focal length about four feet. The first of these photographs was obtained with the Bache telescope in 1885, and since 1889 this instrument has been mounted in Peru, first near Chosica and later at the Arequipa Station of this Observatory, and employed mainly in the study of the southern stars. The 8-inch Draper telescope has, in the same way, been mounted in Cambridge, and used on the northern stars since 1889. About 30,000 eight by ten-inch photographs, each covering a region ten degrees square, have been obtained with each of these telescopes. Photographic charts have been made with these instruments, covering the entire sky on from one hundred to two hundred nights, and showing all stars brighter than about the twelfth magnitude, besides many that are fainter. During the last four years, this work has been supplemented by taking photographs with two anastigmat lenses having clear apertures of about one inch. Each photograph covers a region 30 degrees square, and in general shows stars of the eleventh magnitude and brighter. The number of times the entire sky is covered has thus been greatly increased. The amount of material thus collected has required a special building for its accommodation, and the means of the Observatory have so far permitted but a small part of the astronomical facts contained on the photographs to be gathered. The Henry Draper Memorial has enabled the most important results to be derived from the numerous photographs of the spectra of the stars, and the past history of many of the objects discovered here to be studied. When any object of interest is discovered, the photographs permit its brightness and position to be determined on one hundred or more nights, during the last twelve years, and many important facts not recorded at any other observatory are thus determined. By the aid of the grant mentioned above, a corps of assistants will be organized, whose duty will be the study of the photographs as regards any objects of special interest.

THE STEAM TURBINE.

BY H. M. GLEASON, ASSISTANT NAVAL CONSTRUCTOR, U. S. N.

The steam turbine, although old in principle, is comparatively young in its application to commercial power generators. Since Watt's development of the reciprocating engine, all inventive energy has been employed to perfect a form of power generator which is wrong in principle. If Watt had achieved as great success with a primitive form of rotary engine or steam turbine as he did with the reciprocating engine, it is safe to say that to-day we should have a highly perfected form of steam turbine, and the reciprocating engine would have been looked upon as one of the many queer inventions of the past.

So great has been the inventive genius of the age, that to-day we have a very efficient reciprocating engine, as efficient, perhaps, as this kind of engine will permit of; but who, with any idea of mechanical simplicity, can go into the engine room of any modern steamer without wondering at the ingenious complexity represented there?

To be sure, any machine should be designed for the use intended, and in this way the reciprocating engine is especially adapted for use on certain machines using power exerted in a straight line. The great majority of machines, however, require circular motion, and here the reciprocating engine is handicapped. It may be said, then, that the chief aim in power generation is to develop it along the line of circular motion. For this purpose, leaving other considerations aside, the steam turbine is eminently fitted.

The advantages of the steam turbine over the reciprocating engine are, in general, as follows:

1. The effort of the steam is applied directly without any intervening mechanisms for conversion of motion. This avoids their attendant friction, their costly fitting, and probable lost motion.

2. There being no reciprocating parts, there is no inertia to overcome at the beginning of the stroke, with the necessary consumption of energy required to accelerate them.

3. The absence of reciprocating parts makes it possible to run the shaft at vastly higher speeds than are attainable in a reciprocating engine.

4. The turbine engine becomes very compact from the absence of converting mechanism, and it consequently occupies very little room.

5. The engine has no dead center, but will start from rest in any position.

6. The engine has either no valve gearing, or that which it has is of the simplest character.

7. The simplicity of the engine and absence of expensive mechanism make it cheap to build and, therefore, it should be cheap to buy.

8. Very little skill is required to run the engine, and fewer engines are needed, and there is a consequent saving in the cost of handling.

9. The absence of reciprocating rods and dead-centers results in a construction in which the pressure of condensed steam in the engine does no harm. Water does not stop the engine from turning, it cannot endanger the engine casing. The engine can be started, even if under water, by simply opening the valve which admits pressure to the turbine blades; it will start with solid water as in the case of the water turbine.

10. Its incased construction and the above peculiarity adapt it for outdoor service and places exposed to low temperatures. Weather does it practically no harm, and its protection from outside injury makes it particularly serviceable in mining and stone quarrying.

11. The turbine is easily controlled; it is stopped by simply turning off the steam by means of an ordinary valve, and started again by turning on the valve.

The above advantages apply to its use in general, but for the propulsion of ships it has especial advantages:

1. The absence of vibrations, which are so troublesome in reciprocating engines. The study of vibrations in a reciprocating engine has called forth many valuable and scientific papers by engineers who have made this subject a special study. The necessity of the balancing of engines in ships need not be commented upon, for who has not suffered from it, even on the largest and best designed of our present-day passenger steamers. The continual shaking which the hulls and fittings of ships are subjected to is one great cause of their frequent need of repairs, some, it is true, of minor consequence, but the loss of time incurred in making these seemingly minor repairs results in an appreciable decrease in the vessel's earning capacity. And, when balanced at one speed, it does not follow that the same condition will follow at other speeds; in fact, it generally does not follow. With the turbine engine, all this loss of time and inconvenience is avoided.

2. The use of the turbine engine effects a great saving in weight of machinery. The question of weights on a ship is a very important one, and where a saving can be made in the propulsive machinery, a consequent gain can be effected in cargo or passenger accommodation, in the case of a merchant vessel, or, in the case of a warship, a gain in guns, armor or coal. The weight of machinery per I. H. P. in the case of the "Turbinia" is 21.3 pounds, while in the best designed modern vessels the average weight per I. H. P. is about 150 pounds. These figures show what advantages the turbine has in this connection. Where the weight problem is so vital, as in the case of a battleship, the use of turbines would mean a great gain in offensive or defensive qualities.

