

curves, $73.83 \times 0.5 = 36.91$ sluice-heads. If in boulders, or with unlined sets of timber and bad curves, $73.83 \times 0.4 = 29.53$ sluice-heads.

Example 3.

What quantity of water will a channel carry with plumb sides, 4 ft. width of bottom, $2\frac{1}{2}$ ft. depth of water, and a gradient of 48 ft. per mile?

$$(2.5 \times 2) = (5) + 4 = 9 \quad = \text{wetted border.}$$

$$4 \times 2.5 = 10 \quad = \text{area.}$$

$$\frac{10}{9} = 1.1111 = \text{hydraulic mean depth.}$$

$$96 \times 1.1111 = 10.327 = \text{velocity in feet per second.}$$

$\sqrt{10.327 \times 10} = 103.27 = \text{sluice-heads—if in long, straight, and smooth iron fluming. If in fluming lined with undressed sawn timber, } 103.27 \times 0.7 = 72.289 \text{ sluice-heads.}$

Example 4.

What quantity of water will a flume carry with plumb sides, 4 ft. wide, 2 ft. depth of water, and gradient 24 ft. per mile.

$$(2 \times 2) = (4) + 4 = 8 \quad = \text{wetted border.}$$

$$4 \times 2 = 8 \quad = \text{area.}$$

$$\frac{8}{8} = 1 \quad = \text{hydraulic mean depth.}$$

$$\sqrt{48 \times 1} = 6.9282 = \text{velocity in feet per second.}$$

$6.9282 \times 8 = 55.425 = \text{cubic feet per second (or sluice-heads)—in long, straight, and smooth iron fluming. If in fluming lined with dressed boards, } 55.425 \times 0.8 = 44.34 \text{ sluice-heads. If in fluming lined with undressed sawn boards, } 55.425 \times 0.7 = 38.797 \text{ sluice-heads.}$

In flumes, tunnels, and channels of similar character four times the gradient doubles the velocity or quantity, and four times the hydraulic mean depth also doubles the velocity or quantity.

Velocity is proportional to square root of gradient.

" " H.M.D.

" " gradient $\times$ H.M.D.

FRICTION OF WATER IN PIPES AND CHANNELS.

Experiments show that the forces that retard the flow of water in pipes and channels, all of which are generally included in the term "friction," are in pipes and channels of the same character and of equal hydraulic mean depth proportional to the square of the velocity of the water, but where the H.M.D. is greater the loss of head by friction is less for any specified velocity. A velocity of, say, 10 ft. per second in a small pipe produces more loss of head than the same velocity in a larger pipe, because the fictional surface in proportion to the area is greater in the one case than in the other.

In the conveyance of water through pipes or in channels a portion of the head lost is absorbed in producing the velocity of the water; another portion is absorbed by friction proper; and another portion (in many instances very large) is absorbed by eddies and counter-currents, caused by obstructions, inequalities, and roughness in the pipe or channel conveying the water. The last-named loss of head may be easily seen by observing the flow of water in an unlined tunnel or open ditch, with sets of timber every 3 ft. or 4 ft. Eddies and counter-currents caused by the sets of timber disturb and retard the whole sectional area of the flowing water. Experiment has demonstrated that such a tunnel or channel may be made to carry more than double the quantity of water if smoothly and uniformly lined. As in channels, so in pipes and other conduits for the conveyance of water—perfect smoothness and uniformity are of the utmost importance. A change of form in the sectional area of flowing water produces retardation.

There are several methods of ascertaining the loss of head by friction (which term is taken to include all the retarding forces) in pipes of various diameters, carrying water at various velocities. A pressure-gauge may be used at any point in a line of pipes, and the difference between the readings when the water is at rest and when the water is in motion delivering a certain quantity of water (the pipes being full in both instances) is the exact measure of the loss of head that takes place between the source and the point at which the gauge is used when the pipes are carrying that particular quantity of water. Another method quite as reliable is the calculation of the loss of head from the carrying-capacity of pipes of various diameters under various hydraulic gradients. If a pipe of any specified diameter (or H.M.D.) carries a certain quantity of water on a certain hydraulic gradient, then that gradient is the correct measure of the loss of head in that particular pipe when carrying that particular quantity of water. If a pipe 12 in. in diameter carries four sluice-heads of water on a hydraulic gradient of 1 in 100, then the loss of head in that pipe, carrying that quantity of water, will be 1 ft. of head for every 100 ft. in length of the pipe. Such being the case, any correct formula for ascertaining the carrying-capacity of pipes of various diameters under various hydraulic gradients can, by transposition, be made to give the correct loss of head from friction.

The attached tabulated statement gives the results of experiments made for the purpose of ascertaining which formula in general use gives the most correct results. It will be seen that Eytelwein's general formula is not only the most correct, but by far the most simple, and it is applicable not only to pipes, but to channels also, and is in strict accordance with all the known laws of hydraulics. The formula is, "The mean velocity of water in feet per second is equal to the square root of" (twice the fall in feet per mile multiplied by the hydraulic mean depth). This formula may be stated as $\sqrt{RS 10560} = \text{velocity}$, R being the hydraulic mean depth and S the sine of the inclination, S 10560 being equal to twice the fall in feet per mile. It must, however, be understood that the formula is correct only for long, straight, and smooth pipes or channels, but it gives the correct proportions for pipes or channels of any kind, whether crooked or straight, rough or smooth, and the results multiplied by coefficients suitable to the character of the pipe or