Feb. 17, 1959 R. C. WHITEHEAD, JR 2,873,755

AIR-PRESSURE-OPERATED RELAY

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FIG. 1

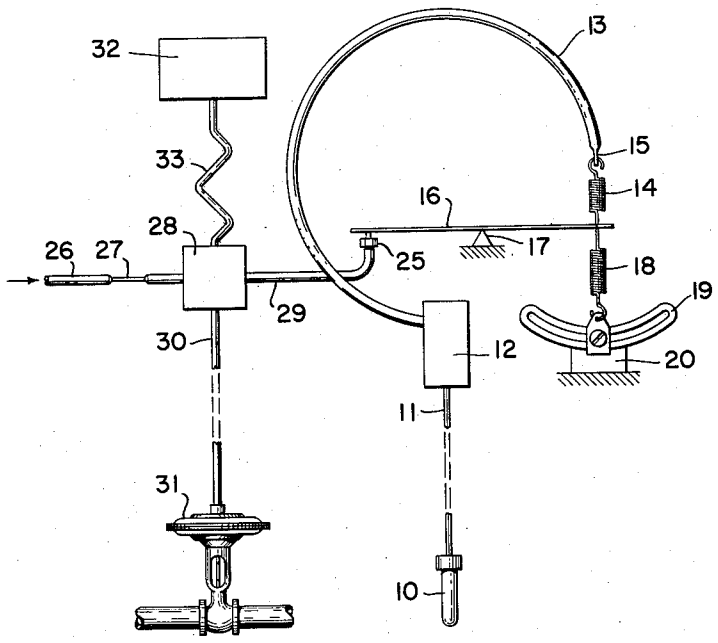


FIG. 2A

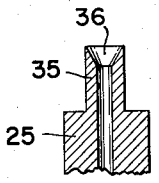


FIG. 2B

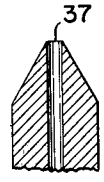
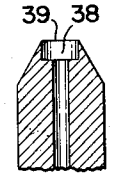


FIG. 2C



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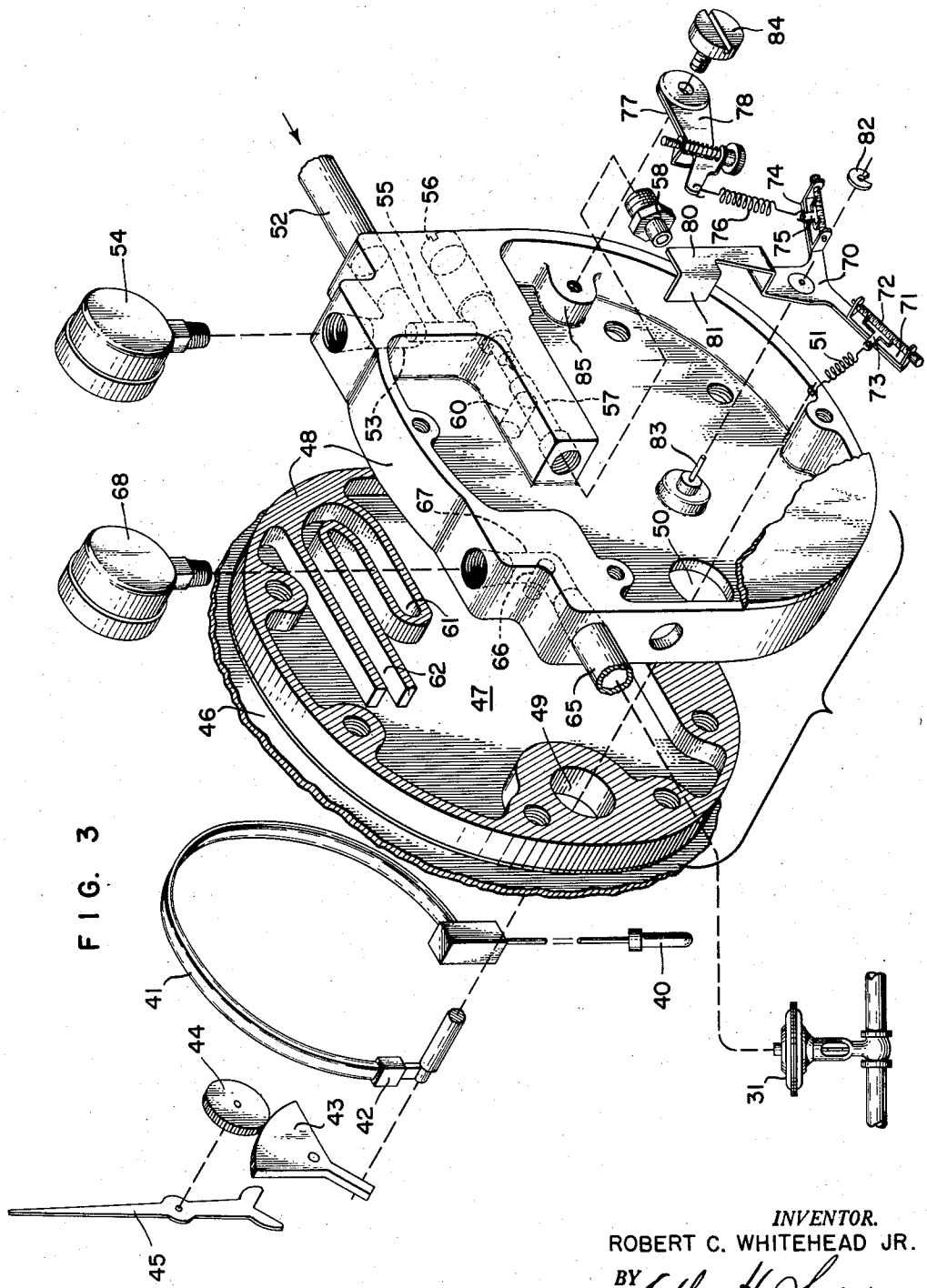


