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(54) **LIQUID MIXING SYSTEM AND LIQUID MIXER THEREFOR**

FLÜSSIGKEITSMISCHVORRICHTUNG UND FLÜSSIGKEITSMISCHER DAFÜR
SYSTÈME DE MÉLANGE DE LIQUIDE ET MÉLANGEUR DE LIQUIDE

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Description

[0001] The present invention relates to a liquid mixing system, and a liquid mixer therefor, for mixing two or more liquids supplied separately.

[0002] There are many applications in which the mixing of two or more liquids are required. Such applications include for instance the mixing of a sample liquid to be tested with a reagent, or the mixing of liquids that react chemically together.

[0003] In sample measurement applications, for instance flow cytometry applications, the volumes of liquids to be mixed are small, for instance in the range of a few microlitres to a few millilitres. In microfluidic applications a good mixing of liquids can be difficult to achieve reliably. Moreover, in many measurement applications there is a need to clean the fluid channels to avoid contamination of liquids in subsequent measurement operations. The cleaning of fluid channels in conventional systems is difficult to achieve reliably and may lead to lengthy and costly cleaning procedures, these being generally more difficult in microfluidic applications. Cleaning is also difficult if the system requires a closed system, for instance to avoid liquid evaporation.

[0004] WO2007/093939 discloses a lab-on-a chip device for sample analyses of small fluid quantities and especially for molecular diagnostics applications. The device is formed as a sandwich structure comprising a substrate, fluid reception chambers and a micro channel structure for establishing a fluid communication between the chambers. The channels in the lab-on-a chip device are formed as a void between a substrate and a membrane by use of laser ablation, etching or micromachining techniques in silicon or silicon dioxide materials.

[0005] WO2009/029445 discloses a self-contained device for testing a material sample. The device in WO2009/029445 is also formed by a multi-layered structure comprising a substrate, deformable layers and adhesive layers.

[0006] A problem with fluid devices such as disclosed in WO2007/093939 and WO2009/029445 is the risk of leakage associated with parts that have been assembled or welded together, the complexity of the microchannels which need to be accurately formed, and the high costs of manufacturing and assembly. A further drawback is the difficulty of cleaning the microchannels and associated risk of contamination in subsequent mixing cycles.

[0007] US 2008/123466 discloses a liquid mixer with a mixer tube and an actuation system, with a supply tube constituting the inlet, outlet and mixing chamber, where the mixing chamber expands in cross sectional area.

[0008] In view of the foregoing, it is an object of this invention to provide a liquid mixer for a liquid mixing system, which enables good and reliable mixing of liquids.

[0009] It is another object of the invention to provide a liquid mixing system that performs good and reliable mixing of liquids.

[0010] It is advantageous to provide a liquid mixer that

is compact, robust and reliable.

[0011] It is advantageous to provide liquid mixer for a liquid mixing system, which enables easy and reliable cleaning of the fluid channels to avoid contamination of subsequent liquids to be mixed, or to avoid biofilms.

[0012] It is advantageous to provide a liquid mixing system that is easy to clean reliably to avoid contamination of subsequent liquids to be mixed.

[0013] It is advantageous to provide a liquid mixing system and a liquid mixer therefor that allows to effectively evacuate air within the fluid channels of the mixing system and avoids capturing air within the valve and a pump system in a reliable manner.

[0014] It is advantageous to provide a liquid mixing system that is cost effective and easy to operate. It is advantageous to provide a liquid mixing system that is easy to use.

[0015] It is advantageous to provide a liquid mixing system and a liquid mixer therefor that is cost effective to manufacture and assemble.

[0016] Objects of the invention have been achieved by providing a liquid mixing system according to claim 1 and a method of operating a liquid mixing system according to claim 11.

[0017] Disclosed herein is a liquid mixer including a mixer tube and an actuation system. The mixer tube comprises a mixer chamber portion defining therein a mixer chamber, an inlet for inflow of fluid into the mixer chamber from a pump system, and an outlet for outflow of fluid from the mixer chamber to a delivery system. The inlet, outlet and mixer chamber portion form part of a continuous section of a supply tube made of a supply material, the mixer chamber portion having a cross-sectional area in an expanded state that is larger than the cross-sectional area of the mixer tube at said outlet and inlet.

[0018] In an embodiment, the ratio of the mixer chamber portion cross-sectional area over the inlet or outlet cross-sectional area A_p/A_i is in a range of 4 to 100, preferably in range of 9 to 64.

[0019] In an advantageous embodiment, the supply material is a polymer.

[0020] In an advantageous embodiment, the mixer chamber portion is a blow molded section of tube.

[0021] In an advantageous embodiment, the actuation system comprises one or more mixer chamber actuators comprising one or more movable tube interface elements biased against a side of the mixer chamber portion, an opposite side of the mixer chamber portion biased against a wall of a support structure of the liquid mixer.

[0022] In an advantageous embodiment, the actuation system comprises an outlet valve in the form of a pinch valve that biases against the mixer tube on an outlet side of the mixer chamber portion, the outlet valve being operated by means of an outlet valve actuator.

[0023] In an advantageous embodiment, the pinch valve biases against an expanded section of the mixer chamber portion.

[0024] In an advantageous embodiment, the outlet

valve comprises an elastic body configured to apply elastic pressure closing together opposing surfaces of the mixer chamber portion.

[0025] In an advantageous embodiment, the mixer chamber actuator and/or the outlet valve actuator is/are passively driven in one direction by means of a spring element.

[0026] In an embodiment, the mixer chamber actuator and/or the outlet valve actuator is/are actively driven in at least one direction by means of an electromagnetic actuator.

[0027] Also disclosed herein is a liquid mixing system comprising a liquid mixer and a pump system. The pump system comprises a valve device and a pump comprising a variable volume pump chamber, the valve device configured to selectively fluidically interconnect the variable volume pump chamber to the mixer chamber and to one or a plurality of liquid supplies.

[0028] In an advantageous embodiment, the pump is in the form of a syringe or piston pump.

[0029] In a variant the pump may be in the form a shuttle pump.

[0030] In an advantageous embodiment, the valve device is a rotary valve comprising a rotor and a stator connected to a plurality of fluid ports, at least two of said plurality of fluid ports for connection to said liquid supplies and at least one fluid port for connection to the liquid mixer.

[0031] In an advantageous embodiment, the stator of the valve device comprises a stator body in which stator fluid channels are formed and fluidically interconnected to said fluid ports, the stator body comprising a bearing surface that bears against a bearing surface of the rotor, the rotor comprising at least one rotor fluid channel that extends between the bearing surface of the rotor to the pump chamber or to a stator channel connected to the pump chamber.

[0032] Also disclosed herein is a method of operating a liquid mixing system to mix a plurality of liquids sourced from a corresponding plurality of liquid supplies, the method comprising at least the steps of: a) transferring liquids from the liquid supplies to the pump chamber; b) transferring liquid in the pump chamber to the liquid mixer chamber; and c) once the liquid mixer chamber is filled with the liquids to be mixed, the liquid in the liquid mixer chamber is transferred back into the pump chamber. Step a) comprises, for each liquid of the plurality of liquids to be mixed, actuating the pump system valve such that the pump chamber is fluidically connected to the supply of the liquid, then actuating the pump to draw a selected volume of the liquid into the pump chamber.

[0033] In an embodiment, the total volume of the plurality of liquids to be mixed are drawn into the pump chamber prior to transfer to the liquid mixer chamber. In another embodiment, a portion of the total volume of the plurality of liquids is drawn into the pump chamber and transferred to the liquid mixer chamber before a subsequent portion of the total volume of the plurality of liquids

to be mixed is drawn into the pump chamber from the liquid supplies, the transfer of portions being repeated until the total volume is transferred into the mixer chamber.

[0034] The plurality of liquids may be transferred into the pump chamber sequentially.

[0035] In an embodiment, only a portion of the required amount of a liquid is transferred per sequence. In another embodiment, the entire required amount of a liquid is transferred per sequence.

[0036] In an embodiment, after step c), one or more additional mixing cycles are performed by transferring the liquid in the pump chamber into the mixer chamber and then back into the pump chamber, optionally repeating the mixing cycle as many times as desired.

[0037] In an advantageous embodiment, at the end of the mixing operation, the outlet valve of the liquid mixer is opened and the pump operated to expel the liquid in the pump chamber through the mixer tube and out through the outlet thereof.

[0038] Also disclosed herein is a method of manufacturing a liquid mixer including a support structure, a pump tube, and an actuation system, the pump tube comprising a pump chamber portion defining therein a pump chamber, an inlet portion for inflow of fluid into the pump chamber, and an outlet portion for outflow of fluid from the pump chamber, wherein the inlet portion, outlet portion and mixer chamber portion form part of a continuous section of tube made of a supple material, the method characterized by forming the pump chamber portion by blow molding. The method may further comprise flattening the mixer chamber portion after the blow molding step.

[0039] Further objects and advantageous features of the invention will be apparent from the claims, from the detailed description, and annexed drawings, in which:

Figure 1 is a schematic view of a liquid mixing system according to an embodiment of the invention;

Figures 2a to 2c are schematic cross-sectional views of a liquid mixing system showing different steps in the mixing cycle, according to an embodiment of the invention, whereby the liquid mixer comprises an active liquid mixer chamber actuator;

Figures 3a and 3b are schematic cross-sectional views of a liquid mixing system showing different steps in the mixing cycle, according to another embodiment of the invention in which the liquid mixer comprises a passive liquid mixer chamber actuator;

Figure 4 is a perspective view of a liquid mixer according to another embodiment of the invention;

Figure 5a is a top view of the liquid mixer shown in figure 4;

Figure 5b is a cross-sectional view through line A-A of figure 5a;

Figure 5c is an enlarged view of the detail B in figure 5b;

Figure 6a is an end view of the liquid mixer shown in figure 4, in which the biasing mechanism of the mixer tube is in a low elastic stiffness (empty) state; Figure 6b is a cross-sectional view through line A-A of figure 6a;

Figure 7a is an end view of the liquid mixer shown in figure 4, in which the biasing mechanism of the mixer tube is in a high elastic stiffness (filled) state; Figure 7b is a cross-sectional view through line A-A of figure 7a;

Figure 8a is a perspective view of a mixer chamber portion of a liquid mixer of a liquid mixing system according to an embodiment of the invention, the mixer chamber portion being in an empty state; Figure 8b is a view similar to figure 3a with the mixer chamber in a partially full state;

Figures 9a to 9d are simplified schematic perspective views illustrating steps in manufacturing the mixer chamber portion of a liquid mixer according to an embodiment of the invention.

[0040] Referring to the figures, a liquid mixing system 2 for mixing two or more liquids from a liquid supply 1, comprises a pump system 4 and a liquid mixer 6. Within the scope of the invention, for certain applications, the liquid system may also be used for mixing a single liquid substance supplied to the system. For instance in applications where better homogenization of a liquid is required, or where a liquid comprising a plurality of substances is supplied and needs better mixing or re-mixing.

[0041] The pump system 4, according to an exemplary embodiment of the invention, comprises a pump 8, a valve device 10, and an electronic control system (not shown). In the illustrated embodiment, the pump 8 is in the form of a syringe or piston pump, however within the scope of this invention other pumps comprising or connected to a liquid reservoir for containing the liquids to be mixed during the mixing operation, could be employed. Other pumps may for instance include a diaphragm pump, or a rotary pump connected to a reservoir, or any other type of pump that allows to draw in one or more liquids from a liquid supply, store the liquids in a reservoir or chamber, and expel the liquid through an outlet of the pump system. Within the scope of the invention any pump with a variable volume pump chamber that allows to store liquid between the drawing in phase and subsequent expulsion phase can be employed depending on the application. The piston type of pump or syringe pump is advantageous in microfluidic applications in view of the accurate control in the amount of liquid that is pumped and the good mixing performance as liquid is drawn into the pump chamber.

[0042] In the illustrated embodiment, the valve device 10 is a rotary valve comprising a stator 14, a rotor 16, an actuator (not shown) coupled to the rotor and a position sensing system (not shown) configured to measure the rotary position of the rotor relative to the stator. The actuator may be an electrical actuator of various types, for instance a rotary motor with a rotor having an output access coupled directly or through a gear train or other type of transmission to the rotor 16 in order to turn the rotor in different positions. In an advantageous embodiment, the motor of the actuator may be a stepping motor, although other types of electrical motors could also be employed.

