guides of a contrary curvature, puts it in motion; its interior periphery revolving as nearly as possible, in contact with the exterior periphery of the inner or guide wheel. This is the Fourneyron turbine in its simplest form. One of the most important improvements effected by Mr. Boyden was the application of the "diffuser," almost universally adopted since. The invention is embodied in the formation of two large stationary discs without and around the wheel, the space between which at the inner periphery is very little greater than that between the crowns of the wheel at the part next to them. These discs curve apart and outward, so that the space at their exterior periphery is twice as great. The section through which the water passes in escaping from the wheel is thus enlarged in the ratio of one to four; hence its action should fall from 1 to 1-16th in the same distance, provided the wheel be submerged. The effect of this arrangement is to reduce the pressure on the escaping water, and thus increase the power as though the fall were increased. The theoretical gain to be derived by this arrangement is equal to about 5 per cent. on the whole power; though from one cause or another only 3 per cent. is usually realized. Mr. Boyden suspended his turbine from above, and was the first to point out the expediency of employing very thin guide-plates and vanes. One of the greatest objections to the Fourneyron wheel and its modifications is, that being always submerged, it is, to some extent, inaccessible for repairs or examination. It is frequently far from convenient to drain away the water, especially when more than one turbine is supplied from the same race. As early as the year 1838 this objection was recognized, and the "Jonval" wheel introduced to obviate it. Instead of revolving outside the stationary guides, the buckets in this turbine revolve below them. Both the fixed and moveable wheels are placed within a tube of sufficient diameter, the orifice of which, placed below the level of the water in the lower race, is so contracted as to allow of only the proper quantity of water passing through, due to the velocity arising from the difference of the two levels above and below the turbine. By this arrangement the wheel may be placed in any part of the height of the fall deemed most desirable; the necessary force and velocity of the water being obtained by the pressure of the atmosphere on the upper surface of the suspended liquid column. When the supply of water is cut off by closing the upper sluices, the wheel is left high and dry for repairs, as the tube is usually large enough to afford ample space for a man to work in it with ease.

When the turbine is employed to render high falls available, the foot-step of the vertical spindle often gives much trouble, as well from the difficulty of lubricating it properly, as from the great weight which it has to sustain, and the high speed at which the shaft revolves. At St. Blasier, in the Black Forest, a wheel only 13 in. in diameter is put in motion by a column of water 354 feet high. Whether all the pressure due to this vast height is rendered available or not we cannot say. The wheel makes 2,200 revolutions per minute, driving 8,000 water spindles, with the necessary machinery for slubbing, roving, &c. Fifteen hundred revolutions per minute are by no means uncommon with larger wheels. Mr. Boyden, in America, and Mr. Mallett, in this country, cut the Gordian knot by hanging the revolving ring and its shaft, and all the weight of the water upon it, from a ring of conical rollers above the pen-trough, running between two faced-up iron plates, the central toe or step being used merely as a steadier. When the foot-step is retained the best practice is to form a cavity in the end of the shaft, which is fitted accurately to a hardened steel pin, projecting upwards, firmly fixed in the base of the wheel pit, on which the entire weight is sustained. The proper shape for this pin and its corresponding cavity has been made the subject of much mathematical disquisition. Oil is usually supplied through an aperture drilled up the centre of the pin, by a very small force-pump, put in motion by an eccentric on some slow running shaft in the mill above. In the great Fairmount Jonval turbines, intended to supply water to the city of Philadelphia, the central shafts are supported on stout cast-iron columns, bolted down to the iron bottom of the draft box or vertical tube. A socket resting on the top of this column contains a circular block of lignumvitæ, 15 in. in diameter and 8 in. or 9 in. thick. Its upper surface is rounded to a partially spherical shape, and a few spiral grooves are cut in its surface to permit the entrance of water, and thus secure constant lubrication. A cast iron socket, hollowed out to fit this block, is keyed on the lower extremity of the vertical shaft, thus forming the bearing. These wheels are, perhaps, the largest of the kind in the world, being not less than 9 ft. in diameter over the buckets; each wheel, we believe, drives a nearly horizontal double-acting pump, 18 in. in diameter, and 6 ft. stroke, intended to make twelve double strokes per minute when pumping against the head of water in the reservoir.

The construction of the turbine suggests some of the most complicated problems in hydraulics, and theory scarcely yet affords the means of solving them. Practice alone supplies us with thoroughly trustworthy results. From this reason there is little doubt that the statements of the usual effect realized from a given fall are frequently over-estimated, the quantity of water passing through the wheel being really in excess of that assumed from calculation. Still, making every allowance, there is no doubt that, with proper care, turbines usually give out a higher co-efficient of useful effect than perhaps any other moving power in existence. At first sight, it appears that the entering water should impart a severe shock to the curved buckets which oppose its motion. This disappears, however, when the wheel moves at a proper velocity. Under correct arrangements, the water enters the wheel without impact, and passing along the whole length of the blades which constitute the buckets, and exercising a pressure at every part, whereby its velocity is constantly reduced, while the direction of its motion is modified by their curve, it finally leaves the wheel with an insensible motion, being deposited as it were in the tail race, from which it flows in obedience to the law of gravitation at a velocity determined by the inclination of the floor on which it rests. In order to secure this action, the most extreme accuracy of workmanship is absolutely essential. It is useless to set out the proper curves with a strictly mathematical preci-