United States Patent [19]

Bowditch

[11] **3,894,552**

[45] **July 15, 1975**

[54] **TRANSDUCER NOZZLE**

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[73] Assignee: **The Foxboro Company,** Foxboro, Mass.

[22] Filed: **Jan. 31, 1974**

[21] Appl. No.: **438,302**

[52] **U.S. Cl.** **137/82;** 73/37.5

[51] **Int. Cl.²** **F15B 5/00;** G01B 13/12

[58] **Field of Search** 73/37.5–37.9; 137/829, 82

[56] **References Cited**

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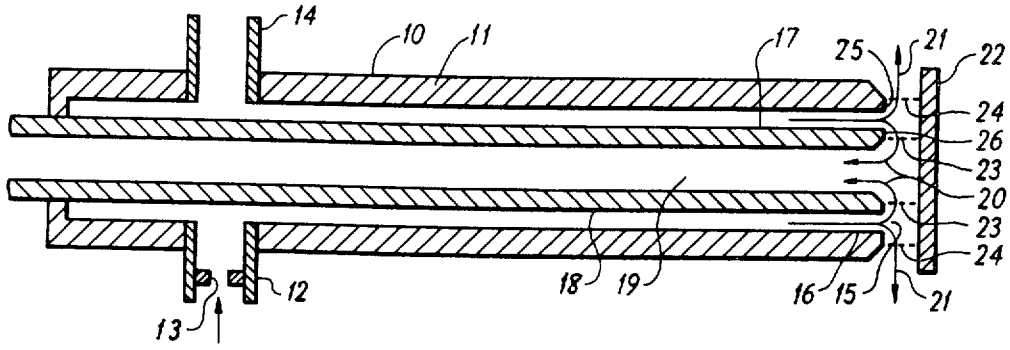
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Primary Examiner—Richard C. Queisser
Assistant Examiner—Frederick Shoon
Attorney, Agent, or Firm—Frank J. Fleming

[57] **ABSTRACT**

A nozzle for use in a pneumatic transducer of either the motion balance type or of the force balance type in which the useful nozzle output pressure is proportional to the mechanical position of a flapper with respect to the nozzle orifice. This nozzle utilizes an endless narrow slot orifice, such as an annular orifice, which provides an inner curtain and an outer curtain through which the fluid flows are regulated by the mechanical position of a single flapper to produce a useful output pressure signal. Various modes of operation of a transducer to introduce rate action using this nozzle are achieved by discharging the fluid from one curtain into auxiliary components. Rate mode is achieved by discharging the fluid from one curtain through a restrictor into a capacity chamber.

