(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 095 776 A1

(12) # EUROPEAN PATENT APPLICATION

(43) Date of publication:
02.05.2001 Bulletin 2001/18

(51) Int. Cl.[7]: **B41J 2/17**, B41J 2/165

(21) Application number: **00309006.5**

(22) Date of filing: **13.10.2000**

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE
Designated Extension States:
AL LT LV MK RO SI

(30) Priority: **29.10.1999 US 430721**

(71) Applicant:
Scitex Digital Printing, Inc.
Dayton, Ohio 45420-4099 (US)

(72) Inventors:
- **Simon, Robert J.**
  Bellbrook, ohio 45305 (US)
- **Lyman, Dan C.**
  Cincinnati, Ohio 45238 (US)

(74) Representative:
Freed, Arthur Woolf et al
Reginald W. Barker & Co.,
Clifford's Inn,
Fetter Lane
London EC4A 1BY (GB)

(54) **Improved ultrasonic cleaning method in ink jet printing systems**

(57) The efficiency of ultrasonic cleaning of a printhead is improved by sweeping the stimulation drive frequency. The cleaning frequency is swept at a constant drive amplitude. The drive amplitude, lower frequency limit, and upper frequency limit are stored in the printhead memory. When the printhead is in an ultrasonic cleaning state, as determined by the state table, the print station varies the frequency at a fixed rate. The drive amplitude is kept constant during the ultrasonic cleaning state.

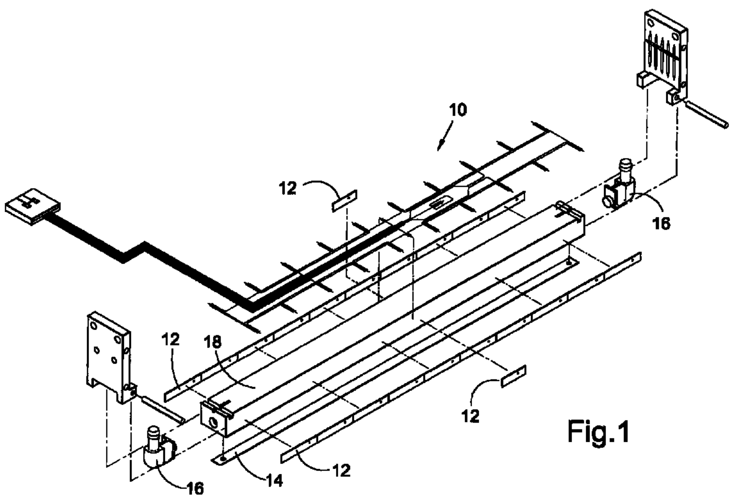

Fig.1

EP 1 095 776 A1

Description

Technical Field

[0001] The present invention relates to continuous ink-jet printing and, more particularly, to the cleaning of printheads in continuous ink jet printing systems.

Background Art

[0002] Continuous ink jet printheads utilize a series of orifices separated from charging leads by a small gap. Fluid is forced through the orifice while the printhead is in operation. Upon shutdown, the ink floods the leads and the area around the orifices. This fluid then dries, leaving behind non-volatile components in the form of solids or gels. Depending on the ink chemistry, this ink may polymerize as it dries, rendering it insoluble. Upon subsequent startups, the failure to remove or redissolve all of this material in the orifice and gap creates disturbances in the shape or direction of the emerging jet. Heavy deposits and pieces of debris may block the orifice altogether. Deposits left on the charging leads may leave films which impair the proper charging of the drops as they form, causing insufficient deflection of the drop. Therefore, debris and dried ink deposits on the orifice plate can cause crooked jets, leading to streakers (where a jet is constantly impinging on the substrate, regardless of whether or not it is charged) and charge plate shorts.

[0003] Although current ink jet systems make an effort to filter out this debris, it is sometimes necessary to ultrasonically clean the resonator and orifice plate in the printhead in order to remove these deposits. This can be accomplished by applying a large stimulation drive (known as ▒superstim▒) to the piezoelectric crystals, as described in U.S. Patent No. 4,563,688.

