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EUROPEAN PATENT APPLICATION

(21) Application number : **94303109.6**

(51) Int. Cl.⁵ : **B41J 2/025, B41J 2/155**

(22) Date of filing : **28.04.94**

(30) Priority : **12.05.93 US 61391**

(43) Date of publication of application :
17.11.94 Bulletin 94/46

(84) Designated Contracting States :
DE FR GB

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(54) **Improved drop generator utilizing damping for mode suppression.**

(57) A print head device is used in continuous ink jet printing. The device comprises a resonator means and ink supply body having a solid formed of high acoustic Q material. Transducer means are attached to the resonator means. The transducer means are energized at a desired drop frequency. Damping means (38) are provided for suppression of undesired interfering vibration modes of the resonator means and ink supply body, to achieve a desired mode. The damping means (38) are placed in regions having relatively high stress in the interfering modes and relatively low stress in the desired mode.

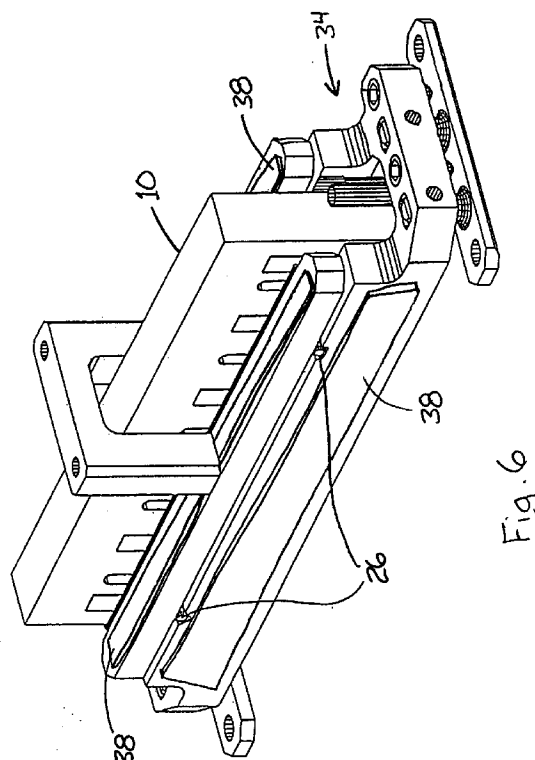


Fig. 6

Technical Field

The present invention relates to ink jet drop generators and, more particularly, to an improved structure for an ink jet drop generator.

Background Art

In continuous ink jet printing, ink is supplied under pressure to a manifold region that distributes the ink to a plurality of orifices, typically arranged in a linear array(s). The ink discharges from the orifices in filaments which break into droplet streams. The approach for printing with these droplet streams is to selectively charge and deflect certain drops from their normal trajectories.

In the field of ink jet printers, it is desirable from the standpoint of throughput to utilize long arrays of ink jets. For example, U.S. Patent No. 4,999,647 discloses a drop generator for use with a long array of holes such that the length is larger than the height. A plurality of slots were employed to insure uniform vibration amplitude of the longitudinal mode (height direction) across the orifice plate face. Co-pending, commonly assigned U.S. Patent Application Serial No. 07/891,492, filed May 29, 1992, incorporated herein by reference, defines an improved drop generator in which the fluid cavity length is established to suppress pressure waves in the fluid cavity. Such pressure waves in the fluid can interfere with stimulation produced by the resonator-induced motion of the orifice plate.

With longer array devices or higher frequencies, it becomes more difficult to excite the desired vibration mode without exciting other modes which can adversely affect stimulation uniformity. For example, in the equation

$$A_n = B_n / [(f_n^2 - f^2) + c],$$

A_n is the vibration amplitude of mode n , B_n is a constant depending on the mode shape, f_n is the resonant frequency of node n , f is the driving frequency, and c is a small value related to attenuation. To drive the n^{th} mode while trying to avoid driving the $n+1^{\text{th}}$ mode, the resonator is driven at a frequency of $f = f_n$. The amplitude A_n would reach its maximum value of B_n/c . The amplitude of A_{n+1} would be $B_{n+1} / ((f_{n+1}^2 - f_n^2) + c)$. As the desired frequency or the resonator length increase, the separation between the resonant modes, $f_{n+1} - f_n$, decreases. As the mode separation, $f_{n+1} - f_n$, decreases, the ratio of their amplitudes A_n/A_{n+1} decreases. It is therefore harder to excite the mode n without also exciting the $n+1$ mode.

