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OPENING/CLOSING UNIT DRIVE MECHANISM FOR CHEMICAL-LIQUID CIRCUIT, AND CHEMICAL-LIQUID INJECTOR

Abstract

An opening/closing unit drive mechanism which includes an opening/closing unit holder which detachably holds an opening/closing unit which includes a housing having flow channels and a piston for opening and closing the flow channels which is movably provided to the housing, a hook to be engaged with the piston of the opening/closing unit, which is disposed leaving a space from the opening/closing unit holder, and a linear motion mechanism which moves the hook back and forth. The opening/closing unit holder is movably supported between a first position at which the piston is engaged with the hook and a second position at which the piston is not engaged with the hook.

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Background/Summary

RELATED APPLICATIONS [0001] This application is a continuation of U.S. patent application Ser. No. 17/310,156, filed Jul. 21, 2021, which is the U.S. National Phase under 35 U.S.C. § 371 of International Application No. PCT/JP2020/003277, filed Jan. 29, 2020, designating the U.S., and published in Japanese as WO 2020/158830 on Aug. 6, 2020, which claims priority to Japanese Patent Application No. 2019-013683, filed Jan. 29, 2019, the entire content of which is incorporated herein by reference.

TECHNICAL FIELD

[0002] The present invention relates to an opening/closing unit drive mechanism in which, a chemical-liquid circuit which includes a plurality of tubes, is installed, and a chemical-liquid injector which is equipped with the opening/closing unit drive mechanism.

BACKGROUND ART

[0003] A chemical-liquid injector is largely used for injecting a chemical liquid into a subject. A large number of chemical-liquid injectors, from a viewpoint of the ease of injecting at a desired injection rate, have a detachably mounted syringe, and are configured to inject a chemical liquid filled into the syringe via a chemical-liquid circuit which fluidically connects the syringe and the subject.

[0004] The syringe, although essentially, is not used for more than once, a chemical liquid is refilled from a bottle into the syringe and is often used for a plurality of times. In that case, the chemical-liquid circuit has a subject line leading from the syringe to the subject and a bottle line leading from the subject line to the bottle upon branching. Although the bottle line is closed at the time of injecting the chemical liquid, at the time of filling the chemical liquid, the bottle line is opened after the subject line is closed at a downstream side of a branching portion of the bottle line. At this time, it is significant to make an arrangement such that, blood of the subject that regurgitates through the subject line (reverse blood) does not reach an upstream side of the closing portion of the subject line.

[0005] As a chemical-liquid circuit which is capable of preventing such reverse flow of blood more reliably, for example, Patent Literature 1 (International Unexamined Patent Application Publication No. 2018/181270) discloses a chemical-liquid circuit which is configured such that the closing portion includes a first moving member having a flow channel, a second moving member which has a flow channel and is positioned on a downstream side of the subject line of the first moving member, and a housing which slidably accommodates the first moving member and the second moving member, and the flow channel of the second moving member opens after the flow channel of the first moving member has opened.

CITATION LIST

Patent Literature

[0006] Patent Literature 1: International Unexamined Patent Application Publication No. 2018/181270

SUMMARY OF INVENTION

Technical Problem

[0007] As mentioned above, by improving a functional capability of a chemical-liquid injector, and moreover, by having a wide variety of instruments to be used, various jobs such as, switching over the chemical-liquid injector in accordance with switching over to injection operation and suction operation are sought. As a result, this involves a large number of complex jobs of connecting unmistakably a chemical-liquid injector including various components such as a plurality of tubes, valves, and connectors, and arranging without hindering the treatment.

[0008] One of the objects of the present invention is to enable safe and easy handling of a chemical-liquid circuit having various components.

Solution to Problem

[0009] An opening/closing unit drive mechanism of the present invention in which, a chemical-liquid circuit equipped with an opening/closing unit which includes a housing having flow channels for a chemical liquid, and at least one piston with one end portion thereof made to protrude from the housing, which is movably held in the housing so as to open and close the flow channels, is detachably installed, includes [0010] an opening/closing unit holder which detachably holds the opening/closing unit, [0011] an engaging portion to be engaged with the piston, which is disposed leaving a space from the opening/closing unit holder, and [0012] a linear motion mechanism which moves the engaging portion back and forth, [0013] wherein the opening/closing unit holder is movably supported between a first position at which, the piston is engaged with the engaging portion, and a second position at which, the piston is not engaged with the engaging portion.

[0014] A chemical-liquid injector of the present invention includes the abovementioned opening/closing unit drive mechanism of the present invention.

Definition of Terms

[0015] In the present specification, ‘upstream’ and ‘downstream’ signify ‘upstream’ and ‘downstream’ with respect to a direction of flow of a chemical liquid at the time of injecting the chemical liquid.

Advantageous Effects of Invention

[0016] According to the present invention, a safe and easy handling of a chemical-liquid circuit having various components becomes possible.

Description

BRIEF DESCRIPTION OF DRAWINGS

[0017] FIG. **1** is a schematic diagram of a medical-image imaging system according to an embodiment of the present invention.

[0018] FIG. **2** is a schematic diagram of a chemical-liquid circuit shown in FIG. **1**.

[0019] FIG. **3** is an exploded perspective view of an embodiment of a syringe that can be used in a chemical-liquid injector shown in FIG. **1**.

[0020] FIG. **4** is a perspective view of an embodiment of a first opening/closing unit shown in FIG. **2**.

[0021] FIG. **4**A is a perspective view of a housing of the first opening/closing unit shown in FIG. **4**.

[0022] FIG. **4**B is a longitudinal sectional view showing a state of the first opening/closing unit shown in FIG. **4** in which a flow channel is closed.

[0023] FIG. **4**C is a cross-sectional view showing a state of the first opening/closing unit shown in FIG. **4** between opening and closing of the flow channel.

[0024] FIG. **4**D is a longitudinal sectional view showing a state of the first opening/closing unit shown in FIG. **4** in which the flow channel is open.

[0025] FIG. **5** is a perspective view of an embodiment of a second opening/closing unit shown in FIG. **2**.

[0026] FIG. **5**A is a longitudinal sectional view showing a state of the second opening/closing unit shown in FIG. **5** in which the flow channel is closed.
[0027] FIG. **5**B is a longitudinal sectional view showing a state of the second opening/closing unit shown in FIG. **5** in which the flow channel is open.
[0028] FIG. **6**A is a perspective view of an injection head shown in FIG. **1**.
[0029] FIG. **6**B is a perspective view of the injection head shown in FIG. **1**, viewed from an angle different from that in FIG. **6**A.
[0030] FIG. **7** is a perspective view of a head body of the injection head shown in FIG. **6**A and FIG. **6**B.
[0031] FIG. **8** is a perspective view of a chemical-liquid circuit operating unit of the injection head shown in FIG. **6**A and FIG. **6**B.
[0032] FIG. **9** is a perspective view of various mechanisms in a chemical-liquid circuit operating unit **102** shown in FIG. **8**.
[0033] FIG. **9**A is a perspective view of a squashing mechanism shown in FIG. **9**.
[0034] FIG. **9**B is a perspective view of a first opening/closing unit drive mechanism shown in FIG. **9**.
[0035] FIG. **9**C is a side view of a holder shown in FIG. **9**B, in a first position.
[0036] FIG. **9**D is a side view of the holder shown in FIG. **9**B, in a second position.
[0037] FIG. **9**E is a perspective view of a hook and a slider assembly shown in FIG. **9**B.
[0038] FIG. **9**F is a perspective view of a second opening/closing unit drive mechanism shown in FIG. **9**.
[0039] FIG. **9**G is a perspective view of a sensor for position detection of the hook, of the second opening/closing unit drive mechanism shown in FIG. **9**.
[0040] FIG. **10**A is a perspective view of a chemical-liquid circuit operating unit in a state of the first opening/closing unit and the second opening/closing unit installed.
[0041] FIG. **10**B is a perspective view of the chemical-liquid circuit operating unit in a state of the first opening/closing unit and the second opening/closing unit, each inserted into a holder at the second position.
[0042] FIG. **11**A is a perspective view showing a lighting module for the first opening/closing unit.
[0043] FIG. **11**B is a perspective view showing a lighting module for the second opening/closing unit.
[0044] FIG. **11**C is a perspective view of an example of a lighting module having a light guide.
[0045] FIG. **12** is a perspective view of a chemical-liquid container holder of the injection head shown in FIG. **6**B.
[0046] FIG. **12**A is a perspective view of the chemical-liquid container holder shown in FIG. **12**, viewed from a side of attaching to a coupling arm.
[0047] FIG. **12**B is a perspective view of an injection head in which the chemical-liquid container holder shown in FIG. **12** is detached.
[0048] FIG. **12**C is a top view of the chemical-liquid container holder shown in FIG. **12**.
[0049] FIG. **12**D is a perspective view of an air sensor assembly of the chemical-liquid container holder shown in FIG. **12**.
[0050] FIG. **12**E is a perspective view of the air sensor assembly shown in FIG. **12**D in which an air sensor stopper is detached.
[0051] FIG. **13** is a perspective view of an injection head when the injection head is directed upward so that a front end of a syringe is directed upward.
[0052] FIG. **14** is a block diagram of another embodiment of a chemical-liquid injector.
[0053] FIG. **15**A is a perspective view of another embodiment of a chemical-liquid circuit operating unit, and shows a state in which a holding lever is at a first position.
[0054] FIG. **15**B is a perspective showing a state in which the holding lever is at a second position in another embodiment of the chemical-liquid circuit operating unit shown in FIG. **15**A.

[0055] FIG. **16** is a perspective view of another embodiment of the air sensor assembly.

DESCRIPTION OF EMBODIMENTS

[0056] Embodiments of the present invention will be described below by referring to the accompanying drawings. Here, the description will be made by citing an example of an angio imaging system which is favorably used in cardiac catheter test by coronary arteriography, but the present invention is not restricted to this, and is also applicable to CT (Computed Tomography) imaging system, MRI (Magnetic Resonance Imaging) system, PET (Positron Emission Tomography) system and the like.

Overall Configuration

[0057] Referring to FIG. **1**, a schematic diagram of a medical-image imaging system according to an embodiment of the present invention having a chemical-liquid injector **10**, a chemical-liquid circuit **30**, and a medical-image imaging apparatus **50** is shown. The chemical-liquid injector **10** has an injection head **10***a* and a console **10***b*. The chemical-liquid circuit **30** fluidically connects the injection head **10***a* and a subject. The chemical-liquid injector **10** and the medical-image imaging apparatus **50** can be mutually connected so as to carry out transmission and reception of data between each other. Connection between the two may be a wired connection or a wireless connection.

[0058] The medical-image imaging apparatus **50** has an imaging operation unit **52** which carries out an imaging operation and an imaging control unit **51** which controls the operation of the imaging operation unit **52**, and is capable of acquiring medical images including a tomographic image and/or three-dimensional image of the subject injected with a chemical liquid by the chemical-liquid injector **10**. The imaging operation unit **52**, normally, has a bed for the subject and an electromagnetic wave irradiation unit which irradiates electromagnetic waves to a predetermined space over the bed. The imaging control unit **51** controls an operation of the overall medical-image imaging apparatus such as, determining imaging conditions and controlling the operation of the imaging operation unit **52** according to the imaging conditions determined. It is possible to configure the imaging control unit **51** by including a so-called microcomputer, and can have a CPU, a ROM, a RAM, and an interface with other instruments. A computer program for a control of the medical-image imaging apparatus **50** is installed in the ROM. The CPU, by executing various functions according to the computer program, can control an operation of each section of the medical-image imaging apparatus **50**.

