US 20080135583A1

(19) United States

(12) Patent Application Publication

Caswell et al.

(10) Pub. No.: US 2008/0135583 A1

(43) Pub. Date: Jun. 12, 2008

(54) LIQUID DISPENSING SYSTEM

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(21) Appl. No.: **11/795,425**

(22) PCT Filed: **Nov. 3, 2005**

(86) PCT No.: **PCT/GB05/04239**

§ 371 (c)(1), (2), (4) Date: **Jul. 13, 2007**

(30) **Foreign Application Priority Data**

Nov. 3, 2004 (GB) 0424313.5

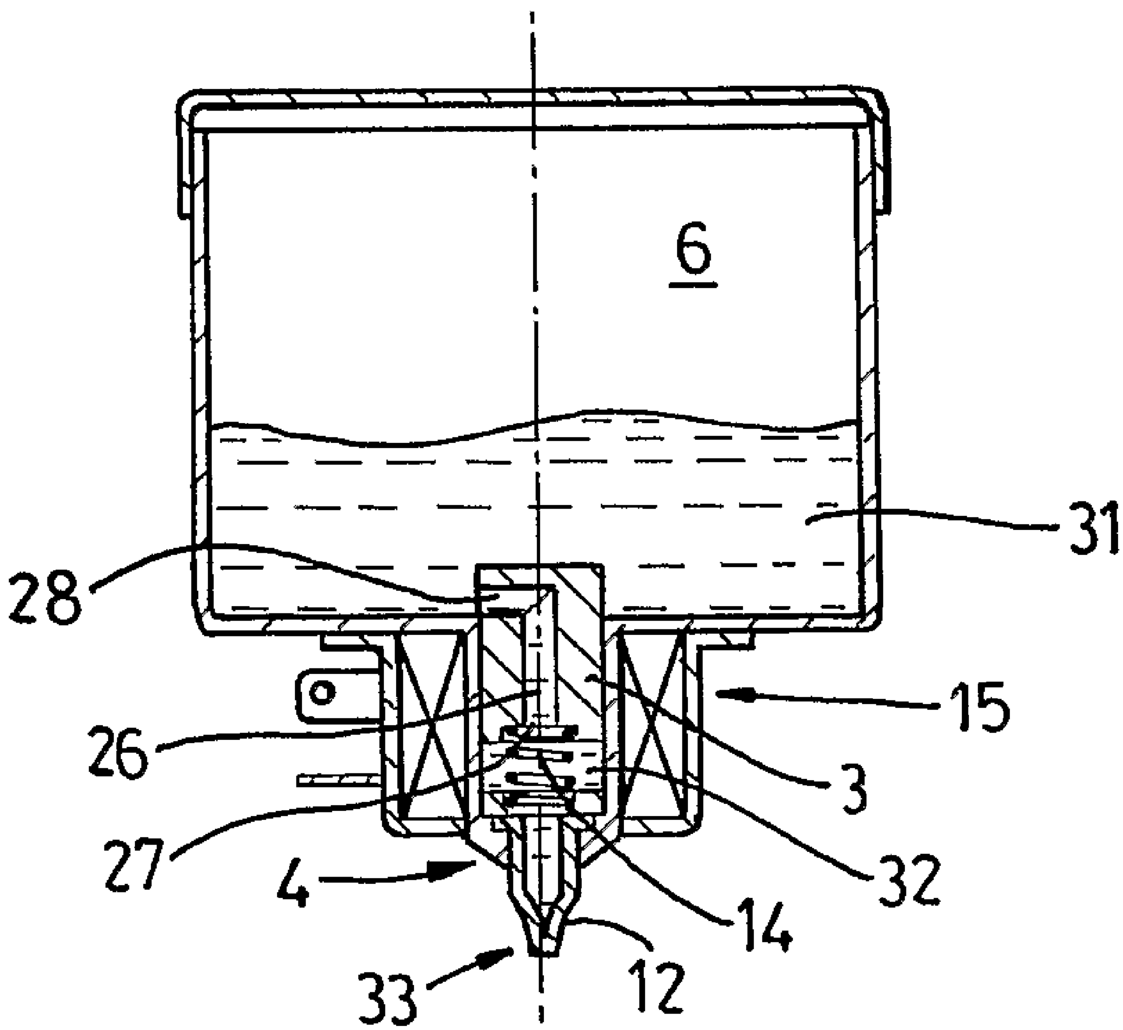
Publication Classification

(51) **Int. Cl.**
B65D 88/54 (2006.01)
B65D 35/38 (2006.01)

(52) **U.S. Cl.** **222/333**; 222/494

(57) **ABSTRACT**

A liquid dispensing system comprises a cartridge (**2**) in which liquid to be dispensed is retained and at least one solenoid assembly. The solenoid assembly comprises a coil (**15**) and an armature (**3**), the armature (**3**) being movably mounted within the cartridge (**2**) and the coil (**15**) being separate from the cartridge (**2**). Movement of the armature (**3**) acts to expel liquid from the cartridge (**2**).



