June 6, 1967 L. LEE II 3,323,550

FLUID RESISTOR

Filed May 21, 1964

FIG. 1

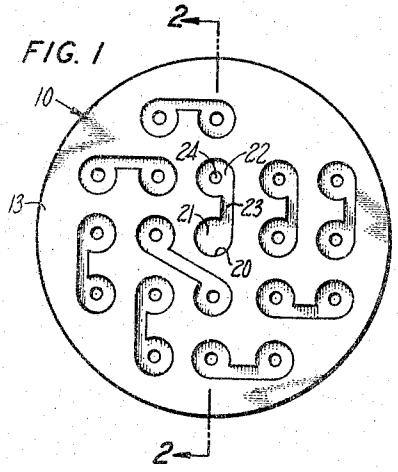


FIG. 2

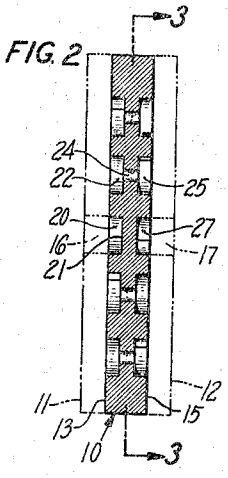


FIG. 3

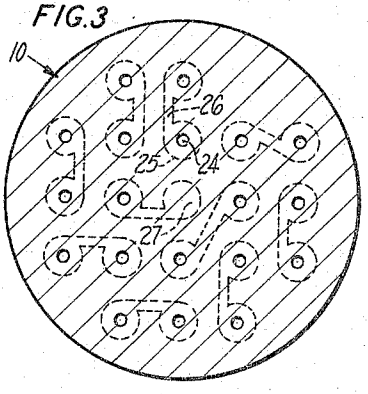
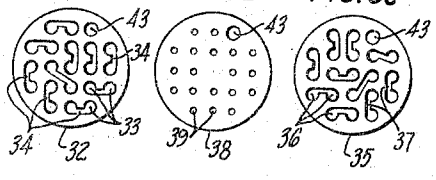


FIG. 5a FIG. 5b FIG. 5c



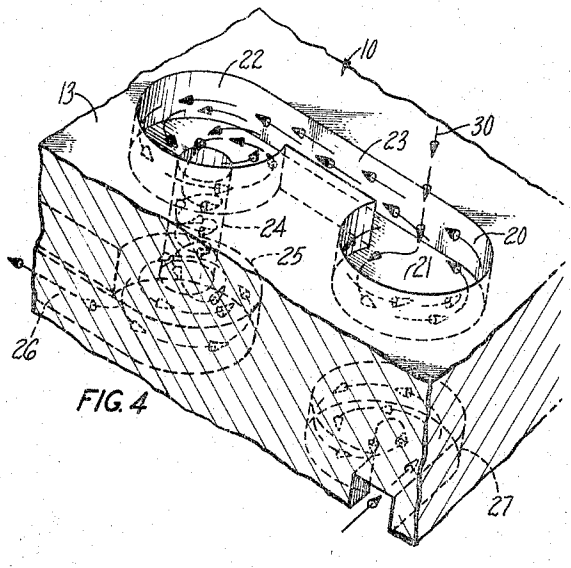
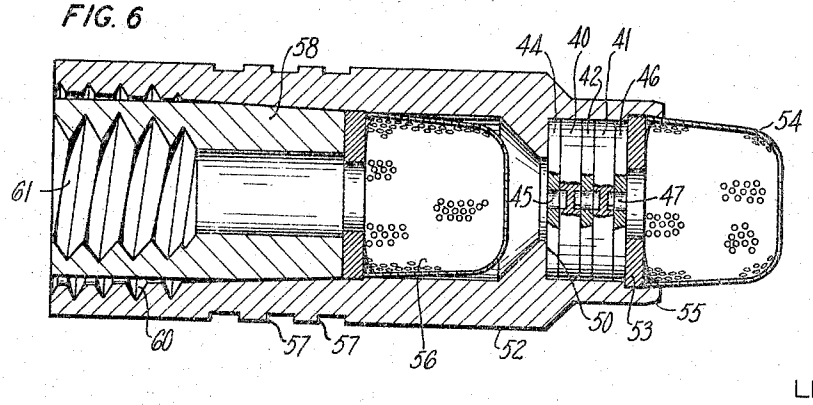


