THE STEAM TURBINE.*

ITS THEORY SIMPLY EXPLAINED.

BY WILLIAM E. SNOW.

MODERN steam turbines are divided into two general classes, known as the *impulse*, and the *reaction*, these terms relating to their methods of steam utilization.

In the ordinary accepted meaning of the terms an impulse is a force acting in a forward direction,

FIG. 1.—SIMPLE REACTION.

and a reaction is a force acting in a backward direction—a resultant of the impulse, and equal to it in magnitude. These terms, however, as applied to steam turbines, are somewhat misleading, as in all impulse turbines the steam acts by impulse on entering and by reaction on leaving the buckets; while

FIG. 2.—SIMPLE IMPULSE.

most so-called "reaction" turbines in reality operate by both reaction and impulse. In order to clearly understand the principal points of difference between the types, let us refer to the graphical illustrations given in Figs. 1, 2, 3 and 4.

Fig. 1 is an example of simple reaction. The ves-

FIG. 3.—PRINCIPLE OF MODERN IMPULSE TURBINE.

sel A is suspended from a cord and filled with water. The water escapes from the orifice or nozzle B, and as there is consequently no resistance at this point to the pressure of the fluid in the vessel,

the unbalanced force exerted on the walls directly opposite B causes the vessel to move reactively in the direction of the arrow.

Hero's turbine, invented 120 B. C., shown in Fig. 5, is an excellent example of a purely reaction type. As will be seen, this consisted of the hollow metal globe A, mounted rotatively on the uprights BB by suitable pivots or bearings. This globe was provided with two bent tubes or nozzles CC pointing in tangentially opposite directions. Steam from the boiler D was conducted to the globe by one of the supports B which was made hollow for this purpose. The steam, issuing from the bent tubes or nozzles CC, caused the globe to rotate reactively in a direction opposite to that of the jets. The principle of operation of this turbine was identical with that of the ordinary lawn-sprinkler of the present day, whose

FIG. 4.—PRINCIPLE OF MODERN REACTION TURBINE.

rotating arms are moved by the reaction of the water escaping from them.

Fig. 2 is an example of simple impulse. As in the previous case, the vessel A, is filled with water, but instead of being suspended it is fixed immovably in place. The jet of water escaping from the orifice or nozzle B is made to impinge upon the flat plate C, suspended from a cord at a suitable height. The pressure of the jet causes the plate C to move by impulse in the direction of the arrow. There will also be a reaction force exerted, equal in magnitude and opposite in direction to the impulse. The vessel being in this case fixed immovably, this reaction force does no work.

Branca's turbine, invented 1629 A. D., shown in Fig. 6, is an excellent example of a purely impulse

pulse" type. As in the previous case, the vessel A is filled with water and fixed immovably in place. In this case, however, the suspended plate C, instead of being flat is given a semi-circular form, approximately the shape of the buckets in an impulse turbine. The jet of water escaping from the orifice or nozzle B impinges upon this curved surface and is turned back upon itself through an angle of 180 degrees, issuing from the bucket in a direction opposite to that by which it entered. It is, therefore, evident that the jet acts by impulse on entering, and by reaction on leaving the bucket. Since action and reaction are equal, neglecting friction, the combined impulse and reaction forces tending to move the plate C, in the direction of the arrow will be twice as great as the impulse force in the previous case, Fig. 2. This is the principle on

FIG. 5.—HERO'S REACTION TURBINE.

FIG. 6.—BRANCA'S IMPULSE TURBINE.

which the buckets of all modern commercial turbines operate, whether of the impulse or of the reaction type.

