UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

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Technical Memorandum No. 333

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HYDRAULIC LABORATORY REPORT HYD. 1.5

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EXPERIMENTS ON CALIBRATION OF OWYHEE TUNNEL NO. 1 VENTURI METER-FLUME

By

JACOB E. WARNOCK, ASSOCIATE ENGINEER

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Fort Collins, Colorado
April 15, 1933

HYD 1.5

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DEPARTMENT OF THE INTERIOR

BUREAU OF RECLAMATION

MEMORANDUM TO CHIEF DESIGNING ENGINEER

SUBJECT: EXPERIMENTS ON CALIBRATION OF OWYHEE TUNNEL NO. 1 VENTURI METER-FLUME

By JACOB E. WARNOCK, ASSOCIATE ENGINEER

Under direction of

E. W. LANE, RESEARCH ENGINEER

TECHNICAL MEMORANDUM No. 333

Fort Collins, Colorado

April 15, 1933

(PRICE $2.10)

SYNOPSIS

A portion of the water stored in the Owyhee Reservoir will be diverted through Tunnel No. 1, thence through Tunnel No. 5 and into a high-line irrigation distribution system for use in the Snake River Valley. To measure the discharge through Tunnel No. 1 with various elevations of the reservoir, a measuring device has been built into the regulating headworks near the intake. This device, while neither strictly a Venturi meter nor a Venturi flume, has characteristics of both and will have the flow conditions of either depending upon the elevation of the water surface in the reservoir, the amount of gate opening and the quantity of discharge.

As a means of determining the laws of flow for the measuring device and to obtain data for construction of discharge diagrams and tables, hydraulic model tests were made by the U. S. Bureau of Reclamation in the hydraulic laboratory of the Colorado Agricultural College, Fort Collins, Colorado.

The discharge data obtained from the model was applied to the prototype by the laws of hydraulic similitude as outlined by Chick.*

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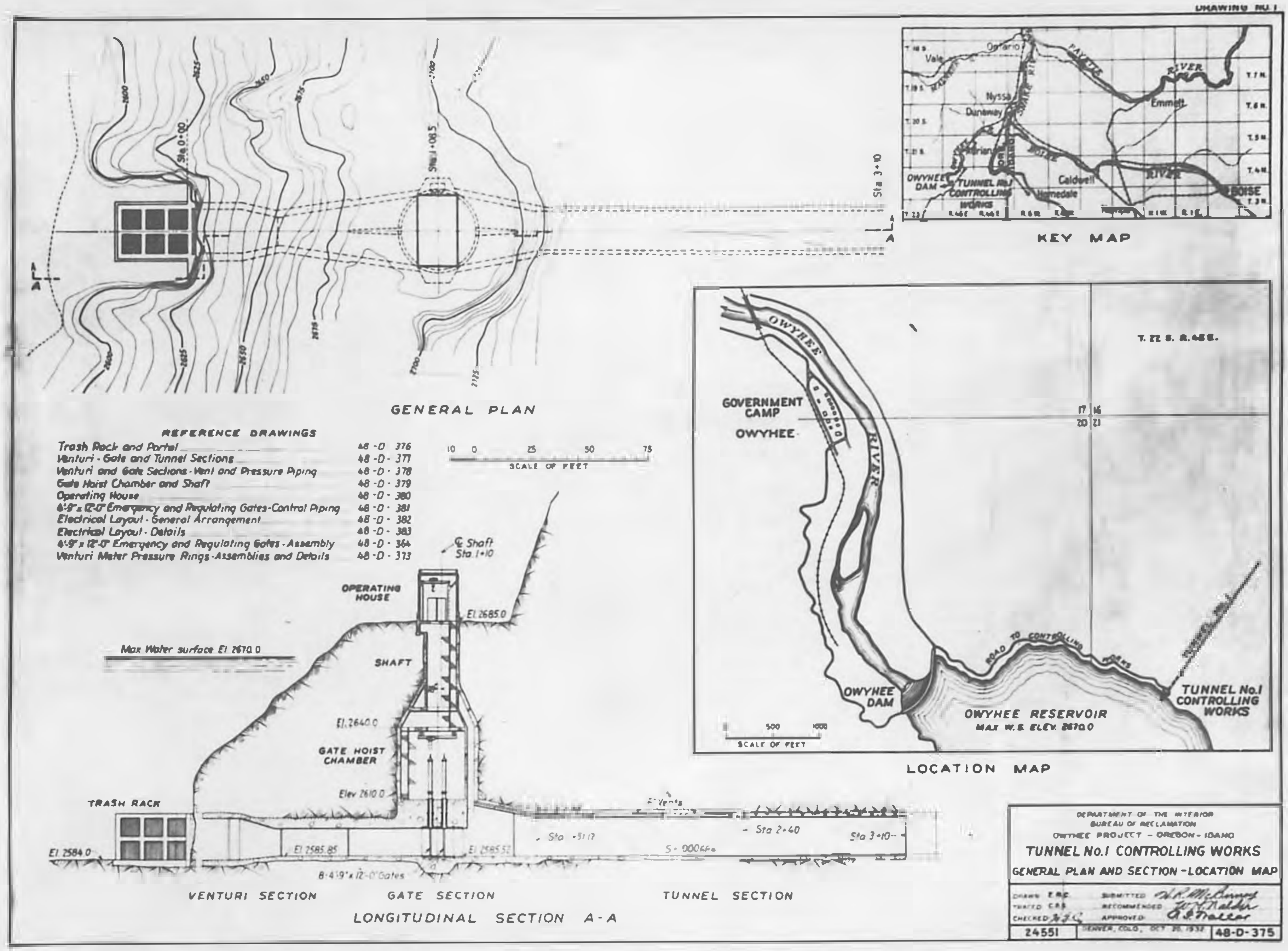
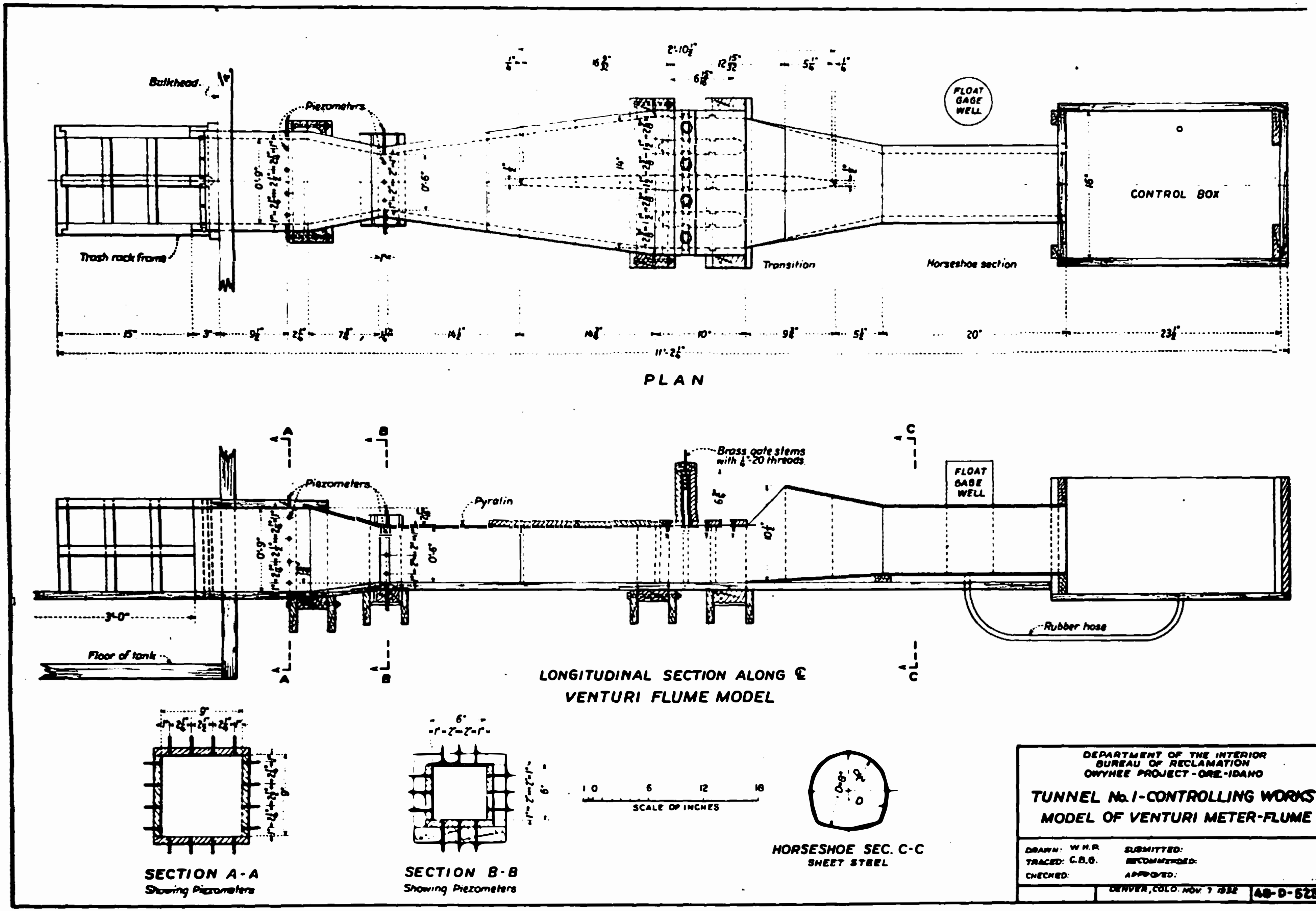
* Transference Equations, Alton C. Chick, Freeman's "Hydraulic Laboratory Practice," page 799.


