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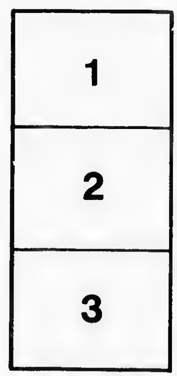
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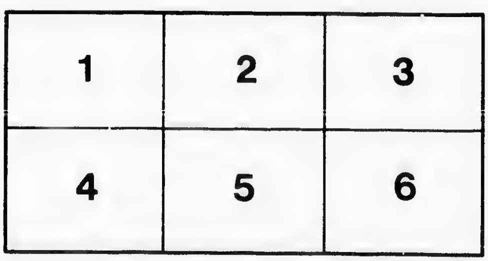
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Canadian Society of Civil Engineers.

INCORPORATED 1887.

ADVANCE PROOF—(*Subject to revision*).

THE MINERS' INCH AND THE DISCHARGE OF WATER THROUGH VARIOUS ORIFICES UNDER LOW HEADS.

By Thos. Drummond, B.A. Sc., A. M. Can. Soc. C. E.

(To be read Thursday, November 8th, 1900.)

The water determinations here recorded were made in the Hydraulic Laboratory, McGill University, Montreal.

This laboratory is unusually well equipped. It is fully provided with the modern scientific apparatus necessary for experimental work in all branches of hydraulics.

General Description. The laboratory is 39 feet long, 31 feet wide, and contains the following:—An experimental tank and flume; a weir with adjustable widths; a number of large orifices; a battery of five measuring tanks of large capacity; smaller measuring vessels of various capacities of from ten to one hundred gallons; standard gallon, quart and litre measures; a large experimental pump, weighing 55,000 pounds, with interchangeable valves and other special apparatus for experimental work; a 16-inch Pelton wheel, with brake attachments; a turbine tester of special design; an experimental centrifugal pump; an hydraulic ram; apparatus for testing hose up to 800 pounds' pressure per square inch, in lengths of 50 feet; Venturi, Piston and Rotary Meters; hook gauges and chronographs; Darcy's Improved Pitot tubes; metal plane tables, with adjustable feet, for use with the movable measuring vessels; a fixed mercury column, 27 feet high, and several smaller movable columns; a set of pipes for use in determining the resistance to flow due to bends, etc.; a set of carefully made nozzles, with pressure gauge attachments at each end; a set of hydrostatic gauges, with a wide range of pressure; apparatus for measuring the impact of water;

apparatus for determining the coefficient of velocity, etc.; jet measuring apparatus; a Rogers' linear comparator; apparatus for studying the inversion of the vein; a large series of standard orifices; special thermometers, scales, verniers and micrometers; glass tanks for illustrating ring motion, critical velocity and stream line phenomena; glass vessels for demonstrating circular and spiral vortex motion, etc., and various other appliances too numerous to mention.

The pumps and shafting in the laboratory are driven by an electric motor. The water is drawn from the city high level reservoir, and is under a pressure of 120 pounds per square inch.

Detailed Description of the Apparatus used. The experimental tank is of cast iron, and is 28 feet high and 5 feet square. All flanges are on the outside, and the inside walls are perfectly flush. The water is admitted into a chamber extending right across the bottom of the tank, which contains perforations through which the water flows to the bottom, and is there deflected upward, and passes through two baffle plates with perforated holes, the first being 12 inches and the second 18 inches above the bottom of the tank. To equalize the flow of water as much as possible, the pitch of the holes in the upper plate was determined by the projections on a horizontal plane of equal distances on a sphere of 10 feet diameter, whose centre coincides with the centre of the orifice.

The tank is provided with various inlet and outlet pipes of different sizes, so that the admission and discharge of varying amounts of water are completely governed.

The head of water is shown by a glass gauge 1½ inches diameter, with a graduated brass scale, both of which extend from top to bottom of tank, the zero on the scale being the centre of the orifice. A sliding carrier with a horizontal wire moves up and down, and any required head is obtained by bringing the required scale division, the bottom of the meniscus of the water in the tube, the horizontal wire and its reflection in a mirror behind into the same horizontal plane.

