June 6, 1967 C. J. CAMPAGNUOLO 3,323,532

FLUID JET MOMENTUM COMPARATOR

Filed Feb. 23, 1965 2 Sheets-Sheet 1

FIG. 1

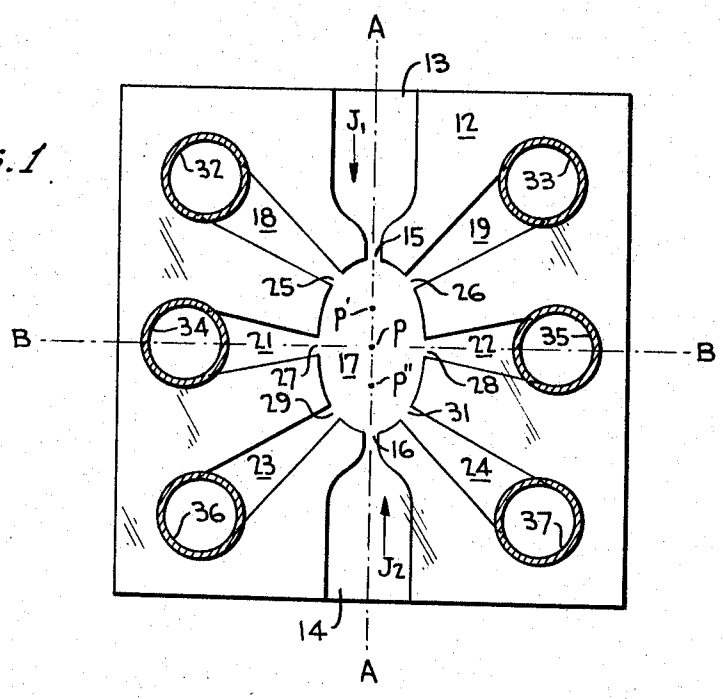
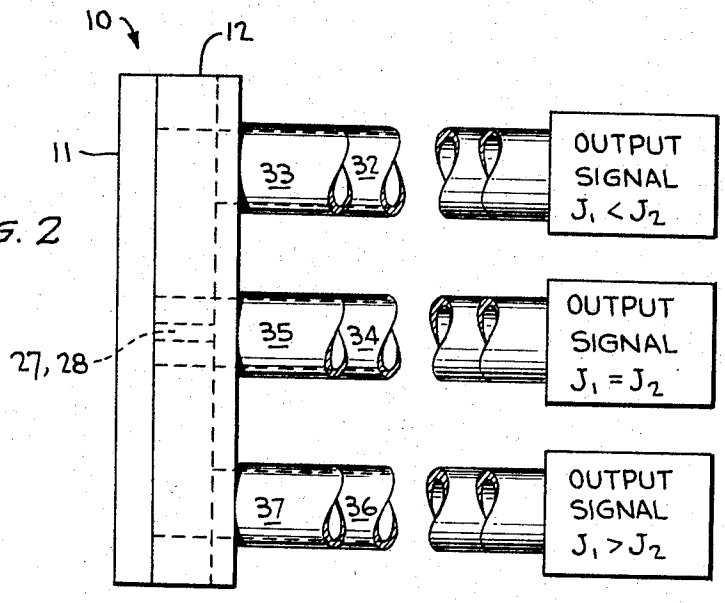