DRAWING No.1
GENERAL PLAN
Sta. 0+00
Sta. 1+08.5
Sta 3+10
KEY MAP
Ontario
Vale
Nyssa
Dunaway
Emmett
OWYHEE DAM
TUNNEL No.1 CONTROLLING WORKS
Homedale
Caldwell
BOISE
FAYETTE RIVER
BOISE RIVER
SNAKE RIVER
LOCATION MAP
GOVERNMENT CAMP
OWYHEE
OWYHEE RIVER
T. 22 S. R. 45 E.
OWYHEE DAM
ROAD TO CONTROLLING WORKS
TUNNEL No.1 CONTROLLING WORKS
OWYHEE RESERVOIR
MAX W.S. ELEV. 2670.0
SCALE OF FEET
REFERENCE DRAWINGS
Trash Rack and Portal 48-D-376
Venturi - Gate and Tunnel Sections 48-D-377
Venturi and Gate Sections - Vent and Pressure Piping 48-D-378
Gate Hoist Chamber and Shaft 48-D-379
Operating House 48-D-380
6'-9" x 12'-0" Emergency and Regulating Gates - Control Piping 48-D-381
Electrical Layout - General Arrangement 48-D-382
Electrical Layout - Details 48-D-383
6'-9" x 12'-0" Emergency and Regulating Gates - Assembly 48-D-364
Venturi Meter Pressure Rings - Assemblies and Details 48-D-373
SCALE OF FEET
℄ Shaft Sta. 1+10
OPERATING HOUSE
El. 2685.0
Max Water surface El. 2670.0
SHAFT
El. 2640.0
GATE HOIST CHAMBER
Elev 2610.0
TRASH RACK
El. 2584.0
El. 2585.85
El. 2585.52
Sta 2+40
Sta 3+10
8-6'-9" x 12'-0" Gates
VENTURI SECTION
GATE SECTION
TUNNEL SECTION
LONGITUDINAL SECTION A-A
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
OWYHEE PROJECT - OREGON - IDAHO
TUNNEL No.1 CONTROLLING WORKS
GENERAL PLAN AND SECTION - LOCATION MAP
DRAWN E.R.C.
TRACED C.R.S.
CHECKED
SUBMITTED
RECOMMENDED
APPROVED
24551
DENVER, COLO., OCT. 20, 1932
48-D-375


Bulkhead
Piezometers
Trash rack frame
FLOAT GAGE WELL
CONTROL BOX
Transition
Horseshoe section
11'-2⅛"
PLAN
Brass gate stems with ¼"-20 threads
Pyralin
Rubber hose
Floor of tank
3'-0"
LONGITUDINAL SECTION ALONG ℄
VENTURI FLUME MODEL
SECTION A-A
Showing Piezometers
SECTION B-B
Showing Piezometers
SCALE OF INCHES
HORSESHOE SEC. C-C
SHEET STEEL
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
OWYHEE PROJECT - ORE.-IDAHO
TUNNEL No. 1-CONTROLLING WORKS
MODEL OF VENTURI METER-FLUME
DRAWN: W.H.B.
TRACED: C.B.G.
CHECKED:
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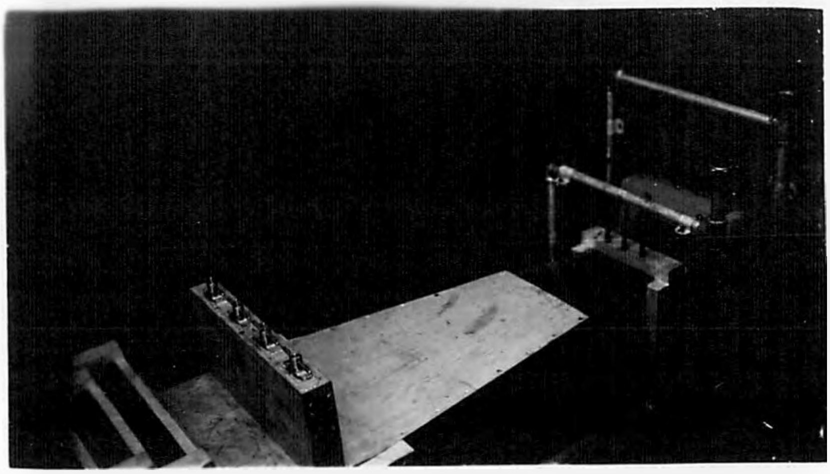
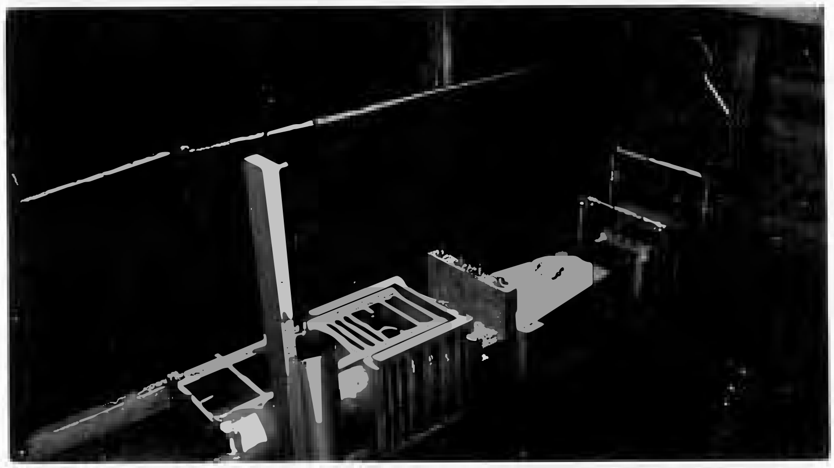
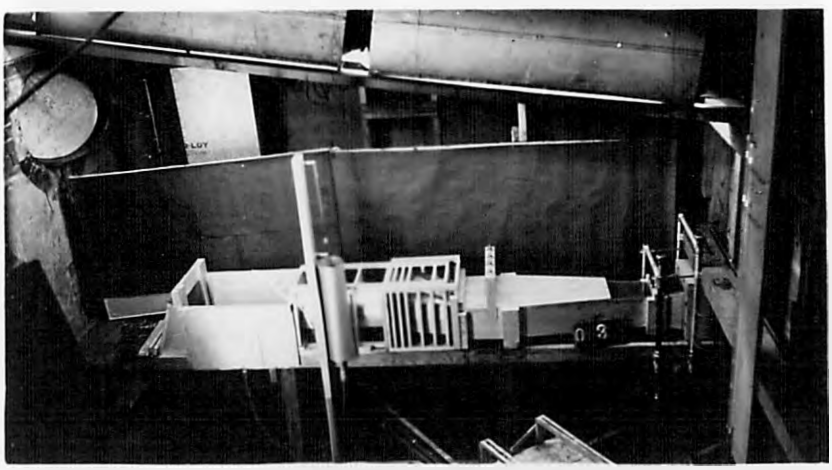
RECOMMENDED:
APPROVED:
DENVER, COLO. NOV. 7 1932



