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WATER SURGE ARRESTER

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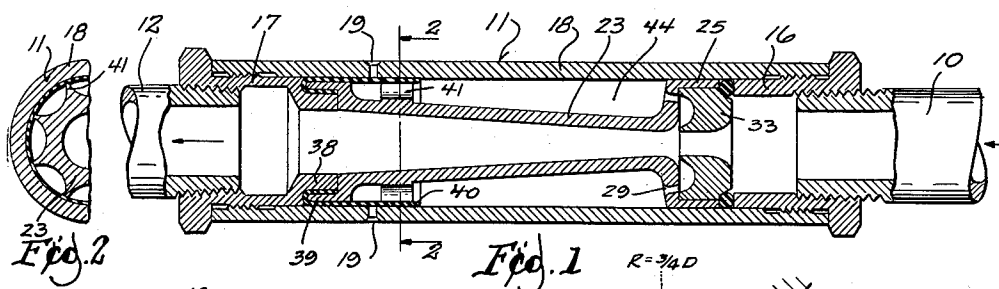


Fig. 1

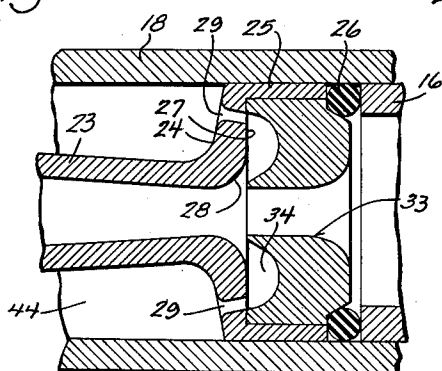


Fig. 3

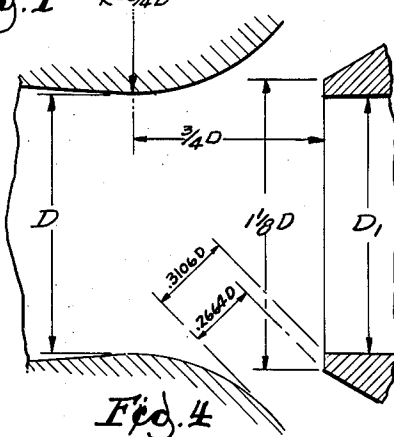


Fig. 4

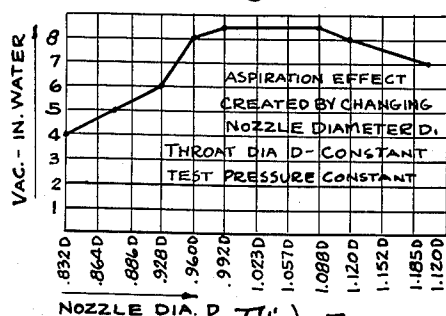


Fig. 5

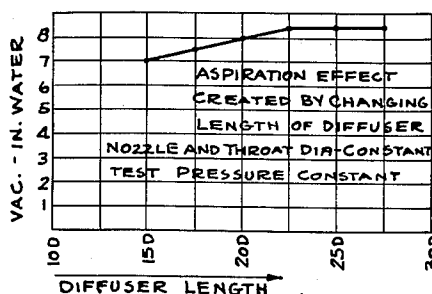


Fig. 6

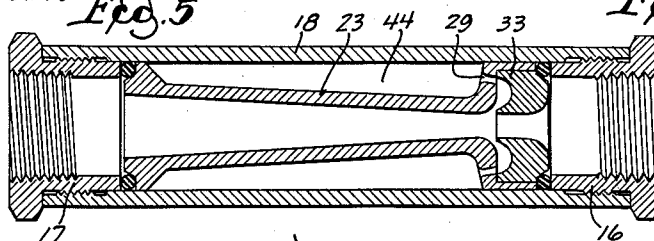


Fig. 7

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3,018,799

WATER SURGE ARRESTER

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This invention relates to improvements in devices for reducing the violence of and interrupting surges in pipe for liquid flow under pressure and in which the flow is to be frequently and quickly stopped.