FIG. 2



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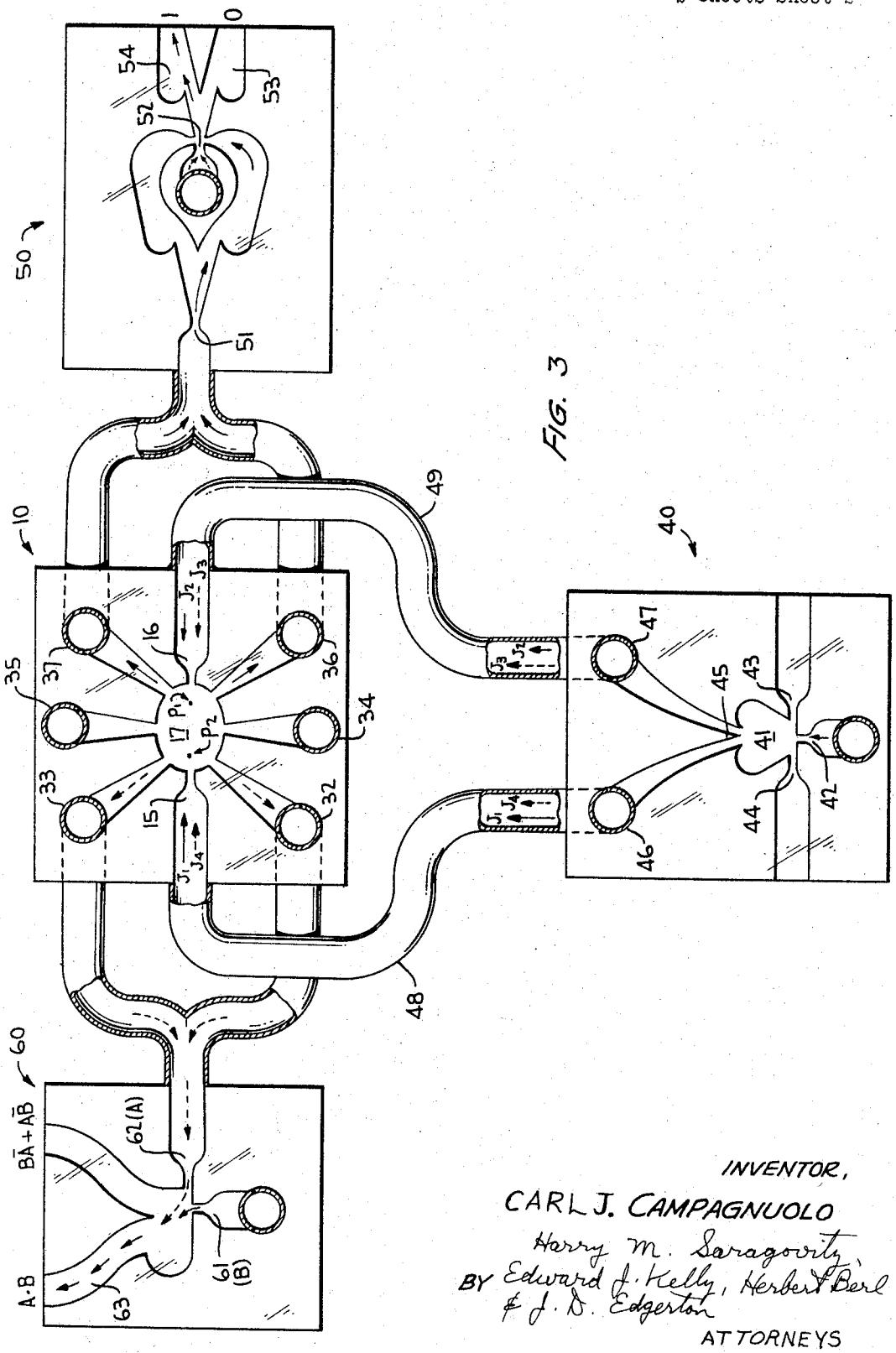


FIG. 3

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United States Patent Office 3,323,532 Patented June 6, 1967

3,323,532

FLUID JET MOMENTUM COMPARATOR

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Filed Feb. 23, 1965, Ser. No. 434,718
8 Claims. (Cl. 137—81.5)

ABSTRACT OF THE DISCLOSURE

Two fluid jets are directed against each other into an interaction region. A plurality of pairs of receiving apertures surround the interaction chamber. As the jets impinge on one another they will be deflected into a predetermined pair of apertures to produce an output signal which is dependent on the relative momenta of the jets.

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment to me of any royalty thereon.

This invention relates to pure fluid amplifiers and more particularly to a pure fluid analog-to-digital converter in the form of a fluid jet momentum comparator.

With the advance of pure fluid amplification, new systems are being developed which utilize no moving parts and on electronics to perform complex functions such as aircraft and missile guidance and industrial process control.

In situations where a rugged, reliable, low cost control system that is highly tolerant to environmental conditions is needed, and where very high speed operation is not a requirement, pure fluid amplifier systems have definite advantages over their electronic and electro-mechanical counterparts.