[0043] It may be noted that in the present invention, the term "rotor" and "stator" designate parts that are relatively rotatable with respect to each other, whereby:

- the rotor may have a fixed position with respect to a reference body (e.g. the pump body 12), and the stator is rotatable with respect to a reference body and the rotor, or
- both the rotor and stator are rotatable with respect to a reference body and with respect to each other, or
- the stator has a fixed position with respect to a reference body and the rotor is rotatable with respect to the reference body and the stator.

[0044] In an embodiment where the stator rotates and the rotor is fixed relative to the reference body, the actuator may be coupled to the stator. In an embodiment where the rotor and stator both rotate relative to the reference body and to each other, actuators can engage both rotor and stator, or one actuator can be provided that couples to the rotor or to the stator if the stator and rotor are coupled together via a transmission.

[0045] In the illustrated embodiment, the pump 8 is a syringe or piston pump comprising a pump body 12 enclosing a pump chamber 18 and a movable pump actuated element, in the present example comprising a pump piston 20 in the form a plunger that is displaced linearly in order to increase the volume in the chamber to draw in liquid or to decrease the volume in the chamber to expel a liquid therefrom.

[0046] The valve device control system comprises an electronic circuit configured to operate the valve device 10, to set the valve and to operate the pump and possibly supply information to and receive inputs from a user or other electronic control systems for operation of the system. The control system may be distributed within devices of the overall system, or form a centralized unit. The general design and configuration of control systems for motors and valves are per se known and shall not be described in detail in the present disclosure. The control system is configured to receive and process signals from a position sensing system of the valve device 10 in order to determine the angular position of the valve and to control the actuator that drives the rotation of the rotor 16 of the valve.

[0047] The rotor 16 comprises at least one rotor fluid channel 26 that extends between a bearing surface 17 of the rotor to the pump chamber 18 or to a stator channel connected to the pump chamber. The stator 14 of the valve device 10 comprises a stator body in which stator fluid channels 22 are formed, the stator body comprising a bearing surface 17 that bears against the bearing surface 15 of the rotor 16. The rotor fluid channel is positioned such that it can interconnect to each of the stator fluid channels, as a function of the rotation angle of the rotor relative to the stator. A valve actuator (not shown) is coupled to the rotor and is controlled by a control system of the liquid mixing system to turn the rotor such that the rotor channel 26 aligns with a selected stator fluid channel at said bearing surface. The stator 14 further comprises fluid ports 24 mounted on the stator body for connection to fluid supply lines 5, a fluid mixer line 9 that may also form a fluid delivery line, and optionally one or more fluid delivery lines 7 that may include a fluid waste line. The fluid ports 24 may be arranged in a distributed manner around the stator 14, for instance as shown in the illustrated embodiments arranged in a spaced apart manner circumferentially around the stator. The illustrated embodiments show four fluid ports 14, however variants of the invention may comprise 2, 3, 5, or more fluid ports, whereby at least one fluid port is connected to a respective liquid supply for mixing at least one liquid and at least one fluid port connects to the liquid mixer 6, any additional fluid ports being used for connecting to additional liquid supplies or for providing additional fluid delivery lines.

[0048] The illustrated embodiments are shown with a single liquid mixer 6, however in variants of the invention, two or more liquid mixers may be connected to different fluid ports 24 of the valve device 10. An in-line succession of liquid mixers may also be arranged in a liquid mixing system according to an embodiment of the invention.

[0049] Each stator fluid channel 22 extends between an end connected to one of said fluid ports 24 and an end positioned at the bearing surface 17. Depending on the position of the valve rotor 16, different inlet liquids may thus be selected and drawn into the pump chamber 18, and different outlets may be selected for expelling the liquid from the pump chamber depending on the intended operation, such as delivery of a liquid to the liquid mixer 6, or to a certain delivery line 7, or washing through of the valve with a liquid sent to a waste line.

[0050] The rotor 16 comprises a rotor body having an outer bearing surface 15 mounted and slidably movable against the inner bearing surface 17 of the stator 14. In the illustrated embodiment, the stator may have a conical or cylindrical inner bearing surface 17 whereas the rotor has a complementary conical or cylindrical outer bearing surface 15 in a snug sliding fit therebetween.

[0051] In variants, the valve device may have other configurations than the one illustrated. For instance, the valve device may comprise a plurality of individual valves connected to each of the input and delivery lines, such

valves for instance being electronically actuated. Various valves for fluid flow lines *per se* known in the art may be employed to open and close the different supply and delivery lines, within the scope of this invention.

5 **[0052]** The liquid mixer 6, according to embodiments of the invention, comprises a mixer tube 28 and an actuation system 30.

[0053] The mixer tube 28 comprises a mixer chamber portion 36 defining therein a mixer chamber 52, an inlet 32 for inflow of fluid into the mixer chamber, and an outlet 34 for outflow of fluid from the mixer chamber. In an advantageous embodiment, the inlet, outlet and mixer chamber portion form part of a continuous section S of tube made of a supple material. The continuous section means that the mixer tube 28 cross-section forms a closed circumference around a fluid flow channel and extends without interruption along a longitudinal section. The circumference of the tube is preferably seamless, i.e. shaped without joints or welds and the longitudinal section of the tube is also preferably seamless and thus without joints or welds. The seamless configuration of the tube enables high accuracy when working with small dimensions and low tolerances. The seamless structure also enables a more uniform stress distribution over the tube section when exposed to internal fluid pressure and external actuators. Such a continuous section of tube may for instance be produced by extrusion as *per se* well known in the art of producing supple tubes. The supple material may include for instance a polymeric material such as PFA [perfluoroalkoxy polymer], FEP [fluorinated ethylene-propylene], a thermoplastic fluoropolymer or various other thermoplastic materials, the choice of which may depend *inter alia* on the intended application and need for compatibility with the liquid to be pumped.

35 **[0054]** In the figures, the outlet is shown with an end face however the outlet may continue with a long section of tube connected at its end to a delivery system. The section of tube may be provided without interruptions such that the mixer chamber portion 36 is connected to the delivery system by a connector at the delivery system. This advantageously ensures a continuous flow of liquid within the liquid mixer 6 separated from the external environment by a continuous wall without the need for sealed moving parts. In an embodiment where the outlet of the liquid mixer leads to a delivery system, the continuous tube ensures a high degree of sterility in the separation of the liquid to be mixed and pumped from the external environment.

[0055] Referring to figures 9a to 9d, the mixer chamber portion 36 may be advantageously manufactured by a blow molding process. As illustrated in figure 9a, a section of polymer tube 36' is placed within a die 46 comprising a cavity 48 configured to form the mixer chamber portion. As is *per se* known in blow molding processes, the section of polymer 36' is heated and gas pressure is applied within the tube so that it expands outwardly until the tube contacts and conforms to the chamber 48 in the die. The die may then be opened and the section of tube removed.

In a subsequent step, the expanded blow molded section 36 may then be flattened to form the mixer chamber portion 36 for assembly within the housing of the micropump.

[0056] The volume of the mixer chamber 52 formed within the mixer chamber portion 36 may be varied for the pumping operation by moving apart the opposed flattened wall portions 36a, 36b of the mixer chamber portion 36 to increase the volume therein, or by moving together the opposite wall portions 36a, 36b to expel fluid out of the mixer chamber. The blow molded mixer chamber portion 36 is particularly cost effective to manufacture while at the same time ensuring a very high level of reliability and safety from contamination.

[0057] In the present invention, the tube section as shown by the illustrated inlets and outlets 32, 34, can have a very small diameter D_i relative to the mixer chamber portion diameter D_p . The ratio of diameters D_p/D_i may advantageously be in a range of 2 to 10, preferably in range of 3 to 8. The relatively small tube reduces the dead volume of liquid between the liquid supply and the delivery system, while at the same time allowing to mix a volume of liquid defined by the expanded mixer chamber portion 36 that has a diameter D_p that may be 2 to 8 times or more the diameter D_i of the inlet and outlet portions of the tube. The actual amount of liquid to be mixed defines the degree of separation of the opposite wall portions 36a, 36b. The number of inflow and outflow cycles defines the number of mixing cycles. Within the scope of the invention, the tube original shape may not necessarily be a circular or essentially circular shape in cross-section, but instead may have a variety of other cross-sectional profiles such as square, polygonal, elliptical and various irregular profiles. More generally, in advantageous embodiments, the ratio A_p/A_i of the mixer chamber portion 36 cross-sectional area A_p (in its fully expanded operational state) over each of the inlet and outlet portions cross-sectional area is in a range of 4 to 100, more preferably in a range of 9 to 64.

[0058] The opposed wall portions 36a, 36b of the mixer chamber portion 36 are positioned between elements that form parts of the actuation system and support structure that move relatively with respect to each other to move apart or move together the wall portions 36a, 36b.

[0059] The actuation system 30 comprises one or more mixer chamber actuators 42 comprising one or more movable tube interface elements 54 positioned against one side of the mixer chamber portion 36 of the mixer tube 28, and an outlet valve 40. In a preferred embodiment the outlet valve 40 is in the form of a pinch valve that biases against the mixer tube 28 on the outlet side of the mixer chamber portion 36. In a variant, the actuation system may optionally also further include an inlet valve (not shown) on the inlet side of the mixer chamber portion 36. In an advantageous embodiment, the pinch valve biases against the expanded section of the mixer chamber portion 36. In a variant however, the pinch valve may also pinch the tube section outside of the expanded portion, on the tube sections that are not expanded (i.e.

not blow molded).

[0060] In variants, other types of valves *per se* known for fluid circulation systems (e.g. check valves, ball valves, rotary valves etc.) may be used for the outlet valve and/or the optional inlet valve.

[0061] The outlet valve 40 may advantageously comprise an elastic body, for instance made of an elastomer, configured to apply elastic pressure closing together the opposing surfaces of the mixer chamber portion while reducing local pressure to avoid damage to the mixer tube 28 while ensuring a good pinch sealing of the valve. The outlet valve may be operated by means of an outlet valve actuator 33.

[0062] In a first embodiment, the opposed wall portions 36a, 36b of the mixer chamber portion 36 are positioned between the elements that form parts of the actuation system and support structure without being bonded to said elements. In this first embodiment, the mixer chamber actuator 42 may be passive or active. In the passive variant, the mixer chamber actuator 42 moves in reaction to the liquid pressure in the mixer chamber 52, which is affected by the control of the pump system 4 and the outlet valve 40 of the liquid mixer. In the active variant, at least one of the movement directions of the mixer chamber actuator 42 is actively driven and controlled by a drive element coupled to the mixer chamber actuator 42.

[0063] In a second embodiment, portions of the opposed wall portion 36a, 36b of the mixer chamber portion 36 may be bonded to the elements that form part of the actuation system and support structure. In this second embodiment, the actuation system of the liquid mixer may comprise an actively controlled mixer chamber actuator 42 that pulls apart the opposed wall portions 36a, 36b during the phase of drawing in of liquid into the mixer chamber 52. The fixing means between the base 27 and wall portion 36b, respectively between the interface element 54 and wall portion 36a may be by welding, brazing, adhesive bonding, cold or hot heading or various other *per se* known bonding techniques between materials. The interface element 54 and base 27 may also be made of a polymeric material, for instance injected plastic of similar or different polymer than that of the tube section, although non-polymeric materials may also be used depending on the applications, provided that fixing technique is also adapted for the pair of materials used. Welding may for instance be performed by known techniques such as ultrasonic welding or laser welding. As best illustrated in figures 8a, 8b, a surface portion 50 of the upper wall portion 36a of the mixer chamber portion 36 may form the attachment portion to a movable tube interface element 54 of the actuation system 30, whereas the opposite side 36b may be fixed to the base wall 27 of the support structure 25.

[0064] The mixer chamber actuator 42 and outlet valve actuator 33 may have similar configurations or may have different actuating mechanisms. In illustrated embodiments, the actuation system comprises a biasing mech-

anism 47 with springs 45 that bias the interface element 54 of the mixer chamber actuator 42 to the empty position of the mixer chamber. The actuation system further comprises biasing mechanism 47 with spring 45 that biases the outlet valve to the closed position, for instance as illustrated in figure 2a, 2b or 3b, where the outlet pinch valve is closed. This configuration may provide a fail safe mode whereby in case of loss of power or failure of the actuation system, fluid flow between liquid supply system and a delivery system downstream of the liquid mixer is closed. Such fail safe mode is useful in many applications, for instance in medical applications. Nevertheless, for certain applications that may require fluid connection between the fluid supply and the delivery system to remain open, the fail safe mode or power off mode may require the springs to bias the biasing mechanism 47 to an open position where the outlet valve is open and the interface element 54 of the mixer chamber actuator is in a raised position to allow liquid to flow through the mixer chamber to the delivery system.

