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(54) MAGNETIC CHUCK

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CPC *B23Q 3/1546* (2013.01); *H01F 7/0226* (2013.01)

(57) **ABSTRACT**

A cylinder member includes a piston assembly and a cylinder tube, and the piston assembly includes a permanent magnet. A holding force adjustment member includes an adjustment body fixed to the cylinder tube and an adjustment ring having a workpiece holding surface. The adjustment ring is screw-engaged with the adjustment body.

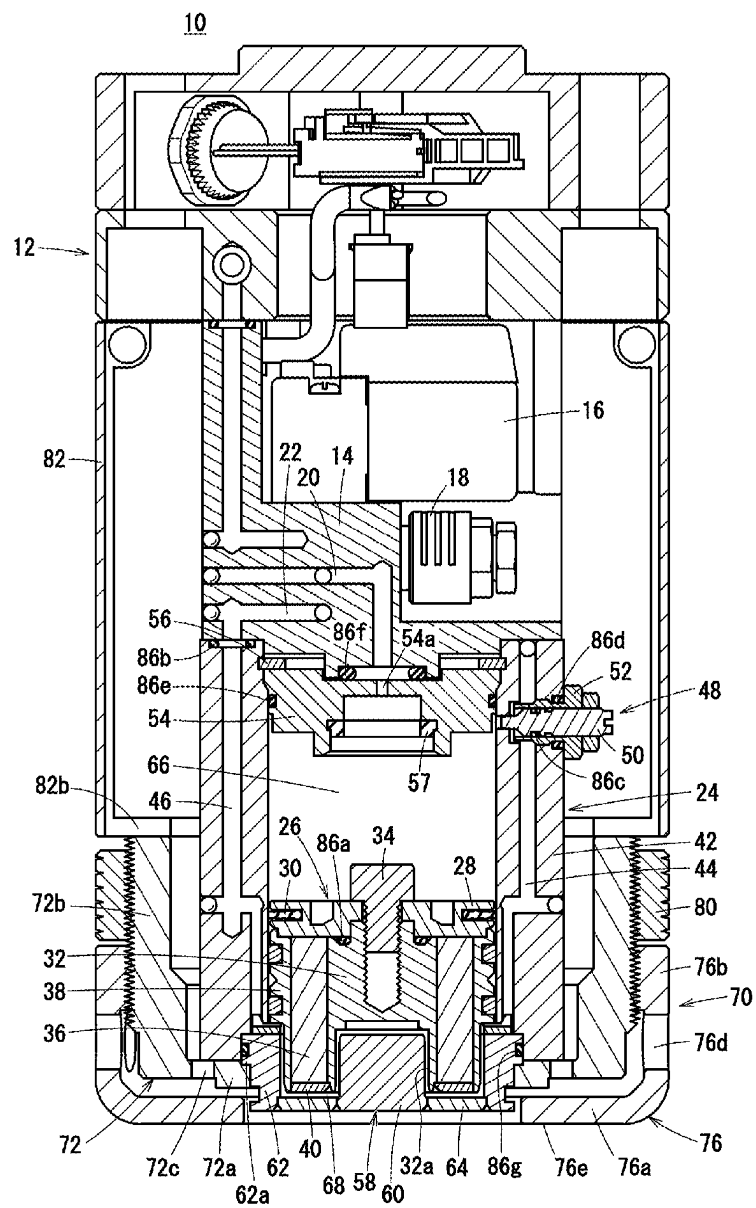
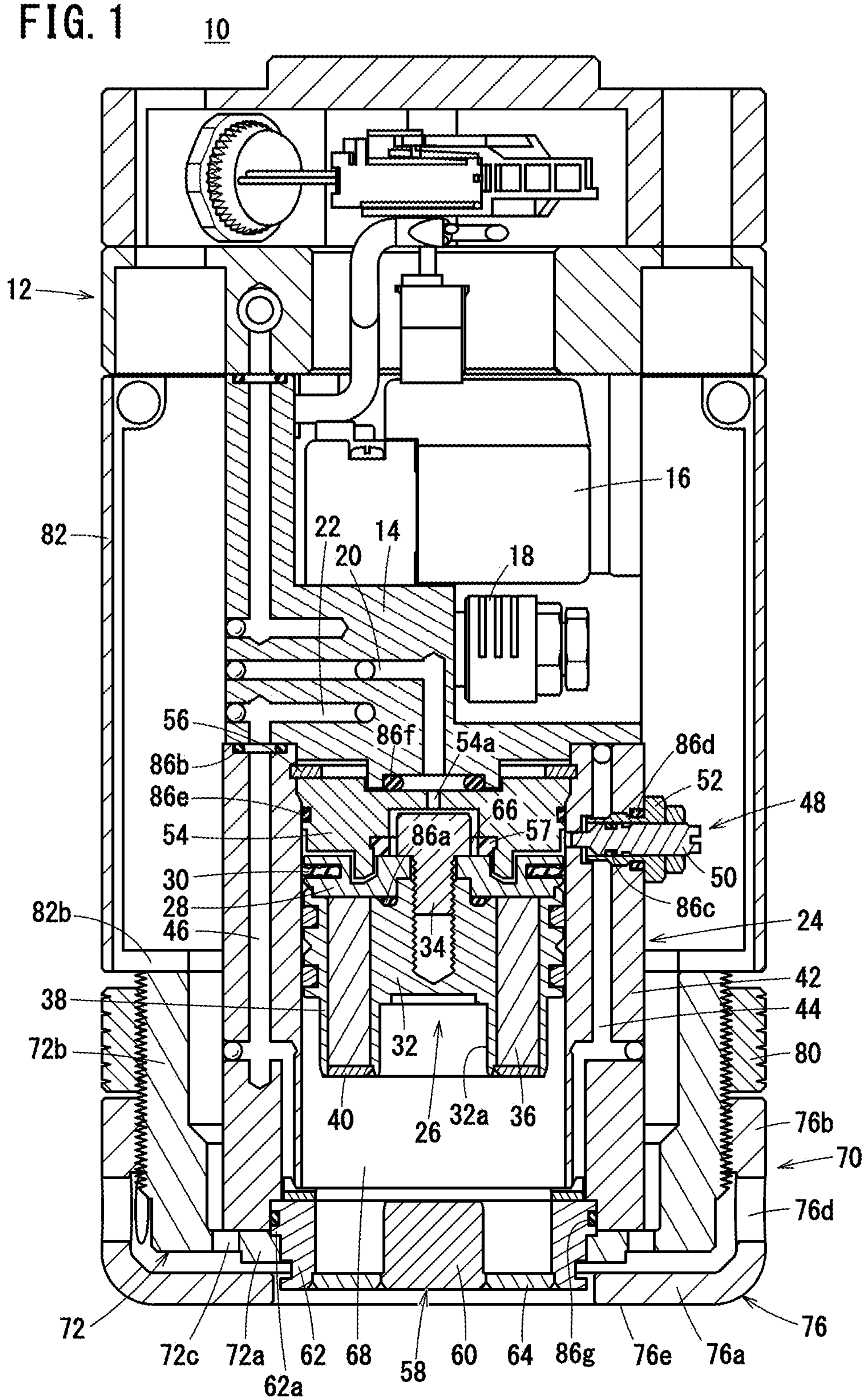