Even with judicious design of the drop generator to insure that the desired mode is uniform, the undesirable excitation of an adjacent resonant mode can produce unacceptable stimulation uniformity across the array. Furthermore, the degree to which the un-

desirable modes are excited and subsequently the level of vibration uniformity across the array may be unacceptably sensitive to the operating frequency and manufacturing tolerances.

It is seen then that there is a need for an improved structure for an ink jet drop generator which can provide mode uniformity and which overcomes the problems and disadvantages of prior procedures.

Summary of the Invention

This need is met by the print head device of the present invention wherein mode uniformity is provided. One important object of the present invention is to provide an improved structure for an ink jet drop generator which can utilize long arrays of ink jets. This is accomplished by an approach wherein the system is designed to include damping means for suppression of undesired vibration modes.

In accordance with one aspect of the present invention, a print head device is used in continuous ink jet printing systems. The print head device comprises a resonator means with an ink supply body formed of a solid high acoustic Q material. Piezoelectric transducer means are attached to the resonator means. The print head device further includes means for energizing the transducer means at a desired drop frequency. Finally, damping means are provided for suppression of undesired vibration modes.

Accordingly, it is an advantage of the present invention that it provides mode suppression in relatively long orifice arrays. Other objects and advantages of the invention will be apparent from the following description, the accompanying drawing and the appended claims.

Brief Description of the Drawing

Fig. 1 illustrates a prior art drop generator; Fig. 2 illustrates a vibrating fluid fitting; Fig. 3 illustrates a fluid fitting with the damping material, according to the present invention; Fig. 4 illustrates prior art fluid cavity walls having undesired flexure mode; Fig. 5 illustrates a drop generator according to the present invention wherein damping suppresses the fluid cavity wall mode; and Fig. 6 illustrates the drop generator of Fig. 5 mounted in a frame.

Detailed Description of the Preferred Embodiments

Referring to the drawings, Fig. 1 schematically illustrates the components that cooperate to comprise a prior art embodiment of a drop ejection device. It will be understood that such drop ejection device, generally referred to as 10, cooperates with other known components used in ink jet printers. The device 10

functions to produce the desired streams of uniformly sized and spaced drops in a highly synchronous condition. Other continuous ink jet printer components, such as charge and deflection electrodes, drop catcher, media feed system and data input and machine control electronics (not shown) cooperate with the drop streams, produced by device 10 to effect continuous ink jet printing.

The drop generator 10 is constructed to provide synchronous drop streams in a long array printer, and comprises a resonator/manifold body 12. The resonator/manifold body 12 is constructed of a high acoustic Q material, e.g. stainless steel, and in the form of a predeterminedly dimensioned rectangular solid, the length (l) of which is substantially greater than its height (h), which body height (h) is substantially greater than the body thickness.

Continuing with Fig. 1, an orifice plate 14 having a plurality of orifices, is bonded onto the resonator body 12. The resonator body 12 also includes an ink supply body or fluid cavity 16, having fluid cavity side walls for containing the ink. It is understood that the resonator/manifold body 12 further includes fluid ports, or fluid fittings 20, for supplying ink from a fluid supply means to the ink supply cavity. The fluid inlet and outlet fittings 20 may comprise thin wall tubing bent to form an elbow 24, over which flexible ink conduit lines 22 may be attached. Pins 26, protruding outward from the front and back faces of the resonator body 12 can be used to mount the drop generator 10 in a support frame, such as frame 34 in Fig. 6.

