Protection of Non-flowing Wells.—Many of the conditions favorable to pollution of the shallow wells likewise favor the contamination of deep wells, but, as the causes and remedies have already been discussed, especially in connection with the section on "Safety Distance," they do not require further consideration at this point.

The water of deep wells when first encountered is usually safe, and rightfully has a good reputation, so that people often go to great expense in drilling for deep rock waters. Unfortunately, however, many fail to realize that, unless care is taken, it is possible for deep wells to become polluted by the entrance of surface waters. In regions where the rock is within a few feet of the surface, for instance, the casing may be carried only to the rock, the fact that pollution can enter the well through the rock crevices being entirely overlooked. The chief precaution necessary against this danger is to carry the casing to a sufficient depth to shut off all surface waters entering through fissures. It is hard to say how deep it must be carried to remove all danger of contamination, but the crevices are usually limited to the upper part of the rock, and every additional foot of casing gives additional safety. Ten feet of casing in the rock would materially reduce the danger, while 25 feet would in most wells probably insure safety. The best plan, however, is to carry the casing from the surface down to the water-bearing seam. The casing should always be set with a tight joint at the bottom to prevent the entrance into the well of surface waters that find their way downward along the outside of the pipe.

Again, it is not unusual to drill new wells in the bottom of old dug wells and to allow the polluted surface waters to mingle with the pure rock waters.

Many towns situated on rock surfaces and using unprotected wells of the type mentioned have been visited by epidemics of typhoid fever, cholera, and other diseases, leading to the loss of many lives.

Another source of pollution, less common and possibly less dangerous than the preceding, arises from the fact that many casings are left open at the top, even when care has been taken to carry them to proper depths.

A fourth and very common means of contamination of deep wells is by leaks in the casing due to imperfect joints or to corrosion. The process of corrosion may be very rapid, the pipe in some wells with acid chalybeate waters lasting only a few years. No one expects a pipe laid in the ground near the surface to last many years, yet many seem to think that a well casing will last indefinitely. Unfortunately, this is far from true.

The detection of leaks is somewhat difficult. In some wells, however, water may be heard trickling in or may be seen by a light ray projected down the well by a mirror when the pump is withdrawn. The admixture of water from outside sources may sometimes be detected by a difference of the hardness of the well water, by an earthly taste or taste of decayed vegetation, or by a cloudiness due to silt brought in by superficial waters.

The remedy is usually to pull out the old casing and replace it by a new one, the length of time the pipe is allowed to remain before replacement being determined by an estimate of its life based on the action of the water on the pump-tube or other pipes. An alternative treatment sometimes employed when the leak is near the surface is to set a packer, designed for the purpose, in the space between the bottom of the pump-tube and the casing and fill the space above with cement.

Flowing Wells.—In order that water may have sufficient head to flow out upon the surface it must be confined under some impervious or relatively impervious clay or other bed. This effectually shuts out pollution from the overlying materials, and any contamination that reaches the well must be transmitted laterally for relatively long distances. As pollution rarely extends through the ground to any great lateral distance from its source, it follows that artesian waters are almost never polluted.

In artesian wells the water, being under greater head than that in the surrounding materials, will pass outward through any leak that may develop rather than admit the water of lower head to the well. Suction, such as is developed in the Richards apparatus in laboratories, which might be conceived as drawing in outside water through openings in the casings, cannot take place with the relatively low velocities of the water in the ordinary artesian wells. Even in a well in which the water has a very high velocity, the suction is so slight in proportion to the immense volume discharged that it may usually be neglected.

Methods of Increasing Original Yield.—Shooting.—The practice of "shooting"—exploding a charge of nitroglycerine or other explosive in a well—has long been successfully employed in the oil regions, and has in late years been used to increase the flow of water wells, in which dynamite is more commonly used. The action of the dynamite is to shatter the surrounding rock, with the result that connection is frequently established with other crevices, in some wells largely increasing the water supply. (See Fig. 1.) The dynamite is most effective in hard, brittle rocks, such as limestone, which are as a rule completely shattered by the explosion, and is least effective in soft, tough shales, which are bent and compressed rather than broken.

Steam Jet.—Shooting, owing to the character of the materials, is not usually practised in unconsolidated deposits, in which the steam jet is sometimes used instead of dynamite. The steam is forced down a small pipe inside of a larger one, and coming into contact with the water at the bottom, turns it quickly into steam, the resulting explosion loosening the material or making a pocket about the bottom of the pipe. Where the materials are dense and clayey, the action of the steam jet may considerably increase the influx of water; in the more porous deposits it has less effect.

Packing with Gravel or Sand.—It frequently happens that where the material is very fine it packs around the well so as to hinder the entrance of water. In such cases it is a common practice to drop a supply of pebbles into the well and with the aid of a drill force them out into the surrounding clay, etc., until a pocket of pebbles is produced through which the water flows freely to the well.

In quicksands, the space between the outer casing and the pump-tube and strainer is often filled with sand through the heavy suction induced by pumping. The sand in many wells keeps back the quicksand while allowing the water to pass through it freely and to enter the well. (See Fig. 1.)

Production of Sand or Other Pockets by Pumping.—Many of the materials yielding water to wells consist of mixtures of sand or gravel and clay. By heavily pumping a new well it is often possible to remove the fine clayey material, leaving the sand grains and pebbles in a sort of pocket about the well (Fig. 2), the result being much like that produced by the artificial gravel pocket described in the preceding section. A similar method is employed in certain stiff clays, in which small, open pockets at the bottom of the well are apparently produced by the heavy pumping.

Methods of Restoring Lost Supplies.—When a deep well is first sunk, it usually gives good supplies, but as time elapses the yield is found to decrease gradually until finally it is but a small fraction of the original amount. This decrease is commonly attributed to a decrease in the genera'