FIG. 3

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AIR-PRESSURE-OPERATED RELAY

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Application January 11, 1954, Serial No. 403,415

5 Claims. (Cl. 137—85)

The general object of the present invention is to provide a new and improved apparatus for producing a pneumatic signal which may be transmitted to some remote point, said signal being proportional in magnitude to the magnitude of some input variable. More specifically, the present invention is directed to a pneumatic pressure transmitter which is characterized by its high degree of linearity, its simplicity, its accuracy, and its stability.

Pressure transmitters are frequently used in transmitting the magnitude of some variable, such as temperature, pressure, or flow, in terms of a pneumatic pressure signal. Such transmitting apparatus must produce a transmitted pressure which accurately follows the input to the transmitter in order for the apparatus to be of utility in some indicating, recording, or control function. Further, it is desirable that a linear relationship exist between the input variable and the transmitted pressure so that the apparatus may be readily adapted for use with standard types of pneumatic receiving apparatus. In addition, such apparatus should be stable and insensitive to supply pressure changes so as to enhance the utility of the apparatus.

The basic pneumatic apparatus of the present invention is of the jet force balance type where the force is applied to a nozzle flapper and this force is balanced by a reaction force caused by an air stream issuing from the nozzle striking the flapper. The nozzle back pressure will vary in accordance with the air stream required to balance the input force of the flapper unit. Apparatus of this general type will be found in the copending application of Frederick W. Side, Serial No. 358,423, filed May 29, 1953. The linearizing of apparatus of the present type has been found to be enhanced by the proper selection of the spring gradient of the resilient members used in the apparatus and as a result it is essential that the apparatus be provided with means for varying the spring gradient of the apparatus without appreciably affecting the other adjustments in the apparatus. The stabilizing of the apparatus may be accomplished by characterizing the nozzle at its outlet and providing the air chamber for the nozzle with a suitable stabilizing pneumatic impedance circuit.

It is therefore a more specific object of the present invention to provide a new and improved pneumatic transmitting apparatus of the jet force balance type having means for varying the spring gradient thereof to enhance the linearity of the apparatus.

A still more specific object of the present invention is to provide a new and improved pneumatic transmitter of the jet balance type having a characterized nozzle opening with said characterized opening providing stability for the transmitter.

Still another more specific object of the present invention is to provide a stabilized jet balance pneumatic transmitter having a nozzle output connection incorporating a stabilizing pneumatic impedance circuit.

A further more specific object of the present invention is to provide a new and improved stabilized jet balance pneumatic transmitter having a flapper unit with a pair of springs connected thereto, one of said springs cooperating with other means to provide a variable input force with the other of said springs providing means for varying the spring gradient of the apparatus to enhance the linearity thereof.

The various features of novelty which characterize the invention are pointed out with particularity in the claims annexed to and forming a part of this specification. For a better understanding of the invention, its advantages, and specific objects attained with its use, reference should be had to the accompanying drawings and descriptive matter in which there has been illustrated and described preferred embodiments of the invention.