A plurality of piezoelectric elements 18 are used to induce the vibration of the resonator/manifold body 12. In such a drop generator 10, the desired vibration mode for good stimulation is typically the longitudinal mode in the h direction. In this mode, the resonator/manifold body 12 expands and contracts in the h direction. The slots 28 ensure that the uniformity of this longitudinal mode is sufficient for proper drop generation operation. In addition to this longitudinal mode, it is possible to excite other vibration modes even when the drop generator has been carefully designed to provide uniform vibration in the desired vibrational mode. These other vibrational modes, which typically vary in amplitude and/or phase across the array, can seriously degrade the vibrational uniformity across the jet array.

In accordance with the present invention, to suppress these undesirable vibrational modes, damping means may be utilized. Although any suitable damping means may be used, a typical damping means comprises a damping material such as viscoelastic materials. As these materials undergo periodic stress or strain, they convert some of the vibrational energy into heat, attenuating the vibration amplitude. Since these materials must undergo periodic stress to attenuate the vibration amplitude, they are most effective when they are attached to the high stress regions

of the resonating system. Suppression of the undesirable vibration mode therefore involves attaching damping materials to those areas of drop generator 10 where the stresses are concentrated for such undesired modes. Conversely, the damping materials should not be attached to those areas of the drop generator 10 having high stress in the longitudinal mode.

Use of damping materials, in accordance with the present invention, can suppress undesirable modes. The following three types of undesirable modes are exemplary of the modes which can be suppressed using the damping concept of the present invention. One undesirable mode involves a resonance of the fitting 20. Fig. 2 illustrates one possible vibration mode of the fittings. In this mode, the elbow 24 can be seen to flex in and out. Of course, it will be obvious to those skilled in the art that Fig. 2 is representative of only one of many possible modes. The resonant mode of Fig. 2 can couple into the resonator body 12 affecting the vibration uniformity at the orifice plate 14, or it can drive a pressure wave in the fluid cavity 16. In accordance with the present invention, the placement of a damping rubber sleeve 30 around the elbow 24 as shown in Fig. 3 can strongly attenuate this mode while having little effect on the resonator body longitudinal mode.

A second type of interfering vibrational mode involves flexure modes of the sides of the cavity. As illustrated in Fig. 4, the side walls 32 around the fluid cavity can undergo flexure modes in the form of standing waves down the array. Again, it will be obvious to those skilled in the art that Fig. 4 is representative of only one of many possible cavity wall flexure modes. Such modes can produce large variations in the stimulation amplitude down the array. In accordance with the present invention, cavity flexure modes can be suppressed by attaching damping material 36, such as E-A-R/SC SD-40PSA material to the side walls 32 of the fluid cavity 16 as shown in Fig. 5. As the stresses are low near the end of the resonator in the longitudinal mode, the longitudinal mode is not strongly attenuated by the damping material.

The third type of interfering resonance involves the drop generator mounting frame. As shown in Fig. 6, the drop generator is mounted in a frame 34 by means of pins 26. Although the pins 26 are located near the nodal plane of the drop generator 10, they are able to couple some vibrational energy from the drop generator 10 to the frame 34. If the frame has a resonance near the operating frequency of the drop generator this can result in the frame 34 resonating. The vibration of the frame 34 can then be coupled back into the drop generator 10 through the pins 26, affecting the stimulation uniformity. In accordance with the present invention, applying damping material 38 to the frame can suppress the frame resonance so that the stimulation uniformity is not degraded, without adversely affecting the longitudinal mode of the

resonator.

The damping rubber sleeve 30, the damping material 36 and the damping material 38 being used for mode suppression may be used singularly or cooperatively, depending on the presence or absence of the interfering modes for a particular drop generator.

The interfering resonant modes illustrated herein are examples of some of the many interfering resonant modes which may be present in drop generator designs, and are not to be considered as limiting the scope of the invention. In accordance with the present invention, the desired suppression of the interfering mode can be produced by placement of the damping material in regions having relatively high stress in the interfering modes and relatively low stress in the desired mode.

Industrial Applicability and Advantages

The present invention is useful in the field of ink jet printing, and has the advantage of suppressing undesired vibration and interfering resonant modes. The present invention has the further advantage of providing such suppression without adversely affecting the longitudinal mode of the resonator.

The invention has been described in detail with particular reference to certain preferred embodiments thereof, but it will be understood that modifications and variations can be effected within the spirit and scope of the invention.

