Dec. 23, 1969 H. D. BAUMANN 3,485,474

ADJUSTABLE FLUID RESTRICTOR

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FIG.2.

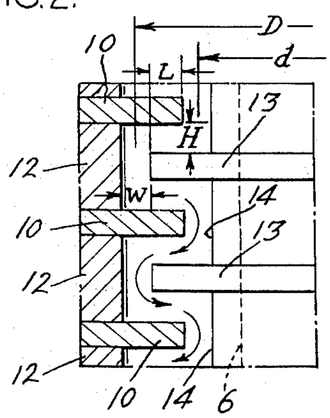
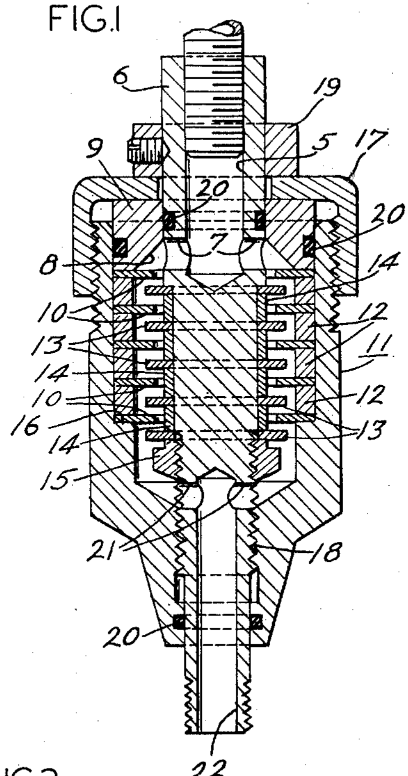


FIG.1



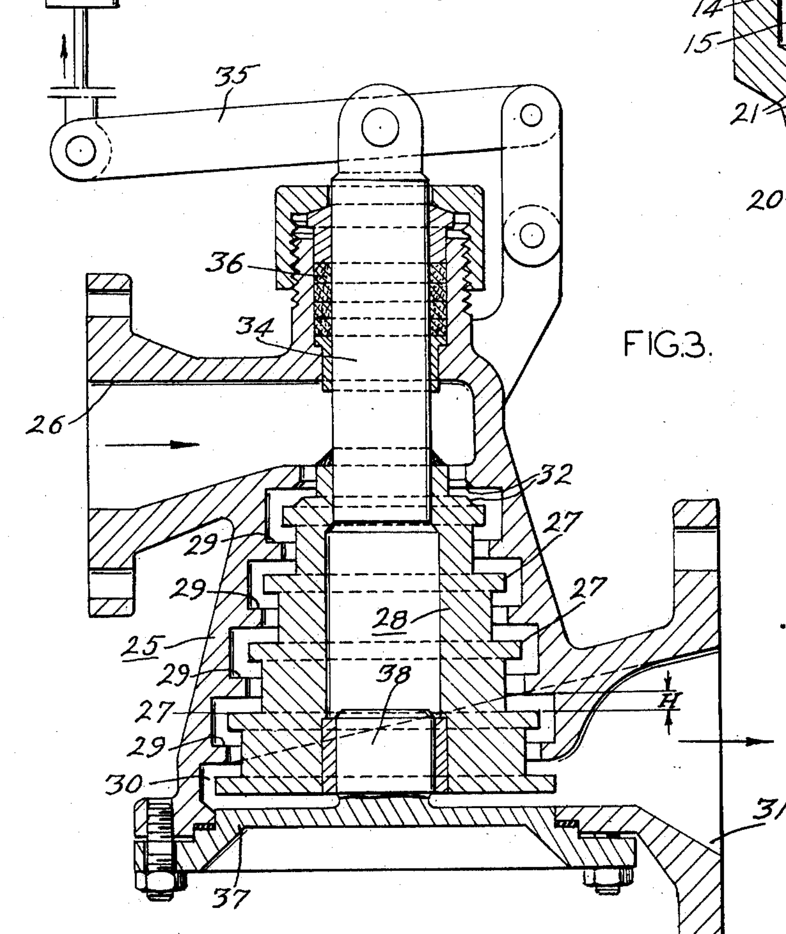


FIG.3.

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FIG.5.

