THE HYDRAULIC RAM—ITS POSSIBILITIES OF DEVELOPMENT AND USE.*

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The hydraulic ram was first invented by John Whitehurst, in 1772, and was made practical by Joseph M. De Montgolfer in 1796. The latter made the action of the waste valve automatic, thus changing the ram from a laboratory toy operated by hand, to a useful pumping device. Although the hydraulic ram was invented and used over 100 years ago, there was but little improvement in its design up to fifteen years ago.

To-day little is known of the hydraulic ram, even by engineers. The average engineer seems to have the most hazy idea of the characteristics of this much neglected pumping device. It is usually looked upon as a type of pump of small capacity and low efficiency, useful for pumping water for isolated dwellings, or where but a small quantity of water is needed and efficiency of no consequence.

Operation.—The essential features of a hydraulic ram are (See Fig. 1) supply or drive pipe A, ram chamber B, waste or impetus valve C, discharge or check valve D, air or equalizing tank E, and discharge or delivery pipe F.

The mere physical operation of the ram is simple, though the attendant phenomena and hydraulic principles involved seem to be but little understood. The general principle of operation is the same in all rams, however the mechanical workings and construction may differ.

Ignoring, for the present, the cause of the action, suppose the waste valve (C) to have just opened, the water in the drive pipe and ram being stationary, when the valve opens the water in the drive pipe starts to flow through the open valve, gaining in velocity, until the increasing velocity and pressure behind the valve are sufficient to close the latter. When the waste valve closes, the water flowing in the drive pipe with the momentum and energy of the moving column of water behind seeks another means of escape, which is secured by opening the discharge valve (D), flowing through the latter into the air chamber (E), and thence out through the delivery pipe (F). The air in the chamber acts as a cushion to the sudden inflow of water and maintains a nearly constant pressure in the chamber and steady flow through the delivery pipe.

The velocity gradually decreases until all the energy of the moving column of water is expended in forcing water into the air chamber and the flow ceases. The pressure in the air chamber then starts a back flow similar to the oscillation of water in a U tube. This instantly closes the check valve, thus retaining the water pumped. The tendency to back flow together with the sudden closing of the check valve, causes a momentary reduction of pressure in ram chamber (B), which allows the waste valve to open. The water then starts to escape as before and the cycle of operation is repeated. The action after once being started is automatic and the ram will continue to operate.

The back surge is usually sufficient to create for an instant a partial vacuum in the ram chamber. This condition may be taken advantage of, to introduce automatically into the upper part of the chamber a small amount of air at each stroke. During the waste period this air rises to the top of the chamber and at the delivery period is carried through with the flow into the air chamber. Thus the air supply is maintained, which otherwise would be gradually absorbed by the water under pressure.

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Details of Operation.—The operation of the ram may be divided into two distinctive periods, namely, the acceleration or power accumulating period, and the retardation or pumping period. In the former, the waste valve is open and the water escaping through it, while the check valve is closed. In the latter, the waste valve is closed and the water is being delivered through the check valve.

In addition to the two periods mentioned there is the instant between the closure of the waste valve and the opening of the check valve, and also between the closing of the check valve and the opening of the waste valve. Each of these periods, though extremely short, has its distinctive functions and attendant phenomena.

We will now follow more in detail a cycle of operation or a stroke as it is commonly called.

When the waste valve opens the static column of water in the drive pipe, due to the inertia of its mass, cannot get up velocity at once, but is accelerated gradually. The time required to attain a certain velocity depending upon the ratio of supply head to length of drive pipe, or, stated in another way, upon the slope of the drive pipe. Neglecting the effect of friction, the acceleration is constant like that of gravity, and may be expressed in the familiar form $V = GT$, modified, of course, by the slope of the drive pipe, into

$$V = GT\frac{H}{L} = GT \sin A,$$ where A equals the angle of slope of the drive pipe, H equals the supply head and L the length of drive pipe. This is approximately correct for small velocities, but the friction varies as the square of the velocity, hence it soon becomes an element that must be considered. For any size pipe on a given slope there is a fixed possible maximum velocity. This is found by the Chezy formula $V = C\sqrt{RS}$ where S is the slope of the drive pipe, $\frac{H}{L}$.

Water Hammer.—Up to a certain point there is practically no resistance to the flow offered by the waste valve, as it will pass the water faster than it comes to it. After attaining a certain velocity, the water begins to head up behind the waste valve and when sufficient velocity and pressure are attained the waste valve is closed. When the valve starts to close the area of flow is further restricted, the pressure rises rapidly and the valve goes shut with a bang.

The sudden stopping of the moving column of water produces an instantaneous rise in pressure, causing what is called "Water Hammer." The intensity of the hammer is limited by the pressure against which the ram is pumping, as when this pressure is reached the discharge valve opens and prevents a further rise.

Experiments have shown that the maximum pressure in the ram exceeds that in the air tank by only a few pounds.

When the waste valve closes the lower filament of water is compressed, and is followed by each succeeding filament under like compression to the head of the drive pipe, while at the same time, the pipe walls due to this compression, are expanded. As this compression wave reaches the open end of the drive pipe, the first filament is relieved, then each in succession as a wave of rarefaction moves down the pipe. Thus the pressure waves race up and down ordinary pipe at a rate of about 4,000 ft. per sec. until worn out by friction.

The intensity of water hammer depends upon the velocity of flow and the rate of its suppression. If it is stopped instantly, the pressure developed is found by the formula,

$$P = \frac{vVW}{G}$$ where P = water hammer pressure (in excess of static pressure) in pounds per square inch.