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(54) **LIQUID DISCHARGE HEAD AND LIQUID DISCHARGE APPARATUS**

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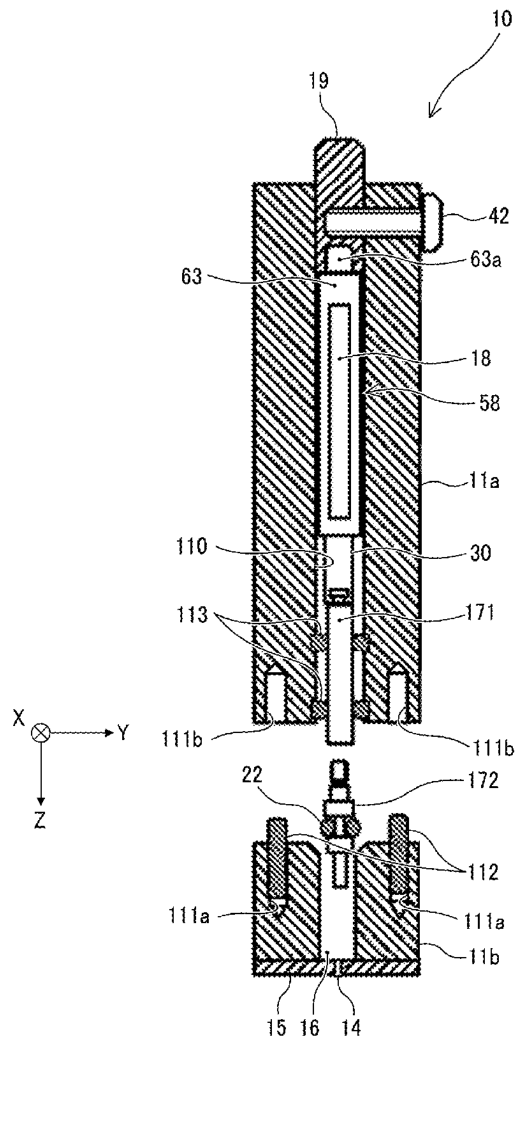
(57) **ABSTRACT**

A liquid discharge head includes a needle valve to open and close a nozzle, the needle valve including: a rear-end member; and a leading-end member detachably attached to the rear-end member; and a mover coupled to the rear-end member of the needle valve, the mover to move the needle valve, in an axial direction, between: a closed position at which the needle valve contacts the nozzle to close the nozzle; and an open position at which the needle valve is separated from the nozzle to open the nozzle. The needle valve further includes: an axial force generator to generate an axial force to abut the leading-end member against the rear-end member; and an axial center restrictor to restrict a position of an axial center of the leading-end member relative to an axial center of the rear-end member.



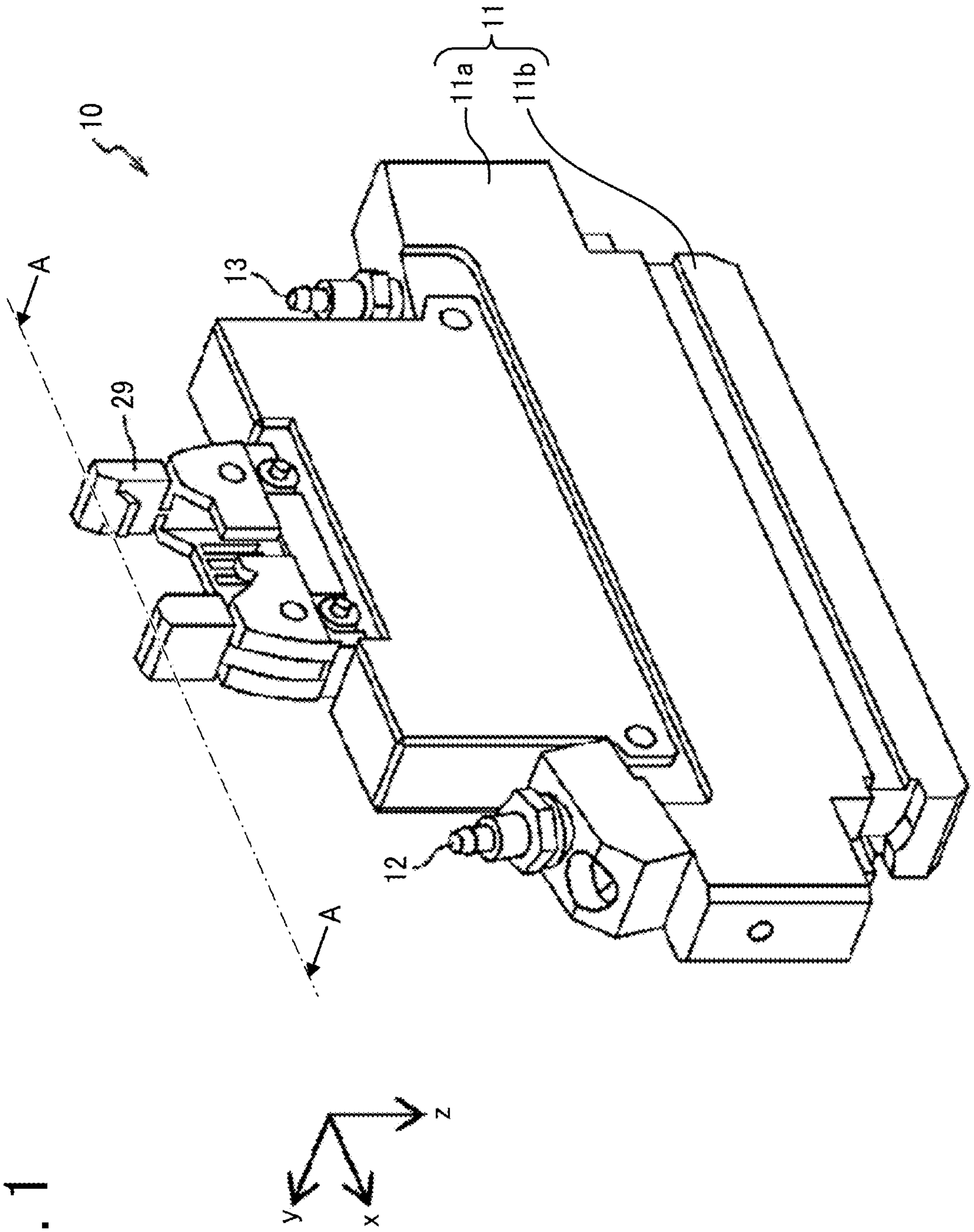


FIG. 1

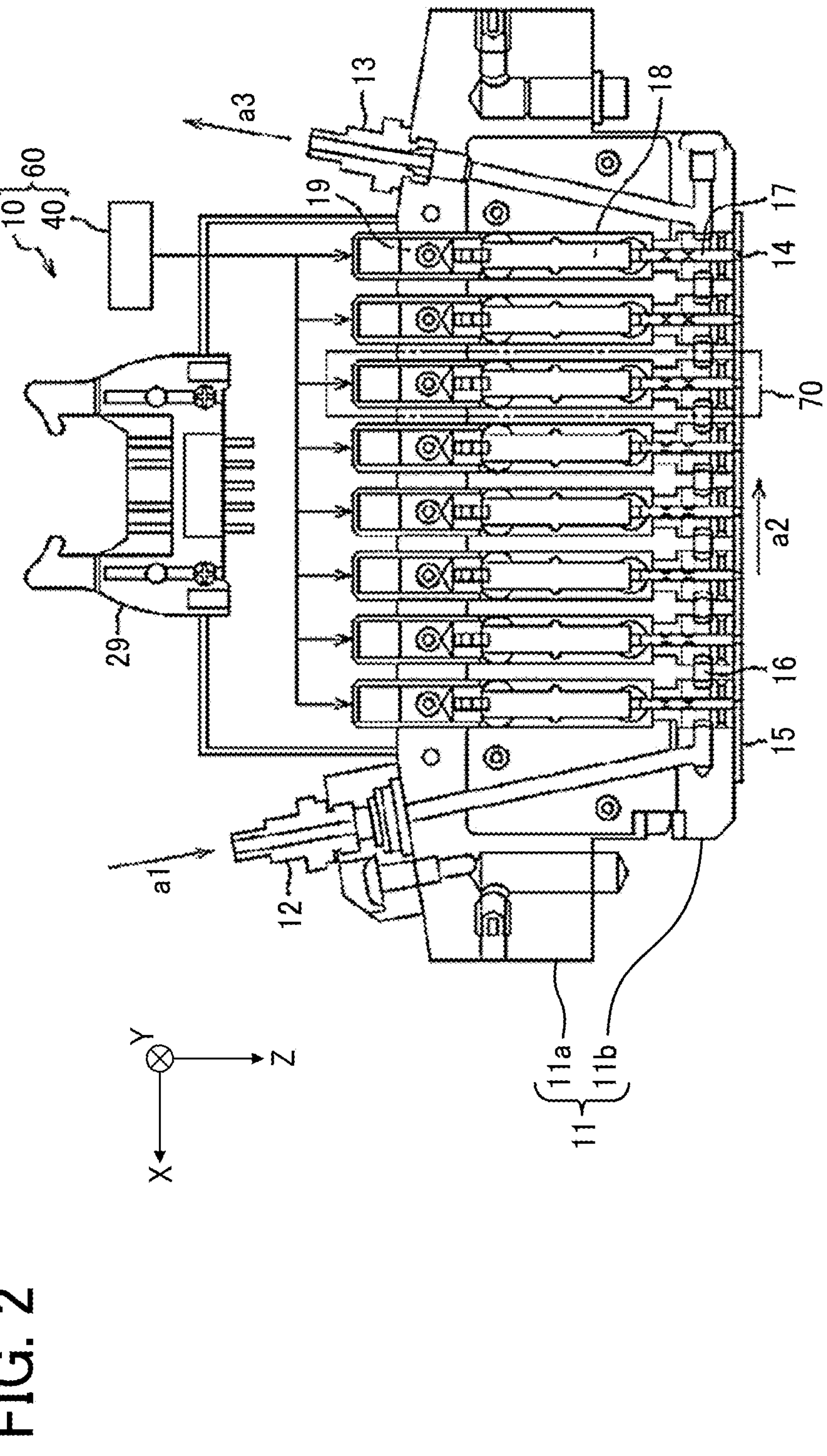
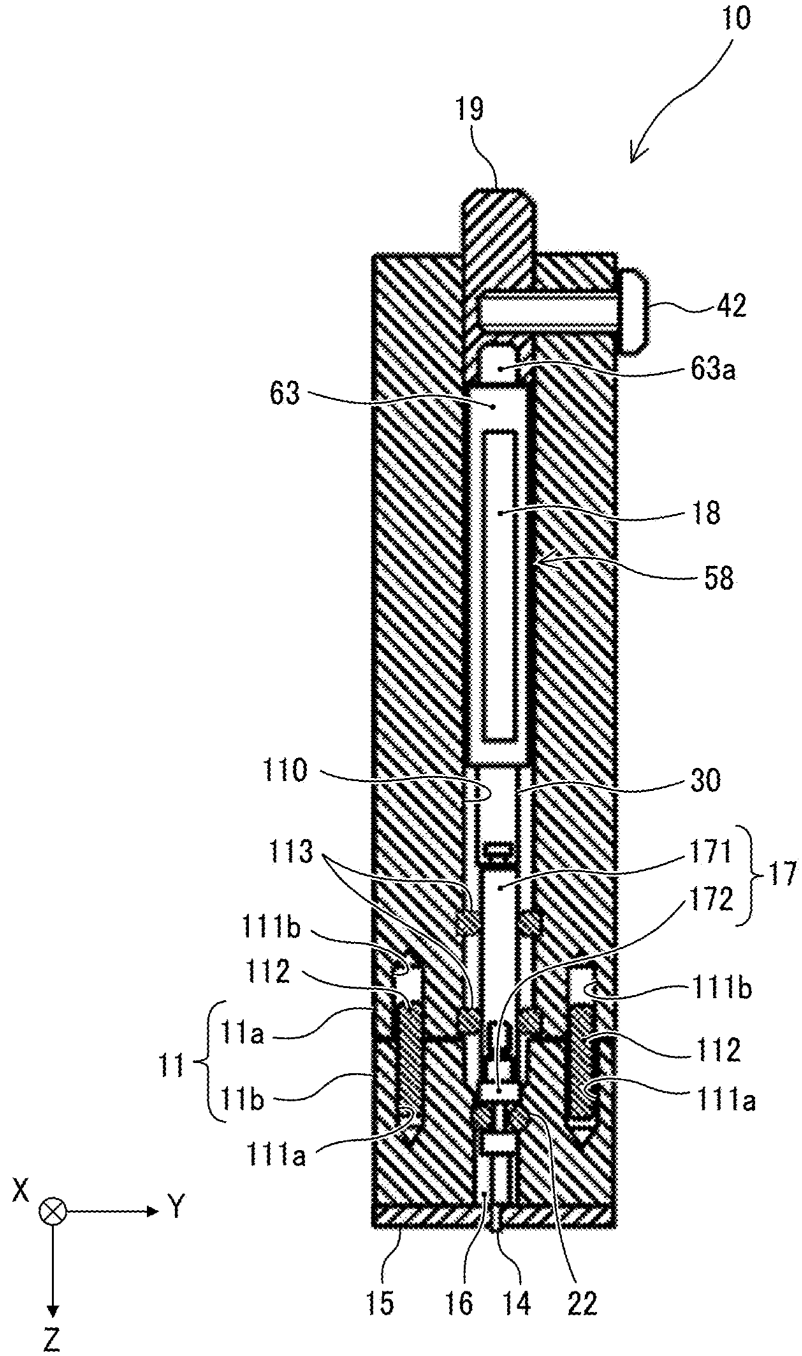


FIG. 2

FIG. 3



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22

FIG. 4A

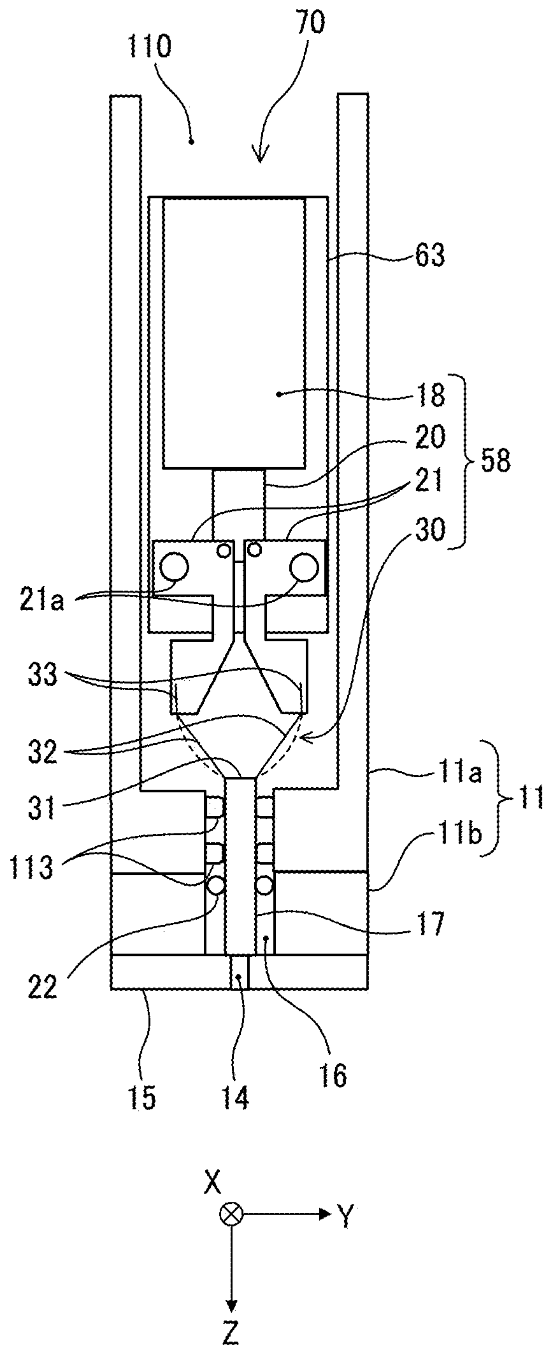
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FIG. 4B

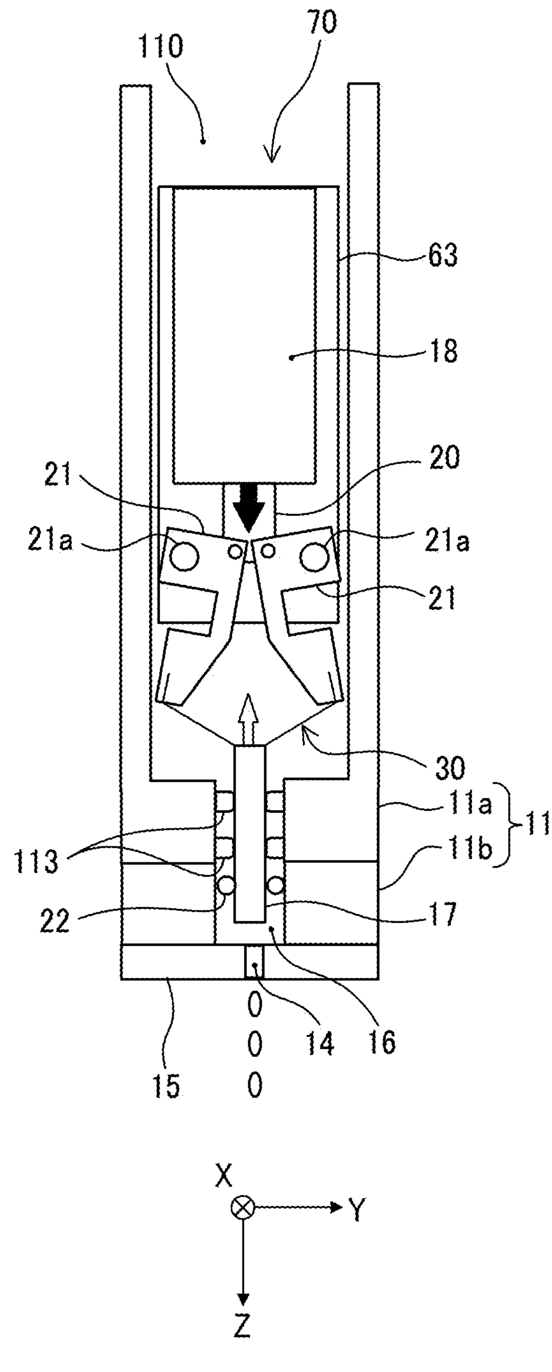
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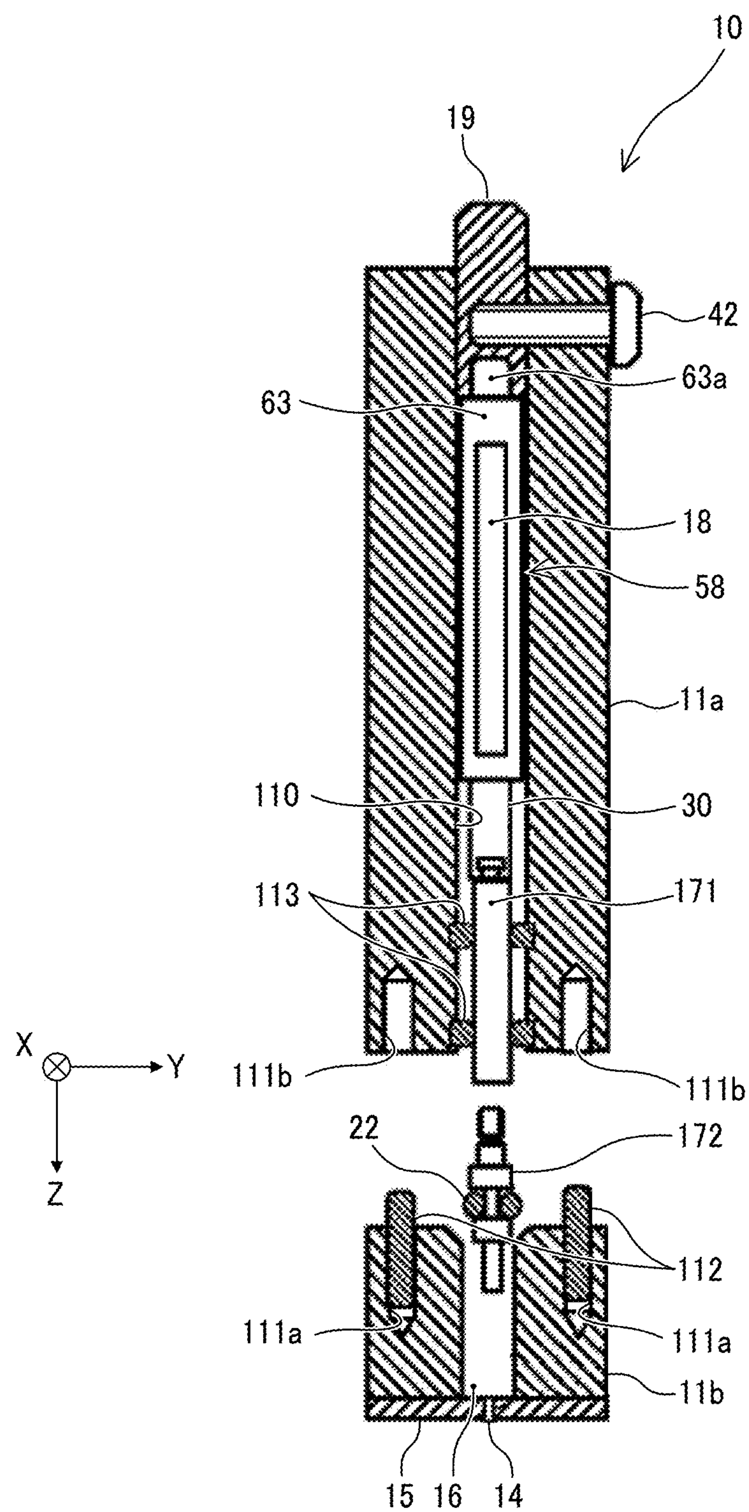
FIG. 5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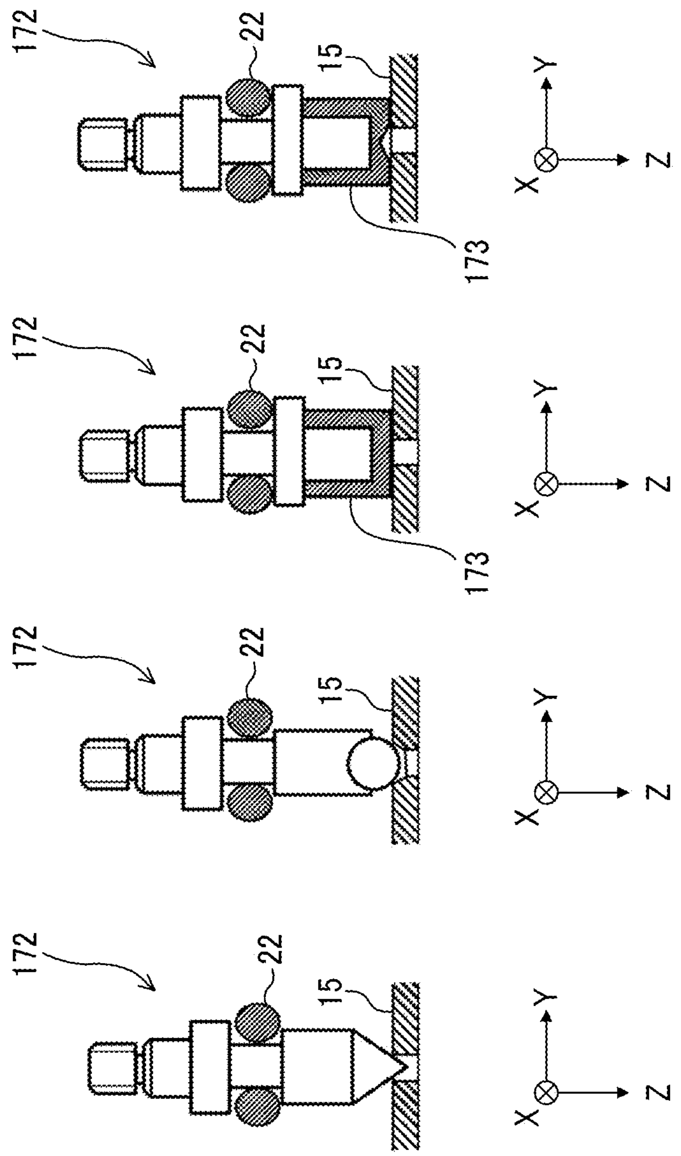


