liers. It was also found, that all attempts to produce a better exhaustion by throwing in more injection, caused a disproportionate waste of steam. On reflection, the cause of this seemed to be the boiling of water in vacuo at low heats, a discovery lately made by Dr Cullen and some other philosophers, (below 100, as I was then in formed,) and consequently, at greater heats, the water in the cylinder would produce a steam which would, in part, resist the pressure of the atmosphere.

“ By experiments which I then tried upon the heats at which water boils under several pressures greater than that of the atmosphere, it appeared that when the heats proceeded in an arithmetical, the elasticities proceeded in some geometrical ratio ; and by laying down a curve from my data, I ascertained the particular one near enough for my purpose. It also appeared that any approach to a vacuum could only be obtained by throwing in large quantities of injection, which would cool the cylinder so much as to require quantities of steam to heat it again, out of proportion to the power gained by the more perfect vacuum ; and that the old engineers had acted wisely in contenting themselves with loading the engine with only six or seven pounds on each square inch of the area of the piston. It being evident that there was a great error in Dr Desaguliers’ calculations of Mr Beighton’s experiments on the bulk of steam, a Florence flask, capable of containing about a pound of water, had about one ounce of distilled water put into it; a glass tube was fitted into its mouth, and the joining made tight by lapping that part of the tube with packthread covered with glaziers’ putty. When the flask was set upright, the tube reached down near to the surface of the water, and in that position the whole was placed in a tin reflecting oven before a fire, until the water was wholly evaporated, which happened in about an hour, and might have been done sooner, had I not wished the heat not much to exceed that of boiling water. As the air in the flask was heavier than the steam, the latter ascended to the top, and expelled the air through the tube. When the water was all evaporated, the own and flask were removed from the fire, and a blast of cold air was directed against one side of the flask, to collect the condensed steam in one place. When all was cold, the tube was removed, the flask and its contents were weighed with care ; and the flask being made hot, it was dried by blowing into it by bellows, and when weighed again, was found to have lost rather more than four grains, estimated at four and a third grains. When the flask was filled with water, it was found to contain about seventeen and one-eighth ounces avoirdupois of that fluid, which gave about one thousand eight hundred for the expansion of water converted into steam of the heat of boiling water.

“ This experiment was repeated with nearly the same result ; and in order to ascertain whether the flask had been wholly filled with steam, a similar quantity of water was, for the third time, evaporated ; and, while the flask was still cold, it was placed inverted, with its mouth (contracted hy the tube) immersed in a vessel of water, which it sucked in as it cooled, until in the temperature of the atmosphere it was filled to within half an ounce measure of water.

“In repetitions of this experiment at a later date, I simplified the apparatus by omitting the tube, and laying the flask upon its side in the oven, partly closing its mouth by a cork, having a notch on one side, and otherwise proceeding as has been mentioned.

“ I do not consider these experiments as extremely ac curate ; the only scale-beam of a proper size which 1 had then at my command not being very sensible, and the

bulk of the steam being liable to be influenced by the heat to which it was exposed, which, in the way described, is not easily regulated or ascertained ; but, from my ex­perience in actual practice, I esteem the expansion to be rather more than I have computed.

“ A boiler was constructed, which showed by inspection the quantity of water evaporated in any given time, and thereby ascertained the quantity of steam used in every stroke by the engine, which I found to be several times the full of the cylinder. Astonished at the quantity of water required for the injection, and the great beat it had acquired from the small quantity of water in the form of steam which had been used in filling the cylinder, and thinking I had made some mistake, the following experiment was tried :—A glass tube was bent at right angles, one end was inserted horizontally into the spout of a teakettle, and the other part was immersed perpendicularly in well water contained in a cylindric glass vessel, and steam was made to pass through it until it ceased to be condensed, and the water in the glass vessel was become nearly boiling hot. The water in the glass vessel was then found to have gained an addition of about one-sixth part from the condensed steam. Consequently, water converted into steam can heat about six times its own weight of wellwater to 212°, or till it can condense no more steam. Being struck with this re markable fact, and not understanding the reason of it, I mentioned it to my friend Dr Black, who then explained to me his doctrine of latent heat, which he had taught for some time before this period, (summer 1764;) but having myself been occupied with the pursuits of business, if I had heard of it, I had not attended to it, when I thus stumbled upon one of the material facts by which that beautiful theory is supported.

“ On reflecting further, I perceived that, in order to make the best use of steam, it was necessary, first, that the cylinder should be maintained always as hot as the steam which entered it; and, secondly, that when the steam was condensed, the water of which it was composed, and the injection itself, should be cooled down to 100°, or lower, where that was possible. The means of accomplishing these points did not immediately present them selves ; but *early in* 1765 *it occurred to me, that if a communication were opened between a cylinder containing steam, and another vessel which was exhausted of air and other fluids, the steam, as an elastic fluid, would immedi­ately rush into the empty vessel, and continue so to do until it had established an equilibrium ;* and if that vessel were kept very cool by an injection, or otherwise, more steam would continue to enter, until the whole was condensed. But both the vessels being exhausted, or nearly so, how was the injection-water, the air which would enter with it, and the condensed steam, to be got out ? This I proposed, in my own mind, to perform in two ways. One was by adapting to the second vessel a pipe reaching downwards more than thirty-four feet, by which the water would descend, (a column of that length overbalancing the atmosphere,) and by *extracting the air by means of a pump.*

“ The second method was *by employing a pump, or pumps, to extract both the air and the water,* which would be applicable in all places, and essential in those cases where there was no well or pit.

“ This latter method was the one I then preferred, and is the only one I afterwards continued to use.

“In Newcomen's engine, the piston is kept tight by water, which could not be applicable in this new method, as, if any of it entered into a partially exhausted and hot cylinder, it would boil and prevent the production of a vacuum, and would also cool the cylinder by its evapora