131. Vertical boilers are extensively used in connexion with small engines. Examples are shown in figs. 47-49. Fig. 48 is an ordinary vertical boiler filled with cross tubes of the Galloway type. Fig.

47 (by Messrs Davey, Paxman, & Co.) is a boiler with curved water tubes, each of which has fitted in the top a loose cap whose function is to deflect the stream of water which circulates up the tubes. Fig. 49 is a form of multitubular boiler by the same makers, in which the hot gases escape at the side after passing from the smoke-box through horizontal tubes grouped in circular arcs. In all these boilers the grate is at the foot, and the fire-door is at a mouthpiece in the side of the boiler near the base. In other

forms of vertical boiler the heating surface is increased by water tubes (fig. 50) which hang from the crown of the fire-box, closed at the lower end but fitted internally with smaller tubes which are open at the bottom. Water circu­lates down the inner tubes and up between them and the outer. Tubes of this kind (called Field tubes) are used in fire-engine boilers and in other cases where it is neces­sary to get up steam with the least possible delay. Vertical boilers of large size are some­times used for utilizing the waste heat of iron furnaces.

132. A great variety of boilers have been designed in which the firing is external, and the water space consists of groups of tubes or other small sections whose outer surface is exposed to heat. Boilers of this type are called sectional or tubulous boilers, in distinction to tubular boilers, or boilers with tubes in which the hot gases circu­late. A successful example of the tubulous or sectional type is the Babcock & Wilcox water- tube boiler, which consists of a series of in-

on the inside of the shell plates. A sloping bridge of fire-brick partially separates the upper part of the fire-box from the lower and prevents the flame from striking the tubes too directly. Under the grate is an ashpan, to whieh the supply of air is regulated by a damper in front. The fire-door opens inwards, and can be set more or less open, to regulate the amount of air admitted above the fire. On top of the barrel is a steam-dome, from which tho steam supply is taken through a pipe S traversing the forward part of the steam space and passing down to the valve-chest through the smoke-box. The stop-valve or “regulator” R is situ­ated in tho smoke-box, and is worked by a rod through the boiler from tho cab at the back. Above the fire-box end of the shell are a pair of Ramsbottom safety-valves, V, V—two valves pressed down by a single spring attached to the middle of a cross bar, which is prolonged to form a hand lever by which the valves may be lifted. In front of the forward tube-plate is the smoke-box, containing the blast-pipe B by which the exhaust steam is used to produce a partial vacuum and so force a draught through the furnace.

134. Instead of stiffening the fire-box roof by the use of girder stays, the plan is sometimes followed of staying it directly to tho shell above. The outer shell above the fire-box is generally cylindrical ; but to facilitate this method of staying it is sometimes made flat. This construction is not unusual in American loco­motive boilers, another feature of which is that the grate is made

clined welded tubes up which water circulates. These are joined at their ends by cast-iron connecting boxes to one another and to a horizontal drum on the top in which the mixture of steam and water which rises from the tube undergoes separation. At the lowest point of the boiler is another drum for tho collection of sediment. Root’s boiler is another in which water is heated by circulating through inclined tubes exposed to the fire ; it differs from the above form chiefly in having the water-level below the top of the tube. Harrison’s boiler is a group of small globular vessels of cast-iron strung like beads on rods which tie them together. Sectional boilers may be constructed without difficulty to bear pressures greatly in excess of those for which other types are suited. Mr Perkins has employed a tubulous boiler to deliver steam at a pressure of 500 lb per square inch.@@1 The Herreshof boiler is a continuous coil of tube, arranged as a dome over the fire. Feed­water is pumped slowly through the coil, and turns to steam before it reaches the end.

133. The locomotive boiler consists of a nearly rectangular fire­box, enclosed above and on the sides by water, and a cylindrical part called the barrel extending horizontally from the fire-box to the front part of the locomotive and filled with numerous tubes. Figs. 51 and 52 show in longitudinal and transverse section a boiler of the London and North Western Railway, which may be taken as typical of modern English practice.

The barrel is 10 feet long and a little more than 4 feet in diameter, and is made up of three rings of steel plates, 13/32 inch thick, arranged telescopically. It contains 198 brass tubes, each 17/8 inches in external diameter. The front tube-plate in which the tubes terminate is of steel 3/4 inch thick ; it is stayed to the back tube-plate by the tubes themselves, and the upper part of the front tube-plate is also tied by longitudinal rods to the back end-plate. The fire-box is of copper 1/2 inch thick. It is nearly rectangular, with a horizontal grate. (A grate sloping down in front is often preferred.) Round its sides, front, and back (except w’here the fire-door interrupts) is a water space about 3 inches wido, which narrows slightly towards the bottom. The flat sides of the fire-box are tied to the flat sides of the shell by copper stay-bolts, 4 inches apart, which are secured by screwing them into both plates and riveting over the ends. The roof of the fire-box is stiffened by a number of girders on the top, to which the plates are secured by short bolts. The girders are themselves hung from the top of tho shell above them by slings which are secured to angle-irons riveted

much larger than in English practice, for the purpose of burning anthracite coal. An extreme instance is furnished by the Wooton engines of tho Philadelphia and Reading Railroad, which burn small coal of poor quality in a fire-box 9⅜ feet long by 8 feet wide, extending over the trailing wheels of the engine. In some cases the fire-box is divided by a sloping partition of plates with water between, which crosses tho fire-box diagonally from front to back and has in its centre an opening resembling a fire-door mouthpiece to allow the products of combustion to pass. In others the fire-bridge is supported by water tubes, and water tubes are also used as grate- bars. This is done rather to promote circulation of the water than to give heating surface. The practice of American and English locomotive engineers differs widely as regards the materials of con­struction. American shells are of mild steel, English shells gene-

@@@1 *Proc. Inst. Mech. Eng.,* 1877. See also a paper by Mr Flannery, “ Οn High- Pressure Steam Boilers,” *Min. Proc. Inst. C.E.,* 1878.