[0059] The medical-image imaging apparatus **50** can further include a display device **54** such as a liquid crystal display which is capable of displaying imaging conditions and a medical image acquired, and an input device **53** for inputting imaging conditions etc. As the input device **53**, it is possible to use at least one type of known input devices such as various buttons, a keyboard, and a mouse. At least a part of data to be used for determining the imaging conditions is input from the input device **53**, and is transmitted to the imaging control unit **51**. Data to be displayed on the display device **54** is transmitted from the imaging control unit **51**. Moreover, it is also possible to use a touch panel in which a touch screen is disposed as an input device on a display which is a display device, as the input device **53** and the display device **54**. It is possible to incorporate a part of the input device **53**, the display device **54**, and the imaging control unit **51** in one housing as a console for a medical-image imaging apparatus.

[0060] The chemical-liquid injector **10** is an apparatus for injecting a chemical liquid filled in a syringe into a blood vessel of a subject via the chemical-liquid circuit **30**. The syringe is detachably mounted on the injection head **10***a*, and at least one syringe drive mechanism which operates a plunger (or a piston) of the syringe is built-in in the injection head **10***a*. In the present embodiment, the injection head **10***a* is configured such that it is possible to mount two syringes **20**A and **20**B in order to be able to inject separately or simultaneously two types of chemical liquids such as a contrast medium and a physiological saline solution for example, and moreover, has two syringe drive mechanisms which operate each of the syringes **20**A and **20**B independently. However, at

least one of the syringe drive mechanism for injecting one chemical liquid and the syringe drive mechanism for injecting the other chemical liquid may be in plurality.

[0061] Here, an embodiment of a syringe that can be used in the present embodiment will be described below by referring to FIG. **3**. A syringe shown in the figure is a syringe normally called as a rod less syringe, and has a cylinder **22** having a flange **22***a* and a nozzle portion **22***b* formed at a tail end and a front end respectively, and a plunger **23** which is inserted to be movable back and forth in the cylinder **22**. At a tail end of the plunger **23**, a projection (not shown) in the form of a flange to be engaged with the cylinder drive mechanism of the injection head **10***a* is formed integrally. The syringe may be a syringe of a pre-filled type which is provided from a manufacturer in a state of a chemical liquid filled therein, or may be a syringe of a type to be filled on site having a chemical liquid filled at a medical site.

[0062] The syringe is inserted into a protective cover **21** and is mounted on the injection head **10***a*. The protective cover **21**, in order to suppress an expansion by a rise in internal pressure of the cylinder **22** during the chemical liquid injection, is a component configured to be circular cylindrical shaped having dimensions such that there is no gap practically between an outer peripheral surface of the cylinder **22** and an inner peripheral surface of the protective cover **21**. In order that the protective cover **21** carries out this function, the protective cover **21** is formed to be thick-walled having a mechanical strength that can adequately withstand the internal pressure acting on the cylinder **22** during the chemical-liquid injection.

[0063] An opening is formed at a front end of the protective cover **21**, and the cylinder **22** is inserted into the protective cover **21** in a state of the nozzle portion **22***b* protruding out through the opening. A cover flange **21***a* having a ring-shaped recess which receives the flange **22***a* of the cylinder **22** formed therein, is formed at a tail end of the protective cover **21**. In the present embodiment, the syringe is used upon being inserted into the protective cover **21**, but the protective cover **21** is not indispensable in the present invention, and the syringe may be mounted directly on the injection head **10***a*.

[0064] Referring again to FIG. **1**, the console **10***b* has an injection control unit **11**, an input device **12**, and a display device **13**. The injection control unit **11** controls an operation of the overall chemical liquid injector such as determining injection conditions such as an injection volume and an injection rate of a chemical liquid by using at least a part of data input from the input device **12**, controlling an operation of the injection head **10***a* so that the chemical liquid is injected according to the injection conditions determined, and controlling a display of the display device **13**. It is possible to configure the injection control unit **11** by including a so-called microcomputer, and can have a CPU, a ROM, a RAM, and an interface with other instruments. A computer program for a control of the chemical-liquid injector **10** is installed in the ROM. The CPU, by executing various functions according to the computer program, can control an operation of each section of the chemical-liquid injector **10**.

[0065] The input device **12** is a device used for inputting data which is to be used for determining the injection conditions of a chemical liquid by the injection control unit **11**. As the input device **12**, it is possible to use at least one type of known input devices such as various buttons, a keyboard, and a mouse. Data input from the input device **12** is transmitted to the injection control unit **11**, and data to be displayed on the display device **13** is transmitted from the injection control unit **11**. The display device **13**, by being controlled by the injection control unit **11**, carries out display of data necessary for determining the injection conditions of a chemical liquid, display of an injection protocol, display of various guidance, and display of various warnings.

[0066] The injection protocol is a protocol indicating as to which chemical liquid, of how much volume, and at what rate is to be injected. The injection rate may be constant or may change with time. Moreover, in a case of injecting a plurality of types of chemical liquids such as a contrast medium and a physiological saline solution, information such as, in which order the chemical liquids are to be injected is also included in the injection protocol. As the injection protocol, it is

possible to use a known arbitrary injection protocol. Moreover, regarding a procedure for setting the injection protocol, it is possible to use a known procedure. Moreover, the injection protocol sometimes includes the maximum permissible value of injection pressure (pressure limit). In a case in which the pressure limit is set, during the injection operation, the injection pressure is monitored, and the operation of the injection head **10***a* is controlled such that the injection pressure does not exceed the pressure limit set.

[0067] As the display device **13**, it may be a known display apparatus such as a liquid crystal display apparatus. Moreover, it is also possible to use a touch panel in which a touch screen is disposed as an input device on a display which is a display device, as the input device **12** and the display device **13**. A part of the input device **12** may be provided separately from the console.

[0068] The chemical-liquid circuit **30** forms flow channels of a chemical liquid connecting the syringe and the subject, and can have at leastone tube, at least one connector, and at least one valve.

Configuration of Chemical-Liquid Circuit

[0069] An embodiment of the chemical-liquid circuit **30** which can be used appropriately in the chemical-liquid injector **10** shown in FIG. **1** is shown in FIG. **2**. In the chemical-liquid circuit **30** shown in FIG. **2**, the syringes **20**A and **20**B are connected and are used at the time of injecting a first chemical liquid and a second chemical liquid accommodated in the respective syringes **20**A and **20**B into the subject. Moreover, the chemical-liquid circuit **30** is capable of connecting a first container **40**A and a second container **40**B accommodating the first chemical liquid and the second chemical liquid respectively, and is also capable of sucking the first chemical liquid and the second chemical liquid from the first container **40**A and the second container **40**B into the syringes **20**A and **20**B respectively. The first chemical liquid and the second chemical liquid are chemical liquids for a medical purpose, and a case in which the first chemical liquid is a contrast medium and the second chemical liquid is a physiological saline solution will be described below.

[0070] The chemical liquid circuit **30** has a first main line **301***a* which is connected to the syringe **20**A containing the contrast medium, a second main line **302***a* which is connected to the syringe **20**B containing the physiological saline solution, a first sub line **301***b* which is connected to the first container **40**A containing the contrast medium, a second sub line **302***b* which is connected to the second container **40**B containing the physiological saline solution, a subject line **303** which is located at a downstream of the first main line **301**, and a transducer line **304** which is connected to a transducer.

[0071] Here, ‘line’ signifies a flow channel through which the chemical liquid flows, and includes members (such as, various types of tubes, T-shaped tubes, various fluid connectors, various valves, and mixing devices) through which the chemical liquid flows. Moreover, in FIG. **2**, each line is indicated conveniently for illustrating diagrammatically, and a relative length of each line do not represent a relative length of an actual line.

[0072] The first main line **301***a* has, in order from an upstream side, a connector **310***a*, a T-shaped tube **311***a*, a first tube **312***a*, a rotating high-pressure adapter **313***a*, a female luer lock connector **314***a*, and a second tube **315***a*. The connector **310***a* is connected to the syringe **20**A. The rotating high-pressure adapter **313***a* and the female luer lock connector **314***a* are connected detachably. Accordingly, the first main line **301***a* is separable between the first tube **312***a* and the second tube **315***a*.

[0073] The first sub line **301***b* connects the first container **40**A and the first main line **301***a*. The first sub line **301***b* has, in order from the first container **40**A side, a spike **310***b*, a third tube **311***b*, a drip chamber **312***b*, a fourth tube **313***b*, and a unidirectional valve **314***b*. The spike **310***b* is connected to the first container **40**A. The unidirectional valve **314***b* is installed in a direction allowing a flow of a chemical liquid only in a direction from the first container **40**A toward the first main line **301***a*, and is connected to the T-shaped tube **311***a* of the first main line **301***a*. The first container **40**A is a bottle-shaped container for example, and the contrast medium flowed from the first container **40**A, after being dripped in the drip chamber **312***b*, is supplied to the first main line

301*a*.
[0074] As described above, by disposing the unidirectional valve **314***b* in the first sub line **301***b*, the chemical liquid is prevented from inflowing to the first sub line **301***b* from the first main line **301***a*.
[0075] The second main line **302***a* has, in order from the upstream side, a connector **320***a*, a T-shaped tube **322***a*, a first tube **322***a*, a rotating high-pressure adapter **323***a*, a female luer lock connector **324***a*, and a second tube **325***a*. The connector **320***a* is connected to the syringe **20**B. The rotating high-pressure adapter **323***a* and the female luer lock connector **324***a* are connected detachably. Accordingly, the second main line **302***a* is separable between the first tube **322***a* and the second tube **325***a*.
[0076] The second sub line **302***b* connects the second container **40**B and the second main line **302***a*. The second sub line **302***b* has, in order from the second container **40**B side, a spike **320***b*, a third tube **321***b*, a drip chamber **322***b*, a fourth tube **323***b*, and a unidirectional valve **324***b*. The spike **320***b* is connected to the second container **40**B. The unidirectional valve **323***b* is installed in a direction allowing a flow of a chemical liquid only in a direction from the second container **40**B toward the second main line **302***a*, and is connected to the T-shaped tube **321***a* of the second main line **302***a*. The second container **40**B is a bag-shaped container for example, and the physiological saline solution flowed from the second container **40**B, after being dripped in the drip chamber **322***b*, is supplied to the second main line **302***a*.
[0077] As described above, by disposing the unidirectional valves **324***a* and **324***b* in the second sub line **302***b*, the chemical liquid is prevented from inflowing to the second sub line **301***b* from the second main line **301***a*.
[0078] The subject line **303** has, in order from the upstream side, a mixing device **330**, a fifth tube **331**, a first opening/closing unit **332**, a unidirectional valve **333**, a T-shaped tube **334**, a sixth tube **335**, and a connector **336**. The mixing device **330** has two inflow ports and one outflow port, and is configured such that the chemical liquids inflowed through the inflow ports are mixed and outflow through the outflow port. The inflow ports of the mixing device **330** are connected to the second tube **315***a* of the first main line **301***a* and the second tube **325***a* of the second main line **302***a* respectively. The outflow port of the mixing device **330** is connected to the fifth tube **331**. As the mixing device **330**, it is possible to use 'SPIRAL FLOW' (registered trademark) manufactured by Nemoto Kyorindo Co., Ltd. Moreover, it is also possible to use a T-shaped connector instead of the mixing device **330**.
[0079] The first opening/closing unit **332** is a unit configured to be capable of controlling opening and closing of flow channels so as to prevent a reverse flow of the chemical liquid from a downstream to an upstream at the time of injection of the chemical liquid. The first opening/closing unit **332** will be described later in detail.
[0080] The unidirectional valve **333** is installed in a direction allowing a flow of the chemical liquid only in a direction from the upstream toward the downstream. The connector **336** is disposed at a downstream end of the subject line **303**, and the subject line **303** is connected to a catheter etc. that is tapped or inserted into the subject, via the connector **336**.
[0081] The transducer line **304** is a line connected to the T-shaped tube **324** of the subject line **303** so as to branch from the subject line **303**, and has, in order from the T-shaped tube **324** side, a seventh tube **340**, a second opening/closing unit **341**, an eighth tube **342**, and a connector **343**. A transducer **70** is connected to the connector **343**, for monitoring a pulse by detecting a blood pressure of the subject. The second opening/closing unit **341** is a unit configured to be capable of controlling opening and closing of flow channels so as to protect the transducer **70** from a high pressure. The second opening/closing unit **341** will be described later in detail. A display (not shown in the diagram) which displays a waveform of the pulse of the subject is connected to the transducer **70**.
[0082] It is possible to divide the chemical-liquid circuit **30** configured as mentioned above into a

