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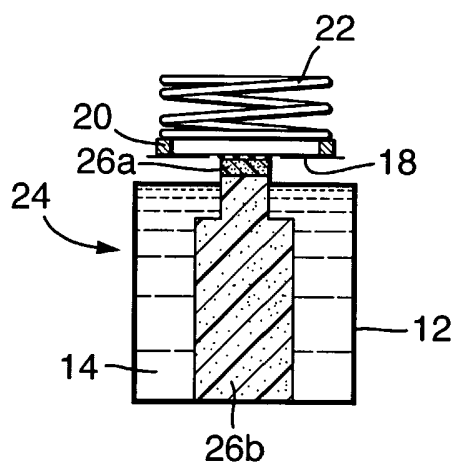
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(54) Title: DROPLET GENERATING DEVICE WITH COMPRESSIBLE WICK



(57) Abstract: A fluid droplet generating device (24) comprises a container (12) for a fluid (14), an electromechanical vibration section (18, 20) incorporating a perforated membrane (18), and a wick (26a/b) for supplying the fluid (14) from the container (12) to the perforated membrane (18), the electromechanical vibration section (18, 20) being operable to form a plurality of droplets of the fluid (14) for dispersal, wherein the wick (26a,b) comprises a lower section (26b) and an upper section (26a), the upper section (26a) being compliant with respect to the lower section (26b).

## DROPLET GENERATING DEVICE WITH COMPRESSIBLE WICK

This invention relates to an electromechanical fluid delivery device, to a method of delivering a fluid electromechanically, and to a container for a fluid delivery device, in particular to a fluid droplet generating device.

Electromechanical devices, such as piezo electric devices for emitting fragrances or for example insect inhibiting fluids are known, for example, in WO 00/5337 or WO 02/09888. Those devices include a fluid reservoir into which projects a wick which transports fluid to a perforated plate. A piezo electric crystal causes vibration of the perforated plate to cause liquid transferred to openings in the plate to be atomised and dispersed into a surrounding atmosphere. It has been found that such prior art devices have disadvantages in that if the wick contacts the perforated plate with too great a pressure then vibration caused by the piezo electric crystal is inhibited causing poor dispersion of the fluid. However, if contact pressure between the wick and the plate is too low, or there is no contact, then insufficient transport of the fluid to the perforated plate results.

A compliant wick has been found to be useful for short-term operation of these devices, because the wick conforms to the shape of the perforated plate and its position, thus ensuring good fluid contact. However, disadvantageously, a compliant wick tends to soften over time when exposed to fluids such as fragrance formulations and takes on a "set" or fixed shape no longer maintaining

contact with the membrane. A compliant wick therefore loses the benefits of a compliant wick over time.

5 A rigid wick does not have the disadvantage of taking on a "set", but the difficulty remains of ensuring that the tip of a rigid wick is aligned with the perforated plate in three dimensions, for repeatable contact.

10 It is an object of the present invention to address the above mentioned disadvantages.

According to a first aspect of the present invention a fluid droplet generating device comprises a container for a fluid, an electromechanical vibration section  
15 incorporating a perforated membrane, and a wick for supplying fluid from the container to the perforated membrane, the electromechanical vibration section being operable to form a plurality of droplets of the fluid for dispersal, wherein the wick comprises a lower section and  
20 an upper section, the upper section being compliant with respect to the lower section.

The lower section is preferably substantially rigid.

25 The upper section is preferably substantially compliant with respect to the perforated membrane, against which the upper section preferably abuts. The upper section preferably assumes a shape of the perforated membrane against which it abuts.

30

The wick preferably extends from a base of the container to the perforated membrane. The wick preferably exerts an upward force on the perforated membrane. The device

preferably incorporates a head section, which preferably incorporates biasing means, preferably operable to exert a downward force on the electromechanical vibration section. Said downward force preferably substantially balances the upward force on the perforated membrane.

The upper section of the wick is preferably narrower than the lower section. The upper section of the wick may have an upper projection. The upper section may incorporate a recess on an upper side thereof, preferably on the side abutting the perforated plate.