"Water hammer" or pressure surges in pipes supplying liquids under pressure is a relatively frequent phenomenon in some liquid supply systems and is both annoying to the users of the liquid and dangerous to the supply system. A good description of the sequence of actions in such pressure surge and a mathematical treatment of such actions and their results is given in an article by N. M. Sverdrup in the September 1953 issue of Product Engineering. However, the palliatives therein suggested are frequently unacceptable. Certainly, increase in time of valve closures or closing valves in steps, increase in pipe diameter or decrease in pipe wall thickness are not adaptable to many of the liquid supply systems in use. Equipping liquid supply systems with chambers to receive and gradually discharge the surging liquid with air cushions of some kind being compressed and expanded as the liquid flows into and discharges from the chamber is also unacceptable as to many systems already in use. Even providing valves with means for discharging the liquid to waste while the surge is being dissipated, has proved acceptable only in hydraulic turbine installations. Moreover, all of such means require relatively large additions to even a residential water supply system, could not be installed in only the space available for the water pipe itself or require moving parts subject to wear and maladjustment or present other disadvantages.

The present device comprises a pair of thimbles connecting spaced inlet and outlet portions of a water supply pipe, by way of a housing, so that the device is only slightly larger than the outer diameter of the supply pipe. A tube in that it has throat and diffuser sections resembling a Venturi tube and having a somewhat similar action is positioned in the housing between resilient members held by the thimbles. The Venturi tube throat is of relatively small diameter adjacent the inlet pipe portion and diverges to an inner diameter of substantially the inner diameter of the outlet pipe portion at the tube end adjacent thereto. Adjacent the throat portion of the Venturi tube, it is formed with a shoulder and a cylindrical portion of a diameter fitting into the housing. Such shoulder provides a seat for a nozzle receiving water from the inlet pipe portion (and forming the converging portion of the Venturi tube) and through which the water is discharged into the Venturi throat. The housing and the divergent Venturi tube portion define a reservoir into which air may be drawn when water is aspirated from the reservoir through orifices in the tube shoulder and is injected into the Venturi throat by a free jet from the nozzle. The nozzle has a cavity receiving water from and guiding water to the orifices, through an opening formed by termination of the nozzle short of the Venturi tube throat and herein called the "aspiration" opening. The dimensions of the Venturi tube throat, the nozzle discharge opening, and the area of the aspiration opening between a surface of the diverging tube and the end of the nozzle have critical dimensional relationships described in detail herebelow.

Advantages and objects other than those above set

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forth will be apparent from the following description when read in connection with the accompanying drawing in which:

FIGURE 1 is a cross-sectional view on the longitudinal axis and on a plane through such axis of the device;

FIGURE 2 is one-half of a transverse cross-section on the plane of line 2—2 of FIGURE 1;

FIGURE 3 is an enlarged fragment of FIGURE 1 parts having critical dimensional relationships and of a critical curvature of one portion of the device;

FIGURE 4 is a diagram showing the critical proportions of some parts illustrated in FIGURE 3;

FIGURE 5 is a graph showing the relative aspirational effect or vacuum produced due to changes in one dimension of the device;

FIGURE 6 is similar to FIGURE 5 but showing the aspirational effect or vacuum produced upon change of another dimension of the device; and

FIGURE 7 is a view similar to FIGURE 1, of a modified form of the device.

Referring to the drawings by reference numerals, 10 designates an inlet pipe by which water is supplied to the surge-arrester generally designated 11, and from which water flows through an outlet pipe 12 under control of a faucet or other valve not shown. The inlet pipe 10 is threaded into or otherwise fastened to a ferrule or thimble 16 and the outlet pipe 12 is threaded or otherwise fastened to a ferrule or thimble 17. A tubular housing or shell 18 is threaded at the ends or otherwise attached on or to the thimbles 16 and 17, it being understood that the joints of the pipe with the thimbles and of the thimbles with the housing are liquid-tight and sufficient to withstand pressures substantially higher than the usual pressure of the liquid flowing through the system. The housing 18 is provided with one or more apertures 19 for a purpose to be described, and dependent on whether the surge-arrester is placed with its longitudinal axis horizontally as shown or vertically. A tube 23 somewhat resembling and having an action of the diverging portion of a Venturi tube, is mounted between and on the thimbles. The inlet or converging portion of the tube has a shoulder 24 and a cylindrical section 25 fitting into the housing adjacent the inlet supply pipe 10. A gasket 26 preferably in the shape of an O-ring is seated between an end of the thimble 16 and the end of the cylindrical tube section 25 and in such manner as to serve also as a seat and seal for another portion of the structure to be described.

The Venturi tube has a relatively small throat of diameter D and a tube shoulder with a plane surface 27 and a rounded surface 28 merging into the tube throat, the rounded surface 28 being on a radius of $\frac{3}{4}D$. The tube shoulder has orifices 29 through the plane surface 27, with their center line at an angle to the center line of the tube and the orifices are arranged around the tube but at a distance from the cylindrical wall 25 of the tube so that the orifices in effect define a circle. The above described portion of the tube is conical with the throat section being of smallest diameter and provides a diffuser or diverging section of diameter increasing to substantially that of outlet pipe 12.

