**MILLOT'S HYDRAULIC WHEEL.**

In the setting up of a hydraulic wheel, the following conditions always have to be satisfied: The water must be led from the head race with the least possible loss of velocity; it must be made to act without shock; and it must be discharged without velocity into the tail race. Such conditions cannot be rigorously fulfilled with undershot wheels, as the water loses a portion of its velocity before reaching the wheel, through friction against the sides of the race, and then, at the moment when it reaches one of the buckets, it suddenly loses its velocity and takes on that of the wheel; and, finally, it leaves the latter with considerable velocity. The performance of such a wheel rarely exceeds 25 per cent.

With the overshot wheel, provided it moves slowly, we obtain better results, since its motion, in which the water in the buckets participates, brings about a centrifugal force that modifies the form of the free surface of the liquid in each bucket. Such surface falls toward the interior of the wheel, and rises toward the exterior, so that the water tends to escape from the bucket before accomplishing its work. On another hand, if the water enters with slight velocity from the channel, it does not produce any shock on running into the buckets, if the wheel is moving slowly, and, when the buckets empty, the water is deposited in the tail race without velocity.

Well arranged overshot wheels utilize 75 per cent of the motive work developed by the action of the water, especially with heads varying from ten to forty feet.

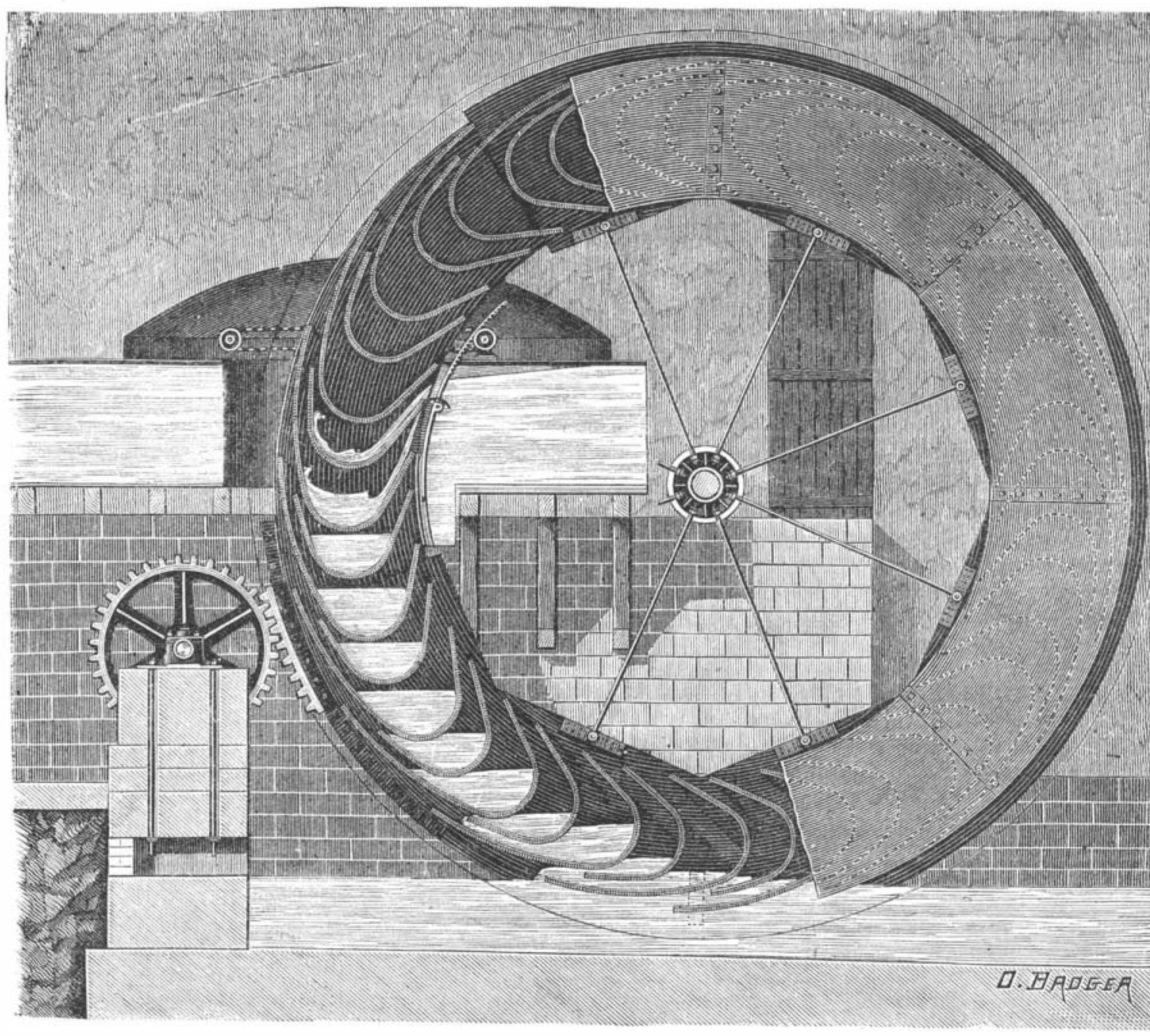
With the breast wheel, the total weight of water that acts does not exert itself solely upon the wheel, for the pressure is merely a component of the weight of the water, and the race supports the other component or part of such weight. It results from this that the wheel, while receiving the same quantity of work from the water, is much less charged, and consequently the friction of its shaft upon the supports is less. But such advantages are counterbalanced by drawbacks due to the fact that the play necessarily existing between the edges of the buckets and the race occasions a loss of water, and also to the fact that the water, in running through the race, experiences quite a good deal of resistance.