[0004] U.S. Patent No. 4,600,928 improved the effectiveness of the superstim cleaning process by modulating the ink pressure in conjunction with the high amplitude vibration. Modulating the ink pressure causes ink to flow through the orifices in both an outward and an inward direction. The inward flow of fluid through the orifice can help remove particles from the orifices in combination with the vibration.

[0005] To ultrasonically clean the fluid cavity of the drop generator, the surface of the fluid cavity should be vibrated at large amplitudes. To increase the vibrational amplitude it is useful to drive the drop generator at or near resonance. This purpose is suggested by the '928 patent where the frequency is shifted to a fixed desired cleaning frequency and the amplitude of the drive signal is increased. Alternatively, the frequency of the oscillator can be shifted across resonance in the cleaning mode until a feedback signal from a detector indicates a resonant condition for the system coupled to the transducer vibrations.

[0006] Typical resonant vibration modes, however, have one or more node regions at the surface of the fluid cavity with little or no vibration. Independent of the drive amplitude used, the cleaning efficiency in these areas will be low. This problem can be overcome by employing more than one resonant mode. The '688 and the '928 patents attempted to meet this need for driving multiple resonances by driving the drop generator with a square wave. The square wave consists of a number of harmonic signals at higher frequencies in addition to the base frequency component. This cleaning drive signal, therefore, has at least some components which are higher in frequency than the substantially sinusoidal drive signal.

[0007] The '688 and the '928 patents failed to recognize that for most drop generator designs, including those illustrated in the patents, little vibrational energy can be transferred to the drop generator at the frequencies of the higher harmonic components. For many drop generator designs, this is the result of the drop generator not having resonant frequencies which correspond to the harmonic frequencies obtained from a square wave. For this reason, the use of a square wave driving function provides no benefit over using a sine wave.

[0008] It is seen, then, that it would be desirable to provide means to utilize more than one resonant mode to clean the printhead.

Summary of the Invention

[0009] To improve cleaning efficiency of the drop generator, the present invention proposes superstim cleaning at multiple frequencies. Improved flexibility in the stimulation drive circuitry has allowed for the method of the present invention whereby the superstim frequency can be varied. By varying the drive frequency, more than one resonance can be used to ensure that all surfaces on the interior of the fluid cavity are vibrated with sufficient vibration amplitude for effective cleaning.

[0010] In accordance with one aspect of the present invention, the efficiency of ultrasonic cleaning of the printhead is improved by sweeping the stimulation frequency. The cleaning frequency is swept at a constant drive amplitude. The drive amplitude, lower frequency limit, and upper frequency limit are stored in the printhead memory. When the printhead is in an ultrasonic cleaning state, as determined by the state table, the print station varies the frequency at a fixed rate (currently 3 Khz/sec) using an Analog Devices Corp. Direct Digital Synthesizer (DDS) AD9850. The drive amplitude is kept constant during the ultrasonic cleaning state.

[0011] Other objects and advantage of the present invention will be apparent from the following description and the appended claims.

Brief Description of the Drawings

[0012]

Fig. 1 is an exploded view of a drop generator to illustrate cross-flushing; and

Figs. 2 and 3 illustrate resonant shapes at different resonances being swept.

Detailed Description of the Invention

[0013] In accordance with the present invention, a cleaning system is employed to cross flush drop generator 10 at a high flow rate, as illustrated in Fig. 1. To enhance the removal of particles from the drop generator, the drop generator is ultrasonically driven by means of its stimulation drive transducers 12 fixed to resonator body 18. When ultrasonically driven at high amplitudes, several times higher than the vibration amplitudes than used for normal stimulation of drop break off, particles can be vibrated loose from the surfaces of the drop generator and the orifice plate 14.

[0014] While an ideal drop generator has uniform amplitude down the entire length of the drop generator, most real drop generators, especially those with long array lengths, have some variation in amplitude down the length. This has been found to be the result of numerous resonances with resonant frequencies close to that of the desired operating frequency. It has been found that with such drop generators, shifting the drive frequency across the operating resonance can change the relative drive amplitude for these closely spaced resonances. As a result, shifting the drive frequency across the resonance can cause the higher vibration regions to shift down the length of the drop generator. To get consistent cleaning down the length of the drop generator, it is therefore desirable to continuously sweep the drive frequency across the resonance. Continuously sweeping the drive frequency across the resonant frequency has therefore been found to be more effective than operating at any fixed frequency.