single-time use section **300**A on the downstream side and a multiple-time use section **300**B on the upstream side. The single-time use section **300**A is a section that can be used only once, and is a so-called disposable section. The multiple-time use section **300**B is a section that can be used repeatedly for a plurality of times. Specifically, the single-time use section **300**A includes a portion on the downstream side separated by the female luer lock connector **314***a* of the first main line **301***a*, a portion on the downstream side separated by the female luer lock connector **324***a* of the second main line **302***a*, and the subject line **303** and the transducer line **304**. The multiple-time use section **300***b* includes a portion of the chemical liquid circuit **30** other than the single-time use section **300**A, or in other words, a portion on the upstream side of the first main line **301***a* separated by the rotating high-pressure adapter **313***a*, the first sub line **301***b*, a portion on the upstream side of the second main line **302***a* separated by the rotating high-pressure adapter **323***a*, and the second sub line **302***b*.

[0083] Moreover, the chemical liquid circuit **30** can further have an auxiliary circuit **350**. The auxiliary circuit **350** has a female luer lock connector **351** with a unidirectional valve, a ninth tube **352**, and a female luer lock connector **353** connected to the female luer lock connector **351** via the ninth tube **352**. The unidirectional valve of the female luer lock connector **351** allows a flow of a chemical liquid only in a direction from the female luer lock connector **351** toward the female luer lock connector. After the multiple-time use section **300**B is connected to the syringes **20**A and **20**B and the chemical liquid containers **40**A and **40**B, air venting is carried out. In the auxiliary circuit **350**, the female luer lock connector **351** is connected to each of the rotating high-pressure adapter **313***a* of the first main line **301***a* and the rotating high-pressure adapter **323***a* of the second main line **302***a* till the air venting comes to an end.

[0084] After the end of the air venting, the auxiliary circuit **350** is detached from the first main line **301***a* and the second main line **302***a*, and the female luer lock connectors **314***a* and **324***a* of the single-time use section **300**A are connected to the rotating high-pressure connectors **313***a* and **323***a* respectively.

First Opening/Closing Unit

[0085] As shown in FIG. **4**, the first opening/closing unit **332** has a housing **501**, two pistons **502** and **503** movably accommodated inside the housing **501**, a bottom cap **504**, and a top cap **505**. The first opening/closing unit **332** will be described below while referring to FIG. **4**A which is a cross-sectional perspective view of the housing **501** and FIG. **4**B which is a longitudinal sectional view of the first opening/closing unit **332**.

[0086] The housing **501** has two cylinder portions **501***c* and **501***d* which slidably accommodate the pistons **502** and **503** respectively. The cylinder portions **501***c* and **501***d* are disposed side by side. Both ends in an axial direction of the cylinder portions **501***c* and **501***d* are open. Moreover, the housing **501** is provided with conduit portions **501***a* and **501***b* extended from an outer wall of the housing **501** in a direction orthogonal to the axial direction of the cylinder portions **501***c* and **501***d*, adjacent to the cylinder portions **501***c* and **501***d* respectively. One conduit portion **501***a* is connected to the sixth tube (refer to FIG. **2**) of the subject line **303**. The other conduit portion **501***b* is connected to the unidirectional valve **333** (refer to FIG. **2**) of the subject line **303**. Therefore, in the embodiment illustrated in the diagram, the arrangement is in an order of the piston **502** and piston **503** from the upstream side toward the downstream side.

[0087] Furthermore, a communicating flow channel **501***e* which communicates with the one conduit portion **501***a* and the cylinder portion **501***c* adjacent to the conduit portion **501***a*, a communicating flow channel **501***f* which communicates with the two cylinder portions **501***c* and **501***d*, and a communicating flow channel **501***g* which communicates with the other conduit portion **501***b* and the cylinder portion **501***d* adjacent to the conduit portion **501***b* are formed in the housing **501**. The conduit portions **501***a* and **501***b* and the communicating flow channels **501***e*, **501***f*, and **501***g* are disposed to be aligned in straight line.

[0088] The piston **502** on the upstream side is a column-shaped member, and has on one end

thereof a head **502***a* having a flange shape spread outward in a radial direction. On an intermediate portion in a longitudinal direction of the piston **502**, a flow channel **502***b* is formed across the piston **502** in a direction orthogonal to the longitudinal direction of the piston **502**. On an outer peripheral surface of the piston **502**, a sealing rings **506** such as an O-ring is mounted on both sides of the flow channel **502***b* in the longitudinal direction of the piston **502**. The piston **503** on the downstream side, similarly, has a head **503***a*, and a flow channel **503***b* is formed therein, and the sealing ring **506** is installed.

[0089] However, for the piston **502** on the upstream side and the piston **503** on the downstream side, a dimension of the flow channels **502***b* and **503***b* in a direction of sliding S of the pistons **502** and **503** differ. More elaborately, the dimension in the direction of sliding S of the flow channel **502***b* of the piston **502** on the upstream side is larger than the dimension in the direction of sliding of the flow channel **503***b* of the piston **503** on the downstream side. For instance, it is possible to make the flow channel **502***b* of the piston **502** on the upstream side have an oval-shaped transverse section which is long in the direction of sliding S, and to make the flow channel **503***b* of the piston **503** on the downstream side have a circular-shaped transverse section.

[0090] The bottom cap **504** and the top cap **505** block open ends of the cylinder portions **501***c* and **501***d* at both ends of the housing **501**. The bottom cap **504** is mounted at an end portion of the housing **501** on an opposite side of a side having the heads **502***a* and **503***a* of the pistons **502** and **503**. The top cap **505** is mounted at an end portion of the housing **501** upon making the heads **502***a* and **503** protrude from the top cap **505**, on the side having the heads **502***a* and **503***a* of the pistons **502** and **503**. Therefore, the top cap **505** has two opening portions through which the pistons **502** and **503** pass. The top cap **505** can be configured by combining a plurality of components so that the pistons **502** and **503** are inserted into the cylinder portions **501***c* and **501***d*, and the heads **502***a* and **503***a* can be installed in the housing **501** in a state of the heads **502***a* and **503***a* made to protrude through the top cap **505**.

[0091] By the first opening/closing unit **332** having the bottom cap **504** and the top cap **505**, it is possible to prevent the dust from entering into the cylinder portions **501***c* and **501***d*. In order to achieve this effect more efficiently, it is preferable to make a clearance between the opening portion of the top cap **505** through which the pistons **503** and **504** pass through and the pistons **504** and **505**, as small as possible.

[0092] An operation of the first opening/closing unit **332** will be described below.

[0093] In a state of the pistons **502** and **503** drawn out through the housing **501**, the flow channels **502***b* and **503***b* of both pistons **502** and **503** do not communicate with conduit portions **501***a* and **501***b*. Moreover, also the flow channels **502***b* and **503***b* of the pistons **502** and **503** do not communicate. In other words, the first opening/closing unit **332** is closed.

[0094] From this state, as both the pistons **502** and **503** are slid down the housing **501** simultaneously and at the same speed, firstly, the flow channel **502***b* of the piston **502** on the upstream side communicates with the conduit portion **501***a* on the upstream side as shown in FIG. **4**C. At this stage, the flow channel **503***b* of the piston **503** on the downstream communicates neither with the flow channel **502***b* of the piston **502** on the upstream side nor with the conduit portion **501***b* on the downstream side.

[0095] From this state, as both the pistons **502** and **503** are slid further down the housing **501**, while the flow channel **502***b* of the piston **502** on the upstream side has still maintained the communication with the conduit portion **501***a*, the flow channel **503***b* of the piston **503** on the downstream side communicates with the conduit portion **501***b*, and the flow channels **502***b* and **503***b* of the pistons **502** and **503** also communicate. In other words, the first opening/closing unit **322** is opened.

[0096] At the time of closing the first opening/closing unit **332** which is opened, the pistons **502** and **503** are drawn out from the housing **501** simultaneously and at the same speed. Accordingly, after the conduit portion **501***b* on the downstream side is cutoff first by the piston **503** on the

downstream side, the conduit portion **501***a* on the upstream side is cutoff by the piston **502** on the further upstream side.

[0097] As described above, the first opening/closing unit **332**, in the course of time till opening from the state of being closed, only the piston **502** on the upstream side assumes a state of communicating. Accordingly, even with the reverse blood supposedly having reached the conduit portion **501***b* on the downstream side, at the time of opening of the first opening/closing unit **332**, the blood is thrust back by the chemical liquid from the upstream side, and there is no inflow of blood to the upstream by the piston **503** on the downstream side. Moreover, at the time of closing of the first opening/closing unit **332**, the reverse blood does not inflow into the flow channel **502***b* of the piston **502** on the upstream side, and accordingly, it is possible to prevent effectively, the reverse flow of the chemical liquid to the upstream side of the first opening/closing unit **332**.

[0098] The first opening/closing unit **332** can have a stopper structure which restricts a range of movement of the pistons **502** and **503** between the open state and the closed state. For instance, as a stopper structure which restricts a drawn-out position of the pistons **502** and **503**, while providing protrusions **502***c* and **503***c* on the pistons **502** and **503** (refer to FIG. **4**B) on one hand, a step portion **501***h* (refer to FIG. **4**A) can be formed as a stopper which makes contact with the protrusions **502***c* and **503***c* at the drawn-out position of the pistons **502** and **503**. Moreover, as a stopper structure which restricts a slid-down position of the pistons **502** and **503**, the pistons **502** and **503**, and the bottom cap **504** can be designed such that an end surface on an opposite side of the heads **502***a* and **503***a* of the pistons **502** and **503** makes contact with an inner surface of the bottom cap **504**, at a position at which the flow channels **502***b* and **503***b* of the pistons **502** and **503** communicate thoroughly with the conduit portions **501***b* and **501***c*.

