July 15, 1947. E. MERTEN 2,424,108

HYDRAULIC RAM SYSTEM

Filed May 31, 1943 3 Sheets-Sheet 1

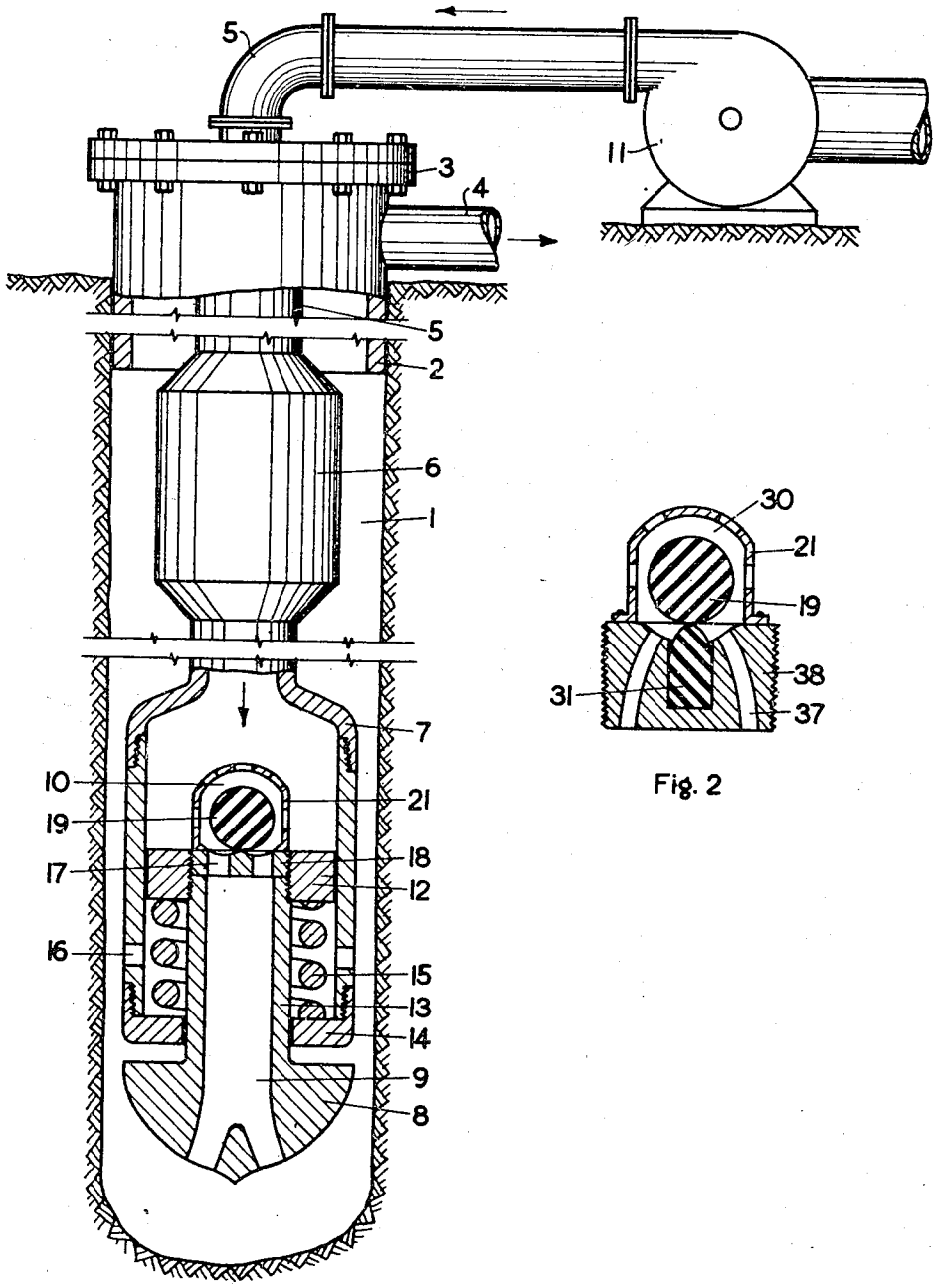


Fig. 1

Fig. 2

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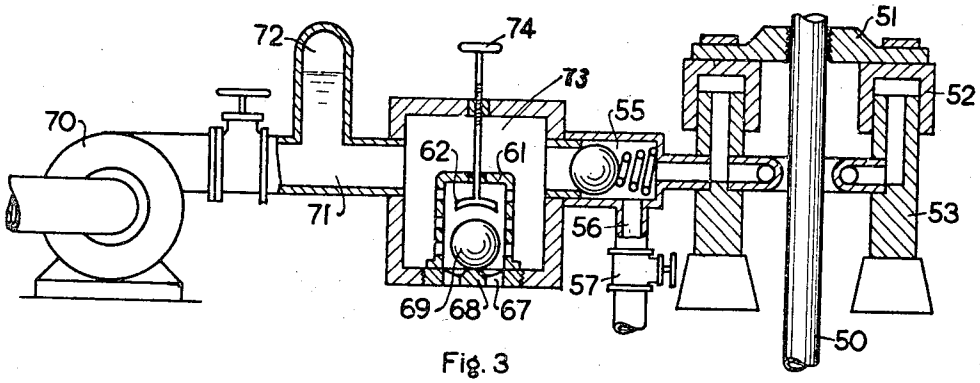


