes.

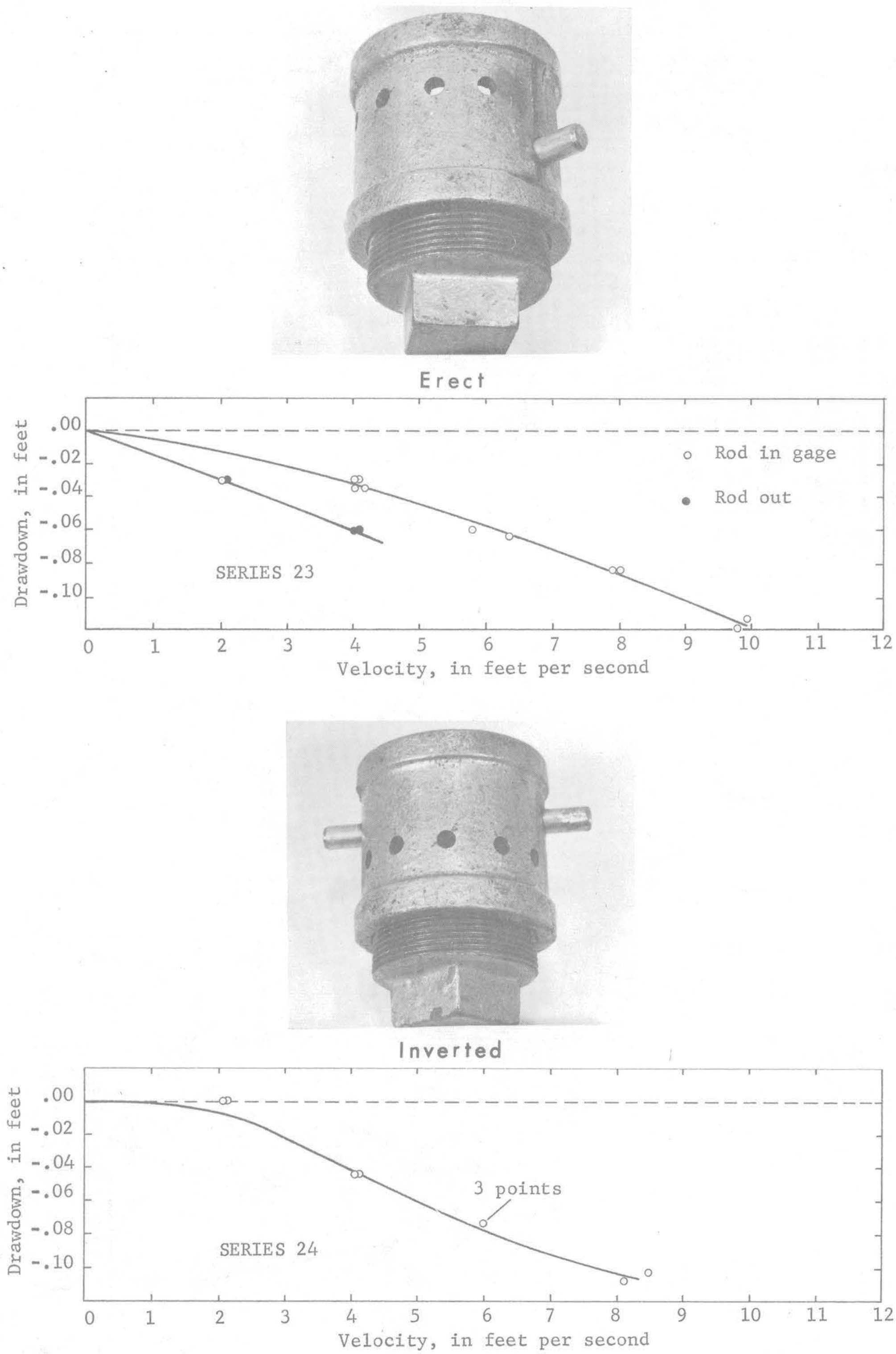


Figure 9. Photograph of the California bottom intake in erect and inverted positions and graphs showing test results.