A second indicator consists of a float attached to a silk fishing line, passing over a pulley on the top of the tank, and then vertically downward in front. It has a plumbob at the lower end to keep it taut, and an adjustable pointer and stationary graduated scale. The inflow and outflow are first roughly regulated and the final adjustment is then made by means of small pipes and valves. In this way the operator has the water fully under control and observation, and a constant head can be maintained for any required

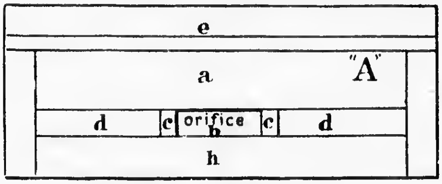
The orifices, when used in the tank, are centred in a circular ring, which fits into a specially designed circular valve, with gun metal bearing surfaces, forming a water-tight joint, and the centre of time when the water has once assumed a uniform régime.

the orifice always coincides with the zero of the scale. The valve is provided with a screw adjustment for fixing the verticality of the sides of the orifice, and a handle by which the orifice can be opened or shut. By means of a special artifice the orifice can be changed without lowering the head.

The base of the experimental tank is on a level with the bottom of, and discharges into, an iron flume 35 feet long, 5 feet wide, and 6 feet deep. It has a clear depth below the bottom of the orifice of 3½ feet. It is provided with movable baffle boards to steady the flow of water, and hook gauges, reading to the thousandth of an inch, for measuring the head. At the lower end it discharges over a weir or through an orifice, and either runs to waste or into a battery of five iron measuring tanks, each holding 1,100 gallons, the united measuring capacity being 882.5 cubic feet. These tanks are carefully calibrated, and can be used either together, separately, or in any combination. The flume is provided with a waste gate. When open the water runs to waste, and when closed into the measuring tanks. The gate is electrically connected with a chronograph, which can be read to the 1-100 of a second, so that the beginning and end of an observation is automatically recorded. A good stop watch may be used to check the chronograph time.

When orifices are used in the side of the experimental tank the water discharges through a switch, either to waste or into a carefully calibrated 100 gallon cylindrical measuring tank, which rests on a plane table. This switch is also electrically connected with the chronograph, and is used as above.

The wooden orifice used in these experiments was adjustable, and it was arranged as follows:—



Side Elevation

End Elevation

A is a wooden frame 2 inches thick, planed and painted, and made the full width of the flume into which it fits; a is a sliding gate, which slips down between two side pieces, e, the lower surface, being varnished and square edged. This rests on dimension blocks c and c, placed at the proper width to make the required orifice b. It is then clamped into place, the lower surface of the orifice being also square edged and varnished. The voids d and d are then filled in with wooden blocks, and the cracks tallowed and made watertight. The blocks c and c as used at first were made of hardwood, and were set end on, but they were subsequently replaced by brass blocks, as it was found that the wood blocks swelled slightly in the water. The orifice was then carefully measured with Brown & Sharpe's vernier micrometers and also with scales and calipers. The width being taken at the top and bottom, and the height at from 3 to 5 points depending on the width, the means of these gave the height and width of the orifice, which had been carefully levelled. This was done for each set of observations and head, and for every change of orifice.

The word gallon as used in this paper means Imperial gallon.

All heads are measured from centre of the orifice.

The valve of g (=32.176) used was determined for Montreal by Commandant Desforges in 1893.

The observations were taken in sets of from 2 to 5, depending upon the agreement and the time available.

The formula $Q = \frac{2}{3} cb \sqrt{2g} H_1^{\frac{3}{2}} - H_2^{\frac{3}{2}}$ was used throughout.

Q = The discharge in cubic feet per second.

C = Coefficient of discharge.

b = Breadth of orifice. }
H_1 = Head from bottom of orifice. } All in feet.
H_2 = Head from top of orifice. }

The discharges here recorded were made under low heads of from 6 to 12 inches, and with two kinds of orifices, viz.:

(1) Standard sharp-edged rectangular orifices in brass from 1 to 4 square inches in area.

(2) Square-edged rectangular orifices in wood, 2 inches thick, 2 to 4 inches in height, and ½ to 24 inches in width.

Condensed tabular statement of the observed discharge Q. The calculated coefficient of discharge C in various orifices with full contraction.

$$Q = \frac{2}{3} c b \sqrt{2g} \left(H_1^{\frac{3}{2}} - H_2^{\frac{3}{2}}\right),\ g = 32.176.$$

