July 2, 1968 R. W. ZIEMER ET AL 3,390,693

PURE FLUID AMPLIFIER

Filed June 28, 1965

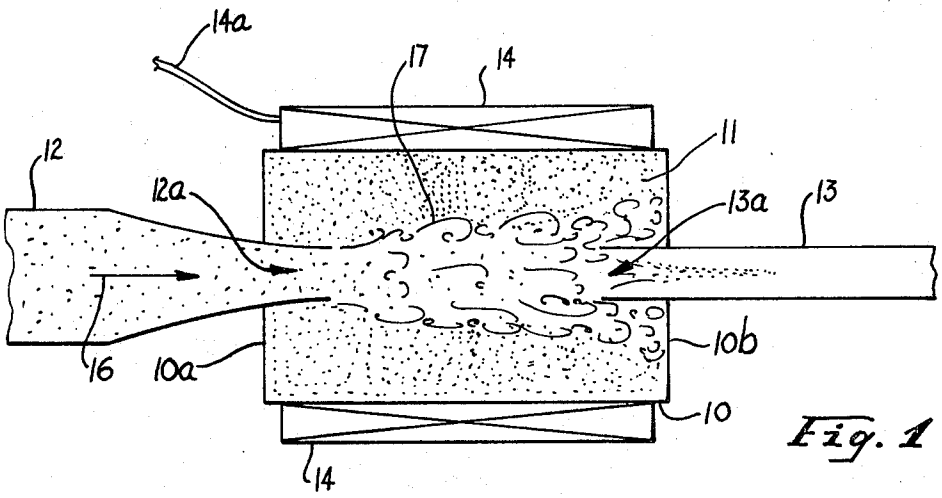


Fig. 1

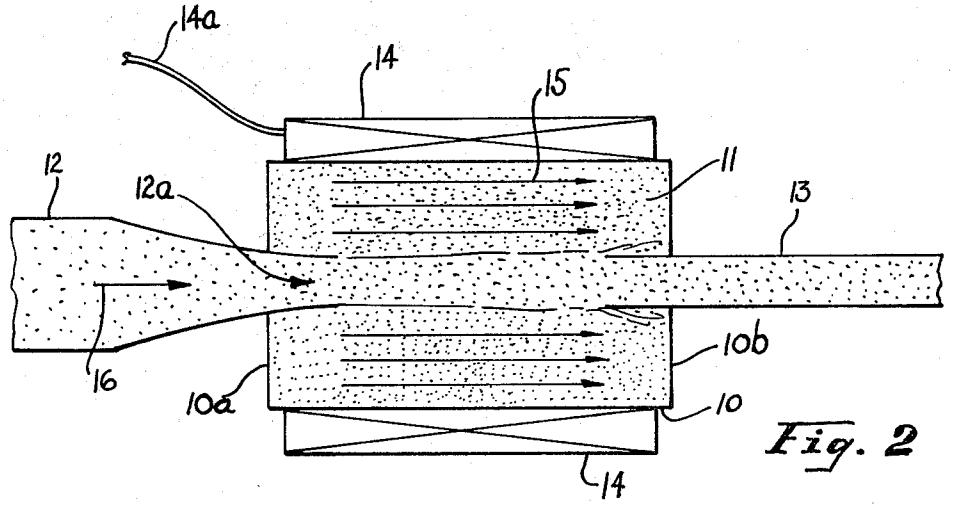


Fig. 2

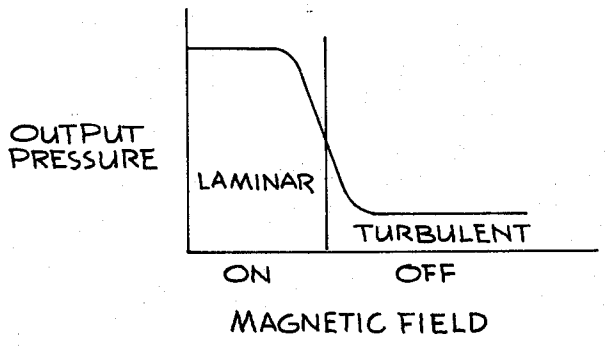


Fig. 3

INVENTORS
RICHARD W. ZIEMER
MATHEW R. DENISON
BY Allen E. Bottney
ATTORNEY

United States Patent Office 3,390,693 Patented July 2, 1968

3,390,693

PURE FLUID AMPLIFIER

Richard W. Ziemer, Altadena, and Mathew R. Denison, Tarzana, Calif., assignors to Electro-Optical Systems, Inc., Pasadena, Calif., a corporation of California