Of the drawings:

Fig. 1 represents a diagrammatic showing of one form of the apparatus;

Figs. 2A, B and C are cross sectional views of preferred forms of pneumatic nozzles for use in the apparatus; and

Fig. 3 is an exploded view of one particular form of the pneumatic transmitter incorporating the principles set forth in Fig. 1.

Referring first to Fig. 1, the numeral **10** represents a variable sensing element, such as a temperature responsive bulb which will have an output pressure proportional to the temperature condition in the area wherein the bulb is located. The pressure connection **11** connects the bulb **10** to a base member **12**, the latter of which has appropriate channels formed therein to provide a pressure connection to a Bourbon spiral **13**. The free end of the spiral **13** has a spring **14** connected thereto at **15**. The other end of the spring **14** is connected to a pneumatic flapper unit **16** which is pivoted at **17**. Also connected to the flapper **16** is a further spring **18**, the latter of which has its lower end adapted for movement in an arcuately slotted member **19** which is fastened to a base member **20**.

Cooperating with the opposite end of the flapper **16** is a nozzle member **25** which has air supplied thereto by an input conduit **26** which passes air through a restriction **27**. The restriction **27** is connected to a channel block **28** which is a straight through connection for supplying air to the nozzle **25** by way of a conduit **29**. The back pressure from the nozzle **25** will be reflected through conduit **29** and a further conduit **30** to a suitable pneumatic valve **31** which may be used in any desirable manner to change the conditions which are affecting the magnitude of the variable sensed by the bulb **10**. It will be readily apparent that the pressure signal in the conduit **30** may also go to any type of pneumatic utilization device, such as an indicator, recorder, or the like.

Also connected to the block **28** in communication with the nozzle back pressure is a pneumatic impedance circuit including a capacity chamber **32** which is connected to the block **28** by way of a resistance tubing **33**.

Considering the operation of Fig. 1 it should first be noted that the Bourdon spiral **13** will assume a position which is proportional to the magnitude of the pressure applied thereto. This position will have the effect of placing the spring **14** under stress so that there is applied to the nozzle **16** a force which is proportional to the position of the end **15** of the spiral **13**. As air is supplied to the nozzle **25** by way of restriction **27**, there will be air issuing from the nozzle and this air will strike the flapper unit **16** and create a reaction force which tends to balance the input force applied to the flapper unit by the spring **14**. For any one particular input force applied to the flapper unit **16** by the spring **14**, there will be a corresponding jet reaction force to balance said input force. In order to achieve this balancing force, it is necessary that the back pressure of the nozzle **25** vary

with the variations in the input force. This variation is effected by the flapper 16 moving a minute distance toward the nozzle and the building up of the back pressure so that the higher back pressure will cause a larger force to be exerted against the flapper to balance the flapper input force.

If a higher input pressure is applied to the spiral 13, the end 15 will deflect upwardly and the spring 14 will cause a larger force to be applied to the flapper unit 16. This larger force will be balanced by a larger jet reaction force produced by the back pressure of the nozzle 25 increasing. The back pressure changes of the nozzle 25 will be reflected through the conduit 30 to the valve 31 which will be repositioned in accordance with the pressure change. The stabilizing of this back pressure is effected in part by the presence of the pneumatic impedance circuit including the resistance 33 and capacity chamber 32. This impedance circuit tends to prevent high frequency fluctuations appearing at the nozzle from being reflected through the system and causing the output pressure to vary. Further, this tends to stabilize the supply pressure variations which also may tend to upset the output controlling action in the apparatus.

As the linearity of this jet force balance type system is dependent in part upon the spring gradient of the apparatus, the spring 18 has been added to provide means for varying the spring gradient so that the highest degree of linearity may be obtained regardless of the type of apparatus with which the transmitter may be used. The spring gradient of the apparatus may be varied by shifting the end of the spring 18 in the arcuately slotted member 19 so that the net effective gradient of the spring 18 in the apparatus will vary in accordance with the angular displacement of the spring with respect to its connection to the flapper unit 16. Inasmuch as the flapper unit 16 has no appreciable movement, the movement of the spring 18 will not appreciably affect the overall span or range of the apparatus.

It was found with one particular embodiment of the apparatus that the maximum linearity error was approximately five tenths percent over the full span of the apparatus. As the spring gradient of the apparatus will vary with different types of Bourdon spirals and changes in the accompanying size of the spring 14, it will be readily apparent that the adjustment provided for the spring 18 is essential in order that the appropriate spring gradient be provided to give maximum linearity.