FIG. 4

FIG. 6



INVENTOR.
LEIGHTON LEE II

BY Lindsey, Prutzman and Hayes

ATTORNEYS

United States Patent Office 3,323,550 Patented June 6, 1967

3,323,550

FLUID RESISTOR

Leighton Lee II, Guilford, Conn., assignor to The Lee Company, Westbrook, Conn., a corporation of Connecticut

Filed May 21, 1964, Ser. No. 369,158
11 Claims. (Cl. 138—39)

This invention generally relates to devices for restricting the flow of fluids in a passageway and has as a primary object the provision of an improved fluid resistor that is easily installed to provide an accurately metered, substantially constant rate of fluid flow under known pressure conditions.

It is also a primary object of this invention to provide an improved fluid resistor that exhibits a very high magnitude of resistance to fluid flow while providing unusually accurate flow over long periods of use.

It is a further object of this invention to provide an improved fluid resistor that is substantially insensitive to changes in viscosity of the fluid passing through the resistor.

It is an additional object of this invention to provide an improved fluid resistor which effectively prevents cavitation in th flow of such fluids as superheated water as it passes through the resistor.

It is also an object of this invention to provide an improved fluid resistor having an unusually high magnitude of resistance to fluid flow which resistor is comparatively easy to manufacture and install in the fluid conduit while being reliable and extremely long lived.

It is an additional object of this invention to provide an improved fluid resistor having a high magnitude of resistance to fluid flow which resistor can be made of extremely small dimension or of very large dimensions and is susceptible of modular construction to permit effective use of a plurality of the resistors in a single device.

Other objects will be in part obvious and in part pointed out more in detail hereinafter.

The invention accordingly consists in the features of construction, combination of elements and arrangement of parts which will be exemplified in the construction hereafter set forth and the scope of the application which will be indicated in the appended claims.

In the drawings:

FIG. 1 is a top plan view of a preferred embodiment of the invention with the top cover plate removed;

FIG. 2 is a cross-section view taken along the lines 2—2 of FIG. 1 with the top and bottom cover plates shown in dotted lines;

FIG. 3 is a cross-section view taken along the lines 3—3 of FIG. 2;

FIG. 4 is a partial perspective view of a preferred embodiment of the invention with the top and bottom cover plates removed and with the direction of fluid flow indicated by the arrows;

FIG. 5*a* is a plan view of the top plate of a second embodiment of my invention;

FIG. 5*b* is a plan view of the center plate of the embodiment of FIG. 5*a*;

FIG. 5*c* is a plan view of the bottom plate of the embodiment of FIG. 5*a*; and

FIG. 6 is a cross-section view showing a plurality of the fluid resistors of this invention assembled in a preferred manner for installation within a fluid conduit.

In accordance with the present invention, there is provided a fluid resistor which can be made extremely small yet which provides a very high resistance rating while overcoming such disadvantages of the prior art as viscosity sensitivity, contamination, etc. In FIGS. 1–4 there is illustrated a preferred embodiment of the improved fluid resistor of this invention, which is shown to have a cylindrical, disc-like three-piece body structure including an orifice plate **10**, a front cover plate **11** and a rear cover plate **12**. The front surface **13** of the orifice plate is ground and lapped for fluid-tight engagement with the ground and lapped face **14** of the front plate **11** thereby to establish fluid-tight engagement. Similarly, the rear face **15** of the orifice plate **10** is ground and lapped to establish fluid-tight engagement with the similarly finished front face of rear plate **12**. The cover plates **11** and **12** are shown in dotted lines in FIG. 2 and are coextensive with the orifice plate **10**. Each plate contains a single aperture which functions as either a fluid entrance or exit hole as the direction of fluid flow in the resistor may dictate. In the illustrated embodiment, a central aperture **16** is provided in front cover plate **11** to form the fluid entrance and a central aperture **17** is provided in rear cover plate **12** to form the fluid exit.

For purposes of clarity, the cover plates are shown removed from FIG. 1 to more clearly disclose the structural detail of the orifice plate. FIG. 3 is taken in the direction of the arrows 3—3 of FIG. 2 thereby showing the details of the rear face of the orifice plate **10** in dotted lines but facilitating explanation of the fluid flow paths.

