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(54) **Electromagnetic-pneumatic current to pressure transducer.**

(57) The present invention entails a current to pressure (I/P) transducer for converting andelectric signal to a proportional pressure signal over a given span. Essentially the I/P transducer comprises a housing having a membrane with magnetic and metal properties extending across and over a seat area. An air supply inlet is provided within said housing as well as a pneumatic output port. Typically, at least a portion of the inlet air supply is directed between the seat and membrane and out the output port. The pressure of the fluid passing from the output port becomes the produced proportional pressure signal of the I/P transducer.

Wire windings are disposed within the housing about a core, and two poles of opposite polarity are disposed on opposite sides of the membrane. An input current signal directed through the wire windings results in a magnetic force acting on the magnetic membrane and effectively loading the membrane. The resulting magnetic force acting on the membrane directly affects the pressure of the pneumatic output signal since the loading of the membrane acts to restrict flow between the seat and membrane. By appropriately adjusting the I/P transducer and particularly the fluid flow therethrough, the output fluid pressure signal is maintained proportional to an input current signal directed through the wire windings.

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ELECTROMAGNETIC-PNEUMATIC CURRENT TO PRESSURE TRANSDUCER

FIELD OF INVENTION

The present invention relates to instrumentation and to current to pressure transducers for converting an input current signal to a proportional output pressure signal. More particularly, the present invention entails an electromagnetic-pneumatic current to pressure transducer that utilizes an input current signal to generate a magnetic electric field that acts on a magnetic membrane for varying the output pressure of the electromagnetic-pneumatic transducer such that the output pressure is proportional to the input current signal for a given span.

BACKGROUND OF THE INVENTION

In flow control systems, it is desirable to utilize a fluid type actuator to drive a flow control element such as a mechanical valve disposed in the flow stream. Fluid actuators are very effective, reliable, and relatively inexpensive compared to the cost of a comparable electrical actuator that would require an electric motor.

Because of basic advancements made in electronics and electrical control systems over the past years combined with the ease in which electronics can be adapted to control systems, one often finds that the control signal to the actuator is in the form of

a current signal. In order to accommodate fluid actuators in such control systems, the instrumentation industry has provided current to pressure converters, often referred to as I/P transducers. While I/P transducers of the prior art have met with success and are presently used in many control systems, they nevertheless have shortcomings and disadvantages.

Virtually without exception, I/P transducers of the prior art have moving parts such as a voice coil disposed in operative relationship with a permanent magnet or magnets. Problems associated with moving parts within an I/P transducer are many.

First, moving parts invariably make conventional I/P transducers susceptible to hysteresis and deadband which means that the instrument has poor repeatability. Poor repeatability means less accuracy and precision, and this ultimately results in poor control of the system.

Secondly, response of I/P transducers of the prior art with moving parts is susceptible and greatly affected by vibration, shock, and change in orientation or attitude. Because the elements of the I/P transducer that produces the output pressure signal are moving parts, vibration, shock or change in attitude or orientation will result in these elements moving. Consequently, the response in situations involving vibration, shock, change in attitude or orientation is not accurate and precise. Again the net result is that the I/P transducer does not accurately and

precisely convert the current signal to a correct proportional pressure signal and, there is error in the final control.

Besides the problems associated with the moving parts, most conventional I/P transducers include permanent magnets. These permanent magnets are the source of an additional shortcoming of conventional I/P transducers. Over a period of time, the permanent magnet or magnets experience a degradation in strength that, of course, directly affects the accuracy and precision of the instrument.

Further, most conventional I/P transducers require some type of dampening medium. In this regard, some conventional I/P transducers, for example, require oil as the dampening medium. This obviously requires the I/P transducer to require maintenance and service.

Finally, I/P transducers of the prior art are big, bulky and often relatively expensive. The size and mass of the I/P transducer is an important consideration since they most often are required to fit in existing panel designs where space is often minimal.

SUMMARY AND OBJECTS OF THE PRESENT INVENTION

The present invention entails a compact, electromagnetic-pneumatic current to pressure transducer that overcomes the shortcomings and disadvantages of I/P transducers of the prior art.