[0099] Here, although the description was made by citing an example of a case in which the pistons **502** and **503** are moved simultaneously and at the same speed, if it is possible to make the flow channels **502***b* and **503***b* of the pistons **502** and **503** communicate with the conduit portions **501***a* and **501***b* in the abovementioned order at the time of opening and closing the first opening/closing unit **332**, the pistons **502** and **503** may be moved separately or the pistons **502** and **503** may be moved at different speeds. Alternatively, the flow channels **502***b* and **503***b* and the conduit portions **501***a* and **501***b* may communicate or be cutoff by rotating the pistons **502** and **503** with an axis in the longitudinal direction as a center of rotation. In these cases, the flow channel **502***b* of the piston **502** on the upstream side and the flow channel **503***b* of the piston **503** on the downstream side may have mutually same shape, size, and position.

Second Opening/Closing Unit

[0100] As shown in FIG. **5**, the second opening/closing unit **341**, similarly as the first opening/closing unit **332**, has a housing **601**, a piston **602**, a bottom cap **604**, and a top cap **605**. As it is evident from FIG. **5**A and FIG. **5**B, it is possible to configure the second opening/closing unit **341** similarly as the first opening/closing unit **332**, except for a point that the number of pistons **602** and the number of cylinder portions of the housing **601** is one each. Moreover, an opening and closing operation of the second opening/closing unit **341**, that is, the second opening/closing unit **341** closes by the piston **602** moving to a position at which a flow channel **602***b* of the piston **602** cuts off conduit portions **601***a* and **601***b* (FIG. **5**A), and the second opening/closing unit **341** opens by the piston **602** moving to a position at which the flow channel **602***b* communicates with the conduit portions **601***a* and **601***b* (FIG. **5**B), is also similar to that of the first opening/closing unit **332**.

Others

[0101] In the abovementioned examples, as the first opening/closing unit **332** provided to the subject line **303**, a unit with a double-piston structure having the housing **501** and two pistons **502** and **503** as shown in FIG. **4** was used, and as the second opening/closing unit **341** provided to the transducer line **304**, a unit with a single-piston structure having the housing **605** and the single piston **602** as shown in FIG. **5** was used. However, as the first opening/closing unit **332**, a unit

having a single-piston structure may be used. Moreover, as the second opening/closing unit **341**, a unit having a double-piston structure may be used, and both the first opening/closing unit **332** and the second opening-closing unit **341** may be units having a double-piston structure.

Configuration of Injection Head

[0102] Next, the injection head **10***a* shown in FIG. **1** will be described below by referring to figures such as FIG. **6**A and FIG. **6**B. The injection head **10***a* has a head body **101** in which a syringe is mounted, a chemical-liquid circuit operating unit **102** which is disposed on a front side (side on which the syringe is mounted) of the head body **101**, and a chemical-liquid container holder **103** which holds the chemical-liquid containers **40**A and **40**B (refer to FIG. **1**).

[0103] Head Body

[0104] A main function of the head body **101** is for mounting a syringe and operating the syringe mounted. For this, the head body **101**, as shown in FIG. **7**, has a clamper **111** which detachably fixes two syringes **20**A and **20**B (see FIG. **1**), a presser **112**, and an operating section **113**.

[0105] The clamper **111** can have a first holding structure **111***a* and two second holding structures **111***b* which hold the syringe in cooperation with the first holding structure **111***a*. The first holding structure **111***a* has two recesses for receiving a part in a circumferential direction of a flange portion (the cover flange **21***a* of the protective cover **21** in the embodiment shown in FIG. **3**) of a tail end of two syringes. The second holding structure **111***b* is disposed corresponding to each recess of the first holding structure **111***a*, and is configured by having a recess which is capable of receiving at least a remaining part of the flange portion received by each recess.

[0106] The second holding structure **111***b* is movably supported between an open position and a closed position with respect to the first holding structure **111***a*, and at the closed position, holds the flange portion of the syringe in cooperation with the first holding structure **111***a* to be immovable in the longitudinal direction. Here, the meaning of the term ‘to be immovable’ includes not only that the intended structure does not move at all, but also that the intended structure moves within a range of clearance occurring due to a design dimensional tolerance etc.

[0107] The presser **112** is made to be movable back and forth by a drive source such as a motor, and forms a part of the syringe drive mechanism. The presser **112**, at a front-end portion thereof, has an engaging portion which is to be engaged with the plunger (or piston) of the syringe. By the engaging portion being engaged with the plunger (or piston), and by moving the presser **112** back and forth in a state of the syringe being held by the clamper **111**, the plunger (or piston) moves back and forth with respect to the syringe. Accordingly, it is possible to inject the chemical liquid from the syringe and to suck the chemical liquid into the syringe.

[0108] The operating section **113** has a plurality of buttons such as a start button, a forward-movement button, and a backward-movement button for operating the presser **112**, and a user can operate the presser **112** as desired, apart from operating according to the conditions set in the injection control unit **11** (see FIG. **1**).

[0109] Moreover, the head body **101** can have a support shaft **114** which is extended in a direction orthogonal to the longitudinal direction of the syringe that is mounted. It is possible to make an arrangement such that the head body **101** is pivotably supported with the support shaft **114** as a center, by a swivel arm (not shown) extended from a ceiling or a stand (not shown), via the support shaft **114**. By supporting the head body **101** in a state of the support shaft **114** directed in a substantially horizontal direction, it is possible to pivotably support the head body **101** between a posture in which the front end of the syringe is directed toward the ceiling (upward posture) and a posture in which the front end of the syringe is directed toward a floor surface (downward posture).

Chemical-Liquid Circuit Operating Unit

[0110] A perspective view of the chemical-liquid circuit operating unit **102** is shown in FIG. **8**. A perspective view of various mechanisms in the chemical-liquid circuit operating unit **102** shown in FIG. **8** is shown in FIG. **9**. As shown in FIG. **8** and FIG. **9**, the chemical-liquid circuit operating unit **102**, with the single-time use section **300**A (see FIG. **2**) of the chemical-liquid circuit **30**

detachably installed therein, has a plurality of mechanisms which control the flow channels of the single-time use section **300**A. These mechanisms are to be driven electrically, and in order that no chemical liquid comes in contact with these mechanisms, these mechanisms are accommodated in a casing which is configured by having an upper cover **102***a* and a lower cover **102***b*, excluding a portion which is necessary for drawing around the chemical-liquid circuit **30**.

[0111] The chemical-liquid circuit operating unit **102** has connecting arms **102***c* and **102***d* by which the chemical-liquid circuit operating unit **102** is connected to the head body **101**, and accordingly, it is possible to fix the chemical-liquid circuit operating unit **102** to the head body **101**. By fixing the chemical-liquid circuit operating unit **102** to the head body **101**, it is possible to dispose the chemical-liquid circuit **30** in an orderly manner without the tubes in the chemical-liquid circuit **30** being bent.

[0112] The chemical-liquid circuit operating unit **102** may have been supported by the head body **10** by being pivotably connected by a hinge around an axis Ra (direction of an arrow A) parallel to the support shaft **114** for example, so as to be retractable from a front side of the head body **101** when not to be used. Moreover, the chemical-liquid circuit operating unit **102** may be detachably attached to the head body **101**.

[0113] The mechanisms provided to the chemical-liquid circuit operating unit **102** includes air sensors **710** and **780**, two squashing mechanisms **720**, a first opening/closing unit drive mechanism **740**, and a second opening/closing unit drive mechanism **760**.

Air Sensor

[0114] The air sensors **710** and **780** detect air inside the flow channels, in a portion of flow channels in which the air sensors **710** and **780** are disposed. The two air sensors **710** detect the existence of air inside third tubes **317***a* and **327***b* (see FIG. **2**) of the first and second main lines **301***a* and **302***a* respectively in the chemical-liquid circuit **30**. The air sensor **780** detects the existence of air inside an eighth tube **340** (see FIG. **2**) of the transducer **304** of the chemical-liquid circuit **30**. As the air sensors **710** and **780**, known arbitrary sensors can be used, provided that the sensors are capable of detecting air inside the tube. In the present embodiment, sensors of ultrasonic type having a transmitter and a receiver disposed face-to-face with the tubes in between are used.

Squashing Mechanism

[0115] The squashing mechanism **720** cuts off a flow of a fluid in a portion of a flow channel in which the squashing mechanism **720** is disposed. The squashing mechanism **720** can be disposed at a downstream side of the air sensor **710**, and as shown in FIG. **9**A, has a base **721** in which a recess **721***a* into which a tube is inserted in a radial direction is formed, a pushing member **722** which is slidably supported by the base **721**, a motor **723** which is a drive source of the pushing member **722**, and a circular cylindrical cam **725** which is rotationally driven via a rotation transmission mechanism **724**. The pushing member **722** is configured to reciprocate between a first position at from which a front end of the pushing member **722** is drawn from the recess **721***a* of the base **721**, and a second position which transects the recess **721***a*, in conjunction with the rotation of the circular cylindrical cam **725**.

[0116] In a state of a tube disposed in the recess **721***a*, when the pushing member **722** is at the first position drawn from the recess **721***a*, the fluid can flow through the tube. Whereas, in a state of the tube disposed in the recess **721***a*, when the pushing member **722** is at the position of transecting the recess **721***a*, the tube is squashed by the pushing member **722**, and the flow of the fluid through the tube is blocked. Itis possible to control the movement of the pushing member **722** by the drive of the motor **723** by a command from the injection control unit **11** (refer to FIG. **11**) according to a procedure determined in advance and an operation of the user.

First Opening/Closing Unit Drive Mechanism

[0117] The first opening/closing unit drive mechanism **740**, by having a first opening/closing unit **332** installed therein (see FIG. **4**), and by driving the first opening/closing unit **332**, opens and

closes the flow channels in the first opening/closing unit **332**. The first opening/closing unit drive mechanism **740** will be described below by referring to FIG. **9**B to FIG. **9**E.

[0118] The first opening/closing unit drive mechanism **740**, as shown in FIG. **9**B, has a holder **741**, a hook **742** which is an engaging portion to be engaged with the two pistons **502** and **503** of the first opening/closing unit **332** (see FIG. **4**), and a linear motion mechanism **743** which moves the hook **742**.

[0119] The holder **741** has a recess **741***a* in which a bottom portion of the first opening/closing unit **332** is inserted, and by the bottom portion of the first opening/closing unit **332** being inserted into the recess **741***a*, the holder **741** detachably holds the first opening/closing unit **332**. Moreover, the holder **741** is supported by a pair of supporting plates **744** disposed on both sides thereof. Each supporting plate **744** is provided with a pivot shaft **745**, and accordingly, the holder **741** is movably supported between a first position and a second position.

[0120] At the first position, as shown in FIG. **9**C, the holder **741** assumes a posture in which the recess **741** is directed transversely so that the recess **741***a* is facing the hook **742**, and at the second position, as shown in FIG. **9**D, the holder **741** assumes a posture in which the recess **741***a* is directed upward upon being rotated through 90 degrees from the first position with the pivot shaft **745** as a center of rotation so that the recess **741***a* is not facing the hook **742**.

[0121] For detecting that the holder **741** is at the first position, the first opening/closing unit drive mechanism **740** can have a holder position detection sensor **751** (refer to FIG. **9**C and FIG. **9**D). As the holder position detection sensor **751**, it is possible to use an arbitrary sensor such as an optical sensor, a proximity sensor, and a mechanical switch.