CLOSE UP OF MODEL SHOWING GATE CONTROL MECHANISM AND PEIZOMETER CONNECTIONS

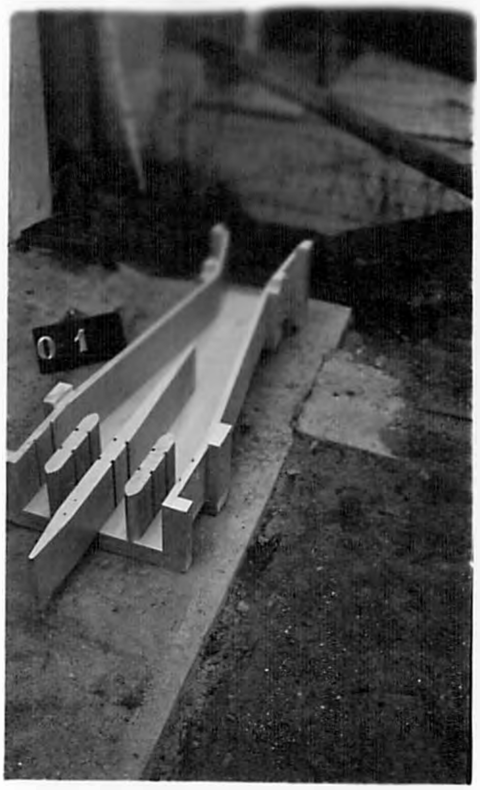


SIDE VIEW OF MODEL AFTER INSTALLATION

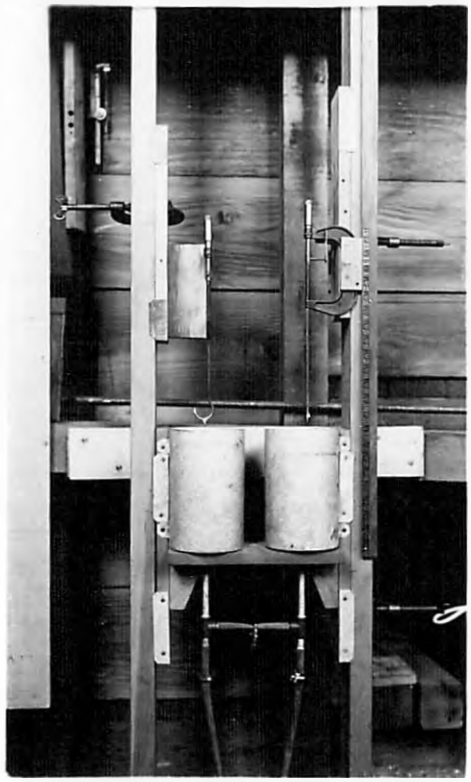


SIDE VIEW OF MODEL AFTER INSTALLATION SHOWING TAILWATER CONTROL BOX

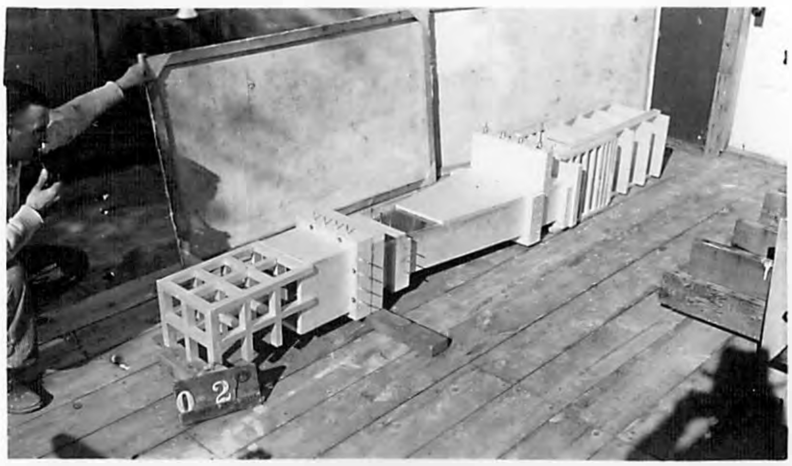
MODEL OF OWYHEE VENTURI METER-FLUME



MODEL DURING CONSTRUCTION



MICROMETER HOOK GAGES AND WELLS



COMPLETE ASSEMBLY OF MODEL BEFORE INSTALLATION

MODEL OF OWYHEE VENTURI METER-FLUME

DESCRIPTION OF MODEL

The model of the Owyhee flume was constructed of redwood on a theoretical scale ratio of 1 to 24 with a pyralin top extending six inches upstream and downstream from the throat or control section (see Plate A). The meter and the approach conditions were duplicated in the model but only about forty feet of the discharge tunnel was used. A control box was built at the end of this short section of tunnel to give the flow conditions in the tunnel.

The model was placed near the bottom of a tank that served as a reservoir and the elevation of the water in this tank was determined by means of a hook gage. A 90-degree V-notch weir was used to measure the quantity. The piezometer rings for determining the difference in head between the entrance section and throat section were placed as in the prototype except that the ring at the throat was placed 1/4-inch upstream (1/2 foot on the prototype) so that the openings would not occur at a corner. There were twelve openings at the upstream ring and nine at the control section, all equally spaced in top, bottom and sides.

During the first twenty-five runs piezometer tubes were used to determine the difference in pressure head between the entrance and throat sections. With this set-up it was necessary to estimate the thousandths of a foot. For low discharges the difference in head was less than a thousandth of a foot so that it was necessary to install a more accurate measuring device. The piezometer rings were, therefore, connected to cylindrical wells and micrometer hook gages, graduated to thousandths of an inch, were used as illustrated on Plate C.

CONDITIONS OF FLOW

The flow in the Venturi meter-flume was divided into three conditions, each of which required a different analysis. These three conditions were:

(1) The meter-flume was operating as a Venturi meter with both the entrance and throat sections flowing full. The standard Venturi formula was used in the analysis of the data for this condition.

(2) The meter-flume was operating as a Venturi meter with the entrance section flowing partly full and throat section was flowing full. The standard Venturi formula was used in this case with the substitution of the actual water area at the entrance piezometer cross-section and the cross-sectional area of the meter at the throat.

(3) The meter-flume was operating as a Venturi measuring flume with both the entrance and throat sections flowing partly full. In the analysis of this data, the formula for discharge over a weir was used with the correction due to submergence included in the coefficient "C" which is a variable dependent upon the percentage of submergence, h_b/h_a.

RESULTS AND CONCLUSIONS

The action of the model was satisfactory except when the discharge condition changes from that of a Venturi meter to that of a Venturi flume. As the water breaks free from the throat-section a disturbance is set up which affects the gage reading at the throat. However, this condition prevails only over a slight range in flow and can probably be remedied by a slight change in the control gate settings.

The gate openings have an influence on the discharge coefficient both when the meter is flowing full and flowing partly full. As a result, it is recommended that all gates should be operated together; i. e., all raised or lowered the same amount. Several runs were made with different gate combinations and all showed a marked deviation in the coefficient of discharge. These runs are not shown in the summary of data for that reason.

The elevation of the water in the discharge tunnel had no effect on the discharge coefficient for the condition where the meter was flowing full, but it did have a decided effect when the throat was flowing free.

As the coefficient of flow in the tunnel cannot be forecast and as it will be subject to change with years of usage, the derivation of the discharge data for the condition of the meter acting as a Venturi flume was made in terms to eliminate that variable. A wide variation of tailwater conditions was made in the model to obtain a wide variation of the ratio of submergence. In turn, the ratio of submergence was related to the elevation head h_a in the entrance section.

Several runs were made with the same discharge but different reservoir elevations but no effect was found in the coefficient of the meter due to that variable.

At the beginning of the experiments, an air-pocket formed below the throat section and extended downstream about twenty feet (prototype) for high flows and reservoir elevation 2600±. To eliminate that condition, vents were installed in the top of the model eight feet and twenty feet (prototype) downstream from the throat section. The vents eliminated the air pockets and were in operation throughout the tests.

Two separate sets of gages will be needed to record the heads at the entrance and throat sections; (1) a differential gage to record the difference in pressure head $(h_a - h_b)$ between the entrance and throat piezometer sections when the meter is acting as a Venturi meter and (2) a set of float gages to record the elevation head at the entrance and throat piezometer sections when the meter is acting as a Venturi flume.

ACKNOWLEDGMENTS

The experiments on the Owyhee Venturi Meter-Flume were conducted in the hydraulic laboratory at the Colorado Agricultural College, Fort Collins, Colorado, by the permission of the Colorado Agricultural College and the staff of the U. S. Bureau of Agricultural Engineering.

The model was built and installed and the first experiments performed by Mr. Walter H. Price, Junior Engineer, under the supervision of the writer.

TABLE NO. 1

SUMMARY OF DATA FOR OWYHEE TUNNEL VENTURI METER-FLUME.

(Venturi Meter Conditions with Both Sections Full)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Weir Tailwater Gage		Reservoir Elevation										
Run No.	Quan., c.f.s.	Change during Run, Feet.	Correction due to Pondage, c.f.s.	Model Elevation, Feet	Change during Run, Feet	Correction due to Pondage, c.f.s.	Model Q Corrected for Pondage, c.f.s.	(h_a-h_b)	$(h_a-h_b)^{\frac{1}{2}}$	$Q_c = 2.21 \times (h_a-h_b)^{\frac{1}{2}}$	Diff. Q_o-Q_c	Deviation Percent	No. of Gates Used.	Gates Raised Percent
26	0.7961	-	-	111.125	-0.004	+0.0005	0.7966	0.12413	0.35232	0.7786	+0.0180	+2.3	All	21.68
27	.7077	+0.004	-0.0005	111.188	+0.014	-0.0017	.7055	.09908	.31477	.6956	+ .0099	+1.4	"	18.75
28	.6166	+ .001	- .0001	111.131	- .002	+ .0003	.6168	.07625	.27613	.6102	+ .0066	+1.1	"	16.05
29	.5629	+ .001	- .0001	111.125	+ .011	- .0014	.5614	.06316	.25132	.5554	+ .0060	+1.1	"	14.58
30	.4967	+ .001	- .0001	111.132	+ .005	- .0006	.4960	.05108	.22601	.4995	- .0035	-0.7	"	12.50
31	.4258	+ .002	- .0003	111.112	+ .004	- .0005	.4250	.03807	.19512	.4312	- .0062	-1.5	"	10.84
32	.3521	-	-	111.114	+ .004	- .0005	.3516	.02636	.16236	.3588	- .0072	-2.0	"	9.17
33	.2802	+ .002	- .0003	111.118	+ .007	- .0009	.2790	.01616	.12712	.2809	- .0019	-0.7	"	7.48
34	.2242	+ .002	- .0003	111.124	+ .004	- .0005	.2234	.00997	.09985	.2207	+ .0027	+1.2	"	5.42
35	.1406	+ .001	- .0001	111.109	- .041	+ .0050	.1455	.00402	.06340	.1401	+ .0054	+3.7	"	3.33
37	.0702	+ .001	- .0001	109.677	- .011	+ .0012	.0713	.00119	.03450	.0762	- .0049	-6.9	"	1.67
38	.1406	+ .001	- .0001	109.713	+ .009	- .0010	.1395	.00429	.06550	.1448	- .0053	-3.8	"	4.91
39	.2235	+ .003	- .0004	109.715	+ .004	- .0004	.2227	.01080	.10392	.2297	- .0070	-3.1	"	7.71
40	.2807	+ .002	- .0003	109.726	+ .002	- .0002	.2802	.01624	.12744	.2816	- .0014	-0.5	"	9.58
41	.3506	+ .001	- .0001	109.731	+ .004	- .0004	.3501	.02526	.15893	.3512	- .0011	-0.3	"	12.49
42	.4223	-	-	109.709	+ .006	- .0007	.4216	.03748	.19360	.4279	- .0063	-1.5	"	15.00
43	.5032	+ .001	- .0001	109.722	+ .007	- .0008	.5023	.05124	.22636	.5003	+ .0020	+0.4	"	17.70
44	.5631	+ .006	- .0008	109.724	-	-	.5623	.06480	.25456	.5626	- .0003	-0.0	"	20.00
45	.6151	-	-	109.732	- .006	+ .0007	.6144	.07658	.27673	.6116	+ .0028	+0.5	"	22.09
46	.7080	+ .004	- .0005	109.722	+ .019	- .0021	.7054	.10008	.31635	.6991	+ .0063	+0.9	"	25.82
47	.7651	-	-	109.717	- .006	+ .0007	.7058	.11296	.33610	.7428	- .0370	-5.2	"	27.49
48	.7650	+ .002	- .0003	108.515	-	-	.7647	.12630	.35539	.7854	- .0207	-2.7	"	100.00
49	.7052	+ .002	- .0003	108.496	-	-	.7049	.10750	.32787	.7246	- .0197	-2.8	"	100.00
60	.0704	+ .004	- .0005	111.129	+ .011	- .0014	.0685	.00100	.03162	.0699	- .0014	-2.0	"	1.04
61	.1401	+ .001	- .0001	111.128	+ .005	- .0006	.1394	.00421	.06489	.1434	- .0040	-2.9	"	3.02
62	.1426	+ .002	- .0003	109.732	- .001	+ .0001	.1424	.00473	.06878	.1520	- .0096	-6.8	"	4.38
63	.2205	+ .003	- .0004	109.729	+ .006	- .0007	.2194	.00953	.09762	.2157	+ .0037	+1.7	"	7.08
64	.2205	-	-	111.136	+ .006	- .0007	.2198	.00985	.09925	.2193	+ .0005	+0.2	"	5.21
65	.2802	+ .005	- .0007	111.139	+ .001	- .0001	.2794	.01603	.12661	.2798	- .0004	-0.1	"	6.67
66	.2804	-	-	109.718	- .009	+ .0010	.2814	.01649	.12841	.2838	- .0024	-0.9	"	8.96
76	.7169	+ .003	- .0004	108.502	+ .003	- .0003	.7162	.10882	.32988	.7290	- .0128	-1.8	"	100.00
77	.7651	+ .003	- .0004	108.522	+ .001	- .0001	.7646	.12429	.35255	.7791	- .0145	-1.9	"	100.00
78	.0504	+ .002	- .0003	111.101	- .004	+ .0005	.0506	.00051	.02258	.0499	+ .0007	+1.4	"	0.83
79	.1681	-	-	111.127	- .001	+ .0001	.1682	.00500	.07071	.1563	+ .0119	+7.1	"	3.75
80	.2527	+ .002	- .0003	111.136	+ .001	- .0001	.2523	.01269	.11265	.2490	+ .0033	+1.3	"	6.25
81	.3206	+ .002	- .0003	111.121	+ .002	- .0002	.3201	.02103	.14502	.3205	- .0004	-0.1	"	7.92
90	.7651	+ .003	- .0004	109.120	+ .002	- .0002	.7645	.11770	.34307	.7582	+ .0063	+0.8	No.3	100.00
102	.0967	-	-	111.137	+ .001	- .0001	.0966	.00189	.04347	.0961	+ .0005	0.0	All	2.08
103	.0967	+ .007	- .0009	110.428	+ .002	- .0002	.0956	.00165	.04062	.0898	+ .0058	+6.0	"	2.92
104	.0967	+ .009	- .0012	109.710	+ .005	- .0006	.0949	.00178	.04219	.0932	+ .0017	+1.7	"	3.75
105	.0767	+ .001	- .0001	109.731	+ .001	- .0001	.0765	.00114	.03376	.0746	+ .0019	+2.4	"	2.92