FIG. 6A FIG. 6B FIG. 6C FIG. 6D

FIG. 7A

COMPARATIVE EXAMPLE

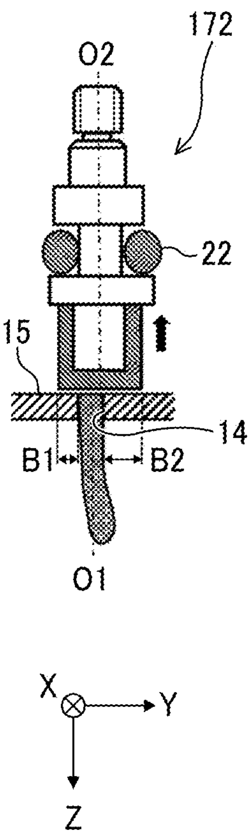


FIG. 7B

COMPARATIVE EXAMPLE

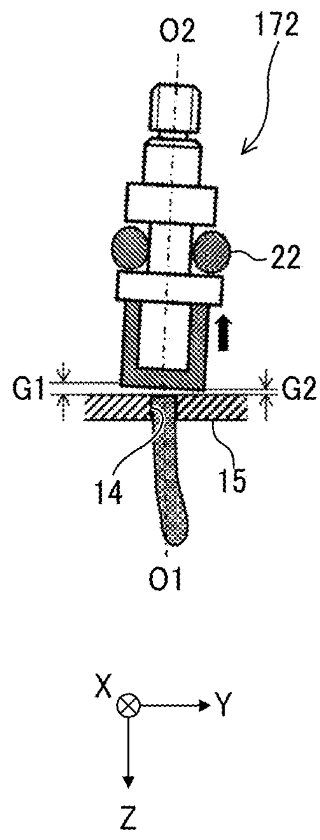


FIG. 8A

COMPARATIVE EXAMPLE

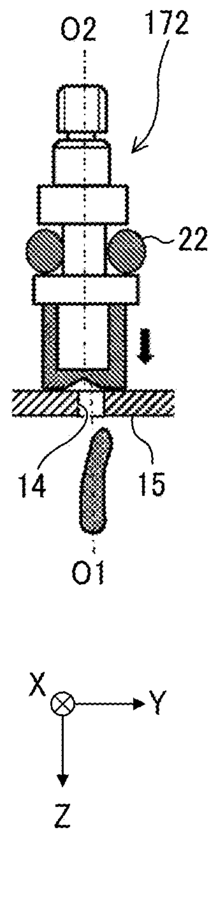


FIG. 8B

COMPARATIVE EXAMPLE

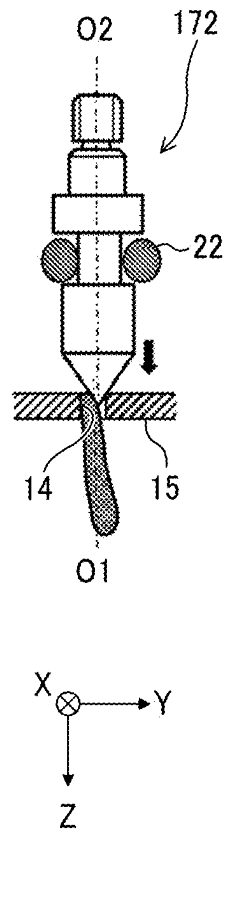


FIG. 9

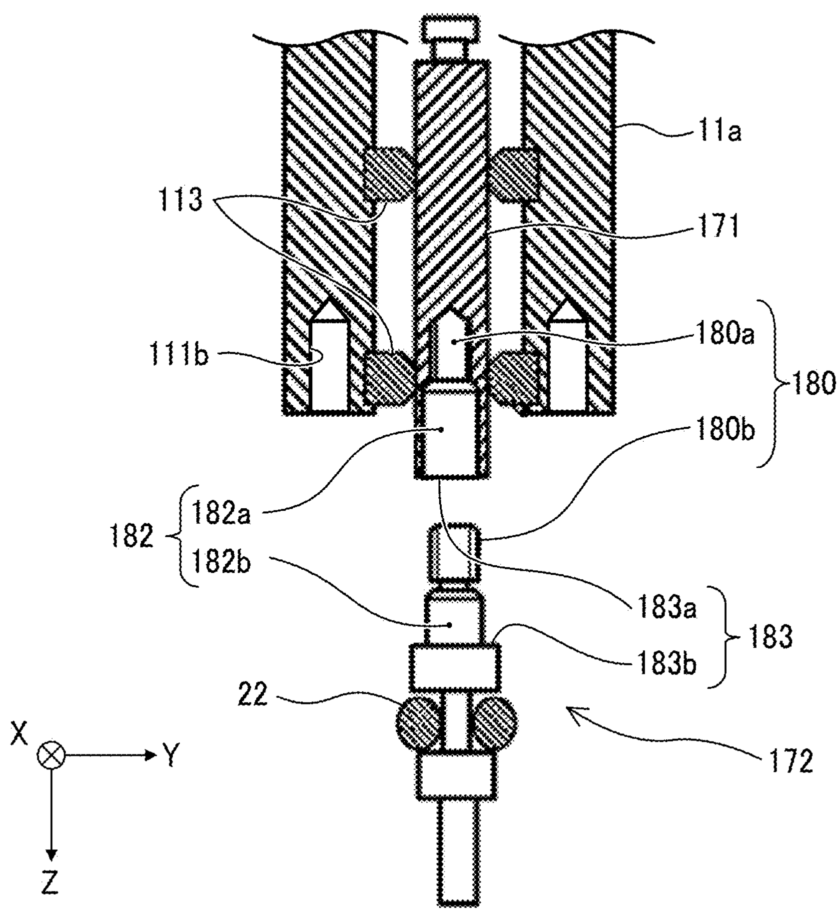

11a
113
171
180a
111b
180
180b
182a
182
182b
183a
183
183b
22
172
X
Y
Z

FIG. 10A

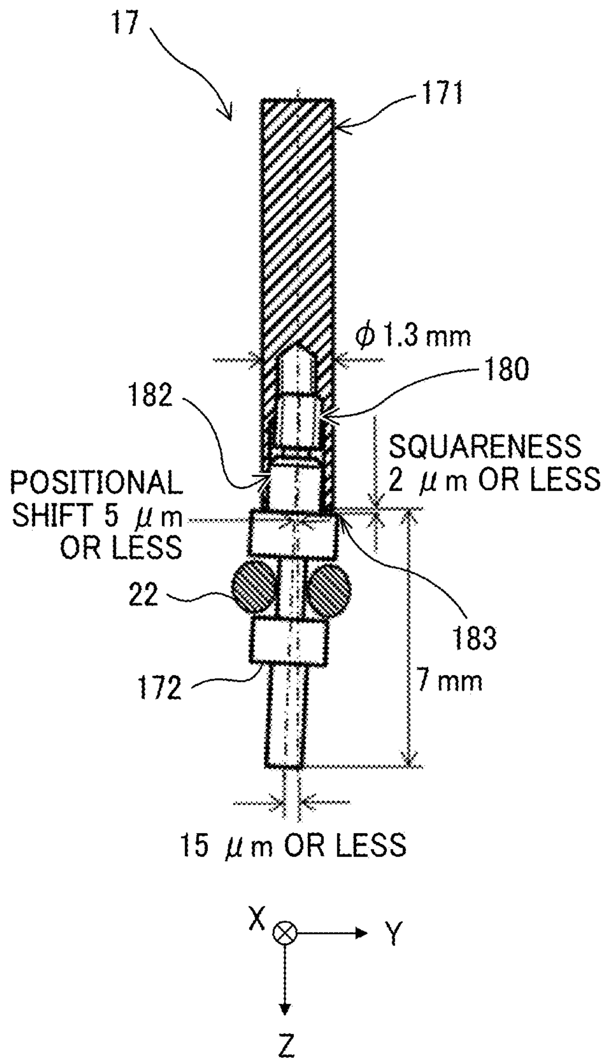


FIG. 10B

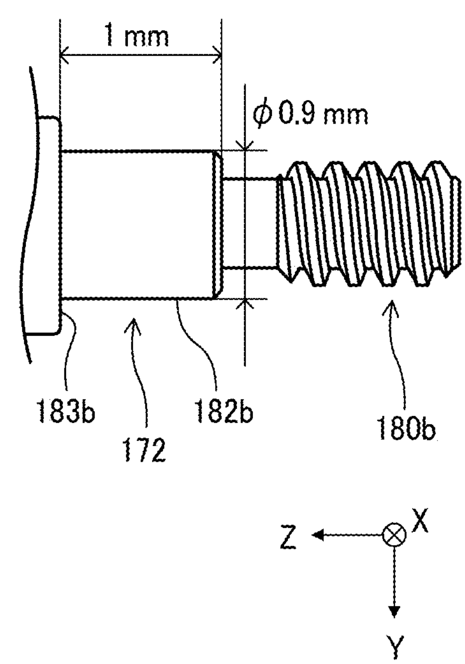


FIG. 11