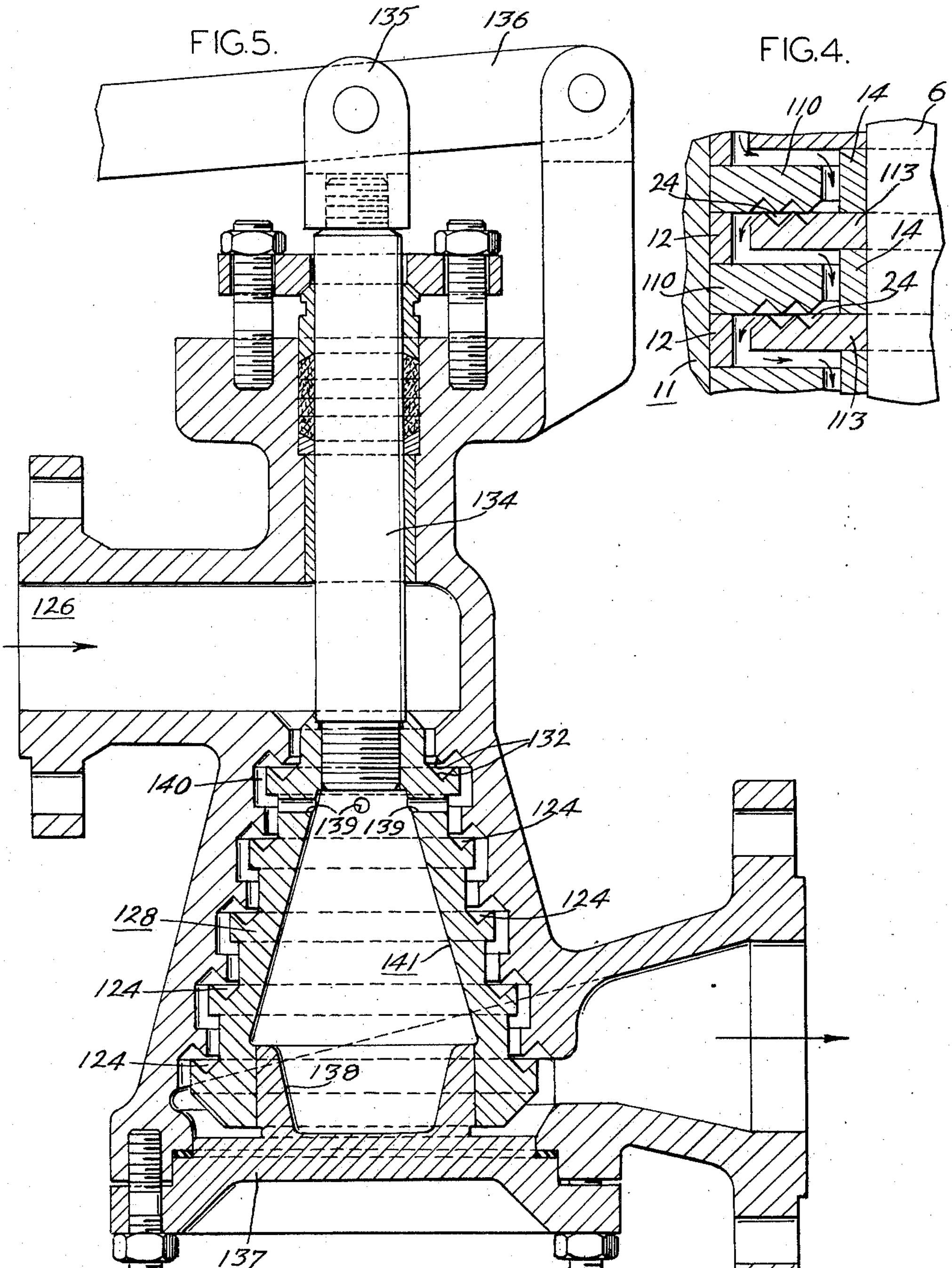

FIG.4.