The lower section of the wick may be made of a rigid foam, which may be a polyethylene foam, which may be hard sintered polyethylene.

The upper section of the wick may be made of a foam, preferably an open-cell foam. The upper section may be made of thermosetting plastics material, preferably from the amino-plastics group.

The fluid may be a fragrance fluid, or may be an insect inhibiting fluid.

The upper section of the wick may have a compressive stress at 10% strain approximately in the range 1 to 40 kPa, preferably in the range 4 to 20 kPa.

According to a second aspect of the invention, a container for a fluid droplet generating device incorporates a wick for supplying fluid from the container to a dispersal section of a fluid droplet generating device, wherein the wick comprises a lower section and an upper section, the

upper section being compliant with respect to the lower section.

Preferably, the upper section is more compliant than the  
5 lower section.

Preferably, the dispersal section includes an electromechanical vibration section.

10 The invention extends to a method of dispersing a fluid with an electromechanical fluid droplet generating device comprising supplying a fluid to a perforated membrane of an electromechanical vibration section of the device from a container via a wick, which wick comprises an upper  
15 section and a lower section, wherein the upper section is compliant with respect to the lower section.

The invention extends to a bicomponent wick for an electromechanical fluid droplet generating device, the  
20 wick having an upper section that is compliant with respect to a lower section thereof.

The term compliant should also be taken to mean compressible, in that the upper section is compressible  
25 with respect to the lower section.

All of the features described herein may be combined with any of the above aspects, in any combination.

30 For a better understanding of the invention, and to show how embodiments of the same may be carried into effect, reference will now be made, by way of example, to the accompanying diagrammatic drawings in which:

Figure 1 is a schematic side cross-sectional view of a prior art fragrance-containing receptacle having a piezo electric crystal and a perforated plate and a (schematic) dispersing head section;

Figure 2 is a schematic view of a first embodiment of fragrance emitting device having a container, perforated plate, and piezo electric crystal;

Figure 3 is a view of the perforated plate with the piezo electric crystal from above;

Figure 4 is a schematic side view of the perforated plate with the piezo electric crystal;

Figure 5 is a table of results for the device of Figure 1;

Figure 6 is a table of results for the device of Figure 2; and

Figures 7a to 7c show different potential shapes for an upper compliant section of a wick element of the device in Figure 2.

It has been found through experiments that a key factor that effects performance of the prior art fluid droplet generating or fragrance dispersing devices discussed above is the fluid feed contact with the perforated plate. If the wick does not contact the perforated plate then fluid cannot reach the plate and the device does not work. If the wick is pushed too tightly against the perforated

plate then this causes damping of the piezo electric vibrational frequency and a decrease in performance.

In order to achieve improvement on the disadvantages associated with prior art devices a fragrance dispersing device 10 as shown in Figure 1 has been tested. The fragrance dispersing device 10 comprises a container 12 filled with a fragrance fluid 14, which fluid is transported out of the container 12 by a wick 16. The wick 16 contacts a perforated plate 18 which carries an annular piezo electric crystal 20 (see figure 3) and is used to cause the plate 18 to vibrate in the manner well known to persons skilled in the art. A head section 22 is shown schematically in Figure 1. The head section 22 incorporates a power supply to power the piezo electric crystal 20 and a dispersal section to allow emission of atomised fragrance from the perforated plate 18. The head section 22 is typically secured to the lower section consisting of the container 12, fluid 14 and wick 16 by, for example, a bayonet or screw fitting. The lower section consisting of the fluid filled container 12 and wick 16 may be sold as a separate part, as a replacement for a spent container 12 for attachment to a head section 22.

25

In Figure 1 the head section 22 is shown schematically as incorporating a spring bias which bears down on the piezo electric crystal 20 and perforated plate 18. The spring mounted support was used in order to achieve the correct pressure and contact between the perforated plate 18 and the wick 16. The pressure exerted depends on how tightly the head section 22 is screwed on to the lower section.