A nozzle 33 seats on the O-ring 26 and against the Venturi plane shoulder surface 27. The nozzle has a convergent inlet opening merging into a cylindrical opening of the diameter D_1 equal to the diameter D of the Venturi throat. The surface of the nozzle adjacent the shoulder 27 is formed as a semi-toroidal cavity 34 with its surface extending to a circle tangent with the wall of and inclosing the tube orifices 29. The end of the nozzle terminates at a distance from the convergent surface 28 of the tube portion 23, thus providing an opening between such convergent surface and the nozzle cavity 34

and the orifices 29 through the tube shoulder and communicating with the cavity.

The thimble 17 is formed with an extension 38 of reduced diameter to coact with the housing 18 in defining a substantially annular space and the diverging tube 23 is formed with an extension 39 of enlarged diameter so that the extensions of the thimble and of the tube overlap in the manner of a half-lap joint. A tubular sleeve 40 of flexible and resilient material of a diameter to fit quite closely into the housing 18, is turned over and into the tube extension 39 so that the end of the diverging tube 23 is cushioned and sealed by the sleeve 40 to the thimble and the housing. The sleeve 40 forms a valve shutting off and opening the housing apertures 19 dependent on pressures in a reservoir space 44 defined by the housing and the outer surfaces of the tube 23 as compared to pressure outside of the housing. Outwardly extending fins 41 are formed on tube 23 adjacent the end of sleeve 40 to prevent collapse or undesired distortion of such sleeve when air is being admitted.

Referring now to FIGURE 4, it will be seen that the diameter of the Venturi throat and of the cylindrical portion of nozzle 33 are equal and are respectively designated D and D_1 . The surface of nozzle cavity 34 terminates on a circle of $1\frac{1}{2}D$ which is also indicated in FIGURE 4. The convergent Venturi surface 28 is on a radius of $\frac{3}{4}D$ from a center on a line perpendicular to the center line of tube 23 and nozzle 33 at the smallest diameter of the throat in tube 23. Hence, it will be seen that the width of the aspiration opening is dependent on the radius of surface 28 and that the area of the aspiration opening has a direct relationship to D. The effective width of the aspiration opening is shown on a line connecting the inside nozzle edge with the center of the diagram circle and is the distance between parallel lines tangent to the circle and through the outside nozzle edge, which is $.2664D$. The distance between the line tangent to the curving wall of the Venturi tube throat portion and the inner surface of the nozzle, at a certain point as shown in FIG. 4, is $.3106D$ and is also shown in the diagram. It will be understood that variation of throat diameter D will vary the dimensions shown in FIGURE 4.

It is well known that the normal Venturi tube has a low pressure area in the throat so that air or liquid can be aspirated into such throat from outside of the tube and until the pressures within the tube are balanced. The present substitution of a high velocity free jet in place of the normal converging cone on one side of the usual Venturi tube throat gives a maximum aspirational effect on orifices 29. In developing the present device, it was assumed that the throat section of the Venturi tube should be of uniform diameter, that the location and size of the aspiration opening would have an effect on the overall efficiency and that particular dimensional relationships should be maintained between the tube diffuser cones on the opposite sides of the throat. Tests were accordingly made at constant throat diameter D and constant water pressure to determine permissible variations and manufacturing tolerances in the diameter D_1 of the nozzle and the result of such tests are shown in FIGURE 5. It will be seen that the nozzle diameter may vary only from $.992D$ to $1.088D$ if the maximum vacuum is to be obtained at the opening of the nozzle cavity 34.

FIGURE 6 shows the results of tests when diameters D and D_1 and water pressure are kept constant while the length of the diffuser cone from the Venturi tube to the discharge end of the cone are varied. It will be seen that a length of 22.5 times D (and over) is permissible and that such length cannot be made less than 22.5 times D without loss of efficiency. Hence, it will be seen from FIGURES 5 and 6 that the present device presents a number of critical relationships if its maximum efficiency is to be attained.

