means the working-stroke may be adjusted much more surely than by the pins or plugs.

The working of the injection-cock by the forked end of the F lever was found to be defective, and Mr Smeaton, in the engines which he afterwards constructed, fixed a toothed sector on the end of the lever, which was made to act upon a toothed wheel, carried by the axis of the injection-cock, somewhat in the manner of the parts of Beighten's gear represented in figs. 25, 29.

III. *The Era Of Watt.—*Before the time of James Watt, the steam or atmospheric engine was a more costly power than horses, except where fuel was extremely cheap. At the mouth of a coalpit almost any sort of steam-engine or fire engine is better than horses, because it consumes the produce, and often the refuse of the pit, and is valuable for the purpose of volatilising the mass of small coals which would otherwise lumber the mouth of the pit. The worst sort of engine would raise more coal in twelve minutes than it would consume in twelve hours. In such circumstances, almost any fire-engine is cheaper than the labour of horses, and the more voracious of fuel the more economical of labour. We find that the rudest, most antiquated, worst made and worst tended engines in the world, are the engines of Durham coalfields and around Newcastle, where there are more bad engines than in all the rest of the world. The reason is obvious ; the only constant expense attending the use of these engines is the labour of shovelling in coals. The atmospheric engine, even after it had received all the improvements of three quarters of a cen tury, and attained in the hands of Smeaton all the perfection of which it was capable, still continued an extravagant consumer of coals. Watt was the man who turned the scale of expense so as to give a great preponderance in favour of the fire-engine. In his hands it ceased to be an *atmospheric engine,* and became wholly a *steam-engine,* capable of being employed in an immense variety of applications, on a much larger scale, and at much less expense than the power of horses, wherever the prices of fuel and of fodder were not in greater dis parity than in this country.

We have seen that hitherto the fire-engine, even in Smeaton's hands, was an engine that wasted a large quantity of fuel and of steam in doing what was useless, namely, heating the cylinder, which was cooled alternately in each stroke by the cold water injected into it. In Long Benton colliery engine, out of sixty-three cubic feet of steam thirtytwo feet were thus wasted, and the remaining thirty-one feet alone performed useful work. There remained, therefore, one-half of the power of the steam and expense of the fuel to be saved by future improvements, provided the useless heating and cooling of the cylinder could be superseded. The vacuum formed below the cylinder was also far from being perfect. Watt found the atmospheric fire-engine in the hands of Smeaton, produced from it the pure steam-engine, and left it to us in its present state of high improvement. This portion of the history of the steam-engine has been contributed as a commentary upon the original article of this Encyclopædia by the person of all others best qualified to do it justice, Watt himself. For the purpose **of fu**rther illustration, we have added some figures, as well as some remarks.

“ My attention was first directed in the year 1759 to the subject of steam-engines by the late Dr. Robison, himself then a student in the University of Glasgow, and nearly of my own age. He at that time threw out an idea of applying the power of the steam-engine to the moving of wheel carriages, and to other purposes, but the scheme was not matured, and was soon abandoned on his going abroad.

“ About the year 1761 or 1762, I tried some experiments on the force of steam, in a Papin's digester, and form ed a species of steam-engine by fixing upon it a syringe one-third of an inch in diameter, with a solid piston, and furnished also with a cock to admit the steam from the digester, or shut it off at pleasure, as well as to open a communiυation from the inside of the syringe to the open air, by which the steam contained in the syringe might escape. When the communication between the digester and syringe was opened, the steam entered the syringe, and by its action upon the piston raised a considerable weight (fifteen lbs.) with which it was loaded. When this was raised as high as was thought proper, the communication with the digester was shut, and that with the atmosphere opened ; the steam then made its escape, and the weight descended. The operations were re peated, and though in this experiment the cock was turned by hand, it was easy to see how it could be done by the machine itself, and to make it work with perfect regularity. But I soon relinquished the idea of construct­ing an engine upon this principle, from being sensible it would be liable to some of the objections against Savary's engine, viz. the danger of bursting the boiler, and the difficulty of making the joints tight, and also that a great part of the power of the steam would be lost, be cause no vacuum was formed to assist the descent of the piston,

“ The attention necessary to the avocations of business prevented me from then prosecuting the subject further ; but in the winter of 1763·4, having occasion to repair a model of Newcomen’s engine belonging to the Natural Philosophy Class of the University of Glasgow, my mind was again directed to it. At that period, my knowledge was derived principally from Desaguliers, and partly from Belidor. 1 set about repairing it as a mere mechanician, and when that was done and it was set to work, I was surprised to find that its boiler could not supply it with steam, though apparently quite large enough ; (the cylinder of the model being two inches in diameter, and six inches stroke, and the boiler about nine inches diameter.) By blowing the fire it was made to take a few strokes; but required an enormous quantity of injection water, though it was very lightly loaded by the column of water in the pump. It soon occurred to me, that this was caused by the little cylinder exposing a greater surface to condense the steam, than the cylinders of larger engines did, in proportion to their respective contents. It was found that by shortening the column of water in the pump, the boiler could supply the cylinder with steam, and that the engine would work regularly with a moderate quantity of injection. It now appeared that the cylinder of the model, being of brass, would conduct heat much better than the cast-iron cylinders of larger engines, (generally covered on the inside with a stony crust.) and that considerable advantage could be gained by making the cylinders of some substance that would receive and give out heat slowly. Of these, wood seemed to be the most likely, provided it should prove sufficiently durable. A small engine was therefore constructed, with a cylinder six inches diameter and twelve inches stroke, made of wood, soaked in linseed oil, and baked to dry ness. With this engine many experiments were made; but it was soon found that the wooden cylinder was not likely to prove durable, and that the steam condensed in filling it still exceeded the proportion of that required for large engines according to the statements of Desagu