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ADJUSTABLE FLUID RESTRICTOR

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Continuation-in-part of application Ser. No. 570,040, Aug. 3, 1966. This application Apr. 8, 1968, Ser. No. 719,427

Int. Cl. F16k *47/00;* F16l *55/02*

U.S. Cl. 251—121 11 Claims

ABSTRACT OF THE DISCLOSURE

The present invention constitutes an adjustable fluid restrictor providing throttling means to reduce pressure of liquid or gaseous media through a process of adiabatic flow with friction in contrast to conventional orifice type throttling devices which utilize rapid acceleration and deceleration as primary means of energy conversion. Said adjustable fluid restrictor containing labyrinth-type restrictions which are adjusted by conventional actuating means and provide constant enthalpy pressure reduction at substantially constant velocity regardless of variations in flow area.

This application is a continuation-in-part of U.S. patent application Ser. No. 570,040, filed Aug. 3, 1966, by Hans D. Baumann.

Energy transported in fluid form has to be transformed quite frequently into a lower form of state (increased entropy) to suit process requirements. Such energy conversion is most common in the form of fluid pressure reduction. In a so-called "throttling process" potential energy of the fluid is transformed into kinetic energy (high velocity), then by a process of rapid deceleration (turbulence) into heat through friction. However, not all of the kinetic energy is converted into heat. A certain amount of it produces sound power, more commonly known as throttling noise. The amount of sound power produced in a fluid system is generally a function of the fluid velocity. It has been determined, for instance, that the sound level of a free jet increases to the 8th power of the velocity below Mach 1 (sonic velocity) and to the 6.5th power above Mach 1. In practice this means that the sound power produced by a single throttling orifice will increase 256 times, if the throttling velocity across it is doubled. Now, since the velocity in an orifice is a function of $\sqrt{2gh}$, where h is the created pressure drop, one can state that a 4-times increase in pressure drop could produce 256 times more noise. This simple arithmetic explains why high pressure reduction necessary in today's power plants can create intolerable noise levels in residential neighborhoods. Such noise cannot only be annoying but also be a vital factor in the successful operation of submarines. Noise produced through pressure reduction in the ship's powerplant can lead to sonar detection with disastrous consequences. In addition, sound vibrations can cause structural damages to adjacent piping and pressure vessels.

From the foregoing it is obvious that a significant reduction in velocity is necessary to achieve a tolerable low noise level. With conventional plug and orifice valves such velocity reduction is only possible by employing a lower pressure drop, thereby seriously limiting the usefulness of such a device.

Besides the obvious high throttling noise level, there is the added effect of wear. Conventional throttling orifice valves, for instance, show substantial effects of erosion at or near the plug and orifice, when subjected to high pressure drop. Again, the higher the pressure drop the more pronounced the wear and the shorter the lifetime of the valve.

In the present invention, a drastic reduction in pressure drop across each individual throttling station can eliminate wear, in particular the erosion caused by cavitating liquids. By use of a step-reduction process outlined below, cavitation can be completely avoided.

The present invention has for an important object to provide a device capable of limiting throttling velocity by providing a large number of throttling restrictions in series. This way the pressure drop (and velocity) across each individual step is limited, even though the total pressure drop across the complete device can still be quite large. More important, the invention allows this "split-up" in pressure drop to be maintained despite variations in flowing quantities and flow areas by simply varying all throttling areas in series by the same amount.

Other objects are to provide an adjustable flow restrictor that requires only a relatively small amount of positioning motion, thereby permitting the use of sealing stem bellows or membranes, and greatly reducing required positioning power.

Still another object is the creation of a device producing a large number of adjustable fluid restrictions in series within a very small volume and with minimum weight requirements, which can be built economically with readily available parts, such as stamped washers and rings that do not require elaborate machining techniques or tolerances.

Finally, an adjustable fluid restrictor is provided, which offers fluid restrictions in series, which can produce either a laminar or turbulent flow pattern, with a gradually increasing flow area able to compensate for a change in density of the fluid between its primary and final throttling station.

These, and many more objects are more fully described and will be better understood from the following detailed description, considered in conjunction with the annexed drawings, wherein:

FIG. 1 is a vertical, central, cross-sectional view showing the structure and arrangement of parts of a restrictor made in accordance with the present invention suitable for the pressure reduction of incompressible fluids;

FIG. 2 shows an enlarged fragmentary view of a central sectional portion of the invention;

FIG. 3 is a vertical, central, cross-sectional view, of a modified embodiment of the invention having gradually enlarging flow areas for use with compressible fluids;

FIG. 4 is an enlarged fragmentary view showing a central sectional portion of an embodiment of the invention with individual throttling stations modified to include radial grooves for added fluid resistance; and

FIG. 5 is a vertical, central, cross-sectional view, showing the structure and arrangement of parts of another embodiment of the invention suitable for the pressure reduction of compressible fluids which incorporates additional means to balance hydrostatic forces acting on the shaft.