A pure fluid control system will often incorporate analog signal producing devices such as proportional amplifiers of the beam deflection type with digital logic elements such as flip-flops, OR-NOR gates, half-adders, counters and the like. In order to process the data received from the analog device, e.g. variations in fluid pressure, by means of a digital computer, the data must first be converted to a form usable by the computer. A pure fluid analog-to-digital converter will fulfill this need. In addition, in certain pure fluid logic systems, the strengths of fluid signals need to be compared for computer trend analysis.

Accordingly, it is an object of the present invention to provide a pure fluid analog-to-digital converter.

Another object of the invention is to provide a pure fluid device that will convert a variable fluid input signal to a binary fluid output signal.

A further object of the instant invention is to provide a pure fluid element that will compare the momenta of two input fluid jet streams to produce a binary output signal.

Still a further object of the invention is the provision of a pure fluid unit which utilizes stream interaction to compare the momenta of two fluid jets.

In accordance with an aspect of the present invention, the foregoing and other objects are attained by providing a pure fluid element wherein two fluid jet streams are directed towards each other into an interaction region surrounded by a plurality of pairs of receiving apertures that are positioned to receive the fluid resulting from the interaction of the jet streams. As the jet streams impinge on each other in the interaction region, they will be deflected into a predetermined pair of apertures to produce an output signal which will be dependent upon the relative momenta of the jets.

The specific nature of the invention, as well as other objects, aspects, uses and advantages thereof, will clearly appear from the following description and from the accompanying drawing, in which:

FIGURE 1 is a plan view of one embodiment of a fluid jet momentum comparator according to the teachings of the invention;

FIGURE 2 is a side elevation of the device of FIGURE 1; and

FIGURE 3 is a plan view showing the embodiment of FIGURE 1 as an analog-to-digital converter in combination with three other types of pure fluid devices.

The fluid jet momentum comparator of the present invention utilizes the well-known stream interaction or momentum control principles for causing one fluid jet stream to be directed into a receiving aperture by having a second jet of fluid impinge on the first jet. A detailed description of stream interaction fluid amplifiers may be found in B. M. Horton's Fluid System, Patent No. 3,122,165, issued Feb. 25, 1964.

The comparator, generally indicated by reference number **10**, may be made of the same materials and may be constructed in the same way as are other forms of pure fluid devices such as in the Horton patent supra. One mode of construction is shown in FIGURE 2 and consists essentially of flat plates **11** and **12** composed of a suitable material such as plastic, ceramic, glass or metal, with bottom plate **12** cut out to provide the nozzles, apertures and passages of the configuration of FIGURE 1 by any conventional method like cutting, stamping, etching or moulding. Top plate **11** serves as a cover plate and is secured in fluid-tight relation with plate **12** by means of screws (not shown), adhesive, or the like.

Referring more specifically now to FIGURE 1, comparator **10** is supplied with fluid under pressure from a source (not shown) to input channels **13** and **14** provided in plate **12**. Input channels **13** and **14** terminate in input jet nozzles **15** and **16** respectively which are disposed at the opposite ends of a flat, disk-like, substantially elliptically-shaped interaction chamber **17** having a major axis A—A and a minor axis B—B. Communicating with the interaction chamber **17** and positioned at selective points around the chamber are a series of output passages **18**, **19**, **21**, **22**, **23** and **24**, into which fluid from chamber **17** enters by means of receiving apertures **25**, **26**, **27**, **28**, **29** and **31** respectively and out of which the fluid leaves comparator **10** via suitable output conduits **32**, **33**, **34**, **35**, **36** and **37** respectively.

