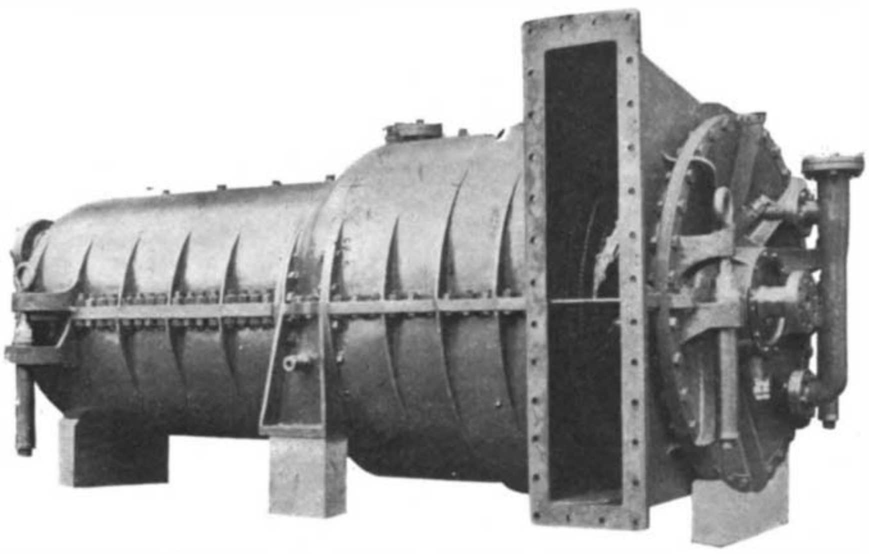
THE INTRODUCTION OF THE STEAM TURBINE FOR LIGHT AND POWER WORK.

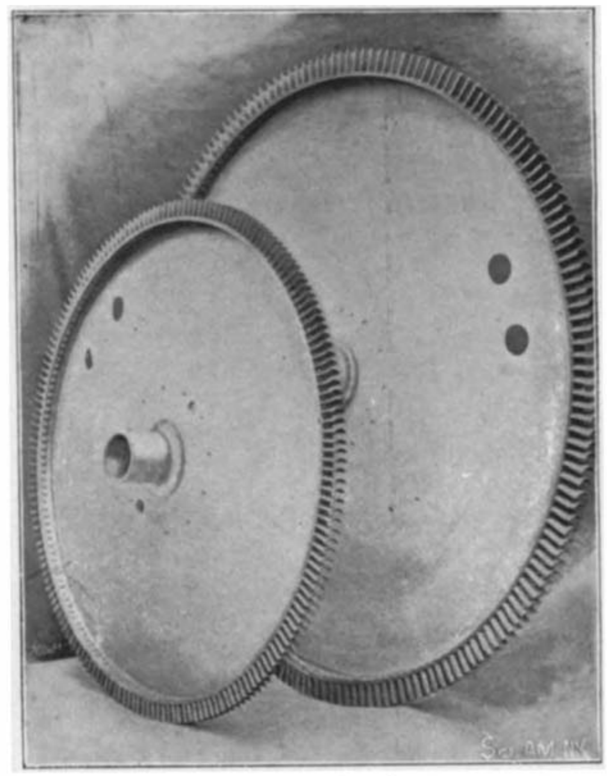
BY FRANK C. PERKINS.

The use of the steam turbine has developed wonderfully of late, and it would not be surprising if the practice of using high-power slow-speed steam engines directly connected to heavy flywheel alternators should be entirely reversed in the near future, these slow-speed units being replaced by the high-speed steam turbine and direct-connected alternators of comparatively small size. The small space which the steam turbine and alternator occupy for a given large output will hasten their introduction, especially as the economy of operation may be fully as high as the best compound or triple-expansion slow-speed engines of the present time. The low cost of both steam turbine and high-speed alternating current generator will also be a factor which is not to be disregarded. The accompanying illustrations, Figs. 1, 2, 3 and diagram, Fig. 7, show a type of steam turbine being introduced by the Maschinenfabrik Oerlikon in Switzerland. This turbine was designed and constructed by Prof. A. Rateau, in connection with Sautter, Harle & Co., of Paris, and consists of a number of Laval or Pelton wheels arranged in series on a shaft, each of which revolves in a separate chamber, the whole forming a multiple-step impulse turbine, the steam being conveyed to the vanes on the wheels by distributing nozzles which are fixed, and the expansion taking place in the latter. There are two sizes of wheels in the turbine; one system of fifteen smaller wheels and another of ten wheels of larger diameter. The turbines give in effective work from 65 to 70 per cent of the thermodynamic capacity. At an admission pressure of 13 atmospheres and 0.1 atmosphere of vacuum, the theoretical consumption per horse power hour is given at 3.7 kilogrammes; while the actual consumption is from 5.7 to 5.3 kilogrammes per horse power hour; and when the turbine is direct-connected to the electrical generator, 8.1 to 7.5 kilogrammes is the consumption per kilowatt per hour. Reckoning an economy of 10 per cent at 60 degrees superheating, the consumption is 7.3 to 6.8 kilogrammes per kilowatt hour. A number of Rateau steam turbines have been constructed of 1,200 horse power whose weights are 3,500 kilogrammes each, or about 3 kilogrammes per effective horse power. Another machine of 1,800 horse power is expected to have a steam consumption of about 12 pounds per brake horse power per hour; while the turbine of this type of 2,500 horse power is not expected to run over 1.4 kilogrammes per effective horse power in total weight, without the generator.