[0122] In the present embodiment, a proximity sensor is used as the holder position detection sensor **751**. The proximity sensor detects the presence or absence and a position of an object with magnetism as a detecting medium. A sensor such as a hall sensor can be cited as an example of the proximity sensor. Moreover, a magnet **753**, which is a piece to be detected by the proximity sensor, is disposed on an outer peripheral surface of the holder **741**.

[0123] The holder position detection sensor **751** is disposed at a position of being capable of detecting the magnet **753** when the holder **741** is at the first position, and accordingly, the holder **741** is detected to be at the first position by the holder position detection sensor **751**. An output from the holder position detection sensor **751** is transmitted to the injection control unit **11** (see FIG. **1**), and in the injection control unit **11**, a judgment that the holder **741** is at the first position is made.

[0124] Moreover, the first opening/closing unit drive mechanism **740** can have a restricting structure which restricts a range of movement of the holder **741** between the first position and the second position. An example of the restricting structure includes a combination of a guide groove **741***g* having a predetermined length corresponding to the range of movement from the first position up to the second position and a pin **744***a* which moves in this guide groove **741***b* as shown in FIG. **9**C and FIG. **9**D. It is possible to form the guide groove **741***b* on an end (edge) surface of the holder **741**, and to provide the pin **744***a* to be protruding from the supporting plate **744** to the supporting plate **44** facing the end surface of the holder **741** on which the guide groove **741***b* is formed. Alternatively, the guide groove **741***b* may be formed on the supporting plate **744** and the pin **744***a* may be provided to the holder **741**.

[0125] Referring again to FIG. **9**B, the linear motion mechanism **743** has a motor **746** which is a drive source of the first opening/closing unit drive mechanism **740**, a slider assembly **747**, and a piston **748**.

[0126] A rotational motion which is an output from the motor **746** is transmitted via an appropriate transmission mechanism such as a pulley and a timing belt. The slider assembly **747** includes a motion conversion mechanism which converts the rotational motion transmitted via the transmission mechanism to a linear motion, and a structure which undergoes linear motion by the motion conversion mechanism. As the motion conversion mechanism, it is possible to use an

arbitrary mechanism such as a linear actuator in which a rack is used and a ball screw mechanism.
[0127] In the present embodiment, the slider assembly **747** includes a ball shaft and a ball nut. The piston **748** is fixed to the slider assembly **747**, and the hook **742** is fixed to a front-end portion of the piston **748**.
[0128] Receiving portions **742***a* to be engaged with the heads **502***a* and **503***a* of the pistons **502** and **503** of the first opening/closing unit **332** (see FIG. **4**) are formed in the hook **742** as shown in FIG. **9**E.
[0129] When the bottom portion of the first opening/closing unit **332** is inserted into the recess **741***a* of the holder **741** at the first position, and the holder **741** in this state is pivoted up to the second position, the heads **502***a* and **503***a* of the pistons **502** and **503** of the first opening/closing unit **332** are received in the receiving portion **742***a* of the hook **742**. Accordingly, the pistons **502** and **503** of the first opening/closing unit **332** are engaged with the hook **742**, and the first opening/closing unit **332** is fixed to the first opening/closing unit drive mechanism **740**. Therefore, regarding the positions of the holder **741**, it can be said that the first position is a position at which the pistons **502** and **503** are engaged with the hook **742** and that the second position is a position at which the pistons **502** and **503** are not engaged with the hook **742**.
[0130] By the operation of the slider assembly **747**, the hook **742** moves between an advanced position and a receded position. At the advanced position, the hook **742** slides down the pistons **502** and **503** of the first opening/closing unit **332** inside the housing **501**, and accordingly, the flow channels of the first opening/closing unit **332** open. At the receded position, the hook **742** draws out the pistons **502** and **503** of the first opening/closing unit **332**, and accordingly, the flow channels of the first opening/closing unit **332** are closed.
[0131] The first opening/closing unit drive mechanism **740** can further be provided with a sensor which detects whether the hook **742** is at the advanced position or at the receded position. As an example of such sensor, it is possible to dispose two sensors **755** and **756** adjacent to the slider assembly **747** as shown in FIG. **9**B. By detecting a position of the slider assembly by these sensors **755** and **756**, it is possible to detect whether the hook **742** is at the advanced position or at the receded position.
[0132] The sensors **755** and **756** are not restricted in particular, and it is possible to use an arbitrary sensor which is capable of detecting the position of the slider assembly **747**. In the present embodiment, optical sensors of transmission type having a light emitting portion and a light receiving portion are used as the sensors **755** and **756**, and a light shielding plate **747***a* provided to be protruding from the slider assembly **747** (see FIG. **9**E) is detected by these sensors **755** and **756**. The sensors **755** and **756** are disposed along a direction of movement of the hook **742**. At the receded position of the hook **742**, the light shielding plate **747***a* is detected by the sensor **756** disposed on a side distant from the holder **741**, and at the advanced position of the hook **742**, the light shielding plate **747***a* is detected by the sensor **755** disposed on a side near the holder **741**. An output from the sensors **755** and **756** is transmitted to the injection control unit **11** (see FIG. **1**), and in the injection control unit **11**, a judgment of whether the hook **742** is at the advanced position or at the receded position is made.
[0133] The first opening/closing unit drive mechanism **740** can further be provided with a sensor which detects whether or not the first opening/closing unit **332** has been installed in the first opening/closing unit drive mechanism **740**. Such sensor is not restricted in particular, and it is possible to use an arbitrary sensor which is capable of detecting that the first opening/closing unit **332** has been installed in the first opening/closing unit drive mechanism **740**.
[0134] In the present embodiment, as an example, an opening/closing unit detection sensor **749** which is an optical sensor of reflecting type having a light emitting portion and a light receiving portion is disposed between the holder **741** and the hook **742** as shown in FIG. **9**B. According to this embodiment, as the holder **741** is pivoted to the second position in a state of the first opening/closing unit **332** held by the holder **741**, the first opening/closing unit **332** is positioned at

a position facing the opening/closing unit detection sensor **749**, and accordingly, the first opening/closing unit **332** is detected. Whereas, as the holder **741** is pivoted to the second position in a state of the holder **741** not holding anything, nothing exists at the position facing the opening/closing unit detection sensor **749**, and the opening/closing unit detection sensor **749** does not detect anything. An output from the opening/closing unit detection sensor **749** is transmitted to the injection control unit **11**, and in the injection control unit **11**, a judgment of whether or not the first opening/closing unit **332** has been installed in the first opening/closing unit drive mechanism **740** is made.

[0135] It is possible to use a result of detection by the holder position detection sensor **751** and the opening/closing unit detection sensor **749** for a control of the operation of the chemical liquid injector **10** such as, not to carry out the injection operation when it has been detected that the holder **741** is at the first position by the holder position detection sensor **751** and the first opening/closing unit **332** has not been detected by the opening/closing unit detection sensor **749**.

Second Opening/Closing Unit Drive Mechanism

[0136] The second opening/closing unit drive mechanism **760**, by having installing the second opening/closing unit **341** (see FIG. **5**) therein and by driving the second opening/closing unit **341**, opens and closes flow channels in the second opening-closing unit **341**. The second opening/closing unit drive mechanism **760** will be described below by referring to FIG. **9**F and FIG. **9**G.

[0137] The second opening/closing unit drive mechanism **760** is basically configured similarly as the first opening/closing unit drive mechanism **740**, and as shown in FIG. **9**F, has a holder **761**, a hook **762** which is an engaging portion to be engaged with the piston **602** of the second opening/closing unit **341** (see FIG. **5**), and a linear motion mechanism **763** which moves the hook **762**.

[0138] It is possible to configure the holder **761** similarly as the holder **741** of the first opening/closing unit drive mechanism **740**, except for a point that, a shape of a recess in which a bottom portion of the second opening/closing unit **341** is to be inserted is a shape matching with the bottom portion of the second opening/closing unit **341**, and the holder **761** is movably supported between a first position and a second position. The first position and the second position are similar as the first position and the second position in the first opening/closing unit. It is possible to configure the hook **762** similarly as the hook **742** of the first opening/closing unit drive mechanism **740**, except for a point that, a receiving portion **762***a* which receives the head **602***a* of the second opening/closing unit **341** has a shape matching with the second opening/closing unit **341**.

[0139] It is possible to configure the linear motion mechanism **763** similarly as the linear motion mechanism **743** of the first opening/closing unit drive mechanism **740**, and in the embodiment illustrated, the linear motion mechanism **763** has a linear actuator **766** and a shaft **768** which couples a rod of the linear actuator **766** and the hook **762**.

[0140] The second opening/closing unit drive mechanism **760** can further include a sensor which detects whether the hook **762** is at an advanced position or at a receded position. The sensor is not restricted in particular, and as an example, it is possible to dispose two sensors **775** and **776** as shown in FIG. **9**G. As the sensors **775** and **776**, arbitrary sensors can be used, and for instance, it is possible to use the optical sensor of transmission type similar to that used in the first opening/closing unit drive mechanism **740**.

[0141] For detecting the position of the hook **762** by these sensors **775** and **776**, in the present embodiment, a slider **767** provided with a light shielding plate **767***a* to be protruded is fixed to the shaft **768**, and an arrangement is made such that the light shielding plate **767***a* is detected by the sensors **775** and **776**. The sensors **775** and **776** are disposed along a direction of movement of the hook **762**. At the receded position of the hook **762**, the light shielding plate **767***a* is detected by the sensor **776** disposed on a side distant from the holder **761**, and at the advanced position of the hook **762**, the light shielding plate **767***a* is detected by the sensor **775** disposed on a side near the holder

761. An output from the sensors **775** and **776** is transmitted to the injection control unit **11** (see FIG. **1**), and in the injection control unit **11**, a judgment of whether the hook **762** is at the advanced position or at the receded position is made.

[0142] The second opening/closing unit drive mechanism **760** can further be provided with an opening/closing unit sensor which detects whether or not the second opening/closing unit **341** has been installed in the first opening/closing unit drive mechanism **760**, and a holder position detection sensor which detects that the holder **761** is at the first position. These sensors may be arbitrary sensors, and in the present embodiment, an opening/closing unit detection sensor **769** and a holder position detection sensor (not shown) similar to those used in the first opening/closing unit drive mechanism **740** are disposed similarly as in the first opening/closing unit drive mechanism **740**. Moreover, a control of an operation of the chemical liquid injector **10** in which results of detection by the abovementioned sensors are used may be similar as in the first opening/closing unit drive mechanism **740**.

[0143] In FIG. **10**A, a state in which, each of the holder **741** of the first opening/closing unit drive mechanism **740** and the holder **761** of the second opening/closing unit drive mechanism **760** is at the first position, and the first opening/closing unit **332** and the second opening/closing unit **341** are installed in the first opening/closing unit drive mechanism **740** and the second opening/closing unit drive mechanism **760** respectively, is shown. In this state, the first opening/closing unit **332** and the second opening/closing unit **341** are engaged with the hook **742** of the first opening/closing unit drive mechanism **740** and the hook **762** of the second opening/closing unit drive mechanism **760** respectively. Moreover, in FIG. **10**B, a state in which, the first opening/closing unit **332** and the second opening/closing unit **341** are inserted into the holder **741** of the first opening/closing unit drive mechanism **740** and the holder **761** of the second opening/closing unit drive mechanism **760** respectively, but each of the holders **741** and **761** being at the second position, the first opening/closing unit **332** and the second opening/closing unit **341** are not installed in the first opening/closing unit drive mechanism **740** and the second opening/closing unit drive mechanism **760** respectively, is shown. In this state, the first opening/closing unit **332** and the second opening/closing unit **341** are not engaged with the hook **742** of the first opening/closing unit drive mechanism **740** and the hook **762** of the second opening/closing unit drive mechanism **760** respectively.

