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(54) Current to pressure transducer employing magnetic fluid with self-correcting nozzle.

(57) A current-to-pressure transducer that is insensitive to shock employs a magnetic fluid (30) that deforms a flexible diaphragm (13) in response to an electrical input current that is applied to a coil (33) and magnetic circuit. The deformed diaphragm (13) varies the air space between the diaphragm (13) and a nozzle (10) connected to the air line so that the pressure within the air line is effectively controlled. A nozzle (10) and pole piece (11) are formed from a single magnetic part so that the ends of the nozzle (10) and pole piece (11) are substantially coplanar. When used with a current-to-pressure transducer, the coplanar design allows proper alignment of the diaphragm (13) employed for sealing the nozzle (10) without canting and misalignment of the diaphragm (13). The integral nozzle (10) and pole piece (11) structure is relatively easy to machine and manufacture.

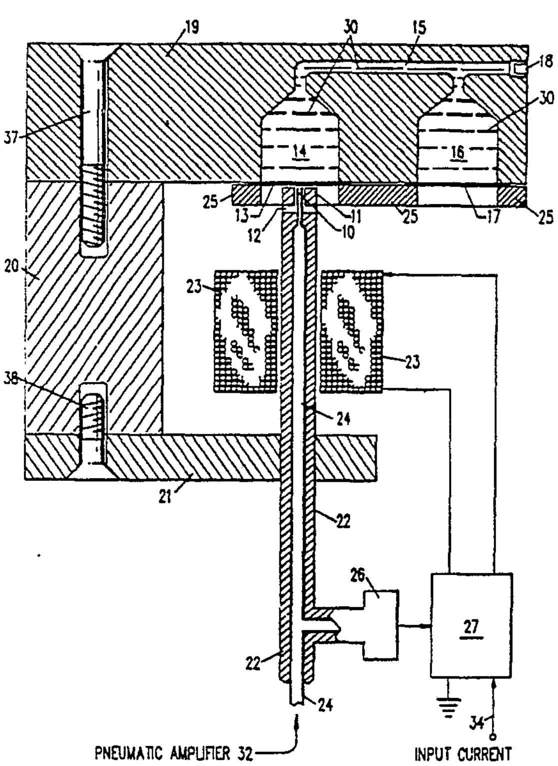

FIG. 1

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CURRENT TO PRESSURE TRANSDUCER EMPLOYING MAGNETIC FLUID WITH SELF-CORRECTING NOZZLE

FIELD OF THE INVENTION

This invention relates to the regulation of air pressure in response to electrical signals and in particular to a transducer for converting an electrical current to a corresponding pressure in a system that uses compressed air. The invention also relates to a nozzle that is useful with the current-to-pressure transducer and in particular to a self-correcting nozzle structure.

BACKGROUND OF THE INVENTION

Description of the Prior Art

Compressed air is used in many systems for controlling machinery because compressed air is immune to electrical interference and is safe in explosive environments. Compressed air is generally used, for example, to control valves and other mechanical devices in industrial systems. When using compressed air in a system, sensors are generally provided that generate small electrical currents, in the range of 4 to 20 milliamperes, for example. These currents are used to establish a corresponding pressure of the compressed air and to provide a sufficient volume of pressurized air for accomplishing the desired mechanical task. In some systems, the conversion from electrical current to a corresponding pressure is accomplished by use of a current-to-pressure transducer that is capable of regulating the pressure of a small volume of air, wherein the volume of air is amplified by using standard pneumatic amplifiers. In the conventional current-to-pressure transducer, a nozzle is supplied that directs compressed air to the atmosphere at a rate determined by the proximity of a flapper valve to a nozzle orifice. The flapper valve is generally mounted on a rotating suspension and is rotated by magnetic forces that are generated by an electromagnet. The flapper is rotated toward the nozzle so that the air that escapes to the atmosphere is reduced. Such prior art devices are formed as delicate mechanical assemblies that require several adjustments during fabrication and are relatively expensive to produce.

A nozzle is a converging or converging-diverging tube attached to the outlet of a pipe, hose or pressure chamber. The purpose of the nozzle is to convert the pressure existing in a fluid into velocity efficiently. A nozzle allows a pressure to be carried in a pipe or hose adjacent to the nozzle.

Presently known nozzles used for controlling air flow generally terminate with an outer diameter slightly larger than the inner diameter. Typically, the outer diameter of a nozzle would be 0.035 inch and the inner diameter would be 0.026 inch, by way of example. The current-to-pressure transducers that use such type nozzles usually incorporate a flapper, which is a pivotable paddle-shaped part, or a diaphragm to vary the flow of air through the nozzle. In either case, it is necessary that a good seal be provided at the end of the transducer from which there is the high flow of air or fluid. In order to achieve the required good seal, the flapper or diaphragm must be precisely aligned in a plane that is perpendicular to the axis of the nozzle. If the alignment is not proper, the flapper or diaphragm will first strike an edge of the nozzle end and will not advance further towards making an effective complete seal. It is relatively difficult to provide the desired orthogonal alignment of the flapper or diaphragm in a planar orientation relative to the nozzle axis.

U.S. Patent 4,579,137 describes a transducer including a membrane 22 on which a magnetic button 22A is positioned. When the magnetic button is attracted to a post 12B, the air gap between the button 22A and a magnetic part 14 in which a port 24 is formed increases in size. The sum of the air gaps between the button 22A and the magnetic part 14, and between the button 22A and the post 12 remains constant. The undesirable air gap between button 22A and the magnetic part 14 adversely affects the efficiency of the magnetic circuit and consequently impairs the proper control of the air pressure in the patented device.