FIG. 4 illustrates the details of construction of a portion of the orifice plate **10**, which portion includes a generally cylindrical, centrally located chamber **20** which acts as the fluid entrance chamber that communicates with aperture **16** in front cover plate **11**. The chamber **20** has an imperforate lower face **21** and communicates with the cylindrical chamber **22**, the next chamber in the fluid path, through a passageway **23** whose outer side wall is tangent to the cylindrical side walls of chambers **20** and **22**. Centrally arranged in passageway **22** is an orifice **24** of diameter smaller than the cylindrical chamber **22** and extending axially through the disc to communicate with a cylindrical chamber **25** which is disposed in disc face **15**. The chamber **25** is of the same outside diameter as the chambers **20** and **22** [each chamber of the preferred embodiment being the same diameter] and communicates with the next chamber (not shown) by a passageway **26** which is arranged tangentially with the chamber **25**. The fluid passage terminates at exit chamber **27** which is disposed opposite to entrance chamber **20** and which communicates with aperture **17** in rear cover plate **12**.

With the foregoing general construction in mind and referring to FIGS. 1, 2 and 3, it is seen that the fluid enters aperture **16** in the cover plate **11** and proceeds to the entrance chamber **20** in plate **10**. The fluid thereafter progresses through passageway **23** to chamber **22**, proceeds through orifice **24** to chamber **25** on the opposite side of plate **10**, from there to passageway **26** and on to the next chamber, back through an orifice and so forth to proceed through a tortuous path comprised of a series of serially arranged orifices with a chamber disposed on each side of each orifice to reach exit chamber **27** and aperture **17**. Adjacent chambers in the fluid path on the same side of the disc are connected by a tangential passageway and for purposes of illustration, FIGS. 1 and 3 described an orifice plate having forty chambers which serve to connect the entrance and exit holes with nineteen serially connected orifices.

Turning again to FIG. 4, the arrows designated **30** generally describe the fluid flow path through that portion of the orifice plate that is illustrated. It will be observed that the fluid flow is generally rotary within the chambers thereby giving rise to the term "spin chamber." The fluid spins in each chamber so as to make many revolutions thereby using the flow passage surfaces in each chamber many times although the exact nature of the fluid spin has not been determined. Such a spinning action tends to reduce clogging of the orifices by foreign particles of

comparatively large size. Moreover, provision of such a chamber to induce fluid spin permits use of a larger orifice for a given pressure drop thereby further minimizing clogging.

The slot **23** which interconnects the chambers **20** and **22** is arranged tangential to each and it is believed that the tangential nature of each of the connecting slots not only serves to assits in imparting spin to the fluid but also serves to overcome the expected sensitivity of such an orifice arrangement to the viscosity of the fluid passing therethrough. As the fluid enters chamber **22**, it spins around the central bore or orifice **24** and exits downwardly, still spinning, to reach the spin chamber **25**. The direction of spin in the chamber **25** is opposite to the direction of fluid flow through the passageway **26** to the next chamber thereby causing the chamber **25** to act as a deceleration chamber. Because the fluid spin direction in each deceleration chamber is in opposition to the direction by which the fluid must exit from the deceleration chamber, the fluid must actually come to rest before it makes its exit from the deceleration chamber. Chambers **22** and **25** can be considered an axial pair of spin chambers attached to opposite ends of the orifice **24** and the fluid flow path heretofore described is repeated over and over again for each axial pair of spin chambers throughout the path of the fluid as it criss-crosses back and forth across the surface of the disc as well as axially through the orifices from one side of the disc to the other.

It is believed that viscosity compensation is obtained in the fluid resistor of this invention by two effects which are independent but both of which can make the fluid flow increase as viscosity increases. The first effect is that of the back pressure on the spin slots. This back pressure varies as the square of the fluid spin velocity and when the viscosity increases, the spin velocity tends to decrease, thereby decreasing the back pressure so as to permit a higher flow of the fluid through the spin slot into the next spin chamber. The second effect which cooperates in the viscosity compensation occurs in the deceleration chamber. If the liquid is spinning at a high speed when it enters a deceleration chamber, energy is absorbed to bring this liquid to rest and to subsequently accelerate it out in the opposite direction. This energy change shows us as a pressure drop such that if the viscosity increases the liquid is not spinning as fast when it enters the deceleration chamber and it will therefore be discharged with a smaller pressure drop.