During the faster velocities, the back hole of the intake nearest the water surface (intake 9) was observed to be clear of the water because of the drawdown of the water surface behind the gage pipe. Also, considerable aeration was observed in the wake of the pipe after test runs. (See fig. 10.) Pipe A was then tested with all intakes open and with intake 4 positioned first at the water surface and then 0.25 foot below the water surface (series 9 and 10). Diagonal cork lines on the measuring stick indicated pileup trends were occurring instead of drawdown trends, as measured when the water surface was 0.5 foot above intake 9. Pileup on the face of the pipe may also have affected the results of these tests, because when intake 4 was positioned 0.25 foot below the water surface, intake 5 was closed for one run (series 11), and drawdown was again measured.

Pipe B

Pipe B was tested in a similar manner (series 12 to 17), and again unstable conditions were observed. This intake system resulted in excessive drawdown and pileup trends. (See fig. 7.) In series 17, three continuous curves were developed, as shown in figure 4. It was on the basis of the curves shown in this figure that measurements of drawdown or pileup were delayed until 12 seconds after the carriage had reached a constant velocity.

Figure 10. Photograph of water turbulence following a test run made at a velocity of 12 feet per second.

Columbus Intake

The test results of the Columbus bottom intakes, mounted on a plain pipe, are shown in figure 8. Two intakes were tested in an early phase of this investigation (series 18 and 19), and considerably more drawdown was measured than had been found in the Carter-Gamble investigation. Consequently, three more test series were run at a later date in an attempt to resolve these differences (series 20 to 22). Because the intakes used in the first tests were not marked for identification, there was no assurance that either of them was again tested in the second phase. The intake used in series 20 could be the same one that was used in series 18, as test results are closely duplicated, but test results of other series indicate there is a difference in the results obtained from presumably identical bottom intakes.

An equally interesting development of the Columbus intake tests was that, although measurements made at velocities of 10 to 12 feet per second indicated erratic fluctuations, they defined a complete reversal of drawdown trends.

California Intake

The test results of the California bottom intake are shown in figure 9. The photographs in this figure show this intake in the erect and inverted positions. The least drawdown occurred when the intake was in an erect position with a rod inside the gage pipe.

CONCLUSIONS

This investigation indicated that a system of intakes positioned on gage pipes such as pipes A and B does not give consistent water-surface readings for all conditions of flow. Although drawdown and pileup were not excessive for some of the intake combinations tested, it was evident that the possibility of either was completely dependent upon the relative location of the water surface and the nearest open intake. However, pipe A would have merit where silt or ice may obstruct the lower intake and velocities are relatively low.

Tests made on the standard Columbus bottom intakes mounted on plain pipe indicated varying amounts of drawdown. These intakes are identical in appearance and were installed on the gage pipes in exactly the same manner. The Columbus intake tested in series 21 gave the best results, a maximum drawdown of 0.055 foot. Conversely, the intake tested in series 19 had 0.215 foot drawdown. Carter and Gamble reported 0.04 foot drawdown as the best results of their investigation.

The California intake, having identical hole arrangements, may have duplicated the results of the Columbus intake if it had been given a more complete testing. The results of this investigation indicate that either the Columbus or California bottom intake, mounted on a plain pipe, is more reliable than the pipe intake systems tested in this investigation.

The unstable conditions observed in this investigation are believed to have resulted from changes in the pressure regime at the intakes due to direct exposure of back-pressure holes resulting from the drawdown of the water surface behind the gage pipe (pipes A and B), or from aeration of the water at high velocities (Columbus intake). When a crest-stage gage is subjected to water velocities, a positive pressure area forms on the upstream face of the pipe at a frontal angle of 60° from the axis of the pipe (Barron, 1952). The remaining area has a negative pressure, and if aeration occurs at the trailing edge of the pipe, the negative pressure tends to become neutralized. This results in a reversal of a drawdown trend or even in a net pileup, as shown in figure 8. In addition to this and the Carter and Gamble investigation, several other reports have been written on the testing of intake systems with radially drilled holes (Barron, 1950, 1951, 1952, and Bodhaine, 1951). A reversal of drawdown trends occurred in all but two of these investigations. If aeration is the cause of these reversals, it would seem to be directly related not only to velocity but also to the length of wetted pipe and possibly to water temperatures. Perhaps the stability of the water in the flume also affects the extent of aeration. More drawdown was consistently measured for a given velocity when the water in the flume was in a calm state prior to the test run.

