



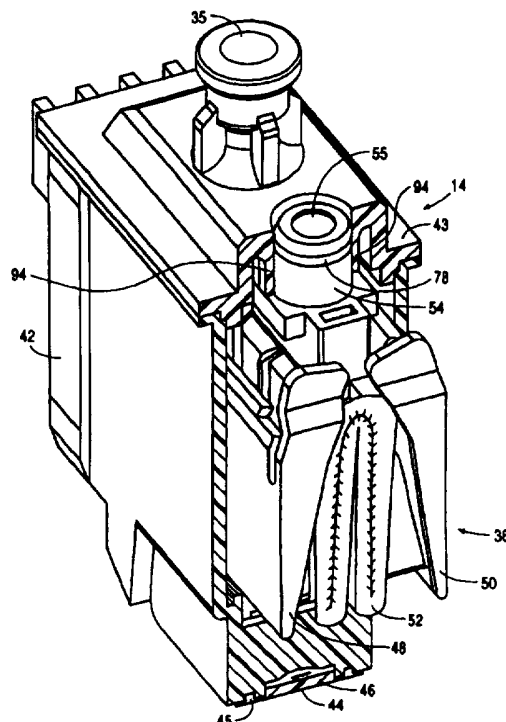
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| <p>(21) International Application Number: PCT/US96/17548<br/>(22) International Filing Date: 31 October 1996 (31.10.96)<br/>(30) Priority Data: 08/550,902 31 October 1995 (31.10.95) US<br/>(71) Applicant: HEWLETT-PACKARD COMPANY [US/US]; 3000 Hanover Street, M/S 20BO, Palo Alto, CA 94304-1181 (US).<br/>(72) Inventors: HAUCK, Mark; 202 N.W. 32 Street, Corvallis, OR 97330 (US). PAWLOWSKI, Norman, E., Jr.; 1455 N.W. 13th Street, Corvallis, OR 97330 (US).<br/>(74) Agent: VALET, Eugene, H.; 25 NW 23rd Place #6-125, Portland, OR 97210 (US).</p> |                  | <p>(81) Designated States: DE, GB, JP, European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).<br/><br/><b>Published</b><br/><i>With international search report.</i><br/><i>With amended claims.</i></p> |

(54) Title: APPARATUS FOR PROVIDING INK TO AN INK-JET PRINT HEAD AND FOR COMPENSATING FOR ENTRAPPED AIR

(57) Abstract

Apparatus for providing ink to an ink-jet print head in a print cartridge (14) at substantially constant pressure and for compensating for air within the print cartridge (14). A flexible bag (52) is maintained at atmospheric pressure within the print cartridge (14) and actuates a pressure regulator also within the print cartridge (14). By expanding and contracting, the flexible bag (52) compensates for changes in pressure and temperature that occur while the pressure regulator is shut and that affect air entrapped within the print cartridge (14).



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**APPARATUS FOR PROVIDING INK TO AN INK-JET PRINT HEAD AND FOR  
COMPENSATING FOR ENTRAPPED AIR**

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**CROSS-REFERENCES TO RELATED APPLICATIONS**

This application is a continuation-in-part application of U.S. Patent Application Serial No.  
10 08/518,847 filed 8/24/95 entitled PRESSURE REGULATED FREE-INK INK-JET PEN  
by Pawlowski Jr. which in turn is a continuation-in-part of U.S. Patent Application Serial  
No. 08/331,453, filed on October 31, 1994 by Pawlowski et al.

**BACKGROUND OF THE INVENTION**

15

The present invention relates generally to the field of inkjet printing and, more particularly,  
to the delivery of ink to ink-jet print heads.

20 Ink-jet technology is relatively well developed. The basics of this technology are described  
by W.J. Lloyd and H.T. Taub in "Ink-Jet Devices", Chapter 13 of *Output Hardcopy  
Devices* (Ed. R.C. Durbeck and S. Sherr, Academic Press, San Diego, 1988) and in various  
articles in the *Hewlett-Packard Journal*, Vol. 36, No. 5 (May 1985), Vol. 39, No. 4 (August  
1988), Vol. 39, No 5. (October 1988), Vol. 43, No. 4, (August 1992), Vol. 43, No. 6  
25 (December 1992) and Vol. 45. No. 1 (February 1994).

The typical thermal ink-jet print head has an array of precisely formed nozzles attached to  
a print head substrate that incorporates an array of firing chambers that receive liquid ink  
(i.e., colorants dissolved or dispersed in a solvent) from an ink reservoir. Each chamber has  
30 a thin-film resistor, known as a "firing resistor", located opposite the nozzle so ink can  
collect between it and the nozzle. When electric printing pulses heat the thermal ink-jet

5 firing resistor, a small portion of the ink near it vaporizes and ejects a drop of ink from the print head. The nozzles are arranged in a matrix array. Properly sequencing the operation of each nozzle causes characters or images to form on the paper as the print head moves past the paper.

10 In an effort to reduce the cost and size of ink-jet printers and to reduce the cost per printed page, engineers have developed ink-jet printers having small, moving print heads that are connected to large stationary ink reservoirs by flexible ink tubes. This development is called "off-axis" printing. In such printers the mass of the print head is sharply reduced so that the cost of the print head drive system and the over all size of the printer can be  
15 minimized. In addition, by separating the ink reservoir from the print head has allowed the ink to be replaced as it is consumed without requiring frequent replacement of costly print heads.

20 With the development of off-axis printing has come the need for numerous flow restrictions to the ink between the ink reservoir and the print head. These restrictions include additional orifices, narrow conduits, and shut off valves. To over come these flow restrictions and also to provide ink over a range of printing speeds, ink is now transported to the print head at an elevated pressure and a pressure reducer has been added to deliver the ink to the print head at optimum back pressure.

25 One complication in the evolution of off-axis printing is the increasing need to maintain the back pressure of the ink at the print head to within as small a range as possible. Changes in back pressure greatly affect print density and print quality, and major changes in back pressure can cause either the ink to drool out of the nozzles or to deprime the print  
30 cartridge.

5 There are several causes for such changes in back pressure. One cause occurs when air is entrapped within the print cartridge and the print cartridge is subjected to changes in environmental parameters such as altitude, acceleration, and temperature. If the air entrapped in a print cartridge acts according to the Ideal Gas Law,  $PV = nRT$ , then any changes in any of these parameters will cause corresponding changes in back pressure.

10 Another cause is the delay between the time the print head starts to eject ink during on-demand printing and the time the pressure regulator actuates to restore the back pressure.

These complications as well as the use of pressurized ink delivery have all resulted in a need for more accurate back pressure regulation in ink-jet print cartridges and for more precise compensation techniques.

15

### SUMMARY OF THE INVENTION

20 Briefly and in general terms, an apparatus according to the present invention includes a pressure regulator in fluid communication with an ink plenum and a flexible bag within the plenum for actuating the pressure regulator.

In an other aspect of the present invention an actuator bears against the bag and increases the bag's compensation for air.

25

Other aspects and advantages of the invention will become apparent from the following detailed description, taken into conjunction with the accompanying drawings, illustrating by way of example the principles of the invention.

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**BRIEF DESCRIPTION OF THE DRAWINGS**

Figure 1 is a diagrammatic, perspective view in section of an ink-jet printer according to the present invention.

10

Figure 2 is a perspective view in section of a portion of the print cartridge of Fig. 1.

Figure 3 is a perspective view of a pressure regulator sub-assembly of the print cartridge of Fig. 1. For clarity the flexible bag is not shown.

15

Figure 4 is a perspective view of a pressure regulator lever of the pressure regulator sub-assembly of Fig. 3.

Figure 5 is a perspective view of the opposite side of the pressure regulator lever of Fig. 4.

20

Figure 6 is a perspective view of an accumulator lever of the pressure regulator sub-assembly of Fig. 3.

Figure 7 is a perspective view of a fitment for the print cartridge of Fig. 2.

25

Figure 8 is a perspective view of the flexible bag and fitment for the print cartridge of Fig. 2

30

Figures 9 through 14 are diagrammatic views of the process for making the flexible bag of Fig. 8.

5 Figure 15 is a perspective view of the crown for the print cartridge of Fig. 2.

Figure 16 is a perspective view, partially cut away, of the crown and the pressure regulator lever of Fig. 3. For clarity the accumulator lever is not illustrated.

10 Figures 17 through 19 are side elevation views, partially in section, illustrating the operation of the print cartridge of Fig. 2.

#### DESCRIPTION OF THE PREFERRED EMBODIMENTS

15 As shown in the drawings for the purposes of illustration, the invention is embodied in a apparatus for providing ink to an ink-jet print head in a print cartridge and for compensating for air within the print cartridge.

Referring to Fig. 1, reference numeral 12 generally indicates a printer including a print  
20 cartridge 14 that ejects drops 16 of ink on command. The drops form images on a printing medium 18 such as paper. The printing medium is moved laterally with respect to the print cartridge 14 by two print rollers 20, 20' and a motor 21 that engages the printing medium. The print cartridge is moved back and forth across the printing medium by a drive belt 23 and a motor 24. The print cartridge contains a plurality of firing resistors, not shown, that  
25 are energized on command by an electrical circuit 26. The circuit sequentially energizes the firing resistors in a manner so that as the print cartridge 14 moves laterally across the paper and the paper moved by the rollers 20, 20', the drops 16 form images on the printing medium 18.

