ENGINEERING

The Steam Turbine
"A Classic Invention"

Forty Years After His Invention of the Steam Turbine Sir Charles A. Parsons Described it in These Words

THE STEAM TURBINE—As a Study in Applied Physics. An address by Sir Charles A. Parsons, on the Occasion of the Centenary Celebration of the Founding of the Franklin Institute and the Inauguration Exercises of the Bartol Research Foundation, September* 17, 18, 19, 1924. *Philadelphia, The Franklin Institute,* (1924?).

THE development of the steam turbine, to which I have directed much attention, may perhaps be taken as an illustration of a research in one class of engineering, and probably as representative of researches in many other lines of manufacture. At the outset, the collection of new data was obviously required before the general line of advance could be determined. Some preliminary experiments were made with high-speed shafts and bearings, but in order to complete these data a small turbine coupled to a high-speed dynamo of primitive design was made: The calculated stresses due to centrifugal force, the laws governing the flow of steam and data from dynamos as approximately known at that time, were taken into account. This machine was tested out on very similar lines to those followed by Joule when trying to improve the electromagnetic engine of Sturgeon. The constants for the flow of steam, the loss by friction in bearings at high surface speeds, the hysteresis and eddy current losses in armature core, conductors, and binding wire at abnormally high speeds, were approximately investigated.

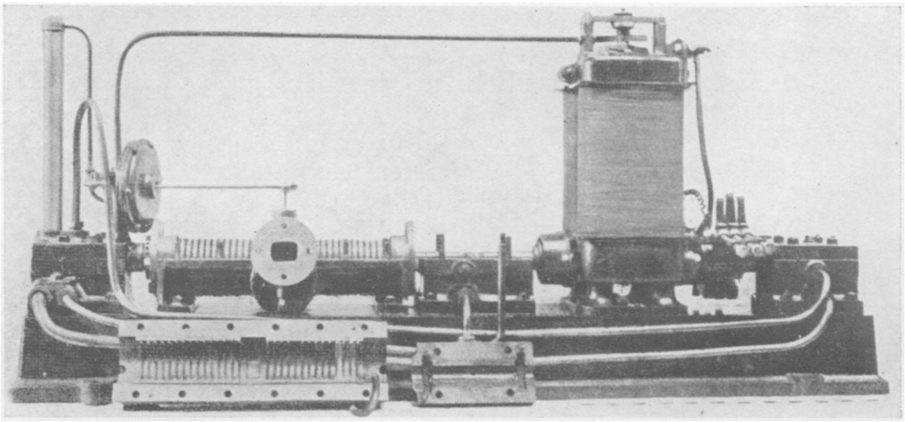
Higher mathematics were not employed in this initial work, but were used much later to coordinate the accumulated data and forecast the effect of improvements and refinements which have, in recent years, considerably increased the thermal efficiency of the turbine; as a matter of fact, it does not now appear that the use of higher mathematics in the earlier stages of development would have been useful; the accumulation of sufficiently accurate data to enable them to be practically and usefully applied would have been at that time an additional burden and a hindrance to progress. This, however, does not imply that a mathematical and physical training is not of very great value, for the two men who directed the work had passed mathematical and physical courses at universities, as well as being trained engineers. All that it is intended to emphasize is that mathematics should be used in the proper place, and in engineering and pioneer work, chiefly to consolidate the rear, assist the communications, but seldom to lead in the advance.

Turbine Stimulated Research

On the other hand, the coming of the steam turbine has had the effect of stimulating mathematical and physical research in certain directions, notably in the dynamics of rotating shafts, the law of flow of saturated and superheated steam through nozzles, and the frictional resistance to flow through passages and over surfaces, also to supercooling and other phenomena.

Present-day knowledge of both the theory and the technique of steam engines has justified Watt in the principles which he laid down. The main development of the steam engine since his time has consisted in an extension of the range of expansion and in an ever-increasing degree of compounding. The separation of the condenser from the cylinder by Watt was followed by the division of the expansion into stages in separate cylinders, finally into four stages in the highest development of the reciprocating engine. The steam turbine carries this subdivision still further, the number of stages included in a reaction turbine of high efficiency being commonly sixty or more. But whilst in the compound reciprocating engine the primary object of compounding is to reduce the temperature range of each individual cylinder, and so to diminish the condensation and loss which occurs when hot steam is admitted into a cylinder, the walls of which have been cooled to the temperature of the steam just discharged from it, in a steam turbine there is no such cyclic variation of temperature. The extensive compounding which is now adopted in all steam turbines of high efficiency is nevertheless of vital importance to their performance.