Fig. 3

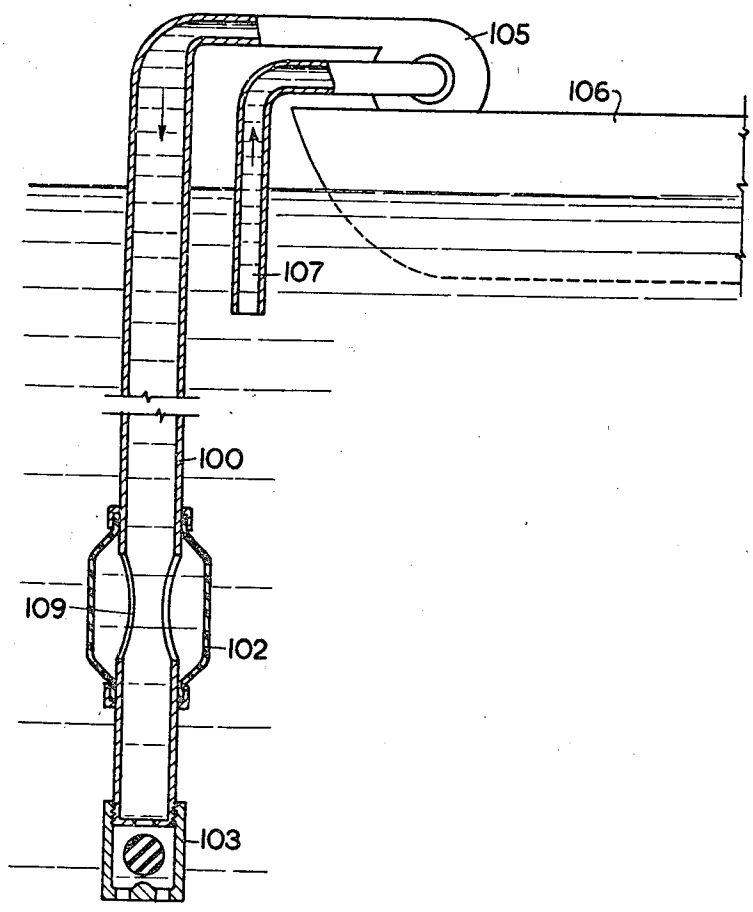


Fig. 5

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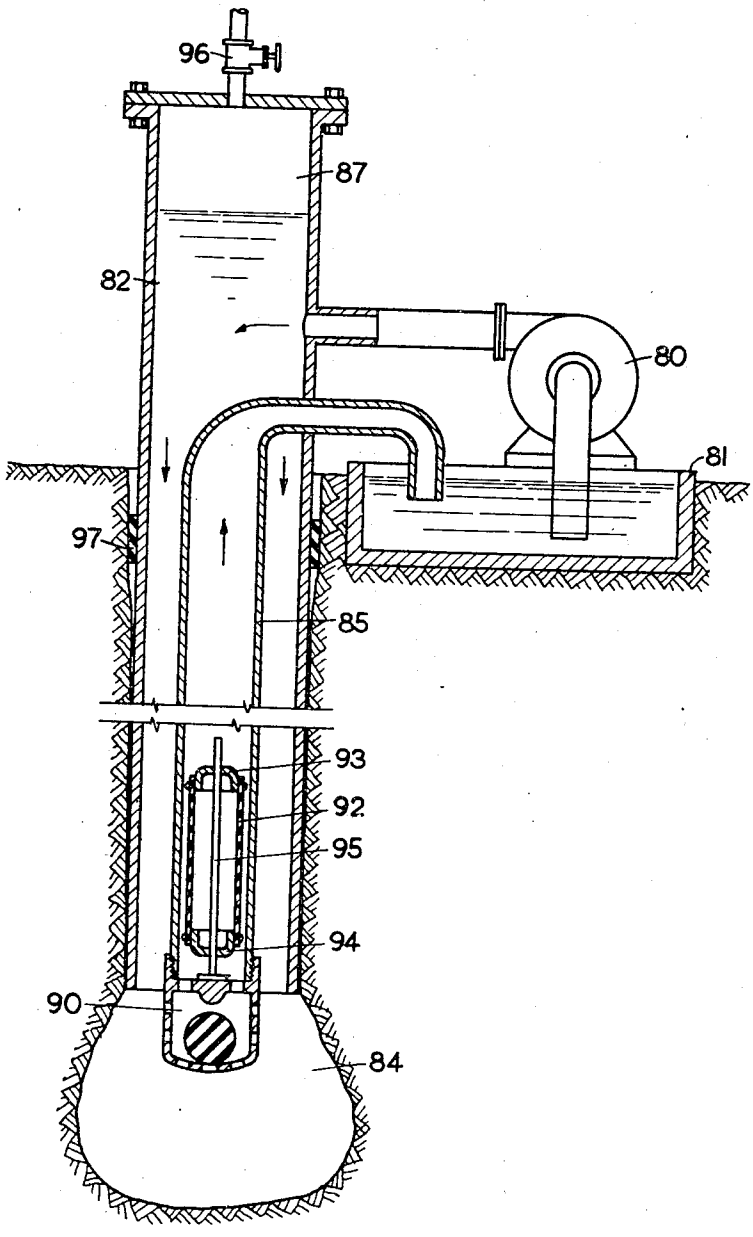


Fig. 4.

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UNITED STATES PATENT OFFICE

2,424,108

HYDRAULIC RAM SYSTEM

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2 Claims. (Cl. 253—17)

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This invention relates to hydraulically operated devices, and pertains more particularly to a valve for systems wherein high pressures generated by the so-called hydraulic ram or water-hammer effect are utilized for various purposes, such as drilling, lifting of loads, generation of seismic impulses, etc., the present application being a continuation-in-part of my co-pending applications Serial Nos. 358,585, filed September 27, 1940, now Patent No. 2,325,264, and 462,629, filed October 19, 1942.

A hydraulic ram converts the kinetic energy of a flowing liquid into static energy manifested in high pressure effects. When a liquid flows from a reservoir or pump through a conduit or drive pipe towards a valve which periodically stops its flow, the high pressures developed in the drive pipe by the sudden stoppage of the liquid produce the so-called hydraulic ram or hammer effect. These high pressures, which are additional to the pressure which may normally prevail in the drive pipe, are expressed by the following formula:

$$P=\frac{VUW}{g}$$

wherein P is the maximum additional unit pressure produced by the closure of the valve, V is the velocity of the liquid in the drive pipe, U is the velocity of transmission of pressure waves in the liquid, W is the weight of a unit volume of the liquid and g is the gravity acceleration constant.

Hydraulic ram systems may be applied in percussion drilling, wherein high hydraulic pressures are used to impact a drill against ground formations, and the present invention will for clarity be first described in its application to such systems, although it is understood that it is in no way limited to drilling systems, but may likewise be used for purposes of lifting loads, generating elastic or audible waves or signals, such as seismic impulses or waves used in geophysical exploration, and the like.

Although valves used for generating hydraulic ram impulses in common hydraulic ram systems, and the valve of the present invention, serve a similar purpose, namely, to stop periodically the flow of water or other liquid, there exist therebetween essential differences forming the subject matter of this invention.

In the common hydraulic ram systems, the

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drive pipe is often of a length such as a thousand feet in order to bring up the time during which the high pressure prevails in the system to a value of several seconds, the frequency of operation being about 10 cycles per minute, and clear water being usually circulated in the system.

