United States Patent

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[54] **LINEAR FLUID RESTRICTOR HAVING A VARIABLE COEFFICIENT OF RESTRICTION AND METHOD FOR MAKING THE SAME**
5 Claims, 5 Drawing Figs.

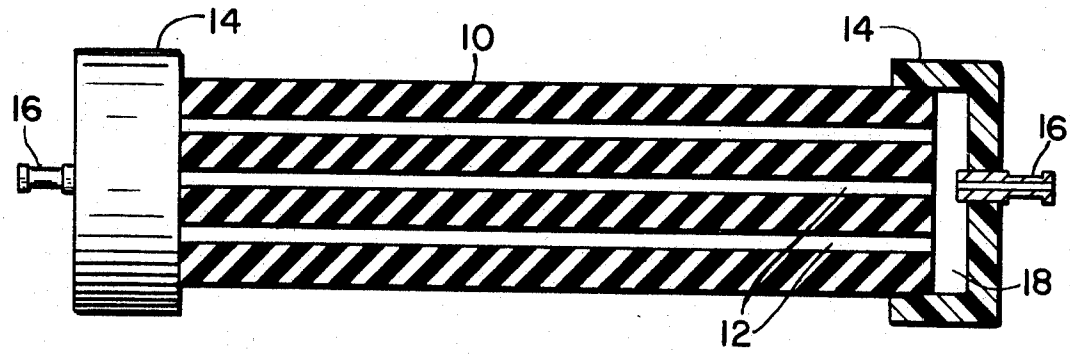
[52] **U.S. Cl.** **138/46**
[51] **Int. Cl.** **F15d 1/02**
[50] **Field of Search** 138/46, 45, 44, 40

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ABSTRACT: A fluid flow restrictor having a resilient compressible body containing one or more fluid conductive passages is disclosed. The passages are of sufficient length with respect to their cross-sectional areas to insure laminar fluid flow therein when the body is in either a compressed or uncompressed state. The coefficient of restriction of the restrictor can be varied over a range of values, without altering the linearity of the fluid volume flow-to-pressure drop relationship thereof, by placing the body in various stages of compression.