A further advantage of the preferred structure is its substantial elimination of fluid cavitation. It is known that an orifice will cavitate whenever the pressure in the throat of the orifice goes below the vapor pressure of the liquid which is flowing through the orifice. Even though there may be a high supply pressure and a high back pressure on an orifice, if the velocity is high, there will be a subsequent lowering of the pressure in the throat of the orifice thereby creating the possibility of cavitation. This improved structure substantially decreases the fluid velocity so as to substantially eliminate the objectionable cavitation presented by the more common fluid resistors.

In the preferred embodiment of FIGS. 1–4, the orifice disc **10** is of sufficient axial length to permit utilization of conventional machining methods to produce not only the spin chambers and tangential connecting passageways on opposite sides of the disc but also the formation of the orifices which interconnect the axial pairs of spin chambers. FIGS. *5a*, *5b* and *5c* illustrate an alternative embodiment of the disc-type fluid resistor wherein a top cover plate **32** is provided with spin chambers **33** and tangential interconnecting passageways **34** such as by electrochemical milling methods. In a similar manner, the back cover plate **35** is provided with the necessary spin chambers **36** and tangential connecting passageways **37**. The orifice plate **38** contains only the interconnecting orifices **39** which establish fluid flow paths between each axial pair of spin chambers formed when the plates are clamped together, proper alignment being achieved by inserting a dowel pin into the aligned apertures **43**. For ease of understanding, the arrangement and number of orifices, chambers, etc, are identical with the resistor of FIGS. 1–3, and the function thereof is the same. Such an arrangement facilitates the construction of the disc-shaped fluid resistors which have extremely small axial lengths. It is to be observed, however, that many different structures formed by varying manufacturing techniques can be used to provide the fluid resistor of this invention wherein a series of orifices are serially connected through utilization of a spin chamber at each end of the orifice together with a tangential connecting passageway to establish the fluid flow path from one spin chamber to the next.

Turning now to FIG. 6, there is disclosed a typical structure for commercial utilization of the fluid resistor of this invention when it is desired to insert the resistor into a fluid passageway. The modular nature of the preferred disc-like construction is illustrated in that there is provided two orifice plates **40** and **41** which are separated by a single cover plate **42** so as to connect the exit hole of orifice plate **40** with the entrance hole of orifice plate **41** while effectively sealing the various spin chambers and tangential connecting passageways in the abutting surfaces of the plates. There is then provided a front cover plate **44** containing a fluid entrance hole **45** and a rear cover plate **46** containing a fluid exit hole **47** which effectively seals the spin chambers and connecting passageways on the outwardly facing sides of the orifice plates **40** and **41**. The various plates are identical with those of FIGS. 1–4 except that only one cover plate is needed between two orifice plates to connect them in series.

In this illustrated commercial form, the orifice plates and cover plates are compressed in sealing engagement by engagement with shoulder **50** formed in generally tubular body member **52** and with washer **53** of first strainer **54** which is positioned by inwardly deforming the outer end **55** of the body member. To make the resistor bi-directional, a second strainer **56** is mounted within the body. A series of noninterconnecting body grooves define lands **57** which are expanded into sealing engagement with the side walls of a suitable passageway by the axially bored expander plug **58** which is inserted into the body of the member after it has been inserted into the proper position within the passageway thereby expanding the grooves into sealing engagement with the passageway side wall. For convenience, the interior of the body member **52** is provided with the threads **60** and the interior of the expander plug **58** is provided with threads at **61**, so as to facilitate withdrawal of both members.

The operation of the commercial structure shown in FIG. 6 is bi-directional and accordingly provided with two strainers so as to protect the orifice plates from clogging with unduly large particles occasioned by fluid flow in either direction. Fluids entering the strainer **56** pass through the entrance hole **45** into orifice plate **40** and thence through plate **42**, orifice plate **41** and out through exit hole **47** so as to provide an extremely high amount of fluid resistance which is carefully precalibrated and remains substantially constant over long periods of use.

From the foregoing, it is believed apparent that the present invention provides a unique serial connection of orifices which through utilization of spin chambers and tangential connecting passageways serves to provide very high fluid resistances while effectively compensating for changes in viscosity of the fluid passing therethrough without utilizing moving parts.

As will be apparent to persons skilled in the art, various modifications and adaptations of the structure above described will become readily apparent without departure from the spirit and scope of the invention, the scope of which is defined in the appended claims.