The nozzle configuration shown in Fig. 2A has been found to contribute measurably to the stability of this jet balance type of apparatus. Here, the nozzle 25 is shown to comprise a reduced section 35 which leads to the opening of the nozzle. The opening of the nozzle has been counter-sunk at 36 to provide a knife edge at the end of the nozzle where it is adjacent the flapper 16. In order that the nozzle be fully effective and not introduce non-linearities into this system, it is essential that the knife edge around the opening of the nozzle be free from any flat sections.

Fig. 2B shows one form of nozzle which has a sharp edge 37 adjacent the nozzle opening with a conical outer surface. This form of nozzle is less sensitive to supply pressure changes and may be desirable where stability is not a problem.

Fig. 2C shows a modified nozzle form which is a compromise between the features found in Figs. 2A and 2B. Here, the nozzle is counter-bored at 38 and has a sharp outer edge at 39. This form is more stable than that of Fig. 2B and slightly more sensitive to supply pressure variations.

The apparatus shown in Fig. 3 is an exploded view of a pneumatic transmitter. Here, a variable sensing bulb 40 is connected to a suitable Bourdon spiral 41 and is arranged to deflect the end of the Bourdon spiral at 42 in accordance with the pressure changes within the sensing element 40. The movement of the end 42 of

the spiral 41 may be applied through a suitable rack 43 and pinion gear 44 to position an indicator needle 45 in accordance with the magnitude of the variable sensed by the unit 40. This entire assembly thus far set forth may be fastened to the back side of a panel member 46, by means not shown.

The panel member 46 is arranged to enclose a chamber 47 formed on the back of the block 48, shown in cut and exploded view. The panel member 46 has an opening 49 extending therethrough which cooperates with a further opening 50 in the block 48. This permits the transmission of a motion signal to spring 51 produced by the movement of the end of the Bourdon spiral 41 through the panel 46 and the block 48 to be utilized in a manner hereinafter described.

The block 48 has an input conduit 52 which may be connected to a suitable supply of air under pressure. A conduit 52 is connected to two drilled channels within the block 48. These channels include a channel 53 which is connected to supply pressure to the supply pressure measuring instrument 54. A further channel 55 is connected to supply air to a restriction 56. The air flowing through the restriction passes to a further channel 57 which is connected to supply air to the nozzle 58. Extending at right angles from the channel 57 is a further channel 60 which extends towards the back of the block 48 and provides an opening into the chamber 47. This opening will cooperate with the closed end 61 of a molded channel 62 which is formed in the chamber 47. The channel 62 provides a resistance connection into the chamber 47 and corresponds in effect to the resistance tubing 33, shown in Fig. 1.

Also included in the block 48 are the output connections for the apparatus. This includes an output conduit 65 which is connected to drilled channels in the block. One of these channels at 66 provides a connection from the chamber 47 to the output conduit 65. A further channel 67 provides a connection for an output pressure measuring instrument 68.

Arranged to be movably mounted within the block 48 is a flapper member 70 formed with three legs. An input leg 71 includes an adjustable element 72 which is movable along the length of the leg 71 and a connection 73 is provided for making a direct mechanical connection to the spring 51 attached to the end of the Bourdon spiral 41. The leg 74 comprises an adjustable member 75 which is used to vary the point of connection of a spring 76 to the leg 74, and therefore provide a linearity adjustment for the apparatus. The opposite end of the spring 76 is carried by a pair of relatively adjustable members 77 and 78 which provide the zero adjustment for the apparatus. The further leg 80 of the flapper unit 70 carries a flapper or baffle plate 81 which is formed at right angles to the flapper leg 80 with the leg 80 providing a shield to prevent interference with the action of the nozzle 58 against the flapper 81 when an appropriate cover, not shown, is placed over the end of the block 48. An appropriate fastening means 82 is provided for fastening the flapper unit 70 into position within the block 48, on the projection 83. A further fastening means 84 is provided for fastening the zero adjusting levers 77 and 78 to an appropriate mounting projection 85.

The apparatus of Fig. 3 operates in substantially the same manner as the apparatus of Fig. 1. Here, an input pressure from the element 40 will produce a predetermined deflection of the Bourdon spiral 41 and this deflection will be reflected by way of the spring 51 into a force which will act upon the connector 73 of the flapper unit 70. This will cause the flapper to be rotated in a clockwise direction toward the nozzle 58. This input force will be balanced by a counterbalancing force from the nozzle 58 caused by the air stream therefrom creating a reaction force against the flapper 81. As soon as the reaction force equals the input force, a predeter-

mined output pressure will exist in the channel **60** of block **48**. This output pressure will be applied through the channel **62** and will then pass into the chamber **47**. The channel **62** and the chamber **47** correspond to the resistance member **33** while the chamber **47** corresponds to the capacity chamber **32** of Fig. 1. The back pressure from the nozzle **58** will be reflected through this restricted passage **62** and the chamber **47** and will then be applied to the output conduit **65** and there to the control valve **31**. It will be noted that this connection differs somewhat from that of Fig. 1 in that the output connection is from the capacity chamber. It has been found that either method of output is satisfactory in providing the desired stabilization.