Illumination of Opening/Closing Unit

[0144] The chemical-liquid circuit operating unit **102** can have a first lighting module which illuminates the first opening/closing unit **332** installed in the first opening/closing unit drive mechanism **740** and a second lighting module which illuminates the second opening/closing unit **341** installed in the second opening/closing unit drive mechanism **760**. Accordingly, the first opening/closing unit **332** and the second opening/closing unit **341** installed in the chemical-liquid liquid operating unit **102** become easily visible. The lighting modules include a light source, and a method of lighting by the lighting module may be arbitrary. As the light source, it is possible to use an arbitrary light source such as a light emitting diode.

[0145] For instance, for illuminating the first opening/closing unit **332**, as shown in FIG. **11**A, it is possible to form an opening in the upper cover **102***a* near the first opening/closing unit drive mechanism **740**, and to provide the first lighting module in which a light emitting diode **731** which is the light source is disposed, for illuminating the first opening/closing unit **332** from the opening.

[0146] Moreover, for illuminating the second opening/closing unit **341**, as shown in FIG. **11**B, it is possible to form an opening in the upper cover **102***a* near the second opening/closing unit drive mechanism **740**, and to provide the second lighting module in which a light emitting diode **732** which the light source is disposed, for illuminating the second opening/closing unit **341** from the opening.

[0147] Both the first lighting module and the second lighting module may be configured such that the light source is disposed at a position different from the opening, and light from the light source

is guided to the opening via an appropriate light guide **735** (see FIG. **11**). Moreover, in a case of using the light emitting diodes **731** and **732** as the light source, it is possible to use light emitting diodes of any of a shell-type and a chip-type as the light emitting diode. However, for illuminating the opening/closing unit more distinctively from the surrounding area, it is preferable to use the light emitting diode of shell-type.

[0148] It is preferable to make an arrangement such that these lighting modules illuminate the opening/closing unit only when the opening/closing unit is installed in the opening/closing unit drive mechanism. Accordingly, it is possible for the user to easily identify visibly that the opening/closing unit has been installed in the opening/closing unit drive mechanism.

Chemical-Liquid Container Holder

[0149] In FIG. **12**, a perspective view of the chemical-liquid container holder **103** is shown. The chemical-liquid container holder **103** can have a suspended supporting column **810**, a supporting portion **820**, and a holder body assembly **830**. Moreover, the chemical-liquid container holder **103** can further have an air sensor assembly **840** according to the requirement.

[0150] The suspended supporting column **810** is a member having a longitudinal direction. The supporting portion **820** is disposed at one end portion of the suspended supporting column **810**, and the air sensor assembly **840** is disposed at the other end portion of the suspended supporting column **810**. The holder body assembly **830** is fixed to the suspended supporting column **810** between the supporting portion **820** and the air sensor assembly **840**.

[0151] The supporting portion **820**, as shown in FIG. **12**A, has a rotating plate **821** having a circular shape and a cap **822** which is combined with the rotating plate **821** to rotate relatively with respect to the rotating plate **821** in a circumferential direction of the rotating plate **821**. The one end portion of the suspended supporting column **810** is fixed to the cap **822**. A supporting hole **821***a* through which a central axis of the relative rotation with respect to the cap **822** passes is made in the rotating plate **821**.

[0152] On the other hand, as shown in FIG. **12**B, the injection head **10***a* (the chemical-liquid container holder is not shown) has a supporting shaft **104** which is extended from the connecting arm **102***c*, and this supporting shaft **104** is fitted in to the supporting hole **821***a* of the rotating plate **821**. Accordingly, the chemical-liquid container holder **103** is supported in a state of being rotatably suspended with the supporting shaft **104** as a center of rotation. This supporting shaft **104** is practically parallel to the support shaft **114** for supporting the injection head **10***a*. Therefore, at the time of using the injection head **10***a*, the supporting shaft **104** is also extended in a substantially horizontal direction.

[0153] The holder body assembly **830**, to deal with a capability to mount two syringes simultaneously on the injection head **10***a*, can have two receiving parts **831** and **832** supporting the respective chemical-liquid containers respectively. Normally, a chemical-liquid container has an opening which is sealed by a spigot through which the spikes **310***b* and **310***b* (see FIG. **2**) are passed at the time of discharging a chemical liquid which is accommodated. Receiving parts **831** and **832** can be configured according to a form of the chemical liquid container in order to be capable of supporting the chemical liquid container from below in a posture of an opening thereof directed downward in a vertical direction.

[0154] For example, one receiving part **831** is configured to have a shape having a substantially circular cylindrical-shaped side wall with a part thereof in a circumferential direction removed, in order to be appropriate for supporting a chemical-liquid bottle. A chemical-liquid bottle is used commonly as a chemical-liquid container for a contrast medium. The other receiving part **832** is configured to have a shape having a substantially elliptical cylindrical-shaped side wall in order to be appropriate for supporting a chemical-liquid bag formed by a flexible film. A chemical-liquid bag is used commonly as a chemical-liquid container for a physiological saline solution. Moreover, as it is evident from FIG. **12**C which is a top view of the chemical-liquid container holder **103**, the receiving parts **831** and **832**, for supporting a periphery of an opening of the chemical-liquid

container, has supporting portions **831***a* and **832***a* respectively extended on the inner side of the receiving parts **831** and **832**. It is preferable that a height of the side wall of the receiving part **832** which is appropriate for supporting the chemical-liquid bag is higher than a height of the receiving part **831** which is appropriate for supporting the chemical-liquid bottle, so that the chemical-liquid bag does not tip over.

[0155] It is preferable that the side wall of each of the receiving parts **831** and **832** has a shape with a part thereof in the circumferential direction removed (that shape is clearly indicated in FIG. **12** and FIG. **12**C). Accordingly, it is possible to carry out the visual check easily when a quantity of the chemical-liquid remained in the chemical-liquid container has become small.

[0156] The air sensor assembly **840**, as shown in FIG. **12** and FIG. **12**A, is fixed to the suspended supporting column **810** via an air sensor holder **850**. The air sensor assembly **840** will be described below by referring to FIG. **12**D and FIG. **12**E.

[0157] The air sensor assembly **840** has a base member **843**, two air sensors **841** attached to the base member **843**, and two tube clips **842** that hold tubes for detecting air by the air sensors **842**.

[0158] The base member **843** has two recesses in which tubes connected to the chemical-liquid container (in the embodiment shown in FIG. **2**, fourth tubes **311***b* and **321***b* of the sub lines) are to be inserted, and the air sensors **841** detect air inside the respective tubes inserted in the recesses. The tube clip **842** prevents the tube inserted into the recess from being lifted off. Moreover, for making the tube detachable, the tube clip **842** is pivotably supported on the base member **843** by a pin. It is possible to use an arbitrary sensor as the air sensor **841**. In the present embodiment, air sensors of ultrasonic type are used.

[0159] As mentioned above, the chemical-liquid container holder **103** has the supporting portion **820** which is pivotable around an axis, and the holder body assembly **830** is connected to the supporting portion **820** via the suspended supporting column **810**. Moreover, the supporting portion **820** is supported by the supporting shaft **104** which is extended from the injection head **10** in a substantially horizontal direction at the time of use. In such manner, by the chemical-liquid container holder **103** being pivotably supported as one of mechanical structures forming the injection head **10***a*, even when the posture of the injection head **10***a* changes in whichever way such as, the injection head **10***a* assumes a posture in which a front end of the syringe directed upward as shown in FIG. **13**, or, assumes a posture opposite to that, the chemical-liquid container holder **103** continues to hold the chemical-liquid container in an invariable posture with the opening of the chemical-liquid container directed downward without positioning the chemical-liquid container at a position higher than the injection head **10***a*.

[0160] By the chemical-liquid container holder **103** being capable of holding the chemical-liquid container in an invariable posture irrespective of the posture of the injection head **10***a*, itis possible to discharge stably the chemical liquid accommodated in the container.

[0161] Moreover, by the chemical-liquid container holder **103** being capable of holding the chemical-liquid container without positioning at a position higher than the injection head **10***a* irrespective of the posture of the injection head **10***a*, the chemical-liquid container does not hinder a surgical procedure even in a case in which the chemical-liquid injector is used together with a surgical procedure such as surgery for example.

[0162] Generally, a chemical-liquid bag, which is a type of the chemical-liquid container, is used by being suspended from a hook set at a position higher than the injection head **10***a*. Moreover, during a surgical procedure such as a surgery, capturing images of a part being treated currently, and displaying the images captured on a large-size display apparatus set in a treatment room, has been carried out in many cases. The display apparatus is set at a relatively higher position so as to prevent hindering an arrangement of other instruments in the treatment room. Treatment staff in the treatment room looks images displayed on the display apparatus and carries out treatment while checking details of treatment that has been currently carried out. In such case, when the chemical-liquid container is at a high position, a part of an image displayed on the display apparatus cannot

be viewed due to being blocked by the chemical-liquid container.
[0163] Therefore, in the present embodiment, by configuring the chemical-liquid container holder **103** as one of the mechanical structures of the injection head **10***a*, it is possible to dispose the chemical-liquid container at a position not hindering the display apparatus. In the present embodiment, the discharge of a chemical liquid from the chemical-liquid container being by forcibly sucking the chemical liquid into the syringe mounted on the injection head **10***a*, it is possible to carry out the discharge favorably even when the chemical-liquid container is not disposed at a high position.
[0164] As described heretofore, when we focus on the chemical-liquid container holder, the chemical-liquid injector of the present embodiment is a chemical-liquid injector having an injection head, which can be characterized by including [0165] a supporting portion which is pivotable around an axis, [0166] a receiving member which receives at least one chemical-liquid container, and. [0167] a connecting member which connects the supporting portion and the receiving part, and [0168] the supporting portion is used upon being supported with a substantially horizontal axis as a center.

Operation of Chemical-Liquid Injector

[0169] Next, an operation of the abovementioned chemical-liquid injector will be described below by referring mainly to an operation of the first opening/closing unit **332**, the second opening/closing unit **341**, and the squashing mechanism **720**. These operations are controlled by the injection control unit **11**. In the description below, a case in which the first main line **301***a* and the first sub line **301***b* are lines for a contrast medium (A), and the second main line **302***a* and the second sub line **302***b* are lines for a physiological saline solution (B) will be described. Moreover, for simplifying the description, the contrast medium is indicated as 'A' and the physiological saline solution is indicated as 'B'. Furthermore, 'injection' and 'priming' are carried out by a forward movement of the presser **112**, and 'suction' is carried out by a backward movement of the presser **112**. In the description below, 'opens' signifies that, that mechanism or unit is driven so that a flow channel between the upstream side and the downstream side thereof is opened, and similarly, 'closes' signifies that, that mechanism or unit is driven so that the flow channel between the upstream side and the downstream side thereof is closed.