EXPLANATION OF SUMMARY OF DATA FOR

OWYHEE TUNNEL VENTURI METER-FLUME

(Venturi Meter Conditions with Both Sections Full)

<u>Table No. 1</u>

All the data both recorded and computed is summarized in Table No. 1. The significance of each column and the methods employed in the derivation of the data therein is explained in the following as a general guide:

Column 1 - Run Number - Each run of the test was given a number which usually is chronological in nature except in cases where it was necessary to make re-runs.

Column 2 - Quantity, c. f. s. - The flow of water into the model was measured by a 90-degree V-notch weir, the formula for which is

$$Q = C H^{5/2} \qquad (1)$$

where C = 2.4972

The head on the weir was measured by a float gage and a hook gage and the results from the two gages were averaged after a correction factor for each was applied. The correction factors were

	Hook Gage	Float Gage
Runs 26 to 101 inclusive	0.5608	3.2197
102 to 126 inclusive	.5666	3.2246
127 to 158 inclusive	.6526	3.2213

Column 3 - Weir Tailwater Gage, Change During Run, Ft. Rise + Fall - - To avoid clogging of the piezometers in the model a screen was placed in the outlet to the weir tailwater box. During the course of a run, material would collect on this screen and cause pondage. To correct for this pondage, a float gage was established and read at regular intervals during a run.

Column 4 - Weir Tailwater Gage, Correction Due To Pondage, C. F. S. - From the measurement of the area of the tailwater box and the rise in the water surface, the amount of pondage was computed for each run, which, in each case, was of ten minutes duration. The horizontal dimensions of the tank were 7.55 feet by 10.04 feet so that for a change in elevation of one foot during a run a correction of 0.13 c. f. s. was made.

Column 5 - Reservoir Elevation, Model Reservoir Elevation, Ft. - The elevation of the water surface in the reservoir was measured by a hook gage mounted near the tank and connected by a 3/4-inch hose to the bottom of the tank. The gage itself was mounted on a staff with holes at regular intervals vertically, making it possible to measure a wide range of elevation.

The datum of the model was assumed to be the datum of the prototype divided by the theoretical scale ratio of the model; i. e., elevation 2600 on the prototype would be 2600/24 or elevation 130.0 on the model. The elevations of the hook gage when set at zero and clamped to the staff at various heights were:

Hole 6 Elevation 110.932 Hole 4 Elevation 107.133

Hole 5 Elevation 109.035 Hole 3 Elevation 105.231

Column 6 - Reservoir Elevation, Change During Run, Feet -

Rise + Fall -

Surges in the model made it impossible to maintain a constant reservoir elevation throughout a run. That condition necessitated a correction for change in pondage.

Column 7 - Reservoir Elevation, Correction Due To Pondage, C. F. S. -

The tank used as a reservoir contained the model of the ~~Hoover~~ Boulder Dam intake tower and the reservoir was irregular in shape. To correct for the change in pondage, a reservoir drawdown curve was made from a topographic survey.

Column 8 - Observed Quantity Corrected For Pondage, Model, C. F. S. -

The correction is made by adding algebraically columns 2, 4 and 7.

Column 9 - Difference in Pressure Head Between Entrance and Throat, $(h_a - h_b)$.

The standard Venturi equation was used in the analysis of the experimental data. This equation is

$$Q = \frac{C A_a A_b \sqrt{(h_a - h_b)\, 2g}}{\sqrt{A_a^2 - A_b^2}} \qquad (2)$$

where A_a = entrance cross-sectional area

A_b = throat cross-sectional area

h_a = pressure head at A_a

h_b = pressure head at A_b

g = acceleration due to gravity

(32.145 at Ft. Collins laboratory)

C = experimental coefficient

$$\text{Equating} \quad K = \frac{A_a \; A_b \; (2g)^{\frac{1}{2}}}{(A_a^2 - A_b^2)^{\frac{1}{2}}} \qquad (3)$$

$$\text{Equation (2) becomes } Q = C\,K(h_a - h_b)^{\frac{1}{2}} \qquad (4)$$

The difference in pressure heads $(h_a - h_b)$ was observed by means of a differential micrometer hook gage arrangement illustrated on Plate 6.

Column 10 - $(h_a - h_b)^{\frac{1}{2}}$ - The results of the tests were plotted Q against $(h_a - h_b)$ on logarithmic paper. The resulting plot was a straight line with a slope of $n = 0.5$ which checked the assumption that, with both measuring sections flowing full, the law of flow was that of the Venturi meter.

Column 11 - Computed Quantity, Q_c - After it was determined that the exponent of the difference in head was 0.5, the square root was computed for each run. Using the observed quantity Q_o in column 8 and the $(h_a - h_b)^{\frac{1}{2}}$ in column 10, the value of (CK) was computed for each run. The average of these values was then used in obtaining a computed quantity Q_c.

Columns 12 and 13 - $(Q_o - Q_c)$ and Per Cent of Deviation - To determine the consistency of the observed data the difference between the observed quantity and the computed quantity was determined and the per cent of deviation was obtained by dividing the difference by the observed quantity.

Columns 14 and 15 - Gates and Gate Openings - The control works in Tunnel No. 1 at the Owyhee development will consist of four Stoney gates each 4'-2" wide by 12' high with suitable control mechanism for lifting. These gates were duplicated in detail in the model and the gate-lifting mechanism was duplicated by using 1/4-inch brass rods with twenty threads to the inch, with thumb-screws on the top to regulate the gate opening. The amount of gate opening was recorded in the model data in terms of number of turns of the thumb-screw but for convenience in applying the data to either the model or prototype this data was converted to percentage of gate opening and is so recorded in Table No. 1.

TABLE 2.

DISCHARGE OF OWYHEE TUNNEL VENTURI METER FLUME

IN CUBIC FEET PER SECOND BY THE FORMULA, Q=1239.44 (h -h)

(Venturi Meter Conditions with both sections full.)

h -h	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	000	124	175	215	248	277	304	328	351	372
0.1	392	411	429	447	464	480	496	511	526	540
0.2	554	568	581	594	607	620	632	644	656	667
0.3	679	690	701	712	723	733	744	754	764	774
0.4	784	794	803	813	822	831	841	850	859	868
0.5	876	885	894	902	911	919	927	936	944	952
0.6	960	968	976	984	992	999	1007	1014	1022	1030
0.7	1037	1044	1052	1059	1066	1073	1081	1088	1095	1102
0.8	1109	1115	1122	1129	1136	1143	1149	1156	1163	1169
0.9	1176	1182	1189	1195	1202	1208	1214	1221	1227	1233
1.0	1239	1246	1252	1258	1264	1270	1276	1282	1288	1294
1.1	1300	1306	1312	1318	1323	1329	1335	1341	1346	1352
1.2	1358	1364	1369	1375	1380	1386	1391	1397	1402	1408
1.3	1413	1419	1424	1429	1435	1440	1445	1451	1456	1461
1.4	1467	1472	1477	1482	1487	1493	1498	1503	1508	1513
1.5	1518	1523	1528	1533	1538	1543	1548	1553	1558	1563
1.6	1568	1573	1578	1582	1587	1592	1597	1602	1606	1611
1.7	1616	1621	1626	1630	1635	1640	1644	1650	1654	1658
1.8	1663	1667	1672	1677	1681	1686	1690	1695	1699	1704
1.9	1708	1713	1717	1722	1726	1731	1735	1740	1744	1748
2.0	1753	1757	1762	1766	1770	1775	1779	1783	1788	1792
2.1	1796	1800	1805	1809	1813	1817	1822	1826	1830	1834
2.2	1838	1843	1847	1851	1855	1859	1863	1867	1871	1876
2.3	1880	1884	1888	1892	1896	1900	1904	1908	1912	1916

TRANSFERENCE OF RESULTS FROM MODEL TO PROTOTYPE

Table No. 2.