[0065] In embodiments with a spring biasing mechanism to the open or the closed position as needed by the system, the actuation system comprises a drive mechanism that acts in the direction opposite to the spring biasing force to effect the opposite action.

[0066] In the embodiment illustrated in figures 4 to 7b, the interface element drive of the mixer chamber actuator 42 is provided in the form of a rotating cam 58 coupled to a motor 59. The rotating cam comprises a cam profile portion 58b that presses down the biasing organ 47 coupled to the interface element 54 to decrease the volume in the mixer chamber, respectively allows the biasing organ to rise to increase the volume in the mixer chamber 52, as a function of the angle of rotation of the cam. The rotating cam may be turned by an electrical motor 59 directly or through a reduction gearing system or by other known electrical actuation means for rotating a component. The rotating cam 58 may further be provided with a cam profile portion 58a for actuating the outlet pinch valve in a similar manner as a function of rotation of the camshaft. In the embodiment illustrated in figures 4 to 7b, the opening and closing of the outlet pinch valve and raising and lowering of the mixer chamber interface element 54 are thus mechanically synchronised.

[0067] In another embodiment, instead of a rotating cam, the mixer chamber actuator 42 and the outlet valve actuator 33 may each comprise a linear actuator, for instance in the form of solenoids or by piezo electric actuators coupled to their respective biasing mechanisms 47. The outlet valve 40 may thus be individually operated with respect to the mixer chamber actuator, the control thereof being performed by an electronic control circuit 11.

[0068] In variants, the actuation means may be provided by other per se well known actuators such as pneumatic or hydraulic actuators, or other forms of electromagnetic actuators.

[0069] The electronic control circuit 11 controlling the

actuators 42, 33 of the liquid mixer may be incorporated in a liquid mixer module as illustrated in figures 4 to 7b, or be integrated in the pump system 4, or form a separate module connected to the liquid mixer and pump systems 4, 6. A single electronic circuit may be provided for control of both the liquid mixer and the pump system, or separate circuits may be provided. In all cases the operation of the pump system and liquid mixer is coordinated by the control system(s) such that the pump 8 and liquid mixer 6 cooperate to effect the steps of liquid mixing.

[0070] In a variant, instead of acting against spring means, the outlet valve actuator 33, and if there is an inlet valve, the inlet valve actuator, may also effect forward and reverse movements without spring means to open and close the valve. The actuator may effect both the forward and reverse movements actively, or in a variant, actively in one direction and passively in the other direction by the force of the spring means. Spring means may also be integrated within the actuator to effect the passive movement in one direction.

[0071] In a variant, instead of acting against spring means, the mixer chamber actuator 42 may also effect forward and reverse movements without spring means to effect the mixer chamber volume variation. The actuator may effect both the forward and reverse movements actively, or in a variant, actively in one direction and passively in the other direction by the force of the spring means. Spring means may also be integrated within the actuator to effect the passive movement in one direction. In yet another variant the actuator may be entirely passive and provided with spring means to ensure the movement of the interface element 54 follows the expansion or reduction in volume of the mixer chamber 52 as liquid enters or leaves the mixer chamber.

[0072] Liquid may enter or leave the mixer chamber, depending on the configuration, due to the following actions:

- liquid is pumped into the mixer chamber 52 by the action of the pump 8,
- liquid is pumped out of the mixer chamber 52 by the action of the pump 8 or the mixer chamber actuator 42 back into the pump chamber 18,
- liquid is pumped out of the mixer chamber 52 under the action of the mixer chamber actuator 42 towards a delivery system by,

- a. opening the outlet valve, or
- b. switching the valve 10 in the pump system to interconnect the liquid mixer inlet 32 to a delivery line 7.

[0073] The actuators may further be provided with position sensors 44a, 44b (see figures 2c, 2b, 3b) for instance in the form of capacitive sensors that detect the height of the interface element 54 and of the outlet valve. The position sensors may also be used to determine a malfunction in the liquid mixer, in particular malfunction

of the outlet valve or the mixer chamber actuator. The sensors may also be used to determine or to control the mixing operation. The latter may also be controlled via a measurement of the volume of the pump chamber 18 (for instance by controlling and measuring the position of the pump chamber piston 20).

[0074] In the illustrated embodiments, the springs 45 of the biasing mechanisms 47 for the actuators 33, 42 are in the form of leaf spring plates with cantilever arms 43 that are pivotally connected to anchor portions 41 of the support structure 25. In other possible variants, various other spring mechanisms may be used that are per se well known to the skilled person.

[0075] Examples of features and operation of a liquid mixing system 2 according to embodiments of the invention are described hereafter.

Example

[0076] The liquid mixing system 2 is used to mix a first liquid A with at least a second liquid B.

[0077] First liquid A may for instance be a liquid sample to be tested or a liquid containing a sample of material to be tested, and second liquid B may for instance be a reagent. Such a system may for instance be employed in a flow cytometer.

[0078] Liquids A and B may however be other types of liquids. For instance liquids A and B may comprise components that react chemically, to produce a third substance being the product of the reaction. Or for instance one of the liquids may be soluble in the other of the liquids. Various other liquid combinations depending on the application may be mixed in embodiments of the invention.

[0079] The liquid mixing system 2 may be used to mix more than two liquids, whereby the pump system may be connected to additional liquid supplies (C, etc.).

[0080] The pump system valve 10 is operated such that the pump chamber 18 is fluidically connected to the fluid port 24 connected to the supply of the first liquid A, and the pump 8 is operated to draw the first liquid into the pump chamber 18. In the illustrated embodiment, the rotary valve 10 is turned such that the rotor fluid channel 26 is aligned with the stator fluid channel 22 leading to the fluid port connected to the supply line 5 of liquid supply A, and the pump piston 20 is displaced to increase the volume in the pump chamber 18 thus drawing in liquid A. Once the required amount of liquid A is filled in the pump chamber 18, the pump system valve 10 is operated such that the pump chamber 18 is fluidically connected to the fluid port 24 connected to the supply of the second liquid B, and the pump 8 is operated to draw the second liquid into the pump chamber 18. In the illustrated embodiment, the rotary valve 10 is turned such that the rotor fluid channel 26 is aligned with the stator fluid channel 22 leading to the fluid port connected to the supply line 5 of liquid supply B, and the pump piston 20 is displaced further to further increase the volume in the pump chamber 18 thus drawing in liquid B. In case of additional liquids

to be mixed, the above operation is repeated for each position of the valve connected to the corresponding additional liquid supply.

[0081] The order in which the liquids are sequentially drawn into the pump chamber may be chosen according to any desired order. Moreover, only a portion of the required amount of a liquid may be drawn per sequence such that the liquids are better mixed already during the pump chamber filling operation. For instance a sequence may comprise: 50% of liquid A is drawn, then 100% of liquid B, then the remaining 50% of liquid B. In another example, the sequence may comprise: 30% of liquid A is drawn, then 50% of liquid B, then 40% of liquid A, then their remaining 50% of liquid B and finally the remaining 30% of liquid A. Sequence combinations may be configured according to the volumes and properties of the various liquids and the optimal mixing results.

[0082] In a variant, after each liquid is drawn into the pump chamber, the valve may be operated to connect the pump chamber to the liquid mixer tube 28 and the pump operated to subsequently expel the liquid into the chamber of the liquid mixer. The subsequent liquid may then be drawn into the pump chamber and expelled into the liquid mixer chamber, the operation being performed for each portion of liquid to be injected into the liquid mixer.

[0083] During filling of the liquid mixer chamber 52, the outlet valve 40 remains closed.

[0084] Once the liquid mixer chamber 52 is filled with the liquids to be mixed, the liquid in the liquid mixer chamber is transferred back into the pump chamber. The transfer back into the pump chamber is effected by increasing the volume of the pump chamber while the valve 10 is set to fluidically interconnect the pump chamber to the mixer chamber. In the illustrated embodiment, this is achieved by displacing the pump piston in the direction to further increase the volume in the pump chamber 18, thus sucking the liquid in the mixer chamber back into the pump chamber. As the liquid flows back into the pump chamber, the fluid channel of the valve 10 leading into the pump chamber may advantageously be configured to generate turbulent flow as the liquid enters into the pump chamber 18 such that a good mixing of the liquids is achieved. During the transfer of liquid from the mixer chamber 52 to the pump chamber 18, the outlet valve 40 remains closed and the interface element 54 of the mixer chamber actuator 42 displaces to reduce the volume of the mixer chamber. In variants provided with a spring biased passive mixer chamber actuator, or an actively biased mixer chamber actuator, the suction pressure of the pump 8 is supplemented with the positive pressure of the mixer actuator on the liquid injected back into the pump chamber, which helps to ensure a high rate of transfer and good turbulent mixing.

[0085] In a variant, the mixing operation may further include an oscillatory motion of the actuator 42, for instance mechanical shaking, use of ultrasound, or other oscillatory actuation motions to improve the mixing within

the chamber.

[0086] A mixing cycle may optionally be repeated, as many times as desired, by transferring the liquid from the pump chamber 18 into the mixing chamber 52 and then from the mixing chamber back into the pump chamber. 5

[0087] At the end of the mixing operation, the outlet valve of the liquid mixer 6 is opened and the pump 8 operated to expel the liquid in the pump chamber through the mixer tube 28 and out through the outlet 34 thereof. 10
The mixer chamber actuator 42 displaces sufficiently to allow passage of the liquid being expelled. The displacement may be actively controlled, or passive under a spring biasing force of the actuator acting on the tube. When the pump chamber 18 is empty, or the desired amount of mixed liquid pumped through the outlet 34, the mixer chamber actuator 42 may displace passively or be displaced actively to squeeze out residual liquid in the mixer chamber portion. In a variant or in a mode of operation, the liquid in the mixer chamber may be not completely squeezed out such that a residual volume remains to allow a flow of liquid through the mixer chamber. 15
20

[0088] In a variant, the mixed liquid can be transferred through a delivery line connected to a fluid port of the pump system valve other than the liquid mixer tube 28. 25

[0089] After the delivery of the mixed liquid, the internal fluid channels of the pump system valve 10, pump 8 and liquid mixer may be cleaned by setting the valve to interconnect the pump chamber 18 to a fluid port connected to a washing or rinsing liquid supply, drawing in the washing or rinsing liquid, setting the pump system valve 10 to interconnect the pump chamber to the liquid mixer chamber, and pumping the liquid out of the pump chamber and through the mixer tube 28. Various washing and/or rinsing cycles may be performed. Since the pump chamber and liquid mixer tube form an inline system connected to a delivery line, the washing through of rising and cleaning liquid provides reliable and easy cleaning. In particular, the mixer tube eliminates dead volumes in which liquid can stagnate without being forced to flow through, thus ensuring good cleaning. 30
35
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[0090] Advantageously, in embodiments of the invention, the liquids to be mixed and the mixed liquids flow out of the pump chamber and through the liquid mixer in an inline manner that has a low internal volume and little or no dead volumes. The inline configuration is also advantageously very easy to clean reliably. The closed system is also advantageous to avoid any evaporation of the liquids. 45
50

List of references used

[0091]

