pels the water into the pipe, want­ing or *minus* that of the head of water which would communicate to it the velocity with which it ac­tually moves. This we shall call *x,* and consider it as the weight of a column of water whose length also is *x.* In like manner H may be the column AB which impels the water into the pipe, and would communicate a certain velocity ; and *h* may re­present the column which would communicate the actual velocity. We have therefore *x =* H —*h*.

In the pipe HIKL, the pressure at the point I is AH —*h —* IO= H — *h* — IO; and the pressure at K is H — A + PK.

And in the pipe DEFG, the pressure on E is = AR —*h* — EM = H — *h —* EM ; and the pressure at F is H — *h* 4+ FN.

We must carefully distinguish this pressure on any square inch of the pipe, from the obstruction or resistance which that inch actually exerts, and which is part of the cause of the pressure. The pressure, by the laws of hydrostatics, is the same with that exerted on the water by a square inch of the piston or forcing head of water. This must balance the united obstructions of the whole pipe, in as far as they are not balanced by the relative weight of the water in an enclosed pipe. Whatever be the inclination of a pipe, and the velocity of the water in it, there is a certain part of this resistance which may not be balanced by the tendency which the water has to slide along it, provided the pipe be long enough ; or if the pipe is too short, the tendency down the pipe may more than balance all the resistances that obtain helow. In the first case, this overplus must be balanced by an additional head of water ; and in the latter case the pipe is not in train, and the water will accelerate. There is something in the mechanism of these motions which makes a certain length of pipe necessary for bring­ing it into train ; a certain portion of the surface which acts in concert in obstructing the motion. We do not completely understand this circumstance, but we can form a pretty distinct notion of its mode of acting. The film of water contiguous to the pipe is withheld by the obstruc­tion, but glides along ; the film immediately within this is withheld by the outer film, but glides through it : and thus all the concentric films glide within those around them, somewhat like the sliding tubes of a spy-glass when we draw it out by taking hold of the end of the innermost. Thus the second film passes beyond the first and outer­most, and becomes the outermost, and rubs along the tube. The third does the same in its turn ; and thus the central filaments come at last to the outside, and all sustain their greatest possible obstruction. When this is accomplished the pipe is in train. This requires a certain length, which we cannot determine by theory. We see however that pipes of greater diameter must require a greater length, and this in a proportion which is probably that of the number of filaments, or the square of the diameter. Du Buat found this supposition agree well enough with his experiments. A pipe of one inch in diameter sustained no change of ve­locity by gradually shortening it till he reduced it to six feet, and then it discharged a little more water. A pipe of two inches diameter gave a sensible augmentation of velocity when shortened to twenty-five feet. He therefore says that the square of the diameter in inches, multiplied by seventy-two, will express, in inches, the length neces­sary for putting any pipe in train.

The resistance exerted by a square inch of the pipe makes but a small part of the pressure which the whole re­sistances occasion to be exerted there before they can be overcome. The resistance may be represented by -, where *d* is the hydraulic depth (one fourth of the diameter), and *s* the length of a column whose vertical height is one inch, and it is the relative weight of a column of water whose base is a square inch, and height is *d.* For the resistance of any length *s* of pipe which is in train is equal to the tendency of the water to slide down (being balanced by it) ; that is, is equal to the weight of this column multiplied by -. The magnitude of this column is had by multiplying its length by its section. The section is the product of the border *h,* or circumference multiplied by the mean depth *d,* or it is *bd.* This multiplied by the length is *bds ;* and this multi­

plied by the slope 1/*s* is *bd,* the relative weight of the column whose length is *s.* The relative weight of one inch is therefore *bd*/*s*; and this is in equilibrio with the resistance of a ring of the pipe one inch broad. This, when unfold­ed, is a parallelogram *b* inches in length. One inch of this therefore is the relative weight of a column of water having *d* for its height and a square inch for its base. Sup­pose the pipe four inches in diameter, and the slope = 253, the resistance is one grain, for an inch of water weighs 253 grains.

This knowledge of the pressure of water in motion is of great importance. In the management of rivers and canals it instructs us concerning the damages which they produce in their beds by tearing up the soil : it informs us of the strength which we must give to the banks, but it is of more consequence in the management of close conduits. By this we must regulate the strength of our pipes ; by this also we must ascertain the quantities of water which may be drawn off by lateral branches from any main conduit.

With respect to the first of these objects, where security is our sole concern, it is proper to consider the pressure in the most unfavourable circumstances, viz. when the end of the main is shut. The case is not unfrequent. Nay, when the water is in motion, its velocity in a conduit seldom ex­ceeds a very few feet in a second. Eight feet per second requires only one foot of water to produce it. We should therefore estimate the strain on all conduits by the whole height of the reservoir.

In order to adjust the strength of a pipe to the strain, we may conceive it as consisting of two half cylinders of insuperable strength joined along the two seams, where the strength is the same with the ordinary strength of the ma­terials of which it is made. The inside pressure tends to burst the pipe by tearing open these scams ; and each of those two seams is equal to the weight of a column of water whose height is the depth of the seam below the surface of the reservoir, and whose base is an inch broad and a diameter of the pipe in length. This follows from the common principles of hydrostatics.

Suppose the pipe to be of lead, one foot in diameter and 100 feet under the surface of the reservoir. Water weighs 62½ pounds per foot. The base of our column is there­fore 1/12th of a foot, and the tendency to burst the pipe is 100 × 62½ × 1/12 = 6250/12 = 521 pounds nearly. There­

fore an inch of one seam is strained by 260½ pounds. A rod of lead one inch square is pulled asunder by 860 pounds (see Strength of Materials). Therefore, if the thickness of the seam is = 260/860 inches, or one third of an inch, it will just withstand this strain. But we must make it much stronger than this, especially if the pipe leads from an en­gine which sends the water along it by starts. Belidor and Desaguliers have given tables of the thickness and weights of pipes which experience has found sufficient for