

XXI. *On the compressibility of Water.* By JACOB PERKINS, Esq.  
*Communicated by the late Right Hon. Sir JOSEPH BANKS, Bart.*  
 G. C. B. P. R. S.

Read June 29, 1820.

HAVING believed for many years that water was an elastic fluid, I was induced to make some experiments to ascertain the fact. This was done by constructing an instrument which I call a piezometer, and which is represented in Plate XXXII, Fig. 1. The cylinder, A, was three inches diameter, and eighteen inches long. The end, B, was made water tight by means of a plate which was soldered firmly to it. At the other end, C, a cap was made to screw on and off at pleasure ; being also made water tight. The rod or plunger, D, which was five-sixteenths of an inch in diameter, was made to pass through a tight stuffing box, E. On the rod immediately above the stuffing box, was fixed a flexible ring, *a*. A cannon, Fig. 2, of a sufficient size to contain the piezometer, was fixed vertically in the earth, the muzzle being left about eighteen inches above ground, and the touch-hole plugged tight. At the mouth a strong cap, A, was firmly screwed on. In the centre of this cap a small forcing pump, B, was tightly screwed, the piston of which was five-eighths of an inch in diameter. There was an aperture, C, in the cap, to introduce a valve for the purpose of ascertaining the degree of pressure. One pound pressure on this valve indicated

an atmosphere. The piezometer was introduced into the cannon, and the water forced in until the cap showed signs of leakage ; the valve at the same time indicating a pressure of one hundred atmospheres. The piezometer was then taken out of the cannon, and the flexible ring found to be eight inches up the rod, evidently proving the rod to have been forced into the cylinder that distance, showing also a compression of about one per cent. We have seen by repeated experiments, that to be able to produce this degree of compression, three per cent must be pumped into the gun. This fact proves, either that the gun expands, or that the water enters the pores of the cast iron ; it is probable both these circumstances contribute to produce this effect.

This experiment was made in America in the year 1819, and before I had time to strengthen my apparatus for the purpose of making farther experiments, I was obliged to embark for this country. On my passage, however, I had frequent opportunities of repeating those I had already made, and of making others by a natural pressure. They were as follows. The piezometer, by the assistance of fifty-four pounds of lead attached to it, was sunk in the ocean to the depth of five hundred fathoms, which is about equal to the pressure of one hundred atmospheres. When drawn in, the gauge or ring was found removed eight inches up the rod, indicating, as in the before-mentioned experiment, a compression of one per cent. This experiment was several times repeated, and with the same result.

The next experiment was that of sinking a strong empty porter bottle to the depth of one hundred and fifty fathoms, having first tightly corked and sealed it, in the following

manner. Six coverings of cotton cloth, saturated with a composition of sealing wax and tar, were strongly fastened over the cork, by a cord wound round them, directly under the projection at the neck of the bottle. After the bottle had been suffered to remain at the depth mentioned a few minutes, it was drawn up. No water was found to have been forced into it, neither was there any visible change at the mouth.

The same bottle was again sunk, and at the increased depth of two hundred and twenty fathoms : when drawn in, it was found to contain about a gill of water ; but not the slightest visible change had taken place in the sealing.

The same bottle was now sunk, for the third time, to the still greater depth of three hundred fathoms, and when drawn up, only a small part of the neck was found attached to the line. Its appearance was truly interesting. The bottle was not broken by external pressure, but evidently by the expansion of the condensed sea-water, which had found its way through the sealing. Upon examination, it was found that the cork had been compressed into half its length, making folds of about one eighth of an inch ; and that the coverings, consisting of six layers of cloth and cement, had been torn up on one side before the bottle burst. The effect produced upon the cork cannot, we imagine, be accounted for but in one way, viz. that the water, divided into very minute particles, must, by the surrounding pressure of water, have been forced through the coverings, and filled the bottle ; that the water thus forced in and condensed, to a great degree, expanded as the pressure was removed by drawing it towards the surface, not only so as to press the cork back into the neck, and, owing to the resistance of the coverings, to

compress it half its size, but to separate the neck from the body of the bottle.

Experiment 4. An empty porter bottle, the strongest that could be found, was stopped in the following manner. A cork with a large head was firmly driven into the neck ; it was then covered with six layers of fine linen, saturated with a composition of tar and wax ; over them was applied a covering of leather, and all perfectly secured by being well bound at the neck. The bottle thus prepared was sunk two hundred and seventy fathoms. When drawn in, it was found perfectly sound, and the sealing unchanged ; but filled with water to within an inch of the cork. The coverings were taken off, layer after layer, but no signs of moisture were visible. Had the bottle remained down a sufficient length of time to have completely filled, it would undoubtedly have been broken by the expansion of the water upon being drawn towards the surface, as was the case in the former experiment. It is worthy of remark, that when the water from this bottle was poured into a tumbler, it effervesced like mineral water.