Average number of cubic feet or gallons in the veins	Number of observations	Number.	Temperature Fahrenheit.	Orifice dimensions in inches. Wide.	High	Head in inches above centre of orifice.	Average time Seconds.	Mean observed discharge Q in cubic feet per second.	Coeff. of discharge C	Corrected coeff. of discharge C.	Width side of orifice to side of flume, inches.	Remarks.
Cub. feet.	Wooden orifices in 2 inch plank planed and painted square edges.											
747.847	4	1	45°–50°	24	2.0167	7	573.8	1.298895	.6365	....	18.5	Slight irregularity.
349.090	4	2	"	18	2.01	7	361.5	0.965961	.6372	....	21.5	" "
164.228	5	3	"	11.992	2.01	7	256.1	0.641266	.6285	....	24.5	Steady stream.
150.144	5	4	"	8.96	2.01	7	313.8	0.478439	.6252	....	26.0	" "
148.156	5	5	"	6.005	2.005	7	461.8	0.388784	.6249	....	27.5	" "
147.800	5	6	"	4.00	2.01	7	701.3	0.210758	.6197	....	28.5	" "
147.508	2	7	"	4.00	2.01	6½	726.4	0.203065	.6195	....	28.5	" "
40.153	2	8	"	2.00	2.005	7	381.6	0.105211	.6180	....	29.5	" "
47.314	1	9	"	2.00	2.005	6½	466.2	0.101490	.6176	....	29.5	" "
37.937	4	10	"	1.00	2.00	7	714.3	0.053105	.6246	....	30.0	" "
28.733	3	11	"	2.00	1.00	7	610.7	0.053325	.6268	....	29.5	Vein partly inverted.
20.625	2	12	"	2.00	1.00	7	317.6	0.064927	.7632	....	29.5	Vein runs full.
15.625	5	13	"	½	2.00	8	436.4	0.035782	.7871	....	30.25	" "
15.664	1	14	"	½	2.00	7	470.7	0.033280	.7829	....	30.25	" "
152.353	4	15	"	5.98	3.0216	7	320.1	0.471471	.6168	....	27.5	Steady stream.
804.200	2	16	48	24.02	3.9924	6.935	319.4	2.517665	.6185	....	18.5	Stream a little irregular.
806.670	4	17	47	17.95	3.992	6.932	431.4	1.880928	.6161	....	21.5	" " "
822.190	2	18	47	11.98	3.9925	7	658.4	1.248712	.6135	....	24.5	Steady stream.
821.690	2	19	47	11.98	3.9925	7	656.5	1.251631	.6149	....	24.5	" "
291.79	5	20	47	6.00	4.00	7	469.7	0.621116	.6104	....	27.5	" " [sion well.
329.47	3	21	48.5	3.993	4.102	7	798.5	0.412593	.6082	....	28.5	" " shews inver-

The orifice ½ x 2 was tested in a horizontal and vertical position with heads of from 6-12 inches and runs full throughout.

THE SAME STATEMENT FOR STANDARD BRASS ORIFICES WITH SHARP EDGES.

Gallons.												
97.192	3	22	43.5	1	1	12	454.9	0.034287	.6152	....	....	Steady stream.
97.119	3	23	43.4	1	1	10	496.7	0.031379	.6171	....	....	" "
97.358	3	24	46.2	1	1	8	556.1	0.028095	.6177	....	....	" "
97.142	3	25	44.4	1	1	7	591.6	0.026347	.6193	....	....	" "
97.100	5	26	43.6	1	1	6	637.3	0.024447	.6208	....	....	" "