Considering Equation (4) on page 11 the value of K for the model can be determined by substituting the actual values of A_a, A_b and g in Equation (3). In the case of the model

where $A_a = 0.566088$ sq. ft.

and $A_b = 0.255753$ sq. ft.

$$K = \frac{0.255753 \times 0.566088 \times (2 \times 32.145)^{\frac{1}{2}}}{\sqrt{(0.566088)^2 - (0.255753)^2}}$$

$$K = 2.298610$$

and since (CK) = 2.21 (see column 11, Table No. 1)

$$C = \frac{2.21}{K}$$

$$= 0.9614$$

In the case of the prototype

where $A_a = (18)^2$, $A_b = (12)^2$ and $g = 32.16$ (Owyhee development)

$$K = \frac{(12)^2 \times (18)^2 \times (2 \times 32.16)^{\frac{1}{2}}}{\sqrt{(324)^2 - (144)^2}}$$

$$= 1289.207$$

Substituting the values for the prototype in Equation 4, page 11:

$$Q = C K (h_a - h_b)^{\frac{1}{2}}$$

$$= 0.9614 \times 1289.207 (h_a - h_b)^{\frac{1}{2}}$$

$$= 1239.44 (h_a - h_b)^{\frac{1}{2}}$$

From this formula the data in Table No. 2 was computed.

TABLE NO. 3-A

SUMMARY OF DATA FOR OWYHEE TUNNEL VENTURI METER-FLUME, (Model).
(Venturi Meter Conditions with Entrance Section Partially Full and Throat Section Full).

1	2	3	4	5	6	7	8	9	10	11	12	13	14
		Weir Tailwater Gage		Reservoir Elevation			Model Q Corrected for Pondage, c.f.s.	Elevation of Water in Throat h_b, Feet.	(h_a-h_b)	Elevation of Water in Entrance, h_a, Feet.	Depth in Entrance Section, d_a, Feet	Area in Entrance Section, A_a, Sq. Ft.	Area in Throat Section, A_b, Sq. Ft.
Run No.	Quan. c.f.s.	Change during Run, Feet	Correction due to Pondage, c.f.s.	Model Elevation Feet	Change during Run, Feet	Correction due to Pondage, c.f.s.							
50	0.6151	-0.001	+0.0001	108.406	-0.002	+0.0002	0.6154	0.55349	0.08113	0.63462	0.70812	0.53504	0.255753
51	.5371	+ .002	- .0003	108.338	- .001	+ .0001	.5369	.51036	.05877	.56913	.64263	.48556	.255753
68	.1413	+ .001	- .0001	106.306	+ .001	- .0001	.1411	.57105	.00409	.57514	.64864	.49010	.255753
69	.2220	-	-	108.326	+ .002	- .0002	.2218	.58042	.01028	.59070	.66420	.50186	.255753
70	.2832	+ .001	- .0001	108.314	-	-	.2831	.55773	.01631	.57434	.64784	.48949	.255753
71	.3506	+ .001	- .0001	108.307	- .004	+ .0004	.3509	.53692	.02454	.56146	.63496	.47976	.255753
72	.4173	+ .004	- .0005	108.322	- .002	+ .0002	.4170	.53605	.03450	.57055	.64405	.48663	.255753
73	.4964	+ .003	- .0004	108.331	+ .001	- .0001	.4959	.52088	.04828	.56916	.64266	.48558	.255753
74	.5626	+ .005	- .0007	108.341	- .001	+ .0001	.5620	.50872	.06196	.57068	.64418	.48673	.255753
75	.6153	+ .002	- .0003	108.401	- .001	+ .0001	.6151	.55338	.07816	.63154	.70504	.53271	.255753
99	.4917	+ .002	- .0003	108.316	- .001	+ .0001	.4915	.50718	.04723	.55441	.62791	.47444	.255753
100	.5349	+ .005	- .0007	108.328	- .003	+ .0003	.5346	.50301	.05678	.55978	.63328	.47849	.255753

TABLE NO. 3-B

TRANSFERENCE OF RESULTS FROM MODEL TO PROTOTYPE.
(Venturi Meter Conditions with Entrance Section Partially Full and Throat Section Full).

1	2	3	4	5	6	7	8	9	10	11	12	13
Run No.	Prototype Q Corrected for Pondage, Q_o, c.f.s.	(h_a-h_b)	Area in Entrance Section, A_a, Sq. Ft.	Area in Throat Section, A_b, Sq. Ft.	$(h_a-h_b)^{\frac{1}{2}}$	K	C	$Q_c = CK(h_a-h_b)^{\frac{1}{2}}$	Q_o-Q_c	Deviation Percent	No. of Gates Used	Gates Raised, Percent
50	1687.8853	1.9250	301.2498	144.000	1.38746	1314.9137	0.9252	1690.6623	- 2.7770	-0.2	All	100.00
51	1472.5798	1.3946	273.3905	144.000	1.18093	1358.7141	.9178	1486.9330	-14.3532	-1.0	"	100.00
68	387.0013	0.0970	275.9467	144.000	0.31151	1353.9350	.9176	390.8490	- 3.8477	-1.0	"	8.85
69	608.3408	.2439	282.5681	144.000	.49389	1342.3451	.9176	614.3751	- 6.0343	-1.0	"	15.42
70	776.4711	.3870	275.6033	144.000	.62210	1354.5681	.9214	780.9086	- 4.4375	-0.6	"	22.09
71	962.4292	.5823	270.1249	144.000	.76307	1365.1052	.9239	965.3164	- 2.8872	-0.3	"	31.69
72	1143.7247	.8186	273.9930	144.000	.90478	1357.5685	.9311	1138.2664	+ 5.4583	+0.5	"	41.68
73	1360.1272	1.1456	273.4018	144.000	1.07035	1358.6953	.9353	1347.6808	+12.4464	+0.9	"	58.35
74	1541.4227	1.4703	274.0493	144.000	1.21254	1357.4654	.9365	1525.3307	+16.0920	+1.1	"	100.00
75	1687.0624	1.8546	299.9379	144.000	1.36184	1316.6300	.9409	1661.6096	+26.4528	+1.6	"	100.00
99	1348.0592	1.1207	267.1295	144.000	1.05861	1371.2587	.9287	1345.2238	+ 2.8354	+0.2	"	70.82
100	1466.2715	1.3474	269.4098	144.000	1.16076	1366.5473	.9244	1469.9626	- 3.6911	-0.3	"	79.20
							0.9267					

EXPLANATION OF SUMMARY OF DATA

OWYHEE TUNNEL VENTURI METER-FLUME

(Venturi Meter Condition with Entrance Section Partly Full and Throat Section Full) Table No. ~~3-A~~

Columns 1 to 8 inclusive - See explanation of Table No. 1.

Columns 9, 10 and 11 - Elevation of Water in Throat of Model, h_b, Feet - Model Difference in Head, $(h_a - h_b)$, Feet - Elevation of Water in Entrance of Model, h_a, Feet - The elevation of the water surface in the entrance and throat piezometer sections of the model was measured by the micrometer hook gages shown in the photograph on Plate G. The throat or h_b gage was referred in elevation to the elevation of the crest in the throat of the model, and, as each run was made, the correction factor between the h_a and h_b gages was determined by closing the tubes leading to the gage wells with pinch-cocks and opening the connecting tube between the wells. This so-called "zeroing" of the gages was necessary on practically every run as the range of the micrometer scales was only one inch. A steel tape on the right-hand side of the gage apparatus was used to refer the h_b gage to the throat crest as it was necessary to raise or lower it for each run. From the scale reading and micrometer reading, the elevation head in the throat was determined. With h_b known, and the difference $(h_a - h_b)$ determined by observation, the value of h_a was found by subtraction.

Column 12 - Depth in Entrance Section of Model, d_a, Feet - The depth of water in the entrance section of the model was obtained by adding the elevation of the water in the entrance above the throat crest and the difference in elevation between the floor of the entrance and the floor of the throat.

Column 13 - Area in Entrance Section, A_a, Square Feet - The area in the entrance section is the depth of water, d_a, (model) multiplied by the width of the section which was obtained by calipering.

Column 14 - Area in Throat Section, A_b, Square Feet - The model area in the throat section was obtained by multiplying the width by the height of the section.

TRANSFERENCE OF RESULTS FROM MODEL TO PROTOTYPE

C-TYPE TUNNEL VENTURI METER-FLUME

(Venturi Meter Condition with Entrance Section Partly Full and Throat Section Full) Table No. ~~3-B~~

Column 1 - See explanation of Table No. 1.

Column 2 - Prototype Quantity, Q_o, C. F. S. - The prototype Q was determined by multiplying the observed model Q by $n^{5/2}$. The value of n was found by dividing the area of the throat on the prototype by the area of the throat on the model and extracting the square root of the result.