30 In Fig. 1, the ink reservoir 28 is a flaccid bag that contains ink 29. The bag is pressurized to a level of between -5" of water to +60" or more of water for delivery to the print

5 cartridge 14. The ink reservoir is connected to a conduit of flexible tubing 30 by a fluid  
interconnect 31. The fluid interconnect contains a valve, not shown, that shuts whenever  
the reservoir is separated from the tubing so that ink does not leak from either the reservoir  
28 or the tubing 30 and air is not ingested into the tubing. The tubing 30 terminates in an  
on-axis fluid interconnect 33 including a hollow, blunt needle 34 and septum 35. The  
10 needle pierces the septum and establishes fluid communication between the flexible tubing  
30 and the print cartridge 14. Within the print cartridge the ink is delivered to a back  
pressure regulator 37 that supplies the ink to an ink plenum 38. The pressure regulator 37  
maintains the back pressure in the plenum so that ink is supplied to the print head 40 at a  
substantially constant pressure. This pressure can range from 0 to -50" of water depending  
15 on the design of the print head, although the preferable range is from -2" to -7" of water.  
Ink is ejected from the print head 40 through a plurality of nozzles, not shown, on to the  
printing medium 18.

Referring to Fig. 2, reference numeral 14 generally indicates the print cartridge that  
20 includes a pen body 42 that is the housing for the cartridge and a crown 43 that forms a cap  
to the housing. Located at a remote end of the pen body is the tab, head assembly 44 or  
THA. The THA includes a flex circuit 45 and a silicon die 46 that forms the print head 40.  
The THA is of conventional construction. Also located within the pen body 42 is a  
pressure regulator lever 48, an accumulator lever 50, and a flexible bag 52. In Fig. 2 the  
25 bag is illustrated fully inflated and for clarity is not shown in Fig. 3. The pressure  
regulator lever 48 and the accumulator lever 50 are urged together by a spring 53, 53'  
illustrated in Fig 3. In opposition to the spring, the bag spreads the two levers apart as it  
inflates outward. The bag is staked to a fitment 54 that is press-fit into the crown 43. The  
fitment contains a vent 55 to ambient pressure in the shape of a helical, labyrinth path. The  
30 vent connects and is in fluid communication with the inside of the bag so that the bag is



5 maintained at a reference pressure. The helical path limits the diffusion of water out of the bag.

The pressure regulator lever 48 is illustrated in detail in Figs. 4 and 5. Reference numeral 57 generally indicates the location of the area where the bag 52 directly bears against the lever. The lever 48 rotates about two opposed axles 58 that form the axis of rotation of the lever. The rotation of the lever is stopped when the lever engages the pen body 42 as illustrated in Fig. 19. The axles are located at the ends of cantilevers 59 formed by deep slots so that the cantilevers and the axles can be spread apart during manufacture and snapped onto place on the crown 43 as illustrated in Fig. 16. Perpendicular to the plane of the regulator level 48 is a valve seat 61 and a valve seat holder 62. The valve seat is pressed into place on the holder and is fabricated from a resilient material. In response to expansion and contraction of the bag 52, the regulator lever 48 rotates about the axles 58, 58' and causes the valve seat to open and shut against a mating surface on the crown 43 as described below. This rotational motion controls the flow of ink into the ink plenum 38, Fig. 1. There is an optimization between maximizing the force on the valve seat and obtaining sufficient motion of the lever. In the embodiment actually constructed the lever ratio between the distance between the centroid of the lever, generally at point 57, and the axles 58 and the distance between the center of the valve seat and the axles 58 is between two to one and five to one with four to one being preferred. The pressure regulator also includes a spring boss 64 and engages the spring 53, Fig. 3. The spring boss is protected during manufacture by two shoulders 65 which are not illustrated in Fig. 3.

The accumulator lever 50 is illustrated in Fig. 6 and includes an actuation area 68 where the bag 52 directly bears against the lever. The lever rotates about two opposed axles 70, 70' that form an axis of rotation of the accumulator lever. The axles are remotely located

5 on cantilevers 71 so that the axles and the cantilevers can be spread apart during  
manufacture and snapped into place on the crown 43 as described below. The accumulator  
lever also includes a spring boss 72 that engages the other end of the spring 53, Fig. 3.  
Like the spring boss 64 on the pressure regulator, the boss 72 on the accumulator is  
protected during manufacture by the shoulders 73. These shoulders are not illustrated in  
10 Fig. 3.

The accumulator lever 50 and the bag 52 operate together to accommodate changes in  
volume due to any air that may be entrapped in the print cartridge 14, Fig. 1 as well as due  
to any other pressure changes. The accumulator acts to modulate any fluctuations in the  
15 back pressure. The accumulator lever squeezes the bag the inside of which is at ambient  
pressure, forces air out of the bag and allows air trapped in the print cartridge to expand.

Although most of the accumulation is provided by the movement of the accumulator lever  
20 50 and the bag 52, there is additional accumulation provided by the pressure regulator lever  
48 in cooperation with the resilient valve seat 61, Fig 4. The valve seat acts as a spring and  
allows some movement of the regulator lever 48 while the valve is shut. In other words,  
as the back pressure in the plenum 38 decreases, the bag 52 exerts less force on the levers  
and the spring 53 urges the levers together. The motion of the regulator lever compresses  
25 the valve seat and the regulator lever shuts a little further. This movement of the regulator  
lever 48 with the bag 52 results in some additional air accommodation.

It should be appreciated that the boss 72 on the accumulator lever 50 is closer to the axis  
of rotation of the accumulator lever than the boss 64, Figs. 4 and 5, on the pressure  
30 regulator lever is to its axis of rotation. This difference in distance causes the accumulator  
lever to actuate before the pressure regulator lever moves.

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The accumulator lever 50 rotates about the axles 70 until a stop 75 on the lever engages a surface 76 within the crown 43 as illustrated in Fig. 15. The stop prevents the lever from moving too close and interfering with the pressure regulator lever 48 when the back pressure in the ink plenum drops. The accumulator lever rotates in the other direction until  
10 coming into contact with the pen body 42 as illustrated in Figs. 18 and 19.

15

Referring to Fig. 3 reference numeral 53 generally indicates a helical extension spring that urges the two levers 48, 50 together. The spring is preloaded and engages the bosses 64, 72 with a coil loop at each distal end. Each loop is a parallel, cross-over, fully closed,  
15 centered loop. This spring is designed to have the least amount of variation in its force constant over its full range of travel so that the back pressure can be regulated as closely as possible.

20

The fitment 54, illustrated in Figs. 2 and 7, supports the bag 52 and attaches the bag to the crown 43. The fitment has a lip 78 that engages the crown and forms a hermetic seal with  
it. Within the fitment is a vent 55 that provides communication between the interior of the bag and ambient pressure. At the distal end of the fitment is a raised, circular boss 79 and a race-track shaped outer boss 80. The bag 52 is staked to both bosses. The circular boss provides the main seal between the bag and the fitment. The race-track shaped boss  
25 provides a secondary, redundant sealing surface as well as provides additional support and positioning for the bag.

30

The flexible bag 52, illustrated in Figs. 2 and 8, expands and contracts as a function of the differential pressure between the back pressure in the ink plenum 38 and ambient pressure  
communicated through the vent 55 in the fitment 54. The bag is shown fully inflated in  
Fig. 8. The bag is designed to push against the two levers 48, 50 with maximum contact

5 area through the entire range of travel of the levers. The bag is formed from a single sheet  
of multilayer film and includes two lungs 82 that expand and contract about an axis 84.  
The lungs communicate with each other and are maintained at the same reference pressure.  
Each lung has two raised areas 83 on either side so that there are four raised areas in all.  
The two inner raised areas that bear against each other are not shown in Fig. 8 but are  
10 indicated by reference numerals 83' and 83". The side opposite the fitment contains a  
raised communication channel 85, Figs. 10,12 between the raised areas which allows a  
path for air to flow when the bag is completely deflated. The raised areas are thinner than  
the rest of the bag and provide greater compliance to the travel of the levers and the motion  
of the lungs about the axis 84. The raised areas are designed to eliminate relative motion  
15 or sliding of the bag with respect to the levers. In systems that actuate on very slight  
pressures this undesirable affect is called hysteresis. The combination of the lungs and  
raised areas provides extra material into which the bag can expand as well as maximizes  
the change in ink volume displaced by the bag with any change in differential pressure.

20 The process for making the bag 52 is illustrated in Figs. 9 - 14. First, a sheet 87 of flat film  
is cut to size, Fig. 9. The film is a multilayer structure between one and three mils (one mil  
is 25.4 microns) thick, which 1.5 mils being the preferred thickness. In the preferred  
embodiment, three materials show acceptable performance: (1) PE/tie/PVDC/tie/PE, (2)  
PE/tie/PVDF/tie/PE, and (3) PE/tie/EVOH/tie/PE. PVDC is polyvinylidene chloride;  
25 DOW version is known as SARAN. EVOH is ethylene-vinyl alcohol copolymer. PE is  
polyethylene. tie is a layer used to bond the dissimilar materials together. PVDF is  
polyvinylidene fluoride and is sold under the trade name of Kynar. Next, the sheet is placed  
over a die plate, and heat and vacuum are applied to form the four raised areas 88, 88', Fig.  
10. Note that two of the four raised areas or pockets 88' are in communication. Thereafter,  
30 the sheet 87 is heat staked to the two bosses 79,80 on the fitment 54, Fig. 7 as shown in  
Fig. 11. Next, a hole 89 is made in the film in the center of the circular boss 79 to establish

5 communication to the vent 55 in the fitment. The sheet is then folded along axis 90 and the  
perimeter of the bag where the margins come together is staked. This staking occurs along  
the three open seams and is indicated by reference numeral 91 in Fig. 13. The perimeter  
of the bag is then trimmed. Thereafter, the bag is folded along the longitudinal axis 92 of  
10 the fitment as illustrated in Fig. 13. This forms the two lungs 82, 82' in the bag. Referring  
to Figs. 13, 14, and 8, the longitudinal axis 92 of the fitment and the line of folding in Fig.  
13 is parallel to the axis 84 of rotation of the two lungs during expansion/contraction of the  
bag.