The necessity for it arises primarily from the low density of the working fluid, in consequence of which, if the steam velocity is to be kept proportionate to the linear velocity of the blades, only a small fraction of the available energy per pound of fluid can be dealt with in each stage. Since the available energy of the steam is first of all converted into kinetic energy, it follows that this must be done in a large num-



PARSONS' ORIGINAL STEAM TURBINE AND GENERATOR

*Sir Charles A. Parsons, whose improvement of the modern steam engine ranks with James Watt's improvement of the primitive one, died January 12, 1931 at the age of 76. He was the youngest son of the Earl of Rosse, the celebrated Irish telescope builder.

ber of stages. The ratio of blade velocity to steam velocity is thus easily controlled by the adoption of a suitable degree of compounding. In large turbines of the reaction type, the velocity of the blades is nearly equal to that of the steam. Under such conditions, the efficiency of reaction blading is practically equal to the efficiency of discharge of well-shaped nozzles.

Ideal For Electricity

The high efficiency of which the steam turbine is capable, the widely extended pressure and temperature range which it can utilize without mechanical difficulties, and the fact that it can be built for very large power output from one unit, have made it the ideal prime mover for electric generating stations. Fortunately, the relation between the output and speed of an alternator follows nearly the same law (the inverse square) as the steam turbine and the combination of turbine and alternator thus rapidly progressed in size to meet the demands for large units and in all large power stations using fuel, steam turbines now provide the motive power, with generating units ranging in capacity up to 60,000 kw. Some of these stations now have a total capacity of supply of 500,000 kw. feeding into widespread distribution systems and covering large areas.

In marine work, there has been a similarly rapid progress both in economy and capacity, the marine turbine having advanced in output during twenty years' development from the 2000 S.H.P. for the *Turbinia* to the 150,000 H.P. of H.M.S. *Hood.*

The first marine turbines were directly coupled to the propeller shafting, but all marine turbines built in recent years are connected to their propeller through some form of gearing. The steam turbine being essentially a high-speed engine, the association with a low-speed propeller put the marine turbine at a disadvantage so long as it remained directly coupled to the propeller shaft, so that its early development was restricted largely to the propulsion of high-speed vessels such as warships, liners and channel steamers; although in such cases the direct coupled turbine soon established its superiority over the reciprocating engine. With the introduction of mechanical gearing in 1910, the marine turbine was freed from this limitation. The turbine has now been applied for the propulsion of all classes of sea-going vessels and considerable improvement in economy effected by the increased efficiencies of both turbines and propeller when these are allowed each to rotate at its most efficient speed. The general result is that steam consumptions have been reduced to less than one-half of that of the early direct coupled turbines.

Whilst mechanical gearing was introduced in the first place with the object of making the turbine applicable to low-speed vessels, it was found to be of value even in higher speed vessels, and the direct coupled turbine may now be said to have been completely superseded by the geared turbine in all classes of later construction.

Mechanical gearing has also assisted in the extension of the field of application of turbines on land. Continuous current generators which have been made in sizes up to 3000 kw. at moderate speeds can now be driven by efficient high-speed turbines, as also can low-frequency alternators and alternators of small or moderate output. The general turbine has also been used to a considerable extent for the driving of mills, such as textile, paper and jute mills. In these installations the high economy of the turbine and the powerful starting torque to be obtained with it are of great value, and so also is the uniform turning moment of a turbine drive of particular advantage in mills where the power is transmitted to the different floors by ropes.

Now, let us consider the theoretical position of the steam turbine. At the present time, the materials at our disposal do not allow in practice a higher temperature than about 750° F. for the superheater, and it has become necessary to search for means of increasing the efficiency of the thermodynamic cycle without increasing the maximum steam temperature.