Column 3 - Prototype Difference in Head, $(h_a - h_b)$, Feet - The prototype $(h_a - h_b)$ was found by multiplying the model $(h_a - h_b)$, column 10, Table No. ~~3-A~~, by the scale ratio, n = 23.7285.

Column 4 - Area in Entrance Section of Prototype, A_a, Sq. Ft. - The prototype area in the entrance section was found by multiplying the model area by n^2, (563.0417).

Column 5 - Area in Throat Section of Prototype, A_b, Sq. Ft. - The prototype area in the throat section was found by multiplying the model area by n^2 (563.0417).

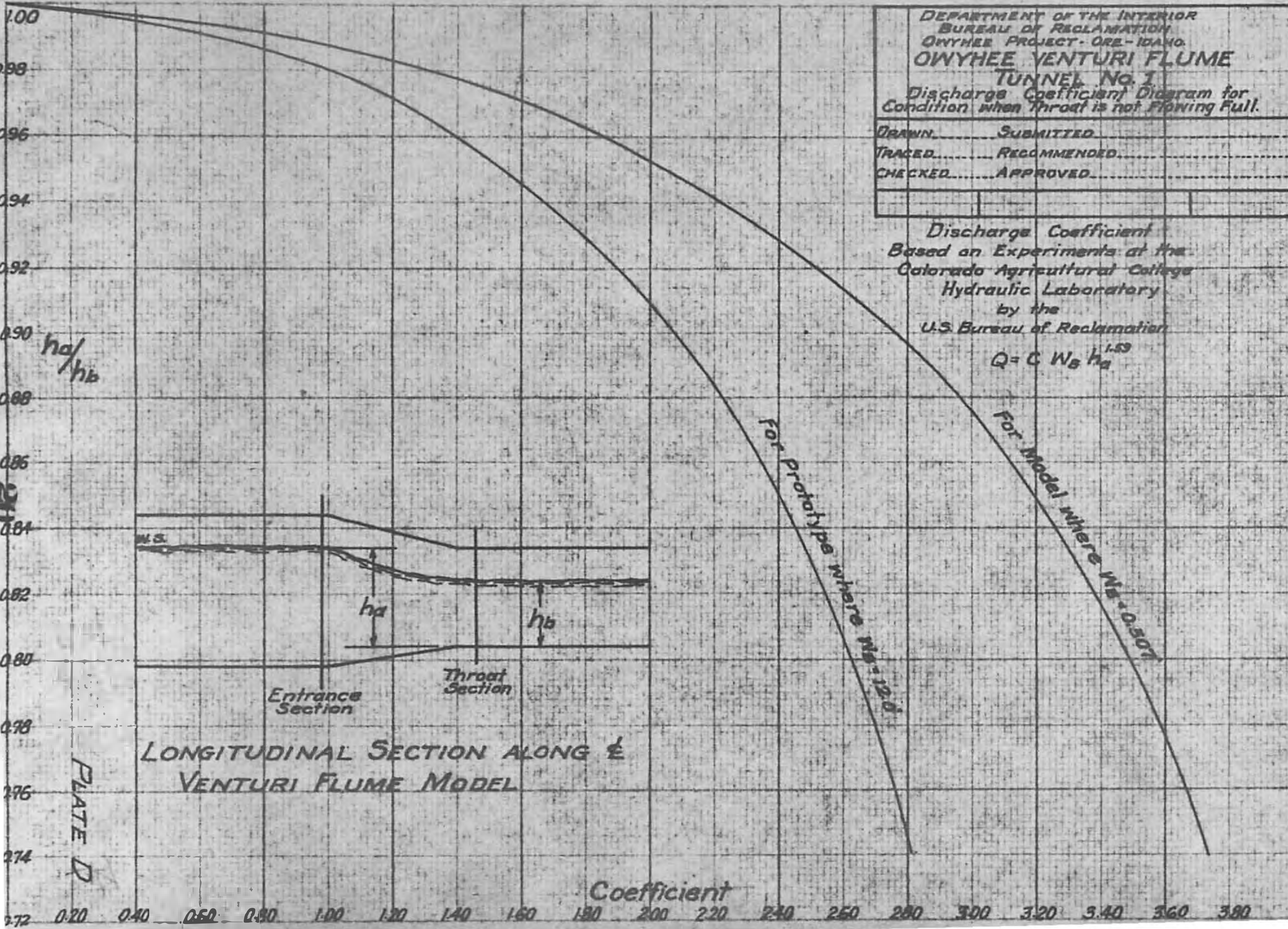
Column 6 - $(h_a - h_b)^{\frac{1}{2}}$ - The square root of $(h_a - h_b)$, column 3.

Column 7 - "K" - In the case of both sections flowing full as in Table No. 1, the value of "K" was a constant. In this case, however, due to A_a being a variable, "K" is a variable and must be computed for each run.

Column 8 - Coefficient of Discharge, C - The observed quantity, Q_o, the square root of the difference in head and the value of "K" were substituted in Equation 4 on page 11 and a value of C was determined for each run. These were averaged and used to compute Q_c. In this case the value of C was 0.9267.

Column 9 - Prototype Computed Quantity, Q_c, C. F. S. - The value of Q_c was found by substituting the values of C, K and $(h_a - h_b)^{\frac{1}{2}}$ in Equation 4 on page 11. The data in this column was plotted on Plate F which is the discharge diagram for the flow condition in the prototype when the throat section is flowing full and the entrance section partly full.

Columns 10 to 13 inclusive - See explanation of columns 12 to 15 inclusive in Table No. 1



DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
OWYHEE PROJECT - ORE - IDAHO
OWYHEE VENTURI FLUME
TUNNEL No. 1
Discharge Coefficient Diagram for Condition when Throat is not Flowing Full.
DRAWN
SUBMITTED
TRACED
RECOMMENDED
CHECKED
APPROVED
Discharge Coefficient
Based on Experiments at the
Colorado Agricultural College
Hydraulic Laboratory
by the
U.S. Bureau of Reclamation
Q = C W_B h_a^1.53
ha/hb
For Prototype where W_B = 12.0'
For Model where W_B = 0.507'
W.S.
ha
hb
Entrance Section
Throat Section
LONGITUDINAL SECTION ALONG ℄
VENTURI FLUME MODEL
PLATE D
Coefficient
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
2.20
2.40
2.60
2.80
3.00
3.20
3.40
3.60
3.80
1.00
0.98
0.96
0.94
0.92
0.90
0.88
0.86
0.84
0.82
0.80
0.78
0.76
0.74
0.72

TABLE NO. 4

SUMMARY OF DATA FOR OWYHEE VENTURI METER-FLUME.

(Venturi Flume Conditions)

1	2	3	4	5	6	7	8	9	10	11	12	13
Run No.	Quan. c.f.s.	Model Pond Elev. Feet.	El. of Water in Throat. h_b, Ft.	(h_a-h_b) Ft.	El. of Water in Entrance h_a, Ft.	h_b/h_a	$h_a^{1.59}$	Computed C	C from Curve on Plate D	Q_c	Q_o-Q_c	Deviation %
127	0.5012	108.218	0.32288	0.11419	0.43707	0.7387	0.26821	3.686	3.734	0.5078	-0.0066	-1.32
128	.5001	108.219	.32290	.11440	.43730	.7384	.26885	3.669	3.735	.5091	- .0090	-1.80
129	.5014	108.227	.34313	.10338	.44651	.7685	.27748	3.564	3.638	.5118	- .0104	-2.08
130	.5006	108.247	.39265	.07987	.47252	.8310	.30362	3.252	3.310	.5095	- .0089	-1.78
131	.5003	108.273	.43991	.06290	.50281	.8749	.33514	2.944	3.001	.5099	- .0096	-1.92
132	.4019	108.153	.28538	.09409	.37947	.7520	.21424	3.700	3.692	.4010	+ .0009	+0.22
133	.4025	108.156	.29003	.09266	.38269	.7579	.21713	3.656	3.675	.4046	- .0021	-0.52
134	.4020	108.154	.28766	.09297	.38063	.7557	.21528	3.683	3.681	.4018	+ .0002	+0.05
135	.4006	108.169	.32412	.07575	.39987	.8106	.23284	3.394	3.435	.4055	- .0049	-1.22
136	.4004	108.194	.37367	.05723	.43090	.8672	.26222	3.012	3.061	.4069	- .0065	-1.63
137	.4000	108.235	.43648	.04143	.47791	.9133	.30914	2.552	2.618	.4103	- .0103	-2.57
138	.3024	108.080	.23969	.07766	.31735	.7553	.16123	3.699	3.681	.3009	+ .0015	+0.50
139	.3026	108.081	.24185	.07651	.31836	.7597	.16205	3.683	3.668	.3014	+ .0012	+0.40
140	.3023	108.087	.25642	.06881	.32523	.7884	.16764	3.557	3.557	.3023	.0000	0.00
141	.3013	108.104	.29140	.05407	.34547	.8435	.18457	3.220	3.228	.3021	- .0008	-0.27
142	.3049	108.152	.36558	.03424	.39982	.9144	.23278	2.584	2.599	.3067	- .0018	-0.59
143	.3043	108.205	.43463	.02460	.45923	.9464	.29015	2.069	2.110	.3104	- .0061	-2.00
144	.3035	108.241	.47840	.01957	.49797	.9607	.33003	1.814	1.840	.3079	- .0044	-1.45
145	.2007	107.996	.18453	.06097	.24550	.7516	.10720	3.693	3.696	.2009	- .0002	-0.10
146	.2007	107.998	.18882	.05842	.24724	.7637	.10841	3.652	3.654	.2008	- .0001	-0.05
147	.2010	108.001	.19657	.05415	.25072	.7840	.11084	3.577	3.573	.2008	+ .0002	+0.10
148	.1994	108.025	.24469	.03434	.27903	.8769	.13140	2.993	2.986	.1989	+ .0005	+0.25
149	.2000	108.055	.28703	.02440	.31143	.9217	.15647	2.521	2.503	.1986	+ .0014	+0.70
150	.2004	108.146	.39477	.01262	.40739	.9690	.23984	1.648	1.667	.2027	- .0023	-1.15
151	.0997	107.898	.12170	.03688	.15858	.7674	.05350	3.676	3.639	.0987	+ .0010	+1.00
152	.0996	107.902	.13227	.03122	.16349	.8090	.05616	3.498	3.445	.0981	+ .0015	+1.51
153	.0991	107.915	.15668	.02160	.17828	.8788	.06446	3.032	2.976	.0973	+ .0018	+1.82
154	.0992	107.940	.19125	.01373	.20498	.9330	.08047	2.432	2.332	.0951	+ .0041	+4.13
155	.0987	107.994	.25528	.00714	.26242	.9728	.11918	1.634	1.575	.0952	+ .0035	+3.55
156	.6745	108.318	.38353	.13832	.52185	.7360	.35555	3.742	3.742	.6745	.0000	0.00
157	.1478	107.946	.15275	.04878	.20153	.7580	.07832	3.722	3.675	.1459	+ .0019	+1.28
158	.0588	107.848	.09001	.02498	.11499	.7820	.03210	3.613	3.581	.0583	+ .0005	+0.85