Fig.15 illustrates the bottom side of the crown 43 which includes a valve face 93 and the  
15 orifice 92 through which ink enters the plenum 38. The valve face mates with the valve  
seat 61, Fig. 4 on the pressure regulator lever 48. This mating is also shown in Fig. 16.  
Ink flows through the fluid interconnect 33, Fig. 1, the septum 35, and the orifice 92. At  
orifice 92 the back pressure within the plenum 38 is controlled by the lever 48. Next to the  
valve face 93 on the crown 43 is a circular boss 94 that receives the lip 78 on the fitment  
20 54, Fig. 8. The boss 94 and the lip form a hermetic seal. The axles 58, 58' Fig. 5 on the  
pressure regulator lever 48 are snapped into the journals 95, 95' as permitted by the  
cantilevered construction described above. In like manner the axles 70, 70' on the  
accumulator lever 50 are received in the journals 97, 97', Fig. 15. Also located on the  
bottom side of the crown is the surface 76 that engages the stop 75, Fig. 6 on the  
25 accumulator lever 50. The stop 75 and the surface 76 prevent the accumulator lever from  
interfering with the pressure regulator lever 48.

The operation of the print cartridge 14 is illustrated in Figs. 17, 18, and 19. In the initial  
condition of the cartridge there is no ink within the ink plenum 38, and the bag 52 is limp.  
30 The back pressure in the plenum equals ambient pressure. The spring 53 urges the two  
levers 48, 50 fully together.

5

Next, the needle 34, Fig.1 is inserted into the septum 35 and a vacuum is drawn on the nozzles in the print head 40 to draw ink into the print cartridge. In response to this vacuum the accumulator lever 50 moves first, and the bag begins to expand as shown in Fig. 18. The accumulator lever continues to rotate about its axis of rotation until it engages the side wall of the pen body 42 as shown in Fig. 18. At this point the pressure regulator lever 48 begins to move, and ink begins to enter the plenum 38 through orifice 92, Fig. 15.

10

The regulator lever 48 can rotate about its axis of rotation until it engages the side wall of the pen body 42 as shown in Fig. 19. This is the "full-open"-open" position of the valve. The regulator lever moves between the states illustrated in Figs.18 and 19 depending on the speed of printing and how fast ink is required by the print head.

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Once the plenum 38 is filled with ink or printing has stopped, the pressure regulator lever 48 will slowly rotate and close the orifice at the urging of the spring 53. The levers 48 and 50 return to the state illustrated in Fig.18 which is the normal or steady state condition of the print cartridge. This state occurs just prior to or subsequent to printing.

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Referring to Fig.18, reference numeral 98 indicates an air bubble that has entered the ink plenum 38. If the print cartridge is subjected to an elevation in temperature or increased altitude, the air bubble will expand in the plenum. The expansion of the air bubble will be compensated for by the contraction of the bag 52 due to a pressure change caused by a volume change of the bubble which in turn causes the accumulator lever to move from the state illustrated in Fig.18 toward that illustrated in Fig. 17. In addition, there will be some accompanying motion of the regulator lever 48 because of the resilience of the valve seat 61. On the other hand, if the air bubble contracts, the bag will expand in response and the pressure regulator lever 48 will open the orifice and admit ink onto the plenum. In other

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5 words, any expansion or contraction of an air bubble will cause the bag to compensate in reverse, that is by contracting to expansion and expanding to contraction. Each of the levers tracks the motion of the bag and the accumulator lever 50 rotates before the regulator lever 48 because of the difference in lever arm distances.

10 When the ink reservoir 28, Fig.1 is depleted of ink, the levers 48, 50 rotate to the "full-open" position in Fig. 19 and the print head stops ejecting ink.

Although specific embodiments of the invention have been described and illustrated, the invention is not be limited to the specific forms or arrangement of parts so described and  
15 illustrated herein. The invention is limited only by the claims.

5

Claims

We claim:

10 1. Apparatus for providing ink to an ink-jet print head in a print cartridge at substantially constant pressure and for compensating for air within the print cartridge, comprising:

a) an ink-jet print head within a print cartridge;

15 b) an ink plenum within the print cartridge in fluid communication with the print head;

c) a pressure regulator in fluid communication with the ink plenum for supplying ink to the print head at substantially constant pressure;

20 d) a flexible bag within the ink plenum maintained at an internal reference pressure, said bag compensates for air within the print cartridge; and

25 e) an actuator for the pressure regulator and connected thereto, said bag directly bears against said actuator and thereby actuates said pressure regulator.

2. The apparatus of Claim 1 further including means, operatively connected to the bag, for urging the bag against said internal reference pressure, thereby increasing said bag's compensation for air within the print cartridge.

30 3. The apparatus of Claim 2 wherein said urging means is an accumulator actuator that applies a substantially constant force against the reference pressure within said bag.



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4. The apparatus of Claim 1 wherein the pressure regulator actuator engages a valve in said pressure regulator, said valve having a resiliently deformable valve seat such that said actuator, valve, and valve seat compensate for air within the print cartridge.

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5. Apparatus for providing ink to an ink-jet print head in a print cartridge at substantially constant pressure and for compensating for air within the print cartridge, comprising:

a) an ink-jet print head within a print cartridge,

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b) an ink plenum within the print cartridge in fluid communication with the print head;

c) a pressure regulator in fluid communication with the ink plenum for supplying ink to the print head at substantially constant pressure;

20

d) an expandable/contractible bag within the ink plenum, said bag having two lungs maintained at an internal reference pressure and with a common axis of expansion/contraction, said lungs communicate with each other and compensate for air within the print cartridge; and

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e) a lever for actuating the pressure regulator and connected thereto, said lever directly bears against said lungs and thereby actuates said pressure regulator, said lever having an axis of rotation parallel with said axis of expansion/contraction of the lungs so that said lever tracks any expansion/contraction of the lungs.

30

6. The apparatus of claim 5 further including an accumulator lever that applies a substantially constant force against the reference pressure in the lungs, said accumulator

- 5 lever having an axis of rotation parallel with said axis of expansion/contraction of the lungs so that said accumulator lever tracks any expansion/contraction of the lungs.
7. The apparatus of claim 5 wherein one lung has a region of enhanced sensitivity to differential pressure across said region and said region bears against the pressure regulator  
10 actuating lever.
8. The apparatus of claim 6 wherein one lung has a region of enhanced sensitivity to differential pressure across said region and said region bears against the accumulator lever.
- 15 9. The apparatus of claim 6 wherein each lung has a region of enhanced sensitivity to differential pressure across said region and each of said regions bears against one of said levers.
10. The apparatus of claim 5 wherein each lung has a region of enhanced sensitivity to  
20 differential pressure across said region and each of said regions bears against the other.
11. Apparatus for providing ink to an ink-jet print head in a print cartridge at substantially constant pressure and for compensating for air within the print cartridge, comprising:
- 25 a) a remote ink reservoir containing ink under a pressure of  $P_1$ ;
- b) an ink-jet print head
- c) an ink plenum in fluid communication with the print head
- 30 d) a conduit for ink connectable between the remote reservoir and the plenum;

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e) a pressure regulator in fluid communication with the ink plenum and connectable thereto for supplying ink to the print head at a substantially constant pressure of P2, where P1 is substantially greater than P2;

10

f) a predetermined area within the print cartridge to collect air;

g) an expandable/contractible bag within the ink plenum maintained at an internal reference pressure, said bag being in fluid communication with the predetermined air collection area and compensates for air within the print cartridge; and

15

h) an actuator for the pressure regulator and connected thereto, said bag directly bears against said actuator and thereby actuates said pressure regulator.

**AMENDED CLAIMS**

[received by the International Bureau on 11 April 1997 (11.04.97);  
original claims 1-11 amended;  
new claims 12-16 added (5 pages)]

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1. A back pressure regulator device for a ink-jet printing apparatus having an ink-jet print  
10 head within a print cartridge, and an ink plenum within the print cartridge in fluid communication  
with the print head, the device comprising:

a mechanism for providing ink to the print head at substantially constant back pressure and  
for compensating for air within the print cartridge, the mechanism including

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a pressure regulator mechanism in fluid communication with the ink plenum for  
supplying ink to the print head at substantially constant pressure;

a flexible bag within the ink plenum maintained at an internal reference pressure,  
said bag compensates for air within the print cartridge; and

20

an actuator mechanism for the back pressure regulator device and connected to  
said pressure regulator mechanism, said bag directly bears against said actuator  
mechanism and thereby actuates said pressure regulator device.