More particularly, the I/P transducer of the present invention is designed to receive an input air supply and to effectively produce an output air flow. It is the pressure of the output air flow that serves as the output pressure signal of the I/P transducer.

Effectively, the I/P transducer of the present invention is designed to accept an input current signal, preferably from four to twenty mA (milliamps). This current signal is directed to wire windings within the I/P transducer. The direction of the current signal through the wire windings about a core results in the generation of a magnetic field that acts on a magnetic membrane also housed within the I/P transducer. The magnetic membrane in turn is designed within the I/P transducer to respond so as to vary the pressure of the output air flow. In the present design for a given span, the I/P transducer produces an output pressure signal that is proportional to the input current signal.

It is, therefore, an object of the present invention to provide an I/P transducer that is compact and relatively inexpensive.

A further object of the present invention

resides in the provision of an I/P transducer that has virtually no moving parts.

Still a further object of the present invention resides in the provision of an I/P transducer that is insensitive to vibration, shock, orientation and attitude.

Another object of the present invention resides in the provision of an I/P transducer that is accurate and precise and which is repeatable.

It is also an object of the present invention to provide an I/P transducer that overcomes the problems of hysteresis and deadband commonly found in current to pressure transducers of the prior art.

Still a further object of the present invention resides in the provision of an I/P transducer that is relatively simple and easy to install and maintain.

A further object of the present invention resides in the provision of an I/P transducer wherein an input current signal is utilized to generate a magnetic force that is directed against a magnetic membrane which in turn is operative to control the pressure of a fluid flow passing from the valve wherein the control pressure of the output fluid flow is proportional to the input current signal.

Another object of the present invention resides in the provision of an I/P transducer of the character referred to above that utilizes an input current signal to generate a magnetic force within

the transducer itself that positively acts on a flowing system of air to produce an output pressure that is proportional to the input current signal.

It is also an object of the present invention to provide an I/P transducer of the character referred to above that has a relatively quick response time.

Still a further object of the present invention resides in the provision of an electromagnetic-pneumatic transducer that operates independently of polarity.

It is also an object of the present invention to provide an I/P transducer that is inherently stable, accurate and precise over a relatively long period of time.

Another object of the present invention resides in the provision of an I/P transducer that has the capability of electromagnetically loading a magnetic membrane that acts on a fluid flow to produce a pressure signal proportional to an input current signal.

Other objects and advantages of the present invention will become apparent from a study of the following description and the accompanying drawings which are merely illustrative of the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a transverse sectional view of the basic I/P transducer module of the present invention.

Figure 2 is a schematic illustration of an I/P transducer design incorporationg a pneumatic amplifier along with a span adjustment circuit.

I/P TRANSDUCER

With particular reference to the drawings, the electromagnetic-pneumatic I/P transducer of the present invention is shown therein and indicated generally by the numeral 10. Viewing I/P transducer 10 in more detail, the same is provided in the form of a nonmagnetic silicone stainless steel housing that includes a first or bottom section 12 and a top or second section 14. The housing formed by first and second sections 12 and 14 is generally cylindrical.

Viewing bottom section 12, it is seen that the same includes an annular side wall 12a and a central post 12b extending upwardly about the center thereof. Formed about the top of center post 12b is a valve seat 12c. Annular wall 12a and center post 12b form what is referred to herein as an E core. The significance of this defined E core will become apparent from subsequent portions of this disclosure.

Continuing to refer to the first or bottom section 12, it is seen that the same is provided with a supply inlet 16 that includes an opening that extends through the lower portion of the transducer housing and completely up and through central post 12b. Communicatively connected to the supply inlet 16 is an output port 18 that is operative to direct portions of

the fluid supply from the transducer.

In addition, there is provided a low port 20 formed in the annular wall 12a that allows supply air passing through the transducer to exit to the atmosphere.

As seen in the drawings, held between the first and second transducer sections 12 and 14 is a membrane 22. Membrane 22 includes magnetic and metallic properties and the present embodiment is formed of a material known as molybdenum stainless steel.

