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THE COLORADO STATUTE INCH AND SOME MINER'S INCH MEASURING DEVICES

By V. M. CONE

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THE COLORADO STATUTE INCH AND SOME MINER'S INCH MEASURING DEVICES

By V. M. CONE

The question is often asked, "What is a Miner's Inch," or an "inch of water?"

The "Inch" is a unit of measure of flowing water which has been handed down to the irrigators of the West by the early day miners. There are several different Miner's Inches, and they are sometimes called "Customary Inches," which means the "Inch" principally used in any certain locality. When the value of the "Inch" or the conditions under which the "Inch" shall be measured is fixed by law, it is called a "Statute Inch."

An "Inch" of water is an indefinite quantity. It is the flow through an inch square orifice, but the flow varies with the size of the orifice, the distance from the top of the orifice to the surface of the water, and the method of placing the orifice. These conditions are not uniform in the different localities and it is not uncommon to see different standards on a single irrigation ditch. The depth of the orifice varies from 1 to 12 inches and the water pressure varies from zero to 6 inches above the top of the orifice. The orifice may be thin edged or a square cut leaving the edge the full thickness of the plank, and the issuing stream of water may flow free into the air or it may be partly covered by "back-water" on the down-stream side. The orifice may be placed in a large box where the water is practically at rest, or it may be placed in a small box where the water approaches the orifice with considerable velocity. Sometimes the orifice is the open end of a long box or tube placed in a nearly horizontal position through the ditch bank. Each of these conditions affect the quantity of water which will flow through a square inch of the orifice and it will therefore be seen that the "Inch" of water may be a variable quantity when measured in accordance with the following Colorado law:

"———; and water sold by the inch by an individual or corporation shall be measured as follows, to-wit: Every inch shall be considered as equal to an inch square orifice under a five-inch pressure and a five-inch pressure shall be from the top of the orifice of the box put into the banks of the ditch, to the surface of the water; said boxes, or any slot or aperture through which such water may be measured, shall in all cases be six inches perpendicular, inside measurement, except boxes delivering less than twelve inches, which may be square, with or without slides; all slides for the same shall move horizontally and not otherwise; and said box put into the banks of the ditch shall have a descending grade from the water in ditch of not less than one-eighth of an inch to the foot." (L. '74, p. 308.)

According to ex-State Engineer, John E. Field, the above law, which was passed in 1874, was drafted to meet the conditions under which irrigation water was being measured at that time in the vicinity of Denver. A box made of boards 16 feet long was placed through the ditch bank, and it was given a grade of at least one-eighth of an inch to the foot. If the irrigator had a water-right of 36 inches, the box would be made 6 inches square, inside measurement, and for 60 inches, it would be made 6 inches deep by 10 inches wide. It is interesting to note that although the law was intended to apply to the flow through such tube-boxes, it is so worded that it applies to practically all types of inch devices. Very few tube-boxes are used in Colorado now, nearly all inch measurements being made through thin edged orifices placed in the vertical side of a box so the issuing stream of water flows free into the air.

Former State Engineer, Nettleton, computed the flow through an orifice to correspond to the Colorado law, and stated the quantity to be 1/38.4 of a cubic foot per second. This value has been assumed to be the value of the Colorado "Statute Inch."

In order to secure definite information concerning the Colorado statute inch a series of experiments were made in the hydraulic laboratory, at Fort Collins, Colorado, during the fall of 1914 and the spring of 1915. The results of these experiments are given in the tables in this bulletin for the use of engineers and others who may have need of the actual data. Experiments were also made with one type of measuring device used in the Uncompahgre Valley, and with one of the Miner's Inch devices used in Southern California known as the Azusa hydrant.

COLORADO STATUTE INCH.

Box-Tubes.—Many of the water rights in Colorado are stated in inches, though there are but few irrigation systems in the state under which the water is actually measured in inches. The water is usually measured in second feet, but it is necessary to know the quantity of water that will flow through orifices under the terms of the Colorado law in order that the irrigator may receive the amount he is entitled to.

In reply to an inquiry concerning the method of installing the outlet or tube-box, Mr. John E. Field gave the following description of the practice of 30 or 40 years ago. "In the earlier practice it was seldom that an effort was made to regulate the head over the outlet boxes. Where this effort was made, it was by means of a box or long-crested weir which would discharge back into the ditch the surplus water entering the box. This box or flume was placed parallel to the bank of the ditch and the outlet box was placed at the lower end. This did not regulate the head absolutely, but only approximately. Where this method was not used, the boxes were placed so that when the ditch was at normal stage there would be a 5-inch pressure. When there was a greater amount of water in the ditch, then the discharge through the box was greater, and when it was less it was in the nature of cutting down the amount purchased and a rough pro-rating of the available amount. When the ditch was very low this pro-rating was done by shutting down the boxes partially.

even below the amount which had been purchased. Sometimes the head was maintained by having a check in the ditch, but when the amount of water in the ditch was small, this was generally prohibited, as those at the upper end of the ditch would receive their full amount and those at the lower end would get practically nothing."