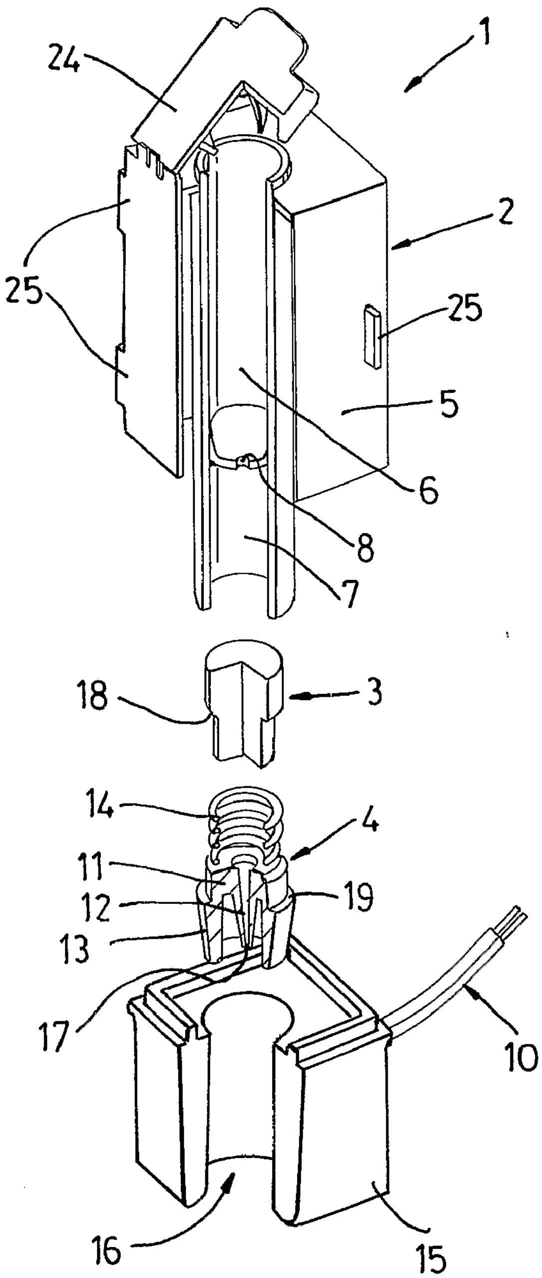


Fig. 1

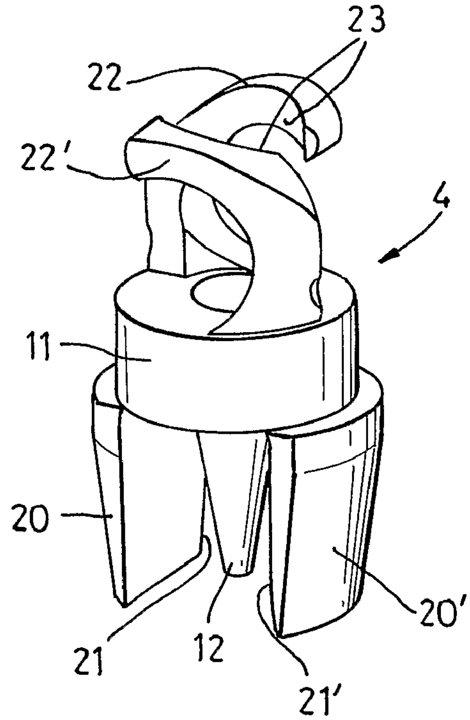


Fig. 2

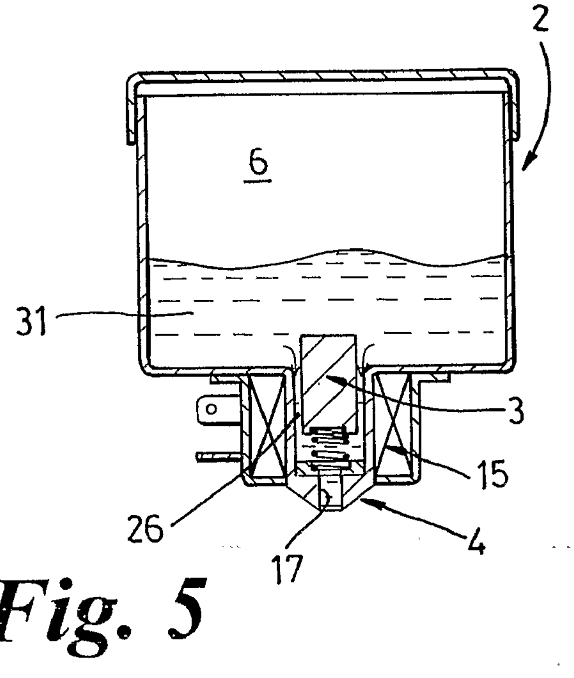


Fig. 5

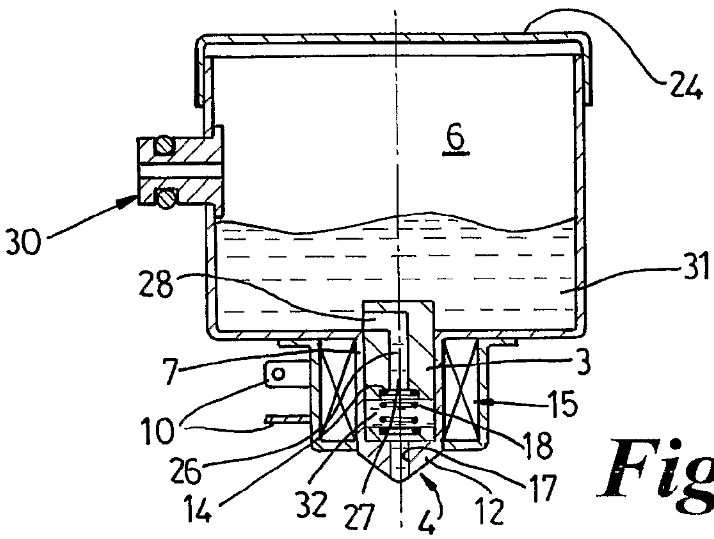


Fig. 3a

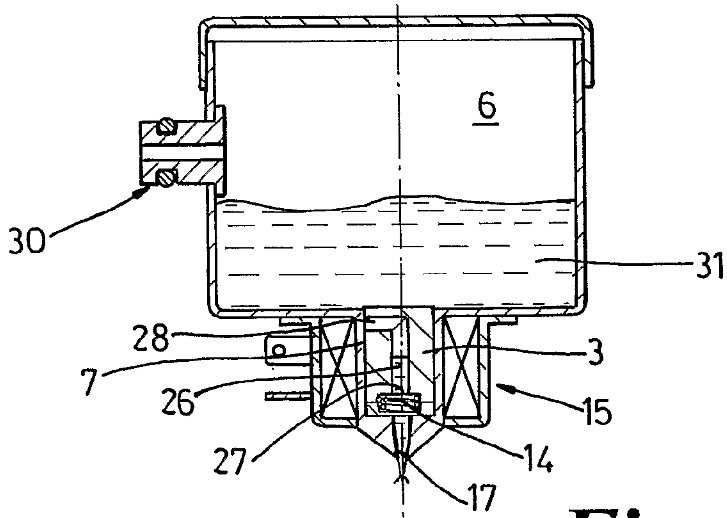


Fig. 3b

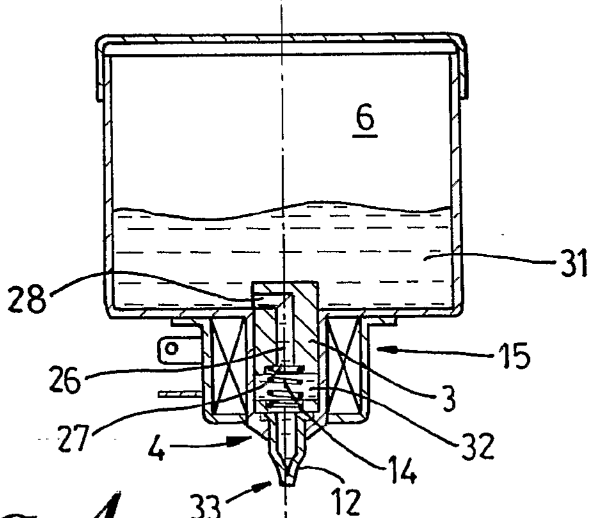


Fig. 4

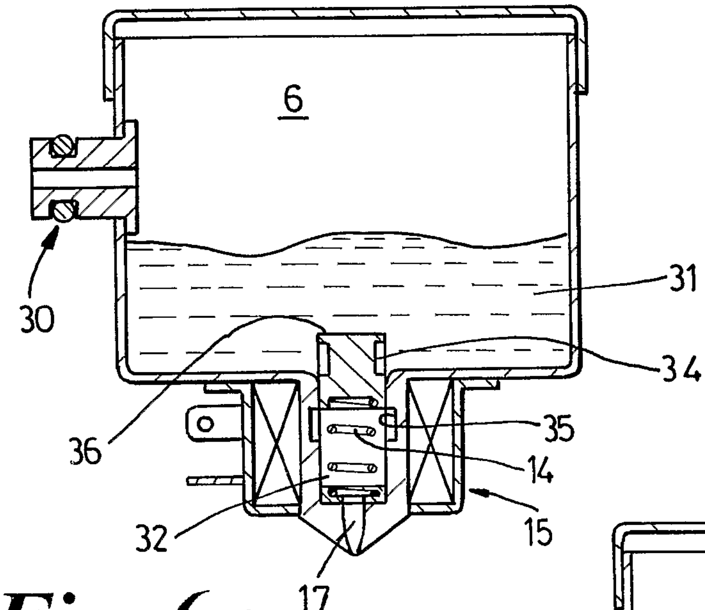


Fig. 6a

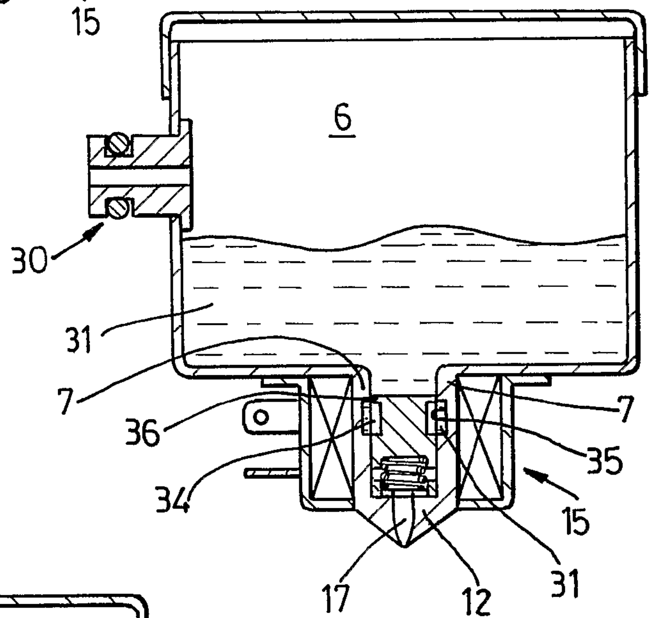


Fig. 6b

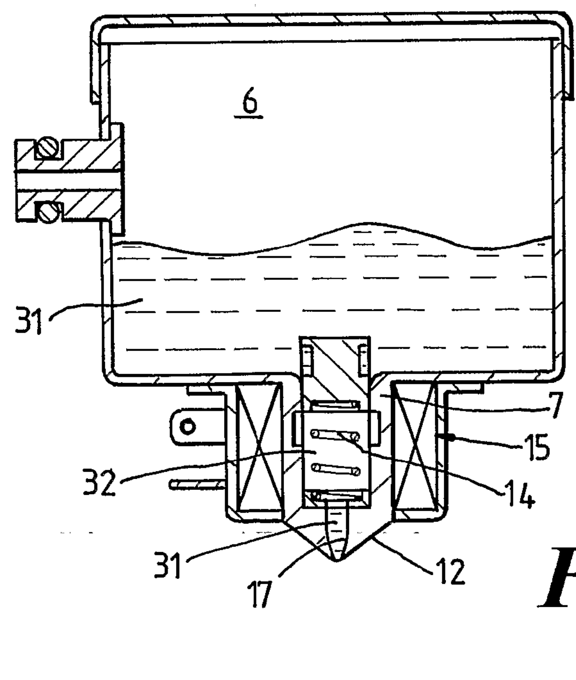


Fig. 6c

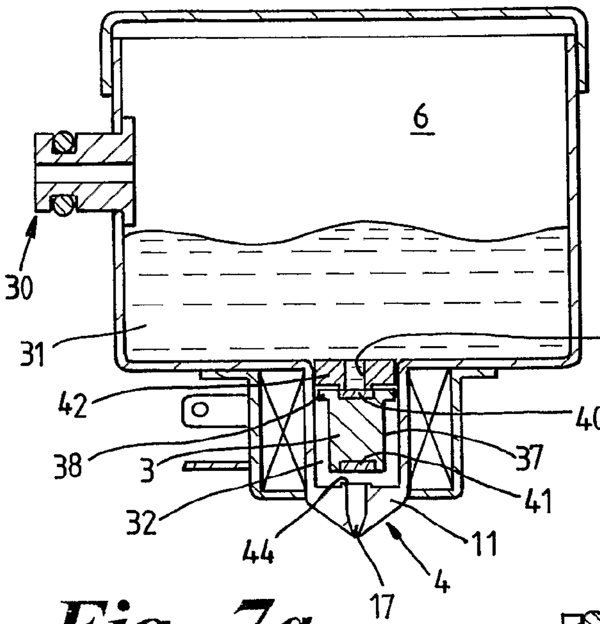


Fig. 7a

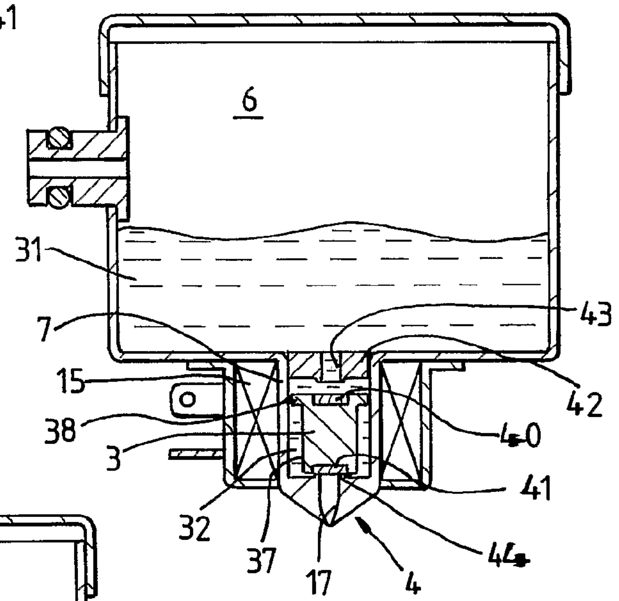


Fig. 7b

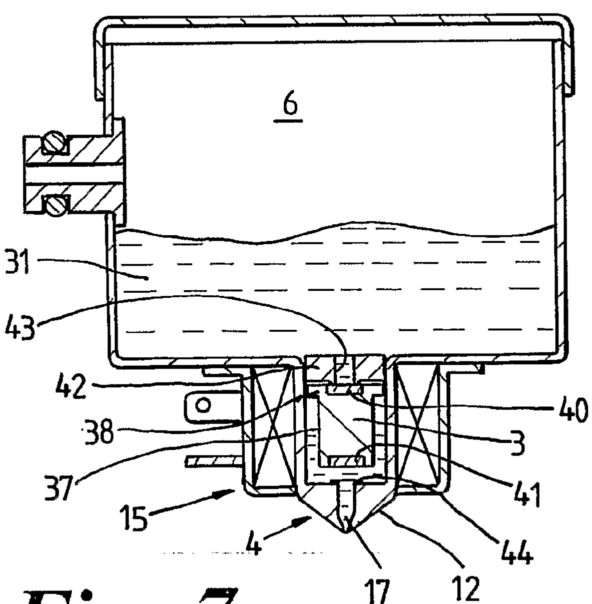


Fig. 7c

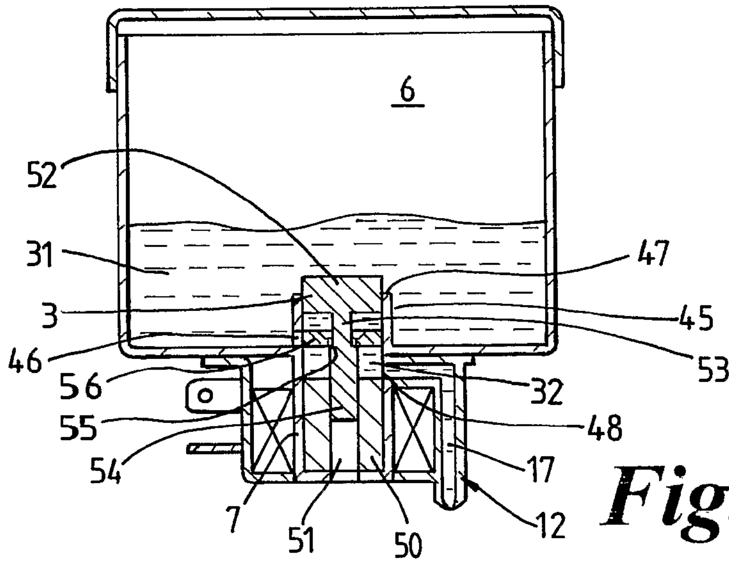


Fig. 8a

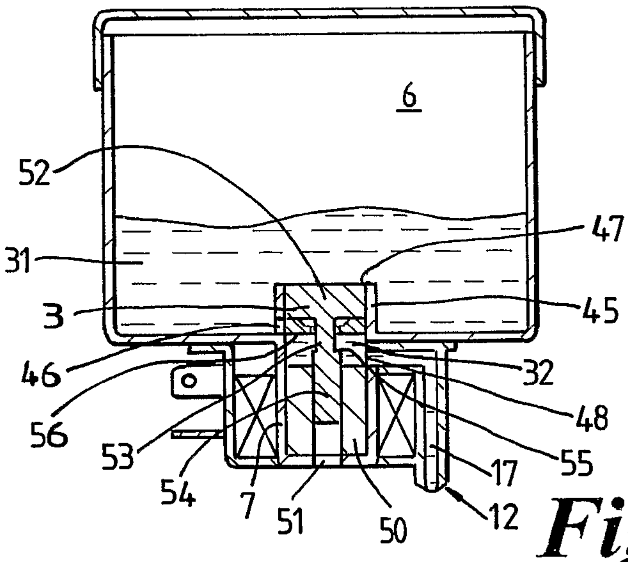


Fig. 8b

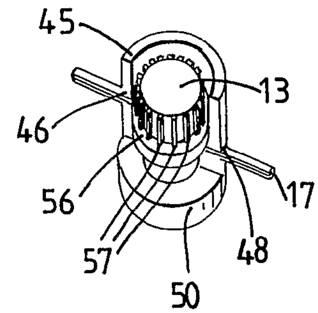


Fig. 9

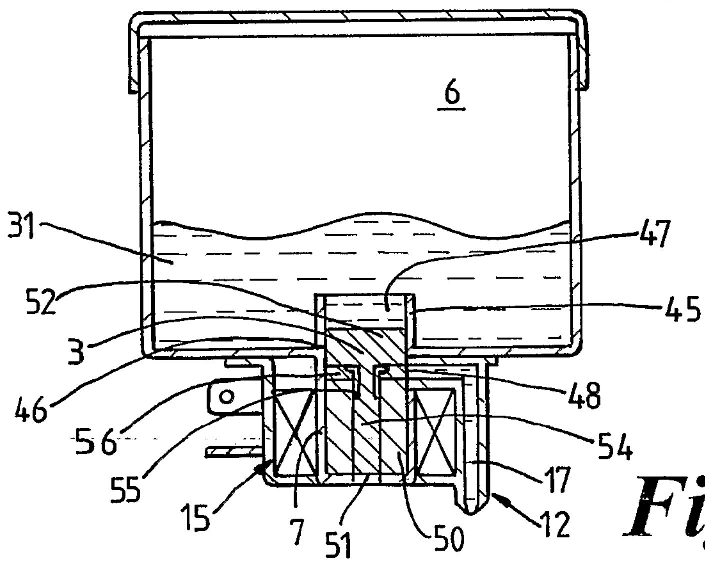


Fig. 8c

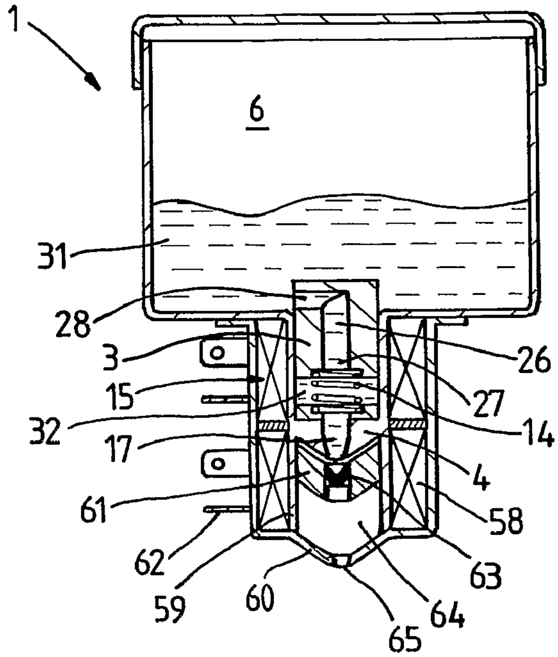


Fig. 10a

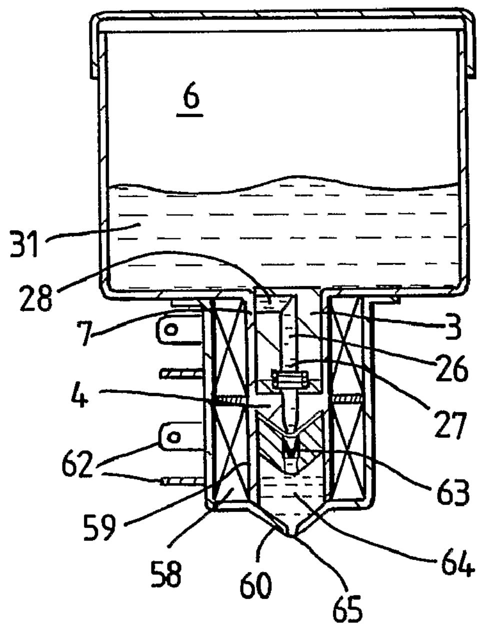


Fig. 10b

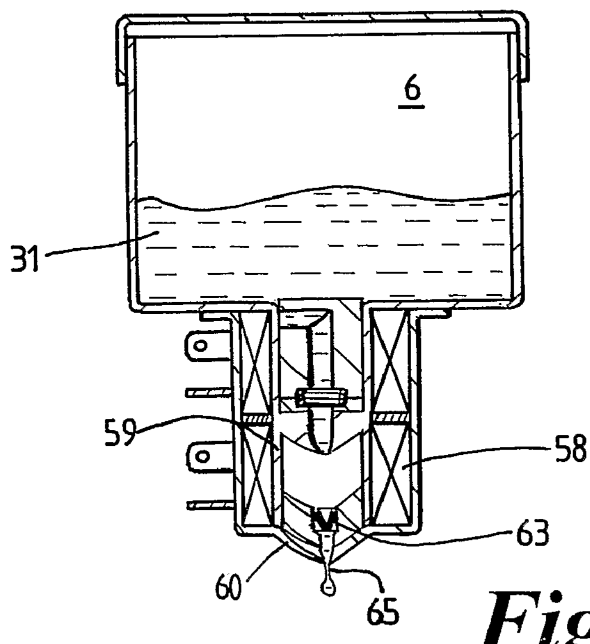


Fig. 10c

LIQUID DISPENSING SYSTEM

[0001] This invention relates to a liquid dispensing system for dispensing sub-millilitre volumes of liquid. Such small volumes are used in laboratory experiments and tests such as in vitro diagnosis of conditions from samples such as blood serum, urine and the like. This invention could also be applied in the field of drink dispensing.