3. The perfect balancing of the turbine engine does away with increased weight in construction of engine bedding and hull fittings, which are necessary to withstand continual vibrations and strains.

4. The increase in stability gained by the use of the turbine is greatly due to the low position of the center of gravity of the engine. This is a very important feature in the turbine, as it enables vessels to carry heavy weights on the upper decks without endangering the stability of the vessel. In the case of a warship this would allow heavy guns and armor to occupy a position of greater elevation than is admissible now; and, in the case of a merchant ship, would enable her to go to sea in a light condition in greater safety. The turbine situated well down in the ship's body would be protected from injury in action without the necessity of armor decks, beyond protection from falling projectiles.

5. The lives of the engine-room crew are not endangered by intricate, fast-moving parts. It is not necessary to call to mind the marine disasters that have been caused by the breaking of a shaft and the consequent racing of the engines, resulting in completely wrecking the engine room and not infrequently injuring the hull seriously. From all this the turbine is free.

6. A much smaller engine-room force is required. This results in a great saving in running expenses, and, in the case of a warship, would enable more men to be carried to man the guns.

7. Last, but not least, of all, the turbine requires very little lubrication, resulting in a great saving of lubricating oil, which in a large vessel is no small item.

The best-known turbines to-day are the Parsons-Westinghouse, the DeLaval, and the Dow. All these different classes of turbines are designed to derive the maximum effect of the kinetic energy of steam under expansion, and this requires that the turbine shaft revolve at a very high speed. This makes the turbine specially adaptable for electric generators, and its use in this connection is becoming general.

For marine propulsion, a high speed of revolution of the propellers is not desirable beyond a certain limit, at which cavitation results. Thus, in some cases, it is necessary to reduce the speed by gearing down. The propellers of the "Turbinia," at a speed of 34½ knots per hour, made 2,000 revolutions per minute. From the limited experience with high-speed propellers, it has been found that under certain conditions the ship does not answer to her helm in the usual way; but this difficulty can be overcome by putting the rudder forward of the propellers.

The question of efficiency is one to be considered. Comparing it with a compound or triple expansion condensing engine, the steam turbine over the widest range of loads is, for general purposes, the most desirable. This the steam turbine has done, as proven by trials, in which the efficiency from full load to half load varied but 8 per cent; this is a far better performance than any attained by reciprocating engines. With the improvements in design that are sure to be made, the turbine's efficiency will be demonstrated even to the most skeptical engineers.

The great problem in steam turbine design is to devise a perfectly reversible one. This is done in marine turbines at present by having a separate turbine on the same shaft—the reversing turbine running idly in a vacuum when the ahead turbine is working, and *vice versa*.

There is nothing that can stay the improvement and popularity of a machine or process which saves money; thus we can see for the steam turbine a great future, both in commercial power generation, and marine propulsion. The reciprocating engine, although very highly developed and universally used, has a dangerous rival in the simple turbine, and there is nothing that appeals to the American mechanic more than simplicity.

SCIENCE NOTES.

Profs. Haga and Wind, of Holland, in 1899 announced that the X-rays were subject to diffraction. They have recently repeated their experiments and have again proved the existence of diffraction phenomena, and conclude that there is no longer a doubt that the X-rays are, like light waves, perturbations of the equilibrium of the ether. They have sought to evaluate the wave-lengths of the X-radiations, and conclude that these radiations have wave-lengths of the same order of magnitude as light waves.

Most people are aware of the power of egg shells to resist external pressure on the ends, but not many would credit the results of tests recently made, which appear to be genuine. Eight ordinary hen's eggs were submitted to pressure applied externally all over the surface of the shell, and the breaking pressures varied between 400 pounds and 675 pounds per square inch. With the stresses applied internally to twelve eggs, these gave way at pressures varying between 32 pounds and 65 pounds per square inch. The pressure required to crush the eggs varied between 40 pounds and 75 pounds. The average thickness of the shells was 13-1000 inch.

The recommendations of the Advisory Board of the Carnegie Institution are of exceptional interest. Prof. S. P. Langley tells of the wide discrepancy of results obtained in an effort to determine the solar constant, the unit of heat exerted by the sun's rays on a given surface in a given time. He gives as the probable cause of the divergence, the absorptive qualities of different layers of atmosphere which absorb heat from the sun's rays. He also suggests a possible periodic variation in the power of the sun. In view of the important effect of the heat imparted by the sun's rays on all life, Prof. Langley advocates the establishment of two laboratories close to the equator, at the greatest possible difference of altitude and yet within sight of each other, so that, under like atmospheric and other conditions, simultaneous observations could be taken, and the variation produced by difference of altitude accurately recorded. Dr. D. S. Jordan advocates the sending of an expedition to study ichthyology in the Pacific Ocean and to make a marine biological survey similar to that being conducted by the United States Fish Commission in American waters. Prof. C. K. Gilbert, of Washington, proposes a deep boring in plutonic rock for the purpose of ascertaining the temperature gradients in the earth's crust. He recommends that a mass of great age be selected, one which has not for many periods been subjected to change, and that a boring be made with some instrument similar to the diamond drill, so that the core produced could be made the subject of special investigation. With such a boring completed to a great depth, temperature observations could be taken at numerous levels, which would contribute largely to geological knowledge, and might prove of great value in the study of seismic disturbance. Dr. Ladd, of Yale, recommends a certain line of work in his special department of psychology and philosophy. Of most importance he considers a bureau of information, a sort of psychological clearing house for the interchange of not only definite results, but of attempted investigations, partial results, etc., with a view to keeping all psychologists posted as to what is being done. Dr. C. O. Whitman, of the University of Chicago, recommends a biological farm for the study of heredity, variation, and evolution.