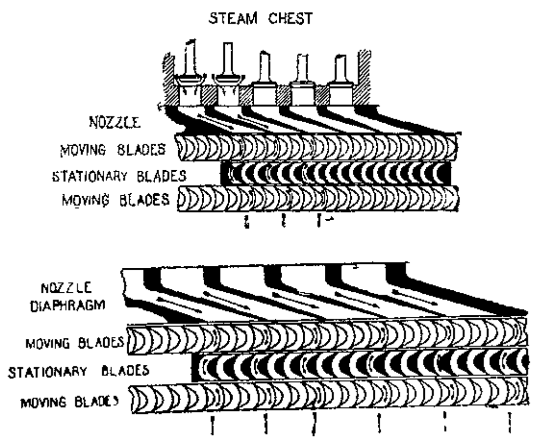
... THE ...

CURTIS TURBINE.

BY J. R. TEMPLIN.

[This article was specially written for PROGRESS *by Mr. Templin, who has until recently represented the General Electric Co. in Christchurch, where his Company has supplied the whole of the electric plant for the new Corporation tramways.]*

THE first steam turbine was probably that built by Heros of Alexandria, in the year 120 B.C. It was then known as a reaction wheel, and worked in much the same way as the latter-day rotating lawn sprinkler. In 1629 one Branca, an Italian, invented an impulse turbine, on the same principle as the impulse water-wheel, in which the water is directed, by means of nozzles, upon a number of vanes mounted on a shaft. Owing to the mechanical difficulties which presented themselves in obtaining suitable materials and tools the Branca machine



SECTION OF CURTIS TURBINE SHOWING NOZZLES AND BLADES.

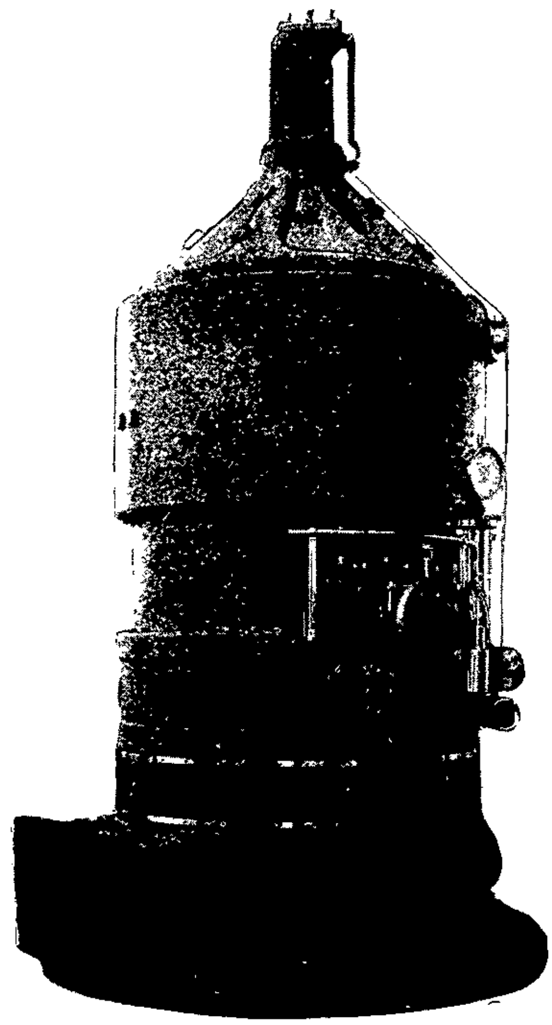
was not developed, and further interest ceased until 1884, in which year a Swede named De Laval perfected the impulse turbine. With improved conditions of manufacture De Laval soon went past the efforts of the earlier experimenters, and gave the world a workable and valuable machine. Steam flowed through a nozzle on to a single vane wheel; and the revolutions per minute went up to as high as twenty thousand.

The invention of the Parsons turbine, which embraced an entirely new principle, was contemporaneous with the De Laval. The Parsons may be termed a reaction-impulse turbine, for instead of steam expanding through nozzles and then impacting its energy to the wheel vanes, the expanding is done in the blades themselves.

The Curtis turbine, which was invented in 1897, differs materially from that of any other type of steam turbine, in that it permits the use of comparatively low rotative speeds without introducing any complicated mechanism. The normal speed is 1800 revolutions per minute; while the guaranteed speed variation is four per cent. no load to full load. However, on small fluctuations of load the variation will not exceed two per cent. The Curtis turbine is designed to work continuously with an overload of twenty-five per cent. and fifty per cent. momentarily. Its efficiency is also demonstrated in its economical consumption of steam per kilowatt*output, for with a full load it requires but 21lbs. of steam per kilowatt hour. This, contrasted with a reciprocating engine's consumption of 20lbs. for each indicated horse power, leaves a great deal to be said in favour of the economy of the later machine. The turbine is divided into stages (1 and 2), in which respect it may be compared to a compound or triple expansion reciprocating engine. Each stage may contain one, two, or more revolving bucket wheels, which utilise the power of the steam after it has been expanded from a set or sets of expansion nozzles. The work is divided between the stages—again similar to a multi-cylinder engine—and thus permits a greater initial velocity of the steam, which renders the action of the steam more efficient and perfect than could be obtained were a lower initial velocity used. By means of this arrangement of working with two stages the energy of the flowing steam is more effectively given up to the revolving parts, as the surface friction caused by the steam moving over the buckets varies as the square of the velocity. The pressure between each stage is so arranged that most efficient results ensue, the required pressures having been obtained after a long and expensive series of experiments. Before proceeding any further it may be well to note the positions of the blades and the nozzles. (Fig. 1).