Liquid mixing system 2

liquid supply system 1

liquid supply lines 5
liquid delivery lines 7
liquid mixer line 9

pump system 4

pump 8

pump body 12
pump chamber 18
pump piston 20

valve device 10 (e.g. rotary valve)

stator 14

stator fluid channels 22
fluid ports 24

input ports 36a
output port 36b

rotor 16
rotor fluid channel 26

liquid mixer 6

housing / support structure 25
base wall 27
mixer tube 28

inlet 32
outlet 34
mixer chamber portion 36

opposing walls 36a, 36b
attachment surface portion 50
mixer chamber 52

Section S
Length L

actuation system 30

outlet valve 40

pinch valve
elastic body
outlet valve actuator 33

mixer chamber actuator(s) 42

movable tube interface element 54
interface element drive

motor 59
rotating cam 58, 58a, 58b
biasing mechanism 47

spring 45
2nd embodiment
 linear actuators

position sensor(s) 44a, 44b

control circuit 11

blow molding die 46
 chamber 48

Claims

1. Liquid mixing system comprising a pump system and a liquid mixer (6), the liquid mixer including a mixer tube (28) and an actuation system (30), the mixer tube comprises a mixer chamber portion (36) defining therein a mixer chamber (52), an inlet (32) for inflow of fluid into the mixer chamber from a pump system, and an outlet (34) for outflow of fluid from the mixer chamber to a delivery system, the inlet, outlet and mixer chamber portion forming part of a continuous section of a supply tube made of a supply material, the mixer chamber portion having a cross-sectional area in an expanded state that is larger than the cross-sectional area of the mixer tube at said outlet and inlet, the pump system comprising a valve device (10) and a pump (8) comprising a variable volume pump chamber (18), the valve device configured to selectively fluidly interconnect the variable volume pump chamber to the mixer chamber and to one or a plurality of liquid supplies. 15
2. Liquid mixing system according to the preceding claim, wherein the ratio A_p/A_i of the mixer chamber portion cross-sectional area A_p over the inlet or outlet cross-sectional area A_i is in a range of 4 to 100, preferably in range of 9 to 64. 20
3. Liquid mixing system according to any preceding claim, wherein the supply material is a polymer, for instance PFA [perfluoroalkoxy polymer], FEP [fluorinated ethylene-propylene], a thermoplastic fluoropolymer or various other thermoplastic materials. 25
4. Liquid mixing system according to any preceding claim, wherein the mixer chamber portion is a blow molded section of tube. 30
5. Liquid mixing system according to any preceding claim, wherein the actuation system comprises one or more mixer chamber actuators comprising one or more movable tube interface elements (54) biased against a side of the mixer chamber portion, an opposite side of the mixer chamber portion biased against a wall (27) of a support structure (25) of the liquid mixer. 35
6. Liquid mixing system according to any preceding claim, wherein the actuation system comprises an outlet valve (40) in the form of a pinch valve that biases against the mixer tube on an outlet side of the mixer chamber portion, the outlet valve being operated by means of an outlet valve actuator (33). 40
7. Liquid mixing system according to any preceding claim, wherein the mixer chamber actuator and/or the outlet valve actuator is/are passively driven in one direction by means of a spring element. 45
8. Liquid mixing system according to any preceding claim, wherein the mixer chamber actuator and/or the outlet valve actuator is/are actively driven in at least one direction by means of an electromagnetic actuator. 50
9. Liquid mixing system according to any preceding claim wherein the pump is in the form of a syringe or piston pump. 55
10. Liquid mixing system according to any preceding claim wherein the valve device is a rotary valve comprising a rotor (16) and a stator (14) connected to a plurality of fluid ports (24), at least two of said plurality of fluid ports for connection to said liquid supplies and at least one fluid port for connection to the liquid mixer and wherein the stator of the valve device comprises a stator body in which stator fluid channels (22) are formed fluidically interconnected to said fluid ports, the stator body comprising a bearing surface (17) that bears against a bearing surface (15) of the rotor, the rotor comprising at least one rotor fluid channel (26) that extends between the bearing surface of the rotor to the pump chamber or to a stator channel connected to the pump chamber. 60
11. Method of operating a liquid mixing system according to any one of the preceding claims to mix a plurality of liquids sourced from a corresponding plurality of liquid supplies, the method comprising at least the steps of: a) transferring liquids from the liquid supplies to a pump chamber; b) transferring liquid in the pump chamber to the liquid mixer chamber; and c) once the liquid mixer chamber is filled with the liquids to be mixed, the liquid in the liquid mixer chamber is transferred back into the pump chamber, step a) comprising, for each liquid of the plurality of liquids to be mixed, actuating a valve of the pump system such that the pump chamber is fluidically connected to the supply of the liquid, then actuating the pump to draw a selected volume of the liquid into the pump chamber. 65
12. Method according to the preceding claim wherein the total volume of the plurality of liquids to be mixed are drawn into the pump chamber prior to transfer 70

to the liquid mixer chamber.

13. Method according to claim 11 wherein a portion of the total volume of the plurality of liquids is drawn into the pump chamber and transferred to the liquid mixer chamber before a subsequent portion of the total volume of the plurality of liquids to be mixed is drawn into the pump chamber from the liquid supplies, the transfer of portions being repeated until the total volume is transferred into the mixer chamber.
14. Method according to any preceding claim wherein the plurality of liquids are transferred into the pump chamber sequentially.
15. Method according to any preceding claim wherein after step c), one or more additional mixing cycles are performed by transferring the liquid in the pump chamber into the mixer chamber and then back into the pump chamber, optionally repeating the mixing cycle as many times as desired, and wherein, at the end of the mixing operation, the outlet valve of the liquid mixer is opened and the pump operated to expel the liquid in the pump chamber through the mixer tube and out through the outlet thereof.

Patentansprüche

1. Flüssigkeitsmischsystem, das ein Pumpsystem und einen Flüssigkeitsmischer (6) umfasst, wobei der Flüssigkeitsmischer ein Mischrohr (28) und ein Betätigungssystem (30) beinhaltet, wobei das Mischrohr einen Mischkammerabschnitt (36), in dem eine Mischkammer (52) definiert ist, einen Einlass (32) zum Einlaufen eines Fluids aus einem Pumpsystem in die Mischkammer und einen Auslass (34) zum Auslaufen eines Fluids aus der Mischkammer zu einem Ausgabesystem umfasst, wobei der Einlass, der Auslass und der Mischkammerabschnitt einen Teil eines durchgehenden Bereichs eines biegsamen Rohrs, das aus einem biegsamen Material besteht, bilden, wobei der Mischkammerabschnitt in einem ausgedehnten Zustand eine Querschnittsfläche aufweist, die größer ist als die Querschnittsfläche des Mischrohrs am Auslass und am Einlass, wobei das Pumpsystem eine Ventilvorrichtung (10) und eine Pumpe (8) umfasst, die eine Pumpenkammer (18) mit variablem Volumen umfasst, wobei die Ventilvorrichtung dazu ausgelegt ist, die Pumpenkammer mit variablem Volumen selektiv fluidisch an die Mischkammer und einen oder eine Vielzahl von Flüssigkeitsvorräten zu koppeln.
2. Flüssigkeitsmischsystem nach dem vorhergehenden Anspruch, wobei das Verhältnis A_p/A_i der Querschnittsfläche A_p des Mischkammerabschnitts zur Querschnittsfläche A_i des Einlasses oder Auslasses

in einem Bereich von 4 bis 100, vorzugsweise in einem Bereich von 9 bis 64 liegt.

3. Flüssigkeitsmischsystem nach einem der vorhergehenden Ansprüche, wobei das biegsame Material ein Polymer ist, beispielsweise PFA [Perfluoralkoxy-polymer], FEP [fluoriniertes Ethylenpropylen], ein thermoplastisches Fluorpolymer oder verschiedene andere thermoplastische Materialien.
4. Flüssigkeitsmischsystem nach einem der vorhergehenden Ansprüche, wobei der Mischkammerabschnitt eine blasgeformte Region des Rohres ist.
5. Flüssigkeitsmischsystem nach einem der vorhergehenden Ansprüche, wobei das Betätigungssystem einen oder mehrere Mischkammeraktuatoren umfasst, die eine oder mehrere bewegbare Rohrschnittstellenelemente (54) umfassen, die gegen eine Seite des Mischkammerabschnitts vorgespannt sind, wobei eine gegenüberliegende Seite des Mischkammerabschnitts gegen eine Wand (27) einer Stützstruktur (25) des Flüssigkeitsmischers vorgespannt ist.
6. Flüssigkeitsmischsystem nach einem der vorhergehenden Ansprüche, wobei das Betätigungssystem ein Auslassventil (40) in Form eines Quetschventils umfasst, das auf einer Auslassseite des Mischkammerabschnitts gegen das Mischrohr vorspannt, wobei das Auslassventil durch einen Auslassventilaktor (33) betrieben wird.
7. Flüssigkeitsmischsystem nach einem der vorhergehenden Ansprüche, wobei der Mischkammeraktor und/oder der Auslassventilaktor durch ein Federelement passiv in eine Richtung gedrängt werden/wird.
8. Flüssigkeitsmischsystem nach einem der vorhergehenden Ansprüche, wobei der Mischkammeraktor und/oder der Auslassventilaktor durch einen elektromagnetischen Aktuator aktiv in mindestens eine Richtung gedrängt werden/wird.
9. Flüssigkeitsmischsystem nach einem der vorhergehenden Ansprüche, wobei die Pumpe die Form einer Spritze oder einer Kolbenpumpe aufweist.
10. Flüssigkeitsmischsystem nach einem der vorhergehenden Ansprüche, wobei die Ventilvorrichtung ein Drehventil ist, das einen Rotor (16) und einen Stator (14) umfasst, die mit einer Vielzahl von Fluidanschlüssen (24) verbunden sind, wobei mindestens zwei der Vielzahl von Fluidanschlüssen der Verbindung mit den Flüssigkeitsvorräten dienen und mindestens ein Fluidanschluss der Verbindung mit dem Flüssigkeitsmischer dient und wobei der Stator der

Ventilvorrichtung einen Statorkörper umfasst, in dem Statorfluidkanäle (22) gebildet sind, die fluidisch an die Fluidanschlüsse gekoppelt sind, wobei der Statorkörper eine Lagerfläche (17) umfasst, die auf einer Lagerfläche (15) des Rotors aufliegt, wobei der Rotor mindestens einen Rotorfluidkanal (26) umfasst, der sich zwischen der Lagerfläche des Rotors und der Pumpenkammer oder einem Statorkanal, der mit der Pumpenkammer verbunden ist, erstreckt.

