A pump dispenser (20) has a pump arrangement for mounting to a reservoir (not shown) for holding a liquid to be dispensed. The pump arrangement includes a liquid pump chamber (43) for pumping liquid from the reservoir, an air pump chamber (50) for pumping air and a common actuator (21) to simultaneously actuate the liquid pump and the air pump. An outlet fluid passageway arrangement (31, 33, 34, 35, and 52) fluidly connects the liquid pump chamber and the air pump chamber with an outlet (36). The dispenser has an outlet valve arrangement (26, 26, 53) for controlling release of liquid from the liquid pump chamber and air from the air pump chamber during a dispensing cycle. The dispenser is configured such that the ratio of air to liquid dispensed varies over the course of each dispensing cycle. Preferably, the ratio of air to liquid is lower during a main dispensing phase, when the pressure of the liquid is at its highest, than during at least one of an initial phase and an end phase during which the pressure of the liquid is lower than during the main phase.
Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).
Manual Pump Type Fluid Dispenser

The present invention relates to a manually actuated pump type fluid dispenser.

Manual pump type fluid dispensers are often used in mass market applications, such as food, perfume, body spray, anti perspirant/deodorant, lotions, pharmaceuticals, soaps, insecticide, paint, and oils etc, to deliver a liquid in the form of a spray, a foam or a bolus of liquid.

In most known spray dispensers, the liquid is broken up into small droplets or atomised by forcing the fluid through a very fine outlet orifice or nozzle under pressure. The size of the droplets produced is a function of the size of the orifice, the pressure of the liquid at the orifice and the properties of the liquid. In most applications, the size of the orifice and the properties of the liquid remain substantially constant during the dispensing cycle so that variations in the pressure of the liquid at the orifice will result in variations in the average droplet size, with a reduction in the pressure leading to an increase in the average droplet size. Ideally, a dispenser should produce a spray in which the average droplet size remains substantially constant throughout the dispensing cycle. However, in the known pump dispensers, the pressure of the liquid at the outlet orifice varies throughout the dispensing cycle leading to a corresponding variation in the average droplet size. The beginning and end of the dispensing cycle are the most problematic with known pump dispensers, as the pressure of the fluid at the spray orifice is at its lowest during these phases.

An example of one known type pump dispenser 1 is shown in Figure 1, which is a vertical cross sectional view through the dispenser. The dispenser 1 shown is of a type often referred to as a "cylindrical dispenser" due to the cylindrical nature pump arrangement. The cylindrical dispenser 1 has an actuator 2, a piston 3, a body 4, a turret collar 5, a closure 6, a seal valve 7, an inlet ball valve 8, and a spray insert 9. The closure 6, is adapted to be mounted to the outlet neck region of a container (not shown) for the liquid product to be dispensed by means of a screw thread or other twist fit connection (not shown). The body 4 is located in closure 6 by means of the
turret collar 5, which also acts as a seal between the closure and the container. The piston 3 is in the form of a hollow tube closed at its lower end. The piston 3 is slidably mounted in the body 4 of the pump through the turret collar 5 and projects through an opening in the upper end of the body for connection with the actuator 2. The actuator 2 has an outlet passage 10 in fluid connection with the interior of the piston and which leads to a final dispenser outlet formed by the spray insert 9.

The seal valve 7 is mounted about a lower end of the piston adjacent a ledge 11 and engages the wall of the body to define a pump chamber 12 in the body below the seal. Openings 13 through the piston fluidly connect the chamber 12 with the interior of the piston. A first upper spring 14 is located about the piston and biases the seal valve into contact with the piston ledge 11, where the seal valve closes the openings 13. A second, lower spring 15 contacts the lower surface of the ledge to bias the piston 3, and hence the actuator 2, upwardly and acts as a return spring. The valve seal 7 is configured to be moved upwardly against the bias of the upper spring to open a flow path from the pump chamber through the openings 13 when the pressure of the liquid in the pump chamber 12 is at or above a first threshold amount above ambient. Typically the first threshold amount is in the range of 0.2 to 1 MPa (2 to 10 bars) with 0.3 to 0.6 MPa (3 to 6 bars) being common (all pressures are quoted above ambient).

A lower end of the body is formed into a hollow spigot 16 to which a dip tube (not shown) can be attached to allow liquid to be drawn into the pump chamber from deep within the container. The one-way ball valve 8 is located at the upper end of the spigot 16 to act as an inlet valve to the pump chamber 12.

In operation, a user applies a force to depress the actuator 2 and the piston 3. Initially, because the liquid in the chamber 12 is relatively incompressible, there is little downward movement of the piston 3, seal valve 7 and actuator 2 but the pressure of the liquid in the pump chamber 12 is increased, which forces the ball valve 8 onto its seat closing the inlet to the pump chamber. As the pressure of the liquid in the pump chamber rises, the seal valve 7 is moved upwardly relative to the piston against the bias of the upper spring 14. Once the pressure reaches the first threshold level, the seal valve 7 is moved sufficiently to open a flow path from the pump chamber 12 into the piston and from there to the dispenser outlet. Continued downward pressure on the
actuator 2 causes the actuator and piston 2 to be moved downwardly forcing the liquid in the pump chamber through the openings 13, along the piston 3 and the outlet passage to be dispensed.

Dispensing continues until the piston 3 reaches its lowermost position, at which time the pressure of the liquid in the pump chamber 12 falls below the threshold value and the seal valve 7 closes the openings 13. When the user releases the actuator 2, the return spring 15 biases the piston 3 and the actuator 2 upwardly back to the start position as shown in Figure 1, with the upper spring 14 holding the seal valve 7 on the ledge so that the openings 13 remain closed. As the piston is moved upwardly, the volume of the pump chamber is increased which, because the openings 13 are sealed, results in a reduction of the pressure in the pump chamber 12 below ambient opening the inlet valve 8 and drawing a fresh charge of liquid into the pump chamber.

During an initial phase of the dispensing cycle, the piston 3 and outlet passage 10 are substantially empty of liquid product and the air inside is at ambient pressure. A small residue of liquid product may be present in the piston and outlet passage but this will also be at ambient pressure. When the seal valve 7 opens, the pressurised liquid enters the piston and flows towards the dispenser outlet, pushing the air and any residue liquid already present inside the piston towards the outlet passage of the actuator and out through the outlet orifice. As the liquid starts to flow, the pressure of the liquid in the piston and outlet passage increases from ambient until it stabilises at a peak value just above the first threshold value (the nominal working pressure), where it remains for the bulk of the dispensing cycle. During an end phase of the dispensing cycle once the actuator has been fully depressed, the pressure of the liquid in the pump chamber 12, the piston 3 and the outlet passage 10 falls back from the nominal working pressure to ambient, with the seal valve 7 closing once the pressure falls below the first threshold value. Once the seal valve 7 has closed, the pressure of the liquid in the piston and the outlet passage falls off rapidly but some flow through the outlet orifice may continue.

In known cylinder pump dispensers, the entire pump discharge time is usually in the range of 0.2 to 0.8 seconds with 0.3 seconds being common. The initial
dispensing phase during which the pressure of the liquid in the piston and outlet passage is increasing may be in the region of 0.07 seconds, whilst the end phase in which the pressure of liquid falls back to ambient may be in the region of 0.05 seconds.

During the initial and end phases of the dispensing cycle, the pressure of the liquid at the spray orifice is lower than the peak operating pressure during the main phase of the dispensing cycle leading to a significant increase in the droplet size at these times, which in turn increases the average droplet size over the whole dispensing cycle. The angle and form of the spray are also adversely affected by the lower pressure and some products may jet at these times rather than forming a spray. During the end phase, the liquid product may dribble through the outlet orifice if there is insufficient energy in the system to eject all the liquid. This is a particular problem as it is unattractive to end users and can result in blocking of the spray orifice as the remaining liquid may dry out leaving a residue which builds up over time to block the outlet orifice. This problem is exacerbated if particulates are present in the liquid or the orifice is very small. In addition, many products can go off once exposed to the air so that any liquid remaining in the outlet passage and orifice may contaminate the fresh product when the dispenser is next actuated. This is potentially a serious problem where pharmaceutical and food products are concerned.

Other known types of manual pump dispenser exhibit similar variations in the pressure of the liquid at the spray orifice over the dispensing cycle.

One solution to the above problems is to use an air dispenser including an air pump chamber to introduce pressurised air into the liquid so that the two flow through the system together when the dispenser is actuated. Mixing air with the liquid is known to improve atomisation of the liquid and the flow of air can be used to maintain the rate of flow of liquid through the outlet orifice even when the pressure of the liquid is below optimum at the beginning and end phases of the dispensing cycle. Occasionally, air pump dispensers will be designed so that the air starts to flow through the system before the liquid exits the liquid pump chamber and continues to flow after the outlet valve of the liquid pump chamber has closed. This is beneficial as the early flow of air helps to draw the liquid through the system and out of spray
orifice, whilst the continuing flow of air at the end of the cycle pushes any remaining liquid out, reducing spluttering and dribbling.

Known air pump dispensers have a second pump chamber in which air is compressed when the actuator is depressed, the outlet of the second chamber being connected with liquid flow path to the outlet. The ratio of air to liquid delivered by the known air pumps is typically in the range of 10:1 to 20:1. The known air pumps are arranged so that the pressure of the air exiting the air chamber and the pressure of the liquid exiting the liquid pump chamber are matched as the product is dispensed. This is necessary so that the air and the liquid can be merged. The need to deliver relatively large volumes of air and to match the pressure of the air and the liquid means that air pumps tend to be larger, more complex and so more expensive to manufacture than equivalent conventional pumps with no air chamber. They also require much greater actuation forces.

The additional manufacturing costs, size and actuation forces associated with air pumps means that they have not made significant inroads in mass market applications, despite producing far superior sprays. A further barrier to market for air pumps is the high cost of tooling and assembly equipment required to introduce any new dispenser pump, which restricts to amount of new devices coming onto the market, irrespective of the nature of the device.

Manual pump dispensers are also known which dispense a fluid product, usually a liquid or gel product, in the form of a foam. Current foam dispensers also have an air chamber and tend to mix air and the fluid product at low pressures, in the region of 0.05 MPa to 0.3 MPa (0.5 to 3 bars) but with high ratios of air to liquid. A ratio of air to liquid in the range of 10:1 to 20:1 is typical. Due to the high volume of air required to produce these ratios, the dispensers tend to be large. Often the whole, or a significant part, of the dispenser is located within the neck of a bottle containing the fluid product. Accordingly, the bottle neck must be sufficiently large to contain the dispenser. Furthermore the combination of bottle and dispenser is often too heavy and prone to toppling over.
There is a need therefore for an improved manual pump dispenser that
overcomes or at least mitigates the problems of the known manual fluid and air pump
dispensers.

There is also a need for an improved manual pump dispenser that can be
brought to market without incurring prohibitive tooling and assembly equipment
costs.

In accordance with a first aspect of the invention, there is provided a pump
dispenser comprising a pump arrangement for mounting to a reservoir for holding a
liquid to be dispensed, said pump arrangement comprising a liquid pump chamber for
pumping liquid from said reservoir, an air pump chamber for pumping air and a
common actuation part to simultaneously actuate the liquid pump and the air pump,
the dispenser having an outlet fluid passageway arrangement for fluidly connecting
the liquid pump chamber and the air pump chamber with an outlet, the dispenser
further comprising an outlet valve arrangement for controlling release of liquid from
the liquid pump chamber and air from the air pump chamber during a dispensing
cycle, in the which the dispenser is configured such that the ratio of air to liquid
dispensed varies over the course of each dispensing cycle.

The dispenser may be configured such that in use during each dispensing
cycle, air begins to flow through the outlet passageway arrangement before liquid is
released from the liquid pump chamber. Alternatively or in addition, the dispenser
may be configured such that in use during each dispensing cycle, air continues to flow
through the outlet passageway arrangement for a limited amount of time after all the
liquid has been dispelled from the outlet passageway.

In use, the dispenser may have a dispensing cycle comprising an initial phase
during which the pressure of the liquid flowing through the outlet fluid passageway
arrangement increases up to a nominal working pressure, a main phase during which
the pressure of the liquid flowing through the outlet fluid passageway arrangement
remains substantially constant at the nominal working pressure and an end phase
during which the pressure of the liquid flowing through the outlet fluid passageway
arrangement falls back from the nominal working pressure, in which case the
dispenser may be configured such that the ratio of air to liquid dispensed during the
main phase is lower than in at least one of the end phase and the initial phase. In one embodiment, the dispenser is configured such that no air is dispensed from the air pump chamber during the main phase. The dispenser may be configured to dispense air from the air chamber only during one of the end phase or the initial phase.

The dispenser may be configured to deliver an overall ratio of air to liquid in the range of 4:1 to 12:1, and more particularly in the range 6:1 to 8:1, over each full dispensing cycle.

The dispenser may be configured so that in use during each actuation, the air in the air chamber is raised to a peak pressure which is less than the peak pressure achieved by the liquid in the liquid pump. The dispenser may be configured such that the liquid in the liquid pump chamber is raised to a peak pressure in the range of 0.3 to 1 MPa (3 to 10 bar), and more particularly in the range of 0.4 to 0.6 MPa (4 to 6 bar), and the air in the air pump chamber is raised to a peak pressure in the range of 0.05 to 0.6 MPa (0.5 to 6 bar).

The outlet valve arrangement may comprise a first outlet valve arrangement for controlling the flow of liquid from the liquid pump chamber to the outlet, and a second outlet valve arrangement for controlling the flow of air from the air chamber to the outlet, in which the first outlet valve arrangement comprises a pre-compression valve configured to open to allow liquid to flow from the liquid pump chamber to the outlet only when the liquid is at or above a first threshold pressure above ambient and the second outlet valve arrangement comprises a one-way valve configured to permit air to flow from the air chamber towards the outlet but to prevent the flow of fluid in the opposite direction. The first outlet valve arrangement may include a pre-compression valve located adjacent an outlet orifice of the dispenser. The first outlet valve arrangement may also include a further pre-compression outlet valve located proximal to the liquid pump chamber. The second outlet valve arrangement may include a pre-compression valve configured to permit air to flow from the air chamber to the outlet only when the air in the air chamber is at or above a second threshold pressure above ambient. The second threshold pressure may be lower than the first threshold pressure.
In one embodiment, the dispenser has a base and a dispensing cap having an outlet mounted to the base, the dispenser further comprising an insert mountable between the base and the cap to define the liquid and air pump chambers between itself and the cap, the insert being adapted to engage with the base to define an inlet through which a fluid can be drawn into the pump chamber from a fluid source, in which the insert comprises a central core and a resiliently flexible upper diaphragm member projecting upwardly and generally radially outwardly from the core for contact with the cap to at least partially define the pump chambers within the cap, the insert being deformable between an initial resiliently biased configuration in which the volume of the pump chambers is at a maximum and a deformed configuration in which the volume of the pump chambers is at a minimum, in the deformed configuration, the upper diaphragm being at least partially folded down about itself and/or the core.

In an alternative embodiment the pump dispenser comprises a mounting member for mounting the dispenser to the reservoir about an opening, a generally cylindrical pump body located within the mounting member for projection into the reservoir and a turret for positioning the body within the mounting member, the dispenser further having a piston movably mounted within the body, a fluid seal member operative between the piston and inner surface of the body to define a fluid pump chamber within the body and an actuator mounted to, or operatively connected with the piston, and means for defining an air pump chamber within the actuator or between the actuator and the fluid pump assembly.

