Oct. 15, 1968 T. D. READER ET AL 3,405,736

PURE FLUID LOGIC ELEMENT

Filed Oct. 13, 1964

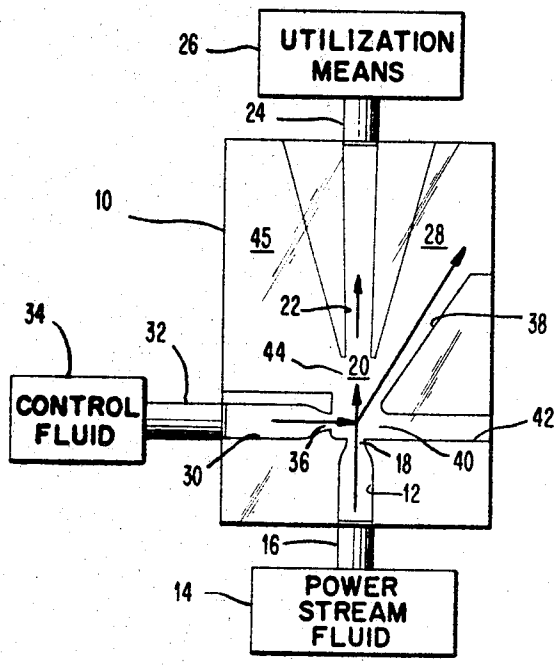


FIG. 1

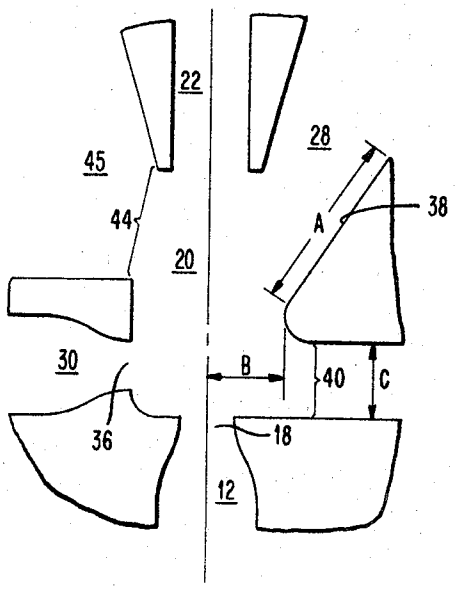
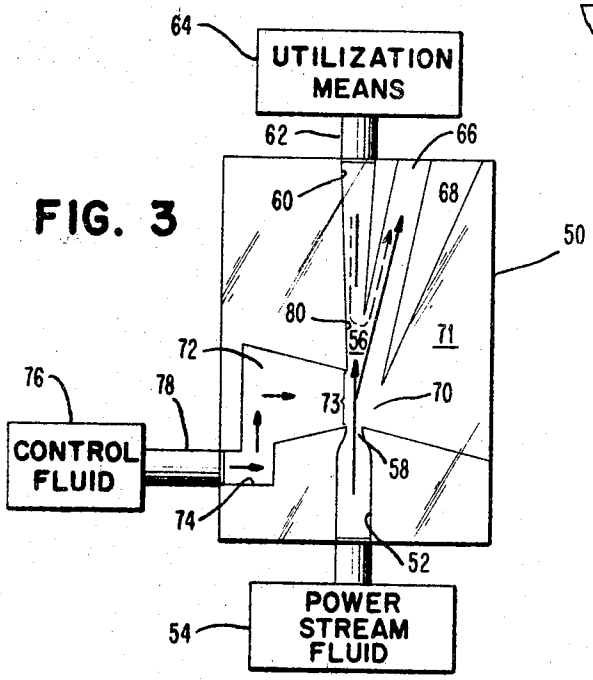


FIG. 2

FIG. 3



INVENTORS
EDWIN R. PHILLIPS
TREVOR D. READER

BY

Griffin and Stokes
ATTORNEYS

United States Patent Office 3,405,736 Patented Oct. 15, 1968

3,405,736

PURE FLUID LOGIC ELEMENT

Trevor D. Reader, King of Prussia, and Edwin R. Phillips, Rosemont, Pa., assignors to Sperry Rand Corporation, New York, N.Y., a corporation of Delaware

Filed Oct. 13, 1964, Ser. No. 403,586
3 Claims. (Cl. 137—81.5)

The present invention generally relates to a pure fluid logic element, and more particularly, to a pure fluid inverter having a relatively high power gain.