Formed in the top 14 of the I/P transducer is a zero-adjust port 24.

Wrapped around the center of the formed E core is a wire winding that is referred to by the numeral 26. In the case of the present I/P transducer 10 that is designed to accommodate an input current signal of four to twenty milliamps, it is contemplated that the wire windings 26 would include approximately 4000 turns of number 32 gauge wire. It is appreciated that the wire windings 26 would extend through the annular wall 12a of the I/P transducer and would operatively connect to a current signal source.

In the design to accommodate four to twenty mA, the same is designed such that the vertical distance from the top of valve seat 12c to membrane 22 is approximately 0.007 inches. Likewise, the distance between the lower surface of top 14 to membrane 22 is approximately 0.003 inches.

The top of valve seat 12c forms one pole while the bottom side of top 14 forms another

pole. It is significant that the smaller pole be spaced furthest from membrane 22 in order to provide proper response of the membrane 22 for a given input current signal.

In operation the basic operation of the I/P transducer 10, a supply fluid, typically air at psig is directed into the supply port 18. This supply air is directed into the transducer 10 and up through the central post 12b where the air is dispersed out and over the valve seat 12c and underneath and around membrane 22. This air exits the I/P transducer through low port 20. It is appreciated that some of the supply air is directed through output port 18.

The presence of an input current signal through wire windings 26 results in a magnetic field occurring throughout the I/P transducer as indicated by the nagnetic flux lines 28 in Figure 1. This generated magnetic field causes a magnetic force to act against membrane 22. Because of the design of the I/P transducer 10 of the present invention and particularly the design of the E core and its components with respect to top 14, the resulting magnetic force tends to act and load the membrane downwardly as viewed in Figure 1. This downward loading results in a restriction being placed on the air passing over the valve seat 12c to the outer side areas of the valve. This restriction causes a correspondingly proportional pressure at output port 18. In the design of

the I/P transducer 10 of the present invention, the pressure found or sensed at the output port 18 is proportional to the current signal directed through the wire windings 26. For an increase in the current signal directed through the wire windings 26, there is a proportional pressure increase in the fluid flow at output port 18 due to the loading of membrane 22 by the resulting magnetic field.

Turning to Figure 2, there is illustrated schematically therein an I/P transducer design utilizing the basic I/P transducer module 10 described hereinbefore.

In Figure 2, there is illustrated a 20 psig supply line 34 that feeds anyone of a plurality of input supply lines. In this regard, supply input line or port 16 is operative to direct a supply flow into the base of I/P transducer 10. As already described, the fluid input, which is typically air, is directed from line 16 up through central post 12b where the air is dispersed over the valve seat 12c and out low port 20.

In Figure 2, the illustration of I/P transducer 10 is only schematically. Therein the wire windings 26 for purpose of illustration is shown disposed over the membrane 22. Wire windings 26 can be disposed on either side of membrane 22 inasmuch as the basic intent of loading membrane 22 for producing a proportional output pressure can be achieved with the wire windings 26 disposed on either side thereof.

Continuing to refer to the basic operation

of the I/P transducer design as illustrated in Figure 2, it is appreciated that while an air flow passes through the I/P transducer 10, that an input current signal typically from four to twenty milliamps is being directed through the wire windings 26. This input current signal causes a magnetic field to be generated about the transducer 10. Reference is made to the magnetic flux lines 28 illustrated in Figure 1. Because membrane 22 has magnetic properties, the generated magnetic field acts to load the same. This loading effect directly affects and determines an output pressure which in the case of this design is the pressure of the output fluid flow flowing in line 18.

It is seen that main supply line 34 also feeds line 36 which directs an input pressure signal to I/P transducer 10. In the case of the present design, it is this input pressure signal that serves to "zero" the I/P transducer. This is typically achieved by directing a selected input current signal, in this case four milliamps, through the wire windings 26 and adjusting the input pressure into port 24 such that the output pressure from the pneumatic relay 32 is 3 psig.

Consequently, it is appreciated that the output pressure signal found in line 18 is proportional to the input current signal directed through the wire windings 26.