The pump dispenser may have a trigger actuator.

The pump dispenser may be configured to dispense a liquid as a spray. The pump dispenser may be configured to dispense a continuous spray of liquid for a period of between 2 to 10 seconds on each actuation.

The pump dispenser may have two liquid chambers and may be configured to simultaneously dispense two different liquids from two liquid sources.

Several embodiments of the invention will now be described with reference to the remaining drawings, in which:
Figure 2 is a longitudinal cross sectional view through a first embodiment of a manual pump dispenser in accordance with the invention;

Figure 3 is a longitudinal cross sectional view through a second embodiment of a manual pump dispenser in accordance with the invention;

Figure 4 is a cross sectional view through an actuator cap assembly forming part of the dispenser of Figure 3;

Figure 5 is a longitudinal cross sectional view through a third embodiment of a manual pump dispenser in accordance with the invention;

Figure 6 is a longitudinal cross sectional view through a fourth embodiment of a manual pump dispenser in accordance with the invention;

Figure 7 is a longitudinal cross sectional view through a fifth embodiment of a manual pump dispenser in accordance with the invention;

Figures 8 and 9 are longitudinal cross sectional views through a sixth embodiment of a manual pump dispenser in accordance with the invention, showing the dispenser in an initial start condition prior to actuation and in mid-actuation with the actuator fully depressed respectively;

Figure 10 is a longitudinal cross sectional view through a seventh embodiment of a manual pump dispenser in accordance with the invention;

Figure 11 is a cross sectional view through an alternative actuator for use with a dispenser as shown in Figures 7 to 10;

Figures 12a and 12b are longitudinal cross-sectional views taken at 90° to one another through part of a dispenser in accordance with the invention illustrating an alternative outlet valve arrangement for the air pump chamber;

Figures 13a and 13b are longitudinal and lateral cross sectional views respectively through a modified filter plug suitable for use in a dispenser in accordance with the invention;

Figures 14a and 14b are longitudinal and lateral cross sectional views respectively through a further modified filter plug suitable for use in a dispenser in accordance with the invention;
Figure 15a is a longitudinal cross sectional view through an outlet arrangement for a dispenser in accordance with the invention adapted to produce foam;

Figure 15b is a lateral cross sectional view through an end wall of the outlet arrangement of Figure 15a taken on line X-X;

Figure 16 is a longitudinal cross sectional view through a further embodiment of an outlet arrangement for a dispenser in accordance with the invention adapted to produce foam;

Figure 17 is a longitudinal cross sectional view through a yet further embodiment of an outlet arrangement for a dispenser in accordance with the invention adapted to produce foam;

Figure 18a is a longitudinal cross sectional view through a flood jet arrangement for use in an outlet passage of a dispenser in accordance with the invention;

Figure 18b is an end view of the flood jet arrangement of Figure 18a, taken in the direction of arrow Y;

Figures 19a and 19b are cross sectional views through part of the outlet region of a dispenser in accordance the invention showing an alternative pre-compression outlet valve arrangement in an open and a closed condition respectively;

Figure 20 is a cross sectional view showing a further embodiment of a dispenser in accordance with the invention including a trigger actuator;

Figure 21 is a cross sectional view through part of the dispenser of Figure 20 taken on line Z-Z;

Figure 22 is a view similar to that of Figure 20 but showing the dispenser in mid-actuation with an insert full deformed; and

Figure 23 is a cross sectional view showing a further embodiment of a dispenser in accordance with the invention.

Figure 2 shows a first embodiment of a manual pump dispenser 20 in accordance with the invention. The dispenser 20 is a modified cylindrical pump dispenser of the type described above in the introductory portion. Accordingly, the
dispenser 20 comprises an actuator 21, a piston 22, a body 23, a turret collar 24, a closure 25, a seal valve 26, an inlet ball valve 27, and a spray insert 28.

The actuator 21 is generally cylindrical in shape with a closed upper end 29, an outer tubular wall portion 30, and an inner tubular wall portion 31. The inner tubular wall 31 is shorter than the outer wall 30 and is dimensioned to receive an upper end of the piston 22 in a conventional manner.

An outlet for the dispenser is formed in the actuator 21 by means of a generally horizontal (as shown) tube extending between the inner and outer tubular walls 31, 30. The tube defines a cylindrical passage 32 that is in fluid communication with a bore 33 in the piston and a further bore defined within the inner tubular wall 31 by means of an orifice 34 through the inner tubular wall 31 and which opens though the outer tubular wall 30. The spray insert 28 is a close fit in the cylindrical passage 32 and defines an inner chamber 35 in fluid communication with the orifice 34. A constricted orifice 36 is formed in an end wall of the insert through which fluid can exit the chamber 35. In the present embodiment, the constricted orifice 36 is a spray nozzle which breaks up the liquid passing through it into droplets to form a fine mist or atomised spray. The spray orifice 36 opens into a conical recess in the outer face of the end wall of the insert and forms a final outlet for the dispenser. The chamber 35 may be shaped so as to promote swirling of the liquid about the axis of the final outlet orifice 36. Alternatively, a swirl chamber may be provided by means of a projection on the actuator, which engages in the spray insert. This swirl arrangement is described in detail below in relation to the embodiment shown in Figures 3 and 4. The shape of the final outlet orifice 36 can be varied as desired to promote atomisation and to produce a desired spray pattern as is known in the art and there may be more than one final outlet orifice.

The term "constricted orifice" in this context refers to an orifice having a cross sectional area which is smaller than the cross sectional area of the liquid flow passage immediately upstream of the orifice. Where the dispenser is a spray dispenser, the orifice will be a spray nozzle that is configured so that liquid forced through it under pressure is broken up into droplets to form a fine mist or atomised spray as noted above. In embodiments in which the dispenser is adapted to dispense a foam or
mousse, as will be described later, the constricted orifice 36 may be a spray orifice or it may be configured to produce a jet or a sheet of liquid.

The closure 25 has a main body portion 38, which is adapted to be mounted to the outlet of a container (typically a bottle) for the liquid to be dispensed by means of a screw thread or other arrangement (not shown) in a known manner. Usually, the closure 25 is mounted to a neck region of the container but this is not necessarily the case. A pair of spaced annular flanges 39, 40 project upwardly (as shown) from the main body portion 38 towards the actuator 21, with an annular recess 41 being defined between the inner and outer flanges. The outer flange 39 is longer than the inner flange 40 and is dimensioned so that the outer tubular wall 30 of the actuator is a fairly close sliding fit inside the outer flange 39. When the actuator is depressed, the outer wall 30 of the actuator is received in the recess 41 between the two flanges 39, 40. This arrangement prevents the actuator from wobbling during actuation of the dispenser.

The inner flange 40 defines an opening through which the piston 22 and body 23 project into the fluid container (not shown). The turret collar 24 is mounted to an upper end of the body 23 and serves to locate the body within the opening defined by the inner flange 40 and to slidably support the piston 22 within the body 23 in a known manner. The turret collar has an inner flange portion 42, which is clamped between the closure 25 and the container to form a seal in use.

The piston 22 is generally cylindrical in shape and has a central bore 33 which is open at the upper end into the interior of the inner tubular wall 31 of the actuator 21, and closed at the lower or inner end. The seal valve 26 locates about a lower end region of the piston and forms a seal between the piston 22 and the inner surface of a reduced diameter portion 23a of the body to define a liquid pump chamber 43 within the body below the seal. One or more openings 44 in a side wall region of the piston fluidly connect the interior bore 33 with the liquid pump chamber 43 to define an outlet for the pump chamber. The openings 44 are formed in a reduced diameter end region 22a of the piston and open into a groove 45 in the outer surface of the body.

The seal valve includes an inner flap 46 which resiliently engages with the surface of the piston over the groove to form an outlet control valve for the pump chamber 43.
When the actuator is depressed the pressure of the liquid in the chamber 43 rises and causes the piston 22 to move downwardly relative to the seal valve until the flap 46 is moved off the groove to open a flow path from the pump chamber 43 through the opening(s) 44. The valve is configured so that the flow path opens when the pressure of the liquid in the pump chamber reaches a first threshold value above ambient, as will be described in more detail later.

Although not shown in Figure 2, a combined return and valve control spring is located in the body 22 in engagement with the seal valve 26 in a similar manner to the spring 85 in the embodiment shown in Figures 8 and 9. A detailed description of the construction and operation of the spring 85 is set out below in relation to the sixth embodiment to which the reader should refer.

A spigot 48 on the lower end of the body is dimensioned to receive a dip tube (not shown) through which liquid can be drawn into the liquid pump chamber 43 from deep within the container in the usual way. A ball valve 27 in the body acts as a one-way valve to admit liquid into the pump chamber 43 through the dip tube when the pressure in the chamber falls below ambient but is pressed into engagement with a valve seat 49 when the dispenser is actuated to close off the inlet to the pump chamber.

In addition to the liquid pump chamber 43, the dispenser 20 incorporates an air pump chamber 50 from which air can be mixed with the liquid during the dispensing cycle.

The turret collar 24 is integrally formed with a frusto-conical seal member or flange 51 that engages the inner surface of the outer tubular wall 30 of the actuator so as to define the air pump chamber 50 within the interior of the actuator 21. The chamber 50 surrounds a region of the piston 22 which is exposed within the actuator. An opening 52 is formed in the wall of the piston within the actuator to fluidly connect the air pump chamber 50 with the inner bore 33 of the piston and a tubular valve member 53 is located within the bore 33 adjacent the opening to act as a one-way valve for admitting air into the bore 33 during the end phase of the dispensing cycle whilst preventing liquid in the bore from exiting through the opening 52.
The tubular valve member 53 locates in an enlarged diameter region 54 of the bore 33 and sits on a shoulder 55 formed at the junction between a larger diameter portion 54 of the bore and a main smaller diameter portion 56. At least the part of the tubular valve that is positioned adjacent the opening 52 is resiliently deformable so that in an initial resiliently biased configuration it engages the inner surface of the piston to close the opening 52. The tubular valve member is configured so that it can be deformed inwardly to allow air to pass through the opening 52 to enter the bore 33 when the pressure of the air in the air chamber 50 is greater than the pressure inside the valve member by a second threshold amount. The second threshold pressure at which the air chamber outlet valve opens being lower than the first threshold pressure at which the seal valve 26 opens to release liquid from the liquid chamber 43. The tubular valve member 53 therefore acts as a pre-compression valve to ensure that air is only expelled from the air chamber once it reaches a desired pressure above the pressure inside the valve member. A groove can be provided in the inner surface of the piston leading upwardly from the opening 52 along which the air can flow when the tubular valve member is deformed.

Operation of the dispenser 20 will now be described, for the purposes of which it is assumed that the pump chamber 43 is primed with a liquid product and the air chamber 50 is full of air. In this embodiment, the seal valve 26 is configured to open when the pressure of the liquid in the liquid pump chambers reaches 0.3 MPa (3 bar) above ambient and the tubular valve is set to open at a threshold pressure of 0.05 MPa (0.5 bar) above the internal pressure inside the tubular valve. The pump discharge time is 0.4 seconds. It will be appreciated, however, that the invention is not limited to the specific values used in this embodiment, which are exemplary only.

When a user applies a force to depress the actuator 21, the pressure of the liquid in the liquid chamber 43 is increased. Depending on the amount of free play in the system, the pressure of the air in the air chamber 50 may also be raised slightly.

After approximately 0.005 seconds, the liquid in the liquid chamber 43 reaches the 0.3 MPa (3 bar) first threshold amount above ambient and the seal valve 26 opens so that liquid starts to flow through the piston bore 33 and the tubular valve member 53. As this liquid begins to flow, the piston 22 and seal valve 26 are able to move
downwardly in the body and the actuator 21 moves closer to the closure 25. This reduces the volume of the air chamber 50 and so raising the pressure of the air which impinges on the tubular valve member 53 through the opening 52. However, the pressure of the liquid in the bore 33 and the tubular member 53 rapidly rises pushing the valve into contact with the wall of the piston closing off the air hole 52. In the present embodiment, this takes place at approximately 0.07 seconds into the dispensing cycle.

The liquid continues to flow through the piston bore 33 and through the outlet orifice 36 in the manner of a conventional cylindrical pump until the liquid chamber 43 is empty or nearly empty at which point the pressure of the liquid flowing through the bore 33 and the tubular valve member 53 rapidly drops, with the valve seal 26 closing once the pressure of the liquid in the liquid chamber 43 falls below the first threshold amount. Meanwhile, the pressure of the air in the air chamber 50 has continued to increase as the actuator 21 is depressed, reducing the volume of the air chamber 50. At approximately 0.3 seconds into the dispensing cycle, the pressure of the liquid in the tubular valve member falls below the pressure of the air in the air chamber 50 by the second threshold amount. The tubular valve member 53 is deformed inwardly, admitting pressurised air from the air chamber 50 through the air hole 52 into the bore 33 where it mixes with the liquid and the mixture flows to the outlet orifice 36. The dispenser 20 is configured so that pressurised air from the air chamber 50 continues to flow into the bore 33 and through the outlet orifice after all of the liquid has been cleared from the bore 33 to drive out any remaining liquid in the system between the bore 33 and the outlet orifice 36. Once the pressure in the air chamber 50 falls to less than the second threshold amount above the pressure inside the valve (which at this stage is at or close to ambient), the tubular valve closes.

Once the dispensing cycle is complete, the actuator 21 is released and the return spring biases the piston 22 and the seal valve 26 upwardly drawing in a fresh charge of liquid into the liquid chamber 43. At the same time, the actuator 21 is moved upwardly away from the closure member increasing the volume of the air chamber 50. As the air hole 52 in the piston is sealed by the tubular valve member 53, the pressure inside the air chamber 50 falls below ambient and the ambient air acting
on the outer surface of the flange 51 deforms it inwardly so that a fresh charge of air is drawn into the air chamber.

Mixing air with the liquid during the end phase of the dispensing cycle improves atomisation of the liquid during a period when the pressure of liquid flowing through the outlet orifice 36 is below the normal operating pressure. This reduces the droplet size during the end phase and so reduces the average droplet size over the whole dispensing cycle. In addition, the continued flow of air after the liquid has been cleared from within the piston bore helps to drive out any remaining liquid in the outlet region of the dispenser, improving atomisation and reducing the tendency for the dispenser to splutter and dribble. Furthermore, because the continuing airflow drives all the liquid from within the piston bore 33 and the outlet region through the outlet orifice 36, no liquid remains to go off and contaminate fluid product dispensed in later actuations or to dry out and block the outlet orifice. The quality of the spray produced by a dispenser 20 in accordance with the invention is therefore improved over a comparable conventional cylinder liquid pump and the chances of the outlet orifice becoming blocked or contaminated are much reduced.