U.S. Patent 4,053,952 describes the use of a magnetic fluid for occluding a tube that is disposed within the body of a human. The patented device used no moving parts in the mechanism, which serves as a valve or a pump selectively. The patent states that when the magnetic field of the permanent magnets is present, the pressure of the magnetic fluid forces the membrane against a pole piece thus occluding the flow passage (column 5, lines 34-37). The patented device serves as an on-off valve or pump, but does not act to vary the size of an air gap in response to an input current that varies the strength of a magnetic field in selected regions of a magnetic fluid. In the patent, a bucking magnetic field is required to counteract the magnetic field from the permanent magnet (col.4, line 11-17) which surrounds the portion of the tube that is to be affected by the pressure which the patent alleges occurs in the magnetic fluid. The patent does not teach how to move a membrane by using a magnetic fluid, and assumes (as shown in Fig. 2) that an essentially uniform magnetic field acting on the entire volume of magnetic fluid creates a pressure within that fluid to cause displacement of a membrane. The patented device requires compression or expansion of the fluid, or the generation of regions of vacuum within the chamber containing the magnetic fluid in order for his device to be operable. As illustrated in Figure 2 of the patent, if the membrane 38 were to move either the volume of magnetic fluid 28 would have to increase, or a region of vacuum would have to be created within the chamber containing the fluid 28. The compressibility of fluids is such that the change in volume is negligible and any region of vacuum would be opposed by the ambient or atmospheric pressure to which the contents of the reservoir 14 are vented. The atmospheric pressure that is transmitted through the membrane 38 to the magnetic fluid at all times is greater than any pressure that can be generated by magnetic means. Therefore the diaphragm 38 described in the patent does not move.

It is highly desirable to employ a simple current-to-pressure transducer that lends itself to facile production at low cost without the need for individual mechanical adjustments.

SUMMARY OF THE INVENTION

An object of this invention is to provide a current-to-pressure transducer that regulates the air pressure within an air supply line so that the pressure differential between this line and ambient air pressure varies substantially linearly with an applied electrical current. Henceforth, the word "pressure" will be used to mean the pressure relative to the environment.

Another object of this invention is to provide a transducer that is relatively efficient and has uniform characteristics so that individual adjustments need not be made.

Another object is to provide a current-to-pressure transducer that can be mass produced at low cost.

A further object is to provide a current-to-pressure transducer that is immune to electrical interference and is safe in explosive environments.

Another object of this invention is to provide a nozzle and pole piece structure that affords an effective complete seal at the nozzle end from which fluid or air flows to the ambient environment.

Another object of this invention is to provide an integral nozzle and pole piece structure which is easier to manufacture than prior known nozzles of this type.

In accordance with this invention, a current-to-pressure transducer incorporates a magnetic fluid that is in contact with a flexible membrane or diaphragm. The diaphragm responds to forces exerted on the magnetic fluid and moves towards a nozzle to narrow the space through which the air flowing from the nozzle is passed to the ambient environment. The diaphragm moves in accordance with an electrical input current. The current is applied to a coil wound around a magnetic circuit that moves the flexible membrane towards the nozzle by means of the magnetic fluid. Movement of the membrane towards the nozzle decreases the flow of air from the nozzle and increases the pressure of the air within the air supple line. In one embodiment pressure sensing means and electronic feedback are used to achieve the desired linearity between the pressure within the line supplying air to the nozzle and the electrical input current.

Another feature of this invention is a self-correcting nozzle and pole piece structure that is useful with a current-to-pressure transducer is formed from an integral piece of magnetic material. The nozzle and pole piece structure is formed so that the respective ends of the nozzle and pole piece which face the sealing element, which in this case is a flexible diaphragm, are coplanar. The nozzle structure provides a self-correcting feature that compensates for any canting or misalignment of the diaphragm. Slots are provided at the end of the integral piece facing the diaphragm to allow the escape of excess air.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be described in greater detail with reference to the drawing in which:

Figure 1 is a side cross-sectional view of a current-to-pressure transducer, made in accordance with this invention;

Figure 2 is a side cross-sectional view of an alternative implementation of the current-to-pressure transducer of this invention;

Figure 3 is a cross-sectional view, partly broken away, of another implementation of the invention/

Figure 4 is an enlarged isometric view, partly broken away, showing the relationship of a pole piece 11 to the nozzle 10 and the nozzle air supply line 24, as used in the transducer of this invention;

Figure 5 is a representative curve plotting pressure against current without electronic feedback to aid in the explanation of the operation of the current-to-pressure transducer;

Figure 6 is a side view of a nozzle and pole piece, made in accordance with this invention;

Figure 7 is an end view at the slotted end of the nozzle and pole piece structure, such as illustrated in Fig. 6;

Figure 8A is an enlarged cross-sectional view, partly broken away, taken across lines A-A′ of Fig. 7;

Figure 8B is an enlarged cross-sectional view, partly broken away, taken across lines B-B′ of Fig. 7;

Figure 9 is an exploded view of an assembly drawing illustrating the housing which encloses the nozzle and pole piece structure; and

Figure 10 s an isometric view illustrating an assembled housing which encloses the nozzle and pole piece structure of this invention.

In accordance with this invention, flexible membranes or diaphragms 13 and 17 are located respectively at the lower open ends of the chambers 14 and 16 to seal the ends of the chambers and to contain the magnetic fluid 30 within the chambers. The flexible membranes 13 and 17 are retained by a nonmagnetic retainer element or ring 25 which abuts the diaphragms. The element 25 is fastened at its exposed surface to the baseplate 19 by screws or other suitable means.

