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Mocarski

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[54] **FLUID DEVICE USING COANDA EFFECT**

[75] Inventor: **Zenon R. Mocarski**, Easton, Conn.

[73] Assignee: **S.R.C. Laboratories, Inc.**, Fairfield, Conn.

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[63] Continuation of Ser. No. 153,172, June 15, 1971, abandoned.

[52] **U.S. Cl.** **239/265.17**, 239/DIG. 7

[51] **Int. Cl.** **B63h 25/46**, B64c 15/10

[58] **Field of Search** .... 239/265.17, DIG. 7

[56] **References Cited**

UNITED STATES PATENTS

3,047,208 7/1962 Coanda 239/DIG. 7

FOREIGN PATENTS OR APPLICATIONS

1,235,302 5/1960 France 239/DIG. 7

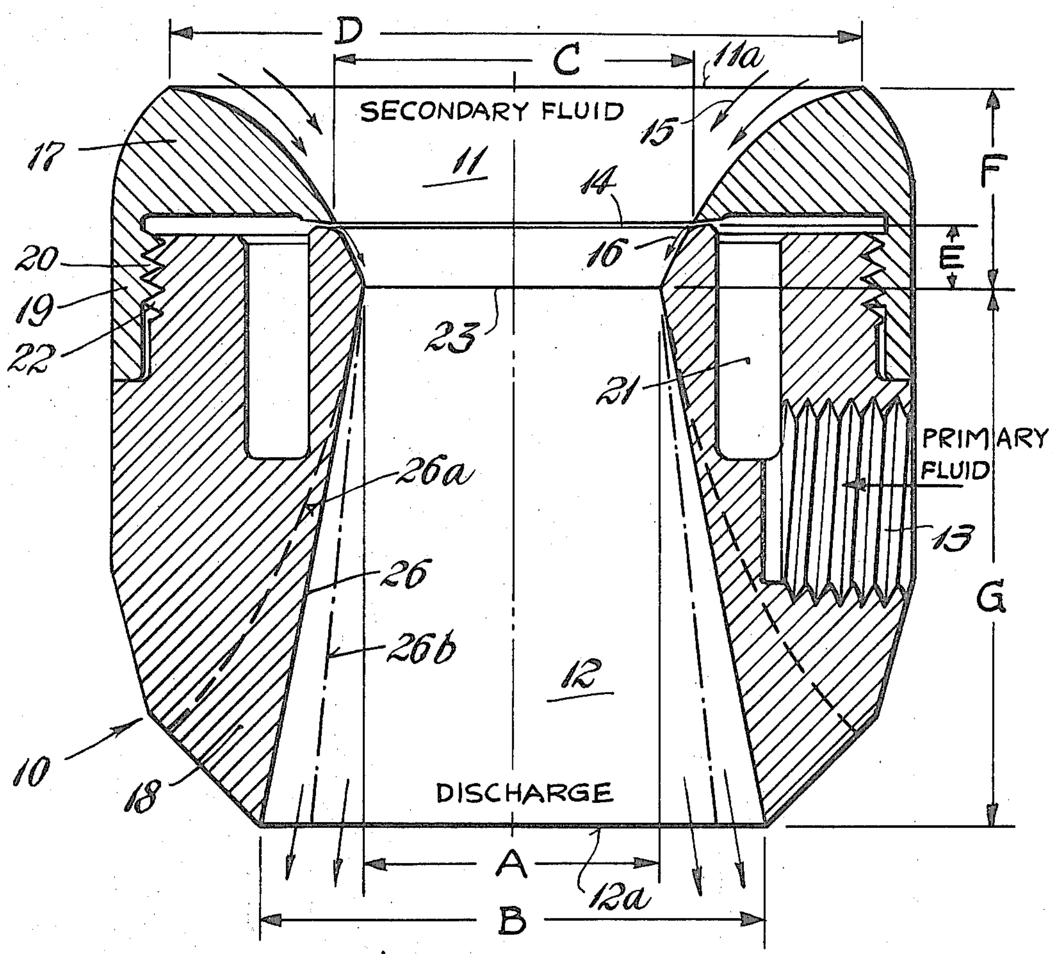
Primary Examiner—Lloyd L. King

Attorney, Agent, or Firm—Ernest M. Junkins

[57] **ABSTRACT**

A device using the Coanda effect by which a primary fluid of high velocity, small volume induces flow of a secondary fluid with the exhaust fluid being a combination of both fluids.

