rotating vanes and the reduction of speed with each pair of vanes, the speed of the Parsons turbine can, by multiplying the vanes, be reduced to almost any amount. The end thrust is counterbalanced by three rotating pistons placed on the turbine shaft. Many of the details of the Parsons turbine are worthy of special study. The method of preventing leak past the balancing piston and the manner of getting the turbine shaft through the case are examples.

The Curtis turbine, Fig. 4, unlike the two types described, has a vertical shaft in sizes above 500 kilowatts. It is perhaps best described in the maker's own words:

"Each stage or element of the Curtis turbine essentially consists of a group of expanding nozzle sections, which delivers steam to the first of a group of wheels or rings of buckets. Between the successive rings of buckets rows of stationary buckets, called "intermediates" are placed in the region opposite to the group of nozzles, the function of these intermediates being to reverse the motion of the steam received from one set of moving buckets, and to deliver it against the following set of moving buckets in an effective direction. The steam from one group of nozzles may thus be passed by the action of successive intermediates through several rows of moving buckets, the number of such rows associated with a single group of nozzles being governed by various mechanical and theoretical conditions. The group of nozzles imparts motion to a column of steam, most of the energy of the steam expansion being transformed into this motion. This motion is then fractionally abstracted by the passage of the steam through the successive rows of moving buckets.

"The above described circle of operations takes place in what is known as one stage of the Curtis steam turbine, and it is generally desirable to use two or more of such stages, in order that the expansive force of steam may be effectually utilized. Where a plurality of stages is used, the turbine conditions are so arranged that all the stages, under normal conditions, will perform approximately equal amounts of work. All the losses and efficiencies of one stage take the form of heat in the steam, and are therefore more or less available as motive force in the succeeding stages.

"In our first commercial machines we adopted two such stages, three or four rows of moving buckets being used in each stage. In some of our later machines we have adopted four stages, with two rows of moving buckets in each stage. Under certain other conditions, other numbers of stages and arrangements of buckets will doubtless be adopted."

Parsons turbines have been running in England for over twelve years, a sufficient length of time to permit of some idea being formed as to their durability.

At Newcastle, a Parsons machine ran for 36,000 hours without interrupted service, and at the end of the run there was no perceptible wear on the blades. The oldest Westinghouse-Parsons machine has been running for four years only. The repairs, however, during this time are said to have been light and of a minor character, with no perceptible wear on the blades.

At the present time there are in England from 600 to 800 turbine plants either actually installed or sold. These aggregate 200,000-h.p. The largest unit installed is 3,500-h.p. A special feature might be noted here in this connection, that many of the plants in which the first installations were made have added further turbine horse-power. On the continent, Messrs. Brown, Boveri & Co., of Baden, Switzerland, manufacture the Parsons turbine. At the end of 1902 they had sold twenty plants, aggregating 29,000-h.p., the largest unit being 3,000-h.p. On this side of the Atlantic, the Westinghouse Machine Company, of Pittsburg, have made, and have in service, turbines to the amount of 6,500 kilowatts, while upwards of 5,000 kilowatts more have been shipped. The total turbine power already installed and in process of erection amounts to 110,000 kilowatts. Fifty-seven units will be in operation before the end of the next nine months.

There are, unfortunately, no figures at hand giving the horse-power of the De Laval turbines installed later than the year 1896, when it was said to be 23,000. Since that time some 13,000 I.P. has been installed in the United States alone.

Recent large contracts for and installation of Parsons and Westinghouse-Parsons turbines include the following: For the Philadelphia Rapid Transit Co., Philadelphia, Pa., 3 units 5,000-K.W. each. De Beers Consolidated Mines, Kimberley, South Africa, 2 units, 1,000-K.W. each. Metropolitan District Ry., London, England, 8 units, 5,000-K.W. each. Metropolitan Railway Co., London, England, 3 units, 3,500-K.W. each. Cleveland, Elyria & Western Ry., Cleveland, Ohio, 2 units, 1,000-K.W. each. West Penn. Ry. & Ltg. Co., Pittsburg, Pa., 3 units, 1,000-K.W. each. Rapid Transit Subway Construction Co., New York, N.Y., 3 units, 1,250-K.W. each. Penn. R. R. Long Island Power House, 3 units, 3,500-K.W. each, and many others.

For the Metropolitan Railway Co.'s plant, the turbines are constructed by the Parsons Steam Turbine Co., and are guaranteed to have a combined efficiency of 17 lbs. of steam per kilowatt hour, delivered at full load, and 20¼ lbs. of steam for each kilowatt hour, delivered at half load, the boiler pressure being 160 lbs. per square inch, with the steam superheated 180 deg. F., 90 per cent. vacuum in the condenser.

Recent large contracts for and installations of Curtis turbines include: Commonwealth Station, Chicago, 1 unit, 5,000-K.W. Lane Cotton Mills, New Orleans, 3 units 500-K.W. each. Fulton Bag and Cotton Mills, Atlanta, Ga., 2 units, 500-K.W. each.

In all, 200,000-H.P. of Curtis turbines are said to be under contract.

These figures show that the turbine must now be seriously considered a rival of the reciprocating engine. For, while it is true that in this country it is used almost entirely for driving electric machinery, yet in England it has already been employed as a blowing machine (the air compressor being a counterpart of the turbine), for driving centrifugal pumps with high lifts, for ventilating purposes, and for marine work. In these various positions its steady growth is the best indication of its performance; and it need not be restricted to these alone, for it is excellently adapted to other services, where its high speed is not a positive disadvantage.

Comparing the steam turbine with the reciprocating engine, it is seen that the former has the following points of advantage: The turbine has no valve gear, no vibration, is very light, and requires only sufficient foundation to bear its weight. It is the more simple of the two. The torque on the shaft is uniform, and there are no moving parts to be brought to rest and accelerated twice in every revolution. Condensation should be small, and full advantage is taken of low exhaust pressures. With three cylinder reciprocating engines, on the other hand, about the same results are obtained, with a 70 per cent. 80 per cent. and 90 per cent. vacuum. The turbine is compact. It is impossible to give figures of general application, but it has been calculated that it requires about 80 per cent. of the floor space of the vertical engine of the same power and one-half the engine room capacity, about 40 per cent. of the floor space required by a horizontal engine and a correspondingly smaller amount of engine room capacity. It is a comparatively simple matter to erect and test at the maker's plant. It is admirably suited for the use of superheated steam. The steam consumption is about the same as that of the reciprocating engine when new, but since there are no rubbing parts, the wearing of which causes leakage, this consumption should be approximately constant throughout the life of the turbine. Its consumption varies less than that of the reciprocating engine over wide ranges of loading. No cylinder lubrication is required by the turbine, in consequence of which the exhaust is pure, a matter of considerable importance where water is dear, while difficulties that are unavoidable in extracting the oil are not encountered. Incidentally because of this, less work is required in the boiler room.

The turbine is, because of the uniformity of its driving force specially suitable as a prime mover for such a system as alternators running in parallel. With it there is no tendency to produce these periodic fluctuations of speed which occur during every revolution of a reciprocating engine. The problem of speed regulation is consequently much simplified. To effect this, it is only necessary to supply a governor, which will keep down fluctuations of speed due to a sudden change of load, prevent surging, and give the drop in speed