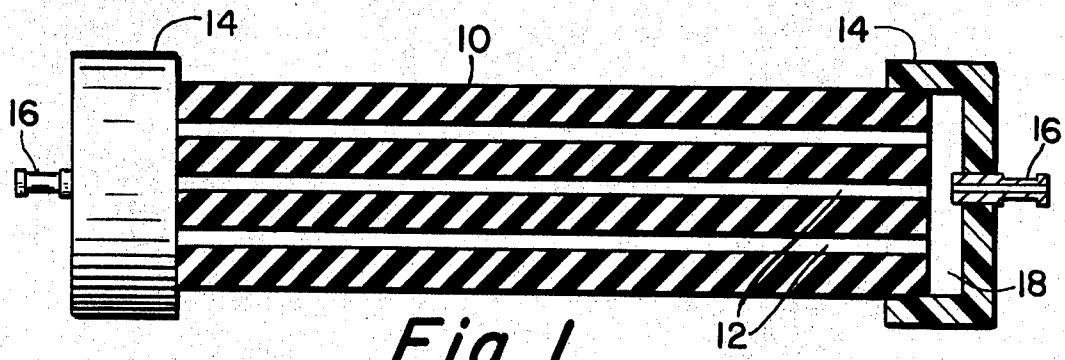


Fig. 1

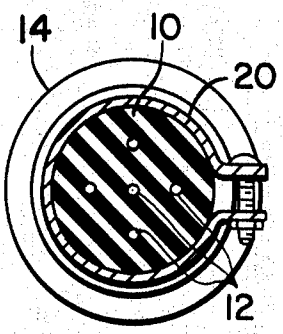


Fig. 3

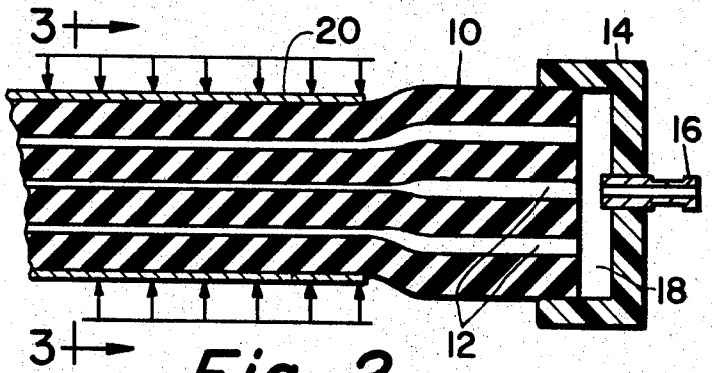


Fig. 2

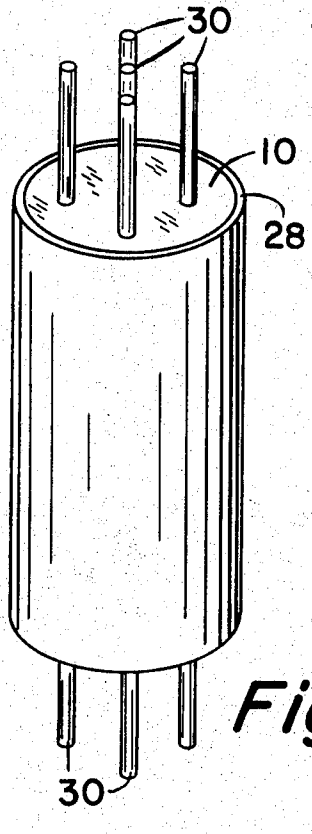


Fig. 5

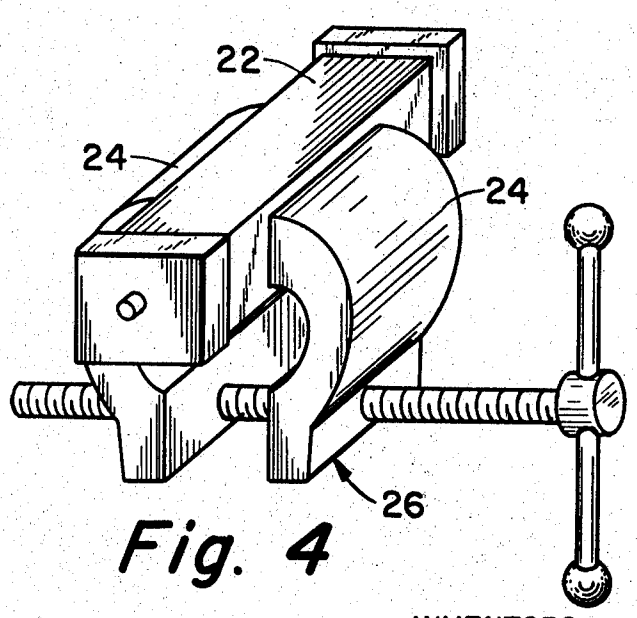


Fig. 4

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LINEAR FLUID RESTRICTOR HAVING A VARIABLE COEFFICIENT OF RESTRICTION AND METHOD FOR MAKING THE SAME

BACKGROUND OF THE INVENTION

Fluid restrictors or valves having laminar flow characteristics, a linear relationship between volume flow and pressure drop, and a variable coefficient of restriction are known to the prior art. Such prior art restrictors are characterized by a hard, nonflexible body in which a plurality of laminar flow fluid passages having fixed dimensions exist. The coefficient of restriction is varied over a range of values by rotating a control which successively opens and closes the ends of the passages, one or more at a time. In such a manner the passages are discretely or stepwise placed in or removed from a set of parallel fluid flow paths.

Accordingly, such a restrictor is limited to possessing a series of discrete values of restriction coefficient. It is not possible to vary the coefficient in a smooth, continuous manner throughout a given range. Further, such a restrictor is relatively expensive to fabricate due to the number of structural parts required and the fact that controllable moving parts must be employed.