[0002] In vitro diagnosis requires the use of between two and five reagents (most commonly three) stored in a machine and added successively to a prepared sample. The reagents are generally expensive, so that it is advantageous to use as little as possible for each test, particularly in view of the fact that medical staff require an increasing number of tests to be done in order to confirm diagnoses. It is important that the volumes of reagent used are measured accurately, so that the test results are accurate and repeatable. Currently, the amount of reagent used is in the range of 200 to 1000 microlitres, as it is difficult and expensive to make a diagnostic machine which can dispense lesser volumes from a reservoir sufficiently accurately. The liquid is usually dispensed via pipettes or syringes, using systems involving valves and seals, which suffer from hysteresis and so affect accuracy.

[0003] A further problem with dispensing liquids is cross-contamination, which occurs when the reagent touches samples, other reagents or non-sterile surfaces. Drops of liquid tend to be left on the dispenser, and these may be difficult to remove without touching. Obviously, cross-contamination needs to be avoided if the tests are to be accurate and repeatable.

[0004] A further problem with dispensing small volumes of liquid is that, in order to maintain accuracy, it must be ensured that all of the liquid intended to be dispensed is actually expelled from the dispensing device.

[0005] The aim of the invention is to increase the accuracy of dispensing small volumes of liquid (from 2 to 80 microlitres) from a machine, while avoiding cross-contamination, and providing ease of replenishment of the liquids in the machine, such as by the use of disposable cartridges.

[0006] According to a first aspect of the invention, we provide a liquid dispensing system comprising a cartridge in which liquid to be dispensed is retained and at least one solenoid assembly, the solenoid assembly comprising a coil and an armature, the armature being movably mounted within the cartridge and the coil being separate from the cartridge, movement of the armature acting to expel liquid from the cartridge.

[0007] This is advantageous as the coil can be made part of the dispensing apparatus and the cartridge, which contains the armature, can be mounted within the coil. Once the liquid has all been dispensed by movement of the armature, the cartridge can be replaced. Thus, preferably the cartridge is disposable. This reduces the chance of contamination and the cartridge can be constructed in a factory to dispense accurate and consistent volumes of liquid, such as a reagent. The use of the armature movement to actively expel the liquid assists in accurate dispensing.

[0008] Preferably the cartridge, when assembled, comprises the cartridge body, the armature, a return spring for the armature, and a nozzle assembly. The liquid is expelled through the nozzle assembly.

[0009] The armature is biased by the return spring towards a first position, and towards a second position by activation of the coil. Thus, the armature is moved in one direction by activation of the coil, and in the opposite direction by the return spring. The armature conveniently moves axially within the cartridge.