[0015] With certain drop generator designs, such as that described in commonly assigned, co-pending patent application Serial No. 09/211,059, the fluid in the drop generator produces sufficient damping that it can be difficult to determine the resonant frequency from the drive or feedback signal. Continuous sweeping of the frequency range known to include the resonance is also advantageous in this case as well.

[0016] To provide efficient cleaning of the drop generator, the present invention improves ultrasonic cleaning of the printhead by sweeping the stimulation frequency. Cross-flush is achieved by flushing the cleaning fluid from one fitting 16 to the opposite fitting 16. The cleaning frequency is continuously swept at a constant drive amplitude.

[0017] In a preferred embodiment, when the printhead is in an ultrasonic cleaning state, as determined by the state table, the print station varies the frequency at a fixed rate (currently 3 Khz/sec). In this preferred embodiment, the frequency sweep is provided by means of an Analog Devices Corp. Direct Digital Synthesizer (DDS) AD9850.

[0018] Due to manufacturing variations, the drive amplitude and the frequency range to be used for ultrasonic cleaning varies from drop generator to drop generator. To deal with this issue, a preferred embodiment of the present invention provides means to store the desired drive amplitude, lower frequency limit, and upper frequency limit in memory within the printhead. These values can then be determined and written into the printhead memory during production. Other uses for the printhead memory and the means for incorporating the data stored in the printhead memory are described in commonly assigned, co-pending patent application Serial No. 08/810,653.

[0019] Even with well designed drop generators, which have quite uniform vibration amplitude down the length of the jet array, the vibration amplitude is not uniform throughout the fluid cavity of the drop generator. Fig. 2 shows a cross-sectional view of a drop generator such as is described in patent application Serial No. 09/211,059. The drop generator 27 includes a fluid cavity 23 through which ink is supplied to the orifices fabricated into the orifice plate 25. Piezoelectric actuators 21 attached to the drop generator are driven by an electronic circuit, not shown, to cause the drop generator to vibrate. When driven at the operating frequency, that provides the proper drop formation, the drop generator assembly vibrates as shown by the deformed shape 27'. The deformed shape corresponds to a peak amplitude of vibration, with every portion of the drop generator vibrating back and forth across the undeformed shape. Hence, 21', 23', and 25' refer to the vibrated amplitudes of the piezoelectric actuators, the fluid cavity and the orifice plate, respectively. As shown, while much of the fluid cavity has large vibration amplitudes, the top of the fluid cavity 31 and sections of the lower portion of the fluid cavity 32 undergo little vibration. With little or no vibration amplitude in these regions, the ultrasonic vibration is largely ineffective in cleaning these portions of the drop generator.

[0020] By utilizing multiple resonant frequencies for cleaning the drop generator this problem can be eliminated. Fig. 3 shows resonant shape for an alternate resonance which can be used for cleaning the drop generator 27. This resonance has significant vibrational amplitude at the top of the cavity 31, indicated as 31', where the normal operating resonance had little amplitude in Fig. 2. This resonance also provides vibration to the regions 32 that had no vibration with the previous resonance, and now have vibration difference indicated by 32'. This resonance, however, has regions 37 on the sides of the fluid cavity with low vibration amplitude. As such, this resonance is more effective than the previous resonance at cleaning the top of the fluid cavity, but is less effective at cleaning the sides of the fluid cavity. By using these two resonances, vibration useful for cleaning can be produced throughout the fluid cavity. One could also employ additional resonances to further complement the cleaning effectiveness of these resonances. In general, any drop generator design will have two or more complementary resonances which can be used to provide vibrational cleaning to the entire inside surface of the fluid cavity. While the resonant shapes for these two resonance are symmetric across the fluid cavity, one could also utilize asymmetric resonances for cleaning as well. For such asymmetric resonances, it may be necessary to drive only some of the piezoelectric elements or to drive some elements out of phase from the others.

