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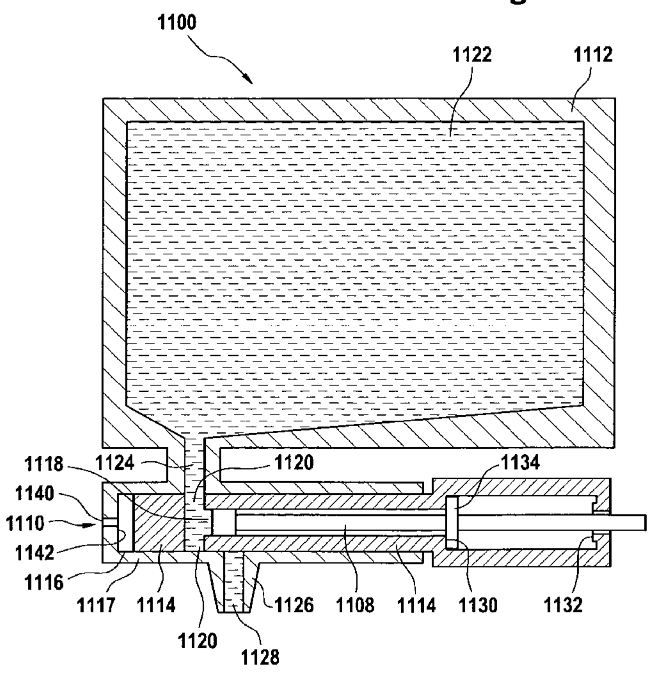
(54) Title: CARTRIDGE FOR DISPENSING A FLUID

Fig. 11



(57) Abstract: A cartridge (100, 414, 502, 502', 502", 1100, 1300, 1350, 1902', 1902") for dispensing fluid (214, 610, 1302, 1302', 1516). The cartridge comprises a valve (110, 1100), wherein the valve comprises a pumping chamber (118, 1118) for pumping the fluid. The valve is operable for positioning a pumping chamber conduit (120, 1120). The pumping chamber conduit is connected with the pumping chamber. The cartridge further comprises a plunger (1108) operable for changing the volume of the pumping chamber. The cartridge further comprises a reservoir conduit (124, 1214) for connecting the reservoir with the valve. The valve is operable for positioning the pumping chamber conduit to connect with the reservoir conduit. The cartridge further comprises an outlet conduit (128, 1128) for dispensing the fluid. The rotary valve is further operable for rotating the pumping chamber conduit to connect with the outlet conduit.

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Cartridge for dispensing a fluid

Description

Field of the invention

The invention relates to cartridges for dispensing a fluid. The invention further relates to an automatic analyzer for dispensing the fluid using the cartridge.

Background and related art

In medical laboratories, in vitro diagnostics are commonly performed on biological samples such as blood, urine, blood plasma and saliva. Such tests may be performed manually using pipettes or maybe performed using an automatic analyzer. Automatic analyzers may automatically add reagents to the biological sample and may measure one or more parameters of the biological sample during analysis. Automatic analyzers are known in the prior art. For example, European patent EP 1 959 257 A2 discloses an automatic analyzer including a reagent cassette holding mechanism for holding a plurality of reagent cassettes.

United States patent US 7,955,302 B2 discloses a dosing device for an infusion system comprising a dosing unit having a variable volume and at least one opening in fluid connection with the variable volume.

Summary

The invention provides for a cartridge for dispensing fluid and an automatic analyzer in the independent claims. Embodiments are described in the dependent claims.

The present invention provides for a cartridge for dispensing a fluid. In some embodiments The cartridge comprises a rotary valve which may be moved in a circular fashion to position a pumping chamber conduit coming from a pumping chamber. Rotation of the rotary valve enables the pumping chamber conduit to be connected to one of a variety of other conduits. The pumping chamber is formed by a cavity within the rotary valve and by a plunger which is operable for changing the volume of the pumping chamber. In some other embodiments a linear valve is used for positioning the pumping chamber conduit.

The cartridge comprises a reservoir for storing the fluid and an outlet conduit for dispensing a fluid. A reservoir conduit connects the reservoir with the valve. In some embodiments, the outlet conduct conduit connects an outlet nozzle to the valve. As the valve is moved in different positions the pumping chamber conduit can be positioned at either the reservoir conduit or the outlet conduit. In some embodiments the valve and the plunger may be able to be operated or actuated independently of each other. Embodiments of this cartridge may have the advantage that they can be operated such that the cartridge does not lose any fluid or that the fluid loss due to priming can be reduced.

A controller as used herein encompasses a device, machine, or apparatus for controlling the operation and/or function of one or more other devices. Examples of a controller may include, but are not limited to: a computer, a processor, an imbedded system or controller, a programmable logic controller, and a microcontroller. A 'computing device' or 'computer' as used herein encompasses to any device comprising a processor. A 'processor' as used herein encompasses an electronic component which is able to execute a program or machine executable instruction.

A 'computer-readable storage medium' as used herein encompasses any tangible storage medium which may store instructions which are executable by a processor of a computing device. The computer-readable storage medium may be referred to as a computer-readable non-transitory storage medium.

'Computer memory' or 'memory' is an example of a computer-readable storage medium. Computer memory is any memory which is directly accessible to a processor or other controller. 'Computer storage' or 'storage' is an example of a computer-readable storage medium. Computer storage is any non-volatile computer-readable storage medium.

A 'user interface' as used herein is an interface which allows a user or operator to interact with a computer or computer system.

A 'hardware interface' as used herein encompasses a interface which enables a processor or other controller to interact with and/or control an external computing device and/or apparatus. A hardware interface may allow a processor to send control signals or instructions to an external computing device and/or apparatus. The hardware interface may enable the processor or other controller to receive sensor data and control the dispensing of the fluid. The hardware interface may be used to form a closed control loop in some embodiments.

In one aspect the invention provides for a cartridge for dispensing fluid. The cartridge comprises a valve. The valve comprises a pumping chamber for pumping the fluid. The valve is operable for positioning a pumping chamber conduit. The pumping chamber conduit is connected with the pumping chamber. The valve further comprises a plunger operable for changing the volume of the pumping chamber. The valve further comprises an reservoir conduit (124, 1214) for connecting the reservoir with the valve, wherein the valve is operable for positioning the pumping chamber conduit to connect with the reservoir conduit. The valve further comprises an outlet conduit for dispensing the fluid. The rotary valve is further operable for rotating the pumping chamber conduit to connect with the outlet conduit.

In another aspect the invention provides for a cartridge for dispensing fluid. The cartridge comprises a rotary valve. The rotary valve comprises a pumping chamber for pumping the fluid. The rotary valve is operable for rotating a pumping chamber conduit. The pumping chamber conduit is connected with the pumping chamber. In other words there is a rotary valve which has a pumping chamber conduit connected to a pumping chamber within it. By rotating the rotary valve the pumping chamber conduit can be rotated into different positions thereby allowing the pumping chamber to be connected to other conduits.

The cartridge further comprises a plunger operable for changing the volume of the pumping chamber. The rotary valve and the plunger are operable for being actuated independently. In other words the plunger and the rotary valve are able to be operated such that the plunger can be used to change the volume of the pumping chamber without affecting the position of the rotary valve and vice versa. This may enable a larger set of pumping actions by the pumping chamber.

The cartridge further comprises a reservoir for storing the fluid. The reservoir can be constructed in a variety of ways. In some embodiments the reservoir may be a hard walled chamber, preferably made of plastics using injection moulding or thermoforming processes. In some embodiments the reservoir may be a chamber with a flexible wall. In some embodiments the reservoir could be a pouch or bladder. In other embodiments the reservoir could be a pouch or bladder supported by an outer container. In other embodiments the reservoir could be a tube.

The cartridge further comprises a reservoir conduit for connecting the reservoir with the rotary valve. The rotary valve is operable for rotating the pumping chamber conduit to connect with the reservoir conduit. When the pumping chamber conduit is rotated into the correct position then there is communication between the pumping chamber and the reservoir.

The cartridge further comprises an outlet conduit for dispensing the fluid and for connecting to the rotary valve. The rotary valve is further operable for rotating the pumping chamber conduit to connect to the outlet conduit. This embodiment may have the advantage that a large variety of pumping actions can be performed with the pumping chamber by controlling the rotational position of the rotary valve and properly operating the plunger. For instance the rotary valve may be positioned such that the pumping chamber conduit is connected to the reservoir conduit. In this case the plunger may be used to either withdraw fluid from the reservoir into the pumping chamber or may be used to pump the fluid from the pumping chamber back into the reservoir.

The present embodiment may enable other types of actions using the pumping chamber. For instance when the pumping chamber conduit is aligned or connected with the reservoir conduit the plunger may be repeatedly used to increase and decrease the volume of the pumping chamber. This may enable the fluid within the reservoir to be mixed. Also the ability to put the fluid back into the reservoir may reduce the amount of fluid that is wasted.

This embodiment may also enable a so called reduced waste priming or non-waste priming function of the pumping chamber whereby none or possibly only a very small amount of the fluid is wasted or discarded when fluid is pumped out through the outlet conduit. For instance when the pumping chamber conduit is connected with the outlet conduit the plunger may be used to decrease the volume of the pumping chamber and thereby force or dispense fluid out through the outlet conduit. During the process of doing this there may be fluid within the outlet conduit which does not exit the outlet conduit. After the correct amount of fluid has been dispensed the plunger may then be used to increase the volume of the pumping chamber thereby withdrawing fluid that may remain within the outlet conduit back into the pumping chamber. Fluid could then be held within the pumping chamber or if the rotary valve is rotated into alignment with the reservoir conduit the fluid which was previously within the outlet conduit may be pumped back into the reservoir.

The rotary valve may also provide a means of preventing fluid from accidentally leaking from the reservoir. For instance the rotary valve may be able to be rotated in some embodiments to a position where it is neither aligned with the outlet conduit nor with the reservoir conduit. This may prevent fluid and/or gas from exiting from the outlet conduit and/or from fluid and/or gas in a reservoir leaking or draining into the pumping chamber.

In another embodiment the cartridge further comprises an outlet nozzle connected to the outlet conduit. An outlet nozzle as used herein encompasses a nozzle design to minimize the waste of fluid and may enables drops to cleanly drip during the dosing process. For instance in a simple tube a drop of the fluid may hang outside the nozzle after the plunger is used to decrease the volume of the pumping chamber. The shape or function of the outlet nozzle can be designed to reduce the chances of a drop of the fluid hanging on it. For instance the outlet nozzle may have a so called duckbill shape and be a duckbill nozzle.

In other embodiments the cartridge may have additional reservoirs and additional reservoir conduits which enable the pumping chamber to be connected to these additional reservoirs. Typically a cartridge may contain only a single fluid or reagent. In some embodiments this may be a diluent that is used or required for various tests. There may also be multiple reservoirs which may be each connected to a conduit accessible to the pumping chamber conduit at a particular rotational position of the rotary valve.

For example for many clinical tests there may be two reservoirs and for immunoassays there may be two or three different fluids within different reservoirs. In some variations of this embodiments the cartridge may have multiple pumping units, with each of the pumping units being connected to one or more reservoirs via its rotary valve. In this way the immunoassays are dispensed using separate pumping units and they are not mixed by the pumping process.

In another embodiment the cartridge further contains a return conduit connected to the reservoir. The pumping chamber conduit is operable for receiving fluid from a first portion of the reservoir. The return conduit is operable for returning fluid to a second portion of the reservoir. The rotary valve is further operable for rotating the pumping chamber conduit to connect to the return conduit. This embodiment may be beneficial because it may for instance reduce the effect of potentially occurring gas bubbles when fluid is returned to the reservoir. This embodiment may further have the benefit of reducing the number of bubbles within the first portion of the reservoir by transmitting the bubbles to the second portion of the reservoir.

For instance fluid could be drawn from the reservoir when the rotary valve is rotated such that the pumping chamber conduit is in alignment with the reservoir conduit. After a certain amount of the fluid has been dispensed through the outlet conduit the rotary valve might be rotated into such a position such that the pumping chamber conduit is in alignment with the return conduit. The reservoir conduit may draw fluid from one portion of the reservoir and the return conduit is used to return the fluid to a different portion of the reservoir. For instance the two locations of the reservoir conduit and the return conduit could be far enough away that it is unlikely that bubbles which enter the reservoir through the return conduit are drawn into the reservoir conduit when fluid is drawn from the reservoir into the pumping chamber.

In another embodiment the cartridge further comprises a secondary reservoir. The cartridge further comprises a secondary reservoir conduit. The rotary valve is further operable for rotating the pumping chamber conduit to connect to the secondary reservoir conduit. This embodiment may be beneficial because it may enable a second or distinct fluid to be stored and dispensed using the cartridge, it may also enable waste fluid to be disposed of in the secondary reservoir.

It should be noted that additional reservoirs may be added to the cartridge by adding a third reservoir and a third reservoir conduit, a fourth reservoir and a fourth reservoir conduit, and so on so that any number of reservoirs and reservoir conduits may be added to the cartridge.

In another embodiment the cartridge further comprises a connecting conduit. The connecting conduit is operable for transporting fluid between the secondary reservoir and the reservoir. This embodiment may be beneficial because the connecting conduit may enable the secondary reservoir to be used as a place to deposit fluid in order to return it to the reservoir.

In another embodiment the cartridge comprises a membrane blocking the connecting conduit. The membrane is permeable to the fluid. This embodiment may be beneficial because it may provide a means of filtering fluid or blocking of gas bubbles when fluid is returning from the secondary reservoir into the reservoir.

In another embodiment the secondary reservoir comprises a bubble guiding structure. A bubble guiding structure as used herein encompasses a structure which is used to guide a gas bubble to a predetermined location in a reservoir or towards a vent. In some implementations the bubble guiding structure may allow fluid to pass around the bubble as it is moving through the reservoir. For instance a bubble structure may be a set of ridges which are used to position and guide a bubble. The structures and ridges may be spaced close enough together such that the surface tension of the fluid prevents the bubble from going into regions which allow the fluid to go around the bubble. This may be beneficial because if the bubble is not properly confined the bubble may get stuck at a particular position in the secondary reservoir and not allowed to go to the top of the secondary reservoir or in the case where there is a connecting conduit to allow the fluid to return to the reservoir.

In another embodiment the reservoir and/or the secondary reservoir comprises a vent. A vent as used herein is a structure which enables air bubbles or other gas volumes to enter or leave the cartridge. Alternatively, the reservoir comprises such a vent or both the reservoir and the second reservoir comprise such vents

In another embodiment the vent is covered or sealed with a filter. The filter is operable for sealing the fluid in the cartridge. The filter may be hydrophobic in some embodiments. In some embodiments the gas filter may have micropores to only let gas through, but no liquids. In some embodiments the filter may be, but is not limited to: a porous form of polytetrafluoroethylene, carbon fibers, carbon fibers coated with PTFE, carbon nanotubes, polymer fibers, or fluoropolymer fibers

In another embodiment the fluid comprises magnetic beads.

In another embodiment the fluid comprises latex beads.

In another embodiment the fluid comprises a blood grouping reagent.

In another embodiment the fluid comprises an immune reagent.

In another embodiment the fluid comprises an antibody.

In another embodiment the fluid comprises an enzyme.

In another embodiment the fluid comprises a recombinant protein.

In another embodiment the fluid comprises a virus isolate.

In another embodiment the fluid comprises a virus.

In another embodiment the fluid comprises a biological reagent.

In another embodiment the fluid comprises a solvent.

In another embodiment the fluid comprises a diluent.

In another embodiment the fluid comprises a dispersion.

In another embodiment the fluid comprises nanoparticles.

In another embodiment the fluid comprises a protein.

In another embodiment the fluid comprises a salt.

In another embodiment the fluid comprises a detergent.

In another embodiment the fluid comprises a nucleic acid.

In another embodiment the fluid comprises an acid.

In another embodiment the fluid comprises a base.

In another embodiment the fluid may comprise a particles suspension, a liquid reagent, a liquid adhesive, a liquid food product, a liquid metal (e.g., a solder), and/or any other liquid

In another embodiment the cartridge further comprises a sensor operable for metering fluid dispensed by the outlet conduit. For instance this sensor may be a capacitive or optical sensor.

In another embodiment the cartridge further comprises a coupling assembly for attaching the rotary valve and the plunger to an actuator assembly. This embodiment may be beneficial because it may enable the rotary valve and the plunger to be conveniently connected to an actuator. The coupling assembly in some embodiments may enable the rotary valve and the plunger to be actuated independently by the actuator assembly.

In some embodiments it may be possible to have a cartridge with its own actuator. In this case the cartridge further comprises an actuator. In some cases the actuator may be connected to the coupling assembly or the actuator may be designed or operable for directly actuating the rotary valve and the plunger independently.

A pumping unit as used here encompasses the rotary valve and plunger for pumping the fluid. When installed into an automatic analyzer there may be one actuator per pumping unit or there may be one actuator which is moved and used to actuate all of the cartridges within the automatic analyzer. In this case there may be a mechanism for moving the relative positions between the cartridge and the single actuator. There may also be an actuator for a group of cartridges.

For example there may be different configurations for the cartridge. In some embodiments the cartridge may have a single pumping unit. This single pumping unit may have conduits connected to different reservoirs. This may enable the cartridge to pump different types of fluids from the same cartridge. In another example the cartridge may have multiple pumping units, with each of the pumping units being connected to one or more reservoirs via its rotary valve.

In some embodiments, the cartridge comprises a pumping unit and an attachable reservoir. This embodiment may be beneficial, because a universal pumping unit can be created and reservoirs attached to it when needed. This may facilitate having a larger variety of fluids available. Reservoirs of different volumes may also be selected. Different pumping units may also be selected. Such different pumping units may for instance have plungers with a different stroke and/or diameter. This may affect the volume of the pumping unit. In some applications it may be desirable to pump a larger volume more accurately and in other applications a smaller but more accurate pumping volume may be desired. So, the use of a pumping unit and an attachable reservoir allows to realize a modular concept which allows to combine reservoirs comprising different types and/or volumes of fluids with an pumping unit which is optimized to dispense a defined volume of this fluid. This modular concept allows to provide a large set of optimized cartridges based on a small set of pumping units and/or reservoirs which can be combined in different ways. The assembly of the pumping unit and the attachable reservoir can be performed on the factory site as a manufacturing step during the cardridge production or on the user site, e.g. by assembing the pumping unit with the attachable reservoir before inserting the cartridge into an automatic analyzer.

In another embodiment the rotary valve comprises a cylindrical portion. The pumping chamber is a cavity within the rotary valve. The pumping chamber is formed by the cavity and the plunger. The cartridge comprises a cartridge body with a cylindrical space for receiving the cylindrical portion. The rotary valve is operable for rotating within the cylindrical space.

In another embodiment the reservoir conduit and the outlet conduit are located on the cylindrical space. The pumping chamber conduit is located on the cylindrical portion.

In another embodiment the cartridge comprises multiple pumping units.

In another embodiment the cartridge comprises multiple reservoirs.

In another embodiment the multiple reservoirs are filled with different fluids.

In another aspect the invention provides for an automatic analyzer for for analyzing a biological sample. The automatic system is operable for holding a cartridge according to an embodiment of the invention. The automatic analyzer comprises an actuator assembly operable for actuation of the plunger and of the valve. The automatic analyzer further comprises a controller (520, 1920) for controlling the operation of the actuator assembly.

In another aspect the invention provides for an automatic analyzer for holding a cartridge according to an embodiment of the invention. An automatic analyzer as used herein encompasses a system for automatically analyzing a biological sample. The automatic analyzer comprises an actuator assembly operable for linear actuation of the plunger and for rotational actuation of the rotary valve. The actuator assembly is further operable for actuating the plunger and the rotary valve independently. The automatic analyzer further comprises a controller for controlling the operation of the actuator assembly.

In some embodiments the automatic analyzer may be adapted for holding multiple cartridges according to an embodiment of the invention. In this case there may be a mechanism for providing relative movement between the cartridges and a reaction tube / cuvette. There may be one actuator per pumping unit or there may be one actuator used for multiple cartridges. In this case there may be a mechanism or a robotic system for providing relative movement between the cartridge and the actuator. There may also be embodiments where there are multiple actuators each used for a group of cartridges. The group of cartridges could be predetermined or the group of cartridges may be determined on the fly. Alternatively, multiple actuators may be used for a cartridge or a group of cartridges, e.g. for different purposes like pre-dispensing or post-dispensing actions.

In another embodiment the automatic analyzer comprises the cartridge.

In another embodiment the controller is operable for controlling the actuator assembly to rotate the pumping chamber conduit to connect with the reservoir conduit by rotating the rotary valve. The controller is further operable for controlling the actuator assembly to fill the pumping chamber by increasing the volume of the pumping chamber with the plunger. The controller is further operable for controlling the actuator assembly to rotate the pumping chamber conduit to connect with the outlet conduit by rotating the rotary valve. The controller is further operable for controlling the actuator assembly to pump the fluid through the outlet conduit by decreasing the volume of the pumping chamber with the plunger. This embodiment may be beneficial because it provides a method of pumping fluid through the outlet conduit.

In another embodiment the controller is operable for controlling the actuator assembly to receive the fluid from the outlet conduit by increasing the volume of the pumping chamber with the plunger.

In another embodiment the controller is operable for controlling the actuator assembly to rotate the pumping chamber conduit to connect with the reservoir conduit by rotating the rotary valve. The controller is further operable for controlling the actuator assembly to return the fluid to the reservoir by decreasing the volume of the pumping chamber with the plunger. This embodiment may be advantageous because it provides operation of the pump without priming. 100% or nearly 100% of the fluid may be used.

In another embodiment the controller is operable for controlling the actuator assembly to rotate the pumping chamber conduit to connect with the reservoir conduit by rotating the rotary valve. The controller is further operable for controlling the actuator assembly to mix the fluid in the reservoir by repeatedly increasing and decreasing the volume of the pumping chamber with the plunger. In the case where the fluid contains beads or particles such as magnetic or latex beads this embodiment may be used to mix the fluid and its compounds.

In another embodiment the the cartridge comprises an outlet nozzle. The automatic analyzer further comprises a meniscus detector for detecting a meniscus of the fluid. The controller is operable for controlling the actuator to force fluid through the outlet nozzle. The controller is further operable for detecting the meniscus using the meniscus detector. The controller is further operable for controlling the actuator to halt the forcing of fluid through the outlet when the meniscus is in a predetermined location. This embodiment may be beneficial because it may enable more accurate and more precise dispensing of the fluid. This embodiment may be beneficial because if the meniscus is in the same place when the fluid dispensing starts then the dispensing of the fluid may be more accurate, more precise and/or more reproducible. The meniscus may be inside or outside the outlet nozzle. For instance the outlet nozzle may be a long tube-like structure and the meniscus may have a particular position within the tube. In other embodiments the meniscus may be formed by a drop of the fluid hanging from the outlet nozzle. In many applications, the meniscus is preferably positioned right at the orifice of the outlet nozzle.

In another embodiment the controller is further operable for controlling the actuator to force a predetermined volume of fluid through the outlet. In some embodiments the actuator may be controlled to force the predetermined volume of fluid through the outlet nozzle after the meniscus is in the predetermined location.

In another embodiment the meniscus detector is any one of the following: a capacitive sensor, an optical sensor and a camera. When the meniscus is inside of the nozzle a capacitive sensor may be used to detect the location of the meniscus. In case the nozzle is optically transparent an optical sensor may also be used to determine the location of the meniscus within the nozzle. If the meniscus extends beyond the nozzle then a capacitive sensor, an optical sensor or a camera may each be used to determine the location of the meniscus.

In another embodiment the automatic analyzer is operable to hold multiple cartridges. Each of the multiple cartridges is according to an embodiment of the invention.

In another embodiment the automatic analyzer further comprises the multiple cartridges.

The embodiment with the multiple cartridges may be implemented in a variety of ways. For example each pumping unit may have its own actuator assembly. This may be a parallel operation. In another example cartridges may be moved and put onto the same actuator assembly or an actuator assembly may be moved between different cartridges or even between different pumping units that are part of the same cartridge. In yet other embodiments there may be multiple actuators and cartridges are moved via a mechanical robotic system between these multiple actuators.

In another embodiment the automatic analyzer comprises a sensor or metering system operable for measuring or metering the dispensing of the fluid. The controller is operable for controlling the dispensing of the fluid in accordance with measurements or data received from the sensor or metering system. In other words the controller is operable for forming a closed loop control system with the sensor or metering sytem for controlling the dispensing of the fluid.

In another aspect the invention provides for a method of operating a cartridge according to an embodiment of the invention. The method comprises the steps of: rotating the rotary valve to rotate the pumping chamber conduit to connect with the reservoir conduit; increasing the volume of the pumping chamber with the plunger to fill the pumping chamber; rotating the rotary valve to rotate the pumping chamber conduit to connect with the outlet conduit; decreasing the volume of the pumping chamber with the plunger to pump the fluid through the outlet conduit.

In another embodiment the method further comprises the step of increasing the volume of the pumping chamber with the plunger to retrieve the fluid from the outlet conduit.

In another embodiment the method further comprises the steps of: rotating the rotary valve to rotate the pumping chamber conduit to connect with the reservoir conduit; and decreasing the volume of the pumping chamber with the plunger to return the fluid to the reservoir.

In another embodiment the method further comprises the steps of: rotating the rotary valve to rotate the pumping chamber conduit to connect with the reservoir conduit; and repeatedly increasing and decreasing the volume of the pumping chamber with the plunger to mix the fluid in the reservoir.

In one aspect the invention provides for a cartridge for dispensing fluid. The cartridge comprises a slide valve. The slide valve has rectilinear motion. The slide valve may also be referred to as a rectilinear valve. The slide valve comprises a pumping chamber for pumping the fluid. The slide valve is operable for translating a pumping chamber conduit. The pumping chamber conduit is connected with the pumping chamber. The cartridge further comprises a plunger operable for changing the volume of the pumping chamber. The cartridge further comprises a reservoir for storing the fluid. The cartridge further comprises a reservoir conduit for connecting the reservoir with the slide valve. The slide valve is operable for translating the pumping chamber conduit to connect with the reservoir conduit. The cartridge further comprises an outlet conduit for dispensing the fluid. The slide valve is further operable for translating the pumping chamber conduit to connect with the outlet conduit. This embodiment may be beneficial because the combination of the slide valve and the plunger allow accurate dispensing of the fluid. Further the embodiment may also enable a reduced amount of waste fluid produced when dispensing fluid by the cartridge.

Embodiments may also have the advantage that a large set of pumping actions by the pumping chamber are possible. This embodiment may have the advantage that a large variety of pumping actions can be performed with the pumping chamber by controlling the translation position of the slide valve and properly operating the plunger. For instance the slide valve may be positioned such that the pumping chamber conduit is connected to the reservoir conduit. In this case the plunger may be used to either withdraw fluid from the reservoir into the pumping chamber or may be used to pump the fluid from the pumping chamber back into the reservoir.

The present embodiment may enable other types of actions using the pumping chamber. For instance when the pumping chamber conduit is aligned or connected with the reservoir conduit the plunger may be repeatedly used to increase and decrease the volume of the pumping chamber. This may enable the fluid within the reservoir to be mixed. Also the ability to put the fluid back into the reservoir may reduce the amount of fluid that is wasted.

This embodiment may also enable a so called reduced waste priming or non-waste priming function of the pumping chamber whereby none or possibly only a very small amount of the fluid is wasted or discarded when fluid is pumped out through the outlet conduit. For instance when the pumping chamber conduit is connected with the outlet conduit the plunger may be used to decrease the volume of the pumping chamber and thereby force or dispense fluid out through the outlet conduit. During the process of doing this there may be fluid within the outlet conduit which does not exit the outlet conduit. After the correct amount of fluid has been dispensed the plunger may then be used to increase the volume of the pumping chamber thereby withdrawing fluid that may remain within the outlet conduit back into the pumping chamber. Fluid could then be held within the pumping chamber or if the slide valve is translated into alignment with the reservoir conduit the fluid which was previously within the outlet conduit may be pumped back into the reservoir.

The slide valve may also provide a means of preventing fluid from accidentally leaking from the reservoir. For instance the slide valve may be able to be translated in some embodiments to a position where it is neither aligned with the outlet conduit nor with the reservoir conduit. This may prevent fluid and/or gas from exiting from the outlet conduit and/or from fluid and/or gas in a reservoir leaking or draining into the pumping chamber.

In some embodiments, the cartridge comprises a pumping unit and an attachable reservoir. This embodiment may be beneficial, because a universal pumping unit can be created and reservoirs attached to it when needed. This may facilitate having a larger variety of fluids available. Reservoirs of different volumes may also be selected. Different pumping units may also be selected. Such different pumping units may for instance have plungers with a different stroke and/or diameter. This may affect the volume of the pumping unit. In some applications it may be desirable to pump a larger volume more accurately and in other applications a smaller but more accurate pumping volume may be desired.