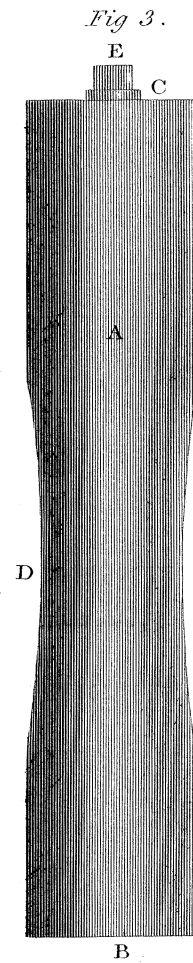
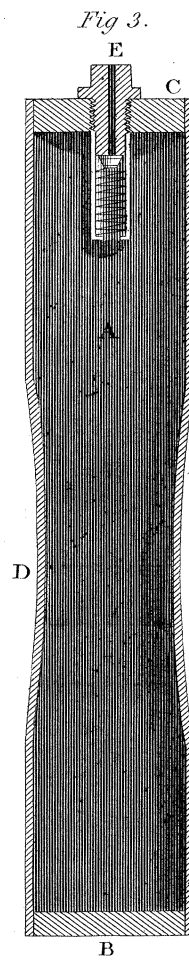
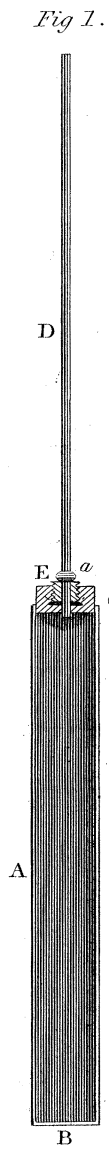
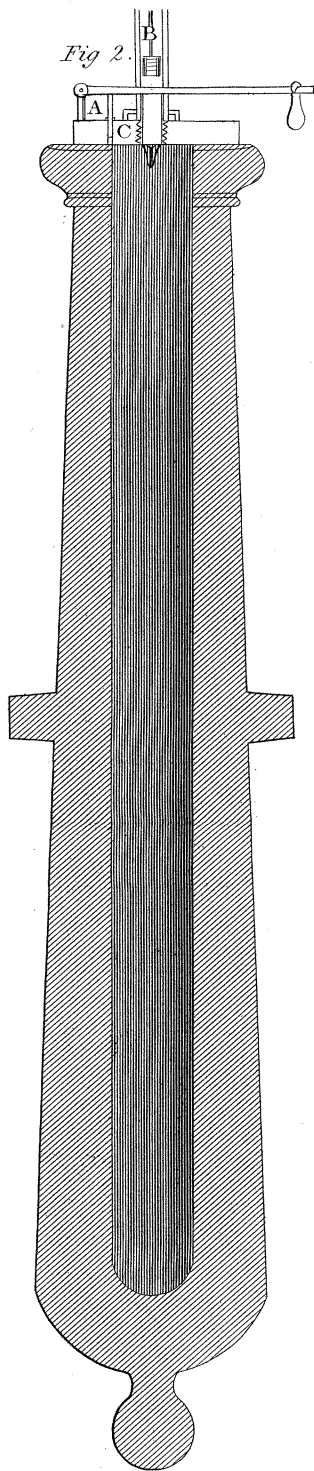
Experiment 5. In this experiment two strong bottles were sunk to the depth of five hundred fathoms. One of them was stopped with a ground glass stopper, and well cemented, then placed in a strong canvass bag. When the bag was drawn in, it was found that the bottle had been crushed into many thousand pieces. The other bottle was very tightly corked, but not having been left down a sufficient length of time, it came up whole, having filled to within one and a half inch. The cork had been driven in and remained so ; but the

cementation was unaltered, excepting at the surface, where it had become a little concave.

Being satisfied that the piezometer as first constructed, would not show all the compression, I determined to make one differently modified. The object was to avoid the friction occasioned by the collapsing of the leather upon the rod under such great pressure. The drawing in Plate XXXII, Fig. 3, shows another modification of the piezometer, made since I have been in this country. This proves my suspicions to have been correct; since, under the same pressure, it indicated nearly double the compression shown by the former.

This instrument is constructed as follows, Fig. 3 being a section of it. It is simply a small tube, A, closed at the end, B, and water-tight. At the upper end, C, the water is allowed to enter through a small aperture, E, closed by a very sensible valve opening inwards. The tube is flattened at D, in order that it may yield to the expansion of the water when taken out of the press.

The experiment with this instrument was made at Mr. KIER's manufactory, in the presence of many scientific gentlemen. The piezometer being perfectly filled with water (the weight of which was accurately known) was put into an hydraulic press, and subjected to a pressure of about three hundred and twenty six atmospheres. When it was taken out and weighed, there was found an increase of water amounting to three and a half per cent. This water had been previously boiled, and cooled down to a temperature of forty eight degrees, and kept at the same temperature during the experiment.



A machine calculated to avoid loss of pressure from destruction of the materials of which it is composed, will be made with all convenient speed. This machine being constructed with metallic stuffings and flexible metallic pistons, will effect a much greater pressure than the hydraulic press, the power of which is limited by the animal stuffing now used. It is probable, a pressure of from two to three thousand atmospheres may be obtained before the metallic piston is destroyed.

It is expected that this machine will be sufficiently accurate to give the exact ratio of the compressibility of water with much greater precision than has hitherto been obtained ; but the results of farther experiments must be the subject of a future communication.

29, *Austin Friars,*  
*June 6, 1820.*