Because the dispenser 20 in accordance with the invention only delivers air during the end phase of the dispensing cycle, a much smaller volume of air is required than an equivalent conventional air pump in which air is introduced over the whole of the dispensing cycle at substantially constant A:L ratio. In a dispenser 20 in accordance with the invention, the air to liquid ratio over the whole of the dispensing cycle may be in range of 4:1 to 12:1 but is preferably in the range of 6:1 to 8:1. This compares with a conventional air pump in which the ratio will typically be in the range of 10:1 to 20:1. As a result, the air chamber 50 can be smaller than that required in an equivalent conventional air pump so that a dispenser 20 in accordance with the invention can be provided that is not significantly larger than a conventional cylindrical liquid only pump dispenser. Indeed, in many cases, an existing cylindrical liquid only pump dispenser design can be modified to incorporate the air chamber within the existing actuator so that there is no increase in the overall size of the dispenser 20.
One of the biggest problems with the conventional air pumps is the increased actuation force required to compress the air to the same pressure as the liquid during the main discharge phase of the dispensing cycle. In a dispenser in accordance with the invention, the increase in actuation force compared with an equivalent conventional cylindrical liquid only pump dispenser is much less. This is partly due to the fact that a smaller volume of air is being compressed but also because the air does not have to be compressed to match the peak operating pressure of the liquid during the main discharge phase. In this regard it should be noted that in the present embodiment the pressure of the air in the air chamber 50 is only increased to something in the range of about 0.2 to 0.25 MPa (2 to 2.5 bar) during the main discharge phase before the pressure of the liquid in the piston bore 33 starts to fall during the end phase. In addition, the flange 51 is configured to give way easily when the actuator is returned to the start position by the return spring, so that the return spring need only be slightly stronger than that used in a conventional cylindrical pump. This also helps to keep the increase in actuation force to a minimum.

The dispenser 20 according to the present embodiment is designed to introduce airflow into the liquid flow principally during the end phase of the dispensing cycle only. If the air pressure in the chamber 50 is raised above the threshold value at which the tubular valve member 53 opens during the initial phase before the pressure of the liquid inside the valve increases to a level at which the valve is closed (i.e. pressure of liquid = the pressure of the air less the threshold value at which the valve opens), then some air may also be admitted into the piston bore 33 during the initial phase. This can be beneficial as the flow of air helps to draw the liquid through the system more quickly and so improves the atomization of the liquid when the pressure of the liquid is below the optimal operating pressure. Generally speaking, a tubular valve having a lower stiffness is required where air is to be mixed with the liquid during the initial phase.

In some applications it may be desirable to introduce a more significant flow of air into the piston during the initial phase. To achieve this, the dispenser 20 is modified so that the actuator 21 is able to move relative to the closure 25 in order to reduce the volume of the air chamber 50 and raise the pressure of the air in the
chamber above the second threshold value, 0.05 MPa (0.5 bar) in this case, before or at the same time as the seal valve 26 opens to allow the liquid to flow from the liquid pump chamber 43. There are numerous ways in which this can be achieved. One approach is to modify the piston to incorporate a flexible region, which can be compressed when the actuator is depressed, or to split the piston into two or more parts that can be moved relative to one another to provide the required actuator movement. The flexible region could be in the form of a bellows, for example. Alternatively, an additional component may be provided between the piston and the actuator to allow for the required movement. In a further alternative arrangement, the actuator with the outlet passage and nozzle can be separated from the piston to allow for the required movement. In this embodiment, a valve may be provided in the actuator to normally close the outlet passage and nozzle, the valve being opened when the piston is brought into contact with the actuator to establish a flow path for the liquid once the actuator has been moved through the required distance. With any of these arrangements, when the actuator 21 is depressed, it is able to move towards the closure 25 to pressurise the air to a required level before a force is applied to the seal valve 26 to pressurise the liquid in the liquid chamber 43. Once the movement in the piston 22 is taken up, further depression of the actuator 21 will result in a force being applied to the seal valve to pressurise the liquid, with the seal valve 26 and the air valve 53 opening once the liquid and the air reach their appropriate threshold pressures. Usually, the dispenser will be configured so that tubular air valve 53 opens to admit air into the piston at the same time or slightly before the seal valve 26 opens.

A different approach to enabling relative movement between the actuator and the mounting member to pressurise the air in the air chamber 50 before the liquid valve 26 opens is to introduce a compressible substance or material into the liquid chamber pump chamber 43. A simple way of achieving this is to allow air to be drawn into the liquid pump chamber 43 along with the liquid, so that when the dispenser is actuated, the air in both chambers compresses before the pressure in the liquid chamber is raised sufficiently to open the seal valve 26. A volume of air can be drawn into the liquid chamber 43 through the final outlet orifice and the seal valve 26, for example. Alternatively, a hollow ball or other compressible object could be placed in
the liquid chamber 43, so that initial movement of the actuator 21 and piston 22 squashes the ball or object allowing sufficient movement of the actuator to raise the pressure of the air in the air chamber 50 before the liquid seal valve 26 opens. Where a ball is used, the ball could also function as the inlet valve ball 27.

A further alternative arrangement for enabling movement of the actuator before the seal valve 26 opens is to form an opening or hole in the body 22 within the liquid chamber 43. The hole is positioned part way between the lower end of the seal valve 26 and the ball valve 27 so that the piston 22 and seal valve 26 are able to move downwardly within the body 22 when the actuator is initially depressed until the seal valve 26 closes the hole in the body. Further downward pressure on the actuator will result in an increase in the pressure of the liquid in the chamber 43 and the dispenser will continue to operate as previously described. The hole is positioned so that the air in the air chamber is raised to the desired value before the seal valve 26 closes the hole. When the actuator is released, liquid will be drawn into the chamber 43 until the hole is uncovered by the valve seal 26, after which air will be drawn in to the chamber through the hole.

Use of a compressible body or the introduction of air into the liquid pump chamber or the provision of a hole part way down the chamber wall will reduce the capacity of the liquid chamber perhaps by about 30-60%.

Operation of the dispenser 20 when modified to allow air to flow from the air pump chamber to mix with the liquid in the initial phase will now be described.

Initial depression of the actuator 21 towards the closure causes the air chamber 50 to compress so that the pressure of the air in the air chamber 50 is raised. Depending on the method used to allow the actuator to move relative to the closure, as discussed above, the pressure of the liquid in the liquid chamber 43 may be raised simultaneously with that of the air or there may be a delay before the liquid pressure begins to rise. In the present embodiment, the second threshold value at which the tubular valve 53 opens this is set at a relatively low pressure of 0.05 MPa (0.05 bar). This is lower than the first threshold value at which the seal valve opens, which is set at 0.3 MPa (3 bar). Once the air in the air chamber reaches the 0.05 MPa (0.5 bar) threshold value, the tubular valve member 53 opens and air begins to flow into the
piston and out towards the outlet orifice 36. After approximately 0.05 seconds, the liquid in the liquid chamber reaches the 0.3 MPa (3 bar) first threshold and the seal valve 26 opens so that liquid begins to flow through the piston bore and the tubular valve member 53 where it meets and mixes with the incoming air. Initially, the pressure of the liquid in the piston bore and the tubular valve member is lower than the pressure of the air in the air chamber by more than the second threshold amount and so the tubular valve remains open, allowing further air to enter the bore 33 to mix with the liquid. However, the pressure of the liquid in the piston bore and the tubular valve member 53 rapidly rises until it approaches and then exceeds that of the air in the air chamber and the tubular valve member is pushed back into contact with the wall of the piston closing off the air hole 52. In the present embodiment, this takes place approximately 0.07 seconds into the dispensing cycle.

The dispenser then continues to operate as described above in relation to the first embodiment 20, with the tubular valve 53 opening during the end phase to admit further air into the bore 33 when the pressure of the liquid falls below that of the air in the air chamber by the second threshold amount.

The introduction of air into the liquid flow during the initial phase before the liquid reaches its optimal operating pressure at the outlet orifice improves the quality of the spray during this phase, reducing the average droplet size. In addition, the flow of air through the bore 33 and the outlet orifice 36 when the seal valve 26 first opens helps to draw the liquid through the system more quickly which also improves the atomization of the liquid.

The modified dispenser 20 enjoys many of the advantages of the basic dispenser 20. Since air is only introduced into the liquid flow during the initial and end phases, when the pressure of the liquid at the outlet orifice is below the normal working pressure, the volume of air required is much less than for an equivalent conventional air/liquid pump dispenser. Furthermore, the air need not be raised to the same pressure as the liquid. Thus, even though the pressure of the liquid in the chamber 43 and the flow path to the outlet orifice 36 is raised to a peak pressure of 0.3 to 0.4 MPa (3 to 4 bar), the air pressure is only raised to about 0.1 to 0.15 MPa (1 to 1.5 bar) at its peak.
The modifications discussed above which enable the air chamber to be compressed before the outlet valve 26 of the liquid chamber opens can be adopted in any of the embodiments described below in which air is to be introduced into the liquid flow during the initial and or main phases of the dispensing cycle.

It is a particular advantage that a dispenser 20 in accordance with the invention can be produced by modifying the design of an existing cylindrical dispenser. In the present example, the turret collar 24 is modified to add the sealing flange 51 and the piston 22 is modified accommodate the tubular valve member 53 and to provide the air hole 52. These changes require only minor alterations to existing tooling. The only other modification that is required is the additional tubular valve member 53. The strength of the return spring may also have to be increased but in many applications this will not be necessary. The minimal changes mean that the existing assembly machinery for the cylindrical dispenser can be used to assemble the new dispenser with only limited changes being required. Furthermore, once assembled, the new dispenser 20 can be handled by the same machinery used for the pre-existing cylindrical pump dispenser. As a result, a dispenser in accordance with the invention can be manufactured, assembled and handled with minimal additional tooling and equipment costs.

It can be seen, therefore, that dispensers in accordance with the invention offer improved performance over conventional cylindrical liquid pump dispensers but without many of the disadvantages that have prevented the known air pumps from successfully entering the mass market. However, the invention is not limited to dispensers based on the modified design of a pre-existing liquid only dispenser. Varying the ratio of air to liquid (A:L) over the course of the dispensing cycle means that more efficient use can be made of the available air enabling purpose designed air/liquid dispensers to be produced which have a smaller air chamber than might otherwise be required and in which the actuation forces are lower.

The tubular valve member 53 could be positioned lower down in the bore 33, with the air hole 52 also suitable repositioned. Generally, speaking, the air hole 52 should be positioned adjacent the upper half of the tubular valve member 53 and preferably near to the upper edge as shown. The tubular valve member may be
arranged so that only a small circumferential region deforms inwardly so that the air is channelled through a narrow section, reducing the likelihood of the liquid escaping through the hole 52.

The strength and resilience of the tubular member 53 determines the pressure differential required across it for it to deform and so the pressure of the air required to open the valve. The region of the tubular valve member 53 below the air hole 52 can be made stronger than that adjacent the air hole so as to resist the flow of air downwardly and to prevent liquid from flowing between the tubular valve member and the piston.

The tubular valve member 53 provides a simple and effective valve arrangement for controlling the flow of air that is cheap to manufacture and easily incorporated in to a modified piston of a pre-existing cylindrical pump arrangement. However, any suitable valve can be used. Furthermore, the air need not be introduced into the piston bore 33 but it could be directed into the liquid flow at any point between the outlet from the liquid pump chamber 43 and the final outlet orifice of the device. So, for example, the air could be directed into the interior of the inner tubular wall member 31, into the chamber 35 or into a swirl chamber by the provision of a suitable flow path connected with the air chamber and a one way valve to prevent liquid from entering the air chamber 50. In some applications, the dispenser has an outlet tube into which the spray orifice 36 directs the spray of liquid. Where this is the case, the outlet of the tube can be considered as the final dispenser outlet and the air from the air chamber may be directed into the tube to mix with liquid and enhance the spray after the spray orifice 36. Since the liquid in the tube will be at a relatively low pressure (at or close to ambient), only a simple one way valve would be required and the air would only ever be at a relatively low pressure just over ambient, say in the range of 0.05 to 0.2 MPa (0.5 to 2 bars). The air could, for example, be directed into the tube through a venturi inlet hole, so that the air is drawn out of the air chamber by the flow of liquid in the tube.

In a conventional cylindrical pump dispenser, the turret collar 5 does not form a seal with the external surface of the piston 3. In a dispenser 20 in accordance with the invention, the turret collar 24 may be arranged so that it seals against the piston 22.
to prevent pressurised air from passing from the air chamber 50 between the turret collar and the piston into the region of the body 23 above the seal valve 26 when the actuator is depressed. If a seal is provided, the pressure of the air in the air chamber 50 can be increased by more than would be possible without a seal. If there is no seal between the turret collar 24 and the piston 22, the interior of the body above the seal valve 26 is fluidly connected with the air chamber 50 effectively providing a larger volume double air chamber, which may be desirable in some applications. For example, it can be arranged for air to be introduced into the liquid flow past the seal valve 26 towards the end of the dispensing cycle by breaking the seal between the seal valve and the body 23. This enables the pressurised air in air chamber 50 and the upper region of the body 23 to flow past the seal valve 26 and enter the bore 33 through the opening 44 following the liquid which is pushed through the bore and outlet nozzle by the air flow. The seal between the seal valve 26 and the body 23 can be broken in any suitable manner. In one embodiment, grooves are provided in the inner surface of the body which are uncovered by the seal valve 26 as the piston 22 approaches the end of its stroke to fluidly connect the interior of the body above 23 the seal valve with the liquid pump chamber 43. Alternatively, up-stands or projections may be provided on the inner surface of the body which deflect the valve seal to create a flow path from the interior of the body above 23 the seal valve 26 to the liquid pump chamber 43. Because the seal between the seal valve and the body 23 is only broken at or very close to the end of the stroke, the seal will be restored and only liquid will be drawn into the liquid pump chamber 43 during the return stroke. This arrangement is advantageous as it means that the tubular valve member can be omitted, reducing the number of additional components and so reducing manufacturing costs.

Where a seal between the turret collar 24 and the piston 22 is required, it is advantageously produced in a way that minimises the resulting increase in actuation force and return spring strength. For example the seal may be configured so that it is only effective when the actuator 21 is being depressed and not when the actuator 21 is being returned to the start position by the return spring. In one such arrangement, the central hole in the turret collar through which the piston protrudes is larger than the
external diameter of the piston 22 and a relatively thin section seal member having an upward conical shape engages the piston. The arrangement is such that as the piston slides down through the hole, the seal member is dragged into close contact with the piston to form a seal. In an alternative arrangement, the turret collar may have a flexible dome portion that is connected to the exterior of the piston to form a seal. In this case, the inner edge of the dome portion is fixed to the piston and the dome flexes as the piston moves. In a further alternative, the seal may be very week so that the piston moves through it easily.

The turret collar 24 can be made wholly from a resilient, flexible material or it may have a substantially rigid main body to which resiliently deformable portions are attached to form the flange 51 and any other required seal or flexible part. In common with most of the components of the dispenser 20, the turret collar is advantageously manufactured from polymeric materials using injection-moulding techniques. Where the turret collar has a rigid main body, bi-injection techniques can be used to form the main body from a first substantially rigid polymeric material and to over mould a second resiliently deformable material onto the main body to form the flange 51 and other seals or flexible portions.

In some embodiments, the closure 25 only has a single outer flange collar 39 and no inner flange 40. In this case, the turret collar 24 will be thicker than is shown in Figure 2 and the outer wall 30 of the actuator will be received in an annular gap 41 between the outer flange 39 and the turret collar 24 when it is depressed. This arrangement can be adopted in any of the embodiments of the invention disclosed herein.