The output apertures with their respective channels are arranged around interaction chamber **17** in a star-like fashion, with one aperture on one side of the major axis A—A of the chamber acting in concert with a second aperture located the same distance from the minor axis B—B on the other side of the axis A—A for the reason to be described below. Nozzle orifices **15** and **16** as well as all of the receiving apertures are shaped to have a high aspect ratio, i.e. the ratio of the orifice depth to the width is high, as more clearly shown on FIGURE 2 with respect to apertures **27** and **28**. Fluid input signals enter the comparator **10** by means of the input channels **13** and **14** and issue from their respective input jet nozzles **15** and **16** in sheet-like fluid jet streams to impinge on one another head on in the interaction chamber **17**. The chamber is formed so that when the streams interact with each other and are deflected, there will be no interaction between the streams and the chamber walls. In the absence of the latter interaction, and with no forces from fluid around the streams, they will act as "free jets," momentum will be conserved and the jets will be deflected at angles proportional to their momenta. When the fluid streams issuing from opposing nozzles

15 and 16 interact, the location of a reference point called the impingement equilibrium point designated p, along the axis A—A, will determine which pair of apertures receives the resulting deflected fluid streams.

In the operation of the comparator 10, a fluid stream entering the chamber 17 from input nozzle 15 having momentum J_1 will interact along the line A—A with a fluid stream entering the chamber from the opposite input nozzle 16 having momentum J_2. If the streams have equal momenta, i.e. $J_1=J_2$, the impingement equilibrium point p will be at the center of chamber 17 and the fluid will exhaust through the pair of receiving apertures 27, 28 located along axis B—B to thereby produce an output signal in conduits 34 and 35 as seen in FIGURE 2. When the input fluid streams have unequal momenta, e.g. $J_1<J_2$, the impingement equilibrium point p will be caused to move along axis A—A to p' by the imbalance in the pressures of the opposing jets and the fluid will exhaust through the pair of output passages 18, 19 to produce a signal in conduits 32, 33. If $J_1>J_2$ then p will be displaced towards the weaker jet stream to the position p'' and the flow will produce a fluid output signal in conduits 36 and 37.

In certain applications, the momentum comparator is utilized to compare a single varying fluid flow signal with a reference fluid signal and in other instances two varying fluid signals are compared. Also, the comparator can have more than six output passages for providing a wider latitude in comparing the strengths of signals by adding additional pairs of receiving apertures with their corresponding output passages and conduits positioned in each quadrant around chamber 17.

FIGURE 3 shows one example of how the momentum comparator 10 can be employed to convert the signals received from an analog pure fluid proportional amplifier 40 to a binary fluid signal in order to trigger either the bistable flip-flop 50 or the AND logic unit 60.

Proportional amplifier 40 is of the well-known stream interaction type that has its interaction chamber 41 chosen to prevent the amplifier from exhibiting bistable characteristics which would result from its power stream 42 locking on to the chamber walls. The Horton patent supra or volume I of the Proceedings of the Fluid Amplifier Symposium sponsored by the Diamond Ordnance Fuze Laboratories (now Harry Diamond Laboratories) in October 1962, may be consulted for a more detailed description of this amplifier. Flip-flop unit 50 is a boundary-layer controlled type fluid amplifier generally employed in a fluid binary counter and is disclosed in detail in Patent No. 3,001,698 issued to R. W. Warren. For a complete description of the logic unit 60, which operates on stream interaction principles, the patent to R. W. Warren and B. M. Horton No. 3,107,850 should be referred to.

Comparator 10 will function as a fluid analog-to-digital converter in the pure fluid system shown in FIGURE 3 in the manner now to be described. With no control signals from left and right control nozzles 44 and 43 respectively of amplifier 40, power jet 42 will be evenly divided by splitter 45 and will produce fluid pressure signals at left and right outputs 46 and 47 respectively, having equal magnitudes. These signals will travel along conduits 48 and 49 and will issue as input jet stream from nozzles 15 and 16 into chamber 17 of comparator 10. Since the jets are of equal pressure they will be of equal momenta and will be deflected at right angles at the center of the chamber as was the case above when $J_1=J_2$, thereby causing the flow to exhaust through outlets 34 and 35. As the pressure of either of the control jets of amplifier 40 increases or decreases, the power jet 42 will be deflected accordingly and a differential fluid pressure signal will be obtained at outputs 46 and 47. If the flow from right control nozzle 43 increases, power jet 42 will be deflected to the left and the strength of the output signal at left output 46 will be greater than at the right output 47