[0010] The arrangement may be such that in the first position the armature closes off flow through the nozzle assembly. This means that the normal position of the armature (that is, with the coil inactive or when the cartridge is not installed in the dispensing system) is to prevent flow from the cartridge. This has the advantage that liquid will not escape in the normal position, so that the cartridge can be filled with liquid, sealed and delivered to the point of use without fear of loss of liquid. It also means that the nozzle assembly is closed off, when the cartridge is installed in the dispensing system, but no liquid is being dispensed.

[0011] Activation of the coil then moves the armature to allow flow through the nozzle assembly, and movement of the armature in response to the return spring actually dispenses the liquid.

[0012] With this arrangement, the spring is normally separate from the cartridge, armature and nozzle assembly.

[0013] Alternatively, the arrangement may be such that in the first position the armature allows flow through the nozzle assembly. Activation of the coil then moves the armature to dispense the liquid, while the return spring simply returns the armature to the first position.

[0014] With this arrangement the return spring may be integrally formed with the nozzle assembly. This is advantageous from a manufacturing point of view, as it reduces the number of components.

[0015] Preferably the armature comprises iron or other magnetic material. The armature can be constructed relatively inexpensively and is thus disposable as the solenoid coil is separate from it. Preferably, the armature slides within the cartridge.

[0016] The cartridge may be disposed within the coil when the cartridge is mounted in the dispensing system.

[0017] Preferably the cartridge has two chambers, of which the first chamber is a reservoir for the liquid and the second chamber retains the armature. Thus, preferably the second chamber is disposed within the coil when the cartridge is mounted in the dispensing system.

[0018] The armature may define a dispensing chamber in the second chamber in which the liquid to be dispensed collects. This is advantageous as a measured quantity of liquid can be transferred to the dispensing chamber from the reservoir before dispensing.

[0019] Preferably the armature has a fluid flow path for transferring fluid from the reservoir to the dispensing chamber. The fluid flow path may comprise a bore through the armature. Alternatively it may comprise an annular groove in its outer surface.

[0020] Preferably axial movement of the armature in one direction dispenses the liquid and in the other direction, pumps liquid from the reservoir into the dispensing chamber.

[0021] The nozzle assembly may also include a one-way valve, such as a "duck-bill" valve. This is advantageous, especially where liquid is dispensed by movement of the armature due to activation of the coil, as no air is also drawn into the dispensing chamber when the armature pumps liquid from the reservoir.

[0022] Preferably the dispensing system includes one solenoid coil. However alternatively it may comprise two solenoid coils. Thus, the cartridge may contain two armatures and two dispensing chambers.

[0023] The reservoir may have a pressure/vacuum source attached thereto. The pressure/vacuum source can be used to control more carefully the amount of fluid dispensed, and, if a vacuum is applied to the reservoir, the hydrostatic pressure of a large head of liquid in the reservoir can be supported.

[0024] Preferably the cartridge includes a lid having a moulded hinge. This allows the liquid in the reservoir to be agitated or refilled as necessary.

[0025] Preferably the nozzle assembly is mounted with the cartridge by interference fit or with adhesive or it may be integrally moulded therewith.

[0026] Preferably the nozzle assembly has a nozzle and a shroud to protect the nozzle from damage or contamination. Further the nozzle or dispensing chamber may have a hydrophobic coating to aid complete expulsion of liquid therefrom. Preferably, they both have a hydrophobic coating.

[0027] Preferably the liquid dispensing system of the invention is adapted to dispense microlitres of liquid.

[0028] There now follows by way of example only a detailed description of the present invention with reference to the accompanying drawings in which;

[0029] FIG. **1** shows an exploded view of the cartridge and solenoid coil according to the invention;

[0030] FIG. **2** shows a modification to the nozzle assembly shown in FIG. **1**;

[0031] FIGS. **3***a* and **3***b* show a first embodiment of the invention;

[0032] FIG. **4** shows a modification to the nozzle of the dispensing system shown in FIGS. **3***a* and **3***b;*

[0033] FIG. **5** shows a second embodiment of the invention;

[0034] FIGS. **6***a*, **6***b* and **6***c* show a third embodiment of the invention;

[0035] FIGS. **7***a*, **7***b* and **7***c* show a fourth embodiment of the invention;

[0036] FIGS. **8***a*, **8***b* and **8***c* show a fifth embodiment of the invention that incorporates a collar section on the armature;

[0037] FIG. **9** is a perspective view of the armature and the collar section of the fifth embodiment; and

[0038] FIGS. **10***a*, **10***b* and **10***c* show a sixth embodiment of the invention that incorporates two solenoid assemblies.

[0039] The liquid dispensing system **1** of FIG. **1** comprises a cartridge **2**, an armature **3** and a nozzle assembly **4**. The cartridge **2** comprises a hollow body **5**, which is divided into a first chamber **6** and a second chamber **7** by a valve seat **8**. The first chamber **6** forms a reservoir which, in use, retains liquid to be dispensed by the system. The second chamber **7** defines an axial armature bore within which the armature **3** can move. The nozzle assembly **4** retains the armature **3** in the bore **7**. The liquid dispensing system **1** also includes a solenoid coil **15** of conventional construction having a bore **16** therethrough. Thus, the solenoid coil **15** and the armature **3** together form a solenoid assembly. The second chamber **7** of the cartridge **2** is, in use, adapted to be mounted within the bore **16**, thereby enabling the magnetic field generated by the coil **15** to move the armature **3**. Movement of the armature **3** causes liquid from the reservoir **6** to be expelled through the nozzle assembly **4**.

[0040] The nozzle assembly **4** comprises a body **11** of a diameter to closely fit within the bore **7**, an elongate nozzle **12**, a shroud **13** and an integrally formed spring member **14**. The elongate nozzle **12** comprises a tapering cylindrical member extending from the body **11**, which has a dispensing bore **17** therethrough. The dispensing bore **17** also extends through the nozzle assembly body **11**. The spring member **14** is helical and is moulded integrally with the body **11**. When the nozzle assembly **4** is mounted within bore **16**, the spring member **14** abuts a shoulder **18** on the armature **3** to bias the armature **3** into a first position in which it is adjacent the reservoir **6**. The shroud **13** is annular and extends from the body **11** concentrically with the nozzle **12**. The annular shroud **13** also extends radially outwards adjacent its junction with the body **11** to define a shoulder **19**. The shoulder **19** is adapted to abut the free end of the second chamber **7** to ensure that the nozzle assembly **4** is appropriately mounted therein. The shroud **13** protects the nozzle **12** from damage. Further, the nozzle **12** may comprise or be coated with a hydrophobic material to aid the expulsion of liquid therefrom.

[0041] A modification to the nozzle assembly **4** is shown in FIG. **2** in which the shroud **13** comprises two arcuate sections **20**, **20'** defining two diametrically opposed slots **21**, **21'**. This allows the shroud **13** to provide protection for the nozzle **12** and is also easier and cheaper to manufacture, as the nozzle assembly can be moulded across the slots **21**, **21'**. FIG. **2** also shows a modification to the spring member **14**. In this modification the spring member **14** comprises two spring sections **22**, **22'**. The spring sections **22**, **22'** first extend in a longitudinal direction from diametrically opposed edges of body **11** and then extend circumferentially. The inwardly facing sides **23** of the spring sections **22**, **22'** are arcuate and define a gap to receive the armature **3**, with the spring sections **22**, **22'** in abutment with the armature shoulder **18**. As can be appreciated, this modification to the spring member **14** results in less linear travel but is easier and cheaper to manufacture.

[0042] The cartridge **2** has a hinged lid **24** that provides access to the reservoir **6**. The lid **24** allows the reservoir **6** of the cartridge **2** to be filled with liquid, such as a reagent for diagnostic testing, and for the liquid to be agitated as necessary. The cartridge **2** also has clips **25** projecting from the body **5** which allow the cartridge **2** to be mounted within dispensing apparatus (not shown), or the like, so that the cartridge **2** can be appropriately positioned with the coil **15**.