30

The device 10 shown in Figure 1 uses a wick 16 that is made of a hard sintered polyethylene, in this example manufactured by Porex Technologies GmbH (product code UHMW PE XM-0266). The material is chosen because it has a porosity enabling fluid to be carried by capillary action through the pores of the material from the container 12 up to the perforated plate 18. In this material the pore diameter is approximately 20 microns, density is 0.95 g/cm<sup>3</sup>, bulk density is 0.40 to 0.47 g/cm<sup>3</sup>, flash point is ca. 350°C.

In Figure 5 there are shown results for eleven devices that were manufactured having the structure described above in relation to Figure 1. The x-axis of the chart gives a device number for a particular device tested and the y-axis gives a weight loss in units of grams per day. Thus, a greater value on the y-axis indicates a greater emission of fluid from the device. It can be seen from Figure 5 that there is great variability between the devices, which were all engineered such that they should give the same flow rate. It is believed that the variation seen between the various devices shown in Figure 5 is due to an incorrect contact between the perforated plate 18 and a wick 16, possibly due to an accumulation of tolerances in the manufacture of the devices. This variation illustrates the problems associated with an entirely solid wick 16.

In view of the variability of the flow rates achieved with the device shown in Figure 1 with the results in Figure 5, it was decided to make amendments to the device shown in Figure 1.

Figure 2 shows a device 24 that is similar to that shown in Figure 1 and like reference numerals have been used for like parts. The device in Figure 2 is sold and used in the same way as that in Figure 1. The difference between the device 10 in Figure 1 and the amended device 24 as shown in Figure 2 is the use of a two-part wick 26 comprising a lower section 26b of hard sintered polyethylene, as used in the device described in relation to Figure 1, but with a capping portion 26a of a white melamine foam, sold as basotect or m-foam. The hard sintered polyethylene section 26b is the same as that described in relation to Figure 1. The melamine foam section 26a is a flexible open cell foam made from melamine resin, a thermoset plastic from the amino plastics group. The physical properties are as follows:

| Property                                        | Value Unit              | Test Method       |
|-------------------------------------------------|-------------------------|-------------------|
| Bulk Density                                    | 8-11 kg/m <sup>3</sup>  | EN ISO 845        |
| Compressive stress, 10% strain                  | 4-20 kPa                | DIN 53421         |
| Max. ram force                                  | ≥ 45 N                  | BASF-method       |
| Tensile strength                                | >120 kPa                | DIN 53571         |
| Elongation at break                             | >10%                    | DIN 53571         |
| Compressive strength, 40%                       | 6-20 kPa                | DIN 53577         |
| Thermal conductivity, 10°C/d=50mm               | >0.035 W/mK             | DIN 52612         |
| Compression set 50%/23°C/72h                    | 10-35%                  | DIN 53572         |
| Compression set 50%/70°C/22h                    | 5-30%                   | DIN 53572         |
| Diffusion resistance factor u                   | Approx 1-2              | DIN 52615         |
| Degree of sound absorption,<br>d=50MM/f=2000 Hz | >90%                    | DIN 52215         |
| d=40mm/f=2000 Hz                                | >90%                    | DIN 52212         |
| Length-specific flow resistance                 | 8-20 kNs/m <sup>4</sup> | DIN EN 29053      |
| Long-term service temperature                   | Approx 150°C            |                   |
| Fogging behaviour                               | >90%                    | DIN 75210, Verf A |
|                                                 | <0.5 mg                 | DIN 75210, Verf B |

The melamine foam section 26a has considerably greater compressibility than that of the hard sintered polyethylene section 26b. The use of the compressible upper section 26a has significant advantages in that it  
5 allows a greater take up of any tolerance mis-match when the wick 26a/b contacts the perforated plate 18. Also, excessive pressure from the wick on the perforated plate 18 is removed, because any excess force due to tolerance differences is absorbed by the compression of the melamine  
10 foam section 26a of the wick.