As installed, the reservoir 44 contains water, and possibly some air at its highest point, under the pressure of

the liquid in the supply line. Flow of the water through the nozzle 33 produces a free jet of high velocity as it passes from the end of the nozzle 33 to the throat in the tube 23. The free jet has a high aspirating effect acting through the annular aspiration opening and into the cavity 34 in the nozzle. Assuming that the device is placed vertically with orifices 29 at the low point, as water is drawn from the piping system, water is aspirated from the reservoir 44 through orifices 29 and any air in the reservoir expands at a rate proportional to the opening of the faucet. Only water is drawn until all of the water in the reservoir is removed and air is drawn thereafter. If the surge-arrester is installed horizontally as shown, only water is drawn until the water level is below the uppermost orifice 29 and both water and air are drawn thereafter. When the pressure in the reservoir 44 drops below atmospheric pressure, sleeve valve 40 flexes inwardly and air is drawn into the reservoir through the housing holes 19. In a test unit for a $\frac{3}{4}$ " pipe at 80 lbs. pressure, all water was removed from reservoir 44 in 2 seconds, at fully opened faucet.

Closing the faucet or other valve stops the flow but the velocity throughout the system builds a pressure wave which surges back until a portion of the surge is stopped at the nozzle 33. Such surge also forces water back through the aspiration opening into the nozzle cavity 34 and through the tube orifices 29 where the pressure is again converted into velocity, the resistance in the orifices reducing the velocity. Each orifice forms a jet which agitates and mixes the air and water in the reservoir and such agitation consumes some of the residual velocity at the orifices. Air bubbles in the water and any mass of air at a high point of the reservoir are compressed to absorb any remaining velocity. The backward wave cannot travel beyond the discharge end of the nozzle and all of the pressure is absorbed as above described so that the tendency to surge is immediately arrested and such arresting action commences while the backward pressure wave is being formed.

The embodiment shown in FIGURE 7 has only the substantial difference as compared to the structure of FIGURES 1 and 2, of omitting the housing apertures 19 and the valve sleeve 40. The action of the present form of device is similar to that described above excepting that no air is drawn into the reservoir when the pressure therein drops below atmospheric pressure. The water supplied is usually aerated and the air is released as relatively small bubbles when the pressure in the reservoir drops, and produces a substantially uniform cloudiness in the reservoir. When a pressure wave occurs in one direction the water is forced into the reservoir which compresses the small bubbles to the point where they again go into solution in the water. Obviously the air content of water cannot have as much cushioning effect as the free air drawn into the reservoir in the first embodiment of the invention. In both embodiments there is loss of output believed to be due to frictional and turbulence losses as the water rushes into and out of the reservoir, the output being three gallons per unit of time at given pipeline pressure, as compared to five gallons when the present devices are not used.

We claim:

1. In a device for damping pressure waves in liquid flow in a pipeline conveying liquid under pressure, a housing to be inserted into the pipeline in liquid-tight relation at the pressures produced by said waves, a tube in the housing and having a throat section and a diffuser section increasing in area from the area of the throat section, the housing and tube forming a reservoir and the tube having orifices therethrough of substantially less area than the tube throat for flow or liquid from and into the reservoir, the orifices restricting flow into and out of the reservoir to a relatively small fraction of the total flow through the tube, and a nozzle in the housing for

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directing a jet of the liquid into the tube throat, the nozzle having a cavity connecting with the tube orifices, the nozzle terminating adjacent the tube throat and co-acting therewith in providing an opening from the cavity for aspirating the liquid from and forcing the liquid into the reservoir through the orifices.

2. In a device for damping pressure waves in liquid flow in a pipeline conveying liquid under pressure, a tubular housing to be inserted into the pipeline in liquid-tight relation at the pressures produced by said waves, a substantially conical tube in the housing and having a throat section and a diffuser section tapering from the throat section to the end remote from the throat section, the housing and the conical tube portion being spaced and forming a reservoir therebetween, the tube having orifices therethrough for flow of liquid from and into the reservoir and restricting flow into and out of the reservoir to a relatively small fraction of the total flow through the tube, and a nozzle in the housing for directing a jet of the liquid into the tube throat, the nozzle having a cavity connecting with the tube orifices, the nozzle terminating adjacent the tube throat and co-acting therewith in providing an opening from the cavity for aspirating the liquid from and forcing the liquid into the reservoir through the orifices, the reservoir and tube being located for respectively receiving the liquid from the inlet part and for discharging the liquid into the outlet part of the pipeline.

