The Hazen-Williams Hydraulic Slide Rule.

The Hazen-Williams Hydraulic Slide Rule is a slide rule designed by Professor Gardner S. Williams, of Cornell University, and Mr. Allen Hazen, of New York, to compute the flow of water in pipes and channels.

In size and general appearance this rule is like an ordinary Mannheim 10-inch slide rule. It has an improved back which will prevent warping. The upper scale on the rule, marked No 1, and the upper scale on each side of the slide, marked No. 2 and No. 5, are like those on the Mannheim rule. One face of the slide is marked V (for velocity) at the right-hand), end and contains scales No. 3a and 3b. Scale 3a, in the middle of the slide, gives hydraulic radii for channels and conduits. Scale 3b, on the lower edge, is graduated for the hydraulic radii of pipes and is marked with diameters in inches. The other side of the slide is marked Q (for quantity) at its right-hand end and contains scales No. 6a and No. 6b, marked for diameters in inches. The lower scale No. 4, on the rule is graduated for slopes in feet per thousand. The scales are made in Germany and the graduation has been very carefully done. Before putting the rule into permanent form, experimental rules were used by the designers for about two years to satisfy themselves of its utility. On the back of the rule are several tables to aid in the convenience of computations to which the rule is applicable.

METHOD OF USE.

To compute velocity: Put the slide in the rule with the side up having V at the right-hand end. Move the slide so that the diameter ot pipe in inches on scale No. 3b will be over the slope on scale No. 4. In case the channel is not circular in form, compute the hydraulic radius in units of one foot, not inches, and, with the aid of the marker, using this on scale No. 3a over the slope.

Determine from the table on the back of the slide rule, or otherwise, the value of *c* to be used. Find this value upon scale No. 2. Opposite to it on scale No. 1 will be found the velocity in feet per second. This procedure gives the numerals in the velocity but does not give the position of the decimal point. To find the position of the decimal point, consult the table on the back of the rule, showing the velocities in feet per second for various sizes of pipe and slopes with $c = 100$. Enough values are given in this table to enable the position of the decimal point to be determined by inspection. If the velocity is known and the value of *c* is to be determined, the rule is set as above described and the value of *c*, on scale No. 2 found under the observed velocity. By a similar procedure the slope or diameter can be computed for a given velocity on scale No. 1 with a known or assumed value of *c*.

To compute Quantity: To compute the quantity, reverse the slide so that the side is up which has Q on the right-hand end. Bring the diameter of the pipe, scale No. 6a or No. 6b, over the slope in scale No. 4. Determine from the table on the back of the rule, or otherwise, the value of *c* to be used. Find this upon scale No. 5, and opposite it in scale No. 1 will be the quantity in American gallons per 24 hours. As before, the numerals are given, but not the position of the decimal point. To find the position of the decimal point, or the number of ciphers to be added, consult the table for that purpose on the back of the rule. The position of the point can be determined by inspection.

To obtain the results in gallons per hours, gallons per minute, cubic feet per second, or any other units, multiply or divide the result obtained on scale No. 1, with the aid of scale No. 2. If a considerable number of computations are to be made, in which the results are required in the same unit other than gallons per day, a special value of *c* can be found which will give directly the desired result at one operation.

In case the pipe is more than 86 inches in diameter (that being the largest diameter shown on the scale) divide the actual diameter by 2.4- find the discharge corresponding to the new size, and multiply the result by 10. Or, divide the diameter by the square of 2.4, namely, 5.76, and multiply the result by 100. To find the discharge of pipes less than 2.7 inches in diameter (that being the smallest size shown on the scale), multiply the diameter by 2,4; find the discharge corresponding to the new size, and divide the result by 10. Care must be exercised in extending the process to very small pipes, as for them the values of *c* may vary considerable from those used for larger pipes. To find the velocity or discharge for hydraulic slopes of more than 50 in 1,000, find the velocity or discharge for a slope that is one hundredth of the actual slope and multiply the result by 12.05.