Power Supply ON

[0170] When a power supply of the chemical liquid injector is ON, the squashing mechanism (side A and side B) **720**, the first opening/closing unit drive mechanism **740** and the second opening/closing unit drive mechanism **760** are open.

Self-Check

[0171] After the power supply is put ON, a check of whether all sensors of the chemical-liquid injector **10** operate normally is carried out automatically. In the self-check, the squashing mechanism **720**, the first opening/closing unit drive mechanism **740** and the second opening/closing unit drive mechanism **760** are operated in order of open.fwdarw.close.fwdarw.open, and a check of, whether operating normally, is carried out.

Setup

[0172] As the self-check is finished, a setup becomes possible. The setup is an operation of installing the chemical-liquid circuit **30** in the chemical-liquid circuit operating unit **102**, and is to be carried out by an operator. The setup includes a setup of a multi kit (multiple-time use section **300**B) and a setup of a single kit (single-time use section **300**A). At the time of carrying out the setup, a guidance screen for the setup may be displayed on the display device **13**.

Multi Kit (Multiple-Time Use Section **300**B)

[0173] At the time of carrying out the setup for the multiple-time use section **300**B of the chemical-liquid circuit **30**, each of the tube squashing mechanism (side A and side B) **720**, the first opening/closing unit drive mechanism **740**, and the second opening/closing unit drive mechanism **760** are let to be in the open state as they have been.

Single Kit (Single-Time Use Section **300**A)

[0174] At the time of carrying out the setup for the single-time use section **300**B of the chemical-liquid circuit **30**, the first opening/closing unit **740** drive mechanism, the second opening/closing unit drive mechanism **760**, and the squashing mechanism (side A and side B) are let to be in open state. However, after installing the single-time use section **300**A, the tube squashing mechanism (side A and side B) **720** is closed by a predetermined operation by the operator.

Injection Condition Setting Screen (Check, Standby, Start OK)

[0175] At the time of setting injection conditions, the tube squashing mechanism (side A and side B) **720** is closed. Regarding the opening/closing units, the first opening/closing unit drive mechanism **740** is closed, and the second opening/closing unit drive mechanism **760** is opened.

Injection, Priming, Manual Forward Movement (Forward-Movement Button)

Injection A or Priming A

[0176] While injecting the contrast medium or while priming the contrast medium line (the first main line and the subject line), the squashing mechanism **720** on the side A is opened, and the squashing mechanism **720** on the side B is closed. Regarding the opening/closing units, the first opening/closing unit drive mechanism **740** is opened and the second opening/closing unit drive mechanism **760** is closed.

Injection B or Priming B

[0177] While injecting the physiological saline solution or while priming the physiological saline solution line (the second main line and the subject line), the squashing mechanism **720** on the side A is closed and the squashing mechanism **720** on the side B is opened. Regarding the opening/closing units, the first opening/closing unit drive mechanism **740** is opened and the second opening/closing unit drive mechanism **760** is closed.

Injection A+B or Priming A+B

[0178] While injecting the contract medium and the physiological saline solution simultaneously or while priming the injection line (the first main line, the second main line, and the subject line) in that case, the squashing mechanisms (side A and side B) are opened. Regarding the opening/closing units, the first opening/closing unit drive mechanism **740** is opened and the second opening/closing unit drive mechanism **760** is closed.

[0179] In such manner, while injecting a chemical liquid, the first opening/closing unit drive mechanism **740** is opened, and as aforementioned, the first opening/closing unit drive mechanism **740** opens the flow channels in stages from the upstream side in the process of the opening operation. Therefore, since the flow channels are opened in a state of a pressure applied to the upstream side of the first opening/closing unit drive mechanism **740**, it is possible to prevent effectively the reverse flow of blood from the downstream side. A timing for a start of the operation of opening the flow channels by the first opening/closing unit drive mechanism **740** may be the same as for a start of the injection operation, or may be after elapsing of time from the start of the injection operation, provided that the flow channels could be opened in the state of the pressure applied to the upstream side of the first opening/closing unit drive mechanism **740**. For applying the pressure effectively from the upstream side of the first opening/closing unit drive mechanism **740**, it is preferable to operate the first opening/closing unit drive mechanism **740** leaving a time from the start of the injection operation, and since the first opening/closing unit drive mechanism **740** is configured to open the flow channels in stages from the upstream side, it is possible to apply pressure even by operating the first opening/closing unit drive mechanism **740** simultaneously with the start of the injection operation. Moreover, the first opening/closing unit drive mechanism **740** being moved by the linear motion mechanism **763**, it is possible to carry out the operations of opening and closing the flow channels at even higher speed, and even by this, it is possible to prevent effectively the reverse flow of blood from the downstream side.

[0180] After the end of the injection operation, the first opening/closing unit drive mechanism **740** is closed. By the first opening/closing unit drive mechanism **740** of the present embodiment being

capable of closing the flow channels at a high speed as described above, it is possible to close the flow channels in a state of upstream side subjected to higher pressure than the downstream side, and to prevent favorably the reverse flow of blood. A timing for a start of the operation of closing the flow channels by the first opening/closing unit drive mechanism **740** may be slightly before the end of the injection operation or may be simultaneously with the end of the injection, provided that the flow channels could be closed in the state of the pressure applied from the upstream side. When there is a residual pressure, the closing operation of the first opening/closing unit drive mechanism **740** may be started after elapsing of time (for example, after two to five seconds) after the end of the injection. By reducing the residual pressure of the upstream side upon starting the closing operation of the first opening/closing unit drive mechanism **740** leaving a time after the end of the injection operation, it is possible to minimize the pressure applied. Accordingly, it is possible to suppress a defect which arises at the time of subsequent injection, such as an occurrence of an unacceptable initial discharge caused due to excessively high pressure being applied at the time of start of the subsequent injection.

[0181] Regarding a timing for opening and closing the second opening/closing unit drive mechanism **760**, it is preferable to close before the injection or simultaneously with the injection, in a pressure range in which the transducer is protected. In a case in which there is a residual pressure after the injection, it may be opened after a predetermined time after the injection in order to the avoid an effect due to the residual pressure.

[0182] Here, a pre charge operation by the opening/closing unit will be described below citing an example of a case in which the opening/closing unit has a double-piston structure. The pre charge operation is an operation for applying a pressure to the upstream side of the opening/closing unit, and more precisely, is an operation of moving the presser **112** forward so that, the pressure on the upstream side (syringe side) of the opening closing unit becomes higher than pressure on the downstream side, letting the pressure on the upstream side (syringe side) to be 20 psi when the pressure on the downstream side (subject side) of the opening/closing unit is 2 psi, in order to prevent the reverse flow of the chemical liquid at the time of opening the opening/closing unit. In a case in which the opening/closing unit has a double-piston structure, it is possible to carry out the opening operation of the opening/closing unit simultaneously with the operation of moving the presser **112** forward or immediately after (for example, 0.01 sec after) the start of the operation of moving the presser **112** forward. Since the opening/closing unit requires a predetermined time (for example, 0.1˜0.2 sec) to open fully after the operation has started, it is possible to make the pressure on the upstream side higher than the pressure on the downstream side even by carrying out the opening operation of the opening/closing unit simultaneously with the operation of moving the presser **112** forward. In one example thereof, the presser **112** is moved forward at a speed of 2.0 ml/sec and in a time of 0.15 sec (an injection volume of the chemical liquid is equivalent to 0.3 ml). In another example of the pre charge operation, in a state of the opening/closing unit closed, the presser **112** is moved forward at a speed of 8.0 ml/sec and in time of 0.15 sec (an injection volume of the chemical liquid is equivalent to 1.2 ml). In both the examples, it is preferable that the timing of the operation of injecting the chemical liquid and the operation of opening the opening/closing unit are controlled such that a predetermined pressure is applied to the upstream side of the opening/closing unit before the opening/closing unit is fully opened.

Forward Movement A

[0183] In a case in which the forward-movement button of the side A of the injection head **10***a* is operated (in other words, in a case in which the forward-movement operation of the plunger of the syringe on A side is carried out manually), while that operation is being carried out, the squashing mechanism **720** on the side A is opened, and the squashing mechanism **720** on the side B is closed. Regarding the opening/closing units, the first opening/closing unit drive mechanism **740** is opened, and the second opening/closing unit drive mechanism **760** is closed.

Forward-Movement B

[0184] In a case in which the forward-movement button of the side B of the injection head **10***a* is operated (in other words, in a case in which the forward-movement operation of the plunger of the syringe on B side is carried out manually), while the operation is being carried out, the squashing mechanism **720** of the side A is closed, and the squashing mechanism **720** of the side B is opened. Regarding the opening/closing units, the first opening/closing unit drive mechanism **740** is opened, and the second opening/closing unit drive mechanism **760** is closed.

Priming of Transducer Line

[0185] During a priming of the transducer, the squashing mechanism **720** of the side A is closed, and the squashing mechanism **720** of the side B, the first opening/closing unit drive mechanism **740**, and the second opening/closing unit drive mechanism **760** are opened.

Priming of Opening/Closing Unit

[0186] It is preferable to carry out the priming of the opening/closing unit in a state of the downstream side of the subject line **303** under a negative pressure. It is possible to carry out the priming of the opening/closing unit drive mechanism by repeating the opening and closing operation of the first opening/closing unit drive mechanism **740** and the second opening/closing unit drive mechanism **760**.

Flush

[0187] During a flush by the physiological saline solution, the squashing mechanism **720** on the side B and the first opening/closing unit drive mechanism **740** are opened, and the squashing mechanism **720** on the side A and the second opening/closing unit drive mechanism **760** are closed.

Suction

[0188] During the suction of the chemical liquid into the syringe from the chemical liquid container, the squashing mechanisms (side A and side B) are closed. Regarding the opening/closing units, the first opening/closing unit **332** is closed, whereas the second opening/closing unit **341** is open. In a case in which there is a possibility that the pressure applied to the upstream side of the opening/closing unit and the squashing mechanism reduces at the time of suction of the chemical liquid, the pre charge operation may be carried out after the end of suction. The pre charge operation after the suction is to be carried out in a state of the squashing mechanism (side A) opened. An example of the pre charge operation after the suction, is moving the presser **112** (side A and side B) forward at a speed of 5.0 ml/sec and in a time of 0.5 sec (an injection amount of the chemical liquid is equivalent to 2.5 ml).

End—Single Kit Removal

[0189] When various operations end, and the single kit removed, the squashing mechanisms (side A and side B) **720**, the first opening/closing unit drive mechanism **740** and the second opening/closing unit drive mechanism **760** are opened.

Air Detection

[0190] When the existence of air is detected by an air sensor, the squashing mechanisms (side A and side B) **720**, the first opening/closing unit drive mechanism **740**, and the second opening/closing unit drive mechanism **760** are closed.

[0191] In table 1, the open/closed state of the squashing mechanism **720** at each timing is shown.

TABLE-US-00001 TABLE 1 Squashing mechanism Side A Side B Power supply ON open open Self-check open .fwdarw. closed .fwdarw. open open .fwdarw. closed .fwdarw. open Setup (multi kit) own open. Setup (single kit) closed closed Setting screen Closed closed (check, standby) Setting screen closed closed (start OK) Injection A, open closed priming A, or forward-movement button A Injection B, Closed open priming B, or forward-movement button B Injection A + B, or open open priming A + B Priming closed open. (transducer line) Flush Closed open Suction closed closed End—single open open kit removal Air detection closed closed

[0192] In table 2, the open/closed state of the first opening/closing unit drive mechanism **740** and the second opening/closing unit drive mechanism **760** at each timing is shown.