98.739	5	27	37.7	2	2	12	116.5	0.135985	.6104			Not so regular, but fairly good
98.710	3	28	37.1	2	2	10	127.5	0.124265	.6113			" "
98.260	4	29	41.0	2	2	8	141.5	0,111451	.6130			" "
98.318	4	30	38.2	2	2	7	151.1	0.104419	.6142			" "
98.161	3	31	38.7	2	2	6	162.9	0.096743	.6147			" "
97.336	3	32	40.3	2	½	6	625.8	0.024983	.6339			Steady stream.
97.418	3	33	39.9	2	½	7	579.6	26971	.6338			" "
97.616	3	34	39.7	2	½	8	544.6	0.028761	.6323			" "
97.099	3	35	46.2	2	½	10	487.7	0,031944	.6282			" "
97.382	3	35	44.1	2	½	12	467.1	0,034949	.6273			" "
97.574	4	37	41.7	½	2	12	448.1	0.034887	.6265			Steady stream.
97.434	3	38	45.[illegible]	½	2	10	489.6	0.032916	.6279			" "
97.767	3	39	41.2	½	2	8	546.6	0.028734	.6321			" "
97.571	3	40	41.1	½	2	7	581.4	0.026931	.6335			" "
97.307	3	41	41.2	½	2	6	625.0	0,024981	.6354			" "
97.615	3	42	39.5	2	1	12	228.4	0,068577	.6153			Steady stream.
97.733	3	43	46.5	2	1	10	249.6	0,062708	.6166			" "
97.602	3	44	39 2	2	1	8	278.8	0,056171	.6176			" "
97.639	4	45	39.2	2	1	7	297.3	0,052699	.6194			" "
97.377	5	46	41.6	2	1	6	319.4	0,048925	.6212			" "
97.362	5	47	38.6	1	2	6	320.1	0.048812	.6203			Steady stream.
97.581	3	48	42.9	1	2	7	297.6	0.052609	.6188			" "
97.860	3	49	39.5	1	2	8	278.8	0.056325	.6196			" "
97.321	3	50	44.1	1	2	10	249.0	0.062827	.6180			" "
97.593	3	51	38.8	1	2	12	228.2	0.068751	.6172			" "
97.573	4	52	41 4	4	½	6	312.1	0.050157	.6372			Slightly irregular.
97.928	3	53	41.2	4	½	7	289.8	0,054223	.6372			" "
97.648	2	54	43.7	4	½	8	271.4	0.057724	.6344			" "
97.617	4	55	38.5	4	½	10	242.8	0,064502	.6342			" "
97.625	4	56	41.3	4	½	12	222.9	0.070309	.6310			" "
97.477	5	57	43.5	½	4	12	221.9	0.070518	.6336			Slightly irregular.
97.692	4	58	40.6	½	4	10	242.9	0.064546	.6357			" "
97.672	6	59	45.0	½	4	8	271.4	0.057740	.6364			" "
97.851	3	60	42.9	½	4	7	290.2	0.054098	.6389			" "
97.520	4	61	43.4	½	4	6	311.4	0.050248	.6408			" "

The brass orifices were carefully measured at a temperature of 65° F.

1 x 1 = 0.9982 x 0.9987 = 0.996902 square inches.
½ x 2 = 0.5008 x 1.9967 = 0.999947 " "
1 x 2 = 1.9983 x 1.000 = 1.9983 " "
2 x 2 = 1.99925 x 1.99924 = 3.996981 " "
½ x 4 = 0.5005 x 3.9983 = 2.001149 " "

Coefficients of discharge for various standard brass orifices of various sizes with various heads.

Orifice dimensions inches. Wide.	High.	Head inches	Coefficient of discharge C	Orifice dimensions inches Wide.	High.	Head inches	Coefficient of discharge C	Orifice dimensions inches. Wide.	High.	Head inches	Coefficient of discharge C
1	1	6	.6208	2	½	8½	.6308	2	1	11	.6156
1	1	6½	.6201	2	½	9	.6302	2	1	11½	.6154
1	1	7	.6194	2	½	9½	.6297	2	1	12	.6153
1	1	7½	.6188	2	½	10	.6292	4	½	6	.6382
1	1	8	.6183	2	½	10½	.6287	4	½	6½	.6371
1	1	8½	.6179	2	½	11	.6283	4	½	7	.6361
1	1	9	.6174	2	½	11½	.6278	4	½	7½	.6352
1	1	9½	.6170	2	½	12	.6274	4	½	8	.6344
1	1	10	.6166	½	2	6	.6359	4	½	8½	.6338
1	1	10½	.6163	½	2	6½	.6347	4	½	9	.6332
1	1	11	.6159	½	2	7	.6336	4	½	9½	.6327
1	1	11½	.6156	½	2	7½	.6325	4	½	10	.6323
1	1	12	.6152	½	2	8	.6315	4	½	10½	.6319
2	2	6	.6151	½	2	8½	.6306	4	½	11	6316
2	2	6½	.6145	½	2	9	.6298	4	½	11½	6313
2	2	7	.6139	½	2	9½	.6290	4	½	12	.6310
2	2	7½	.6134	½	2	10	.6284	½	4	6	.6408
2	2	8	.6130	½	2	10½	6278	½	4	6½	.6392
2	2	8½	.6126	½	2	11	.6274	½	4	7	.6380
2	2	9	.6122	½	2	11½	.6269	½	4	7½	.6370
2	2	9½	.6118	½	2	12	.6265	½	4	8	6364
2	2	10	.6116	2	1	6	.6212	½	4	8½	.6359
2	2	19½	.6112	2	1	6½	.6202	½	4	9	.6354
2	2	11	.6110	2	1	7	.6193	½	4	9½	.6350
2	2	11½	.6107	2	1	7½	.6185	½	4	10	6346
2	2	12	.6104	2	1	8	.6178	½	4	10½	.6343
2	½	6	.6352	2	1	8½	.6172	½	4	11	.6341
2	½	6½	.6341	2	1	9	.6169	½	4	11½	.6338
2	½	7	.6330	2	1	9½	.6164	½	4	12	.6336
2	½	7½	.6322	2	1	10	.6161				
2	½	8	.6314	2	1	10½	.6158				

The brass standard orifices were placed in the valve in the experimental tank, which has adready been described, and in all the experiments the water ran through the switch into the 100 gallon tank, fitted with a glass gauge tube and a scale graduated to gallons.