To prevent too great a loss of water at this place, it becomes necessary to run the wheel with greater velocity than we do an overshot one, and the result is that the water leaves the wheel with a notable velocity that carries with it a loss of work. This wheel, nevertheless, utilizes about 66 per cent of the work developed by the water.

The Poncelet wheel is an undershot one, so modified as to make it utilize a greater fraction of the work furnished by the water, while at the same time allowing it the advantage of speed. Instead of flat buckets, it has curved ones, and its performance amounts to 60 per cent. The Sagebien wheel is a modification of the breast wheel, which, without being too wide, discharges a large volume of water, thus giving a better performance (80 per cent) than the ordinary breast wheel.

Such are the principal peculiarities of common water wheels.

The accompanying figure represents a Millot wheel, as modified by Mr. C. Hauvel. This wheel keeps up a high performance, despite variations in the head of water and in the discharge, since it always utilizes the total height of the fall. Moreover, it admits the water without velocity. Compared with overshot wheels, it presents a greater width of rim, that permits of taking in three or four times more water. If we compare it with breast wheels, or even with the Poncelet water wheel, we find that it does away with the construction and keeping in repair of a wheel race, and it is not exposed to damage or accident from ice or the passage of a foreign body. The objection has been made to it that its diameter is nearly double the height of the fall, and that it is slow, thus multiplying gearings; but the arrangement here illustrated and now used by Mr. Hauvel shows that it is possible to obtain great speed on the driving shaft. As may be seen, the inclination of the buckets allows it to be immersed to some depth without loss, and the slight velocity that is ascribed to it permits of following the current without meeting with resistance therein.




**THE MILLOT-HAUVEL WATER WHEEL.**

Mr. Hauvel employs iron plate buckets. The interior of the rim is toothed, thus rapidly multiplying the velocity of the driving shaft. The long shafts have been suppressed, and the heavy and cumbersome spokes have been replaced by simple bolted rods, that pass between the two distinct parts of the channel. The head race is thus divided into two portions of water, that join each other on their fall into the bucket. This arrangement, which is simple, light, and strong, is very ingenious.