6 Claims, 5 Drawing Figures



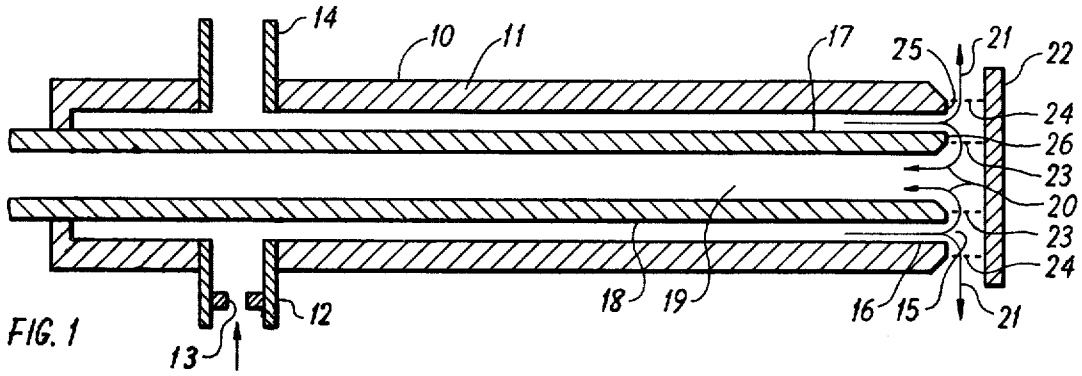


FIG. 1

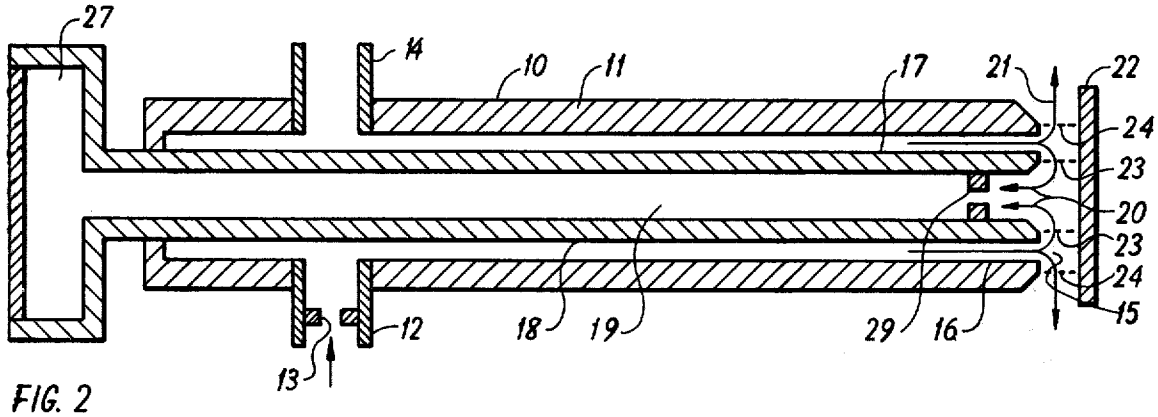


FIG. 2

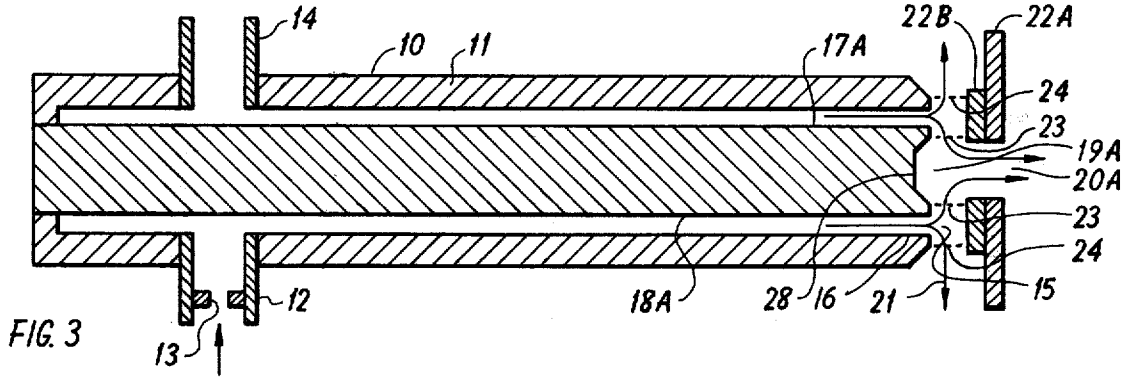


FIG. 3