The results of the experiments with tube-boxes are given in table 1. The boxes were 16 feet long and were given a descending grade of ⅛-inch to the foot. The discharge end was therefore 2 inches lower than the intake end. Metal strips ⅛ inch thick were placed around the intake end of each box so the inside dimensions of the orifice could be accurately determined. The inside depth of the box was practically 6 inches in every case and the water surface was 5 inches above the top of the orifice. So far as the law is concerned, the width of the box need not be the same as the width of the orifice, and experiments were therefore made with different widths of boxes for each width of orifice. A thin metal slide was made to fit between the metal strips on the end of the box, and this was adjusted to give any width of opening from 2 to 16 inches.

TABLE 1.

RESULTS OF EXPERIMENTS WITH COLORADO STATUTE INCH DEVICES (TUBE BOX).

	Orifice				Discharge in Cubic Feet per Sec.			
No. of Experiment	D Depth in Inches	B Breadth in Inches	Nominal Area in Sq. Inches	Width of Box Inches	Observed By Experiment	Corrected for Nominal Area	Curve Value	Statute Inches to One Sec. Ft.
2738	6.025	2.002	12	2	.348	.346	.345	34.8
2739	6.028	2.004	12	2	.347	.345	.345	
2740	6.053	2.005	12	4	.347	.343	.343	35.0
2741	6.053	2.005	12	4	.346	.342	.343	
2745	6.059	2.002	12	6	.344	.340	.341	35.2
2746	6.059	2.002	12	6	.343	.339	.341	
2751	6.068	2.000	12	8	.352	.348	.346	34.7
2752	6.068	2.000	12	8	.351	.347	.346	
2777	6.058	2.005	12	14	.343	.339	.338	35.5
2778	6.058	2.005	12	14	.341	.337	.338	
2791	6.052	2.000	12	16	.359	.356	.356	32.7
2792	6.052	2.000	12	16	.360	.357	.356	
2807	6.034	2.004	12	16	.358	.355	.354	33.9
2809	6.034	2.004	12	16	.357	.354	.354	
2743	6.040	3.995	24	4	.647	.643	.643	37.3
2744	6.040	3.995	24	4	.646	.643	.643	
2747	6.042	3.997	24	6	.658	.654	.653	36.8
2748	6.041	3.999	24	6	.656	.652	.653	
2753	6.057	4.002	24	8	.664	.657	.658	36.5
2754	6.057	4.002	24	8	.664	.657	.658	
2759	6.062	3.998	24	10	.666	.659	.661	36.3
2760	6.062	3.998	24	10	.667	.660	.661	
2767	6.072	4.001	24	12	.672	.664	.664	36.1
2768	6.072	4.001	24	12	.673	.665	.664	
2779	6.058	3.999	24	14	.665	.659	.658	36.5
2780	6.058	3.999	24	14	.663	.657	.658	
2793	6.054	4.004	24	16	.671	.664	.663	36.2
2794	6.054	4.004	24	16	.670	.663	.663	

TABLE 1.—Continued.

RESULTS OF EXPERIMENTS WITH COLORADO STATUTE INCH DEVICES (TUBE BOX).

	Orifice				Discharge in Cubic Feet per Sec.			
No. of Experiment	D Depth in Inches	B Breadth in Inches	Nominal Area in Sq. Inches	Width of Box Inches	Observed By Experiment	Corrected for Nominal Area	Curve Value	Statute Inches to One Sec. Ft.
2749	6.036	6.002	36	6	.953	.947	.945	38.1
2750	6.036	6.002	36	6	.950	.944	.945	
2755	6.051	6.000	36	8	.969	.961	.963	37.4
2756	6.051	6.000	36	8	.970	.962	.963	
2761	6.061	6.002	36	10	.985	.975	.970	37.1
2762	6.061	6.002	36	10	.984	.974	.970	
2769	6.068	6.000	36	12	.986	.975	.976	36.9
2770	6.068	6.000	36	12	.986	.975	.976	
2781	6.061	6.001	36	14	.991	.981	.991	36.3
2782	6.061	6.001	36	14	.989	.979	.991	
2795	6.046	6.001	36	16	.986	.978	.978	36.8
2796	6.046	6.001	36	16	.987	.979	.978	
2757	6.039	8.003	48	8	1.265	1.256	1.252	38.3
2758	6.039	8.003	48	8	1.258	1.249	1.252	
2763	6.054	7.999	48	10	1.285	1.274	1.275	37.6
2764	6.054	7.999	48	10	1.287	1.276	1.275	
2771	6.068	7.998	48	12	1.299	1.285	1.283	37.4
2772	6.068	7.998	48	12	1.296	1.282	1.283	
2783	6.063	8.001	48	14	1.309	1.295	1.291	37.2
2784	6.063	8.001	48	14	1.306	1.292	1.291	
2797	6.050	8.008	48	16	1.301	1.289	1.286	37.3
2798	6.050	8.008	48	16	1.298	1.286	1.286	
2765	6.054	10.004	60	10	1.576	1.561	1.565	38.3
2766	6.054	10.004	60	10	1.586	1.571	1.565	
2773	6.064	10.003	60	12	1.602	1.585	1.586	37.8
2774	6.064	10.003	60	12	1.601	1.584	1.586	
2785	6.068	9.998	60	14	1.603	1.585	1.594	37.6
2786	6.068	9.998	60	14	1.606	1.588	1.594	
2799	6.054	10.004	60	16	1.612	1.597	1.596	37.6
2800	6.054	10.004	60	16	1.607	1.592	1.596	
2775	6.063	12.004	72	12	1.892	1.872	1.873	38.4
2776	6.063	12.004	72	12	1.894	1.874	1.873	
2787	6.073	12.007	72	14	1.931	1.907	1.896	38.0
2788	6.073	12.007	72	14	1.929	1.905	1.896	
2801	6.054	12.000	72	16	1.915	1.898	1.898	37.9
2802	6.054	12.000	72	16	1.916	1.899	1.898	
2789	6.077	14.002	84	14	2.218	2.190	2.190	38.4
2790	6.077	14.002	84	14	2.219	2.191	2.190	
2803	6.058	14.004	84	16	2.234	2.212	2.206	38.1
2804	6.058	14.004	84	16	2.222	2.200	2.206	
2805	6.060	15.996	96	16	2.543	2.518	2.520	38.1
2806	6.060	15.996	96	16	2.547	2.522	2.520	

