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The determination of friction-coefficients of water in small iron pipes

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THE DETERMINATION OF FRICTION-COEFFICIENTS OF WATER IN SMALL IRON PIPES.

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-OBJECT.-

This thesis was undertaken to determine accurately the coefficients of friction of water, flowing at varying velocities in small iron pipes and elbows. It was the intention to obtain the condition of pipes and elbows similar to that met with in general practice.

-APPARATUS-

Pipes and Elbows: Three sizes were used, consisting of three-quarter, one, and two inch galvanized pipes and elbows. They were made up in the following manner: Two lines of pipe, about 100 feet long, were made up of joints 30 feet in length, and laid parallel to each other. At one end the two lines were joined by 90 degree elbows, two nipples and a union, for which a number of elbows connected by short nipples could be substituted. The free ends of the pipe were joined by tees to the water supply and the outlet pipe respectively, interposed by gate-valves. The third opening of the tees communicated with the pressure gauge.

The outlet pipe used in each case was the same, consisting of about 70 feet of 1 1/2 inch pipe, emptying into the

measuring tank.

The pipes were not reamed and were of commercial quality, and the observations were taken on the following:

203.5	feet	of	pipe	and	2	elbows	-- 2 inch
203.5	"	"	"	"	16	"	-- " "
203.6	"	"	"	"	2	"	-- 1 inch
210.0	"	"	"	"	18	"	-- " "
201.8	"	"	"	"	2	"	-- 3/4 inch
(4.9	"	"	"	"	14	"	-- " ")
(88.1	"	"	"	"	2	"	-- 1 ")

Sources of Water Supply: For the two inch pipe, the available head of the school water system was considered sufficient for the velocities desired, and connections were made with the campus hydrant.

The smaller pipes required a greater head, which was obtained in the following manner: A closed cylindrical steel tank, 8 feet long and of 2 foot diameter was mounted in a horizontal position about three feet above the ground. Connections were made for compressed air at the top of the tank by a pipe fitted with a globe valve and a pop safety valve. The water was piped to the tank from the school system, and was admitted by a globe valve. Water was taken from the tank at its lowest point, where it entered the pipe line on which the observations were taken. The tank was fitted with a pressure-gauge and a water-glass.

Pressure Gauges: A differentail mercury gauge was constructed, using six foot glass tubes, connected with packing-nuts to 1/4 inch black iron pipe. The assembling of the fittings and the mounting of gauge are shown in accompanying sketches. (The latter sketch is drawn to a 1 to 10 scale.) The gauge was set up between the two lines of pipe and each side of the gauge connected to the tees by unions and nipples.

For pressures surpassing the limits of the mercury gauge two steam pressure gauges were subtituted. These gauges were tested and readings corrected.

Measuring Tank: To measure the water a wooden tank, 48 inches high and 60.078 inches square, was constructed of 2 inch cypress, tongued and grooved, and bound by wooden and iron braces. The tank was fitted with a water glass and an outlet gate-valve.

-METHOD-

Mercury was introduced into the gauge through the mercury filler, until the glass tubes were half full. The pressure tank was nearly filled with water, the inlet water valve closed tightly, and air admitted to the tank, leaving open

the connections between it and the air reservoirs in the power house. The pressure used was about 150 pounds per square inch. It was necessary to displace all air in the gauge with water, before any observations were taken. Then, while one man was at the measuring tank to ascertain the quantity of water per minute flowing into it, by measuring the water level in the glass, and the other was regulating and reading the difference in pressure, in the effort to obtain velocities with intervals of about one foot, the observations were taken. For each size of pipe, a set of readings were made with two and also with a larger number of elbows connecting the two lines of pipe. With the 2 inch pipe, connection was made direct to the hydrant, and no compressed air was used.

-CALCULATIONS-

To calculate the friction head in feet of water from cm. mercury:

$$\text{cm. Hg.} \times \frac{(13.6 - 1)}{12 \times 2.54} = .4134 \text{ feet of water per cm. Hg.}$$

To change from inches mercury to feet of water:

$$\text{inches Hg.} \times \frac{(13.6 - 1)}{12} = 1.05 \text{ feet of water per inch Hg.}$$

To change pounds per square inch to feet of water:

$$\text{pounds} \times \frac{144}{62.5} = 2.304 \text{ feet of water.}$$

Dimensions of Measuring Tank:

$$\frac{60.078 \times 60.078}{144} = 25.066 \text{ square feet.}$$

Velocities in Pipe:

$$\frac{Q}{A} = V = \frac{\text{Inches water per min.} \times 25.066 \times 144}{12 \times 60 \times .7854 \times d''}$$

For 2 inch pipe,

$V = 1.596 \times$ Inches water per min.

For I inch pipe,

$V = 6.383 \times$ inches water per min.

For 3/4 inch pipe,

$V = 11.3475 \times$ inches water per min.

To obtain the friction head in elbows (fl) :

$$H = F \frac{l\ v^2}{d''\ 2g} + (X \times fl).$$

For instance, for 2 inch pipe and 3 foot velocity,

$$H' = 4.9 = \frac{F \times 203.5 \times 9}{2 \times 64} + 16\ fl.$$

$$H'' = 4.1 = \frac{F \times 203.5 \times 9}{2. \times 64} + 2\ fl.$$

$$.8 = 14\ fl.$$

$$.0571 = fl$$

To obtain F for pipes: From the above equations we get,

$$4.1 = \frac{203.5 \times 9}{2 \times 64} \times F + (2 \times .0571)$$

$$\frac{(4.1 - (2 \times .0571))\ 128}{203.5 \times 9} = F = .279$$

To obtain the length of pipe, to which one elbow is equivalent (L).

$$fl = \frac{F \times L \times V^2}{d'' \times 2\ g}$$

For 2 inch pipe and 3 foot velocity,

$$.0571 = \frac{.279 \times 9}{2 \times 64} \times L, \qquad L = 2.91$$