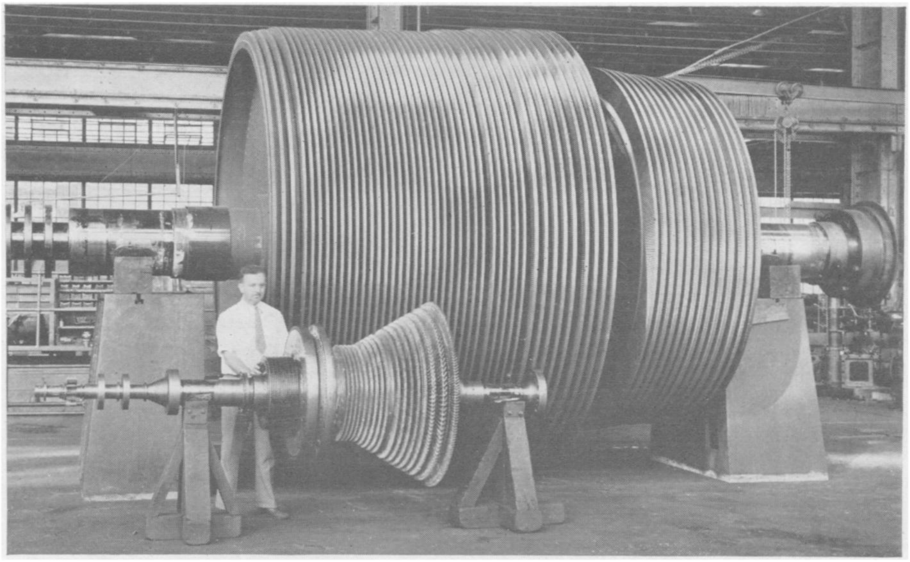
To Increase Efficiency

There are at least four different ways of doing this. These are as follows:

(1) Diminishing the amount of heat thrown away in the condensing water, by utilizing steam withdrawn from the turbine for heating the boiler feed water.

(2) Increasing the mean temperature of heat reception by increasing the boiler pressure.

(3) Increasing the energy and the stage efficiency of the low-pressure part of the expansion by reheating the steam after partial expansion.



GIANT AND PIGMY DELIVER SAME HORSEPOWER

Turbine development has proceeded apace since Sir Charles A. Parsons' first machine. This picture from the Westinghouse shops shows spindles for turbines that will drive U. S. battleships. In spite of their difference in size both deliver 7000 horsepower, but the large one turns at 240 revolutions per minute and the smaller at 3600.

(4) Arranging the exhaust and portions of the blading so as to expand the steam efficiently to the highest vacuum obtainable in the condenser.

Considering these proposals in the order given above, it will be evident, on theoretical grounds, that the necessity to heat the feed water, in other words, to reheat the water of condensation before conversion at constant temperature into steam, is the defect of the Rankine cycle; because it involves heat reception at temperature below the maximum.

Since the steam in the course of its expansion through the turbine is all the time falling in temperature, it is clear that this defect could be overcome if the heating of the feed could be accomplished by transfer of heat from the steam at corresponding stages of equal temperature, or, in other words, by a regenerative process. With the addition of such a process, the cycle would be thermodynamically reversible, and under such conditions, the efficiency of the Rankine cycle for saturated steam would be brought up to that of the Carnot cycle. In practice a close approximation to this regenerative process can be obtained by the employment of a sufficient number of feed-water heaters in cascade supplied with steam tapped off from suitable stages of the turbine.[1] The steam which thus transfers its heat to the feed heater is first of all made to do some work by expansion in the turbine down to the temperature at which it is required for withdrawal to the corresponding heaters, and since a certain amount of heat is required for the feed water in any case, the work obtained from this tapped-off steam is obtained merely at the expense of additional heat equal to the work done by it, in other words, this additional heat is utilized at nearly 100 per cent. efficiency. Expressed in another way, the utilization of some of the heat of the steam to preheat the feed water reduces the amount of heat that has to be taken in by the boiler and also that rejected to the condenser.

[1]Feed heating in a single stage by partly expanded steam is a well-known expedient. It was proposed by James Weit in 1876 and by Normand in 1889; and feed heating in progressive stages was proposed by Ferranti in 1906.

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SEISMOLOGY

Automatic Seismograph Works Only When Quake Starts It

HOW SEISMOGRAPH instruments of a new type, cheaply constructed and starting automatically to register only when an earthquake rocks the actual spot where they are standing, are being planted at various points in California to "trap" earthquakes when they happen, was told before the meeting of the Seismological Society of America in Pasadena last week by Prof. R. R. Martel of the California Institute of Technology. Prof. Martel read a report from Capt. N. H. Heck of the U. S. Coast and Geodetic Survey, who has immediate charge of the work.

Although earthquakes have engaged the attention of scientific men for many years and delicate instruments have been devised to detect them at a distance and tell how far away and how violent they are, strangely enough there has not been until the present time any instrument that could make a record of an earthquake occurring in the immediate neighhood. They are so delicately built that a strong earthquake directly under them would wreck them. The new instruments are more ruggedly built, record only relatively large earth movements near by, and turn themselves on automatically when a quake begins.

The distribution of these instruments has been undertaken by the Federal government largely as a practical aid to engineers and architects in designing and placing buildings so as to avoid earthquake damage as far as possible. California was not chosen as the first area to be investigated by means of the new instruments because it is the most probable scene of great earthquakes, Captain Heck said.

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