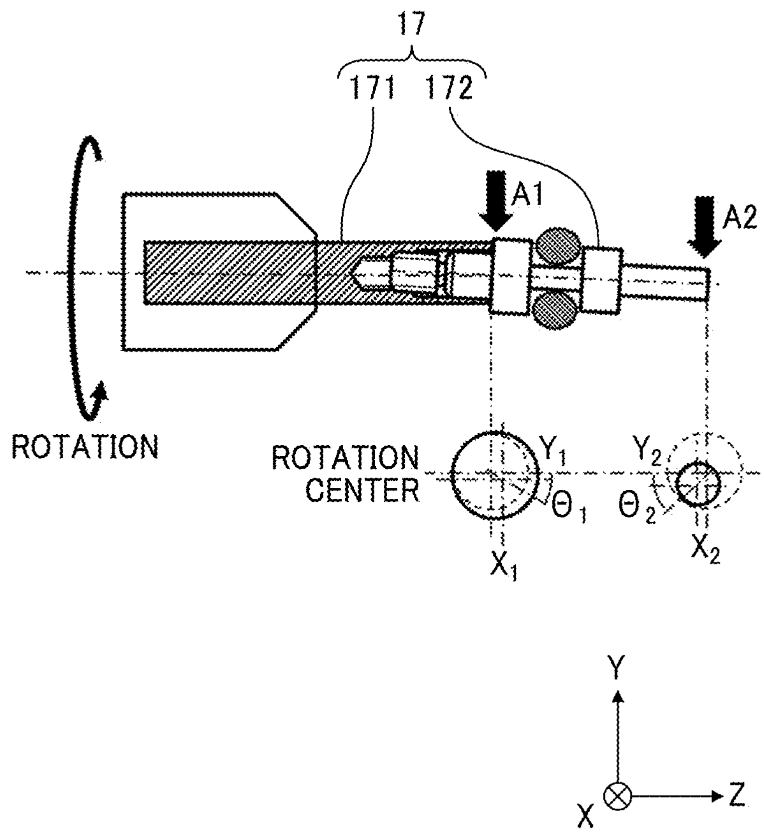


FIG. 12A FIG. 12B FIG. 12C

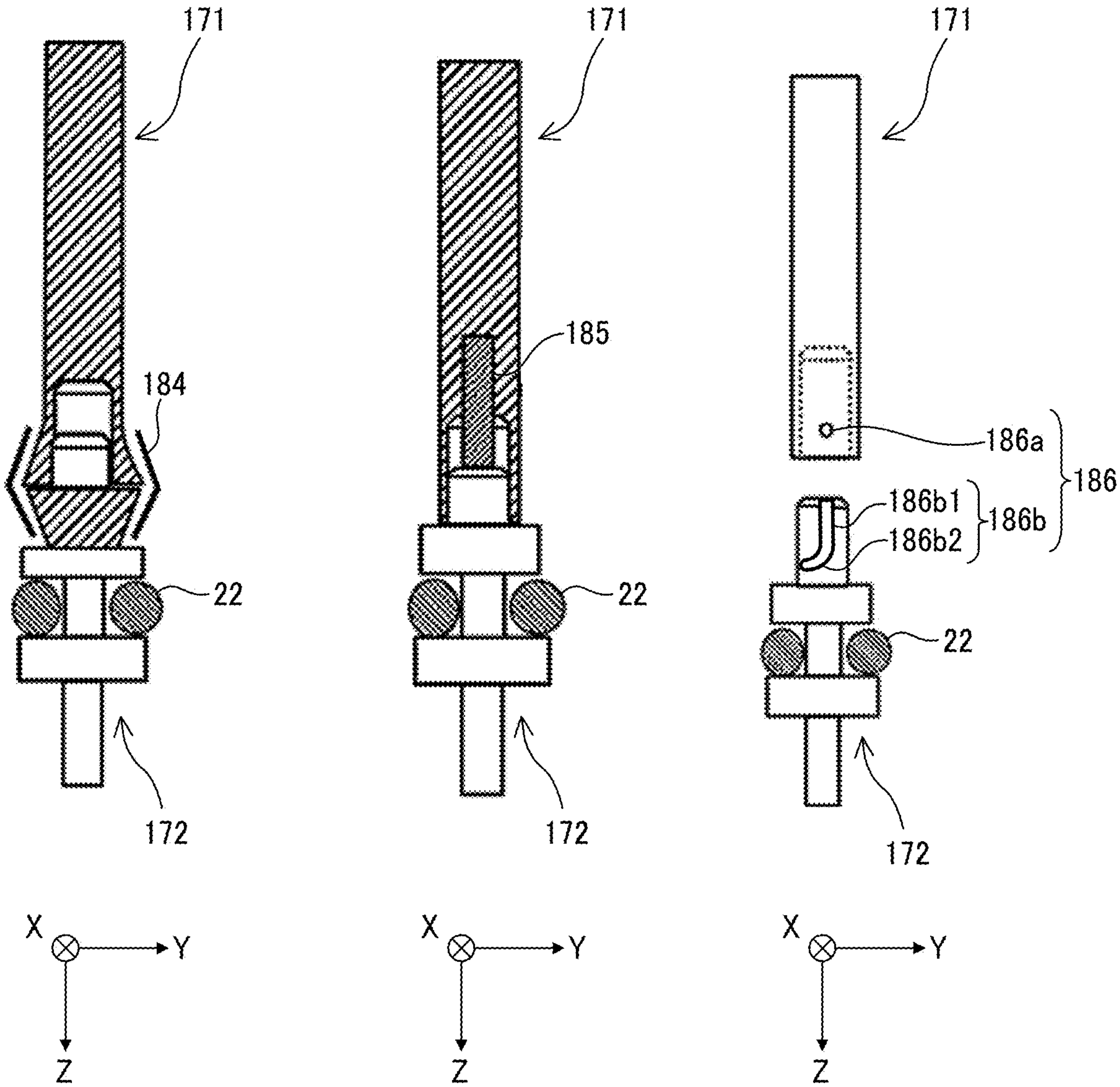


FIG. 13A

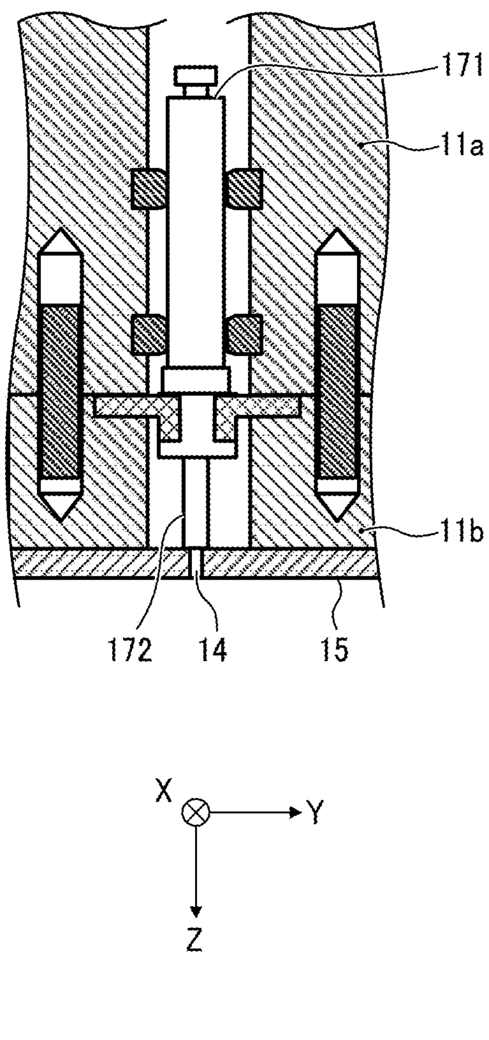


FIG. 13B

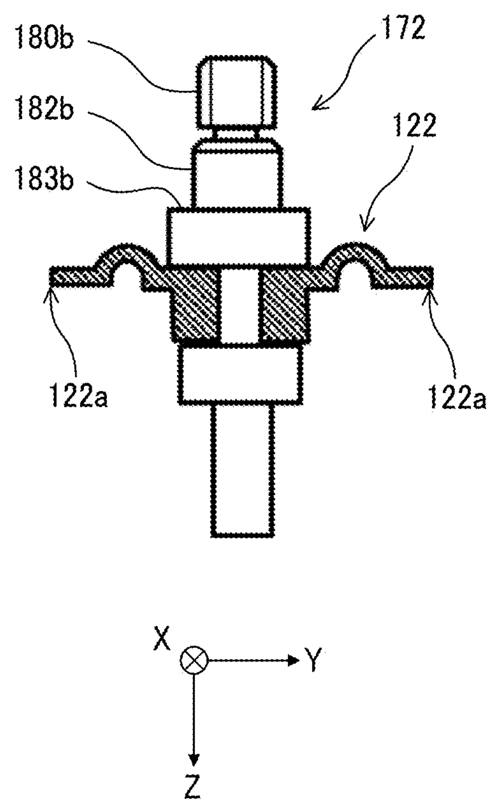


FIG. 14

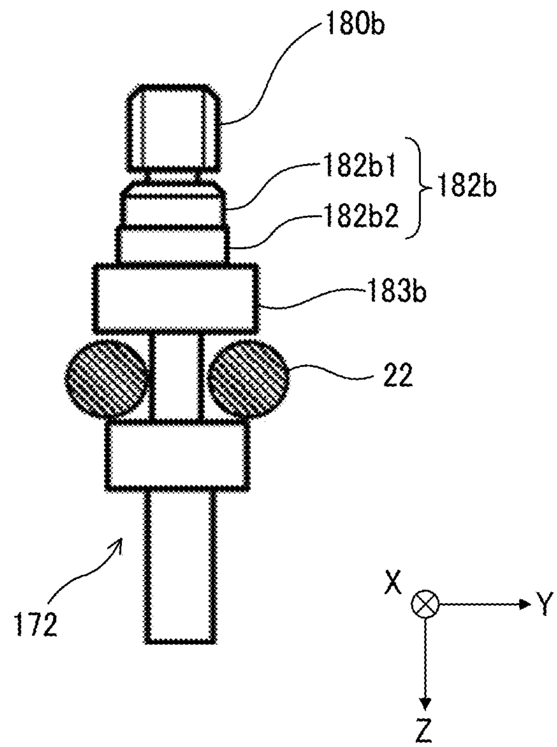


FIG. 15

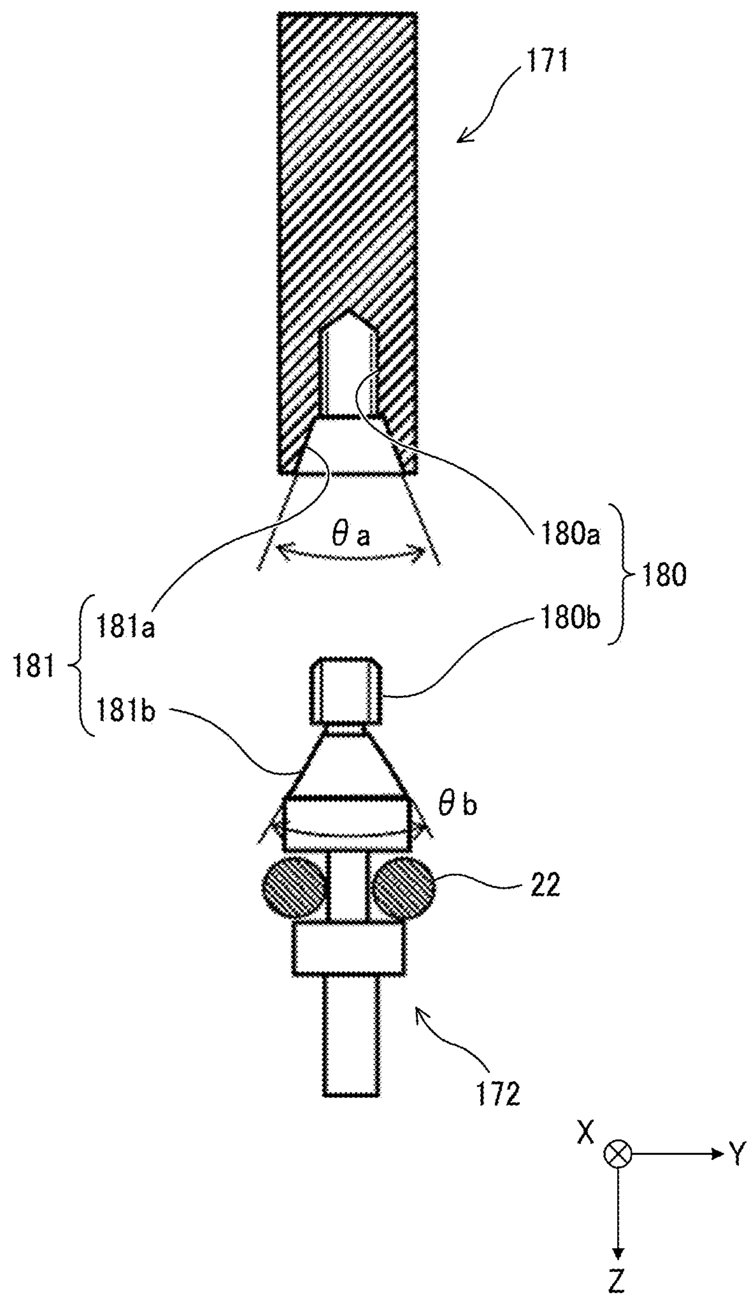


FIG. 16A

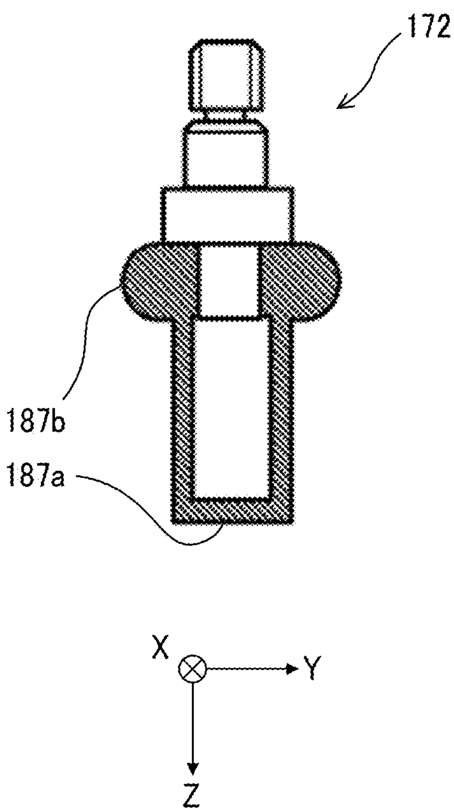


FIG. 16B

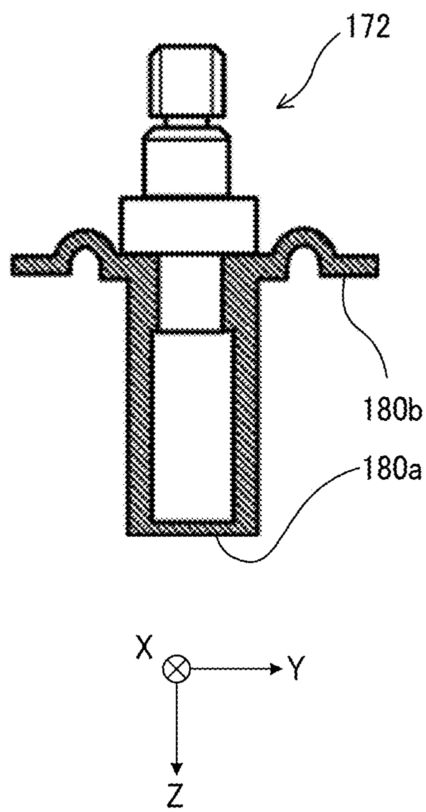


FIG. 17

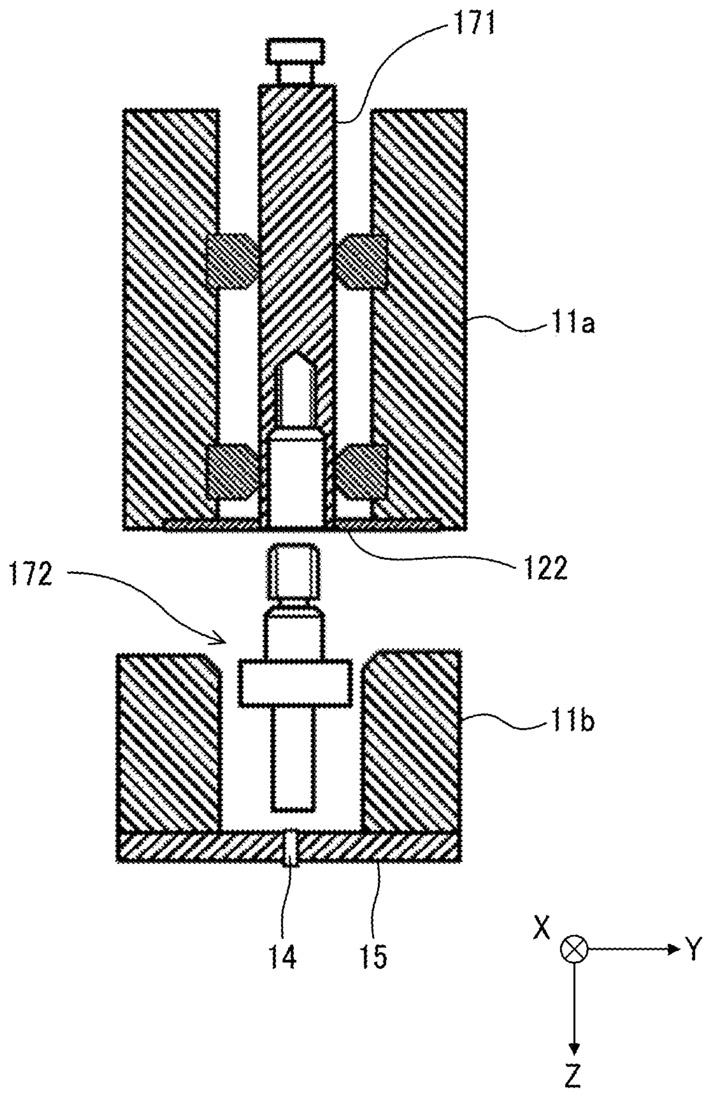


FIG. 18(a)

FIG. 18(b)

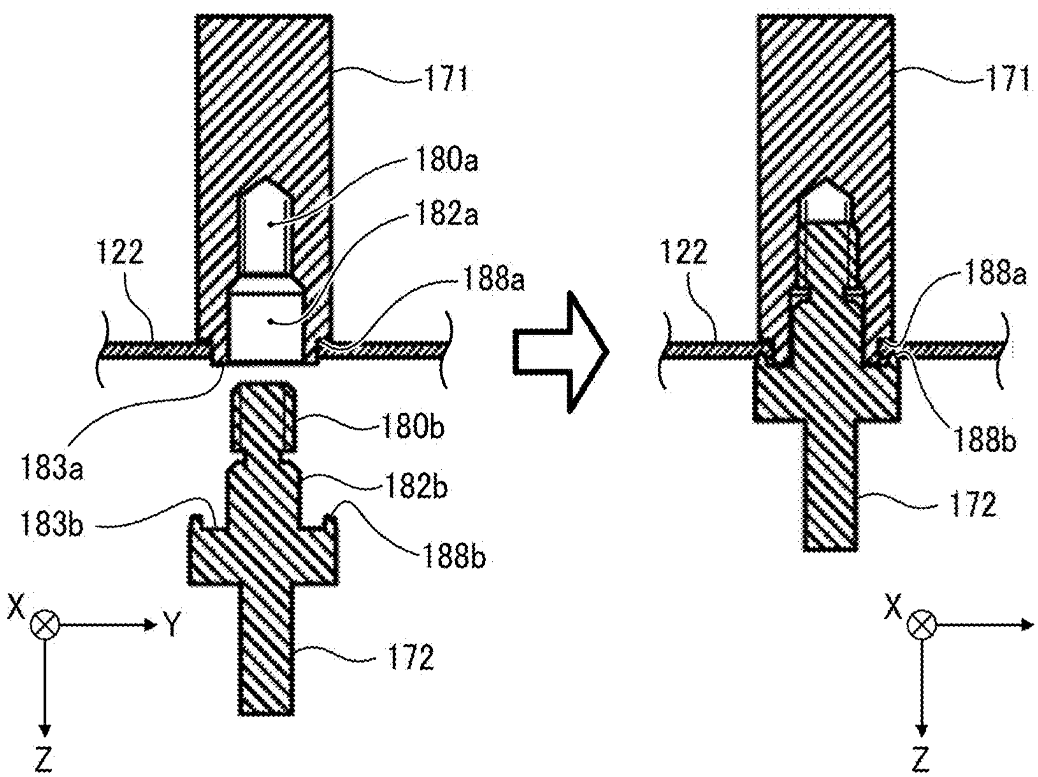


FIG. 18(c)

FIG. 18(d)

