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. 32) 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, which is shown to a larger scale in another part of fig. 32. 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 block 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.

70.—*Radial Gears.—*Many forms of gear for reversing and for varying expansion have been devised with the object of escaping the use of two eccentrics, and in some both eccentrics are dispensed with. Hackworth’s gear, the parent of several others, to which the general name of radial gears is applied, has a single eccen­tric E (fig. 33) 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 intermediate inclinations give various degrees of expansion without altering the lead. The steam distribution is quite satisfactory, 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 symmetry 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 suspension R of this link is thrown over to the position R' (fig. 34). In the example sketched P is beyond Q, but P may be between Q and the crank (as in fig. 33), 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 eccentric is required; and the rod corresponding to the eccentric rod in Hackworth’s gear receives its motion from a point in the connecting rod by the linkage shown in fig. 35, 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. 36 shows Joy’s gear as applied to a locomotive. A slot-guide E is used, and it is curved to allow for the obliquity of the valve connect­ing-rod AE. C is the crank-pin, B the piston path and D a fixed centre.

A form of radial gear very largely used in locomotives, especially on the continent of Europe, is the Walschaert or Heusinger- Waldegg gear, in which the valve receives its motion in part from the piston cross-head through a reducing lever, and in part from a single eccentric set at right angles to the crank, which actuates a rocking link. Reversing is effected by shifting

a sliding block along this rocking link from one side to the other of the centre on which it rocks.

71. *Separate Expansion-Valves.—*When the distribution of steam is effected by the slide-valve alone the are of the crank’s motion during which compression occurs is equal to the arc during which expansion occurs, and for this reason the slide-valve would give an

excessive amount of compression if it were made to cut off the supply of steam earlier than about half-stroke. Hence, where an early cut-off is wanted it is necessary either to use an entirely different means of regulating the distribution of steam, or to supplement the

slide-valve by another valve—called an expansion-valve, usually driven by a separate eccentric—whose function is to effect the cut-off, the other events being determined as usual by the slide-valve. Such expansion-valves belong generally to one or other of two types. I n one the expansion-valve cuts off the supply of steam to the chest in which the main valve works.

In the other the expansion-valve slides on the back of the main slide-valve, which is provided with through ports which the expan­sion-valve opens and closes Fig. 37 shows one form of this type. Here the resultant relative motion of the expansion-valve and main-valve has to be considered. If *ra* and *r* (fig. 38) are the eccentrics working the main and expansion valves respectively, then CR drawn equal and parallel to ME is the *resultant* eccentric which determines the motion of the expansion-valve relatively to the main-valve. Cut-off occurs at Q, when the shaft has turned through an