It has been said that "countless wealth is being squandered in all the torrents and water courses of the world." But it might be added that unless the proper means are taken for its utilization, wealth of energy avails little more to man than that of the tides of Jupiter.

It seems at first sight a very simple matter to place a wheel in position to take up the energy of water; but in practice that arrangement is generally found to involve more or less costly construction in the way of dams, basins, canals, flumes and even tunnels. This is particularly the case where the use of turbines is contemplated, and this consideration is frequently sufficient to annihilate the expediency of thus attempting to utilize a known and otherwise available source of power.

These adverse conditions are forcibly illustrated in the mountainous districts of the North American Continent. Water power is there in abundance, but it is that of mountain torrents: as a rule inconsiderable in volume of water, but, on account of the configuration of the country, affording large heads. The latter circumstance makes any constructive work very costly, and in most instances would put the use of an ordinary turbine out of the question.

It was from such causes that the Western States became the birthplace of that system of water power of which the essential feature is an impulse water wheel. The simplification made possible in this system is that of the substitution of a pipe and nozzle of insignificant dimensions for the massive head race and wheel pit associated with the use of a turbine.

The first impulse wheels brought into use were of the very crudest description; with the increasing use of the system, however, came the development which attends every invention which has a large field of usefulness open to it. The impulse wheel of the present day ranks as fairly efficient among the various means of utilizing natural energy.

At this stage it becomes a question to what extent it may be desirable to employ the impulse wheel outside the conditions under which it first sprang into existence. This problem is specially interesting in a country where there is an abundance of water power, and at a time when the utilization of water power is assuming the place of one of the most important engineering questions of the day. The object of this paper is to record the results of some experimental research on this subject, and also to discuss the question by the light of those results and from other considerations.

The history of the development of the impulse water wheel may advantageously be sketched briefly. The first wheels of this class were simply provided with flat projections on the rim of the wheel, and the jet was arranged to impinge normally on these flat surfaces. This was what was known as the hurdy-gurdy. It can easily be shown from theoretical considerations that the ideal efficiency of such a wheel is 50 per cent., but it is probable that most of those in use did not give a greater efficiency th n from 20 to 30 per cent.

The first notable improvement was that of substituting hollow cups for the flat vanes, so that the jet struck the interior part of the cup and was deflected back again until it left the vane, traveling, with respect to the vane, in almost the opposite direction to that in which it was traveling before impact. This formation at once largely increased the efficiency, but in practice the efficiency was still far from what it theoretically might be.

The next modification was that of so curving the surface of the cup that the jet might follow the surface with very little deviation at the first point of contact. Thus some wheels are formed with a conical projection in the interior of the cup at the point where the jet strikes the surface, so that the water on striking may begin to pass along the generating lines of the cove, and may gradually be deflected further to follow the curved sides of the interior of the vane. The more common construction is to place a wedge-shaped projection across the interior of the cup or vane. This modification was introduced about 1880. The function of the wedge is two-fold.

(1) To prevent the heaping of dead water upon the vane during its passage through the arc of action, or the part of its path in which the vane receives the jet of water. (2) To give the diverted streams a direction of motion which will finally carry them clear of the wheel.

In a bucket unprovided with any conical or wedge-shaped projection, there is no sudden angular deflection of the water. Some of the water is heaped upon the flat surface upon which the jet is impinging, thereby forming a curved surface over which the following water is deflected. With a stationary vane on which the stream is continuously playing, the loss of force due to this cause is very slight. When, however, the impact is taking place intermittently on a moving vane, the dead water is discharged after very inefficient action at the end of every short period of action, and the total loss in effective work may be considerable. This loss is reduced by placing a solid projection in the bucket, which takes the place of that formed by the water and leaves all the water free to be deflected in the most efficient manner. As regards the second function of the wedge, it is well known that when a stream of water strikes normally upon a surface, it is deflected equally in all directions. This is illustrated in the wheel bucket. The same action takes place when the stream strikes centrally upon the apex of a cone. This is undesirable in the case of the vane of a water wheel, as the water which is deflected towards the centre of the wheel gets into position to strike the back of the following vane, thus opposing the useful effect of the action. Then the jet strikes a wedge, it is cut into two portions, which are deflected away from one another in a plane perpendicular to the cutting edge of the wedge. In a wheel this motion causes the water to be discharged at each side of the wheel where it is free from all liability to interfere with any following parts of the wheel.

Numerous modifications of the form of the curved surfaces of the buckets have been brought out at different times by inventors with a view of modifying the passage of the water over the vane in some particular, but it is not necessary to describe them more particularly.

Of the impulse wheels in use at the present day the best known is probably the Pelton water wheel. These wheels are made in sizes varying from 6 in. to 6 ft. in diameter, according to the head of water available, and the velocity required. These wheels have been applied under heads ranging up to 1,700 feet, and, as has been said, there is no doubt that under such conditions the highest efficiency is realized. On the other hand, there are said to be instances in which Pelton wheels are running with good results under heads of from 50 to 75 feet.

The writer recently made a series of tests on a small wheel of this class, catalogued as the Pelton Motor No. 3. This wheel is approximately 18 in. in diameter, and the weight of the whole machine is given as 320 pounds.

The tests were made in the hydraulic laboratory of McGill University, and a brief description of the methods employed will be given. It was impossible to make tests with heads as high as some of those under which these motors run. The maximum head employed was that afforded by the city supply from the high-level reservoir, which gives a pressure of 125 lbs. per square in. in the laboratory, equivalent to a head of 290 feet. Lower pressures were also obtained by throttling the supply from the same source. These trials will give an idea of what may be expected of this type of motor when used under ordinary heads of from 100 to 300 feet. In many districts these are as large heads as are commonly met with. Also, where it is proposed to take power from a water-works system, the pressure under which water is supplied would rarely exceed 125 lbs. per square inch. In the present series of trials the wheel tested was small compared with many in use: the effective work done did not in any case exceed 7 horse-power. There is no doubt that with a machine designed on a larger scale, as with larger heads, the efficiency would show some increase over the values found in the present case. The results obtained in these experiments are offered as bearing directly on the question of the utilization of this system for small amounts of power under the conditions usually met with in districts outside those referred to as abounding in very high falls of water. With reason and judgment, the general conclusions arrived at by the consideration of these results may be extended to cases where the machinery and the generation of power is on a larger scale.

For the purposes of trial the wheel was set up as received from the makers, and the auxiliary apparatus was fitted in accordance with their instructions. The water, after passing through the valve which was used to regulate the pressure, was led along a length of 2½-inch pipe straight for 8 or 10 feet before reaching the nozzle. A Bourdon gauge was fitted on the supply-pipe less than one foot from the mouth of the nozzle-tip. This gauge was arranged on a pressure-chamber, enveloping the pipe and communicating with the interior through a series of small holes. Before being used the gauge was calibrated by means of a gauge tester. In the experiments the