Aeration would therefore be a variable phenomenon, depending on various hydrostatic conditions, and it may cause the scatter of data in the reversal zones. Investigations made to evaluate total drag on bodies immersed in a moving liquid show that, for a two-dimensional cylinder, a drastic change in the behavior of the water can be expected when the Reynolds number ($\mathbb{R}$) is near 2×10^5 (Rouse, 1946, p. 247). In this reference, a resistance diagram showing a coefficient of drag, expressed as a function of $\mathbb{R}$, portrays the change in drag which occurs when $\mathbb{R}$ is in the 10^5 log cycle. $\mathbb{R}$, computed from the equation

$$R = \frac{V\,D}{\gamma}$$

in which

V = velocity of the water

D = diameter of the cylinder

γ = kinematic viscosity of the water (1×10^{-5} at 74°F)

has a value of 2.4×10^5 for a 0.2-foot-diameter cylinder subjected to a water velocity of 12 feet per second. A change in γ due to the temperature variation observed during this investigation (49° to 74° F) causes a corresponding change in $\mathbb{R}$ to 1.7×10^5 at this same velocity. In this critical Reynolds number region, the change in drag probably also causes a change in pressure and wake patterns and therefore might explain the scatter of data at the higher velocities.

The cause and effect of aeration is highly problematical, but the resultant lessening of drawdown characteristics gives some credence to the adaptability of the Columbus-type intakes in situations where swift stream velocities may occur.

REFERENCES CITED

Carter, J. R., and Gamble C. R., 1963, Tests of crest-stage gage intakes: U.S. Geol. Survey open-file report.

Rouse, Hunter, 1946, Elementary mechanics of fluids: New York, John Wiley & Sons, p. 247.

Table 1. Summary of test data for intake systems

The rod referred to under Remarks pertains to an aluminum rod placed in the gage to simulate the presence of a stick normally in that position under field conditions.

Test run	Velocity (fps)	Δ Water surface (ft)	Remarks
SERIES 1			
Pipe A. Intake No. 1 positioned 4.5-ft below the water surface. Intake Nos. 1 and 2 are open. Water temperature, 49°F.			
1	1.95	-0.010	Probe method, rod in gage during runs 1 to 7
2	1.98	-.010	
3	3.95	-.015	
4	3.95	-.020	
5	6.39	-.020	
6	6.39	-.025	
7	7.68	-.090	
SERIES 2			
Pipe A. Tested the same as in series 1, except intake Nos. 1, 2, and 3 are open.			
8	2.17	-0.020	Probe method, rod in gage during runs 8 to 14
9	2.17	-.010	
10	4.12	-.020	
11	4.12	-.015	
12	6.45	-.030	
13	6.45	-.030	
14	7.72	-.125	
SERIES 3			
Pipe A. Tested the same as in series 1, except intake Nos. 1 and 3 are open.			
15	2.16	-0.010	Probe method, rod in gage during runs 15 to 21
16	2.16	-.005	
17	4.18	-.010	
18	4.18	-.005	
19	6.44	-.090	
20	6.44	-.090	
21	7.72	-.170	
SERIES 4			
Pipe A. Tested the same as in series 1, except intake Nos. 1, 3, and 5 are open.			
22	2.05	-0.005	Probe method, rod in gage during runs 22 to 30
23	2.05	-.005	
24	4.06	-.020	
25	4.06	-.015	
26	6.56	-.010	
27	6.56	-.040	
28	6.40	-.020	
29	6.40	+.010	
30	7.67	-.130	
SERIES 5			
Pipe A. Tested the same as in series 1, except intake Nos. 1, 3, 5, 7, and 9 are open.			
31	2.12	-0.005	Probe method, rod in gage during runs 31 to 39
32	2.12	-.010	
33	4.16	-.025	
34	4.16	-.020	
35	6.49	-.085	
36	6.49	+.015	
37	6.50	-.075	
38	6.50	+.005	
39	7.63	-.085	
SERIES 6			
Pipe A. Tested the same as in series 1, except all intakes are open.			
40	1.92	-0.005	Probe method, rod in gage during runs 40 to 46
41	1.92	-.005	
42	4.04	-.015	
43	4.04	-.015	
44	6.31	-.065	
45	6.31	-.065	
46	7.61	-.070	
SERIES 7			
Pipe A. Tested the same as in series 1, except all intakes are open except No. 1.			
47	2.03	-0.025	Probe method, rod in gage during runs 47 to 55
48	2.03	-.020	
49	4.09	-.045	
50	4.09	-.035	
51	6.40	-.005	
52	6.40	+.005	
53	6.44	-.035	
54	6.44	-.055	
55	7.70	-.105	
SERIES 8			
Pipe A. Tested the same as in series 1, except all intakes are open except Nos. 1 and 2.			
56	2.16	0.000	Probe method, rod in gage during runs 56 to 62
57	2.16	-.005	
58	4.18	-.030	
59	4.18	-.020	
60	6.27	-.020	
61	6.27	.000	
62	7.66	-.100	
SERIES 9			
Pipe A. Intake No. 4 positioned at the water surface. All intakes are open. Double readings indicate limits of a diagonal cork line on stick.			
63	2.19	+0.035	Stick method, diagonal line
		+.010	
64	4.34	+.055	
		+.040	
65	6.31	+.110	
		+.085	
SERIES 10			
Pipe A. Intake No. 4 positioned 0.25-ft below water surface. All intakes open.			
66	4.17	+0.060	Stick method, diagonal line
		+.035	
SERIES 11			
Pipe A. Tested the same as in series 10, except intake No. 5 was closed			
67	4.19	-0.030	Stick method, diagonal line
		-.020	