[0043] The cartridge **2** may be of plastics and formed integrally with the hinged lid **24** by injection moulding or any other appropriate method. It will be appreciated that the material used for the cartridge will depend upon the liquid that is to be dispensed, to ensure that the cartridge material does not react or degrade in the presence of the liquid. The nozzle assembly **4** may also be formed by injection moulding. The armature **3** or a proportion thereof may be of iron or other magnetic material. Further, the armature **3** may be coated to ensure it does not react or degrade in the presence of the liquid. Advantageously the cartridge **2**, armature **3** and nozzle assembly **3** are simple and inexpensive to manufacture and thus can be disposable.

[0044] FIGS. **3***a* and **3***b* show, in section, a first embodiment of the liquid dispensing system **1** assembled and mounted in the bore **16** of the solenoid coil **15**. Corresponding reference numerals have been applied to corresponding parts. In this embodiment the armature **3** has a fluid flow path **26** that extends axially part way through the armature and then radially. Thus, aperture **27**, formed in the base of the armature **3**, adjacent the nozzle assembly **4**, is connected via the flow path **26** to aperture **28** formed in a circumferential side of the armature **3**, adjacent the reservoir **6**. The armature ledge **18** is located around the periphery of aperture **27** and thus the spring member **14** has a smaller diameter. Further, the reservoir **6** has a port **30** formed in its side wall for applying pressure or a vacuum to the reservoir **6**. The solenoid coil **15** has terminals **10** for connecting it to a control system of the dispensing apparatus (not shown).

[0045] In use, the reservoir **6** is filled with liquid **31** and is sealed by the lid **24**. In FIG. **3***a* the coil **15** is not activated and thus the spring member **14** urges the armature **3** into the first position. In the first position the nozzle assembly **4** and the armature **3** define therebetween a dispensing chamber **32** in the second chamber **7**. Further, in the first position the armature **3** is adapted such that it projects into the reservoir **6** such that aperture **28** is open to the liquid **31**. Thus, the liquid **31** from the reservoir enters aperture **28**, travels through the fluid flow path **26** and out of aperture **27**, and collects in the dispensing chamber **32**. The liquid is prevented from draining from the nozzle **12** due to the surface tension formed at the free end of the dispensing bore **17**. It will be appreciated that the form, and in particular the diameter, of the nozzle **12** is chosen to ensure that the particular liquid **31** being dispensed is able to exhibit sufficient surface tension to be retained in the dispensing chamber **32**. The pressure port **30** may apply a vacuum to the reservoir **6** to allow a larger "head" of liquid in the reservoir **6** to be supported by the surface tension at the dispensing nozzle **12**. Further, the exact location of the armature **3** in the first position and the diameter of the dispensing chamber **32** is chosen so that a precise measured volume of liquid collects in the dispensing chamber **32**, to ensure accurate and repeatable dispensing.

[0046] In FIG. **3***b*, electrical power has been applied to the coil **15** by the dispensing apparatus resulting in a magnetic field, which has drawn the armature **3** into a second position in which it abuts the nozzle assembly **4**. In moving from the first position to the second position the aperture **28** is closed off from the reservoir **6** by the wall of the second chamber **7**. Further, as the armature **3** moves to the second position the volume of the dispensing chamber **32** is reduced which forces a measured quantity of liquid from the dispensing chamber **32** out of the dispensing bore **17**. Thus, movement of the armature from the first position to the second position is an active dispensing stroke in which liquid is actively expelled thereby improving accuracy.

[0047] Once the liquid has been dispensed the electrical power to the solenoid coil **15** is removed and the armature **3** will be urged to return to the first position by the spring member **14**. In moving from the second position to the first position, the volume of the dispensing chamber **32** increases, which leads to a decrease in pressure within chamber **32**. This decrease in pressure effectively pumps liquid **31** from the reservoir **6** into the dispensing chamber **32**, once the aperture **28** is open to the reservoir **6**. This ensures that the dispensing chamber **32** is reliably filled with liquid after each dispensing stroke and operation of the dispensing system does not have to rely solely on gravity to fill the dispensing chamber, which improves reliability. Thus, movement of the armature **3** from the second position to the first position is a pumping stroke. However, it will be appreciated that during the pumping stroke, air will also be drawn in through the dispensing bore **17** and therefore the system will still rely on gravity to an extent to ensure the dispensing chamber **32** is completely filled.

[0048] In a modification (not shown) the pressure/vacuum port **30** is omitted. Instead, the dispensing bore **17** is elongated with a length of capillary tubing, and the spring **14** is constructed so that the force acting on the armature returns it relatively slowly to the first position. The return force needs to be chosen so that the velocity of the armature creates sufficient force to draw in liquid from the reservoir **6** to the dispensing chamber **32**, but not enough to overcome the surface tension at the capillary end of the bore **17**, so that air is not drawn in. The spring force can be altered for different liquids according to their viscosity to achieve this result. Activation of the coil, however, will cause a more rapid movement of the armature, so that the pressure created in the dispensing chamber **32** is sufficient to overcome the surface tension and dispense the liquid.

[0049] FIG. **4** shows a modification to the nozzle assembly **4** of the embodiment shown in FIGS. **3***a* and **3***b*, which also addresses this problem. In FIG. **4**, the pressure/vacuum port **30** is absent and the nozzle **12** incorporates a one-way "duck-bill" style valve **33**. The valve **33** only permits flow out of the dispensing bore **17**. As the dispensing bore **17** is not open to atmosphere, the dispensing system **1** does not rely on surface tension to retain a measured volume in the dispensing chamber **32**. This obviates the need for the pressure/vacuum port **30**. Further, during the pumping stroke, the valve **33** prevents air entering the dispensing chamber **32** through the dispensing bore **17** and therefore the reduction in pressure in the dispensing chamber **32** will solely cause liquid **31** from the reservoir **6** to be drawn into chamber **32**. This improves the accuracy and the repeatability of the dispensing device. In the embodiment of FIGS. **1** to **4** it will be noted that when the coil **15** has no electrical power (i.e., it is inactive) the nozzle **12** is open, so that it may be possible for liquid to leak out. In a further modification (not shown) the armature **3** and spring **14** are arranged so that the spring force biases the armature **3** to the position where it closes off the dispensing bore **17**, and activation of the coil **15** moves the armature **3** away from the bore **17**. The spring **14** is then provided on the opposite end of the armature **3**, as a separate component.

[0050] In operation, activation of the coil **15** moves the armature **3** away from the bore **17** to allow liquid to flow into the dispensing chamber **32** from the reservoir **6**. When the coil **15** is de-activated the armature **3** returns under the force of the spring **14** to dispense the liquid.

[0051] This has the advantage that, as well as preventing leakage when the cartridge is installed in the system, leakage is also prevented before the cartridge is installed. This means that the cartridge can be manufactured, filled with liquid, sealed and delivered to the point of use without fear of loss of liquid.

[0052] FIG. **5** shows a second embodiment of the invention having a modified armature **3**. The remainder of the liquid dispensing system **1** is the same as the first embodiment and corresponding reference numerals have been applied to corresponding parts. The armature **3** of FIG. **5** does not have a machined fluid flow path **26** through the body of the armature **3**. Instead, it is of a lesser diameter than the second chamber **7** such that a flow path is formed between the armature **3** and the walls of the second chamber **7**. As the armature **3** is not machined, this makes it simpler and cheaper to manufacture.

[0053] In use, the liquid dispensing system **1** of this embodiment operates in a similar manner to the previous embodiment in that liquid **31** collects in the dispensing chamber **32** when the armature **3** is in the first position. Similarly, the surface tension of the liquid **31** at the free end of the dispensing bore **17** retains the liquid **31** in the chamber **32**.

Upon activation of the solenoid coil **15**, the armature **3** is driven into the second position by the magnetic force, against the force of the spring member **14**. This dispensing stroke forces the fluid **31** in the dispensing chamber **32** out of the nozzle **12**. It will be appreciated that a certain amount of liquid will also be forced back into the reservoir **6** through flow path **26**. However, the area of the flow path **26** and the size of the dispensing chamber **32** when the armature **3** is in the first position can be chosen so that a precise and repeatable quantity of liquid is expelled from the nozzle **12** during each dispensing stroke. During the pumping stroke, both liquid from the reservoir **6** and atmospheric air through the dispensing bore **17** will be drawn into the dispensing chamber **32**. The chamber **32** is then completely filled with liquid **31** by it flowing under gravity from the reservoir **6**, through the fluid flow path **26**.

