Jan. 19, 1960 P. F. K. ERBGUTH 2,921,595

PNEUMATIC SYSTEM RESPONSIVE TO CHANGES IN A VARIABLE CONDITION

Filed Feb. 28, 1955

4 Sheets-Sheet 1

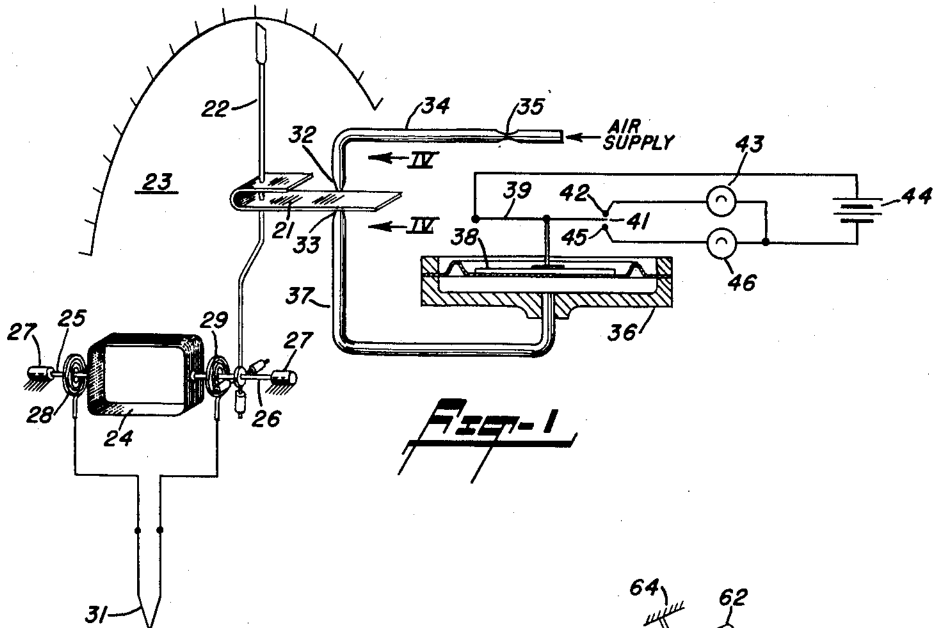

FIG-1

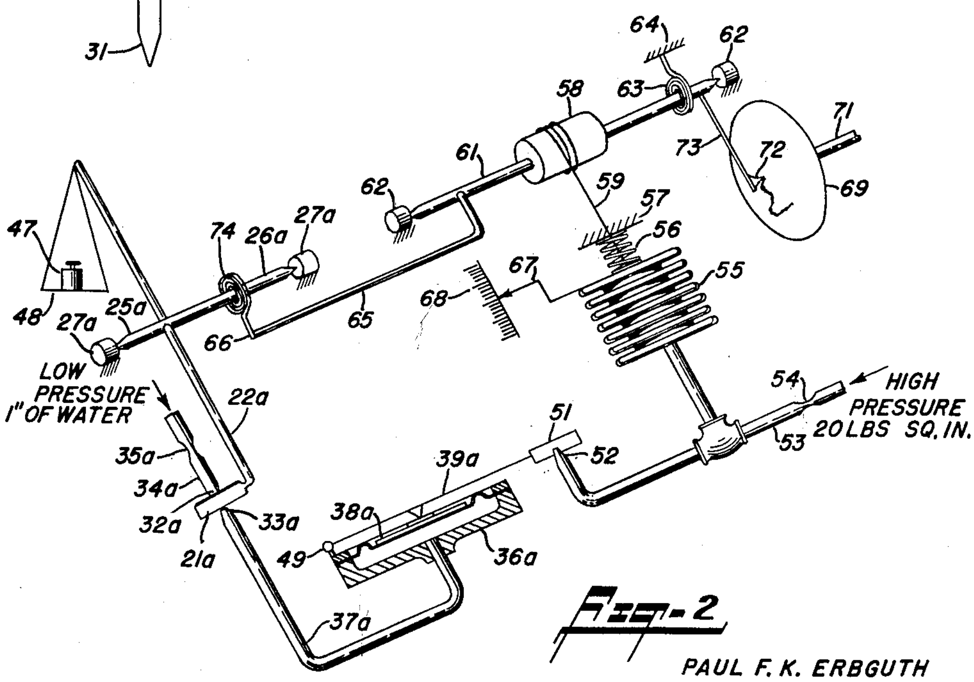

FIG-2

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PNEUMATIC SYSTEM RESPONSIVE TO CHANGES IN A VARIABLE CONDITION

Filed Feb. 28, 1955 4 Sheets-Sheet 2

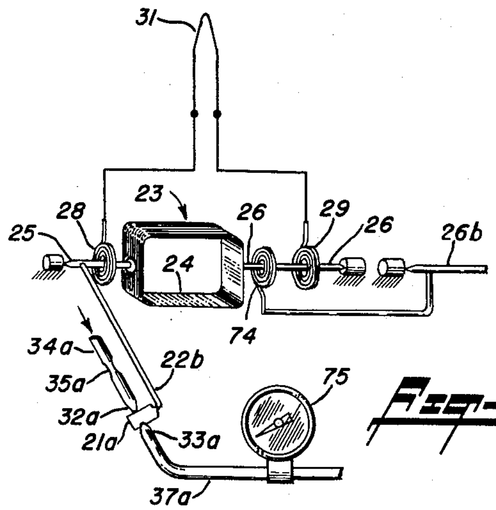

FIG-3

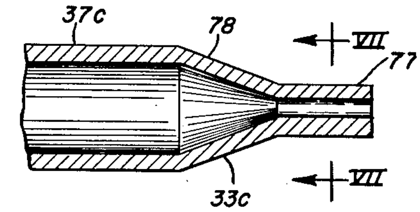

FIG-6

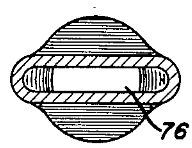

FIG-7

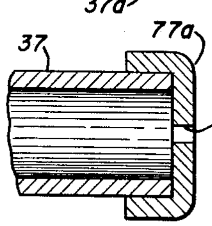

FIG-8

