The valve-rod ends in a block which slides within the link, and when the link is placed so that this block is nearly in line with the forward eccentric rod (R, fig. 71) the valve moves in nearly the same way as if it were driven directly by a single eccentric. This is the position of “full forward gear. ” In “ full backward gear, ” on the other hand, the

link is pulled up until the block is in nearly a line with the back­ward eccentric rod R'. The link-motion thus gives a ready means of reversing the engine,—but it does more than this. By setting the link in an intermediate position the valve receives a motion nearly the same as that which would be given by an eccentric of shorter radius and of greater angular advance, and the effect is to give a distribution of steam in which the cut-off is earlier than in full gear, and the expansion and compression are greater. In mid gear the steam distribution is such that scarcely any work is done in the cylinder. The movement of the link is effected by a hand lever, or by a screw, or (in large engines) by an auxiliary steam-engine. A usual arrangement of hand lever, sketched in fig. 71, has given rise

to the phrase “ notching up,” to describe the setting of the link to give a greater degree of expansion.

154. In Gooch’s link-motion (fig. 72) the link is not moved up

in shifting from forward to backward gear, but a radius rod between the valve-rod and the link (which is curved to suit this radius rod) is raised or lowered—a plan which has the advantage that the lead is the same in all gears. In Allan’s motion (fig.

73) the change of gear is effected partly by shifting

the link and partly by shifting a radius rod, and

the link is straight.

155. The movement of a valve driven by a link-motion may be very fully and exactly analysed by drawing with the aid of a tem­plate the positions of the centre line of the link corresponding to a number of successive positions of the crank. Thus, in fig. 74, two circular arcs passing through *e* and *e*' are drawn with E and E' as centres and the eccentric rods are radii. These are loci of two known points of the link, and a third locus is the circle *a* in which the point of suspension must lie. By placing on the paper a tem­plate of the link, with these three points marked on it, the position

of the link is readily found, and by repeating the process for other positions of the eccentrics a diagram of positions (fig. 74) is drawn for the assigned state of the gear. A line AB drawn across this dia­gram in the path of the valve’s travel determines the displacements of the valve, and enables the oval diagram to be drawn (as in fig. 65), which is shown to a larger scale in another part of fig. 74. The example refers to Stephenson’s link-motion in nearly full forward gear ; with obvious modification the same method may be used in the analysis of Gooch’s or Allan’s motion. The same diagram deter­mines the amount of slotting or sliding motion of the black in the link. In a well-designed gear this sliding is reduced to a minimum for that position of the gear in which the engine runs most usually. In marine engines the suspension-rod is generally connected to the link at the end of the link next the forward eccentric, to reduce this sliding when the engine is in forward gear. A less laborious, but less accurate, solution of link-motion problems is reached by the use of what is called the equivalent eccentric—an imaginary eccen­tric, which would give the valve nearly the same motion as it gets from the joint action of the actual eccentrics. The following ride for finding the equivalent eccentric, in any state of gear, is due to Mr M'Farlane Gray:—

Connect the eccentric centres E and E' (fig. 75) by a circular arc

whose radius = EE' × length of eccentric rod/2 × *ee'*

Then, if the block is at any point B, take

EF such that EF : EE' : : *eB : ed.* CF then

represents the equivalent eccentric both in

radius and in angular position. If the rods of the link-motion are crossed instead of open,—an arrangement seldom used,—the arc EFE' is to be drawn convex towards C.

156. Many forms of gear for reversing and for varying expansion have been devised with the object of escaping the use of two eccentrics, and of obtaining a more perfect distribution of steam than the link-motion can often be made to give. Hackworth’s gear, the parent of several others, has a single eccentric E (fig. 76) oppo­site the crank, with an eccentric-rod EQ, whose mean position is perpendicular to the travel of the valve.

The rod ends in a block Q, which slides on a fixed inclined guide-bar or link, and the valve-rod receives its motion through a connecting rod from an inter­mediate point P of the

eccentric-rod, the locus of

which is an ellipse. To

reverse the gear the guide-

bar is tilted over to the

position shown by the

dotted lines, and inter­

mediate inclinations give

various degrees of expan­

sion without altering the

lead. The steam distribu­

tion is excellent, and the

cut-off is sharper than in

the usual link-motion, but an objection to the gear is the wear of the sliding-block and guide. In Bremme’s or Marshall’s form this objection is obviated with some loss of sym­

metry in the valve’s motion by constraining the

motion of the point Q, not by a sliding-guide, but

a suspension-link,

which makes the

path of Q a circular

arc instead of a

straight line; to reverse

the gear the centre of sus­

pension R of this link is

thrown over to the posi­

tion R' (fig. 77). In the

example sketched P is

beyond Q, but P may be

between Q and the crank

(as in fig. 76), in which

case the eccentric is set

at 180° from the crank.

This gear has been applied

in a number of marine

engines. In Joy’s gear,

which is extensively used

in locomotives, no eccen­

tric is required ; and the

rod corresponding to the

eccentric rod in Hack- . .

worth’s gear receives its motion from a point in the connecting rod by the linkage shown in fig. 78, and is either suspended, as in Marshall’s form, by a rod whose suspension centre R is thrown over to reverse the motion, or constrained, as in Hackworth s, by a slot- guide whose inclination is reversed. Fig. 79 shows Joy's gear as