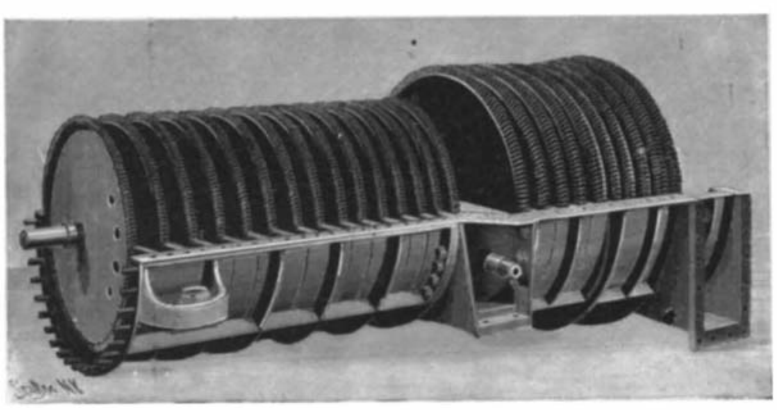


1. 1,200 H. P. RATEAU MULTIPLE-STEP IMPULSE TURBINE.

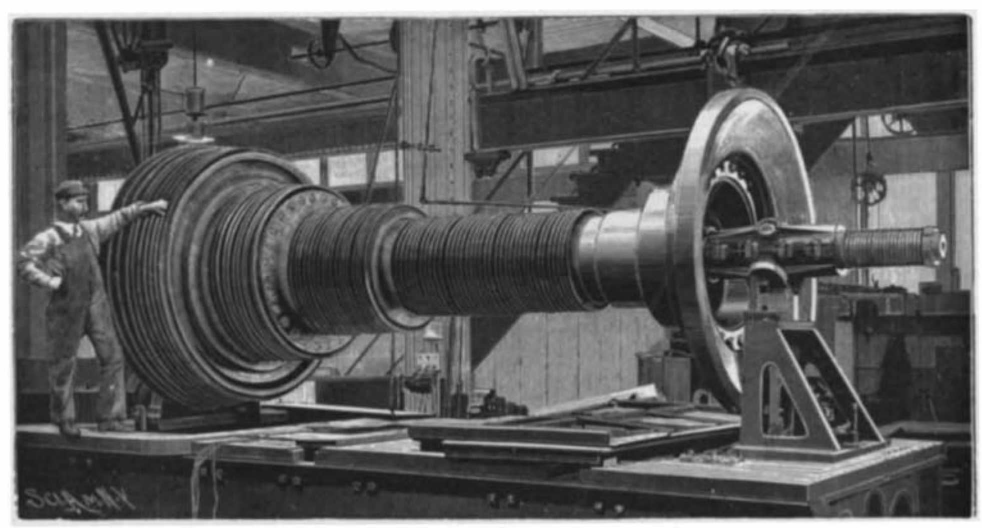
In "Some Notes on Steam Turbines," by F. J. Warburton, read before the North-East Coast Institution of Engineers and Shipbuilders in England recently, he mentions two multiple-expansion steam turbines; one a single-direction motor and the other reversible. The former has fourteen wheels keyed onto a cylindrical shaft, slung between resilient bearings; and cells are cut in the inner faces of these wheels and the walls of the cells form curved vanes. A separate chamber is provided in which each wheel revolves. The steam enters at the center chamber at 75 pounds pressure absolute, then passing to the vanes of the first wheel through four diagonal nozzles piercing the partition. The direction of the jet is reversed as nearly as possible by the curved vanes, the steam passing over the outer periphery. Somewhat larger nozzles are used to guide the steam onto the wheel in the next chamber, and it continues through the various chambers to the last or seventh wheel, when it is again carried back through an ample passage to a center chamber not provided with a wheel, and then the steam expands through the various steps of chambers and wheels to the exhaust, the nozzle areas being so proportioned that each wheel does its share of work. Floating packing rings are used for isolation of chambers and end packing, being held against the surfaces by the



