July 2, 1968 D. R. JONES 3,390,691

DRIFT ATTENUATOR FOR FLUID AMPLIFIER

Filed July 11, 1963

FIG. 1

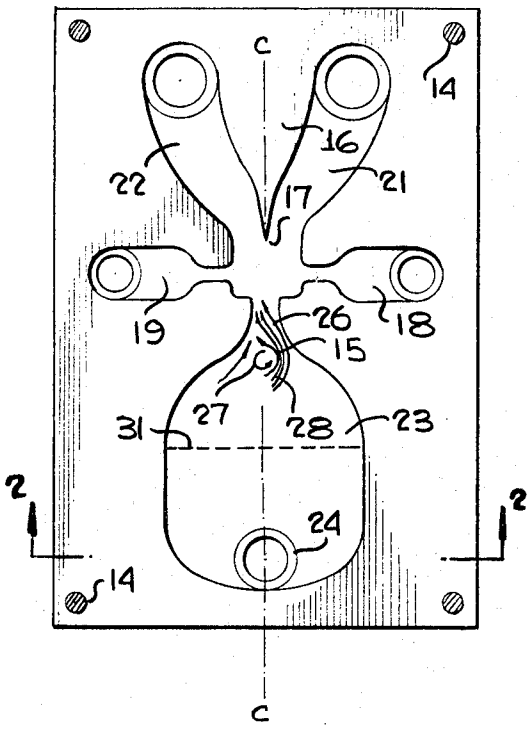



FIG. 3

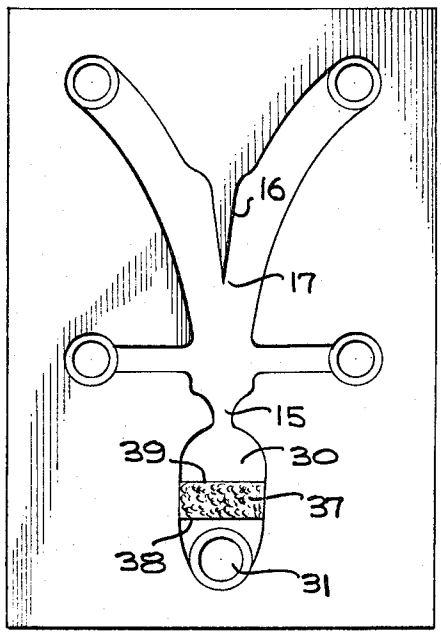



FIG. 2

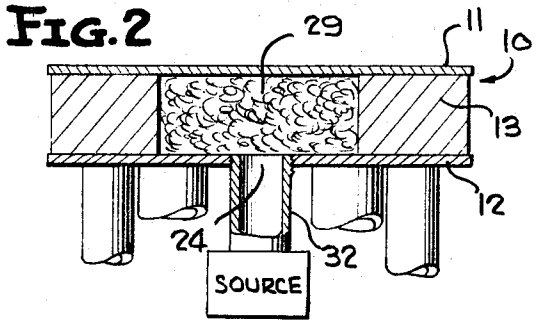
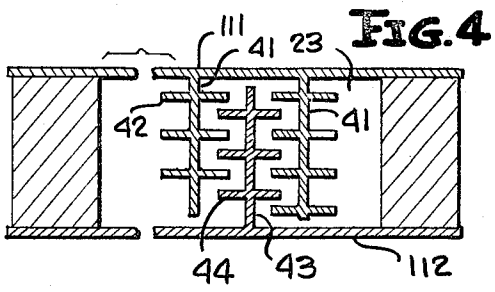



FIG. 4



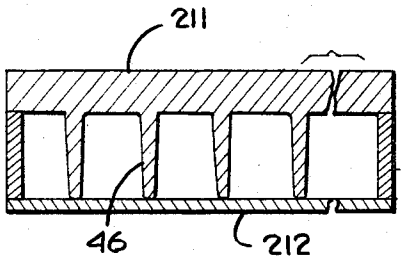




FIG. 5

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# DRIFT ATTENUATOR FOR FLUID AMPLIFIER

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The present invention relates to fluid-operated systems having no solid moving parts, and more particularly to a pure fluid amplifier including a structure in its power nozzle to prevent or attenuate long-term drift.

Fluid amplification systems employing such moving parts as pistons, linkages, valves, diaphragms or vanes have long been used for a multiplicity of purposes. Such systems are now recognized to have many deficiencies which arise due to friction, wear, thermal expansion and inertia of the parts.

A comparatively recent development has been the provision of systems in which only the fluid moves, there being no solid moving parts in the systems. These systems have become known as "fluid amplifier systems" and their general construction and characteristics are now well known.

In a typical embodiment of a pure fluid amplifier, a pair of parallel plates are provided, one of the plates having a plurality of passages, nozzles, etc. formed therein to define a fluid amplifier. The amplifier includes a main power nozzle for issuing fluid into an interaction region, and through the interaction region toward one or more output channels defined in part by one or more divider structures disposed at a predetermined distance from the power nozzle. One or more control nozzles may be placed in a sidewall or sidewalls intermediate the main nozzle and the divider, and control fluid may be introduced through one or more of the control nozzles to deflect fluid issuing from the main or power nozzle.