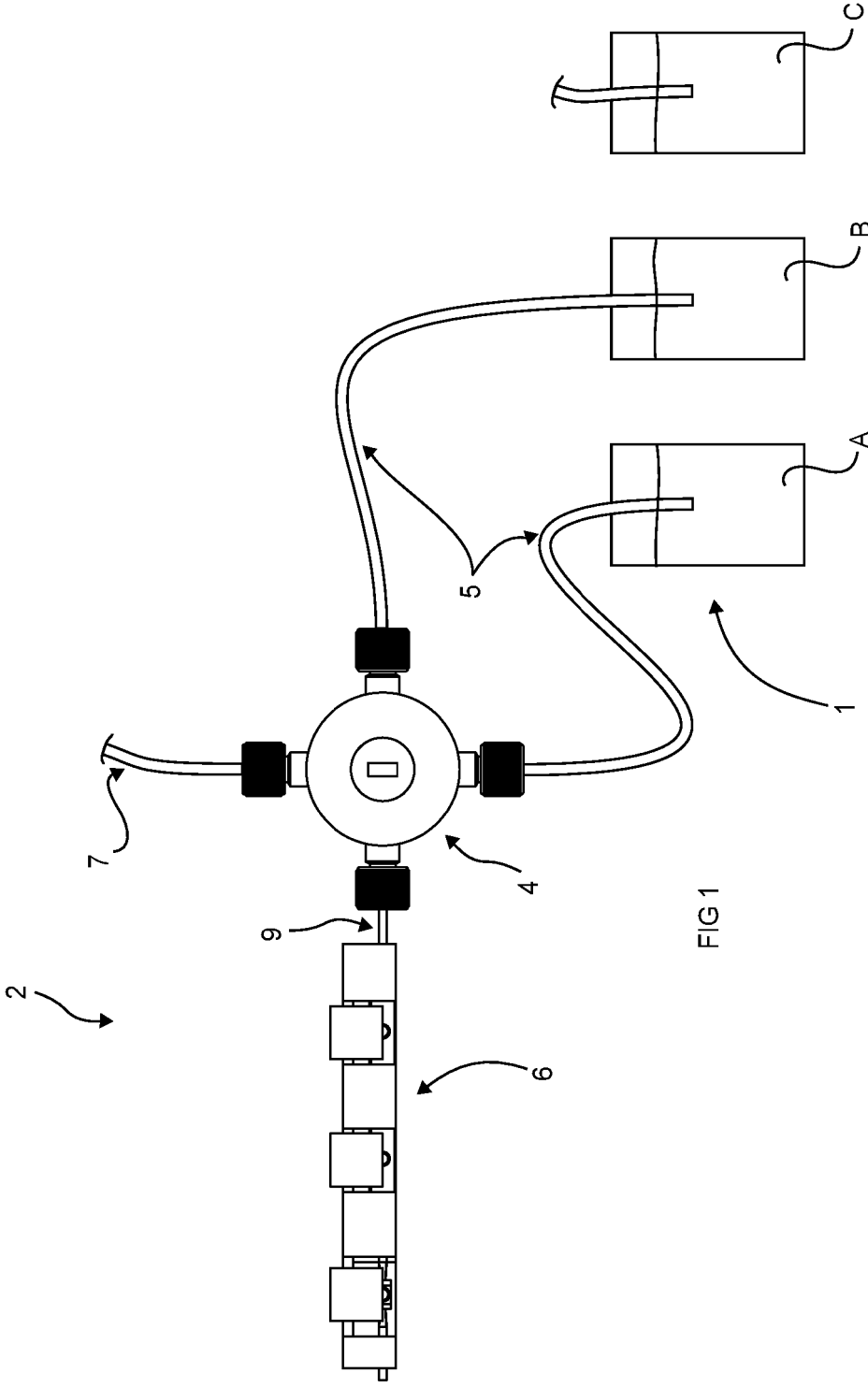
11. Verfahren zum Betreiben eines Flüssigkeitsmischsystems nach einem der vorhergehenden Ansprüche zum Mischen einer Vielzahl von Flüssigkeiten, die einer entsprechenden Vielzahl von Flüssigkeitsvorräten entnommen werden, wobei das Verfahren mindestens die folgenden Schritte umfasst: a) Befördern von Flüssigkeiten von den Flüssigkeitsvorräten zu einer Pumpenkammer; b) Befördern von Flüssigkeit in der Pumpenkammer zur Flüssigkeitsmischkammer; und c) wenn die Flüssigkeitsmischkammer mit den zu mischenden Flüssigkeiten gefüllt ist, die Flüssigkeit in der Flüssigkeitsmischkammer zurück zur Pumpenkammer befördert wird, wobei Schritt a) für jede Flüssigkeit der Vielzahl von zu mischenden Flüssigkeiten das Betätigen eines Ventils des Pumpsystems derart, dass die Pumpenkammer fluidisch mit dem Flüssigkeitsvorrat verbunden wird, dann das Betätigen der Pumpe, um ein ausgewähltes Volumen der Flüssigkeit in die Pumpenkammer zu saugen, umfasst.
12. Verfahren nach dem vorhergehenden Anspruch, wobei das Gesamtvolumen der Vielzahl von zu mischenden Flüssigkeiten vor der Beförderung zur Flüssigkeitsmischkammer in die Pumpenkammer gesaugt wird.
13. Verfahren nach Anspruch 11, wobei ein Abschnitt des Gesamtvolumens der Vielzahl von Flüssigkeiten in die Pumpenkammer gesaugt und zur Flüssigkeitsmischkammer befördert wird, bevor ein nachfolgender Abschnitt des Gesamtvolumens der Vielzahl von zu mischenden Flüssigkeiten von den Flüssigkeitsvorräten in die Pumpenkammer gesaugt wird, wobei die Beförderung von Abschnitten wiederholt wird, bis das Gesamtvolumen in die Mischkammer befördert wurde.
14. Verfahren nach einem der vorhergehenden Ansprüche, wobei die Vielzahl von Flüssigkeiten sequenziell in die Pumpenkammer befördert werden.
15. Verfahren nach einem der vorhergehenden Ansprüche, wobei nach Schritt c) ein oder mehrere zusätzliche Mischzyklen durchgeführt werden, indem die Flüssigkeit in der Pumpenkammer zur Mischkammer und dann zurück zur Pumpenkammer befördert wird, wobei der Mischzyklus wahlweise so oft wie

gewünscht wiederholt wird und wobei am Ende des Mischbetriebs das Auslassventil des Flüssigkeitsmischers geöffnet und die Pumpe betrieben wird, um die Flüssigkeit in der Pumpenkammer durch das Mischrohr und durch den Auslass davon auszugeben.

Revendications

1. Système de mélange de liquide comprenant un système de pompe et un mélangeur de liquide (6), le mélangeur de liquide comprenant un tube de mélangeur (28) et un système d'actionnement (30), le tube de mélangeur comprenant une partie de chambre de mélangeur (36) définissant, à l'intérieur de cette dernière, une chambre de mélangeur (52), une entrée (32) pour l'entrée de fluide dans la chambre de mélangeur à partir d'un système de pompe, et une sortie (34) pour la sortie du fluide de la chambre de mélangeur jusqu'à un système de distribution, l'entrée, la sortie et la partie de chambre de mélangeur faisant partie d'une section continue d'un tube souple réalisé avec un matériau souple, la partie de chambre de mélangeur ayant une surface transversale dans un état expansé qui est supérieure à la surface transversale du tube de mélangeur au niveau de ladite sortie et de l'entrée, le système de pompe comprenant un dispositif de valve (10) et une pompe (8) comprenant une chambre de pompe à volume variable (18), le dispositif de valve étant configuré pour interconnecter sélectivement, de manière fluidique, la chambre de pompe à volume variable à la chambre de mélangeur et à une ou plusieurs alimentations de liquide.
2. Système de mélange de liquide selon la revendication précédente, dans lequel le rapport A_p/A_i de la surface transversale de partie de chambre de mélangeur A_p sur la surface transversale d'entrée ou de sortie A_i est dans une plage de 4 à 100, de préférence dans une plage de 9 à 64.
3. Système de mélange de liquide selon l'une quelconque des revendications précédentes, dans lequel le matériau souple est un polymère, par exemple le PFA (polymère perfluoroalkoxy), le FEP (éthylène-propylène fluoré), un polymère fluoré thermoplastique ou différents autres matériaux thermoplastiques.
4. Système de mélange de liquide selon l'une quelconque des revendications précédentes, dans lequel la partie de chambre de mélangeur est une section de tube moulée par soufflage.
5. Système de mélange de liquide selon l'une quelconque des revendications précédentes, dans lequel le

- système d'actionnement comprend un ou plusieurs actionneurs de chambre de mélangeur comprenant un ou plusieurs éléments d'interface de tube mobiles (54) sollicités contre un côté de la partie de chambre de mélangeur, un côté opposé de la partie de chambre de mélangeur sollicitée contre une paroi (27) d'une structure de support (25) du mélangeur de liquide.
6. Système de mélange de liquide selon l'une quelconque des revendications précédentes, dans lequel le système d'actionnement comprend une valve de sortie (40) se présentant sous la forme d'un robinet à manchon déformable qui applique une sollicitation contre le tube mélangeur sur un côté de sortie de la partie de chambre de mélangeur, la valve de sortie étant actionnée au moyen d'un actionneur de valve de sortie (33).
 7. Système de mélange de liquide selon l'une quelconque des revendications précédentes, dans lequel l'actionneur de chambre de mélangeur et/ou l'actionneur de valve de sortie est/sont entraîné(s) de manière passive dans une direction au moyen d'un élément de ressort.
 8. Système de mélange de liquide selon l'une quelconque des revendications précédentes, dans lequel l'actionneur de chambre de mélangeur et/ou l'actionneur de valve de sortie est/sont entraîné(s) de manière active dans au moins une direction au moyen d'un actionneur électromagnétique.
 9. Système de mélange de liquide selon l'une quelconque des revendications précédentes, dans lequel la pompe se présente sous la forme d'une seringue ou d'une pompe à piston.
 10. Système de mélange de liquide selon l'une quelconque des revendications précédentes, dans lequel le dispositif de valve est une valve rotative comprenant un rotor (16) et un stator (14) raccordés à une pluralité d'orifices de fluide (24), au moins deux de ladite pluralité d'orifices de fluide pour le raccordement auxdites alimentations de liquide et au moins un orifice de fluide pour le raccordement au mélangeur de liquide et dans lequel le stator du dispositif de valve comprend un corps de stator dans lequel des canaux de fluide de stator (22) sont formés, interconnectés de manière fluïdique auxdits orifices de fluide, le corps de stator comprenant une surface de palier (17) qui s'appuie contre une surface de palier (15) du rotor, le rotor comprenant au moins un canal de fluide de rotor (26) qui s'étend entre la surface de palier du rotor jusqu'à la chambre de pompe ou jusqu'à un canal de stator raccordé à la chambre de pompe.
 11. Procédé pour actionner un système de mélange de liquide selon l'une quelconque des revendications précédentes pour mélanger une pluralité de liquides provenant d'une pluralité correspondante d'alimentations de liquide, le procédé comprenant au moins les étapes suivantes : a) transférer des liquides des alimentations de liquide à une chambre de pompe ; b) transférer le liquide dans la chambre de pompe à la chambre de mélangeur de liquide ; et c) une fois que la chambre de mélangeur de liquide est remplie avec les liquides à mélanger, le liquide dans la chambre de mélangeur de liquide est transféré à nouveau dans la chambre de pompe, l'étape a) comprenant, pour chaque liquide de la pluralité de liquides à mélanger, l'étape pour actionner une valve du système de pompe de sorte que la chambre de pompe est raccordée, de manière fluïdique, à l'alimentation du liquide, actionnant ensuite la pompe pour aspirer un volume sélectionné du liquide dans la chambre de pompe.
 12. Procédé selon la revendication précédente, dans lequel le volume total de la pluralité de liquides à mélanger, est aspiré dans la chambre de pompe avant le transfert dans la chambre de mélangeur de liquide.
 13. Procédé selon la revendication 11, dans lequel une partie du volume total de la pluralité de liquides est aspirée dans la chambre de pompe et transférée dans la chambre de mélangeur de liquide avant qu'une partie consécutive du volume total de la pluralité de liquides à mélanger soit aspirée dans la chambre de pompe à partir des alimentations de liquide, le transfert des parties étant répété jusqu'à ce que le volume total soit transféré dans la chambre de mélangeur.
 14. Procédé selon l'une quelconque des revendications précédentes, dans lequel la pluralité de liquides sont transférés dans la chambre de pompe, de manière séquentielle.
 15. Procédé selon l'une quelconque des revendications précédentes, dans lequel, après l'étape c), un ou plusieurs cycles de mélange supplémentaires sont réalisés en transférant le liquide dans la chambre de pompe dans la chambre de mélangeur et en revenant ensuite dans la chambre de pompe, en répétant facultativement le cycle de mélange autant de fois que nécessaire, et dans lequel, à la fin de l'opération de mélange, la valve de sortie du mélangeur de liquide est ouverte et la pompe actionnée pour expulser le liquide dans la chambre de pompe par le tube de mélangeur et sortir par sa sortie.



