steam distribution are determined by drawing lines AB and CD parallel to the piston’s path and dis­tant from it by the amount of the outside and inside lap respectively.

Then *a, b, c,* and *d,* and the corre­sponding points *p, q, r,* and *s* deter­mine the four events as in former diagrams. Fig. 65 shows at a glance the amount of steam-opening at any part of the period of admission.

AE is the lead. The events for the other side of the piston are determined by drawing AB above and CD below the middle line.

147. 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

line AB (fig. 66), 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 displace­

ment of the valve from its middle position.

That this is so will be seen by drawing PM (as in fig. 59) and join­ing QB, when it is obvious that CQ = CM, which is the displace­ment of the valve. The line AB with the circles 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. 67. This makes the direction of CQ (the

eccentric) coincide on the paper with the simultaneous direction of the crank, and hence to find the displacement of the valve at any position of the crank we have only to draw CQ in fig. 67 parallel to the crank, when CQ represents the displacement of the valve to the scale on which the diameter of each valve circle represents the half-travel of the valve. CQ0 is the valve displacement at the beginning of the stroke shown by the arrow. Draw circular arcs *ab* and *cd* with C as centre and with radii equal to the outside lap *o* and the inside lap *i* respectively. C*a* is the position of the crank at which preadmission occurs. The lead is *a*0Q0, The greatest steam opening is *a*1B. The

cut-off occurs when the crank has

the direction C*b.* C*c* is the position

of the crank at release, and *Cd* marks

the end of the exhaust.

148. In this diagram radii drawn from C mark the angular positions of the crank, and their intercepts by the valve circles determine the corresponding displacement of the valve. It remains to find the corre­sponding displacement of the piston.

For this Zeuner employs a supple­mentary graphic construction, shown

in fig. 68. Here *ab* or *a'b,* represents the connecting rod, and *bc* or *b'c* the crank. With centre *c* and radius *ac* a circle *ap* is drawn, and with centre *b* and radius *ab* another circle *aq.* Then for any

position of the crank, as *cb',* the intercept *pq* between the circles is easily seen to be equal to *aa',* and is therefore the distance by which the piston has moved from its extreme position at the beginning of the stroke. In practice this diagram is combined with that of fig. 67, by drawing both about the same centre and using different scales for valve and piston travel. A radius vector drawn from the centre parallel to the crank in any position then shows the valve’s displacement from the valve’s middle position by the intercept CQ of fig. 67, and the piston’s displacement from the beginning of the piston’s motion by the intercept *pq* of fig. 68.

149. In all the figures which have been sketched the events refer to the front end of the cylinder, that is the end nearest to the crank (see fig. 63). To determine the events of steam distribution at the back end, the lap circles shown by dotted lines in fig. 67 must also be drawn, *Ca,* being the outside lap for the back end, and C*c*' the inside lap. These laps are not necessarily equal to those at the other end of the valve. From fig. 65 it is obvious that, especially with a short connecting-rod, the cut-off and release occur earlier and the compression later at the front than at the back end if the laps are equal, and a more symmetrical steam distribution can be produced by making the inside lap greater and the outside lap less on the side which leads to the front end of the cylinder. On the other hand, an unsymmetrical distribution may be desirable, as in a vertical engine, where the weight of the piston assists the steam during the down-stroke and resists it during the up-stroke, and this may be secured by a suitable inequality in the laps.

150. By varying the ratio of the laps *o* and *i* to the travel of the valve, we produce effects on the steam distribution which are readily traced in the oval diagram of fig. 65 or in the other figures. Reduction of travel (which is equivalent to increase of both o and *i)* gives later preadmission, earlier cut-off, later release, and earlier compression ; the ratios of expansion and of compression are both increased. The effect of a change in the angular advance is more easily seen by reference to Zeuner’s diagram, which shows that to increase θ accelerates all the events and causes a slight increase in the ratio of expansion.

151. In designing a slide-valve the breadth of the steam ports in the direction of the valve’s motion is determined with reference to the volume of the exhaust steam to be discharged in a given time, the area of the ports being generally such that the mean velocity of the steam during discharge is less than 100 feet per second. The travel is made great enough to keep the cylinder port fully open during the greater part of the exhaust; for this purpose it is 21/2 or 3 times the breadth of the steam port. To facilitate the exit of steam the inside lap is always small, and is often wanting or even *negative.* During admission the steam port is rarely quite un­covered, especially if the outside lap is large and the travel mode­rate. Large travel has the advantage of giving freer ingress and egress of steam,

with more sharp­

ly-defined cut­

off, compression,

and release, but

this advantage

is secured at the

cost of more

work spent in

moving the

valve and more wear of the faces. To lessen the necessary travel without reducing the area of steam ports, double- and eveu treble- ported valves are often used. An example of a double-ported valve is shown in fig. 85. Fig. 69 shows the Trick valve, an ingenious device for the same purpose.

152. The eccentric must stand in advance of the crank by the angle 90° + θ, as in fig. 70, where CK is the crank, and CE the corre­sponding position of the eccentric when the engine

is running in the direction of the arrow *a.* To set

the engine in gear to run in the opposite direction (*b*)

it is only necessary to shift the eccentric into the

position CE', when it will still be 90°+ 0 in advance

of the crank. In the older engines this reversal was

effected by temporarily disengaging tho eccentric-rod from the valve-rod, working the valve by hand until the crank turned back through an angle equal to ECE', the eccentric meanwhile remaining at rest, and then re-engaging the gear. The eccentric sheave, instead of being keyed to the shaft, was driven by a stop fixed to the shaft, which abutted on one or other of two shoulders projecting from the sheave. In some modern forms of reversing gear means are provided for turning the eccentric round on the shaft, but the arrangement known as the link-motion is now the most usual gear in locomotive, marine, winding, and other engines which require to be often and easily reversed.

153.. In the link-motion two eccentrics are used, and the ends of their rods are connected by a link. In Stephenson’s link-motion— the earliest and still the most usual form—the link is a slotted bar or pair of bars curved to the same radius as the eccentric rods (fig. 71), and capable of being shifted up or down by a suspension rod.

@@@1 Zeuner, *Treatise on Valve Gears,* transl. by M. Müller, 18G8.