The discharge for each size of orifice and box is given in second feet in the next to the last column in table 1, and the number of statute

inches equal to one second foot is given in the last column. It will be seen that, in general, the discharge for any certain size of orifice increases as the width of the box is increased, except for a slight reduction when the orifice is nearly the same size as the box. The number of statute inches to one second foot therefore decreases with a decrease in the size of the box, and it will also be noticed that the number of statute inches to one second foot increases as the size of the orifice is increased, which means that the discharge of each square inch of orifice decreases as the size of the orifice is increased. This is the opposite to the results obtained with thin-edged orifices having free flow, as given in tables 2 and 3. Box-tubes with orifices from 12 to 96 square inches gave discharges with the number of statute inches to one second foot varying from 33.7 to 38.4, and a greater number would no doubt be obtained for still larger orifices.

Thin-Edged Orifices With Free Flow.—A large majority of the present day Miner's Inch devices have a thin-edged orifice placed in the vertical side of a box, so the water passes into the air as it flows through the orifice. Experiments were made with this type of orifice in sizes ranging from 1 inch square to 6 inches deep by 16 inches wide. The depth of water above the top of the orifice was five inches in every case. The brass orifice taples were placed in the end of a concrete box having a cross-section of 10 feet by 6 feet deep. The experimental results are given in tables 2 and 3.

TABLE 2.

RESULTS OF EXPERIMENTS WITH COLORADO STATUTE INCH DEVICES.
(Thin edged orifices.)

	Orifice			Discharge in Cubic Feet Per Sec.		
No. of Experiment	D Depth in Inches	B Breadth in Inches	Nominal area in Sq. Inches	Observed by experiment	Corrected for Nominal area	Curve Values
1395	1.005	1.004	1	.024	.024	.024
1396	1.005	1.004	1	.024	.024	.024
1393	1.000	2.003	2	.047	.047	.047
1394	1.000	2.003	2	.047	.047	.047
1387	1.005	3.011	3	.072	.071	.071
1388	1.005	3.011	3	.072	.071	.071
1385	1.000	4.003	4	.095	.095	.095
1386	1.000	4.003	4	.095	.095	095
1379	1.005	5.000	5	.119	.118	.118
1380	1.005	5.000	5	.119	.118	118
1391	2.003	1.000	2	.049	.049	.049
1392	2.003	1.000	2	.049	.049	.049
1377	2.006	2.001	4	.096	.096	.097
1378	2.006	2.001	4	.097	.097	.097
1373	2.001	2.998	6	.145	.145	.145
1374	2.001	2.998	6	.145	.145	.145
1369	2.005	4.004	8	.194	.193	.193
1370	2.005	4.004	8	.194	.193	.193
1365	2.009	5.007	10	.243	.242	.242
1366	2.009	5.007	10	.243	.242	.242

TABLE 2.—Continued.

RESULTS OF EXPERIMENTS WITH COLORADO STATUTE INCH DEVICES.

(Thin edged orifices.)