The use of a pumping unit and an attachable reservoir may allows to realization a modular system which allows to the combination of reservoirs comprising different types and/or volumes of fluids with an pumping unit which is optimized to dispense a defined volume of this fluid. This modular system may provide a large set of optimized cartridges based on a small set of pumping units and/or reservoirs which can be combined in different ways. The assembly of the pumping unit and the attachable reservoir can be performed on the factory site as a manufacturing step during the cardridge production or on the user site, e.g. by assembling the pumping unit with the attachable reservoir before inserting the cartridge into an automatic analyzer.

The reservoir can be constructed in a variety of ways. In some embodiments the reservoir may be a hard walled chamber, preferably made of plastics using injection moulding or thermoforming processes. In some embodiments the reservoir may be a chamber with a flexible wall. In some embodiments the reservoir could be a pouch or bladder. In other embodiments the reservoir could be a pouch or bladder supported by an outer container. In other embodiments the reservoir could be a tube.

In some embodiments the pumping chamber conduit is aligned with the reservoir conduit and/or outlet conduit using mechanical stops. As an alternative to using mechanical stops, the alignment can also be achieved by other means. For example by spatially defined changes of physical or geometrical properties, e.g. by changes in friction coefficients or diameter. In other embodiments mechanical stops are not used and the alignment is performed by an actuator system which is attached to the cartridge during use.

In another embodiment the cartridge further comprises an outlet nozzle connected to the outlet conduit. An outlet nozzle as used herein encompasses a nozzle design to minimize the waste of fluid and may enables drops to cleanly drip during the dosing process. For instance in a simple tube a drop of the fluid may hang outside the nozzle after the plunger is used to decrease the volume of the pumping chamber. The shape or function of the outlet nozzle can be designed to reduce the chances of a drop of the fluid hanging on it. For instance the outlet nozzle may have a so called duckbill shape and be a duckbill nozzle.

In other embodiments the cartridge may have additional reservoirs and additional reservoir conduits which enable the pumping chamber to be connected to these additional reservoirs. Typically a cartridge may contain only a single fluid or reagent. In some embodiments this may be a diluent that is used or required for various tests. There may also be multiple reservoirs which may be each connected to a conduit accessible to the pumping chamber conduit at a particular rectilinear position of the slide valve.

For example for many clinical tests there may be two reservoirs and for immunoassays there may be two or three different fluids within different reservoirs. In some variations of this embodiments the cartridge may have multiple pumping units, with each of the pumping units being connected to one or more reservoirs via its slide valve. In this way the immunoassays are dispensed using separate pumping units and they are not mixed by the pumping process.

In some embodiments the slide valve and the plunger are operable for being actuated independently. In other embodiments the plunger or the actuation of the plunger is used to also actuate the slide valve.

In another embodiment the cartridge further comprises a return conduit connected to the reservoir. The pumping chamber conduit is operable for receiving fluid from a first portion of the reservoir. The return conduit is operable for returning fluid to a second portion of the reservoir. The slide valve is further operable for translating the pumping chamber conduit to connect to the return conduit. This embodiment may have the benefit of reducing the number of bubbles within the first portion of the reservoir by transmitting the bubbles to the second portion of the reservoir.

For instance fluid could be drawn from the reservoir when the slide valve is translated such that the pumping chamber conduit is in alignment with the reservoir conduit. After a certain amount of the fluid has been dispensed through the outlet conduit the slide valve might be translated into such a position such that the pumping chamber conduit is in alignment with the return conduit. The reservoir conduit may draw fluid from one portion of the reservoir and the return conduit is used to return the fluid to a different portion of the reservoir. For instance the two locations of the reservoir conduit and the return conduit could be far enough away that it is unlikely that bubbles which enter the reservoir through the return conduit are drawn into the reservoir conduit when fluid is drawn from the reservoir into the pumping chamber.

In another embodiment the cartridge further comprises a secondary reservoir. The cartridge further comprises a secondary reservoir conduit. The slide valve is further operable for translating the pumping chamber conduit to connect to the secondary reservoir conduit. This embodiment may be beneficial because it may enable a second or distinct fluid to be stored and dispensed using the cartridge, it may also enable waste fluid to be disposed of in the secondary reservoir.

In another embodiment the secondary reservoir comprises a vent. A vent as used herein is a structure which enables air bubbles or other gas volumes to enter or leave the cartridge. Alternatively, the reservoir comprises such a vent or both the reservoir and the secondary reservoir comprise such vents.

It should be noted that additional reservoirs may be added to the cartridge by adding a third reservoir and a third reservoir conduit, a fourth reservoir and a fourth reservoir conduit, and so on so that any number of reservoirs and reservoir conduits may be added to the cartridge. The additional reservoirs may also comprise vents.

In another embodiment the cartridge further comprises a connecting conduit. The connecting conduit is operable for transporting fluid between the secondary reservoir and the reservoir. This embodiment may be beneficial because the connecting conduit may enable the secondary reservoir to be used as a place to deposit fluid in order to return it to the reservoir.

In another embodiment the cartridge comprises a membrane or grid or filter located within the connecting conduit. If a membrane is used, the membrane is permeable to the fluid. Such membranes are described, e.g. in "Unimpeded Permeation of Water Through Helium-Leak–Tight Graphene-Based Membranes" (R. R. Nair et al.; Science 335, 442 (2012). If a grid or mechanical filter is used, the mesh or hole size has to be smaller than the gas bubble size to prevent the gas bubbles from transition through the grid or filter. This embodiment may be beneficial because it may provide a means of filtering fluid or blocking of gas bubbles when fluid is returning from the secondary reservoir into the reservoir.

In another embodiment the secondary reservoir comprises a bubble guiding structure. A bubble guiding structure as used herein encompasses a structure which is used to guide a gas bubble to a predetermined location in a reservoir or towards a vent. In some implementations the bubble guiding structure may allow fluid to pass around the bubble as it is moving through the reservoir. For instance a bubble structure may be a set of ridges which are used to position and guide a bubble. The structures and ridges may be spaced close enough together such that the surface tension of the fluid prevents the bubble from going into regions which allow the fluid to go around the bubble. This may be beneficial because if the bubble is not properly confined the bubble may get stuck at a particular position in the secondary reservoir and not allowed to go to the top of the secondary reservoir or in the case where there is a connecting conduit to allow the fluid to return to the reservoir.

In another embodiment, the reservoir and/or the the secondary reservoir comprises a vent. The vent is sealed with a filter. The filter is permeable to air. The filter is operable for sealing the fluid in the cartridge. The filter may be hydrophobic in some embodiments. In some embodiments the gas filter may have micropores to only let gas through, but no liquids. In some embodiments the filter may be, but is not limited to: a porous form of polytetrafluoroethylene, carbon fibers, carbon fibers coated with PTFE, carbon nanotubes, polymer fibers, or fluoropolymer fibers

In another embodiment the fluid comprises magnetic beads.

In another embodiment the fluid comprises latex beads.

In another embodiment the fluid comprises a blood grouping reagent.

In another embodiment the fluid comprises an immune reagent.

In another embodiment the fluid comprises an antibody.

In another embodiment the fluid comprises an enzyme.

In another embodiment the fluid comprises a recombinant protein.

In another embodiment the fluid comprises a virus isolate.

In another embodiment the fluid comprises a virus.

In another embodiment the fluid comprises a biological reagent.

In another embodiment the fluid comprises a solvent.

In another embodiment the fluid comprises a diluent.

In another embodiment the fluid comprises a dispersion.

In another embodiment the fluid comprises nanoparticles.

In another embodiment the fluid comprises a protein.

In another embodiment the fluid comprises a salt.

In another embodiment the fluid comprises a detergent.

In another embodiment the fluid comprises a nucleic acid.

In another embodiment the fluid comprises an acid.

In another embodiment the fluid comprises a base.

In other embodiments, the fluid is a particle suspension, a liquid reagent, a liquid adhesive, a liquid food product, a liquid metal (e.g. a solder) or any other liquid.

In another embodiment the cartridge further comprises a sensor operable for metering fluid dispensed by the outlet nozzle. For instance this sensor may be a capacitive or optical sensor.

In another embodiment the cartridge further comprises a coupling assembly for attaching the slide valve and the plunger to an actuator assembly. In some embodiments the coupling assembly only attaches to the plunger. In other embodiments the coupling assembly attaches to both the slide valve and to the plunger so that they may be actuated independently.

In some embodiments it may be possible to have a cartridge with its own actuator. In this case the cartridge further comprises an actuator. In some cases the actuator may be connected to the coupling assembly or the actuator may be designed or operable for directly actuating the slide valve and the plunger independently.

A pumping unit as used here encompasses the slide valve and plunger for pumping the fluid. When installed into an automatic analyzer there may be one actuator per pumping unit or there may be one actuator which is moved and used to actuate all of the cartridges within the automatic analyzer. In this case there may be a mechanism for moving the relative positions between the cartridge and the single actuator. There may also be an actuator for a group of cartridges.

For example there may be different configurations for the cartridge. In some embodiments the cartridge may have a single pumping unit. This single pumping unit may have conduits connected to different reservoirs. This may enable the cartridge to pump different types of fluids from the same cartridge. In another example the cartridge may have multiple pumping units, with each of the pumping units being connected to one or more reservoirs via its slide valve.

In another embodiment the cartridge comprises multiple pumping units.

In another embodiment the cartridge comprises multiple reservoirs.

In another embodiment the multiple reservoirs are filled with different fluids.

In another embodiment the slide valve comprises a piston. The pumping chamber is a cavity within the piston. The pumping chamber is formed by the cavity and the plunger. The piston is operable for translational motion within the volume.

The piston and the volume may have different cross-sectional shapes which corresponds to each other. For instance, both the piston and the corresponding volume may have a round, oval, or other cross-sectional shape.

In another embodiment the piston and the slide valve are operable for co-linear motion. In other words the piston and the slide valve are operable to have translational motion that is parallel or in the same direction.

In another embodiment the slide valve comprises a reservoir conduit mechanical stop for aligning the pumping chamber conduit with the reserve conduit. In other words there is a mechanical stop which aligns the piston such that the pumping chamber conduit is aligned with the reservoir conduit.

In another embodiment the slide valve comprises an outlet conduit mechanical stop for aligning the pumping chamber conduit with the outlet conduit. In other words the slide valve has a mechanical stop which aligns the piston such that the pumping chamber conduit lines up with the outlet conduit.

In another embodiment the piston comprises two plunger mechanical stops for limiting the motion of the plunger relative to the piston. The plunger is operable for actuating the piston. This embodiment may be beneficial because it enables the cartridge to be operated with a single linear actuator. This is particularly true when there are the combined embodiments of also having a reservoir conduit mechanical stop and an outlet conduit mechanical stop.

In another aspect the invention provides for an automatic analyzer for analyzing the biological sample. The automatic analyzer is operable for holding a cartridge according to an embodiment of the invention. The automatic analyzer comprises an actuator assembly operable for linear actuation of the plunger and the slide valve.

The actuator assembly may have either one or two actuators depending upon the design of the cartridge. For instance in some embodiments the linear actuator may only actuate the plunger. In other embodiments there may be a linear actuator which actuates the slide valve and the plunger independently. The automatic analyzer further comprises a controller for controlling the operation of the actuator assembly.

In another embodiment the automatic analyzer comprises the cartridge.

In another embodiment the automatic analyzer is operable for holding a cartridge according to an embodiment. The piston comprises two plunger mechanical stops for limiting the motion of the plunger relative to the piston and where the plunger is operable for actuating the piston. The actuator assembly is operable for linear actuation of the plunger. This embodiment may be beneficial because only a single linear actuator is used.

The actuation of the slide valve is done through or by the plunger.

In another embodiment the actuator assembly is operable for a separate linear actuation of the plunger and for the linear actuation of the slide valve. In this embodiment there are two linear actuators in the actuator assembly and the plunger and the slide valve are actuated independently. This embodiment may be beneficial because it enables more complex behavior or pumping protocols by the automatic analyzer.

In another embodiment the controller is operable for controlling the actuator assembly to translate the pumping chamber conduit to connect with the reservoir conduit by translating the slide valve. The controller is further operable for controlling the actuator assembly to fill the pumping chamber by increasing the volume of the pumping chamber with a plunger. The controller is further operable for controlling the actuator assembly to translate the pumping chamber conduit to connect with the outlet conduit by translating the slide valve. The controller is further operable for controlling the actuator assembly to pump the fluid through the outlet conduit by decreasing the volume of the pumping chamber with the plunger.

Translating the slide valve is equivalent herein to translating the piston in those embodiments where the slide valve has a piston.

In another embodiment the controller is operable for controlling the actuator assembly to translate the pumping chamber conduit to connect with the reservoir conduit by translating the slide valve. The controller is further operable for controlling the actuator assembly to return the fluid to the reservoir by decreasing the volume of the pumping chamber with a plunger. This embodiment may be advantageous because it provides operation of the pump without priming. 100% or nearly 100% of the fluid may be used.

In another embodiment the controller is operable for controlling the actuator assembly to translate the pumping chamber conduit to connect with the reservoir conduit by translating the slide valve. The controller is further operable for controlling the actuator assembly to mix the fluid in the reservoir by repeatedly increasing and decreasing the volume of the pumping chamber with the plunger. In the case where the fluid contains beads or particles such as magnetic or latex beads this embodiment may be used to mix the fluid and its compounds.

In another embodiment the controller is further operable for controlling the actuator assembly to retrieve fluid from the outlet conduit by increasing the volume of the pumping chamber with the plunger.

In another embodiment the cartridge comprises an outlet nozzle. The automatic analyzer further comprises a meniscus detector for detecting the meniscus of the fluid. The controller is further operable for controlling the actuator assembly to force fluid through the outlet nozzle. The controller is further operable for detecting the meniscus using the meniscus detector. The controller is further operable for controlling the actuator to halt the forcing the fluid through the outlet when the meniscus is in a predetermined location. This embodiment may be beneficial because it may enable more accurate and more precise dispensing of the fluid. This embodiment may be beneficial because if the meniscus is in the same place when the fluid dispensing starts then the dispensing of the fluid may be more accurate, more precise and/or more reproducible. The meniscus may be inside or outside the outlet nozzle.

For instance the outlet nozzle may be a long tube-like structure and the meniscus may have a particular position within the tube. In other embodiments the meniscus may be formed by a drop of the fluid hanging from the outlet nozzle. In many applications, the meniscus is preferably positioned right at the orifice of the outlet nozzle.

In another embodiment the controller is further operable for controlling the actuator to force a predetermined volume of fluid through the outlet. In some embodiments the actuator may be controlled to force the predetermined volume of fluid through the outlet nozzle after the meniscus is in the predetermined location.

In another embodiment the meniscus detector is any one of the following: a capacitive sensor, an optical sensor and a camera. When the meniscus is inside of the nozzle a capacitive sensor may be used to detect the location of the meniscus. In case the nozzle is optically transparent an optical sensor may also be used to determine the location of the meniscus within the nozzle. If the meniscus extends beyond the nozzle then a capacitive sensor, an optical sensor or a camera may each be used to determine the location of the meniscus.

In another embodiment the automatic analyzer is operable to hold multiple cartridges. Each of the multiple cartridges is according to an embodiment of the invention.

In another embodiment the automatic analyzer further comprises the multiple cartridges.

The embodiment with the multiple cartridges may be implemented in a variety of ways. For example each pumping unit may have its own actuator assembly. This may be a parallel operation. In another example cartridges may be moved and put onto the same actuator assembly or an actuator assembly may be moved between different cartridges or even between different pumping units that are part of the same cartridge. In yet other embodiments there may be multiple actuators and cartridges are moved via a mechanical robotic system between these multiple actuators.

In another embodiment the automatic analyzer is operable to hold multiple cartridges. Each of the multiple cartridges is according to an embodiment of the invention. In this case there may be a mechanism for providing relative movement between the cartridges and a reaction tube / cuvette. There may be one actuator per pumping unit or there may be one actuator used for multiple cartridges. In this case there may be a mechanism or a robotic system for providing relative movement between the cartridge and the actuator. There may also be embodiments where there are multiple actuators each used for a group of cartridges. The group of cartridges could be predetermined or the group of cartridges may be determined on the fly. Alternatively, multiple actuators may be used for a cartridge or a group of cartridges, e.g. for different purposes like pre-dispensing or post-dispensing actions.

In another embodiment the automatic analyzer comprises a sensor or metering system operable for measuring or metering the dispensing of the fluid. The controller is operable for controlling the dispensing of the fluid in accordance with measurements or data received from the sensor or metering system. In other words the controller is operable for forming a closed loop control system with the sensor or metering system for controlling the dispensing of the fluid.

In another aspect the invention provides for a method of operating the cartridge according to an embodiment of the invention. The method comprises the step of translating the slide valve to translate the pumping chamber conduit to connect with the reservoir conduit. The method further comprises the step of increasing the volume of the pumping chamber with the plunger to fill the pumping chamber. The method further comprises the step of translating the slide valve to translate the pumping chamber conduit to connect with the outer outlet conduit. The method further comprises the step of decreasing the volume of the pumping chamber with the plunger to pump the fluid through the outlet conduit.

Embodiments descriptive of an automatic analyzer may also be be applicable to an automatic system for dispensing fluids.

In another aspect the invention provides for an automatic system for dispensing fluids. The automatic system is operable for holding a cartridge according to an embodiment of the invention. The automatic system comprises an actuator assembly (200, 400, 904, 904', 904") operable for linear actuation of the plunger and of the slide valve. The automatic system further comprises a controller (920) for controlling the operation of the actuator assembly.

In another embodiment the actuator assembly is operable for linear actuation of the plunger.

In another embodiment the automatic system is operable for separate linear actuation of the plunger and for linear actuation of the slide valve.

In another embodiment the cartridge comprises an outlet nozzle (126). The automatic analyzer further comprises a meniscus detector (1002, 1002', 1002") for detecting a meniscus of the fluid. The controller is operable for: controlling the actuator assembly to force fluid through the outlet nozzle; detecting the meniscus using the meniscus detector; and controlling the actuator to halt the forcing of fluid through the outlet when the meniscus is in a predetermined location.

It is understood that one or more claims and/or embodiments may be combined as long as the combined elements are not mutually exclusive.

Brief description of the drawings

In the following embodiments of the invention are explained in greater detail, by way of example only, making reference to the drawings in which:

Fig.1 illustrates a cartridge and an actuator assembly according to an embodiment of the invention;

Fig. 2 illustrates how the cartridge may be used to pump fluid through the outlet conduit;

Fig. 3 illustrates a pumping method similar to that shown in Fig. 2 except additional steps are performed to remove fluid from the outlet conduit;

Fig. 4A and 4B illustrates how fluid can be pumped through the outlet conduit where the fluid is taken from the reservoir and then excess fluid from the outlet nozzle and outlet conduit is pumped into the secondary reservoir;

Fig. 5 illustrates an automatic analyzer according to an embodiment of the invention;

Fig. 6 illustrates a bubble guide according to an embodiment of the invention;
Fig. 7 illustrates an automatic analyzer according to a further embodiment of the invention;
Fig. 8A, 8B, 8C, and 8D illustrate the operation of a cartridge using a meniscus detector;
Fig. 9 illustrates the correlation of the target volume and measured volume for an embodiment of a rotary valve;
Fig. 10 shows a plot indicating the accuracy and the coefficient of variation for the dispensing of fluids of different viscosities and surface tensions by an embodiment of a rotary valve
Fig. 11 shows a cartridge according to an embodiment;
Fig. 12 shows the cartridge of Fig. 1 connected to an actuator assembly;
Fig. 13A shows a cartridge according to a further embodiment;
Fig. 13B shows a cartridge according to a further embodiment;
Fig. 14 shows the cartridge of Fig. 2 connected to an actuator assembly;
Fig. 15A and 15B show views on different phases of the slide valve and plunger of the embodiment shown in Fig. 1;
Fig. 16A and 16B illustrate a slide valve and a piston combination according to a further embodiment;
Fig. 17 shows two views of a slide valve and plunger combination according to a further embodiment;
Fig. 18A and 18B illustrate one way of operating the slide valve and piston of the embodiment shown in Fig. 3;
Fig. 19 illustrates an automatic analyzer according to an embodiment;
Fig. 20 illustrates an automatic analyzer according to a further embodiment;
Fig. 21 shows a cartridge according to a further embodiment
Fig. 22 illustrates an alternative slide valve design;
Fig. 23 illustrates an alternative slide valve design;
Fig. 24 illustrates an alternative slide valve design;
Fig. 25 illustrates an alternative slide valve design;
Fig. 26 illustrates an alternative slide valve design; and
Fig. 27 illustrates an alternative slide valve design.

Detailed description

Like numbered elements in these figures are either equivalent elements or perform the same function. Elements which have been discussed previously will not necessarily be discussed in later figures if the function is equivalent.

Fig. 1 illustrates a cartridge 100 and an actuator assembly 102 according to an embodiment of the invention. The actuator assembly 102 comprises a linear actuator 104 which is able to actuate in direction 105. The actuator assembly 102 further comprises a rotational actuator 106 able to actuate in the direction 107.

The cartridge 100 comprises a plunger 108 and a rotary valve 110. The cartridge 100 comprises a cartridge body 112 which has a cylindrical space 116. In this case the cylindrical space 116 is formed by a bearing material. The rotary valve 110 has at least a cylindrical portion 114 adapted to fit into the cylindrical space 116 of the cartridge body 112. The rotary valve 110 has a hollow space which forms a pumping chamber 118 which is formed by the hollow space and the plunger 108. The pumping chamber 118 has a pumping chamber conduit 120 which is formed in a wall of the rotary valve 110. The rotary valve 110 is operable for rotating within the cylindrical space 116 to position the pumping chamber conduit 120 at different angular positions.

The cartridge 100 further comprises a reservoir 122 for being filled with a liquid. It is not shown in Fig. 1 but the cartridge 100 may also comprise a vent for allowing gas to be vented into the reservoir 122. The cartridge 100 further comprises a reservoir conduit 124. The reservoir conduit 124 provides the reservoir 122 access to the pumping chamber conduit 120 when the pumping chamber conduit is in the correct rotational position. The cartridge 100 also comprises an optional outlet nozzle 126 for dispensing the fluid. The outlet nozzle 126 is connected to an outlet conduit 128. The outlet conduit 128 allows the pumping chamber 118 to dispense the fluid. The outlet conduit 128 in this embodiment is connected to the outlet nozzle 126 when the pumping chamber conduit 120 is in the correct rotational position. There is further shown a coupling assembly 130 which couples the actuator assembly 102 to the cartridge 100. The coupling assembly 130 is designed for being and actuating the piston 108 in the linear direction 105. The coupling assembly 130 is also adapted for being able to independently rotate the rotary valve 110. For instance there may be grooves cut into the rotary valve 110 and there may be a shape on the coupling assembly 130 which mates into the groove of the rotary valve 110. The example shown in Fig. 1 is only one way in which the rotary valve 110 and the piston 108 may be actuated. Other equivalent mechanisms may also be used to actuate and attach to the rotary valve 110 and the piston 108.

Fig. 2 illustrates four views 200, 202, 204, 206 of the cartridge 100. Fig. 2 illustrates how the cartridge 100 may be used to pump fluid through the outlet conduit128. In view 200 the pumping chamber conduit 120 is aligned with the reservoir conduit 124. The plunger 108 is fully depressed and the pumping chamber 118 has no volume or is extremely small. In this example the plunger 108 is fully depressed. However, fully depressing the plunger 108 is not a requirement for the operation. In the examples described herein the relative motion of the plunger is what is relevant. For example, depressing the plunger 108 causes the volume of the pumping chamber to decrease and this forces the fluid through the outlet conduit.

Next in view 202 the plunger is withdrawn in direction 208. This causes fluid from the reservoir 122 to enter the pumping chamber 118. Next in view 204 the rotary valve 110 is rotated 210 such that the pumping chamber conduit 120 is aligned with the outlet conduit 128. The pumping chamber 118 is now isolated from the reservoir 122. Next in view 206 the plunger 108 is depressed in direction 212 and fluid 214 exits via the outlet conduit 128.

Fig. 3 illustrates a pumping method similar to that shown in Fig. 2 except additional steps are performed to remove fluid from the outlet nozzle 126 and the outlet conduit 128. The same views 202, 204 and 206 are again shown. There are three additional views 300, 302 and 304 of the cartridge 100 are presented. The step according to view 300 is performed after view 206. The plunger 108 is withdrawn in the direction 306 to withdraw fluid from the outlet nozzle 126 in the outlet conduit 128. In this example the plunger 108 is withdrawn enough such that a bubble 208 forms in the pumping chamber 118. Next in view302 the rotary valve 110 is rotated in direction 310 such that the pumping chamber conduit 120 is aligned with the reservoir conduit 124. Finally in view 304 the plunger 108 is depressed in direction 312 thereby forcing fluid out of the pumping chamber 118 into the reservoir 122. In addition the bubble 308 was also forced into the reservoir 122.

Figs. 4A and 4B shows seven views 400, 402, 404, 406, 408, 410, 412 of a different embodiment of a cartridge 414. In this embodiment the cartridge 414 has a reservoir 122 and a secondary reservoir 416. Fig. 4 illustrates how fluid 214 can be pumped through the outlet conduit 128 where the fluid is taken from the reservoir 122 and then excess fluid from the outlet nozzle 126 and outlet conduit 128 is pumped into the secondary reservoir 416. In this cartridge 414 it can be seen that there is a connecting conduit 418 between the reservoir 122 and the secondary reservoir 416. The connecting conduit 418 is not necessarily present in all embodiments. In some alternative embodiments there is also a membrane which is permeable to the fluid may be placed some place in the connecting conduit 418. View 400 shows the plunger 108 as being fully depressed and the pumping chamber conduit 120 being aligned with the reservoir conduit 124. Next in view 402 the plunger is withdrawn in direction 420 filling the pumping chamber 118 with the fluid 214. Next in view 404 the rotary valve 110 is rotated such that the pumping chamber conduit 120 is aligned with the outlet conduit 128.

The rotary valve is rotated in direction 422. Next in view 406 the plunger 108 is depressed in direction 424 and fluid 214 is forced out of the outlet conduit 128. Next in view 408 the plunger 108 is withdrawn in the direction 426 to withdraw the fluid 214 that was previously in the outlet conduit 128 and the pumping chamber conduit 120 back into the pumping chamber 118. Next in view 410 a rotary valve 110 is rotated in direction 428 to align the pumping chamber conduit 120 with the secondary reservoir conduit 430. Finally in view 412 the plunger 108 is depressed in direction 432 driving the bubble 308 and the fluid 126 into the secondary chamber 416. In some embodiments the secondary chamber 416 may have a vent to atmosphere. In some embodiments the vent may be covered with a filter which allows gas to pass but which keeps the fluid 416 from exiting the cartridge 414. In view 412 the pumping chamber conduit 120 and the secondary reservoir conduit 430 are being shown as being filled with the bubble 308..

Fig. 5 illustrates an automatic analyzer 500 according to an embodiment of the invention. This automatic analyzer is shown as having three cartridges 502, 502' and 502". There is an actuator assembly 504 connected to cartridge 502. There is an actuator assembly 504' attached to cartridge 502'. There is an actuator assembly 504" attached to cartridge 502". The actuator assemblies 504, 504', 504" are for actuating the rotary valve and plunger of the cartridges 502, 502', 502". The automatic analyzer 500 is shown as having a relative movement means 510 which provides relative movement 512 between a reagent container or cuvette 506 and the cartridges 502, 502' and 502". The reagent container or cuvette 506 is shown as containing a biological sample 508. The cartridges 502, 502', 502" may be used to add one or more fluids to the biological sample 508. The automatic analyzer 500 is shown as further containing a sensor system 514. The sensor system comprises one or more sensors for measuring a quantity or a physical or chemical or biochemical property of the biological sample 508. For example the sensor system 514 may comprise an nuclear magnetic resonance (NMR) system, an optical transmission or reflectance measurement system, a pH meter, a camera system, a polymerase chain reaction (PCR) apparatus, a Electrochemiluminescence (ECL) apparatus, a spectroscopic measurement system, an electrochemical or an optical sensor, and a chromatography system. The relative movement means 510 is also operable for moving the reagent container or cuvette 506 to the sensor system 514.