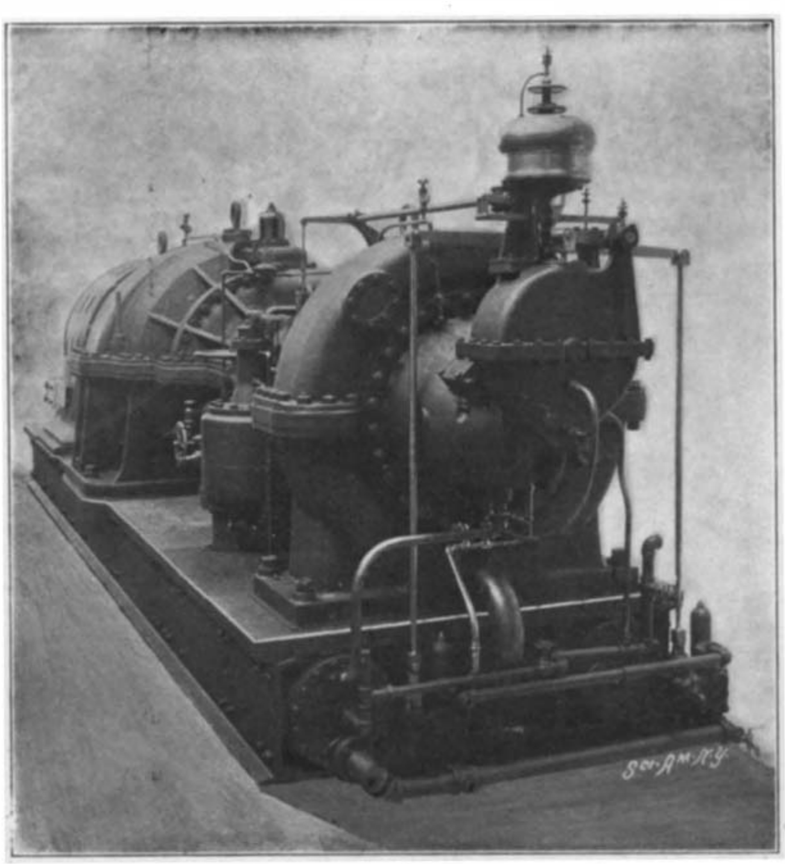
2. LARGE AND SMALL DISKS OF THE 1,200 H. P. RATEAU TURBINE.



