The same effect was next obtained in many of the boilers of Newcomen, in the way represented in fig. 202, so that the flame in the flues impinged upon a surface directly over them ; the flues in this case forming a recess in the sides of the boiler, instead of being built around it by the brickwork alone. In process of time, boilers of much larger size came to be required, and the spherical shape was found cumbrous and too capacious, that is to say, contained an enormous mass of water, which it required much time and fuel to heat to the boiling point before any steam could be raised. The diameter, also, of the boiler was so great when much steam was required, that the enormous dome became weakened. To make a stronger boiler, and one which should, at the same time, cover a large fire, the *waggon boiler* was introduced by Mr Watt ; an oblong boiler, of whose form no better definition can be given than the descriptive epithet which forms its name. It closely re­sembles those long, heavily laden, four-wheeled wag gons, which a team of six or eight horses may occasion ally be seen dragging along with difficulty.

The waggon boiler is made of considerable length, and its transverse section, fig. 203, resembles that of the old circular boiler.

' In this form the boiler was long made by Messrs Watt and Bolton. It was afterwards improved by hollowing inwards the sides, for the purpose of bringing them more immediately over the flame. Of this form of the waggon boiler, which is universally used at the present day, fig. 204 exhibits a transverse, and fig. 205 a longitudinal section. These forms of boiler, although very convenient, are weak : they are very different from the spherical or cylindro-spherical boilers in strength and

safety. The metal of which they consist is not in the form that will resist, to the utmost of its tensile force, a change of shape ; but, on the contrary, a very small pres sure has been found sufficient to bulge these boilers downward towards the fire, and outwards at the sides.

From this circumstance it has been found necessary to place in them strong iron stays, for the purpose of connecting a given part of the surface of the boiler having a tendency to bulge out in one direction, with a similar portion of surface, having a tendency to bulge out in the opposite direction ; so that this tie-bar being stretched in opposite ways, is made to resist, by its tensile force, the outward or bursting pressure. These stays are essential to strength and security in boilers having large surfaces, concave outwardly, or perfectly flat. Their application to the forms of boilers which we have just described, is seen in figs. 206, 207, and 208.

To avoid the use of stays, and to secure great strength without any other metal than the shell of the boiler itself, is the object of that construction of cylindric boiler now much in use, especially where considerable pressure is used. It is certainly one of the cheapest, safest, and best boilers. A cylinder, figs. 209 and 210, perhaps thirty feet in length and four feet in diameter, with two hemispherical ends, is laid with its axis nearly horizontal ; and below it, at one end, is placed the fire, enclosed by brick, as usual. The flame traverses the bottom of the boiler, beating directly upon its under horizontal surface till it reaches the end farthest from the fire. The flame and hot air then return along the one side of the cylinder, being confined in a brick flue, and, passing along in front of the end which is over the fire, traverses the other side towards the chimney, which it enters after having thus traversed the length of the boiler three times, and applied its heat successively to every point of the cylinder which is covered with water. This is a boiler that requires no stays, and is valuable where room is not important. It contains much water, requires much heat to raise its temperature after being cooled at night, and is very bulky.

The Americans have adopted this boiler to a great ex tent. It was introduced among them by the ingenious Evans. It is generally of a smaller diameter than three feet, and has flat cast-iron ends of great thickness, which they call heads.

These boilers, the spherical, cylindrical, and waggon shaped, may properly be denominated the simple boilers. But some hundreds of kinds of boilers have been invented for different purposes ; almost all of them designed to save either bulk, weight, or fuel. Some of these have been much more successful than others ; and it