surface, leads to a less efficient expenditure of fuel. With a given type of engine there is a certain ratio of expansion which gives a minimum in the ratio of weight to power ; when this ratio of expan­sion is exceeded the engines have to he enlarged to an extent that

more than counterbalances the saving in boiler weight ; when a less ratio of expansion is used the boilers have to be enlarged to an extent that more than counterbalances the reduction of weight in the engine proper.@@1

XIII. Locomotive Engines.

229. The ordinary locomotive consists of a pair of direct acting horizontal or nearly horizontal engines, fixed in a rigid frame under the front end of a boiler of the type described in § 133, and coupled to the same shaft by cranks at right angles, each with a single slide-valve worked by a link-motion, or by a form of radial gear. The engine is non-condensing, except in special cases, and the exhaust steam, delivered at the base of the funnel through a blast-pipe, serves to produce a draught of air through the furnace. In some instances a portion of the exhaust steam, amounting to about one-fifth of the whole, is diverted to heat the feed-water. In tank engines the feed-water is carried in tanks on the engine itself; in other engines it is carried behind in a tender.

230. On the shaft are a pair of driving-wheels, whose frictional adhesion to the rails furnishes the necessary tractive force. In some engines a single pair of driving- wheels are used ; in many more a greater tractive force is secured by having two equal driving-wheels on each side, connected by a coupling-rod between pins on the outside of the wheels. In goods engines a still greater proportion of the whole weight is utilized to give tractive force by coupling three and even four wheels on each side. These arrangements are distinguished by the terms “ four- coupled,” “six-coupled,” and “ eight-coupled ” applied to the engines. In *inside-cylinder* engines the cylinders are placed side by side within the frame of the engine, and their connecting-rods work on cranks in the driving shaft. In *outside-cylinder* engines the cylinders are spread apart far enough to lie outside the frame of the engine, and to work on crank-pins on the outsides of the driving wheels. This dispenses with the cranked axle, which is the weakest part of a locomotive engine. Owing to the frequent

alternation of strain to which it is subject, a locomotive crank axle is peculiarly liable to rupture, and has to be removed after a certain amount of use.

In some locomotives the leading wheels are coupled to driving wheels behind them, but it is now generally pre­ferred to have under the front of the engine two or four smaller wheels which do not form part of the driving system. These are carried in a *bogie,* that is, a small truck upon which the front end of the boiler rests by a swivel- pin or plate which allows the bogie to turn, so as to adapt itself to curves in the line, and thus obviate the grinding of tyres and danger of derailment which would be caused by using a long rigid wheel-base. The bogie appears to have been of English origin ;@@2 it was brought into general use in America, and is now common in English as well as in American practice. Instead of a four-wheeled bogie, a single pair of leading wheels are also used, carried by a Bissel *pony* truck, which has a swing-bolster pivoted by a radius bar about a point some distance behind the axis of the wheels. This has the advantage of combining lateral with radial movement of the wheels, both being required if the wheel base is to be properly accommodated to the curve. Another method of getting lateral and radial freedom is the plan used by Mr Webb of carrying the leading axle in a box curved to the arc of a circle, and free to slide laterally for a short distance, under the con­trol of springs, in curved guides.@@3

231. In inside-cylinder engines the slide-valves are fre­quently placed back to back in a single valve-chest between the cylinders. The width of the engine within the frame leaves little room for them there, and they are reduced to the flattest possible form, in some cases with split ports, half above and half below a partition in a central hori­zontal plane. In some of Mr Stroudley’s engines the valves are below the cylinders, with faces sloping down towards the front, while the cylinders themselves slope slightly up. In many engines the valves work on hori­zontal planes above the cylinders ; this position is specially suitable when Joy’s or some other form of radial gear is used instead of the link-motion. Radial valve-gears have the advantage, which is of considerable moment in inside-cylinder engines, that the

part of the shafts’ length which would

otherwise be needed for eccentrics is

available to increase the width of

main bearings and crank-pins, and to

strengthen the crank-cheeks. Wal-

shaert’s gear is very extensively used

on Continental locomotives, and Joy’s

has now been applied to a large num­

ber of British engines.

232. In a powerful locomotive of the ordinary type the cylinders are 17 to 19 inches in diameter, with a stroke of about 26 inches. The steam pressure is 130 to 175 lb.

The horse-power ranges up to about 700. A passenger engine for express service has driving-wheels from 7 to 8 feet in diameter, and weighs, with­out the tender, about 40 tons. Of this nearly 15 tons is borne by each driving axle.@@4

Fig. 138 shows a half section through the smoke-box and one cyl­inder of an inside-cylinder engine (of the Midland Railway), and illustrates how in an engine of

@@@1 Οn the general subject of marine engines, reference should be made to Mr A. E. Seaton's *Manual of Marine Engineering* ; to Mr R. Sennett's *Treatise on the Mar­ine Steam Engine* ; and to Mr W. H. Maw’s *Recent Practice in Marine Engineering,*

*@@@*2 *Min. Proc. Inst. C.E.,* vol. liii. 3, p. SO.

@@@3 *Proc. Inst. Mech. Eng.,* 18S3.

@@@4 For account of many details in recent English practice in locomotive build­

ing, reference should be made to a valuable paper by Mr Stroudley, and a discus­sion upon it *(Min. Proc. Inst. C. E.,* lxxxi.).