This ram was installed with a 43-ft. drive head and 2,200 ft. of 10-in. cast-iron drive pipe. The makers assured Mr. Mead that such an installation was impossible, as the water hammer, due to stopping such a volume of water, would tear any machine to pieces. The ram was designed to suit the conditions; that is, with a large discharge valve area and with a very heavy spring to operate the waste valve, which was given a small movement. Needless to say, the machine operated successfully, and has continued to do so for the last 16 years.

The pressure in the ram exceeded that in the stand tower by about 2.5 lbs. There was no excessive hammer, as the column of water is not stopped or started suddenly, but gradually. This machine developed from 73 per cent. to 75 per cent. efficiency. This seems to be about the average efficiency of commercial rams in the larger sizes.

A New Type of Ram.—Last year the writer had occasion to investigate the subject of pumping machinery with a special view to the use of water power for its operation. The hydraulic ram, on account of its reasonable cost, automatic operation without the necessity of an attendant, low operating costs, durability and reliability, seemed particularly suited for use on irrigation projects, where conditions permit of its installation.

A particular case was presented to the writer some time ago for his consideration, where the supply head was so high that no ram obtainable would operate.

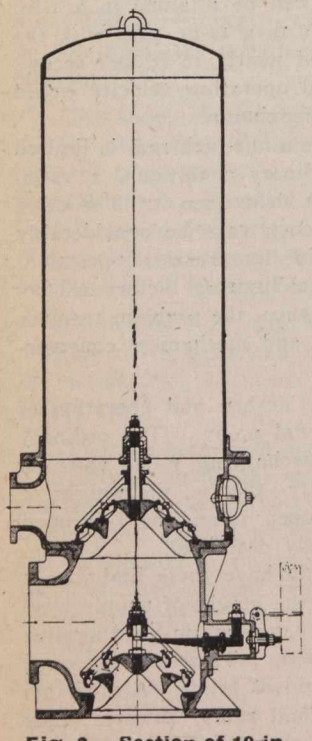

Fig. 2.—Section of 10-in. Sterling Ram.

After a careful study of the principles involved in the operation of rams, there appeared no fundamental reason why their operation should be limited to the narrow bounds of present practice. This being the case, it seemed that it should be possible to design a ram that would operate under a much wider range of conditions. With this idea in mind, a further investigation of existing makes of rams and their construction and operation was made.

It was apparent that a new type of waste valve was necessary in order to increase the strong, and have as large free capacity or field of operation of the ram. This valve must be so constructed as to eliminate the excessive hammer on its seat, must be light and strong and have as large free waterway as possible with a small movement of the valve.

The upward discharge was abandoned on account of the amount of head wasted on the larger sizes. The horizontal side discharge was considered, but passed because the machine would have to be submerged to above the valves to prevent their inhaling an excessive amount of air through the upper half of the valve during the fore part of the waste period. The solution seemed to lie in a balance valve of some description, having a downward discharge and operated with a heavy spring.

After numerous designs had been made and abandoned, a type of valve was finally evolved that seemed to fill the various requirements. This valve is composed of one or more concentric rings of increasing diameter, the number of rings depending upon the size of the machine. The plural rings are carried on a frame consisting of four radial arms, guided by a central stem, so they act as a single valve. The rings were changed from short cylindrical sections to ones having an arched cross section. See Fig. 2.

This allowed the water to escape over, as well as under, each ring when raised, thus nearly doubling the capacity of each ring with a given opening. This shape has the further advantage of offering smooth curved guides to the flow of the water and increasing the strength of the valve ring.

This arrangement of valves gives the greatest amount of clear waterway, with a minimum of weight of moving parts and space occupied, thus giving large capacity with high efficiency.

The valves being thin circular rings, with the vertical ram pressure practically balanced, they close very lightly, eliminating the excessive pounding. The hammer on the seats is the same in large rams, with this type of valves, as in the smaller ones, as they have practically the same shape and size of valve section.

A ram with valves of this type has been built and tested by Hill Bros. (See Fig. 2). It has a 10-in. supply pipe and a two-ring waste valve. The check valve is of similar construction, except that it has one ring and a central disc.

These valves, with a maximum movement of less than one inch, have an unobstructed opening nearly equal to the section of the supply pipe. The large efficient valve opening, with small movement of light valves, gives the machine large capacity without sacrificing efficiency.

The valve rings close on thick rubber seats consisting of a rubber ring inset in a dovetail groove in the metal seats. The rubber is forced into the groove and is just flush with the metal. This type of rubber seat cannot hammer to pieces as do other types of flat rubber packing seats having exposed edges.

The top of the valve ring closes flush with the outer edge of the valve seat above, the crack between being sealed with a rubber packing carried on the top of the valve. The valves are absolutely watertight, and constructed so they will remain so till the rubber disintegrates with age. The rubbers are easily renewed.

Test of 10-in. Sterling Ram.—The experimental machine was set up on the campus of the University of Washington, and a series of careful tests made under the supervision of the Department of Hydraulics. All measuring apparatus was carefully calibrated. A 50-ft. supply head was used and 140 ft. of 10-in. wrought-iron drive pipe.

The conditions were purposely made severe, the drive head being the highest yet used. The machine operated very satisfactorily, and the efficiencies developed were even better than anticipated. Various velocities were used, with lifts ranging from 100 ft. to 325 ft. The efficiencies ranged from 80 per cent, on the high lift, to 95 per cent. on the low (DeAubuisson formula). The drive pipe was too short to give the best results, especially on the higher lifts. Eight runs with a 115-ft. lift showed over 90 per cent. efficiency, the average being about 93.5 per cent.

It was hoped to secure a sufficient range of experiments to determine the characteristics and coefficients of the ram, but on account of the limited water supply available this proved impossible at the time. However, much valuable knowledge was obtained in regard to the fine points of ram operation.

A series of pressure indicator cards were secured on the ram, half way up the pipe and 20 ft. from the head of the drive pipe. These show the variations of pressure at these points. They seem to bear out the theory of the water hammer waves. The vibration in the drive pipe was very noticeable, especially near the head of the pipe, while in the ram