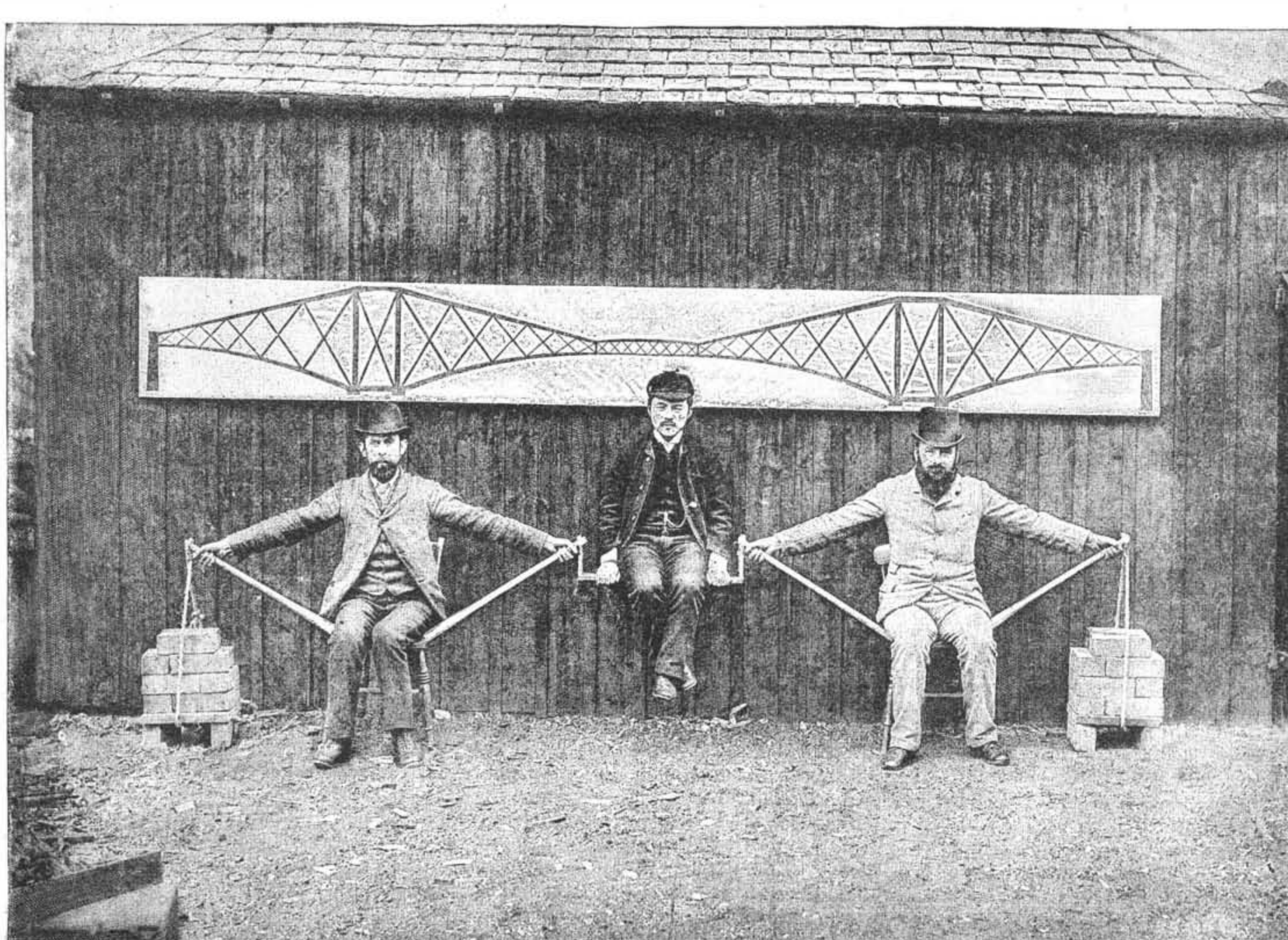
In order to facilitate the exit of the water, the external lips of the buckets are made alternately long and short, so that the starting section is doubled. This receiver can, therefore, be applied to the utilization of a large discharge without the necessity of increasing its width out of measure. This arrangement does not produce any diminution in the performance due to the anticipated overflow of the water, because the latter does not fall into the race, but into the succeeding bucket. An official committee has found that the performance of this motor reaches 86 per cent.—*Revue Industrielle.*

---

**THE FIRTH OF FORTH BRIDGE**

BY B. BAKER, M. INST. C. E.*

If we could transport one of the tubes of the great Britannia Bridge from the Menai Straits to the Forth, we should find it would span little more than one-fourth of the space to be spanned by each of the great Forth Bridge girders. And yet it was of this Britannia Bridge that Stephenson, its engineer, thirty years ago, said: "Often at night I would lie tossing about seeking sleep in vain. The tubes filled my




**THE PRINCIPLE OF THE FIRTH OF FORTH BRIDGE.**

* From a lecture delivered at the Royal Institution.—*Engineering.*

head. I went to bed with them and got up with them. In the gray of the morning, when I looked across Gloucester Square, it seemed an immense distance across to the houses on the opposite side. It was nearly the same length as the span of my tubular bridge!"