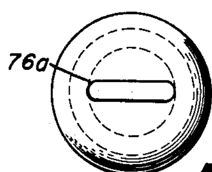

FIG-9

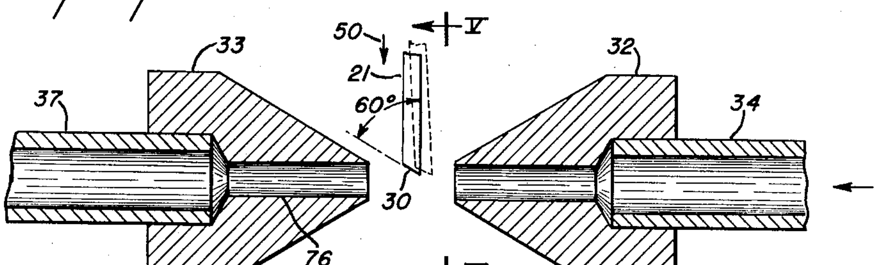

FIG-4

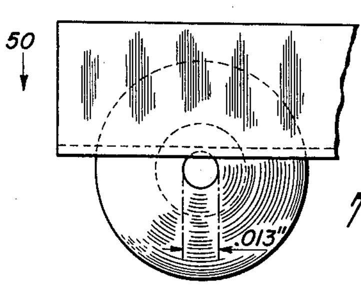

FIG-5

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PNEUMATIC SYSTEM RESPONSIVE TO CHANGES IN A VARIABLE CONDITION

Filed Feb. 28, 1955

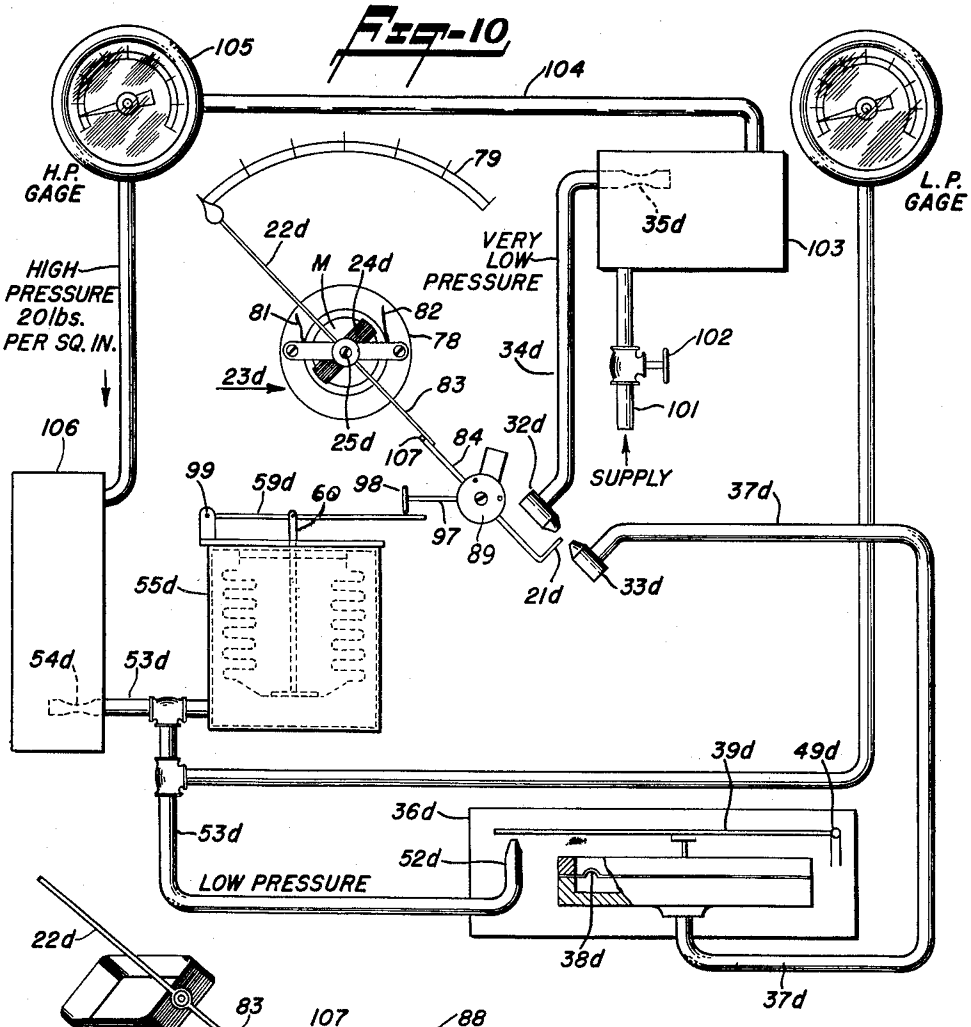

Fig-10

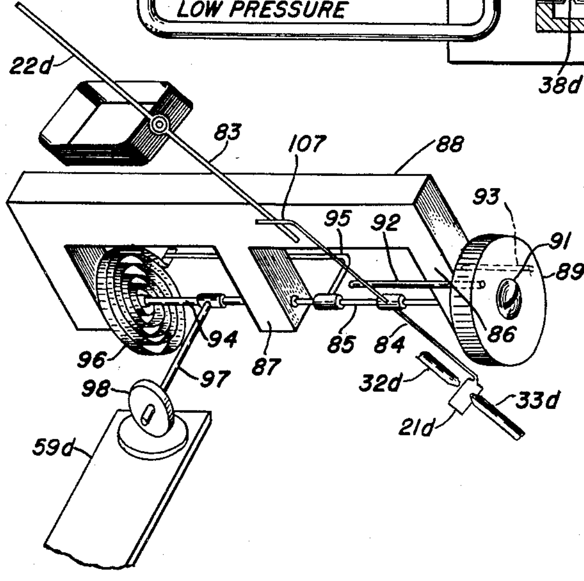

Fig-11

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PNEUMATIC SYSTEM RESPONSIVE TO CHANGES IN A VARIABLE CONDITION

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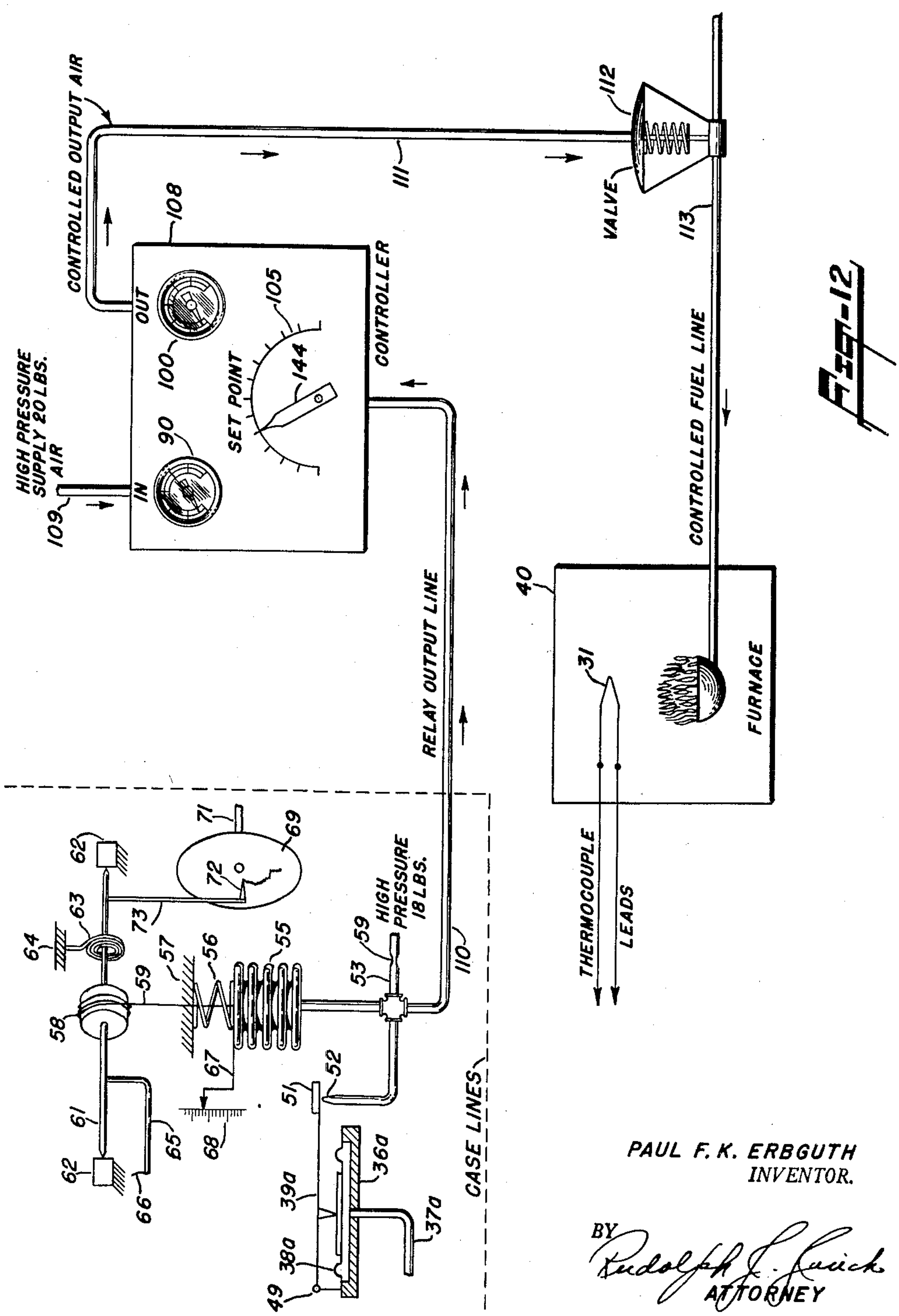

Fig-12

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United States Patent Office

2,921,595

Patented Jan. 19, 1960

2,921,595

PNEUMATIC SYSTEM RESPONSIVE TO CHANGES IN A VARIABLE CONDITION

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Application February 28, 1955, Serial No. 490,907

11 Claims. (Cl. 137—85)

This invention relates to pneumatic systems responsive to changes in a variable condition to effect a corresponding indication, recording or control action and more particularly to a novel system of this class responsive to condition-sensing devices having low torque.

