ter at *a*, to come into the vessel A, perpendicularly, and A to revolve as fast as the water issues at *b*, equal to 16 feet per second. Then the whole of the force at *b*, will be expended in giving the water as it enters the vessel A, a velocity equal to that of the vessel. The retarding force will equal the impellent force, and the effect will be nothing. 22-1 $w-v=v$, consequently the expression, $m\div g(v-w\times v)w$, vanishes. But if the vessel A, move half as fast as the water issues at *b*, equal to 8 feet per second; then the retarding force will equal half the impelling force, and the effect will equal half the power. E,$=20\div32(16-8+0)\ 8=40$, and, as in this case the head is the highth of the vessel A, $P=20\times4=80$, or the effect equals half the power. Hence, the effect of the machine is double by using one half the head to give the water a whirling motion before acting.

If the vessel A, be suffered to revolve with a greater or less velocity than that with which the water issues at *b*, and comes in at *a*,; the effect will be diminished. But a slight variation will not alter the effect perceptibly; for if A move one eighth slower or faster than the water at the jets, the effect will be reduced only one sixty fourth (1·64) of the whole amount. But if its motion should be increased, or reduced one half, (to 24, or 8 feet per second) the effect will be reduced one fourth.

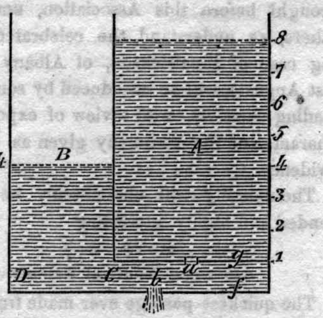
And if the issues *a*, and *b*, be dissimilar in size, the effect will be less; though not appreciable, when the difference is small; for when the orifice at *a*, is twice that at *b*, the diminution in effect will only be one tenth. This may be demonstrated by lowering the water in the cistern B, down to the dotted line one foot above *a*, and enlarging the orifice at *a*, to double that at *b*, and letting A revolve at a mean rate between that of the water at *a*, and *b*,—equal 12 feet per second, when the effect will be 9, and the power 10.

Here we have a machine that will realize as great a percentage of the power as it is possible to obtain; the principle of action of which is embraced, to a greater or less extent, in all turbines. And the efficiency of the different varieties of this class of motors, depends entirely on how far this principle is carried out in their operation.

THE CONSTRUCTION OF THE MACHINE.—23. Figure 3 is intended to show that water when issuing at two apertures, as at *a* and *b*, will have a velocity at each equal to that due one half the head.

22-2

FIG. 3.

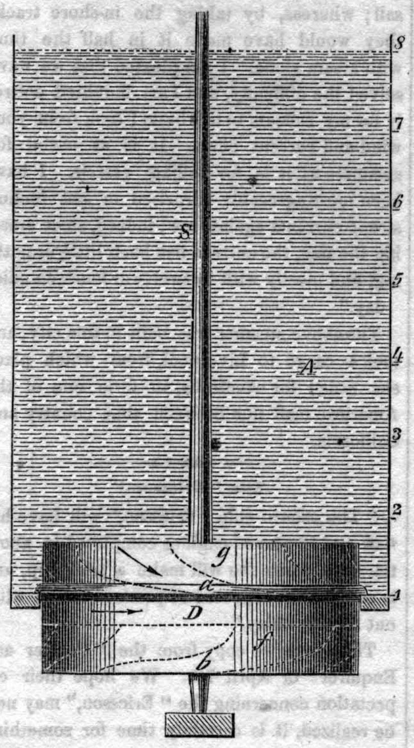


A is a cistern eight feet in depth, with two bottoms, *g*, and *f*, each of which have an aperture, *a* and *b*, of equal size. B is a cistern attached to A, with a communication at *c*, and an outlet at D. If A be filled with water to 5, equal 4 feet above the bottom *g*, and C and D be open, the water will escape at *a*, with a velocity of 16 feet per seeond. If D be closed, and the cistern A, kept full of water to *g*, the water in B will rise to 4, and the velocity at each aperture will equal 16 feet per second.—For the perpendicular highth of the water above *b*, is 4 feet, and the difference in perpendicular highth of the surface of the water in A and B, is 4 feet; consequently, by arts. 9, 10 and 11, the pressure on each bottom will equal a column of water 4 feet in highth, and the velocity at each aperture will equal that due at *a* 4 feet head.

As the water does not move in either direction at C, if this communication should be closed it will not affect the velocity at the jets, *a* and *b*, nor the pressure on the bottom *g* and *f*, and if the vessel B, should be entirely removed, the pressure on the bottoms and velocity at the jets would not be raised. Therefore, if water pass through an aperture into a close apartment, from which it issues again at a similar aperture; the velocity at each aperture will equal that due one half the whole head, and the pressure in the apartment will equal the weight of half the head.

24. By making a circular space in the bottom, *g*, and moving the bottom, *f*, fig. 3, a turbine wheel may be placed in it, with guides and shaft arranged as in fig. 4. The cistern, A, is, in section; the turbine guides and shaft are in elevation.