The arrangement of the cartridges 502, 502', 502" and the sensor system 514 is representative. In some embodiments the reagent container or cuvette 506 may remain in a fixed position and the cartridges 502, 502', 502" may move. The actuation systems 504, 504', 504" and the sensor system 514 are shown as being connected to a hardware interface 522 of a computer system 520. The computer system 520 functions as a controller for the automatic analyzer 500. The computer 520 is further shown as containing a processor 524 which is able to control the operation and function of the automatic analyzer 500 using the hardware interface 522. The processor 524 is shown as further being connected to a user interface 526, computer storage 528 and computer memory 530. The computer storage 528 is shown as containing an analysis request 532. The analysis request 532 contains a request to analyze the biological sample 508.

The computer storage 528 is shown as further containing sensor data 534 received from the sensor system 514. The computer storage 528 is shown as further containing an analysis result 536 which was determined using the sensor data 534. The computer memory 530 contains a control module 540. The control module 540 contains computer executable code which enables the processor 524 to control the operation and function of the automatic analyzer 500. For instance the control module 540 may use the analysis request 532 to generate commands to generate and send to the actuation systems 504, 504', 504", the sensor system 514 and the relative movement system 510. The control module 540 may also generate the analysis result 536 using the sensor data 534.

Various algorithms may be used for controlling the dispensing of the fluid in different embodiments. For instance the actuator assembly may be controlled by the processor to perform a series of predetermined actions to dispense the fluid. In another example a sensor or metering system could be integrated into the automatic analyzer to measure the dispensing of the fluid. In this case a algorithm which uses the actuator assembly and the sensor to form a closed loop feedback to accurately control or meter the dispensing of the fluid.

Fig. 6 illustrates a bubble guiding structure 600 according to an embodiment of the invention. The bubble guiding structure 600 may for instance be located within a reservoir or secondary reservoir of a cartridge according to an embodiment of the invention. The bubble guiding structure 600 comprises a bubble channel 602 surrounded by various fluid channels 604. The bubble channel 602 provides a path for a bubble 606. The fluid channels 604 have a space or width 608 which is narrow enough such that the bubble 606 is prevented from entering the fluid channel 604 by the surface tension of the fluid. The bubble channel 602 confines the bubble 606 and allows the bubble to rise while allowing the fluid 610 to go around the bubble.

Fig. 7 illustrates a automatic analyzer 700 according to an embodiment of the invention that is similar to the embodiment shown in Fig. 5. The automatic analyzer 700 is similar to the automatic analyzer 500 shown in figure 5. The automatic analyzer 700 of figure 7 additionally has a meniscus detector 702, 702', 702". Each meniscus detector 702, 702', 702" is positioned adjacent to the outlet nozzle 126. The meniscus detector 702, 702', 702" are each connected to the hardware interface 522. This enables the processor 524 to control the actuator assemblies 504, 504', 504" to control the location of the meniscus. This for instance may enable the processor to more accurately and or reproducibly dispense fluid from the cartridges 502, 502', 502".

Figure 8 shows 11 views 800, 802, 804, 806, 808, 810, 812, 814, 816, 818, 822 illustrates the functioning of a cartridge 100 in conjunction with a meniscus detector 702. In these examples the meniscus detector 702 is an optical sensor. The use of the optical sensor 702 is exemplary. Other types of sensors may also be used.

In view 800 the pumping chamber conduit 120 has been rotated into position such that it is aligned with the reservoir conduit 124. The plunger 108 is shown in this view 800 as being fully depressed. The pumping chamber 118 is therefore extremely small and is not visible in this view 800. The position of this plunger 108 in this position is not necessarily required as long as the plunger 108 is still able to increase or withdraw a reasonable amount of fluid 214 from the reservoir 122. Next in view 802 the plunger 108 is withdrawn to increase the volume of the pumping chamber 118 and draw fluid 214 from the reservoir 122 into the pumping chamber 118. Next in view 804, the pumping chamber conduit 120 is rotated into position such that is it is aligned with the outlet conduit 128.

In view 806 the plunger 108 is depressed which decreases the volume of the pumping chamber 118. This forces fluid 214 into the outlet conduit 128 and the outlet nozzle 126. The plunger 108 is controlled in accordance with the meniscus detector 702. When the meniscus 822 reached a predetermined position the meniscus detector 702 was used to detect this and the depression of the plunger 108 was halted. Next in view 808 the pumping chamber conduit 120 is again rotated into alignment with the reservoir conduit 124. In view 810 the plunger 108 is withdrawn thereby increasing the volume of the pumping chamber 118 and drying fluid 214 from the reservoir 122. Next in view 812 the pumping chamber conduit 120 is rotated into position so that it is aligned the outlet conduit 128. The pumping chamber 118 is filled with the fluid and the meniscus a 22 is in the predetermined location. Next in view 814 the plunger 108 is depressed forcing fluid out of the outlet nozzle 126. It can be seen in view 814 that there is still fluid within the outlet conduit 128 and the outlet nozzle 126. Next in view 816 the plunger 108 is retracted to withdraw the fluid 214 that was in the outlet conduit 128 and the outlet nozzle 126 back in two the pumping chamber 118 in view 818 the pumping chamber conduit 120 is rotated into position with the reservoir conduit 124. Then finally in view 820 a 20 the plunger 108 is depressed forcing the fluid back into the reservoir 122. A bubble 308 which was inside the pumping chamber is forced out of the pumping chamber and into the reservoir 122.

Fig. 9 illustrates the correlation of the target volume and measured volume for an embodiment of a rotary valve comprising a pumping chamber volume of 10 µL. Fig. 9 shows a plot of the target volume (in µL) 900 vs the measured volume (in µL) 902. The measured points are connected by a linear fit indicated by the dashed line 904. For each data point water was used as the test fluid. The measured volume has been determined using a calibrated scale. Each data point indicates an average of three trials performed for the same target volume. In each trial or run, the pumping was repeated 24 times. In other words, at each target volume three trials or runs were performed. For each of these three runs, the fluid was dispensed 24 times and averaged. The data shown in Fig. 9 illustrate both the very high accuracy (small error bars, even for very small target volumes) and linearity (linear fit is very close to the ideal bisector line) over an large range of target volumes which can be achieved by using an rotary valve according to the invention.

Fig. 10 shows a plot indicating the accuracy and the coefficient of variation (CV) for the dispensing of fluids by an embodiment of a rotary valve comprising a pumping chamber volume of 10 µL for fluids of different viscosities and surface tensions. The X-axis 1000 indicates the viscosity of 19 different fluids A-S in terms of mPas. The left Y-axis 1002 indicates the surface tension of each of these fluids in terms of mN/m. The plot of viscosity vs. surface tension for each fluid is indicated by the line 1004. The measured volume has been determined using a calibrated scale. For each fluid, a trial comprising 21 subsequent dispenses of a target volume of 1 µL has been performed.

The right Y-axis 1006 indicates the accuracy of the dispensing 1008 (left column, in %) and the coefficient of variation 1010 (right column, in %) for each fluid.

The data shown in Fig. 10 illustrate that the accuracy and reproducibility of dispensing which can be achieved by using an rotary valve according to the invention is very high and (almost) independent of the viscosity and/or surface tension of the fluid which is dispensed: If comparing the accuracy and CV values of the different fluids A - S in consideration of their increasing viscosity (indicated on the X-axis), no effect of the viscosity both on accuracy and CV can be identified. Also, if comparing the accuracy and CV values of the different fluids A - S in consideration of their respective surface tension (shown in 1004 and indicated on the left Y-axis), also no effect of the surface tension both on accuracy and CV can be identified.

Fig. 11 shows a cartridge 1100 according to an embodiment of the invention. The cartridge comprises a plunger 1108 which is able to slide within a piston 1114. The piston 1114 and a volume 1116 form a slide valve 1110. The volume 1116 may be formed in a housing 1117 or a portion of the cartridge 1100. The slide valve 1110 is capable of rectilinear motion. As the piston moves 1114 there is a pumping chamber conduit 1120 that is moved along with the piston 1114. There is a hole within the piston 1114 that the plunger 1108 can move in. This hole in the piston 1114 and the plunger 1108 form a pumping volume 1118.

The piston 1114 is able to move the pumping chamber conduit 1120 into different locations. In this view it is shown as being aligned with a reservoir conduit 1124. The reservoir conduit 1124 connects a reservoir 1122 filled with a fluid with the pumping chamber 1118. The reservoir 1122 is surrounded by a cartridge body 1112. In this position the plunger 1134 can be moved such as to increase or decrease the volume of the pumping chamber 1118. When the plunger 1108 is moved to increase the volume of the pumping chamber 1118 when the piston 1114 is in this location fluid can be withdrawn from the reservoir 1122.

The piston 1114 can be moved such that the pumping chamber conduit 1120 is aligned with an outlet conduit 1128. The outlet conduit 1128 provides access to an outlet nozzle 1126. When the pumping chamber conduit 1120 is aligned with the outlet conduit 1128 the fluid can be expelled from the pumping chamber 1118 through the nozzle 1126 by decreasing the volume of the pumping chamber 1118.

In this embodiment the piston 1114 is shown as having a first plunger mechanical stop 1130 and a second plunger mechanical stop 1132. The plunger in this example has a mechanical extension 1134 that is operable for contacting the first plunger mechanical stop or the second plunger mechanical stop. In this embodiment the entire pumping arrangement may be done only be actuating the plunger 1108. When the mechanical extension 1134 contacts the first plunger mechanical stop 1130 the plunger 1108 is able to push the piston 1114 such that the pumping chamber conduit 1120 is aligned with the reservoir conduit 1124. When the mechanical extension 1134 contacts the second plunger mechanical stop 1132 the plunger 1108 is able to move the piston 1114 such that the pumping chamber conduit 1120 is aligned with the outlet conduit 1128.

The first plunger mechanical stop 1130, the second plunger mechanical stop 1132 and the mechanical extension of the plunger 1134 may not be present in all embodiments.

In an alternative embodiment the cartridge may have a reservoir mechanical stop. The reservoir mechanical stop is able to contact a contacting surface. This provides a reservoir mechanical stop that roughly aligns the pumping chamber conduit 1120 with the reservoir conduit 1124. In some embodiments, there may also be an outlet mechanical stop present and corresponding contacting surface for aligning the pumping chamber conduit with the outlet conduit.

In an alternative embodiment an end of the volume 1116 may provide a mechanical stop for aligning the pumping chamber conduit 1120 with the reservoir conduit. For instance in this example the volume 1116 is closed at one end with the exception of an air vent 1140. The ending surface 1142 may be used in some embodiments as a mechanical stop for the piston 1114 also.

In some embodiments the plunger 1134 may operate in the position of the piston 1114 without the use of the reservoir mechanical stop or even a conduit mechanical stop. For instance the surface between the piston 1114 and the volume 1116 may be constructed such that it is more difficult to move piston 1114 than it is the plunger 1108, e.g. because the static friction between the piston 1114 and the volume 1116 is larger than the static friction between the plunger 1108 and the corresponding hole in the piston 1114. In this case the plunger 1108 can be moved without dislocating the piston 1114 unless the plunger 1108 contacts one of the first plunger mechanical stop 1130 or the second plunger mechanical stop 1132.

Fig. 12 shows the cartridge 1100 of Fig. 11 connected to an actuator assembly 1200. The actuator assembly 1200 comprises a linear actuator 1202 which moves along a linear track 1204 in the direction 1206. The linear actuator 1202 is connected by a coupling assembly 1208 to the plunger 1108.

Fig. 13A shows a further example of a cartridge 1300. The example in Fig. 13 is similar to that shown in Figs. 11 and 12 with several additional features. In this embodiment there is a secondary reservoir 1322. The secondary reservoir 1322 is connected to a secondary reservoir conduit 1324 which can be aligned with the pumping chamber conduit 1120. There is an optional connection for a connecting conduit 1326 between the reservoir 1122 and the secondary reservoir 1322. In this example there is also an optional membrane 1327 covering the surface of the connecting conduit 1326. The membrane 1327 for instance may prevent bubbles from the secondary reservoir 1322 from entering the reservoir 1122. This structure may for instance be useful for pumping fluid 1302 out of the reservoir 1122 and returning unused fluid 1302 to the secondary reservoir 1322. The reservoir 1122 has an optional vent 1328 and the secondary reservoir 1322 has an optional vent 1330. There is a side wall 1332 which divides the reservoir 1122 from the secondary reservoir 1322. In some embodiments this dividing wall 1332 may not be present in which case the primary reservoir forms a first portion of the reservoir and the secondary reservoir 1322 forms a second portion of the reservoir. In this example the plunger 1108 and the piston 1114 are actuated independently. Such a structure for the plunger 1108 and the piston 1114 may also be used as an alternative to the structure shown in Fig. 11.

Fig. 13B shows an alternative example of a cartridge 1350 that is similar to the cartridge 1300 shown in Fig. 13A. In the embodiment of Fig. 13B there is a separate reservoir 1122'and a separate secondary reservoir 1322'. The connecting conduit 1326 of Fig. 13A is not present. The reservoir 1122' may contain a first fluid 1302 and the secondary reservoir 1322' may contain a second fluid 1302'. The first fluid 1302 and the second fluid 1322' may be different fluids.

Fig. 14 shows the cartridge 1300 in Fig. 13 connected to an actuator assembly 1400. In this embodiment both the plunger 1108 and the piston 1114 are actuated independently. There is a linear actuator 1202 which moves along a linear track 1204 which is connected to the plunger 1108 by a coupling assembly 1208. There is a linear actuator 1402 which moves along linear track 1404 which is connected to the piston 1114 by a coupling assembly 1408. Both linear actuators 1202 and 1402 are able to move in the direction 1206. The actual implementation of the actuator assembly 1400 is intended to be representative and other actual constructions may be used also.

Figs. 15A and 15B show five different views 1500, 1502, 1504, 1506, 1508 of the slide valve 1110 with a plunger 1108 and piston 1114 of the embodiment shown in Fig. 11. Figs. 15A and 15B show an example of how the piston 1114 and plunger 1108 can be used to pump fluid from the reservoir chamber through the outlet nozzle 1126. In view 1500 the pumping chamber conduit 1120 is aligned with the reservoir conduit 1124. The pumping chamber volume 1118 is at its minimum volume. The mechanical extension 1134 is in contact with the first plunger mechanical stop 1130. Next in view 1502 the plunger 1108 is withdrawn in direction 1510. The plunger is withdrawn until the mechanical extension 1134 contacts the second plunger mechanical stop 1132. In this embodiment, the piston 1114 requires more force to move than the plunger 1108. In other words the plunger 1108 slides easier than the piston 1114. This could be accomplished by designing the plunger 1108 so that it has less friction than the piston 1114. This enables the piston 1114 and the plunger 1108 to be operated using a single actuator. Mechanical stops 1130 and 1132 are used to restrict the motion of the plunger 1108. The frictional force on the plunger cause the plunger 1108 to move first when a linear force is applied to the plunger 1108. When the plunger 1108 hits a mechanical stop 1130, 1132 then the plunger 1108 and the piston 1114 move together.

The pumping chamber 1118 is filled with fluid from the fluid reservoir. Next in view 1504 the plunger 1108 is withdrawn further. The mechanical extension 1134 is in contact with the second plunger mechanical stop 1132 so the plunger 1108 exerts force on the piston 1114. The plunger 1108 is moved so far such that the piston 1114 moves the pumping chamber conduit 1120 into alignment with the outlet conduit 1128. Next in view 1506 plunger 1108 is moved in direction 1514. The fluid is forced out of the pumping chamber 1118 by the plunger 1108 and through the outlet conduit 1128. Fluid exits the outlet nozzle 1126 and forms droplets 1516 exiting the cartridge through the outlet nozzle 1126.

Finally in view 1508 the plunger 1108 is depressed 1516 further such that the mechanical extension 1134 exerts force on the second plunger mechanical stop 1132 to force the piston 1114 to align the pumping chamber conduit 1120 with the reservoir conduit 1124 again. In this embodiment there is no mechanical stop to align the piston with the reservoir conduit 1124. This would most likely be performed by controlling the actuator of the plunger 1108. View 1508 is substantially the same as view 1500. In this position the pumping process can begin again.

Figs. 16A and 16B illustrate an alternative embodiment to the slide valve 1110 of Fig. 11. In the embodiment shown in Fig. 16A and 16B the slide valve comprises a piston 1114 with a plunger 1108. The operation of this alternative embodiment is also illustrated in Figs. 16A and 16B by views 1600, 1602, 1604, 1606, and 1608. In the embodiment shown in Figs. 16A and 16B the linear position of the reservoir conduit 1124 and the outlet conduit 1128 are reversed with respect to those in Fig. 15A and 15B. In contrast to the embodiment shown in Fig. 15A and 15B, the piston 1114 requires less force to move than the plunger 1108. In other words the piston 1114 slides easier than the plunger 1108. This could be accomplished by designing the plunger 1108 so that it has more friction than the piston 1114. As is described below, the mechanical stops 1130, 1132, 1609 and 1610 in combination with the frictional plunger 1108 enable pumping to be accomplished with a single actuator.

This embodiment has an outlet mechanical stop 1610 that aligns the piston 1114 such that the pumping chamber conduit 1120 aligns with the outlet conduit 1128. This embodiment also has a reservoir mechanical stop 1609 that is shown as extending out from the slide valve 1110. The piston has a contacting surface 1611. When the contacting surface 1611 contacts the reservoir mechanical stop 1609, the reservoir conduit 1124 is aligned with the pumping chamber outlet 1120. There is also an outlet mechanical stop 1610 on the slide valve 1110 that is operable for becoming in contact with contacting surface 1613. When the outlet mechanical stop 1610 contacts contacting surface 1613 the pumping chamber conduit 1120 is aligned with the with the outlet conduit 1128.

In view 1600 the pumping chamber conduit 1120 is aligned with the reservoir conduit 1124. The pumping chamber 1118 is at its minimum and the contacting surface 1611 of the piston 1114 is in contact with the reservoir mechanical stop 1609. The slide valve 1110 is shown as having a first plunger mechanical stop 1130 and a second plunger mechanical stop 1132. When mechanical extension 1134 is in contact with the first plunger mechanical stop 1130 then the volume of the pumping chamber 1118 is at a minimum. When the mechanical extension 1134 is in contact with the second plunger mechanical stop 1132 then the volume of the pumping chamber 1118 is at a maximum.

The piston 1108 has its mechanical extension 1134 in contact with the first plunger mechanical stop 1130. Next in view 1602 the plunger 1108 is withdrawn in direction 1612. The volume of the pumping chamber 1118 increases and fluid is withdrawn from the reservoir chamber until the mechanical extension 1134 contacts the second plunger mechanical stop 1132. The reservoir mechanical stop 1609 prevents the piston 1114 from moving during this.

Next in view 1604 the piston 1108 is moved in direction 1614. The volume of the pumping chamber 1118 stays the same and the contacting surface 1613 of the piston 1114 comes in contact with the outlet mechanical stop 1610. This aligns the pumping chamber conduit 1120 with the outlet conduit 1128.
Next in step 1606 the plunger 1108 is depressed further until the mechanical extension 1134 contacts the first plunger mechanical stop. The piston 1114 is already in

contact with the outlet pumping chamber conduit mechanical stop 1610. As the plunger 1108 is depressed in direction 1616 the piston 1114 cannot move any further. The plunger 1108 then forces fluid out of the pumping chamber 1118 through the outlet conduit 1128 and the nozzle 1126. Droplets of fluid 1516 form exiting the cartridge. The plunger 1108 can be depressed until the mechanical extension 1134 comes in contact with the first plunger mechanical stop 1130.
Next in step 1608 the plunger 1108 is moved in direction 1618. The plunger is moved in direction 1618 until the contacting surface 1611 of the piston 1114 contacts the reservoir mechanical stop 1609. The piston 1114 and plunger 1108 are now in the same position they were in in view 1600. The pumping cycle has been completed. This process may be repeated to pump more fluid 1516 out of the cartridge.

Fig. 17 shows two views 1700, 1702 of a slide valve 1110 and plunger combination 1108 that is an alternative to that shown in Fig. 11. In this embodiment there are no mechanical stops and the piston 1114 and the plunger 1108 may be operated independently. In view 1700 the piston 1114 has been moved such that the pumping chamber conduit 1120 is in alignment with the reservoir conduit 1124. Fluid may be pumped into the pumping chamber 1118 by moving the plunger 1108 outwards. Fluid may also be moved back into the reservoir conduit 1124. For instance used fluid may be moved back into the reservoir chamber 1124 or the plunger 1108 may be moved in a reciprocating fashion to mix the fluid. View 1702 shows the piston 1114 in a different position such that the pumping chamber conduit 1120 is in alignment with the outlet conduit 1128. The piston 1108 can be moved in the direction 1704 to pump fluid through the outlet conduit 1128 and the outlet nozzle 1126 thus forcing droplets 1516 of fluid out of the cartridge.

Figs. 18A and 18B illustrate one way of operating the slide valve 1110 of the embodiment shown in Fig. 13. The method illustrated in Figs. 18A and 18B illustrate how the amount of fluid waste may be reduced during operation. This method is illustrated in eight different views, 1800, 1802, 1804, 1806, 1808, 1810, 1812, and 1814. The piston 1114 and plunger 1108 are operated independently. The method starts in view 1800. In view 1800 the pumping chamber conduit 1120 is aligned with the reservoir conduit 1124. The plunger 1108 is in a position where the pumping chamber 1118 has a relatively small volume. In view 1802 the plunger 1108 is withdrawn in direction 1816. This causes fluid to be drawn from the fluid reservoir into the pumping chamber 1118. Next in view 1804 both the plunger 1816 and the piston 1818 are both withdrawn simultaneously in direction 1820, 1818. The piston 1114 and the plunger 1108 are both moved the same amount. They are both moved until the pumping chamber conduit 1120 is aligned with the outlet conduit 1128.

Next in view 1806 the piston 1114 remains in the same position and the plunger 1108 is depressed 1822. This forces the fluid out of the pumping chamber 1118 and through the outlet conduit 1128. This forces the fluid in droplets 1516 out of the outlet nozzle 1126.
Next in view 1808, to remove fluid remaining within the outlet conduit 1128, the plunger 1108 is withdrawn in direction 1824 with the piston 1114 remaining in the same position. The plunger 1108 has been withdrawn 1824 sufficiently such that the majority of fluid has been removed from the outlet conduit 1128. Also a quantity of air may be withdrawn also forming a bubble 1826. This results in a complete emptying of the outlet conduit 1128 from remaining fluids and thereby avoids the drying of fluid compounds within this outlet conduit 1128. Due to this complete emptying of the outlet conduit 1128, no washing or “priming” steps before the next dispensing step are necessary resulting in a maximum efficiency of the use of the fluid volume within the reservoir. Thus far the amount of fluid used for cleaning purposes has been reduced; however the presence of a bubble may cause inaccuracies in the dispensing of fluid.

Next in view 1810, to eliminate this problem both the piston 1114 and the plunger 1108 are simultanously withdrawn in direction 1830, 1832. Both the piston 1114 and the plunger 1108 are moved the same amount. They are moved such that the pumping chamber conduit 1120 is aligned with the secondary reservoir conduit 1324.

Next in view 1812 the piston 1114 remains stationary and the plunger 1108 is depressed in direction 1834. This forces the bubble 1826 to the secondary reservoir. This has removed the bubble 1826 from the pumping chamber 1118 and the pump-

ing chamber conduit 1120. The bubble 1826 can no longer interfere with the proper metering of the fluid in the pumping chamber 1118.
Finally in view 1814 both the piston 1114 and the plunger 1108 are depressed simulatously in direction 1836, 1838 the same amount. The pumping chamber outlet 1120 is again aligned with the reservoir conduit 1124 and the pumping cycle is complete. The pump may be used again without the bubble 1826 interfering with the correct measurement or metering of the fluid.

Fig. 19 illustrates an automatic analyzer 1900 according to an embodiment of the invention. This automatic analyzer is shown as having three cartridges 1902, 1902' and 1902". There is an actuator assembly 1904 connected to cartridge 1902. There is an actuator assembly 1904' attached to cartridge 1902'. There is an actuator assembly 1904" attached to cartridge 1902". The actuator assemblies 1904, 1904', 1904" are for actuating the slide valve and plunger of the cartridges 1902, 1902', 1902". The automatic analyzer 1900 is shown as having a relative movement means 1910 which provides relative movement 1912 between a reagent container or cuvette 1906 and the cartridges 1902, 1902' and 1902". The reagent container or cuvette 1906 is shown as containing a biological sample 1508.

The cartridges 1902, 1902', 1902" may be used to add one or more fluids to the biological sample 1908. The automatic analyzer 1900 is shown as further containing a sensor system 1914. The sensor system comprises one or more sensors for measuring a quantity or a physical or chemical or biochemical property of the biological sample 1908. For example the sensor system 1914 may comprise an nuclear magnetic resonance (NMR) system, an optical transmission or reflectance measurement system, a pH meter, a camera system, a polymerase chain reaction (PCR) apparatus, a Electrochemiluminescence (ECL) apparatus, a spectroscopic measurement system, an electrochemical or an optical sensor, and a chromatography system. The relative movement means 1910 is also operable for moving the reagent container or cuvette 1906 to the sensor system 1914.

The arrangement of the cartridges 1902, 1902', 1902" and the sensor system 1914 is representative. In some embodiments the reagent container or cuvette 1906 may remain in a fixed position and the cartridges 1902, 1902', 1902" may move. The actuation systems 1904, 1904', 1904" and the sensor system 1914 are shown as being connected to a hardware interface 1922 of a computer system 1920. The computer system 1920 functions as a controller for the automatic analyzer 1900. The computer 1920 is further shown as containing a processor 1924 which is able to control the operation and function of the automatic analyzer 1900 using the hardware interface 1922. The processor 1924 is shown as further being connected to a user interface 1926, computer storage 1928 and computer memory 1930. The computer storage 1928 is shown as containing an analysis request 1932. The analysis request 1932 contains a request to analyze the biological sample 1908.

The computer storage 1928 is shown as further containing sensor data 1934 received from the sensor system 1914. The computer storage 1928 is shown as further containing an analysis result 1936 which was determined using the sensor data 1934. The computer memory 1930 contains a control module 1940. The control module 1940 contains computer executable code which enables the processor 1924 to control the operation and function of the automatic analyzer 1900. For instance the control module 1940 may use the analysis request 1932 to generate commands to generate and send to the actuation systems 1904, 1904', 1904", the sensor system 1914 and the relative movement system 1910. The control module 1940 may also generate the analysis result 1936 using the sensor data 1934.

Various algorithms may be used for controlling the dispensing of the fluid in different embodiments. For instance the actuator assembly may be controlled by the processor to perform a series of predetermined actions to dispense the fluid. In another example a sensor or metering system could be integrated into the automatic analyzer to measure the dispensing of the fluid. In this case a algorithm which uses the actuator assembly and the sensor to form a closed loop feedback to accurately control or meter the dispensing of the fluid.

Fig. 20 illustrates an automatic analyzer 2000 according to an embodiment of the invention that is similar to the embodiment shown in Fig. 19. The automatic analyzer 2000 is similar to the automatic analyzer 1900 shown in Fig. 19. The automatic analyzer 2000 of Fig. 20 additionally has a meniscus detector 2002, 2002', 2002". Each meniscus detector 2002, 2002', 2002" is positioned adjacent to the outlet nozzle

1126. The meniscus detector 2002, 2002', 2002" are each connected to the hardware interface 1922. This enables the processor 1924 to control the actuator assemblies 1904, 1904', 1904" to control the location of the meniscus. This for instance may enable the processor to more accurately and/or reproducibly dispense fluid from the cartridges 1902, 1902', 1902".

Fig. 21 shows a further example of a cartridge 2100. The cartridge 2100 shown in Fig. 21 is similar to that shown in Fig. 11. The cartridge 2100 shown in Fig. 21 comprises two parts. There is a attachable reservoir 2102 and a pumping unit 2104. The pumping unit 2104 has a first connection 2106 and the attachable reservoir 2102 has a second connection 2108. The first connection 2106 is operable for connecting to the second connection 2108. This attaches the attachable reservoir 2102 to the pumping unit 2104. The attachable reservoir 2102 in this example is shown as having a vent 1328. Near the second attachment 2108 the reservoir 1122 is sealed with a seal 2110. Near the first connection 2106 there is a knife edge 2112 that is operable for opening the seal 2110 when the first connection 2106 is connected to the second connection 2108.

The embodiment shown in Fig.21 enables more flexibility and economy in preparing multiple cartridges. For instance the volume of the attachable reservoir could be varied as well as the type of fluid filling the reservoir 1122. The pumping unit 2104 may also be varied. For instance the diameter of the plunger 2108 as well as its stroke could be varied. This may allow for either a more accurate or a high-volume pumping unit to be selected.