Furthermore, the two-part wick 26 chosen has advantages over a wick made completely of a highly compressible or compliant material, because it avoids the disadvantages of  
15 a fully compliant wick referred to above. In particular, a wick having at least a portion thereof being substantially rigid is easier to place precisely, especially in confined areas, for example positioning the wick in the neck of a refill bottle. This will have particular manufacturing  
20 advantages. The thin compliant layer 26a accommodates mis-alignment between the rigid lower section 26b and the perforated plate 18. The layer 26a, which forms a fluid bridge between the lower rigid wick section 26b and the perforated plate 18, also provides a network of fibres  
25 along which fluid can flow from the rigid lower section 26b to the perforated plate 18.

Furthermore, the provision of the sprung head section 22 described in relation to Figure 1, but also used in the  
30 embodiments shown in Figure 2, provides an effective balance for the upward pressure on the perforated plate 18 from the wick. Thus, any tendency of the wick to push the plate 18 is accordingly balanced by the head section 22.

Figure 6 shows a bar chart of results from a number of devices constructed as shown in Figure 2 and described in relation thereto. As can be seen from the results which  
5 show device number and weight loss, in the same way as Figure 5, the results are significantly improved, with greater consistency of output.

The significant improvement is due to the compliance of  
10 the melamine foam section 26a of the wick. It is also the case that the melamine foam section 26a does not cause excessive damping of the perforated plate 18 due to its compliant nature.

15 The device 24 is driven so that the piezo electric crystal 20 is powered approximately every 50 seconds for a period of approximately 175 milliseconds to achieve an emission of approximately 200 $\mu$ g. The period between the pulsations of the piezo electric crystal 20 causing vibration of the  
20 perforated plate 18 allows fluid 14 to be taken up the wick 26 to fill the perforations in the perforated plate 18, effectively charging the perforated plate 18 for dispersal of the fluid 14. Thus, when vibration of the perforated plate 18 recommences after 50 seconds the  
25 perforations have already been filled with fluid 14 so the fluid can be emitted into the atmosphere in a plume. In this way an emission/filling cycle is performed.

The device 24 described in relation to Figure 2 has  
30 significant advantages over the prior art devices in that there is much greater consistency of flow rate achieved for the devices bearing in mind the manufacturing tolerances readily achievable. Thus, the provision of the

two-part wick 26 provides good longevity due to the hard sintered polyethylene part 26b and good pressure balance on the perforated plate 18 with the melamine foam section 26a.

5

The relative height proportions of the melamine foam section 26a to the harder less compressible section 26b is approximately in the range 10cm: 1cm to 20cm: 1cm. In effect the melamine foam section 26a forms a soft cap to  
10 allow for take up of tolerance differences.

The perforations in the perforated section 18 have a diameter of approximately 5 $\mu$ m. The area of perforations in Figure 3 is approximately 4mm across, giving  
15 approximately 100-200 holes.

Figures 7a 7b and 7c show three different variations on the shape of the section 26a. In Figure 7a the compliant section is a disc, as shown in Figure 2.

20

In Figure 7b the compliant section 26a has an upper narrow drum-shaped section 30 and a lower disc-shaped section 32. It has been found that this shape has advantageous properties in relation to an initial emission of fluid 14  
25 after charging of the compliant section 26a. The disc of Figure 7a occasionally splutters unless the compliant layer 26a is charged, for example by inverting the device.

In Figure 7c, the compliant section 26a has a disc shape  
30 with a central circular incision 34. The upper part in each of the designs in Figures 7a-7c contacts the perforated plate 18 and the lower face contacts the hard sintered part 26b of the wick.

Attention is directed to all papers and documents which are filed concurrently with or previous to this specification in connection with this application and  
5 which are open to public inspection with this specification, and the contents of all such papers and documents are incorporated herein by reference.

All of the features disclosed in this specification  
10 (including any accompanying claims, abstract and drawings), and/or all of the steps of any method or process so disclosed, may be combined in any combination, except combinations where at least some of such features and/or steps are mutually exclusive.