EXPLANATION OF SUMMARY OF DATA

FOR OWYHEE VENTURI METER-FLUME

(Venturi Flume Conditions)

TABLE 5

<u>Columns 1 to 3 inclusive</u> - See explanation of columns 1, 2 and 5 in Table No. 1.

<u>Columns 4, 5 and 6</u> - See explanation of columns 10, 11 and 13 in Table No. 3.

<u>Columns 7 and 8, h_b/h_a and $h_a^{1.59}$</u> - An analysis of the observed data showed that the law of flow through the measuring section of the flume when it was partly full followed that of the flow over an ogee dam crest when it is submerged. Horton made such an assumption in his analysis of the discharge over submerged dams in the U. S. Department of Waterways Experiments.* By plotting the data from the runs with the

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* W. S. Paper No. 200, page 146.

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same degree of submergence on logarithmic paper, a straight line was found which has a slope ratio of 1.59 which is the exponent of h_a in the equation

$$Q = C\, W_b\, h_a^n$$

where C = an experimental coefficient dependent on the ratio of submergence, h_b/h_a.

W_b = width of the throat section

h_a = elevation of the water surface in the entrance section above the crest of the throat section

Column 9 - Coefficient of Discharge, C (Computed) - From the value of $h_a^{1.59}$ in column 8 and the observed quantity in column 2, the coefficient of discharge was found by substituting in the formula:

$$C = \frac{Q}{W_b \ h_a^{1.59}}$$

where W_b = 0.507 ft.

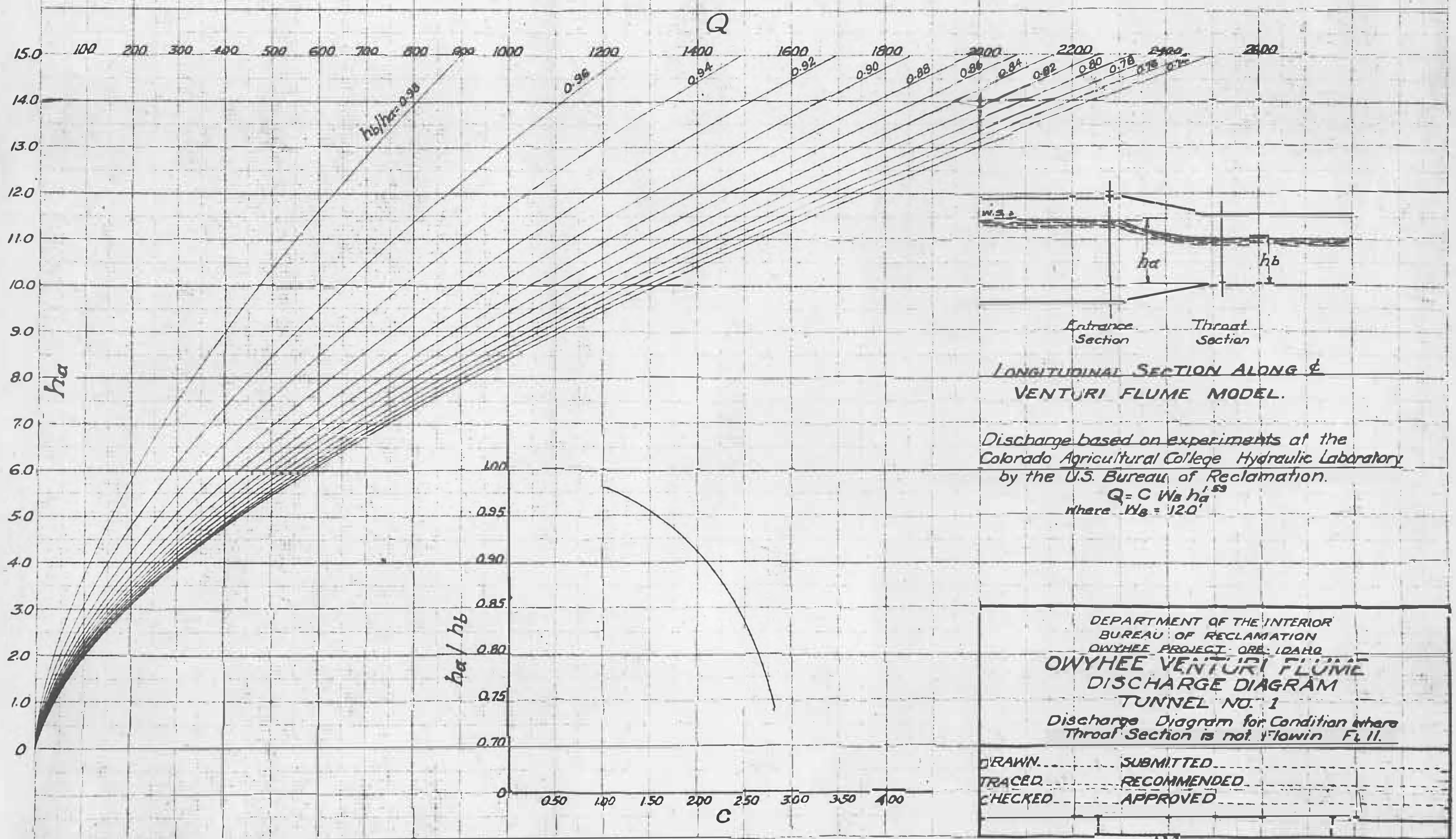
Column 10 - Coefficient of Discharge, C (From Curve) - From the values of h_a/h_b in column 7, the curve shown on Plate V may be entered and the coefficient of discharge found.

Column 11 - Calculated Discharge, Q_c - From the values of $h_a^{1.59}$ in column 8 and the coefficient of discharge in column 10

$$Q_c = C \ W_b \ h_u^{1.59}$$

where W_b = 0.507

Columns 12 and 13 - Q_o - Q_c and Deviation in Per Cent - See columns 12 and 13 in Table No. 1.



Q
100 200 300 400 500 600 700 800 900 1000 1200 1400 1600 1800 2000 2200 2400 2600
hb/ha = 0.98
0.96
0.94
0.92
0.90
0.88
0.86
0.84
0.82
0.80
0.78
ha
15.0 14.0 13.0 12.0 11.0 10.0 9.0 8.0 7.0 6.0 5.0 4.0 3.0 2.0 1.0 0
ha / hb
1.00 0.95 0.90 0.85 0.80 0.75 0.70 0
0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00
C
W.S.
ha
hb
Entrance Section
Throat Section
LONGITUDINAL SECTION ALONG ℄
VENTURI FLUME MODEL.
Discharge based on experiments at the
Colorado Agricultural College Hydraulic Laboratory
by the U.S. Bureau of Reclamation.
Q = C Wв ha1.58
where Wв = 12.0'
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
OWYHEE PROJECT - ORE - IDAHO
OWYHEE VENTURI FLUME
DISCHARGE DIAGRAM
TUNNEL NO. 1
Discharge Diagram for Condition where
Throat Section is not Flowing Full.
DRAWN
TRACED
CHECKED
SUBMITTED
RECOMMENDED
APPROVED

TABLE 5-A

COMPUTATION OF DISCHARGE Q, FOR [illegible] VENTURI METER-FLUME MODEL.

h_a	h_b/h_a → / $h_a^{1.59}$ ↓ C →	0.74	0.76	0.78	0.80	0.82	0.84	0.86	0.88	0.90	0.92	0.94	0.96	0.98
		3.730	3.668	3.590	3.491	3.380	3.252	3.116	2.962	2.771	2.525	2.221	1.856	1.340
0.6	0.44386	0.83938	0.82544	0.80786	0.78560	0.76063	0.73182	0.70122	0.66656	0.62358	0.56822	0.49981	0.41767	0.30155
0.5	.33217	.62817	.61773	.60459	.58792	.56923	.54767	.52477	.49883	.46666	.42524	.37404	.31257	.22567
0.4	.23296	.44055	.43323	.42402	.41232	.39921	.38410	.36803	.34984	.32728	.29823	.26232	.21921	.15827
0.3	.14744	.27883	.27419	.26836	.26096	.25266	.24309	.23293	.22142	.20714	.18875	.16602	.13874	.10017
0.2	.07736	.14634	.14390	.14084	.13696	.13260	.12758	.12225	.11621	.10871	.09906	.08713	.07281	.05257
0.1	.02570	.04861	.04780	.04678	.04549	.04405	.04238	.04061	.03860	.03611	.03291	.02894	.02419	.01746