In pure fluid technology, it is well known that a fluid power stream jet of realtively high energy may be deflected through a small acute angle without losing its integrity by the application thereto of a control fluid jet of lesser energy, generally at a right angle in order to provide maximum deflection per unit of control stream energy. This is the well known "stream interaction" or momentum exchange type amplifier. Prior art fluid logic elements as, for example, inverters have been built using this approach, i.e., the power fluid jet, when present by itself, is recovered in an output channel leading to some utilization device whereas, with the application of control signal fluid, said power jet is deflected away from the output recovery channel so that no fluid signal is directed to said utilization means. The power gain here is inversely proportional to the energy of the control stream necessary to deflect the power stream jet to a degree where the latter is completely removed from the output recovery channel. Since greater control stream energy is necessary for larger values of power stream deflection, the requirement in such a momentum exchange inverter to completely switch power stream flow away from the output recovery channel thereby lowers the gain of the unit to a value where it is not too attractive.

The present invention in one aspect thereof reduces, if not completely obviates, the difficulties leading to relatively low gain of prior art momentum exchange inverters by placing an attraction wall near the power stream jet on the side opposite the control signal jet. This wall, by virtue of its positioning and dimension, permits the creation of a low pressure boundary layer almost as soon as power stream deflection commences which then acts as an aid to further power stream deflection without, however, subsequently causing any permanent or stable power stream lockon to the attraction wall in the absence of a control stream. Thus, only as the power stream begins its deflection away from the output recovery channel (in response to an impinging control stream) is said boundary layer formed to thereby assist the control stream in completing power stream deflection to the maximum degree whereby no fluid is directed to the utilization means. Upon termination of the impinging control stream, this wall attraction is insufficient to maintain this large power stream deflection, such that the power stream now swings back towards its normal, undeflected path. In so doing, this reduces and then finally destroys whatever boundary layer had been present during the presence of the control stream. Thus, the same degree or amount of power stream deflection as obtained in prior art momentum exchange inverters can be provided in the present device by a control stream of lesser energy so as to result in higher gain.

Therefore one object of the invention is to provide a novel pure fluid logic element which employs an attraction wall adjacent the deflected path of a fluid power stream in order to increase the gain of the unit.

Another object of the present invention is to provide a pure fluid inverter with an attraction wall therein in such a position as to avoid any permanent lockon of the power stream thereto.

In order to further insure non-stable boundary layer adhesion of the power stream along the attraction wall

and to provide for a quick return of the power stream at the termination of the control signal, an additional novel feature of the invention is the use of means providing constant communication of the boundary layer region with a source of fluid whose static pressure is such as to rapidly dissipate the low pressure boundary layer during the swing back of the power stream away from the attraction wall. This source of fluid further acts, at least in one of the embodiments of the invention, as a base reference point on one side of the power stream against which a control static pressure signal operates on the opposite side of the power stream in order to selectively cause deflection thereof. Furthermore, second means can also be provided for communication of the opposite side of the power stream with said source of fluid in order to prevent the formation of any transverse pressure gradient across the power stream due to causes other than control signal activity or the boundary layer region adjacent the attraction wall.

Therefore a further object of the present invention is to provide a fluid logic unit with an attraction wall, wherein there is constant communication of one or both sides of the power stream with a source of fluid at a fixed pressure.