In operation, the pneumatic amplifier 32 provides compressed air through the air supply line 24 to the nozzle 10. The air passes through the space between the diaphragm 13 and the surface of the nozzle 10. Escape holes 12 or other suitable means are provided in the upper portion of the magnetic member 22, as shown in Fig. 4 to prevent undesirable pressure build up between the pole piece 11 and diaphragm 13. An air pressure sensor 26 senses the pressure of the compressed air that is passing through the air supply line 24 and generates a signal representative of the pressure value. The signal is provided to an electronic feedback circuit 27, which also receives the input current through lead 34. The input current and the signal representative of the pressure value are compared in the circuit 27 and a current representative of this comparison is provided to the coil 23. The electronic feedback circuit 27 adjusted the actual current to the coil 23 so that the pressure in the air line 24 is substantially linear with the input current. The input current during operation maintains the coil in an excited state and as a result the pole piece 11 distributes magnetic flux in the area adjacent to the diaphragm 13. The magnitude of the magnetic flux emanating from the pole piece 11 varies with variations in the current supplied to the coil 23. The magnetic fluid 30 in chamber 14 is attracted towards the pole piece 11 and the diaphragm 13 is deformed to an extent directly related to the magnitude of the current which is applied to the coil 23. The diaphragm 13 deforms and moves partially towards the pole piece 11 so that the space between the diaphragm 13 and the nozzle 10 decreases. As a result, the pressure of air within the air line 24 supplying air to the nozzle 10 is increased. During the deformation of the diaphragm 13 resulting from the magnetic fluid 30 being moved towards the pole piece 11, the volume of magnetic fluid that is displaced in chamber 14 associated with the displacement of diaphragm 13 is provided from chamber 16 to chamber 14. The diaphragm 17 moves inwardly to the chamber 16 in an equal and opposite direction to diaphragm 13.

With reference to Fig. 2, the air supply line 24 including the nozzle 10 is located under the chamber 16. The coil 23 and the associated magnetic members 20, 21, 22, baseplate 19 and pole piece 11 remain in association with the chamber 14 for coaction with the diaphragm 13. An increase in current to the coil 23 causes the diaphragm 13 to deform toward the pole piece 11 and the volume of magnetic fluid that is displaced from chamber 16 to chamber 14 causes the diaphragm 17 to move away from the nozzle 10. Consequently, the pressure of the air in line 24 is decreased. In this embodiment of Fig. 2, the air line 24 is made of nonmagnetic material such as aluminum, or alternatively is magnetically isolated from the magnetic circuit which includes the coil 23 and the magnetic member 22, inter alia.

A feature of this invention is the insensitivity to gravitational or acceleration forces. Because the magnetic fluid 30 is relatively incompressible, the diaphragms 13 and 17 move equally in opposite directions. In those embodiments in which the diaphragms are coplanar, the transducer is insensitive to forces that are applied perpendicularly to the plane of the diaphragms. The transducer is relatively insensitive to forces that are applied perpendicularly to the plane of the drawing and a line through the centers of the chambers, irrespective of whether the diaphragms are coplanar. Also the viscous damping that is associated with transport of the fluid 30 through the capillary 15 causes the transducer to be insensitive to shock in any direction. The damping is enhanced as the viscosity of the magnetic fluid 30 is increased and the conductance of the capillary 15 is decreased. Damping also can be used to limit the high frequency response of the transducer.

As illustrated in Fig. 3 in another implementation of the invention, a further increase in sensitivity is achieved by affixing an element 28 made of a solid, magnetically soft material, such as iron, to the center of the diaphragm 13. The element 28 is disposed within the magnetic fluid in chamber 24 and has a higher saturation magnetization than the magnetic fluid. The element 28 also can provide stiffness to the central portion of the diaphragm. To preserve shock insensitivity, an element 29 is located in the chamber 16 and is affixed to the diaphragm 17. The element 29 may be substantially identical to the element 28,or may be of a nonmagnetic material with suitable size and shape to achieve the desired insensitivity.

Fig. 5 is a curve representing the changes in pressure (psi) as a function of current (milliamps). In an actual implementation of the invention, a 450 Gauss, 400 cp Ferrofluid was used. The element 28 is a steel slug of 3/8-inch diameter and 3/16-inch long cemented to the diaphragm 13 with RTV silicone sealant. The air supply pressure is 18 psi. It should be understood that these parameters, materials and dimensions are exemplary and the invention is not limited thereby.

In an alternative approach the transducer comprises a single chamber and a single flexible diaphragm. In such case an air space is provided above the level of the magnetic fluid to allow displacement of the diaphragm.

In another approach, nozzle 10 is made of magnetic material and functions also as pole piece 11. In this approach, the outer coaxial member 11 and holes 12 shown in Figure 4 are eliminated.

The novel current-to-pressure transducer disclosed herein employs a magnetic fluid to coact with flexible diaphragms disposed in close juxtaposition to a nozzle of an air line. The transducer lends itself to mass production and low cost, is efficient in operation, and does not require individual adjustments.

Another feature of this invention is a nozzle and pole piece structure that is formed from a rod 40 made of a magnetic material, such as Carpenter High Permeability "49" Alloy, for example. The rod 40 has a diameter of about 3/16 inch in this particular embodiment. As illustrated in Fig. 6, the magnetic rod 40 is formed with functional pole pieces 41 at a slotted end of the rod 40. Slots 43 allow the escape of excess air and are relatively easy to machine, with saw blades or slot cutters, as compared to the formation of individual bleed holes 12 and the associated deep circumferential groove between elements 10 and 11 to which the holes connect, shown in Fig. 2. The pole pieces 41 provide magnetic flux for coaction with electric current flowing through the electrical coil (not shown) of the electromagnetic circuit. Application of electric current to the coil causes the magnetic fluid 30 to move which, in turn, causes the deformation of the flexible diaphragm as explained heretofore thereby controlling air flow through the nozzle .

The rod 40 has a threaded part 42 for engagement with a threaded cap 44 of a housing assembly, shown in Fig. 9. The rod 40 also has a hexagonal part 46 formed at the end adjacent to the threaded part 42 to allow the rod to be turned so that the height of the nozzle relative to the diaphragm can be adjusted for proper operation, and locked with nut 68.

Figure 7 shows an.end view of the nozzle and pole piece structure 40 viewed from the slotted end. The rod 40 is formed with one or more of the longitudinal slots 43, which extend inwardly to at least the outer diameter of a relatively shallow groove 46 formed within the end of the rod 40. The slots 43 serve the same purpose as the holes 12 depicted in Fig. 2 to allow the escape of excess air, but are easier to machine and fabricate than the transverse holes. Groove 46 may be eliminated if the slots 43 extend inward to the proximity of the constricted passage 49.