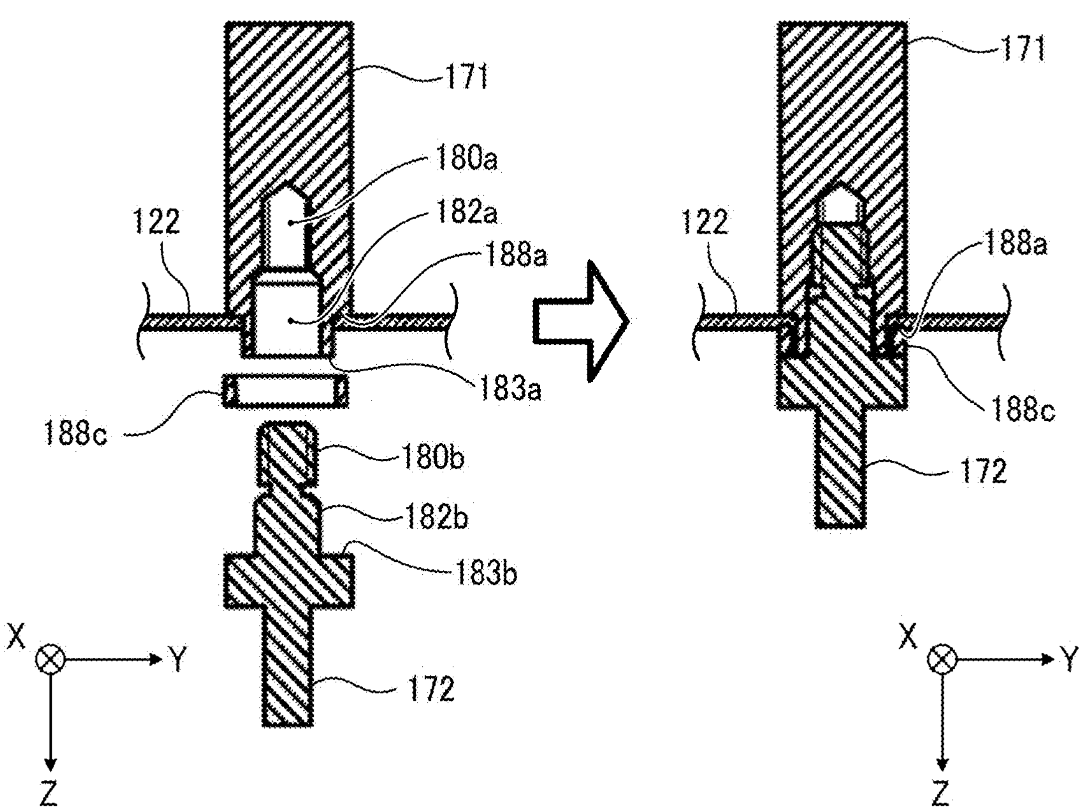


FIG. 19

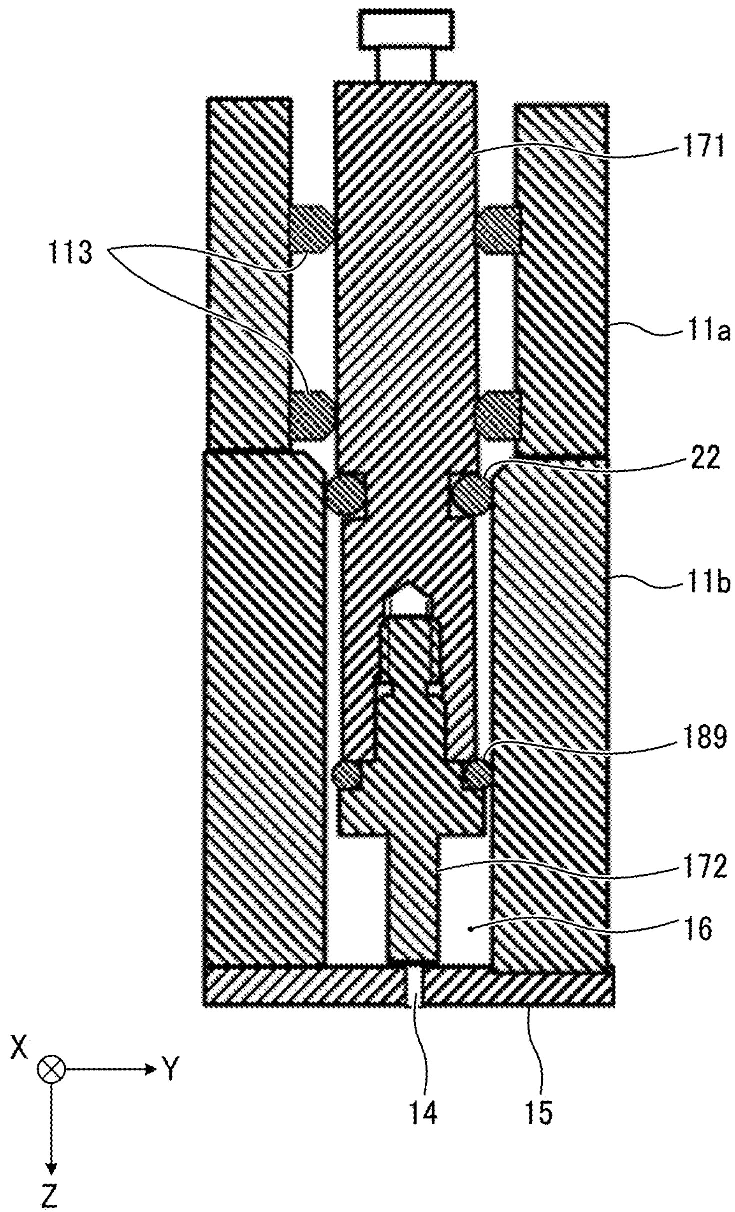


FIG. 20

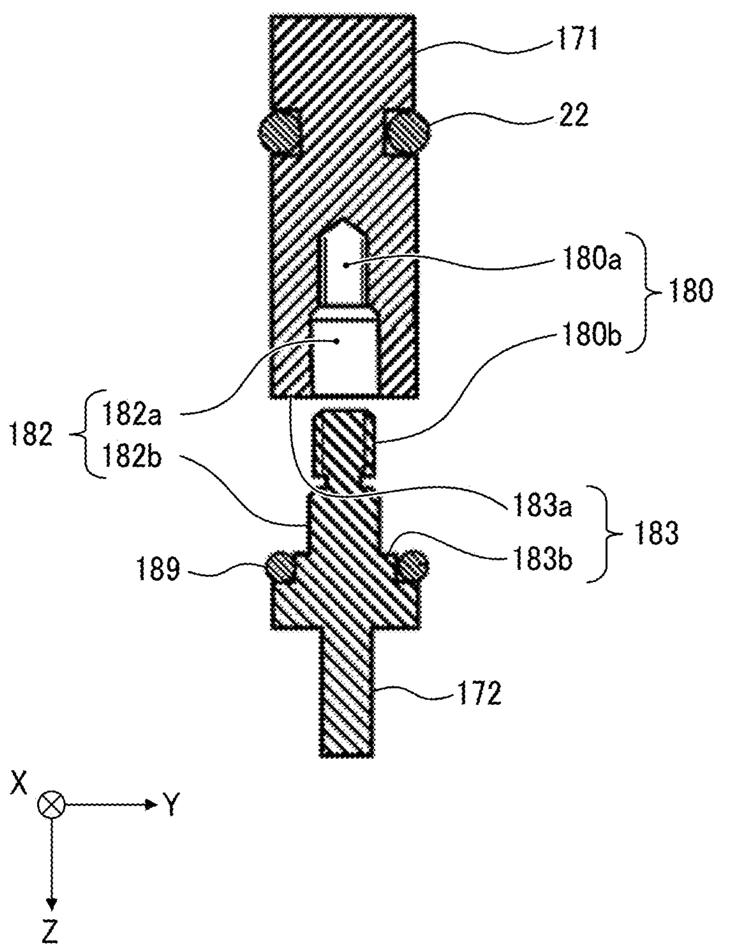
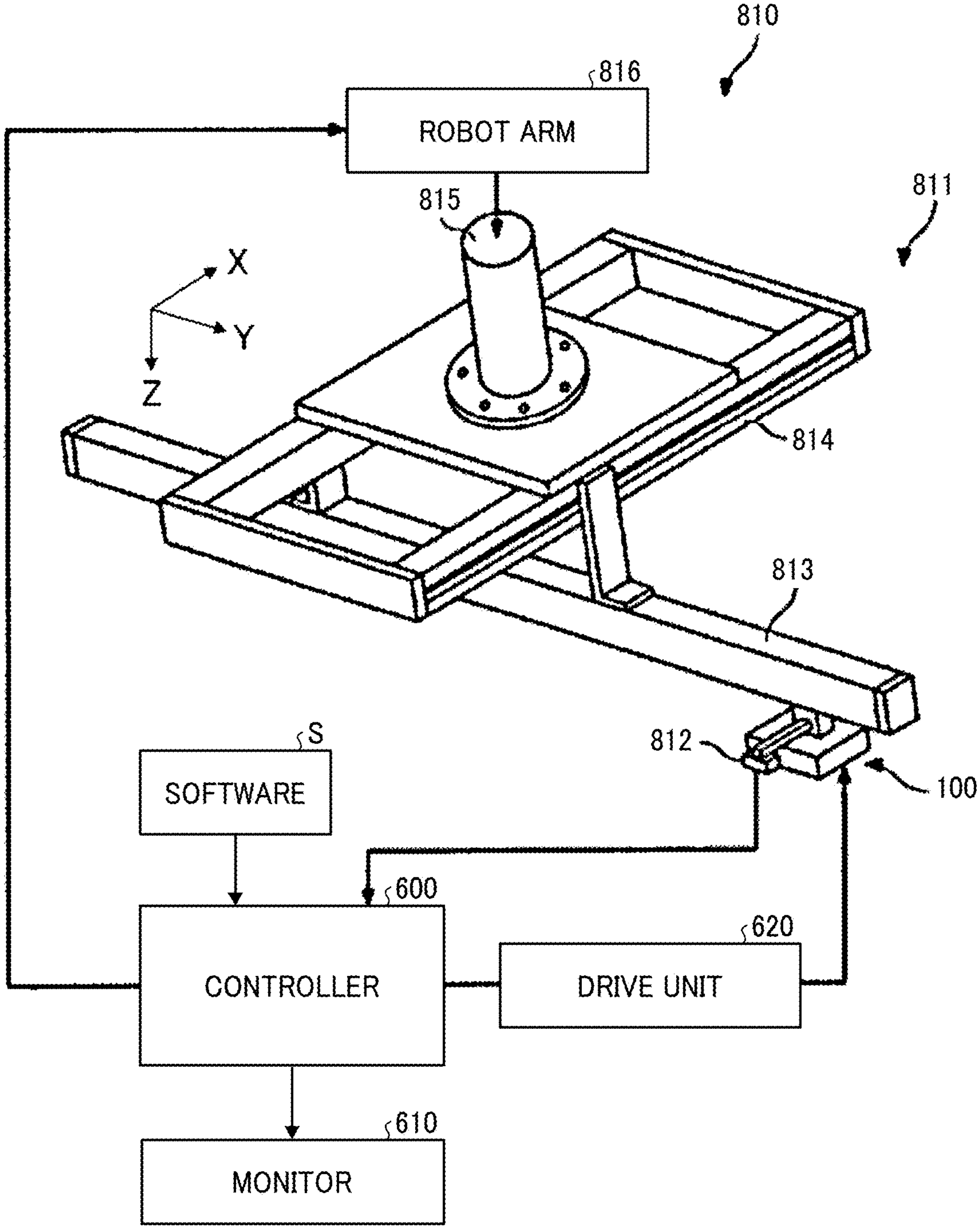


FIG. 21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ROBOT ARM
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100
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SOFTWARE
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CONTROLLER
620
DRIVE UNIT
610
MONITOR

FIG. 22A

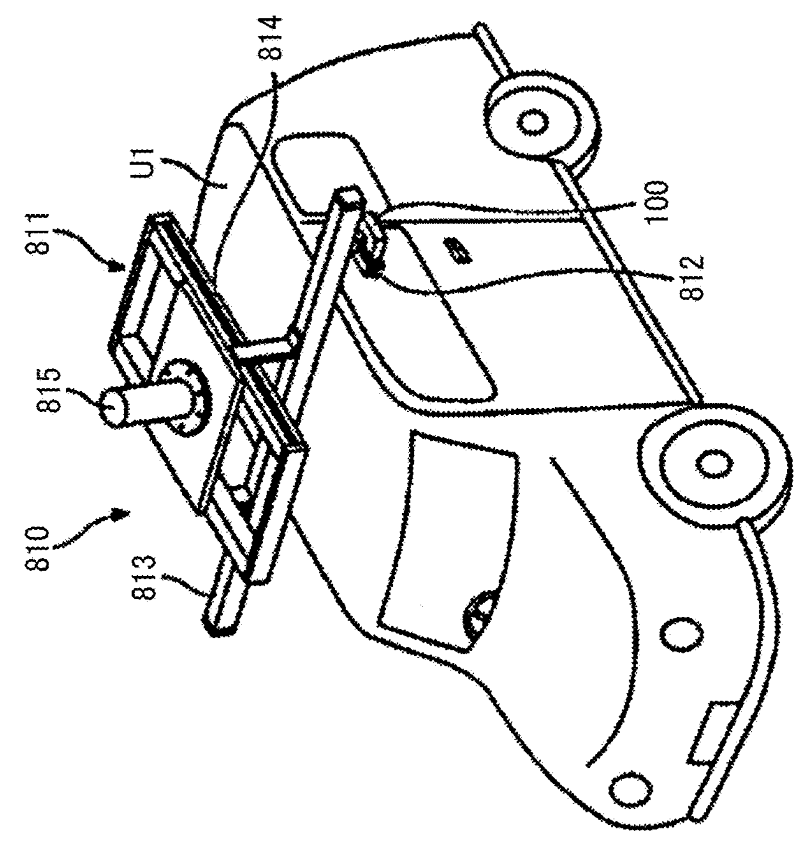


FIG. 22B

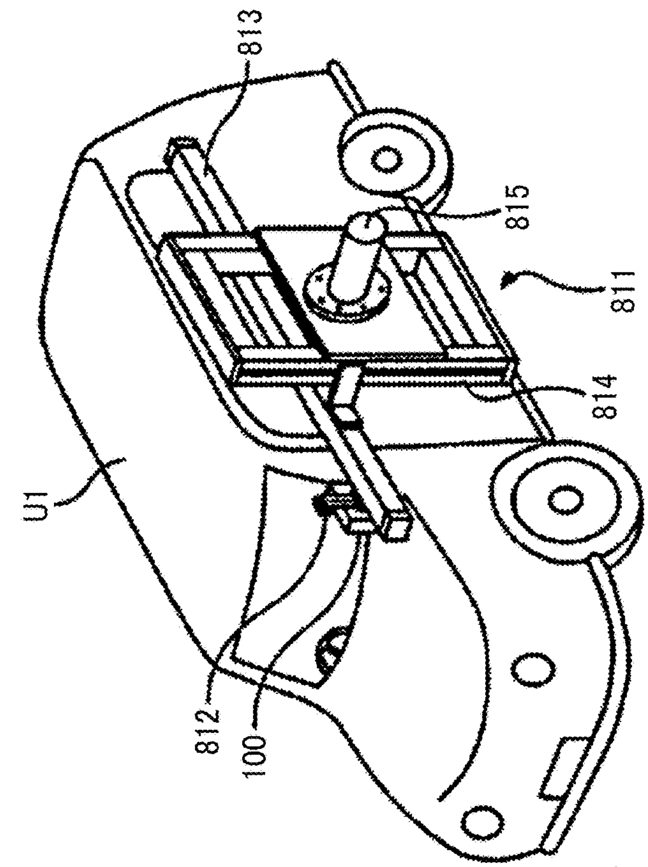


FIG. 23

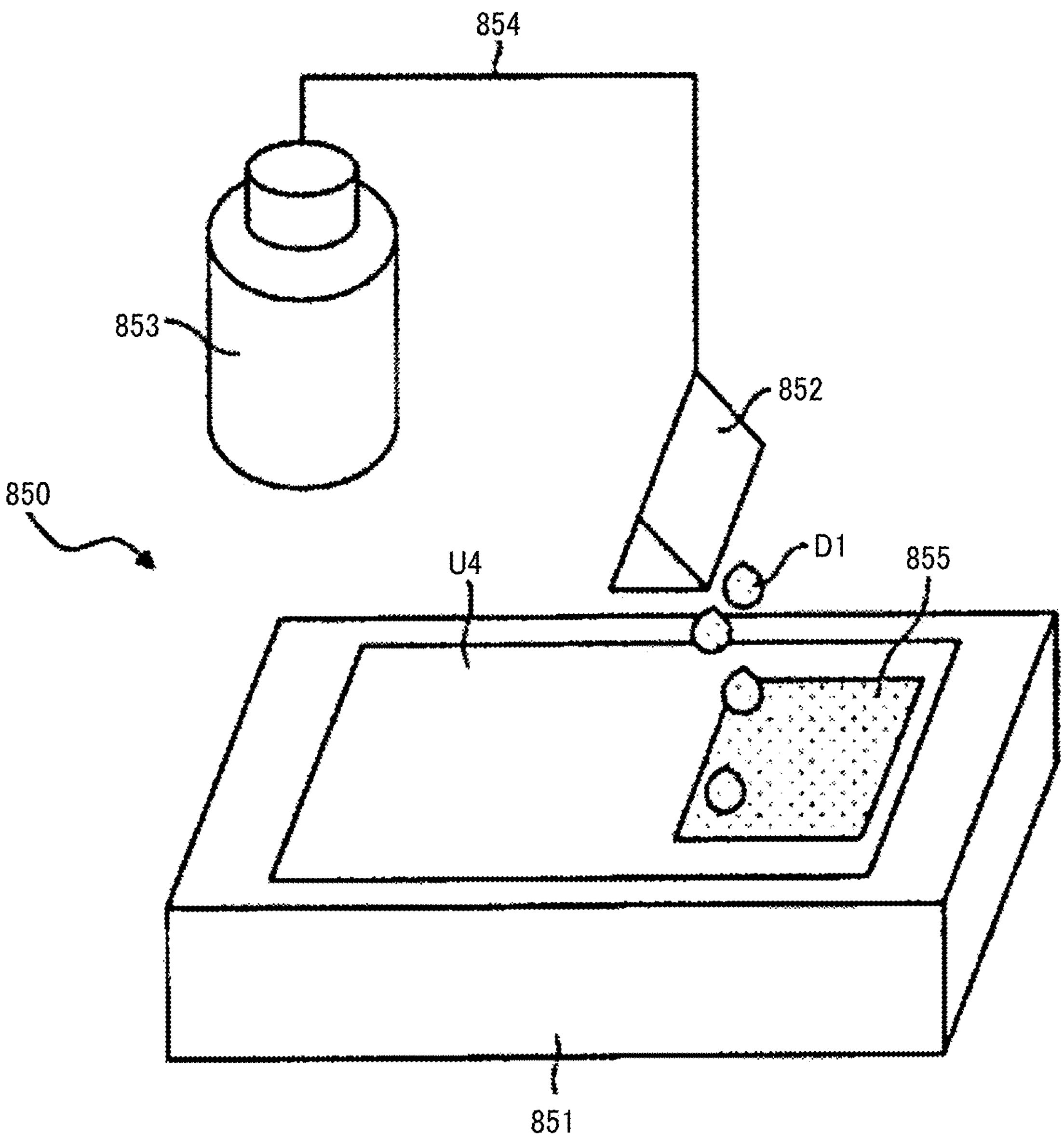
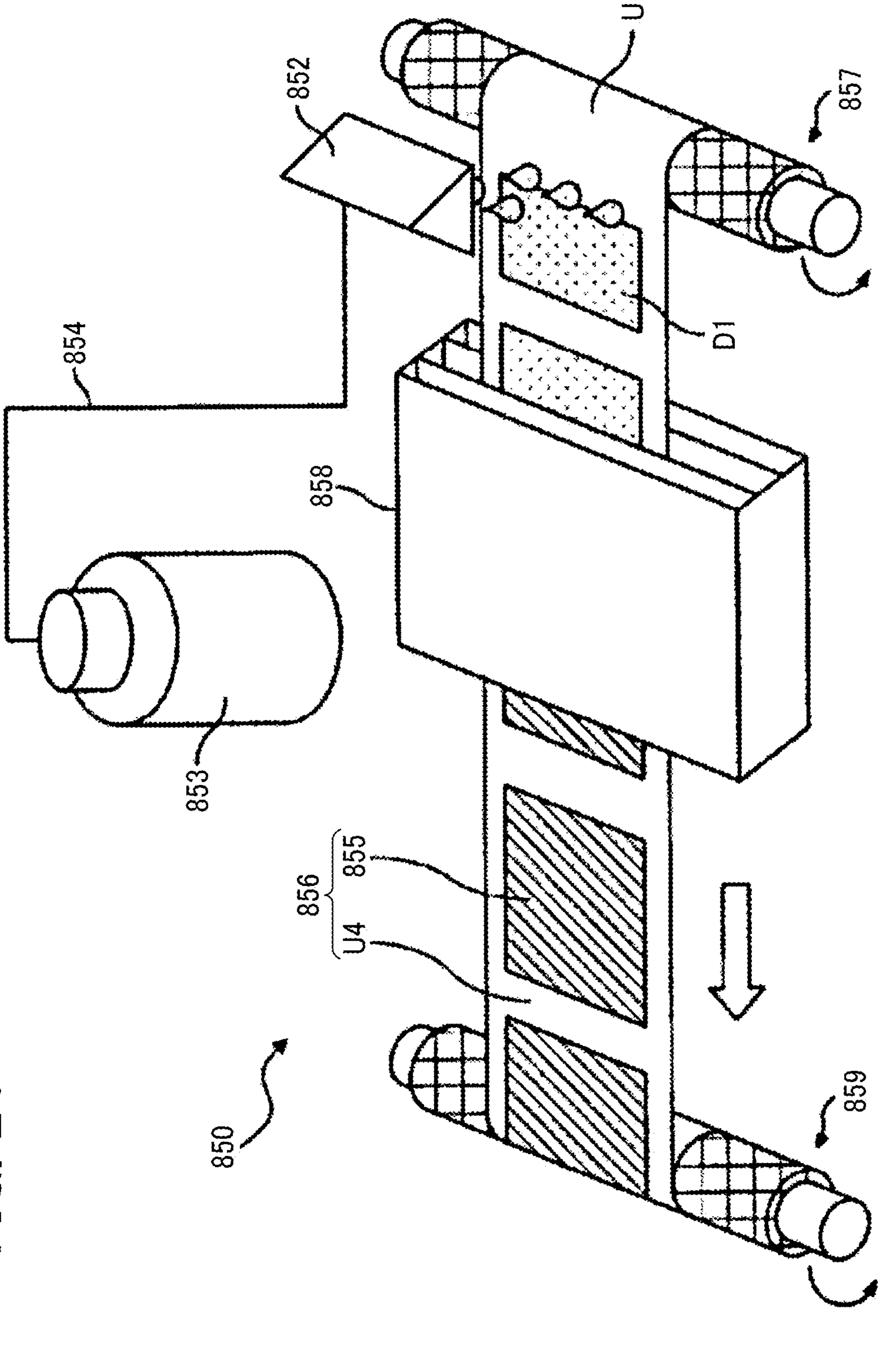


FIG. 24



LIQUID DISCHARGE HEAD AND LIQUID DISCHARGE APPARATUS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This patent application is based on and claims priority pursuant to 35 U.S.C. § 119 (a) to Japanese Patent Application No. 2024-018674, filed on Feb. 9, 2024, in the Japan Patent Office, the entire disclosure of which is hereby incorporated by reference herein.

BACKGROUND

Technical Field

[0002] The present embodiment relates to a liquid discharge head and a liquid discharge apparatus.

Related Art

[0003] A liquid discharge head includes a needle valve that opens and closes a nozzle, and a mover that moves the needle valve between a closed position at which the nozzle is closed and an open position at which the nozzle is opened, in which the needle valve includes a rear-end member connected to the mover and a leading-end member attached to the rear-end member.

SUMMARY

[0004] In an aspect of the present disclosure, a liquid discharge head that includes a needle valve to open and close a nozzle, the needle valve including: a rear-end member; and a leading-end member detachably attached to the rear-end member; and a mover coupled to the rear-end member of the needle valve, the mover to move the needle valve, in an axial direction, between: a closed position at which the needle valve contacts the nozzle to close the nozzle; and an open position at which the needle valve is separated from the nozzle to open the nozzle. The needle valve further includes: an axial force generator to generate an axial force to abut the leading-end member against the rear-end member; an axial center restrictor to restrict a position of an axial center of the leading-end member relative to an axial center of the rear-end member; and an inclination restrictor to restrict an inclination of the leading-end member relative to the rear-end member.

BRIEF DESCRIPTIONS OF DRAWINGS

[0005] A more complete appreciation of embodiments of the present disclosure and many of the attendant advantages and features thereof can be readily obtained and understood from the following detailed description with reference to the accompanying drawings, wherein:

[0006] FIG. **1** is an entire perspective view of a liquid discharge head;

[0007] FIG. **2** is a schematic configuration diagram illustrating a head unit;

[0008] FIG. **3** is a schematic cross-sectional view of the liquid discharge head;

[0009] FIGS. **4**A and **4**B are schematic configuration diagrams illustrating a basic configuration of a liquid discharge module;

[0010] FIG. **5** is a diagram for illustrating replacement of a leading-end member and a nozzle plate;

[0011] FIGS. **6**A to **6**D are diagrams illustrating an example of the leading-end member to be replaced;

[0012] FIG. **7**A illustrates a comparative example in which trouble occurs such that the axial center of the leading-end member is shifted in a direction orthogonal to a Z direction relative to the axial center of a rear-end member, and FIG. **7**B illustrates a comparative example in which trouble occurs such that the leading-end member is attached to the rear-end member in an inclined manner;

[0013] FIG. **8**A illustrates a comparative example in which trouble occurs such that the axial center of the leading-end member is shifted from the center of the nozzle in a case where a leading-end member shape is a concave shape, and FIG. **8**B illustrates a comparative example in n which trouble occurs such that the axial center of the leading-end member is shifted from the center of the nozzle in a case where the leading-end member shape is a conical shape;

[0014] FIG. **9** is a schematic diagram illustrating the vicinity of a connection portion between the leading-end member and the rear-end member;

[0015] FIGS. **10**A and **10**B are diagrams for illustrating a dimensional example of a needle valve;

[0016] FIG. **11** is a diagram for illustrating a positional shift of the axial center of the leading-end member relative to the axial center of the rear-end member and measurement of the inclination of the leading-end member relative to the rear-end member;

[0017] FIG. **12**A to **12**C are diagrams illustrating another example of a unit for generating an axial force;

[0018] FIGS. **13**A and **13**B are schematic configuration diagrams illustrating an example in which a diaphragm seal is used as a seal for sealing between a storage and a flow path;

[0019] FIG. **14** is a schematic configuration diagram illustrating a first modification of the present embodiment;

[0020] FIG. **15** is a schematic configuration diagram illustrating a second modification of the present embodiment;

[0021] FIGS. **16**A and **16**B are schematic configuration diagrams illustrating a third modification of the present embodiment;

[0022] FIG. **17** is a schematic configuration diagram illustrating a fourth modification of the present embodiment;

[0023] FIGS. **18**(*a*) to **18**(*d*) are diagrams illustrating an example of a diaphragm interposing structure of the needle valve;

[0024] FIG. **19** is a schematic configuration diagram illustrating a fifth modification of the present embodiment;

[0025] FIG. **20** is a schematic diagram of a needle valve in a fifth modification;

[0026] FIG. **21** is a schematic configuration diagram of an inkjet printer;

[0027] FIGS. **22**A and **22**B are perspective views illustrating an arrangement example of an inkjet printer relative to an automobile;

[0028] FIG. **23** is a schematic perspective view illustrating an example of an electrode manufacturing apparatus; and

[0029] FIG. **24** is a schematic perspective view illustrating another example of the electrode manufacturing apparatus.

[0030] The accompanying drawings are intended to depict embodiments of the present disclosure and should not be interpreted to limit the scope thereof. The accompanying drawings are not to be considered as drawn to scale unless explicitly noted. Also, identical or similar reference numerals designate identical or similar components throughout the several views.

DETAILED DESCRIPTION OF EMBODIMENTS

[0031] In describing embodiments illustrated in the drawings, specific terminology is employed for the sake of clarity. However, the disclosure of this specification is not intended to be limited to the specific terminology so selected and it is to be understood that each specific element includes all technical equivalents that have a similar function, operate in a similar manner, and achieve a similar result.