[0054] FIGS. **6***a*, **6***b* and **6***c* show a third embodiment that includes a modified armature **3** and second chamber **7**. The armature **3** comprises a cylindrical body having a circumferential groove **34** therein, such that when the armature **3** is in the first position (see FIG. **6***a*), the groove **34** is open to the reservoir **6**. The second chamber **7** also has a groove in its inner wall that forms an intermediate chamber **35**. The intermediate chamber **35** is positioned such that when the armature **3** is in the second position the groove **34** aligns with the chamber **35**. In the second position, liquid **31** is prevented from flowing freely from the reservoir **6** to the intermediate chamber **35** by a radial flange **36** of the armature **3**.

[0055] Upon first use, liquid **31** from the reservoir **6** collects within the groove **34** when the armature **3** is in the first position. Activation of the solenoid coil **15** draws the armature **3** downwards into the second position against the force of the spring member **14**. The liquid that has collected with the groove **34** is drawn downwards with the armature **3**. In the second position, the groove **34** is aligned with the intermediate chamber **35**. Thus, the liquid in the groove **34** flows freely into the intermediate chamber **35** (as shown in FIG. **6***b*). Thus, in this embodiment the pumping stroke, in which liquid **31** is urged from the reservoir **6**, occurs when the armature moves from the first position to the second position. When the solenoid coil **15** is deactivated, the armature returns to the first position under the force of spring member **14**. The liquid **31** transferred to the intermediate chamber **35** is then able to flow from the chamber **35** into the dispensing chamber **32**. As shown in FIG. **6***c*, the majority of the liquid collects in the dispensing bore **17** and the majority of the dispensing chamber **32** is filled with air. The liquid is held in the dispensing bore **17** by surface tension. The liquid is dispensed when the solenoid coil **15** is activated once again and the armature **3** moves to the second position. The resulting pressure from reduction in volume of the dispensing chamber **32** overcomes the surface tension and forces the liquid from the dispensing bore **17**. The air in the dispensing chamber **32** is also forced out of the bore **17**, which helps to ensure that all of the liquid is actively expelled from the dispensing chamber **32** and bore **17**. Thus, movement of the armature **3** from the first position to the second position is also an active dispensing stroke. Although, the first dispense from this embodiment requires two cycles of the armature **3** (i.e. the solenoid coil **15** is activated and deactivated twice), it will be appreciated that liquid is dispensed on every cycle thereafter.

[0056] A fourth embodiment of the invention is shown in FIGS. **7***a*, **7***b* and **7***c*, in which there are modifications to the armature **3**, the second chamber **7** and nozzle assembly **4**. Firstly, the armature **3** comprises a body **37** of smaller diameter than the second chamber **7** and has an annular peripheral flange **38** that extends radially outward to a diameter that approaches the internal diameter of the second chamber **7**. The armature **3** also carries seals **40**, **41** in its top and bottom faces respectively. The second chamber **7** includes an annular elastomeric inlet seal **42** mounted within the second chamber **7**, adjacent the junction with the reservoir **6**. The inlet seal **42** prevents flow between itself and the wall of the second chamber **7** and has an aperture **43**. The seal **42** is comparable to the valve seat **8** shown in FIG. **1**. The nozzle assembly **4** also has an annular elastomeric outlet seal **44** in the nozzle body **11**, which surrounds the proximal end of the dispensing bore **17**. The spring member **14** has been omitted from these Figures for clarity, but would extend from the nozzle assembly body **11** and abut flange **38** of the armature **3**.

[0057] In FIG. **7***a* the armature **3** is shown in the first position, wherein the dispensing chamber **32** is sealed from the reservoir **6** by seal **40** on the armature **3** abutting the inlet seal **42**. On activation of the solenoid coil **15**, the armature **3** moves to the second position. The seal **40** moves away from the inlet seal **40** and into sealing contact with the outlet seal **44** on the nozzle assembly **4**. This movement of the armature **3** acts as a pumping stroke, drawing liquid **31** from the reservoir **6**, past the flange **38** into the dispensing chamber **32** (as shown in FIG. **7***b*). Deactivation of the solenoid coil **15** causes the armature **3** to return to the first position under the force of the spring member (not shown). Thus, seals **41** and **44** are separated, which allows a proportion of the liquid in the dispensing chamber **32** to flow into the dispensing bore **17**. The liquid **31** is retained in the dispensing bore **17** by surface tension (see FIG. **7***c*). When the solenoid coil **15** is activated again and thus the armature **3** moves to the second position, a proportion of the liquid in the dispensing chamber is expelled from the nozzle **12**. As with the previous embodiment, after the first cycle as described above, liquid is dispensed and pumped from the reservoir **6** on the same stroke of the armature **3** from the first to the second position.

[0058] A fifth embodiment is shown in FIGS. **8***a*, **8***b* and **8***c*. In this embodiment the nozzle assembly **4** comprises an elongate nozzle **12** that first extends radially from an aperture **48** in the second chamber **7** and then axially, adjacent the coil **15** (when the second chamber **7** is mounted within the solenoid coil aperture **16**). The second chamber **7** includes an extension portion **45** that extends into the reservoir **6** and has an open end **47** and an inlet aperture **46** in its side wall. The second chamber **7** also includes a hollow guide member **50** having a cylindrical open bore **51**. The armature **3** comprises a head portion **52** having a support section **53** and a guide section **54**, separated by a shoulder **55**, depending axially therefrom. The guide section **54** is received in the bore **51** of the guide member **50** and can axially slide therein. An annular slider member **56** is slidably mounted on the support section **53** of armature **3**. Thus, the slider member **56** can slide between the head portion **52** and shoulder **55**. The slider member **56** has a series of circumferentially spaced axial channels **57** (see FIG. **9**) that allows liquid to flow through the member **56**.

[0059] FIG. **8***a* shows the armature **3** biased into the first position by the spring member (not shown) in which the head **52** extends into the extension portion **45**, adjacent the reservoir **6**. The slider member **56** abuts the shoulder **55** and as such, seals the inlet aperture **46**. Liquid **31** from previous cycles is shown in the dispensing chamber **32** and the dispensing bore **17**. Upon activation of the coil **15** the armature **3** is drawn into the second position where, in this embodiment, the slider member **56** abuts the guide member **50**. This downward movement of the armature **3** is the active dispensing stroke, which reduces the volume of the dispensing chamber **32** and therefore causes liquid **31** to be expelled from the dispensing chamber **32** and bore **17**. As the slider member **56** seals the inlet aperture **46**, movement of the armature **3** can only force liquid out of the dispensing chamber **32** and bore **17** and therefore a precise and reliable volume is dispensed. Before the active dispensing stroke is complete (as shown in FIG. **8***b*) the head **52** abuts the slider member **56** and draws it downward with the armature **3**. In the second position the slider member **56** seals the outlet aperture **48** (as shown in FIG. **8***c*). Thus, when the coil **15** is deactivated and the armature **3** is urged by the spring member (not shown) to return to the first position (the pumping stroke), no air can be drawn in through the dispensing bore **17** and therefore only liquid **31** from reservoir **6** is drawn into the dispensing chamber **32** through aperture **46**. Before the pumping stroke is complete the slider member **56** abuts the shoulder **55** and is drawn upwards with the armature **3** and returns to the position shown in FIG. **8***a* for further cycles.