SUMMARY OF THE INVENTION

It is, therefore, an object of the instant invention to provide a linear restrictor or valve having a variable coefficient of restriction which substantially overcomes the aforementioned difficulties.

It is a further object of the instant invention to provide a linear restrictor or valve having a variable coefficient of restriction which is particularly characterized by its ease and economy of fabrication.

Briefly, in accordance with the instant invention a linear restrictor having a variable coefficient of restriction is provided having a body of resilient compressible material containing at least one fluid passage therethrough having laminar flow properties. By placing the body of the restrictor in compression over at least a portion of the length of the passage, the coefficient of restriction of the restrictor can be changed over a range of values without altering the linear relationship between volume flow and pressure drop.

The restrictor of the instant invention can be fabricated by forming a body of resilient compressible material in a mold of the desired shape through which one or more wires having a selected diameter are held under sufficient tension to keep them from bending or crimping. After the material has cured or solidified, the mold is removed and the wires are withdrawn. Appropriate end terminations may thereafter be formed on the body to permit fluid access to the passages.

Additional objects, features and advantages of the instant invention will become apparent to those skilled in the art from the following detailed description and attached drawing on which, by way of example, only the preferred embodiments of the instant invention are illustrated.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows a partially cross-sectioned elevation view of a linear variable restrictor of cylindrical shape illustrating one embodiment of the instant invention.

FIG. 2 shows a fragmentary elevation view partially cross-sectioned of the linear restrictor of FIG. 1 illustrating the application of compression forces thereto to alter the coefficient of restriction.

FIG. 3 shows a cross-sectioned end view of the restrictor of FIG. 2 with a band clamp attached to the body as viewed along lines 3–3 thereof.

FIG. 4 shows, in an oblique view, an example of the application of compression forces to the body of a restrictor of rectangular cross section to alter the coefficient of restriction thereof.

FIG. 5 shows, in an oblique view, a stage in the fabrication of the restrictor of FIGS. 1, 2 and 3.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. 1 there is shown a cylindrical body 10 of compressible resilient material such as rubber, silicone rubber, teflon, urethane, or the like. However, the body 10 may be of any desired cross-sectional shape such as rectangular. Extending through the body 10 is at least one fluid channel or passage 12. At the ends of the body 10 are a pair of terminals 14 through which a fluid can be introduced into and removed from the passages 12 by means of a pair of port fixtures 16. Fluid is introduced into the terminal 14 and thereafter apportioned between the passages 12 if more than one passage 12 exists, in proportion to the resistances offered by each of the passages 12 to the entry of the fluid therein. The fluid flows through the passages 12, mixes together and is accumulated in the enclosed region 18 within the terminal 14 after which it flows out of the terminal 14 through the port 16.

In order that the restrictor or valve of the instant example provides a linear relationship between fluid volume flow therein and pressure drop thereacross, it is necessary that fluid flow in the passages 12 be laminar. As is well known to those skilled in the art, laminar flow properties require that the length of the passages 12 should be relatively long in comparison to the cross-sectional area of the passages 12 so that nozzlelike end effects are minimized. The limits of length to cross-sectional area of the passages 12 which will permit laminar flow therein cannot be stated with exactness as the roughness of the passage defining surfaces of the body 10, the viscosity of the particular fluid medium in use, the temperature of the fluid medium Reynolds Number, and a host of other well known variables all contribute to the nature of laminar fluid flow. Where a large volume flow capability is desired in circumstances where the cross-sectional area of the passages 12 must be kept small, the number of passages 12 can be increased as necessary. In some cases the desired flow capacity with laminar flow characteristics can be obtained by providing only a single passage 12. Ordinarily, the range of volume flow and pressure drop properties desired will dictate the number of passages 12 required.