[0032] Referring now to the drawings, embodiments of the present disclosure are described below. As used herein, the singular forms “a,” “an,” and “the” are intended to include the plural forms as well, unless the context clearly indicates otherwise.

[0033] A best mode for carrying out the present embodiment will be hereinafter described with reference to the drawings. It is to be understood that those skilled in the art can easily change and correct the present embodiment within the scope of claims to form other embodiments, and these changes and corrections are included in the scope of claims. The following description is an example of the best mode of the present embodiment, and does not limit the scope of claims.

[0034] FIG. **1** is an entire perspective view of a liquid discharge head **10**. In FIG. **1**, a longitudinal direction of the liquid discharge head **10** (arrangement direction of nozzles **14**) is defined as an X direction, and a lateral direction of the liquid discharge head **10** is defined as a Y direction. A height direction of the liquid discharge head **10** (an opening/closing direction of a needle valve **17**, a moving direction of the needle valve **17**, a liquid discharge direction from the nozzle **14**) is defined as a Z direction. In the subsequent drawings, the definition of coordinates is similar unless otherwise specified.

[0035] The liquid discharge head **10** is provided with a housing **11** as a housing. The housing **11** is made of metal or resin. The housing **11** includes a nozzle housing **11***b* and a main body housing **11***a*. The main body housing **11***a* is provided with a connector **29** for communication of electric signals on its upper portion. The housing **11** includes a supply port **12** for supplying liquid such as ink into a head on one end in the X direction, and a recovery port **13** for ejecting the liquid from the head on the other end in the X direction.

[0036] FIG. **2** is a schematic configuration diagram illustrating a head unit **60**, and is also a cross-sectional view of the liquid discharge head **10** taken along line A-A in FIG. **1**. The head unit **60** includes the liquid discharge head **10** and a drive controller **40**.

[0037] The liquid discharge head **10** includes a nozzle plate **15**. The nozzle plate **15** is joined to the nozzle housing **11***b*. On the nozzle plate **15**, a plurality of nozzles **14** for discharging the liquid is arranged in the longitudinal direction (X direction) of the liquid discharge head **10**. A liquid chamber **16** through which the liquid flows is provided in the housing **11**. The liquid chamber **16** serves as a path through which the liquid supplied from the supply port **12** is transmitted to the recovery port **13** via the nozzle plate **15**. The liquid is transmitted on the liquid chamber **16** in a direction indicated by arrows a**1** to a**3** illustrated in FIG. **2**.

[0038] With the above-described configuration, the supply port **12** takes in the liquid in a pressurized state from outside, transmits the liquid in the direction indicated by arrow a**1**, and supplies the ink to the liquid chamber **16**. The liquid chamber **16** transmits the liquid from the supply port **12** in the direction indicated by arrow a**2**. The recovery port **13** ejects the liquid that is not discharged from the nozzles **14** arranged along the liquid chamber **16** in the direction indicated by arrow a**3**.

[0039] A plurality of liquid discharge modules **70** is arranged between the supply port **12** and the recovery port **13**. The number of the liquid discharge modules **70** corresponds to the number of the nozzles **14**, and in this example, a configuration is illustrated in which eight liquid discharge modules **70** corresponding to eight nozzles **14** arranged in one row are provided. The number and arrangement of the nozzles **14** and the liquid discharge modules **70** are not limited to the above description. For example, the number of the nozzles **14** and the number of the liquid discharge modules **70** may be one instead of plural. The number may be eight or larger or smaller. The nozzles **14** and the liquid discharge modules **70** may be arranged in a plurality of rows instead of one row.

[0040] Each liquid discharge module **70** is provided with the needle valve **17** that opens and closes the nozzle **14** and a piezoelectric element **18** as an actuator that drives the needle valve **17**. By displacing the piezoelectric element **18**, the needle valve **17** is opened and closed, and the liquid is discharged from the nozzle **14**.

[0041] The housing **11** is provided with a plurality of storages **110** (refer to FIG. **3**) as mover storages for storing a moving mechanism **58** (refer to FIG. **3**) of the liquid discharge module **70**. Each storage **110** is provided with a piezoelectric element restriction member **19** that restricts a position of the piezoelectric element **18** in the Z direction.

[0042] A sealing member as a sealing portion is provided in a leading-end member portion of the needle valve **17**. When the sealing member of the needle valve **17** is pressed against the nozzle plate **15**, the sealing member is compressed, so that the needle valve **17** surely closes the nozzle **14**.

[0043] When a voltage is applied to the piezoelectric element **18** by the drive controller **40**, the piezoelectric element **18** is displaced in the Z direction, and the needle valve **17** is raised in a direction separated from the nozzle **14** by the moving mechanism **58** to be described later. As a result, the needle valve **17** is separated from the nozzle **14** to open the nozzle **14**. As a result, the liquid pressurized and supplied to the liquid chamber **16** is discharged from the nozzle **14**. When no voltage is applied to the piezoelectric element **18**, the needle valve **17** closes the nozzle **14**. In this state, even if the liquid is pressurized and supplied to the liquid chamber **16**, the liquid is not discharged from the nozzle **14**.

[0044] The drive controller **40** includes a waveform generation circuit **41** serving as a drive pulse generator and an amplification circuit. The waveform generation circuit generates a drive pulse waveform to be described later, and the amplification circuit amplifies a voltage value to a necessary value. The amplified voltage is applied to the piezoelectric element **18**. By the application of the voltage, the drive controller **40** controls opening and closing of the needle valve **17** and controls discharge of the liquid from the liquid discharge head **10**. Note that, in a case where the waveform generation circuit can apply a voltage of a sufficient value, the amplification circuit may be omitted.

[0045] The waveform generation circuit **41** generates a drive pulse that is a waveform of a voltage, applied to the piezoelectric element **18**, changing over time. The waveform generation circuit receives print data input from an external PC or a microcomputer in an apparatus, and generates the drive pulse on the basis of this input data. The waveform generation circuit can change the voltage applied to the piezoelectric element **18** and generate a plurality of drive pulses. As described above, the waveform generation circuit generates the drive pulse, so that the piezoelectric element **18** expands and contracts in accordance with the drive pulse to open and close the needle valve **17**.

[0046] FIG. **3** is a schematic cross-sectional view perpendicular to the X direction of the liquid discharge head **10**.

[0047] The nozzle housing **11***b* is provided with the liquid chamber **16** and holds the nozzle plate **15**. The main body housing **11***a* is provided with a plurality of storages **110** that stores the moving mechanism **58** of the liquid discharge module **70**.

[0048] A pin fitting hole **111***a* is formed in an upper portion of the nozzle housing **11***b*, and a positioning pin **112** is fitted into the pin fitting hole **111***a*. A positioning hole **111***b* is formed on a lower surface of the main body housing **11***a*. When the positioning pin **112** fitted into the pin fitting hole **111***a* of the nozzle housing **11***b* is inserted into the positioning hole **111***b* of the main body housing **11***a*, the nozzle housing **11***b* is positioned relative to the main body housing **11***a*. The nozzle housing **11***b* is fastened to the main body housing **11***a* with a screw.

[0049] In addition to the needle valve **17** that opens and closes the nozzle **14**, the liquid discharge module **70** includes the moving mechanism **58** as a mover provided with the piezoelectric element **18**. The piezoelectric element **18** is held by a holder **63**.

[0050] A protrusion **63***a* is provided on a proximal end side opposite to the nozzle **14** side of the holder **63**, and the protrusion **63***a* is fitted into a concave portion of the piezoelectric element restriction member **19**. The piezoelectric element restriction member **19** includes a screw hole extending in the Y direction. A positioning screw **42** is screwed into the screw hole from the outside of the main body housing **11***a*.

[0051] The positioning screw **42** is inserted into a long hole elongated in the Z direction in an upper end portion of the main body housing **11***a*. Therefore, the positioning screw **42** is movable by a predetermined length in the Z direction. The positioning screw **42** is fastened in a state in which the piezoelectric element restriction member **19** is positioned in the Z direction. As a result, an upper portion of the piezoelectric element **18** is immovably secured.

[0052] The needle valve **17** includes two members: a leading-end member **172** that seals the nozzle **14**, and a rear-end member **171**, an upper end of which is secured to a leaf spring member **30** of the moving mechanism **58**. On the nozzle side of the storage **110** of the main body housing **11***a*, two bearings **113** for receiving the rear-end member **171** are provided at a predetermined interval in the Z direction (the vertical direction and also the liquid discharge direction). The rear-end member **171** is held in a posture parallel to the Z direction so as to be movable parallel in the Z direction by the two bearings **113**. The rear-end member is also referred to as “rear-end member”.

[0053] The leading-end member **172** holds an O-ring **22** as a seal that seals between the storage **110** and the liquid chamber **16**.

[0054] FIGS. **4**A and **4**B are schematic configuration diagrams illustrating a basic configuration of the liquid discharge module **70**.

[0055] FIG. **4**A is a schematic configuration diagram illustrating a state in which the needle valve **17** closes the nozzle **14**, and FIG. **4**B is a schematic configuration diagram illustrating a state in which the needle valve **17** opens the nozzle **14**.

[0056] The liquid discharge module **70** is provided with the needle valve **17** as a valve member that opens and closes the nozzle **14**, and the moving mechanism **58**. The moving mechanism **58** includes a moving member **20**, a pair of arm members **21**, and the leaf spring member **30** in addition to the piezoelectric element **18**. The moving member **20** includes one end secured to the piezoelectric element **18** and the other end to which a pair of arm members **21** is rotatably attached, and is attached to the holder **63** that holds the piezoelectric element **18** so as to be movable in the Z direction. The pair of arm members **21** is rotatably supported by a support shaft **21***a* attached to the holder **63**.

[0057] By bending a sheet metal made of SUS, the leaf spring member **30** forms a valve connection portion **31** connected to the needle valve **17**, a pair of inclined portions **32** as elastic deformation portions, and a pair of arm connection portions **33**. The needle valve **17** is joined to the valve connection portion **31** with an adhesive, and the inclined portions **32** as the elastic deformation portions extend obliquely upward in the drawing from both ends of the valve connection portion **31**. The arm connection portion **33** is fitted into a slit portion provided on the arm member **21** and attached to the arm member **21**.

[0058] As illustrated in FIG. **4**A, when the needle valve **17** closes the nozzle **14** (a state in which the needle valve **17** is at the closed position), the pair of inclined portions **32** of the leaf spring member **30** elastically deforms as indicated by a broken line in the drawing. As a result, a biasing force that presses the needle valve **17** against the nozzle plate **15** is generated.

[0059] As indicated by a black arrow in FIG. **4**B, when the piezoelectric element **18** is displaced toward the nozzle **14**, the moving member **20** moves toward the nozzle and pushes the pair of arm members **21** toward the nozzle. As a result, the pair of arm members **21** rotates about the support shaft **21***a* as a fulcrum. When the pair of arm members **21** rotates, both ends of the leaf spring member **30** move in a direction separating from each other. As a result, the needle valve **17** is raised to open the nozzle **14**, and the liquid is discharged from the nozzle **14** (corresponding to a state in which the needle valve **17** is at the open position to open the nozzle **14**).

[0060] Since the needle valve **17** and the nozzle plate **15** repeatedly come into and out of contact with each other, a needle leading-end member portion, which is a contact portion of the leading-end member **172** with the nozzle plate **15**, and a contact portion of the nozzle plate **15** with the needle valve **17** are worn, or dirt adheres thereto in continuous use. As a result, a discharge state might be deteriorated, or a seal failure might occur and the liquid oozes out of the nozzle **14**. Therefore, it is necessary to periodically replace the leading-end member **172** and the nozzle plate **15**.

[0061] FIG. **5** is a diagram for illustrating replacement of the leading-end member **172** and the nozzle plate **15**.

[0062] First, the nozzle housing **11***b* that holds the nozzle plate **15** fastened to the main body housing **11***a* is removed with a screw to expose the leading-end member **172** of the needle valve **17**. Next, the leading-end member **172** the leading-end member of which is worn is removed from the rear-end member **171** and replaced with a new leading-end member **172**.

[0063] The O-ring **22**, which is the seal that seals between the storage **110** and the liquid chamber **16**, slides on an inner wall surface of the nozzle housing **11***b* to be worn when the needle valve **17** is opened and closed. By holding the O-ring **22** by the leading-end member **172**, the worn O-ring **22** can be replaced with a new one together with the leading-end member **172**. As a result, it is possible to satisfactorily seal between the storage **110** and the liquid chamber **16** over time, and it is possible to satisfactorily suppress the liquid in the liquid chamber **16** from leaking to the storage **110**.

[0064] After replacement with the new leading-end member **172**, the nozzle housing **11***b* that holds a new nozzle plate **15** is positioned in the main body housing **11***a* by the positioning pin **112**. Thereafter, by being fastened to the main body housing **11***a* with a screw, the nozzle plate **15** is replaced. By fastening the nozzle plate **15** to the nozzle housing **11***b* with a screw, the nozzle plate **15** may be configured to be detachable from the nozzle housing **11***b*, so that only the nozzle plate **15** is replaced.

[0065] The housing **11** may be formed of a single member including the liquid chamber **16** and the storage **110**, and the nozzle plate **15** may be configured to be detachable from the housing. Specifically, after the positioning pin of the nozzle plate **15** is inserted into the positioning hole of the housing to position, the nozzle plate **15** is fastened to the housing with a screw.

[0066] An optimum leading-end member shape, and a material of the leading-end member of the needle valve **17** that can satisfactorily seal are different according to a type and viscosity of the liquid to be discharged, a solid content ratio of fillers contained in the liquid, a shape of the solid content, and a size of the solid content. The optimum leading-end member shape of the needle valve **17** also varies depending on a discharge amount. In the present embodiment, the needle valve **17** includes two members of the leading-end member **172** and the rear-end member **171**, and the leading-end member **172** can be easily replaced. Therefore, it is possible to easily change to the leading-end member **172** having a different leading-end member shape. As a result, by changing the leading-end member **172** according to the type and viscosity of the liquid to be discharged, the solid content ratio of the fillers contained in the liquid, the shape of the solid content, the size of the solid content, and the discharge amount, the nozzle **14** can be satisfactorily sealed, and a target discharge amount can be achieved.

[0067] FIGS. **6**A to **6**D are diagrams illustrating an example of the leading-end member **172** to be replaced.

[0068] FIG. **6**A illustrates the leading-end member **172** including a conical leading-end member, and FIG. **6**B illustrates the leading-end member **172** including a leading-end member fitted with a ball. FIG. **6**C illustrates the leading-end member **172** to the leading-end member of which the sealing member **173** made of an elastic member such as resin or rubber is attached, the member having a planar leading-end member shape (lower surface of the sealing member **173**). FIG. **6**D illustrates the leading-end member **172** to the leading-end member of which the sealing member **173** made of an elastic member such as resin or rubber is attached, the member having a concave leading-end member shape.

[0069] The leading-end member **172** having the conical leading-end member shape illustrated in FIG. **6**A and the leading-end member **172** having a spherical leading-end member shape illustrated in FIG. **6**B come into contact with an edge of the nozzle **14** and a nozzle inner peripheral surface to remove the solid content contained in the liquid to seal. As illustrated in FIGS. **6**C and **6**D, the leading-end member **172** provided with the sealing member **173** made of an elastic member seals such that the sealing member **173** is elastically deformed, and a non-adhesive portion is not generated by the solid content of the liquid that cannot be removed from a sealing portion between the nozzle **14** and the leading-end member of the needle valve **17**.

[0070] A user attaches the leading-end member **172** having a leading-end member shape and including a leading-end member material that can satisfactorily seal the nozzle **14** to the rear-end member **171** on the basis of the type and viscosity of the liquid to be discharged, the solid content ratio of the filler contained in the liquid, the shape of the solid content, the size of the solid content, and the discharge amount. This makes it possible to cope with various liquids.

[0071] Depending on the type and viscosity of the liquid to be discharged, the solid content ratio of the fillers contained in the liquid, the shape of the solid content, and the size of the solid content, as illustrated in FIG. **6**A, there is a case where it is better that the leading-end member of the needle valve **17** be in close contact with the edge of the nozzle **14** to seal. As illustrated in FIG. **6**B, there also is a case where it is better to make the shape of the nozzle **14** on the needle valve side conform to the leading-end member shape of the needle valve **17** and bring the leading-end member of the needle valve **17** into close contact with the nozzle inner peripheral surface to seal. There also is an optimum nozzle diameter according to the discharge amount.

[0072] In the present embodiment, the nozzle plate **15** can also be replaced, and a combination of the leading-end member **172** that can satisfactorily seal and the nozzle plate (nozzle) can be obtained according to the liquid to be discharged. This makes it possible to further cope with various liquids.

[0073] However, when the needle valve **17** includes two members of the leading-end member **172** and the rear-end member **171**, and the leading-end member **172** is configured to be easily replaceable, the following problem might occur. That is, there is a problem that the leading-end member **172** might be attached to the rear-end member **171** with a significant shift between the position at the axial center of the leading-end member **172** and the position at the axial center of the rear-end member **171** in a direction orthogonal to the Z direction by an attachment error. There also is a problem that the leading-end member **172** might be attached to the rear-end member **171** in an inclined manner.

[0074] FIG. **7**A illustrates a comparative example in which trouble occurs such that the axial center of the leading-end member **172** is shifted in the direction orthogonal to the Z direction relative to the axial center of the rear-end member **171**. FIG. **7**B illustrates a comparative example in which trouble occurs such that the leading-end member **172** is attached to the rear-end member **171** in an inclined manner.

[0075] When the axial center of the leading-end member **172** is shifted in the direction orthogonal to the Z direction relative to the axial center of the rear-end member **171**, a position of the axial center O**2** of the leading-end member **172** might be shifted relative to the center O**1** of the nozzle **14** as illustrated in FIG. **7**A.

[0076] In this manner, when the position of the axial center O**2** of the leading-end member **172** is shifted relative to the center O**1** of the nozzle **14**, a distance from the nozzle **14** to an end portion of the needle leading-end member becomes non-uniform as illustrated in B**1** and B**2** in FIG. **7**A. Therefore, a fluid resistance becomes non-uniform when a gap between the needle valve leading-end member and a nozzle periphery is narrow immediately after the discharge is started or immediately before the discharge is finished. As a result, as illustrated in FIG. **7**A, discharge bending in which the liquid discharged from the nozzle **14** is bent might occur. There also is a trouble of pour draining. When the discharge bending occurs, a pitch variation of droplets might occur at the time of continuous liquid discharge, and a streak might occur in an image.

[0077] In a case where the leading-end member **172** is attached to be inclined relative to the rear-end member **171** as illustrated in FIG. **7**B, the gap between the needle valve leading-end member and the nozzle periphery becomes non-uniform as indicated by G**1** and G**2**. As a result, as in a case of FIG. **7**A, the fluid resistance becomes non-uniform when the gap between the needle valve leading-end member and the nozzle periphery is narrow immediately after the discharge is started or immediately before the discharge is finished. Therefore, even in a case where the leading-end member **172** is attached to be inclined relative to the rear-end member **171**, a trouble such as discharge bending and pour draining occurs.

[0078] As illustrated in FIG. **8**A, a case where the leading-end member shape of the leading-end member **172** is a concave shape, a trouble such as discharge bending due to a difference in distance from the nozzle **14** to the end portion of the needle leading-end member due to the shift between the center O**1** of the nozzle **14** and the axial center O**2** of the leading-end member **172** is reduced. However, when the needle valve **17** is closed, a discharge draining might be disturbed when discharging the liquid in the concave portion on the needle leading-end member. A part of the liquid might remain in the concave portion on the needle leading-end member and the liquid might flow down from the nozzle **14** after a discharge operation is finished.

[0079] As illustrated in FIG. **8**B, even in a case where the leading-end member of the leading-end member **172** has a conical shape, if the position of the axial center O**2** of the leading-end member **172** is shifted relative to the center O**1** of the nozzle **14**, the discharge bending might occur at the time of closing.

[0080] In any of cases where the leading-end member shape of the needle valve **17** is the planar shape illustrated in FIG. **7**, the concave shape illustrated in FIG. **8**A, or the conical shape illustrated in FIG. **8**B, when the leading-end member **172** is attached to be inclined relative to the rear-end member **171**, a portion where an abutting pressure between the needle leading-end member and the nozzle **14** or the nozzle plate **15** is low is generated. As a result, the liquid might leak from the nozzle **14**.

[0081] Therefore, it is necessary to attach the leading-end member **172** to the rear-end member **171** with high accuracy.

[0082] FIG. **9** is a schematic diagram illustrating the vicinity of a connection portion between the leading-end member **172** and the rear-end member **171**.

[0083] As illustrated in FIG. **9**, the needle valve **17** includes a screw portion **180**, which also serves as an attachment unit for attaching the leading-end member **172** to the rear-end member **171** and as an axial force generator for generating an axial force, an inlay portion **182**, which serves as an axial center restrictor, and an inclination restrictor **183**.