One embodiment of the present invention uses a control fluid jet to provide power stream deflection by virtue of momentum exchange, whereas another embodiment employs a fluid static pressure cushion applied against a relatively long length of the moving power stream. The particular advantage of using said static pressure, rather than the dynamic or kinetic pressure of a moving control jet, is that it permits the power stream to deflect through a greater angle with less control power being required. This novel static pressure control also is of use in other types of pure fluid amplifiers apart from particular embodiments herein with the attraction wall.

Therefore, another object of the invention is to provide a fluid amplifier unit which includes control means for providing a body or cushion of static pressure fluid as the power stream deflecting agent.

These and other objects of the present invention will become apparent during the course of the following description to be read in view of the drawings, in which:

FIGURE 1 is a plan view in section of a first embodiment of the present invention which employs a control jet for power stream deflection;

FIGURE 2 is a diagrammatic enlarged view of the critical dimensions of the attraction wall used in obtaining high gain; and

FIGURE 3 is a second embodiment of the present invention which employs means for applying control fluid static pressure against the power jet.

FIGURE 1 shows a first embodiment of the novel inverting element which uses the basic principle of an attraction wall in order to enhance its gain. A block or body **10** of fluid impervious material, which can be metal, plastic, or the like, has cut or otherwise formed therein a plurality of interconnected fluid channels and chambers, preferably of rectangular cross-section as is customary in the art. In particular, a power stream input channel **12** receives relatively high energy power stream fluid from some source **14** via a connecting pipe **16**, with said power stream input channel **12** terminating in a nozzle orifice **18** located in one end of a fluid interaction chamber **20**. At the opposite chamber end wall, a first power stream output channel **22** is located directly in line with power stream input channel **12**, so that the normal undeflected trajectory of power stream fluid across chamber **20** will take it into output channel **22** from whence it is transferred via a pipe **24** to some fluid utilization means **26** (which in turn could be another pure fluid logical element). The side walls of channel **22** need not and do not

provide any boundary layer lock on effect, since the flow energy of the power stream is sufficient to establish this path through chamber **20**. Also leaving the opposite end of chamber **20** is a second power stream output channel **28** which makes an acute angle with output channel **22** and lies to one side of it at about the juncture of the chamber opposite end wall and one chamber side wall. Channel **28**, in the case of a pneumatic amplifier, usually exhausts into the surrounding lower pressure atmosphere which thus acts as a low pressure dump. However, where a gas or fluid other than air is employed, then the output of channel **28** can be connected back to source **14** via a low pressure return manifold or dump. If the power stream fluid from nozzle **18** is deflected (by means subsequently to be described) from its normal undeviated path to a path through channel **28**, the fluid normally applied to utilization means **26** is discontinued for the length of time that the power stream deflecting means is in operation. In this way the inverting logical function is performed. It would, of course, also be possible to further connect channel **28** to some form of utilization means which responds to the power stream in its deflected position.