3. ROTATING PART OF 1,200 H. P. MULTIPLE-STEP RATEAU TURBINE.

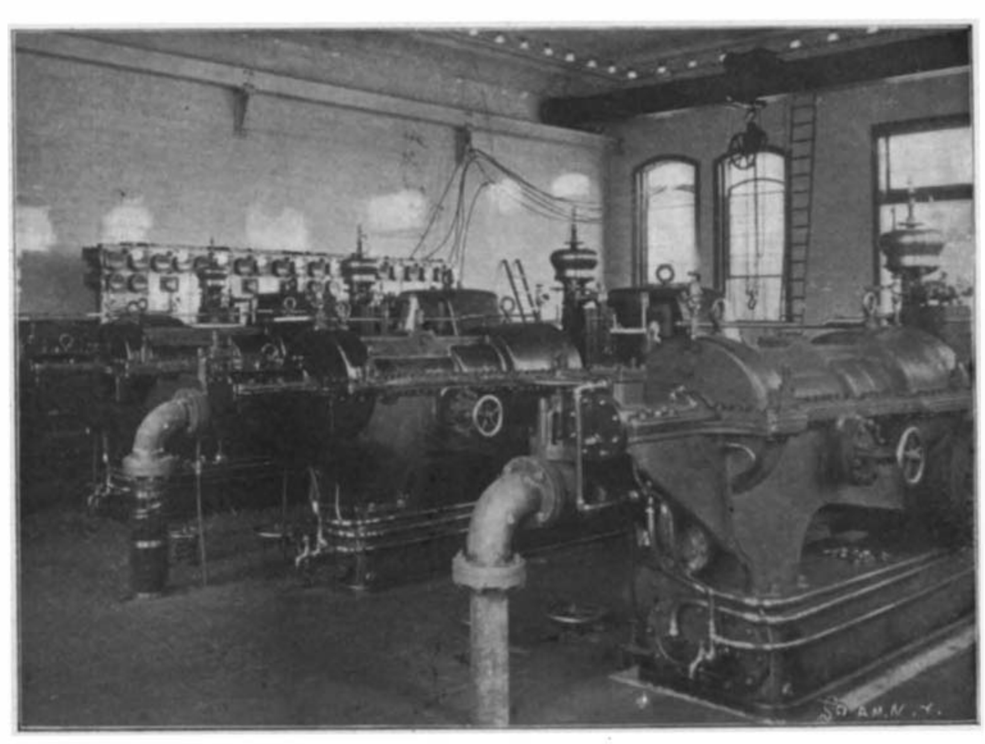


4. REVOLVING PART OF THE 2,500 H. P. PARSONS TURBINE. TOTAL LENGTH, 20 FEET. WEIGHT, 14 TONS.



Total Weight, 60 tons; Length, 33 feet 8 inches; Speed, 1,200 revolutions.

5. 1,500 K. W. WESTINGHOUSE-PARSONS TURBINE AND ALTERNATOR.



6. GROUP OF FOUR 300 K. W. WESTINGHOUSE-PARSONS TURBO-ALTERNATORS.

steam pressure. When running, it was found that no internal lubrication was necessary, with no wear on the rings and shaft, the rings not revolving with the shaft, but remaining stationary and floating on a thin layer of steam between the shaft and ring. With superheat this turbine was very economical in steam consumption, running well at a speed of 5,000 revolutions per minute.

The reversible turbine mentioned has two oppositely inclined sets of nozzles pierced in each chamber wall, the "go-ahead" sets playing on the most efficient side of the wheel vanes. This turbine was reversed from 4,000 revolutions per minute ahead to 4,000 revolutions in the opposite direction in five seconds, giving 75 per cent power backward with the same steam pressure.

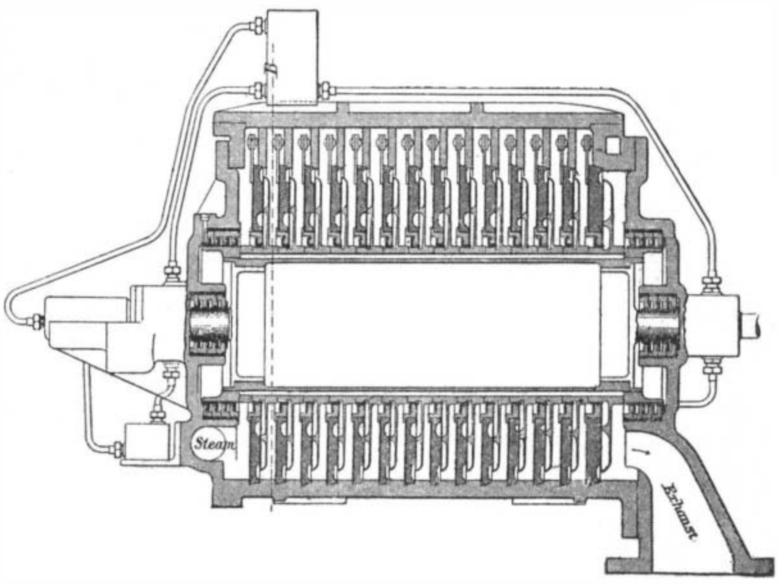
If equal reversing power is desired, the astern nozzles may have 25 per cent more area. A very thin circular valve is placed in front of each partition, the ports corresponding to the entrances of the nozzles, and a lever and shaft rotate these valves through a small angle, one way or the other, to produce forward or backward motion.

The simplest form of impulse steam turbine is the De Laval; but the disk turbines in this type must revolve at enormously high speeds, which in the case of a one-foot turbine reach about 15,000 revolutions per minute, with a pressure of about 75 pounds. In this form, which greatly resembles a Pelton waterwheel, the fixed nozzles guide the jets of steam onto the vanes or buckets on the outer rim of the rotating wheel.

