from the other vessel, and is ready to be condensed there. The valves B and D open only upwards. The supplementary boiler and furnace E are for feeding water to the main boiler; E is filled while cold and a fire is lighted under it; it then acts like the vessel of De Gaus in forcing a supply of feed­water into the main boiler F. The gauge cocks G, G are an inter­esting feature in detail. Another form of Savery’s engine had only one displacement-chamber and worked intermittently. In the use of artificial means to condense the steam, and in the appli­cation of the vacuum so formed to raise water by suction from a level lower than that of the engine, Savery’s engine was probably an improvement on Worcester’s; in any case it found what Worcester’s engine had failed to find—considerable employment in pumping mines and in raising water to supply houses and towns, and even to drive water-wheels. A serious difficulty which prevented its general use in mines was the fact that the height through which it would lift water was limited by the pressure the boiler and vessels could bear. Pressures as high as 8 or 10 atmospheres were employed—and that, too, without a safety-valve—but Savery found it no easy matter to deal with high-pressure steam; he complains that it melted his common solder, and forced him, as Desaguliers tells us, "to be at the pains and charge to have all his joints soldered with spelter.” Apart from this drawback, the waste of fuel was enormous, from the condensation of steam which took place on the surface of the water and on the sides of the displacement-chamber at each stroke; the consumption of coal was, in proportion to the work done, some twenty times greater than in a good modem steam engine. In a tract called *The Miner's Friend* Savery alludes thus to the alternate heating and cooling of the water-vessel: “ On the outside of the vessel you may see how the water goes out as well as if the vessel were transparent, for so far as the steam continues within the vessel so far is the vessel dry without and so very hot as scarce to endure the least touch of the hand. But as far as the water is, the said vessel will be cold and wet where any water has fallen on it; which cold and moisture vanishes as fast as the steam in its descent takes the place of the water.” Before Savery’s engine was entirely displaced by its successor, Newcomen’s, it was improved by J. T. Desagu­liers, who applied to it the safety valve (invented by Papin), and substituted condensation by a jet of cold water within the vessel for the surface condensation used by Savery. To Savery is ascribed the first use of the term “ horse power ” as a measure of the performance of an engine.

7. So early as 1678 the use of a piston and cylinder (long before known as applied to pumps) in a heat-engine had been

suggested by Jean de Hautefeuille, who proposed to use the explosion of gun-powder either to raise a piston or to force up water, or to produce, by the sub­sequent cooling of the gases, a partial vacuum into which water might be sucked up. Two years later Christian Huygens described an engine in which the explosion of gun­powder in a cylinder expelled part of the gaseous contents, after which the cooling of the remainder caused a piston to descend under atmospheric pressure, and the piston in descending did work by raising a weight.

8. In 1690 Denis Papin, who ten years before had invented the safety-valve as an adjunct to his “ digester,” suggested that the condensation of steam should be employed to make a vacuum under a piston previously raised by the expansion of the steam. Papin’s was the earliest cylinder and piston steam engine, and his plan of using steam was that which afterwards took practical shape in the atmo­spheric engine of Newcomen. But his scheme was made unworkable by the fact that he proposed to use but one vessel as both boiler and cylinder. A small quantity of water was placed at the bottom of a cylinder and heat was applied. When the piston had risen the fire was removed, the steam was allowed to cool, and the piston did work in its down-stroke under the pressure of the atmosphere. After hearing of Savery’s engine in 1705 Papin turned his attention to improving it, and devised a modified form, shown in fig. in which the displacement- chamber A was a cylinder, with a floating diaphragm or piston on the top of the water to keep the water and steam from direct contact with one another. The water was delivered into a closed air-yessel B, from which it issued in a continuous stream, against the vanes of a water-wheel. After the steam had done its work in the displacement-chamber it was allowed to escape by the stop-cock C instead of being condensed. Papin’s engine was, in fact, a non-condensing single-acting steam pump, with steam cylinder and pump cylinder in one. A curious feature of it was the heater D, a hot mass of metal placed in the dia­phragm for the purpose of keeping the steam dry. Among the many inventions of Papin was a boiler with an internal fire-box—the earliest example of a construction that is now almost universal.@@1

9. While Papin was thus going back from his first notion of a piston engine to Savery’s cruder type, a new inventor had appeared who made the piston engine a practical success by separating the boiler from the cylinder and by using (as Savery had done) artificial means to condense the steam. This was Thomas New­comen, who in 1705, with his assistant, John Cawley, gave the steam engine the form shown in fig.

4. Steam admitted from the boiler to the cylin­der allowed the piston to be raised by a heavy counterpoise on the other side of the beam. Then the steam valve was shut and a jet of cold water entered the cylin­der and condensed the steam. The piston was consequently forced down by the pressure of the atmosphere and did work on the pump. The next entry of steam expelled the condensed water from the cylinder

@@@1 For an account of Papin’s inventions see his *Life and Corre­spondence,* by Dr E. Gerland (Berlin, 1881).