Referring now to the drawing in greater detail, one embodiment of the invention is illustrated in FIG. 1 as an in-line throttling device having five (or, if desired, any larger number of) separate throttling stations which are shown in more detail in FIG. 2. Fluid entering port **5** in a shaft **6** passes through a horizontal bore **7** into a cavity **8** formed by a sealing ring **9** and a number of concentric rings **10**. Said rings are contained in a housing **11** and are separated in equal intervals by outer tubular members **12**. Between each of said rings **10** there are circular protrusions **13**, formed in the embodiment of FIG. 1 by stamped washers stacked and separated in equally spaced relation on the shaft **6** by inner tubular members **14**. Said set of protrusions and inner tubular members are clamped together and held in place by a nut **15**, while the outer set of rings is retained within said housing and between a shoulder **16** and said sealing ring **9** by threaded closure **17**. The complete housing **11** containing the rings **10** can be rotated around the shaft **6** which, in turn, is threadedly engaged with said housing at **18**. A right-hand turn of housing **11** will now reduce throttling distance H (better shown in FIG. 2) by an equal amount within each throttling station thereby reducing the quantity of passing fluid. Rotation of housing **11** is limited by the physical contact between the rings **10** and the protrusions **13** in the "to close" direction, and, by a collar **19** on shaft **6** in the "to open" direction. Suitable O-ring seals **20** are located between shaft **6** and sealing ring **9**, or housing **11**, respectively, to prevent escape of fluid.

Reduction of fluid pressure is accomplished by forcing the flowing media to make two sharp U-turns while passing through each throttling station formed by alternate rings **10** and the intermediate protrusion **13**. The final discharge of the fluid is accomplished through a second horizontal hole **21** and a central bore **22** in the shaft **6**.

In the wide-open position of the adjustable fluid restrictor (as illustrated), distance H equals distance W and the fluid is able to pass through a constant area channel having the general configuration (per throttling station) of four 90° elbows arranged in series. Here the energy conversion (velocity head loss) is accomplished by forcing the fluid to change direction constantly while passing through the device, thereby producing turbulent friction. Even though the turbulence is high, it is concentrated with a relatively small cross-section and distributed over a wide area formed between the circumferences d and D, respectively.

With a smaller throttling opening (smaller H/W ratio) the head loss produced by change in direction diminishes. However, now the entrance and exit losses of the fluid passing from a relatively large flow area (W) into and out of a smaller area (H) become pronounced, thereby keeping the average velocity head loss coefficient K relatively high, regardless of lift or H/W ratio.

The total sum of velocity head loss coefficient K can be calculated as follows:

$$K=n(1+R)(1.30^2+1.5)$$

wherein n=the total number of throttling stations; $R=(d/D)^2$; and $C=H/W$ ratio.

It can now be seen that a fluid restrictor having five throttling stations and a d/D ratio of 0.8 will provide a velocity head loss coefficient of 23 when wide open. This is in contrast to a common plug and orifice type valve, which possesses only a K value of approximately 0.8. The practical significance of the increased K value lies in the fact that the mentioned fluid restrictor has only to generate 18% of the fluid velocity necessary in a plug and orifice valve, in order to create an identical pressure drop, since

$$h=K\frac{v^2}{2g}$$

For a very small H/W ratio, additional friction losses along the length L can be quite high, in particular when the Reynolds number is reduced below 2000 and the flow pattern becomes laminar. Under these conditions

$$K=n\frac{64}{N_r}\frac{L}{H}$$

wherein N=Reynolds number

$$\frac{0.237Q\rho}{\left(\frac{d+D}{2}\right)\mu}$$

μ=absolute viscosity of the fluid, lb.-sec./ft.^{2};
ρ=density of fluid, lb./ft.^{3};
Q=the volumetric flow, ft.^{3}/sec.;
L, d, D and H in inches.