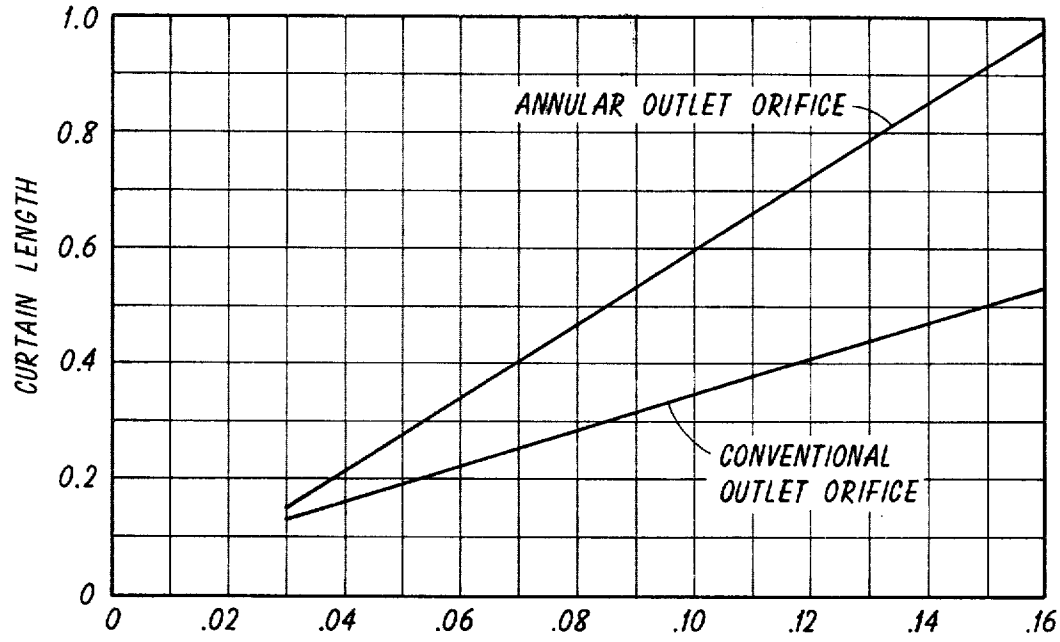

1.0
0.8
0.6
0.4
0.2
0
CURTAIN LENGTH
ANNULAR OUTLET ORIFICE
CONVENTIONAL
OUTLET ORIFICE
0
.02
.04
.06
.08
.10
.12
.14
.16
OUTLET ORIFICE DIA.