15

Each feature disclosed in this specification (including any accompanying claims, abstract and drawings) may be replaced by alternative features serving the same, equivalent or similar purpose, unless expressly stated  
20 otherwise. Thus, unless expressly stated otherwise, each feature disclosed is one example only of a generic series of equivalent or similar features.

The invention is not restricted to the details of the  
25 foregoing embodiment(s). The invention extends to any novel one, or any novel combination, of the features disclosed in this specification (including any accompanying claims, abstract and drawings), or to any novel one, or any novel combination, of the steps of any  
30 method or process so disclosed.

**Claims**

1. A fluid droplet generating device comprises a container for a fluid, an electromechanical vibration section incorporating a perforated membrane, and a wick for supplying fluid from the container to the perforated membrane, the electromechanical vibration section being operable to form a plurality of droplets of the fluid for dispersal, wherein the wick comprises a lower section and an upper section, the upper section being compliant with respect to the lower section.
2. A fluid droplet generating device as claimed in claim 1, in which, the lower section is substantially rigid.
3. A fluid droplet generating device as claimed in claim 1 or claim 2, in which the upper section is substantially compliant with respect to the perforated membrane, against which the upper section abuts.
4. A fluid droplet generating device as claimed in any preceding claim, in which the wick exerts an upward force on the perforated membrane.
5. A fluid droplet generating device as claimed in any preceding claim, which incorporates a head section incorporating biasing means, operable to exert a downward force on the electromechanical vibration section.
6. A fluid droplet generating device as claimed in claim 5 when dependant on claim 4, in which said downward force substantially balances the upward force on the perforated membrane.

7. A fluid droplet generating device as claimed in any preceding claim, in which the upper section of the wick is narrower than the lower section thereof.

5

8. A fluid droplet generating device as claimed in any preceding claim, in which the upper section of the wick has an upper projection.

10 9. A fluid droplet generating device as claimed in any preceding claim, in which the upper section incorporates a recess on an upper side thereof.

10. A fluid droplet generating device as claimed in any  
15 preceding claim, in which the lower section of the wick is made of a rigid foam.

11. A fluid droplet generating device as claimed in any preceding claim, in which the upper section of the wick is  
20 made of a thermosetting plastics material.

12. A fluid droplet generating device as claimed in any preceding claim, in which the fluid is a fragrance fluid or an insect inhibiting fluid.

25

13. A fluid droplet generating device as claimed in any preceding claim, in which the upper section of the wick has a compressive stress at 10% strain approximately in the range 1 to 40 kPa.

30

14. A container for a fluid droplet generating device incorporates a wick for supplying fluid from the container to a dispersal section of a fluid droplet generating

device, wherein the wick comprises a lower section and an upper section, the upper section being compliant with respect to the lower section.

5 15. A container for a fluid droplet generating device as claimed in claim 14, in which the upper section is more compliant than the lower section.

10 16. A method of dispersing a fluid with an electromechanical fluid droplet generating device comprises supplying a fluid to a perforated membrane of an electromechanical vibration section of the device from a container via a wick, which wick comprises an upper section and a lower section, wherein the upper section is  
15 compliant with respect to the lower section.

17. A bicomponent wick for an electromechanical fluid droplet generating device, the wick having an upper section that is compliant with respect to a lower section  
20 thereof.

18. A fluid droplet generating device substantially as described herein with reference to Figures 2 to 4 and 7 of the accompanying drawings.

25

19. A container for a fluid droplet generating device substantially as described herein with reference to Figures 2 to 4 and 7 of the accompanying drawings.

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Fig.1.

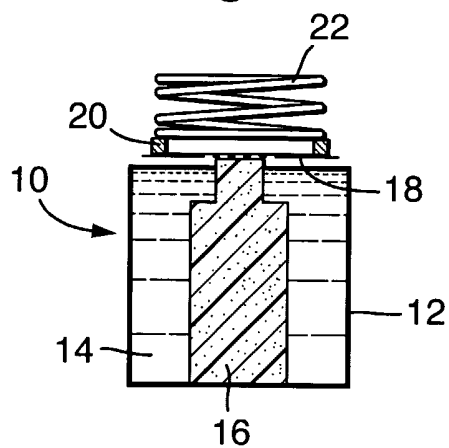


Fig.2.