2. The apparatus of claim 1 further comprising:

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an urging mechanism, operatively connected to the bag, for urging the bag against said  
internal reference pressure, thereby increasing said bag's compensation for air within the print  
cartridge.

3. The apparatus of claim 2 wherein said urging mechanism further comprises:

30

an accumulator actuator that applies a substantially constant force against the reference  
pressure within said bag.

5 4. The apparatus of claim 1 further comprising:  
a valve mechanism adapted for coupling said pressure regulator device to a supply of ink,  
wherein the actuator mechanism engages said valve, said valve having a resiliently deformable  
valve seat such that said actuator, valve, and valve seat compensate for air within the print  
cartridge.

10 5. Apparatus for providing ink to an ink-jet print head in a print cartridge at substantially  
constant pressure and for compensating for air within the print cartridge, comprising:

an ink-jet print head;

an ink plenum within the print cartridge in fluid communication with the print head;

15 a pressure regulator in fluid communication with the ink plenum for supplying ink to the  
print head at substantially constant pressure;

an expandable/contractible bag within the ink plenum, said bag having two lungs  
maintained at an internal reference pressure and with a common axis of expansion/contraction,  
said lungs are coupled to communicate with each other and compensate for air within the print  
20 cartridge, wherein said axis of expansion/contraction is substantially defined by a region of  
coupling of said lungs; and

a pressure regulator actuating lever mechanism for actuating the pressure regulator and  
connected thereto, said lever directly bears against said lungs and thereby actuates said pressure  
regulator, said lever mechanism having an axis of rotation parallel with said axis of  
25 expansion/contraction of the lungs so that said lever mechanism tracks any expansion/contraction  
of the lungs.

6. The apparatus of claim 5 further comprising:

30 an accumulator lever mechanism for applying a substantially constant force against the  
reference pressure in the lungs, said accumulator lever mechanism having a axis of rotation

- 5 parallel with said axis of expansion/contraction of the lungs so that said accumulator lever mechanism tracks any expansion/contraction of the lungs.
7. The apparatus of claim 5 further comprising:  
a first lung has a region of enhanced sensitivity to differential pressure across said region  
10 and said region bears against the pressure regulator actuating lever mechanism.
8. The apparatus of claim 6 further comprising:  
a second lung has a region of enhanced sensitivity to differential pressure across said  
region and said region bears against the accumulator lever mechanism.  
15
9. The apparatus of claim 6 further comprising:  
each lung has a region of enhanced sensitivity to differential pressure across said region  
and each of said regions bears against an adjacent lever mechanism.
- 20 10. The apparatus of claim 5 further comprising:  
each lung has a region of enhanced sensitivity to differential pressure across said region  
and each of said regions bears against the other region.
- 25 11. Ink-jet printing apparatus, comprising:  
a remote ink reservoir containing ink under a pressure of P1;  
an ink-jet print head;  
an ink plenum in fluid communication with the print head;  
a conduit for ink selectively connecting the remote reservoir and the plenum;  
a pressure regulator in fluid communication with the ink plenum and connectable thereto  
30 for supplying ink to the print head at a substantially constant back pressure of P2, where P1 is

5 substantially greater than P2;  
a predetermined area within the print cartridge to collect air;  
an expandable/contractible bag within the ink plenum maintained at an internal reference  
pressure, said bag being in fluid communication with the predetermined air collection area and  
compensates for air within the print cartridge; and  
10 an actuator for the pressure regulator and connected thereto, said bag directly bears  
against said actuator and thereby actuates said pressure regulator.

12. The apparatus as set forth in claim 11, said remote reservoir further comprising:  
a replaceable ink reservoir to dispense ink under ambient atmospheric pressure or greater.

15 13. The apparatus as set forth in claim 11, said remote reservoir further comprising:  
an ink reservoir refillable with a supply of ink and to provide ink to said cartridge under  
ambient atmospheric pressure or greater.

20 14. The apparatus as set forth in claim 11, said remote reservoir further comprising:  
a flaccid bag pressurized to a predetermine level at least equal to ambient atmospheric  
pressure.

25 15. The apparatus as set forth in claim 11, further comprising:  
said actuator is a first lever having a range of motion limited by engagement with a first  
inner wall of said print cartridge; and  
said regulator is a second lever having a range of motion limited by engagement with a  
second inner wall of said print cartridge, such that said first lever engages said first inner wall prior  
to said second lever engaging said second inner wall of said print cartridge.

30

- 5 16. A method for delivering ink to a ink-jet pen, having a print head operating at a gauged predetermined print head back pressure, the method comprising the steps of:
- providing a supply of ink from a positive pressure container;
  - controlling flow of ink from said container into said pen, compensating for trapped gases within said pen, and regulating said negative pressure simultaneously via a compliant means for
- 10 balancing ambient atmospheric pressure against a positive bias acting to compress an integral means for controlling print head back pressure and ink flow into said pen, said compliant means automatically compensating for gases trapped within said pen.