The particular control means in FIGURE 1 for so deflecting the power stream comprises at least one control stream input channel **30** which receives, via a pipe **32**, control fluid from a selectively actuated source **34**. The control channel **30** terminates in a nozzle orifice **36** located in that side wall of chamber **20** which is opposite to the chamber side wall from which channel **28** branches. By selectively applying fluid to channel **30** from source **34**, the channel static fluid pressure is converted by nozzle **36** into a control fluid jet having primarily kinetic energy which issues forth into chamber **30** so as to strike the power stream at about a right angle thereto. By virtue of momentum exchange between the control stream and power stream particles, the direction of the power stream is shifted right to cause flow through channel **28** and eventual exhaust to the low pressure dump. Normally, the angle of power stream deflection is proportional to the energy of the control stream fluid. Since a fairly large angle of deflection is required in FIGURE 1 in order to shift the power stream completely away from output channel **22**, it is seen that relatively large control stream energy (although not as large as the power stream energy) might thus be required, which in turn lowers the gain of the device since gain may be defined as the ratio of the output utilization signal (power stream energy) to the control signal energy required for negation of same. If channel **28** does not have any side wall in the direction of power stream deflection, or includes such a side wall which is not strategically placed in the manner taught by the present invention, deflection of the power stream is due entirely to said stream interaction (momentum exchange) in chamber **20**. However, in the present invention an attraction wall **38** is placed near the deflected path of the power stream on the side opposite to the control signal jet from orifice **36**. Attraction wall **38** may actually be an extension of the side wall of chamber **20** as it turns to follow power stream output channel **28** to the point of exhaustion into the low pressure dump. Also provided in FIGURE 1 is a cavity volume **40** which separates the upstream end of wall **38** from the end wall of chamber **20** in which orifice **18** is located. This cavity **40** is preferably permanently connected to a source of static pressure fluid such as the low pressure dump to which channel **28** is connected by means of a fluid communication channel **42**, but this feature is not absolutely necessary in the FIGURE 1 embodiment if the width of cavity **40** mouth along the power stream axis is made sufficiently large. The communication of cavity **40** with the low pressure dump permits a more rapid return of the power stream from channel **28** to channel **22** at termination of control stream activity, since the low pressure of the boundary layer along wall **38** is quickly raised by addition of fluid via cavity **40** and channel **42** once the entrainment ability of the power stream decreases as the switch back is in progress. Where channel **42** is employed, a second cavity **44** is also preferably provided on the opposite side of chamber **20** at a location downstream from control channel **30**, with this cavity **44** being in constant communication with the same source of fluid as is channel **42** (illustrated to be the low pressure dump) by means of the large opening **45** in body **10**. Cavity **44** cooperates with cavity **40** and channel **42** in equalizing the static pressure across the power stream in chamber **20** so as to insure the absence of power stream lockon to the attraction wall **38** due to causes other than presence of the control signal jet and/or the creation of the low pressure boundary layer region against wall **38**.

FIGURE 2 is an expanded view of the chamber **20** vicinity in the FIGURE 1 fluid amplifier. It is provided for the purpose of explaining the critical dimensions of attraction wall **38**, relative to other dimensions of the amplifier, in order to provide a small boundary layer effect to enhance gain but without causing stable power stream flow in output channel **28**. The three critical dimensions are shown in FIGURE 2 to be the "length A" of attraction wall **38**, the "distance B" of the upstream edge of attraction wall **38** from the centerline of power stream nozzle **18**, and "width C" of the cavity **40** mouth. These dimensions are adjusted relative to one another and also to the power stream energy, such that any predetermined degree of power stream deflection into channel **28** thereafter causes a boundary layer effect between it and wall **38** so as to provide some attraction by said wall to the now deflected power stream. "Boundary layer effect" may be defined as the entrainment of fluid by a flowing stream in a region between said stream and a side wall such that the pressure in said boundary layer region is reduced, thus permitting the stream to be attracted toward the wall. Any such boundary layer effect will obviously reduce the power or energy required of the control stream fluid in forcing the power stream completely into channel **28**. As more of the power stream flows through channel **28** and moves closer to wall **38**, its entrainment efficiency rises to thereby reduce the boundary layer pressure to an even greater extent which in turn increases the wall attraction effect aiding in the power stream deflection. Consequently, by use of the attractive effect of wall **38**, the required degree of power stream deflection can be procured in the present invention with less control stream energy than formerly required in prior art inverters, so as to result in an increase in gain. Restated in a different way, the power stream is deflected by the control signal such that the closer the power stream gets to wall **38**, the less power is necessary from the control fluid because the now created boundary layer adjacent the wall itself aids in the power stream deflection. In other words, the wall shares in providing the total force necessary to keep the power stream totally deflected into channel **28**. However, wall **38** must be positioned such that maximum boundary layer attraction offered by it to the deflected power stream cannot maintain said power stream in a path through channel **28** during the absence of control signal input. That is to say, when control fluid source **34** subsequently becomes de-energized or de-activated so as to terminate the control fluid jet from nozzle **36** (or alternatively, at least reduced to have lesser energy), the deflected power stream in channel **28** must now be able to tear itself away from wall **38**, thus weakening the boundary layer because of less efficient power stream entrainment, and then return to its undeflected path through channel **22** at which time the boundary layer is completely destroyed. The attraction wall **38** is thus placed far enough away from the undeflected power jet to have no effect or influence thereon, and comes into play only when the power stream is moved closer thereto by action of the control jet. For any given control fluid energy, a po-