As depicted in Figs. 8A and 8B, an open channel 48 is formed within the interior of the nozzle tube 46 to allow the passage and escape of air. The nozzle tube 46 may be tapered at the end portion that faces the diaphragm so that a constricted passage 49 is formed at the end of the nozzle channel 48. The constricted portion 49 of the channel 48 (Figs. 8A and 8B) reduces the volume of air that escapes from the nozzle at a given pressure. The amount of air flow from the channel portion 49 is regulated by the position of the diaphragm 13, which is controlled by the action of the magnetic fluid in response to the electric current supply to the coil of the electromagnetic circuit.

The exploded view of Fig. 9 shows the main housing 50 for the integral nozzle and pole piece structure which is made of soft iron. Diaphragms 52 and 54 are spaced by a soft iron spacer 56 formed with magnetic fluid chambers 58 and 60. O-ring seals 62 and 64 are provided with the chambers. A threaded aluminum retainer 66 is located adjacent to the diaphragm 54 for connection to the spacer 56. A lock nut 67 is located against the retainer 66 and four cap screws 70 tie the spacer 56 and retainer 66 with the diaphragms 52 and 54 to the main housing 50. A second nozzle (not shown) may be threaded into retainer 66 to coact with diaphragm 54, as described in the referenced copending application.

At the other end of the housing 50, the threaded element 44, which is made as a soft iron cap with internal threads for engaging the nozzle, is joined with a lock nut 68 by means of four Allen socket cap screws 72 to the main housing 50.

Fig. 10 depicts the assembled unit which has a notch 74 in the housing 50 to allow connection of electrical circuitry to the electrical coil of the electromagnetic circuit and to permit escape of excess air.

By virtue of the integral structure of a nozzle and pole piece which are machined from a single magnetic rod, the end of the nozzle tube 46 and the end of the pole piece 41 are substantially coplanar. When the electromagnetic force is applied to the top surface of the diaphragm 13 by the magnetic fluid 30, the lower surface of the diaphragm conforms to the shape of the pole piece 41. Since the alignment of the ends of the pole piece 41 and nozzle tube 46 are in substantial planar alignment, the diaphragm will provide a complete seal at the face of the nozzle. With the present design, the torque applied to the flapper valve acts through a point further from the nozzle than the point of first contact between the flapper valve and nozzle 10, and if the flapper valve does not contact the nozzle squarely, further torque will only distort the flapper valve and worsen the incomplete seal. With the nozzle and pole piece structure design as disclosed herein, any canting of the diaphragm 13 is self-corrected because the force on the diaphragm acts between a point of first contact of the diaphragm 13 with the end of the larger diameter pole piece 41 and the coplanar end of the nozzle tube. The integral nozzle and pole piece structure also is easier to fabricate with the slots 44 formed at the end of the rod structure to allow the desired air escape instead of with transverse holes as used in prior nozzle assemblies. Such transverse holes either require a difficult process to machine a deep groove between the nozzle 10 and pole piece 11, or require fabricating the nozzle 10 and pole piece 11 separately, in which case it would be difficult to assemble these parts to achieve the desired coplanarity.

Claims

1. A current-to-pressure transducer comprising:
at least one chamber 14 having an open end;
magnetic fluid 30 contained within said chamber;
a flexible diaphragm 13 for sealing said open end of said chamber;
air supply means 24 disposed closely adjacent to said diaphragm for supplying air;
electromagnetic means 23 energized by an input current and disposed adjacent to said diaphragm for attracting said magnetic fluid and for deforming said diaphragm towards said air supply means so that the pressure of said air in said air supply means is regulated.

2. A current-to-pressure transducer as in Claim 1, wherein said air supplying means and said electromagnetic means are both disposed adjacent to said diaphragm.

3. A current-to-pressure transducer as in Claim 1, wherein said electromagnetic means comprises a magnetic tubular element 22 and an electrical coil 23 wound about said element.

4. A current-to-pressure transducer as in Claim 3, wherein said air supplying means comprises a tube disposed coaxially within said magnetic tubular element, and a nozzle 10 disposed at one end of said tube closely adjacent to said selected diaphragm.

5. A current-to-pressure transducer as in Claim 1, including a magnetic piece 28 positioned within said chamber adjacent to said diaphragm.

6. A current-to-pressure transducer as in Claim 1, wherein an air space is provided within said magnetic fluid.

7. A current-to-pressure transducer as in Claim 1, including a pressure sensing means 26, and an electronic feedback circuit 27 for limiting the current to said electromagnetic means so that the pressure is substantially linearly related to the input current.

8. A current-to-pressure transducer as in Claim 1, including retainer means 25 for maintaining said diaphragm in position at said open end of said chambers.

9. A current-to-pressure transducer comprising:
means for supplying a flow of air;
first and second chambers 14,16 and a means 15 connecting said chambers, each of said chambers having an open end;
magnetic fluid 30 disposed within said chambers and said connection means;
first and second flexible diaphragms 13,17 respectively positioned against said open ends for containing said fluid within said chambers; and
electromagnetic means 23 energized by an input electrical current for coacting with said magnetic fluid to deform a selected one of said diaphragms thereby varying the air pressure in said supply means.

10. A current-to-pressure transducer as in Claim 9, wherein said electromagnetic means is positioned for coacting with said magnetic fluid in one of said chambers to deform a selected one of said diaphragms, and said air supply means is positioned for coacting with the other one of said diaphragms.

11. A current-to-pressure transducer as in Claim 9 wherein the diaphragms are coplanar.

12. An integral nozzle and pole piece structure for use with a current-to-pressure transducer comprising:
a longitudinal rod 40 made of magnetic material;
a nozzle tube 48 formed in a central portion of said rod for allowing the passage of air received from an air supply;
one end of said rod forming a magnetic pole piece 41, said pole piece end being substantially coplanar with an end of said nozzle tube.