Often as a practical matter, the pressure

signal found in line 18 requires amplification in order to be easily and efficiently utilized.

To achieve this, the I/P transducer design illustrated in Figure 2 is shown with a conventional pneumatic amplifier, indicated generally by the numeral 30. Details of pneumatic amplifier 30 are not dealt with herein in detail because such is known and appreciated in the prior art. For a complete and unified understanding of such, one is referred to the disclosure found in U. S. Patent 3,844,529, the disclosure being expressly incorporated herein by reference. This patent discloses the basic pneumatic amplifier "pi-valve" manufactured by Brandt Industries, Inc., of Triple W Air Park, Fuquay-Varina, North Carolina 27526.

In effect, this pneumatic amplifier 30, which also utilizes a membrane, acts to amplify the output pressure signal of the I/P transducer module 10. In the present design, air flow line 38 serves as a supply input to amplifier 30 and the same has a communicatively joined output 40 and a low port line 42 that leads to ground (atmosphere). Essentially what occurs is that the output signal of the I/P transducer 10 found in line 18 is directed into amplifier 30 as an input pressure signal. Amplifier 30 acts to amplify this input signal to an output pressure signal found in line 40.

To boost the output pressure signal in line 40, a pneumatic relay 32, of a conventional type, is utilized. Pneumatic relay 32 simply boosts the pressure signal directed thereto. It is understood and

appreciated that the boosted pressure signal leaving pneumatic relay 32 is still proportional to the input current signal received by the I/P transducer module 10.

In order to adjust for span, portions of the flow being directed from the pneumatic relay 32 is directed through a variable flow restrictor span adjustment 44 prior to joining the low port ground line 20 of the I/P transducer module 10. By effectively dumping a portion of the final output flow back through the low port line 20 and to ground or atmosphere, one can adjust the span of the I/P transducer module. For example, after properly zeroing, the input current signal can be changed to another selected current signal such as 20 milliamps. With this input current signal, the variable flow restrictor 44 is adjusted such that the output pressure of flow leaving pneumatic relay 32 is at a desired magnitude, which in this case would be 15 psig. Consequently, for any given input signal from four to twenty milliamps, there would be a proportional output pressure signal produced from three to fifteen psig.

In the present disclosure, reference has been made to both fluid flow and air. It is appreciated that the amplifier valve 30 and the I/P transducer 10 of the present invention is basically designed to accommodate fluid flow. As a practical matter, air is typically used as a supply fluid although other fluids may very well be utilized.

In addition it is appreciated that certain specifications referred to herein will change and vary depending on the input current signal range and the desired pressure output.

The present invention, of course, may be carried out in other specific ways than those herein set forth without departing from the spirit and essential characteristics of the invention. The present embodiments are, therefore, to be considered in all respects as illustrative and not restrictive, and all changes coming within the meaning and equivalency range of the appended Claims are intended to be embraced therein.

CLAIMS:

1. An electromagnetic-pneumatic I/P transducer for converting an input current signal to a proportional output pressure signal comprising: a housing structure; a magnetically responsive membrane disposed within said housing structure of said I/P transducer; supply fluid inlet means associated with said housing structure for directing a supply fluid to said housing structure; output means operatively associated with said I/P transducer for channeling a resulting output fluid from said I/P transducer; and means for directing an input current signal into operative relationship with said I/P transducer and utilizing the input current signal to electromagnetically load said membrane for producing a resulting pressure signal within the output fluid flow that is proportional to the input current signal.

2. The electromagnetic-pneumatic I/P transducer of Claim 1 wherein said means for directing an input current signal into said housing for effectively electromagnetically loading said membrane comprises a wire coil winding that is operative to generate a magnetic field in response to an electrical current passing therethrough, wherein the electric field yields a magnetic force that is operative to load said membrane which in turn acts upon fluid flow passing in operative relationship with said housing to produce an output

flow that includes a pressure proportional to the input current signal.

3. The electromagnetic-pneumatic I/P transducer of Claim 2 wherein said housing includes a non-magnetic core and wherein said wire core winding is wrapped therearound.