FIG. 4. 22-3

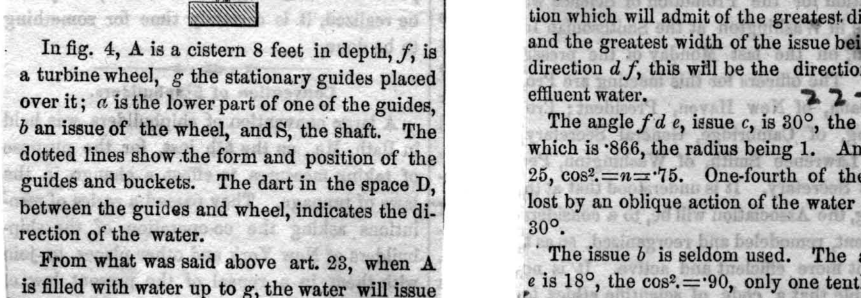


In fig. 4, A is a cistern 8 feet in depth, *f*, is a turbine wheel, *g* the stationary guides placed over it; *a* is the lower part of one of the guides, *b* an issue of the wheel, and S, the shaft. The dotted lines show the form and position of the guides and buckets. The dart in the space D, between the guides and wheel, indicates the direction of the water.

From what was said above art. 23, when A is filled with water up to *g*, the water will issue through the guides, *a*, into the space D, between them and the wheel, and issue out at *b*, of the wheel *f*, with a velocity at eaeh equal to that due one half the head, 16 feet per second; and the pressure in the space, D, will equal that of, a collumn of water the highth of half the head, 4 feet. When the turbine, *f*, is moving in the direction of the arrow with a velocity equal that of the water in the space D, 16 ft. per sec., by art. 20, the water will act on the turbine, tending to impell it forward, as it would do if it was at rest, and the water in A lowered down to 4, four feet above the lower part of the turbine, and the guides removed. Here we have

22-4

FIG. 5.



and the line of motion is to the radius. An inspection of fig. 4, and the diagram, fig. 5, will show, that the water issues at an angle to the plane of rotation of the wheel: and that, by arts. 2 and 15, the force of pressure, or re-action is in the direction *f d*, and not that of *e d*; consequently, the intensity of the force, in the direction *e d*, will be to that in the direction *f d*, as the cosine of the angle *f d e* is to the radius. By effecting the formula, art. 18, with this quantity, we obtain, cos^2.$=n$; whence $E=n(m\div g(e-w+v)w)$.

the principles of the machine, fig. 3, carried out in a practical way. The cistern, A, with guides, *g*, represents B, fig. 3, with issue *a*; and the turbine *f*, with space D, and issues *b*, represents the vessel A, with issue *b*, and the same reasoning made use of in reference to fig. 3, will apply to fig 4. 22-5

25. The experimental coefficient, *n*, art. 18, will now be discussed. A corollary deduced from the parallelogram of forces, is, that the intensity of a force tending to impel a body which can move in one direction only, is to the direct intensity of that force, as the cosine of the angle formed by the direction of its action

The friction of the water on the machine, and various other causes, will diminish the velocity of the issuing water below that due the highth of head, which will further reduce the effect.—When this originates from the friction of the water alone, which can only be determined by experiment, it may be neglected, as one of the data on which the calculation is based is the velocity of the water. But when the diminution takes place in consequence of bad construction, it should be taken account of in comparing the efficiency of different machines.

26. Fig. 5 is a diagram intended to illustrate the difference in efficiency of wheel with different kinds of issues. A B represents part of a section of a wheel, with the different forms of issue, *a*, *b*, and *c*, discharging equal quantities of water, and each occupying an equal space of the wheel, A B, the lower points of the guides, *e* and *d*, being equally distant from each other.

The form of issue at *c* is extensively used, and until quite recently was almost the only kind in use in re-action wheels. A mistaken notion in relation to this form of guide is very generally entertained. It is supposed that as the bottom of the guide at *d* curves to nearly a horizontal position, the water will leave it nearly horizontally: but the water will leave it in that direction which will admit of the greatest discharge; and the greatest width of the issue being in the direction *d f*, this will be the direction of the effluent water. 22-6

The angle *f d e*, issue *c*, is 30°, the cosine of which is ·866, the radius being 1. And by art. 25, cos^2.$=n=$·75. One-fourth of the effect is lost by an oblique action of the water equal to 30°.

The issue *b* is seldom used. The angle *f d e* is 18°, the cos^2.$=$·90, only one tenth lost.—But from art. 14, the velocity of the water, on account of bad adjutage, will be ·8, that due the head; hence, $n=$·576. Over 42 per cent lost.

The form of issue represented at *a* is one for which a patent was obtained in 1847. The guides are formed with a view to letting the water escape with the greatest possible velocity, and with the least angle possible to the plane of rotation, or tangent of the wheel. The part of the guide *d h* is a plane, from *h* upwards is cycloidal, *h* being the cusp of the cycloid.

The angle *f d e*, issue *a*, is 15°, which gives cos.$=$·933. Hence, $n=$·933. Not quite 7 per cent lost. 22-7

27. By effecting the equation, art 18, with *n*, we will obtain $E=\frac{(v-w+gv)wmn.}{g}$

The practical rule for determining the effect deduced from this equation, may be expressed in words as follows:

RULE—To the velocity with which the water