No. of Experiment	Orifice		Nominal area in Sq. Inches	Discharge in Cubic Feet Per Sec.		
	D Depth in Inches	B Breadth in Inches		Observed by experiment	Corrected for Nominal area	Curve Values
1389	3.011	1.005	3	.077	.076	.076
1390	3.011	1.005	3	.077	.076	.076
1375	2.998	2.001	6	.150	.150	.150
1376	2.998	2.001	6	.149	.149	.150
1363	3.018	3.005	9	.227	.225	.223
1364	3.018	3.005	9	.227	.225	.223
1359	3.002	4.008	12	.299	.298	.298
1360	3.002	4.008	12	.299	.298	.298
1355	3.007	5.033	15	.378	.375	.375
1356	3.007	5.033	15	.378	.375	.375
1383	4.003	1.000	4	.106	.106	.105
1384	4.003	1.000	4	.105	.105	.105
1371	4.004	2.005	8	.208	.207	.207
1372	4.004	2.005	8	.208	.207	.207
1361	4.008	3.002	12	.313	.312	.309
1362	4.008	3.002	12	.310	.309	.309
1353	3.999	4.007	16	.411	.410	.410
1354	3.999	4.007	16	.411	.410	.410
1349	4.005	5.020	20	.515	.512	.513
1350	4.005	5.020	20	.515	.512	.513
1381	5.000	1.005	5	.137	.136	.137
1382	5.000	1.005	5	.138	.137	.137
1367	5.007	2.009	10	.271	.269	.268
1368	5.007	2.009	10	.271	.269	.268
1357	5.033	3.007	15	.403	.399	.398
1358	5.033	3.007	15	.401	.397	.398
1351	5.020	4.005	20	.533	.530	.530
1352	5.020	4.005	20	.529	.526	.530
1347	5.014	5.006	25	.663	.660	.662
1348	5.014	5.006	25	.665	.662	.662
1345	6.006	2.005	12	.331	.330	.332
1346	6.006	2.005	12	.333	.332	.332
1343	6.006	3.998	24	.652	.652	.650
1344	6.006	3.998	24	.651	.651	.650
1341	6.006	6.002	36	.975	.974	.972
1342	6.006	6.006	36	.982	.981	.972
1339	6.006	7.997	48	1.306	1.305	1.302
1340	6.006	7.997	48	1.308	1.307	1.302
1337	6.006	9.995	60	1.636	1.635	1.631
1338	6.006	9.995	60	1.637	1.636	1.634
1335	6.006	11.997	72	1.968	1.967	1.970
1336	6.006	11.997	72	1.972	1.971	1.970
1333	6.006	13.997	84	2.303	2.301	2.304
1334	6.006	13.997	84	2.301	2.299	2.304
1331	6.006	15.998	96	2.645	2.643	2.641
1332	6.006	15.998	96	2.640	2.638	2.641
2335	12.069	12.066	144	4.588	4.537	
2336	12.069	12.066	144	4.577	4.526	

TABLE 3.

DISCHARGE THROUGH MINER'S INCH ORIFICES OF VARIOUS SIZES*

†B	‡D—1 Inch			D—2 Inches			D—3 Inches			D—4 Inches			D—5 Inches			D—6 Inches		
	Discharge—Cu. ft. per sec.	Discharge—Cu. ft. per sec. per sq. in. of opening.	Number of Miners' Inches to one sec. ft.	Discharge—Cu. ft. per sec.	Discharge—Cu. ft. per sec. per sq. in. of opening.	Number of Miners' Inches to one sec. ft.	Discharge—Cu. ft. per sec.	Discharge—Cu. ft. per sec. per sq. in. of opening.	Number of Miners' Inches to one sec. ft.	Discharge—Cu. ft. per sec.	Discharge—Cu. ft. per sec. per sq. in. of opening.	Number of Miners' Inches to one sec. ft.	Discharge—Cu. ft. per sec.	Discharge—Cu. ft. per sec. per sq. in. of opening.	Number of Miners' Inches to one sec. ft.	Discharge—Cu. ft. per sec.	Discharge—Cu. ft. per sec. per sq. in. of opening.	Number of Miners' Inches to one sec. ft.
1....	.024	.0240	41.7	.049	.0245	40.8	.076	.0253	39.5	.105	.0263	38.1	.137	.0273	36.6	.169	.0282	35.5
2....	.047	.0235	42.6	.097	.0243	41.2	.150	.0250	40.0	.207	.0259	38.7	.268	.0268	37.3	.331	.0276	36.3
3....	.070	.0233	42.9	.145	.0242	41.4	.223	.0248	40.4	.309	.0257	38.8	.398	.0265	37.7	.491	.0273	36.7
4....	.094	.0235	42.6	.193	.0241	41.5	.298	.0248	40.3	.410	.0256	39.0	.530	.0265	37.7	.650	.0271	36.9
5....	.118	.0236	42.4	.242	.0242	41.3	.375	.0250	40.0	.513	.0257	39.0	.662	.0265	37.8	.810	.0270	37.0
6....	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	.973	.0270	37.0
7....	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	1.14	.0271	36.9
8....	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	1.30	.0271	36.9
9....	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	1.47	.0272	36.8
10....	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	1.64	.0273	36.7
11....	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	1.80	.0273	36.6
12....	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	1.97	.0274	36.6
13....	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	2.14	.0274	36.5
14....	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	2.30	.0274	36.5
15....	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	2.47	.0275	36.4
16....	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	2.64	.0275	36.3

*Shapes of orifices conform to Colorado Statute. Head was 5 inches above top of orifice opening in all cases.

†B—Breadth or horizontal dimension of orifice in inches.

‡D—Depth or vertical dimension of orifice in inches.

Table 3 shows some interesting points. The discharge for each square inch of opening increases as the size of the opening is increased. For a constant depth of orifice the discharge per square inch of opening is the greatest for a width of 1 inch, decreases as the width is increased for a few inches, or approximately until the orifice is square for the larger sizes of orifices, and then increases as the width is increased. The number of Statute Inches to one second-foot varies from 42.9 to 35.5, but for the sizes of orifices commonly used, for measuring water to the individual irrigator, it is probable the value would be from 36 to 37, and as low as 35 might be obtained for wider orifices. The discharges given in table 3 are probably the least quantities that can be obtained for orifices of that type, because they were thin-edged, the velocity of approach was negligible, and the contractions were complete.