Some of the alternative arrangements discussed above are incorporated into a dispenser 120 in accordance with a further embodiment of the invention as shown in Figures 3 and 4. The dispenser 120 is essentially the same as the dispenser 20 in accordance with the first embodiment and only those features that are different will be described in detail. The same reference numerals will be used to designate the same or similar features in this and all further embodiments described below.

In the dispenser 120, the tubular valve 53 is located in an enlarged bore section at the upper end of the piston so that the upper edge of the tubular valve is generally
level with the upper edge of the piston. One or more grooves 57 are provided on the outer surface of the piston at its upper end where it is received in the inner tubular wall portion 31 of the actuator. The groove or grooves 57 extend from a position below the lower end of the inner tubular wall portion 31 to the upper end of the piston where an opening 58 is provided through the piston to connect the, or each, groove 57 fluidly with the liquid flow path where the piston bore 33 opens into the further bore defined inside the inner tubular wall member 31.

An upper end region 53a of the tubular valve member 53 is thinner than the remainder of the valve member and acts as a resilient flap valve for controlling the flow of air through opening 58. In its initial resiliently biased condition, as shown, the upper end region 53a contacts the inner surface of the piston closing off the opening 58 to prevent air from entering the liquid flow path and liquid from flowing in the reverse direction. Air in the chamber 50 is able to enter the groove(s) 57 and impinges on the outer surface of the upper end region 53a of the tubular valve member. When the dispenser is operated, the pressure of the air in the chamber 50 increases and this increasing air pressure acts on the upper end region 53a. When the pressure of the air acting on the outer surface of the upper end region 53a of the tubular valve member is greater then the pressure acting on the inner surface by the second threshold amount or more, the upper end region 53a of the valve member is deflected inwardly so that air from the chamber 50 can enter the liquid flow path. The upper end region 53a of the tubular valve member will revert to its initial resiliently biased configuration to close the opening 58 when the pressure differential across it falls below the second threshold amount.

This alternative tubular valve arrangement could be adopted in the dispenser as described above or in any other embodiments where appropriate.

The dispenser 120 also differs from the first embodiment 20 in that the closure 25 does not have an inner flange 40. Rather, in this embodiment, the turret collar 24 has an inner portion 59 with an outer annular wall region 60, which fulfils the same function as the inner flange 40 in the first embodiment. The turret collar also has an outer portion 61, which includes the seal member 51 for contact with the inner surface of the outer tubular wall 30 of the actuator. In addition, the outer portion 61 also has
an inner seal flange 62 that engages with the exterior of the piston 22 to form a seal therewith as discussed above. The inner portion 59 of the turret collar may be manufactured from a substantially rigid material, which may be a polymeric material that is generally rigid once set after moulding. The outer portion 61 of the turret collar may be manufactured from a resiliently flexible material, such as a polymeric material that is resiliently flexible at normal operating temperatures once set after moulding. The inner and outer portions 59, 61 may be separate parts or they may be formed integrally. In one embodiment, the inner and outer portions 59, 61 are formed integrally from polymeric materials using bi-injection techniques in which the resiliently flexible outer portion 61 is over moulded onto the rigid inner portion 59.

As can best be seen in Figure 4, the outlet region of the dispenser 120 has been adapted to provide a swirl chamber or an equivalent "backspinner" means for encouraging the liquid/air to spin about the axis of the orifice 36 before passing through the orifice. Thus, a generally cylindrical projection 63 extends from the inner tubular wall portion 31 of the actuator into the interior of the spray insert 28. The outer end of the projection has a chamfer 64 which abuts a correspondingly chamfered region 65 inside the spray insert. The end surface 66 of the projection is spaced slightly from the inner end surface 67 of the insert so that a swirl chamber (not shown) is defined between the end surfaces. Alternatively, the end surface 66 of the projection may abut the inner end surface 67 of the insert 28 and the swirl chamber defined by means of one or more recess in one or both of the end surfaces 66, 67.

The outer diameter of the projection 63 is smaller that the inner diameter of the insert, so that liquid or a liquid/air mixture flowing through the dispenser outlet region is able to pass between the projection 63 and the insert 28 towards the chamfered regions 64, 65. One or more flow channels are defined between the chamfered regions 64, 65 to direct the fluid into the swirl chamber and are shaped to encourage the fluid to spin about the axis of the outlet orifice 36. The flow channels may be defined by means of grooves in one or both of the chamfered regions 64, 65. The end surfaces 66, 76 may also be shaped so as to promote swirling of the liquid, liquid/air mixture.
A similar swirl chamber arrangement may be provided in the dispenser 20 in accordance with the first embodiment or in any of the other embodiments described herein as appropriate.

The dispenser 120 is otherwise constructed and operated as described above in relation to the first embodiment 20 and may be configured to deliver air into the liquid flow only during the end phase of the dispensing cycle or it may be adapted to deliver air only during an initial phase of the dispensing cycle or during both the initial and end phases.

Figure 5 illustrates a further embodiment of a dispenser 220 in accordance with the invention in which the design is modified to eliminate the need for separate tubular valve member. The dispenser 220 is otherwise identical with the first embodiment 20.

In the dispenser 220, the turret collar 24 has a flexible domed upper portion 24a with a central tubular portion 24b which projects upwardly into the actuator 21. The piston 22 is a close sliding fit in the tubular portion 24b and has an air hole 52 which is closed by the tubular portion 24b of the turret collar when the dispenser is in an initial rest position as shown. Two spaced holes 68, 69 extend through the tubular portion 24b of the turret collar and are positioned to align with the air hole 52 in the piston during the initial and end phases only of the dispensing cycle to admit air from the air chamber into the piston. During actuation of the dispenser, the dome 24a on the turret collar initially deflects downwardly becoming inverted as the actuator 21 is depressed. Once the dome 24a reaches its limit of movement, the piston slides within the tubular portion 24a until the air hole 52 is brought into alignment with the upper hole 68 in the tubular portion and air is admitted into the piston bore to mix with the liquid. This occurs during the initial phase of the dispensing cycle just prior to the seal valve 26 opening and/or as the pressure of the liquid in the bore 33 is building. Further movement of the piston 22 relative to the tubular portion 24b moves the air hole 52 to the region between the two holes 68, 69 so that the air hole 52 again covered. The hole 52 remains covered during the main discharge phase until the piston reaches the end of its stroke during the end phase of the dispensing cycle, when the air hole 52 aligns with the second hole 69 in the turret collar tube 24b so that
pressurised air is again admitted into the bore 33 to mix with the liquid and travel to
the outlet orifice. The dispenser is configured so that air continues to flow after valve
seal 26 closes to drive all the liquid out of the piston and the outlet passages on the
actuator.

When the actuator 21 is released, the piston and actuator are biased upwardly
back to the rest position by the return spring (not shown). During an initial part of the
return travel, the tubular portion 24b of turret collar travels with the piston to bring the
dome back to its initial configuration. Once the dome reaches its limit of travel, the
piston slides through the tubular portion so closing off the air hole 52 in the piston
again. The liquid chamber 43 and the air chamber are refilled during the return stroke
as described in relation to the previous embodiment 20.

Rather than a dome 24a, the turret collar could be provided with a bellows or
any other suitable arrangement, which enables the tubular portion 24b to move with
the piston 22 over a limited range. In some embodiments, no movement of the tubular
portion 24b is required and the piston can be arranged to slide through the tubular
portion 24b to align the piston air hole 52 with the tubular portion air holes 68, 69 at
the appropriate times during the dispensing cycle. Figure 6 shows an embodiment of
a dispenser 320 in which the turret collar has a flat upper portion 24c that has no, or
only limited, travel when compared to the dome 24a in the previous embodiment. The
dispenser 320 is otherwise identical to the dispenser 220 described previously.

As described, the dispensers 220, 320 have two holes 68, 69 in the tubular
portion 24b of the turret collar so that air is admitted into the piston bore 33 during
both the initial and end phases of the dispensing cycle. This will require the dispenser
220, 320 to be modified as discussed above in relation to the first embodiment 20 to
enable the actuator 21 to move relative to the closure 25 to raise the pressure of the air
in the air chamber 50 before the seal valve 26 opens. In some applications it may
advantageous to introduce air into the liquid flow only during one of the initial and
end phases. This may be due to a limit in the amount of air that can be provided
without increasing the size of the actuator, for example. Usually, air would be added
to the liquid flow during the end phase only as there tends to be more problems
associated with the reduced pressure in the end phase than in the initial phase, as
discussed previously. This can be simply achieved by providing only a single hole 69 in the tubular portion 24b of the turret collar for alignment with the air hole 52 in the piston at the appropriate time in the dispensing cycle. For example, if the dispenser 220 shown in Figure 5 is to be adapted to admit air into the piston bore 33 only during the end phase; only the lower hole 69 will be provided in the tube portion 24b. Thus during operation as the actuator 21 is depressed, the turret collar dome 24a will initially deflect downwardly to become inverted before the piston begins to slide through the tubular portion 24b. As the piston 22 approaches the end of its actuation stroke, during the end phase, the hole 52 in the piston is brought into alignment with the hole 69 in the tubular portion so that pressurised air is admitted into the bore 33 to mix with the liquid and drive it through the outlet. Air continues to flow from the air chamber 50 into the bore 33 after the seal valve 26 has closed to drive all the liquid through the piston and out of the outlet thus improving the quality of the spray and reducing the tendency to splutter or dribble. Where air is only introduced into the liquid flow during the end phase, no modification of the dispenser to allow relative movement between the actuator 21 and the closure 25 prior opening of the seal valve 26 is necessary.

In Figures 5 and 6, the spray insert 28 has been omitted but may take the same form as that shown in Figure 2 or that as shown in Figures 3 and 4.

The dispensers 20, 120, 220, 320 in accordance with the invention described above are all configured so that air is only introduced into the liquid flow stream during the initial and/or end phases of the dispensing cycle when the pressure of the liquid is below its peak pressure. This is particularly advantageous as it means that the air need not be pressurised to the peak pressure of the liquid and so the actuation force is not as high as would be the case for a conventional air pump. However, dispensers in accordance with the invention can be configured to mix air into the liquid flow throughout the dispensing cycle. This is particularly so where the pump has a relatively low peak pressure for the liquid and/or where a small air to liquid ratio, say less than 10 to 1 and more particularly less than 6 to 1, is required.

Where the air is to be dispensed throughout the dispensing cycle, or at least the majority thereof, the valve controlling admission of the air into the liquid flow path is
arranged so as to allow the air through whilst preventing the liquid from escaping. Any suitable one-way valve could be used. Because the air has to be raised to a higher pressure overall during the dispensing cycle, the threshold pressure difference at which the air chamber outlet valve opens will usually be set at a higher pressure than in the previous embodiments and the dispenser configured so that valve remains open whilst the fluid is flowing at its peak pressure. Such a dispenser could have a tubular valve member 53 similar to that used in the dispenser 20 described above but adapted so that it opens at a higher pressure, in the region of 0.2 to 0.3 MPa (2 to 3 bar) for example, so that the air does not exit the air chamber until the seal valve 26 opens and the liquid begins to flow or just before, and remains open for the majority of the remaining dispensing cycle. The valve member 53 may, for example, be configured so that it is distorted by the flow of liquid to open and/or maintain a flow path from the air chamber 50 into the liquid flow. Alternatively, the liquid flow through the bore 33 may be arranged to move the tubular valve member to maintain a flow path from the air chamber 50 into the liquid flow, at least during the main phase of the dispensing cycle during which the liquid would otherwise close the valve 53. In one embodiment (not shown) the tubular valve member 53 is mounted so as to be moved upwards over grooves in the piston or on to an up-stand to open the flow path.

Since the pressure of the air in the air chamber needs to be raised up to the same pressure of the liquid before the seal valve 26 is opened, the dispenser will have to be modified as described above in relation to the first embodiment 20 to provide relative movement between the actuator 21 and the closure 25 so that the volume of the air chamber 50 is reduced sufficiently to raise the pressure of the air to the required level before seal valve 26 opens. Any of the methods discussed above in relation to the first embodiment 20 can be adopted.

A dispenser in accordance with the invention in which the air is introduced into the liquid flow over the whole, or majority, of the dispensing cycle will require a higher actuation force than would be the case when the air is only admitted to the liquid flow path during low pressure phases of the dispensing cycle and will provide a lower air to liquid ratio during the initial and phases than would be the case with an equivalent dispenser in which air is only introduced during the low pressure phases at
the beginning and end of the dispensing cycle. However, dispensers in accordance with the invention can be configured so that a lower ratio of air to liquid is delivered during the main dispensing phase when the pressure of the liquid is at its highest then during the initial and end phases. This makes efficient use of the available air. Because of the problems potentially caused by higher actuation forces, it is expected that only dispensers having a relatively small discharge volume up to 5mls and more typically up to 2 ml will be arranged to have air mixed with the liquid during the main discharging phase.

The keep the actuation force as low as possible where air is to be mixed with the liquid during the main dispensing phase, the dispenser may be configured to introduce the air into a low pressure part of the fluid outlet passageway. For example, the air may be directed into the centre a swirl chamber through a back wall of the chamber. Where the swirl chamber is formed in the manner shown in Figure 4, a suitable passageway can be provided through the projection 63 and a one-way valve used to prevent the liquid entering the air pump chamber. Alternatively, the air could be introduced into an expansion chamber in the liquid flow path upstream of the outlet orifice 36. For example, the outlet passage could incorporate any of the flow control means disclosed in W00189958 A, and the air could be introduced into the flow control means. As described in W00189958 A, to which the reader should refer for a detailed explanation, the control means may include any one or more of the following:
a) an expansion means in which a dimension of the passage transversely to the direction of fluid flow is increased relative to the same dimension of the remainder of the passage; b) inner orifice means in which the dimension of the passage transversely to the direction of fluid flow is decreased relative to the same dimension of the remainder of the passage; c) a multiple channel means wherein at least a part of the passage is divided into from 2 to 12 channels each of which has a decreased dimension transversely to the direction of fluid flow relative to the same dimension of the remainder of the passage; d) a dog leg means in which the flow through the passage is redirected in a direction substantially transversely to the direction of flow in the passage over the length of the means; e) a swirl means wherein rotational flow is induced in the fluid about the direction of flow of fluid in the passage; and/or f)
venturi means comprising a narrow passage broadening to a relative wide passage with a narrow air inlet entering the passage near the point at which the passage broadens. In this case, the air could be introduced into one of the control means. The content of WO1 89958 A is incorporated by reference.

A further alternative outlet valve arrangement 128 for the air chamber is shown in Figures 12a and 12b. The mounting member is omitted from these drawings. In the arrangement shown, the free end of the piston abuts a pair of ledges 130 in the further bore 131 of the actuator 21 in a known manner. A longitudinally extending groove 132 is provided between the free end region of the piston 22 and the inner surface of the inner tubular wall 31 to allow air to flow from the air chamber towards the free end of the piston. The outer diameter of the free end of the piston 22 has a stepped or tapered portion 133 of reduced diameter and a resiliently flexible O-ring 134 is mounted about the reduced diameter portion 133 to act as a valve member. In its naturally resiliently biased condition the O-ring forms a seal between the piston and the wall 31 to prevent air from flowing through the groove and entering the further bore. However, under certain circumstances, the pressure of the air acting on the O-ring can distort the O-ring, or part of it, to open a flow path through the groove 130 into the further bore and hence to the outlet 36.

