The same is true of each following section 3, 4,—(n-1) and n; each of these sections, as it is arrested, being compressed to the pressure P.

During process (1) a small quantity of water flows from the reservoir into the pipe, to occupy the space formed by the compression of the water and the extension of the pipe walls. Finally, when all the sections have been arrested, the entire column will be under pressure, P. The entire energy of the water column is now stored (as potential energy) in elastic deformation, *viz.*, in the compression of the water column and in the extension of the pipe walls.

But this condition cannot be maintained: for (2) as soon as the additional pressure, P, has been produced in

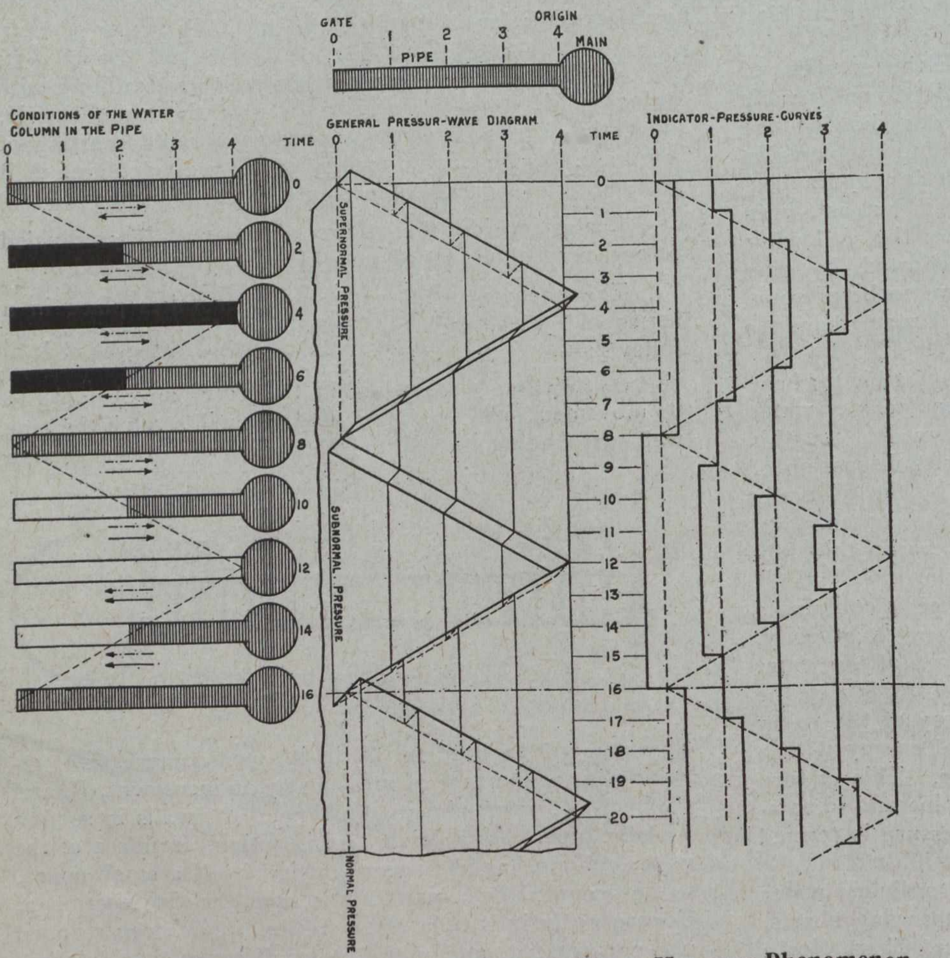

Fig. 2.—Diagrammatic Representation of Water Hammer Phenomenon.

the last section, n, the water in that section will again expend, and the walls of that section of the pipe will again contract, restoring the original conditions in that section and pushing the water of that section back into the reservoir from which the pipe issues, and restoring the original normal pressure in section n.

This operation will now be repeated by each section (n-1)—4, 3, etc., in turn, until all the potential energy stored in the water column when it was under the pressure, P (neglecting the portion, lost in friction), has been reconverted into kinetic energy.

During process (2) the water which entered the pipe during process (1) is forced back into the reservoir. The condition of the water column is now what it was just before the gate was closed, except that its velocity, v, has now the opposite direction, *i.e.*, toward the origin.

(3) The kinetic energy of the water column, moving toward the origin or away from the gate, is now reconverted into potential energy, which manifests itself in an extension of volume of the water to a subnormal pressure,* beginning with section 1 and concluding only when the entire water column has been reduced to the subnormal pressure.

(4) When the subnormal pressure has been established throughout the length of the pipe, and all the water has come to rest, the water from the reservoir will again direct itself into the pipe, restoring the normal pressure, first in section n, next to the reservoir, and then, in rapid succession, in the other sections (n-1)—4, 3, etc., until, when the normal pressure reaches the gate, we have once more the conditions which existed just before the gate was closed, *viz.*, the normal pressure is restored and the water is moving toward the gate with the original velocity, V.

We have now followed these pulsations of pressure (with the accompanying transformations of energy and flow of water into and back from the pipe) through a complete cycle of four movements, each extending through the length of the pipe. For convenience, we may consider two successive movements of the kind as a "round trip" through the pipe.

The gate remaining closed, the whole process is now repeated in a second cycle, which, in turn is followed by a third, and so on, the amplitude of the pressure vibrations gradually diminishing (because of friction) until the pipe and the water come to a state of rest.

But although the intensity of the pressure becomes gradually less, the time required for each cycle remains constant for all repetitions. This propagation of pressure, consisting of its transmission through all points of the length of the pipe, each point successively repeating the same periodical movements, is in its nature, simply a case of wave motion, like that of a sound wave.

The velocity of wave propagation is independent of the intensity of the pressure, and depends only upon the properties of the medium through which the propagation takes place—in the case of water hammer, upon the elasticity of the water and of the pipe.

We now find that the time required for each cycle of pressure transmission (including two round trips through the pipe) is equal to $\frac{4L}{a}$, where L is the length of the pipe and a is the velocity of wave propagation. This is the period of an entire pressure vibration in every point of the pipe.

A general diagrammatic representation of the principles of water hammer, as just described, is given in Fig. 2. Here we see on the right, pressure curves corresponding to the different points of the pipe indicated at the top. On the left of Fig. 2 the conditions of the water column

*During process (3) water continued flowing from the pipe into the reservoir.