continuous revolving motion to a shaft provided with a flywheel. He had invented the crank and connecting-rod for this purpose, but it had meanwhile been patented by one Pickard, and Watt, rather than make terms with Pickard, whom he regarded as a plagiarist of his own ideas, made use of his sun-and-planet motion until the patent on the crank expired. The reciprocating motion of earlier forms had served only for pumping; by this invention Watt opened up for the steam engine a thousand other channels of

usefulness. The engine was still single-acting; the connecting- rod was attached to the far end of the beam, and that carried a counterpoise which served to raise the piston when steam was admitted below it.

14. In 1782 Watt patented two further improvements of the first importance, both of which he had invented some years before. One was the use of double action, that is to say, the application of steam and vacuum to each side of the piston alternately. The other (invented as early as 1769) was the use of steam expan­sively, in other words the plan (now used in all engines that aim at economy of fuel) of stopping the admission of steam when the piston had made only a part of its stroke, and allowing the rest of the stroke to be performed by the expansion of the steam already in the cylinder. To let the piston push as well as pull the end of the beam Watt devised his so-called parallel motion, an arrangement of links connecting the piston- rod head with the beam in such a way as to guide the rod to move in a very nearly straight line. He further added the throttle valve, for regulating the rate of admission of steam, and the centrifugal governor, a double conical pendu­lum, which controlled the speed by acting on the throttle-valve. The stage of development reached at this time is illustrated by the engine of fig. 7 (from Stuart’s *History of the Steam Engine),* which shows the parallel motion *pp,* the governor *g,* the throttle-valve *t,* and a pair of steam and exhaust valves at each end of the cylinder. Among other inventions of Watt were the “ indicator,” by which diagrams showing the relation of the steam pressure in the cylinder to the movement of the piston are automatically drawn; a steam tilt-hammer; and also a steam locomotive for ordinary roads—but this invention was not prosecuted.

In partnership with Matthew Boulton, Watt carried on in Birmingham the manufacture and sale of his engines with the utmost success, and held the field against all rivals in spite of severe assaults on the validity of his patents. Notwithstanding his accurate knowledge of the advantage to be gained by using steam expansively, he continued to employ only low pressures— seldom more than 7 lb per sq. in. over that of the atmo­sphere. His boilers were fed, as Newcomen’s had been, through an open pipe which rose high enough to let the column of water in it balance the pressure of the steam. He gave a definite numerical significance to the term “ horse-power” *(q.v.)* as a mode of rating engines, defining it as the rate at which work is done when 33,000 lb are raised one foot in one minute.

15. In the fourth claim in Watt’s first patent the second sentence describes a non-condensing engine, which would have required steam of a higher pressure. This, how­ever, was a line of invention which Watt did not follow up, perhaps because so early as 1725 a non-condensing engine had been described by Jacob Leupold in his *Theatrum machinarum.* Leupold’s proposed engine is shown in fig. 8, which makes its action sufficiently clear. Watt’s aversion to high - pressure steam was strong, and its influence on steam engine practice long survived the expiry of his patents. So much indeed was this the case that the terms “ high-pressure ” and “ non-condensing ” were for many years synonymous in contradistinction to the “ low-pressure ” or condens­ing engines of Watt. This nomenclature no longer holds; in modem practice many condensing engines use as high pressures as non-con­densing engines, and by doing so are able to take advantage of Watt’s great invention of expansive working to a degree which was impossible in his own practice.

16. The introduction of the non-condensing and, at that time, relatively high-pressure engine was effected in England by Richard Trevithick and in America by Oliver Evans about 1800. Both Evans and Trevithick applied their engines to propel carriages on roads, and both used for boiler a cylindrical vessel with a cylindrical flue inside—the construction now known as the Cornish boiler. In partnership with William Bull, Trevithick had previously made direct acting pumping-engines, with an inverted cylinder set over and in line with the pump-rod, thus dis­pensing with the beam that had been a feature in all earh\*er forms. But in these “ Bull ” engines, as they were called, a condenser was used, or, rather, the steam was condensed by a jet of cold water in the exhaust-pipe, and Boulton and Watt successfully opposed them as infringing Watt’s patents. To Trevithick belongs the distinguished honour of being the first to use a steam carriage on a railway; in 1804 he built a locomotive in the modem sense, to run on what had formerly been a horse-tramway, in Wales, and it is noteworthy that the