The capillary action is so eliminated. The tubes are of large size; they were always kept wet, and the scales were gradnated by reading the bottom of the meniscus under these conditions of calibration.

The observed discharges from the brass orifices rarely differed by more than 2-1000 of a cubic foot per minute, and they often agreed almost exactly.

The correct size of the brass orifices, as measured at a temperature of 65 degrees F., is given elsewhere in the paper.

The discharges from the wooden orifices were observed at the lower end of the flume, and measured in the large tank. The agreement was not so close as was anticipated with the larger quantity of water.

With the 12, 18 and 24 inch orifices, vertices were formed, and there was an appreciable velocity of approach. No corrections were applied, as their effect would be very slight, and practically nil.

With these same orifices there was a slight breaking up of the water, and the clearance was not as good as it might have been. From this cause the discharge for these orifices is probably slightly less than it should be. This was tested in the case of the 12 x 4 inch orifice, and it gave a slightly increased discharge, amounting to about 3-1000 of a cubic foot per second.

With two of the largest orifices there was a pulsation in the water affecting the head. In such cases the mean head from a number of readings was adopted.

Regarding the wooden orifices, it can be said that wood is not an absolutely stable material. The wood, however, was made practically waterproof, and any change that may have occurred from swelling was inappreciable in the interval of time necessary for one set of observations.

No attempt was made to get exact inch dimensions for the orifice; it was levelled, set, and measured as described above.

Full contraction of the vein was maintained throughout, except in a particular case referred to later on.

Great care was taken to make and keep the edges square and sharp, and, this being done, the thickness of the orifice within certain limits makes little or no difference.

The large jets show more irregularity and disturbance in the stream lines. Corrugations appear on the surface, and they undulate and move slightly.

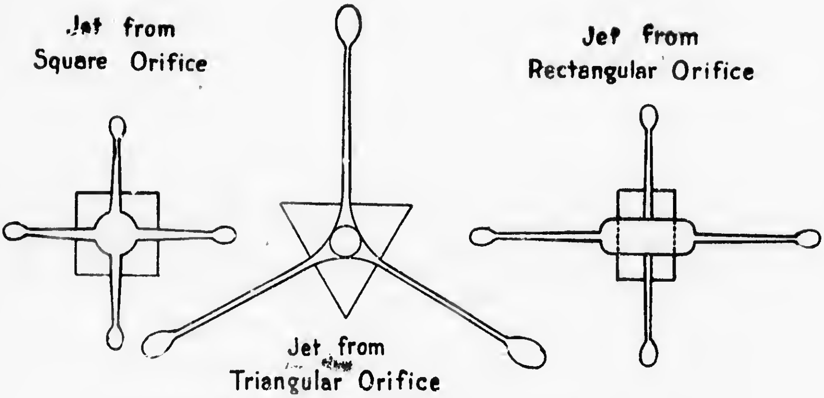
The shape of the orifice has a perceptible effect upon the discharge. Circular orifices give the least discharge, rectangular orifices the greatest, and square orifices are intermediate. As the rectangular orifice becomes narrower, the width being the same, it will discharge proportionately more water, and the coefficient of discharge C becomes greater. C increases as the width increases, the depth remaining constant, and it decreases as the size of the orifice increases, the same shape being maintained. C has a smaller value for large than for small orifices, and for the same orifice it decreases as the head increases.

The curve of coefficients for a particular orifice is a curve resembling the cubical parabola. With great heads it tends to become assymtotic, and the coefficient C probably eventually becomes a constant. Several of these curves are drawn to scale, with the head in inches, and the calculated coefficient as co-ordinates. A curve is then drawn in to accord with these points as nearly as possible, so that the coefficient for any point within its limits can be read off directly.