Claims

1. A print head device for use in continuous ink jet printing, the device comprising:
 - a. a resonator means having an ink supply body formed of a solid high acoustic Q material;
 - b. transducer means attached to the resonator means;
 - c. a means for energizing the transducer means at a desired drop frequency; and
 - d. damping means for suppression of undesired interfering vibration modes of the resonator means, to achieve a desired mode.
2. A print head device as claimed in claim 1 wherein the damping means are placed in regions having relatively high stress in the interfering modes and relatively low stress in the desired mode.
3. A print head device as claimed in claim 1 wherein the damping means comprises a viscoelastic material.
4. A print head device for use in continuous ink jet printing, the device comprising:
 - a. a resonator means having an ink supply

body formed of a solid high acoustic Q material and further having fluid ports for supplying ink from a fluid supply means to the ink supply body;

- b. transducer means attached to the resonator means;
 - c. a means for energizing the transducer means at a desired drop frequency; and
 - d. means for applying a damping means to the fluid ports for suppression of undesired interfering vibration modes, to achieve a desired mode.
5. A print head device as claimed in claim 4 wherein the damping means comprises a viscoelastic material.
 6. A print head device for use in continuous ink jet printing, the device comprising:
 - a. a resonator means having an ink supply body formed of a solid high acoustic Q material, the ink supply body including fluid cavity side walls for containing the ink;
 - b. transducer means attached to the resonator means;
 - c. a means for energizing the transducer means at a desired drop frequency; and
 - d. means for attaching a damping means to the fluid cavity side walls for suppression of undesired interfering vibration modes, to achieve a desired mode.
 7. A print head device as claimed in claim 6 wherein the damping means comprises a viscoelastic material.
 8. A print head device for use in continuous ink jet printing, the device comprising:
 - a. a resonator means having an ink supply body formed of a solid high acoustic Q material, the resonator means mounted in a support frame;
 - b. transducer means attached to the resonator means;
 - c. a means for energizing the transducer means at a desired drop frequency; and
 - d. means for applying a damping means to the support frame for suppression of undesired interfering vibration modes, to achieve a desired mode.
 9. A print head device as claimed in claim 8 wherein the damping means comprises a viscoelastic material.
 10. A print head device as claimed in claim 8 wherein the resonator means is mounted in a support frame using a plurality of pins.