3. In a device for damping pressure waves in liquid flow in a pipeline conveying liquid under pressure, a housing insertable into the pipeline for connection in liquid-tight relation at the pressures produced by said waves, a tube in the housing and having a circular throat section and a circular diffuser section increasing in area from the area of the throat section, the housing and tube forming a reservoir and the tube having orifices therethrough for flow of liquid from and into the reservoir and restricting flow into and out of the reservoir to a fraction of the total flow through the tube, and a nozzle in the housing and having a passage therethrough of cylindrical form of substantially the same diameter as and in alignment with the throat of the tube, the nozzle having a cavity connected with the tube orifices, the nozzle terminating adjacent the tube throat and co-acting therewith in providing an opening from the cavity for aspirating the liquid from and forcing the liquid into the reservoir through the orifices.

4. In a device for damping pressure waves in liquid flow in a pipeline conveying liquid under pressure, a housing insertable into the pipeline for connection in liquid-tight relation at the pressures produced by said waves, a tube in the housing and having a throat section adjacent one end thereof and a diffuser section tapering uniformly from the throat section to the other end of the tube, the housing and tube forming a reservoir and the tube having orifices therethrough for flow of liquid from and into the reservoir and restricting flow into and out of the reservoir to a relatively small fraction of the total flow through the tube, and a nozzle in the housing for directing a jet of the liquid into the tube throat, the nozzle having a cavity connecting with the tube orifices, the nozzle having a cylindrical passage therethrough aligned with the tube throat and being .992-1.008 of the diameter of the tube throat and terminating adjacent the tube throat and co-acting therewith in forming an opening from the cavity for aspirating liquid from and forcing liquid into the reservoir through the orifices.

5. In a device for damping pressure waves in liquid flow in a pipeline conveying liquid under pressure, a tubular housing to be inserted into the pipeline in liquid-tight relation at the pressures produced by said waves, a tube in the housing and having a conical passage therethrough tapering from a throat section to a diffuser section, the housing and tube forming a reservoir and the

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tube having orifices therethrough for flow of liquid from and into the reservoir and restricting flow to a fraction of the total flow through the tube, the length of the diffuser being about 22.5 times the diameter of the tube throat, and a nozzle in the housing for directing a jet of the liquid into the tube throat, the nozzle having a cavity connecting with the tube orifices, the nozzle terminating adjacent the tube throat and co-acting therewith in providing an opening from the cavity for aspirating the liquid from and forcing the liquid into the reservoir through the orifices.

6. In a device for damping pressure waves in liquid flow in a pipeline conveying liquid under pressure, a housing to be inserted into the pipeline in liquid-tight relation at the pressures produced by said waves, a tube in the housing and having a conical passage therethrough tapering from a throat section to a diffuser section, the housing and tube forming a reservoir and the tube having orifices therethrough for flow of liquid from and into the reservoir and restricting flow to a fraction of the total flow through the tube, and a nozzle in the housing for directing a jet of the liquid into the tube throat, the nozzle having a cavity connecting with the tube orifices, the nozzle terminating short of the tube throat and co-acting therewith in providing an opening from the cavity for aspirating the liquid from and forcing the liquid into the reservoir through the orifices, the diameter of the outer surface of the nozzle forming one boundary of the aspiration opening and said diameter being of substantially $1\frac{1}{2}$ times the diameter of the tube throat.

7. In a device for damping pressure waves in liquid flow in a pipeline conveying liquid under pressure, a housing insertable into the pipeline for connection in liquid-tight relation at the pressures produced by said waves, a tube in the housing and having a cylindrical throat section and a diffuser section increasing in area from the area of the throat section, the housing and tube forming a reservoir and the tube having orifices therethrough for flow of liquid from and into the reservoir and restricting flow to a fraction of the total flow through the tube, and a nozzle in the housing having a cylindrical passage therethrough aligned with the tube throat and being from .992-1.008 of the diameter of the tube throat for directing a jet of the liquid into the tube throat, the nozzle having a cavity connecting with the tube orifices, the nozzle terminating adjacent the tube throat and co-acting therewith in defining an annular opening having an inner diameter of substantially $1\frac{1}{4}$ the diameter of tube throat for aspirating liquid from the cavity and forcing liquid into the reservoir through the orifices.

8. In a device for damping pressure waves in liquid flow in a pipeline conveying liquid under pressure, a housing insertable into the pipeline for connection in liquid-tight relation at the pressures produced by said waves, a tube in the housing and having a throat section and a diffuser section increasing in area from the area of the throat section, the housing and tube forming a reservoir and the tube having orifices therethrough for flow of liquid from and into the reservoir and restricting flow to a fraction of the total flow through the tube, and a nozzle in the housing for directing a jet of the liquid into the tube throat, the nozzle terminating short of the tube throat and co-acting therewith in providing an opening for aspirating the liquid from and forcing the liquid into the reservoir through the orifices, the nozzle having a substantially semi-toroidal cavity adjacent the wall of the tube having the orifices therethrough, the cavity connecting with the orifices for receiving the liquid from and guiding the liquid to the orifices through the aspiration opening.