There are slight discordances, as may be seen, which are due to several causes. First, there is the exaggerated scale, making the difference appear much greater than it really is. Again, the observations were started with heads of 6, 7, 8 and 12 inches, and some of the observations under the 10-inch head were taken with a separate setting of the orifice, but with the same agreement, and the same care as before. These latter observations for some reason do not agree well, and several have been rejected. The errors of observation are only slight, and would not account for them. They are caused (1) by temperature effects; (2) by certain inherent irregularities in the flow of water under low heads. Temperatures were taken, and an attempt was made to apply corrections by using the recognized coefficients of expansion for iron, brass, copper and water. Theoretically, they can be reduced to a common temperature; practically, however, it is uncertain. In the case of the orifices and tanks, one side of the metal only is in the water, and the air has access to the other. We can only assume that the contained water is of the same temperature as the metal, and this does not appear to be the case. Till more is known, these corrections cannot be applied with certainty.

With the head and observed discharge as co-ordinates, the curve of discharge is practically a parabola, but not exactly so. If it were, the whole theory of hydraulics would be much simplified.

A curious and beautiful phenomenon is the *inversion of the vein*, and as this term has been used, and is not generally described in text-books, a short description may be given. With a carefully made standard circular orifice the jet issues like a clear crystal bar of glass, and seems to be perfectly rigid. With other orifices of three or more sides, there is a remarkable change. The jet develops wings or rays in certain wave lengths. The first are at right angles to the edges of the orifice, and the number is the same as the sides. This is because the issuing water from the corners of the orifice has a greater convergent tendency than elsewhere in the jet, and it presses the water out into these rays. All the brass orifices show this phenomenon well, and the wooden ones show it to a lesser extent, depending upon the size. Several examples are given.



The observations here recorded should be especially useful in British Columbia as furnishing data for the delivery of water at mines, and this leads to the question of the miner's inch of water.

The Miner's Inch of Water, it may be explained, is an arbitrary module adopted in mining districts for selling water. It is variously defined as being the amount of water discharged by an orifice one inch square, or an equivalent fraction of a larger orifice with a head of from 6 to 9 inches. The thickness of the orifice is usually 2 inches.

One great difficulty is that it is a variable quantity depending upon the specified head, and therefore all such modules should also define the flow in cubic feet per minute.

In British Columbia it is defined as being 1.68 cubic feet of water per minute, or that quantity of water which will pass through an orifice ½ an inch wide, 2 inches high and 2 inches thick, with a constant head of 7 inches above the top of the orifice, and every additional inch shall mean so much as will pass through the said orifice extended horizontally ½ an inch. As a definition, unfortunately, this is completely wrong. In the first place, widening the orifice as above changes the coefficient of discharge, and therefore the discharge itself. In the second place, this orifice actually discharges 2.147 cubic feet of water per minute, instead of 1.68 cubic feet, and this brings out a curious point referred to above, that certain shaped orifices, with a thickness of 2 inches run full like a short tube, the vein is not contracted, and they actually give a greater discharge than they are supposed to give. The orifice in question runs full in the horizontal and vertical positions with heads of from 6 to 12 inches.

A 1 x 2 inch orifice 2 inches think is just on the margin between flow with contraction and full bore. If fixed in the vertical position, with longest diameter vertical, the vein contracts. If fixed in the horizontal position, with the longest diameter horizontal, it will also contract, but if rubbed with the fingers on the edge it will run full for a time and then contract again. If kept running full in this way it will discharge about 1 cubic foot of water per minute more than when full contraction takes place.

There are practical difficulties in the way of delivering absolutely exact quantities of water, and they cannot be measured out as a pound of tea is weighed over the counter. The definition of the module or unit, however, should be correct within a reasonable limit of error. If it is a definition of a single miner's inch from an orifice of one square inch, it should go no farther. If the inch is defined as being some practical part of the discharge from a larger orifice, it should go no farther than the capacity of that orifice, and as it is an unknown quantity to the outside world the discharge should be given in cubic feet per minute. Convenient discharges are 1½ and 2 cubic feet. The flow under low heads is irregular. Heads of 1 ft. or more are not convenient because the water is delivered from ditches or flumes where the depth of water is never great. The question thus resolves itself into a choice of a standard module or unit from a flow under two conditions.

(1) With a low head of 6¼ inches above the centre of the orifice, giving a discharge of 1½ cubic feet per minute, with the advantage that it is already partially recognized as the miner's inch, and with the disadvantage that the flow is irregular.

(2) With a head of 11½ inches above the centre of the orifice, and a discharge of 2 cubic feet per minute, the flow being much more regular, but the quantity discharged new to the people.

Definitions of both inches are given, and a choice can be made, but the author favours the last.