For a further increase in K value, as illustrated in FIG. 4, the mating surfaces of the rings **110** and the protrusions **113** can be formed in an intermeshing pattern to provide grooves **24**. Here the fluid is again forced to change directions with a resultant loss in pressure while passing from one circular groove **24** to the next.

After establishment of K, the overall flow capacity can be determined by employing a flow coefficient C_v which defines the number of gallons of water passing a restriction under 1 p.s.i. pressure drop.

$$C=38.1d\pi R/\sqrt{K}$$

To provide the best possible equalization of pressure drop between each throttling station, account has to be taken of the variations in density experienced with compressible fluids such as steam.

Since with each successive throttling step the pressure is reduced (which means a volumetric flow increase due to lower density) one has to enlarge the successive flow areas to maintain nearly uniform throttling velocities. The embodiment of the invention shown in FIG. 3 exemplifies a solution to such a design requirement. Here the fluid enters a housing **25** through an inlet flange **26**. The fluid is now forced to travel through a successive number of throttling stations as described above and formed by protrusions **27** (here forming an integral part of a hollow shaft **28**) and concentric rings **29** (being an integral part of a housing **25**). By successively increasing the diameters of both, protrusions **27** and concentric rings **29**, a gradually enlarging flow area is provided to accommodate the change in density. The final low pressure fluid is collected in a channel **30** and is allowed to leave at a larger outlet flange **31**. A valve seat **32** is formed between the shaft **28** and the housing **25** to allow for tight shut-off, in case no fluid is allowed to pass.

Distance H between each protrusion and respective concentric ring is varied through an external positioning device **33** of conventional design, operated, for instance, by pneumatic signal pressure or electrical energy. Said positioning device moves shaft **28** through an extension **34** and a lever **35** in axial direction. Said extension **34** is sealed by means of a stuffing box **36** to prevent escape of fluid from housing **25**. The latter is closed at the bottom by means of a closure flange **37**, having an integral central guide post **38** to aid in the proper alignment of shaft **28**. The cross-sectional area of the extension **34** is dimensioned to provide a reduction in the area of shaft **28** subjected to the high fluid inlet pressure. This allows hydrostatic balance between the latter and the lower outlet pressure acting on the complete lower cross-section of the shaft **28**.

Another way of balancing the hydrostatic forces acting on the shaft is illustrated in FIG. 5. In this embodiment of the invention, the shaft **128**, here shown with circular grooves **124**, has a number of holes **139** connecting a flow area **140**, located after the valve seat **132** with an internal chamber **141** contained within shaft **128**. Said internal chamber **141** is closed at the bottom by the enlarged guide post **138** projecting upwardly from a bottom cover **137**. Fluid pressure admitted through the inlet **126** near the inlet level is now transmitted through said holes **139** to the inside chamber **141** the moment valve seat **132** opens. Said inlet pressure is now acting over the cross-sectional area of guide post **138**, thus providing an upward thrust on shaft **128** which is identical to the accumulated downward forces distributed over the total outside diameter of shaft **128** by the various pressure levels acting on the individual protrusions. Thus an effective pressure balance is created, reducing the force requirements of the positioning device which is connected to the shaft **128** by a stem **134**, yoke **135**, and lever **136**.

The rings and protrusions provide offset axial flow passages which are interconnected by radial flow passages in each of the embodiments shown in the drawing. In the embodiments of FIGS. 3 and 5, the increasing diameters of the rings and protrusions provide increasing flow areas successively along the shaft. An increasing flow area may also be obtained by altering the shapes of the rings and protrusions successively along the shaft, either instead of or in addition to the increase provided by the increasing diameters.

The invention has been disclosed in connection with specific embodiments of the same, but it will be understood that these are intended by way of illustration only and that numerous changes can be made in the construction and arrangement of parts. For instance, the device shown in FIG. 3 can be built to have the fluid enter and leave through a central bore of shaft **28** (similar to FIG. 1). It is also possible to mount two sets of throttling stations on a common shaft with fluid entering between said sets to compensate for hydrostatic forces acting on said shaft.