13. A structure as in Claim 12, including longitudinal slots 43 formed at said one end of said rod for allowing the escape of air.

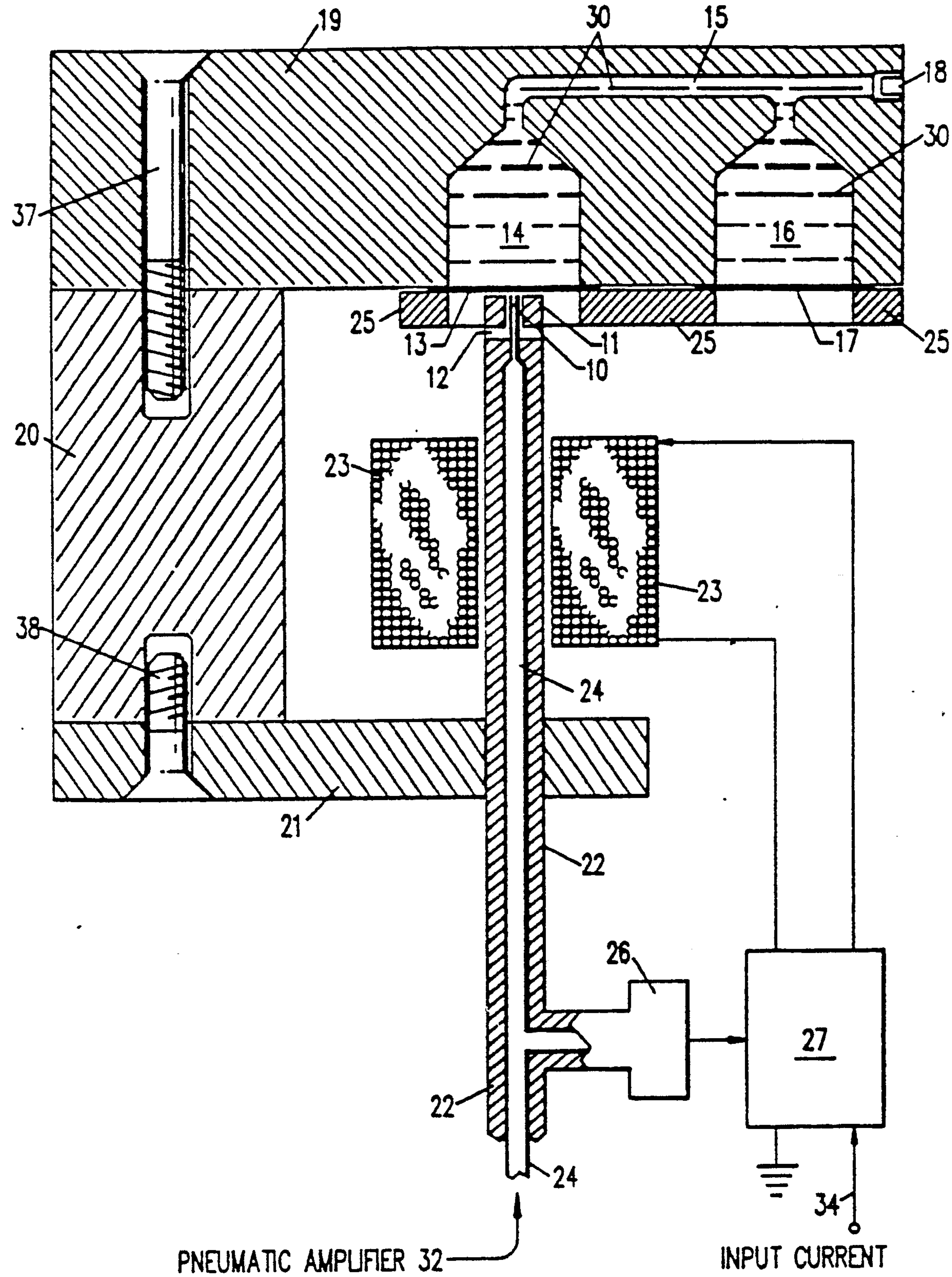
14. A structure as in Claim 13, including a groove 46 encompassing said nozzle tube, said slots being connected to said groove.

15. A structure as in Claim 12, including a threaded element 42 seated on a portion of said rod adjacent to the other end of said rod, a housing cap 47 for engaging said threaded element, and means formed integral with said rod for rotating said rod and said threaded element for adjusting the position of said nozzle tube.

16. A structure as in Claim 12, wherein said nozzle tube encompasses an air channel 48, said nozzle tube being tapered at one end to form a constricted portion 49 of said air channel for changing the pressure of said air flow.