Filed June 28, 1965, Ser. No. 467,201
5 Claims. (Cl. 137—81.5)

The present invention relates in general to the relatively new technology of fluidics, the term "fluidics" as used herein referring to that field of technology that deals with the use of fluids, either gaseous or liquid, in motion to perform functions such as signal or power amplification, logic or computation, control, and the like. More particularly, the present invention relates to a magnetically controlled turbulence.

Fluid devices are known wherein the output flow of a relatively high-energy fluid stream is controlled by a relatively low-energy input fluid jet as, for example, by making the low-energy fluid impinge upon and thereby deflect the high-energy fluid stream to a selectable outlet channel. Since the output flow is thus of greater energy than that of the input, these devices have been referred to in the art as "fluid amplifiers." These amplifiers are small, rugged, may be constructed of almost any material, such as plastic, metal, or ceramic, and basically comprise a plurality of fluid ducts or channels formed within substantially solid blocks of material. Moreover, these devices possess the advantages of being inexpensive and of requiring no movable solid elements except for the fluid itself.

Several different types of fluid amplifiers are known. One such type is known as the stream interaction or momentum interchange type, basically an analog device, while a second type of fluid amplifier is known as a boundary layer fluid amplifier, this latter type basically being a digital type of device because of its bistable or flip-flop nature. Still a third type of fluid amplifier is the turbulence amplifier which uses an entirely different operating principle than the other two. More specifically, at low Reynolds numbers, a submerged jet (air in air, water in water, etc.) can remain laminar for a relatively long distance and a receiver placed in the path of the jet will provide good pressure recovery as long as the jet remains laminar up to the receiver. However, pressure recovery is low when the jet becomes turbulent. In the turbulence amplifier, therefore, the pressure at the power nozzle is adjusted so that the jet becomes turbulent just after the receiver. Then, small disturbances, such as flow in the control nozzle, will make the jet become turbulent before it reaches the receiver, thereby drastically lowering the receiver pressure. With multiple control nozzles (up to four have been used) such a device provides "NOR" logic and several of them can be combined to form logic elements of the "flip-flop" and "AND" types.

As indicated above, in the turbulence amplifiers found in the prior art, the power jet is normally laminar and is made turbulent by the impingement of a control jet thereon, the power jet returning to its initial laminar flow when the control jet is removed. Thus, in the prior art, control jets and the control channels and orifices through which they act, are essential to the amplifier's operation.

The present invention eliminates this need for control jets by providing the amplifier device with the combination or an electrically-conducting fluid for the power jet and means for electromagnetically controlling the condition of this fluid. More particularly, in this invention, the fluid is an electrically conducting fluid and the flow conditions are controlled so that the Reynolds number is slightly above ten thousand and the jet is normally turbulent. By the application of a transverse or longitudinal magnetic field, the turbulent jet can be made to become

laminar if the Hartmann number is above twenty-five or higher. Hence, the state of the jet can be controlled by a magnetic field instead of by the normal fluid control jet or in combination with the fluid control jet, thereby accomplishing control of the fluid amplifier by electrical (through the generation of an electromagnetic field) inputs.

The advantages of a turbulence amplifier embodying the subject invention are obvious. Briefly stated, however, it eliminates the dependence on fluid control jets, and with it the need for control channels and additional pressure sources. Furthermore, magnetic fields are inherently faster acting than fluid jets so that higher-speed turbulence amplifiers are thereby made possible. In addition, since the features of the present invention may also be combined with existing fluid control techniques, the flexibility and versatility of turbulence amplifiers is very greatly enhanced.