//



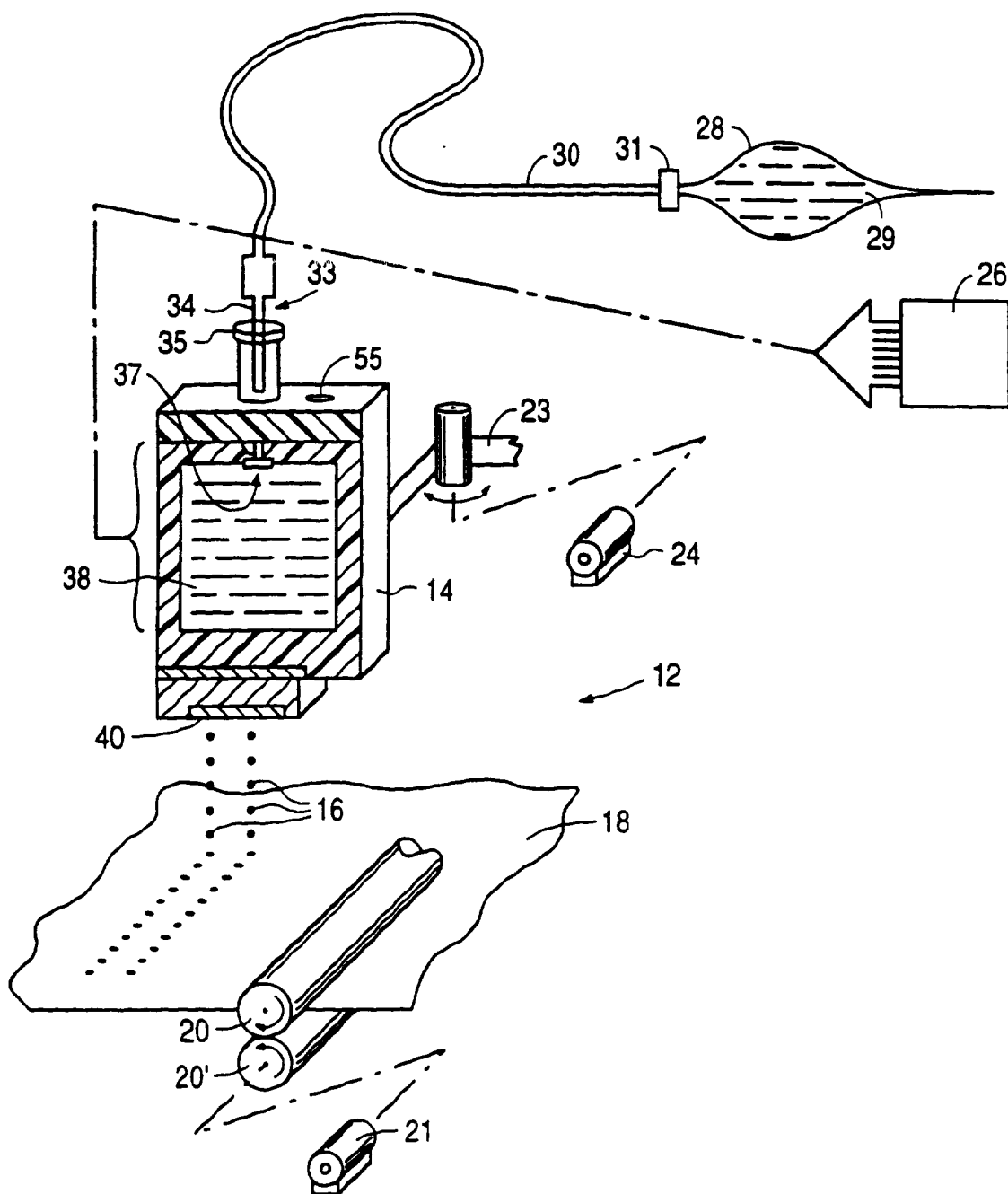


FIG. 1

2/11

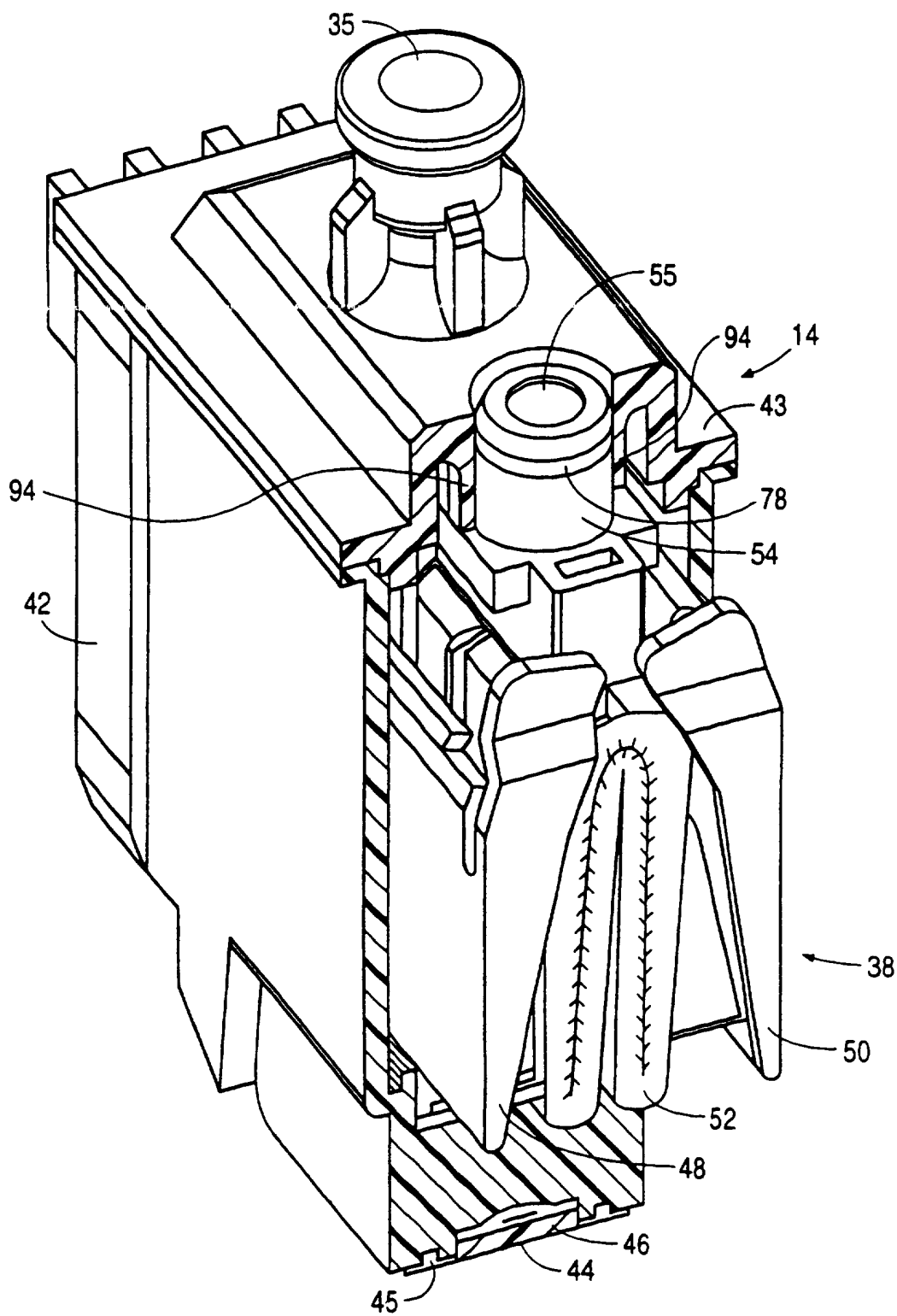


FIG. 2

3/11

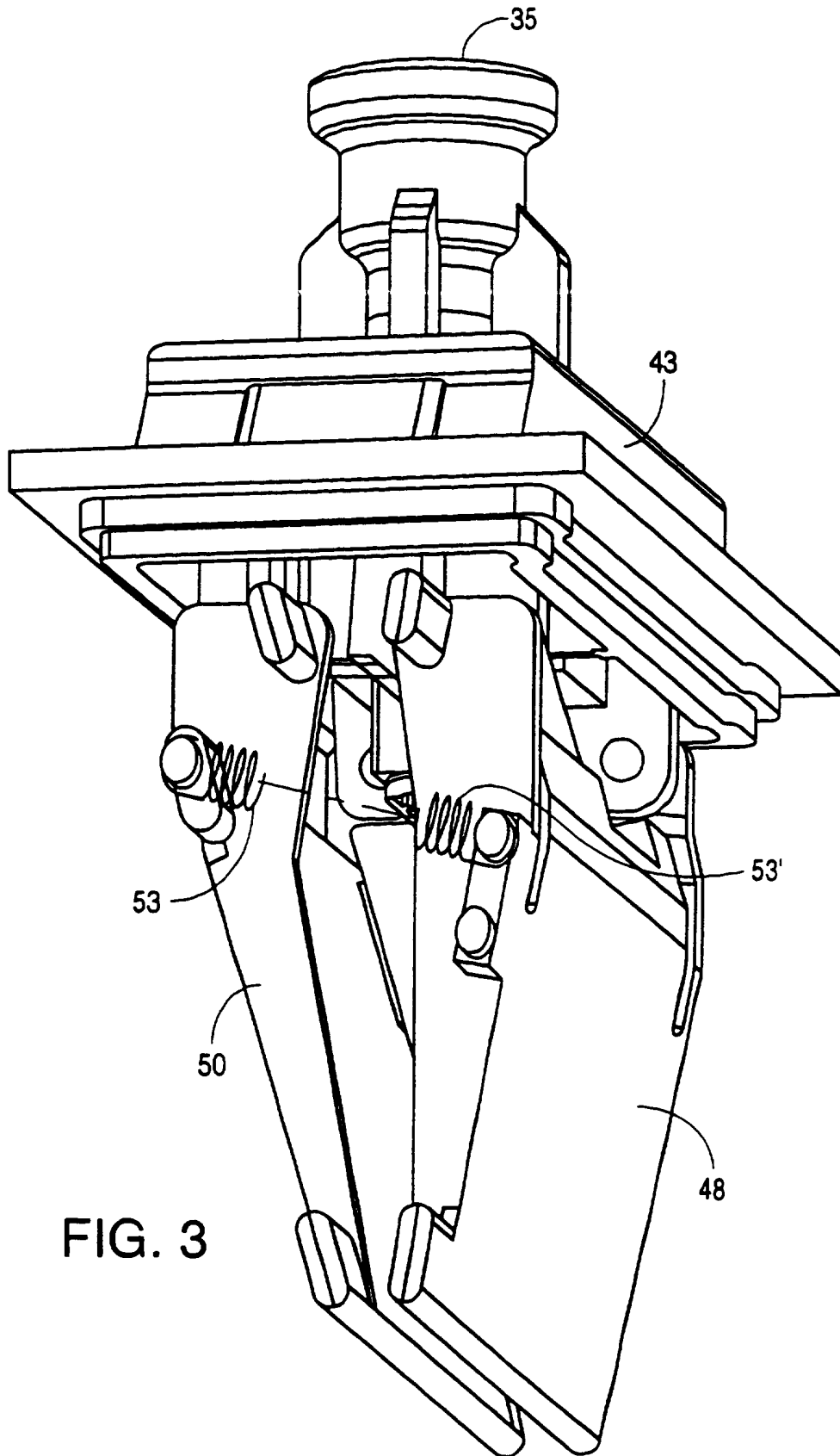


FIG. 3

4/11

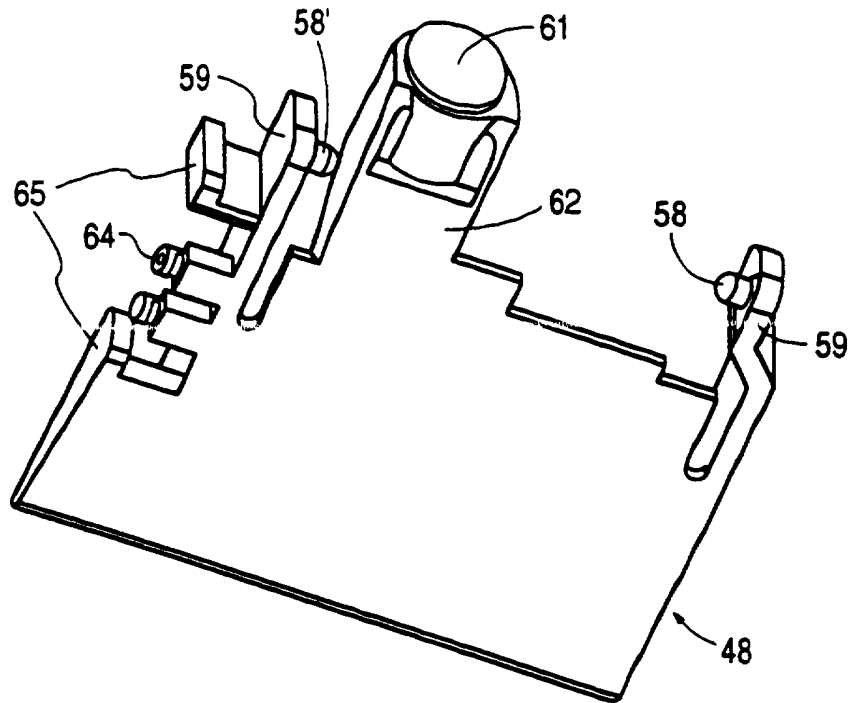


FIG. 4

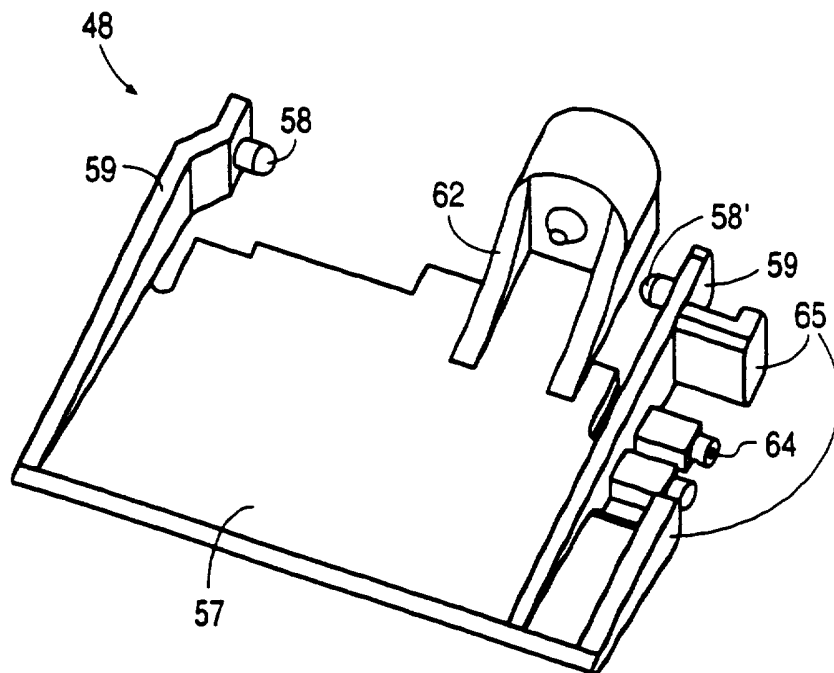


FIG. 5

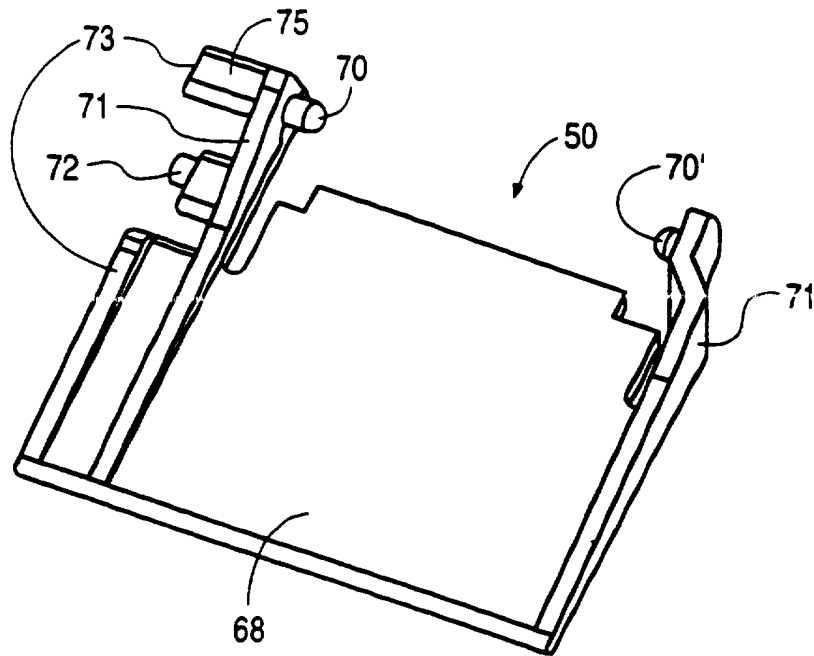


FIG. 6

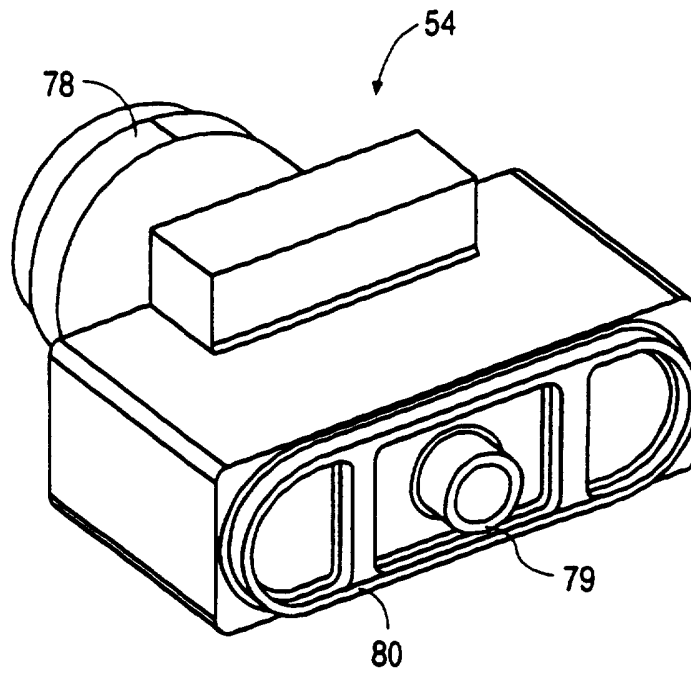


FIG. 7

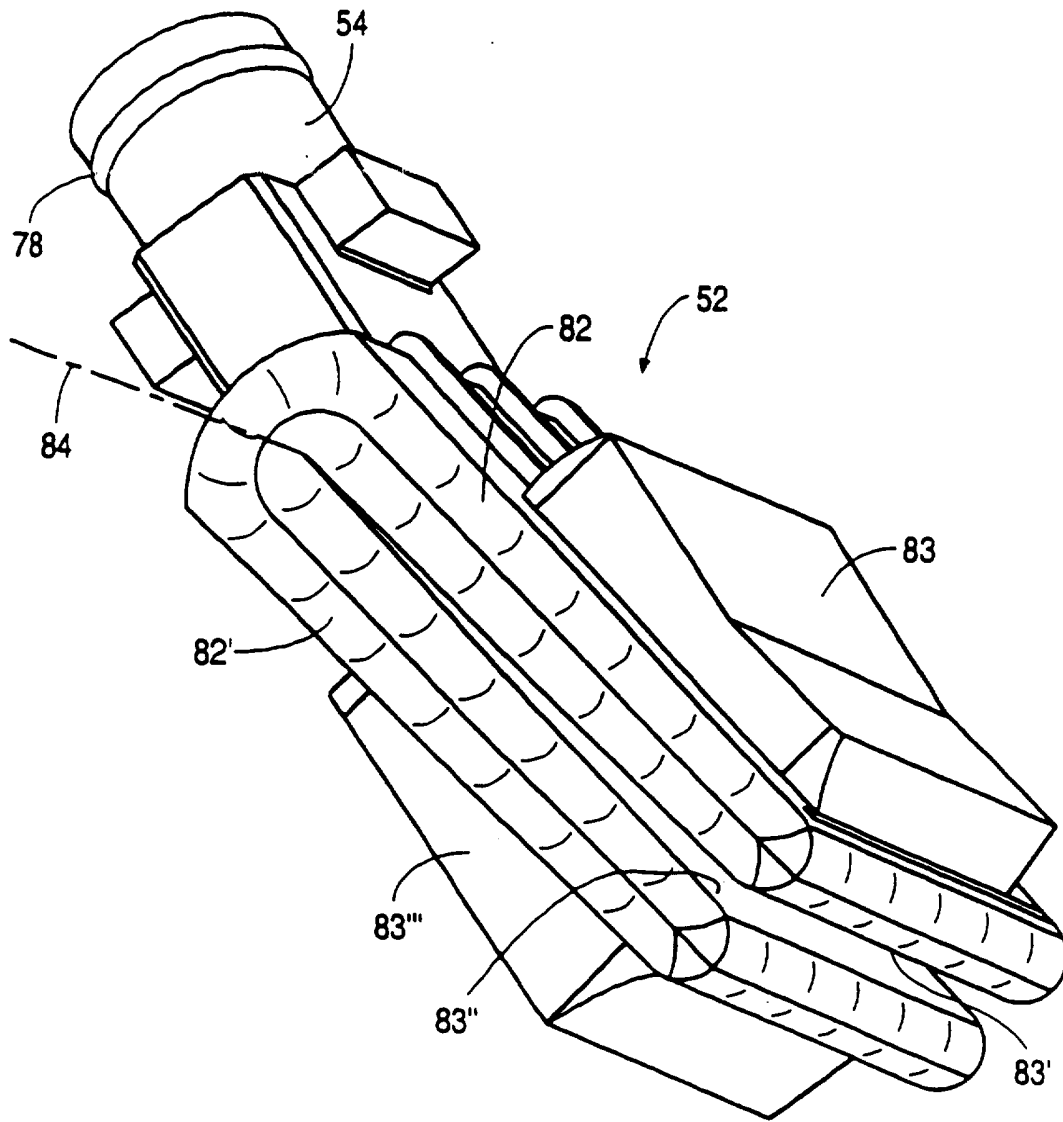


FIG. 8

7/11

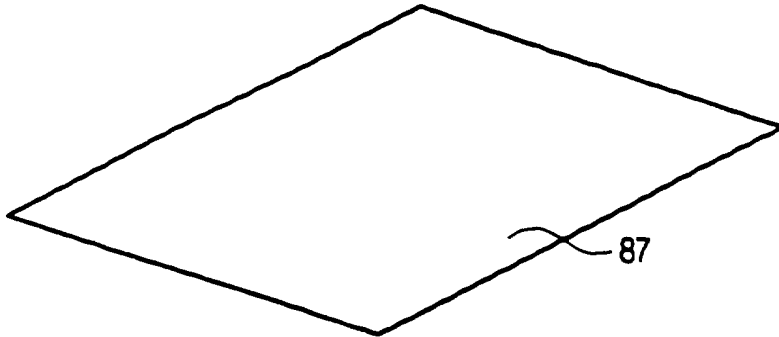


FIG. 9

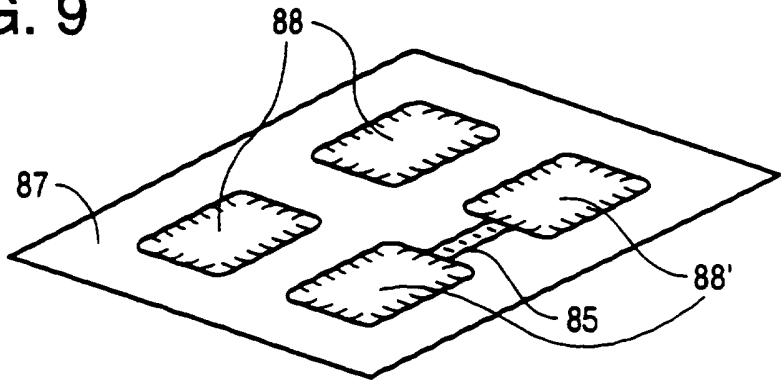


FIG. 10

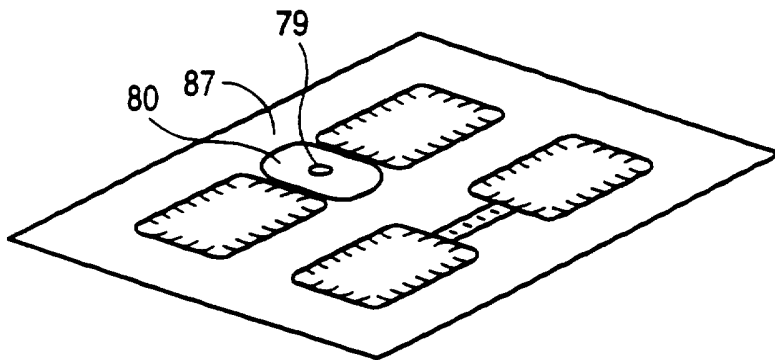


FIG. 11

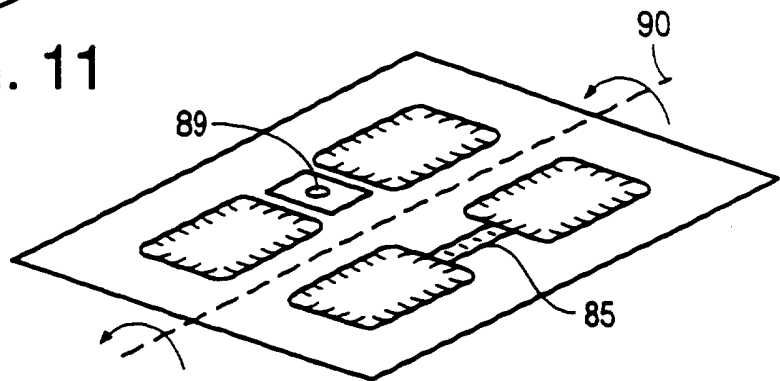


FIG. 12

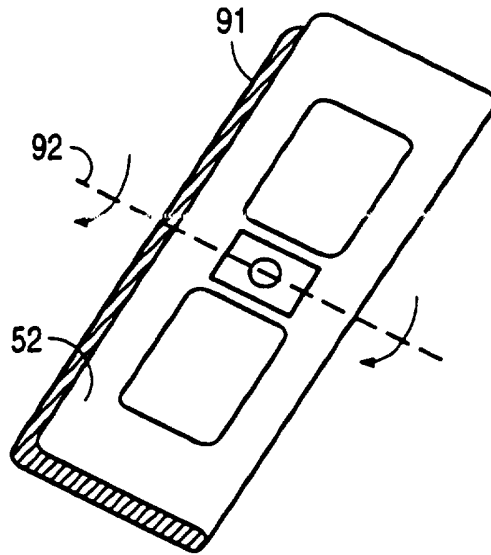


FIG. 13

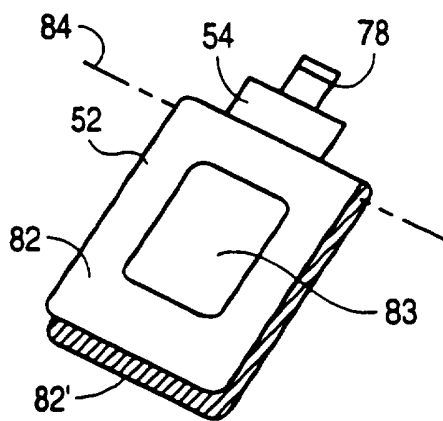


FIG. 14



9/11

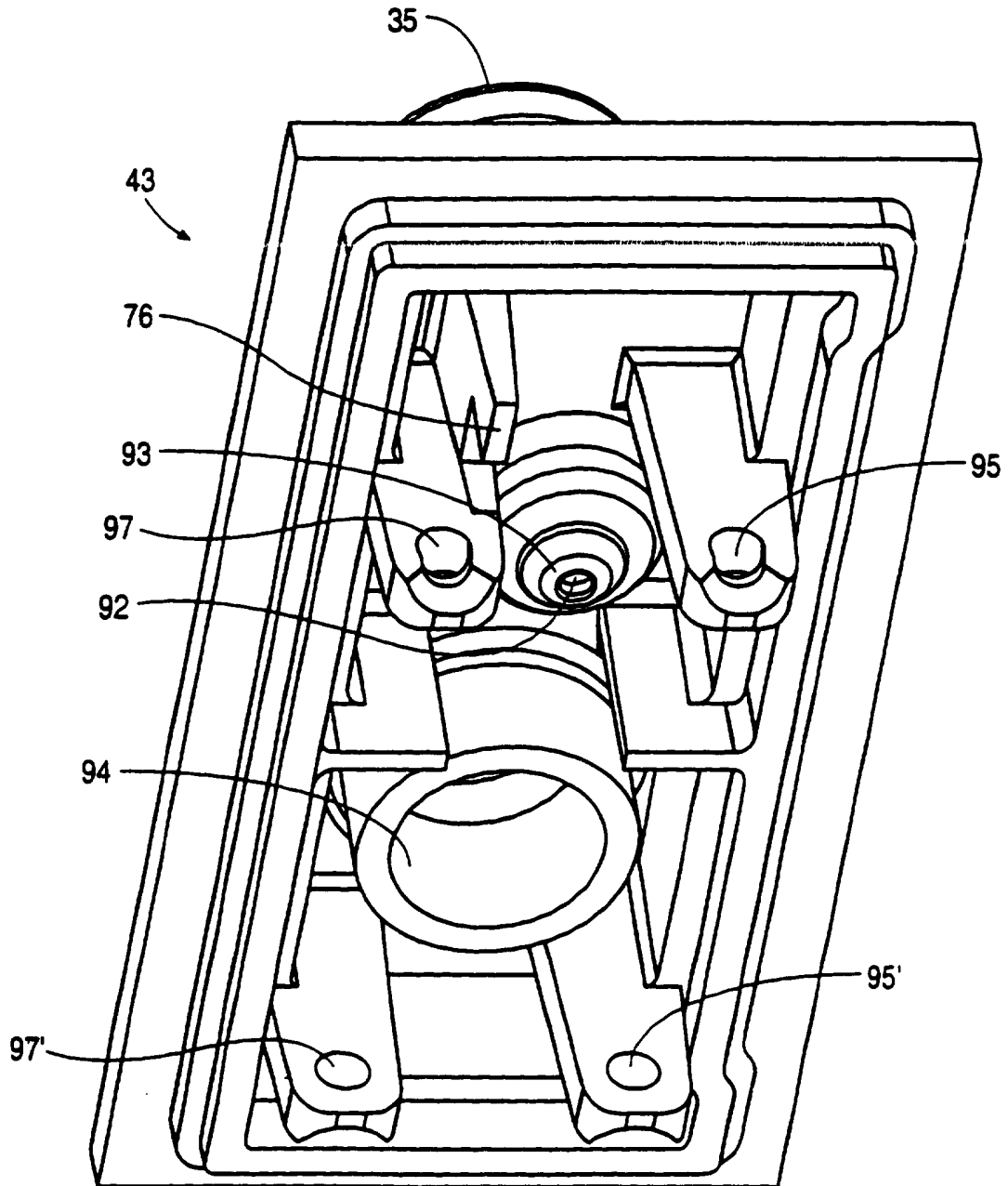