I claim:

1. A fluid resistor comprising a body having a fluid passageway therein, an orifice in said passageway, an

enlarged generally cylindrical entrance chamber in said passageway communicating with said orifice along the axis of the cylinder defined by the generally cylindrical entrance chamber, and an enlarged generally cylindrical exit chamber in said passageway communicating with said orifice along the axis of the cylinder defined by the generally cylindrical exit chamber, said passageway communicating with said entrance chamber and said exit chamber in a direction generally tangent to the respective cylinders defined thereby and being positioned to effect reversal of the fluid velocity vector at the exit of said exit chamber of said orifice.

2. The resistor as set forth in claim 1 wherein the fluid passageway enters the entrance chamber and leaves the exit chamber on opposite sides of the respective cylinders defined thereby.

3. A fluid resistor comprising a body having a fluid passageway, an orifice in said passageway, an enlarged chamber in said passageway at each end of the orifice, and means forming a fluid entrance at the outer periphery of one chamber and a fluid exit at the outer periphery of the other chamber, said fluid entrance being positioned to impart a spin velocity to the fluid entering in said one chamber, and said fluid exit being positioned to conduct fluid away from said other chamber in a direction opposed to the direction of the fluid spin velocity in said other chamber.

4. A fluid resistor comprising a body having a plurality of orifices therein and means serially connecting said orifices to form a fluid flow path, said means serially connecting said orifices comprising an enlarged chamber at each end of each orifice and a connecting passageway extending from the exit chamber of one orifice to the entrance chamber of the next orifice, the entrance to the entrance chamber and the exit from the exit chamber of each orifice being on opposite sides thereof for effecting reversal of the fluid velocity vector at the exit of the exit chamber of each orifice.

5. The fluid resistor as set forth in claim 4 wherein each entrance and exit chamber is cylindrical in shape and communicates with its orifice along the axis of the cylinder defined by the respective chamber and the connecting passageway extends along a line generally tangent to the respective cylinders defined by the chambers.

6. A fluid resistor comprising a flat disc-like cylindrical body having a front face and a rear face, a plurality of passageways extending axially through said body, each passageway having a cylindrical enlargement at each end coaxial therewith, grooves in each face of the body extending between adjacent pairs of cylindrical enlargements to connect the passageways in series, a front plate in sealing engagement with said front face, a back plate

in sealing engagement with said back face, each said plate forming the end walls of the cylindrical enlargements and the side wall of the grooves in the respective body faces, and an aperture in each said plate forming the fluid resistor entrance and exit aperture respectively.

7. The fluid resistor as set forth in claim 6 wherein each groove extends along a line tangent to the two cylindrical enlargements that it interconnects.

8. The fluid resistor as set forth in claim 7 wherein the body front plate and back plate are positioned within a tubular member for insertion within a fluid conduit, said front plate, body and back plate being clamped in sealing engagement between shoulders provided on the interior of the member, said member having non-intersecting lands expandable into sealing engagement with the side walls of the fluid conduit.

9. The fluid resistor as set forth in claim 4 wherein said body is comprised of a front plate, a back plate, and a center plate, said orifices extend through said center plate and said chambers and said connecting passageways are in the front and back plates.

10. A fluid resistor comprising a flat disc-like cylindrical body having a plurality of orifices therein extending axially of the body and means serially connecting said orifices to form a fluid flow path, said means serially connecting said orifices comprising grooves formed in the surface of said body on opposite faces thereof and a cover member on each face of said body closing the open side of the grooves to preclude fluid flow other than through the path defined by said grooves and orifices.

11. A fluid resistor comprising a body having a plurality of orifices therein and means serially connecting said orifices to form a fluid flow path, said body being comprised of a plurality of members with said orifices in one of the members and said means serially connecting said orifices in another of the members and means being provided to clamp the members together in fluid-tight engagement.

References Cited

UNITED STATES PATENTS

2,118,295	5/1938	Crawford et al.	138—42
2,200,788	5/1940	Coy	138—42 X
2,664,109	12/1953	Iager	138—42
2,893,432	7/1959	Gibson	138—42 X
3,109,459	11/1963	Lee et al.	138—41 X
3,198,214	8/1965	Lorenz	138—37
3,216,439	11/1965	Manion	137—81

LAVERNE D. GEIGER, *Primary Examiner.*

H. S. BELL, *Assistant Examiner.*