It is, therefore, an object of the present invention to provide a turbulence amplifier which does not require fluid control signals to control the flow condition of its power jet.

It is another object of the present invention to provide a turbulence amplifier that operates with only one fluid stream.

It is a further object of the present invention to provide electromagnetic means for controlling the output pressure in a turbulence amplifier.

It is still another object of the present invention to enhance the flexibility and versatility of turbulence amplifiers by providing electrical actuation of the amplifier in addition to the normal fluid means.

The novel features which are believed to be characteristic of the invention, both as to its organization and method of operation, together with further objects and advantages thereof, will be better understood from the following description considered in connection with the accompanying drawing in which an embodiment of the invention is illustrated by way of example. It is to be expressly understood, however, that the drawing is for the purpose of illustration and description only, and it is not intended as a definition of the limits of the invention.

FIGURE 1 is a diagrammatic showing of a turbulence amplifier constructed for electromagnetic control in accordance with the present invention and illustrates the power jet in a turbulent state;

FIGURE 2 again presents the FIG. 1 embodiment but with the power jet in a laminar flow condition; and

FIGURE 3 illustrates the principles of the present invention by means of a graph in which output or receiver pressure is plotted against magnetic field.

For a consideration of the invention in detail, reference is now made to the drawings wherein like or similar parts or elements are given like or similar designations throughout the several figures. In FIGS. 1 and 2, a turbulence amplifier according to the present invention is shown to include a chamber **10** in which an electrically neutral, electrically conducting fluid **11** is contained. For convenience, the input or near wall of the chamber is designated **10***a* and the output or far wall of the chamber is designated **10***b*. An inlet channel or tube **12** is mounted on and extends through chamber wall **10***a*, and an output channel or tube **13** is mounted on and extends through chamber wall **10***b*, the tubes mentioned being mounted and oriented so as to be coaxially aligned with one another. Again, for sake of convenience, those ends of tubes **12** and **13** that protrude into chamber **10** and face each other are respectively designated **12***a* and **13***a*.

Finally, an embodiment of the present invention includes an electromagnet consisting of a coil **14** wound around the chamber and having input leads designated **14***a* that are connected to a source of electrical current

(not shown) of the direct-current kind. Coil **14** is wound so as to produce a longitudinally directed magnetic field in chamber **10**, as is figuratively illustrated by means of arrows **15** in FIG. 2. However, coils wound in other ways on or around chamber **10** may also be used since the direction of the magnetic field in chamber **10** is basically unimportant, that is to say, the magnetic field can be in any direction through the chamber. Thus, by way of example, apparatus capable of establishing a transverse field would also be satisfactory in meeting the needs of the present invention.

Before proceeding to a consideration of the operation of the invention, it should be mentioned that chamber **10** and tubes **12** and **13** may be made of almost any kind or type of material, such as glass, a plastic, ceramic, metal, etc. However, since the present invention does involve the use of a magnetic field, in the event an embodiment thereof is to be made out of metal, it is preferred for reasons that will become more apparent later that the metal be non-magnetic so as not to adversely affect its operation.

Considering now the operation, electrically conducting fluid of the same kind contained in chamber **10** is forced under pressure into and through inlet tube **12** in the direction of arrow **16**. This fluid passes through nozzle **12***a* to chamber **10** where it enters the fluid therein, namely, fluid **11**, as a jet, with the result that the fluid passing through nozzle **12***a* is a submerged jet. In accordance with the present invention, the flow conditions of the fluid are controlled, as by keeping the Reynolds number slightly above ten thousand, so that the submerged jet is normally turbulent as is indicated by the designation **17** in FIG. 1.

