Compounding V3 with *u* we find V4, which is the absolute velocity of the steam after exit, and this should be no greater than is required to get the steam clear of the wheel. The most favourable condition of running would be when the bucket velocity *u* is such that V4 is perpendicular to the plane of the wheel, for V4 would then have its feast possible value. Assuming the angle of discharge *β'* to be equal to *β*, we should in that event have u = 1/2V1cosα, which approximates more and more closely to 1/2V1 the smaller α is made. The ideal efficiency would be (V12-V42)/V12 or 1—sin2α in a turbine in which the jet enters the buckets without shock and travels over them without friction. In practice α is about 20°. Owing to the impossibility of making the bucket speed so high as the above condition implies the steam enters the buckets of a De Laval turbine with some shock and leaves them with a velocity inclined to the plane of the wheel, with a backward component, and the turbine loses something in efficiency through this exit velocity being greater than the ideal minimum.

Taking a test of a De Laval turbine of 300 h.p. in which the steam consumed was 15·6 lb per horse-power-hour, Stodola estimates that the losses in the nozzle amount to about 15 % of the available energy or total heat drop, the losses in the buckets (due to friction and to eddy currents set up by shock) to 21 % and the losses due to the velocity retained by the steam at exit to nearly 5%. The losses due to friction in the mechanism consume about 5 % more, leaving a net return of about 54 % of the available energy.

115. *Curtis Turbine.—*The Curtis turbine, like that of De Laval, is a pure impulse turbine, but the velocity of the jet is extracted not by one ring of buckets but by a series of rings, each of which extracts a certain part. Between the first and second rings of buckets there are fixed guide blades which serve to turn the remaining motion of the steam into a direction proper for its action on the second ring, and so on. The jet, having acquired its velocity in a nozzle in the first place, often acts on three successive rings of moving buckets, with two sets of fixed guide blades between, the three co-operating to extract its kinetic energy. But the Curtis turbine is generally compound in the further sense that the total drop from admission to con­denser pressure is itself divided into two, three or more stages, the steam acquiring velocity anew at each stage and then giving up that velocity in passing through a series of impulse turbine rings generally either two or three in number before undergoing the next drop in pressure.

116. *Action of the Steam in the Curtis Turbine.—*In this division of the heat drop or pressure drop into stages Curtis follows Parsons. The distinctive feature in Curtis is the multi-impulse action which occurs at each pressure stage. This is illustrated in the diagram (fig. 57), which shows the nozzle and blades of a two-stage Curtis turbine, with three rings of moving blades or buckets in each stage, arranged, of course, round the periphery of a wheel. The velocity acquired in the nozzles is extracted as the steam pursues its sinuous course between moving and fixed blades, and it leaves the third ring in each case with only a small residual velocity, the direction of which is approxi­mately parallel to the axis of the wheel. The changes of velo­city are illustrated in fig. 58, which, for the sake of simpli­fication, is drawn for the ideal case of no friction. There *u* is the velocity of the buckets, V1 the initial velocity of the jet, and V2 the initial relative velocity on entrance to the first moving ring. V3 is the absolute velocity on entering the second moving ring, and V4 the relative velocity. V5 is the absolute velocity on entering the third moving ring and V6 the relative velocity. Finally, V7 is the absolute velocity on leaving the third moving ring, and this in the example here drawn is parallel to the axis of the turbine. The first moving blades have sides parallel to OB, BP; the first fixed blades have sides parallel to CP, PD. The second moving blades have sides parallel to PE, EQ; the second fixed blades to FQ, QG, and the third moving blades to QH, HR.

The steam then passes on to a second set of divergent nozzles in which it undergoes a second drop’ in pressure, acquiring velocity afresh, which it loses as before in passing through a set of three rings of moving buckets. In some Curtis turbines this is followed by a third and often a fourth similar process before the condenser is reached. In a four-stage Curtis turbine the speed of the buckets is usually about 400 ft. per second; the steam issues from each set of nozzles with a velocity of about 2000 ft. per second, and each set of moving rings reduces this by something like 400 ft. per second. The losses due to steam friction are somewhat serious, although the blade speed in each set is sufficient to let the steam enter without shock; on the other hand, the Curtis turbine escapes to a great extent losses due to leakage which are present in the Parsons type. The velocity diagram shown in fig. 58 may readily be modified to allow for effects of friction. Owing to the progressive reduction of velocity in passing from ring to ring a larger and larger area of blade opening is required, and this is provided for by making the height of the blades increase in the successive rings of each series.

117. *Performance of Curtis Turbines.—*Curtis turbines have been successfully applied in large sizes, especially in America, to drive electric generators, with outputs of as much as 9000 kilowatts, and in a few instances they have been adapted to marine propulsion. In large sizes, and using moderately super­heated steam, the Curtis turbine has achieved a high degree of efficiency. The advantage of superheating, in any type of turbine, is to reduce the wetness which the steam develops as it expands during work. The prejudicial effect of wetness is chiefly that it increases friction, especially in the later stages of the expansion. Tests of Curtis turbines show that they maintain a very uniform efficiency throughout a wide range of loads, and are capable of being much overloaded without