The discharge through full contraction, thin-edged, free-flow orifices having a depth or vertical dimension of 6 inches and a head of 5 inches above the top of the orifice, is represented by the formula,

$$Q = 0.169b - 0.06 + \frac{0.06}{1 + 0.015\ b^{2.6}}$$

in which Q is in second-feet, and b is the breadth or horizontal dimension of the orifice in inches.

Uncompahgre Orifice.—The type of orifice shown in figures 1 and 2 has been used for years on some of the canal systems now included in the Uncompahgre project of the U. S. Reclamation Service, and they conform to the Colorado Inch law in all respects as long as a 5-inch depth of water is maintained over the top of the orifice. The side of the box in which the orfice is placed is made 5 inches higher than the top of the orifice for a length of 5 feet, which acts as a spillway to regulate the head, but it is occasionally necessary to run a greater or less amount of water for short periods. When necessary to deliver 90 or 75 per cent of the full head temporarily the depth of water in the box will decrease as the depth decreases in the ditch, which saves changing the size of all of the orifices and they act somewhat as proportional dividers of the flow because all of the boxes on a ditch are set under almost identical conditions. When the supply of water in the ditch is greater than normal, the boxes act as spill-boxes. Mr. F. D. Pyle, manager of the Uncompahgre Project, has added a heavy galvanized iron orifice plate to the original device. The orifice is 6 inches deep and is provided with a slide which moves horizontally. Holes punched through the orifice plate and slide allow the slide to be set for each 0.05 second-foot up to 2 second feet and a padlock placed through the hole prevents the size of the orifice being tampered with after it is set by the ditch rider. Graduations on the side of the orifice indicate its discharge when operating as a weir.

The discharges through the Uncompahgre orifice under various conditions are given in table 4. Although the original water-rights are expressed in inches, the water is delivered in second-feet. By comparing tables 3 and 4 it will be seen that the discharge is greater through the

TABLE 4.

DISCHARGE FROM UNCOMPAHGRE ORIFICE IN CUBIC FEET PER SECOND

Width of Opening in Inches.	Depth of Water Surface to Bottom of Orifice Opening in Inches.																				
	2	2½	3	3½	4	4½	5	5½	6	6½	7	7½	8	8½	9	9½	10	10½	11	11½	12
2	.04	.05	.07	.09	.11	.13	.15	.17	.20	.22	.24	.25	.27	.29	.30	.31	.32	.34	.35	.36	.37
2½	.05	.06	.08	.10	.13	.16	.19	.21	.24	.27	.30	.32	.34	.36	.38	.40	.41	.42	.43	.44	.45
3	.06	.08	.10	.13	.16	.19	.22	.26	.29	.33	.36	.38	.40	.43	.45	.47	.49	.51	.52	.53	.54
3½	.06	.09	.12	.15	.18	.22	.26	.30	.34	.38	.42	.45	.47	.50	.53	.55	.57	.59	.61	.62	.63
4	.07	.10	.13	.17	.21	.25	.29	.34	.39	.43	.47	.51	.54	.57	.60	.63	.65	.67	.69	.71	.72
4½	.08	.11	.15	.19	.23	.28	.33	.38	.43	.48	.53	.57	.60	.64	.67	.70	.73	.76	.78	.80	.82
5	.08	.11	.15	.19	.23	.31	.33	.38	.43	.48	.59	.63	.67	.71	.74	.78	.81	.84	.86	.89	.91
5½	.10	.14	.18	.23	.28	.34	.40	.46	.52	.59	.65	.69	.73	.78	.82	.86	.89	.92	.95	.98	1.00
6	.11	.15	.20	.25	.30	.36	.43	.50	.56	.64	.70	.75	.80	.85	.89	.93	.97	1.00	1.03	1.06	1.09
6½	.12	.16	.21	.27	.33	.39	.46	.54	.61	.69	.76	.81	.86	.91	.96	1.00	1.04	1.08	1.12	1.15	1.18
7	.13	.18	.23	.29	.35	.42	.50	.57	.65	.74	.81	.87	.92	.98	1.03	1.08	1.12	1.16	1.20	1.24	1.28
7½	.14	.19	.25	.31	.38	.45	.53	.61	.69	.79	.87	.93	.98	1.04	1.10	1.15	1.20	1.25	1.29	1.33	1.37
8	.14	.20	.26	.33	.40	.48	.56	.64	.73	.83	.92	.99	1.05	1.11	1.17	1.23	1.28	1.33	1.37	1.42	1.46
8½	.15	.21	.28	.35	.42	.50	.59	.68	.78	.88	.97	1.05	1.11	1.18	1.24	1.30	1.36	1.41	1.46	1.51	1.56
9	.16	.22	.29	.37	.44	.53	.63	.72	.82	.93	1.02	1.10	1.17	1.24	1.31	1.37	1.43	1.49	1.54	1.60	1.65
9½	.17	.24	.31	.39	.47	.56	.66	.76	.86	.97	1.07	1.16	1.23	1.31	1.38	1.45	1.51	1.57	1.63	1.69	1.74
10	.18	.25	.33	.41	.49	.59	.69	.79	.90	1.02	1.13	1.22	1.30	1.38	1.45	1.52	1.59	1.65	1.71	1.77	1.83
10½	.19	.27	.34	.43	.51	.61	.72	.83	.94	1.07	1.18	1.28	1.36	1.44	1.51	1.59	1.66	1.73	1.79	1.85	1.91
11	.20	.28	.36	.45	.54	.64	.75	.87	.99	1.12	1.23	1.33	1.42	1.50	1.58	1.66	1.73	1.80	1.87	1.94	2.00
11½	.21	.29	.38	.46	.56	.67	.78	.90	1.03	1.16	1.28	1.38	1.48	1.57	1.65	1.73	1.81	1.88	1.95	2.02	2.09
12	.22	.30	.39	.48	.58	.69	.81	.94	1.07	1.21	1.33	1.44	1.54	1.63	1.72	1.80	1.88	1.96	2.03	2.10	2.17

