found advisable to build the timber work and footing courses of masonry considerably (1 to 2 feet) larger than the neat work, which is laid out after the crib is in its final position. This provides for some permissible inaccuracy in sinking. The cribs are well drift-bolted together and the boxes caulked with oakum and dove-tailed or bolted down to the bottom, so as to prevent them lifting when the sinking process is going on.

Bottomless Caissons or Cofferdams.—Where no timber is desired under the masonry, or where the current is very swift, the method shown in Fig. 71 has been found best, but is only admissible where good foundations are easily obtainable. The bottomless box is floated into place, loaded until it sinks to the bottom, and then is either unwatered by having a large canvas flap around the outside of the bottom, held down by bags of concrete, thus nearly sealing the bottom, the caisson being then pumped out and the bottom excavated or levelled off with concrete, or else, if the bottom is already firm, as is usually the case in swift currents, there is no necessity for unwatering until a great depth of concrete has been put in, forming a watertight bottom; in the latter case, if there is an irregular rock bottom, the caisson cannot be made to fit it, and in order to keep the undertow from carrying away the concrete as fast as deposited, or even dissolving out the cement, it is found necessary to fasten a canvas flap around the inside of the bottom and load it down with bags of concrete, pea straw, etc., until a bottom has been formed And in depositing the concrete it is done by lowering an iron box, with a hinged bottom, containing about one cubic yard down to the bottom; the box is tripped, allowing the concrete to slide gently out, whereas it would become dissolved if allowed to fall any distance through water. After such a bed of concrete has been formed as is considered sufficient, the caisson may be pumped out and construction continued in open air.

Compressed Air.—Where a great depth of water and soft foundations are encountered the methods previously described must be abandoned. Early in this century the vacuum air process was tried, by which the excess of outside pressure forced soft materials up inside a vacuum chamber, this material being excavated, air was again extracted, and each time the hollow chamber of wood or iron sank down by its own or added weight; but this method was found uncertain in its means of directing the sinking, was capable of only limited application and failed entirely on encountering stiff clay or boulders, besides it did not enable the bottom to be personally examined and properly prepared for the foundation layers.

Very soon the plenum or compressed air process was tried, and to-day it is recognized as being in every way most satisfactory until greater depths than about 100 feet below water level are to be obtained, when open dredging through wells must be resorted to. Figs. 72, 73 and 74 show common forms of the same process. The drawings are almost self-explanatory, the pressure of air in the working chamber is constantly maintained, and the extent of the pressure must always be sufficient to keep out water; the tendency being for compressed air to be continually escaping around the working edges, and bubbling up to the surface outside the chamber. Where pneumatic cylinders are used, they are in pairs, sometimes braced together, the two supporting one end of a truss, and being completely filled with concrete after bottom is reached. See Plate XVI. One larger cylinder, as in the Hawkesbury bridge, with elliptical ends will, however, be much more stable.

Where large timber working chambers are used they must be very strong, as the whole weight of the pier will be carried on their backs until the working chamber is filled in, which is not until firm bottom is reached. It may be shod with iron or merely with timber, depending on the materials to be met with, and on top of this chamber may first be constructed a timber crib as in Fig. 74, extending up to the ground surface and filled with alternate pockets of concrete or broken stone sufficient to sink the chamber, which crib is built up gradually as the process goes on. Or, if advisable, the masonry may be commenced immediately on top of the working chamber as in Fig. 73, this will usually be done where the foundation is not a very deep one. The support which a deep caisson sunk by this method, or by open dredging gives to a pier and bridge, is partly by the bearing on the bottom and partly by friction on the sides, which is estimated at from 300 to 600 lbs. per square foot of surface, and is an enormous item in such a structure as that of Fig. 74, amounting to 2,000 or 3,000 tons. Of course, this resistance is not all to be overcome while sinking, for the continual movement and escape of a film of compressed air tends to aid sinking by lessening friction.

The material to be excavated is forced out of the discharge pipes by the compressed air, if it is finely divisible, by opening valves at the mouths of flexible pipes, but boulders, gravel, logs, etc., must be laboriously taken out of the air lock in small quantities, making the operation costly. The air shaft and lock form the means of ingress and egress, and it is a question whether it is safer and

Plate XX

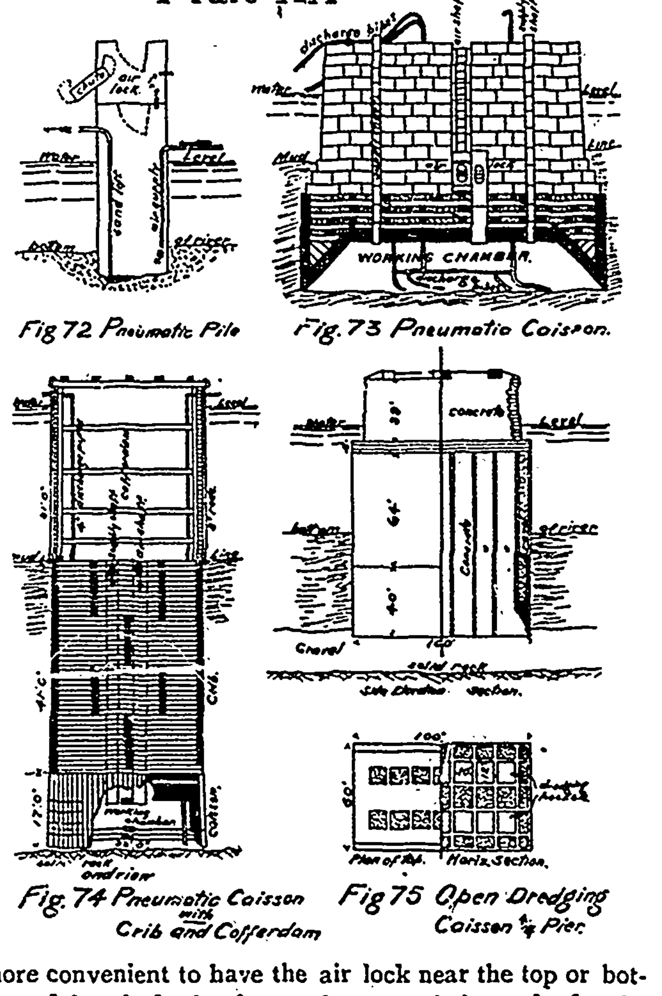

Fig 72 Pneumatic Pile. Fig. 73 Pneumatic Caisson. Fig. 74 Pneumatic Caisson with Crib and Cofferdam. Fig 75 Open Dredging Caisson & Pier.

more convenient to have the air lock near the top or bottom of the shaft, the former, however, being safer for the men. The process of working the lock is to open one door, pass in, close the door, open a valve so as to raise or lower the pressure as the case may be, and then open the other door and pass on, some time being necessary to prevent injury to the lungs and ear drums; men can work in about