[0084] The screw portion **180** includes a female screw portion **180***a* provided on the rear-end member **171** and a male screw portion **180***b* provided on the leading-end member **172**. By fastening the male screw portion **180***b* to the female screw portion **180***a*, the leading-end member **172** is attached to the rear-end member **171**.

[0085] The inlay portion **182** includes a cylindrical fitting hole **182***a* provided on the rear-end member **171** and a columnar fitting portion **182***b* provided on the leading-end member **172**. By fitting the leading-end member **172** into the fitting hole **182***a* of the rear-end member **171**, the axial center of the leading-end member **172** is accurately restricted relative to the axial center of the rear-end member **171**.

[0086] The inclination restrictor **183** is a lower end face of the rear-end member **171**, and includes a first seat surface **183***a* perpendicular to the Z direction and a second seat surface **183***b* extending in a radial direction from a lower end of the fitting portion **182***b* of the leading-end member **172** and perpendicular to the Z direction. By bringing the second seat surface **183***b* into close contact with the first seat surface **183***a*, the inclination of the leading-end member **172** relative to the rear-end member **171** is accurately restricted.

[0087] FIGS. **10**A and **10**B are diagrams for illustrating a dimensional example of the needle valve **17**, in which FIG. **10**A is a schematic cross-sectional view of the entire needle valve **17**, and FIG. **10**B is an enlarged view of an upper side of the leading-end member **172** (a rear-end member side of the leading-end member **172**).

[0088] The needle valve **17** illustrated in FIGS. **10**A and **10**B has a diameter of 1.3 mm, and the screw portion **180** is a micro screw having a screw size of S0.8. The diameter of the needle valve **17** is the diameter in a case of a minimum mountable nozzle pitch of 2 mm in a valve jet type liquid discharge head including a nozzle row.

[0089] In a case where an inner diameter of the nozzle **14** on the needle valve side is 0.3 mm, the leading-end member illustrated in FIG. **6**D is used as the leading-end member, and an inner diameter of the leading-end member concave portion is 0.5 mm, it is necessary to suppress the shift between the nozzle center and the axial center of the leading-end member of the needle valve **17** to 50 μm or less.

[0090] In addition to attaching accuracy of the leading-end member **172** to the rear-end member **171**, there is a following factor that cause the shift between the nozzle center and the center of the leading-end member of the needle valve. That is, there are joining accuracy of 30 μm of the nozzle plate **15** relative to the nozzle housing **11***b* and assembling accuracy (restricting accuracy of the bearing **113** that receives the rear-end member **171**) of 24.5 μm of the rear-end member **171** relative to the main body housing **11***a*. There also is a center shift error of 19.8 μm when forming the concave portion on the needle leading-end member and positioning accuracy of 19.6 μm when the nozzle housing **11***b* is attached to the main body housing **11***a*. A cumulative tolerance (square root of sum of squares) of the shift between the nozzle center and the center of the leading-end member of the needle valve **17** due to these factors is $\sqrt{(30^2+24.5^2+19.8^2+19.6^2)}=47.7$ (μm). Therefore, in order to set the shift between the nozzle center and the center of the leading-end member of the needle valve **17** to 50 μm or less, it is necessary to set the shift between the nozzle center and the center of the leading-end member of the needle valve **17** caused by the attaching accuracy of the leading-end member **172** to the rear-end member **171** to 15 μm ($\sqrt{(50^2-47.7^2)}=15$ μm) or less. In the present embodiment, by providing the inlay portion **182** and the inclination restrictor **183**, the shift between the nozzle center and the center of the leading-end member of the needle valve **17** caused by the attaching accuracy of the leading-end member **172** to the rear-end member **171** can be made 15 μm or less.

[0091] Specifically, an outer diameter of the fitting portion **182***b* of the inlay portion **182** is set to 0.9 mm, and an inner diameter of the fitting hole **182***a* of the inlay portion **182** is made larger than the outer diameter of the fitting portion **182***b* by about 1 to 5 μm. As a result, the axial center of the leading-end member **172** is restricted with an accuracy of 5 μm or less relative to the axial center of the rear-end member **171**. A height of the inlay portion **182** (Z direction length) is 1 mm. An outer peripheral surface of the fitting portion **182***b* and an inner peripheral surface of the fitting hole **182***a* are simple circular arc surfaces, and the outer diameter of the fitting portion **182***b* and the inner diameter of the fitting hole can be easily and accurately processed by cutting. Therefore, the fitting hole **182***a* and the fitting portion **182***b* can be formed with an accuracy of the gap therebetween of 5 μm or less.

[0092] Squareness of the first seat surface **183***a* and the second seat surface **183***b* of the inclination restrictor **183** relative to the Z direction is 2 μm or less. As a result, when the second seat surface **183***b* is in close contact with the first seat surface **183***a*, the inclination of the leading-end member **172** relative to the rear-end member **171** is restricted at 5 minutes (0.083°) or less. The first seat surface **183***a* and the second seat surface **183***b* are flat surfaces orthogonal to the Z direction. Therefore, the first seat surface **183***a* and the second seat surface **183***b* can be easily formed with accuracy of squareness of 2 μm or less by cutting and polishing.

[0093] As illustrated in FIG. **10**A, in a case of the following dimension, when the leading-end member **172** is inclined relative to the rear-end member **171** by 5 minutes (0.083°) or less, the shift between the center of the needle leading-end member and the axial center of the rear-end member is 10 μm or less. That is, a case where a length from the second seat surface **183***b* to the needle leading-end member (the lower end of the leading-end member) of the leading-end member **172** is 7 mm and an outer diameter of the needle leading-end member is 1 mm.

[0094] With the axial center shift in the inlay portion **182**, the shift between the center of the needle leading-end member and the axial center of the rear-end member is 15 μm at the maximum. As a result, the shift between the nozzle center and the center of the leading-end member of the needle valve can be set to 50 μm or less, and it is possible to suppress the discharge bending and pour discharge draining due to the shift between the nozzle center and the center of the leading-end member of the needle valve **17**.

[0095] By making the inner diameter of the fitting hole **182***a* of the inlay portion **182** larger than the outer diameter of the fitting portion **182***b* by about 1 to 5 μm, the leading-end member **172** can be moved in an inclined manner in a predetermined range relative to the rear-end member **171**. As a result, when the inclination is restricted by the inclination restrictor **183**, the leading-end member **172** moves relative to the rear-end member **171** to correct the inclination, and the inclination restrictor **183** accurately restricts the inclination of the leading-end member **172** relative to the rear-end member **171**.

[0096] When a fastening torque of the screw portion **180**, which is the micro screw having the screw size of S0.8, is managed to 0.9 to 1 cN·m, an axial force of about 50 to 60 Nis generated. As a result, the second seat surface **183***b* can be satisfactorily brought into close contact with the first seat surface **183***a* of the inclination restrictor **183** by the axial force generated by the screw portion **180**. As a result, the inclination of the leading-end member **172** relative to the rear-end member **171** can be accurately restricted by the inclination restrictor **183**.

[0097] Here, the state in which the second seat surface **183***b* is in close contact with the first seat surface **183***a* indicates a stable state in which surface roughness and minute unevenness of the first seat surface **183***a* and the second seat surface **183***b* fit by the axial force, and the seat surfaces are in contact with each other at least three or more contact points. A frictional force between the seat surfaces generated by the axial force can prevent the screw portion **180** from being loosened by a load due to an opening/closing operation of the needle valve. As a result, it is possible to prevent close contact between the first seat surface **183***a* and the second seat surface **183***b* from being released due to a decrease in axial force and prevent the inclination from being restricted with pour accuracy.

[0098] By restricting the inclination of the leading-end member **172** relative to the rear-end member **171** to 5 minutes (0.083°) or less by the inclination restrictor **183**, in a case where a diameter of the needle leading-end member is 1 mm, a difference in height of the needle leading-end member (a difference in position in the Z direction) is suppressed to 2 μm or less. As illustrated in FIG. **7**B, the discharge bending or sealing failure occurs due to non-uniformity of the gap between the needle valve leading-end member and the nozzle periphery when the difference in height exceeds approximately 5 μm. Therefore, by restricting the inclination of the leading-end member **172** relative to the rear-end member **171** to 5 minutes (0.083°) or less, the difference in height of the end portion of the needle leading-end member in the direction orthogonal to the Z direction can be set to 5 μm or less, and the discharge bending and sealing failure due to the difference in height can be satisfactorily suppressed.

[0099] As described with reference to FIG. **8**A, in a case where the needle leading-end member shape is concave, an influence by the difference in distance from the nozzle **14** to the end portion of the needle leading-end member due to the shift between the center O**1** of the nozzle **14** and the axial center O**2** of the leading-end member **172** is small. Therefore, the shift between the center O**1** of the nozzle **14** and the axial center O**2** of the leading-end member **172** could be allowed up to 15 μm. However, as illustrated in FIG. **7**A, in a case where the leading-end member shape of the needle valve is a shape that is greatly affected by the difference in distance from the nozzle **14** to the end portion of the needle leading-end member due to the shift between the center O**1** of the nozzle **14** and the axial center O**2** of the leading-end member **172**, it is necessary to further suppress the axial center shift. Depending on the leading-end member shape of the needle valve, the influence of the difference in distance from the nozzle **14** to the end portion of the needle leading-end member is less than that of the leading-end member shape illustrated in FIG. **8**A in some cases, and the axial center shift can be further allowed in some cases. Therefore, the squareness of the second seat surface **183***b* and the outer diameter dimension of the fitting portion **182***b* (gap from the fitting hole **182***a*) are appropriately set according to the leading-end member shape of the needle valve **17**.

[0100] FIG. **11** is a diagram for illustrating a positional shift of the axial center of the leading-end member **172** relative to the axial center of the rear-end member **171** and measurement of the inclination of the leading-end member **172** relative to the rear-end member **171**.

[0101] A contact portion of the rear-end member **171** with the bearing **113** is chucked, and the needle valve **17** is rotated around the axial center of the rear-end member **171**. A micro gauge is brought into contact with a portion indicated by arrow A**1** in the drawing, and deflection of a portion of the second seat surface **183***b* is measured. An amount of positional shift of the axial center of the leading-end member **172** relative to the axial center of the rear-end member **171** can be calculated from the measured deflection amount and rotation angle information.

[0102] As for the inclination of the leading-end member **172** relative to the rear-end member **171**, the micro gauge is brought into contact with the position of the second seat surface **183***b* indicated by arrow A**1** in the drawing and the needle leading-end member portion indicated by arrow A**2** in the drawing, and the deflection amount is measured. The inclination of the leading-end member **172** relative to the rear-end member **171** can be measured from each deflection amount and each rotation angle information.

[0103] Also by the screw portion **180**, which is the axial force generator, according to an angle of a screw thread, by fastening the screw, a centering function to some extent is provided, and the axial center of the leading-end member can be aligned with the axial center of the rear-end member to some extent. However, even if the screw portion **180** has a high screw grade and high accuracy, the effect is limited, and it is difficult to position on a micron order. Positional shift occurs due to a balance of friction generated when the seat surface comes into contact and a balance of a force at the time of fastening.

[0104] In the present embodiment, in addition to the screw portion **180**, the inlay portion **182** that restricts the axial center of the leading-end member **172** relative to the axial center of the rear-end member **171** and the inclination restrictor **183** that restricts the inclination of the leading-end member **172** relative to the rear-end member **171** are provided.

[0105] The inner peripheral surface of the fitting hole **182***a* and the outer peripheral surface of the fitting portion **182***b* of the inlay portion **182** are both circular arc surfaces, and the inner diameter of the fitting hole **182***a* and the outer diameter of the fitting portion **182***b* can be accurately formed by simple processing such as cutting. Since each of the first seat surface **183***a* and the second sear surface **183***b* of the inclination restrictor **183** is a flat surface, it is possible to accurately form by simple processing such as cutting. This makes it possible to perform accurate attachment with an inexpensive configuration. Screw tolerance can be general screw tolerance, the leading-end member **172** can be easily attached to and detached from the rear-end member **171**, and the leading-end member **172** can be easily replaced.

[0106] In the needle valve having a dimensional relationship illustrated in FIGS. **10**A and **10**B, five samples were prepared for each of a comparative example including only the inclination restrictor **183** without the inlay portion **182**, and the needle valve of the present embodiment. The shift between the center O**1** of the nozzle **14** and the axial center O**2** of the leading-end member **172** was measured three times for one sample (15 times in total). An average value±standard deviation (3σ) of the shift between the center O**1** of the nozzle **14** and the axial center O**2** of the leading-end member **172** of the comparative example was 60±40 μm. In contrast, the average value±standard deviation (3σ) of the shift between the center O**1** of the nozzle **14** and the axial center O**2** of the leading-end member **172** of the present embodiment was 4±9 μm. In the comparative example without the inlay portion **182**, the shift between the center O**1** of the nozzle **14** and the axial center O**2** of the leading-end member **172** was about 100 μm (99.7% probability) at the maximum, whereas in the present embodiment, the shift was about 13 μm (99.7% probability) at the maximum, and could be suppressed to 15 μm or less.

[0107] Even in the comparative example without the inlay portion **182**, the inclination of the leading-end member **172** relative to the rear-end member **171** is restricted by the inclination restrictor **183**, and the inclination of the leading-end member **172** is restricted to the same extent as in the present embodiment (5 minutes or less, 0.083° or less). Therefore, the shift between the center of the needle leading-end member portion and the nozzle center due to the inclination of the leading-end member **172** is 10 μm or less.

[0108] In contrast, the axial center of the leading-end member **172** is restricted relative to the axial center of the rear-end member **171** by the above-described centering function of the screw portion **180** in the comparative example. However, with the centering function of the screw portion **180**, it was difficult to position on the micron order, and in the comparative example, the average value±standard deviation (3σ) of the shift between the center O**1** of the nozzle **14** and the axial center O**2** of the leading-end member **172** was 40=60 μm.

[0109] In contrast, in the present embodiment, the inlay portion **182** in which the gap between the fitting portion **182***b* and the fitting hole **182***a* is 5 μm or less is provided. Therefore, it is possible to perform positioning on the micron order, and the shift between the center O**1** of the nozzle **14** and the axial center O**2** of the leading-end member **172** due to the shift of the axial center of the rear-end member **171** relative to the axial center of the leading-end member **172** can be made 5 μm or less. As a result, in the present embodiment including the inlay portion **182**, the average value±standard deviation (3σ) of the shift between the center O**1** of the nozzle **14** and the axial center O**2** of the leading-end member **172** was 4±9 μm, and could be suppressed to 15 μm or less.

[0110] By forming the inlay portion **182** with high accuracy and fitting the fitting portion **182***b* into the fitting hole **182***a* without any gap, the inlay portion **182** can restrict the inclination of the leading-end member **172** relative to the rear-end member **171** with high accuracy. However, in order to accurately restrict the inclination by the inlay portion **182**, it is necessary to increase the length of the inlay portion **182** in the Z direction to some extent and press-fit the fitting portion **182***b* into the fitting hole **182***a*. As a result, a large axial force is necessary to screw the leading-end member **172** to the rear-end member **171** while press-fitting the fitting portion **182***b* into the fitting hole **182***a*. When the diameter of the needle valve **17** is small, it is difficult to generate a large axial force in the screw portion **180**, and attachment is difficult. Since the inner peripheral surface of the fitting hole **182***a* is worn or enlarged in diameter by repeated attachment and detachment, it is difficult to accurately restrict the inclination by the inlay portion **182** over time.

[0111] In the present embodiment, by providing the inclination restrictor **183** separately from the inlay portion **182**, the fitting portion **182***b* may be fitted in the fitting hole **182***a* with a gap, and the leading-end member **172** can be easily attached to the rear-end member **171**. The inclination of the leading-end member **172** relative to the rear-end member **171** can be accurately restricted over time.

[0112] The axial force generator that generates the axial force is not limited to the screw portion **180**. For example, as illustrated in FIG. **12**A, the leading-end member may be attached to the rear-end member **171** by a heat shrinkable tube **184** used for insulation protection of an electric wire. In a configuration illustrated in FIG. **12**A, an outer periphery on the rear-end member side (upper end side) of the leading-end member **172** and an outer periphery on the leading-end member side (lower end side) of the rear-end member **171** have a tapered structure in which the outer diameter increases toward the end portion. These tapered structures are covered with the heat shrinkable tube **184**, and hot air is applied to the heat shrinkable tube **184**. Then, the heat shrinkable tube **184** shrinks in the Z direction, and the axial force to press the leading-end member **172** against the rear-end member **171** is generated. As a result, the seat surfaces of the inclination restrictor **183** can be brought into close contact with each other.

[0113] As illustrated in FIG. **12**B, by generating the axial force by a magnetic force, the leading-end member **172** may be attached to the rear-end member **171**. As illustrated in FIG. **12**B, a magnet **185** is attached to a concave portion on a leading-end member side (lower end side) of the rear-end member **171**, and the leading-end member **172** made of a magnetic material such as metal is attracted by the magnetic force of the magnet **185**. As a result, the axial force that presses the leading-end member **172** against the rear-end member **171** is generated, and the seat surfaces of the inclination restrictor **183** can be brought into close contact with each other. It is preferable that the magnet **185** is provided so as not to come into contact with the rear-end member (upper end) of the leading-end member **172**, and the position of the leading-end member **172** in the vertical direction (Z direction) is restricted by the magnet **185**, so that a situation in which the seat surfaces do not come into close contact with each other does not occur. A magnet may be provided on the leading-end member **172**.

[0114] As illustrated in FIG. **12**C, by generating the axial force with a bayonet lock structure, the leading-end member **172** may be attached to the rear-end member **171**. A bayonet lock structure unit **186** includes an engagement pin **186***a* provided on the rear-end member **171** and a lock groove **186***b* provided on the rear-end member **171**. The lock groove **186***b* includes a guide groove **186***b***1** extending straight in the Z direction from the rear-end member (upper end) of the leading-end member **172** and a cam groove **186***b***2** inclined relative to the Z direction. The engagement pin **186***a* provided on the rear-end member **171** is inserted to a lower end of the guide groove **186***b***1** of the lock groove **186***b*. Next, the leading-end member **172** is rotated while being pushed into the rear-end member **171**, and the engagement pin **186***a* is engaged with the cam groove **186***b***2**. By engaging the engagement pin **186***a* with the cam groove **186***b***2**, the axial force that presses the leading-end member **172** against the rear-end member **171** is generated, and the seat surfaces of the inclination restrictor **183** can be brought into close contact with each other.

[0115] FIGS. **13**A and **13**B are schematic configuration diagrams illustrating an example in which a diaphragm seal **122** is used as a seal for sealing between the storage **110** and the liquid chamber **16**.

[0116] The diaphragm seal **122** includes a hole through which the needle valve **17** penetrates at the center, an edge of the hole is secured to the needle valve **17**, and an outer end portion of the diaphragm seal **122** is interposed to be secured between the main body housing **11***a* and the nozzle housing **11***b* to seal so as to partition the storage **110** and the liquid chamber **16**.

[0117] Since the diaphragm seal **122** is elastically deformed in the vertical direction along with opening and closing movement of the needle valve **17**, cracking or breakage might occur due to fatigue caused by use over time. Therefore, also in a case of the diaphragm seal **122**, as illustrated in FIG. **13**B, this is preferably configured to be held by the leading-end member **172** and replaced together with the leading-end member **172**.

Modification 1

[0118] FIG. **14** is a schematic configuration diagram illustrating a first modification of the present embodiment.

[0119] In this Modification 1, a fitting portion **182***b* of a leading-end member **172** has a two-stage configuration including an introduction portion **182***b***1** and a final fitting portion **182***b***2** having an outer diameter larger than that of the introduction portion **182***b***1**.

[0120] In this Modification 1, the outer diameter of the introduction portion **182***b***1** is made smaller than an inner diameter of a fitting hole **182***a* by about 5 to 10 μm. In contrast, the outer diameter of the final fitting portion **182***b***2** is larger than the inner diameter of the fitting hole **182***a* by about 1 to 2 μm.

[0121] A gap between the introduction portion **182***b***1** and the fitting hole **182***a* is 5 μm to 10 μm, and is larger than the gap (1 to 5 μm) of the fitting portion **182***b* relative to the fitting hole **182***a* of the present embodiment illustrated in FIGS. **10**A and **10**B. As a result, the fitting portion **182***b* can be easily inserted into the fitting hole **182***a* as compared with the embodiment, and attaching workability of the leading-end member **172** can be improved.

[0122] The outer diameter of the final fitting portion **182***b***2** is larger than the inner diameter of the fitting hole **182***a* by about 1 to 2 μm, and the final fitting portion **182***b***2** is lightly press-fitted into the fitting hole **182***a*. As a result, the axial center of a rear-end member **171** and the axial center of the leading-end member **172** can substantially conform to each other. A screw portion **180** is less likely to be loosened by light press-fitting.