Table 1. Summary of test data for intake systems--Continued

SERIES 12

Pipe B. Intake No. 1 positioned 4.5-ft below water surface. Intake No. 3 open, all others closed. Water temperature, 49°F.

Test run	Velocity (fps)	Δ Water surface (ft)	Remarks
68	2.11	+0.010	Probe method, rod in gage
69	2.11	+.015	during runs 68 to 77
70	4.27	+0.35	
71	4.27	+.050	
72	4.16	+.030	
73	4.16	+.050	
74	6.17	+.020	
75	6.17	+.070	
76	7.78	-.030	
77	7.78	-.060	

SERIES 13

Pipe B. Tested the same as in series 12, except intake Nos. 1 and 3 are open.

Test run	Velocity (fps)	Δ Water surface (ft)	Remarks
78	2.08	-0.030	Probe method, rod in gage
79	2.08	-.020	during runs 78 to 84
80	4.14	-.040	
81	4.14	-.030	
82	6.18	-.055	
83	6.18	-.030	
84	7.77	-.110	

SERIES 14

Pipe B. Tested the same as in series 12, except intake Nos. 1, 5, 9, and 13 are open.

Test run	Velocity (fps)	Δ Water surface (ft)	Remarks
85	2.20	0.000	Probe method, rod in gage
86	2.20	-.005	during runs 85 to 91
87	4.22	-.040	
88	4.22	-.040	
89	6.21	-.040	
90	6.21	-.035	
91	7.78	-.080	

SERIES 15

Pipe B. Tested the same as in series 12, except intake Nos. 1, 3, 5, 7, 9, 11, 13, 15, and 17 are open.

Test run	Velocity (fps)	Δ Water surface (ft)	Remarks
92	2.05	0.000	Probe method, rod in gage
93	2.05	+.005	during runs 92 to 99
94	4.15	-.010	
95	4.15	-.005	
96	6.23	+.020	
97	6.23	+.030	
98	7.72	+.080	
99	7.72	+.050	

SERIES 16

Pipe B. Tested the same as in series 12, except all intakes are open.

Test run	Velocity (fps)	Δ Water surface (ft)	Remarks
100	2.09	0.000	Probe method, rod in gage
101	2.09	+.020	during runs 100 to 105
102	4.15	+.030	
103	4.15	+.035	
104	6.16	+.225	
105	6.16	+.225	

SERIES 17

Pipe B. Tested the same as in series 12, except intake Nos. 1, 4, 7, 10, and 13 are open.

Test run	Velocity (fps)	Δ Water surface (ft)	Remarks
106	2.18	* +0.005	Float method, rod in gage
107	4.27	* +.020	Float method, rod in gage
108	6.45	* +.055	Float method, rod in gage
109	6.30	+.050	Probe method, rod in gage

SERIES 18

Columbus-type intake I mounted on a plain pipe and positioned 2.0-ft below the water surface . Water temperature, 49°F.