4. The electromagnetic-pneumatic I/P transducer of Claim 2 wherein said housing structure includes a non-magnetic E core with said E core including a central core post having said wire core winding wrapped therearound.

5. The electromagnetic-pneumatic I/P transducer of Claim 2 wherein said transducer includes two poles with each pole being disposed on opposite sides of said membrane.

6. The electromagnetic-pneumatic I/P transducer of Claim 5 wherein one pole has a smaller surface area than the other and wherein the pole with the smaller surface area is spaced a greater distance from said membrane than the other pole.

7. The electromagnetic-pneumatic I/P transducer of Claim 2 wherein there is provided in addition an amplifier operatively connected to said I/P transducer for receiving said output pressure signal therefrom and amplifying the same.

8. The electromagnetic-pneumatic I/P transducer of Claim 7 wherein there is provided a booster relay operatively connected to said amplifier for receiving an amplified pressure signal and boosting the

same to produce a boosted pressure signal.

9. The electromagnetic-pneumatic I/P transducer of Claim 8 including a feed-back loop operative to direct at least a portion of the fluid flow associated with anyone of the output pressure signals back to said I/P transducer such that by varying the quantity of flow back to the I/P transducer, the span thereof can be appropriately adjusted such that for a given range of input current signals, a proportional range of pressure signals results.

10. An electromagnetic-pneumatic I/P transducer for converting an input current signal to a proportional output pressure signal comprising: a housing structure; a relatively thin magnetically responsive membrane supported about its outer border by said housing structure and extending thereacross so as to define at least one chamber area about one side of said membrane; said chamber area including a fluid inlet, a fluid outlet, and a seat disposed in spaced apart relationship relative to said membrane, and wherein said I/P transducer is adapted to be operatively connected to a supply fluid wherein the supply fluid is directed into said fluid inlet, between said seat and said membrane and into operative engagement with said membrane, and out said fluid outlet; said housing including a core that defines first and second poles with said poles being disposed on opposite sides of said magnetically responsive membrane; and wire winding means operatively disposed about said core for receiving an input current signal and for generating a magnetic field across said poles for effectively loading said magnetically responsive membrane against the flow of fluid between said seat and said membrane to produce an output pressure signal associated with the flow of said supply fluid that is proportional to the input current signal received by said wire winding means.

11. The electromagnetic-pneumatic I/P transducer of Claim 10 wherein said core includes a central post disposed within said chamber and wherein said wire winding means includes a series of wire turns wrapped around said central post.

12. The electromagnetic-pneumatic I/P transducer of Claim 11 wherein said seat forms a top portion of said central post; and wherein said fluid inlet includes a continuously opening through said central post wherein the flow of supply fluid passes through said central post and exits between said

13. The electromagnetic-pneumatic I/P transducer of Claim 10 wherein said housing structure includes a second inlet formed therein opposite said chamber wherein a pressure signal may be received therethrough and applied against said membrane opposite said chamber for zeroing or adjusting said I/P transducer.

14. The electromagnetic-pneumatic I/P transducer of Claim 13 wherein said housing structure includes a top, bottom, and surrounding side wall structure and is of a two piece construction that is adapted to receive said magnetically responsive membrane therebetween in a sandwiched fashion.

15. The electromagnetic-pneumatic I/P transducer of Claim 10 wherein one pole has a surface area that is smaller than said other pole and wherein said pole with the smaller surface area is spaced a greater distance from said membrane than the other pole.

16. The electromagnetic-pneumatic I/P transducer of Claim 15 wherein said smaller pole is disposed on the side of said membrane where said chamber is formed and where said supply fluid is flowing between said seat and said membrane and out said fluid outlet.

17. The method of converting an input current signal to a proportional pressure signal comprising the steps of:

directing a supply fluid flow into and through a chamber having a magnetically responsive membrane disposed therein wherein the pressure of the supply fluid flow may be varied by effectively loading the magnetically responsive membrane against the flow of supply fluid; directing an input current signal to a wire winding operatively disposed within said chamber; and utilizing the input

current signal and the current flow associated therewith passing through said wire winding to generate an electric field that is operative to effectively load said magnetically responsive membrane so as to act against said flow of supply fluid to generate a pressure signal associated with said fluid supply flow that is proportional to said input current signal.