[0123] In this Modification 1, when a male screw portion **180***b* of the leading-end member **172** is screwed into a female screw portion **180***a* of the rear-end member **171** to some extent, the final fitting portion **182***b***2** of the fitting portion **182***b* is lightly press-fitted into the fitting hole **182***a*. A length of the final fitting portion **182***b***2** in a Z direction is 100 to 150 μm in a configuration of a micro screw in which an inner diameter of the fitting hole **182***a* is 0.9 mm and a screw size of the screw portion **180** is S0.8. After the final fitting portion **182***b***2** of the fitting portion **182***b* is lightly press-fitted into the fitting hole **182***a*, a second seat surface **183***b* of an inclination restrictor **183** immediately comes into close contact with a first seat surface **183***a*, and screw fastening is completed. In this manner, since the final fitting portion **182***b***2** is lightly press-fitted into the fitting hole **182***a* in a final stage of the screw fastening, only the final stage of the screw fastening requires force. As a result, the attaching work of the leading-end member **172** to the rear-end member **171** can be easily performed.

[0124] The final fitting portion **182***b***2** is only slightly fitted into a lower end of the fitting hole **182***a*, and the inclination of the leading-end member **172** relative to the rear-end member **171** cannot be accurately restricted only by the final fitting portion **182***b***2**. Therefore, even in Modification 1, by providing the inclination restrictor **183** separately from the inlay portion **182**, the inclination of the leading-end member **172** relative to the rear-end member **171** can be accurately restricted.

[0125] The leading-end member holds the seal at a position closer to a leading-end side than the axial center restrictor and the inclination restrictor in the axial direction.

Modification 2

[0126] FIG. **15** is a schematic configuration diagram illustrating a second modification of the present embodiment.

[0127] As illustrated in FIG. **15**, in the second modification, a needle valve **17** includes a screw portion **180**, which also serves as an attachment unit and as an axial force generator, and a tapered portion **181**. The tapered portion **181** accurately restricts the axial center of a leading-end member **172** relative to the axial center of a rear-end member **171**, and accurately restricts inclination of the leading-end member **172** relative to the rear-end member **171**. That is, the tapered portion **181** serves as both an axial center restrictor and an inclination restrictor.

[0128] As illustrated in FIG. **15**, the tapered portion **181** includes a first tapered surface portion **181***a* provided on the rear-end member **171** and a second tapered surface portion **181***b* provided on the leading-end member **172**. The first tapered surface portion **181***a* has a substantially mortar shape an inner diameter of which increases toward a lower side (nozzle side), and the second tapered surface portion **181***b* has a substantially conical shape an outer diameter of which increases toward the lower side.

[0129] When a male screw portion **180***b* of the leading-end member **172** is screwed into a female screw portion **180***a* of the rear-end member **171**, the second tapered surface portion **181***b* comes into close contact with the first tapered surface portion **181***a*. Since the second tapered surface portion **181***b* is in close contact with the first tapered surface portion **181***a*, the axial center of the leading-end member **172** is accurately restricted relative to the axial center of the rear-end member **171**. The inclination of the leading-end member **172** relative to the rear-end member **171** is accurately restricted.

[0130] In this Modification 2, as compared with the configuration including the inlay portion **182** of the embodiment, (a portion in which the male screw portion **180***b* and the second tapered surface portion **181***b* are formed of) the leading-end member **172** can be easily inserted into a concave portion (portion in which the female screw portion **180***a* and the first tapered surface portion **181***a* are formed) provided on a leading-end member side of the rear-end member **171**. The first tapered surface portion **181***a* can guide the male screw portion **180***b* to the female screw portion **180***a*. As a result, the leading-end member **172** can be easily attached to the rear-end member **171**.

[0131] Damage (wear, distortion) to the needle valve **17** can be suppressed as compared with a case where the axial center of the leading-end member **172** is accurately restricted relative to the axial center of the rear-end member **171** by light press-fitting of Modification 1. As a result, it is possible to suppress a decrease in restriction accuracy due to repeated attachment and detachment of the leading-end member **172**. Since each of the first tapered surface portion **181***a* and the second tapered surface portion **181***b* is a surface inclined relative to a Z direction, dirt adhered to the tapered surface portion is likely to fall. Therefore, as compared with a configuration in which seat surfaces orthogonal to the Z direction are brought into close contact with each other to perform the inclination restriction with high accuracy, there is an advantage that the accuracy of the inclination restriction due to the adhesion of dirt is less likely to decrease, and the dirt is easily removed by cleaning.

[0132] In contrast, the configuration of the embodiment in which the inlay portion **182** and the inclination restrictor **183** are provided has an advantage that high accuracy can be obtained by simple processing and manufacturing cost can be reduced as compared with the tapered portion.

Modification 3

[0133] FIGS. **16**A and **16**B are schematic configuration diagrams illustrating a third modification of the present embodiment.

[0134] As illustrated in FIGS. **16**A and **16**B, in Modification 3, a seal portion **187***b* for sealing between a storage **110** and a liquid chamber **16** and a sealing portion **187***a* for sealing a nozzle **14** are integrally molded with a leading-end member **172**. The seal portion **187***b* of the leading-end member **172** illustrated in FIG. **16**A is an O-ring type that abuts an inner wall surface of a housing **11** and slides on the inner wall surface of the housing. In contrast, the seal portion **187***b* of FIG. **16**B is a diaphragm type an end portion of which is interposed between a main body housing **11***a* and a nozzle housing **11***b*.

[0135] The seal portion **187***b* and the sealing portion **187***a* are integrally molded with the leading-end member by insert-molding rubber and resin using a main body of the leading-end member **172** made of metal as a cored bar. Since the seal portion **187***b* is integrally molded with the main body of the leading-end member **172**, the center of the seal portion **187***b* can conform to the center of the leading-end member **172** with high accuracy, and an abutting pressure with the housing inner wall surface can be made uniform. As a result, it is possible to suppress a variation in sliding resistance relative to the housing inner wall surface and a variation in elastic deformation of the seal portion, to satisfactorily open and close the needle valve, and to satisfactorily seal with the housing inner wall surface.

[0136] For example, even in the leading-end member having a configuration not including a sealing member **173** illustrated in FIGS. **6**A and **6**B, the seal portion **187***b* for sealing between the storage **110** and the liquid chamber **16** may be integrally molded with the main body of the leading-end member **172** by insert molding. Even in this case, the variation in sliding resistance relative to the housing inner wall surface and the variation in elastic deformation of the seal portion can be suppressed.

[0137] However, in a case where the nozzle is sealed with the main body of the leading-end member made of metal, progress of wear of the needle leading-end member is slower than progress of wear of the seal portion made of rubber or resin. Therefore, as for the leading-end member not including the sealing portion made of rubber or resin on the needle leading-end member, it is preferable to configure that an O-ring **22** and a diaphragm seal **122** are held and only the O-ring **22** and the diaphragm seal **122** can be replaced.

[0138] The liquid discharge head includes: a liquid chamber to store a liquid discharged from the nozzle; a mover storage to store the mover; a first seal to seal a portion between the liquid chamber and the mover storage; and a second seal at a leading end of the leading-end member to seal the nozzle, and the first seal and the second seal are formed as a single member.

Modification 4

[0139] FIG. **17** is a schematic configuration diagram illustrating a fourth modification of the present embodiment.

[0140] As illustrated in FIG. **17**, in this Modification 4, a diaphragm seal **122** for sealing between a storage **110** and a liquid chamber **16** is attached to a lower end of a main body housing **11***a*. An edge of a hole through which a needle valve **17** penetrates of the diaphragm seal **122** is interposed to be secured by a leading-end member **172** and a rear-end member **171**. Accordingly, when the leading-end member **172** is attached to the rear-end member **171**, the edge of the hole through which the needle valve **17** penetrates of the diaphragm seal **122** can be secured to the needle valve. Therefore, the diaphragm seal **122** is easily secured to the needle valve **17**.

[0141] The liquid discharge head includes: a housing to house the needle valve; a mover storage to store the mover; a liquid chamber to store a liquid discharged from the nozzle; a diaphragm seal having a through hole through which the needle valve is penetrable. The diaphragm seal has: a peripheral portion secured to the housing; and an inner edge portion of the through hole secured between the leading-end member and the rear-end member of the needle valve, and the diaphragm seal seals a portion between the liquid chamber and the mover storage.

[0142] FIGS. **18**(*a*) to **18**(*d*) are diagrams illustrating an example of a diaphragm interposing structure of the needle valve **17**.

[0143] In FIGS. **18**(*a*) and **18**(*b*), a ring-shaped cutout **188***a* is provided on an end portion of a first seat surface **183***a* of the rear-end member **171**, and a ring-shaped protrusion **188***b* is provided on an end portion of a second seat surface **183***b* of the leading-end member **172**.

[0144] The edge of the hole, through which the needle valve **17** penetrates, of the diaphragm seal **122** is located in the cutout **188***a* on the end portion of the first seat surface **183***a*, and a position of the hole, through which the needle valve **17** penetrates, of the diaphragm seal **122** is restricted. As illustrated in FIG. **18**(*b*), when the leading-end member **172** is attached to the rear-end member **171**, the edge of the hole through which the needle valve **17** penetrates of the diaphragm seal **122** is crushed by the ring-shaped protrusion **188***b*. As a result, the edge of the hole through which the needle valve **17** penetrates of the diaphragm seal **122** is interposed to be secured by the leading-end member **172** and the rear-end member **171**, and sealing is performed.

[0145] In FIGS. **18**(*c*) and **18**(*d*), the edge of the hole through which the needle valve **17** penetrates of the diaphragm seal **122** is crushed by a ring-shaped washer **188***c*, and the edge of the hole is interposed between the leading-end member **172** and the rear-end member **171** via the washer **188***c* to perform sealing.

[0146] In a configuration illustrated in FIGS. **18**(*a*) and **18**(*b*), when the leading-end member **172** is attached to the rear-end member **171** by screwing, the protrusion **188***b* rotates together with the leading-end member **172**. Therefore, a force in a rotation direction is applied to the diaphragm seal **122**, and the diaphragm seal **122** might be twisted. In contrast, as illustrated in FIGS. **18**(*c*) and **18**(*d*), by using the washer **188***c*, it is possible to suppress the washer **188***c* from rotating together with the leading-end member **172** when the leading-end member **172** is screwed. As a result, it is possible to suppress the diaphragm seal **122** from being twisted.

Modification 5

[0147] FIG. **19** is a schematic configuration diagram illustrating a fifth modification of the present embodiment.

[0148] As illustrated in FIG. **19**, in Modification 5, a connection portion between a leading-end member **172** and a rear-end member **171** is located in a liquid chamber **16**.

[0149] As illustrated in FIG. **19**, by configuring such that the connection portion between the leading-end member **172** and the rear-end member **171** is located in the liquid chamber **16**, a length of the leading-end member **172** can be shortened. As a result, it is possible to suppress positional shift between the axial center of the needle leading-end member and the center of the nozzle **14** when the leading-end member **172** is inclined relative to the rear-end member **171**.

[0150] FIG. **20** is a schematic diagram of a needle valve **17** in a configuration of Modification 5.

[0151] As illustrated in FIG. **20**, an O-ring **22** that seals between the liquid chamber **16** and a storage **110** is held by the rear-end member **171**. A ring-shaped cutout is formed on an end portion of a second seat surface **183***b* of the leading-end member **172**, and a valve connection seal **189** (O-ring) is held by the cutout. When the leading-end member **172** is attached (screwed) to the rear-end member **171**, the valve connection seal **189** abuts a first seat surface **183***a* of the rear-end member **171** and is crushed. As a result, the connection portion between the leading-end member **172** and the rear-end member **171** is sealed by the valve connection seal **189**.

[0152] In this manner, since the connection portion between the leading-end member **172** and the rear-end member **171** is sealed with the valve connection seal **189**, it is possible to prevent liquid in the liquid chamber **16** from entering a screw portion **180**, an inlay portion **182**, and an inclination restrictor **183**. As a result, it is possible to suppress dirt of the screw portion **180**, the inlay portion **182**, and the inclination restrictor **183**, and the leading-end member **172** can be easily attached to and detached from the rear-end member **171**.

[0153] The liquid discharge head **10** described above is of a valve jet type, and can discharge a highly viscous liquid or a large droplet (having a diameter of several tens to several hundred μm) toward a discharge target at a distance (several tens mm ahead). The nozzle diameter can be increased, and liquid containing a material having a large particle diameter can be satisfactorily discharged. In this manner, since liquid having high viscosity can be discharged, the liquid discharge head **10** described above is suitable for painting a vehicle body of a vehicle or a truck, a body of an aircraft, a wall surface of a building, and a road surface, and printing an image. This can also be suitably used for forming an electrode of a lithium ion battery mounted on a vehicle body.

[0154] Hereinafter, an example of a liquid discharge apparatus including the above-described liquid discharge head **10** will be described.

[0155] FIG. **21** is a schematic configuration diagram of an inkjet printer **810** as a liquid discharge apparatus, and FIGS. **22**A and **22**B are perspective views illustrating an arrangement example of the inkjet printer **810** relative to an automobile U**1**.

[0156] As illustrated in FIG. **21**, the inkjet printer **810** is provided with a liquid discharge unit **100** provided with a liquid discharge head, and a camera **812** as an image capturing unit arranged in the vicinity of the liquid discharge unit **100**. An X-Y table **811** as a scan moving mechanism that moves the liquid discharge unit **100** and the camera **812** in the X direction and the Y direction is provided.

[0157] The inkjet printer **810** is provided with a controller **600**. The controller **600** operates the X-Y table **811** on the basis of image editing software S for editing an image captured by the camera **812** and a control program set in advance to discharge ink from the liquid discharge unit **100** and control printing on a printed surface. The inkjet printer **810** is provided with a drive unit **620** that positions the camera **812** and the liquid discharge unit **100** at predetermined positions on the basis of the control from the controller **600** to perform an operation such as image capturing and printing. The X-Y table **811** serves as a scanner to move the liquid discharge head. Thus, the liquid discharge apparatus includes the liquid discharge head and the scanner to move the liquid discharge head.

[0158] The liquid discharge unit **100** is provided with a plurality of liquid discharge heads that discharges ink toward a surface to be coated of the automobile U**1** (refer to FIGS. **22**A and **22**B) as an object to be coated. Note that, the term "ink" as used herein also includes "paint". A nozzle surface of the liquid discharge head is parallel to an X-Y plane formed by movement of the X-Y table **811**, and ink dots discharged from each nozzle are discharged in the Z direction perpendicular to the X-Y plane.

[0159] Each of the plurality of liquid discharge heads included in the liquid discharge unit **100** is coupled to an ink tank of a predetermined color, and the ink tank is pressurized by a pressurizer. The ink in the ink tank is supplied from the supply port **12** (refer to FIG. **1**) of the liquid discharge head and ejected from the recovery port **13** (refer to FIG. **1**) of the liquid discharge head. The ink ejected from the recovery port **13** is recovered in the ink tank.

[0160] When a distance between the nozzle surface of the liquid discharge head and the print surface of the automobile U**1** is about 20 cm, the ink dots can be discharged onto the print surface of the automobile U**1** without any problem.

[0161] The X-Y table **811** is provided with a Y-axis rail **813** formed with a linear moving mechanism, and an X-axis moving mechanism **814** that moves the Y-axis rail **813** in the X direction while holding the Y-axis rail **813** with two arms.

[0162] The liquid discharge unit **100** and the camera **812** to be described later are attached to a slider held by the Y-axis rail **813**. The X-axis moving mechanism **814** is provided with a shaft **815**, and the shaft **815** is held by a robot arm **816**. The robot arm allows the liquid discharge unit **100** to be freely arranged at a predetermined position where printing is to be performed on the automobile U**1**.

[0163] For example, this can be arranged above the automobile U**1** as illustrated in FIG. **22**A, or can be arranged at a lateral position of the automobile U**1** as illustrated in FIG. **22**B by the robot arm **816**. Note that, the operation of the robot arm **816** is controlled on the basis of a program stored in advance in the controller **600**.

[0164] The camera **812** is arranged on the slider of the Y-axis rail **813** in the vicinity of the liquid discharge unit **100**, and captures images in a predetermined range of the printed surface of the automobile U**1** at constant minute intervals while moving in the X-Y direction. The camera **812** is a so-called digital camera, and as described above, specifications of a lens that can capture a plurality of subdivided images in a predetermined range of the printed surface, and specifications of resolution are appropriately selected. The plurality of subdivided images of the printed surface are continuously and automatically captured by the camera **812** according to a program provided in advance in the controller **600**.

[0165] The controller **600** is provided with a storage device that records and stores various programs, data of captured images, and data of images to be printed, and a central processing unit that executes various types of processing according to the programs. The controller **600** is configured by a so-called microcomputer provided with an input device such as a keyboard and a mouse, and a DVD player as necessary.

[0166] The inkjet printer **810** is further provided with a monitor **610**, and displays input information to the controller **600** and a processing result by the controller **600**.

[0167] The controller **600** performs image processing on a plurality of pieces of subdivided image data captured by the camera **812** using image processing software, and generates a composited print surface obtained by projecting the printed surface of the automobile U**1**, which is not a flat surface, onto a flat surface to be described later. The controller **600** edits an image to be drawn to generate an edited image to be drawn in the following manner. That is, this superimposes the image to be drawn, which is the image that should be printed so as to be continuous to the image already printed on the printed surface on the composited print surface, and edits the image to be drawn so as to be continuous to an edge portion of the printed image.

[0168] For example, as for the image to be drawn, by editing (deforming) the image to be drawn so as to be aligned with the composited print surface such that a non-printed region is not formed between the same and an adjacent image, the edited image to be drawn is generated. Printing is actually performed by the liquid discharge unit

100 on the basis of the edited image to be drawn. As a result, the print image can be printed without a gap from the printed print image. Note that, the operation of capturing the plurality of subdivided images by the camera **812** and printing by discharging ink from the nozzle of each liquid discharge head of the liquid discharge unit **100** is performed by the drive unit **620** of which operation is controlled by the controller **600**.

[0169] Next, an electrode manufacturing apparatus will be described as another example of a liquid discharge apparatus provided with the liquid discharge head of the present embodiment.

[0170] FIG. **23** is a schematic perspective view illustrating an example of an electrode manufacturing apparatus **850**.

[0171] The electrode manufacturing apparatus **850** illustrated in FIG. **23** is an apparatus that manufactures a negative electrode used for an electrochemical element such as a primary battery, a secondary battery, a capacitor, or a condenser, for example. The electrode manufacturing apparatus **850** is provided with a liquid discharge unit **852** including the liquid discharge head **10** of the present embodiment, and discharges liquid to a negative electrode substrate U**4** on a stage **851** using an inkjet method.

[0172] A liquid tank **853** stores a liquid composition D**1** for forming a negative electrode mixture layer **855**, and supplies the liquid composition D**1** from the liquid tank **853** to the liquid discharge unit **852** via a tube **854**.

[0173] FIG. **24** is a schematic perspective view illustrating another example of the electrode manufacturing apparatus **850**.

[0174] The electrode manufacturing apparatus **850** illustrated in FIG. **24** winds a strip-shaped negative electrode substrate U**4** made of stainless steel and copper around a cylindrical core, and loads the same onto a feeding roller **857** and a winding roller **859** with a surface on which the negative electrode mixture layer **855** is to be formed facing upward. The feeding roller **857** and the winding roller **859** rotate counterclockwise, and the negative electrode substrate U**4** moves from right to left in the drawing.

[0175] The liquid tank **853** stores the liquid composition D**1** for forming the negative electrode mixture layer **855**, and supplies the liquid composition D**1** from the liquid tank **853** to the liquid discharge unit **852** via the tube **854**. The liquid discharge unit **852** is installed above the negative electrode substrate U**4** between the feeding roller **857** and the winding roller **859**. A plurality of liquid discharge units **852** may be installed in a direction substantially parallel or perpendicular to a conveyance direction of the negative electrode substrate U**4**.

[0176] The feeding roller **857** and the winding roller **859** convey the negative electrode substrate U**4** on which the liquid composition D**1** is placed to a dryer **858**. As a result, the liquid composition D**1** on the negative electrode substrate U**4** is dried by the dryer **858** to become the negative electrode mixture layer **855**, and a negative electrode **856** obtained by binding the negative electrode mixture layer **855** on the negative electrode substrate as the negative electrode substrate U**4** is formed. Thereafter, the negative electrode **856** is cut into a desired size by punching.

[0177] The dryer **858** is not particularly limited as long as this does not come into direct contact with the liquid composition D**1**, and can be appropriately selected. Examples thereof include a resistance heater, an infrared heater, and a fan heater, for example. The dryer **858** may be installed on either the upper or lower side of the negative electrode substrate U**4**. A plurality of dryers **858** may be provided.