5 Claims, 3 Drawing Figures



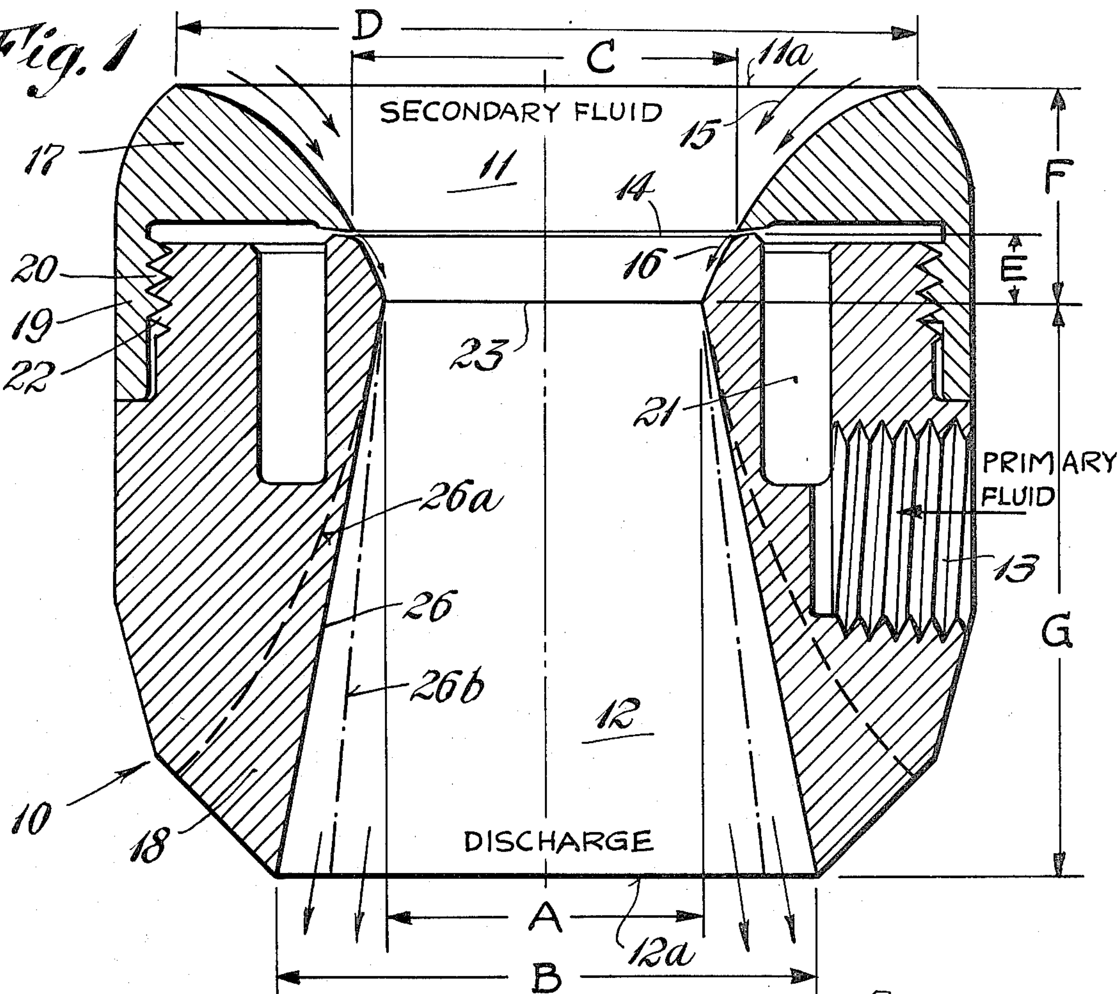


Fig. 1

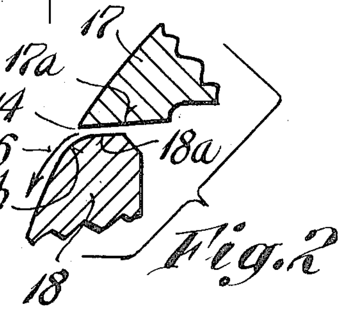


Fig. 2

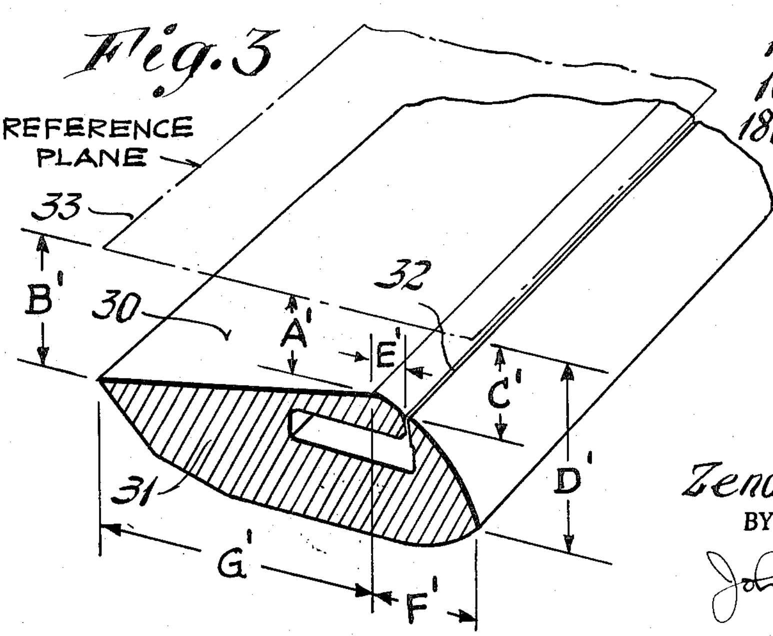


Fig. 3

INVENTOR.
Zenon R. Mocarski
BY
Johnson and Kline
ATTORNEYS

FLUID DEVICE USING COANDA EFFECT

This is a continuation, of application Ser. No. 153,172 filed June 15, 1971, now abandoned.

In U.S. Pat. No. 2,052,869 granted Sept. 1,1936 to H. Coanda there is disclosed a principle of fluid flow now sometimes referred to as the Coanda effect. Basically the effect involves discharging a small volume of fluid under high velocity from a nozzle with there being a shaped surface adjacent the nozzle. The stream of fluid (herein called the primary fluid) tends to follow the shaped surface and as it does it induces surrounding fluid (secondary fluid) to flow with it. Thus, along the shaped surface there is discharged an exhaust consisting of a combination of both the primary and secondary fluids.

This effect has been known for many years and at least the discoverer thereof has secured many patents on devices utilizing the principle (for example those disclosed in U.S. Pat. Nos. 2,713,510, 2,920,448 and 3,047,208). However, insofar as the present Applicant is aware, devices utilizing this effect have not been found to have widespread commercial acceptance even though they would appear to be capable of functioning. One reason which perhaps could serve as a basis for a lack of wide acceptance is that the efficiency of heretofore constructed devices has been of such relatively low value that it renders the devices somewhat commercially impractical.

It is accordingly an object of the present invention to provide fluid devices utilizing the Coanda effect which are more efficient than heretofore known devices.

Another object of the present invention is to achieve the above object simply by altering the relative relationship of the parts and the shapes of the surfaces.

A further object of the present invention is to provide a fluid device utilizing the Coanda effect for inducing movement of one fluid by the discharging of another fluid which though attaining the above objects is extremely simple in construction and reliable in use.

One type of device which has been suggested using the Coanda effect is conveniently called a nozzle and it is used for moving a quantity of available air (secondary fluid) by use of a discharge of compressed air (primary fluid) thereinto. Such a device consists of a tubular member having an entrance open to the atmosphere or other source of secondary fluid and an exhaust with a portion therebetween having a restricted cross-sectional area which forms a throat. The throat serves as a boundary between the exhaust and entrance and secondary fluid flows from the entrance through the throat to be discharged from the exhaust. Formed in the tube prior to the throat along the line of movement of the secondary fluid is an annular slit through which the primary fluid is ejected to cause the flow of the secondary fluid so that both fluids flow through the throat and the exhaust to be discharged as a jet containing both fluids in combination.

