When $V^2 = 2gh$, we have, from (5), neglecting friction,

$$\text{efficiency} = \frac{(\sqrt{2} - 1)\, V^2}{gh} = 0.828, \qquad (7)$$

about 17 per cent. of the energy of the fall being carried away by the water discharged. The actual efficiency realized of these machines appears to be about 60 per cent., so that about 22 per cent. of the whole head is spent in overcoming frictional resistances, in addition to the energy carried away by the water.

Sch.—The reaction wheel in its crudest form is a very old machine known as "*Barker's Mill.*" It has been employed to some extent in practice as an hydraulic motor, the water being admitted below and the arms curved. In this case the water is transmitted by a pipe which descends beneath the wheel and then turns vertically upwards. The vertical axle is hollow, and fits on to the extremity of the supply pipe with a stuffing box. In this construction the upward pressure of the water may be made equal to the weight of the wheel, so that the pressure upon the axis may be nothing. These modifications do not in any way affect the principle of the machine, but the frictional resistances may probably be diminished.

159. The Centrifugal Pump.—When large quantities of water are to be raised on a low lift, no pump is so suitable as a centrifugal pump. In this pump, water is raised by means of the centrifugal force given to the water in a curved vane or arm, proceeding from the vertical axis. The dynamic principles of this machine are the same as those of the reaction wheel (Art. 158); but they differ in their objects. In the latter machine, a fall of water gives a rotatory motion to a vertical axis, while in the former a rotatory motion is given to a vertical axis in order to elevate a column of water.