[0178] In the above description, the apparatus for manufacturing the negative electrode used for the electrochemical element has been described as an example, but it is of course possible to apply to an apparatus for manufacturing a positive electrode. In a case of manufacturing the positive electrode, the negative electrode substrate is replaced with a positive electrode substrate, and the liquid composition D**1** for forming the negative electrode mixture layer **855** is replaced with a liquid composition for forming a positive electrode mixture layer. The configuration other than the electrode mixture layer in the electrochemical element is not particularly limited, and a known configuration can be appropriately selected, and examples thereof include a positive electrode, a negative electrode, and a separator, for example.

[0179] By providing an external tank and controlling a valve, it is also possible to supply the liquid composition D**1** from the external tank **860** to the liquid tank **853** when the liquid composition D**1** in the liquid tank **853** is reduced.

[0180] Although preferred embodiments of the present embodiment have been described above, the present embodiment is not limited to such specific embodiments, and unless particularly limited in the above description, various modifications and changes can be made without departing from the scope of the gist of the present embodiment recited in claims.

[0181] In the above description, an example in which the needle valve **17** is opened and closed by the piezoelectric element **18** has been described. However, the present embodiment is not limited thereto, and the needle valve **17** may be opened and closed by pneumatic pressure or hydraulic pressure. In this case, the drive pulse generated by the drive controller **40** is a drive waveform for driving the pressurizing mechanism by pneumatic pressure or hydraulic pressure with a set pressure.

[0182] In the present application, the "liquid discharge apparatus" is an apparatus provided with the liquid discharge head or the liquid discharge unit obtained by integrating functional parts and mechanisms with the liquid discharge head, the apparatus that drives the liquid discharge head to discharge the liquid. The integration includes a combination in which the liquid discharge head and the functional parts and mechanisms are secured to each other through fastening, bonding, and engaging, and a combination in which one is movably held by the other. The liquid discharge head may be detachably attached to the functional parts and mechanisms.

[0183] There also is the liquid discharge unit in which the liquid discharge head and the head tank are integrated and the liquid discharge unit in which the liquid discharge head and the head tank are connected to each other with a tube to be integrated. Here, a unit including a filter may be added between the liquid discharge head and the head tank of the liquid discharge unit.

[0184] Examples of the liquid discharge unit include the unit in which the liquid discharge head and a carriage are integrated, and the liquid discharge unit in which the liquid discharge head, the carriage, and the scan moving mechanism are integrated. Examples of the liquid discharge unit include the liquid discharge unit in which the liquid discharge head is movably held by a guide member that forms a part of the scan moving mechanism, and the liquid discharge head and the scan moving mechanism are integrated.

[0185] Examples of the liquid discharge unit include the liquid discharge unit in which a cap member as a part of a maintenance recovery mechanism is secured to the carriage to which the liquid discharge head is attached, and the liquid discharge head, the carriage, and the maintenance recovery mechanism are integrated. Examples of the liquid discharge unit include the liquid discharge unit in which a tube is connected to the liquid discharge head to which the head tank or flow path parts are attached, and the liquid discharge head and a supply mechanism are integrated. Liquid in a liquid reservoir source is supplied to the liquid discharge head through this tube.

[0186] The scan moving mechanism includes a guide member single body. The supply mechanism includes a tube single body and a loading unit single body.

[0187] The "liquid discharge apparatus" includes not only an apparatus that can discharge liquid to a material on which liquid can adhere but also an apparatus that discharges liquid toward gas or into liquid.

[0188] The "liquid discharge apparatus" may include a unit regarding feeding, conveyance, and ejection of a material on which liquid can adhere, a pretreatment apparatus, and a post-treatment apparatus.

[0189] The "liquid discharge apparatus" may be, for example, an image forming apparatus to form an image on a sheet by discharging ink, or a stereoscopic fabrication apparatus (three-dimensional fabrication apparatus) to discharge fabrication liquid to a powder layer in which powder material is formed in layers to fabricate a stereoscopic fabrication object (three-dimensional fabrication object).

[0190] The "liquid discharge apparatus" is not limited to an apparatus to discharge liquid to visualize meaningful images, such as letters or figures. For example, an apparatus to form meaningless images or fabricate three-dimensional images is also included.

[0191] The "material on which liquid can adhere" is the above-described liquid discharge target, and means a material to which the liquid can at least temporarily adhere and to which the liquid adheres and adheres, a medium to which the liquid adheres and permeates. Specific examples include recording media such as a sheet, recording paper, a recording sheet, a film, and a cloth, electronic components such as an electronic substrate and a piezoelectric element, and media such as a powder layer, an organ model, and a testing cell, and include any material on which liquid can adhere, unless particularly limited.

[0192] Examples of the "material on which liquid can adhere" include any materials on which liquid can adhere even temporarily such as paper, thread, fiber, fabric, leather, metal, plastic, glass, wood, and ceramic.

[0193] The "liquid discharge apparatus" may be an apparatus in which the head unit and the material on which the liquid can adhere move relative to each other; however, the liquid discharge apparatus is not limited to this. Specific examples include a serial type apparatus that moves the head unit, and a line type apparatus that does not move the head unit.

[0194] Examples of the "liquid discharge apparatus" further include a treatment liquid applying apparatus to discharge treatment liquid to a sheet for applying the treatment liquid to a sheet surface to reform the sheet surface. There also is an injection granulation apparatus for injecting composition liquid in which raw materials are dispersed in a solution through a nozzle hole to granulate fine particles of the raw material.

[0195] According to the present embodiment, the leading-end member can be accurately attached to the rear-end member.

[0196] The above-described embodiments are limited examples, and the present disclosure includes, for example, the following aspects having advantageous effects.

Aspect 1

[0197] According to Aspect 1, in a liquid discharge head including a needle valve **17** that opens and closes a nozzle **14**, and a mover such as a moving mechanism **58** that moves the needle valve **17** between a closed position at which the nozzle **14** is closed and an open position at which the nozzle **14** is opened, the needle valve **17** including a rear-end member **171** coupled to the mover and a leading-end member **172** attached to the rear-end member **171**, an axial force generator such as a screw portion **180** that generates an axial force for making the leading-end member **172** abut the rear-end member **171** is included, the needle valve **17** includes, in addition to the axial force generator, an axial center restrictor such as an inlay portion **182** that restricts a position of an axial center of the leading-end member **172** relative to an axial center of the rear-end member **171**, and an inclination restrictor **183** that restricts inclination of the leading-end member **172** relative to the rear-end member **171**.

[0198] By generating the axial force by the axial force generator such as the screw portion **180** and cause the leading-end member **172** to contact with the rear-end member **171**, the leading-end member **172** can be attached to the rear-end member **171** without play. For example, the screw portion disclosed in Japanese Patent No. 3247123 is used as the axial force generator, and the axial force is generated by screwing with the screw portion, so that the leading-end member can be attached to the rear-end member without play relative to the rear-end member.

[0199] However, it is difficult to accurately process a thread shape of the screw of the screw portion and the pitch of the screw. As a result, the leading-end member might be attached to the rear-end member in a state in which the axial center of the leading-end member is significantly shifted in a direction orthogonal to the axial direction relative to the axial center of the rear-end member, or the leading-end member is inclined relative to the rear-end member. In this manner, in the screw portion as the axial force generator, the position of the axial center of the leading-end member relative to the axial center of the rear-end member and the inclination of the leading-end member relative to the rear-end member cannot be accurately restricted, and there has been a problem that the attaching accuracy of the leading-end member to the rear-end member is poor.

[0200] In contrast, in Aspect 1, the axial center restrictor that restricts the position of the axial center of the leading-end member relative to the axial center of the rear-end member and the inclination restrictor that restricts the inclination of the leading-end member relative to the rear-end member are provided separately from the axial force generator. In this manner, by providing these restrictors separately from the axial force generator having a complicated shape such as a screw shape in which accuracy is difficult to obtain in order to generate the axial force, the axial center restrictor and the inclination restrictor can be formed into a shape such as a circular arc surface or a flat surface in which accuracy is easily obtained, and it is possible to attach with the position relative to the axial center of the rear-end member and the inclination of the leading-end member relative to the rear-end member accurately restricted. As a result, the leading-end member can be accurately attached to the rear-end member.

Aspect 2

[0201] According to Aspect 2, in the liquid discharge head of Aspect 1, the inclination restrictor **183** includes a first seat surface **183***a* provided on the rear-end member **171** and perpendicular to an axial direction of the rear-end member **171**, and a second seat surface **183***b* provided on the leading-end member **172** and perpendicular to an axial direction of the leading-end member **172**, and the second seat surface **183***b* is brought into close contact with the first seat surface **183***a* by the axial force generated by the axial force generator such as the screw portion **180**.

[0202] According to this, as described in the embodiment, the second seat surface **183***b* and the first seat surface **183***a* are flat surfaces, and the squareness relative to the axial direction such as the Z direction can be accurately obtained by cutting. Accordingly, by bringing the second seat surface **183***b* into close contact with the first seat surface **183***a*, the inclination of the leading-end member **172** relative to the rear-end member can be restricted with high accuracy. As a result, the leading-end member **172** can be attached to the rear-end member with satisfactorily suppressed inclination, and positional shift between the center of the needle valve leading-end member and the nozzle center can be suppressed. As a result, the discharge bending and sealing failure of the nozzle can be satisfactorily suppressed.

Aspect 3

[0203] According to Aspect 3, in the liquid discharge head of Aspect 1 or 2, the axial center restrictor such as the inlay portion **182** includes a fitting hole **182***a* provided on the rear-end member **171** and a fitting portion **182***b* provided on the leading-end member **172** and fitted into the fitting hole **182***a*.

[0204] According to this, as described in the embodiment, the inner diameter dimension of the fitting hole **182***a* and the outer diameter dimension of the fitting portion can be easily and accurately formed by cutting. As a result, by fitting the fitting portion **182***b* into the fitting hole **182***a*, the axial center of the leading-end member can be accurately restricted relative to the axial center of the rear-end member.

Aspect 4

[0205] According to Aspect 4, in the liquid discharge head of Aspect 3, the fitting portion **182***b* includes an introduction portion **182***b***1** having an outer diameter smaller than an inner diameter of the fitting hole **182***a*, and a final fitting portion **182***b***2** having an outer diameter larger than the inner diameter of the fitting hole **182***a*.

[0206] According to this, as described in Modification 1, since the introduction portion **182***b***1** having an outer diameter smaller than the inner diameter of the fitting hole **182***a* is included, the fitting portion **182***b* can be easily fitted into the fitting hole **182***a*, and the attaching workability of the leading-end member **172** to the rear-end member **171** can be improved.

[0207] By including the final fitting portion **182***b***2** having an outer diameter larger than the inner diameter of the fitting hole **182***a*, the final fitting portion **182***b***2** is press-fitted into the fitting hole **182***a*. As a result, the position of the axial center of the leading-end member can be accurately aligned with the position of the axial center of the rear-end member. Since the press-fitting is performed only at last, deterioration in attaching workability of the leading-end member **172** relative to the rear-end member **171** can be suppressed.

Aspect 5

[0208] According to Aspect 5, in the liquid discharge head of Aspect 1, the rear-end member **171** and the leading-end member **172** include the first tapered surface portion **181***a* and the second tapered surface portion **181***b* serving as the axial center restrictor and the inclination restrictor that widen toward a nozzle side in a cross section parallel to an axial direction of the needle valve **17**, and the tapered surface portion such as a second tapered surface portion **181***b* of the leading-end member **172** is brought into close contact with the tapered surface portion such as a first tapered surface portion **181***a* of the rear-end member **171** by the axial force generated by the axial force generator such as the screw portion **180**.

[0209] According to this, as described in Modification 2, by bringing the tapered surface portion such as the second tapered surface portion **181***b* of the leading-end member **172** into close contact with the tapered surface portion such as the first tapered surface portion **181***a* of the rear-end member **171**, it is possible to accurately restrict the inclination of the leading-end member and the axial center of the leading-end member.

Aspect 6

[0210] According to Aspect 6, in the liquid discharge head of any one of Aspects 1 to 5, the leading-end member **172** holds a seal such as an O-ring **22** that seals between a liquid chamber **16** that stores liquid discharged from the nozzle **14**, and a mover storage such as a storage **110** that stores the mover such as the moving mechanism **58**.

[0211] According to this, as described in the embodiment, when the needle valve **17** is opened and closed, the seal such as the O-ring **22** that slides on the inner peripheral surface of the housing such as the housing to be worn can be replaced together with the leading-end member **172**.

Aspect 7

[0212] According to Aspect 7, in the liquid discharge head of Aspect 6, the seal such as the O-ring **22** is held on a leading-end member side of the needle valve **17** relative to the axial center restrictor such as the inlay portion **182** and the inclination restrictor **183**.

[0213] According to this, it is possible to prevent the liquid in the liquid chamber from entering the axial center restrictor such as the inlay portion **182** and the inclination restrictor **183**, and it is possible to prevent a decrease in accuracy due to dirt by the liquid. It is possible to prevent the occurrence of adherence due to liquid, and the leading-end member can be easily detached from the rear-end member.

Aspect 8

[0214] According to Aspect 8, in the liquid discharge head of any one of Aspects 1 to 7, a seal that seals between a liquid chamber **16** that stores liquid to be discharged from the nozzle **14** and a mover storage such as a storage **110** that stores the mover such as the moving mechanism **58** is integrally molded with a main body of the leading-end member **172**.

[0215] According to this, as described in Modification 3, the center of the main body of the leading-end member and the center of the seal portion can accurately conform to each other, and the abutting pressure of the seal portion with the housing can be made uniform. As a result, it is possible to suppress variations in sliding resistance of the seal portion with the housing and deformation of the seal.

Aspect 9

[0216] According to Aspect 9, in the liquid discharge head of any one of Aspects 1 to 5, a diaphragm seal **122** including a through hole, with an end portion secured to a housing such as a housing **11**, through which the needle valve **17** penetrates, with an edge portion of the through hole secured to the needle valve **17**, the diaphragm seal **122** that seals between a liquid chamber **16** and a mover storage such as a storage **110** that stores the mover such as the moving mechanism **58** is included, in which the edge portion of the through hole of the diaphragm seal **122** is interposed to be secured between the leading-end member **172** and the rear-end member **171**.

[0217] According to this, as described in Modification 4, when the leading-end member **172** is attached to the rear-end member **171**, the edge of the hole through which the needle valve **17** penetrates of the diaphragm seal **122** can be secured to the needle valve **17**, and the diaphragm seal **122** can be easily secured to the needle valve **17**.

[0218] As illustrated in FIGS. **18**(*a*) to **18**(*d*), the edge portion of the through hole of the diaphragm seal **122** can be interposed and secured with a simple structure.

Aspect 10

[0219] According to Aspect 10, in the liquid discharge head of any one of Aspects 1 to 5, a connection portion between the leading-end member **172** and the rear-end member **171** is located in a liquid chamber **16** that stores liquid to be discharged from the nozzle **14**, and a seal such as a valve connection seal **189** that seals the connection portion is provided. The leading-end member **172** is referred to also as “the leading-end member”.

[0220] According to this, as described in Modification 5, the axial direction (Z direction) length of the needle valve of the leading-end member **172** can be shortened as compared with a case where the connection portion between the leading-end member **172** and the rear-end member **171** is located in the mover storage such as the storage **110** that stores the mover such as the moving mechanism **58**. As a result, it is possible to suppress the shift between the axial center of the needle leading-end member and the center of the nozzle due to the inclination of the leading-end member relative to the rear-end member.

[0221] The seal such as the valve connection seal **189** can prevent the liquid from entering the attachment unit such as the screw portion **180**, the axial center restrictor such as the inlay portion **182**, and the inclination restrictor **183**, and can prevent the decrease in accuracy due to dirt by the liquid. It is possible to prevent the occurrence of adherence due to liquid, and the leading-end member can be easily detached from the rear-end member.

Aspect 11

[0222] According to Aspect 11, in the liquid discharge head of any one of Aspects 1 to 10, a member provided with the nozzle **14** (formed of a nozzle plate **15** and a nozzle housing **11***b* in the present embodiment) is configured to be attachable to and detachable from a main body housing such as a main body housing **11***a*.

[0223] According to this, as described in the embodiment, by removing the member provided with the nozzle **14** (in the present embodiment, formed of the nozzle plate **15** and the nozzle housing **11***b*) from the main body housing **11***a*, the leading-end member is exposed and the leading-end member can be easily replaced.

[0224] A combination of the leading-end member **172** that can satisfactorily seal and the member provided with the nozzle (nozzle) can be obtained according to the liquid to be discharged. This makes it possible to cope with various liquids.

Aspect 12

[0225] According to Aspect 12, in the liquid discharge head of any one of Aspects 1 to 11, the axial force generator has a screw structure, a magnet, a shrinking tube, or a bayonet structure.

[0226] According to this, as described in the embodiment, the axial force can be generated.

Aspect 13

[0227] According to Aspect 13, in a liquid discharge apparatus including a liquid discharge head **10**, the liquid discharge head of any one of Aspects 1 to 13 is used as the liquid discharge head **10**.

[0228] According to this, it is possible to satisfactorily seal the nozzle over time, and cope with various liquids.

[0229] The above-described embodiments are illustrative and do not limit the present invention. Thus, numerous additional modifications and variations are possible in light of the above teachings. For example, elements and/or features of different illustrative embodiments may be combined with each other and/or substituted for each other within the scope of the present invention.

1. A liquid discharge head comprising:

a needle valve to open and close a nozzle, the needle valve including:

a rear-end member; and

a leading-end member detachably attached to the rear-end member; and

a mover coupled to the rear-end member of the needle valve, the mover to move the needle valve, in an axial direction, between:

a closed position at which the needle valve contacts the nozzle to close the nozzle; and

an open position at which the needle valve is separated from the nozzle to open the nozzle,

wherein the needle valve further includes:

an axial force generator to generate an axial force to abut the leading-end member against the rear-end member;

an axial center restrictor to restrict a position of an axial center of the leading-end member relative to an axial center of the rear-end member; and

an inclination restrictor to restrict an inclination of the leading-end member relative to the rear-end member.

2. The liquid discharge head according to claim **1**, wherein the inclination restrictor includes:

a first seat surface on the rear-end member and perpendicular to the axial direction; and

a second seat surface on the leading-end member and perpendicular to the axial direction, and

the axial force generator generates the axial force to cause the second seat surface to contact with the first seat surface.

3. The liquid discharge head according to claim **1**, wherein the axial center restrictor includes:

a fitting hole in the rear-end member; and

a fitting portion in the leading-end member, and

the fitting portion is fitted into the fitting hole.

4. The liquid discharge head according to claim **3**, wherein the fitting portion includes:

an introduction portion having an outer diameter smaller than an inner diameter of the fitting hole; and

a final fitting portion having an outer diameter larger than the inner diameter of the fitting hole.

5. The liquid discharge head according to claim **1**, wherein each of the axial center restrictor and the inclination restrictor includes a tapered surface portion on each of the rear-end member and the leading-end member,

the tapered surface portion widens toward the nozzle in a cross-section parallel to the axial direction, and

the axial force generator generates the axial force to cause the tapered surface portion on the leading-end member to contact with the tapered surface portion on the rear-end member.

6. The liquid discharge head according to claim **1**, further comprising:

a liquid chamber to store a liquid discharged from the nozzle;

a mover storage to store the mover; and

a seal to seal a portion between the liquid chamber and the mover storage,

wherein the leading-end member holds the seal.

7. The liquid discharge head according to claim **6**, wherein the leading-end member holds the seal at a position closer to a leading-end side than the axial center restrictor and the inclination restrictor in the axial direction.

8. The liquid discharge head according to claim **1**, further comprising:

a liquid chamber to store a liquid discharged from the nozzle;

a mover storage to store the mover;

a first seal to seal a portion between the liquid chamber and the mover storage; and

a second seal at a leading end of the leading-end member to seal the nozzle,

wherein the first seal and the second seal are formed as a single member.

9. The liquid discharge head according to claim **1**, further comprising:

a housing to house the needle valve;

a mover storage to store the mover;

a liquid chamber to store a liquid discharged from the nozzle;

a diaphragm seal having a through hole through which the needle valve is penetrable,

wherein the diaphragm seal has:

a peripheral portion secured to the housing; and

an inner edge portion of the through hole secured between the leading-end member and the rear-end member of the needle valve, and

the diaphragm seal seals a portion between the liquid chamber and the mover storage.

10. The liquid discharge head according to claim **1**, further comprising:

a liquid chamber to store a liquid discharged from the nozzle;

a connection portion between the leading-end member and the rear-end member of the needle valve in the liquid chamber; and

a seal sealing the connection portion.

11. The liquid discharge head according to claim **1**, further comprising:

a housing to house the needle valve and the mover; and

a nozzle plate detachably attachable to the housing.

12. The liquid discharge head according to claim **1**, wherein the axial force generator has one of:

a screw structure;

a magnet;

a shrinking tube; or

a bayonet structure.

13. A liquid discharge apparatus comprising:

the liquid discharge head according to claim **1**; and

a scanner to move the liquid discharge head.

* * * * *