17. A structure as in Claim 12, including a housing 50 for containing said nozzle and pole piece.

18. A structure as in Claim 17, including an opening 74 formed in said housing for allowing access of electrical circuit connection and for permitting escape of excess air.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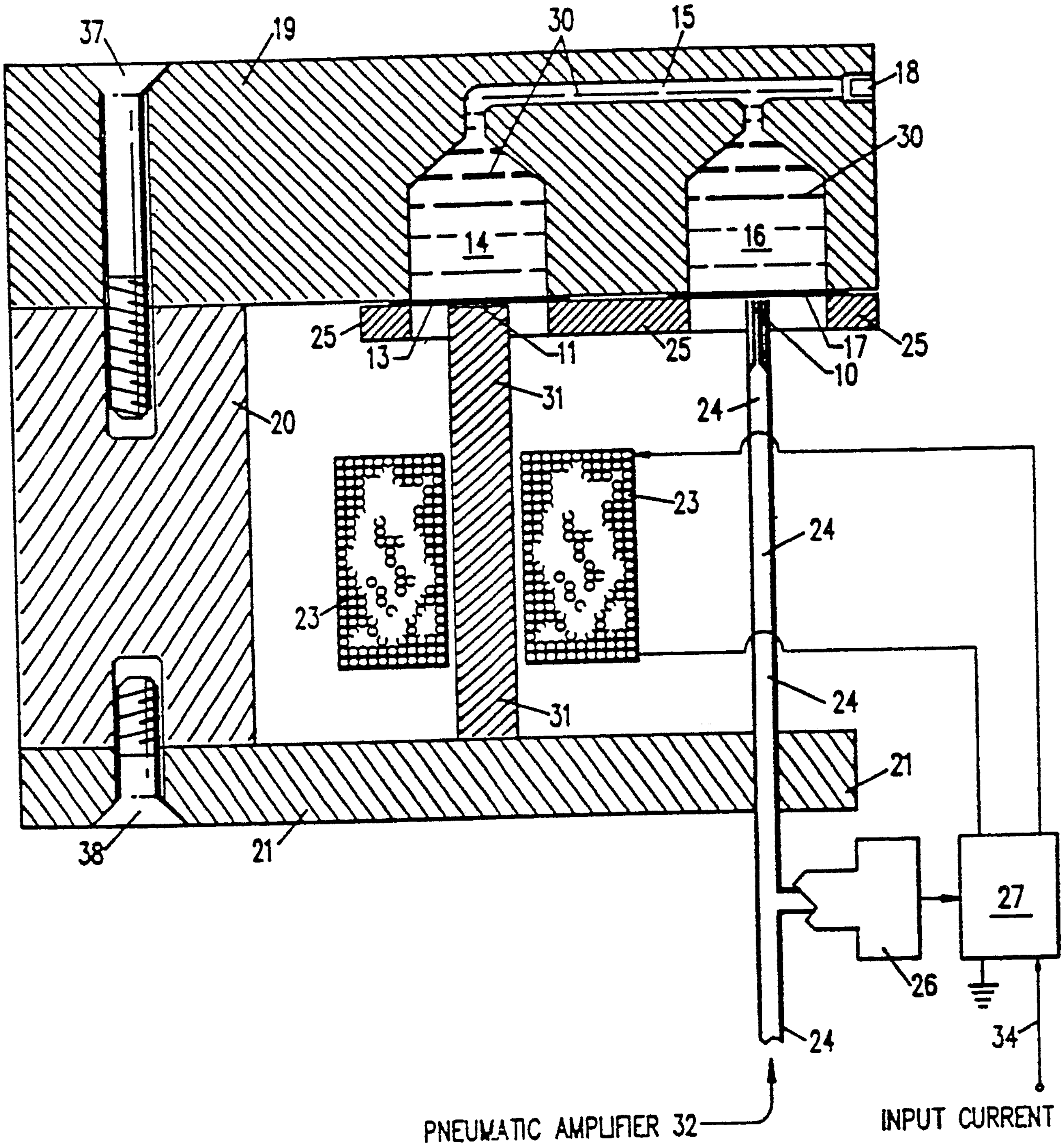
PNEUMATIC AMPLIFIER 32
INPUT CURRENT

FIG. 1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PNEUMATIC AMPLIFIER 32
INPUT CURRENT