Definition No. 1 of the Miner's Inch:—

The water taken into a ditch or sluice shall be measured at the ditch or sluice head. It shall be taken from the main ditch, flume or canal, through a box or reservoir arranged at the side. The orifice shall be fixed vertically at right angles to the delivering water way, and the edges and corners shall be sharp. The vein shall be fully contracted. The distance between the sides and bottom of the orifice and the sides and bottom of the water way shall be at least three times the least dimension of the orifice. The orifice shall discharge freely into air.

One Miner's Inch of water shall mean ¼ of the quantity which will discharge through an orifice two (2) inches wide and two (2) inches thick, made in a two inch plank, planed and made smooth. The water shall have a constant head of $7\frac{1}{4}$ inches above the centre of the orifice. It shall mean a discharge of $1\frac{1}{2}$ cubic feet per minute.

In definition No. 2 the first part is precisely the same, the latter part is changed as follows:—

One Miner's Inch of water shall mean $\frac{1}{4}$ of the quantity which will discharge through an orifice two inches wide, and two inches thick, made in a two-inch plank, planed and made smooth. The water shall have a constant head of $11\frac{1}{2}$ inches above the centre of the orifice. It shall mean a discharge of 2 cubic feet per minute.

A one-inch orifice may run full, but no experiments were made on this point.

These discharges are from a standard brass orifice, and are actually .478 and 1.997 cubic feet per minute. The discharge through a wooden orifice 2 inches thick is slightly greater than for a standard orifice, so that these discharges should be almost exactly $1\frac{1}{2}$ and 2 cubic feet per minute.

As stated above, no attempt was made to reduce the observations to a common temperature. The temperatures for the brass orifice varied between 31.7 degrees and 46.5 degrees F., a range of 9.5 degrees F., with an average temperature of 48 degrees F.

The temperature for the wooden orifices varied between 45 degrees and 50 degrees F., with an average of 48 degrees F.

The mean temperature for the whole was 45 degrees F.

Every precaution was taken to remove disturbing effects, and to make the work as accurate as possible.

Altogether some 235 observations were made in sets of from 2 to 5, involving a considerable amount of labour, both in the work and calculations.

With a more careful examination of the results it may be possible to give a useful discussion upon the paper.

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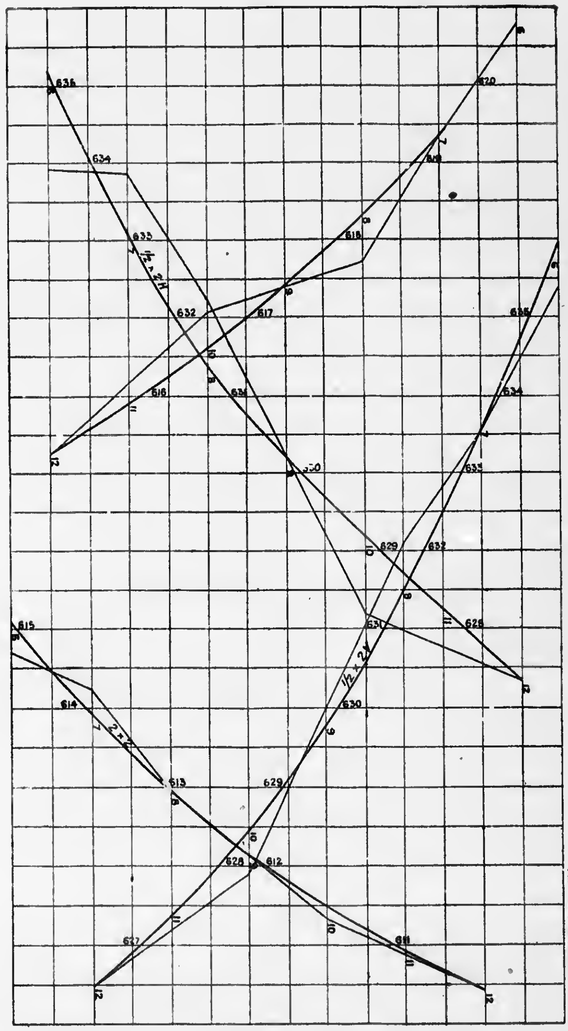