In the hydraulic hammer systems used according to the present invention, the drive pipe is of a length such, for example, as only about six feet, in order to reduce the duration of the high pressure cycles and to increase the frequency of operation to a high value, such, for example as about 1800 cycles per minute, the high pressure enduring only for about .004 second, and the time during which the valve has to close being of the order of about .001 second. The valves commonly used in hydraulic ram systems, such as spring loaded valves, have therefore been found to be unable to withstand the stresses imposed upon them under these extremely severe conditions, and have consistently failed after relatively very short periods of use.

It is therefore an object of this invention to provide a hydraulic system comprising a valve capable of suddenly stopping the fluid flow in a conduit to generate high-pressure hydraulic or water-hammer effects.

It is also an object of this invention to provide for this purpose a hydraulic system comprising a valve adapted to operate at extremely high frequencies of pressure variations.

It is also an object of this invention to provide a valve capable to stand without failure for protracted periods the extremely severe operating conditions incident to the high frequencies and high pressures used.

These and other objects of the present invention will be understood from the following description, taken with reference to the attached drawing, wherein:

Fig. 1 is a schematic view, partly in cross-section, of a hydraulic drilling system embodying the hydraulic ram valve of the present invention.

Fig. 2 is a view in cross section of a somewhat modified embodiment of the present valve.

Fig. 3 is a diagrammatic view of a hydraulic lifting system embodying the valve of the present invention.

Figs. 4 and 5 are diagrammatic views of systems

used for generating seismic impulses, embodying the valve of the present invention.

Fig. 1 shows the application of the valve of the present invention to an impact drilling system. A borehole 1, which may be provided with a casing 2, closed at the surface by a casinghead 3, contains a liquid conduit such as a drill string 5 comprising a plurality of internal and external air chambers or flow equalizers 6, more particularly described in my co-pending applications referred to hereinabove. The operating liquid is supplied to the conduit or drill string by means such as a pump 11. The lower portion of the drill string is enlarged as shown at 7 and partially encloses a drill bit 8, adapted for axial reciprocating motion. The drill bit is provided with a conduit such as a passage or passages 9 for liquid circulation, said circulation being adapted to be interrupted by the operation of a valve structure generally shown at 10, which is mounted on the drill bit, as will be described hereinbelow.

The upper portion of the bit forms a piston 12, adapted to fit slidingly within the enlarged portion 7 of the drill pipe, while the stem portion 13 of the bit fits slidingly within a plug 14, closing the bottom of the enlarged drill pipe 7. Mounted around the stem 13 between the piston 12 and the plug 14 is a powerful spring 15, adapted to urge the drill bit upwards.

The valve structure shown at 10 comprises a valve seat 18, provided with liquid passages 17, a resilient ball valve 19, and an apertured valve cage 21 adapted to confine loosely the resilient ball 19 adjacent the high pressure or upstream side of the passage 17. The valve seat 18 is preferably formed with a concave face having a convex or elevated central portion, as shown in the drawing, or is otherwise formed so as to provide ample space for the passage of the liquid until the resilient ball valve is compressed against the seat, as will be described hereinbelow.

Operation is started by flowing or pumping a liquid such as water, brine or any suitable drilling fluid down the drill string 5, through the cage 21, passages 17, passage 9, and up through the annular space between the drill string and the walls of the borehole, said liquid being returned to a suitable pit or reservoir at the surface by means of a conduit 4.

When such circulation of liquid down the string 5 is established, a differential pressure is created by the flow of liquid through the relatively restricted passages 17, between the upstream space above said passages and the downstream space therebelow, said differential pressure being a function of the rate of flow in tubing 5 and passages 17 respectively.

The ball valve 19 is made of a resilient material, such for example, as natural or synthetic rubber, whose compressive strength is selected so that it will permit the ball valve 19 to be deformed and pressed against the seat 18, thus closing passages 17, when said differential pressure reaches a value corresponding to a predetermined velocity of the liquid being pumped down the tubing 5, for example 20 feet per second.

This operation is extremely rapid, since, as soon as the ball begins to deform and to approach the seat, it also begins to restrict the flow of liquid through the passages 17, which increases the differential pressure and, in turn quickens the closure of the valve. In general, the valve 10 is adapted to close in a time period smaller than 2 L/U, wherein L is the length of the drive pipe, that is, the distance between the valve and the flow equalizers 6, and U is the velocity of transmission of pressure waves in the liquid, which has usually a value of from 4200 to 4600 feet per second.