[0021] To provide for effective cleaning of the drop generator, the present invention provides means to utilize such complementary resonances. In a preferred embodiment, this is accomplished by stepping the frequency from resonance to resonance. While a frequency sweep between resonances could be used, a sweep would waste a considerable amount of time between the useful resonances where minimal cleaning is obtained.

[0022] In a preferred embodiment of the present invention, means are provided to sweep the drive frequency continuously across an effective resonance. After a period of time, the drive frequency can be stepped to the frequency of a complementary resonance. The drive frequency would then be continuously sweep across this resonance. In a particularly preferred embodiment, the frequency sweep ranges and amplitudes would be stored in the printhead memory.

<u>Industrial Applicability and Advantages</u>

[0023] The present invention is useful in the cleaning of printheads in an ink jet printing system. The system of the present invention, which cleans the printhead by sweeping the stimulation frequency, has the particular advantage of improving the efficiency of the cleaning operation.

[0024] 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 system for cleaning the printhead of a continuous ink jet printing system having a drop generator, the drop generator having a plurality of resonances and further having an associated orifice plate and piezoelectric elements for stimulation of the orifice plate, the system comprising:

    means for applying a stimulation drive frequency to the piezoelectric elements;
    means for flushing fluid through the drop generator; and
    means for varying the stimulation drive frequency to employ more than one of the plurality of resonances of the drop generator for ultrasonic cleaning of the drop generator, so that low amplitude regions of the drop generator produced by driving of one resonance can be cleaned by high vibration amplitudes in those same regions by driving of at least one other complementary resonance.

2. A system as claimed in claim 1 wherein the means for varying the stimulation drive frequency comprises means for continuously sweeping the stimulation drive frequency across a frequency range.

3. A system as claimed in claim 1 wherein the means for varying the stimulation drive frequency comprises means for stepping the stimulation drive frequency from one frequency to another frequency.

4. A system as claimed in claim 1 wherein the means for varying the stimulation drive frequency comprises:

    means for sweeping the stimulation drive frequency across a frequency range; and
    means for stepping the stimulation drive frequency to sweep at least one other range.

5. A system as claimed in claim 1 further comprising a printhead memory for storing frequency sweep ranges and amplitudes.

6. A system for cleaning the printhead of a continuous ink jet printing system having a fluid cavity and a drop generator with associated orifice plate and piezoelectric elements for stimulation of the orifice plate, the system comprising:

    means for identifying complementary resonances in the drop generator;
    applying a stimulation drive frequency to the piezoelectric elements;
    means for varying the stimulation drive frequency to resonant frequencies of the complementary resonances to provide vibrational cleaning to an entire inside surface of the fluid cavity.

7. A system as claimed in claim 6 wherein the means for varying the stimulation drive frequency comprises means for continuously sweeping the stimulation drive frequency across a frequency range.

8. A system as claimed in claim 6 wherein the means

for varying the stimulation drive frequency comprises means for stepping the stimulation drive frequency from one frequency to another frequency.

9. A system for applying optimum cleaning conditions for a printhead of a continuous ink jet printer, the system comprising:

means for applying a stimulation drive frequency to the piezoelectric elements;
means for determining an optimum drive amplitude and frequency range of the stimulation drive frequency for optimum ultrasonic cleaning of a given printhead; and
means for sweeping the optimum cleaning frequency at a constant optimum drive amplitude to improve cleaning of the printhead.

10. A system as claimed in claim 9 further comprising a printhead memory for storing the optimum drive amplitude and upper and lower optimum cleaning frequency limits from the determined optimum frequency range.