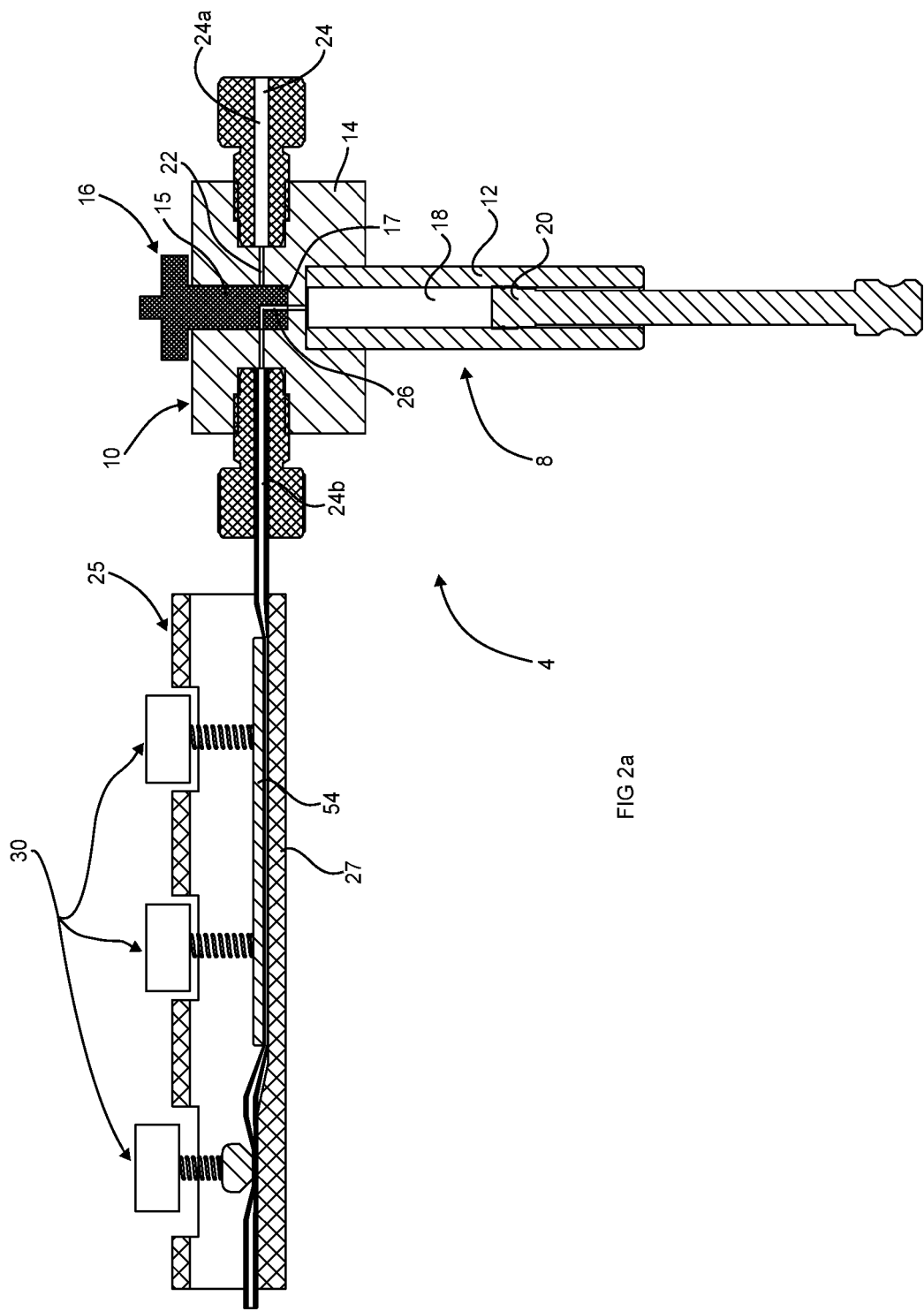
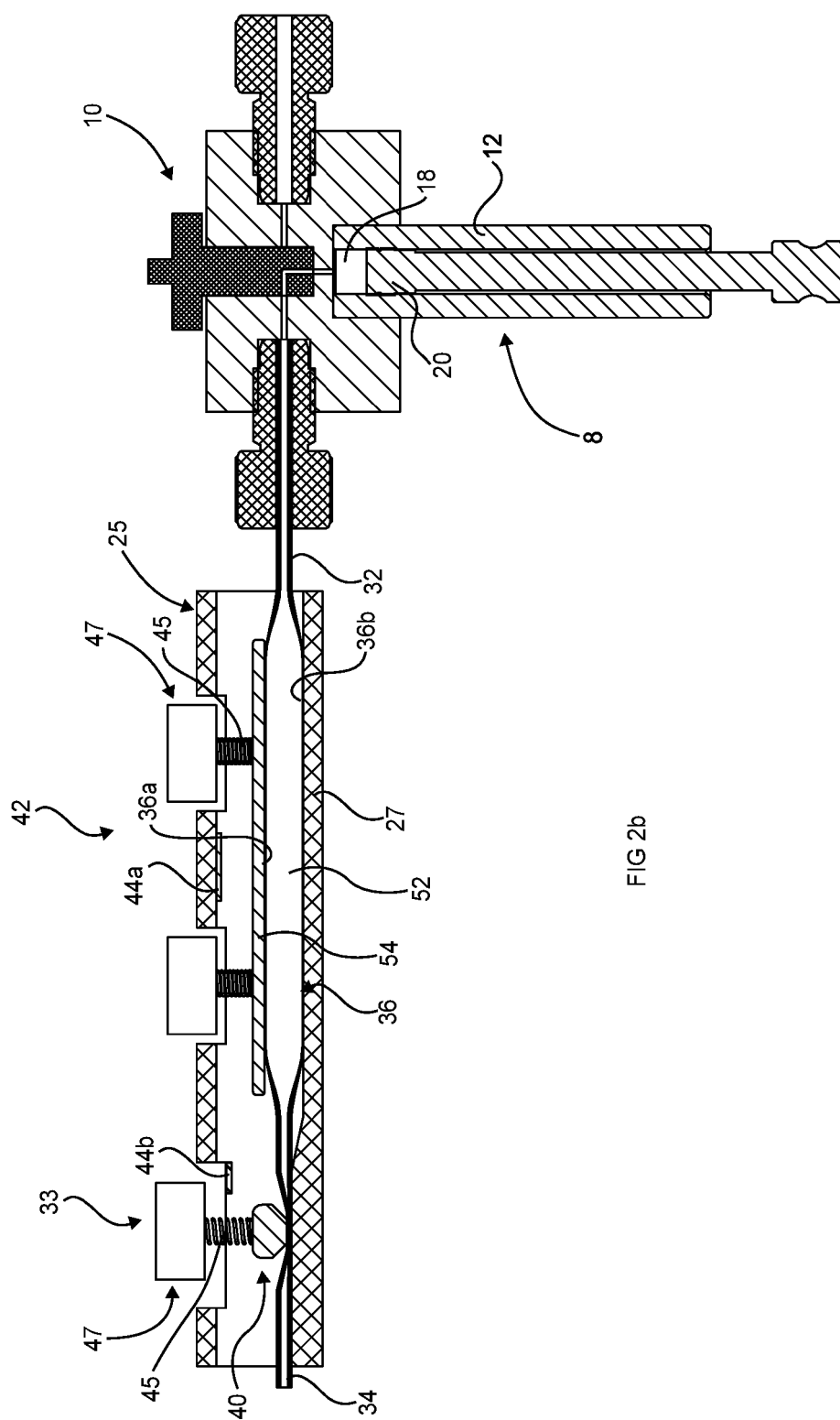
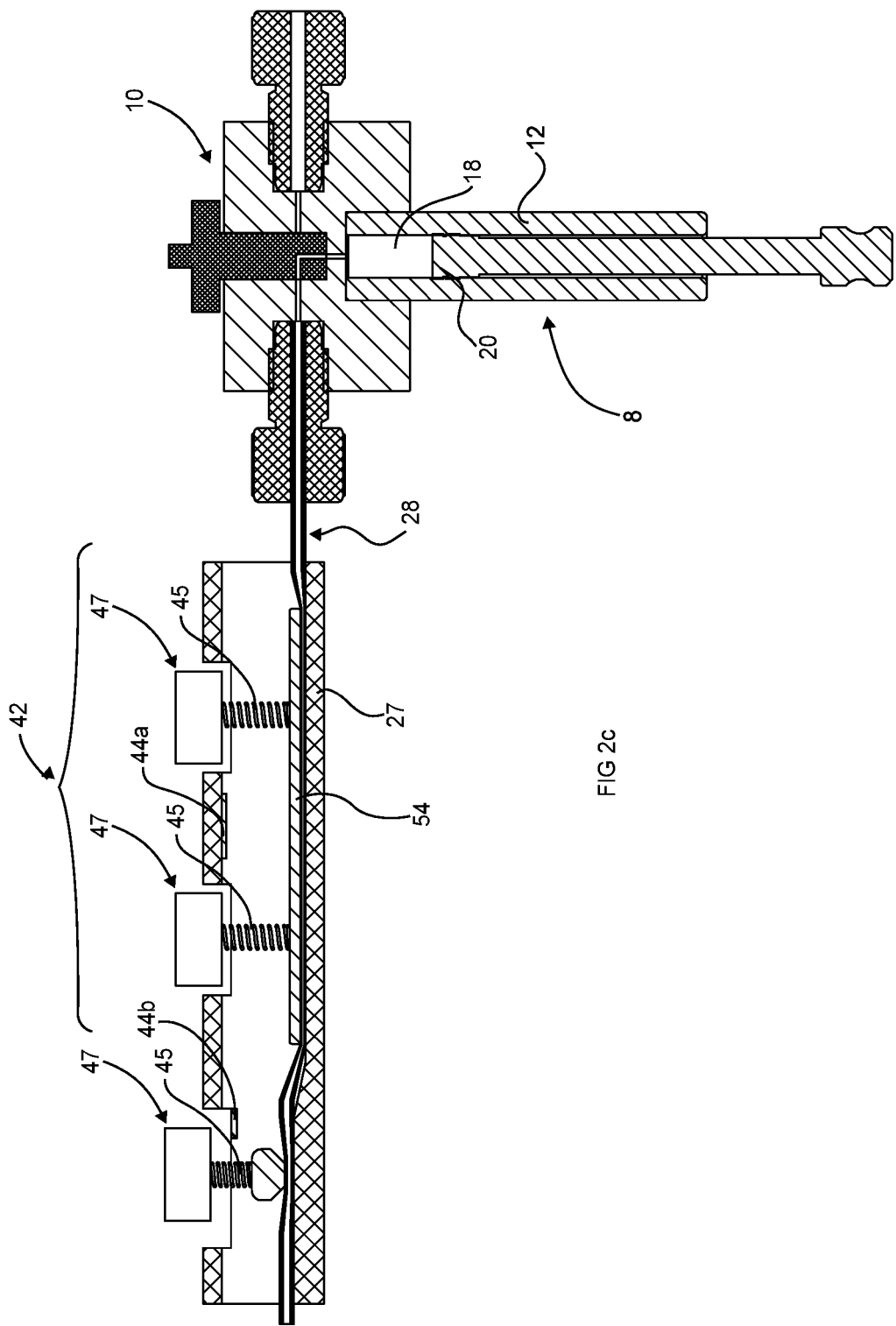
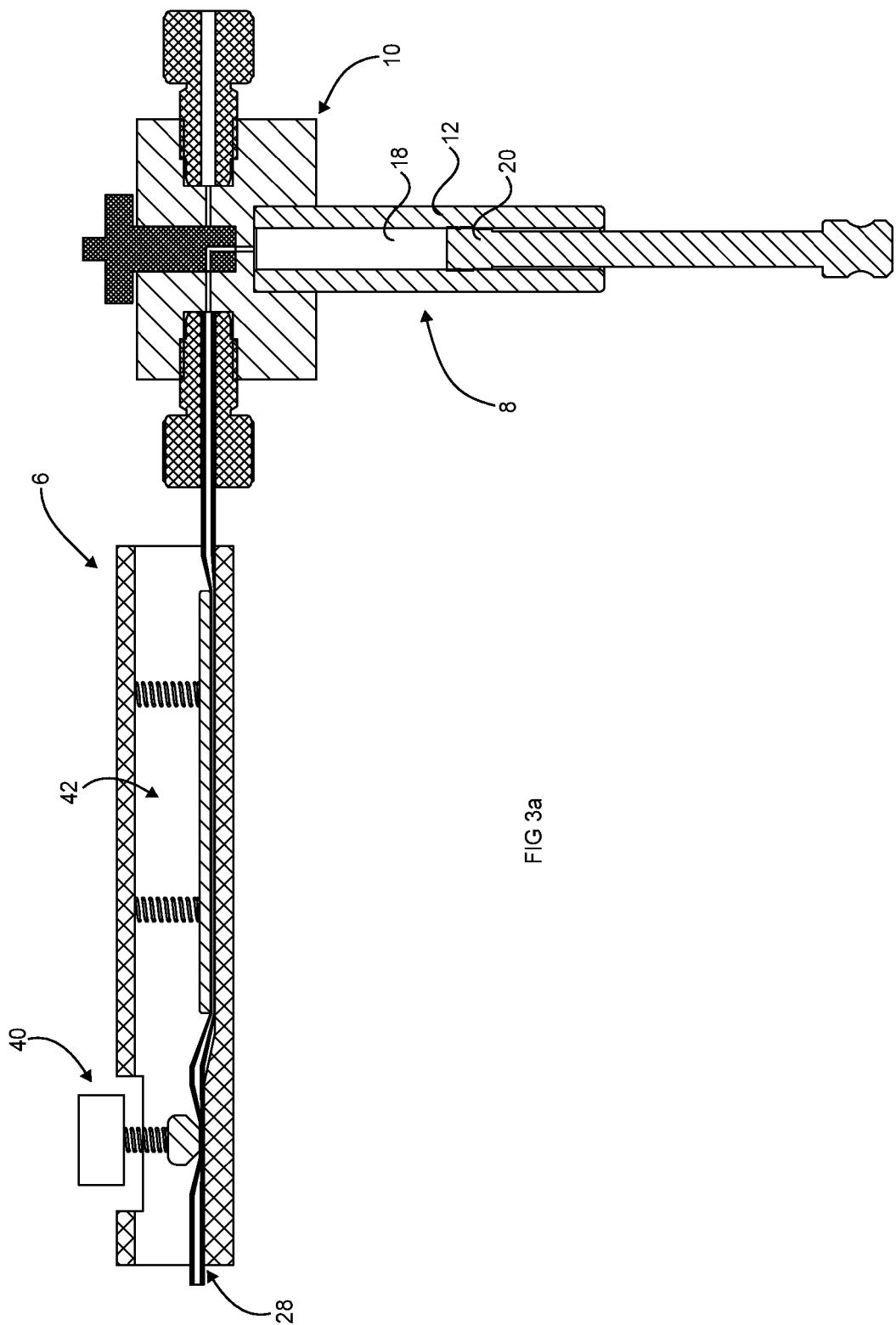
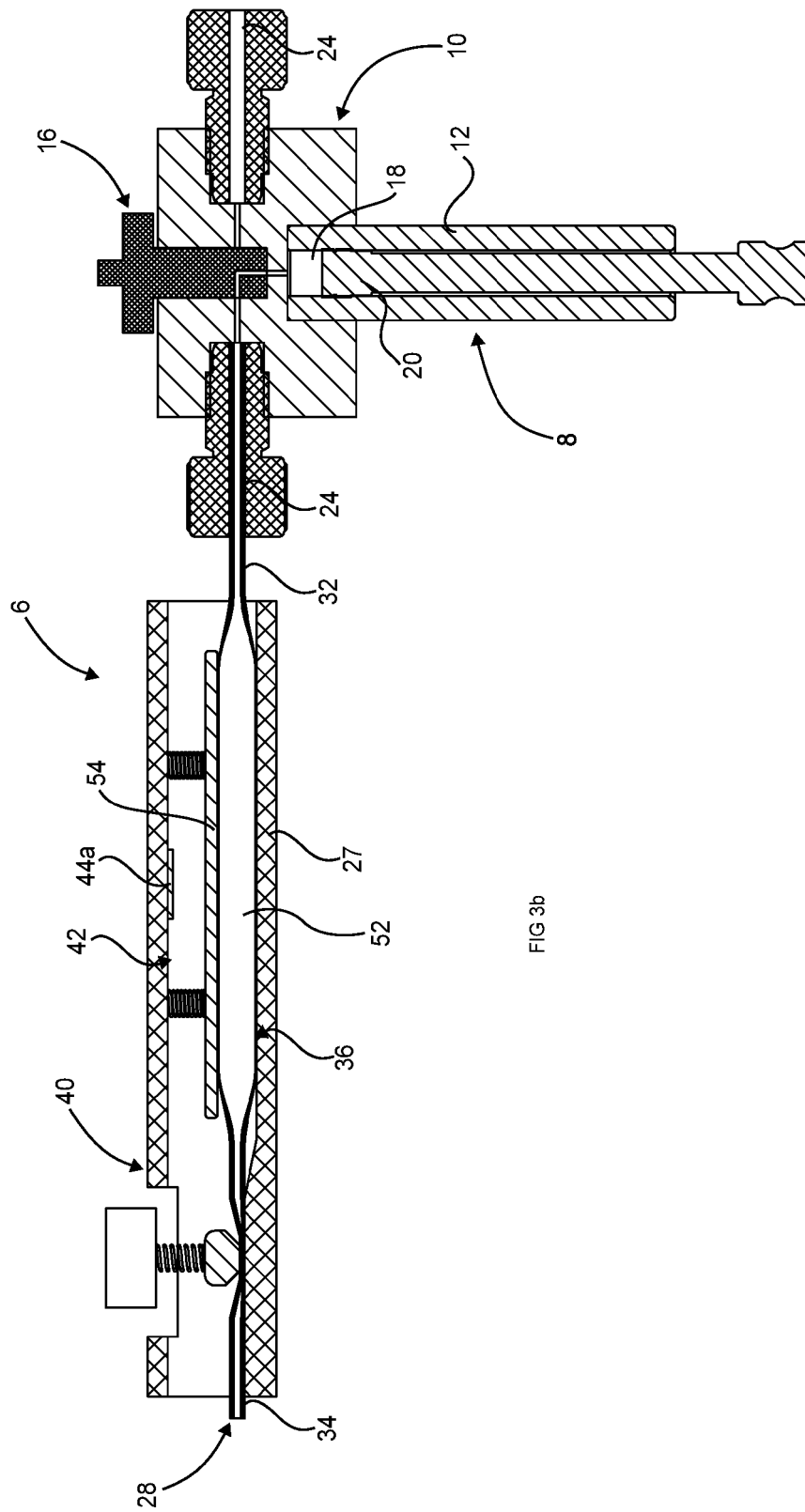