Apparatus of the class contemplated by this invention comprises a means for sensing changes in a variable condition such as, for example, an electrical indicating instrument having a pointer and responsive to electrical current, balanced lever systems deflectable in response to changes in weight, humidity, etc., telemetering arrangements for selectively positioning and/or controlling a remotely-positioned member, etc. Such condition-sensing means include a vane, or baffle, movable between a pair of aligned nozzles across which flows an elastic fluid, generally air. Movement of the vane in the air stream inhibits, more or less, the flow of air from the discharge nozzle to the receiving nozzle resulting in corresponding variations in the air pressure in an air relay connected to the receiving nozzle. The resulting air pressure variations in the output of the air relay effects a desired operation such as a control of signal means, or a follow-up action effecting return of the vane to, or maintenance of the vane at, substantially its initial position relative to the aligned nozzles. Such operation is accompanied, if desired, by a simultaneous indicating, measuring or recording function.

Prior systems of this type are of complex construction and, more importantly, are not adapted for actuation by a condition-sensing means developing only a low torque.

An object of this invention is the provision of a pneumatic system responsive to changes in a condition-sensing device developing only a low torque and which system provides a measurement, record or control of a variable condition.

An object of this invention is the provision of a pneumatic system responsive to changes in a variable condition and in which a vane is movable between axially aligned air nozzles, said vane being movable by a low torque element such as the pointer of an electrical millivoltmeter.

An object of this invention is the provision of a pneumatic system in which low pressure air, not exceeding 3″ of water, passes from a discharge nozzle to an axially-aligned receiving nozzle unless cut off by a vane movable between the nozzles in response to changes in a variable condition, the variation in the air pressure in the receiving nozzle effecting the operation of suitable mechanisms to provide a measuring, recording or control function.

An object of this invention is the provision of a pneumatic system in which the position of a pair of axially-aligned nozzles may be adjusted with respect to an intercepting vane in order to effect a desired operation of the system.

An object of this invention is the provision of a pneumatic system comprising a discharge nozzle and an axially-aligned receiving nozzle, means for maintaining a flow

of air at low pressure between said nozzles, a device responsive to changes in a variable condition and carrying a vane movable into and out of the air stream, an air relay responsive to the variations in air pressure in the receiving nozzle, and means responsive to the output of the air relay to effect a movement of the vane until a balance is restored in the system.

An object of this invention is the provision of a pneumatic system comprising a discharge nozzle and an axially-aligned receiving nozzle, means for maintaining a flow of air at low pressure between the nozzles, a device responsive to changes in a variable condition and carrying a vane movable into and out of the air stream, an air relay responsive to variations in the air pressure in the receiving nozzle as the vane moves further into or out of the air stream, a bellows controlled by the air output of the air relay, and means movable by the bellows to effect a movement of the vane in a direction to maintain the system in balance.

An object of this invention is the provision of an electro-pneumatic system comprising axially-aligned discharge and receiving nozzles, means maintaining a flow of air at low pressure between the nozzles, an electrical instrument responsive to changes in an electrical quantity, a pivotally-mounted arm mechanically-coupled to the pointer and carrying a vane movable in the air stream in response to displacement of the pointer, an air relay responsive to changes in the air pressure in the receiving nozzle as the vane moves further into or out of the air stream, a bellows movable by the air output of the air relay, a second pivotally-mounted arm mechanically-coupled to the bellows, and resilient spring means coupling together the said pivotally-mounted arms, the arrangement being such that a movement of the vane effects an operation of the system to restore the vane substantially to its initial position.

These and other objects or the advantages of the invention will become apparent from the following specification when taken with the accompanying drawings. It will be understood, however, that the drawings are for purposes of illustration and are not to be construed as defining the scope or limits of the invention, reference being had for the latter purpose to the claims appended hereto.

In the drawings wherein like reference characters denote like parts in the several views:

Figure 1 is a diagrammatic view of the electric and pneumatic circuits in an instrument embodying my invention;

Figure 2 is a diagrammatic view similar to Figure 1 but showing another embodiment of this invention;

Figure 3 is a diagrammatic view corresponding to the left hand end portion of Figure 2 but showing a modification;

Figure 4 is an enlarged axial sectional view of the cooperating nozzles of a preferred shape, viewed as on the line IV—IV of Figure 1, in the direction of the arrows;

Figure 5 is a sectional view on the line V—V of Figure 4, in the direction of the arrows;

Figures 6 and 8 are axial sectional views of nozzles as in Figure 4 but showing modifications;

Figures 7 and 9 are, respectively, a transverse sectional view on the line VII—VII of Figure 6, in the direction of the arrows and an end elevational view of the form of Figure 8;

Figure 10 illustrates a practical embodiment of my invention;

Figure 11 is a perspective view of a portion of the mechanism of Figure 10; and

Figure 12 is a diagrammatic view of the electric and pneumatic circuits which may be employed for controlling a furnace, in accordance with this invention.