In other types of steam turbines the steam expands either through a great number of successive rows of buckets, without the use of nozzles, or the expanding steam is used by expanding in nozzles and absorbing the kinetic energy in the one revolving bucket wheel, thus requiring an enormous peripheral speed, and rendering the turbine unpractical for direct driving of electric generators, or for other similar purposes. To give an idea of the enormous velocity of this steam expanding through a diverging nozzle from 150 lbs. boiler pressure to atmospheric pressure, it can be said to have a velocity of nearly 3000 feet per second In order to utilise all the kinetic energy of the steam the peripheral velocity of a turbine having a single bucket wheel would have to be nearly one half of the initial velocity of the steam, or 1500 feet per second, which is over three times the peripheral velocity of the wheels in the Curtis turbine.

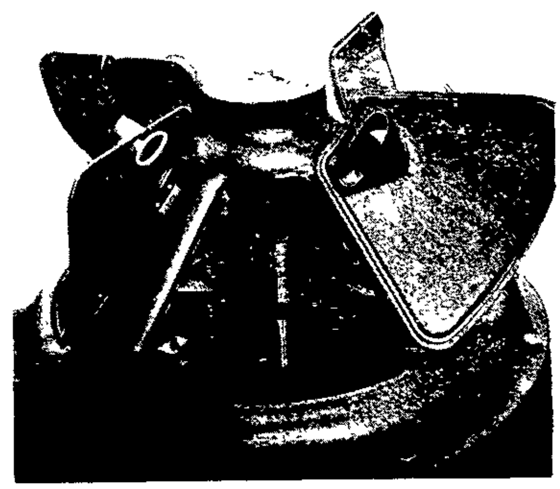
The Curtis steam turbine is made in a number of sizes, ranging from $1\frac{1}{4}$ kilowatts to 5000. All of the machines below 500 kilowatts are made with a horizontal shaft, and are direct-current machines.



500-K.W. CURTIS TURBINE.

Those of 500 kilowatts, and over, are made with a vertical shaft, thereby avoiding all imposition of weight on cylindrical bearings and the tendency to deflect the shaft, which might be due to unequal expansion—a very important factor in large-sized turbines. The result of this is compactness and simplicity of construction.

The vertical shaft is supported on what is called a step-bearing, upon which the whole of the revolving parts are supported, and which maintains the revolving and stationary parts in exact relation to each other continually. This step-bearing consists of two cylindrical, cast-iron discs bearing upon each other, and with a central recess in the bottom part to receive the lubricant which is forced in with sufficient pressure to lift the revolving parts and the top piece of the step. Thus, the whole revolving part turns on a thin film of water, as water is the lubricant used. The water, after passing between the discs, flows upwards and lubricates a guide-bearing which is supported by the same casing, and which helps to align and steady the shaft. The shaft is protected from rusting by a base sleeve which is shrunk over it. After the water passes through this bearing it flows off into the base of the turbine and into the condenser. The sleeve is made of white metal, and can easily be removed in case of necessity. It is therefore clear that the friction must be very slight. For example a 500 kilowatt turbine will revolve four or five hours after the steam is shut off. All of the



TOP OF CURTIS TURBINE SHOWING COMMUTATOR.

latest designs are, therefore, provided with a brake which bears on the lower surface of a chilled-iron ring carried by the lower wheel. Thus, in case of necessity the machine can be stopped very quickly. Should the water pressure be lost the bearings will score somewhat and slowly wear away; but such a contingency is not likely to prevent the continuance of operation if the pressure is re-established. However, in the event of the bearing becoming much cut it can be taken out and faced off and used again. The failure of the lubricating system is reduced to a minimum, as almost all power houses have a hydraulic accumulator which will keep up the pressure even though the pumps were to stop; and the pumps are duplicated so that should one stop the other would start up. The pressure required to hold up the revolving parts depends upon the size of the turbine, ranging from 185lbs. to 1250lbs. in the case of a 5000 kilowatt machine. The amount of water required by the turbine is regulated by a baffler, which consists of a square-threaded screw, around which the water has to flow, and the longer the thread the less the water flowing. Thus there is a constant relation between the revolving and the stationary parts.

One of the most important features of the Curtis turbine is the method of governing. The machine is governed by changing the number of nozzles in flow; thus the variation of the load affects the efficiency of the machine very little, barring the rotation losses, which are constant with all loads. Thus it is quite apparent that the efficiency of the machine is much higher than if throttling were used. The governor is attached to the top of the shaft. It is a centrifugal governor designed by the General Electric Company. It may be remarked, in passing, that one of the greatest problems of the steam turbine is to obtain a suitable governor for high-speed work. There are plenty of governors for low speed, but when high speed is required none of them will stand the test. The centrifugal governor acts upon levers which operate a drum, and on which there are segments of same number as the valves. These segments, or cams, operate fingers carrying contact points, which close an electro-magnetic circuit controlling a pilot valve, which in turn operates the main valve. The main valve is a balanced valve, having live steam pressure on the top and bottom when it is in the closed position. By the action of the solenoid on the pilot valve the live steam pressure is cut off, and at the same time an exhaust port is opened, which releases the steam on top of the main valve and thus allows the main valve to be opened by the steam pressure under it. As the load varies the number of valves in operation changes. On a regular load one valve will be opening and closing constantly.

A very important item in operating a turbine is

* About $1\frac{1}{4}$ indicated horse power.