In order to change the span of the apparatus, the adjustment **72** is moved to vary the point at which the input from the Bourdon spiral acts upon the leg **71** of the flapper unit **70**. In addition, the movement of the connector **75** along the leg **74** has the effect of varying the linearity of the apparatus by varying spring gradient of the entire flapper system. In addition, the zero of the apparatus may be adjusted by adjusting the relative positions of the levers **77** and **78**.

It will be readily apparent that changes in the input force from the Bourdon spiral **41** will be effective to cause corresponding changes of output pressure from the apparatus with the input force acting on the flapper unit **70** being balanced by the jet reaction force of the nozzle **58** which strikes the flapper **81**. This form of the apparatus has been found to be highly stable, linear, and adaptable to operation over wide ranges of input forces.

While, in accordance with the provisions of the statutes, there has been illustrated and described the best forms of the embodiment of the invention known, it will be apparent to those skilled in the art that changes may be made in the form of the apparatus disclosed without departing from the spirit of the invention as set forth in the appended claims, and that in some cases certain features of the invention may be used to advantage without a corresponding use of other features.

Having now described my invention, what I claim as new and desire to secure by Letters Patent is:

1. A pressure transmitter comprising a Bourdon spiral having a pressure input for deflecting one end thereof by an amount proportional to the input pressure, an air-pressure-controlling valve comprising a flapper and a cooperating nozzle having an outlet air stream positioned to strike said flapper and to create a reaction force on said flapper, a first resilient member connected to said spiral at the deflecting end thereof and to said flapper and constituting the sole means for applying a force from said spiral to said flapper, said force being proportional to the deflection of the movable end of said spiral, a second resilient member connected at one end to said flapper and at the other end to a base member which is fixed relative to said flapper, said second resilient member creating a force on said flapper which is in opposition to the force from said first resilient member, and means permitting adjustment of said second resilient member and for holding said second resilient member in adjusted position.

2. Apparatus as defined in claim 1 wherein said pneumatic nozzle has its open end countersunk and has a supply chamber having a restricted air inlet thereto and an outlet comprising a further air restriction and a capacity chamber.

3. A pressure transmitter comprising a Bourdon spiral having a pressure input for deflecting the end thereof by an amount proportional to the pressure input, a first resilient member connected to said spiral at the deflecting end thereof, a pneumatic flapper having a force applied thereto by said resilient member, said force being proportional to the deflection of the end of said spiral, a second resilient member connected at one end to said flapper and at the other to a base member which is fixed relative to said flapper, said second resilient member creating a force on said flapper which is in opposition to the force from said first resilient member, and a pneumatic nozzle having an outlet air stream positioned to strike said flapper and create a reaction force on said flapper to balance the net input force to said flapper, said nozzle having a passage extending therethrough with the opening adjacent said flapper being formed with a diameter larger than said passage.

4. Pneumatic apparatus comprising, a pivoted flapper, means for applying an input force to said flapper, a spring member fastened to said flapper and adjustably attached for angular movement relative to said flapper and to a base member for varying the spring gradient of said apparatus, and a pneumatic nozzle cooperating with said flapper, said nozzle having air issuing therefrom and striking said flapper to create a reaction force which will balance the input force on said flapper and having a counterbored opening adjacent to said flapper.

5. A pressure transmitter comprising a Bourdon spiral having a pressure input for deflecting the end thereof by an amount proportional to the pressure input, a first resilient member connected to said spiral at the deflecting end thereof, a pneumatic flapper having a force applied thereto by said resilient member, said force being proportional to the deflection of the end of said spiral, a second resilient member connected at one end to said flapper and at the other to a base member which is fixed relative to said flapper, said second resilient member creating a force on said flapper which is in opposition to the force from said first resilient member, and a pneumatic nozzle having an outlet air stream positioned to strike said flapper and create a reaction force on said flapper to balance the net input force to said flapper, said pneumatic nozzle having its open end countersunk and having a supply chamber having a restricted air inlet thereto and an outlet comprising a further air restriction and a capacity chamber.

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