A 100 horse power Laval steam turbine was installed some time ago in some German paper mills, and worked with such satisfaction that a 300 horse power turbine was installed later, a test of which was mentioned by W. Jacobson in the Zeitschrift Vereines Deutsch. Ingr. The dynamo was constructed by Ganz & Co. and the turbine by the Actiebolaget de Lavals Angturbin, of Stockholm. The speed of the turbine was 10,500 revolutions per minute, and the generator speed was 750 revolutions per minute, gearwheels being used for the reduction of speed; and an electric motor for operating an independent air pump. A Kausch superheater was employed and a Durr boiler; and with a steam pressure of 132 pounds and a vacuum of 26 inches, the steam consumption was about 18 pounds per horse power hour, the power developed being 300 horse power. The consumption was reduced to about 17 pounds per horse power hour with the steam at 572 deg. F. The length of the test was a trifle over five hours, and the mean steam temperature at the superheater was 415.6 deg., while the mean steam pressure in the boiler was 154.5 pounds. The temperature of the steam due to 154.5 pounds pressure was 364.8 deg. F., while the mean vacuum was 27 inches of mercury. The brake horse power was 342.1 with a mean reduced speed of 754.66 revolutions per minute. The water per brake horse power per hour was 15.67 pounds with an output of 337.6 brake horse power. In this test the steam for driving the feed pump, as well as the power to generate the current which was used to run the air pump electric motor, was taken from another independent boiler.

In a paper on Steam Turbines before the Engineers' Society of Western Pennsylvania, some time ago, Mr. F. Hodgkinson mentions a test made in France, where a Laval turbine working at 307.8 horse power with a speed of 772 revolutions per minute and a steam pressure of 192 pounds gave 13.92 pounds of steam per horse power hour. The superheat at this consumption was 69 deg. F. He also cites a Parsons turbo-alternator of 1,200 kilowatts capacity, which, when running under a pressure of 130 pounds and a superheat of 18 deg. F., produced an electrical horse power with a steam consumption of 14.025 pounds, which is equivalent to 11.9 pounds per indicated horse power hour, and in this case the turbine was driving its own air pump.

It is well known that geared motors are very undesirable, and are avoided wherever possible, and the multiple-step steam turbine of the Parsons type was devised to give a reduced speed of rotation suitable for the driving of machinery direct without the gears necessary with the Laval high-speed types. The first parallel-flow turbines constructed by Parsons consisted of a collection of zig-zag nozzles, the walls being formed of projecting rings of blades and intermeshing. One set was fixed on the periphery of a revolving cylinder, and the other set on the inner surface of the stationary hollow cylinder. The shape of the steam passages has been changed in the latest types of these turbines to smooth sinuous curves, and



7. EXPERIMENTAL, REVERSIBLE, MULTIPLE-STEP, STEAM TURBINE OF RATEAU.

the steam does not have to pass any sharp corners or turns. The highest economy of steaming of the modern Parsons steam turbines compares most favorably with the best reciprocating engines of high power and economy of the compound and triple-expansion types. The clearance and the workmanship in the construction of these turbines must be of the very finest, and the passage of steam from one end to the other acts as in a continuous nozzle, the expansion taking place between the moving and the fixed blades.

Fig. 1.—A ROCK PILLAR AT ACOMA, NEW MEXICO.