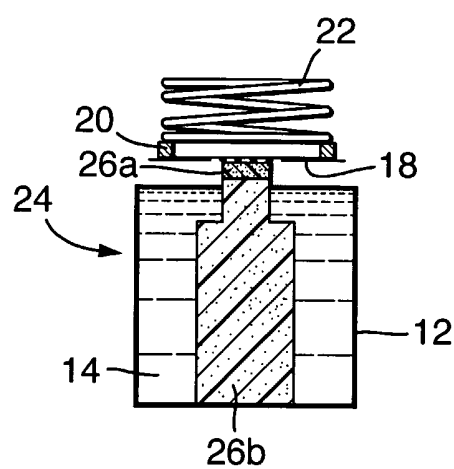


Fig.3.

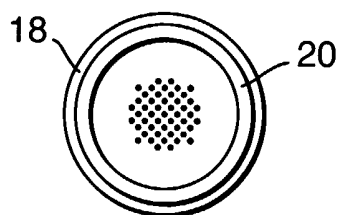
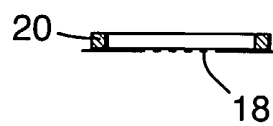


Fig.4.



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Fig.5.

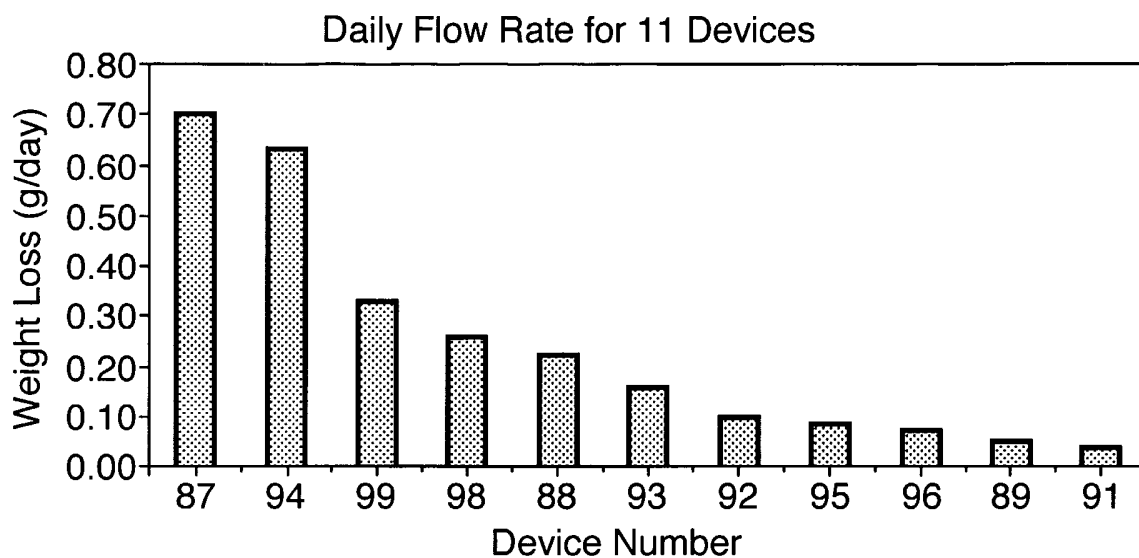
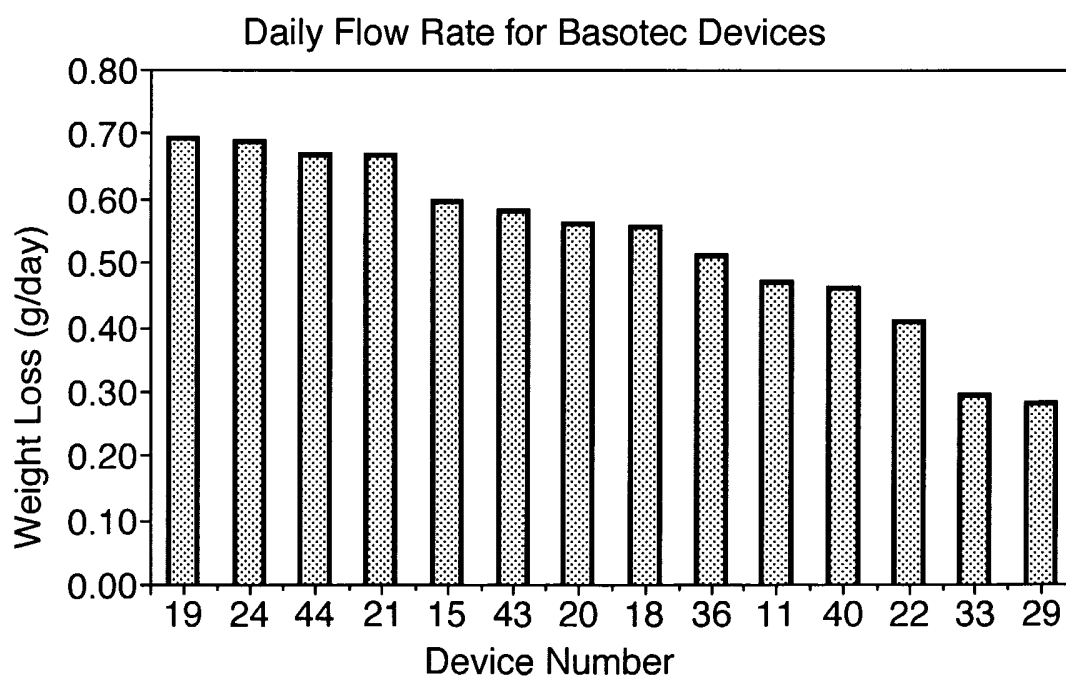


