United States Patent

[11] 3,545,492

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Middletown, Ohio
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[54] MULTIPLE PLATE THROTTLING ORIFICE
7 Claims, 8 Drawing Figs.

[52] U.S. Cl. 138/42, 138/44
[51] Int. Cl. F15d 1/02
[50] Field of Search 138/42, 44; 48/180; 251/127

[56] References Cited

UNITED STATES PATENTS

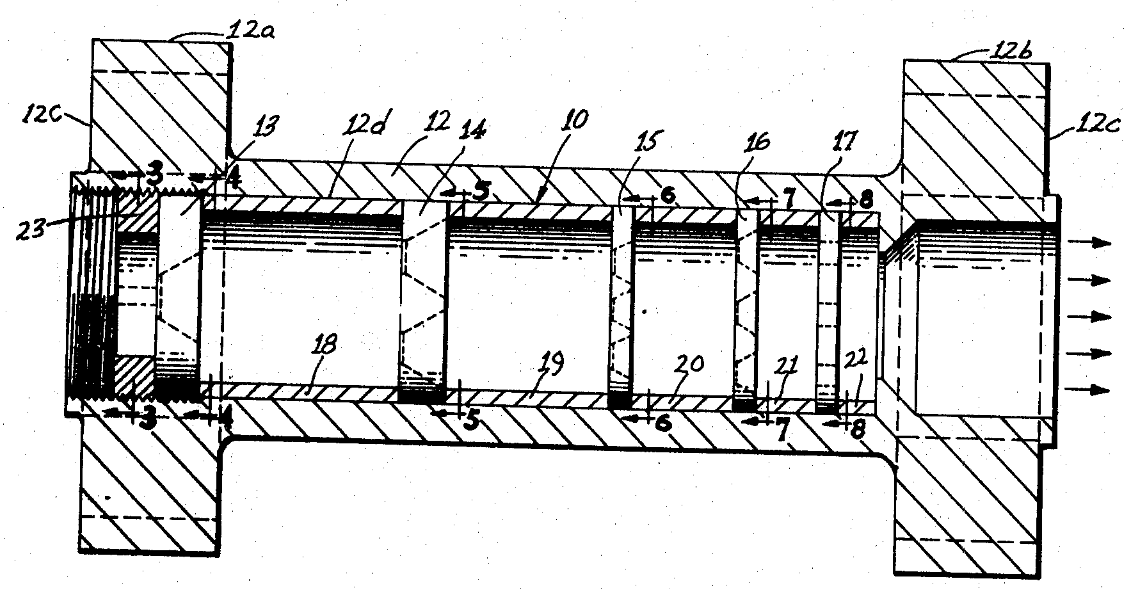
1,078,834	11/1913	Cook	48/180
3,111,091	11/1963	Hopkinson	138/44X

FOREIGN PATENTS

520,083	4/1940	Great Britain	138/40

Primary Examiner—Laverne D. Geiger
Assistant Examiner—R. J. Sher
Attorney—Melville, Strasser, Foster and Hoffman

ABSTRACT: A throttling device for hydraulic systems which prevents the cavitation of metal conduits by liquids under differential pressure comprising a series of orifice plates spaced at intervals along the axis of the conduits, each plate having one or more orifices therein to lower the pressure of the liquid passing therethrough, the axes of the orifices being displaced radially and circumferentially about the plate centers so as to be in misalinement with the axes of the orifices in adjacent plates.



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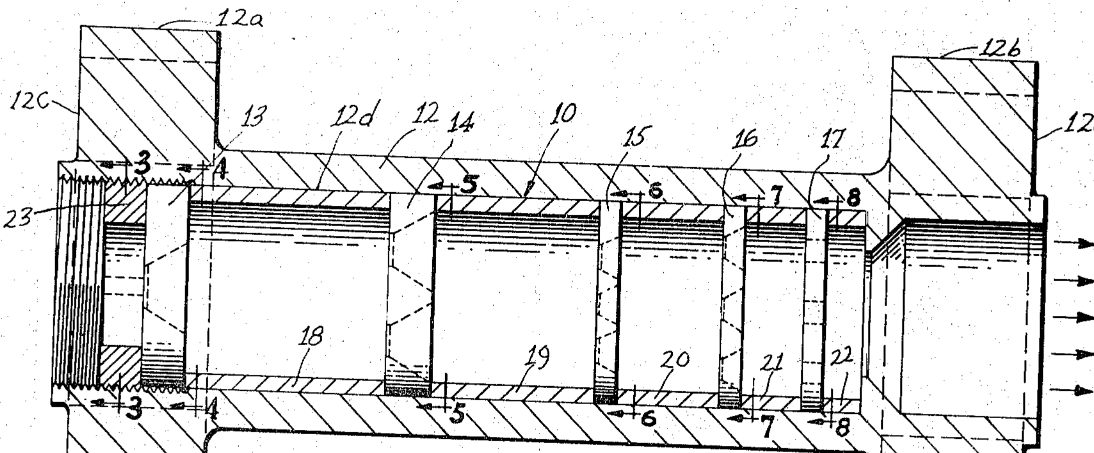