FIG. 4

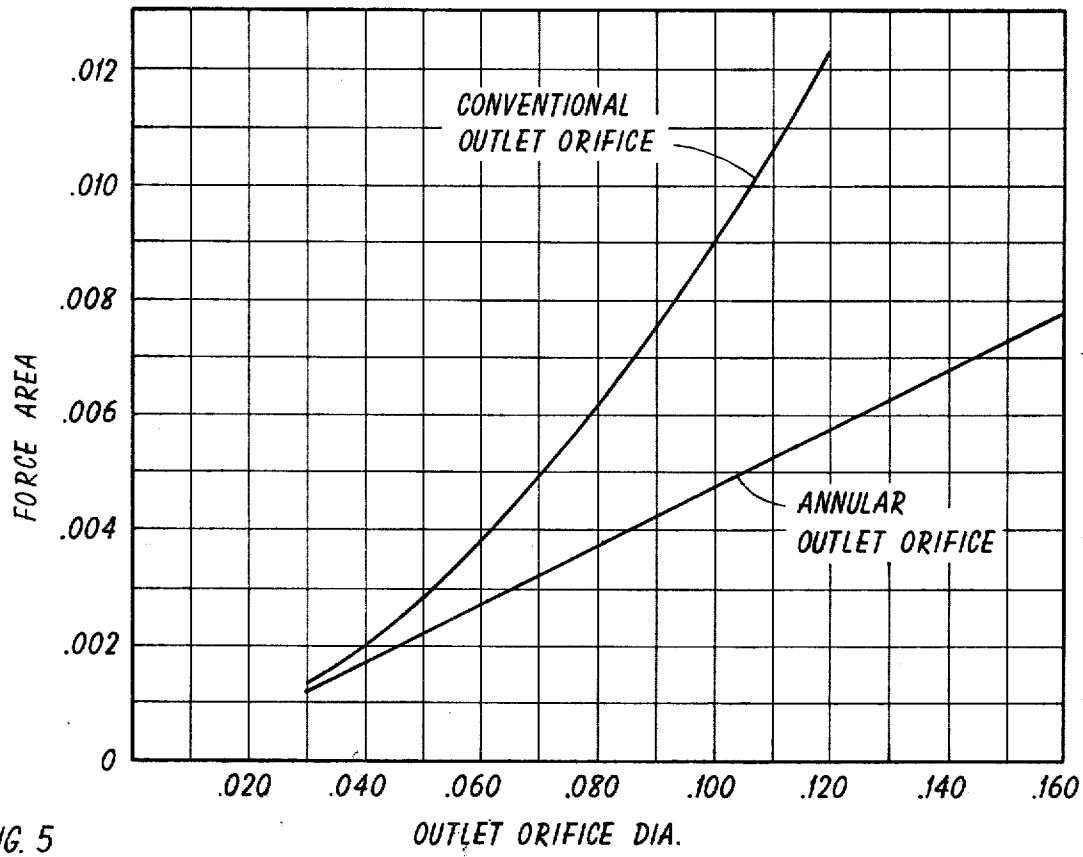

.012
.010
.008
.006
.004
.002
0
FORCE AREA
CONVENTIONAL
OUTLET ORIFICE
ANNULAR
OUTLET ORIFICE
.020
.040
.060
.080
.100
.120
.140
.160
OUTLET ORIFICE DIA.

FIG. 5

TRANSDUCER NOZZLE

FIELD OF INVENTION

This invention relates generally to industrial pneumatic transducers of either the motion balance type or of the force balance type in which the useful nozzle output pressure signal is proportional to the mechanical position of a flapper with respect to the face of the nozzle orifice. Industrial pneumatic transducers are used in combination with measuring devices to produce output signals proportional to the value of a process variable, or in combination with measuring devices to produce an output control signal, or in combination with other pneumatic transducers as computers. This invention is more particularly related to the nozzle used in such transducers.

DESCRIPTION OF THE PRIOR ART

U.S. Pat. No. 2,652,066, issued to applicant, is an example of an industrial pneumatic transducer of the motion balance type in which the nozzle of the present application could be advantageously substituted for the conventional nozzle **26** of the patent.

U.S. Pat. No. 2,930,231, also issued to applicant, is an example of an industrial pneumatic transducer of the force balance type in which the nozzle of the present application could be advantageously substituted for the conventional nozzle **106** of the patent.

The following patents are cited as examples of the prior art relating to nozzles useful in the general field of the present invention: Scharpf U.S. Pat. No. 2,128,378 (FIG. **2**); Knobel U.S. Pat. No. 2,692,498; Ranfenbarth U.S. Pat. No. 3,099,995 (FIG. **3**).

Each of the nozzles disclosed in the above cited art has a conventional single curtain area and is incapable of providing both an inner curtain area and an outer curtain area through which the fluid flows are simultaneously regulated by the position of a single flapper.

Hudson U.S. Pat. No. 3,127,764, FIG. **2***b*, is an example of a layer nozzle which functions on a different principle and is not useful in the general field of the present invention.

SUMMARY OF THE INVENTION

For a better understanding of the invention, the basic structure of a nozzle and terms used in discussing its operating characteristics are defined.

The term "nozzle" is used herein to mean a complete assembly including, in combination, an output pressure chamber, an inlet passage for connecting the interior of the chamber to a supply of constant pressure fluid, an inlet restrictor located in the inlet passage, an outlet orifice providing a passage from the interior of the chamber to its exterior, and an outlet pressure passage for connecting the interior of the chamber to a utilization device. The term "flapper" is used herein to mean any device having a surface used to restrict the flow of fluid through the outlet orifice of the nozzle. Applicant's invention resides in the modification made to a conventional nozzle which results in substantial improvement in at least three of the operating characteristics of the nozzle.

In order to regulate the flow of fluid through the outlet orifice of a nozzle to produce an output pressure within the operating limits of the nozzle, the distance of the flapper from the face of the outlet orifice must be small in relation to the diameter of the outlet orifice.

The term "curtain" is used herein to mean the surface of the fluid discharging between the flapper and face of the outlet orifice at which the pressure drop occurs. For a circular outlet orifice, the curtain has a cylindrical surface with a diameter slightly larger than the diameter of the outlet orifice. The length of the curtain is the perimeter or circumference of the curtain. The area of a curtain is dependent on the distance of the flapper from the face of the outlet orifice.