Figs. 22 through 25 show various embodiments of the slide valve 1110. All of the embodiments shown in Figs. 22 through 25 show a plunger 1108 with a mechanical extension 1134 on the plunger. The piston 1114 in each of these embodiments has a first plunger mechanical stop 1130 and a second the plunger mechanical stop 1132 as is described in Fig. 11.

The embodiment of the slide valve 1110 shown in Fig. 22 does not have air vent 1140. There is also no reservoir mechanical stop or outlet mechanical stop. Precise alignment of the pumping chamber conduit 1120 with the reservoir conduit 1124 or outlet conduit 1128 may be done or provided by an actuator.

In Fig.23, the slide valve 1110 is shown as comprising an air vent 1140 as is shown in Fig. 11. The slide valve 1110 is shown as comprising a reservoir mechanical stop 1609 for contacting a surface 1611 of the piston 1114. The reservoir mechanical stop 1609 alignes the pumping chamber conduit 1120 with the reservoir conduit 1124. However, there is no mechanical stop which aligns the outlet conduit 1128 with the pumping chamber conduit 1120. Precise alignment of the pumping chamber conduit 1122 the outlet conduit 1128 may be done by a linear actuator.

In Fig. 24 an air vent is not shown. In the embodiment shown in Fig. 24. The slide valve 1110 comprises a outlet mechanical stop 1610 for contacting a surface 1613 of the piston 1114. The outlet mechanical stop 1610 is operable for aligning the outlet conduit 1128 with the pumping chamber conduit 1120. However there is no mechanical stop for aligning the pumping chamber conduit 1120 with the reservoir conduit 1124. Precise alignment of the reservoir conduit may be provided by a linear actuator.

In Fig.25 an air vent 1140 is shown. The embodiment shown in Fig. 25 comprises a reservoir mechanical stop 1609 for contacting a surface 1611 of the piston 1114. The reservoir mechanical stop 1609 aligns the pumping chamber conduit 1120 with the reservoir conduit 1124. The embodiment shown in Fig. 25 also shows a outlet mechanical stop 1610 on the slide valve 1110. The outlet mechanical stop 1610 is operable for contacting the cut surface 1613 of the piston 1114. The outlet mechanical stop 1610 is operable for aligning the pumping chamber conduit 1120 with the outlet conduit 1128.

The examples shown in Figs. 22 through 25 are intended to be exemplary and are not all possible combinations of how the slide valve 1110 could be constructed. For example the relative position of the reservoir conduit 1124 and the outlet conduit 1128 could be juxtaposed linearly.

Figs. 26 and 27 illustrates how the friction between the plunger 1108 and the piston 1114 may be increased. In Fig. 26 the slide valve 1110 is shown as having a vent 1110 as is shown in Fig. 11. The slide valve 1110 further comprises a reservoir mechanical stop 1610 and an outlet mechanical stop 1609 for contacting the piston 1114. As described previously these mechanical stops 1609, 1610 serve to align the pumping chamber conduit 1120 with the reservoir conduit 1124 and the outlet conduit 1128. The plunger 1108 is shown as having the mechanical extensions 1134. However in the embodiment shown in Fig. 26 there are no first plunger mechanical stops 1130 or second plunger mechanical stops 1132 as has been previously shown. The mechanical extensions 1134 contact a surface 2600 within the piston 1114. The contacting mechanical extension 1134 and the surface 2600 increases the friction between the plunger 1108 and the piston 1114. This enables the piston 1114 to be actuated by motion of the plunger 1108. As there are no plunger mechanical stops in this embodiment the movement of the plunger 1108 will be controlled by a linear actuator.

Fig. 18 shows an embodiment of a slide valve 1110 similar to that shown in Fig. 26. The embodiment shown in Fig. 27 is similar to that shown in Fig. 26 except with the addition of a first plunger mechanical stop 1130 and a second plunger mechanical stop 1132 for limiting the travel of the plunger 1108 relative to the piston 1114. Mechanical extensions 1134 still contact a surface 2600 which increases the friction between the plunger 1108 and the piston 1114. This enables the piston 1114 to be actuated by the plunger 1108.

List of reference numerals

100	cartridge
102	actuator assembly
104	linear actuator
105	direction of linear motion
106	rotational actuator
107	direction of rotational motion
108	plunger
110	rotary valve
112	cartridge body
114	cylindrical portion
116	cylindrical space
118	pumping chamber
120	pumping chamber conduit
122	reservoir
124	reservoir conduit
126	outlet nozzle
128	outlet conduit
130	coupling assembly
200	first view
202	second view
204	third view
206	fourth view
208	plunger withdrawn
210	rotary valve rotated
212	plunger depressed
214	fluid
300	fifth view
302	sixth view
304	seventh view
306	plunger withdrawn
308	bubble

310	rotary valve rotated
312	plunger depressed
400	first view
402	second view
404	third view
406	fourth view
408	fifth view
410	sixth view
412	seventh view
414	cartridge
416	secondary reservoir
418	connecting conduit
430	secondary reservoir conduit
500	automatic analyzer
502	cartridge
502'	cartridge
502"	cartridge
504	actuator assembly
504'	actuator assembly
504"	actuator assembly
506	reagent holder or cuvette
508	biological sample
510	relative movement means
512	relative movement
514	sensor system
520	computer
522	hardware interface
524	processor
526	user interface
528	computer storage
530	computer memory
532	analysis request
534	sensor data
536	analysis result

540	control module
600	bubble guiding structure
602	bubble channel
604	fluid channel
606	bubble
608	space
610	fluid
700	automatic analyzer
702	meniscus detector
800	rotary valve rotated
802	plunger withdrawn
804	rotary valve rotated
806	plunger depressed
808	rotary valve rotated
810	plunger withdrawn
812	rotary valve rotated
814	plunger depressed
816	plunger withdrawn
818	rotary valve rotated
820	plunger depressed
900	target volume
902	measured volume
904	linear fit
1000	viscosity
1002	surface tension
1004	viscosity vs. surface tension
1006	percentage
1008	accuracy
1010	coefficient of variation (CV)
1100	cartridge
1108	plunger
1110	slide valve
1112	cartridge body
1114	piston

1116	volume
1117	housing
1118	pumping chamber
1120	pumping chamber conduit
1122	reservoir
1122'	reservoir
1124	reservoir conduit
1126	outlet nozzle
1128	outlet conduit
1130	first plunger mechanical stop
1132	second plunger mechanical stop
1134	mechanical extension of plunger
1140	air vent
1142	inner surface
1200	actuator assembly
1202	linear actuator
1204	linear track
1206	direction of actuation
1208	coupling assembly
1300	cartridge
1302	fluid
1302'	fluid
1322	secondary reservoir
1322'	secondary reservoir
1324	secondary reservoir conduit
1326	connecting conduit
1327	membrane
1328	vent
1330	vent
1332	dividing wall
1400	actuator assembly
1402	linear actuator
1404	linear track
1408	coupling assembly

1500	view of slide valve and plunger
1502	view of slide valve and plunger
1504	view of slide valve and plunger
1506	view of slide valve and plunger
1508	view of slide valve and plunger
1510	plunger withdrawn
1512	plunger withdrawn
1514	plunger depressed
1516	droplet
1600	view of slide valve and plunger
1602	view of slide valve and plunger
1604	view of slide valve and plunger
1606	view of slide valve and plunger
1608	view of slide valve and plunger
1609	reservoir mechanical stop
1610	outlet mechanical stop
1611	contacting surface
1612	plunger withdrawn
1613	contacting surface
1614	plunger depressed
1616	plunger depressed
1618	plunger withdrawn
1700	view of slide valve and plunger
1702	view of slide valve and plunger
1704	plunger depressed
1800	view of slide valve and plunger
1802	view of slide valve and plunger
1804	view of slide valve and plunger
1806	view of slide valve and plunger
1808	view of slide valve and plunger
1810	view of slide valve and plunger
1812	view of slide valve and plunger
1814	view of slide valve and plunger
1816	plunger withdrawn

1818 plunger withdrawn
1820 piston withdrawn
1822 plunger depressed
1824 plunger withdrawn
1830 piston withdrawn
1832 plunger withdrawn
1834 plunger depressed
1836 piston depressed
1838 plunger depressed
1900 automatic analyzer
1902 cartridge
1902' cartridge
1902" cartridge
1904 actuator assembly
1904' actuator assembly
1904" actuator assembly
1906 reagent holder or cuvette
1908 biological sample
1910 relative movement means
1912 relative movement
1914 sensor system
1920 computer
1922 hardware interface
1924 processor
1926 user interface
1928 computer storage
1930 computer memory
1932 analysis request
1934 sensor data
1936 analysis result
1940 control module
2000 automatic analyzer
2002 meniscus detector
2002' meniscus detector

2002"	meniscus detector
2100	cartridge
2102	attachable reservoir
2104	pumping unit
2106	first connection
2108	second connection
2110	seal
2112	knife edge
2600	contact surface

Claims

1. A cartridge (100, 414, 502, 502', 502", 1100, 1300, 1350, 1902', 1902") for dispensing fluid (214, 610, 1302, 1302', 1516)) comprising:
   - a valve (110, 1100), wherein the valve comprises a pumping chamber (118, 1118) for pumping the fluid, wherein the valve is operable for positioning a pumping chamber conduit (120, 1120), wherein the pumping chamber conduit is connected with the pumping chamber;
   - a plunger (1108) operable for changing the volume of the pumping chamber;
   - an reservoir conduit (124, 1214) for connecting a reservoir with the valve, wherein the valve is operable for positioning the pumping chamber conduit to connect with the reservoir conduit; and
   - an outlet conduit (128, 1128) for dispensing the fluid, wherein the valve is further operable for postioning the pumping chamber conduit to connect with the outlet conduit.

2. The cartridge (1100, 1300, 1350, 1902, 1902', 1902") of claim 1, wherein the valve is a slide valve (1110), wherein the slide valve is operable for translating a pumping chamber conduit (1120); wherein the slide valve is operable for translating the pumping chamber conduit to connect with the reservoir conduit; and wherein the slide valve is further operable for translating the pumping chamber conduit to connect with the outlet conduit.

3. The cartridge of claim 2, wherein the cartridge further comprises a return conduit (1324) connected to the reservoir, wherein the pumping chamber conduit is operable for receiving fluid via the reservoir conduit, wherein the return conduit is operable for returning fluid to a second portion (1322) of the reservoir, wherein the slide valve is further operable for translating the pumping chamber conduit to connect to the return conduit.

4. The cartridge of claim 2 or 3, wherein the cartridge further comprises:
   - a secondary reservoir (1322'); and

- a secondary reservoir conduit (1324), wherein the slide valve is further operable for translating the pumping chamber conduit to connect to the secondary reservoir conduit.

5. The cartridge of claim 4, wherein the cartridge further comprises a connecting conduit, wherein the connecting conduit is operable for transporting fluid between the secondary reservoir and the reservoir and wherein the cartridge comprises a membrane blocking the connecting conduit, and wherein the membrane is permeable to the fluid.

6. The cartridge of any one of claims 2 to 5, wherein the cartridge further comprises a coupling assembly for attaching the slide valve and the plunger to an actuator assembly

7. The cartridge of any one claims 2 to 6, wherein the slide valve comprises a piston (1114), wherein the pumping chamber is a cavity within the piston, wherein the pumping chamber is formed by the cavity and the plunger (1108), wherein the cartridge comprises a volume (1116) for receiving the piston, and wherein the piston is operable for translational motion within the volume.

8. The cartridge of any one claims 2 through 7, wherein the piston (1114) and the slide valve (1110) are operable for co-linear motion.

9. The cartridge of claim 7 or 8, wherein the slide valve comprises a reservoir conduit mechanical stop (1609) for aligning the pumping chamber conduit with the reservoir conduit and/or an outlet conduit mechanical stop (1610) for aligning the pumping chamber conduit with the outlet conduit

10. The cartridge of claim 7, 8, or 9, wherein the piston comprises two plunger mechanical stops (1130, 1132) for limiting the motion of the plunger relative to the piston, wherein the plunger is operable for actuating the piston.

11. The cartridge (100, 414, 502, 502', 502") of claim 1, wherein the valve is a rotary valve (110), wherein the rotary valve is operable for rotating a pumping chamber conduit (120), wherein the rotary valve and the plunger are operable for being actuated independently, wherein the rotary valve is operable for rotating the pumping chamber conduit to connect with the reservoir conduit, and wherein the rotary valve is further operable for rotating the pumping chamber conduit to connect with the outlet conduit.

12. The cartridge of claim 11, wherein the cartridge further comprises a return conduit connected to the reservoir, wherein the pumping chamber conduit is operable for receiving fluid from a first portion of the reservoir, wherein the return conduit is operable for returning fluid to a second portion of the reservoir, wherein the rotary valve is further operable for rotating the pumping chamber conduit to connect to the return conduit.

13. The cartridge of claim 11 or 12, wherein the cartridge further comprises:
- a secondary reservoir (416); and
- a secondary reservoir conduit (430), wherein the rotary valve is further operable for rotating the pumping chamber conduit to connect to the secondary reservoir conduit.

14. The cartridge of claim 13, wherein the cartridge further comprises a connecting conduit (418), wherein the connecting conduit is operable for transporting fluid between the secondary reservoir and the reservoir.

15. The cartridge of claim 14, wherein cartridge comprises a membrane blocking the connecting conduit, and wherein the membrane is permeable to the fluid.

16. The cartridge of claim 14 or 15, wherein the secondary reservoir comprises a bubble guiding structure (600).

17. The cartridge of claim 14, 15, or 16, wherein the secondary reservoir comprises a vent, wherein the vent is sealed with a filter, wherein the filter is permeable to air, and wherein the filter is operable for sealing the fluid in the cartridge.

18. The cartridge of any one of claims 11 to 17, wherein the fluid comprises any one of the following: magnetic beads, latex beads, a dispersion, nanoparticles, a blood grouping reagent, an immune reagent, an antibody, an enzyme, a recombinant protein, a virus isolate, a virus, a biological reagent, solvent, diluent, a protein, a salt, a detergent, a nucleic acid, an acid, a base, and combinations thereof.

19. The cartridge of any one of claims 11 to 18, wherein the cartridge further comprises a sensor operable for metering fluid dispensed by the outlet nozzle.

20. The cartridge of any one of claims 11 to 19, wherein the cartridge further comprises a coupling assembly (130) for attaching the rotary valve and the plunger to an actuator assembly.

21. The cartridge of any one claims 11 to 20, wherein the rotary valve comprises a cylindrical portion (114), wherein the pumping chamber is a cavity within the rotary valve, wherein the pumping chamber is formed by the cavity and the plunger, wherein the cartridge comprises a cartridge body (112) with a cylindrical space (116) for receiving the cylindrical portion, and wherein the rotary valve is operable for rotating within the cylindrical space.

22. An automatic analyzer (500, 1900, 2000) for analyzing a biological sample (508, 1908), wherein the automatic system is operable for holding a cartridge according to any one of the preceding claims, wherein the automatic analyzer comprises:
- an actuator assembly (504, 504', 504", 1200, 1400, 1904, 1904', 1904") operable for actuation of the plunger and of the valve;
- a controller (520, 1920) for controlling the operation of the actuator assembly.

23. The automatic analyzer (1900, 2000) of claim 22, wherein the automatic system is operable for holding a cartridge according to any one of claims 2 through 10, and wherein the actuator assembly (1200, 1400, 1904, 1904', 1904") is operable for linear actuation of the plunger and of the slide valve.

24. The automatic analyzer of claim 23, wherein the automatic analyzer is operable for holding a cartridge according to claim 10, wherein the actuator assembly is operable for linear actuation of the plunger.

25. The automatic analyzer of claim 23, wherein the actuator assembly is operable for separate linear actuation of the plunger and for linear actuation of the slide valve.

26. The automatic analyzer of claim 23, 24, or 25, wherein the cartridge comprises an outlet nozzle (1126), wherein the automatic analyzer further comprises a meniscus detector (2002, 2002', 2002") for detecting a meniscus of the fluid, wherein the controller is operable for:

- controlling the actuator assembly to force fluid through the outlet nozzle;
- detecting the meniscus using the meniscus detector; and
- controlling the actuator to halt the forcing of fluid through the outlet when the meniscus is in a predetermined location.

27. The automatic analyzer of claim 25 or 26, wherein the controller is operable for:

- controlling (1516, 1618, 1836, 1838) the actuator assembly to translate the pumping chamber conduit to connect with the reservoir conduit by translating the slide valve;
- controlling (1510, 1612, 1816) the actuator assembly to fill the pumping chamber by increasing the volume of the pumping chamber with the plunger;
- controlling (1512, 1614, 1818, 1820) the actuator assembly to translate the pumping chamber conduit to connect with the outlet conduit by translating the slide valve; and

- controlling (1514, 1616, 1704, 1822) the actuator assembly to pump the fluid through the outlet conduit by decreasing the volume of the pumping chamber with the plunger.

28. The automatic analyzer (500) of claim 22, wherein the automatic analyzer is operable for holding a cartridge (100, 414, 502, 502', 502") according to any one of claims 11 through 21, and wherein the actuator assembly (504, 504', 504") operable for separate linear actuation (105, 208, 212, 306, 312, 420, 424, 426, 432) of the plunger and for rotational actuation (107, 210, 310, 422, 428) of the rotary valve.

29. The automatic analyzer of claim 28, wherein the controller is operable for:
- controlling (200) the actuator assembly to rotate the pumping chamber conduit to connect with the reservoir conduit by rotating the rotary valve;
- controlling (202) the actuator assembly to fill the pumping chamber by increasing (208) the volume of the pumping chamber with the plunger;
- controlling (204) the actuator assembly to rotate (210) the pumping chamber conduit to connect with the outlet conduit by rotating the rotary valve; and
- controlling (206) the actuator assembly to pump (212) the fluid through the outlet conduit by decreasing the volume of the pumping chamber with the plunger.

30. The automatic analyzer of claim 28 or 29, wherein the controller is operable for controlling (300) the actuator assembly to retrieve the fluid from the outlet conduit by increasing (306) the volume of the pumping chamber with the plunger.

31. The automatic analyzer of any one of claim 28, 29, or 30, wherein the controller is operable for:
- controlling (302) the actuator assembly to rotate (310) the pumping chamber conduit to connect with the reservoir conduit by rotating the rotary valve; and
- controlling (304) the actuator assembly to return the fluid to the reservoir by decreasing (312) the volume of the pumping chamber with the plunger.

32. The automatic analyzer of any one of claims 28 through 31, wherein the controller is operable for:
-controlling the actuator assembly to rotate the pumping chamber conduit to connect with the reservoir conduit by rotating the rotary valve; and
- controlling the actuator assembly to mix the fluid in the reservoir by repeatedly increasing and decreasing the volume of the pumping chamber with the plunger.

33. The automatic analyzer of any one of claims 28 through 31, wherein the cartridge comprises an outlet nozzle, wherein the automatic analyzer further comprises a meniscus detector (702, 702', 702") for detecting a meniscus of the fluid, wherein the controller is operable for:
- controlling the actuator to force fluid through the outlet nozzle;
- detecting the meniscus using the meniscus detector; and
- controlling the actuator to halt the forcing of fluid through the outlet when the meniscus is in a predetermined location.

34. The automatic analyzer of any one of claims 28 through 33, wherein the automatic analyzer is operable to hold multiple cartridges (504, 504', 504"), wherein each of the multiple cartridges is according to any one of claims 1 through 11.

35. A method of operating a cartridge according to any one of claims 2 through 10, wherein the method comprises the steps of:
- translating (1516, 1618, 1836, 1838) the slide valve to translate the pumping chamber conduit to connect with the reservoir conduit;
- increasing (1510, 1612, 1816) the volume of the pumping chamber with the plunger to fill the pumping chamber;
- translating (1512, 1614, 1818, 1820) the slide valve to translate the pumping chamber conduit to connect with the outlet conduit; and
- decreasing (1514, 1616, 1704, 1822) the volume of the pumping chamber with the plunger to pump the fluid through the outlet conduit.

36. The method of claim 35, wherein the method further comprises retrieving the fluid from the outlet conduit by increasing (1824) the volume of the pumping chamber with the plunger.

37. The method of claim 35 or 36, wherein the method further comprises the steps of:
- translating (1830, 8132) the pumping chamber conduit to connect with the reservoir conduit by translating the slide valve; and
- returning (1834) the fluid to the reservoir by decreasing the volume of the pumping chamber with the plunger.

38. A method of operating a cartridge according to any one of claims 11 through 21, wherein the method comprises the steps of:
- rotating the rotary valve to rotate the pumping chamber conduit to connect with the reservoir conduit;
- increasing the volume of the pumping chamber with the plunger to fill the pumping chamber;
- rotating the rotary valve to rotate the pumping chamber conduit to connect with the outlet conduit; and
- decreasing the volume of the pumping chamber with the plunger to pump the fluid through the outlet conduit.

39. An automatic system (900, 1000) for dispensing fluids (908), wherein the automatic system is operable for holding a cartridge according to any one of claims 2 through 10, wherein the automatic system comprises:
- an actuator assembly (200, 400, 904, 904', 904") operable for linear actuation of the plunger and of the slide valve;
- a controller (920) for controlling the operation of the actuator assembly.

40. The automatic system of claim 39, wherein the automatic system is operable for holding a cartridge according to claim 9, wherein the actuator assembly is operable for linear actuation of the plunger.

41. The automatic system of claim 40, wherein the actuator assembly is operable for separate linear actuation of the plunger and for linear actuation of the slide valve.

42. The automatic system of any one of claim 39, 40, or 41, wherein the cartridge comprises an outlet nozzle (126), wherein the automatic analyzer further comprises a meniscus detector (1002, 1002', 1002") for detecting a meniscus of the fluid, wherein the controller is operable for:
- controlling the actuator assembly to force fluid through the outlet nozzle;
- detecting the meniscus using the meniscus detector; and
- controlling the actuator to halt the forcing of fluid through the outlet when the meniscus is in a predetermined location.

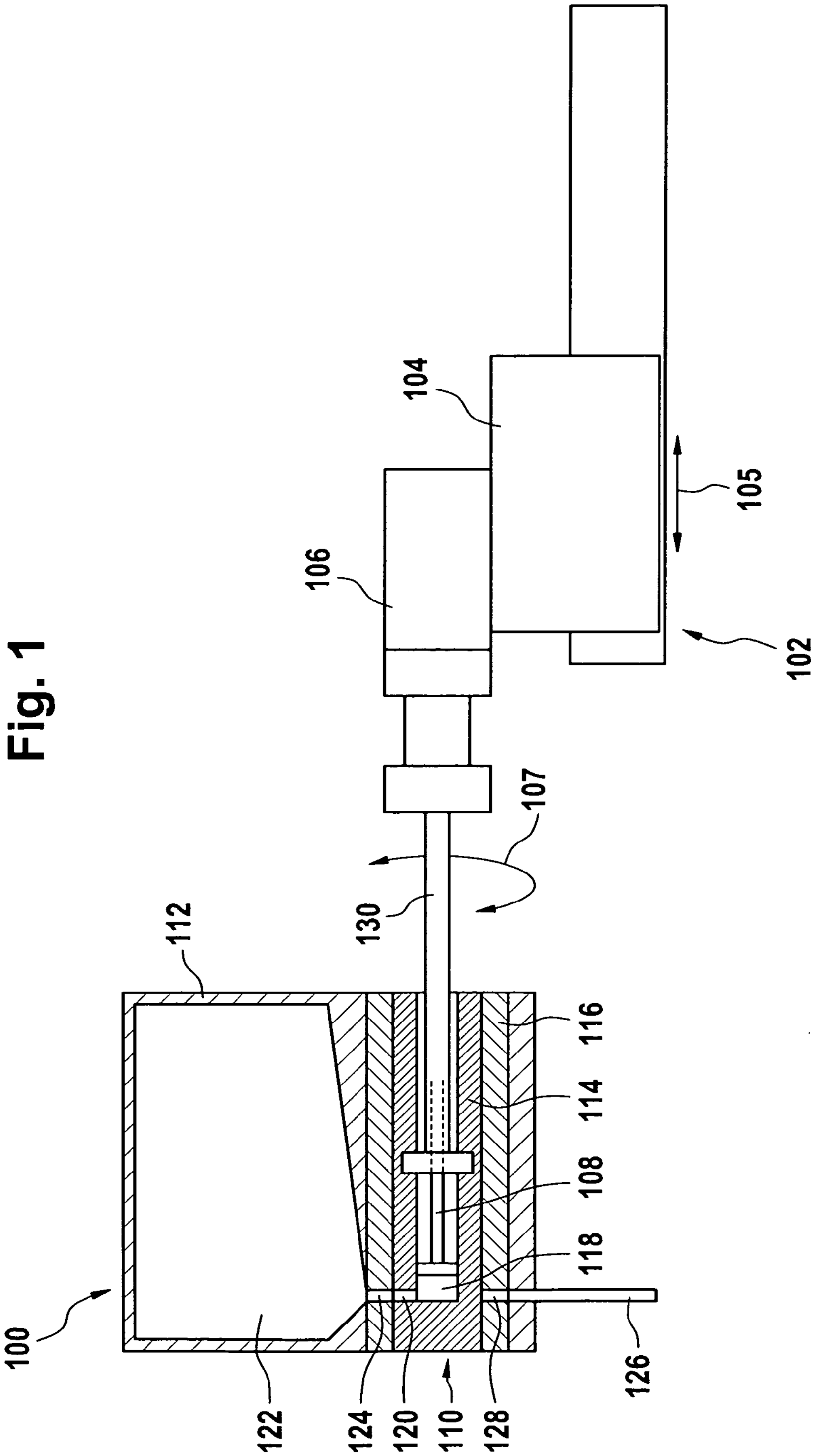

100
102
104
105
106
107
108
110
112
114
116
118
120
122
124
126
128
130

Fig. 1

Fig. 2

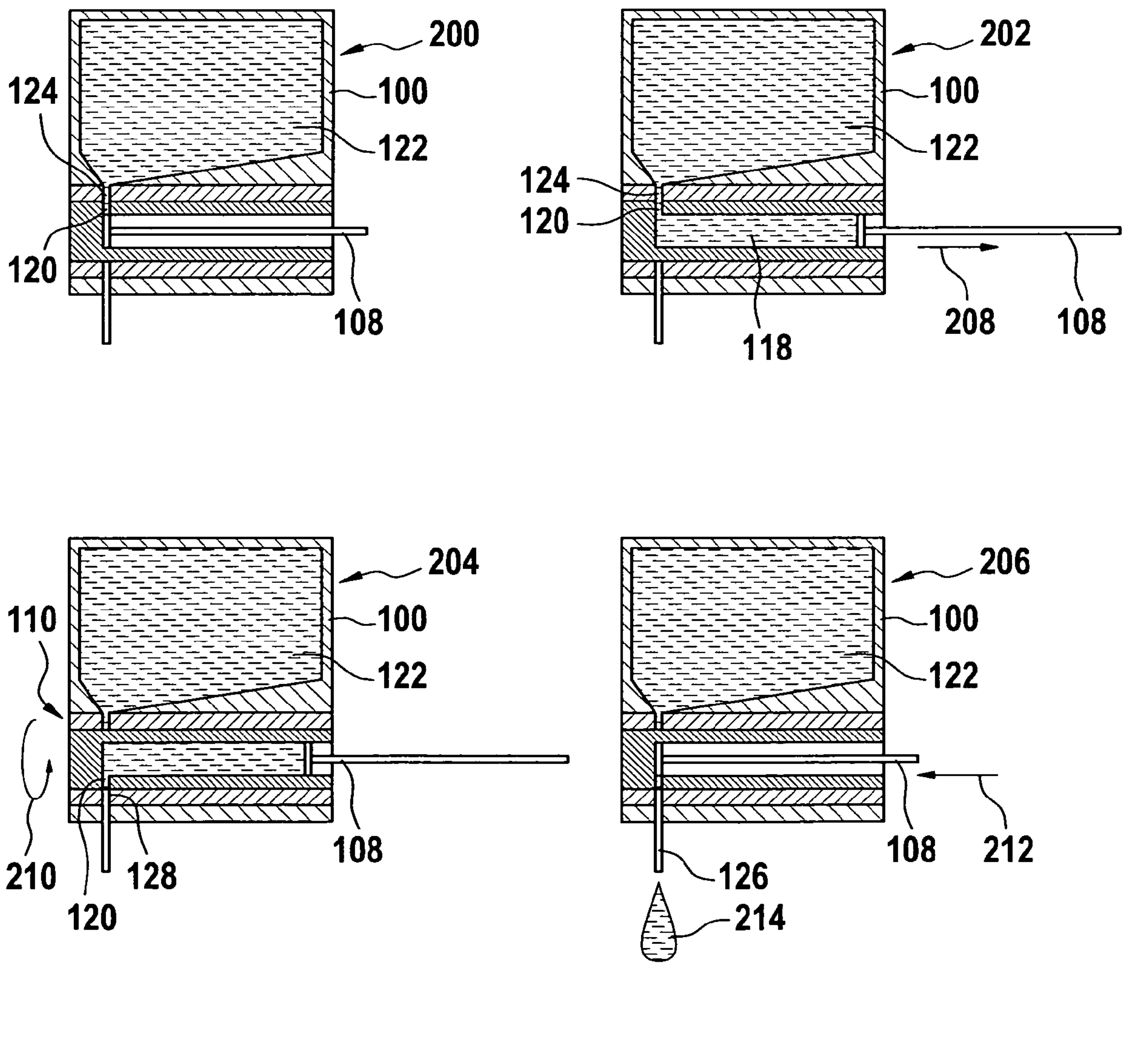

200
124
100
122
120
108
202
124
100
122
120
118
208
108
204
110
100
122
210
128
120
108
206
100
122
126
214
108
212