Referring to FIGS. 2 and 3 the restrictor of FIG. 1 is shown under the influence of compressive forces, indicated by arrows, applied uniformly to the body 10 over a portion of the length of the passages 12 by a clamp or band 20. The action of the band 20 in bearing upon the body 10 produces constriction of the cross-sectional areas of the passages 12 with respect to their uncompressed state. This in turn increases the coefficient of restriction of the valve over that of its uncompressed state. However, the linearity of volume flow to pressure drop in the passages 12 is not altered over a wide range of compression forces applied by the band 20 to the body 10. It should be noted that the body 10 must be constructed of a material having sufficient resiliency to return to its undeformed shape once the compression forces produced by the band 20 are removed.

Referring to FIG. 4, the compression forces necessary to constrict the passages of a rectangular compressible resilient body 22 having laminar flow passages therethrough, not shown, can be applied in any well known manner such as by applying the compression plates 24 of a vise 26 to opposing surfaces of a body 22 as shown. Where the body of the restrictor of the instant invention is of cylindrical shape as in FIGS. 1 and 2, a well known band clamp 20 is one example of the manner in which constriction of the fluid passages therein can be obtained.

Referring to FIG. 5, there is shown the manner in which the restrictor of FIGS. 1, 2 and 3 can be fabricated. A cylindrically shaped plastic tube 28 is provided as a molding form through which is drawn one or more wires 30 which are thereafter held stationary under sufficient tension to prevent them from bending or crimping. The number of wires 30 used corresponds to the number of passages 12 desired to be formed in the body 10. The diameter of the wires 30 chosen will produce the passages 12 having about the same diameters. The material to be molded to form the body 10 should be of any well-known

type which will produce a resilient compressible material once the molding process is completed. A typical example of such material is Flexane, a urethane composition sold by the Devion Corporation of Danver, Massachusetts. The advantage in using Flexane is that it is curable at room temperature. The tube **28** has an inside diameter equal to the desired diameter of the body **10**. The material of the mold or tube **22** is not critical and may be any suitable material which, when either coated or uncoated, will release from the material of body **10** after it cures or sets. Flexane material is injected into the interior of the plastic tube **28** and permitted to cure or harden at room temperature. After curing is complete, the tube **28** is removed and the wires **30** are withdrawn leaving a compressible resilient body **10** of cylindrically shaped material having the desired fluid conductive passages therethrough.

The body **10** can just as well be molded in any desired shape such as in the form of a rectangular parallelepiped by the foregoing method. Any other material having suitable compressibility and resiliency can be used for the body **10** such as silicone rubber, rubber, or the like. Further, any suitable wirelike members **30** such as nylon thread, rigid cylindrically shaped rods of any material that will release from the body material, or the like can be used to form the passages **12** so long as their diameters are selected to provide the passages having the desired diameters.

Although the instant invention has been described with respect to specific details of certain embodiments thereof, it is not intended that such details be limitations on the instant invention except insofar as set forth in the following claims.

We claim:

1. A fluid restrictor having a variable coefficient of restriction comprising:

a body of resilient compressible material containing at least one fluid passage therethrough, said passage having a length- to cross-sectional-area relationship so as to permit laminar flow to be maintained therethrough; and

means for compressing said body substantially perpendicular to the longitudinal axis thereof along at least a portion of the length of said passage whereby a linear relationship between flow volume and pressure drop is maintained.

2. The restrictor according to claim **1** further comprising terminating means attached to said body for providing fluid access to said passage.

3. The restrictor according to claim **1** wherein said body is in the shape of the cylinder, said at least one passage extending through said body parallel to the longitudinal axis thereof.

4. The restrictor of claim **1** wherein said resilient compressible material is selected from the group consisting of rubber, silicone rubber, teflon, and urethane.

5. A linear fluid restrictor having a variable coefficient of restriction comprising:

an elongated parallelepiped body of resilient compressible material containing at least one fluid passage extending therethrough parallel to the longitudinal axis thereof; and

means for compressing said body along at least a portion of the length of said passage.