As the discharge involves both fluids and has velocity, one manner of measuring the efficiency of such a nozzle consists of determining the thrust which the discharged fluid has and comparing it to the thrust which the primary fluid is capable of causing. If the thrust of the primary fluid is considered to be 1 then the values of thrust reported in heretofore available literature of this type of device has been on the order of 1.23 to 1.4 and generally referred to as the thrust agumentation ratio. Thus the device augments the thrust of the primary fluid by a factor of .23 to .4 as the 1 in the ratio is that thrust which the primary fluid introduces in the system.

In similar devices constructed according to the present invention as hereinafter described, such nozzles have consistently achieved a thrust augmentation ratio of 1.8. This is an increase in the thrust augmentation ratio over the highest heretofore known or reported ratio of .4 and when compared to the latter, provides when just thrust increase is considered, an increase of more than 25 percent (.4 over 1.4). However, the ratio also indicates that the flow of secondary fluid has essentially doubled (from .4 to .8) and if the device is used as a pump for pumping secondary fluid, the efficiency has been increased by about 100 percent.

The substantial increase in efficiency has been obtained by altering the relationship of the parts and the shapes of the surfaces from that heretofore known and suggested. Specifically the throat is made to be extremely thin, essentially just a line caused by the junction between adjacent boundaries of the entrance surface and the exhaust surface, the exhaust surface diverges outwardly from the throat as it recedes from the throat but in a shape which maintains laminar flow of both fluids, the entrance is shaped to diverge exceedingly rapidly from the throat as it progresses therefrom and the primary fluid annular slit is positioned extremely adjacent the throat. These particular relationships have been found to all contribute to the substantial increase in efficiency of devices utilizing the Coanda effect for moving a secondary fluid by use of a primary fluid.

Other features and advantages will hereinafter appear.

In the drawing:

FIG. 1 is an axial section of a fluid device using the Coanda effect and is particularly referred to herein as a nozzle.

FIG. 2 is an enlarged detail of the annular slit through which the primary fluid is ejected.

FIG. 3 is a representation of a linear device in which the present invention is incorporated.

Referring to the drawing, one embodiment of a fluid device utilizing the present invention is shown in FIGS. 1 and 2 and generally is indicated by the reference numeral 10. This device may conveniently be referred to as a nozzle as it is circular, having an entrance 11 and an exhaust 12 with fluid being discharged from the exhaust. The exhausted fluid is made up of the combination of a primary fluid and a secondary fluid. The secondary fluid surrounds the end 11a of the entrance 11 (as so indicated in FIG. 1) and the flow of the secondary fluid through the nozzle is caused by introducing the primary fluid into an inlet 13 and ejecting it through an annular slit 14. The secondary fluid flow is indicated by arrows 15 while the primary fluid flow is indicated by arrows 16 and the fluids combine to produce a discharge at the end 12*a* of the exhaust.

Structurally the nozzle 10 is formed of just two annular parts 17 and 18 with the part 17 serving to define the portion of the entrance 11 that is prior to the slit while the part 18 defines the remainder of the entrance 11, and all the exhaust 12. Each of the parts may be made of rigid material such as metal.

The part 17 has the diametric cross-section shown and includes an annular flange 19 formed with threads

20. The part 18 also has the diametric cross-sectional shape shown and is formed to provide an annular passageway 21 which communicates with the inlet 13. The interior of the inlet may be threaded to facilitate connection to a source of primary fluid. Additionally, the part 18 has threads 22 which mate with the threads 20 to effect unifying of two parts, and serve as a seal to prevent primary fluid escaping from the passageway 21.

Referring to FIG. 2 there is shown an enlarged section of the shape of the adjacent portions of the two parts 17 and 18 which define the slit 14. Particularly the part 17 has a flat surface 17*a* while the part 18 is formed to also provide a surface 18*a* which is also somewhat flat but has a small radius 18*b* (such as .030 inch) at its end between the surface 18*a* and the interior of the part 18. The two surfaces may be parallel and basically perpendicular to the axis of the nozzle or there may be a slight angle to one, as for example, 5 degrees for the surface 17*a* but in any even the exiting of primary fluid through the slit 14 will be caused to follow the surface of the part 18 in the direction of the arrow 16 by reason of the Coanda effect.