Fig. 1

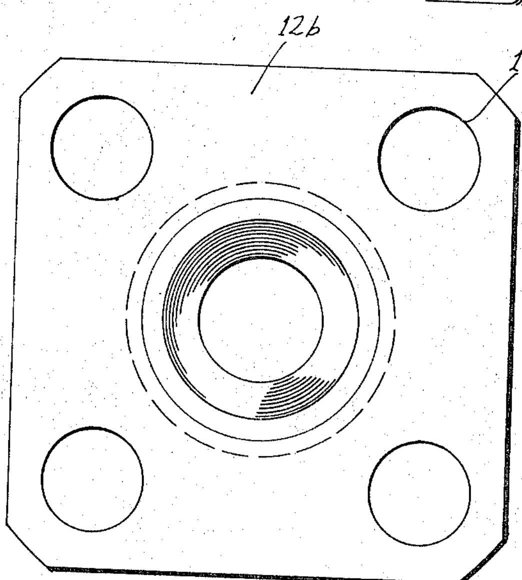

Fig. 2

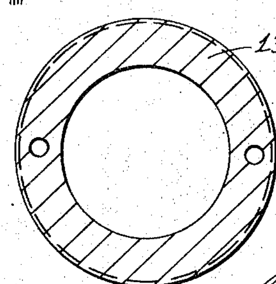

Fig. 3

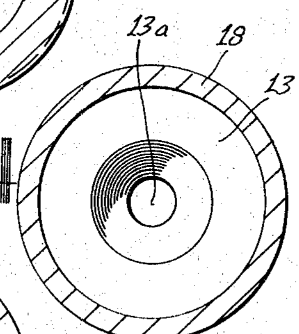

Fig. 4

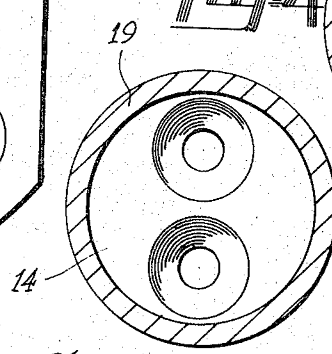

Fig. 5

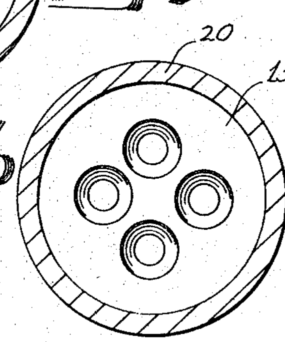

Fig. 6

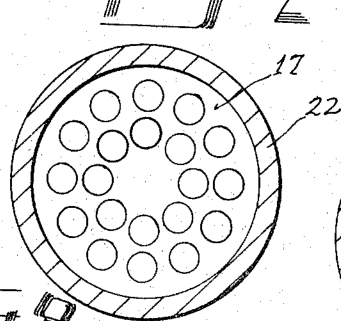

Fig. 8

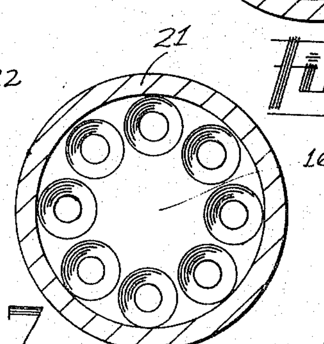

Fig. 7

INVENTOR/S

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MULTIPLE PLATE THROTTLING ORIFICE

BACKGROUND OF THE INVENTION

1. Field of the Invention.

This invention relates to throttling devices and in particular to a multiplate throttling orifice for hydraulic systems which prevents the cavitation of metal conduits by liquids under differential pressure.