In the instrument illustrated in Figure 1, which is a mechanism for sensing changes in a variable condition, there is shown a vane **21** with straight edges and carried by the pointer **22** of a sensitive electrical instrument, generally designated **23**. In the present embodiment, this instrument may be for sensing changes in varying electrical currents or voltages, as, for example, a milliammeter or millivoltmeter, and may comprise wire wound coil **24** rotatably mounted on pivots **25** and **26** carried by suitable bearings **27**. Each of the pivots **25** and **26** has secured thereto a spiral hair spring, **28** and **29**, resiliently causing the coil **24** to occupy a given position with respect to the poles of an associated permanent magnet (not shown) until electric current is passed therethrough. Such current may be generated by a thermocouple **31**, which may serve as a temperature-sensing element as, for example, in the furnace **40** shown in Figure 12.

A pair of axially-aligned nozzles **32** and **33**, forming a pneumatic couple, are positioned so that the leading edge of the vane **21** is normally disposed therebetween. The vane **21** is desirably as illustrated, that is, formed of thin metal and has an edge beveled, or formed by a diagonal plane, to provide a knife edge to thereby facilitate the movement of the vane into an air stream. The nozzle **32** is connected to a source of elastic fluid, under pressure, such as a compressed air supply, through a tube **34**. The tube **34** has a flow restrictor **35** therein to cause the air to pass from the discharge nozzle **32** at a low pressure, say about 1" of water and no more than 3" of water, which is a pressure of about .11 lb. per square inch. The receiving nozzle **33** is connected to an air relay **36** by tube **37**.

When the vane **21** is displaced, a variable amount of air flows into the nozzle **33** and through the tube **37** and into the chamber of an air relay **36**. The resulting change in air pressure within the chamber moves the air relay diaphragm **38**, thereby moving a connected member, such as the pivoted lever **39** of a switch **41**, so that it may engage one or the other of the upper and lower stationary contacts **42** and **45**. The engagement of the movable member with either of the contacts **42**, **45** completes a circuit for energizing one or the other of the lamps **43**, **46** from the battery **44**.

From the foregoing description, it will be seen that I have devised a system whereby movement of the pointer of an electrical instrument beyond a predetermined balance point effects a desired control of signal lamps so that when the vane changes position between the nozzles one lamp is de-energized and another energized. It will be noted that in this arrangement there is no follow-up action, that is, there is merely a change in the signal indication as the vane moves to either side of a preset position between the opposed nozzles.

Those skilled in this art will understand that the preset position of the vane edge in the air stream may be altered as by adjusting the normal zero position of the instrument pointer or by a physical setting of the aligned nozzles along the arcuate path of travel of the vane **21**.

Referring now to the embodiment of my invention illustrated in Figure 2, there is shown a modified pneumatic system, involving mechanism for sensing changes in a variable condition as in the preceding embodiment, but in which a follow-up action is provided to return the vane to a throttling position between the aligned nozzles, such vane position being precisely that position in which the entire system is in balance. In this embodiment I show a pneumatic force-balance system which may measure, record or control forces such as weight, torque or humidity. In this instance, the vane **21a** is carried by a balance arm **22a** that is secured to a pivoted shaft **26a**, rotatable in the bearings **27a** and normally held in one position by a hair spring **74**. The lever **22a**, therefore, tends to stay in the position illustrated until moved therefrom, as by means of a weight **47** carried by a pan **48** suspended from one end of the lever **22a**.

A pair of aligned nozzles **32a** and **33a** forming a pneumatic couple are positioned so that the leading edge of the vane **21a** is normally disposed in the air stream between the nozzles. This vane is desirably formed of thin metal and has an edge beveled to a knife edge to thereby facilitate the movement of the vane into the air stream. The nozzle **32a** is connected to a source of air under pressure through tube **34a**, which tube has a flow restrictor **35a** therein to cause the air to flow from the nozzle **32a** at a low pressure, say about a pressure of 1" and no more than a pressure of 3" of water. The receiving nozzle **33a** is connected to the chamber of the air relay **36a** by tube **37a**.

When the vane **21a** is moved, a variable amount of air flows into the receiving nozzle **33a**, thereby causing a movement of the air relay diaphragm **38a**. Assuming that such vane movement results in an increase in the quantity of air flowing to the receiving nozzle **33a**, there results an increase in air pressure within the air relay chamber. The diaphragm **38a**, therefore, moves upwardly thereby rotating the connected member, such as the pivoted lever **39a**, in a counterclockwise direction. The free end of the lever **39a** carries a flapper **51** cooperating with a nozzle **52** that is connected to the source of air pressure by the tube **53** containing a flow restrictor **54** therein.

It may be pointed out that the pressure of the air supplied to the nozzle **52** may be relatively high, that is, in the order of pounds per square inch and the actual air pressure in the tube **53** depends upon the spacing of the flapper **51** from the nozzle **52**. On the other hand, the pressure of the air supplied to the discharge nozzle **32a** is very low, in the order of a fraction of a pound per square inch, thereby reducing to an insignificant degree the reaction effects between the air stream flowing across the aligned nozzles **32a**, **33a** and the vane **21a**. This is important since my systems are adapted for use with condition-sensing devices producing very low torques, such as sensitive electrical instruments, sensitive balances, etc.