It will be understood that the width of the slit between the surfaces 17*a* and 18*a* is one factor in setting the quantity of primary fluid that may flow, and typical values of the width range on the order of .002 to .010 inch for the specific embodiments hereinafter described. The extent of the width may be advantageously controlled by relative rotation between the parts 17 and 18 which provides linear movement along the axis of the nozzle through the cooperating threads 20 and 22.

The exterior shape of the nozzle is not particularly critical and, as shown, is generally cylindrical while the shape of the interior path through the nozzle has been found to be extremely critical in obtaining the substantial increase in efficiency of the present invention. The path includes a throat 23 which defines the smallest cross-sectional area of the path and serves as a boundary between the entrance 11 and the exhaust 12. The exhaust 12 may have the frusto-conical shape 26 shown in solid lines when it is desired to maximize thrust; or a more bell shape as shown by the dotted line 26*a* when it is desired to provide for maximum flow or a shape such as shown by the dotted line 26*b* when it is desired to more accurately control the direction of the discharged fluid. With all shapes the exhaust increases in area from the throat by diverging from the reference axis as it recedes from the throat in such a manner that it maintains laminar flow of the fluid and does not create turbulence.

The entrance 11 has been found to be quite critical in its shape and it enlarges from the throat 23 towards the entrance end 11a with the increase being at an increasing rate as the entrance progresses from the throat. The sharp increase in the size of the entrance has been found to be essential to the present invention for reasons which are not yet completely understood but the shape of the entrance should be such as to enable the secondary fluid to have laminar flow and not turbulence upon entering the path.

The throat 23 is shown as a line caused by the abutting of the entrance 11 and exhaust 12 and it has been found that the length of the throat along the path should be minimum. Accordingly, the throat is essentially only a line which may be somewhat visually absent if the boundary between the entrance 11 and the exhaust 12 is caused to be radiused so as to elimininate a sharp intersection. It is also pointed out that the slit 14 must be quite close to the throat in order to achieve the substantial efficiency increase.

The nozzle portrayed in FIG. 1 is a scale drawing of a tested nozzle drawn four times actual size and hence the shapes shown are accurate representations of those which an existing nozzle has. In order to enable a person skilled in the art to practice the invention there is herein tabulated dimensions (in inches) for four nozzles which have been found to achieve the increased efficiency with model 00 being the model for the nozzle shown in FIG. 1 as it appears by testing to date to be the most efficient nozzle.

Model	A	B	C	D	E	F	G
00	.556	.937	.666	1.312	.122	.363	.980
01	.550	.875	.580	1.250	.187	.468	.927
02	.550	.843	.660	1.343	.157	.375	.812
03	2.218	3.375	2.562	5.125	.437	1.562	2.812

The dimension A in the table is the throat diameter; B is the exhaust end (12*a*) diameter; C is the slit diameter; D is the entrance end (11*a*) diameter; E is the distance from the slit to the throat; F is the distance from the entrance end 11*a* to the throat and G the distance from the throat to the exhaust end 12*a*.

With respect to the above table it will be appreciated that certain ratios are useful in the design of the nozzle. One ratio is the distance from the entrance end to the throat divided by the distance from the slit to the throat (F divided by E) along the reference axis and this has been typically found to be about 3 and thus within a range of 2 to 4. It will also be understood that F and E may vary slightly as the width of the slit 14 is varied with the slit width being normally as small as possible to cause the primary fluid to be ejected with as large a velocity as possible and yet at a quantity which will maintain laminar flow and effect ejection of the necessary mass of primary fluid to induce the flow of the secondary fluid.

Another important ratio is the diameter of the slit 14 (C) as compared to the diameter of the throat (A). This has typically been found to be about 1.2 (C divided by A) which falls within a range of 1.1 to 1.3.

Another ratio which is also considered to be of importance in the present invention is the ratio between the throat diameter (A) and the entrance end diameter (D) with the entrance diameter being about 2.35 for the first nozzle and falling within the range of about 2.0 to 3.0 for the remaining nozzles thus showing that the entrance diameter is substantially larger than the throat diameter but yet the entrance end area is only a short axial length from the throat.