FIG. 15

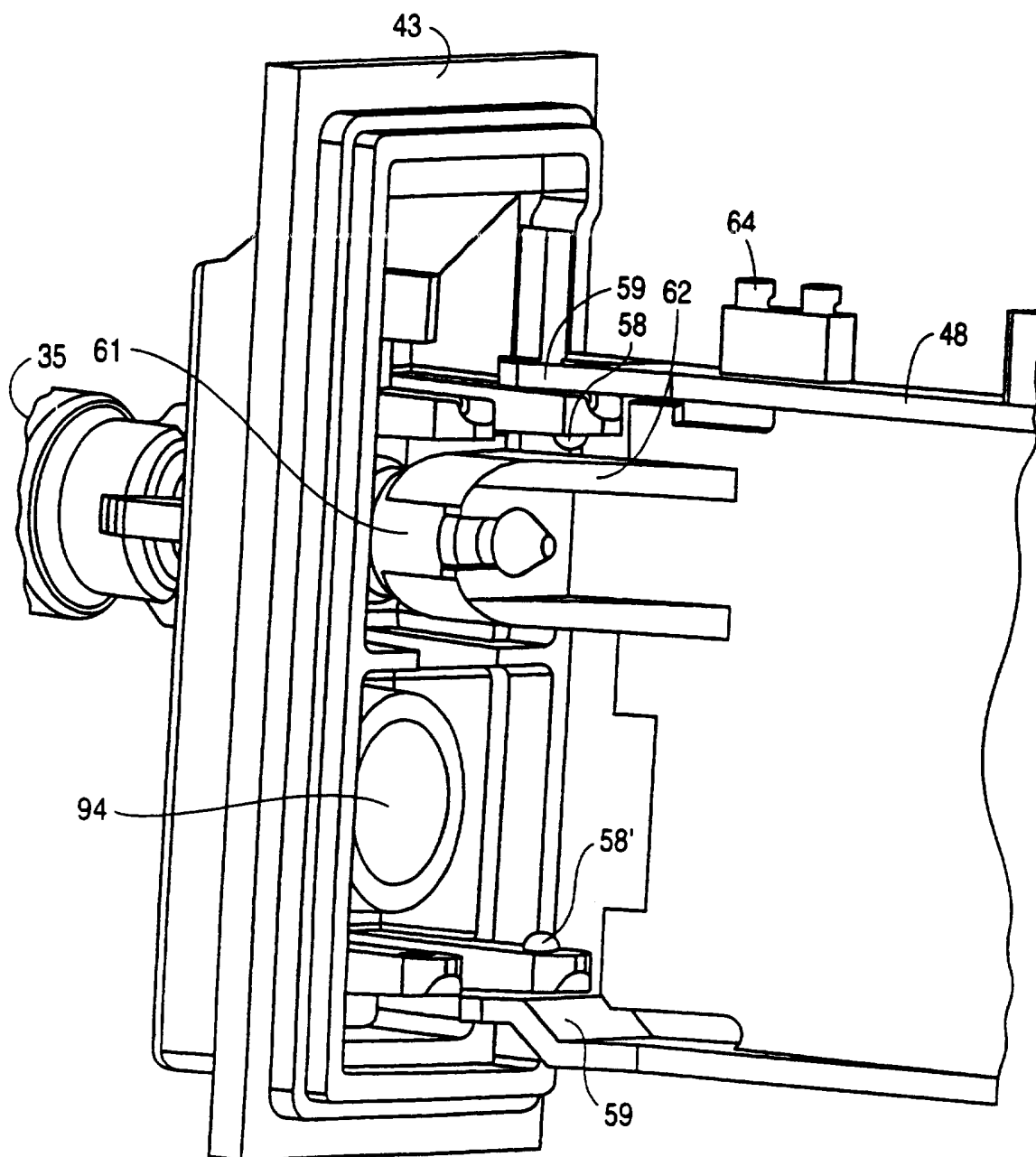


FIG. 16

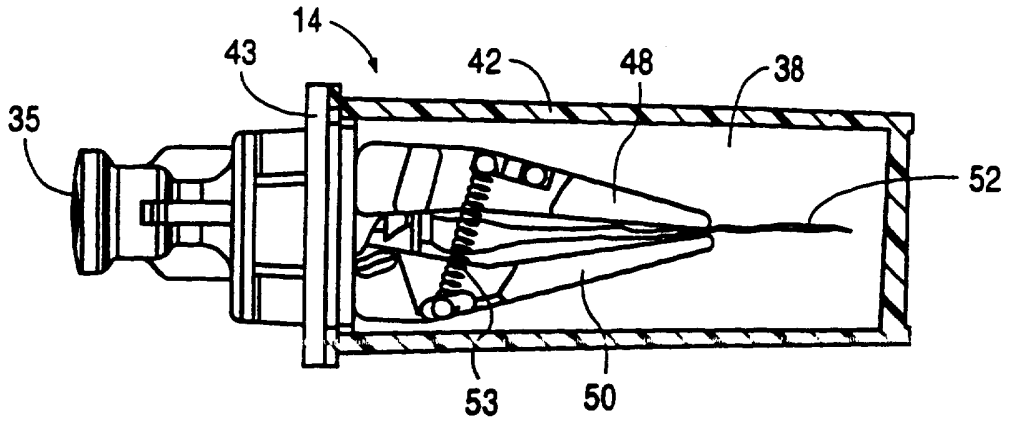


FIG. 17

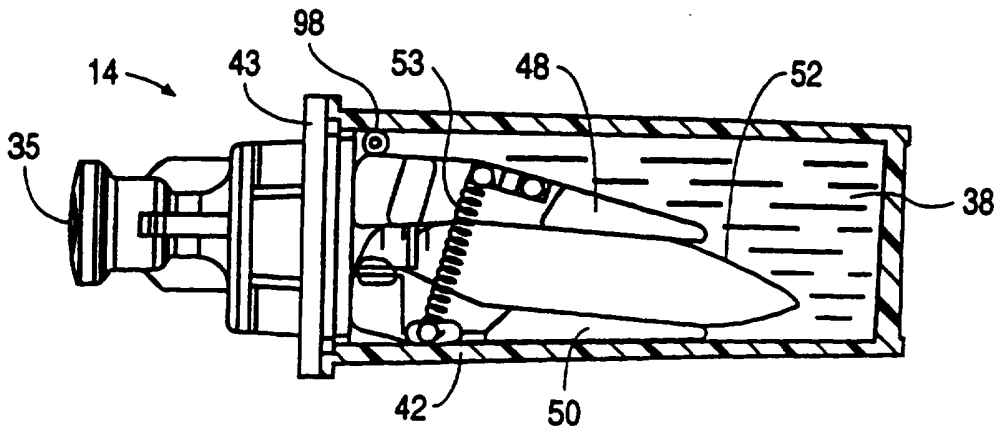


FIG. 18

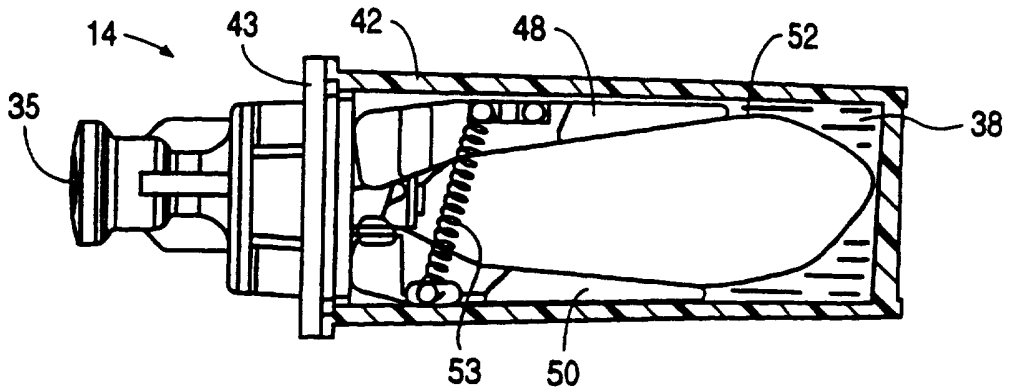


FIG. 19

## INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US96/17548**A. CLASSIFICATION OF SUBJECT MATTER**

IPC(6) :B41J 2/175

US CL :347/86

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 347/7, 85, 86, 87

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category* | Citation of document, with indication, where appropriate, of the relevant passages   | Relevant to claim No. |
|-----------|--|-----------------------|
| X         | US 4,475,116 A (Sicking et al.) 02 October 1984, col. 4, line 20 to col. 5, line 19. | 1-3, 11               |