Opening of the valve arrangement 128 depends on the stiffness and/or resilience of the O-ring as well as the relative pressure differential across. Thus the designer can determine a minimum air pressure required to distort the O-ring to open the valve by selecting an O-ring having suitable stiffness. If an O-ring having a suitably low stiffness is used, the valve can be arranged to open during the initial phase of the dispensing cycle when the pressure of the air in air chamber is relatively low but before the liquid begins to flow from the liquid chamber. Once the liquid outlet valve opens, the liquid will flow through the bore 33 of the piston 22 to mix with the air initially. However, as the pressure of the liquid flowing from the liquid chamber to the outlet rises to equal or surpass that of the air in the air chamber, the pressure of the liquid acts on the O-ring to close the valve so that no air is admitted into the further bore during the main phase of the dispensing cycle. During the end phase of the dispensing cycle after the liquid chamber outlet valve has closed, the O-
ring will be deflected to open the valve again once the pressure of the liquid acting on the O-ring falls below that of the air in the air chamber. This enables air to flow through the groove 132 again during the end phase to improve the quality of the spray and to clear out the remaining liquid in the outlet passage. It should be noted that the pressure of air flowing from the air chamber will be higher at the start of the end phase than the pressure of the air flowing during the initial phase.

If it is desired that air should only be dispensed during the end phase of the dispensing cycle, then an O-ring having a higher stiffness/resilience can be used, the stiffness being selected so that the pressure of the air in the air chamber is insufficient to deflect the O-ring and open the valve during the initial phase but so that the valve will open during the end phase, when the pressure of the air in the air chamber is higher. The valve 128 can also be configured so that it opens once the air pressure has reached a pre-determined value during the initial phase and remains open throughout the remaining dispensing phase by using an O-ring having a suitable stiffness. In this case, it will be necessary to raise the pressure of the air to match or exceed that of the liquid. Again it could be arranged that the flow of liquid during the main phase distorts to O-ring to hold the valve open. However, the valve can be configured so that the flow liquid partially closes or throttles the valve during the main dispensing phase when the pressure of the liquid is at its peak so that a lower ratio of air to liquid is delivered to the outlet during the main phase than during the initial and/or end phases.

The stiffness/resilience of the O-ring is dependent on the hardness of the material and the thickness of the ring and can be appropriately determined by varying these parameters.

Rather than mounting the O-ring to the free end of the piston, the O-ring could be mounted within the further bore. For example, the O-ring could be positioned between the ledges 130 and the free end of the piston 22 so that part of it is pushed into the gap between the ledges by the air flowing through the groove to allow the air to flow past it into the liquid outlet passage. Furthermore, whilst an O-ring is particularly effective, any suitable annular, resiliently deformable valve member could be used such as an annular washer of resiliently deformable material.
The embodiments of the invention discussed so far have been pumps for dispensing a liquid product, such as a liquor, in the form of a spray. However, the invention is also applicable to dispensers that are configured to dispense a liquid, including gels, as a foam or mousse.

Current foam dispensers tend to mix air and the fluid product at very low pressures, in the region of 0.05 MPa to 0.3 MPa (0.5 to 3 bars) but with high ratios of air to liquid, a ratio of air to liquid in the range of 10:1 to 20:1 being typical. Due to the high volume of air required to produce these ratios, the known dispensers tend to be large. Often the whole, or a significant part, of the dispenser is located within the neck of a bottle containing the fluid product. Accordingly, the neck region of the bottle must be sufficiently large to contain the dispenser. In addition, the combination of bottle and known dispenser tends to be top heavy and prone to toppling over.

Contrary to the accepted practice, the applicant has discovered that it is possible to generate acceptable foam for mass market applications with much lower ratios of air to liquid, in the order of 4:1 to 9:1 and in particular with ratios of 6:1 to 8:1. Because a lower volume of air is required, the principles discussed above in relation to the previous embodiments can be adopted to adapt the design of an existing liquid pump dispenser to produce an air/liquid foam dispenser. This is advantageous as a new foam dispenser in accordance with the invention based on the modified design of an existing liquid pump dispenser can be brought to market at considerably lower tooling and equipment costs than would be incurred with the design and manufacture of an entirely new foam dispenser using conventional liquid to air ratios. However, many advantages of the present invention can be gained even when producing a new foam dispenser as the resulting dispensers will tend to be smaller than an equivalent conventional foam dispenser, meaning that they can be accommodated in a bottle having a smaller neck region.

Figure 7 shows a further embodiment of the invention, which illustrates how a conventional existing cylindrical liquid pump design can be modified to provide a foam dispenser 420. The general construction of the dispenser 420 is similar to the previous embodiments and it has a modified turret collar 24 with a seal flange or bell
51 arranged to contact the inner surface of the outer wall 30 of the actuator 21 to
define an air chamber 50 within the actuator.

An over cap 72 is mounted over the actuator 21 and has an outlet spout arrangement 73. Rather than having an over cap, the actuator 21 can be modified to include an integral outlet spout 73. The outlet spout defines a first mixing chamber 74 into which liquid product is sprayed from the constricted nozzle orifice 36 in the spray insert 28. An air inlet passage 75 fluidly connects the air chamber 50 with the mixing chamber 74 so that the air and liquid are mixed in the chamber 74 before passing out through a narrow opening or throttle 76 into an outlet foam passage 77. At least one mesh screen 78 extends across the outlet foam passage to filter the foam and improve its quality in a known manner. Although only one mesh screen 78 is shown in Figure 7, in many applications two or more screens will be used as this produces an improved quality of foam.

A swirl chamber (not shown) will usually be provided prior to the spray nozzle orifice 36, though in some applications acceptable foam can be generated using only a spray orifice with no swirl chamber. The swirl chamber can be formed by means of a projection 63 within the insert 28, as described above in relation to the second embodiment 120 and as shown in Figure 4. Rather than a swirl chamber as such, any equivalent means for causing the liquid to spin about the axis of the orifice 36 prior to passing through the orifice can be used.

In the present embodiment, the dispenser is configured so that the liquid is delivered from its pump chamber to the spray orifice 36 at a pressure in the region of 0.1 to 0.4 MPa (1 to 4 bar). In general, the higher the pressure of the liquid the better the quality of foam produced. Once the liquid passes through the spray orifice 36 into the mixing chamber 74, its pressure falls. Where the pump pressure is 0.4 MPa (4 bar), the pressure of the liquid in the chamber 74 may be in the region of say 0.2 MPa (2 bar). In addition, because the liquid does not occupy the whole of the chamber, the pressure in the chamber is lower than that of the liquid entering the chamber, though it is still above ambient in order to drive the foam out. Because the air from the chamber 50 is being introduced into the liquid flow downstream of the spray orifice and swirl chamber (where one is provide) where the pressure is low, the air need only be
pressurised to just over ambient, say in the region 0.01 MPa to 0.05 MPa (0.1 bar to 0.5 bar). The precise pressure of the air can vary depending on the application and the air may be pressurised up to approximately 0.1 MPa (1 bar), which is particularly advantageous where the liquid pressure upstream of the spray orifice is towards the higher end of the range mentioned above. Because the air is being directed into a low-pressure part of the liquid flow path, no pre-compression outlet valve is required at the air passage 75, which tends to act like a venturi hole so that the air is automatically drawn into the mixing chamber 74 from the air chamber by the liquid flow. The design of the chamber 74 and the passage 75 can be configured to encourage the venturi effect. However, a one-way valve (not shown) may be required to prevent liquid from entering the air pump chamber.

In operation, when the actuator 21 is depressed, the liquid in the liquid chamber 43 is pressurised to bring the liquid to the desired operating pressure, at which time the seal valve 26 opens and the liquid flows through the piston 22, the swirl chamber (if present), the spray orifice 36 and into mixing chamber 74. Once the valve 26 opens, downward movement of the actuator 21 reduces the volume of the air chamber 50 so increasing the pressure of the air contained in the air chamber 50. Air from the chamber passes through the passage 75 into the mixing chamber 74 where it mixes with the liquid. The air may be drawn through the passage 75 due to the venturi effect of the liquid flow through the mixing chamber 74 or due to the increased pressure of the air in the chamber 50 or a combination of the two. The liquid/air mixture passes through the throttle 76 into the outlet foam passage 77. The mixture passes along the passage through the mesh screen filter(s) 78 where the foam is refined before passing through the outlet 79 of the passage 77.

Once dispensing is complete, the piston 22 and actuator 21 are biased back to the start position by a return spring closing the seal valve 26 and drawing a fresh charge of liquid into the liquid pump chamber 43 and a fresh charge of air into the air chamber 50, as described in relation to the previous embodiments.

Introducing the air into a low pressure region of the liquid flow path has the advantage that the overall actuation force is kept low because the air in the chamber 50 does have to be raised to the same pressure as the liquid. The position of the air
passage 75 can be varied and, for example, may be arranged to direct air into the outlet foam passage 77 downstream of the throttle in some cases.

Because of the limitations of converting an existing liquid pump design, the volume of air available in each actuation will typically be 20 mis or less and usually 18 mis or less with a maximum liquid discharge of 2.5 mis and usually 2 mis or less.

Whilst it is advantageous to mix the air and liquid in a low-pressure region of the liquid flow path to the outlet 79, the air could be introduced upstream of the spray orifice 36 and swirl chamber (where provided). In this configuration, it is necessary to raise the pressure of the air so that it matches that of the liquid in the high-pressure part of the flow path and a pre-compression one-way outlet valve will be required at to control the flow of air from the air pump chamber. This arrangement is most advantageously used where the liquid pressure is relatively low, say in the region of 0.1 MPa (1 bar), though it could be used where the liquid pressure at the spray orifice is in the range of 0.06 MPa to 0.3 Mpa (0.6 to 3 bar) or more.

Where the air is to be introduced into a high pressure part of the liquid flow path, it is necessary to allow the actuator 21 to move relative to the closure 25 to reduce the volume of the air chamber 50 raising the pressure of the air to the desired threshold value before the seal valve 26 opens, as with the modified version of the first embodiment 20 described above. Any of the methods of achieving this described above in relation to the previous embodiments 20 can be employed.

Where the air is introduced into a low pressure region of the liquid flow path it and need only be raised to a relatively low pressure when compared with the pressure of the liquid in the liquid chamber 43, the necessary air pressure can be generated by using a small diameter air passage 75 which restricts the air flow and creates a back pressure, raising the pressure of the air in the air chamber 50. In this case, it will usually not be necessary to reduce the volume of the air chamber before the seal valve 26 opens. In addition, the reduction in volume of the air chamber 50 after the seal valve 26 has opened will push the air through the air passage 75 raising the air to the required pressure whilst the liquid is being discharged. As discussed above, the venturi effect of the liquid flow can also be used to draw the air through the air passage 75.
Figures 8 and 9 show a further embodiment of a foam dispenser 520 in accordance with the invention. The dispenser 520 is in essence similar to the previous embodiment 420 though there are a number of variations which will be described.

In the dispenser 520, the outlet spout 73 is formed as an integral part of the actuator 21 rather than being provided as part of an over cap. In addition, the outer wall 30 of the actuator is located on the outside of the annular flange 39 on the closure 25. In this instance, the closure 25 only has a single annular flange 39, which is equivalent to the outer annular flange 39 as described in relation to the first embodiment 20. The closure could, however, have two annular flanges, in which case the outer wall 30 would be arranged to locate about the outside of the outer annular flange. In order to form an air chamber 50 in the actuator 21, a seal member 79 is mounted to the turret collar 24. The seal member has an inner seal 62 that engages on the outside of the piston 22 and an outer seal 51 that engages on the inner surface of the outer wall 30 of the actuator. Between the inner and outer seals 62, 51, the seal member 79 has a body portion with a downwardly depending annular flange 80 which locates in the gap between the turret collar 24 and the flange 39 of the closure 25. The seal member 79 thereby effectively closes of the open lower end of the actuator to create the air chamber 50. The seal member 79 could be formed integrally with the turret collar 24 rather than as a separate component.

By arranging for the outer wall 30 of the actuator to locate on the outside of the flange 39, the volume of the air chamber 50 is larger than would be the case if it located on the inside as in previous embodiments. This is advantageous in applications in which a larger volume of air is required and can be adopted in any of the embodiments described, including those dispensers that are configured to produce a spray rather than foam.

The dispenser 520 is provided with a twist lock arrangement to prevent accidental actuation. The twist lock is formed by means of an up stand 81 on the seal member 79. The up stand 81 is configured so that when the actuator is in a first locked position, as shown in Figure 8, a tubular portion 83 of the actuator which extends generally horizontally (as shown) between the inner and outer annular walls 31, 30
and which houses part of the outlet passage from the piston 22 to the spout 73 contacts the up stand to prevent the actuator being depressed. In order to actuate the dispenser 520, the user must first rotate the actuator 21 to an unlocked position in which the up stand 81 does not make contact with the tubular portion 83 of the actuator. A similar twist lock arrangement can be adopted in any of the other embodiments disclosed herein.

In the dispenser 520, a swirl chamber is provided immediately up steam of the spray orifice 36 by means of a projection 63. The projection 63 is formed as part of the actuator and engages in the spray insert 28 in a manner similar to that described above in relation to the second embodiment 120 and as shown in Figure 4.

The dispenser 520 in accordance with the present embodiment has a single upper spring 85 that acts both as a return spring and to control the opening of the seal valve 26. The spring 85 is a coil spring having a larger diameter upper portion 86 and a smaller diameter lower portion 87 with a conical tapering region 88 in between. The exterior of the piston within the body 23 is correspondingly shaped having a larger diameter portion 22b above a smaller diameter portion 22a connected by means of a conical or tapered region 22c. The spring is positioned about the piston so that its larger diameter portion 86 locates about the larger diameter portion 22b of the piston and its smaller diameter portion 87 locates about the smaller diameter portion 22a of the piston with the conical or tapered region 88 of the spring contacting the tapered region 22c of the piston. The upper end of the spring locates tightly about a flange 89 on the turret collar 24 so that it is fixed in position, whilst the lower end of the spring engages an upper surface of the seal valve 26 so as to bias seal valve downwardly bringing the flap 46 into contact with a stop 22d on the piston. In this position, the flap 46 seals against the piston to prevent fluid from entering the opening 44 through the piston wall into the bore 33. Rather than a taper 88, the piston may have a step between the larger and smaller diameter portions of the body and the spring shaped to engage under the step.

Operation of the spring 85 and the seal valve 26 will now be described.

When a force is applied to depress the actuator 21, the force is tends to move the piston 22 and the seal valve downwardly to reduce the volume of the liquid pump
chamber 43. However, because the ball valve 27 is closed and the liquid in the chamber is substantially incompressible, downward movement of the seal valve 26 is prevented. Accordingly, the piston 22 is moved downwardly through seal valve. Because the conical region 88 of the spring is in contact with the conical region of the piston 22c, downward movement of the piston compresses the lower smaller diameter portion 87 of the spring. This increases the spring force applied to the seal valve and hence the force applied to the liquid in the chamber 43 by the seal valve, raising the pressure of the liquid in the chamber. At the same time, the upper, larger diameter region 86 of the spring is stretched.