As to the dimensions B and C which are those of the exhaust end 12*a* and the axial distance that the end is from the throat, they are not especially critical provided the exhaust is shaped to provide laminar flow. The length of the exhaust section is again variable depending upon whether it is desired to use the nozzle for volume flow, thrust or to control the direction of the discharged fluid.

Shown in FIG. 3 is a further embodiment of the present invention in which rather than providing a closed path for the fluids such as the nozzle 10, they follow the upper surface 30 of a linear section 31. The primary fluid may be directed through a slit 32 to induce flow of secondary fluid over the surface 30 to thereby create lift or a vacuum above the section. The shape of the upper surface is identical with the shape of the entrance, exhaust and throat of the path through the nozzle and the above-noted ratios apply. However, the various distances instead of being diameters are distances (equal to radii) from a reference plane 33 located above the section and corresponding to the axis of the path of the nozzle in FIG. 1. They are indicated in this embodiment by using the same letter with the addition of a prime thereto.

It will accordingly be appreciated that there has been disclosed a fluid device which utilizes the Coanda effect on a primary fluid to cause movement of a secondary fluid into which the primary fluid is ejected. The particular construction and relationship of the parts wherein the throat is made to have essentially no axial length, the entrance is made to very substantially increase from the throat and the primary inlet is placed close the throat together with having the exhaust extend from the throat outwardly in a shape which maintains laminar flow of the combined fluids enables the present invention to provide a substantial increase in efficiency over the heretofore known similar type devices.

Variations and modifications may be made within the scope of the claims and portions of the improvements may be used without others.

I claim:

1. A nozzle for effecting movement of a secondary fluid by a pressurized primary fluid comprising means forming a passageway having an entrance and an exhaust and an intermediate throat, said throat being the smallest cross-sectional area of the passageway nearest the entrance, a slit communicating with the passageway between the throat and the entrance, said throat and slit each having a diameter and being axially spaced along the passageway, said entrance being open to the secondary fluid and a source of pressurized primary fluid being adapted to be connected to the slit whereby flow of primary fluid through the slit induces flow of secondary fluid into and through the passageway with both fluids being discharged from the exhaust, the improvement comprising said slit being located closely adjacent said throat with the ratio of the throat diameter divided by the linear axial distance between the throat and slit being greater than essentially 3 and with the ratio of the throat diameter to slit diameter being less than 1.5.

2. The invention as defined in claim **1,** in which the range of the ratio of the throat diameter to slit diameter is 1.1 to 1.3.

3. The invention as defined in claim **1** in which the angle of discharge between the slit and the axis of the passageway is greater than essentially 60° and is determined by the complement of the tangent of the angle of the ratio of the difference between the throat and slit radii divided by the linear axial distance between the throat and slit.

4. The invention as defined in claim **1** in which the entrance has an entrance end and in which the ratio of the linear axial distances from the throat to the entrance end and the throat to the slit is in the range of 2 to 4.

5. A fluid device for inducing movement of a secondary fluid by the use of an ejected primary fluid with the discharge being a combination of the two fluids comprising a first and a second surface, said surfaces being aligned and having one end common to define a throat, a common reference with said throat being the nearest part of the surfaces to the reference, the first surface forming an exhaust and diverging from the reference as it recedes from the throat and being shaped to effect laminar flow of fluid thereover, said second surface forming an entrance and diverging from the reference as it progresses from the throat in the opposite direction to the receding of the first surface and having its other end form an entrance end that is positioned in a supply of secondary fluid, a slit formed through the second surface and means adapted to connect the slit to a source of primary fluid under pressure so that a flow of primary fluid under pressure through the slit induces a flow of secondary fluid from the entrance along a path past the slit and throat and the first surface to have the combined fluids discharge from the first surface, the improvement comprising said throat having essentially no length along the path, the slit is just slightly further from the reference than the throat is from the reference and is located closely adjacent the throat with the ratio of twice the distance from the reference to the throat divided by the linear distance along the reference between the throat and slit being greater than essentially 3 and with the ratio of the distance from the reference to the slit divided by the distance from the reference to the throat being less than 1.5.

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