As stated above, this time of closure of the present valve is made extremely small, of a value such as about 0.001 second, and the abrupt stoppage of the liquid flow creates extremely high hydraulic ram or hammer pressures, which may have values such as from about 600 to about 1200 lbs. per square inch when the pump 11 delivering the liquid to the string 5 works at pressures from 60 to 100 lbs. per square inch.

These high water-hammer pressures act on the upper face of piston 12 to compress the spring 15 and to impact the drill bit sharply against the formation to be drilled. Since, however, a water-hammer cycle consists of a high pressure period followed by a low or sub-normal pressure period, both the spring 15 and the resilient ball valve 19 return to their unstressed shape during the latter period, whereby the drill bit is returned to its original position, and the ball 19 is pushed by its resiliency away from the seat, thus opening the passages 17.

The shape of the seat is a function of the elastic properties of the ball, and of the speed at which the valve is designed to close, and a proper selection of the shape of the seat base gives a proper control of the desired speed of operation and permits the valve to open against a given liquid head. Thus valves with sharply pointed central seat portions close at low speeds, and valves with low central seat portions open at low water heads. In general, high speeds and high water-hammer pressures require also a greater hardness of the material of the ball, in order that the ball may not be pressed into or through the passages 17.

Although the ball is held loosely within the cage, and the liquid flow is in general sufficiently violent and turbulent to bounce and rotate the ball between the seat and the cage, whereby the ball is caused to wear evenly over its entire surface, and although the useful life of a rubber ball valve of the present invention is incomparably longer than that of any steel spring controlled valve used under the same conditions, the continuous operation of the valve at high pressures still produces severe deformations of the ball, and internal friction generates heat and tends to reduce its life, so that a proper selection in the qualities of the elastic material of the ball is of importance.

It has, however, been found that a modification of the present valve, as shown in Fig. 2, is effective in considerably reducing the wear of the ball. Fig. 2 shows, disengaged from the bit structure, a valve 30 generally similar to valve 10 of Fig. 1, having a seat 38 provided with passages 37 and a cage 21 enclosing the ball 19. The concave valve seat 38, however, instead of having an elevated or pointed central portion, as in valve 10, has formed therein a recess adapted to receive a supporting member 31, which is elevated and protrudes above the concave upper face of the seat 38. The head of the member 31 may be given any desired convex shape, in general similar to that of the elevated central portion of the seat 18. The member 31 is, however, made of a material such as rubber, hard rubber, ebonite or any other suitable resilient plastic material, it having been found that the use of such materials in the central portion of the seat of the valve diminishes to a very great degree the wear on the ball 19.

Another application of the valve of the present invention is described with reference to Fig. 3.

It sometimes happens that a drilling, tubing or casing string becomes stuck or frozen in the borehole, so that the force exerted by ordinary raising devices is insufficient to free said equipment. In such cases, it has been found that the hydraulic ram effects generated by the valves described above are highly effective in overcoming the interfering obstacles and in raising the string to the surface.

Referring to Fig. 3, a pump 70 supplies the pressure liquid for such an arrangement through a conduit 71, provided with a flow equalizer or air chamber 72. The conduit 71 opens to a chamber 73, containing the valve of the present invention, which comprises the usual cage element 61, the resilient ball 69 and a seat 68. A stem member 74 extends through the walls of the cage and of the chamber 73 and is adapted for screw-threaded axial motion. The stem member has, within the valve cage, a head 62, adapted to engage the ball 69 and to press it against the seat, thus closing the passages 67. The chamber 73 is in liquid communication, through a non-return valve 55, provided with an exhaust conduit 56, normally closed by a valve 57, with a hydraulic jack comprising stationary piston members 53 and movable cylinder members 52. Jaws or slips 51 are attached to the movable cylinder members and serve to engage the tubing string 50, which it is desired to raise from a borehole.

In operation, a liquid under pressure is delivered to the hydraulic jack by the pump 70 with the ball 69 pressed by the stem member 62—74 against the passages 67 and the valve 57 being likewise closed. The pressure of the liquid causes the cylinders 52 to move upwards together with the slips and the tubing string gripped thereby.