An essential element of a reliable device is its long-term stability; that is, its ability to produce the same output signal over extended periods of time in response to a given amplitude of control signal or also its ability to produce a prescribed output function in the absence of an input signal. As applied to simple analog amplifiers having a single divider defining two output channels symmetrical with respect to the centerline of the power nozzle, long-term stability requires that the same amount of flow appears in both output channels in the absence of an input signal or the presence of equal input signals and that this condition persist over extended periods.

It has now been learned that despite great accuracy in manufacturing these units, including the provision of plates sufficiently flat to insure two-dimensional flow and accurate alignment of the divider leading edge with the axis of the power nozzle, true long-term stability is not normally achieved.

More particularly, it has been found that there is a phenomenon designated as "drift" which occurs in these units, even though they are precisely made. In accordance with this phenomenon, the power stream divides unequally so that more fluid is delivered on one side than on the other of the divider, the drift being completely random in nature.

The power stream drift hereinabove discussed has deleterious effects on the devices or units being controlled, since over a period of time, the inaccuracies present in the amounts of fluid delivered cause the subsequent units or controlled devices to function in manners not intended. For example, a further unit in a system may be caused to exert a control function due to a drift error in a preceding unit, where no such control function was intended or desirable.



An object of the present invention is to provide a fluid-operated system having no appreciable drift.

Another object of the present invention is the provision of a pure fluid amplifier in which the initial division between output channels of flow issuing from a power nozzle is maintained over extended periods in the absence of changes in control flow conditions in the amplifier.

Yet another object of the present invention is to provide a fluid-operated amplifying system including readily manufactured and installed means for attenuating drift.

The above and still further objects, features and advantages of the present invention will become apparent upon consideration of the following detailed description of several specific embodiments thereof, especially when taken in conjunction with the accompanying drawings, wherein:

FIGURE 1 is a plan view of a fluid-operated system in accordance with the present invention;

FIGURE 2 is a cross-sectional view taken on the line 2—2 of FIGURE 1;

FIGURE 3 is a plan view of a fluid-operating system incorporating another form of drift attenuator;

FIGURE 4 is a cross-sectional view similar to FIGURE 2, but showing another embodiment of the present invention; and

FIGURE 5 shows still another embodiment of the present invention.

Referring now to the drawings of the accompanying application, wherein like or corresponding reference numerals are used to designate like or corresponding parts throughout the several views, there is shown in FIGURE 1, a fluid-operated system or amplifier generally designated **10**, and comprising, as shown in FIGURE 2, a sandwich construction including an upper plate **11**, a lower plate **12** and an intermediate plate **13**. Upper plate **11** is assumed to be transparent for purposes of clarity and explanation. The several plates are secured together by any suitable means, such as the screws **14** shown in FIGURE 1.

Intermediate plate **13** is cut away so as to provide elements of the fluid amplifier. The present invention is applicable to all types of fluid amplifiers, the type illustrated in FIGURE 1 being chosen for purposes of explanation only. The amplifier is provided with a power nozzle **15**, a divider **16** having an apex or leading edge **17** located downstream of nozzle **15**, a pair of control nozzles **18** and **19** and output channels **21** and **22** having adjacent walls defined by divider **16**. In the embodiment illustrated, the divider **16** is symmetrical with respect to and the leading edge **17** thereof lies on the centerline C—C of power nozzle **15**.

The power nozzle **15** comprises two regions, a chamber **23** into which fluid flows from a suitable source via a tube **24** and a shaped outlet orifice **26** which imparts directivity and the desired flow characteristics to the stream issued into the amplifier.

The fluid amplifiers heretofore known have been subject to drift, as noted above, and it has been determined that a major portion of the drift results from phenomena occurring in the chamber **23** which produce variations in the directivity of the stream issued by the shaped orifice **26**. It has been determined that vorticity of fluid introduced into the chamber **23** and other turbulences produce a stream having both a non-uniform velocity profile and non-parallel flow lines. For instance, if a vortex, such as a vortex **27**, is generated adjacent the shaped orifice **26**, the flow pattern about the vortex is about as indicated by the flow lines **28**. Obviously, such a pattern affects the directivity of the out-flow from the orifice **26**. This effect, if it were stable, may be compensated by applying a bias signal to one of the control nozzles. How-

ever, the vortex pattern is not invariable and over long periods, it changes position, disappearing, reasserts itself, becomes of greater and lesser intensity, all in a relatively random manner. The vortex **27** is illustrated adjacent orifice **26** so that its effect on flow is immediately apparent. As a practical matter, however, vortices are produced adjacent the inlet to the chamber **23** whether this be a right angle inlet as illustrated or an in-plane inlet flow tube. Even though the vortices may be formed at a point in the chamber remote from orifice **26**, their effects are felt throughout the entire chamber and manifest themselves as curved flow lines in the region of orifice **26**.