Knowing the discharge in a given size of pipe at a given slope, what size of pipe must be used to produce the same discharge for any other slope? Have the quantity side of the slide up. Bring the known size over the known slope. Other sizes will then be found over the corresponding slopes. In case it is desired to compare sizes in scale No. 6a with sizes in scale No. 6b, it will be necessary to move the scale exactly its length, marking the first position of the end with the marker, as in multiplying on the lower scales of an ordinary slide rule when the operation runs off the scale.

To compute the discharge through a compound pipe, that is a pipe of larger diameter connecting with a pipe of smaller diameter, or a series of such pipes: Assume some quantity of water. Compute the total friction in each part of the pipe, corresponding to that quantity, by multiplying he computed slope in that pipe by the length of pipe. The sum of these frictions will be the total friction with the assumed discharge. Place the marker at this head on the slope scale, and move the scale until the quantity assumed is opposite the marker, on scale No. 2 or scale No. 5; other corresponding quantities will then be opposite other heads on the respective scales.

Example: To find the discharge through a compound pipe consisting of 16,000 feet of 30-inch pipe, 5,500 feet of 24-inch pipe, and 8,700 feet of 36-inch pipe, when the total loss of head is 30 feet. The pipe being moderately old take c=100 and compute the losses of head first for a discharge of 10,000,000 gallons daily. The computation may be tabulated as follows:

Quantity.	Diameter, inches.	Slope, per 1000.	Length, feet.	Loss of head, feet.
10.000.000	30	1.72	16,000	27.50
10.000.000	24	5.05	5,500	27.80
10.000 000	36	0.71	8,700	6.18

Total loss of head for 10.000.000 gollons 61.48

Set marker on 61.48 on slope scale and bring 10 on No. 2 scale to it. Then move marker as desired, e g.: taking it to a loss of head of 30 feet we find the corresponding discharge to be 6.8 million gallons daily.

Allowance for loss of head at entrance and in curves. Allowance for velocity heads and for extra friction in curves can be most accurately made separately, but allowance can be made with sufficient accuracy for most practical purposes by adding to the length of pipe, before computing the slope, such an amount that the friction of water in passing through it would equal the velocity head, and the additional losses in passing curves. In general it may be assumed that it takes about two velocity, heads to give the water in a pipe a given velocity and approximately one is recovered when the water is discharged into a receptacle above the end of the pipe, leaving a net loss of one velocity head; and it may further be assumed that about one-quarter of a velocity head will be lost for each quarter bend of pipe. The allowance is therefore made by adding to the length of pipe that amount in which the friction is equal to the velocity head, and in addition, one-quarter of this amount for each quarter bend in the line of pipe. The lengths of pipe in which the friction is equal to a velocity head for a number of sizes and for two values of c are shown in a table on the back of the rule.

To get with one setting of the slide the quantities of water discharged by pipes of different sizes for a given slope and coefficient. Put the slide in with the Q side showing, but inverted. Bring the coefficient over the slope, and the quantities will appear directly over the respective pipe sizes.

Value of C.

Some approximate values of c are given upon the back of the rule. There is much more detailed information upon this point in "Hydraulic Tables," by Williams & Hazen, published by John Wiley & Sons, New York, to which the reader is referred for many experimental results.

The values of c selected by the authors of this book, for a number of kinds of pipe, are as follows:

For cast iron pipe:

Age of pipe in yrs.	DIAMETER OF PIPE IN INCHES.								
	4	6	8	10	12	16	24	36	60
0	130	130	130	130	130	130	130	130	130
10	106	108	109	110	110	111	112	112	112
20	88	92	94	96	97	98	99	99	100
30	75	80	83	85	86	87	89	90	91
40	64	71	74	76	78	79	81	83	84
50	56	63	67	69	71	73	75	76	78

For steel pipe:

With lock bar joints, the same as cast iron pipe.

With double riveted joints, about the same as for cast iron pipe 10 years older, or about 112 for new pipe and 100 for pipe 10 years old

Sewers of tile pipe, 110; of brick, 100.

Masonry aqueducts, with very smooth sides, 125, but this will be reduced if the sides are not perfectly smooth or if the water forms deposits upon them.

For pipes of uncertain age and miscellaneous channels, as a basis of general calculation, use 100 most frequently.