In Fig. 4 is an example of the impulse and reaction forces exerted by the working fluid on the buckets of a modern turbine of the reaction type. As in the previous case, the vessel A is filled with water, but instead of being fixed immovably in place it is suspended from a cord, as in Fig. 1. The plate C, provided with a semi-circular bucket, is also suspended from a cord, as in Fig. 3. The jet of water escaping from the orifice or nozzle B impinges on the curved surface of the bucket, tending by its combined impulse and reaction forces to move it in the direction of the arrow. In this case, however, the reaction force, equal in magnitude but

FIG. 7.—BUCKETS AND NOZZLE ARRANGEMENT OF IMPULSE TURBINE.

type. As will be seen, this consisted of the wheel A, mounted rotatively on the support B by means of suitable bearings. This wheel was provided with paddles or buckets C similar to those used in water-wheels. A tube or nozzle D was placed close to the wheel, so that the issuing steam would impinge on the buckets C. Steam was supplied from the boiler E, and issuing from the nozzle D by its impulse caused the wheel to rotate in the direction of the impinging jet. It is interesting to note that, crude as the Hero and Branca turbines were, they clearly establish the two distinctive classes from which all modern turbines are derived.

In Fig. 3 is an example of the impulse and reaction forces exerted by the working fluid on the buckets of a modern turbine of the so-called "im-

opposite in direction to the impulse force, is free to move the vessel A in the direction of the second arrow. This is the principle on which modern commercial turbines of the reaction type operate.

It is easy to determine whether a turbine belongs in the impulse or the reaction class from the fact that in all impulse turbines the steam pressure is the same on both sides of any one row of buckets; in all reaction turbines there is a fall of the steam pressure in passing any one row of buckets, and the pressure on the two sides of the buckets is not equal. This will be seen more clearly by referring to Figs. 7 and 8.

Fig. 7 shows the bucket and nozzle arrangement of a turbine of the impulse class. In this drawing B is the nozzle, CC are the rotating buckets moving

*Power and Engineer.

in the direction of the large arrows, and *D* are the stationary buckets or reversing guide. The steam enters the nozzle *B* at boiler pressure, and is expanded completely in the nozzle right down to the back pressure of the exhaust, all its available pressure energy being thus converted into velocity energy. The steam, delivered in this form to the

Reaction Turbines—Fall of pressure in passing any one row of buckets.

While the principle of operation of all commercial turbines of the reaction class is practically the same, impulse turbines can be subdivided into several different types, according to their particular method of steam utilization, as follows:

FIG. 9.—VARIOUS TURBINE TYPES.

buckets, is incapable of any further expansion; consequently the pressure must be the same on both sides of any one row of buckets. This rule holds good, regardless of the number of stages that may be used.

The principle of operation of this type of turbine is shown by the small arrows, indicating the flow of the steam. The steam from the nozzle enters the first set of moving buckets at high velocity, but no appreciable pressure, and is turned through an arc of approximately 150 degrees, whereby a certain portion of its velocity is abstracted and converted into useful work. As the steam issues at greatly reduced velocity from this first set of moving buckets, it is caught by the stationary buckets or guide *D* and redirected at proper angle into the second set of moving buckets. Here it is again turned through an arc of 150 degrees, and most of its remaining velocity abstracted and turned into useful work.

Fig. 8 shows the arrangement of the stationary and the moving buckets of the turbine of the reaction type. The stationary buckets or guides *BB* correspond to the nozzles in the impulse type of turbine, and *CC* are the moving buckets similar in form to the stationary guides. The steam enters the first set of stationary buckets or guides *B* at boiler pressure. Owing to the nozzle-like form of these blades, the steam here undergoes a partial drop in pressure, with a corresponding expansion and increase in velocity. As the drop in pressure per stage in this type of turbine rarely exceeds 10 or 12 pounds, the velocity of the steam is not nearly as high as in the case of the greater expansion that occurs in the nozzle of the impulse turbine. The steam issues at moderate velocity, and but slightly reduced pressure, from the guides *B* and impinges upon the first set of moving buckets *C*, imparting to them by impulse that portion of its pressure energy that has been converted into velocity by its passage through the guides *B*. Owing to the shape of the moving buckets, which have the same nozzle-like form as the guides, the steam undergoes a still further pressure drop, with a corresponding expansion and increase in velocity in its passage through. As a result of this increase in velocity, the issuing steam imparts to the buckets by reaction a portion of the pressure energy that has been converted into velocity by its passage through. This same process is repeated in the second set of stationary guides and moving buckets, and so on throughout as many stages as are required to abstract all the available energy from the steam.