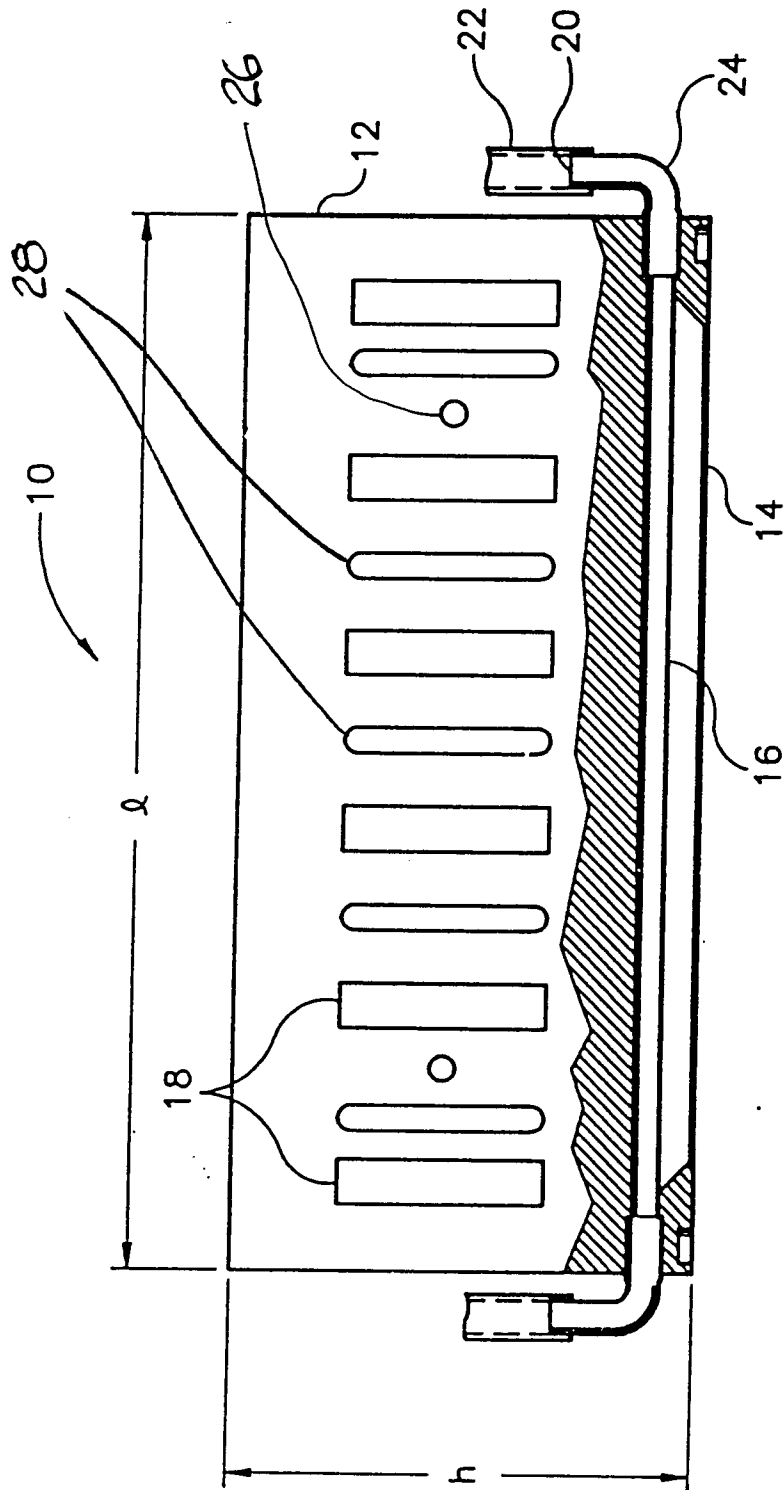


FIG. 1

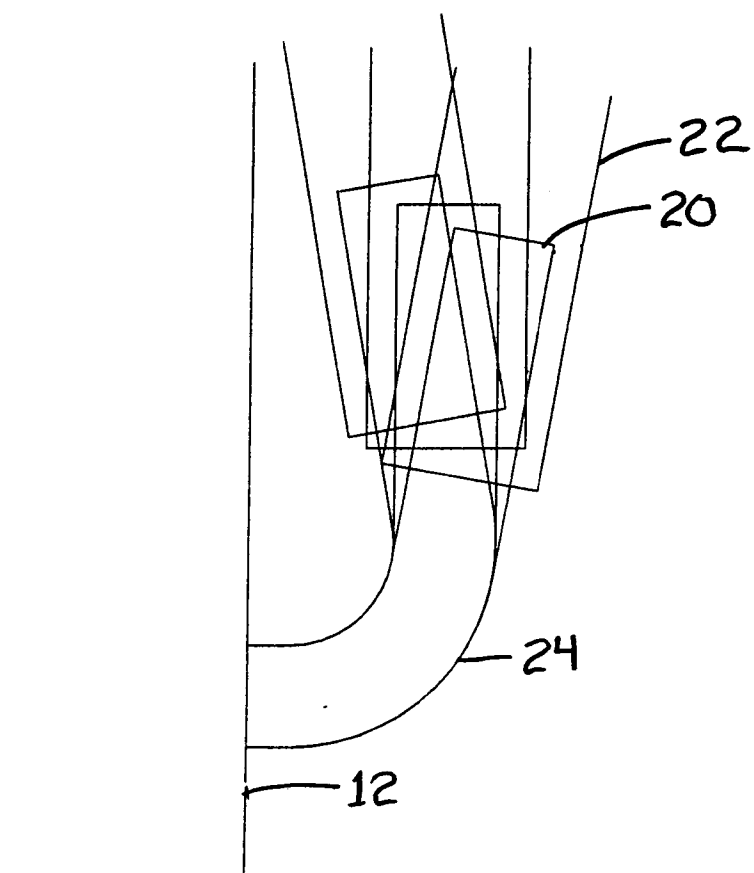


Fig. 2

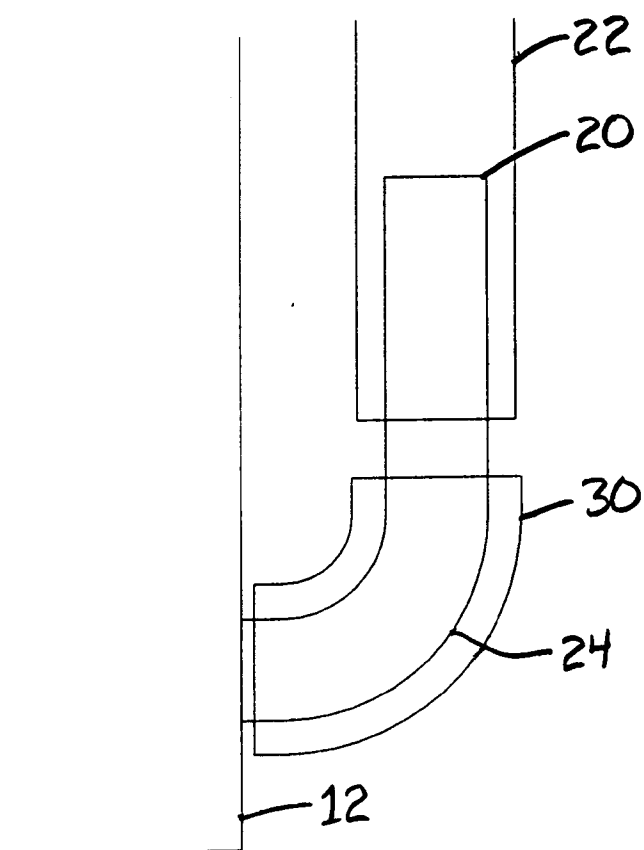


Fig. 3

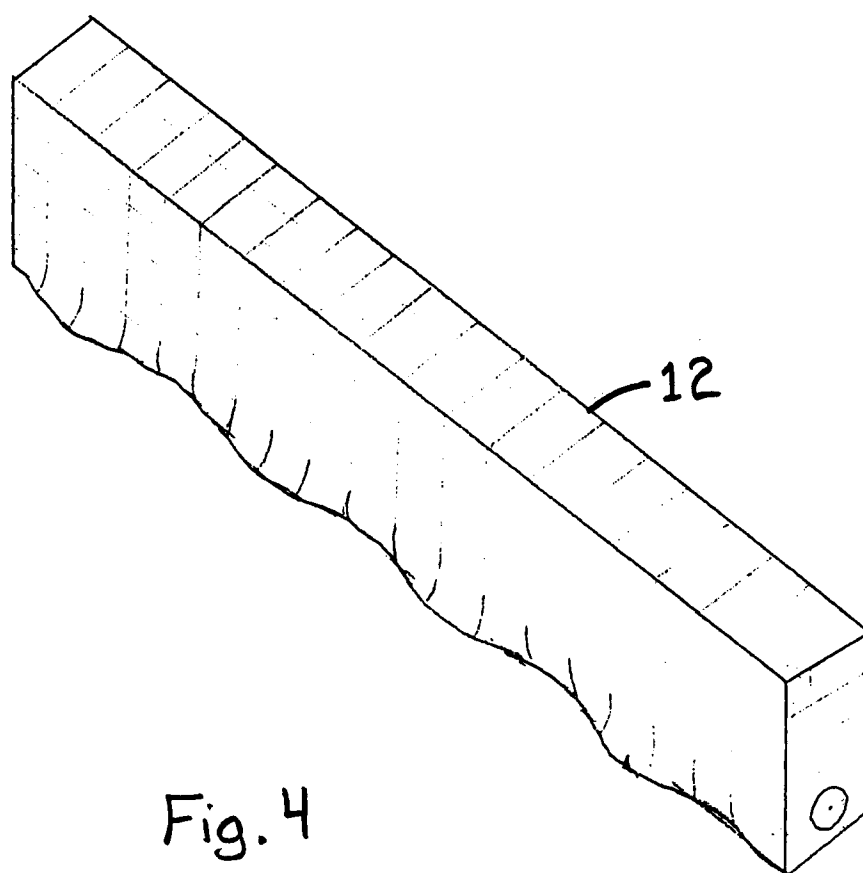


Fig. 4

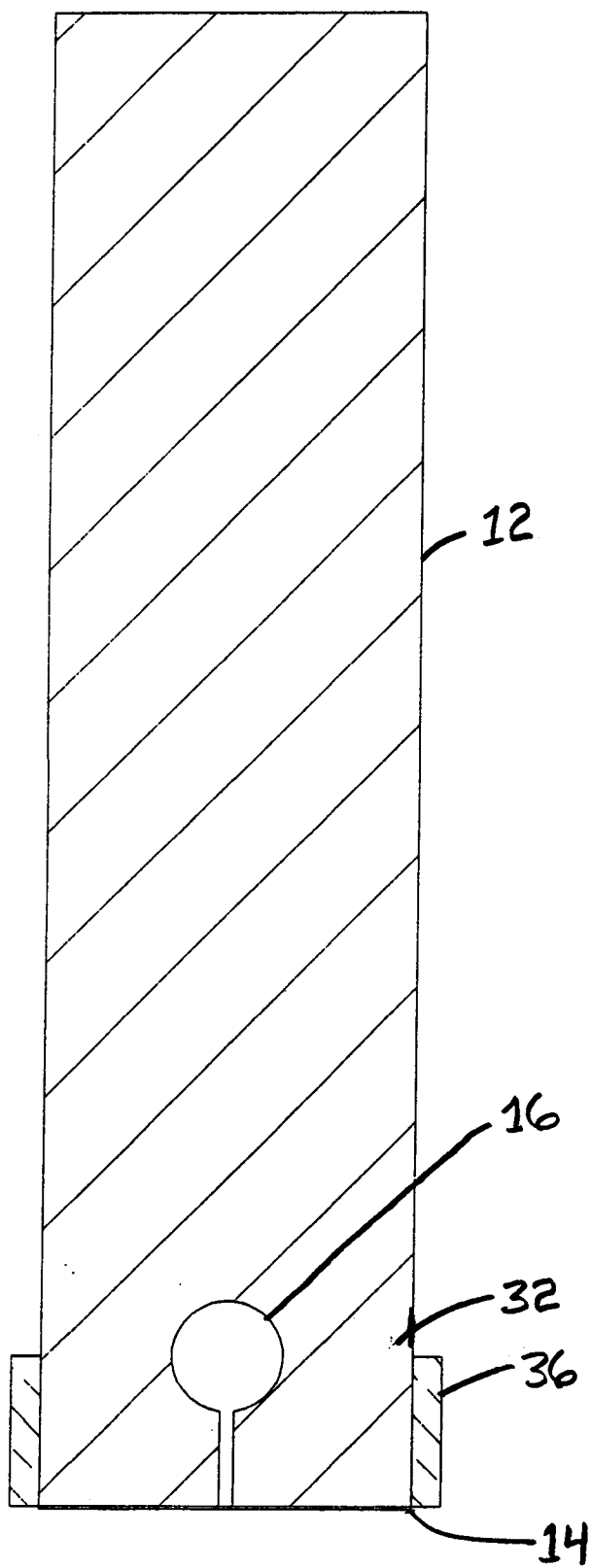


Fig.5

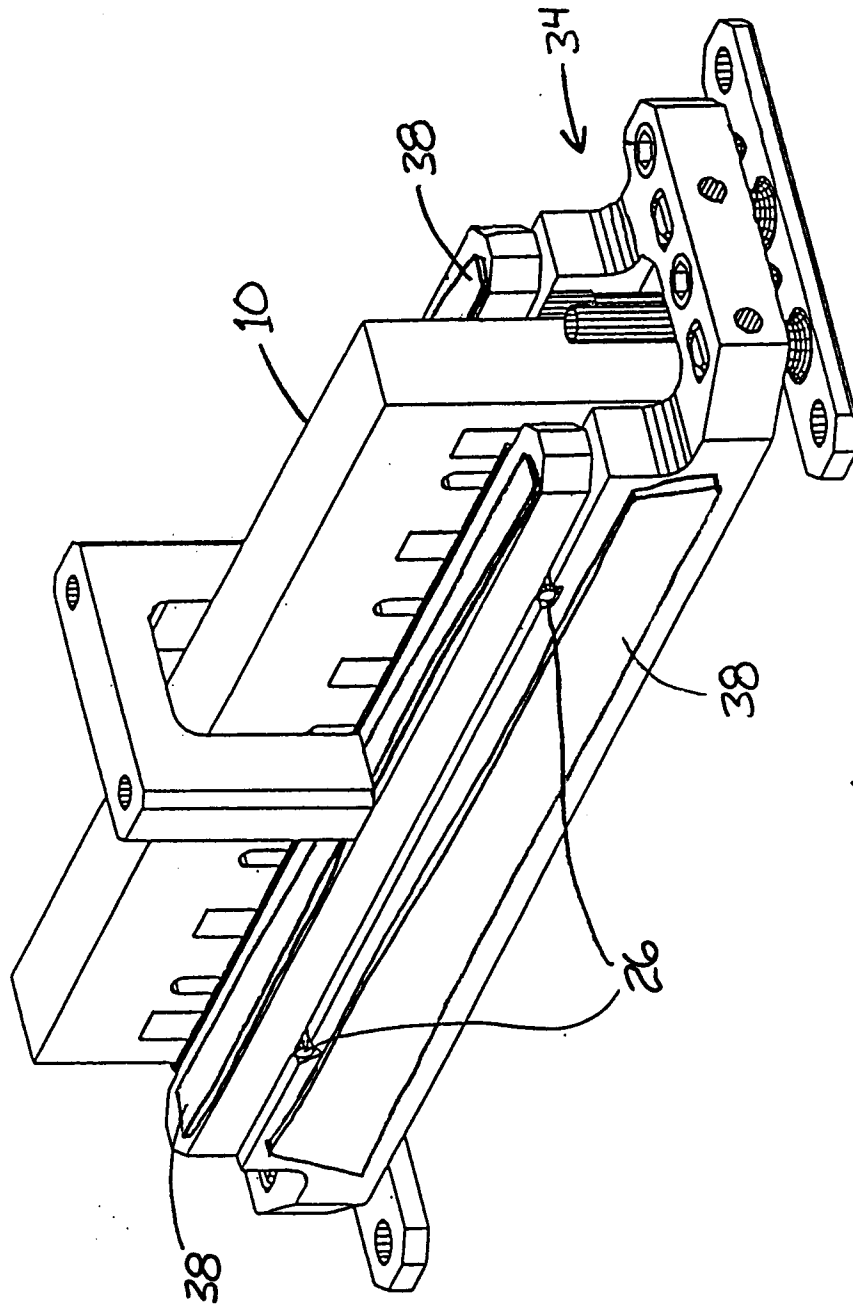


Fig. 6



European Patent
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EUROPEAN SEARCH REPORT

Application Number

EP 94 30 3109

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	EP-A-0 126 649 (THE MEAD CORPORATION) * page 13; claim 1; figure 1 * ---	1,3,6-8	B 41 J 2/025 B 41 J 2/155
X	US-A-4 135 197 (L.G. STONEBURNER) * columns 1-3; figures 1,2 * ---	1,3	
D,Y	US-A-4 999 647 (W.L. WOOD et al.) * abstract; figure 1 * ---	1,4	
Y	EP-A-0 150 958 (ING. C. OLIVETTI & C.) * page 2, lines 9-12; claims 1,6; abstract * ---	1,4	
A	PATENT ABSTRACTS OF JAPAN, vol. 13, no. 122 (M-807), 1989; & JP-A-63296957 (FUJI XEROX CO LTD) * abstract * ---	1	
A	EP-A-0 034 777 (SIEMENS AG) -----		
			TECHNICAL FIELDS SEARCHED (Int. Cl.5)
			B 41 J
The present search report has been drawn up for all claims			
Place of search BERLIN		Date of completion of the search 01-08-1994	Examiner ZOPF K H M
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			

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