TABLE-US-00002 TABLE 2 Opening/closing unit Side A Side B Power supply ON open open

Self-check open .fwdarw. closed .fwdarw. open open .fwdarw. closed .fwdarw. open Setup (multi kit) open open Setup (single kit) closed closed Setting screen closed closed (check, standby) Setting screen closed closed (start OK) Injection A, open closed priming A, or forward-movement button A Injection B, closed open priming B, or forward-movement button B Injection A + B, Or open open primi ng A + B Priming closed open (transducer line) Flush closed open Suction closed closed End—single open open kit removal Air detection closed closed

Other Embodiments

Configuration of Overall Chemical-Liquid Injector

[0193] In FIG. **14**, another embodiment of the chemical-liquid injector is shown. As shown in FIG. **14**, the chemical-liquid injector **10** may have a plurality of consoles **10***b***1** and **10***b***2**. Each of the consoles **10***b***1** and **10***b***2** has an injection control unit, an input device, and a display device so that each of the consoles **10***b***1** and **10***b***2** is capable of controlling setting of injection conditions thereof and an operation of the injection head **10***a* in accordance with injection conditions set. It is possible to configure the injection control unit, the input device, and the display device as aforementioned by referring to FIG. **1**. The consoles **10***b***1** and **10***b***2** may be same or may be different (in shape and/or function). Each of the consoles **10***b* may be disposed in a different room (for example, a test room, a control room etc.) of hospital facilities. Moreover, each of the consoles **10***b***1** and **10***b***2** may be communicably connected between the consoles **10***b***1** and **10***b***2**.

[0194] It is possible to make one of the plurality of consoles **10***b***1** and **10***b***2**, for example, the console **10***b***1**, function as a master. In that case, it is possible to make the other remaining console **10***b***2** function as a slave. The console **10***b***1** on the master side is capable of receiving data input from the user via the input device, data/signal output from the injection head **10***a*, and data/signal output from a device (for example, a hand switch **14**) connected to the injection head **10***a* or the console **10***b***1**, and performing a predetermined operation according to the data/signal received. The console **10***b***2** on the slave side, basically, does not receive these data/signal. However, a display of the display device may be synchronized with the display device of the console **10***b***1** on the main side.

[0195] The plurality of consoles **10***b***1** and **10***b***2** may be switchable to the master side and the slave side. In this case, a master/slave switching button (not shown) may be provided to any one of the plurality of consoles **10***b***1** and **10***b***2**, and it is possible to make an arrangement such that, the user can switch between the master side and the slave side by operating the master/slave switching button. The console which has the master/slave switching button receives the operation of the master/slave switching button irrespective of whether it is the master side or the slave side. The master/slave switching button may be a mechanical push-button switch or may be a switch which is displayed as an icon on the display device of the consoles **10***b***1** and **10***b***2**. In a case in which, the master/slave switching button is an icon, the master/slave switching button may be displayed only on the console on the master side.

[0196] The chemical-liquid injector **10** may further have at least one hand switch **14**. The hand switch **14** is a type of an input device for enabling the user to inject a chemical liquid at an arbitrary injection rate and injection time, apart from an injection according to an injection protocol set in the injection control unit. In the embodiment illustrated in diagram, the hand switch **14** is communicably connected to the console **10***b***1**, but may be communicably connected to the injection head **10***a*. In a case in which the chemical-liquid injector **10** has a plurality of hand switches **14**, the hand switches **14** may be connected to separate consoles **10***b***1** and **10***b***2** or may be connected to one injection head **10***a*.

Chemical-Liquid Circuit Operating Unit

[0197] Another embodiment of the chemical-liquid circuit operating unit will be described below by referring to FIG. **15**A and FIG. **15**B. The chemical-liquid circuit operating unit **102** shown in FIG. **15**A and FIG. **15**B further has a plurality of holding levers **771** as chemical-liquid circuit holding members which hold the chemical-liquid circuit so that it is not lifted off from the

chemical-liquid circuit operating unit **102**. The holding levers **771** are supported by a casing (the upper cover **102***a* for example) to turn freely between a first position holding the chemical-liquid circuit (see FIG. **15**A) and a second position releasing the chemical-liquid circuit (see FIG. **15**B). A front-end portion of the holding lever **771** can have a protrusion for holding the chemical-liquid circuit more favorably. The number and positions of the holding levers **771** may be arbitrary. In the embodiment illustrated, the holding levers **771** are disposed at respective positions of holding a portion of tubes to be detected for the presence or absence of air by the two air sensors **710**, a position of holding a portion of a tube to be detected for the presence or absence of air by the air sensor **780**, a position of holding the first opening/closing unit installed in the first opening/closing unit drive mechanism **740**, and a position of holding the second opening/closing unit installed in the second opening/closing unit drive mechanism **760**.

[0198] The chemical-liquid circuit operating unit **102** may further have a chemical-liquid circuit holding detection sensor which detects that the holding lever **771** is at the first position. As the chemical-liquid circuit holding detection sensor, it is possible to use an arbitrary sensor such as an optical sensor, a proximity sensor, and a mechanical switch. It is possible to use a detection result of the chemical-liquid circuit holding detection sensor for the control of the operation of the chemical-liquid injector **10**, such as not to carry out a chemical-liquid injection operation when it is detected that all the holding levers **771** are not at the first position.

Air Sensor Assembly of Chemical-Liquid Container Holder

[0199] Another embodiment of the air sensor assembly of the chemical-liquid container holder will be described below by referring to FIG. **16**. As aforementioned, the air sensor assembly **840** has two air sensors **841** (see FIG. **12**E). In the embodiment shown in FIG. **16**, the air sensor assembly is configured such that it can be divided into a first sensor section **845***a* and a second sensor section **845***b* having one air sensor **841** each. Each of the first sensor section **845***a* and the second sensor **845***b* has the base member **843**, the air sensor **841** (see FIG. **12**E), and the tube clip **842**.

[0200] The first sensor section **845***a* and the second sensor section **845***b* can have a coupling structure which enables mutual separating and joining. As the coupled structure, it is possible to use an arbitrary structure such as a mutually detachable engagement structure. In a structure shown in FIG. **16**, a magnet **848** is used as the coupling structure. Moreover, the first sensor section **845***a* and the second sensor section **845***b* can have an alignment structure at the time of mutual joining. As the alignment structure, it is possible to configure by a projection **846** and a recess **847** fitting mutually. In the embodiment shown in FIG. **16**, the projection **846** and the recess **847** are formed on a surface of the first sensor section **845***a* facing the second sensor section **845***b*, and a recess and a projection fitting with the projection **846** and the recess **847** of the first sensor section **845***a* are formed on a surface of the second sensor section **845***b* facing the first sensor section **845***a*.

[0201] At the time of detecting air in a tube connected to the chemical-liquid container, detecting in a state of the tube hanging vertically downward is preferable for a favorable detection. Accordingly, as aforementioned, in a case in which the chemical-liquid container holder has a structure holding two chemical-liquid containers, a spacing between the two air sensors **841** in the air sensor assembly depends on a spacing between the two containers held by the chemical-liquid container holder and specifically, on a spacing between the tubes connected to the two chemical-liquid containers. Therefore, for a chemical-liquid container holder which holds a chemical-liquid container of even larger capacity, the spacing between the containers, or in other words, the spacing between the tubes connected thereto is large, and accordingly, a size of the air sensor assembly **840** also increases.

[0202] Therefore, by letting the air sensor assembly **840** to be separable into the first sensor section **845***a* and the second sensor section **845***b* as in the embodiment shown in FIG. **16**, it is possible to detect air in a state of the tube hanging vertically downward by separating the first sensor section **845***a* and the second sensor section **845***b* at the time of use and clipping the tube, while making the air sensor assembly **840** compact.

EXPLANATION OF SYMBOLS

TABLE-US-00003 10 chemical-liquid injector 10a injection head 10b console 30 chemical-liquid circuit 101 head body 102 chemical-liquid circuit operating unit 103 chemical-liquid container holder 301a first main line 301b first sub line 302a second main line 302b second sub line 303 subject line 304 transducer line 332 first opening/closing unit 341 second opening/closing unit 501, 601 housing 501a, 501b, 601a, 601b conduit portion 502, 503, 602 piston 502a, 503a, 602a head 502b, 503b, 602b flow channel 504, 604 bottom cap 505, 605 top cap 740 first opening/closing unit drive mechanism 741 holder 742 hook 743 linear motion mechanism 760 second opening/closing unit drive mechanism 761 holder 762 hook 763 linear motion mechanism 810 suspended supporting column 820 supporting portion 830 holder body assembly

Claims

1. An opening/closing unit drive mechanism in which, a chemical-liquid circuit equipped with an opening/closing unit which includes a housing having a flow channel for a chemical liquid, and at least one piston with one end portion thereof made to protrude from the housing, which is movably held in the housing so as to open and close the flow channel, is detachably installed, comprising: an opening/closing unit holder which detachably holds the opening/closing unit; an engaging portion to be engaged with the piston, which is disposed leaving a space from the opening/closing unit holder; and a linear motion mechanism which moves the engaging portion back and forth, wherein the opening/closing unit holder is movably supported between a first position at which the piston is engaged with the engaging portion and a second position at which the piston is not engaged with the engaging portion.

2. The opening/closing unit drive mechanism according to claim 1, wherein the opening/closing unit holder has a recess for receiving an end portion on an opposite side of an end portion of the housing from which the piston protrudes.

3. The opening/closing unit drive mechanism according to claim 2, wherein: the opening/closing unit holder and the engaging portion are disposed face-to-face; and the opening/closing unit holder is pivotably supported such that the recess is directed toward the engaging portion at the first position.

4. The opening/closing unit drive mechanism according to claim 2, wherein the linear motion mechanism has a ball screw mechanism which is coupled with the engaging portion.

5. The opening/closing unit drive mechanism according to claim 2, wherein the linear motion mechanism has a linear actuator which is coupled with the engaging portion.

6. The opening/closing unit drive mechanism according to claim 1, further comprising a unit holder position detection sensor which detects that the opening/closing unit holder is at the first position.

7. The opening/closing unit drive mechanism according to claim 1, further comprising an opening/closing unit detection sensor which detects the opening/closing unit which is installed in the opening/closing unit holder.

8. The opening/closing unit drive mechanism according to claim 7, wherein the opening/closing unit detection sensor is disposed at a position of detecting an existence of the opening/closing unit when the opening/closing unit holder is at the first position.

9. The opening/closing unit drive mechanism according to claim 1, further comprising a lighting module which illuminates a space between the opening/closing unit holder and the engaging portion.

10. The opening/closing unit drive mechanism according to claim 8, further comprising a lighting module which illuminates a space between the opening/closing unit holder and the engaging portion.

11. The opening/closing unit drive mechanism according to claim 10, wherein the lighting module illuminates the space when the opening/closing unit holder is detected to be at the first position by

the unit holder position detection sensor and the existence of the opening/closing unit is detected by the opening/closing unit detection sensor.

12. A chemical-liquid injector comprising an opening/closing unit drive mechanism according to claim 1.