2. Description of the Prior Art.

Hydraulic systems such as those found on presses and the like have generally heretofore utilized oil as the hydraulic medium, and throttle valves, such as globe-type throttle valves, have proved generally satisfactory. Due to the fact that oil as the hydraulic fluid is relatively dangerous, many newer hydraulic systems have adopted water rather than oil as the hydraulic fluid. However, the cavitation problem is much greater with water since the vapor pressure of oil is lower than that of water. Also, since hydraulic oils are more compressible than water and thus exhibit more deflection under the same pressure, the design of conduits and other vessels to accommodate water must allow for a greater dissipation of energy through the walls.

By cavitation is meant the gradual erosion of a surface caused by the collapse of vapor bubbles in a fluid. These bubbles form when the static pressure in a fluid is lowered to the vapor pressure of the fluid. When the bubbles collapse the fluid slaps the surface, causing a small part of the surface to be stressed beyond its yield point. This eventually results in fatigue and pitting of the surface.

Cavitation, of course, causes frequent shutdowns of hydraulic systems so that new valves may be installed. The shutdowns become very expensive in terms of man hours of maintenance because of the general inaccessibility of the valves.

Prior art devices have offered no solution to this problem. Indeed, the prior art does not seem to even recognize the cavitation problem. For example, U.S. Pat. No. 1,078,834, in the name of Cook, discloses a gaseous fuel mixer which comprises a number of agitating plates within a tubular housing. The plates are mounted on a shank and may be rotated to properly mix the gas flowing therethrough. Each of the plates has a number of apertures, the number of apertures increasing from the first to last plate, with respect to the flow, while the size of the apertures decreases as the number of holes increases. Cook does not indicate that the rotating orifice plates are to serve any other purpose than to properly mix the gaseous fuel.

Another exemplary prior art patent U.S. Pat. No. 2,125,245 in the name of McCray, which discloses an apparatus for dispersing thermoplastic hydrocarbon materials in water. The apparatus includes a series of spaced foraminous dispersing plates mounted in fixed relation to a dispersing chamber and intermediate fixed baffle plates between the dispersing plates. The dispersing plates contain a plurality of holes and the holes in each plate are identical with each other. The baffle plates are positioned between the dispersing plates and are formed with restricted passages through which the materials being dispersed are passed. McCray makes no mention of the cavitation problem.

The aforementioned references are simply exemplary of prior art teachings which disclose multiple orifice plates. The references are not concerned with the problem of cavitation and its prevention, and the multiple orifice plates are primarily used to mix various materials passing therethrough.

SUMMARY OF THE INVENTION

The present invention provides a throttling device for hydraulic systems which prevents the cavitation of metal conduits by liquids under differential pressure. Broadly speaking, the device comprises a series of orifice plates spaced at intervals along the axes of the conduits. Each plate has one or more orifices therein to lower the pressure of the liquid passing therethrough, and the axes of the orifices are displaced radially and circumferentially about the plate centers so as to be in misalignment with the axes of the orifices in adjacent plates. This prevents the jet leaving one orifice plate from entering directly an orifice in an adjacent plate. The orifice plates are positioned such that the upstream plate provides the greatest pressure drop thereacross and each succeeding plate provides a gradually decreasing pressure drop, whereby the static pressure in the liquid under differential pressure is at all points greater than the vapor pressure of the liquid.

The spaced intervals between orifice plates will preferably be such as to allow the most length for dissipation where the pressure drop is greatest, so that the flow entering the next orifice plate will be as undisturbed as possible.

In practice, the throttling device of the present invention will prevent the cavitation of metal conduits by any liquid under differential pressure. However, since in practice it has been found that cavitation is much more serious when water is utilized as the hydraulic fluid, the present invention will be most applicable in this connection.

In a preferred embodiment, the number of orifice plates was found to be five. The first four orifice plates were provided with sharp edge orifices and the last orifice plate was a short tube orifice type.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a cross section taken through the center of a multiple plate throttling orifice according to the present invention.

FIG. 2 is an end elevation of the multiple plate throttling orifice of FIG. 1.