Fig. 3

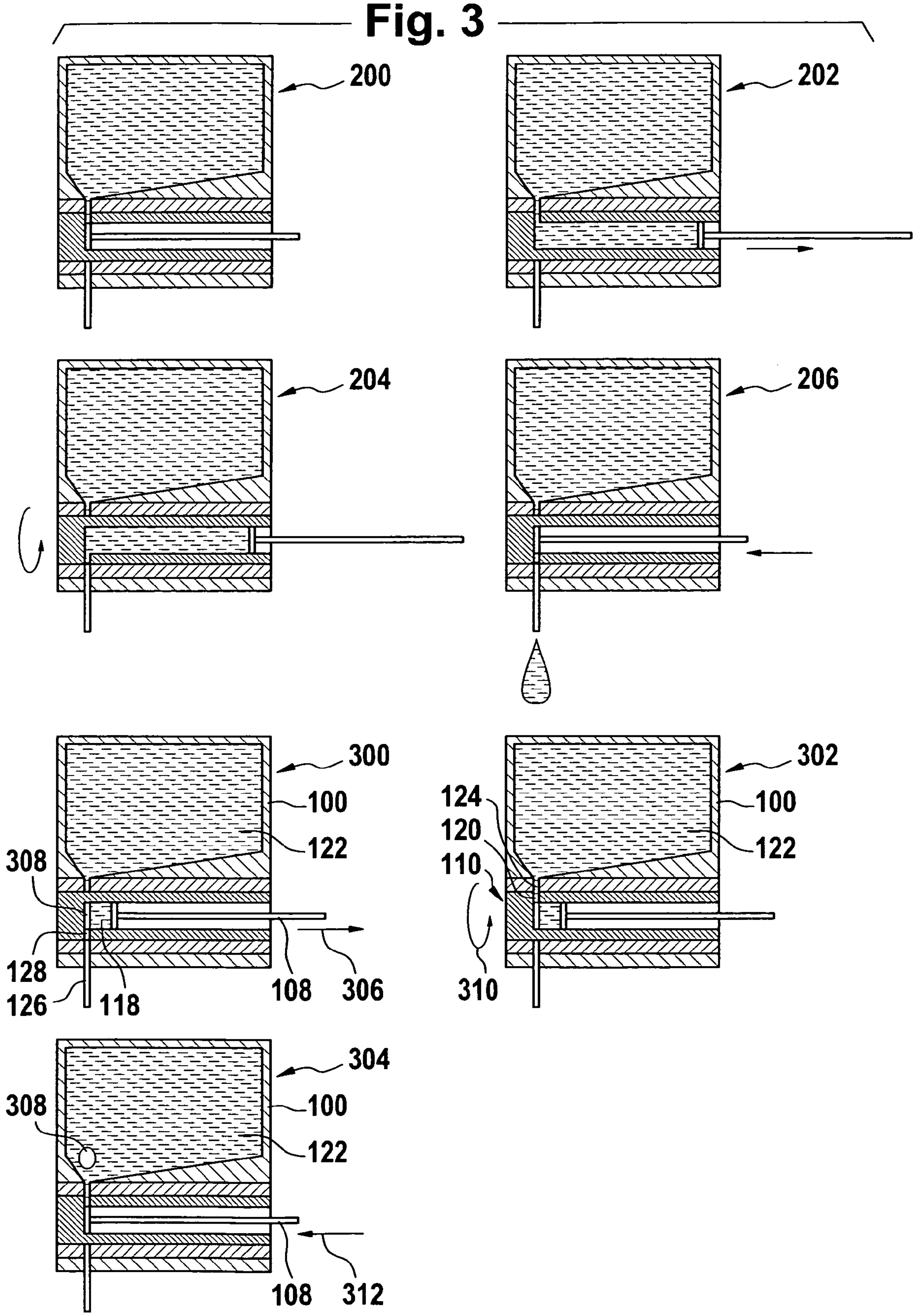

200
202
204
206
300
100
122
308
128
126
118
108
306
302
124
120
110
310
304
312

Fig. 4A

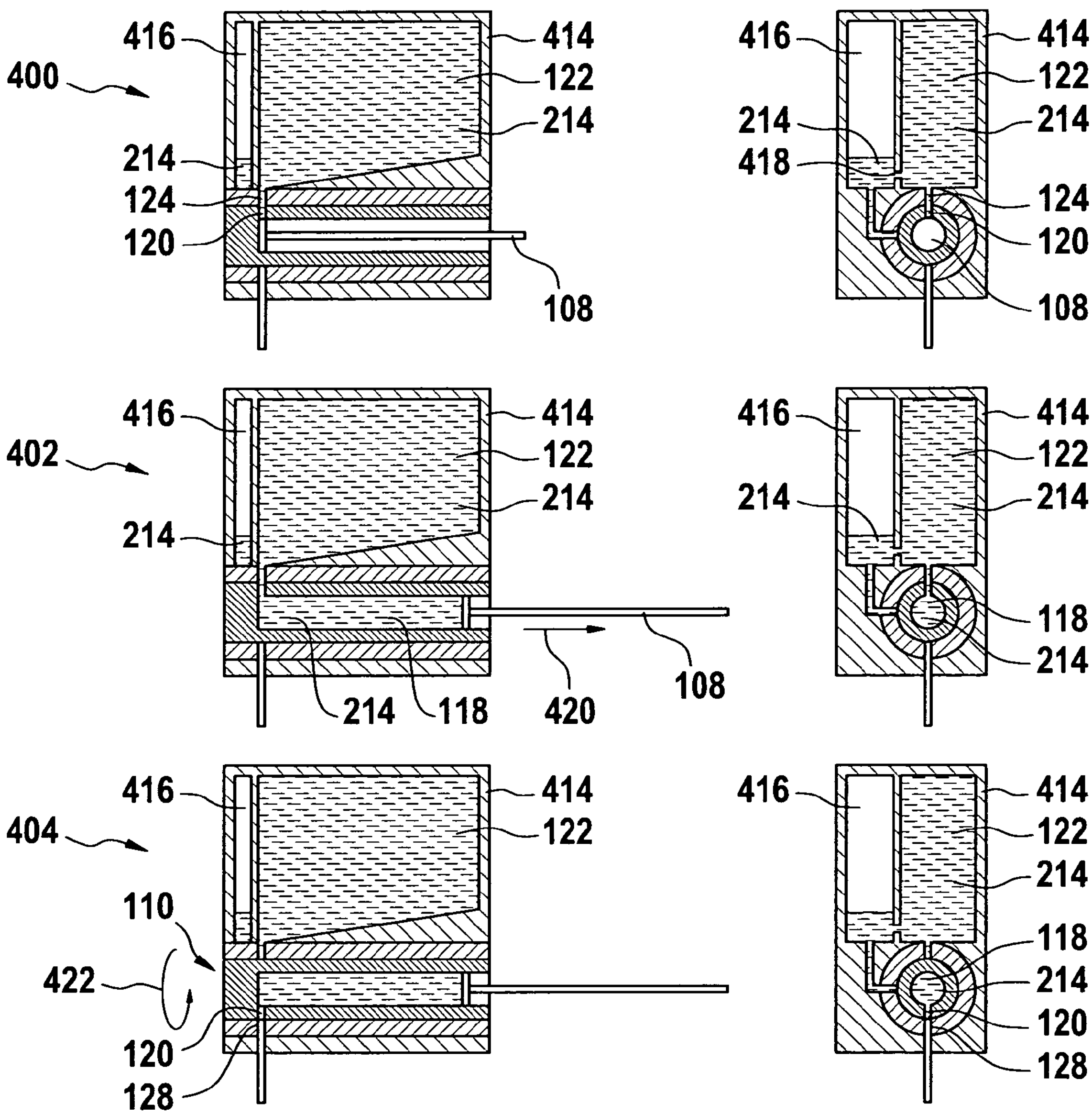
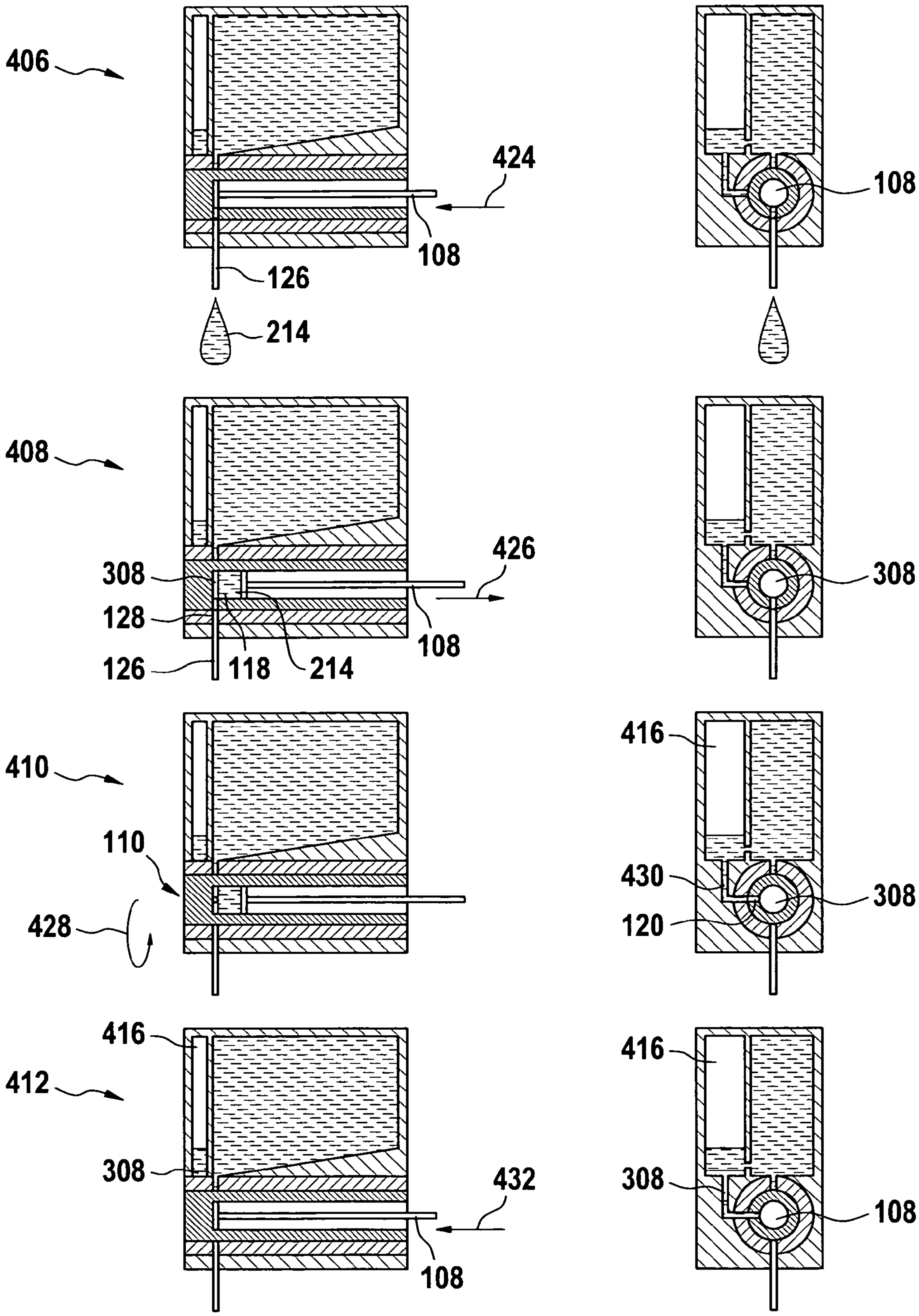

416
414
122
214
400
214
124
120
108
416
414
122
214
214
418
124
120
108
416
414
122
214
402
214
214
118
420
108
416
414
122
214
214
118
214
416
414
122
404
110
422
120
128
416
414
122
214
118
214
120
128

Fig. 4B


406
424
108
126
214
408
426
308
128
126
118
214
108
308
410
110
428
416
430
120
308
416
412
308
432
108
416
308
108

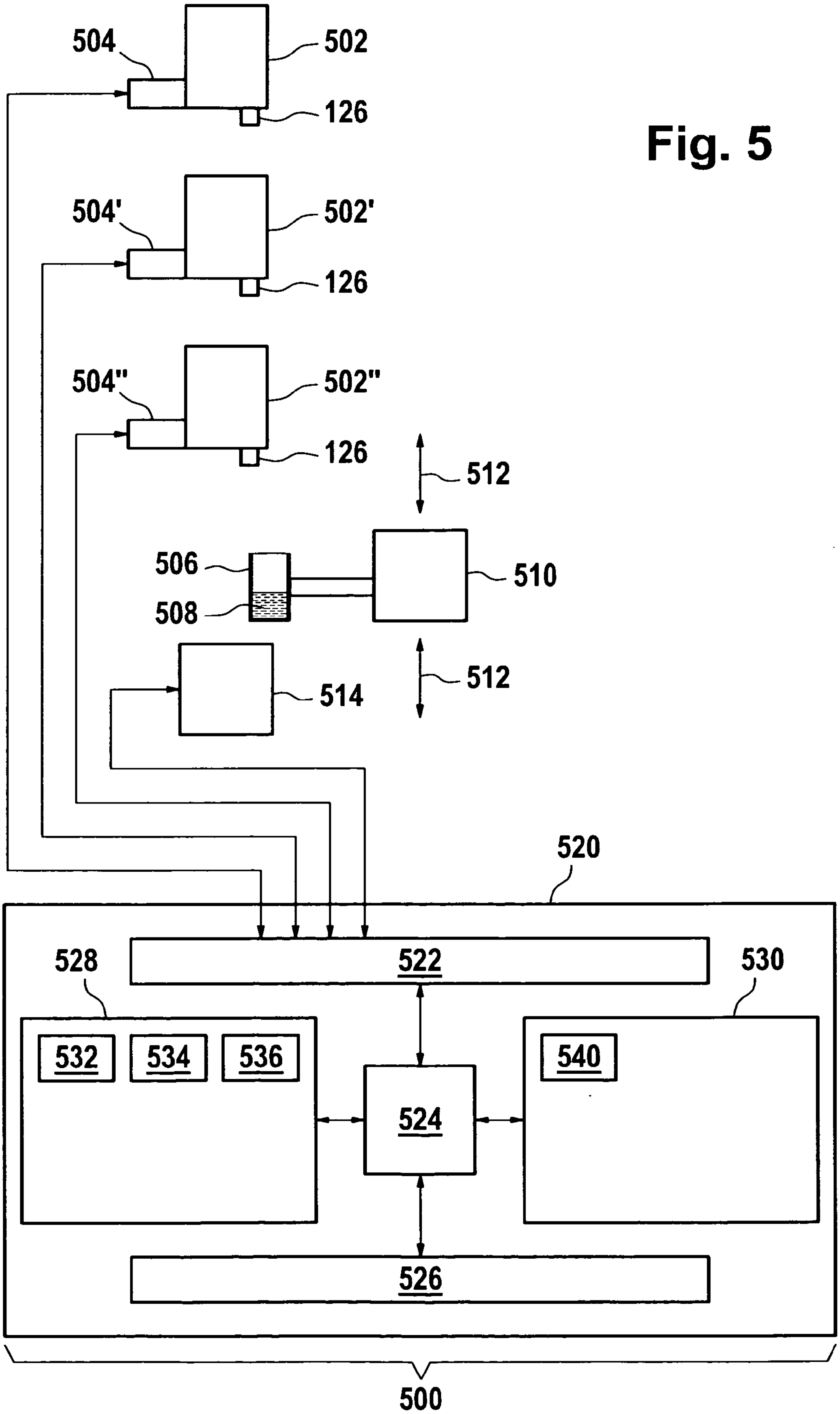
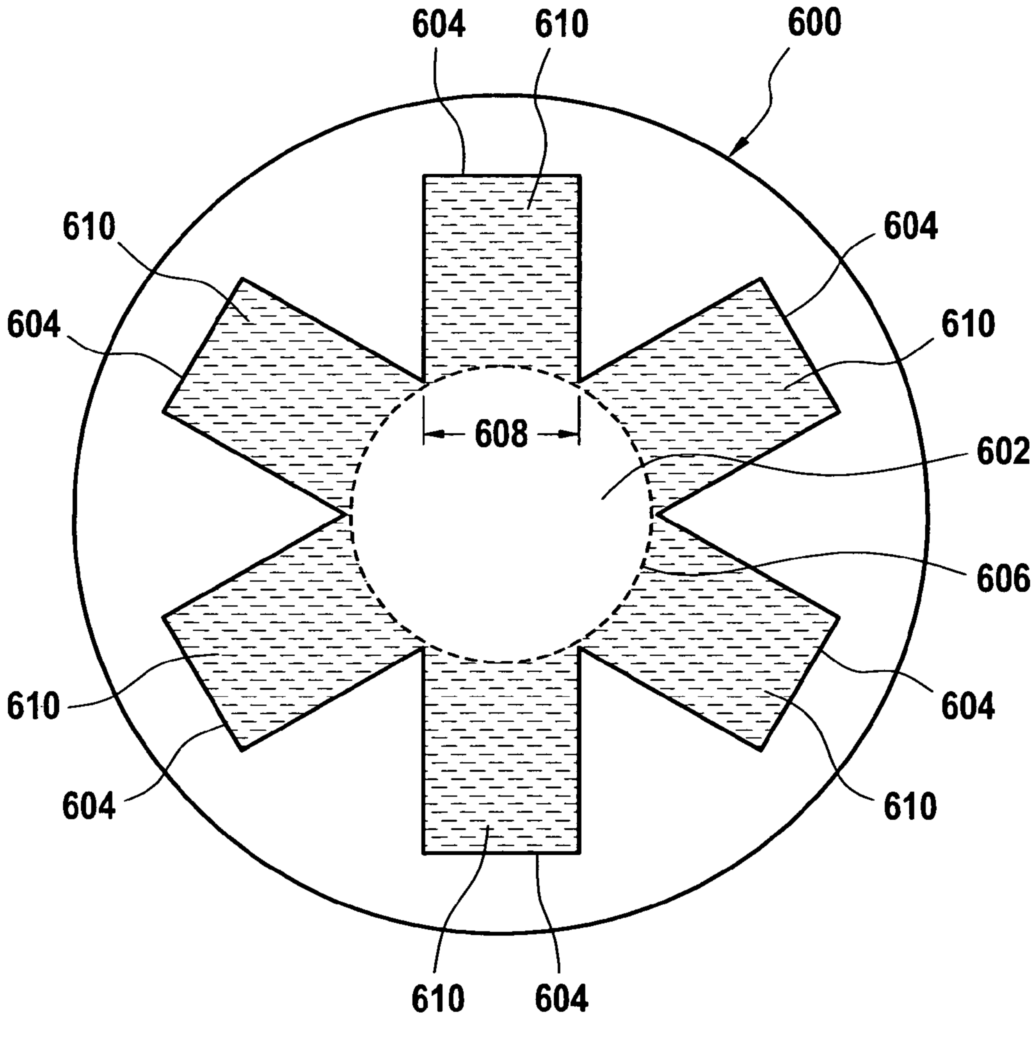

504
502
126
504'
502'
126
504"
502"
126
512
506
508
510
514
512
520
522
528
530
532
534
536
540
524
526
500

Fig. 5

Fig. 6



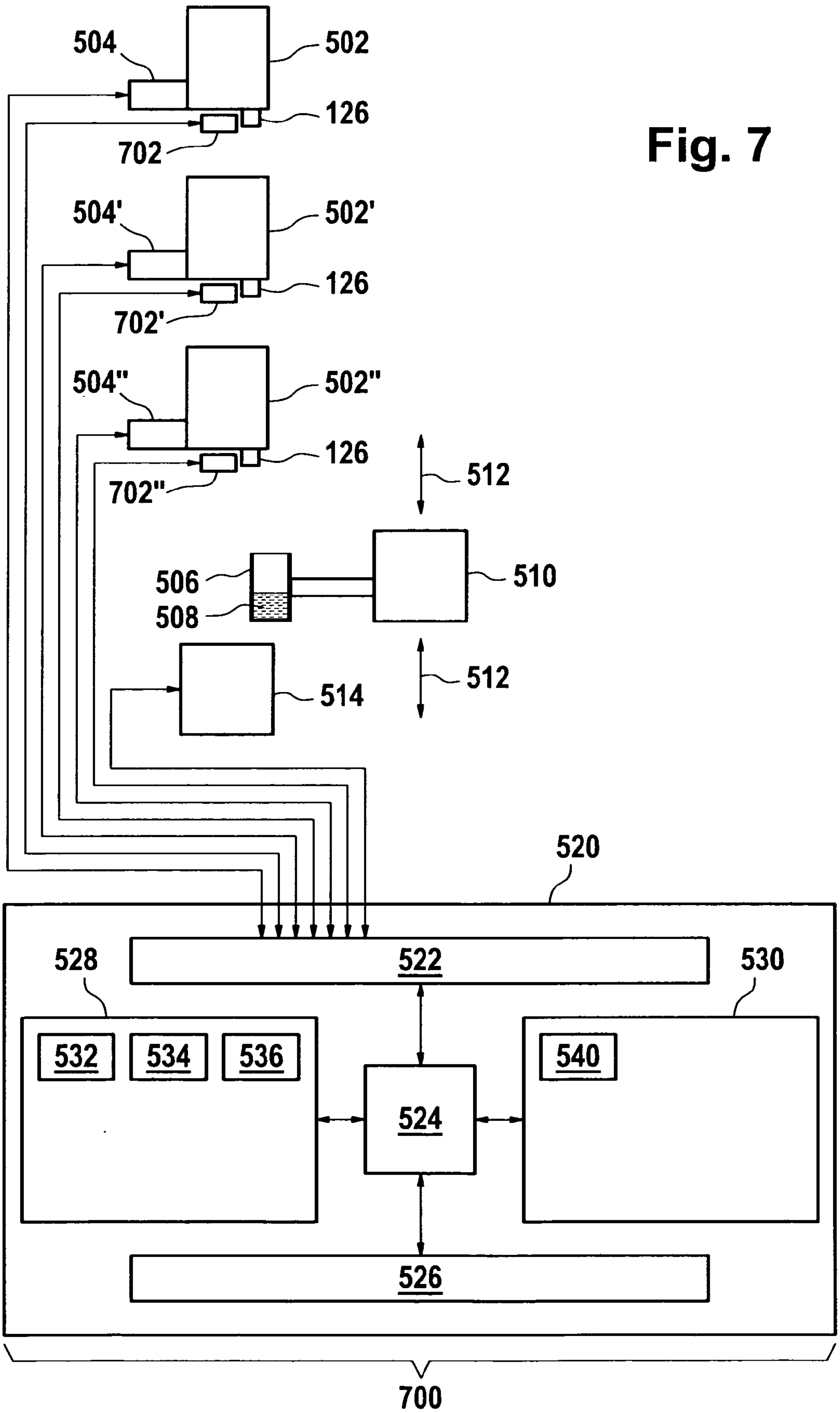

504
502
126
702
504'
502'
126
702'
504"
502"
126
702"
512
506
508
510
514
512
520
522
528
530
532
534
536
540
524
526
700