[0060] A sixth embodiment is shown in FIGS. **10***a*, **10***b* and **10***c*. The construction of the liquid dispensing system **1** in this embodiment is similar to the first embodiment except that the cartridge **2** includes third section **59** which extends within an aperture of a second coil **58** and has a second nozzle **60** and second armature **61** mounted within. The second coil has terminals **62** for connecting it to the control system of the dispensing apparatus (not shown). The second armature **61** has a bore therethrough in which is mounted a one-way valve **63**. The third section **59** defines a second dispensing chamber **64** having a second dispensing bore **65**. Operation of the first armature **3** is the same as described for the first embodiment, except that downward movement of the armature **3** performs a dosing stroke, in which a measured amount of liquid is transferred through the one-way valve **63** of the second armature **61**, into the second dispensing chamber **64** (as shown in FIG. **10***b*). Then, the second coil **58** can be activated to move the second armature **61** through an active dispensing stroke from a first position in which it is adjacent the nozzle **4**, downward to a second position where it abuts the second nozzle **60**. During the active dispensing stroke, the liquid in the second dispensing chamber **64** is expelled from the second dispensing bore **65** (as shown in FIG. **10***c*). The solenoid coils **15** and **58** can then be deactivated so that the first armature **3** returns to the first position under the force of spring member **14** and the second armature returns to its first position under the force of a return spring (not shown). As a measured quantity of liquid **31** is transferred between dispensing chambers **32**, **64** it is isolated from the effect of the hydrostatic pressure in the reservoir **6**. This is advantageous as the volume of liquid to be dispensed is unaffected by the change in hydrostatic pressure as the quantity of fluid in the reservoir decreases. The use of two armatures **3**, **61** and two dispense chambers **32**, **64** also erasures a consistent dispense volume irrespective of the viscosity of the liquid as at no stage does movement of the armature force liquid back into the reservoir **6**. By appropriately sequencing the activation of the solenoid coils **15**, **58** a fast and reliable dispense rate can be achieved.

[0061] It will be appreciated that the pressure/vacuum source may be incorporated in any of the embodiments shown or equally omitted, depending upon the application of the liquid dispensing system and the type of liquid being dispensed. The pressure/vacuum source can be used to allow greater control of the amount of liquid being dispensed. For example, a vacuum can be applied to reduce the pressure in the reservoir **6**, thereby impeding the flow of liquid from the reservoir **6**. Alternatively, pressure could be applied to urge liquid from the reservoir **6**, to promote rapid and complete filling of the dispense chamber **32**, for example. The "duck-bill" valve **33** or any other suitable one-way valve may also be included in any of the embodiments. The armature or nozzle assembly may be coated in or comprise a material suitable for use with the liquid being dispensed which, in particular, may be a hydrophobic material to promote full expulsion from the dispensing chamber **32** and bore **17** on the active dispensing stroke. In all the embodiments, the spring member **14** may be omitted and the armature **3** may be returned to its first position by a reversal of the magnetic field generated by coil **15**.

[0062] It will also be appreciated that the modifications described in relation to FIGS. **3** and **4**, (the choice of the spring force dependent on the viscosity of the liquid to ensure filling of the dispensing chamber without drawing in air, and the reversal of the normal position of the armature) could equally be applied to the embodiments of FIGS. **5** to **10**.

1. A liquid dispensing system comprising a cartridge (**2**) in which liquid to be dispensed is retained and at least one solenoid assembly, the solenoid assembly comprising a coil (**15**) and an armature (**3**), the armature (**3**) being movably mounted within the cartridge (**2**) and the coil (**15**) being separate from the cartridge (**2**), movement of the armature (**3**) acting to expel liquid from the cartridge (**2**).

2. A liquid dispensing system according to claim **1**, in which the cartridge (**2**) is disposable.

3. A liquid dispensing system according to claim **1**, in which the cartridge (**2**), when assembled, comprises a cartridge body (**5**), the armature (**3**), a return spring (**14**) for the armature (**3**) and a nozzle assembly (**4**).

4. A liquid dispensing system according to claim **3**, in which the armature (**3**) is biased by the return spring (**14**) towards a first position, and towards a second position by activation of the coil (**15**).

5. A liquid dispensing system according to claim **1**, in which the armature (**3**) slides within the cartridge (**2**).

6. A liquid dispensing system according to claim **4**, in which in the first position the armature (**3**) closes off flow through the nozzle assembly (**4**).

7. A liquid dispensing system according to claim **6**, in which activation of the coil (**15**) moves the armature (**3**) to allow flow through the nozzle assembly (**4**), and movement of the armature in response to the return spring (**14**) dispenses the liquid.

8. A liquid dispensing system according to claim **3**, in which the return spring (**14**) is a separate component from the cartridge (**2**), armature (**3**) and nozzle assembly (**4**).

9. A liquid dispensing system according to claim **4**, in which in the first position the armature (**3**) allows flow through the nozzle assembly (**4**).

10. A liquid dispensing system according to claim **9**, in which activation of the coil (**15**) moves the armature (**3**) to dispense the liquid.

11. A liquid dispensing system according to claim **3**, in which the return spring (**14**) is formed integrally with the nozzle assembly (**4**).

12. A liquid dispensing system according to claim **1**, in which the armature (**3**) comprises iron or other magnetic material.

13. A liquid dispensing system according to claim **1**, in which the cartridge (**2**) is disposed within the coil (**15**) when the cartridge (**2**) is mounted in the dispensing system (**1**).

14. A liquid dispensing system according to claim **1**, in which the cartridge (**2**) has two chambers, of which the first chamber (**6**) is a reservoir for the liquid and the second chamber (**7**) retains the armature (**3**).

15. A liquid dispensing system according to claim **14**, in which the second chamber (**7**) is disposed within the coil (**15**) when the cartridge (**2**) is mounted in the dispensing system (**1**).

16. A liquid dispensing system according to claim **14**, in which the armature (**3**) defines a dispensing chamber (**32**) in the second chamber (**7**) in which the liquid to be dispensed collects.

17. A liquid dispensing system according to claim **16**, in which the armature (**3**) has a fluid flow path (**26**) for transferring fluid from the reservoir (**6**) to the dispensing chamber (**32**).

18. A liquid dispensing system according to claim **17**, in which the fluid flow path (**26**) comprises a bore through the armature (**3**).

19. A liquid dispensing system according to claim **17**, in which the fluid flow path (**26**) comprises an annular groove in the outer surface of the armature (**3**).

20. A liquid dispensing system according to claim **16**, in which axial movement of the armature (**3**) in one direction dispenses the liquid and in the other direction, pumps liquid from the reservoir (**6**) into dispensing chamber (**32**).

21. A liquid dispensing system according to claim **3**, in which the nozzle assembly (**4**) includes a one-way valve.

22. A liquid dispensing system according to claim **21**, in which the one-way valve is a “duck-bill” valve (**33**).

23. A liquid dispensing system according to claim **1**, in which the dispensing system (**1**) includes one solenoid coil (**15**).

24. A liquid dispensing system according to claim **1**, in which the dispensing system (**1**) includes two solenoid coils (**15**, **58**).

25. A liquid dispensing system according to claim **24**, in which the cartridge (**2**) contains two armatures (**3**, **61**) and two dispensing chambers (**32**, **64**).

26. A liquid dispensing system according to claim **14**, in which reservoir (**6**) has a pressure/vacuum source (**30**) attached thereto.

27. A liquid dispensing system according to claim **1**, in which the cartridge (**2**) includes a lid (**24**) having a moulded hinge.

28. A liquid dispensing system according to claim **3**, in which the nozzle assembly (**4**) is mounted with the cartridge (**2**) by interference fit.

29. A liquid dispensing system according to claim **3**, in which the nozzle assembly (**4**) is mounted with the cartridge (**2**) with adhesive.

30. A liquid dispensing system according to claim **3**, in which the nozzle assembly (**4**) is integrally moulded with the cartridge (**2**).

31. A liquid dispensing system according to claim **3**, in which the nozzle assembly (**4**) has a nozzle (**12**) and a shroud (**13**).

32. A liquid dispensing system according to claim **31**, in which the nozzle (**12**) has a hydrophobic coating to aid complete expulsion of liquid therefrom.

33. A liquid dispensing system according to claim **16**, in which dispensing chamber (**32**) has a hydrophobic coating to aid complete expulsion of liquid therefrom.

34. A liquid dispensing system according to claim **1**, adapted to dispense quantities of liquid in the order of microlitres.

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