Test run	Velocity (fps)	Δ Water surface (ft)	Remarks
110	2.13	-0.020	Probe method, no rod in gage
111	2.04	-.005	during runs 110 to 126
112	2.05	-.005	
113	4.16	-.020	
114	4.16	-.020	
115	4.13	-.020	
116	6.02	-.040	
117	6.02	-.045	
118	8.22	-.065	
119	8.57	-.065	
120	10.12	-.080	
121	10.15	-.070	
122	9.79	-.080	
123	11.28	-.080	
124	11.42	-.090	
125	11.74	-.065	
126	11.73	-.065	

SERIES 19

Columbus-type intake II mounted on a plain pipe and positioned 2.0-ft below the water surface. Water temperature, 49°F.

Test run	Velocity (fps)	Δ Water surface (ft)	Remarks
127	12.00	-0.215	Probe method, no rod in gage
128	11.31	-.200	Probe method, rod in gage
129	11.73	-.180	Probe method, rod in gage
130	11.48	-.135	Stick method used for
131	11.75	-.135	runs 130 to 141
132	11.74	-.190	
133	11.67	-.130	
134	9.98	-.130	
135	9.08	-.130	
136	11.89	-.150	
137	6.34	-.085	
138	4.33	-.045	
139	4.32	-.040	
140	2.20	-.020	
141	2.17	-.020	
142	11.55	* -.140	Float method, rod in gage
143	10.44	* -.140	during runs 142 to 148
144	9.03	* -.130	
145	6.30	* -.075	
146	4.30	* -.040	
147	2.18	.000	
148	2.18	* -.010	

SERIES 20

Columbus-type intake III mounted on a plain pipe and positioned 2.0-ft below the water surface. Water temperature, 74°F.

Test run	Velocity (fps)	Δ Water surface (ft)	Remarks
149	12.17	-0.040	Stick method used for
150	12.21	-.010	runs 149 to 160
151	11.22	-.100	
152	10.84	-.080	
153	10.40	-.080	
154	8.24	-.060	
155	8.22	-.060	
156	6.58	-.050	
157	6.58	-.050	
158	4.20	-.030	
159	4.23	-.025	
160	2.30	-.010	

* Continuous curve developed.

Table 1. Summary of test data for intake systems--Continued

SERIES 21

Columbus-type intake IV mounted on a plain pipe and positioned 2.0-ft below the water surface. Water temperature, 74°F.

Test run	Velocity (fps)	Δ Water surface (ft)	Remarks
161	12.20	+0.040	Stick method used for runs 161 to 171
162	12.22	+.035	
163	10.26	-.035	
164	10.96	-.030	
165	9.32	-.055	
166	8.30	-.040	
167	7.58	-.045	
168	7.35	-.025	
169	6.65	-.045	
170	5.04	-.025	
171	3.29	-.015	

SERIES 22

Columbus-type intake V mounted on a plain pipe and positioned 2.0-ft below the water surface. Water temperature, 73°F.

Test run	Velocity (fps)	Δ Water surface (ft)	Remarks
172	11.99	+0.045	Stick method used for runs 172 to 179
173	11.77	+.015	
174	11.14	-.055	
175	10.02	-.050	
176	10.19	-.050	
177	9.26	-.085	
178	8.22	-.060	
179	6.57	-.060	

SERIES 23

California district intake, in an erect position, mounted on a plain pipe and positioned 2.0-ft below the water surface. Water temperature, 49°F.

Test run	Velocity (fps)	Δ Water surface (ft)	Remarks
180	2.09	-0.030	Probe method, no rod in gage during runs 180 to 182
181	4.13	-.060	
182	4.09	-.060	
183	2.09	-.030	Stick method used for runs 183 to 185
184	4.13	-.030	
185	4.09	-.030	
186	4.23	-.035	Probe method, rod in gage during runs 186 to 193
187	4.10	-.035	
188	5.87	-.060	
189	6.43	-.065	
190	8.10	-.085	
191	8.00	-.085	
192	9.82	-.120	
193	9.99	-.115	

SERIES 24

California district intake, in an inverted position, mounted on a plain pipe and positioned 2.0-ft below the water surface. Water temperature, 49°F.

Test run	Velocity (fps)	Δ Water surface (ft)	Remarks
194	2.15	0.000	Probe method, no rod in gage during runs 194 to 201
195	2.12	.000	
196	4.21	-.045	
197	4.16	-.045	
198	6.09	-.075	
199	6.08	-.075	
200	8.20	-.110	
201	8.55	-.105	
202	6.05	-.075	Probe method, rod in gage

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