| A         | US 5,409,134 A (Cowger et al.) 25 April 1995, col. 6, line 59 to col. 8, line 37.    | 1-11                  |
| A         | US 4,509,062 A (Low et al.) 02 April 1985, col. 2, line 27 to col. 3, line 27.       | 1-11                  |
| A         | US 4,739,347 A (Ishikawa et al.) 19 April 1988, col. 3, line 40 to col. 6, line 24.  | 1-11                  |
| A         | US 5,453,772 A (Aono et al.) 26 September 1995, col. 3, line 1 to col. 5, line 61.   | 1-11                  |
| A         | US 5,040,001 A (Dunn et al.) 13 August 1991, col. 3, line 31 to col. 5, line 54.     | 7-10                  |

Further documents are listed in the continuation of Box C.

See patent family annex.

|   |  |
|---|--|
| * Special categories of cited documents:  | "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention  |
| "A" document defining the general state of the art which is not considered to be of particular relevance  | "X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone   |
| "E" earlier document published on or after the international filing date  | "Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art |
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| "O" document referring to an oral disclosure, use, exhibition or other means  |  |
| "P" document published prior to the international filing date but later than the priority date claimed  |  |

Date of the actual completion of the international search

17 JANUARY 1997

Date of mailing of the international search report

21 FEB 1997

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