of the cylinder’s being sufficiently cooled to condense the steam, this cooled surface must again be presented to the steam during the rise of the piston, and must con dense the steam a second lime. The piston cannot rise another inch till the part of the cylinder which the piston hag already quitted has hern wanned up to the boiling point, and steam must be expended in this warming. The inner surface of the cylinder is not only of the heat of boiling water while the piston rises, but is also perfectly dry ; fur the film of water left on it by the ascending piston must be completely evaporated, otherwise it will be condensing steam. That the quantity thus wasted is considerable, appears by the experiments of Mr Beighton. He found that five pints of water were boiled off in a minute, and produced 16 strokes of an engine whose cylinder contained 113 gallons of 282 inches each ; and he thence concluded that steam was 2886 times rarer than water. But in no experiment made with scrupulous care on the expansion of boiling water does it appear that the density of steam exceeds 1/10000th of the density of water. Desaguliers says that it is above 14,000 times rarer than water. We have frequently attempted to measure the weight of steam which filled a very light vessel which held 12,600 grains of water, and found it always less than one grain ; so that we have no doubt of its being much more than 10,000 times rarer than water. This being the case, we may safely suppose that the number of gallons of steam, instead of being 16 times 113, were nearly five .times as much ; and that only 1/5 was employed in allowing the piston to rise, and the remaining 4/5ths were employed, to warm the cylinder. But no distinct experi­ment shows so great an expansion of water when con­verted into steam at 212°. Mr Watt never found it, under the pressure of the air, more than 1800 times rarer than water.

The moving force during the ascent of the piston must be considered as resulting chiefly, if not solely, from the preponderating weight of the pit piston-rods. The office of this is to return the steam-piston to the 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 counterweight 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 pushed 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 that motion differs greatly from the descent. It can hardly be supposed to accelerate, even if the steam in the cylinder were in a moment annihilated. 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 of 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 ns 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 instantaneous 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 piston-rods is extremely uniform, whereas the working stroke is very sensibly accelerated. Before quitting this part of the subject, and lest 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 circum stances, 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.

It was in 1718, as already mentioned, that Mr Henry Beighton improved the steam-engine of Newcomen, by a simple and effective arrangement of minor details, which left so little to be desired for the practical use of the engine in pumping water, that for more than half a century it remained in general use, without any change of form or arrangement. The following excellent dia grams and quaint descriptions are from the pen of Des aguliers, who had made himself very well acquainted with the subject as it existed in his time.