FIG. 3 is a cross-sectional view taken along the line 3–3 of FIG. 1.

FIG. 4 is a cross-sectional view taken along the line 4–4 of FIG. 1.

FIG. 5 is a cross-sectional view taken along the line 5–5 of FIG. 1.

FIG. 6 is a cross-sectional view taken along the line 6–6 of FIG. 1.

FIG. 7 is a cross-sectional view taken along the line 7–7 of FIG. 1.

FIG. 8 is a cross-sectional view taken along the line 8–8 of FIG. 1.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

As was previously explained, the cavitation problem is much greater when water is used as a fluid in an hydraulic system than when oil is used as the fluid. This is so because the vapor pressure of oil is lower than that of water. Accordingly, since in actual practice it has been the view that the cavitation problem with oil as the hydraulic fluid in hydraulic systems is so minimal that it can be ignored, it can reasonably be said that the cavitation problem was really first encountered in hydraulic systems when water was substituted for oil as the hydraulic fluid therein.

With the aforementioned statement in mind, FIG. 1 discloses a preferred embodiment of the multiple plate throttling orifice of this invention. This throttling device was designed to replace an existing globe-type throttle valve and to throttle water, which was used as the hydraulic fluid, from 4,200 p.s.i. to slightly above atmospheric pressure.

For purposes of explanation, the multiple plate throttling device **10** of this invention is held within a housing **12** having a bore **12*a*** therein. The housing **12** may join two conduits in a hydraulic system. It is, of course, obvious that the throttling device **10** of this invention may be used in any hydraulic system where it is desired to throttle the flow across a large pressure drop and where cavitation is a problem.

The housing **12** has been designed such that both the upstream and downstream ends thereof have flanged connections which permit them to be joined to other sections of conduit by bolts and the like through the bolt holes **12*c***.

As can be seen from FIG 1, the multiple plate throttling orifice of this invention comprises a series of orifice plates **13** through **17** which are separated by the spacers **18** through **21**.

Additionally, the spacer **22** provides a distance between the last orifice plate **17** and the end of the bore **12***d* within the housing **12**. Both ends of the housing **12** may be provided with a retaining ring, such as the retaining ring **23**, as best seen in FIG. 3.

FIG. 4 shows that the first orifice plate **13** is provided with an orifice **13***a* in the center thereof. The remaining orifice plates **14** through **17** contain a plurality of orifice holes therethrough. The axes of the orifices in each of the plates **14** through **17** are displaced radially and circumferentially about the respective plate centers so as to be in misalignment with the axes of the orifices in adjacent plates. This prevents the jet leaving one orifice plate, the upstream plate, from entering directly an orifice in an adjacent downstream plate.

It will be observed that the orifice plates **13** through **17** are positioned such that the upstream plate **13** provides the greatest pressure drop thereacross and each succeeding plate provides a gradually decreasing pressure drop. In this manner the static pressure in the liquid under differential pressure is at all points greater than the vapor pressure of the liquid.

It is, of course, well known that for a single orifice plate the flow rate Q is equal to CA**2*g* (Δh), where C is the coefficient of discharge, which is a combination of a velocity coefficient C_v) and a contraction coefficient (C_c), A is the total cross-sectional area of the orifice, *g* is the coefficient for gravity, and Δh is the difference in head upstream of the orifice and downstream at the vena contracta. The velocity head which is recovered is equal to the standard orifice differential pressure (Δh in the above formula) minus the net head loss due to metering. Thus, the static pressure at the vena contracta is less than the static pressure further downstream and will in fact decrease towards a static pressure reading of zero. In actual practice, the static pressure at the vena contracta may not be lower than the vapor pressure of the liquid, because once this happens a bubble forms and cavitation occurs.

Since the above formula is for a single orifice plate, and the present invention utilizes a number of orifice plates in series, a certain desired flow rate was assumed. This flow rate and the elevated position of the fluid system utilizing this throttling device, a hydraulic press, resulted in a certain inherent back head. The area of the orifices in the furthest downstream orifice plate was determined so that the static pressure at the vena contracta, taking into account the inherent back head and the velocity head recovered, was above the vapor pressure of the liquid. The area of the orifices in the next orifice plate upstream was then determined in the same manner using the inherent back head plus the net head loss due to metering of the farthest downstream orifice. The total pressure drop across the multiplate throttling orifice plates could then be calculated as the sum of the net headloss due to metering for each orifice plate. It was then necessary to make several iterations of the whole calculation until the total calculated pressure drop for the throttling device was equal to the available pressure drop supplied by the hydraulic system, at which time the initially assumed flow rate was proved.