TABLE 5-[illegible]

[illegible] OF DISCHARGE Q, FOR [illegible] PROTOTYPE

h_a	h_b/h_a → / $h_a^{1.59}$ ↓ C →	0.74	0.76	0.78	0.80	0.82	0.84	0.86	0.88	0.90	0.92	0.94	0.96	0.98
		2.806	2.759	2.700	2.626	2.542	2.446	2.344	2.228	2.084	1.899	1.671	1.396	1.008
14.2014	67.9527	2287.749	2249.755	2201.895	2141.170	2073.114	1994.592	1911.191	1816.724	1699.581	1548.696	1362.243	1138.869	821.881
11.8345	50.8521	1712.091	1683.637	1647.823	1602.389	1551.449	1492.687	1430.272	[illegible]	1271.892	1159.001	1019.404	851.916	615.068
9.4676	35.6633	1200.729	1180.775	1155.676	1123.787	1088.056	1046.873	1003.074	[illegible]	892.009	812.802	714.959	597.462	431.368
7.1007	22.5720	759.957	747.311	731.421	711.252	688.630	662.547	[illegible]	603.485	564.565	514.442	[illegible]	378.139	273.016
4.7338	11.8463	398.853	392.203	383.863	373.287	361.404	347.722	[illegible]	316.733	[illegible]	[illegible]	237.475	198.445	143.280
2.3669	3.9350	132.488	130.280	127.514	12[illegible].984	120.069	115.508	110.[illegible]	105.205	[illegible]	[illegible]	78.977	[illegible]	47.568

DATA

Model

$Q = C\ W_{bm}\ h_a^{1.59}$

where $W_{bm} = 0.507$

Prototype

$W_b = 12.0'$

$W_{bm} = 0.507'$

$n = \frac{W_b}{W_{bm}} = \frac{12.0}{0.507}$

$= 23.669$

$h_a = n\ h_{am}$

$= 23.669\ h_{am}$

$Q = n^{5/2}\ Q_m$

$= 2725.122\ Q_m$

TRANSFERENCE OF RESULTS FROM MODEL TO PROTOTYPE
(Venturi Flume Conditions)

The computed coefficient of discharge "C" in column 9, Table No. 4, was plotted on Plate C as the ordinate and the ratio of submergence as the abscissa and a curve drawn through the points.

The discharge Q in the model was computed for different ratios of submergence and the different values of h_a. These results are shown in Table No. ~~5-A~~,

The original plans for the model were made with a scale ratio of 1:24 but as wood was used for the construction the expansion of the model due to absorption of water changed the scale ratio slightly.

In this case, where the throat was flowing partly full, it was assumed that the width of the throat would have the major effect and the ratio of the actual width of the throat in the model to that in the prototype was taken as a scale ratio; i. e.,

$$n = \frac{0.507}{12.000} = 23.669$$

With this value of n: from the laws of hydraulic similitude

$$Q:Q_m = n^{5/2} :1$$

$$\text{or } Q = 2725.522\ Q_m$$

$$W_b:W_{bm} = n : 1$$

$$\text{or } W_b = 23.669\ W_{bm}$$

$$h_a:h_{am} = n : 1$$

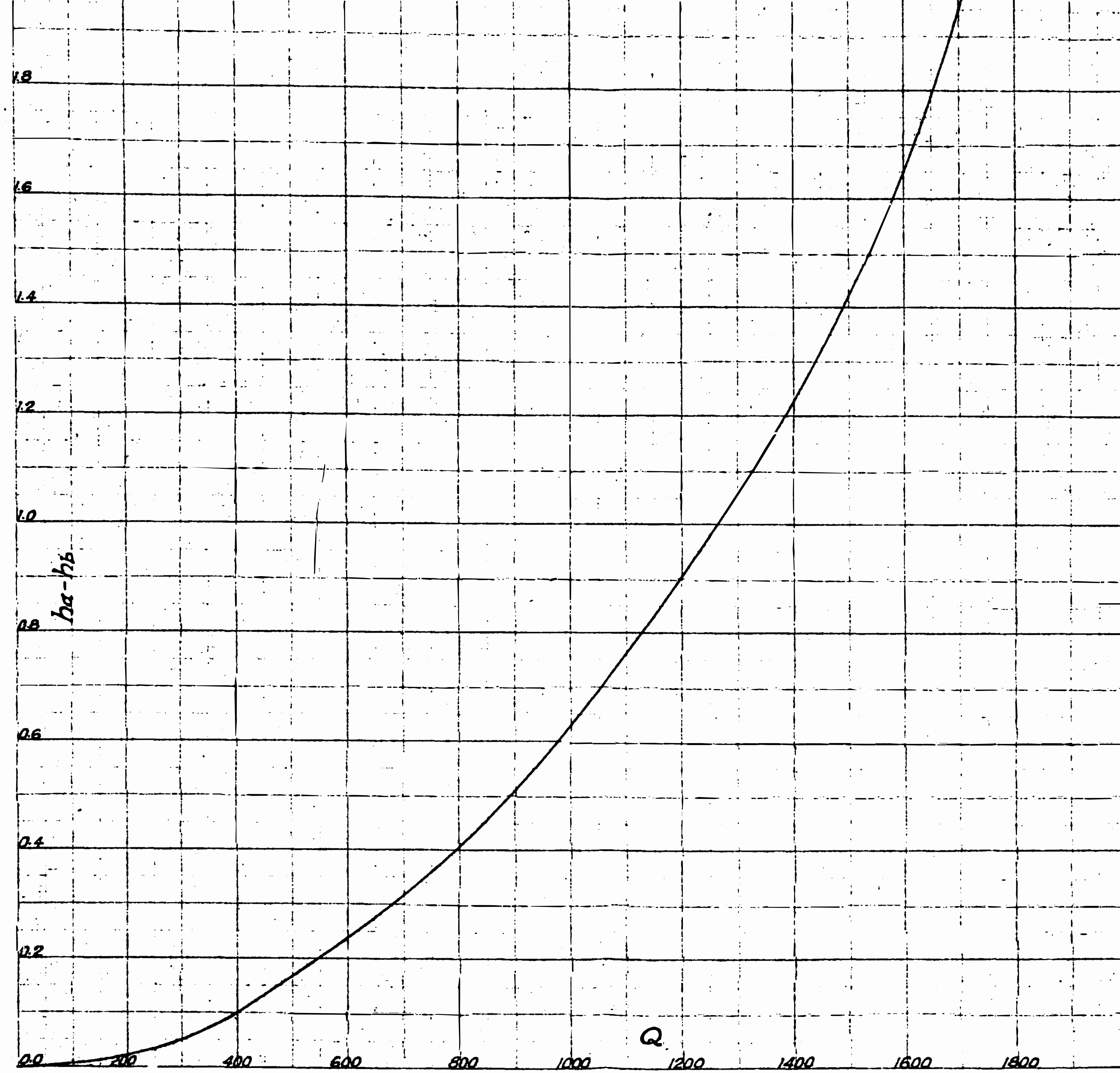
$$\text{or } h_a = 23.669\ h_{am}$$

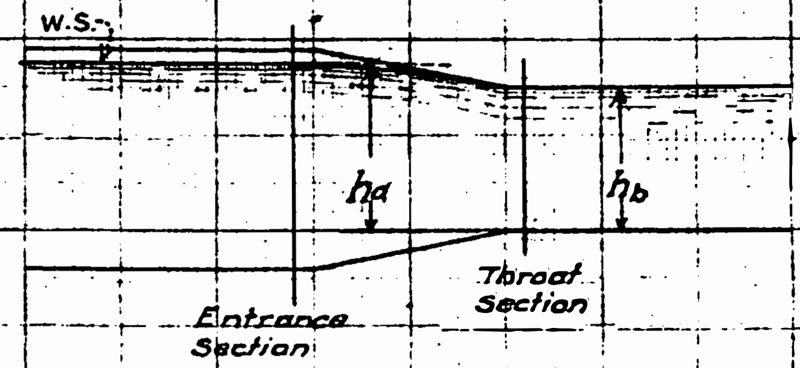
in which Q stands for discharge; W_b, the width of the throat section; h_a, the elevation of the water surface in the entrance section above the crest of the throat section; and the subscript m indicates values for the model.

The discharge data for the prototype was computed by multiplying the values of h_a in Table No. ~~5-A~~ by the scale ratio, n, and the discharge quantities were computed by multiplying the model quantities by $n^{5/2}$. The prototype data is recorded in Table No. ~~5-B~~.

With the h_a, Q and W_b known, the value of C was computed and plotted on Plate D.

The discharge diagram, ~~Plate F~~, was plotted using the values of h_a, h_b/h_a and Q in Table No. ~~5-B~~.





LONGITUDINAL SECTION ALONG CENTER LINE
VENTURI-METER FLUME MODEL.

Discharge based on experiments at the Colorado Agricultural College Hydraulic Laboratory by the U.S. Bureau of Reclamation.

$$Q = C K (h_a - h_b)^{1/2}$$

where $K = \sqrt{\dfrac{A_b^2 \; 2g}{1-\left(\dfrac{A_b}{A_a}\right)^2}}$

and $C = \dfrac{Q}{K(h_a - h_b)^{1/2}}$

DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
OWYHEE PROJECT - ORE - IDAHO

OWYHEE VENTURI-METER FLUME DISCHARGE DIAGRAM TUNNEL NO. 1

Discharge Diagram for Condition where Entrance Section Partially Full and Throat Section Full.

DRAWN........ SUBMITTED........
TRACED........ RECOMMENDED........
CHECKED........ APPROVED........

PLATE I