Uncompahgre orifice, because of the comparatively high velocity of approach in the orifice box. Orifices are used for delivering only a part of the water under this project, rectangular weirs being also used.

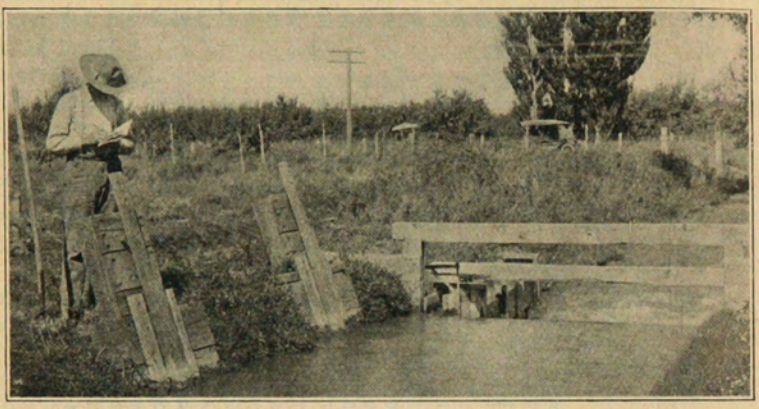

Figure 1. (a) Showing the usual method of placing an Uncompahgre orifice box in a ditch.

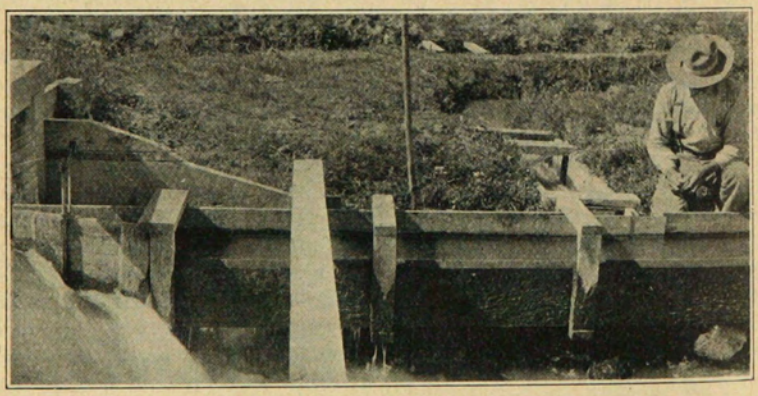

Figure 1. (b) Side view of Uncompahgre orifice spill-box.

AZUSA HYDRANT.

Where the price of irrigation water is high, as in Southern California, it is often desirable to do away with surface ditches and conduct the water to the land through underground pipes. This decreases the loss of water by seepage and evaporation, permits all of the land to be cultivated, and is especially desirable for orchard irrigation. The water is brought to the surface of the ground by standpipes which are arranged to deliver the water to several furrows. There are several

different kinds of measuring devices used in connection with underground pipe systems, but only one was experimented with.

The Azusa hydrant is used in the vicinity of Azusa, California. The essential features are shown in figure 3, and the details of the orifices are shown in figure 4. It consists of a concrete box about 6 feet high placed in the supply pipe line, with the orifice plate set in the side of the box so the tops of the orifices are 12 inches below the top of the box. An overflow crest placed on the top of a dividing wall in the box is 2 inches above the top of the orifices. The flow through the orifices is regulated by a gate in the dividing wall near the floor. There are 4 orifices each 4 inches deep and of different widths which are supposed to deliver 10, 15, 25 and 50 miner's inches upon the basis of 50 miner's inches to 1 second foot and they may be used singly or in a combination. The orifice plate is made of cast iron carefully machined.