Having thus clearly shown and described the invention, what is claimed as new and desired to secure by Letters Patent is:

1. An adjustable fluid restrictor having a longitudinal axis and including an elongated housing member comprising interior wall segments extending in a series along said axis, and a series of axially-spaced concentric rings projecting inwardly of said housing member toward said axis and having inner surfaces along said axis; a shaft member passing axially through said housing member and through said rings and comprising exterior wall segments substantially parallel to and confronting the inner surfaces of said rings, and a series of axially-spaced protrusions projecting outward of said wall segments and terminating in outer surfaces substantially parallel to and confronting said interior wall segments, the interior wall segments of said housing member and the outer surfaces of said protrusions defining a series of outer axial flow passages intermediate said rings, the exterior wall segments of said shaft member and the inner surfaces of said rings defining a series of inner axial flow passages intermediate said protrusions, each protrusion projecting outwardly toward said housing and cooperating with an adjacent ring to define therebetween a radial flow passage having substantially parallel spaced-apart walls, a pair of adjoining rings and the intermediate protrusion defining a throttling station in which the protrusion directs flow radially outward in a radial passage beyond the first ring of the pair from an inner axial flow passage to the outer axial flow passage, and the second ring of the pair directs flow radially inward in a radial passage from said outer axial passage to the next inner axial flow passage in said series, whereby the flow of fluid through said throttling station is directed through a plurality of abrupt changes of direction, and means mounting said members for relative axial adjustment to thereby vary the spacing of the substantially parallel walls of the radial flow passages without varying the spacing between the substantially parallel walls and surfaces of said axial flow passages.

2. An adjustable fluid restrictor as set forth in claim **1** including fluid inlet and outlet ports located respectively at the opposite terminating ends of said shaft, said fluid ports connecting to the flow passages intermediate said housing and shaft members and located respectively at opposite ends of said series of rings and protrusions.

3. An adjustable fluid restrictor as set forth in claim **1**, wherein said protrusions and rings are circular, and said shaft is threadably engaged with said housing for axial adjustment.

4. An adjustable fluid restrictor as set forth in claim **1**, wherein said series of concentric rings and protrusions are circular and have progressively larger diameters from one end of said series to the opposite end.

5. An adjustable fluid restrictor as set forth in claim **1** wherein said shaft member is formed about its outer periphery as a valve element and said housing member is formed as a valve seat with a similar configuration located within the hollow housing and cooperable with said shaft to provide a valve for interrupting flow through said passages.

6. An adjustable fluid restrictor as set forth in claim **1**, said housing member having an inlet and an outlet flange providing fluid access to areas within said housing located respectively at opposite ends of said series of rings and protrusions.

7. An adjustable fluid restrictor as set forth in claim **1** including actuating means cooperatively connected to said shaft to vary the axial position of the same together with its series of protrusions, in order to vary the axial distance between the latter and said concentric rings, and thus the axial width of said radial flow passages.

8. An adjustable fluid restrictor as set forth in claim **1** including means forming angular grooves and ridges on the confronting substantially parallel walls of the radial flow passages, the ridge on one wall registering with the groove on the other wall to maintain equal spacing between the substantially parallel walls of said radial flow passages and to provide additional changes of direction of the flow as the fluid flows through said radial passages.

9. An adjustable fluid restrictor as set forth in claim **1** wherein said shaft passes through said housing at the inlet end and including a seal intermediate said shaft and housing to close said inlet end beyond the end of said series of rings and protrusions to apply inlet pressure against the inlet end of said series of protrusions, and closure means on said housing beyond the other end of said series to apply discharge pressure against said shaft at the outlet end of said series of protrusions to provide hydrostatic balance on said shaft.

10. An adjustable fluid restrictor as set forth in claim **9** including means defining an internal chamber within said shaft, means carried by said housing to close said chamber at the outlet end of said shaft throughout its range of axial adjustment, and means affording fluid communication between said chamber and the hollow of said housing member adjacent the inlet end.

11. A fluid restrictor according to claim **1** wherein the width of said inner and outer axial passages are uniformly equal throughout said series, and including a stop cooperable with said means mounting said members for relative axial adjustment to position said protrusions equidistant between said rings, the width of the radial passages formed thereby being equal to the width of the axial passages.

References Cited

UNITED STATES PATENTS

352,273	11/1886	Solano	251—127 X
1,112,050	9/1914	Berberich	251—210 X
1,645,601	10/1927	Lee	251—127 X

FOREIGN PATENTS

1,261,398	4/1961	France.
1,334,387	7/1963	France.
592,870	5/1959	Italy.

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