When the air relay diaphragm moves the flapper **51** a greater distance away from the associated nozzle **52** there is effected a corresponding decrease in the air pressure in the bellows assembly **55** (connected to the output tube **53**) causing a partial collapse thereof. In the particular arrangement illustrated in the drawing, the bellows **55** are biased by a compressed spring **56** disposed between the upper surface of the bellows and a fixed surface **57**. A connecting wire **59** is wrapped around the drum **58**, one end of the wire being secured to the drum and the other to the upper surface of the bellows **55**.

The drum **58** is mounted on a second shaft **61** pivotally supported by bearings **62**, coaxial and in tandem with respect to the shaft **26a**, and normally held resiliently in a certain position as by means of a hair spring **63**. The inner end of the spring **63** is connected to the shaft **61** and the outer end thereof is connected to a fixed abutment **64**. The shaft **61** has a rigid angular member **65** extending toward the first shaft **26a** and to the end of which the outer portion of the hair spring **74** is connected, as indicated at **66**. Consequently, a partial collapse of the bellows **55** effects a rotation of the shaft **61** to act on the hair spring **74** and tend to restore the vane **21a** to its throttling position between the aligned nozzles **32a** and **33a**, thereby restoring the system to a new balance point. It will now be apparent that the air pressure in the bellows **55** is a meature of the force applied to the lever **22a**.

In addition to the restoration of the shaft **22a** to its throttling position, the movement of the bellows may be measured by a carried pointer **67**, movable over a calibrated scale **68** to thereby indicate the magnitude of the particular weight **47**. This factor may also be recorded on a chart **69**, carried by a rotating shaft **71**, as by a pen

72 carried by an arm 73 extending from the shaft 61 and into engagement with the chart.

Referring now to the embodiment of the invention illustrated in Figure 3, there is shown instead of the lever **22a**, the pointer **22b** of an electrical measuring instrument such as a millivoltmeter. The vane **21a** is attached to the pointer and is movable between the aligned nozzles **32a**, **33a** to effect operation of the system in response to a change in the electrical quantity controlling rotation of the instrument movable coil **24** as, for example, the thermocouple **31**. The remainder of the apparatus may be the same as illustrated in Figure 2.

As an alternative, however, the tube **37a** may be connected directly to a bellows, such as indicated by the reference character **55** in Figure 2, the pressure being indicated on a gauge **75**. However, if this embodiment is adopted, it is necessary that the bellows, like **55**, be relatively large because of the low operating pressure of the air within the tube **37a**. For this reason, it is generally better to operate the bellows from an air relay such as that designated **36a** in Figure 2.

Referring now to Figures 4 and 5 there is shown one form of the nozzles **32** and **33**, and the vane **21** which may be employed in any or all of the described embodiments of my invention. To facilitate manufacturing thereof, these nozzles **32** and **33** are formed as tapered members having apertures **76** smaller than the bore of the air-carrying tubes **34** and **37**, so as to form a stepped construction. The cutting, or leading, edge of the vane **21** is desirably beveled, as indicated at **30**. In other words it has an approximately 60 degree knife edge, as indicated.

The direction of movement of the vane **21**, further into the air stream, from what may be the normal position illustrated in Figures 4 and 5 wherein the vane cuts off part of the air stream, is in the direction of the arrow **50**. The full-line position of the vane is normal to the direction of air flow, from right to left as viewed in Figure 4. However, to further facilitate the cutting of the air stream by the vane **21**, the plane of the vane may be turned slightly at an angle to the position illustrated by the dotted lines in Figure 4.

Referring now to Figures 6 and 7, there is shown a modified form of nozzle **33c** wherein the aperture at the tip, instead of being circular, is transversely elongated as indicated at **76** in Figure 7. This elongation in the tip portion **77** is formed by flattening the end of the tube. When nozzles of this form are used the vane may move in a direction either longitudinally of the elongated aperture, transversely thereof, or any intermediate relation. In the first instance, the cut off action is much more gradual and less sensitive than in the second instance, as will be understood.

Figures 8 and 9 illustrate an embodiment in which the nozzle aperture **76a**, elongated or circular as desired, is formed in a cap or tip portion **77a**, which is in turn connected to the carrying tube **37** by solder or other suitable means.

Referring now to the embodiment of this invention illustrated in Figures 10 and 11, there is shown a practical instrument embodying preferred features shown diagrammatically in the preceding embodiments. The mechanism for sensing changes in a variable condition is here an electrical measuring instrument, such as a millivoltmeter or milliammeter, generally designated **23d**. This instrument is more or less conventional so the parts are not described fully. Suffice it to say that the part **78** is a soft-iron yoke or housing having an axial bore in which rotates a coil **24d** mounted on pivots operating in suitable bearings such as the upper jewel screw **25d** shown in the drawing. Each of the pivots has a conventional spiral hair spring (not shown) resiliently causing the coil **24d** to stay in a given position with respect to the poles of the permanent magnet core M until electrical current is passed therethrough. Such current may be generated as described in connection with the preceding embodiments. The pointer secured to the coil is designated by the reference character **22d**, the end of said pointer moving over a scale **79** and between suitable limiting stops **81** and **82**.