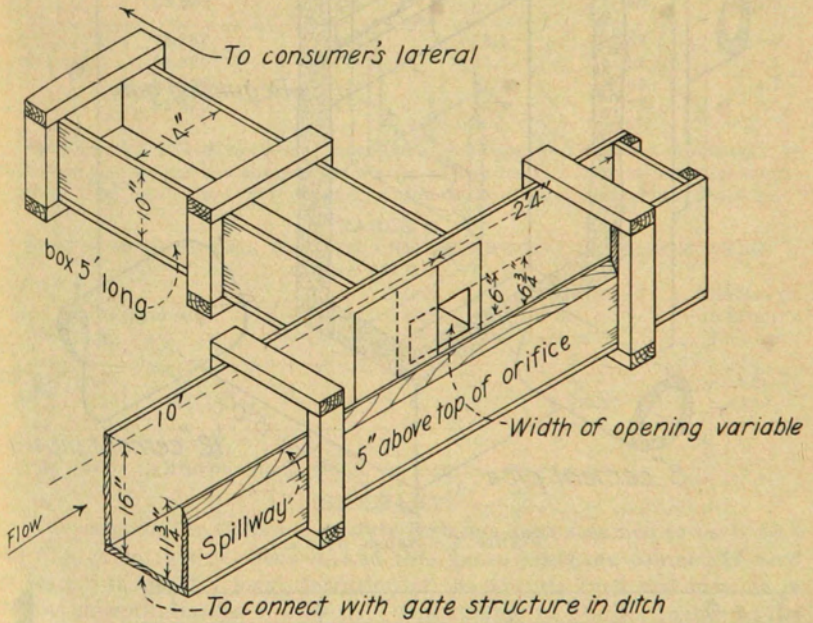

Figure 2. Some details of the Uncompahgre orifice.

The results of the experiments with the Azusa hydrant given in table 5, indicate the actual discharges to be from 2.0 to 6.4 percent less than the intended discharges. Table 6 gives the dimensions of orifices which will discharge the intended number of miner's inches. However, in actual practice the orifices become larger, due to the edges rusting, and the head of water is usually greater than 2 inches because a small amount is allowed to pass over the spillway or overflow.

In Bulletin 247 of the California Expkeriment Station, Mr. Frank Adams states the cost of the Azusa hydrant to be from $18 to $20 under a large contract, and about $30 when built singly. The orifice plate costs an additional $12.

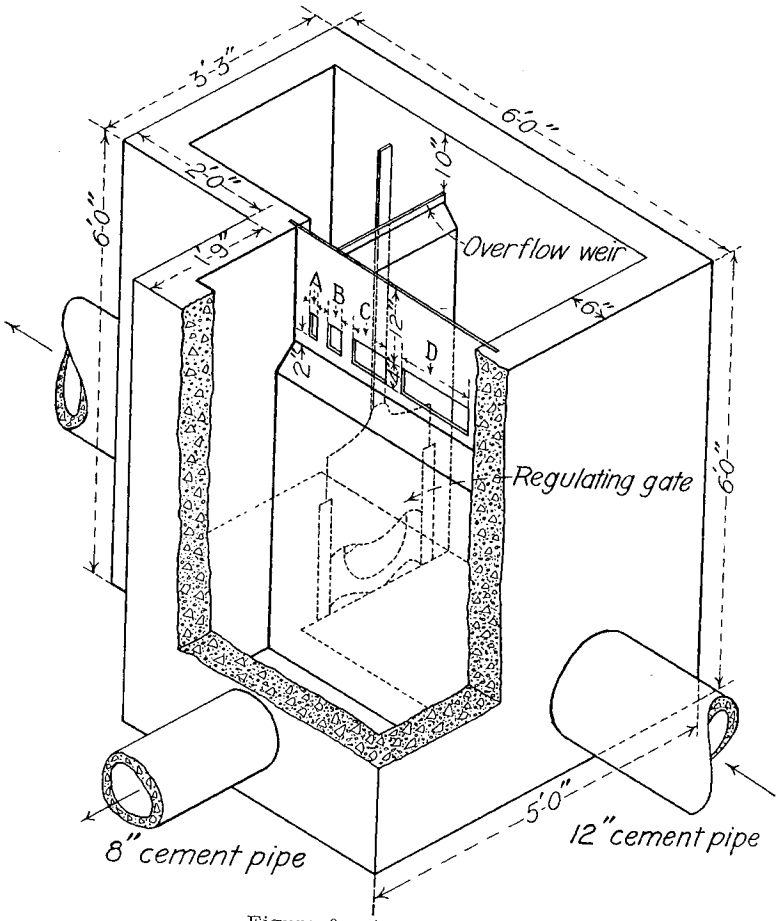

Figure 3. Azusa hydrant.

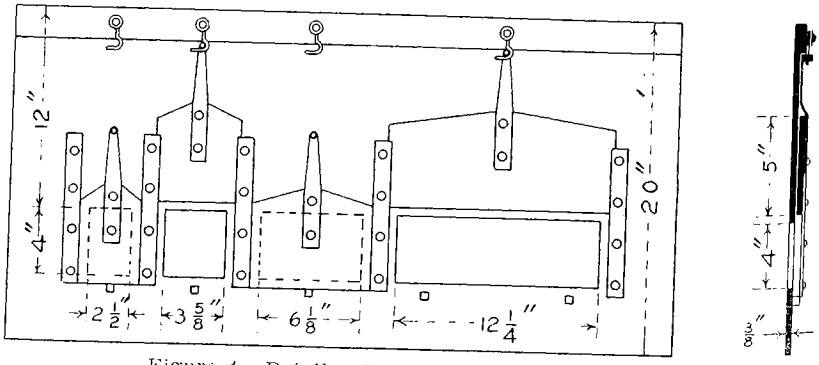

Figure 4. Details of Azusa hydrant orifice plate.

TABLE 5.
RESULTS OF EXPERIMENTS WITH AZUSA HYDRANT.