In a nozzle, the curtain and inlet restrictor form a pressure divider which is adjustable by moving the flapper to adjust the area of the curtain. The operating characteristics of a specific nozzle may be changed by altering only the outlet orifice.

The term "gain in the motion system" of a transducer is used herein to mean the ratio of the distance the flapper moves to the output pressure signal change of the nozzle. The gain of the motion system of a transducer is increased linearly in proportion to the increase in the length of the curtain of the outlet orifice of its nozzle. An increase in the gain of a motion system means that a corresponding shorter movement of the flapper is required for a full range change in the output pressure signal of the nozzle. In a conventional nozzle having a single curtain area, the motion gain is directly proportional to the diameter of the outlet orifice.

The term "speed of response" of a transducer is used herein to mean the lapsed time required from the moment the flapper is moved to a new position for the output pressure signal to change to the corresponding new value. The speed of response of a transducer changes as a function of any changes made in the curtain length of the outlet orifice of the nozzle. In a conventional nozzle having a single curtain, the speed of response of the transducer using the nozzle is a function of the diameter of the outlet orifice of the nozzle. The larger the diameter of the outlet orifice, the faster the speed of response will be.

The term "gain of the force system" of a transducer is used herein to mean the ratio of the available operating force applied to the flapper to the feedback force applied to the flapper by the fluid discharging from the outlet orifice of the nozzle. The gain of the force system of a transducer is inversely proportional to the area of the outlet orifice. In a conventional nozzle, the feedback force is a function of the square of the diameter of the outlet orifice multiplied by the fluid pressure of the fluid flowing from the outlet orifice.

The term "mode of operation" of a transducer is used herein to mean the introduction of dynamic compensation into the feedback loop of the transducer. One example is the use of rate action to reduce the affect of lags in the response of a thermal system.

In examining the three operating characteristics discussed above, it can be seen that when the diameter of the outlet orifice of a conventional nozzle is increased in order to increase the gain of the motion system and improve the speed of response, there is a deleterious reduction in the gain of the force system.

It is the principal object of this invention to provide a nozzle in which a change in the dimensions of the outlet orifice will act to improve simultaneously the gain of the motion system, the speed of response and the gain of the force system.

It is another object of this invention to provide an improved nozzle which is economical to manufacture to close tolerances in quantity lots.

It is a further object of this invention to provide an improved nozzle which is adapted to be combined with other components to produce modifications in the mode of functioning of a transducer in which the nozzle is used.

It is still a further object of this invention to provide an improved nozzle which is adapted to be combined in a novel manner with a capacity chamber to provide rate action to a transducer in which the nozzle is used.

The objectives of this invention are achieved by constructing the outlet orifice of the nozzle in the form of an endless slot, such as an annular orifice, to provide an inner curtain and an outer curtain through which the fluid flows are regulated by the mechanical position of a single flapper to produce a useful output pressure signal.

As a result of the dual curtains, gain of the motion system and the speed of response of the transducer in which the nozzle is used are substantially improved as compared to a conventional nozzle. In addition, the dual curtains result in an improvement in the gain of the force system of a transducer in which the nozzle is used proportional to the square of the difference in the diameters of the curtains as compared to a conventional nozzle having the same nominal outlet orifice diameter.

Other objectives of this invention are achieved by the physical separation of the two curtains such that the discharge from each curtain may be independently discharged to an external area to introduce selected modes of operation of the transducer in which the nozzle is used. Rate mode may be introduced, for example, by discharging the inner curtain through a restrictor into a capacity chamber.

DESCRIPTION OF THE DRAWINGS

The objectives and advantages of this invention will be more fully understood from the description taken in connection with the accompanying drawings, wherein:

FIG. 1 shows schematically a cross-sectional view of a preferred embodiment of the nozzle according to this invention.