Fig. 7

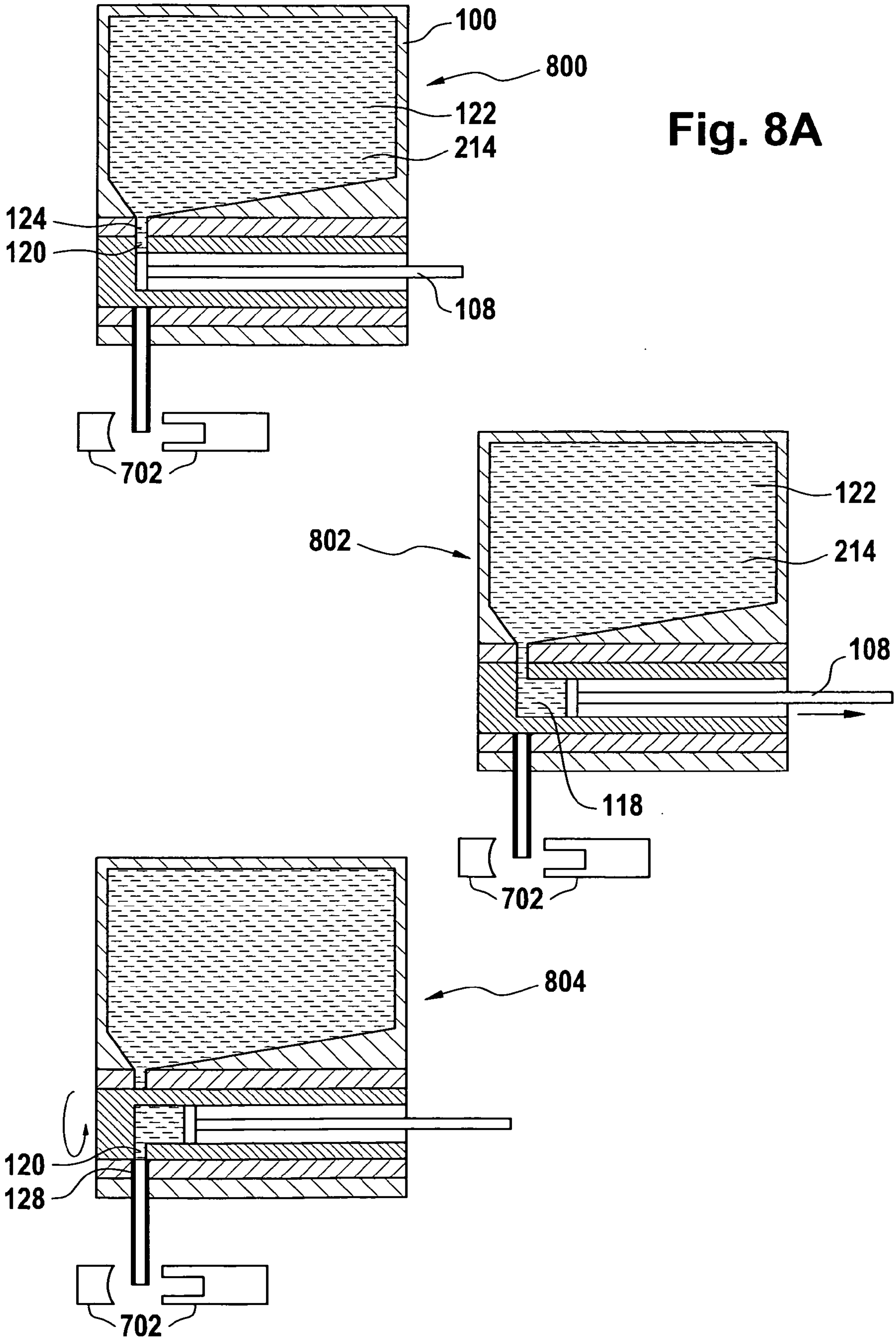

100
800
122
214
124
120
108
702
122
802
214
108
118
702
804
120
128
702

Fig. 8A

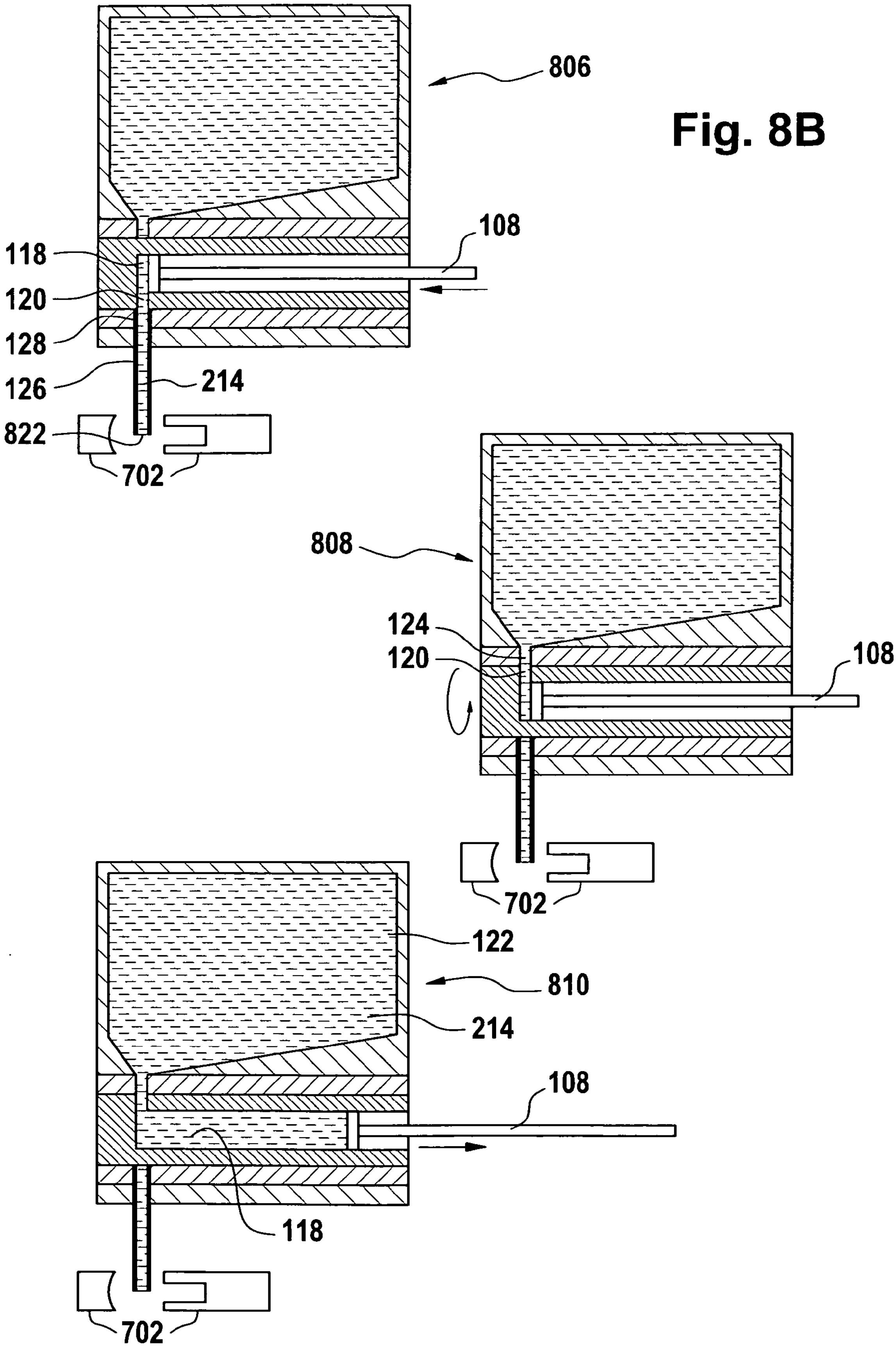

806
108
118
120
128
126
214
822
702
808
124
120
108
702
122
810
214
108
118
702

Fig. 8B

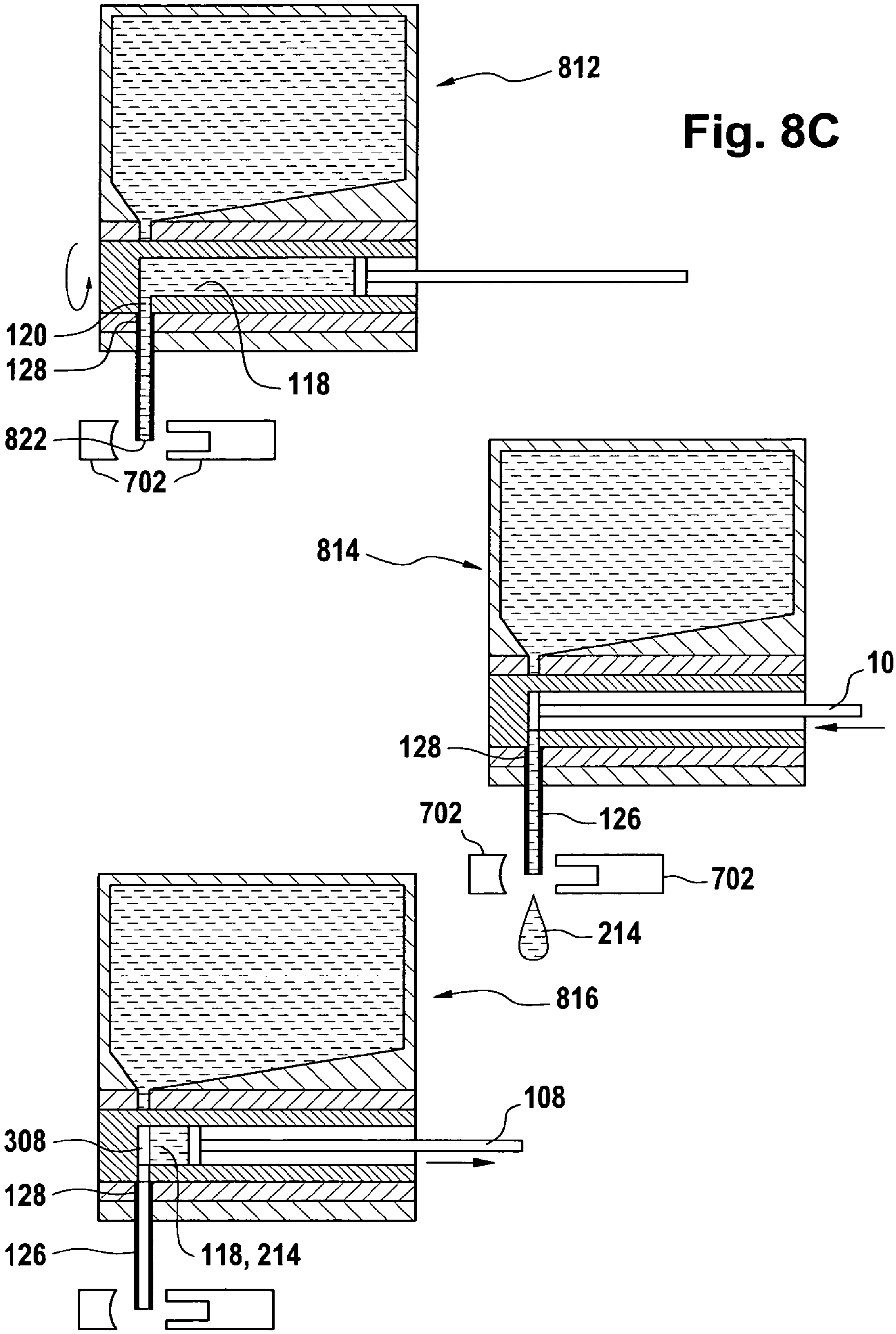

812
120
128
118
822
702
814
108
128
702
126
702
214
816
108
308
128
126
118, 214

Fig. 8C

Fig. 8D

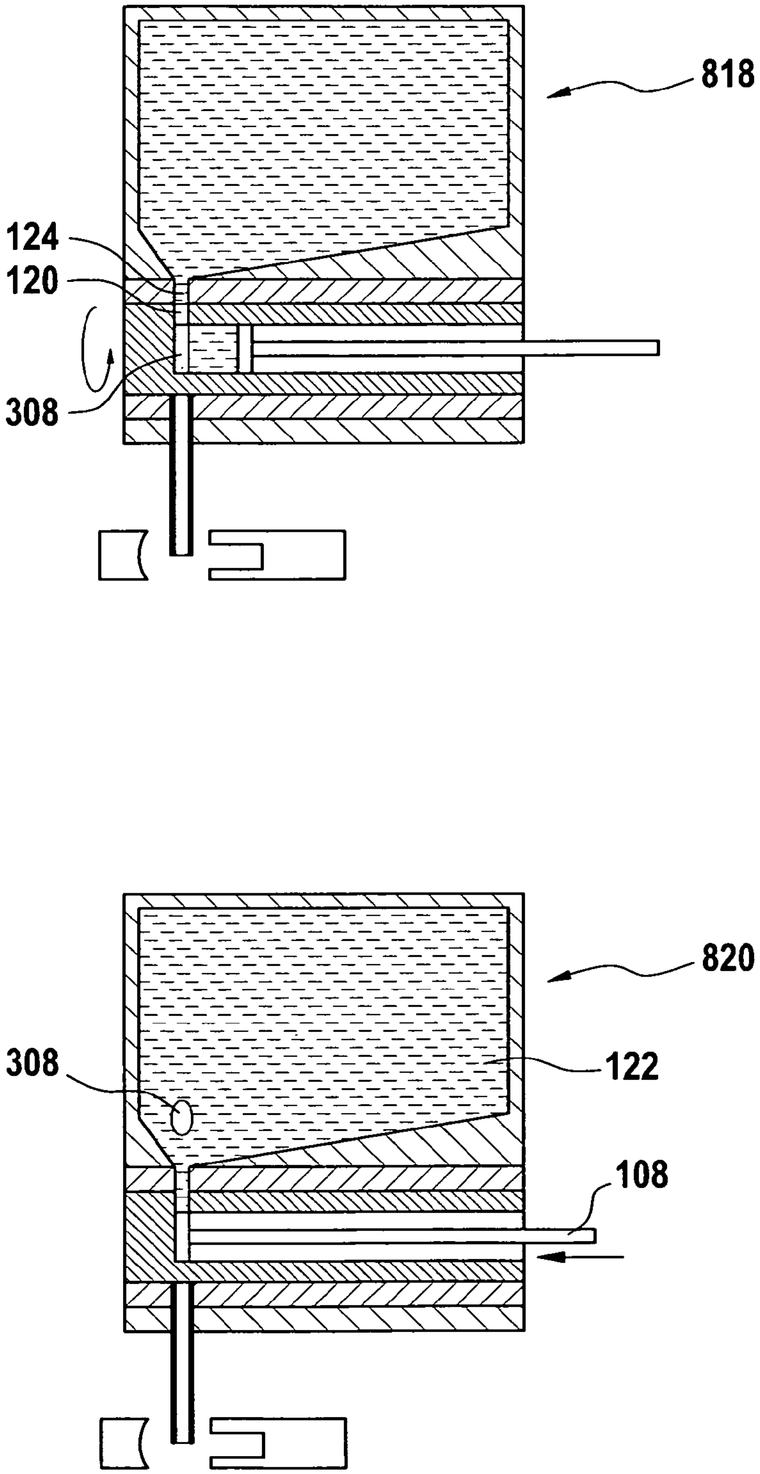


Fig. 9

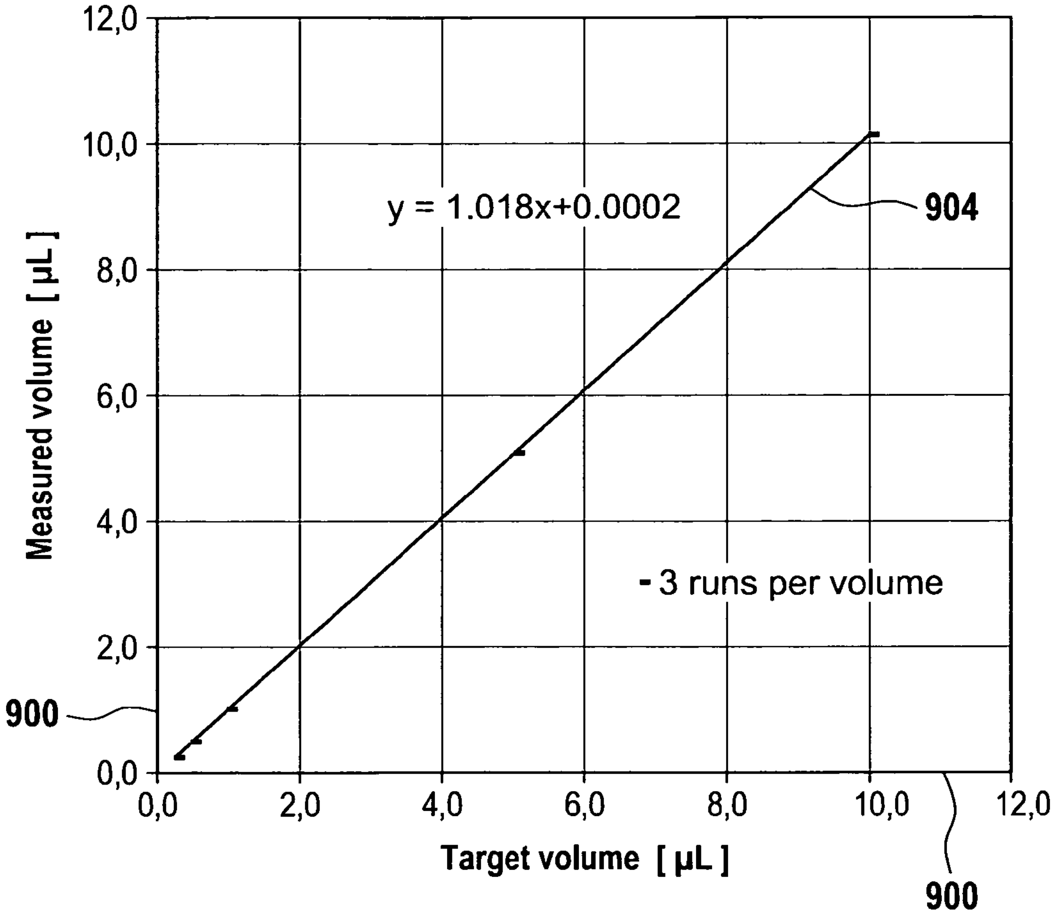

12,0
10,0
8,0
6,0
4,0
2,0
0,0
Measured volume [µL]
y = 1.018x+0.0002
904
- 3 runs per volume
900
0,0
2,0
4,0
6,0
8,0
10,0
12,0
Target volume [µL]
900

Fig. 10

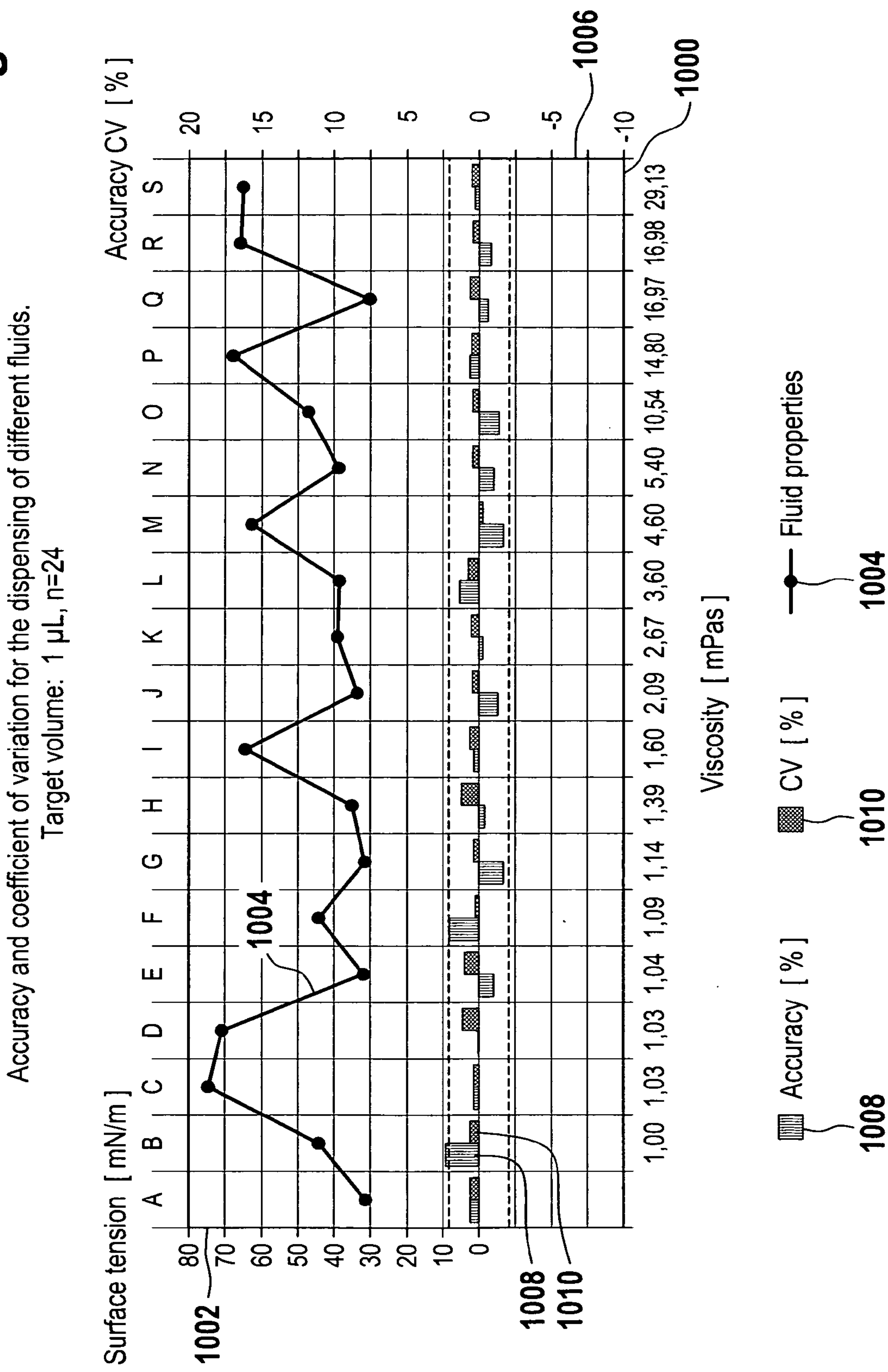
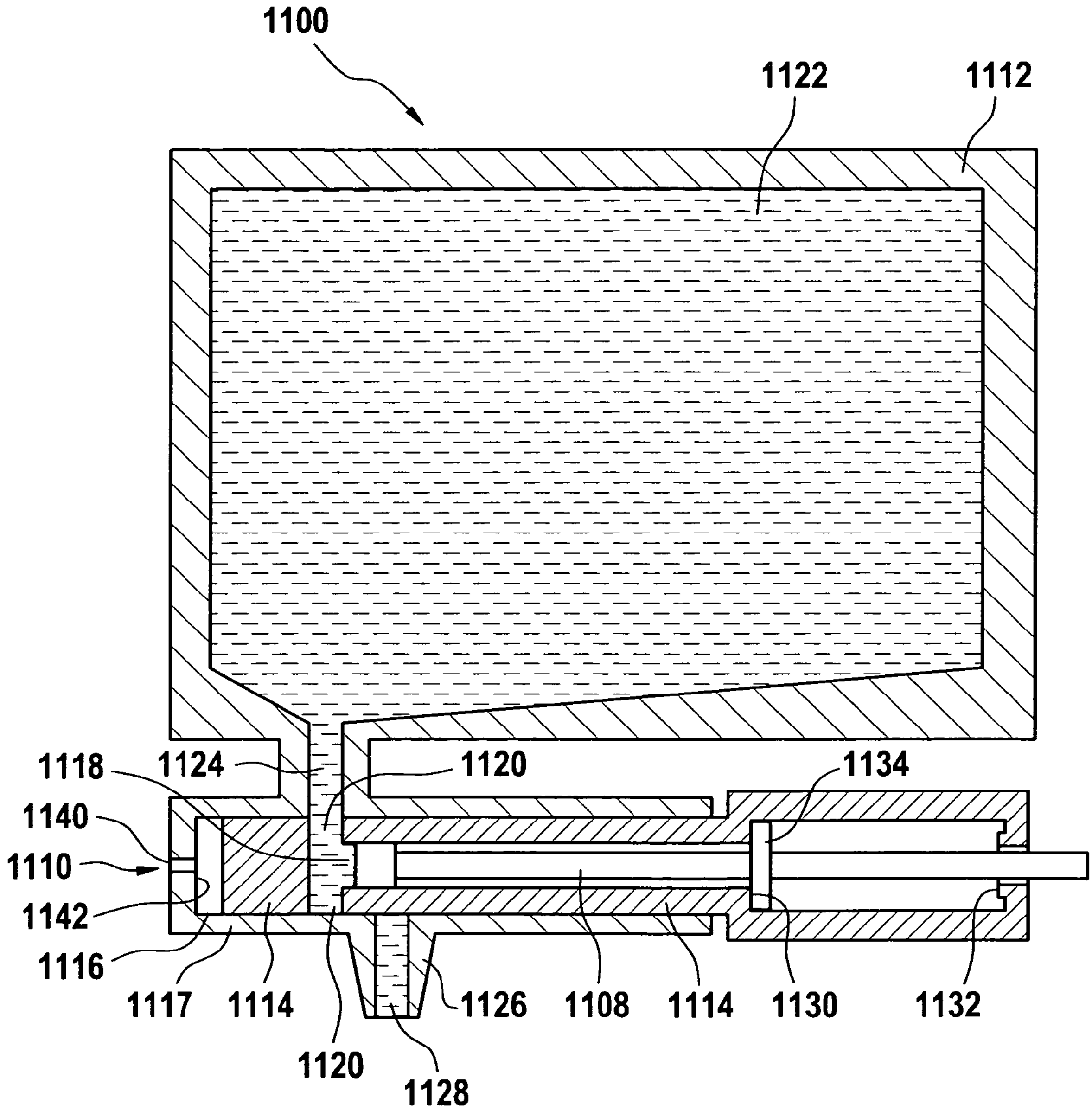

Accuracy and coefficient of variation for the dispensing of different fluids.
Target volume: 1 µL, n=24
Surface tension [mN/m]
Accuracy CV [%]
Viscosity [mPas]
A B C D E F G H I J K L M N O P Q R S
1,00 1,03 1,03 1,04 1,09 1,14 1,39 1,60 2,09 2,67 3,60 4,60 5,40 10,54 14,80 16,97 16,98 29,13
80 70 60 50 40 30 20 10 0
20 15 10 5 0 -5 -10
Accuracy [%]
CV [%]
Fluid properties
1000
1002
1004
1006
1008
1010

Fig. 11


1100
1122
1112
1118
1124
1120
1134
1140
1110
1142
1116
1117
1114
1120
1128
1126
1108
1114
1130
1132

