before going on to the main turbines. This arrangement is shown in fig. 67, where C.H.P. and C.I.P. are the two cruising turbines. In cruising at low speeds the whole group of turbines is used in series : when the speed is increased a larger amount of power is got by admitting steam direct to the second cruiser turbine; and finally at the highest speed both cruiser turbines are cut out. The arrange­ment shown in fig. 67 has been used in some torpedo-boat destroyers and small cruisers. In some large cruisers and battleships a four- shaft system is employed and a longitudinal bulkhead divides the whole group into two independent sets. On each of the outer shafts there is a high-pressure ahead and also a separate high-pressure astern turbine. On each of the inner shafts there is a combined low-pressure ahead and astern turbine and also a cruising turbine. All four shafts can be reversed.

131. *Application of Parsons Turbine.—*The Parsons was the earliest steam turbine to be made commercially successful, and it has found a wider range of application than any other. Its chief employment is as an electric generator and as a marine engine, but it has been put to a considerable number of other uses. One of these is to drive fans and blowers for exhausting air, or for delivering it under pressure. The turbine-driven fans and blowers designed by Mr Parsons are themselves com­pound turbines driven reversed in such a manner as to pro­duce a cumulative difference in the pressure of the air that is to be impelled.

An interesting field for the application of steam turbines is to economize the use of steam in non-condensing engines of the older type, by turning their exhaust to the supply of a turbine provided with an efficient condenser. It is a characteristic of the turbine that it is able to make effective use of low pressure steam. No condensing piston and cylinder can compete with it in this respect; for the turbine continues to extract heat energy usefully when the pressure has fallen so low that frictional losses and the inconveniences attaching to excessive volume make it impracticable to continue expansion to any good purpose under a piston.

132. *Parsons Vacuum Augmenter.—*For the same reason it is especially important in the turbine to secure a good vacuum: any increase in condenser pressure during a turbine test at once shows its influence in making a marked reduction of steam economy. In the region of usual condenser pressures a differ­ence of 1 in. changes the steam consumption by about 5%. With this in mind Mr Parsons has invented a device called a vacuum augmenter, shown in fig. 68. The condensed water passes to the air-pump through a pipe bent to form a water- seal. The air from the condenser is extracted by means of a small steam jet pump which delivers it into an "augmenter condenser" in which the steam of this jet is condensed. The vacuum in the augmenter condenser is directly produced by the action of the air-pump. The effect of this device is to maintain in the main condenser a higher vacuum than that in the augmenter condenser, and consequently a higher vacuum than the air-pump by itself is competent to produce. This is done with a small expenditure of steam in the jet, but the effect of the augmented vacuum on the efficiency of the turbine is so beneficial that a considerable net gain results.

133. *Rateau and Zölly Turbines.—*Professor Rateau has designed a form of steam turbine which combines some of the features of the Parsons turbine with those of the De Laval. He divides the whole drop into some twelve or twenty-four stages and at each stage employs an impulse wheel substantially of the De Laval type, the steam passing from one stage to the next through a diaphragm with nozzles. This form can scarcely be called an independent type. It has been applied as an exhaust steam turbine in conjunction with a regenerative thermal accumulator which enables steam to be delivered steadily to the turbine although supplied from an intermittent source. The Zölly turbine, which has found considerable application on a large scale, acts in a precisely similar manner to that of Rateau: it differs only in mechanical details.

134. *Combined Reciprocating and Turbine Engines.—*The combination of a reciprocating engine with a turbine is sug­gested by Parsons for the propulsion of cargo or other low-speed steamers where the speed of the screw shafts cannot be made high enough to admit of a sufficient blade velocity for the efficient treatment in the turbine of high-pressure steam. With a small speed of revolution blade velocity can be got only by increasing the diameter of the spindle, and a point is soon reached when this not only involves an unduly large size and weight of turbine, but also makes the blades become so short (by augmenting the circumference of the annulus) that the leakage loss over the tips becomes excessive. This consideration confines the practical application of turbines to vessels whose speed is over say 15 knots. But by restricting the turbine to the lower part of the pressure range and using a piston and cylinder engine for the upper part a higher economy is possible than could be reached by the use of either form of engine alone, the turbine being specially well adapted to make the most of the final stages of expansion, whereas the ordinary reciprocating engine in such vessels makes little or no use of pressure below about 7 lb per sq. in.

135. *Consumption of Steam in the Parsons Turbine.—*In large sizes the Parsons turbine requires less steam per horse-power-hour than any form of reciprocating engine using steam under similar conditions. Trials made in April 1900, by the present writer, of a 2000 h.p. turbine coupled to an electric generator showed a con­sumption of 181/4 lb per kilowatt hour, with steam at 155 lb per sq. in. superheated 84° F. Since 1 kilowatt is 1∙34 h.p. this consumption is equal to 13∙6 lb per electrical horse-power-hour. The best piston engines when driving dynamos convert about 84 % of their indicated power into electric power. Hence the above result is as good, in the relation of electric power to steam consumption, as would be got from a piston engine using only 11 ∙4 lb of steam per indicated norse-power-hour. An important characteristic of the steam turbine is that it retains a high efficiency under comparatively light loads. The figures below illustrate this by giving the results of a series of trials of the same machine under various loads.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Load in kilowatts .  Steam used per kilowatt-hour in pounds | 1450 | 1250  18·5 | 1000 | 750 | 500  22∙6 | 250 |
| 18·1 | 19·2 | 20∙3 | 34·0 |

Still better results have been obtained in more recent examples, in turbines of greater power. A Parsons turbine, rated as of 3500 but working up to over 5000 kilowatts tested in 1907 at the Carville power station of the Newcastle-on-Tyne Electric Supply Company, showed a consumption of only 13∙19 lb of steam per kilowatt-hour, with steam of 200 lb pressure by gauge and 67° C. superheat (tem­perature 264∙7° C.), the vacuum being 29∙04 in. (barometer 30 in.). It is interesting to compare this performance with the ideal amount of work obtainable per pound of steam, or in other words with the ideal “ heat drop.” At the temperature and pressure of supply the total heat l1 is 709. After expansion to the pressure correspond­ing to the stated vacuum (0∙96 in.) the total heat of the wet mixture would be 486, the dryness being then 0∙792, if the expansion took place under ideal adiabatic conditions. Hence the heat drop I1-I2 is 223 units, and this represents the work ideally obtainable under the actual conditions as to temperature and pressure of supply and exhaust. Since I kilowatt-hour is 1896 thermal units (lb-degree C.), each pound of steam was generating an amount of electrical energy equivalent to 1896/13·19 or 143·7 thermal units, and the electric output consequently corresponds to 641/2% of the. ideal work. If we allow for the loss in the electric generator by taking the electrical output as 92 % of the mechanical power, this implies that 70 % of the ideal work in the steam was mechanically utilized.

136. *Torsion Meters for Power,—*No measurement correspond­ing to the “ indicating" of a piston engine is possible with a