FIG. 3 shows schematically a cross-sectional view of another form of the nozzle according to this invention, with the discharge of the inner curtain area through an opening in the flapper.

FIG. 2 shows schematically a cross-sectional view of the nozzle according to this invention, having the inner curtain area discharge through a restrictor into a capacity chamber to provide rate action.

FIG. 4 is a chart comparing curtain lengths of a conventional outlet orifice with an annular outlet orifice.

FIG. 5 is a chart comparing force areas of a conventional outlet orifice with an annular outlet orifice.

DESCRIPTION OF PREFERRED EMBODIMENTS

Referring to FIG. 1, the nozzle of a preferred embodiment of this invention comprises a tubular cylindrical body **10** having a wall **11.** The interior of body **10** is connected to a source of fluid at constant pressure (not shown) by inlet connection **12.** A restrictor **13** is located in the inlet connection **12** to restrict the flow of fluid from the source to the interior of body **10.** The interior of body **10** is also connected to a utilization device (not shown) such as to the feedback component of a transducer in which the nozzle is used, by output pressure connection **14.** The nozzle thus far described is the same as conventional nozzles and the size and proportions of internal volume of the body **10** and restrictor are determined by well-known techniques.

The heart of this invention is the configuration of the outlet orifice **15.** The orifice **15** is in the form of an endless slot. Although an endless slot having any shape is within the scope of this invention, the preferred embodiment uses an annular slot. Outlet orifice **15** in the annular shape is formed by the inner surface **16** of one end of the tubular cylindrical body **10** and the outer surface **17** of plug **18** which is mounted in body **10** with the surfaces **16** and **17** concentric to each other. The outer end of cylindrical body **10** is shaped to form narrow face **25.** Plug **18** has a central passage **19** through its entire length. The outer end of central passage **19** is shaped to form narrow face **26.** Flapper **22** is movable towards and away from outlet orifice **15** to regulate the flow of fluid discharging from the outlet orifice **15.**

In operation, fluid discharges from outlet orifice **15** through the space between the flapper **22** and narrow faces **25** and **26.** The surface of flapper **22** and the surfaces of narrow faces **25** and **26** provide a resistance to the flow. Tests have shown that the effective surface of a curtain is located at the mid point in the width of the narrow face as indicated by the dotted lines **23** and **24.** One path of fluid flow is from the outlet orifice **15** through inner curtain surface **23** and central passage **19** to atmosphere as indicated by arrows **20.** A second path of fluid flow is from the outlet orifice through outer curtain surface **24** to atmosphere as indicated by arrows **21.** Outlet orifice **15** in cooperation with flapper **22** and restrictor **13** form an adjustable pressure divider for fluid supplied at a constant pressure to the restrictor **13.**

The advantage of the endless narrow slot orifice having dual curtains is shown by the graphs in FIGS. **4** and **5** and the following explanation thereof. The comparison is based on the assumption that the only change made in a specific nozzle is in the dimensions and type of outlet orifice. The comparison is further simplified by assuming that narrow faces **25** and **26** are **0.010** inches wide and the width of the slot formed between surfaces **16** and **17** is 0.006 inches. The curtain length L_c for a conventional outlet orifice having a diameter D is calculated as follows:

$$L_c = (D + 0.010). \pi$$

The curtain length L_a for an annular outlet orifice having an outer diameter D (surface **16**) and an inner diameter *d* (surface **17**) is calculated as follows:

$$L_a = (D + 0.010). \pi + (d - 0.010). \pi$$

$$L_a = (D + d). \pi$$

FIG. 4 shows graphs of the curtain lengths of conventional outlet orifices and of annular outlet orifices plotted for a range of diameter D. This graph demonstrates the substantial increase in the curtain length achieved by using the endless slot outlet orifice of this invention. The increase in curtain length results in a substantial increase in both the motion gain and speed of response of the transducer using the nozzle.