The piston continues to move downwardly relative to the seal valve 26 until the opening 44 in the piston is uncovered and the liquid is able to flow through the piston bore 33 to the outlet in the usual manner. Continued depression of the actuator 21 causes the piston 22 to move downwardly with the seal valve 26 also moving downwardly due to the spring force applied by the smaller diameter portion 87 of the spring thus forcing the liquid in the chamber to flow through the opening 44 to the outlet. At the same time, downward movement of the actuator 21 relative to the closure reduces the volume of the air chamber 50 forcing air through the passage 75 into the outlet nozzle as will be described in more detail below.

When the actuator 21 reaches the limit of its downward travel and all the liquid in the chamber 43 has been displaced, as shown in Figure 9, the seal valve 26 engages with a step 90 in the body and is held in contact with the step by the lower, smaller diameter portion 87 of the spring. At this stage, the upper, larger diameter portion 86 of the spring is stretched and applies a restoring force to the conical region 22c of the piston. When the user releases the actuator 21, the upper, larger diameter portion 86 of the spring acts on the conical portion 22c of the piston to pull the piston upwardly and return the piston 22 and actuator 21 to the start portion. Initially as the piston begins to move upwardly, the seal valve 26 is held in contact with the step 90 by the lower, smaller diameter portion 87 of the spring 85 so that the piston is pulled upwardly through the seal valve 26 until the stop 22d on the piston contacts the seal valve 26. At this point, the opening 44 in the piston is closed by the flap 46 on the seal valve and the seal valve 26 is constrained to move upwardly with the piston. As the
piston and seal valve 26 move upwardly within the body to the start position, a fresh charge of liquid is drawn into the chamber 43 through the ball valve 27. At the same time, the upward movement of the actuator 21 increases the volume of the air chamber 50 so that a fresh charge of air is drawn into the air chamber past the seal 51, in a similar manner to that described in relation to the previous embodiments.

The spring 85 and seal valve 26 arrangement used in this embodiment 520 can be used in any of the other embodiments 20, 120, 220, 320, 420 as described herein. Alternatively, a separate return and valve control spring arrangement can be used as described above in relation to the prior art dispenser 1.

The outlet spout 73 in the dispenser 520 can be provided with a foam passage 77 in which one or more mesh screens 78 are located to refine the foam, in a manner similar to the previous embodiment as shown in Figure 7. However, in an alternative arrangement as shown in Figures 8 and 9, the screen filter arrangement is replaced by a plug 91 of open celled foam or an equivalent three dimensional mesh in the outlet.

In the present embodiment, the plug 91 is held in an insert 92 that locates in a bore 93 of the spout. The insert 92 has a central bore 94 that aligns with the spray orifice 36 to define the outlet passage 7T at the inlet end, the bore 94 of the insert tapers at 94a to direct the liquid sprayed through the orifice 36 into the main portion of the bore 94. The bore 94 has an enlarged diameter central region 95 in which the plug is located. A locking ring 96 is moulded integrally with the actuator 21 and is connected with the spout by means of a flexible tab 97. The locking ring is a tight fit in the bore 93 of the spout and is inserted in the end of the bore 93 to hold the plug insert 92 in place after the insert 92 has been assembled into the spout 73.

The air chamber 50 is fluidly connected with the tapered inlet end of the bore 94a in the foam plug insert 92 by means of the air passage 75. During actuation of the dispenser 520, air is drawn or pushed through the passage 75 to mix with the liquid as it leaves the spray orifice 36. The mixture of air and liquid then passes along the bore 94 where it foams and passes thorough the plug 91 before exiting the nozzle through the final outlet, which in this case is defined by the inner opening of the locking ring 96.
The foam plug 91 acts in a similar manner to the mesh screens 78 to filter and refine the foam as it passes through but the plug is easier to manufacture and assemble into the dispenser nozzle than a screen mesh arrangement. This reduces manufacturing costs, which is an important consideration in the field of mass-market foam dispensers.

In tests, it has been found that a plug 91 made from open celled foam in which the average cell sizes, in situ, are in the range of 0.3 to 0.6 mm dia. are effective, with a foam having average cell sizes in the range of 0.37 to 0.5 mm dia. being particularly preferred. In its relaxed state, the foam used in the trials had cell sizes between 0.4 and 1mm dia., giving an average cell size of about 0.7 mm dia. When formed into the plug 91, the open celled foam was compressed so that the average cell size was reduced to the range specified. Two different foam plugs were tested as follows:

1) Initial foam plug size 7mm X 10mm dia. located in a chamber 6mm x 6mm dia. (compression ratio 2.9)
2) Initial foam plug size 4.5mm x 12 mm dia. located in a chamber 5mm x 3mm dia. (compression ratio 6.9)

The foam used in the trials had a density of 22 Kg/m³ with approximately 14 cells per cm in a relaxed condition. In the compressed condition, plug 1 had approximately 20 cells per cm whilst plug 2 had approximately 27 cells per cm. However, the foam need not be compressed provided it has the required density and average cell size.

The plug 91 will typically have a length in the range of 3 to 10 mm and a diameter in the range of 3 to 10 mm. Two or more foam plugs 91 could be used. The plug need not be mounted in an insert 92 but could be fitted directly into the nozzle. Any suitable open celled foam may be used provided that it is not water absorbent. Whilst it is convenient for the plug to be generally cylindrical, it can be suitable shape.

A plug of open celled foam 91 or another 3D mesh as described above can be used in any type of manual pump foam dispenser instead of a conventional mesh screen arrangement and so is not limited to use with dispensers in accordance with the invention as otherwise described herein. Accordingly, this arrangement may be
claimed independently. In addition, it has been found that use of a foam plug or 3D mesh in combination with lower ratios of air to liquid, in the order of 6:1 to 8:1, make it possible to produce foam from an aerosol dispenser, in which a liquid or gas propellant is present inside the container to pressurise the contents. Typically, the outlet nozzle of the aerosol dispenser will comprise a swirl chamber adjacent a constricted orifice and the plug or 3D mesh is positioned in an outlet tube following the orifice. Air or gas from the propellant is mixed with the liquid product. This would normally be carried out in the aerosol valve by means of a vapour phase tap prior to the swirl. This arrangement may also be claimed independently.

It has been found that the performance of the plug 93 is enhanced if the foam is passed through two or more distinct regions of the open celled material, with adjacent regions being separated by a gap. This acts in the same manner of spaced meshes, with the foam forming in the gap and being further refined as it passes through the next region of filter material. This arrangement can be provided by using two or more discrete plugs 91 in the outlet spout with a gap between each plug. However, in a particularly convenient arrangement, a single plug of material can be provided with one or more slots or openings in which none of the open celled material is present to form a gap between adjacent regions of the filter material. The slots or openings are positioned so that most of the foam passing through the plug passes through at least one gap. Figures 13a, 13b and 14a, 14b illustrate two embodiments of a modified plug 91’, 91” which each have two enlarged cavities or slots 214 to form gaps in the filter material spaced along its length. The gaps 214 are positioned so that they extend across at least a central third region of the cross sectional area of the plugs through which a majority of the liquid/foam passing through the plug will flow. The gaps 214 divide the plug into separate filter portions along its length. In the plug 91’ as shown in Figures 13a and 13b, two slots 214 extend from opposite sides of the plug across the central region. In the plug 91” shown in Figures 14a and 14b, cavities 214 are formed so as to extend only across a central region through which the majority of the foam will pass. The number and shape of the slots or cavities 214 can be varied to suit the application.
The modified plugs 91', 91" are inexpensive to manufacture and can be easily inserted into the outlet passage but have been found to highly effective. These modified plugs 91', 91" can be used in any of the foam dispenser embodiments disclosed herein.

Figure 10 shows a further embodiment of a dispenser 620 in accordance with the invention. The dispenser 620 is very similar to the dispenser 520 of the previous embodiment, except for the arrangement for sealing the actuator 21 to the closure 25 to produce an air chamber 50.

In the dispenser 620, there is no sealing member mounted to the turret collar 24. Rather a seal member 99 is formed at the lower end of the outer wall 30 of the actuator 21 for contact with the outer surface of the flange 39 on the closure 25. As can be seen best in the detailed view, the seal member 99 comprises a resiliently deformable flap 99 which angles inwardly and upwardly into contact with the flange 39. When the actuator is depressed, the flap 99 is biased into contact with the flange 39 by its resiliency. In addition the increasing air pressure inside the chamber 51 acts on the inner surface of the flap 99 helping to maintain the seal. When the actuator 21 is returned to the start position, the pressure inside the air chamber 50 falls as the volume of the chamber increases, allowing ambient air to deflect the flap away from the flange to enter the chamber. As shown in chain dotted lines in the inset detailed view in Figure 10, the flap 99 may be moulded in a position in which it projects generally in line with the outer wall 30 of the actuator and folded inwardly during assembly of the dispenser. The hinge type connection between the flap 99 and the wall 30 is resilient so that the flap is resiliently biased into contact with the flange 39 when assembled.

In this embodiment, the up stand 81 for the twist lock is provided on the turret collar 24 which also carries an inner seal member 62 for contact with the outer surface of the piston 22. The arrangement in which an up stand is provided as part of the turret collar for a twist can be adopted in any of the embodiments described herein. Indeed, a twist lock arrangement may be provided in any of the embodiments disclosed by forming an up stand on the turret collar or a separate component mounted to the turret collar which contacts a portion of the actuator or a component mounted to
the actuator to prevent the actuator being depressed when it is in a locked position. The arrangement being such that the actuator can be rotated to an unlocked position in which the portion of the actuator or other component does not contact the up stand when the actuator is depressed so that the dispenser can be actuated.

In all other respects, the dispenser 620 is the same as the previous embodiment 520 described above to which the reader should refer for details.

Although it is not necessary to use a pre-compression valve to control the flow of air from the air chamber 50 into a low pressure region of the liquid flow path, it may be advantageous to provide a one-way valve in association with the air passage 75 to prevent foam or other liquid being drawn into the air chamber 50 when the actuator recovers to the start position. Figure 11 illustrates an alternative actuator 21 for use with any of the dispensers as shown in Figures 7 to 10. In the actuator 21 as shown in Figure 11, the spray orifice and swirl chamber are located close to the center of the actuator and the air passage 75 is directed straight up into the outlet passage 77.

The insert 92 which holds foam plug 91 has a thin flange 100 of flexible material at its inner end which overlies the air passage 75 where it opens into the outlet passage 77. The flange is resiliency flexible and is deflected away from the surface of the passage 77 to admit air into the outlet passage during the dispensing cycle. When the actuator 21 returns to the start position and air is drawn into the air chamber 50, the flange covers the air passage 75 to prevent foam being drawn through the air passage 75 into the air chamber. Whilst any suitable one-way valve arrangement can be used, in the present embodiment, a valve flap is conveniently formed as an integral part of the foam plug insert 21. The insert 92 may be formed wholly of a suitably flexible material or a flexible flange can be over moulded onto a substantially rigid part of the insert to form the valve flap. The valve flap could of course be provided separately from the insert 92, for example as part of a tubular valve inserted into the bore 93.

In a further modification, the insert 92 is held in position in the actuator by means of a ridge 101 on outside of the body of the insert which locates in a corresponding groove 103 in the bore 93 of the actuator.

In the foam dispenser embodiments described above in relation to Figures 7 to 11, the liquid is sprayed through a constricted outlet nozzle orifice 36 which is
configured to break the liquid up into droplets and preferably to form a conical spray. However, in some applications where the liquid is viscous and/or where there is insufficient distance between the nozzle and the screen or plug filter, a conical spray may not be formed and the liquid will jet through the nozzle 36 adversely affecting the quality of the foam produced and may, in certain circumstances, prevent any foaming from taking place. In order to address this problem, it has been found that good quality foam can be produced by using one or more fan jets to produce a fan shaped spray rather than a cone shaped spray. This has been found to be effective with viscous fluids or in other circumstances where a cone shaped atomised spray could not be formed. The fan jet nozzle may be in the form of an elongate or eye-shaped orifice.

In a further alternative arrangement, a flood jet nozzle is used to create a sheet of liquid in the mixing chamber 74 rather than an atomised spray as such. This has also been found to be effective in producing high-quality sprays, in particular with viscous liquids. Figures 15a and 15b illustrate one embodiment of a flood jet nozzle which is being used in combination with a modified plug 91’ of expanded foam, though this is not essential. In this embodiment, the liquid is introduced into the chamber 74 through a lateral opening 218 and is directed on to a curved ramp 221 which turns the direction of movement of liquid through an angle so that it is directed on to the plug 91’. The ramp 221 may turn the liquid through an angle of approximately 90° but the angle could be anywhere between 60° and 120°. This creates a fan shaped sheet of liquid, which in the present embodiment is aligned substantially vertically when the dispenser is upright. The ramp 221 may have side walls to prevent the fan spreading and could be formed as a groove in the end wall region 222. The width of the ramp is selected as appropriate for any particular application. The lateral opening 218 and the ramp 221 are positioned substantially centrally along a diameter of the circular end wall 222. Air is introduced into the chamber 74 through a series of orifices 224 in an axial direction through the end wall 222 of the passage to mix with the liquid but the air can be introduced in any direction and in any suitable position. The surface of the ramp 221 may be smooth or it may be shaped or textured, as illustrated at 226 in Figure 16, to break up the fan of liquid into droplets. In a further alternative the ramp 221 could be constructed so that it moves
when the liquid impacts on it to break up the fan. The dispenser outlet could be
provided with more than one liquid inlet 218 and ramp 221. A further alternative
embodiment is illustrated in Figure 17 in which the liquid is introduced into the
chamber 74 though an inlet passage 228 which is aligned axially with the outlet spout
and the ramp 220 is arranged to direct the fan on to a side wall of the chamber 74 so
that it is deflected off the wall onto the plug 91'.

The above embodiments all produce a fan shaped sheet of liquid which may be
broken up in the chamber 74. Figures 18a and 18b illustrate an embodiment in which
a flood jet nozzle 36 is arranged to produce a conical sheet of liquid. In this
embodiment, the liquid flow passage has a conically divergent region 248 through
which the liquid flows into the chamber 74. A flow divider 250 is suspended centrally
within the conically divergent outlet region 248 by means of three links 252. The flow
divider has a conical region 254 which locates within the divergent outlet region 248
so that the outer surface of the conical region 254 is spaced from the surface of the
passage to define an annular frusto-conical passage 256 about the divider through
which the liquid flows to enter the chamber 74. The outer end of the flow divider is
hemispherical in this embodiment but can be any suitable shape. The liquid flowing
through the annular frusto-conical passage 256 about the divider passes through the
gaps between the links 252 to form a generally conical sheet of liquid in the chamber
74 which is directed on to a plug 91, which can be of any of the types described above
or may be replaced by any other suitable screen or filter for refining the foam. Air is
introduced separately into the chamber 74 to mix with the liquid by any suitable
means, including any of those described above in relation to Figures 15 to 17. This
arrangement differs from a cone spray nozzle as the liquid is not formed into a spray
as it passes through the jet nozzle but forms a conical sheet of liquid. This has been
found to be particularly effective at producing good quality foams with viscous liquids
which are unsuitable for producing a conical spray in the outlet of a foam dispenser of
the types used to dispense consumer products.

In most of the embodiments shown, the outlet nozzle is contained within the
actuator 21. However, the invention is also applicable the dispensers in which the
outlet nozzle is housed in a separate spout on the actuator. Where the spout is large, an additional tube may be located in the spout to house the nozzle.