18. The methd of Claim 17 further including the step of directing the produced proportional output pressure signal to a pneumatic amplifier and amplifying the proportional pressure signal such that the same remains proportional to said input current signal.

19. The method of Claim 18 further including the step of directing the amplified pressure signal produced by said pneumatic amplifier to a pneumatic relay for producing a boosted pressure signal that remains proportional to said input current signal.

20. The method of Claim 19 including directing a portion of the flow associated with the pneumatic boosted pressure signal back to said chamber and into operative relationship with said supply fluid flow passing therethrough for effectively adjusting the span of the final pressure output signal being emitted by said pneumatic booster.

21. The method of Claim 17 further including directing an adjusting pressure signal to said chamber for purposes of zeroing and/or adjusting span.

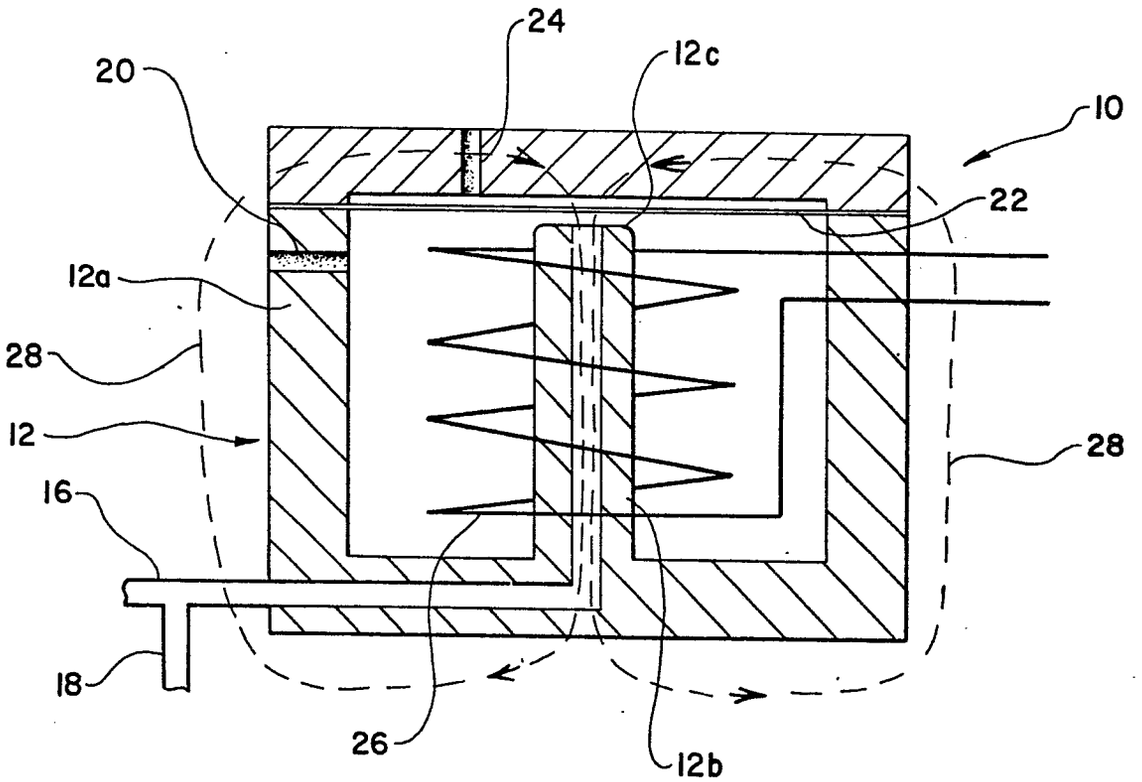

FIG. 1

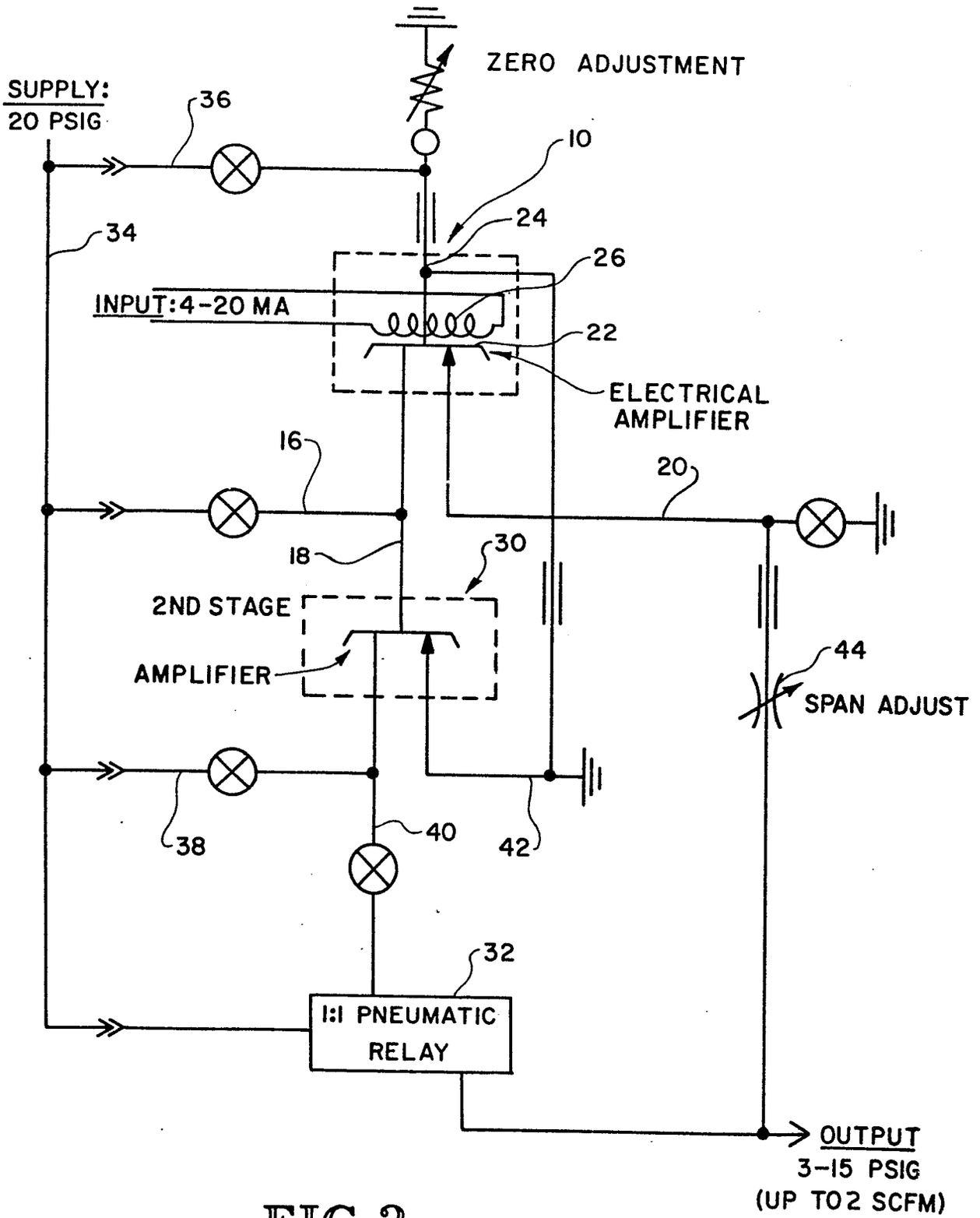
ZERO ADJUSTMENT
SUPPLY:
20 PSIG
36
10
24
34
26
INPUT:4-20 MA
22
ELECTRICAL
AMPLIFIER
16
20
18
30
2ND STAGE
AMPLIFIER
44
SPAN ADJUST
38
40
42
32
1:1 PNEUMATIC
RELAY
OUTPUT
3-15 PSIG
(UP TO 2 SCFM)

FIG. 2