FIG 2a









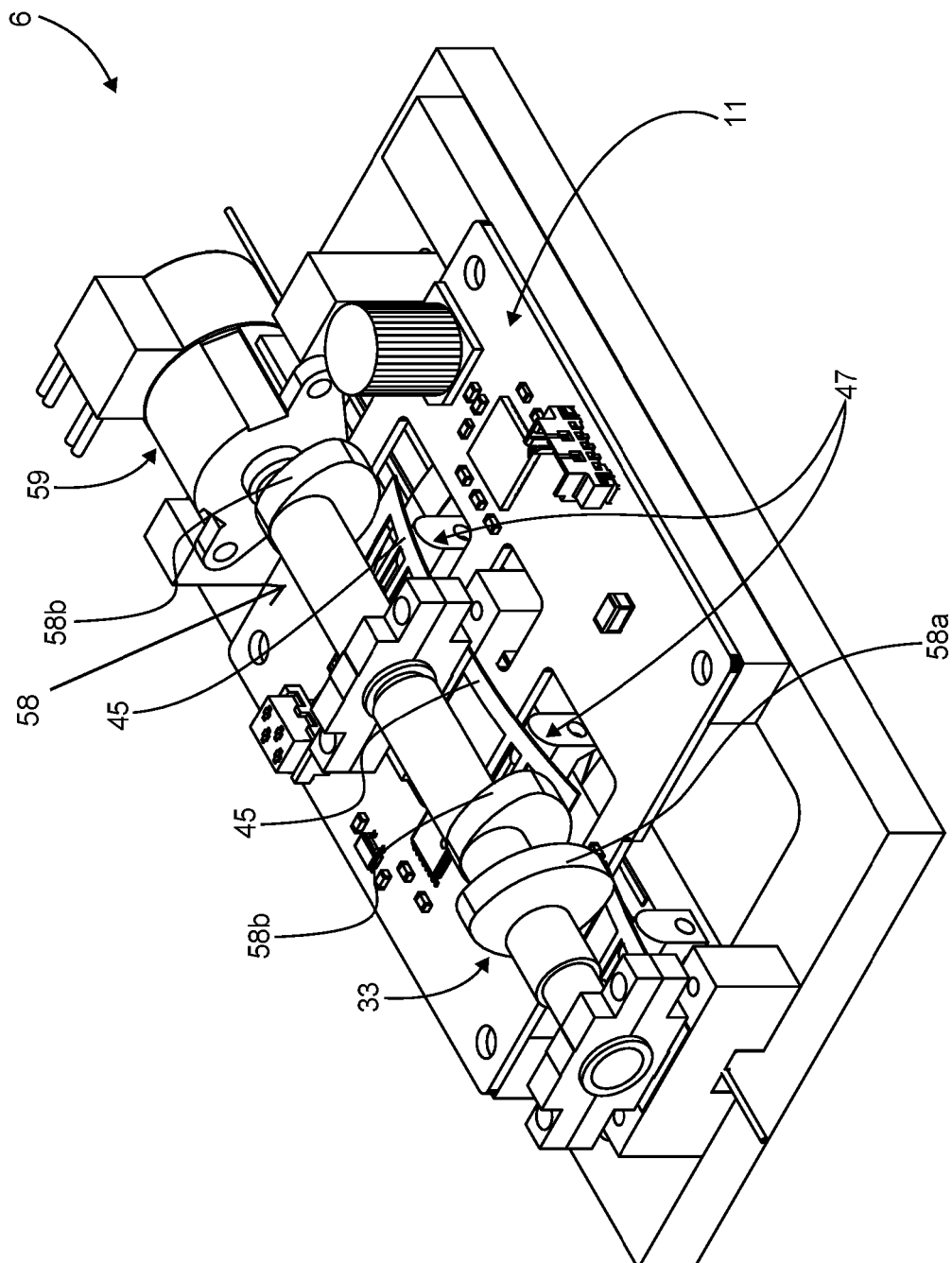
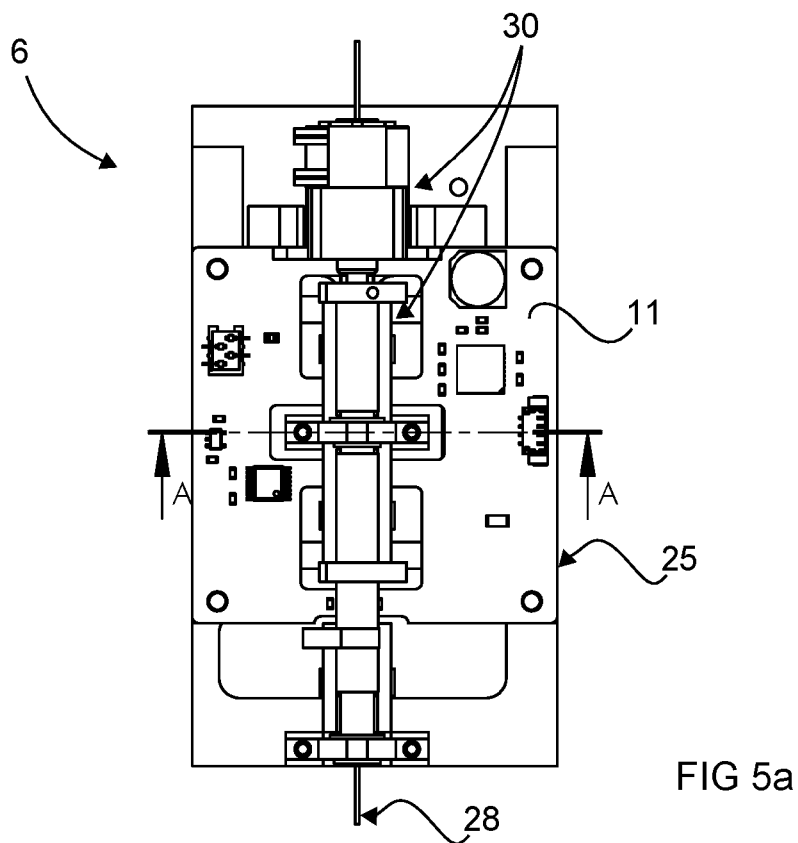
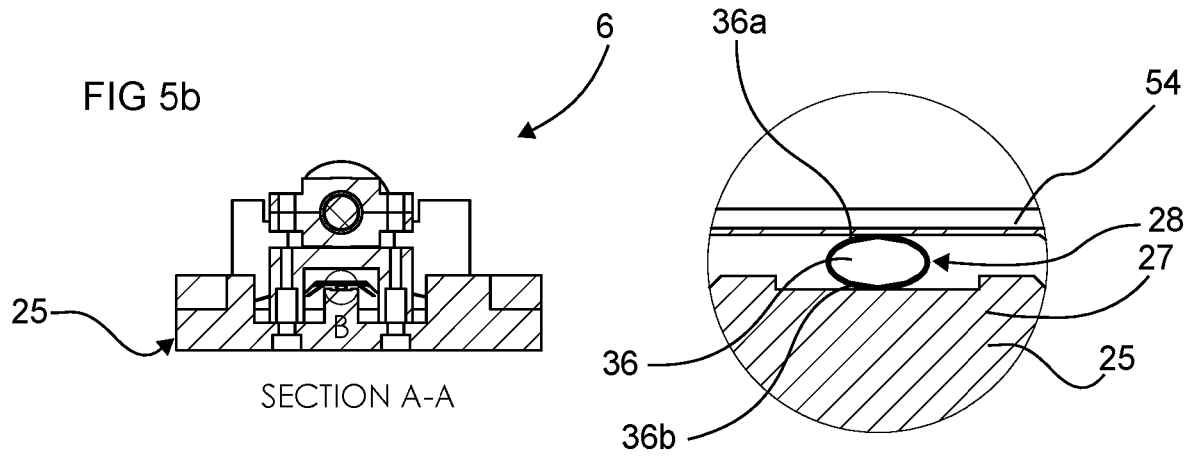
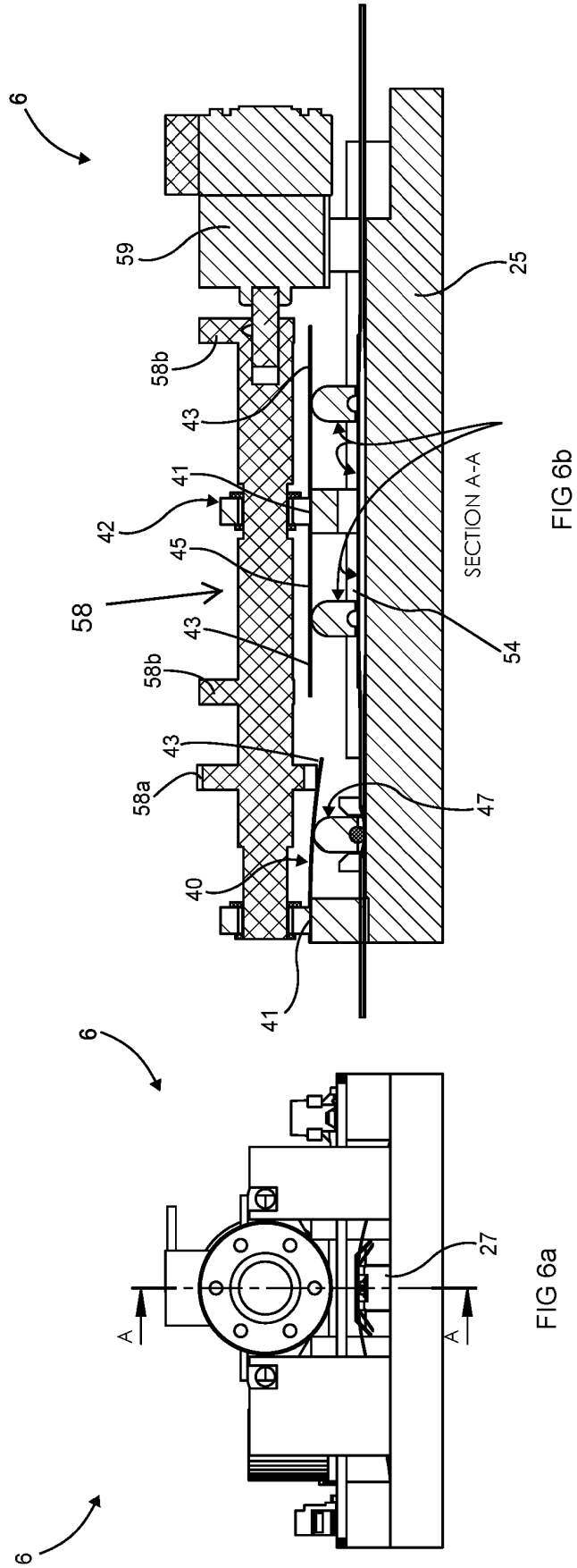