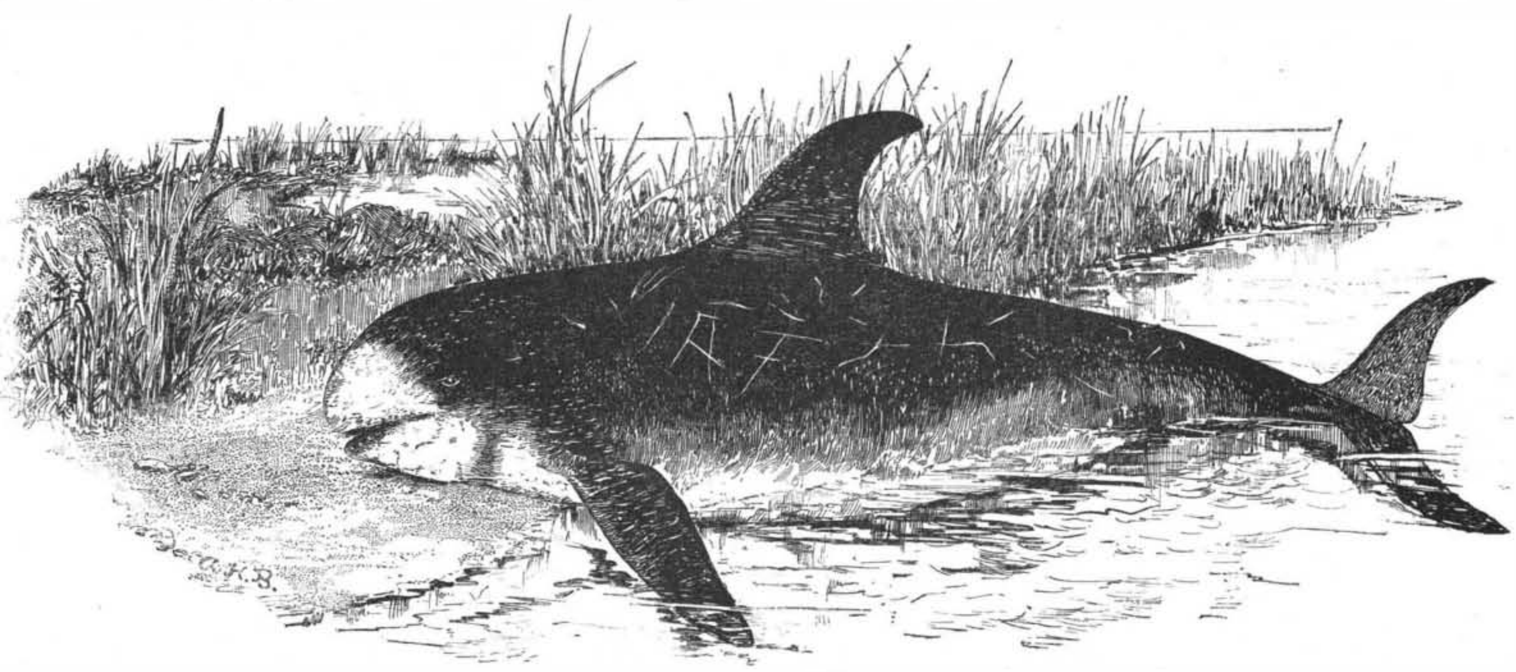
Our spans, as I have said, are each nearly four times as great as Stephenson's. To get an idea of their magnitude, stand in Piccadilly and look toward Buckingham Palace, and then consider that we have to span the entire distance across the Green Park, with a complicated steel structure weighing 15,000 tons, and to erect the same without the possibility of any intermediate pier or support. Consider also that our rail level will be as high above the sea as the top of the dome of the Albert Hall is above street level, and that the structure of our bridge will soar 200 feet yet above that level, or as high as the top of St. Paul's. The bridge would be a startling object indeed in a London landscape.

It is not on account of size only that the Forth Bridge has excited so much general interest, but also because it is of a previously little known type. I will not say novel, for there is nothing new under the sun. It is a cantilever bridge. One of the first questions asked by the generality of visitors at the Forth is, Why do you call it a cantilever bridge? I admit that it is not a satisfactory name, and that it only expresses half the truth, but it is not easy to find a short and satisfactory name for the type. A cantilever is simply another name for a bracket, but a reference to the diagram will show that the 1,700 feet openings of the Forth are spanned by a compound structure consisting of two brackets or cantilevers and one central girder. Owing to the arched form of the under side of the bridge, many persons hold the mistaken notion that the principle of construction is analogous to that of an arch.