In the embodiments described, the air chamber 50 is formed principally within the actuator 21. However, in some known liquid dispensers, the actuator is spaced from the closure even when fully depressed. In such cases, a bellows or other suitable structure can be provided between the actuator 21 and the closure 25 or the turret collar 24 to define an air chamber. Indeed any suitable arrangement can be adopted for providing an air chamber between the actuator and the closure and turret collar or other components that mount to the bottle or container.

In the embodiments described, the dispenser outlets are aligned generally perpendicular to the longitudinal axis of the dispenser, so as to extend generally horizontally when the dispensers are upright. However, the invention is not limited to this arrangement and the outlets can be arranged at any suitable angle. For example, the outlets could be aligned vertically, in line with the longitudinal axis of the dispenser. In this type of arrangement, the outlet nozzle orifice 36 and the swirl chamber (where provided) can be located in or on the upper end of the piston rather than in the actuator itself. Where the dispenser is a foam dispenser, a vertically extending outlet nozzle may be provided in which the mesh or plug type filters are located. The outlet nozzle will usually be formed as part of the actuator but this is not essential.

The invention is also applicable to dispensers which have a trigger handle which passes over the top of the actuator and down a front of the dispenser. The trigger handle is configured so that pulling the trigger pushes the actuator down to actuate the dispenser. It will be appreciated that such known liquid dispensers can also be adapted to form an air or foam dispenser in the manner described herein.

The presence of a pre-compression outlet valve to control the flow of liquid from liquid pump chamber is advantageous as this ensures that spraying is commenced only when the pressure of the liquid is sufficiently high to create a good quality spray. Ideally a pre-compression valve should be located close to the outlet nozzle or orifice 36 so that the pressure at the orifice builds very quickly when the valve opens and so that there is a minimum of liquid downstream from the valve.
continuing to flow through the outlet orifice when the valve closes. To this end, a pre-compression outlet valve may be located in the flow path from the liquid pump chamber close to the nozzle and configured to open to allow liquid to be dispensed only when the pressure of the liquid at the valve is above a minimum pre-determined value required to generate an acceptable quality spray in the particular application.

Figures 19a and 19b illustrate one embodiment of a pre-compression valve 260 close to spray orifice 36. The valve 260 comprises a resiliency deformable valve member 262 having a cylindrical body portion with larger diameter flange 264 at one end. The valve member 262 is located in a bore 266 forming part of the liquid flow path immediately upstream of the spray nozzle or other constricted orifice 36 with the opposite end of the body from the flange being received in the insert 28 in which the orifice is formed. The end of the body closest to the orifice abuts an inner face of the insert to define a swirl chamber 268 between the body and the insert. In this regard, the valve member takes the place of the projection 63 in the arrangement described above in relation to Figure 4. Grooves (not shown) on the end face of the body and/or on the inner surface of the insert form channels for directing the liquid into the swirl chamber. A seal land 270 projects inwardly from the surface defining the bore 266. The valve member 262 is resiliently deformable. In its initial resiliently biased configuration as shown in Figure 19b, the flange 264 is aligned with and contacts the land 270 to form a seal preventing the liquid from flowing past the valve member to the swirl chamber and the orifice. When the dispenser is actuated and liquid is delivered under pressure from the pump chamber, the liquid contacts the inner end 272 of the valve member 262 and compresses the valve member against the insert 28. As the pressure of the liquid acting on the valve member rises, the valve member is increasingly compressed until eventually the flange 264 is moved off the land 270 to open a flow path to the swirl chamber and the orifice 36, as shown in Figure 19a. The valve member 264 is constructed so that the flow path is opened only when the pressure of the liquid reaches a desired threshold value above ambient required to produce an acceptable quality spray at the orifice. When the pressure of the liquid falls off during the end phase, the valve member 264 will recover its initial shape and recloses the flow path once the pressure of the liquid falls below the threshold.
Because the valve 260 is located close to the spray nozzle 36, the build up of pressure at the spray nozzle 36 is very quick when the valve 260 opens reducing the length of the initial phase of the dispensing cycle. Similarly, once the valve closes 260 there is very little liquid remaining in the passage downstream of the valve to continue to flow through the outlet so that the end phase of the dispensing cycle is also shortened. This results in a very sharp beginning and end to the spray cycle with little spluttering or dribbling.

The valve 260 may be the only pre-compression valve used to control the flow of liquid from the liquid chamber or it may be used in addition to a pre-compression outlet valve located closer to the liquid chamber. Other types of valve could be used. For example an O-ring valve could be used in conjunction with the projection 63 in the arrangement shown in Figure 4. In addition, air from the air chamber can be introduced into the liquid flow path in the vicinity of the valve member 264 which can be arranged to also act as an air release valve.

Whilst this arrangement is most beneficial in spray dispensers, it can also be adopted in foam dispensers with the valve being located adjacent the constricted orifice. A pre-compression valve adjacent the orifice 36 can be incorporated into any of the embodiments disclosed herein.

The concept of varying the ratio of air to liquid over the dispensing cycle is not limited to application in cylindrical pump dispensers but can be applied to manual pump dispensers of all types.

Figures 20 to 22 illustrate an alternative embodiment of a dispenser 720 in accordance with the invention which is adapted to incorporate a trigger actuator.

The dispenser 720 comprises a container 300 having an open neck region 302, a dispenser cap 304 mounted to the container, and an insert 306. The dispenser cap comprises a body having a cylindrical chamber portion 308, an outlet spout portion 310 and a neck engaging portion 312. The neck engaging portion is adapted to be a push fit on the open neck region 302 of the container and has an annular abutment 314 which engages in a groove 316 formed in the outer surface of the neck region to hold
the cap firmly on the container. The neck of the container constitutes a base of the dispenser.

The insert 306 has a resiliency flexible upper diaphragm 306a which defines an air pump chamber 50 between itself and a domed upper wall 318 of the cap within the cylindrical chamber portion 308. A second, lower diaphragm or flange 306b of the insert seals against the side wall 319 of the cylindrical portion 308 of the cap to define a liquid pump chamber 43 between the side wall and the upper and lower diaphragms 306a, 306b.

The insert 306 also includes a tubular core portion 322 which inter-connects the upper and lower diaphragms and extends below the lower diaphragm. A flexible cover 324 on the lower end of the tubular core 322 mounts over and closes the open end of the neck of the container. The cover 324 is in the form of a flexible inverted dome and has a flange 326 on its outer diameter which locates over the rim of the neck and is received in a recess 328 in the neck engaging portion of the cap so as to close and seal the neck region. A leak valve arrangement (not shown) is provided to enable air to enter the container as the liquid in the container is used up, to prevent the container from collapsing. The tubular portion 322 extends from a position above the lower diaphragm 306b into a central region of the cover 324 where it is in fluid communication with a dip tube 325 which extends into the container. The dip tube 325 may be a separate component or it may be formed integrally with the insert or integrally with the container.

The insert 306 is formed from a combination of flexible and rigid materials using bi-injection moulding techniques. The tubular portion 322 is formed from a substantially rigid material. An annular disc 330 of rigid material also projects outwardly from the tubular portion to provide a base for the lower diaphragm 306b and an actuation surface for contact by a trigger actuator 332. A first region of flexible material is over moulded on to an upper region of the tubular portion to define the upper and lower diaphragms 306a, 306b. The flexible material also forms a seal 334 for the lower diaphragm and various valve members for the chambers as will be described below. A further region of flexible material is over moulded on to the lower end of the tubular portion to define the cover 324.
At an upper end of the tubular portion 322, part of side wall is omitted and an inlet 336 into the liquid pump chamber 43 is formed through the flexible material as shown in Figure 21. The inlet 336 is in the form of a slit which opens to admit liquid into the liquid chamber 43 when the pressure in the liquid chamber is below atmospheric but which is closed when the pressure in the chamber is above atmospheric so as to act as a one way inlet valve. Liquid can be drawn into the chamber 43 from the container through the dip tube 325, the tubular portion 322 and the inlet 336.

The upper diaphragm 306a is held in position adjacent an upper end of the cylindrical chamber portion 308 by means of a flange 306c which locates in an annular recess or groove in the cap. The upper diaphragm also comprises an annular flexible valve member 306d which forms a ring valve to control the release of liquid from the chamber 43 into an outlet passage 337.

An air inlet 338 for the first chamber 50 is provided in the upper wall 318. A resiliently flexible valve member 306e formed as an integral part of the upper diaphragm is positioned over the inner opening of the inlet 338 and acts as a one-way valve to admit air into the chamber when the pressure inside falls below atmospheric and to close the inlet when the dispenser is actuated and the pressure inside increases.

The dispenser 720 is configured to produce a spray and the outlet includes a spray nozzle insert 28 with an atomising nozzle 36 which is mounted at the end of the outlet sprout 310. An air outlet passage 341 from the air chamber 50 passes through the centre of the outlet spout 310. A second insert 344 is located within the first insert 340 and forms an outlet for the air passage 341 to direct air centrally into a swirl chamber 346 which is defined between the two inserts. The liquid outlet flow passage 337 from the liquid pump chamber 43 passes through the spout and is arranged to direct the liquid into the swirl chamber from the side. The liquid may be directed into the swirl chamber through a flood jet.

The trigger actuator 332 is pivotally mounted to the cap and comprises a trigger portion 348 and a curved actuating arm 350 that engages with the rigid disc 330 of the lower diaphragm 306b. In use the trigger portion 348 is pulled towards the container and the main body of the dispenser, as shown in Figure 22. This movement
results in the curved actuating arm 350 pushing on the lower diaphragm 306b to move the insert 306 upwardly (as shown) relative the cap 304 to compress the air and liquid pump chambers, and so dispense a charge of liquid. The movement of the insert 306 is accommodated by the flexibility of the cover 324. When the trigger is released, resilience in the upper diaphragm 306a and/or the cover 324 biases the insert back to the rest position as shown in Figure 20. The curved actuator arm may be bifurcated so as to contact the lower diaphragm 306b on either side of the tubular portion.

As can be seen in Figure 22, when the insert 306 is moved to its uppermost position, the upper diaphragm 306a conforms closely to the profile of the domed wall 318 so that very little dead space remains in the air pump chamber 50. The upper diaphragm also encases an upper region of the tubular portion so that very little dead space is left in the liquid pump chamber 43.

Mixing air with a liquid in a dispenser helps to improve the quality of the spray produced, particularly at the start and end of the spray cycle during which the pressure of the liquid flowing through the outlet nozzle is building up and falling away. It can also be useful to configure the dispenser so that air begins to flow from the air chamber through the nozzle before the liquid flow commences at the start of the spray cycle and that air continues to flow after the liquid has stopped at the end of the spray cycle.

Most prior art dispensers which incorporate an air chamber mix the air with the liquid at a substantially constant ratio throughout the dispensing cycle. This requires the air to be pressurised to the same pressure as the liquid during the whole of the dispensing cycle, including the main phase of the dispensing cycle when the pressure of the liquid passing through the outlet is at its peak. It also requires a relatively high volume of air meaning that a large air chamber is required. Because of these drawbacks and the additional manufacturing costs involved, air/liquid dispensers have not generally been adopted for mass market dispensers despite the known advantages of mixing air with liquid in terms of the quality of spray produced. However, the applicant has found that dispensers in accordance with the invention can be modified so that a higher ratio of air to liquid is delivered at the outlet nozzle during at least one of the initial and end phases of the dispensing cycle, where the air
is most effective at improving the quality of the spray, and a reduced ratio of air to liquid delivered during the remainder of the dispensing cycle. This reduces the volume of air required which means that a smaller air chamber can be used. In many cases, air will only be delivered from the air chamber to the nozzle during the initial and/or end phases of the dispensing cycle where the pressure of liquid is less than its peak value so that the air in the air chamber does not have to be raised to the peak pressure of the liquid.

In order for the dispenser 720 to deliver air to the nozzle before the liquid flow commences, it is necessary for the air chamber to be compressed before the outlet valve for the liquid chamber opens. However, because liquid is incompressible, this is not possible where one of the chambers is full of liquid. To overcome this problem in the present embodiment, a quantity of air is drawn into the liquid chamber 43 through the outlet nozzle during the recovery phase. A small bleed hole (not shown but typically in the order of 0.1mm in diameter) is provided in the ring valve 306d through which the air can be admitted into the liquid chamber 43 from the nozzle as the insert recovers after each actuation. Typically, about 20% of the volume of the liquid chamber is taken up by air and the remainder by liquid drawn from the container but this can be varied as required.

The presence of air in the liquid chamber 43 enables the volume of the chamber 43 to be reduced slightly before the outlet valve 306d opens. This in turn enables the insert 306 to move upwardly so that the volume of the air chamber is reduced and air begins to flow from the first chamber to the dispenser outlet 342. In the embodiment as shown, there is no outlet valve for the air chamber so that the air is able to flow from the air chamber at a relatively low pressure, which may be only just above ambient. Once the outlet valve 306d of the liquid chamber 43 opens, a mixture of air and liquid will flow along the passageway 337 to the swirl chamber 346 where it mixes with the air from the air chamber 50. Once the pressure of the liquid/air mix from the liquid chamber 43 in the passage 337 and the swirl chamber 346 rises, the flow of air from the air chamber 50 is reduced so that over the main phase of the dispensing cycle, the majority of the air in the mixture passing through the nozzle 342 comes from the liquid chamber 43 and the ratio of air to liquid in this phase is
reduced. Towards the end of the dispensing cycle after the outlet valve 306d of the liquid chamber has closed, the pressure of the liquid/air mixture from the liquid chamber in the passage 337 and the swirl chamber 346 falls and air will again begin to flow from the air chamber 50 into the swirl chamber 346 where it mixes with the liquid/air mixture from the liquid chamber 43 to improve the quality of the spray at the end of the cycle. The flow of air from the air chamber 50 at this stage also helps to draw all the liquid out of the outlet passage 337. The dispenser is arranged so that air continues to flow from the air chamber 50 or a short while after the flow of liquid has stopped to ensure all the liquid is dispensed and to clear our the nozzle 342.

In an alternative arrangement, a pre-compression one-way outlet valve (not shown) can be provided at the swirl chamber end of the outlet passage 341 from the air chamber. The air outlet valve is arranged to open at a lower pressure than the outlet valve 306d of the liquid chamber 43 so that the air begins to flow from the air chamber 50 before the liquid at the beginning of the spray cycle. Once the outlet valve 306d of the liquid chamber 43 opens, the pressure of the liquid/air mix flowing into the swirl chamber acts on the opposite side of the valve so as to close the air chamber outlet passage 341 once the pressure of the liquid/air mix increases beyond the pressure of the air in the first chamber. This will take place shortly after the dispensing cycle has begun. The valve will remain shut until the pressure of the liquid/air mixture from the liquid chamber 43 falls below that of the air in the air chamber 50 towards the end of the dispensing cycle. The air outlet valve will then re-open to allow air to flow from the air chamber 43 during the end phase of the dispensing cycle and for a short period after the flow of liquid through the nozzle has stopped.