9. In a device for damping pressure waves in liquid flow in a pipeline conveying liquid under pressure, the pipeline having spaced inlet and outlet portions, tubular thimbles joined with adjacent ends of the inlet and outlet

pipeline portions, a tubular housing joined with the thimbles and connecting the spaced inlet and outlet pipeline portions, the joints being liquid-tight at pressures produced by said waves, a tube having a throat section and a diffuser section increasing the area from the area of the throat section, the housing and tube forming a reservoir and the tube having orifices therethrough for flow of liquid from and into the reservoir and restricting flow to a relatively small fraction of the total flow through the tube, and a nozzle in the housing for directing a jet of the liquid into the tube throat, the nozzle having a cavity connecting with the tube orifices, the nozzle terminating short of the tube throat and co-acting therewith in providing an opening from the cavity for aspirating the liquid from and forcing the liquid into the reservoir through the orifices, the thimbles holding the nozzle and tube in predetermined position in the housing.

10. In a device for damping pressure waves in liquid flow in a pipeline conveying liquid under pressure, a housing to be inserted into the pipeline in liquid-tight relation at the pressures produced by said waves, the housing having an aperture through the wall thereof for admission of air into the housing when pressure therein drops below atmospheric pressure, a valve in the housing for closing the aperture responsive to pressures within the housing above the pressures externally of the housing, a conical tube in the housing and having a throat section and a diffuser section increasing in area from the area of the throat section, the housing and tube forming a reservoir and the tube having orifices therethrough for flow of liquid from and into the reservoir and restricting flow to a relatively small fraction of the total flow through the tube, and a nozzle in the housing for directing a jet of the liquid into the tube throat, the nozzle having a cavity connecting with the tube orifices, the nozzle terminating short of the tube throat and co-acting therewith in providing an opening from the cavity for aspirating the liquid from and forcing the liquid into the reservoir through the orifices.

11. In a device for damping pressure waves in liquid flow in a pipeline conveying liquid under pressure, a housing insertable into the pipeline for connection therewith in liquid-tight relation at the pressures produced by said waves, a tube in the housing and having a substantially conical passage therethrough forming a throat section and a diffuser section of increasing area from the throat section, the housing and tube forming a reservoir and the tube having orifices therethrough for flow of liquid from and into the reservoir and restricting flow

thereinto to a relatively small fraction of the flow through the tube, the housing having an aperture through the wall thereof adjacent the end of the reservoir remote from the tube orifices for addition of air into the housing when pressure therein drops below atmospheric pressure, a flexible sleeve secured in and conforming to the inner surface of the housing for closing the aperture through the housing responsive to pressures in the housing above pressure externally thereof, and a nozzle in the housing for directing a jet of the liquid into the tube throat, the nozzle having a cavity connecting with the tube orifices, the nozzle terminating short of the tube throat and co-acting therewith in providing an opening from the cavity for aspirating the liquid from and forcing the liquid into the reservoir through the orifices.

12. In a device for damping pressure waves in liquid flow in a pipeline conveying liquid under pressure, the pipeline having spaced inlet and outlet portions, a pair of tubular thimbles joined with adjacent ends of the inlet and outlet pipeline portions, a tubular housing joined with a pair of thimbles and connecting the spaced inlet and outlet pipeline portions, the joints being liquid-tight at pressures produced by said waves, a tube having a substantially conical passage therethrough forming a throat section of minimum diameter and a diffuser section of increasing diameter, the housing and tube forming a reservoir and the tube having orifices therethrough for flow of liquid from and into the reservoir, the housing wall having an aperture therethrough connecting the interior of the housing with atmosphere for admission of air into the housing when the pressure therein drops below atmospheric pressure, a resilient and flexible sleeve held in the housing between one thimble and an end of the tube for closing the aperture responsive to pressure within the housing, a nozzle in the housing for directing a jet of the liquid into the tube throat, the nozzle having a cavity connecting with the tube orifices, the nozzle terminating short of the tube throat and co-acting therewith in providing an opening from the cavity for aspirating the liquid from and forcing the liquid into the reservoir through the orifices and a resilient member seated between the other thimble and the nozzle and an end of the tube for holding the nozzle and tube in predetermined position in the housing.

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