Fig.6.



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Fig.7a.

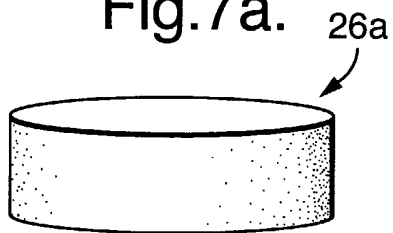


Fig.7b.

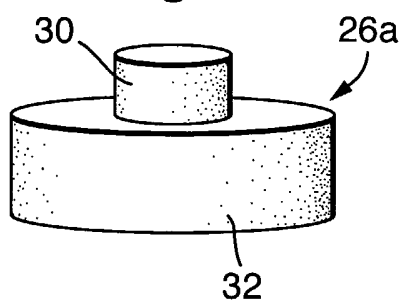
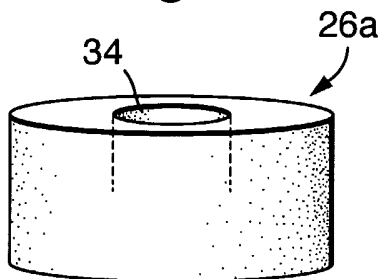


Fig.7c.



# INTERNATIONAL SEARCH REPORT

PCT/GB2005/001340

## A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 B05B17/06

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)

IPC 7 B05B

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 practical, search terms used)

EPO-Internal

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

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| X          | US 2003/000520 A1 (IVRI YEHUDA ET AL)<br>2 January 2003 (2003-01-02)<br>paragraphs '0107! - '0113!; figures 18-22<br>-----  | 1-19                  |
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☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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Date of the actual completion of the international search

21 July 2005

Date of mailing of the international search report

01/08/2005

Name and mailing address of the ISA

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# INTERNATIONAL SEARCH REPORT

PCT/GB2005/001340

| C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT |                                                                                                                                                     |                       |
|------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|
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