FIG 4





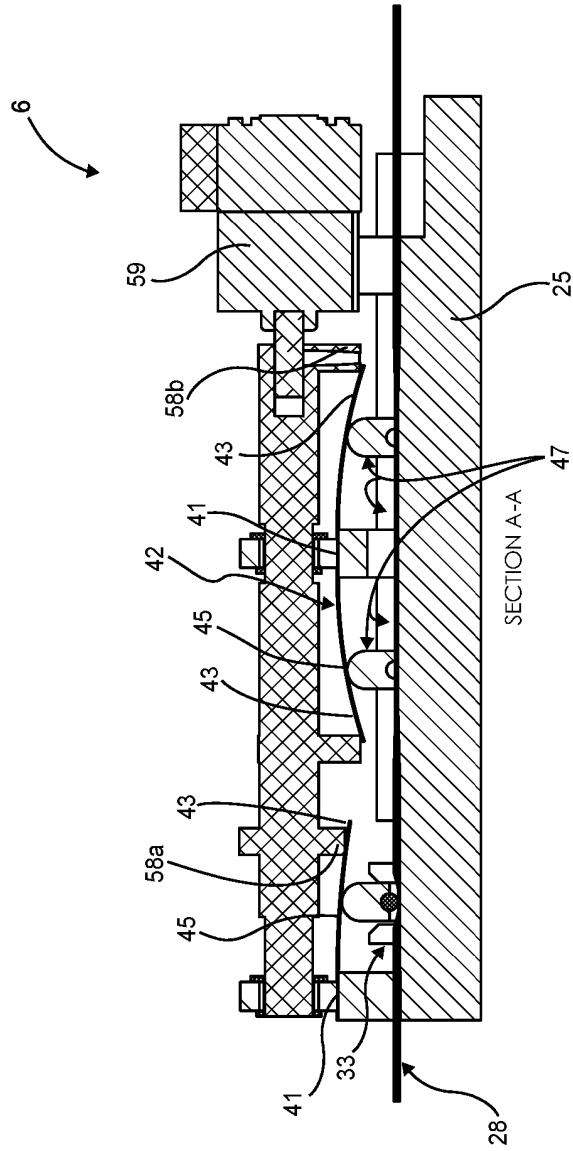


FIG 7b

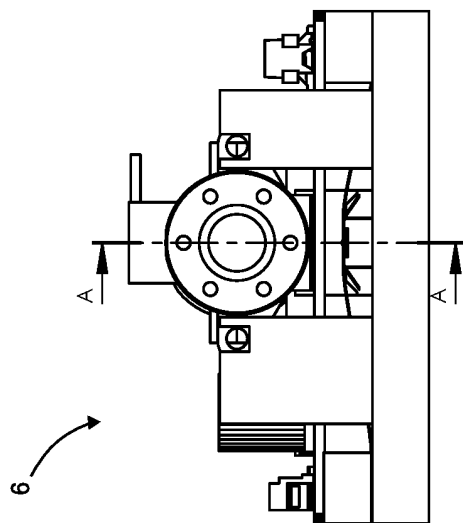
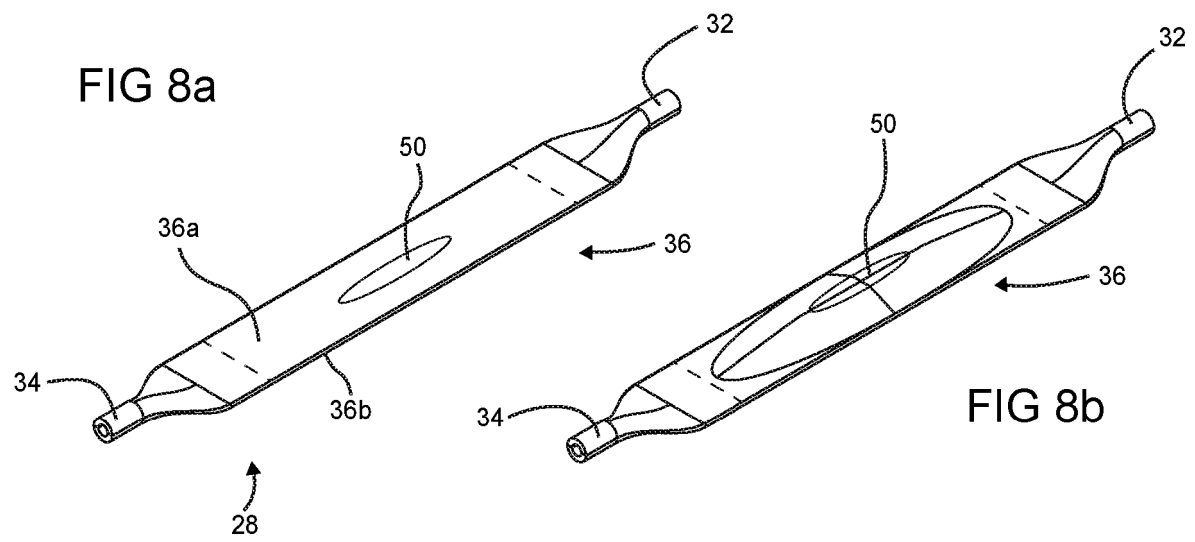
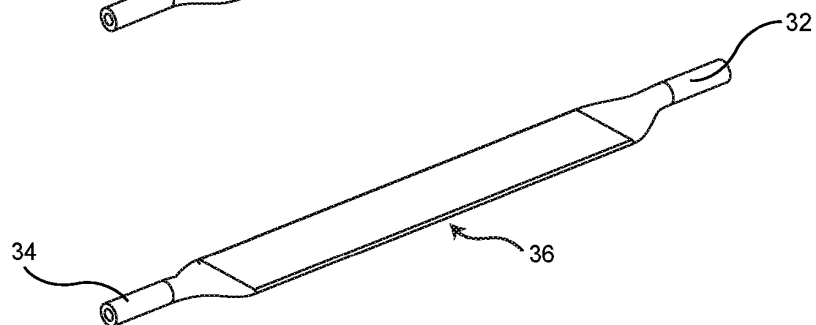
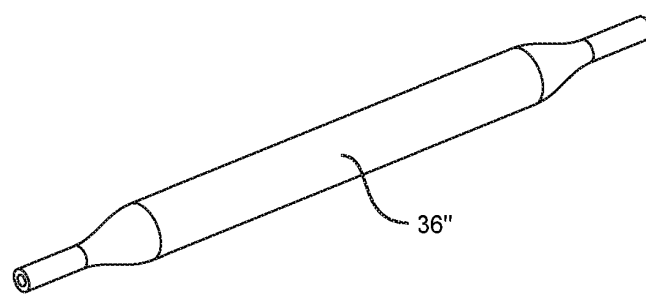
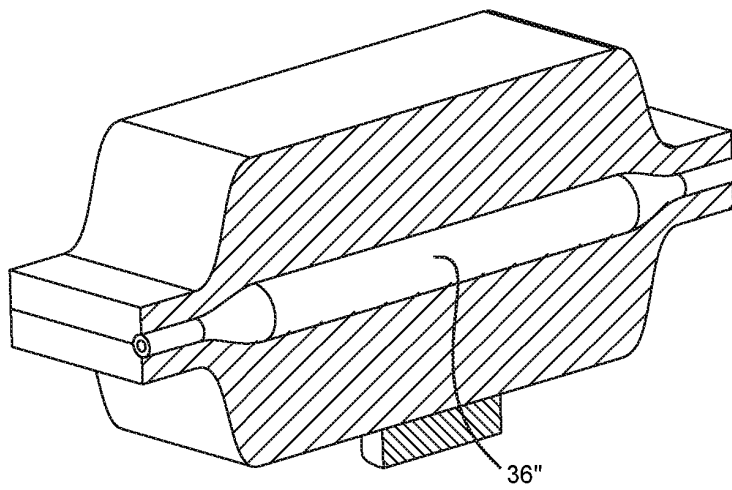
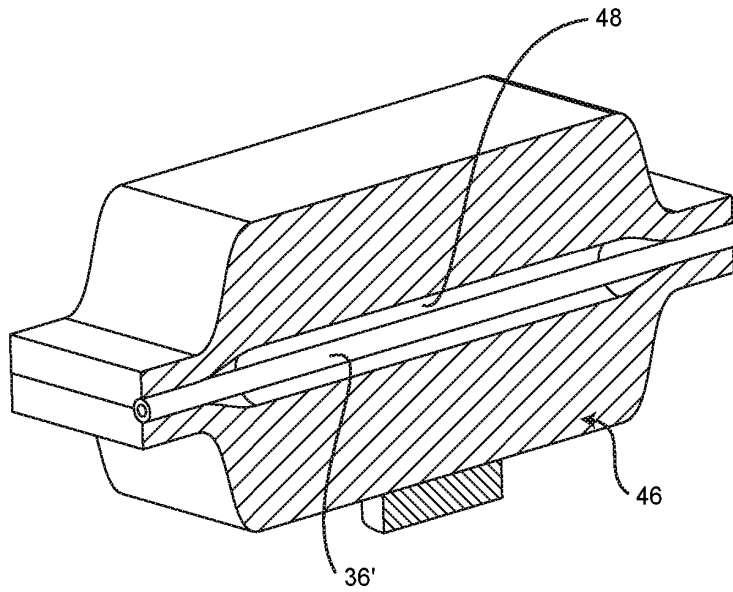


FIG 7a





REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- WO 2007093939 A [0004] [0006]
- WO 2009029445 A [0005] [0006]
- US 2008123466 A [0007]