sition of wall **38** can be chosen to accomplish the above described functions.

It has been found that the smaller the value B in FIGURE 2, the greater will be the effect of wall attraction on a deflected power jet. The larger dimension A is, the greater is the effect of said wall attraction, but a change in dimension A has a lesser effect than does a change in dimension B. A change in dimension C apparently produces the greatest effect of changes in any of said three dimension. The smaller C is, the greater the said wall attraction.

FIGURE 3 shows a second embodiment of the present invention which also employs the basic feature of an attraction wall to obtain a gain increase, but wherein the control signal applied against the power stream jet is in the form of a fluid body having primarily static pressure energy rather than a mass flow dynamic jet having primarily kinetic energy. This additional feature will be described in subsequent paragraphs, but generally it may be said here that a control static pressure signal applied over a relatively large power stream area also permits of greater power stream deflection with less control power being required such that the attraction wall inverter of FIGURE 3 has even higher gain than does FIGURE 1. For this reason, too, the use of a control fluid pressure cushion in other types of fluid amplifier units is novel and useful because of the gain increase afforded thereby. The FIGURE 3 embodiment is further capable of operating at very low Reynolds numbers and is responsive to short input pulse rise times. It also permits greater tolerances in element geometry. As in the FIGURE 1 embodiment, the pure fluid inverter of FIGURE 3 is comprised of a group of interconnected fluid channels formed in a body **50** of fluid impervious material. A power stream input channel **52** and power stream source **54** are provided to produce a power stream jet of relatively large energy which issues forth into a chamber **56** from a nozzle **58** formed in one end wall thereof. Leaving the opposite end wall of chamber **56**, and directly in line with channel **52**, is a first power stream output channel **60** which receives the normally undeflected power stream jet and conveys same via pipe **62** to some utilization means **64**. No boundary layer lockon effect need be provided in channel **60**. A second power stream output channel **66** also leaves said opposite chamber end wall at an acute angle with channel **60**, with said channel **66** being separated from channel **60** by a divider edge **80** and further including an attraction wall **68** so located in the manner of FIGURE 1 to provide a boundary layer effect which enhances gain for deflection of power stream fluid into said channel **66**. A cavity **70** lies between the upstream edge of wall **68** and the nozzle end wall of chamber **56**. Although distance B (between the upstream edge or corner of said wall **68** and the power stream flow centerline) is shown to be smaller than in the case of FIGURE 1, it should be noted that the width C of the cavity **70** mouth (measured along the power stream flow axis) is larger so as to compensate for the smaller B dimension. Output channel **66** exhausts to a low pressure dump or return manifold here illustrated to be the atmosphere in the case of a pneumatic inverter.