as illustrated by the size of the arrows J_1 and J_2 respectively. Since $J_1>J_2$, the impingement equilibrium point will be displaced to p_1, whereby the flow will exhaust through outputs 36 and 37 and will become an input pulse at nozzle 51 to flip-flop 50. The power jet issuing from nozzle 52 will be switched from channel 53 to channel 54 thereby registering the digit 1 as in the Warren patent above. Logic unit 60 will be switched to indicate the AND function A.B when the relation of the strengths of the output signals of the proportional amplifier 40 is as shown by the dashed arrows J_3 and J_4. This condition will exist when the left control 44 increases sufficiently to deflect power jet 42 to the right, and J_3 becomes greater than J_4 to move the equilibrium point to the left to p_2. The fluid flow will exhaust via outputs 32 and 33 and arrive at nozzle 62 (A) to combine with the flow from nozzle 61 (B) to cause the switching of the logic unit.

It will be evident to those skilled in the art that the momentum comparator disclosed above may be employed in ways other than as a fluid analog-to-digital converter. It may be employed in other and different fluid systems, singly or in combination, whenever its unique characteristics are to be advantageously utilized.

It will be apparent that the embodiments shown are only exemplary and that various modifications can be made in construction and arrangement within the scope of the invention as defined in the appended claims.

I claim as my invention:

1. A pure fluid element of the type utilizing stream interaction principles for obtaining a fluid output signal comprising:
   (a) a substantially rigid, fluid tight body having an elongated elliptically shaped interaction chamber formed therein,
   (b) first and second nozzle means for introducing pressurized fluid jet streams into said chamber in opposite directions along the major axis of said chamber,
   (c) a plurality of channel means communicating with said chamber for selectively exhausting fluid out of said chamber,
   (d) said jet streams interacting with one another and being deflected at angles away from the path of said jet streams,
   (e) whereby said deflected jet streams being exhausted from said chamber via said channel means produce output signals in response to the relative momenta of said jet streams.

2. The pure fluid element of claim 1, wherein
   (a) said nozzles are of a high aspect ratio, and
   (b) said channel means communicating with said chamber by means of high aspect ratio apertures positioned around the periphery of said chamber.

3. The pure fluid element according to claim 2, wherein,
   (a) a plurality of equal number of apertures are located at predetermined positions on either side of the major axis of said chamber to thereby provide cooperating pairs of apertures,
   (b) the predetermined positions of each of said pairs of apertures corresponding to the location of the impingement of equilibrium point of said interacting jet streams, whereby
   (c) output signals will be produced in said channels in response to the displacement of said point along said major axis of said chamber,
   (d) the location of said point being dependent on the relative momenta of said impacting jet streams.

4. In combination with a pure fluid analog device and a pure fluid digital device, a pure fluid element for converting the analog fluid signals produced by said analog device to binary fluid signals to be used by said digital device comprising:
   (a) first nozzle means for introducing a varying fluid signal received from said analog device as a jet stream into an interaction chamber formed in said element,

(b) second nozzle means for introducing a second fluid jet stream into said chamber,

(c) said jet streams impinging head-on with respect to each other and being deflected away from the path of said streams according to their momenta,

(d) receiving means positioned at predetermined locations around said chamber for exhausting said deflected streams from said chamber and transmitting said streams to said digital device as binary signals.

5. In the combination of claim 4,

(a) said chamber having a flat disk-like elliptical configuration,

(b) said nozzle means being located at opposite ends of said chamber along the major axis thereof and having high aspect ratio openings.

6. A pure fluid momentum comparator comprising:

(a) first fluid conductor means symmetrical about an axis for producing a first jet stream,

(b) second fluid conductor means symmetrical about an axis for producing a second jet stream,

(c) said first means axis and said second means axis positioned along a common imaginary line and said first means and said second means a short distance from each other so said jet streams impinge on one another and deflect one another, and

(d) third means for receiving said deflected jet streams positioned on opposite sides of said imaginary line and terminating said streams as fluid signals.

7. A device according to claim 6 wherein said first means and said second means comprise nozzles.

8. A device according to claim 6 wherein said third means includes a pair of apertures, said apertures being set back from and positioned on opposite sides of said imaginary line to act in concert with one another to receive said deflected fluid.

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