The feedback force is a function of the area of the fluid under pressure acting on the flapper. The area of the fluid exerting the feedback force for a conventional outlet orifice A_c is calculated as follows:

$$A_c = \frac{(D + .010)^2}{4} \cdot \pi = (D + .010)^2 \cdot 0.785$$

The area of the fluid exerting the feedback force for an annular outlet orifice A_a is calculated as follows:

$$A_a = \frac{(D + .010)^2}{4} \cdot \pi - \frac{(d - .010)^2}{4} \cdot \pi$$

$$A_a = [(D + 0.010)^2 - (d - 0.010)^2] \cdot 0.785$$

FIG. 5 shows graphs of the force areas of conventional outlet orifices and of annular outlet orifices plotted for a range of diameters D. This graph demonstrates the substantial reduction in the force areas achieved by using the endless slot outlet orifice of this invention. The decrease in force area results in a desirable substantial increase in force gain of the transducer using the nozzle.

FIG. 3 discloses another embodiment of this invention. In this embodiment, a solid plug **18***a* is substituted for the plug **18** of FIG. 1 with the outer surface **17***a* thereof concentric to the surface **16** of body **10**. A recess **28** at the outer end of plug **18***a* is provided to reduce the resistance to the flow of fluid through the inner curtain area **23**. Flapper **22***a* has an orifice **19***a* which provides a passage for the discharge of fluid from the inner curtain as denoted by arrows **20***a*. A washer **22***b* is attached to the flapper **22***a* concentric with orifice **19***a* to reduce the resistance to the flow of fluid through the inner curtain area **23**.

The isolation of the discharge through the inner curtain from that through the outer curtain makes it possible to modify the action of a transducer utilizing the nozzle of this invention. For example, in FIG. **2**, the nozzle disclosed in FIG. 1 is modified by the addition of restrictor **29** in passage **19** and a capacity chamber **27** attached at the end of passage **19**. In this embodiment, the fluid discharged through the inner curtain **23** flows through restrictor **29** and passage **19** into capacity chamber **27** when the pressure in capacity chamber **27** is below the output pressure of orifice **15**. When the reverse condition prevails, then fluid flows from capacity chamber **27** through passage **18**, restrictor **29** and combines with the fluid flowing out of orifice **15** to discharge through the outer curtain **24**. The addition of the restrictor **29** and capacity tank **27** produces a rate action in a transducer utilizing the nozzle. Inasmuch as a rate action, is well known to those skilled in the art, no explanation of the dynamic characteristics need be made. Another example, not shown, is to connect two transducers in cascade so that the output pneumatic pressure signal for a first transducer is connected to the passage **18** (FIG. 1) of a second transducer to modify its action.

What I claim is:

1. A nozzle of the type having an outlet pressure chamber with a restricted inlet passage, an outlet signal passage and an outlet orifice arranged so that when constant pressure fluid is supplied through said restricted inlet passage to said outlet pressure chamber and discharges therefrom through said outlet orifice to ambient pressure, the outlet pressure signal in said inlet pressure chamber and outlet signal passage is a function of the distance the surface of a flapper is positioned from said outlet orifice, the improvement comprising:

said outlet orifice in the form of a continuous slot whereby the fluid discharging from the outlet pressure chamber through said outlet orifice flows in one direction through an outer curtain to ambient pressure, and in the opposite direction through an inner curtain to ambient pressure and the rate of flow through both said curtains is simultaneously responsive to the position of said surface of said flapper from said outlet orifice.

2. A nozzle of the type claimed in claim 1 wherein said continuous slot is annular in form.

3. A nozzle of the type claimed in claim 1 wherein said nozzle includes:

a vent whereby the flow of fluid discharged through said inner curtain is vented to an area external of said nozzle.

4. A nozzle of the type claimed in claim 3 wherein said vent is an orifice in said flapper.

5. A nozzle of the type claimed in claim 3 wherein said annular orifice comprises:

a circular orifice, and

a plug concentric with said circular orifice.

6. A nozzle of the type claimed in claim 5 wherein said vent is a longitudinal passage through said plug.

* * * * *