As has already been mentioned, a different form of fluid control signal is provided in FIGURE 3 from that shown in FIGURE 1. A large chamber **72** is formed in the upstream portion of that side wall of chamber **56** which is opposite to the side wall from which channel **66** branches. The mouth **73** of said chamber **72** is considerably wider (as seen in the illustrated plan view) than the width of control nozzle **36** in FIGURE 1 so that it fronts along the power stream flow path through chamber **56** for a fairly long distance, preferably greater than one-third of the chamber length. This makes the area of the power stream, which is exposed to control fluid force, substantially greater in FIGURE 3 than the power stream area against which the considerably smaller diameter control jet in FIGURE 1 impinges. A control fluid input channel **74** is supplied with fluid from a selectively actuable control fluid source **76** via pipe **78** so as to fill chamber **72** with fluid to thereby increase the static pressure therein without, however, causing any significant conversion of static fluid pressure to dynamic or kinetic fluid pressure as is the case in channel **30** and nozzle **36** of FIGURE 1. Consequently, a fluid control jet, as such, does not strike the power stream jet in FIGURE 3, but there is rather a cushion of control fluid from chamber **72** bearing against the power jet curtain created by nozzle **58**. Although no specific means has been hereinbefore described for use as the sources **34** (FIGURE 1) or **76** of control fluid, one such input, among others, can come from the output of fluid logical OR circuit such as the one disclosed in a pending application S.N. 332,554, Fluid OR Gate, by Trevor D. Reader, now U.S. Patent 3,282,281. Since the control fluid in chamber **72** has little, if any, velocity in the direction of chamber **58**, there is no appreciable exchange of momentum between the control and power fluids. Cavity **70** furthermore constantly communicates via an opening **71** in body **50**, with a source of static pressure lower than the active signal presure in chamber **72**. This last named source may in certain cases conveniently be the same low pressure dump or return manifold to which channel **68** is connected, as shown in FIGURE 3. Any increase in control fluid static pressure at the mouth **73** of chamber **72** above the static fluid pressure existing at the mouth of cavity **70** produces a transverse static pressure differential or gradient across the power stream as it issues from nozzle **58**, which in turn deflects said power stream away from channel **60** and towards channel **66**. As soon as some power stream fluid commences to flow in channel **66**, a boundary layer region is created between it and wall **68**. When there is sufficient power stream flow through channel **66**, entertainment thereby of fluid in the boundary layer region adjacent wall **68** is at a faster rate than the rate at which fluid may be supplied to said boundary layer region via cavity **70** from the source connected to opening **71**. This causes said boundary layer static presure to be reduced below the cavity **70** pressure which thereupon aids the control fluid static pressure differential to further deflect the power stream completely into channel **66**. Upon a subsequent and sufficient decrease in the chamber **72** static pressure, as by termination of source **76** activity and withdrawal of fluid from chamber **72**, the transverse fluid static pressure differential across the power stream at the region of nozzle **58** thereupon disappears. In order to almost immediately reduce to zero this transverse control signal pressure gradient across the power stream at practically the instant of termination of control source **76** activity, FIGURE 3 can, if desired, also be provided with an additional cavity leading from chamber **58** downstream from mouth **73** in the manner of cavity **44** in FIGURE 1, with said additional cavity being connected to the same source of fluid as is cavity **70**, e.g., the low pressure dump to which channel **68** is also connected. The attractive effect exerted by the boundary layer region at wall **68** is by itself insufficient to maintain power stream flow completely in channel **66** and the power stream now begins to switch back into channel **60** thus weakening the wall attraction force so that it has a decreasing effect upon the power stream. As an additional aid to fast power stream return into channel **68**, the diminishing power stream entrainment in channel **68** finally fails to exhaust fluid from the boundary layer region faster than the rate at which fluid is being supplied to said region from cavity **70**. Consequently, the low pressure boundary region very quickly disappears so as to effect a rapid return of power stream flow into channel **60**. The particular location of wall **68** relative to other parts of the unit, and the communication of cavity **70** with a body of fluid for replenishing entrained fluid in the boundary layer region, therefore causes power jet fluid in channel **66** to quickly switch back into output channel **60** at the conclusion of control signal activity.