Opening	Actual Area of Opening in Square Inches	Actual Discharge in Cubic Feet per Second	Discharge in Miner's Inches Corrected for Nominal Area	Intended Discharge in Miner's Inches	Percent* of Error
A	9.991	.195	9.8	10	2.0
B	14.488	.281	14.1	15	6.4
C	24.494	.474	23.7	25	5.5
D	49.008	.967	48.4	50	3.3
A+B	24.479	.478	23.9	25	4.6
A+B+C	48.973	.959	48.0	50	4.2
A+B+C+D	97.981	1.925	96.3	100	3.8
A+B+D	73.487	1.439	72.0	75	4.2
A+C	34.485	.668	33.4	35	4.8
A+C+D	83.493	1.641	82.1	85	3.5
A+D	58.999	1.157	57.9	60	3.6
B+C	38.982	.762	38.1	40	5.0
B+C+D	87.990	1.729	86.5	90	4.1
B+D	63.496	1.248	62.4	65	4.2
C+D	73.502	1.451	72.6	75	3.3

*Percent of Error between intended discharge and correct discharge in Miners' inches, using the correct discharge as the basis. The Miners' Inch was taken as 1-50 cubic foot per second, which is Southern California practice.

TABLE 6.
WIDTH OF OPENINGS TO GIVE THE INTENDED DISCHARGE WITH AZUSA HYDRANT.

Opening	Depth in Inches	Width in Inches	Discharge in Miner's Inches*
A	4	2 9-16	10
B	4	3 7/8	15
C	4	6 15-32	25
D	4	12 5/8	50

*Southern California inch, which is 1-50 cu. ft. per sec.

SUMMARY.

The value of the Colorado Statute Inch has been assumed to be 1/38.4 part of a cubic foot per second, and this figure has been commonly used for years. It is not a legal definition of the Statute Inch and may be in error as shown in tables 1, 2 and 3. The number of Statute Inches to the second foot may vary from at least 33.7 to 42.9 and still conform to the law in every particular. Although the use of the Statute Inch is somewhat limited at the present time, it is used in connection with interpreting water rights, and it would be well to have its value fixed by law as a definite part of a second foot.

The discharges obtained in these experiments are probably less than would be obtained in actual practice where one or more of the following conditions are usually found, and they all tend to increase the flow through an orifice: thick edges, such as an opening cut in a plank without outward bevel to the edges; rounding edges; velocity of approach which would be caused by an orifice placed in a small box, or an accumulation of sand which would reduce the distance from the bottom of the

orifice to bottom of the box; an appreciably greater head due to the depth of water pouring over the spill-crest.

Some of the Miner's Inch measuring devices are well adapted to the conditions under which they are used. They are especially applicable to the measurement of small flows of water and when used in connection with a spill-box they act somewhat as a proportional divider. They are not well suited to the rotation method of delivery of water where large quantities are delivered for short periods, and they will not deliver a flow much in excess of their normal capacity. These measuring devices are often unjustly condemned, for the fault is not with the orifice structures as much as with the unit of measurement used, the Inch, whether it be called Miner's, Statute, Customary, or Farmer's Inch. These orifices are reasonably accurate in their measurement of water, but they should be calibrated or built according to plans which will give a known discharge, and this discharge should be expressed in cubic feet per second or some other equally definite quantity.

UNITS OF MEASURE.

The Cubic Foot Per Second, called second-foot, is a unit of measure for flowing water. When a stream discharges 1 cubic foot of water in one second, there is a second-foot flow.

The Acre-Foot is a unit of measure for standing water, and is that volume which will cover one acre one foot deep. An acre-inch is one-twelfth of an acre-foot, or the volume which will cover one acre to a depth of one inch.

The Miner's Inch is unsatisfactory and rapidly losing favor as a unit for measuring water, because it is not a definite quantity. It varies with the conditions under which it is used, and is therefore being replaced by the second-foot. In several of the Western states the Miner's Inch has been defined by law as being a certain fractional part of a second-foot, and these values are given in the accompanying table of Hydraulic Equivalents.

TABLE OF HYDRAULIC EQUIVALENTS.

1 cubic foot equals 7.48 gallons, or approximately 7½ gallons.

1 cubic foot of water weighs approximately 62½ pounds.

1 cubic foot per second equals 448.83 gallons per minute, or approximately 450 gallons per minute.

1 cubic foot per second flowing for 1 hour equals approximately 1 acre-inch.

1 cubic foot per second flowing for 12 hours equals approximately 1 acre-foot.

1 cubic foot per second flowing for 24 hours equals approximately 2 acre-feet.

1 acre foot equals 43,560 cubic feet, equals 325,851 gallons.

1,000,000 cubic feet (1 million cu. ft.) equals 22.95 acre-feet.

In California, Nevada, and Montana, 1 Miner's Inch (Statutory Inch) equals 1-40 of 1 cubic foot per second.

In Utah, Idaho, Arizona, and New Mexico, 1 Miner's Inch (Statutory Inch) equals 1-50 of one cubic foot per second.

In Colorado it has been generally assumed that 1 Miner's Inch (Statutory Inch) equals 1-38.4 of one cubic foot per second.