If, however, the hydraulic jack lacks, for any reason, sufficient power to raise the load imposed upon it, the ball 69 is released by retracting the stem 74, which causes the present valve to generate high pressure water-hammer impulses in a manner already described hereinabove, which impulses are transmitted to the cylinder and piston structure of the hydraulic jack, and are effective in overcoming the forces or obstacles impeding the upward motion of the drill stem. The pressure in the hydraulic jack can subsequently be released by opening the valve 57. The air chamber 72 serves to protect the pump 70 from hydraulic ram effects.

Still another application of the valve of the present invention is described with regard to Fig. 4.

A pump, such as a centrifugal pump 80, forces a liquid from a reservoir 81 into a stand or string of tubing or casing 82 extending into a borehole having in its bottom portion an enlarged cavity 84. A second string 85, located within the string 82, serves to return the liquid to the reservoir 81. The hydraulic ram valve of the present invention, generally designated at 90, is located at the end or within the string 85, and serves to generate, in the manner described hereinabove, high pressure water-hammer impulses which are transmitted to the surrounding ground formations through the walls of the cavity 84. An air chamber or flow equalizer 87 provided with a valve 96 is provided to protect the pump and reservoir from water-hammer shocks. A second flow equalizer may be installed within the string 85, and comprises, for example, a flexible rubber sleeve 92, affixed in fluid-tight manner to end pieces 93 and 94 screw-threadedly movable on a stem 95 mounted above the valve structure. The frequency of the vibrations transmitted to the ground may be varied within wide limits by changing the dimensions and the characteristics of the valve 90, the working pressure of the pump, and the location and size of the flow equalizers. A packer 97 can be used to seal the space between the walls of the borehole and the string 82.

Fig. 5 shows the adaptation of the system of Fig. 4 to the generation of seismic impulses in marine sites, lakes, rivers, etc.

A pump 105, mounted on a boat or shore installation 106, receives water through a conduit 107 and forces it at a desired pressure down a conduit 100. The conduit 100 has, near its lower end, a section provided with perforations 109. The conduit section 109 is surrounded by an elastic fluid-tight sleeve or spherical envelope 102, which is made sufficiently strong to withstand the working pressure of the pump. The hydraulic ram valve of the present invention is shown at 103 attached to the end of the conduit 100. The return pipe and second flow equalizer of Fig. 4 are unnecessary in the system of Fig. 5.

I claim as my invention:

1. A system for generating high-frequency hydraulic ram impulses, comprising a conduit, pump means connected to one side of said conduit capable of maintaining a unidirectional liquid flow from said pump through said conduit, a valve for generating hydraulic ram impulses in said conduit, said valve comprising a valve seat bridging said conduit, said valve seat having a concave upstream face, with a convex portion positioned centrally of said concave face, passage means through said seat laterally of said member for creating between the upstream and the downstream sides of said valve seat a unidirectional differential pressure as a function of the unidirectional liquid flow rate in said conduit, a resilient ball member loosely confined adjacent the upstream side of the valve seat, said resilient ball member being capable of being cyclically deformed by said unidirectional differential pressure against said seat to close suddenly said passage means, thereby generating a hydraulic ram impulse, and of returning to its unstressed shape during the short duration low pressure period following said impulse, whereby the cycle is repeated and high frequency hydraulic ram impulses are generated by the system, the frequency of said impulses depending on the shape of the convex member and the hardness of the ball.

2. A high-frequency hydraulic ram system, comprising a conduit, pump means connected to one end of said conduit capable of maintaining a unidirectional liquid flow from said pump through said conduit, a cylinder in communication with said conduit at its other end, a piston adapted for displacement with regard to said cylinder in response to hydraulic ram impulses, a valve seat bridging said conduit, said valve seat having a concave upstream face, a convex resilient member positioned centrally of said concave face and affixed thereto, restricted passage means through said valve seat laterally of said elastic member for creating between the upstream and downstream sides of said valve seat a unidirectional differential pressure as a function of the unidirectional liquid flow rate in said conduit, and a resilient ball member loosely confined adjacent the upstream side of the valve seat, said resilient ball member being capable of being cyclically deformed by said unidirectional differential pressure

against said seat to close suddenly said passage means, thereby generating a hydraulic ram impulse, and of returning to its unstressed shape during the short duration low pressure period following said impulse, whereby the cycle is repeated and high frequency hydraulic ram impulses are generated by the system, the frequency of said impulses depending on the shape of the convex resilient member and on the hardness of the ball.

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