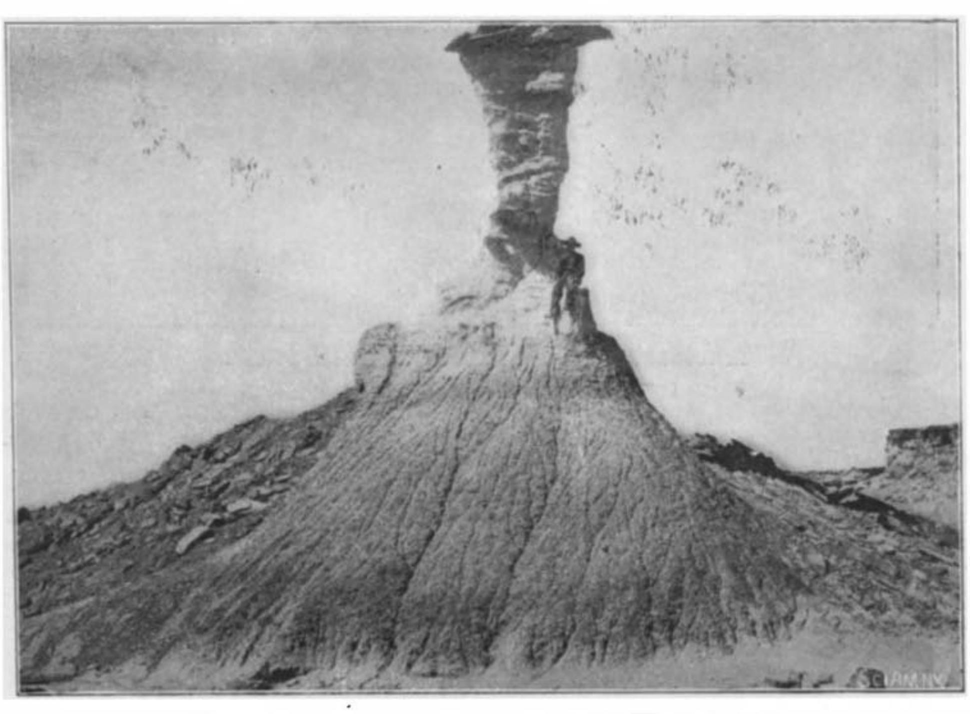


Fig. 2.—A COLUMN OF SHALE, SHOWING ERODED BASE.

There are four of the Westinghouse-Parsons steam turbines in operation in the electrical power house of the Westinghouse Air Brake Company, each driving a 300-kilowatt alternator. The direct-current exciters are continuous-current, four-pole dynamos, driven by Westinghouse vertical engines. The speed of the turbo-alternators is 3,600 revolutions per minute, the alternators being constructed as bipolar machines. With a boiler pressure of 125 pounds per square inch and a vacuum of 26 inches, the full load consumption of these machines is about 16.4 pounds per electrical horse power hour, rising to about 22 pounds at a quarter load.

Prof. R. H. Thurston is quoted as stating that there is a considerable gain in both efficiency and capacity of a steam turbine by the use of superheated steam, but that the gain is greatly in excess of what would be expected from the increase of thermodynamic efficiency due to the higher range of temperature. The experiments made at the Sibley College at Cornell University on a 10 horse power Laval turbine show a gain of one per cent in efficiency for each three degs. superheat, while the increase would not be over one-tenth of this. The gain in efficiency is proportional to the amount of superheat; in the above case the capacity was doubled by the use of a superheat of 37 deg. F. The additional gain, Prof. Thurston says, seems to be due to the elimination of the loss by friction caused by moisture in the steam as it passes through the turbine.

In the Curtis steam turbine a few wheels of large diameter are used. The Curtis turbine is constructed with provision for changing the nozzle areas by opening or closing the tapered walls according to the load. In this way it is said to correct the expansion ratios for various loads and steam pressures. The fixed steam nozzles play only on part of the periphery of disks, in some cases only two nozzles being employed on the first disk.

The Westinghouse-Parsons steam turbo-alternator, which is now in operation at the Hartford Electric Light Company's plant, consists of a 2,500 horse power steam turbine direct-connected on the same base to a Westinghouse 1,500-kilowatt, sixty-cycle, two-phase alternator. The speed of this unit is 1,200 revolutions per minute, and the polyphase current delivered by the generator has a potential of 2,400 volts. The size of the generator is comparatively small for an output of 1,500 kilowatts, on account of the high speed of the turbine, and at a frequency of 60 periods per second the number of poles required is only six. The revolving part of the turbine is nearly 20 feet long and about 12 feet between bearings, while it weighs about 14 tons. The total unit, including generator and turbine, is nearly 34 feet long and about one-fourth as wide; while the total weight is about 90 tons. A worm gear is used to drive the governor and oil pump. The turbine is automatic and requires little attention, while the repairs and renewals of this class of machinery are very low, on account of the few working parts; and because of the absence of rubbing surfaces, high superheated steam and condensers can be employed to the best advantage, as no internal lubrication is necessary.

Unquestionably the day of steam turbines has come, particularly of large sizes, not alone on account of the wonderful economy of steam consumption; but also because of the advantages of economy of space, absence of oil from the condensed steam, and the excellent conditions for the use of superheated steam, as well as almost an entire absence of vibration. The sizes mentioned above have in each case been for increased output, those at Hartford, Conn., having a capacity of 2,500 horse power.

BUTTES AND THEIR FORMATION.

BY CHARLES FREDERICK HOLDER.

It is demonstrated that if the dry land of the globe, the continents and islands, could be leveled or shoveled into the ocean the latter would cover the entire globe, so vast and deep is the watery envelope. The continents, then, and their inhabitants, might be considered simple accidents, as had the globe remained quiescent and upheavals of the crust not occurred, the globe would have been a vast sea. Happily for the human race the reverse held, and man has made his home upon what are virtually the tops of mountains or long elevated