The pointer **22d** has a tail **83** extending away from the scale **79** and which engages a lever **84** secured to a shaft **85** journalled in the bearings **86** and **87** forming part of a supporting frame **88** (see particularly Figure 11). The upper end of this shaft **85** has a knurled setting wheel **89**, secured thereto as by means of a screw **91**. The setting wheel **89** carries a disengaging rod **92** for the lever **84** and a stop rod **93** for limiting turning movement of itself, as by engaging the frame **88**. The shaft **85** corresponds with the shaft **26b** of Figure 3, in that it is operated by a shaft **94**, corresponding with the shaft **61** in Figure 2, so that it effects turning of the shaft **84** by means of a shaft extension **95**, the free end of which is connected to the outer end of a hair spring **96** carried by the shaft **94**. In the present instance also, the lever **84** carries a vane **21d** disposed between the aligned nozzles **32d** and **33d**, rather than having the vane carried directly by the pointer **22d** of the instrument as in the previously-described embodiments.

The shaft **94** carries an arm **97** having a wheel **98** movable by a lever **59d**, the latter corresponding to the wire **59** of Figure 2, in that it effects turning of the shaft **94**. This lever is pivoted at **99** and operated by a bellows device **55d** corresponding with that designated **55** in Figure 2, but in this case by a link **60** connected between the lower end of the bellows and a point intermediate the ends of said lever **59d**, instead of by a wire wrapped around a drum. There is also an air relay **36d**, corresponding with that designated **36a** in Figure 2, in which the diaphragm **38d** is moved (when the vane **21d** moves in the air stream between the aligned nozzles **32d** and **33d**) in response to a change in air pressure in the tube **37d**, thereby operating the lever **39d** pivoted at **49d**, so as to move the free end thereof further from the nozzle **52d** and thereby correspondingly decrease the pressure in the output tube **53d**.

The operation of the apparatus illustrated in Figures 10 and 11 is similar to that of the apparatus illustrated in Figures 2 and 3. However, the apparatus illustrated in Figures 10 and 11 is more than merely diagrammatic. In this latter apparatus, air is received from the main supply tube **101** through a shut-off valve **102** where it passes to a manifold or box **103**, such air being normally at a pressure of 20 lbs. per square inch, as is commonly available. From the manifold **103** there extends a pipe **104** to the high-pressure gauge **105**, from whence air passes to a manifold or box **106**.

From the manifold **103** there extends a tube **34d** to the discharge nozzle **32d**, the pressure of the air in this tube being very low, as has already been described. Thus, the operation of the apparatus, here disclosed more in detail, corresponds with the operation of the apparatus of Figure 3, in that the vane **21d** is movable between the aligned nozzles **32d** and **33d** by corresponding movement of the pointer **22d**, although not directly by said pointer.

In other words, the pointer tail **83** which extends in a direction opposite to the scale **79**, engages an angular extension **107** on the lever **84** and, on upscale movement of the pointer, moves it counterclockwise, as viewed in Figures 10 and 11. This effects a corresponding movement of the vane **21d** further into the air stream between the aligned nozzles **32d** and **33d**. When the vane cuts further into the air stream, the pressure in line **37d** is reduced, thereby causing a corresponding collapse of the air relay diaphragm **38d**. The lever **39d**, therefore, moves toward the nozzle **52d**, thereby correspondingly increasing the pressure of the air in the output tube **53d** and bellows system **55d**, and causing the lever **59d** to rotate counterclockwise. This rotation effects turning of the shaft extension **97** clockwise, as viewed in Figure 10, and effects, through the hair spring **96** (Figure 11), a corresponding movement of the lever **84** and a return of the vane **21*d*** from the air stream to its initial throttling position, wherein the forces of meter torque and the air system are in balance. The foregoing description presents the functional operation of the apparatus, but those skilled in this art will understand that the vane is always partially in the air stream (see Figures 4 and 5), that is, in the throttling position when the actuating pointer is in the mechanical zero position. Consequently, any slight movement of the pointer results in an immediate change in the relay output and a corresponding rebalancing force is applied to said pointer.

To illustrate the control function of my invention, reference is now made to Figure 12, wherein there are shown the components required for the control of temperature in a furnace **40**. The relay and chart components correspond with the form of my invention illustrated in Figure 2, and described in connection therewith, but the condition-sensing device is an electrical millivoltmeter as shown in Figure 3. Such instrument deflects in accordance with the voltage developed by the thermocouple **31** which in turn depends upon the temperature of the furnace **40**.

The pressure controller **108**, here used, has an operating pressure range generally equal to the air pressure range of the air relay **36*a***, that is, 3–15 pounds per square inch. The air relay tube **53** is connected to the controller by a tube **110**. Relatively high pressure air is supplied to the controller through the tube **109** and the controlled air passes through the tube **111** to the control valve **112** inserted in the fuel line **113** of the furnace. The input and output air pressures of the controller are indicated by the air supply pressure gauge **90** and the controlled air pressure gauge **100**.

The system operates in the following manner. With an increase or decrease of furnace temperature, the electrical output of the thermocouple in the furnace changes. This change is sensed by the moving coil **24** (Figure 3) and motion is transmitted to the vane **21*a*** by pointer **22*b***. The movement of this vane, as previously described, properly alters the position of the air relay flapper **51** in relation to the associated nozzle **52**, thereby resulting in a corresponding movement of the bellows **55** and the recorder pen **72**.