In preparing for this lecture the other day, I had to consider how best to make a general audience appreciate the true nature and direction of the stresses on the Forth Bridge; and after consultation with some of our engineers on the spot, a living model of the structure was arranged as follows (see illustration): Two men sitting on chairs extended their arms and supported the same by grasping sticks butting against the chairs. This represented the two double cantilevers. The central girder was represented by a short stick slung from one arm of each man and the anchorages by ropes extending from the other arms to a couple of piles of brick. When stresses are brought on this system by a load on the central girder, the men's arms and the anchorage ropes come into tension and the sticks and chair legs into compression. In the Forth Bridge you have to imagine the chairs placed a third of a mile apart, and the men's heads to be 360 feet above the ground. Their arms are represented by huge steel lattice members, and the sticks or props by steel tubes 12 feet in diameter and 1¼ inches thick.

I have remarked that the principle of the Forth Bridge is not novel. When Lord Napier of Magdala accompanied me over the works one day, he said: "I suppose you touch your hat to the Chinese?" and I replied, "Certainly," as I knew that a number of bridges on the same principle had existed in China for ages past. Indeed, I have evidence that even savages when bridging in primitive style a stream of more than ordinary width have been driven to the adoption of the cantilever and central girder system, as we were driven to it at the Forth. They would find the two cantilevers in the projecting branches of a couple of trees on opposite sides of the river, and they would lash by grass ropes a central piece to the ends of their cantilevers and so form a bridge. This is no imagination, as I have actual sketches of such bridges taken by exploring parties of engineers on the Canadian Pacific and other railways, and in an old book in the British Museum I found an engraving of a most interesting bridge in Thibet upward of 100 feet in span, built between two and three centuries ago and in every respect identical in principle with the Forth Bridge. When I published my first article on the proposed Forth Bridge, some four years ago, I protested against its being stigmatized as a new and untried type of construction, and claimed that it probably had a longer and more respectable ancestry even than the arch.

The best evidence of approval is imitation, and I am pleased to be able to tell you that since the first publication of the design for the Forth Bridge, practically every big bridge in the world has been built on the principle of that design, and many others are in progress.



A TATTOOED WHALE.

### BRUIJN'S ECHIDNA (PROECHIDNA BRUIJNI), NEW GUINEA ANT EATER.

Our engraving shows the rare and extraordinary echidna that has quite recently been discovered in Northern New Guinea (*Proechidna bruijni*). This curious animal in outward appearance resembles the hedgehogs in its spine-covered body and the ant eaters in its long and tapering snout. The latter is incapable of being opened, and the mouth consists of a small hole at the apex, through which the long and vermiform tongue is protruded. The spines are short and stout, but of needle-like sharpness, and spring from a thick coat of dark brown fur. The forefoot is furnished with three broad and nail-shaped claws, while those of the hinder limb are long, sickle-like, and very sharp. Worked by the powerful muscles with which the creature is provided, these are admirably adapted for digging. The tail is rudimentary. Bruijn's echidna, which is over two feet in length, and is thus considerably larger than its Australian representative, is said by the natives to live in burrows in rocky ground.—*Dr. F. H. H. Guillemard, Cruise of the Marchesa.*

### A TATTOOED WHALE.

The accompanying sketch is taken from a cetacean, about twelve feet long, caught in a bluefish gill net by fishermen at Nantucket Island, off Cape Cod, on the fourth of July. Owing to arrangements made with the lighthouse board and life-saving service, in 1883, members of these departments of the government are instructed to inform the commissioner of fisheries, at once, by telegraph, of the occurrence of stranded or captured marine animals such as whales, porpoises, blackfish, and other forms of cetaceans.

Among the papers forming the report of the fish commissioner for 1883 is a circular of instructions to fishermen and others on the coast, giving descriptions and drawings of most of the known forms of cetaceans, and directions for the proper preservation of specimens, so affording sufficient knowledge to secure the safety of valuable and rare forms until they can be taken charge of by the necessary experts.

In consequence of the peculiarity of the animal captured at Nantucket, news of the fact was sent to the summer headquarters of the United States Fish Commission, at Wood's Holl, Mass., and the "whale," as the fishermen described it, was taken there, whence it will be sent, as a skeleton, to the National Museum at Washington, to form a part of the osteological collection there. The animal is a *grampus* (*Grampus griseus*), a species which is somewhat common throughout the North Atlantic.

Several specimens have been taken, their capture being chiefly due to the habit of the species of skirting very near the shore, in pursuit of its food of small fishes and minute surface

BRUIJN'S ECHIDNA (PROECHIDNA BRUIJNI), NEW GUINEA ANT EATER.