the cylinder and the ports and passages leading to its ends. The seat, or surface on which the valve slides, is a plane surface formed on or fixed to the side of the cylinder, with three ports or openings which extend across the greater part of the cylinder’s width. The central opening is the exhaust port through which the steam escapes; the others, or steam ports, which are narrower, lead to the two ends of the cylinder respectively. The valve is a box-shaped cover which slides over the seat, and the whole is enclosed in a chamber called the valve-chest, to which steam from the boiler is admitted. When the valve moves a sufficient distance to either side of the central position, steam enters one end of the cylinder from the valve-chest and escapes from the other end of the cylinder through the cavity of the valve into the exhaust port. The valve is generally moved by an eccentric on the engine shaft, which is mechanically equivalent to a crank whose radius is equal to the eccentricity, or distance from the centre of the shaft to the centre of the eccentric sheave. The eccentric rod is generally so long that the motion of the valve is sensibly the same as that which it would receive were the rod infinitely long. Thus if a circle (fig. 19) be drawn to represent the path of the eccentric centre during a revolution of the engine, and a perpendicular PM be drawn from any point P on a diameter AB, the distance CM is the displacement of the valve from its middle position at the time when the eccentric centre is at P. AB is the whole travel of the valve.

61. *Lap and Lead.—*If the valve when in its middle position did not overlap the steam porζs (fig. 20), any movement to the right or the left would admit steam, and the admission would continue until the valve had returned to its middle position, or, in other words, for half a revolution of the engine. Such a valve would not serve for expansive working, and as regards the relative position of the crank and eccentric it would have to be set so that its middle position coincided with the extreme position of the piston ; in other words, the eccentric radius would make a right angle with the crank. Expansive working, however, becomes possible when we give the valve what is called “ lap,’’ by making it project over the edges of the steam ports, as in fig. 21, where *o* is the ‘’outside lap ” and *i* is the “ inside lap.” Admission of steam (to either side) then begins only when the displacement of the valve from its middle position exceeds the amount of the outside lap, and continues only until the valve has returned to the same distance from its middle position. Further, exhaust begins only when the valve has moved past the middle by a distance equal to *i*, and continues until the valve has again returned to a distance *i* from its middle position.. Thus on the diagram of the eccentric’s travel (fig. 22) we find, by setting off *o* and *i* on the two sides of the centre, the posi­tions *a*, *b, c* and *d* of the eccentric radius at which the four events of admission, cut-off, release and compression occur for one side of the piston. As to the other side of the piston, it is only neces­sary to set off *o* to the right and *i* to the left of the centre, but for the sake of clearness we may confine our attention to one of the two sides. Of the whole revolution, the part from *a* to *b* is the arc of steam admission, from *b* to *c* is the arc of expansion, from *c* to *d* the arc of exhaust, and from *d* to *a*, the arc of compression. The relation of these, however, to the piston’s motion is still undefined. If the eccentric were set in advance of the crank by an angle equal to AC*a*, the opening of the valve would be coincident with the beginning of the piston’s stroke. It is, however, desirable, in order to allow the steam free entry, that the valve be already some way open when the piston stroke begins, and thus the eccentric may be set to have a position *Ca'* at the begin­ning of the stroke. In that case the valve is open at the beginning of the stroke to the extent *mm',* which is called the “ lead.” The amount by which the angle between *Ca'* (the eccentric) and CA (the crank) exceeds a right angle is called the *angular advance,* this being the angle by which the eccentric is set in advance of the position it would occupy if the primitive arrangement without lap were adopted. The quantities lap, lead and angular advance *(θ)* are connected by the equation

outside lap+lead = half travel X cos *θ.*

An effect of lead is to cause *preadmission,* that is to say, admis­sion before the end of the back stroke, which, together with the compression of steam left in the cylinder when the exhaust port closes, produces the mechanical effect of “cushioning,” to which reference has already been made. To examine the distribution of steam throughout the piston’s stroke, we may now draw a circle to represent the path of the crank pin (fig. 23, where the dotted lines have been added to show the assumed configuration of piston, con­necting-rod and, crank) and transfer to it from the former diagram the angular positions *a, b, c* and *d* at which the four events occur. To facilitate this transfer the diagrams of eccentric path and of crank-pin path may by a suitable choice of scales be drawn of the same actual size. Then by projecting these points on a diameter which represents the piston’s path, by circular arcs drawn with a radius equal to the length of the connecting-rod, we find *p,* the position of the piston at which admis­sion occurs during the back stroke, also *q* and *r*, the position at cut-off and release, during the stroke which takes place in the direction of the arrow, and *s,* the point at which compression begins. It is obviously unnecessary to draw the two circles of figs. 22 and 23 separately; the single diagram (fig. 24) contains the solution of the steam distribution with a slide-valve whose laps, travel and

angular advance are known, the same circle serving, on two scales, to show the motion of the crank and of the eccentric.

*Zeuner's, Diagram.*—The graphic construction most usually employed in slide-valve investigations is the ingenious diagram published by Dr G. Zeuner in the *Civilingenieur* in 1856.@@1 On the ine AB (fig. 25), which represents the travel of the valve, let a pair of circles (called valve- circles) be drawn, each with diameter equal to the half travel. A radius vector CP, drawn in the direction of the eccentric at any instant, is cut by one of the circles at Q, so that CQ re­presents the corresponding displacement, of the valve from its middle position. That this is so will be seen by drawing PM (as in fig. 19) and joining QB, when it is obvious that CQ = CM, which is the displacement of the valve. The line AB with the circle on it may now be turned back through an angle of 90°+*θ* *(θ* being the angular advance), so that the valve-circles take the position shown

to a larger scale in fig. 26. This makes the direction of CQ (the eccentric) coincide on the paper with the simultaneous direction of

@@@1 Zeuner, *Treatise on Valve Gears,* trans, by Μ. Müller (1868).