FIG. 2

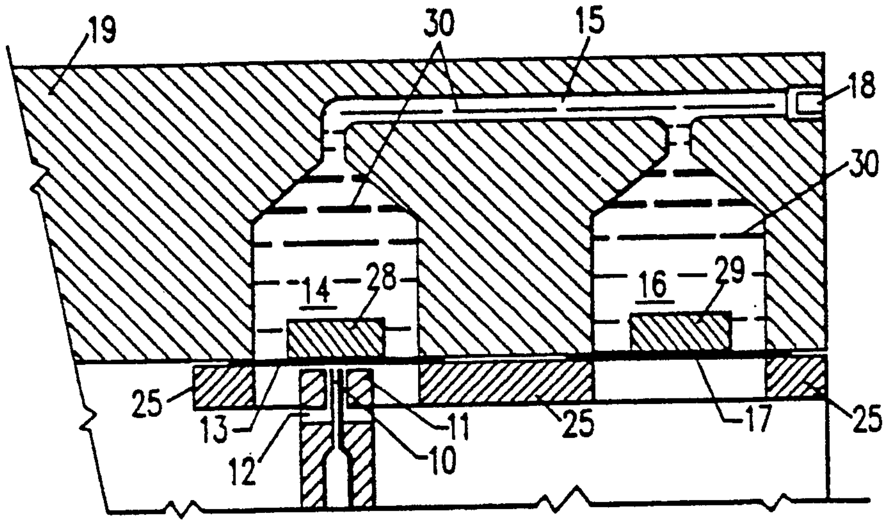


FIG. 3

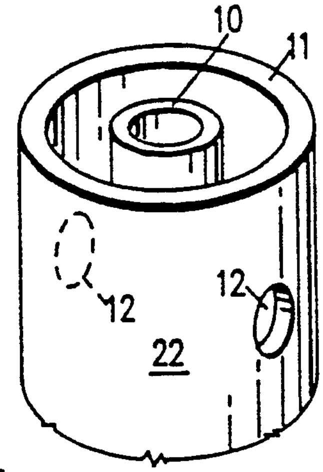


FIG. 4

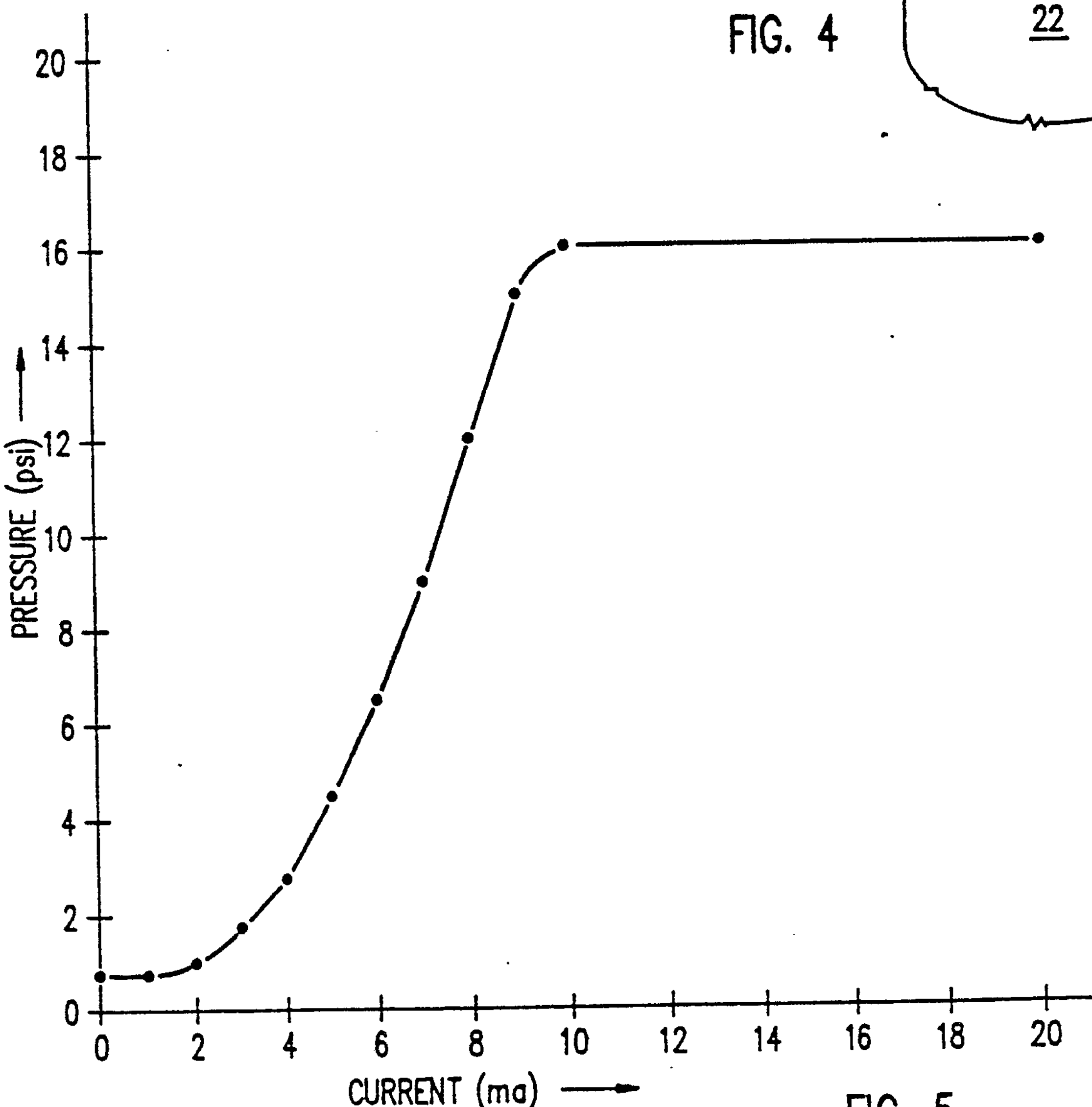


FIG. 5

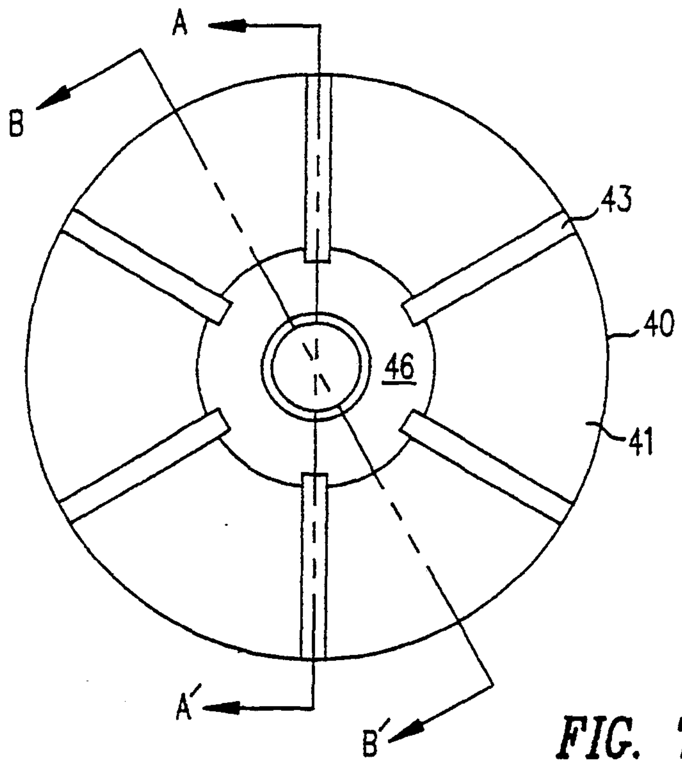
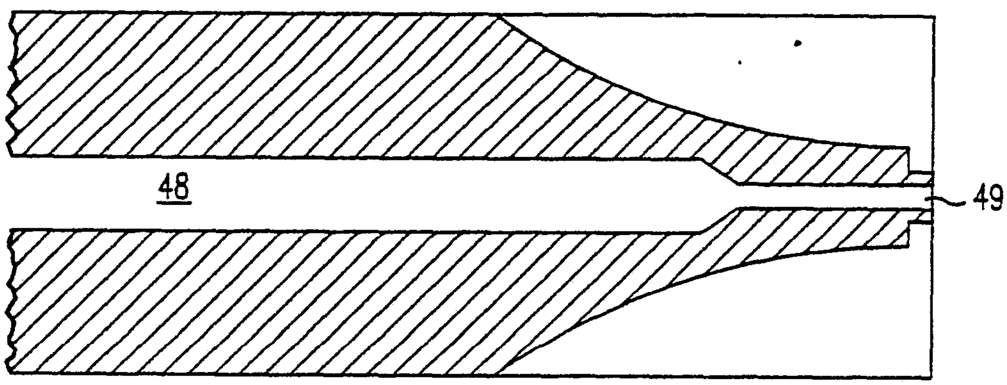
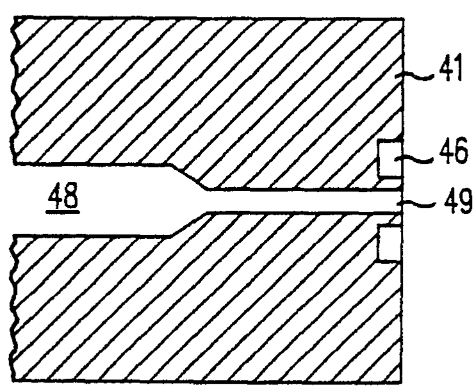