TRANSACTIONS CAN SOC. C.E.
VOL. XIII. PLATE 7

CO-EFFICIENT CURVES

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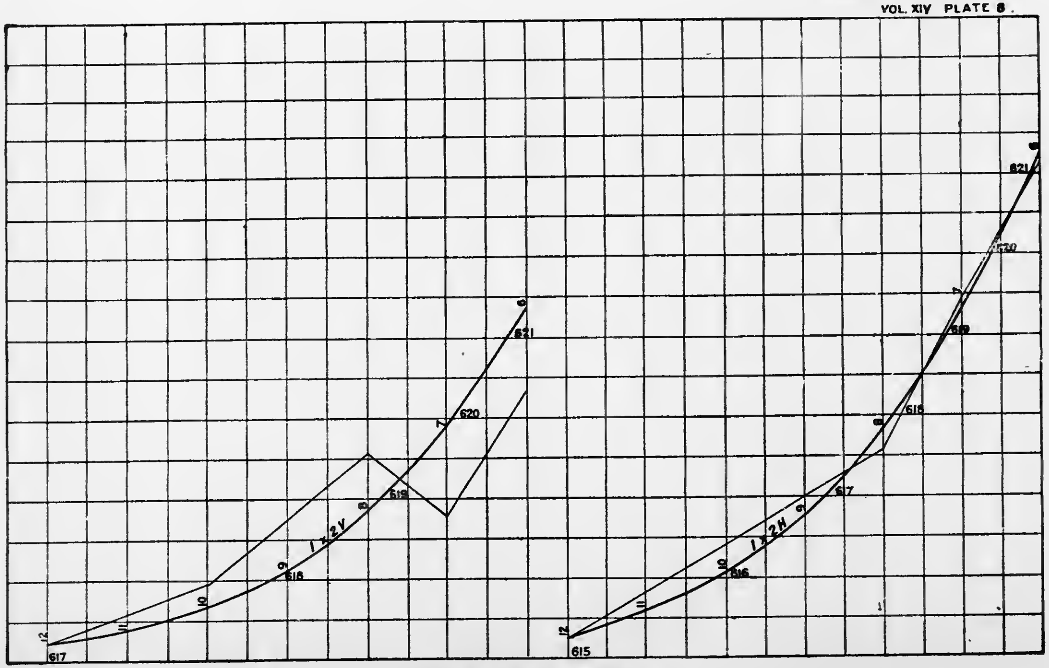
VOL. XIV PLATE 8.



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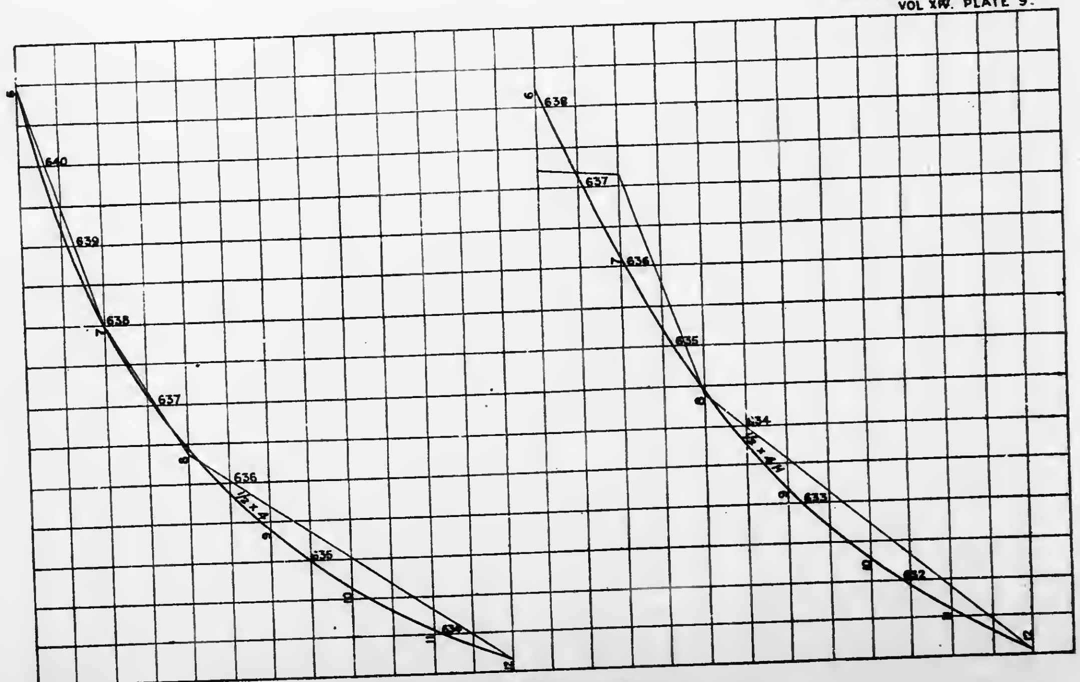
TRANSACTIONS CAN. SOC. C. E.
VOL XIV. PLATE 9.



CO-EFFICIENT CURVES.