However, the abovesaid turbulent jet can be converted to a laminar jet if it is so desired and this can here be done by causing a suitable current to flow through coil **14**. More specifically, assuming that the Hartmann number is about twenty-five or higher, the generation of a magnetic field of suitable strength within chamber **10** has the salutary effect of damping out the eddys that produce the turbulent flow, with the result that laminar flow is thereby obtained. On the other hand, if the magnetic field is removed, then the jet returns to one of turbulent flow. Hence, the state of the jet can be controlled by a magnetic field instead of by the fluid control jet found in the prior art. It will be recognized, however, that the magnetic field control technique of the present invention can be combined with the fluid control technique of the prior art and that it may at times be advantageous to do so.

Referring now to outlet tube **13**, a laminar jet or stream can be projected over substantial distances before it goes suddenly turbulent and forms a divergent cone. Accordingly, by positioning outlet tube **13** so that the jet remains laminar until just after nozzle **13***a*, good pressure recovery in the tube will be had. This is the situation obtained with the application of the magnetic field. On the other hand, in the absence of the magnetic field, the jet is entirely turbulent and the pressure recovery in the tube is thereby low. Stating it more succinctly, nozzle **13***a* is located in the path of the submerged jet and at a point therein where it will receive the jet laminar flow when the magnetic field is turned on, with the result that the pressure inside tube **13** is either high or low depending on whether the jet's flow is laminar or turbulent.

The effect of the magnetic field on the output pressure in tube **13** is pictured in FIG. 3 wherein Output Pressure is plotted against Magnetic Field. As is clearly shown therein, when the magnetic field is ON, that is to say, when the magnetic field permeates chamber **10**, the jet is laminar and the pressure in tube **13** due to the jet is high whereas when the magnetic field is OFF, that is to say, when chamber **10** is devoid of a field, the jet is turbulent and the pressure in tube **13** resulting therefrom is low. It can thus be seen that the turbulence amplifier is basically a logical NOR device and can be used in digital logic applications to construct any other logic function. These devices also can be combined to form logic elements of the flip-flop and "AND" types. A flip-flop, for example, is constructed by crossing the outputs and inputs of two turbulence amplifiers.

Although a particular arrangement of the invention has been illustrated and described above by way of example, it is not intended that the invention be limited thereto. Accordingly, the invention should be considered to include any and all modifications, alterations or equivalent arrangements falling within the scope of the annexed claims.

Having thus described the invention, what is claimed is:

1. A turbulence amplifier comprising: a chamber in which an electrically neutral, electrically conducting fluid is contained; means for directing a turbulent jet of said electrically neutral, electrically conducting fluid into said chamber and through the fluid therein; and means for selectively converting said turbulent jet to one of laminar flow, said means including apparatus for selectively generating a magnetic field throughout said chamber.

2. The turbulence amplifier defined in claim **1** wherein said apparatus generates a magnetic field that is transverse to the direction of flow of said jet.

3. The turbulence amplifier defined in claim **1** wherein said apparatus generates a magnetic field in the direction of flow of said jet.

4. A turbulence amplifier comprising: a chamber filled with an electrically neutral, electrically conducting fluid; an inlet tube coupled to said chamber at one end thereof; apparatus for injecting a turbulent jet of said electrically neutral, electrically conducting fluid through said inlet tube and into said chamber; means for selectively converting said turbulent jet to one of laminar flow, said means including additional means for selectively generating a magnetic field in said chamber; and an outlet tube mounted on and extending through said chamber opposite said inlet tube, the end of said outlet tube inside said chabber being positioned in the path of said laminar jet.

5. A fluid amplifier comprising: means for producing a turbulent jet of an electrically neutral, electrically conducting fluid submerged in a body of said electrically neutral, electrically conducting fluid; and electromagnetic means for selectively converting said turbulent jet to one of laminar flow.

References Cited

UNITED STATES PATENTS

2,763,125	9/1956	Kadosch et al.	137—81.5
3,071,154	1/1963	Cargill et al.	137—81.5
3,182,674	5/1965	Horton	137—81.5
3,234,955	2/1966	Auger	137—81.5
3,258,685	6/1966	Horton	137—81.5 X
3,266,514	8/1966	Brooks	137—81.5

SAMUEL SCOTT, *Primary Examiner.*