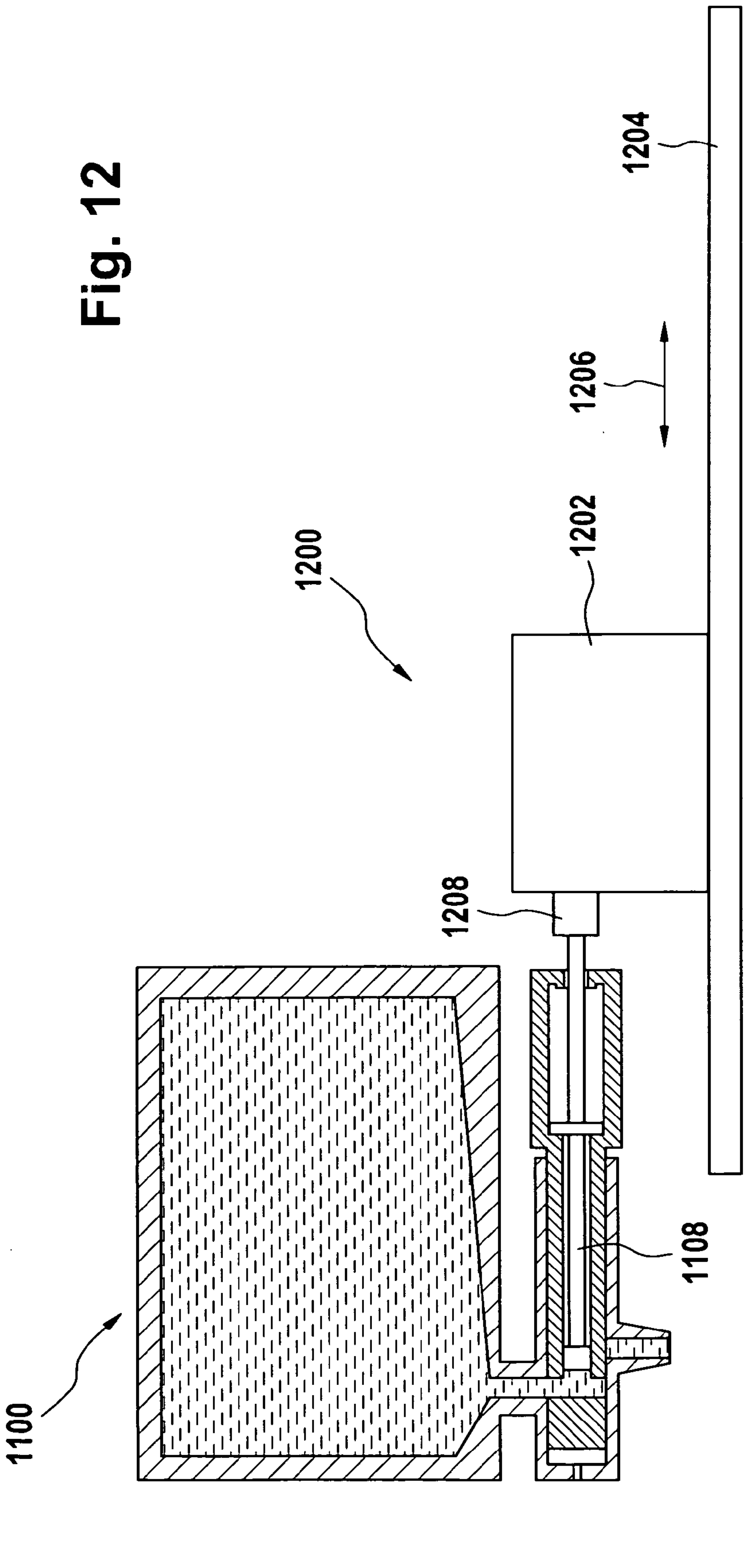


Fig. 12

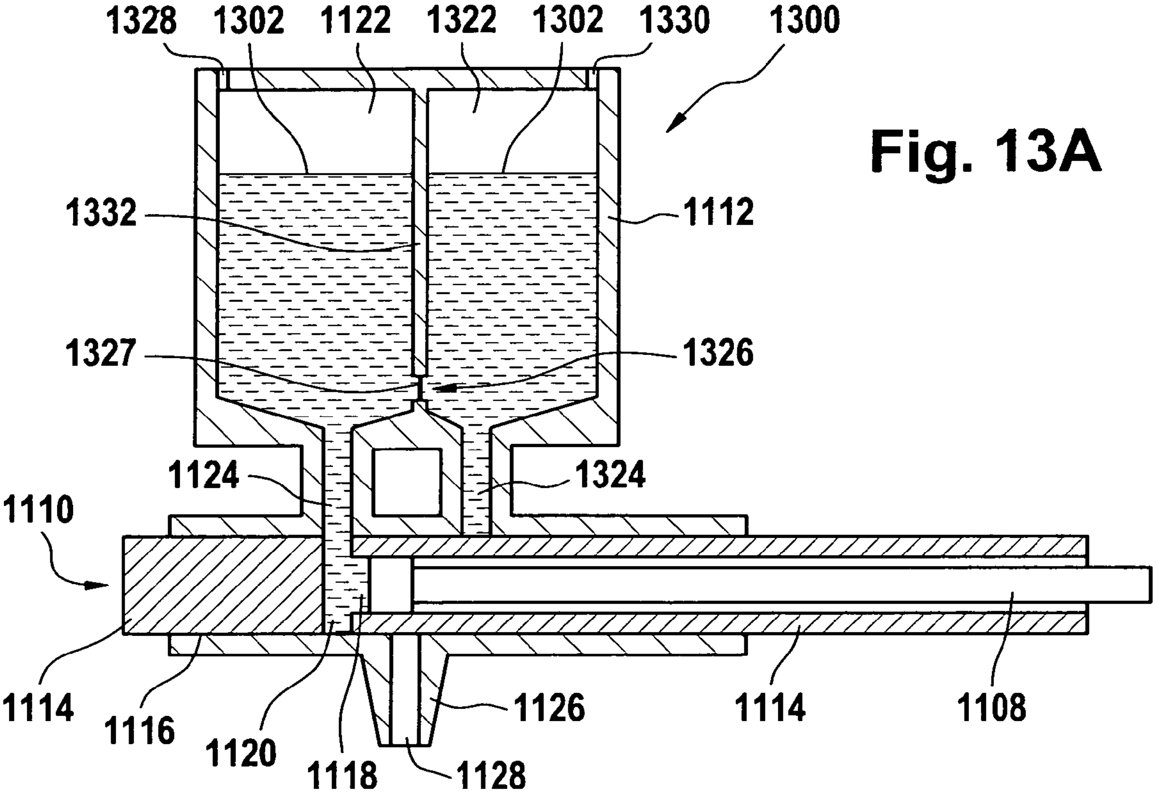


Fig. 13A

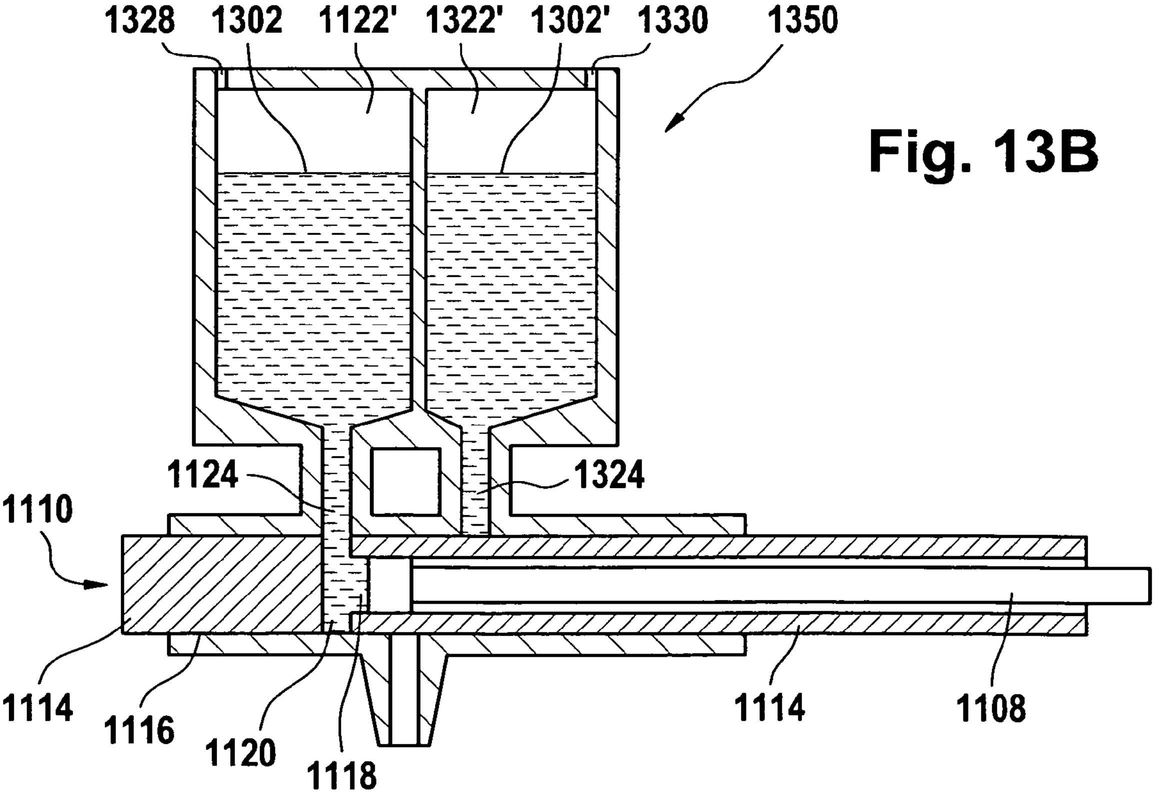


Fig. 13B

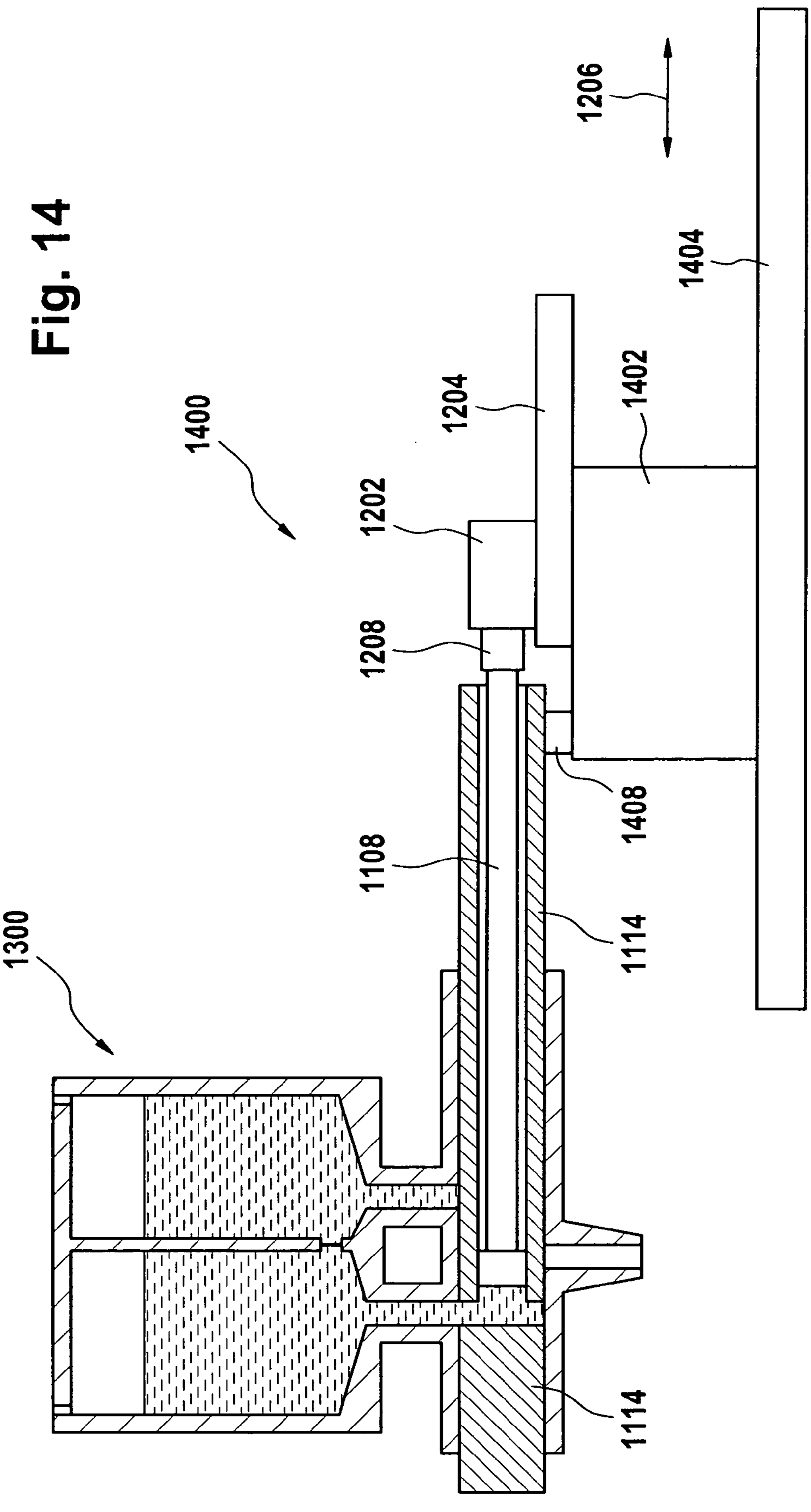


Fig. 14

Fig. 15A

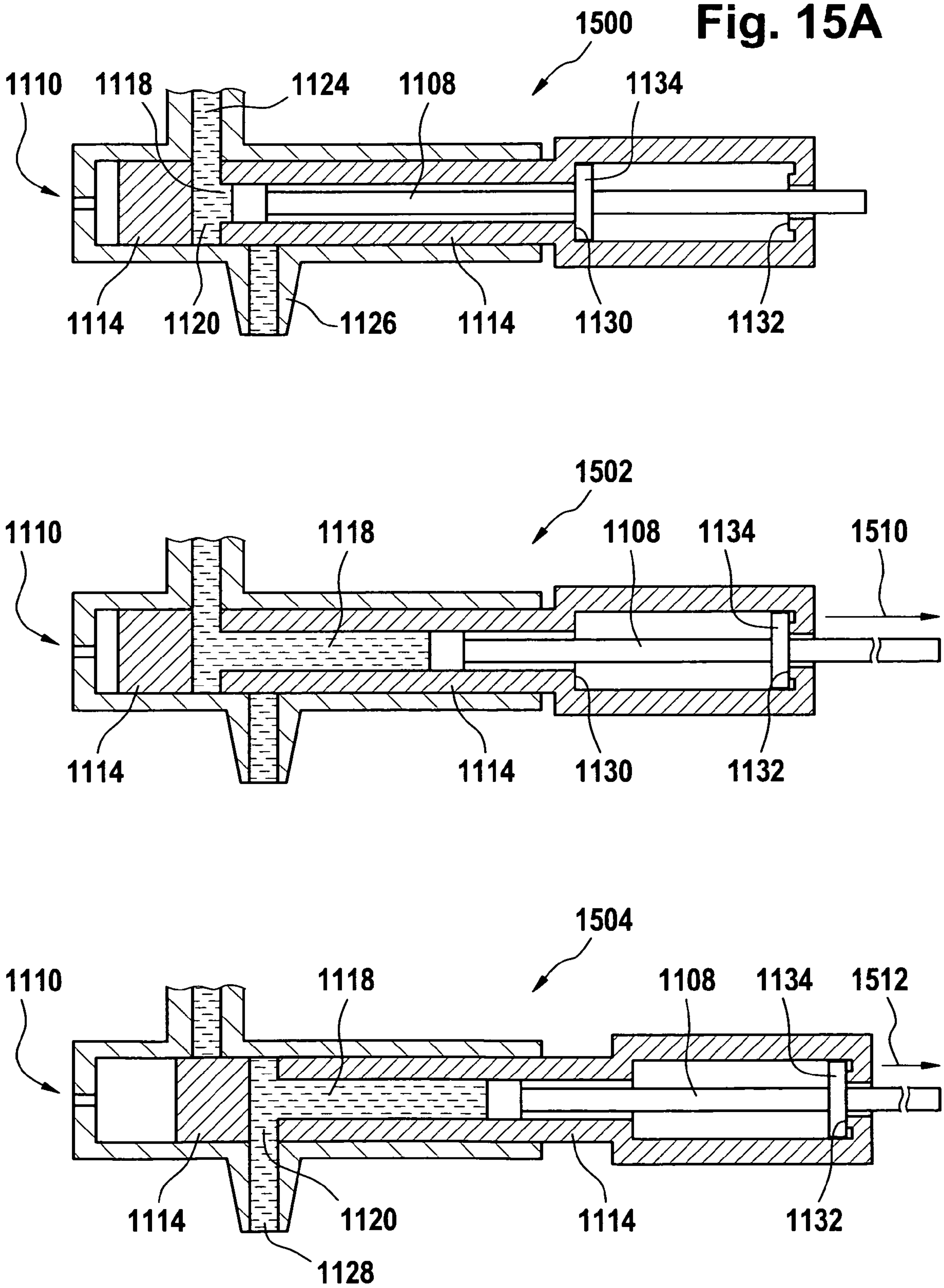

1500
1110
1118
1124
1108
1134
1114
1120
1126
1114
1130
1132
1502
1110
1118
1108
1134
1510
1114
1114
1130
1132
1504
1110
1118
1108
1134
1512
1114
1120
1114
1132
1128

Fig. 15B

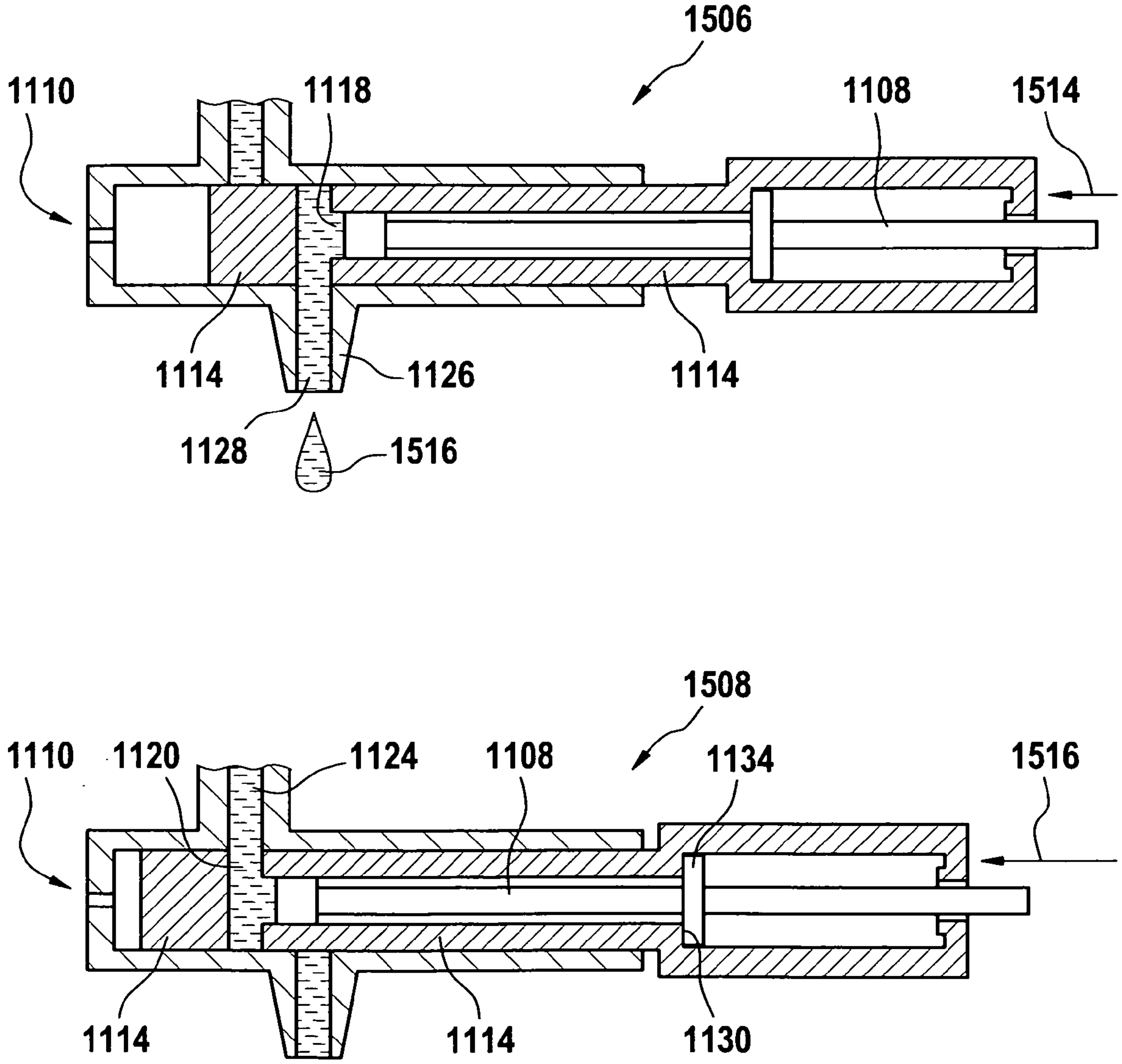

1506
1110
1118
1108
1514
1114
1126
1114
1128
1516
1508
1110
1120
1124
1108
1134
1516
1114
1114
1130

Fig. 16A

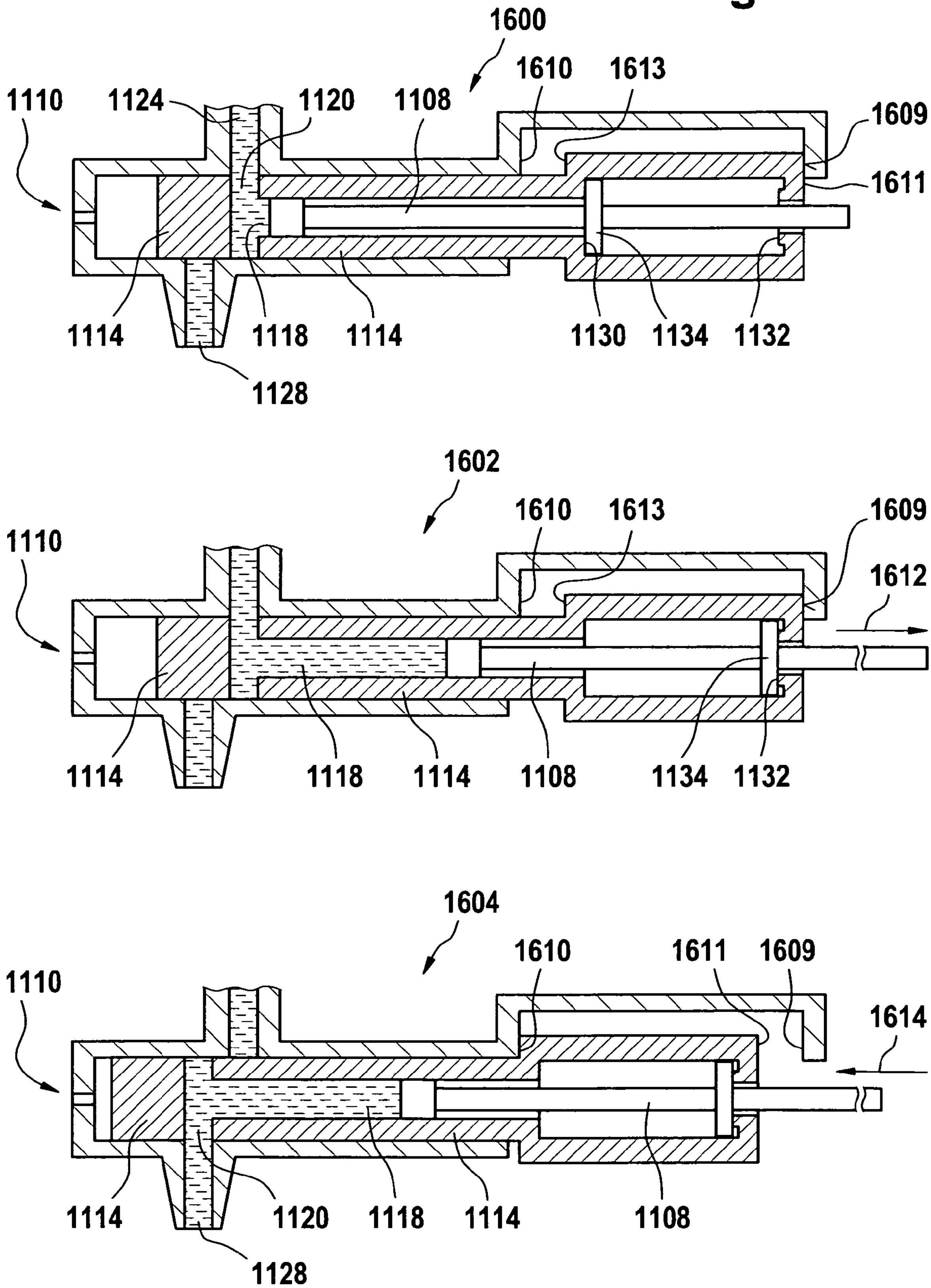
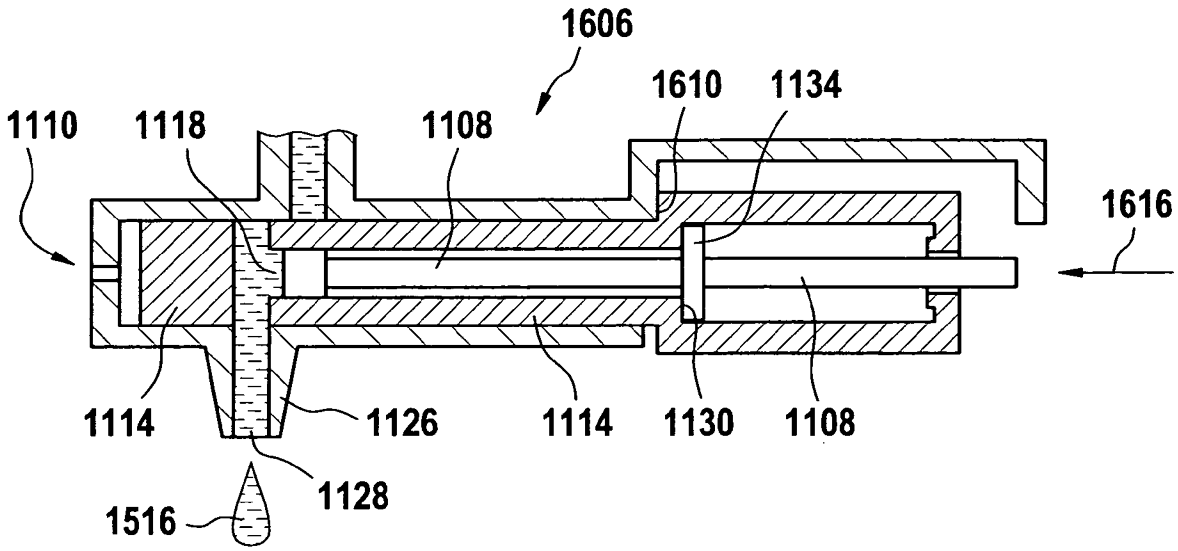

1600
1110
1124
1120
1108
1610
1613
1609
1611
1114
1118
1114
1130
1134
1132
1128
1602
1110
1610
1613
1609
1612
1114
1118
1114
1108
1134
1132
1604
1110
1610
1611
1609
1614
1114
1120
1118
1114
1108
1128

Fig. 16B


1606
1110
1118
1108
1610
1134
1616
1114
1126
1114
1130
1108
1128
1516

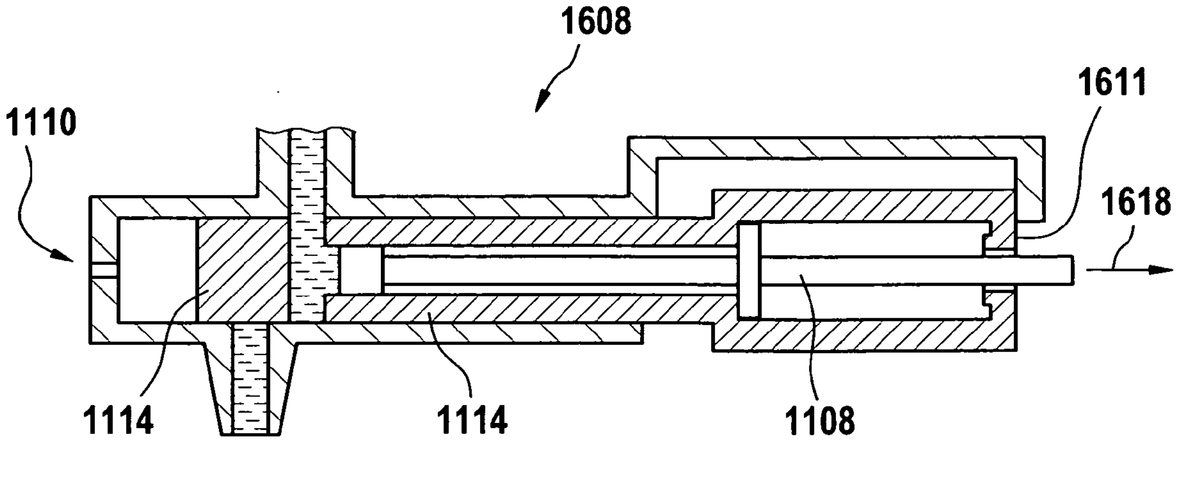

1608
1110
1611
1618
1114
1114
1108

Fig. 17

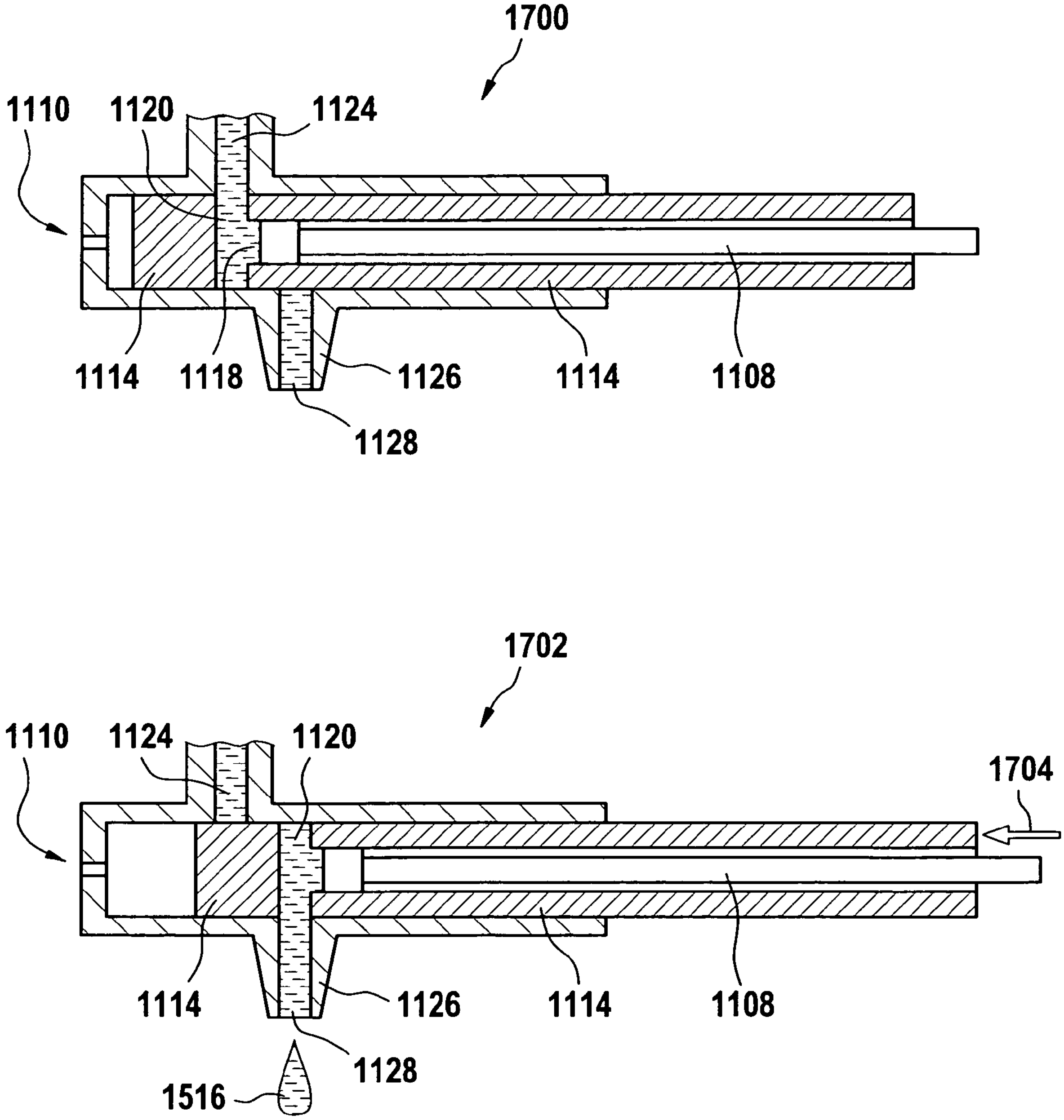

1700
1110
1120
1124
1114
1118
1126
1114
1108
1128
1702
1110
1124
1120
1704
1114
1126
1114
1108
1128
1516

