top of the cylinder, where it may again be preſſed down by the air, and make another working ſtroke by raiſing the pump rods. But the counter-weight at E has another ſervice to perform in this uſe of the engine ; namely, to return the pump piſtons into their places at the bottom of their reſpective working barrels, in order that they alſo may make a working ſtroke. This re­quires force independent of the friction and inertia of the moving parts ; for each piſton muſt be pulhed down through the water in the barrel, which muſt riſe through the piſton with a velocity whoſe proportion to the velo­city of the piſton is the ſame with that of the bulk of the piſton to the bulk of the perforation through which the water riſes through the piſton. It is enough at preſent to mention this in general terms : we ſhall con­ſider it more particularly afterwards, when we come to calculate the performance of the engine, and to deduce from our acquired knowledge maxims of conſtruction and improvement.

From this general conſideration of the aſcent of the piſton, we may see that the motion differs greatly from the deſcent. It can hardly be ſuppoſed to accelerate, even if the ſteam in the cylinder were in a moment annilated. For the reſiſtance to the deſcent of the piſton is the ſame with the weight of the column of water, which would cauſe it to flow through the box of the pump piſton with the velocity with which it really riſes through it, and muſt therefore increaſe as the ſquare of that velocity increaſes ; that is, as the ſquare of the ve­locity of the piſton increaſes. Independent oſ friction, therefore, the velocity of deſcent through the water muſt ſoon become a maximum, and the motion become uniform. We ſhall ſee by and by, that in ſuch a pump as is generally uſed this will happen in leſs than the 10th part of a ſecond. The friction of the pump will diminiſh this velocity a little, and retard the time of its attaining uniformity. But, on the other hand, the supply of ſteam which is neceſſary for this motion, being ſuſceptible of no acceleration from its previous motion, and depending entirely on the briſkneſs of the ebulli­tion, an almoſt inſtantaneos ſtop is put to acceleration.

Accordingly, any perſon who obſerves with atten­tion the working of a ſteam-engine, will ſee that the rise of the piſton and deſcent of the pump-rods is ex­tremely uniform, whereas the working ſtroke is very ſenſibly accelerated. Before quitting this part of the ſubject, and left it ſhould afterwards eſcape our recol­lection, we may obſerve, that the counter weight is dif­ferent during the two motions of the pump-rods. While the machine is making a working ſtroke, it is lifting not only the column of water in the pump, but the abſolute weight of the piſtons and piston-rods alſo: but while the pump-rods are descending, there is a di­minution of the counter weight by the whole weight loſt by the immerſion of the rod in water. The wood­en rods which are generally uſed, ſoaked in water, and joined by iron ſtraps, are heavier, and but a little hea­vier than water, and they are generally about one third of the bulk of the water in the pumps.

Theſe two motions complete the period of the ope­ration ; and the whole may be repeated by ſhutting the ſteam-cock and opening the injection-cock whenever the piſton has attained the proper height. We have been very minute in our attention to the different circum­stances, that the reader may have a diſtinct notion of the ſtate of the moving forces in every period of the operation. It is by no means ſufficient that we know in general that the injection of cold water makes a void which allows the air to preſs down the piſton, and that the readmiſſion of the ſteam allows the piſton to rise again. This lumping and ſlovenly way of viewing it has long prevented even the philoſopher from seeing the defects of the conſtruction, and the methods of remo­ving them.

We now ſee the great difference between Savary’s and Newcomen’s engine in reſpect ot principle. Savary’s was really an engine which raiſed water by the force of ſteam ; but Newcomen’s raiſes water entirely by the preſſure of the atmoſphere, and ſteam is em­ployed merely as the moſt expeditious method of pro­ducing a void, into which the atmospherical preſſure may impel the *first mover* of his machine. The elaſticity of the ſteam is not the firſt mover.

We ſee alſo the great ſuperiority of this new ma­chine. We have no need of ſteam of great and dange­rous elaſticity ; and we operate by means of very mode­rate heats, and conſequently with much ſmaller quan­tities of fuel ; and there is no bounds to the power of this machine. How deep ſoever a mine may be, a cylinder may be employed of ſuch dimenſions that the preſſure of the air on its piſton may exceed in any de­gree the weight of the column of water to be raiſed. And laſtly, this form of the machine renders it appli­cable to almoſt every mechanical purpoſe ; because a skilful mechanic can readily find a method of convert­ing the eciprocating motion of the working beam into a motion of any kind which may suit his purpoſe. Savary’s engine could hardly admit of such an imme­diate application, and ſeems almoſt reſtricted to raising water.

Inventions improve by degrees. This engine was firſt offered to the public in 1705. But many difficul­ties occurred in the execution, which were removed one by one ; and it was not till 1712 that the engine ſeemed to give confidence in its efficacy. The moſt exact and unremitting attention of the manager was required to the preciſe moment of opening and ſhutting the cocks; and neglect might frequently be ruinous, by beating out the bottom of the cylinder, or allowing the piſton to be wholly drawn out of it. Stops were con­trived to prevent both of theſe accidents ; then ſtrings were uſed to connect the handles of the cocks with the beam, ſo that they ſhould be turned whenever it was in certain positions. Theſe were gradually changed and improved into detents and catches oſ different ſhapes ; at last, in 1717, Mr Beighton, a very ingenious and well informed artiſt, simplified the whole of thele ſubordinate movements, and brought the machine into the form in which it has continued, without the ſmalleſt material change, to the preſent day. We ſhall now deſcribe one of theſe improved engines, copying almoſt exactly the drawings and deſcription given by Boſſut in his *Hydrodynamique* ; theſe being by far the moſt accurate and perſpicuous of any that have been publiſhed.

Fig. 8. n⁰ 1. is a perſpective view of the boiler cy­linder, and all the parts neceſſary for turning the cocks. Fig. 8. n⁰ 2. is a vertical ſection of the ſame ; and the ſame pieces of both are marked with the ſame letters of reference.