It will be noted that the pressure in each successive clearance space between the stationary and moving buckets is lower than in the preceding one. Thus, the pressure at *E* is lower than at *D*, the pressure at *F* is lower than at *E*, the pressure at *G* is lower than at *F*, etc.

From the preceding the following rule is derived for the proper classification of all turbines:

Impulse Turbines—Equal pressure on the two sides of any one row of buckets.

IMPULSE TYPES.

Single-Stage Type—Turbines with but one set of nozzles and one row of moving buckets.

Velocity Compounded—Turbines with one set of nozzles only, but with two or more rows of moving buckets, with intermediate guides.

Pressure Compounded—Turbines with two or more stages, each stage comprising one set of nozzles and one row of moving buckets.

Pressure and Velocity Compounded—Turbines with two or more pressure stages, each pressure stage comprising one set of nozzles and two or more rows of moving buckets, with intermediate guides.

FARM POULTRY PAYS WELL UNDER RIGHT MANAGEMENT.

"If farm poultry keeping does not pay, there is usually something vitally wrong with the management of the farm," states Prof. J. G. Halpin, in charge of the poultry department of the College of Agriculture of the University of Wisconsin, in an article in the current number of the Student Farmer, the monthly journal published by students in the college.

"One reason why poultry can be made to pay on the farm," writes Prof. Halpin, "is that the fowls consume much feed that would otherwise be wasted. On the average farm where the poultry is numbered by dozens rather than by thousands, the by-products form a very important part of the poultry feed.

Waste materials may be utilized, such as waste from the kitchen table and garden, grains, screenings, etc.

SKIM MILK GOOD CHICK FOOD.

"Skim milk makes an excellent poultry feed, and may be used to moisten a mixture of ground grains, or the milk may be given to hens to drink. When skim milk is abundant it may be heated until the curd forms and this curd fed to the flock. On many farms the supply of meat and milk will be ample to meet the needs of the flock, while on others the supply will be limited and beef scraps or fresh ground green bone should be purchased. Green bone or other meat may form about eight per cent of the total ration in winter. In the summer a well managed farm flock secures many insects which supply the necessary meat for egg production.

"No class of farm stock can utilize screenings so well as poultry. Where the hens are kept in colony houses, they may be moved to different grain

FIG. 8.—STATIONARY AND MOVING BUCKETS IN REACTION TURBINE.

fields as soon as the crop has been harvested, and find plenty of feed for several weeks.

"Clover or alfalfa chaff may be gathered in the barn and given to poultry every few days. We are gradually learning," continues Prof. Halpin, "that bulky feeds, such as the clovers, make good feeds for a part of the egg ration, and form a decided advantage in small cost.

KEEP HENS IN COLONY HOUSES.

"Farm poultry is too often allowed to run in one large flock. The chicks cannot be fed properly, and are almost sure to become infested with lice from the older fowls. Often ducks, geese, chickens and turkeys are all turned together to fight for supremacy. The more the fowls are distributed over the farm in summer the more productive they will be.

"A small patch of sunflowers makes ideal shade, and furnishes excellent feed for fall use. Economy demands that poultry be kept in comfortable houses, not warm, stuffy, damp, ill-smelling places, but in dry, well-ventilated houses, free from drafts. All windows should be removed in the spring and left open until cold weather. Economy also demands that only good stock be kept, and that the poor producers be disposed of. Hens must also be kept free from lice and mites."

It is stated that Mr. Marconi intends to make a series of tests shortly with a view to ascertaining the practicability of sending wireless messages across Canada.

FIG. 10.—VARIOUS TURBINE TYPES.