FIG. 7



SECTION A–A′

FIG. 8A



SECTION B–B′

FIG. 8B

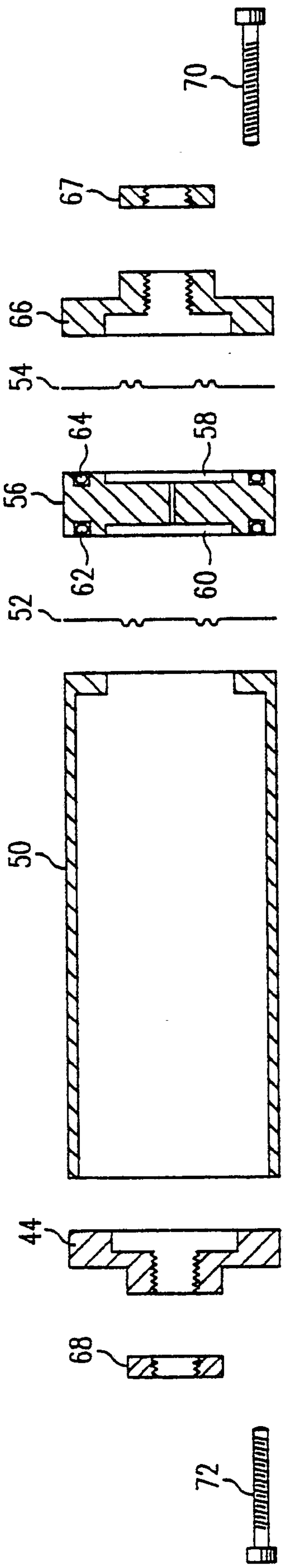


FIG. 9

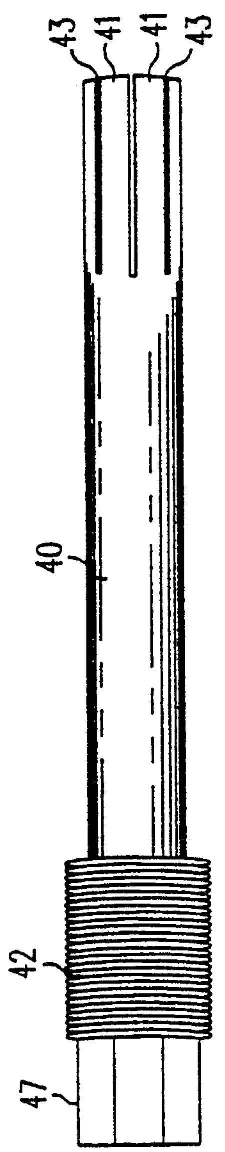


FIG. 6

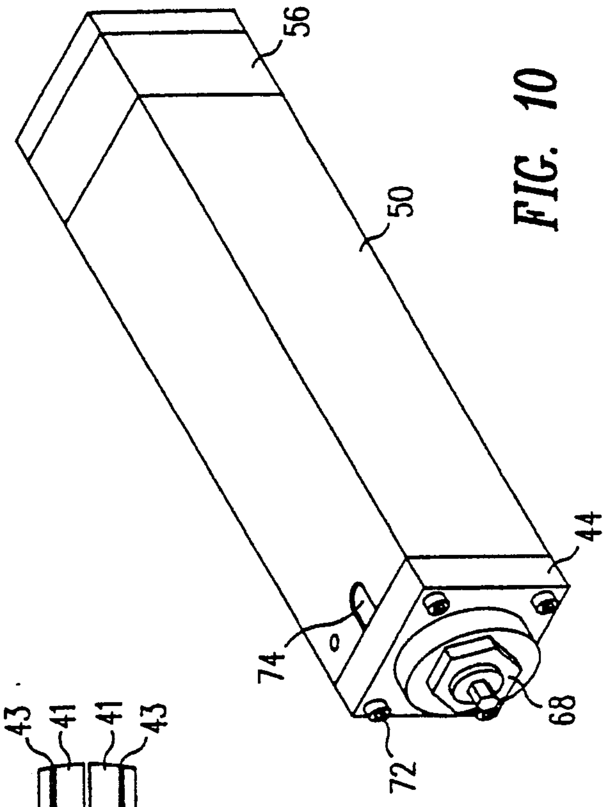


FIG. 10

European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 89 11 9767

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
X	US-A-2 939 673 (ROSHOLT) * Entire document * ---	1-4,8	F 15 B 5/00
A	US-A-3 817 488 (MACK) * Column 4, lines 23-26 * ---	5,12	
A	GB-A-1 140 785 (SPERRY RAND) * Page 2, lines 93-100 * ---	12	
A	US-A-3 426 970 (HEDLUND) * Column 3, lines 22-33 * ---	14	
A	US-A-3 272 078 (WILKS) * Column 1, lines 51-55 * ---	15	
A	GB-A-2 181 818 (DOMESTIC APPLIANCES) ---		
A	US-A-2 869 818 (FLEURET) ---		
A	FR-A-1 553 302 (LICENTIA) -----		

TECHNICAL FIELDS SEARCHED (Int. Cl.5)

F 15 B
F 15 C
F 16 K

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	28-01-1990	KNOPS J.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P0401)