Vorticity is only one form of turbulence that may be produced in nozzle **15** which effects the stability of the system. As to the manner in which the fluid is introduced, particularly when introduced in the manner illustrated in FIGURE 1, a non-uniform velocity profile may be generated which may persist through the orfice **26** and produce deflection of the stream. Again, these flow patterns are subject to random changes and may produce drift.

In accordance with the present invention, a mechanism is introduced into the nozzle **15** which prevents the establishment of vortices and minimizes turbulence and non-uniformity of velocities of flow. Referring again specifically to FIGURES 1 and 2, in a first embodiment of the invention, a porous mass **29** is disposed in the nozzle **15**. The porous mass may be a soft or hard foamed plastic, a metallic structure, made porous by sintering, etc. Fluid conducted into the chamber **23** through conduit **24** enters the mass **29** and issues from the downstream boundary thereof, designated by reference numeral **31**, and thence flows to the inlet of orifice **26** in a flow pattern exhibiting, ideally, an absence of turbulence, vorticity and having a uniform velocity. As the fluid passes through the orifice **26**, the velocity profile may change somewhat but, on the whole, retains its regularity, and the fluid stream is directed along the centerline of the nozzle **15**.

In actual operation, the porous mass prevents free circulation of fluid therein, permitting flow substantially only toward the orifice **26**. Restriction of circulation also tends to maintain a uniform pressure in the porous mass resulting in a substantially uniform velocity profile of fluid in the nozzle. In consequence, the two major causes of drift are eliminated.

The use of the porous mass has been so effective that, in a series of tests, an instrument capable of detecting pressure changes of 0.015 p.s.i. and connected across channels **21** and **22** was unable to detect any drift over a ten hour period of continuous operation. Repeated start-up tests also failed to show any change in pressure as between all operating intervals.

Referring now to FIGURE 3, there is shown another embodiment of the present invention. There is provided in the chamber **23** a porous mass **37** having an upstream boundary **38** lying in a region spaced from the inlet **24** and a downstream boundary **39** lying at a point spaced from the orifice **26**. The operation of this system is about the same as in FIGURES 1 and 2.

In FIGURE 4, there is shown yet another embodiment of the present invention in which a honeycomb is provided in the chamber **23** to establish the flow characteristics above noted. An upper plate **111** is provided with a plurality of vanes **41** which extend downwardly from the undersurface thereof, each of the vanes **41** having a plurality of horizontally extending vanes **42**. Similarly, the lower plate **112** is provided with upwardly extending vanes **43**, each of which has extending therefrom the horizontal vanes **44**. The horizontal vanes **42** and **44** are interdigitated, as shown, and the construction provides a



substantial honeycomb effect which permits fluid to pass therethrough, but which causes the fluid to have the velocity profile and low turbulence characteristics as noted hereinabove.

In FIGURE 5, there is illustrated yet another embodiment of the present invention wherein the upper plate **211** is provided with a series of ridges **46** which extend into contact with a lower plate **212** and are parallel to the centerline of the nozzle **15**. The effect is to provide a series of flow straighteners which serve to impart to the fluid stream issuing therefrom the above-noted characteristics.

There has been provided a drift attenuator for a fluid amplifier or fluid-operated system, the drift attenuator serving to impart desirable and substantially idealistic flow characteristics to the fluid entering the power nozzle **15** of the system. Consequently, the power jet issuing from the power nozzle maintains its position relative to the apex **17** and consequently the two channels which lie on either side of the divider. There is a marked attenuation of the drift heretofore noted in fluid amplifiers. Consequently, control devices, other amplifiers, etc., which are operated from such an amplifier as herein provided are reliable and predictable in their operations.

While I have described and illustrated several specific embodiments of my invention, it will be clear that variations of the details of construction which are specifically illustrated and described may be resorted to without departing from the true spirit and scope of the invention as defined in the appended claims.

What I claim is:

**1.** A fluid amplifier comprising a power nozzle including an outlet orifice for issuing a stream of fluid, means for delivering fluid to said power nozzle at an angle relative to the axis of said power nozzle, fluid intercepting regions located downstream of said nozzle, means for developing a variable pressure gradient across said stream of fluid to vary the quantities of fluid directed to said intercepting regions and structural means located in said power nozzle between said means for delivering and said outlet orifice of said power nozzle for reducing transverse movement of fluid in said power nozzle to reduce movement of said power stream transversely of said intercepting regions in the absence of a change in said pressure gradient.

**2.** A fluid amplifier or the like in accordance with claim **1**, wherein said last-mentioned means comprises a porous mass in said nozzle.

**3.** A fluid amplifier or the like in accordance with claim **2**, said porous mass being foamed plastic material.

**4.** A fluid amplifier or the like in accordance with claim **2**, said porous mass being a porous metal mass.

**5.** A fluid amplifier or the like in accordance with claim **2**, said porous mass being sintered metal.

**6.** A fluid amplifier or the like in accordance with claim **1**, wherein said last-mentioned means comprises honeycomb means in said nozzle.


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