By arranging the dispenser so that a higher ratio of air to liquid is delivered to the nozzle at the beginning and end of the dispensing cycle than during the remainder of the dispensing cycle, the quality of the spray can be maintained throughout using a lower volume of air than with previous known air/liquid dispensers and the air need only be raised to a lower pressure which may be just above atmospheric. This means that a smaller volume air chamber can be used and the actuation forces can be kept low.
By careful design of the flow rates of the liquid and air, it is possible to configure the dispenser so that it is able to deliver a continuous spray lasting anywhere from 2 to 10 seconds each time the trigger is actuated. A continuous spray is enabled in part by having a smaller than usual spray orifice to restrict the flow rate of the liquid being dispensed in combination with the addition of air, particularly at the beginning and end of the spray cycle, to ensure that the a good quality spray is produced. Any of the spray dispenser embodiments disclosed herein can be configured to produce a continuous spray.

Figure 23 illustrates a further alternative embodiment of a dispenser 820 which is configured to deliver a higher ratio of air to liquid during the initial and end phases of the dispensing cycle. The dispenser 820 has an actuator cap 21 slidably mounted to an adaptor 350 having a screw thread for mounting on the neck region of a container. The adaptor 350 constitutes a base of the dispenser and has a closed upper end with a tubular portion defining an outlet for the container when in situ. An insert 306 is mounted between the adaptor and the actuator and has a central core 322. A lower portion of the central core is received in the tubular portion of the adaptor 350. The insert has an upper diaphragm 306a which projects upwardly and radially outwardly from the core to define a liquid pump chamber 43 between itself and a domed upper surface region of the actuator. The insert also has a lower diaphragm 306b which projects radially outwardly from the core below the upper diaphragm and sealingly engages the wall of the actuator to define an air pump chamber 50 within the actuator between itself and the upper diaphragm 306a surrounding the core 322.

A bore 352 extends through the core 322 to form an inlet passage for the liquid chamber 43. The lower end of the bore 352 can be fluidly connected with a dip tube (not shown) to allow liquid to be drawn into the liquid chamber 43 from the container. A duck type one-way inlet valve 354 is located at the upper end of the bore 352 which opens to admit liquid into the chamber 43 when the pressure in the chamber is below that in the container but is closed at other times to prevent liquid flowing from the chamber back to the container.

A resiliently deformable valve flap 306d engages an outer surface of an inner edge of the domed upper surface region of the actuator to form an outlet valve for the
liquid chamber 43. The valve flap 306d is resiliently deformable and normally engages the surface to prevent liquid flowing out of the chamber through openings 356. However, when the of the liquid in the chamber 43 exceeds a first threshold pressure, the flap 306d is deformed away from the surface to allow liquid to flow through the openings into an upper annular channel 358 from where it can flow along passages 360 into a swirl chamber 362 and through an outlet nozzle 36.

A second valve flap 306e on the upper diaphragm acts as an outlet valve to control the flow of air from the air chamber 50 into a lower annular channel 364 from where it can also flow via suitable passageways into the swirl chamber 362. The upper and lower annular channels are fluidly connected so that liquid from the liquid chamber 43 is also able to enter the lower annular channel when the outlet valve 306d is open. The outlet valve 306e from the air chamber is configured to open at a lower pressure above ambient than the outlet valve 306d of the liquid chamber.

When the actuator cap 21 is depressed to dispense a liquid, the upper diaphragm 306a, which is resiliently deformable, folds down about the core 322 to reduce the volume of the air chamber 50. At the same time, the curved central portion of the diaphragm inboard of the valve flap 306d enters domed upper surface region of the actuator to reduce the volume of liquid chamber. When the actuator is first depressed, liquid in the liquid chamber 43 prevents the insert 306 from being deformed to a large extent. However, typically some air will be present in the liquid chamber owing to the presence of dead space in the chamber. This enables insert 306 to deform far enough to raise the pressure of the air in the air chamber 50 sufficiently to open the outlet valve 306e of the air chamber before the outlet valve 306d of the liquid chamber. Thus initially air begins to flow through the outlet passageway and nozzle 36 before the liquid is released from the liquid chamber 43. Once the pressure of the liquid in the liquid chamber has been raised to the appropriate threshold value, the outlet valve 306d of the liquid chamber 43 opens and liquid begins to flow through the outlet to mix with the air from the air chamber in the swirl chamber 362. During this initial phase of the dispensing cycle, the pressure of the liquid flowing through outlet increases until it becomes higher than that of the air flowing from the air chamber and some liquid will flow into the lower annular channel 364 where it
acts on and closes the outlet valve 306e of the air chamber 50. During the subsequent main dispensing phase the air outlet valve 306e is held closed by the pressure of the liquid in the channel 364. During the end phase of the dispensing cycle when the valve 206d closes, the pressure liquid in the outlet passageway falls below that of the air in the air chamber 50. This allows the air outlet valve 306e to re-open so that air again flows through the outlet passageways to the nozzle 36, helping to drive all the remaining liquid in the outlet passageways through the outlet nozzle.

Once the dispensing cycle is complete, the user releases the actuator and the resiliently deformable upper diaphragm 306a recovers to its initial configuration, as shown in Figure 23. This causes the pump chambers to reform drawing a fresh charge of liquid into the liquid chamber 43 through the inlet valve 354 and a fresh charge of air is drawn in past the edges of the lower diaphragm 306b.

In a modification, the adaptor 350 can be omitted and the insert 306 adapted to engage directly in the neck of a container as with the dispenser 720 described above. In this arrangement, the neck region of the container will constitute a base of the dispenser. It should also be noted that the dispenser 720 could be modified to include an adaptor instead of having the insert 306 mounted directly to the container.

The valve arrangement shown in Figure 23 can be adopted in a trigger actuated dispenser such as that shown in Figures 20 to 22.

As discussed above in relation to the various embodiments shown, there are numerous ways in which dispensers in accordance with the invention can be arranged to vary the ratio or air to liquid over the dispensing cycle. In arrangements were the air is introduced into a low pressure region of the liquid flow path to the outlet, the increased back pressure of the liquid flowing through the outlet passageway arrangement can be used to reduce the flow rate of the air during the main phase of the dispensing cycle. However, it is expected that in most applications at least a simple one-way valve will be required in the outlet flow path from the air chamber to prevent liquid from entering the air chamber. In this case, the dispenser can be configured so that the one-way air valve is closed or throttled during the main phase by the pressure of the liquid in the outlet passageway to either prevent air being mixed with the liquid or to reduce the flow rate of the air and so reduce the air to liquid ratio. In other
arrangements the air release valve can be a pre-compression valve which is configured to open only when the pressure of the air reaches a particular threshold value (the second threshold) above ambient. As the pressure of the air in air chamber is higher during the end phase than during the initial phase, the air chamber outlet valve threshold pressure can be set so that air is added to the liquid during both the initial and end phases or only during the end phase. Alternatively, the pre-compression valve can be arranged to stay open over the whole or the majority of the dispensing phase with the valve being partially closed or throttled during the main phase so that a reduce flow of air is added to the liquid.

Each of the various outlet valve arrangements disclosed has particular advantages and the outlet valve arrangement shown in relation any one embodiment could be incorporated into any of the other embodiments as appropriate. In this regard, patent protection for the various outlet valve arrangements may be claimed independently of any other features of the particular embodiments in which they are shown.

Depending on the nature of the dispenser, the air and liquid chambers can be shaped so that the ratio of air to liquid is varied over the dispensing cycle as the chambers are compressed. For example, the air chamber can be in the form of a cylindrical chamber which delivers a substantially constant flow rate of air as it is compressed and the liquid chamber can be shaped, say in the form of a dome, so as to deliver a lower flow rate of liquid during the initial and end phases of each actuation than during the main phase as the chamber is compressed. Other suitable shapes and combinations of shapes can be used as will be apparent to those skilled in the art.

Whereas the invention has been described in relation to what is presently considered to be the most practical and preferred embodiments, it is to be understood that the invention is not limited to the arrangements disclosed but rather is intended to cover various modifications and equivalent constructions included within the spirit and scope of the invention. For example, dispenser in accordance with the invention may have more than one liquid pump chamber so as to be able to dispenser two liquids simultaneously from different sources.
Dispensers in accordance with the invention can also be configured to deliver a liquid as a bolus rather than as a spray or foam. In this type of dispenser, air will usually be used only during the end phase of the dispensing cycle to drive out any remaining liquid from the outlet passageways when the liquid pump chamber outlet valve has closed.
Claims

1. A pump dispenser comprising a pump arrangement for mounting to a reservoir for holding a liquid to be dispensed, said pump arrangement comprising a liquid pump chamber for pumping liquid from said reservoir, an air pump chamber for pumping air and a common actuation part to simultaneously actuate the liquid pump and the air pump, the dispenser having an outlet fluid passageway arrangement for fluidly connecting the liquid pump chamber and the air pump chamber with an outlet, the dispenser further comprising an outlet valve arrangement for controlling release of liquid from the liquid pump chamber and air from the air pump chamber during a dispensing cycle, in which the dispenser is configured such that the ratio of air to liquid dispensed varies over the course of each dispensing cycle.

2. A pump dispenser as claimed in claim 1, the dispenser having in use a dispensing cycle comprising an initial phase during which the pressure of the liquid flowing through the outlet fluid passageway arrangement increases up to a nominal working pressure, a main phase during which the pressure of the liquid flowing through the outlet fluid passageway arrangement remains substantially constant at the nominal working pressure and an end phase during which the pressure of the liquid flowing through the outlet fluid passageway arrangement falls back from the nominal working pressure, in which the dispenser is configured such that the ratio of air to liquid dispensed during the main phase is lower than in at least one of the end phase and the initial phase.

3. A pump dispenser as claimed in claim 2, in which the dispenser is configured such that no air is dispensed from the air pump chamber during the main phase.

4. A pump dispenser as claimed in claim 3, in which the dispenser is configured to dispense air from the air chamber only during the end phase.

5. A pump dispenser as claimed in claim 3, in which the dispenser is configured to dispense air from the air chamber only during the initial phase.
6. A pump dispenser as claimed in any one of claims 1 to 5, in which the
dispenser is configured to deliver an overall ratio of air to liquid in the range of
4:1 to 12:1 over each full dispensing cycle.

7. A pump dispenser as claimed in any one of claims 1 to 5, in which the
dispenser is configured to deliver an overall ratio of air to liquid in the range of
6:1 to 8:1 over each full dispensing cycle.

8. A pump dispenser as claimed in any one of the previous claims, in which the
dispenser is configured so that in use during each actuation, the air in the air
chamber is raised to a peak pressure which is less than the peak pressure
achieved by the liquid in the liquid pump.

9. A pump dispenser as claimed in claim 8, in which the dispenser is configured
such that the liquid in the liquid pump chamber is raised to a peak pressure in
the range of 0.3 to 1 MPa (3 to 10 bar), and more particularly in the range of
0.4 to 0.6 MPa (4 to 6 bar), and the air in the air pump chamber is raised to a
peak pressure in the range of 0.05 to 0.6 MPa (0.5 to 6 bar).

10. A pump dispenser as claimed in any one of the previous claims, in which the
outlet valve arrangement comprises a first outlet valve arrangement for
controlling the flow of liquid from the liquid pump chamber to the outlet, and
a second outlet valve arrangement for controlling the flow of air from the air
chamber to the outlet, in which the first outlet valve arrangement comprises a
pre-compression valve configured to open to allow liquid to flow from the
liquid pump chamber to the outlet only when the liquid is at or above a first
threshold pressure above ambient and the second outlet valve arrangement
comprises a one-way valve configured to permit air to flow from the air
chamber towards the outlet but to prevent the flow of fluid in the opposite
direction.

11. A pump dispenser as claimed in claim 10, in which the first outlet valve
arrangement comprises a pre-compression valve located adjacent an outlet
orifice of the dispenser.
12. A pump dispenser as claimed in claim 11, in which a the first outlet valve arrangement comprises a further pre-compression outlet valve located proximal to the liquid pump chamber.

13. A pump dispenser as claimed in any one of claims 10 to 12, in which the second outlet valve arrangement comprises a pre-compression valve configured to permit air to flow from the air chamber to the outlet only when the air in the air chamber is at or above a second threshold pressure above ambient.

14. A pump dispenser as claimed in claim 13, in which the second threshold pressure is lower than the first threshold pressure.

15. A pump dispenser as claimed in any one of the previous claims, in which the dispenser comprises a base and a dispensing cap having an outlet mounted to the base, the dispenser further comprising an insert mountable between the base and the cap to define the liquid and air pump chambers between itself and the cap, the insert being adapted to engage with the base to define an inlet through which a fluid can be drawn into the pump chamber from a fluid source, in which the insert comprises a central core and a resiliency flexible upper diaphragm member projecting upwardly and generally radially outwardly from the core for contact with the cap to at least partially define the pump chambers within the cap, the insert being deformable between an initial resiliently biased configuration in which the volume of the pump chambers is at a maximum and a deformed configuration in which the volume of the pump chambers is at a minimum, in the deformed configuration, the upper diaphragm being at least partially folded down about itself and/or the core.

16. A pump dispenser as claimed in any one of claims 1 to 14, in which the dispenser comprises a mounting member for mounting the dispenser to the reservoir about an opening, a generally cylindrical pump body located within the mounting member for projection into the reservoir and a turret for positioning the body within the mounting member, the dispenser further having a piston movably mounted within the body, a fluid seal member operative between the piston and inner surface of the body to define a fluid
pump chamber within the body and an actuator mounted to, or operatively connected with the piston, and means for defining an air pump chamber within the actuator or between the actuator and the fluid pump assembly.

17. A pump dispenser as claimed in any one of the previous claims, in which the dispenser comprises a trigger actuator.

18. A pump dispenser as claimed in any one of the previous claims, in which the dispenser is configured to dispense a liquid as a spray.

19. A pump dispenser as claimed in claim 18, in which the dispenser is configured to dispense a continuous spray of liquid for a period of between 2 to 10 seconds on each actuation.

20. A pump dispenser as claimed in any one of claims 1 to 17, in which the dispenser is configured to dispense a liquid as a foam.

21. A pump dispenser as claimed in any one of the previous claims, in which the dispenser has two liquid chambers and is configured to simultaneously dispense two different liquids from two liquid sources.

22. A pump dispenser as claimed in claim 1, in which the dispenser is configured such that in use during the dispensing cycle, air begins to flow through the outlet passageway arrangement before liquid is released from the liquid pump chamber.

23. A pump dispenser as claimed in claim 1 or claim 23, in which the dispenser is configured such that in use during the dispensing cycle, air continues to flow through the outlet passageway arrangement for a limited amount of time after all the liquid has been dispelled from the outlet passageway.
# INTERNATIONAL SEARCH REPORT

## A. CLASSIFICATION & SUBJECT MATTER

### INV

**B05B11/00**

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

### B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

**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

<table>
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<tr>
<th>Category</th>
<th>Citation of document with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No</th>
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<td>A</td>
<td>JP 09 118352 A (YOSHINO KOGYOSHO CO LTD) 6 May 1997 (1997-05-06) abstract</td>
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### D

Further documents are listed in the continuation of Box C

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<td>document referring to an oral disclosure, use, exhibition or other means</td>
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| **T** | later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle of theory underlying the invention |
| **X** | document of particular relevance, the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone |
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| **S** | document member of the same patent family |

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Name and mailing address of the ISA/Authorized officer:

European Patent Office, P.B 5818 Patentlaan 2 NL - 2280 HV Rijswijk
Tel (+31-70) 340-2040, Fax (+31-70) 340-3016

Eberwein, Michael
<table>
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<td>WO 9316809</td>
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