the different materials and depths. Desaguliers says, that a leaden pipe of three fourths of an inch in thickness is strong enough for a height of 140 feet and diameter of seven inches. From this we may calculate all others. Belidor says, that a leaden pipe twelve inches diameter and sixty feet deep should be half an inch thick. But these things will be more properly computed by means of the list given in the article Strength of Matertials.

The application which we are most anxious to make of the knowledge of the pressure of moving waters, is the de­rivation from a main conduit by lateral branches. This occurs very frequently in the distribution of waters among the inhabitants of towns ; and it is so imperfectly under­stood by the greater part of those who take the name of engineers, that individuals have no security that they shall get even one half of the water they bargain and pay for ; yet this may be as accurately ascertained as any other pro­blem in hydraulics by means of our general theorem. The case therefore merits our particular attention.

It appears to be already determined, when we have as­certained the pressures by which the water is impelled into these lateral pipes, especially after we have said that the experiments of Bossut on the actual discharges from a la­teral pipe fully confirm the theoretical doctrine. But much remains to be considered. We have seen that there is a vast difference between the discharge made through a hole, or even through a short pipe, and the discharge from the far end of a pipe derived from a main conduit. And even when this has been ascertained by our new theory, the dis­charge thus modified will be found considerably different from the real state of things : for when water is flowing along a main with a known velocity, and therefore exert­ing a known pressure on the circle which we propose for the entry of a branch, if we insert a branch there, water will go along it ; but this will generally make a consider­able change in the motion along the main, and therefore in the pressure which is to expel the water. It also makes a considerable change in the whole quantity which passes along the anterior part of the main, and a still greater change on what moves along that part of it which lies be­yond the branch : it therefore affects the quantity necessary for the whole supply, the force that is required for propel­ling it, and the quantity delivered by other branches. This part therefore of the management of water in conduits is of considerable importance and intricacy. We can propose in this place nothing more than a solution of such leading questions as involve the chief circumstances, recommending to our readers the perusal of original works on this subject. Μ. Bossut’s experiments are fully competent to the esta­blishment of the fundamental principle. The hole through which the lateral discharges were made was but a few feet from the reservoir. The pipe was successively lengthened, by which the resistances were increased, and the velocity di­minished : but this did not affect the lateral discharges, ex­cept by affecting the pressures ; and the discharges from the end of the main were supposed to be the same as when the lateral pipe was not inserted. Although this was not strictly true, the difference was insensible, because the lateral pipe had but about the eighteenth part of the area of the main.

Suppose that the discharge from the reservoir remains the same after the derivation of this branch, then the motion of the water all the way to the insertion of the branch is the same as before ; but beyond this the discharge is diminish­ed by all that is discharged by the branch, with the head *x* equivalent to the pressure on the side. The discharge by the lower end of the main being diminished, the velocity and resistance in it are also diminished. Therefore the dif­ference between *x* and the head employed to overcome the friction in this second case, would be a needless or ineffici­ent part of the whole load at the entry, which is impossible ; for every force produces an effect, or it is destroyed by some

re-action. The effect of the forcing head of water is to pro­duce the greatest discharge corresponding to the obstruc­tions ; and thus the discharge from the reservoir, or the supply to the main, must be augmented by the insertion of the branch, if the forcing head of water remains the same. A greater portion therefore of the forcing head was employ­ed in producing a greater discharge at the entry of the main, and the remainder, less than *x,* produced the pressure on the sides. This head was the one competent to the obstruc­tions resulting from the velocity beyond the insertion of the branch ; and this velocity, diminished by the discharge already made, was less than that at the entry, and even than that of the main without a branch. This will appear more distinctly by putting the case into the form of an equation. Therefore let H — *x* be the height due to the velocity at the entry, of which the effect obtains only hori­zontally. The head *x* is the only one which acts on the sides of the tube, tending to produce the discharge by the branch, at the same time that it must overcome the obstruc­tions beyond the branch. If the orifice did not exist, and if the force producing the velocity on a short tube be repre­sented by 2 G, and the section of the main be A, the supply at the entry of the main would be A√2G √H—*x* ; and if the orifice had no influence on the value of *x,* the discharge by the orifice would be \*\*\*D^/jE., D being its discharge by means of the head H, when the end of the main is shut ; for the discharges are in the subduplicate ratio of the heads of water by which they are expelled ; and therefore \*\*\*√,H : *y/x =* D : Dι^∕jL= *i.* But we have seen that *x* must diminish ; and we know that the obstructions are nearly as the square roots of the velocities, when these do not differ much among themselves. Therefore, calling *y* the pressure or head which balances the resistances of the main without a branch, while *x* is the head necessary for the main with a branch, we may institute this proportion, \*\*\*y : H — *y = x:* ~,(~—~; and this fourth term will express the head pro­ducing the velocity in the main beyond the branch (as H—*y* would have done in a main without a branch). This velocity beyond the branch will be \*\*\*√2G ⅛∕~> an^

- ∕∙x, ( H ?/)

the discharge at the end will be A √2 G√ — ——. If

to this we add the discharge of the branch, the sum will be the whole discharge, and therefore the whole supply. Therefore we have the following equation, \*\*\*A√2G √H — *g* = A√2Gj^∕j\* —— +D^∕∩. From this we deduce the value of *x = 2^A\ -1 .*

(a√2-G√H^+-) +2gA\*

This value of *x* being substituted in the equation of the dis­charge *δ* of the branch, which was = \*\*\**ι)J L·,* will give the

H

discharges required, and they will differ so much the more from the discharges calculated according to the simple theory, as the velocity in the main is greater. By the simple theory, we mean the supposition that the lateral dis­charges are such as would be produced by the head H—*h,* where H is the height of the reservoir, and *h* the head due to the actual velocity in the main.

And thus it appears that the proportion of the discharge by a lateral pipe from a main that is shut at the far end, and the discharge from a main that is open, depends not only on