As may be seen from FIG. 1 and FIGS. 4 through 8, all but the last orifice plate have sharp edge orifices while the last plate is of the short tube orifice type. Appropriate orifice coefficients were used for each in the aforementioned calculations. However, it should be emphasized that the type of orifice which is ultimately selected is merely a matter of design so long as the appropriate orifice coefficients are utilized in the aforementioned calculations.

It should be pointed out that the number of orifices in each orifice plate is not important, only their total area. Thus plates with multiplate holes were considered as having a single hole, the area of which was equal to the sum of the area of the multiple holes. The reason for using multiple holes and their specific location was to prevent the jet leaving one orifice plate from entering directly a hole in the next plate.

Obviously, if the static pressure of the liquid at any point in the housing is too close to the vapor pressure thereof, some cavitation will occur. It then becomes necessary to increase the number of orifice plates.

The distance between the orifice plates **13** through **17**, established by the spacers **18** through **21**, has not been found to be critical. However, it has been found preferable to allow the most length for dissipation where the pressure drop is the greatest in order that the flow entering the next orifice plate will be as undisturbed as possible.

While certain preferred embodiments of the invention have been specifically illustrated and described, it is understood that the invention is not limited thereto, as many variations will be apparent to those skilled in the art, and the invention is to be given its broadest interpretation within the terms of the following claims.

I claim:

1. A throttling device for hydraulic systems which prevents cavitation of metal conduits by liquid under differential pressure comprising a series of fixed orifice plates spaced at intervals along the axes of said conduits, each plate having one or more orifices therein to lower the pressure of the liquid passing therethrough, the axes of said orifices being displaced radially and circumferentially about the plate centers so as to be in misalignment with the axes of the orifices in adjacent plates and to prevent the jet leaving one orifice plate from entering directly an orifice in an adjacent plate, the total area of said orifices in each succeeding orifice plate on the downstream side being successively larger so that the upstream plate provides the greatest pressure drop thereacross and each succeeding plate provides a gradually decreasing pressure drop, whereby the static pressure in said liquid under differential pressure is at all points greater than the vapor pressure of said liquid.

2. The throttling device according to claim **1**, wherein the spaced intervals between orifice plates successively decrease from the plate furthest upstream to the plate furthest downstream so as to allow the most length for dissipation between two orifice plates where the pressure drop is greatest and to ensure that the flow entering the next adjacent orifice plate will be as undisturbed as possible.

3. The throttling device according to claim **1**, wherein the total area of the orifices in each orifice plate is determined so that the minimum static pressure between said orifice plates is above the vapor pressure of the fluid according to the formula Q=Ca**2*g* (δh), where Q is the flow rate, C is the coefficient of discharge and is a combination of a velocity coefficient and a contraction coefficient, A is the total cross-sectional area of the orifice, *g* is the coefficient for gravity, and δh is the difference in head upstream of the orifice plate and downstream at the vena contracta.

4. The throttling device according to claim **1**, wherein said orifice plates are successively positioned in a housing joining two conduits in a hydraulic system.

5. The throttling device of claim **1**, wherein said liquid is water.

6. The throttling device of claim **5**, wherein the number of orifice plates is five.

7. The throttling device according to claim **6**, wherein all but the last orifice plate are provided with sharp edge orifices while the last plate is of the short tube orifice type.

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,545,492 Dated December 8, 1970

Inventor(s) CHARLES H. SCHEID, JR.

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 3, Line 22, please amend "CA ** 2g (Δh)" to read -- CA $\sqrt{2g (\Delta h)}$ --.

Column 3, Line 24, please amend "C_v)" to read --(C_v)--.

Column 4, Line 50, in claim 3, please amend "Ca ** 2g (δh)" to read --CA $\sqrt{2g (\Delta h)}$--.

Column 4, Line 53, in claim 3, please cancel "δh" and insert --Δh --.

SIGNED AND SEALED
MAR 16 1971

(SEAL)
Attest:

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Attesting Officer

WILLIAM E. SCHUYLER, JR.
Commissioner of Patents