A further feature of FIGURE 3 is the provision of slightly diverging side walls in channel **66** such that said channel acts as a diffuser for power stream flow therethrough. This in turn permits the static pressure at the channel **66** entrance (in the vicinity of divider edge **80**) to be lower than the normal quiescent or ambient static pressure existing at the output of channel **60** in the absence of any power stream flow through the latter. This low channel **66** entrance pressure causes some entrainment, by the moving power stream fluid in channel **66**, of the quiescent fluid standing in channel **60** so as to cause a small reverse fluid flow in channel **60** in the direction of the dotted arrow. This reverse flow travels a path around edge **80** and into channel **66** for eventual exhaust into the low pressure dump, thereby causing the static pressure at the channel **60** output to utilization means **64** to be slightly lower than the dump pressure. This reverse flow effect makes even more pronounced the difference between the two pressure levels which exist at the output of channel **60** according to the presence or absence of power stream flow therethrough.

While several different embodiments of this invention have been shown and/or described, modifications may obviously be made thereto by those skilled in the art without departing from the novel principles defined in the appended claims.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A fluid inverter comprising; a body member having a fluid interaction chamber disposed therein, said interaction chamber having an end wall in which a fluid power nozzle is disposed, said fluid power nozzle being adapted when subjected to fluid input pressure to project a power jet through the interaction chamber, an output duct positioned to receive the undeflected power jet, said output duct comprising first and second spaced apart wall members located down stream from the power nozzle and on opposite sides of the axis of the power nozzle, a control signal chamber having an input duct at one end thereof for receiving control fluid input signals and a mouth portion at the other end thereof which opens into the interaction chamber on the same side of the power nozzle as the first wall member of the output duct, the said mouth portion extending from the power nozzle to a point at least one third the length of the interaction chamber downstream from the power nozzle, said control signal chamber being operative so that when a control fluid is applied thereto a static pressure signal will exist at said mouth portion thereby to deflect the power jet away from said output duct, a vent for said interaction chamber comprising the area between the said end wall and the second of said wall members comprising said output duct, and a divider block located in the said vent dividing said vent into two unloaded vent channels the first vent channel of which is defined by a first surface of said divider block and the said end wall and the second vent channel of which is defined by a second surface of said divider block and the second of said wall members of said output duct; the second vent channel providing an exhaust path for the power jet when it is deflected by a suitable pressure applied to the control chamber, said second surface of said divider block forming an acute angle with the axis of the power jet and being positioned and dimensioned to provide a boundary layer attraction force for the power jet only when said power jet is in its deflected position, and said first vent acting to reduce the boundary layer attraction force of the second surface of said divider block so that it is insufficient to maintain said power jet in its deflected position in the absence of a suitable control pressure applied to said control orifice.

2. The fluid inverter of claim **1** wherein the said two-vent channels exhaust into the same static low pressure dump.

3. The fluid inverter of claim **1** wherein said divider block is shaped to provide the said one-vent channel with a cross sectional area of expanding size.

References Cited

UNITED STATES PATENTS

3,001,539	9/1961	Hurvitz	137—81.5
3,159,168	12/1964	Reader	137—81.5
3,187,762	6/1965	Norwood	137—81.5
3,204,652	9/1965	Bauer	137—81.5
3,208,463	9/1965	Hurvitz	137—81.5
3,258,023	6/1966	Bowles	137—81.5
3,262,466	7/1966	Adams et al.	137—81.5
3,107,850	10/1963	Watten et al.	137—81.5 X
3,233,622	2/1966	Boothe	137—81.5
3,275,013	9/1966	Colston	137—81.5
3,282,281	11/1966	Reader	137—81.5

FOREIGN PATENTS

1,083,607	6/1960	Germany.

SAMUEL SCOTT, *Primary Examiner.*

U.S. DEPARTMENT OF COMMERCE

PATENT OFFICE

Washington, D.C. 20231

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,405,736 October 15, 1968

Trevor D. Reader et al.

It is certified that error appears in the above identified patent and that said Letters Patent are hereby corrected as shown below:

Column 8, line 22, "orifice" should read -- chamber --.

Signed and sealed this 3rd day of March 1970.

(SEAL)
Attest:

Edward M. Fletcher, Jr.
Attesting Officer

WILLIAM E. SCHUYLER, JR.
Commissioner of Patents