In addition to these indicating and recording functions, the air pressure change in the tube **53** is transmitted through the tube **110** to the sensing mechanism of the controller **108**. The controller senses this air pressure change and corrects the opening of the valve **112** to return the furnace temperature to the desired value. Those skilled in this art will understand that the desired operating temperature of the furnace may be set by rotating the knob **144** of the controller-sensing mechanism to the proper value as indicated by an associated scale **105** calibrated in terms of temperature. It is here pointed out that my system does not depend upon the particular type of pressure controller used. The particular controller used will depend upon the particular application and may be one of numerous conventional types such as a simple on-off, high sensitivity, full throttling, reset, or etc.

From the foregoing disclosure, it will be seen that I have provided pneumatic apparatus which is adapted to respond to changes in a variable condition as sensed by a low torque element. The system has a high overall sensitivity and is adapted to provide a measurement and/or record of the variable condition or to maintain the condition at a predetermined value.

Having now described this invention in detail in accordance with the requirements of the patent statutes, various changes and modifications will suggest themselves to those skilled in this art, and it is intended that such changes and modifications shall fall within the scope and spirit of the invention, as recited in the following claims.

I claim:

1. A pneumatic system comprising in combination, a sensing member movable in response to changes in a variable condition, a discharge nozzle, an axially-aligned receiving nozzle spaced from the discharge nozzle, means normally maintaining a low pressure air stream between the said nozzles, a vane movable in the air stream in response to movement of the sensing member and thereby to vary the amount of air passing into the receiving nozzle, a tube connected to a high pressure air supply, an air relay connected to the receiving nozzle and responsive to variations in the air pressure within the receiving nozzle to produce corresponding variations in air pressure within the said tube, a bellows movable in response to variations in the air pressure within said tube, and mechanical coupling means connected between the bellows and the sensing member and arranged to move the vane in a direction opposite to that brought about by a change in the sensing member.

2. The invention as recited in claim 1, wherein the sensing member is a balance arm carried by a rotatable shaft and said mechanical coupling means includes a second rotatable shaft co-axial and in tandem with respect to the first shaft, means coupling the two shafts together, spring means normally biasing the shafts to a predetermined position, and means coupling the second shaft to the said bellows to effect a turning of the shaft in response to collapse or expansion of the bellows.

3. The invention as recited in claim 2, wherein the means coupling the second shaft to the bellows comprises a drum carried by the second shaft and a filamentary member entwined about the drum, said filamentary member having one end secured to the drum and the other end secured to the bellows.

4. The invention as recited in claim 1, wherein the sensing member is an electrical instrument having a pointer to which the vane is attached.

5. The invention as recited in claim 1, wherein the sensing member is an electrical instrument having a pointer, and the vane is carried by a rotatable arm having an end lying in the path of travel of the pointer.

6. An electro-pneumatic system comprising an electrical instrument having a pointer, a rotatable arm having an end disposed in the path of travel of the pointer, a vane carried by said rotatable arm, a discharge nozzle disposed on one side of the vane and connected to a low pressure air supply, an axially-aligned receiving nozzle disposed on the other side of the vane and receiving air from the discharge nozzle except as cut off by the vane, an air relay operated by the variation in air pressure within the receiving nozzle, an output tube connected to a source of air pressure, means operated by said air relay to vary the air pressure in said output tube, a bellows movable in response to variations in the air pressure in said output tube, and means coupling the bellows to the said rotatable arm carrying the vane.

7. The invention as recited in claim 6, including means adjustable to space the said rotatable arm a predetermined distance from the pointer when the latter is in its normal zero position.

8. The invention as recited in claim 6, wherein the means coupling the bellows to the rotatable arm comprises a shaft rotatable about the rotational axis of the said rotatable arm, a lever pivoted at one end and connected to the bellows at a point intermediate of its ends, a rigid arm secured to the said shaft and engaging the said lever, a resilient spring having one end secured to the said shaft, and a rigid member secured to the other end of the spring and to the said rotatable arm.

9. An electro-pneumatic system comprising an electrical instrument including a pointer cooperating with a calibrated scale, a rotatable arm having an end lying in

the path of travel of the pointer tail, axially-aligned discharge and receiving nozzles, a tube connecting the discharge nozzle to a constant pressure air supply having a pressure not exceeding three inches of water, a vane carried by the rotatable arm and movable between the nozzles to vary the quantity of air flowing from the discharge nozzle to the receiving nozzle, an air relay having a chamber closed by a diaphragm, a first tube connecting the receiving nozzle to the said chamber whereby the diaphragm will move in response to changes in the quantity of air passing into the receiving nozzle, a second tube connected to a source of air pressure exceeding one (1) pound per square inch, means operated by the said diaphragm to vary the air pressure in the second tube in accordance with the variation of air pressure in the said chamber, a bellows movable in accordance with the air pressure variations in the said second tube and means coupling the said bellows to the rotatable arm carrying the vane.

10. The invention as recited in claim 9, wherein the means coupling the bellows to the rotatable arm comprises an extension carried by the said rotatable arm, a lever pivoted at one end engaging the said extension and a link connected between an end of the bellows and a point intermediate the ends of said lever.

11. A pneumatic system comprising in combination, a discharge nozzle connected to a source of low air pressure, an axially alined receiving nozzle spaced from the discharge nozzle so that air from the latter tends to flow thereinto, a vane element with an edge portion beveled to provide an approximately 60° knife edge at a portion normally lying in the air stream between said nozzles, and the plane thereof turned slightly so that the flow of air thereagainst has a component aiding said vane element in cutting into the air stream.

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