CHAPTER III.

HYDRAULICS.

PRELIMINARY REMARKS.

THE science which treats upon the mechanical properties and effects of water and other fluids, has most commonly been divided into two branches, HYDROSTATICS and HYDRAULICS. *Hydrostatics* treats of the weight, pressure, and equilibrium of fluids, when in a state of rest. *Hydraulics* treats of water in motion, and the means of raising, conducting, and using it for moving machinery, or for other purposes. These two divisions are so intimately connected with each other, that the latter could not be at all understood without an acquaintance with the former; and it is not necessary, in a work like the present, to treat of them separately. Considered abstractedly, the same laws obtain in the pressure and motion of water, as those which belong to solid bodies; and in the last chapter, on Mechanics, this similarity has led to some notice of the effects produced by water, which, strictly speaking, would belong to the present. In doing this, utility has been preferred to a strict adherence to system.

In treating of the elementary principles of Hydraulics, it is necessary to proceed upon theoretical principles; but let it always be recollected that from various causes resulting from the constitution of fluids, and particularly from that essential property in them, the perfect mobility of their particles among each other, the phenomena actually exhibited in nature, or in the processes of art, in which the motion of water is concerned, deviate so very considerably from the deductions of theory, that the latter must be considered as a very imperfect guide to the practical mill-wright and engineer. It

is not to be inferred from this circumstance, that such theoretical investigations are false and useless; they are still approximations, which serve as guides to a certain extent. Their defectiveness arises from our inability to form an estimate of the many disturbing causes which influence the motion of fluids; whilst in the mechanics of solids we have, in many cases, no other correction to make in our theoretical deductions, than to allow for the effect of friction.

"The only really useful method of treating a branch of knowledge so circumstanced, is to accompany a very concise account of such general principles as are least inapplicable to practice, by proportionately copious details of the most accurate experiments which have been instituted, with a view to ascertain the actual circumstances of the various phenomena." (*Lardner*'s *Hydrostatics*. Such has been the course pursued, to a considerable extent, by the author of this work, and in pursuing this subject, under the present head of Hydraulics, we shall consider only such parts of the science as immediately relate to our purpose: namely, such as may lead to the better understanding of the principles and powers of water, acting on mill-wheels, and conveying water to them.

ARTICLE 45.

OF SPOUTING FLUIDS.

Spouting fluids observe the following laws:—

1. Their velocities and powers, under equal pressures, or equal perpendicular heights, and equal apertures, are equal in all cases.*

2. Their velocities, under different pressures or perpendicular heights, are as the square roots of those pres-

* It makes no difference whether the water stands perpendicularly, or inclined, above the aperture, [see Plate III. fig. 22.] provided the perpendicular height be the same; or whether the quantity be great or small, provided it be sufficient to keep the fluid up to the same height.

sures or heights, and their perpendicular heights or pressures, are as the squares of their velocities.*

3. Their quantities expended through equal apertures, in equal times, under unequal pressures, are as their velocities simply.†

4. Their pressures or heights being the same, their effects are as their quantities expended.‡

5. Their quantities expended being the same, their effects are as their pressure, or height of their head directly.§

6. Their instant forces with equal apertures, are as the squares of their velocities, or as the height of their heads directly.

7. Their effects are as their quantities, multiplied into the squares of their velocities.‖ See Art. 46.

8. Therefore, their effects or powers with equal apertures are as the cubes of their velocities.¶

* This law is similar to the 4th law of falling bodies, their velocities being as the square root of their spaces passed through; and by experiment it is known, that water will spout from under a 4 feet head, with a velocity of 16,2 feet, per second, and from under a 16 feet head, 32,4 feet per second, which is only double to that of a 4 feet head, although there be a quadruple pressure. Therefore, by this law, we can find the velocity of water spouting from under any given head: for as the square root of 4 equal 2, is to 16,2 its velocity, so is the square root of 16 equal 4, to 32,4 squared, to 16, its head: by which ratio we can find the head that will produce any velocity.

† It is evident, that a double velocity will vent a double quantity.

‡ If the pressure be equal, the velocity must be equal; and it is evident, that double quantity, with equal velocity, will produce a double effect.

§ That is, if we suppose 16 cubic feet of water to issue from under a 4 feet head in a second, and an equal quantity to issue in the same time from under a 16 feet head, then their effects will be as 4 to 16. But we must note, that the aperture in the last case, must be only half of that in the first, as the velocity will be double.

‖ This is evident, from this consideration; namely: that a quadruple impulse is required to produce a double velocity, by law 2d, where the velocities are as the square roots of their heads: therefore, their effects must be as the squares of their velocities.

¶ The effects of striking fluids with equal apertures are as the cubes of their velocities, for the following reasons; namely: 1st. If an equal quantity strike with double velocity, the effect is quadruple on that account by the 7th law; and a double velocity expends a double quantity by 3d law; therefore, the effect is augmented to the cube of the velocity.—The theory for undershot wheels agrees with this law also.

9. Their velocity, under any head, is equal to the velocity that a heavy body would acquire in falling from the same height.*

10. Their velocity is such, under any head or height, as will pass over a distance equal to twice the height of the head, in a horizontal direction, in the time that a heavy body falls the distance of the height of the head.

11. Their action and re-action are equal.†

12. They being non-elastic, communicate only half their real force by impulse, in striking obstacles; but by their gravity produce effects, equal to elastic or solid bodies.‡

A SCALE

Founded on the 3d, 6th, and 7th laws, showing the effects of striking Fluids with different Velocities.

Velocity.		Aperture.		Multiplied by the		Quantity expended.		Is equal the	Square of the velocity,	Which multiplied by the	Quantity expended.		Is equal the	Effect.	Which is as the	Cubes of the velocity.
1	×	1	=	1	×	1	=	1	as	1						
1	×	2	=	2	×	4	=	8	as	8						
1	×	3	=	3	×	9	=	27	as	27						
1	×	4	=	4	×	16	=	64	as	64						

* The falling body is acted on by the whole force of its own gravity, in the whole of its descent through any space; and the whole sum of this action that is acquired as it arrives at the lowest point of its fall is equal to the pressure of the whole head or perpendicular height above the issue; therefore their velocities are equal.

† That is, a fluid re-acts back against the penstock with the same force that it issues against the obstacle it strikes; this is the principle by which Barker's mill, and all those that are denominated improvements thereon, move.

‡ When non-elastic bodies strike an obstacle, one half of their force is spent in a lateral direction, in changing their figure, or in splashing about. See Art. 9.

For want of due consideration or knowledge of this principle, many have been the errors committed by applying water to act by impulse, when it would have produced a double effect by its gravity.