this type the cylinders are situated with regard to the frame, which consists of a single pair of steel plates, ex­tending from end to end and united by other transverse plates, one of which, called the motion-plate, gives support to the guide-bars, and another holds the draw-bar. Another form of frame is built up of two longitudinal plates on each side. In the engine illustrated the valves are above the cylinders, and are worked by Joy’s gear. A bogie truck ap­pears in section below the engine. S is the steam-pipe, and B the blast-pipe, which is tapered in the fore-and-aft plane.

233. The outside-cylinder type is adopted by several British makers ; in America it is universal. There the cylinders are in castings which are

bolted together to form a saddle on

which the bottom of the smoke-box

sits. The slide-valves are on the

tops of the cylinders, and are worked

through rocking levers from an ordi­

nary link-motion. Other features

by which American practice is dis­

tinguished are the use of bars in­

stead of plates for the frames, of

cast-iron wheels with chilled rims

instead of wrought-iron wheels with

steel rims shrunk or forced on, and

steel fire-boxes and wrought-iron

tubes instead of copper fire-boxes

and brass tubes. Fig. 139, which

is a half section through one cyl­

inder of an American locomotive,

by the Balwin Company of Phila­

delphia, shows the position of the cylinders and valves.

234. Locomotive engines have been compounded in

cylinders are fixed outside the frames, and drive the rear driving axle by crank-pins at right angles to one another. A single low-pressure cylinder of very large size is set beneath the smoke-box, and drives a crank in the middle of the forward driving axle. The driving axles are not coupled, and the phase relation of the low-pressure to the high-pressure stroke is liable to alter through unequal slip on the part of the wheels. This, however, is of no material consequence, on account of the large size of the intermediate receiver and the uniformity with which the two high-pressure cylinders deliver steam to it. The receiver is formed, as in M. Mallet’s arrangement, by lead­ing long connecting pipes through the smoke-box. All three slide-valves are worked by Joy’s gear. Those of the low-pressure cylinders are placed below the cylinders (an arrangement which has the advantage of letting the valve fall away from the port-face when the engine is running down hill with the steam-valve closed); the valve of the large cylinder is above it. The arrangement is completely symmetrical ; it has the important mechanical advantage of dispensing with coupling rods, while retaining the

several ways. In 1876 M. A. Mallet@@1 introduced, on tho Bayonne and Biarritz Railway, a type of compound loco­motive in which one small high-pressure cylinder and one large low-pressure cylinder were used in place of the two equal cylinders of a common locomotive. Outside cylinders were used in the first instance, but Mallet’s system is also applied to inside-cylinder engines. The pipe from the high to the low-pressure cylinder takes a winding course through the smoke-box ; this gives a sufficient volume of intermediate receiver, and also dries the steam before it enters the large cylinder. A reducing valve is provided through which steam of a pressure lower than that of the boiler can be admitted direct to the low-pressure cylinder to facilitate starting. The reversing gear is arranged to act on both cylinders by one movement, and also to permit a separate adjustment of the cut-off in each. Engines on Mallet’s system have been successfully used on other Con­tinental railways and in India, in some instances by con­version from the non-compound form.@@2 His plan has the advantage of permitting this (in certain cases), and of re­quiring scarcely any more working parts than are needed in a common locomotive ; but it gives an unsymmetrical engine. He has also proposed an engine with four cylinders,—one high-pressure cylinder tandem with one low-pressure cylinder on each side. Another symmetrical form has been used, in which a pair of outside high- pressure cylinders are compounded with a pair of inside low-pressure cylinders.

235. The most important experiment yet made in the compounding of locomotives is that which Mr F. W. Webb, of the London and North-Western Railway, has been conducting on a large scale since 1881.@@3 In Mr Webb’s system three cylinders are used. Two equal high-pressure

greater tractive power of four drivers ; only one axle is cranked, and that with a single crank in the centre, which leaves ample room for long bearings. A plan of Mr Webb’s engine, half in section, is given in fig. 140. The results of Mr Webb’s experiments have been, in his judg­ment, so satisfactory that for express passenger service he is now building engines only of the compound type. In some recent examples the small cylinders are 14 inches, and the large cylinder 30 inches in diameter, with a stroke of 24 inches, and the boiler pressure is 175 lb. Engines of the same type are also being introduced in India, South America, aud the continent of Europe.

236. Experiments on the saving of fuel by compound­ing locomotives point to an economy of from 10 to 20 per cent. It may be expected, for reasons which have been discussed above, that a compound engine, even when working at the high speed of a locomotive, will have a somewhat higher efficiency than a non-compound engine.

1 *Proc. Inst. Mech. Eng.,* 1879

2 Von Borries, *Ztschr. des Ver. deutscher Ingenieure,* 1880 ; Sandiford, *Proc.*

*Inst. Mech. Eng.,* 1886.

3 See *Proc. Inst. Mech. £ng.,* 1883 ; also *Engineerιng,* May 1885.