Fig. 18A

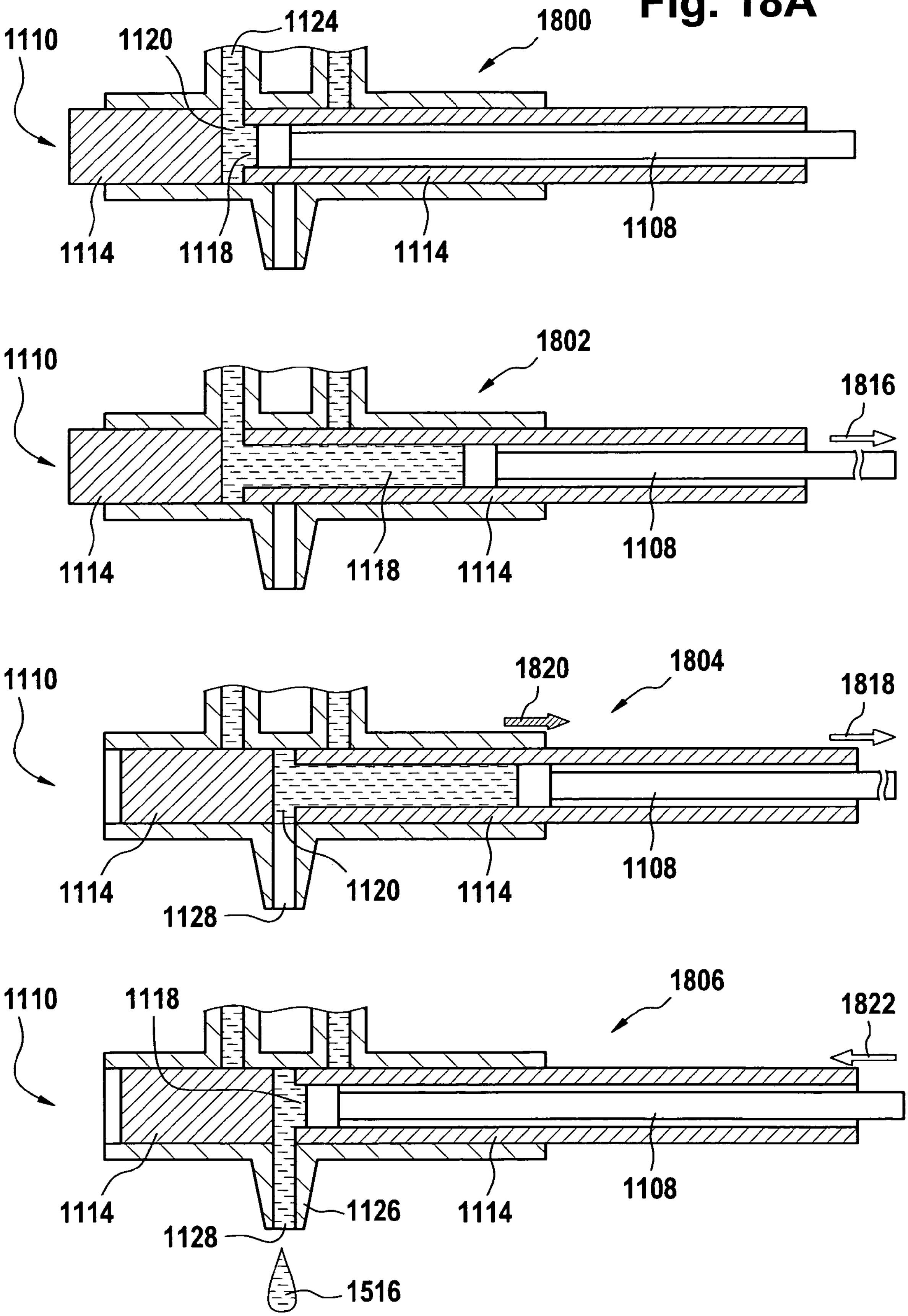

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Fig. 18B

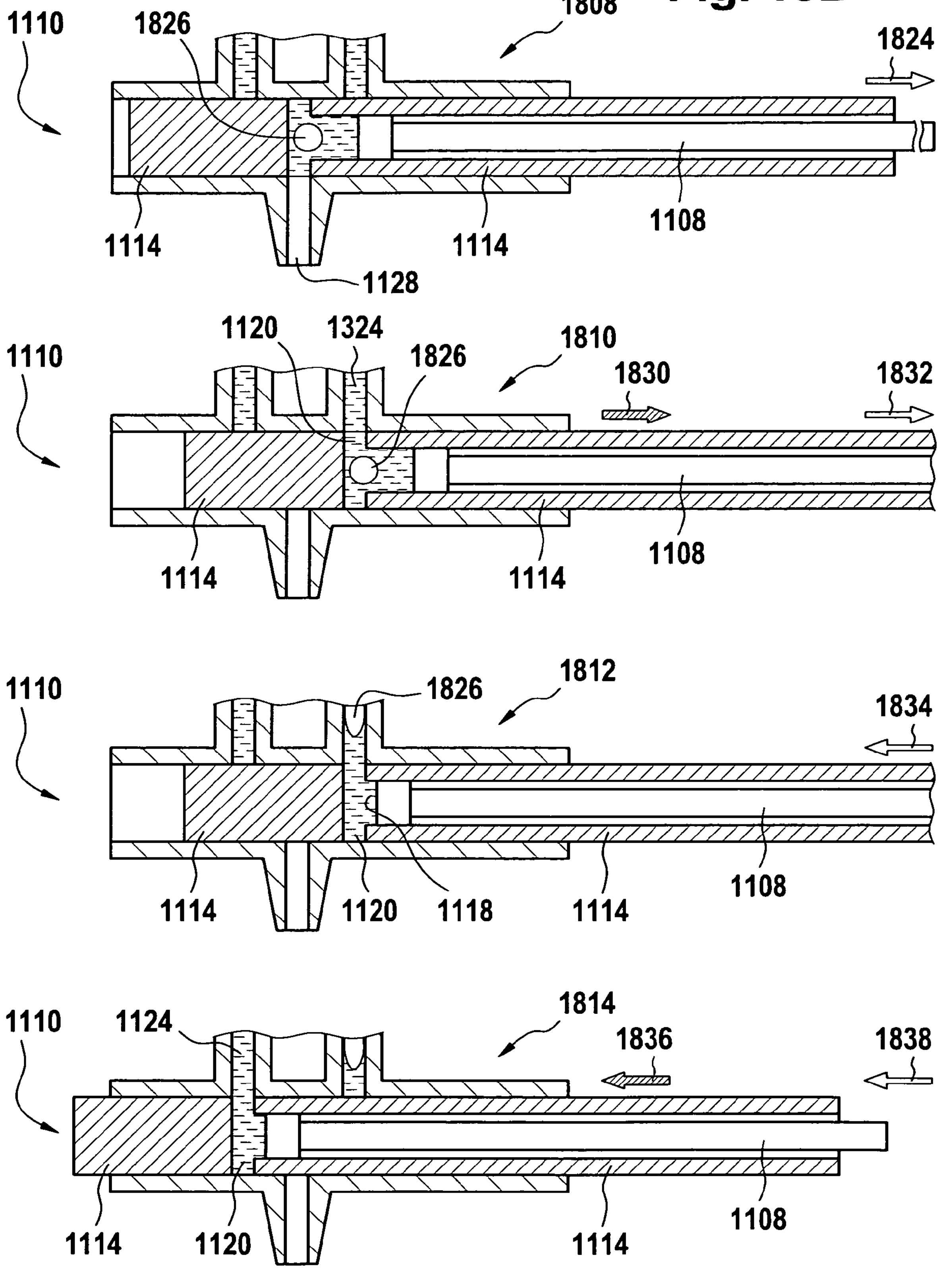
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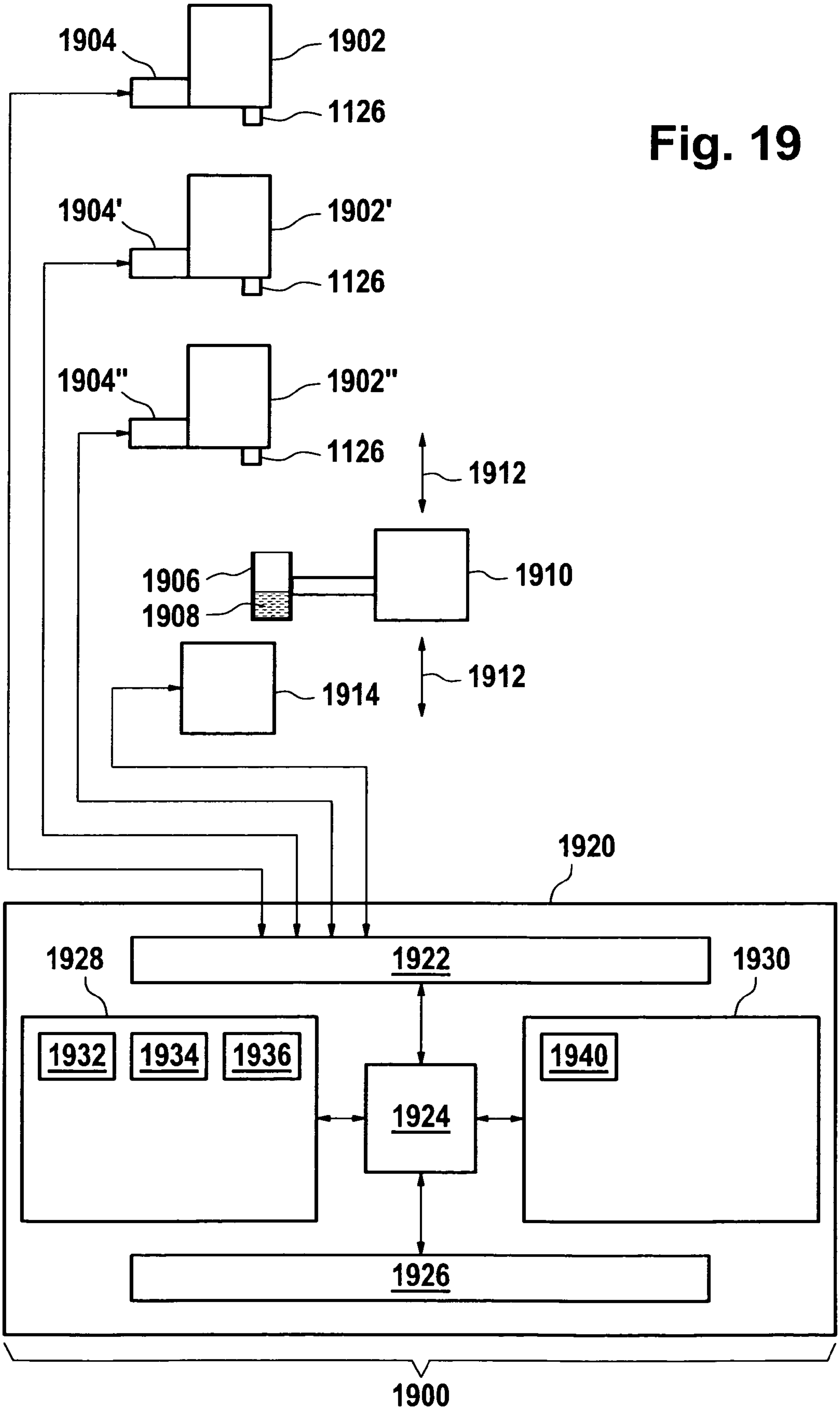
Fig. 19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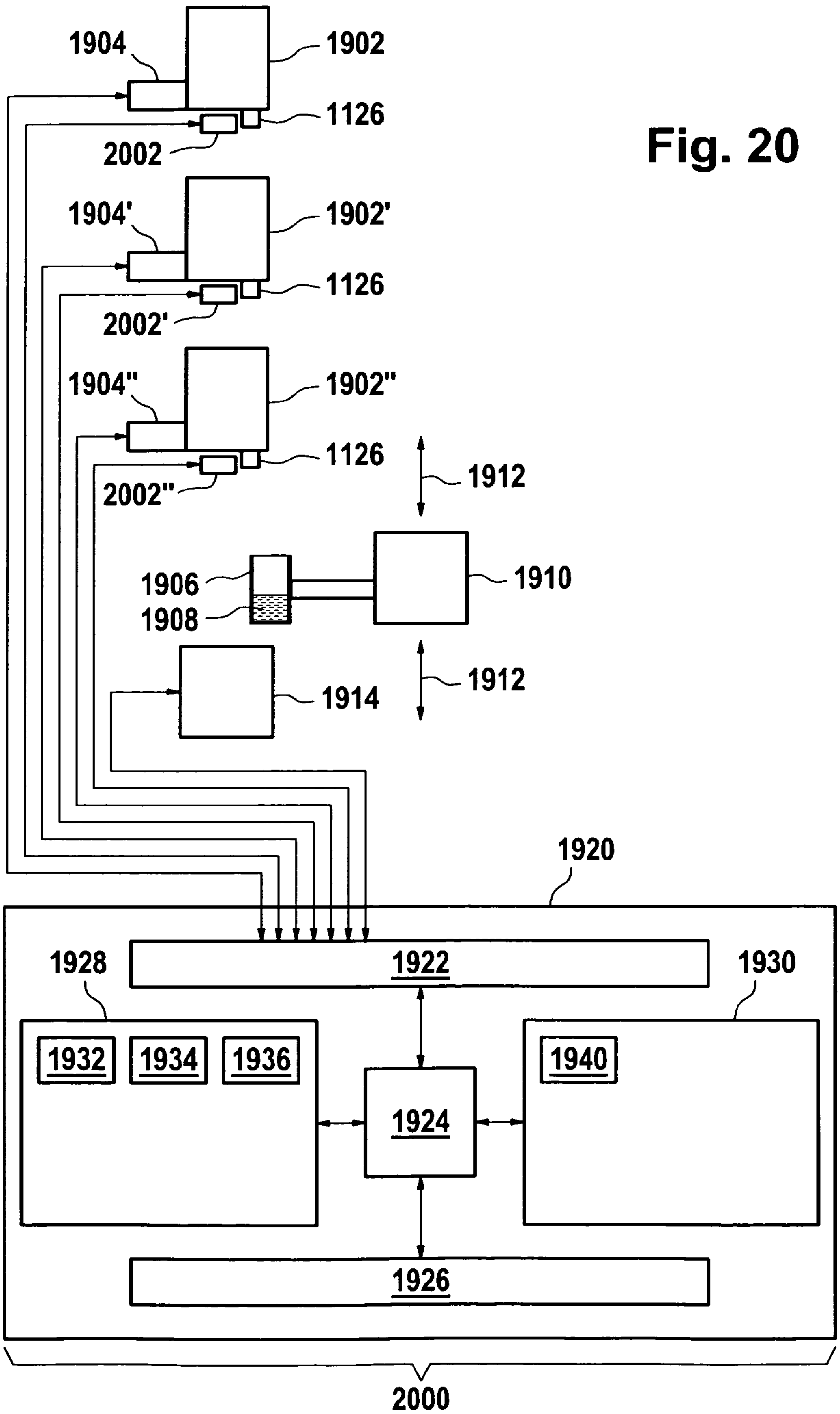
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Fig. 20

Fig. 21

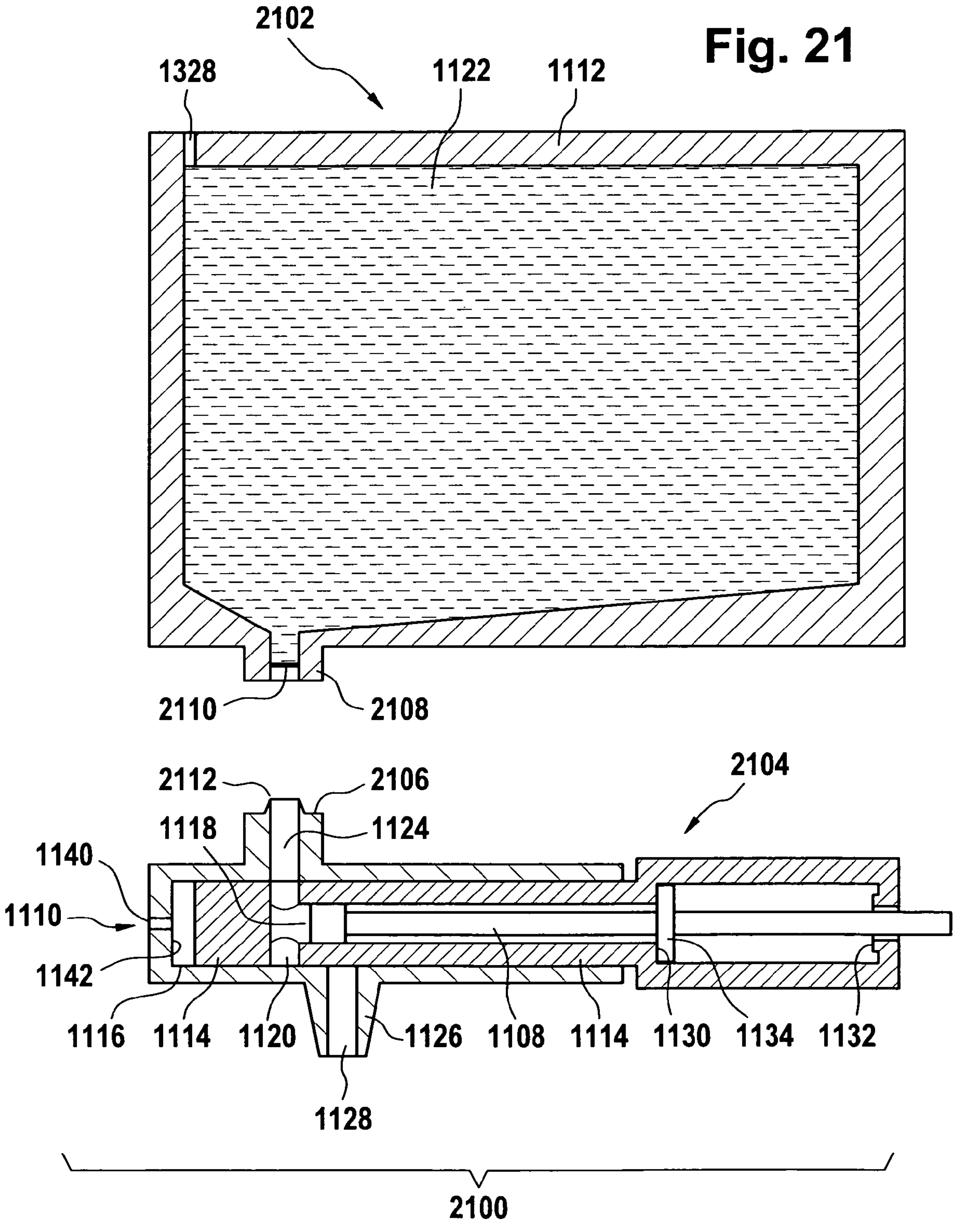
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Fig. 22

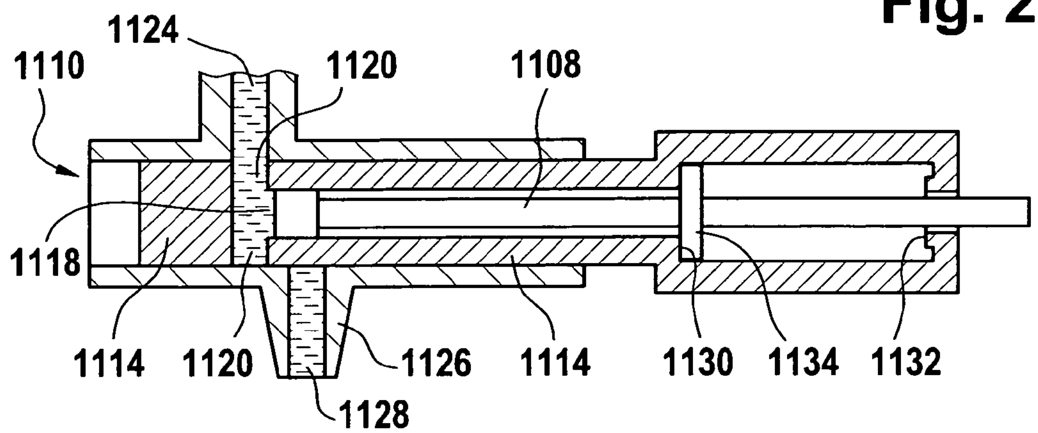


Fig. 23

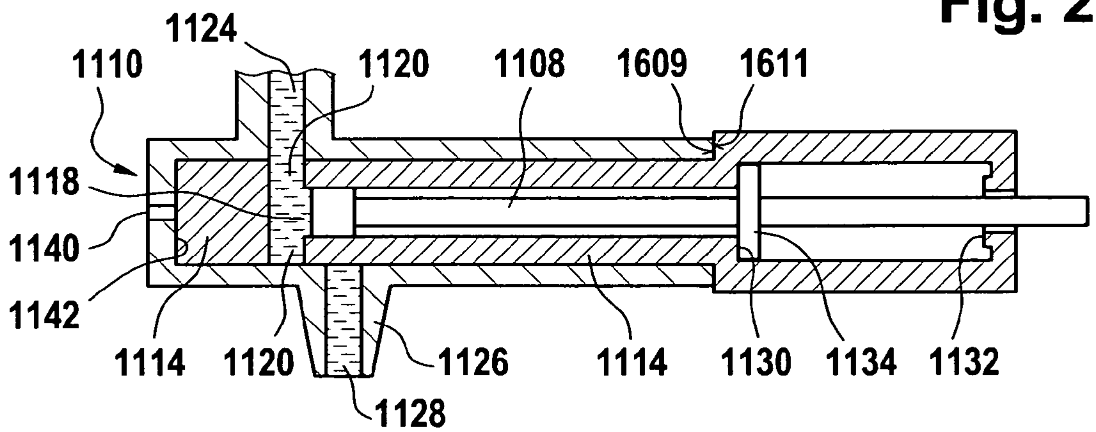


Fig. 24

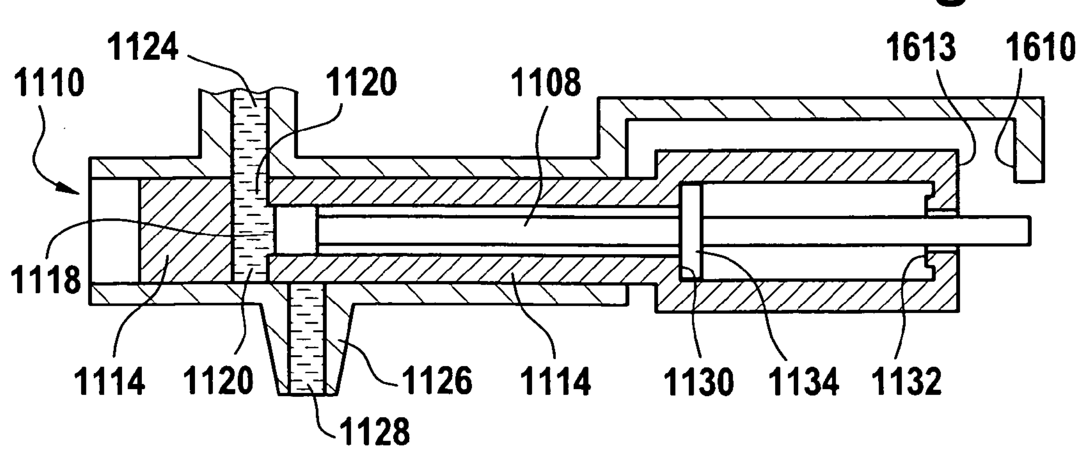


Fig. 25

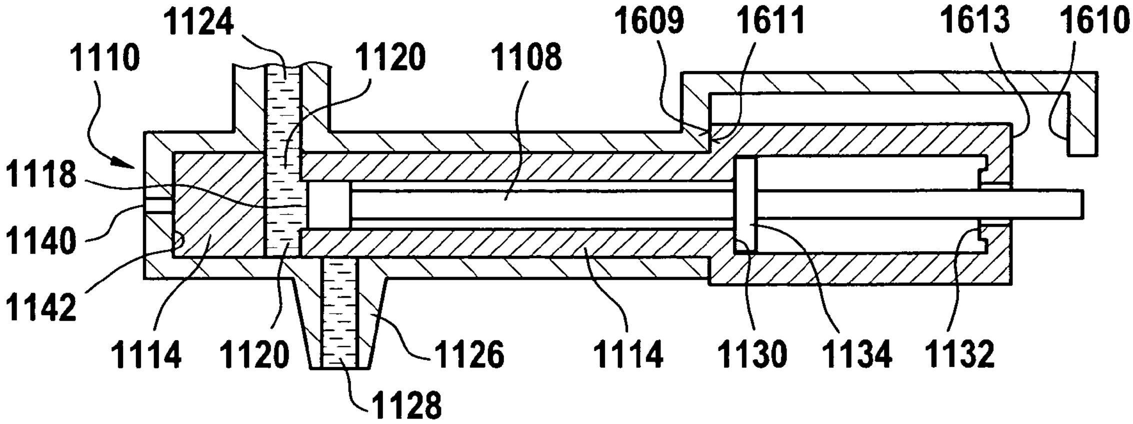


Fig. 26

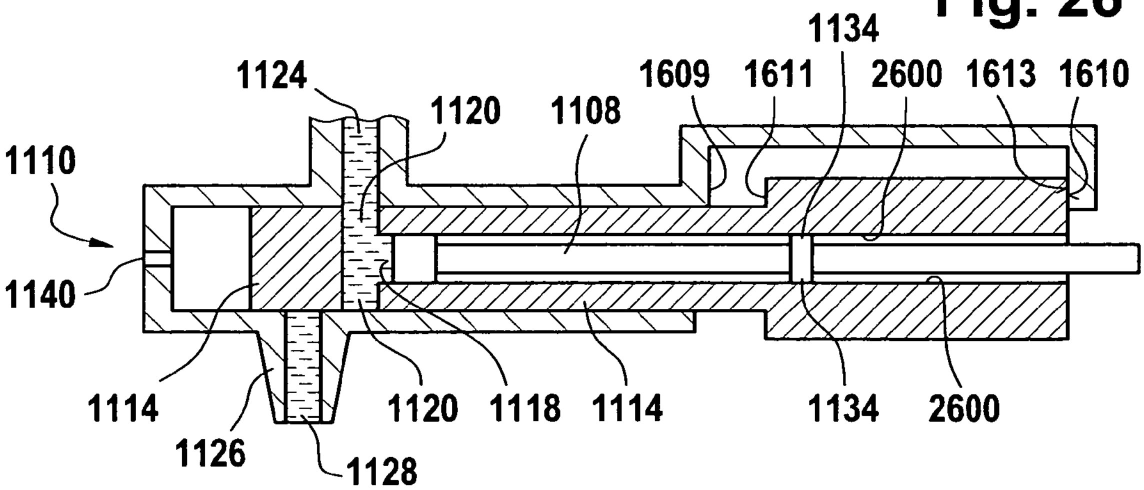
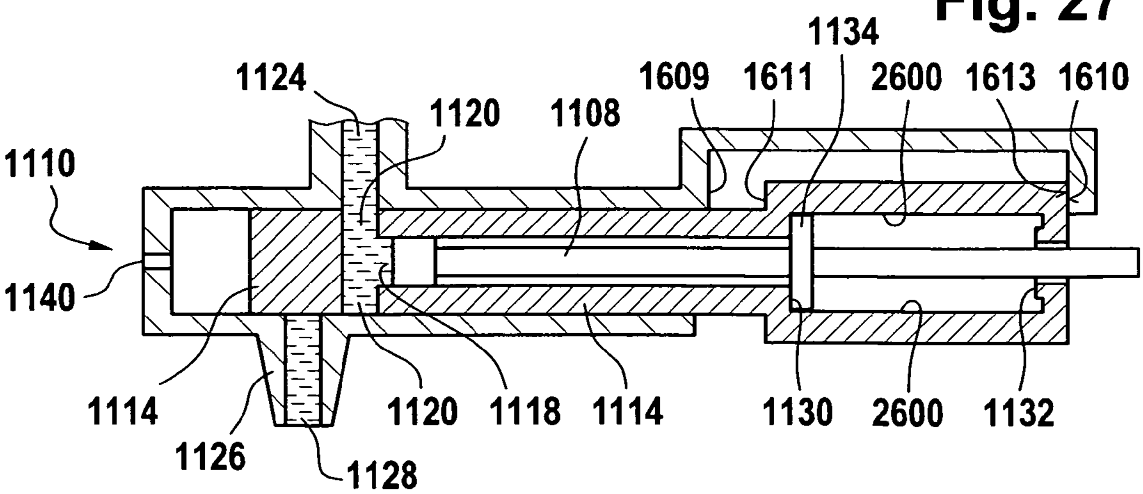


Fig. 27



INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2012/072733

A. CLASSIFICATION OF SUBJECT MATTER
INV. G01F11/02
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G01F G01N B01F A61M B62D F16K B01L

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 practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Y	EP 1 987 890 A1 (MUSASHI ENGINEERING INC [JP]) 5 November 2008 (2008-11-05) paragraph [0021] - paragraph [0030]; figures 7,8,10	1-42
Y	US 2009/176314 A1 (STEINBOECK WOLF-DIETRICH [AT] ET AL) 9 July 2009 (2009-07-09) paragraph [0034] - paragraph [0040]; figures 1-4	1-42
Y	US 5 441 173 A (KOVAL MICHAEL J [US] ET AL) 15 August 1995 (1995-08-15) the whole document	1-42
Y	US 3 753 632 A (MILLS A) 21 August 1973 (1973-08-21) the whole document	1-42

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☒ See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
2 May 2013	23/05/2013

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	Fenzl, Birgit

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2012/072733

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