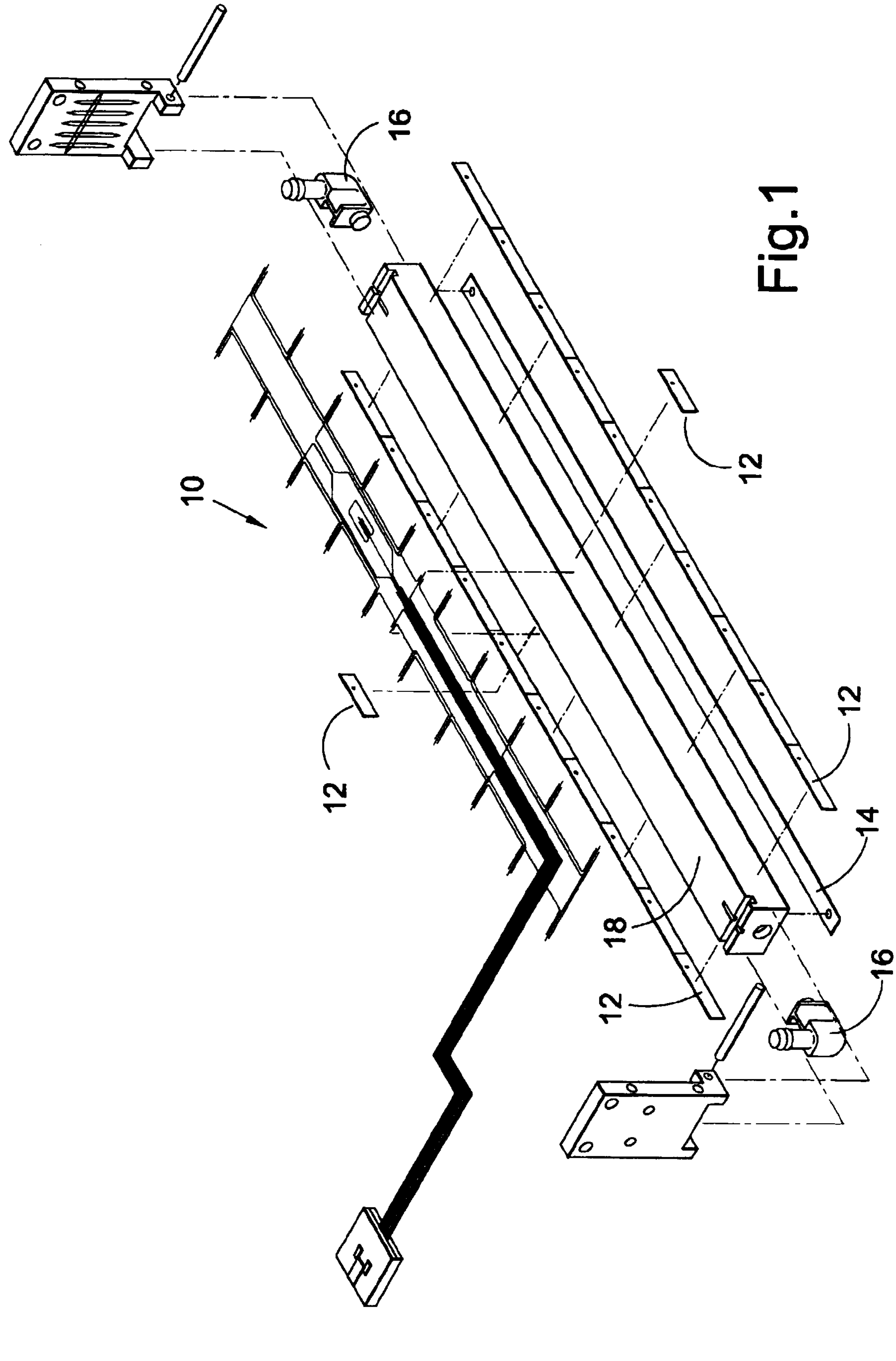

Fig.1

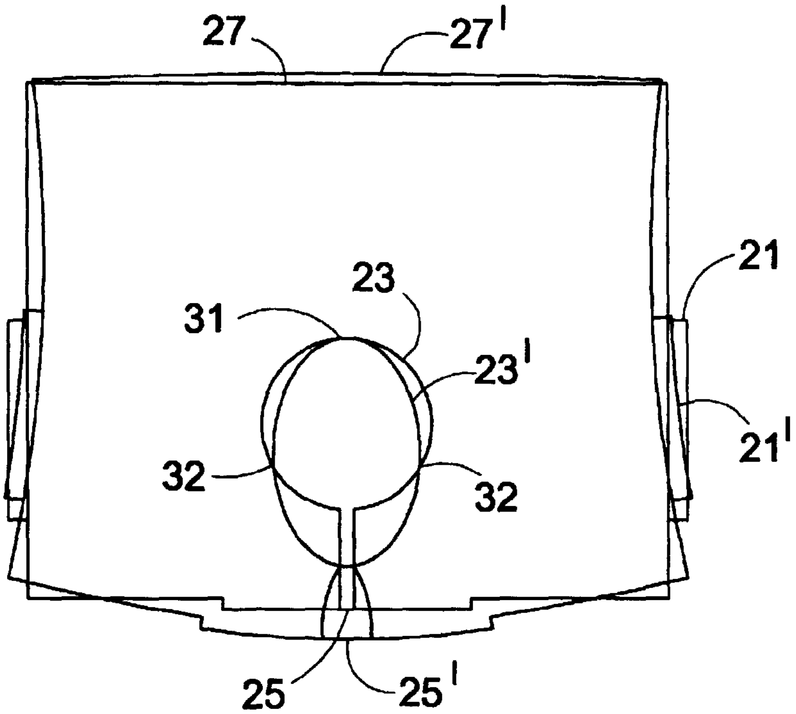

Fig.2

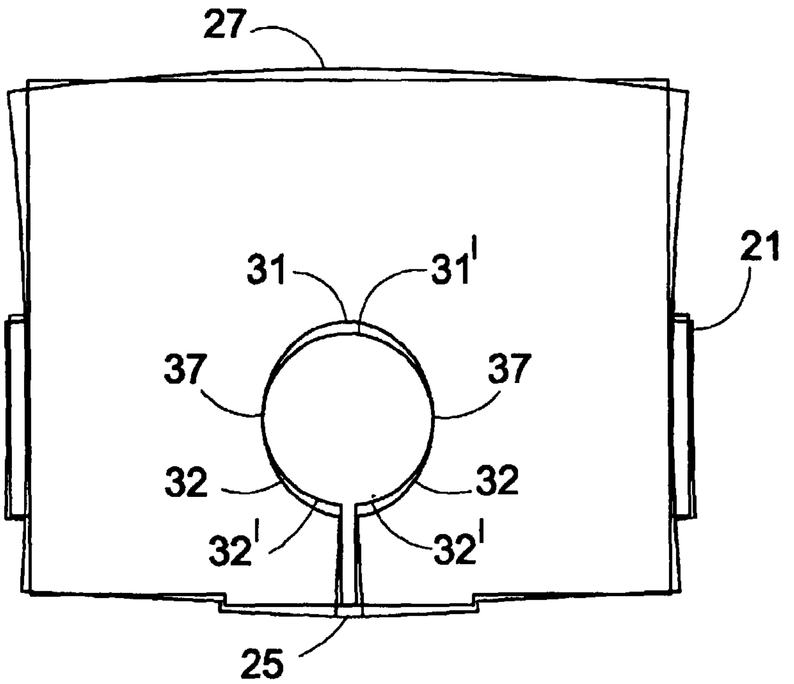

Fig.3

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 00 30 9006

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.7)
D,A	US 4 563 688 A (BRAUN HILARION) 7 January 1986 (1986-01-07) * the whole document *	1,6,9	B41J2/17 B41J2/165
D,A	US 4 600 928 A (BRAUN HILARION ET AL) 15 July 1986 (1986-07-15) * the whole document *	1,6,9	

TECHNICAL FIELDS SEARCHED (Int.Cl.7)
B41J

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	5 February 2001	De Groot, R

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 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 00 30 9006

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

05-02-2001

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 4563688 A	07-01-1986	CA 1220667 A	21-04-1987
		DE 3466769 D	19-11-1987
		EP 0126536 A	28-11-1984
		JP 59212273 A	01-12-1984
US 4600928 A	15-07-1986	CA 1257503 A	18-07-1989
		DE 3673309 D	13-09-1990
		EP 0218686 A	22-04-1987
		JP 6073960 B	21-09-1994
		JP 62500649 T	19-03-1987
		WO 8606025 A	23-10-1986

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82