FIG. 1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72b
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26
32a
36
76b
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72c
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76e
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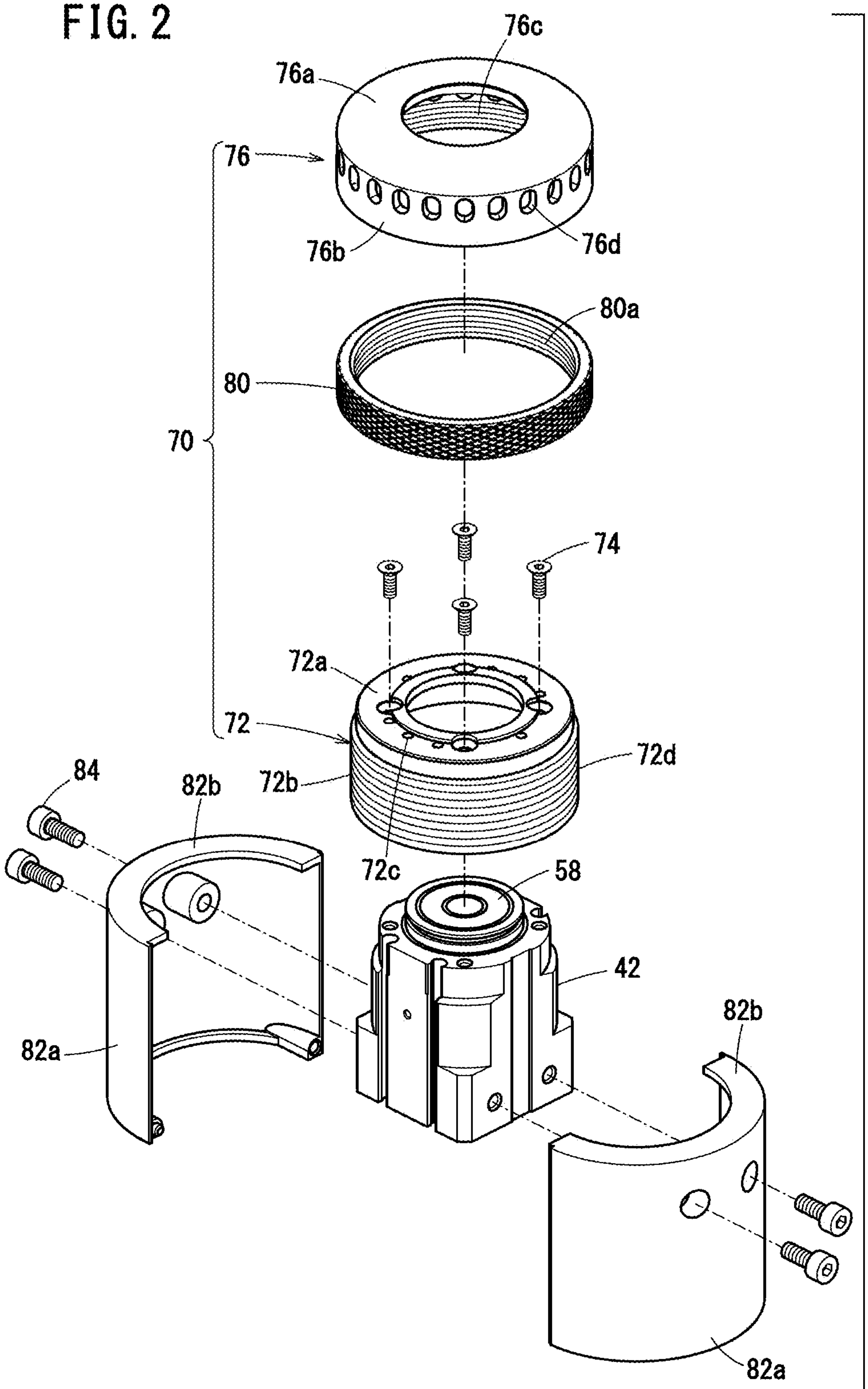
76
62a
58

FIG. 2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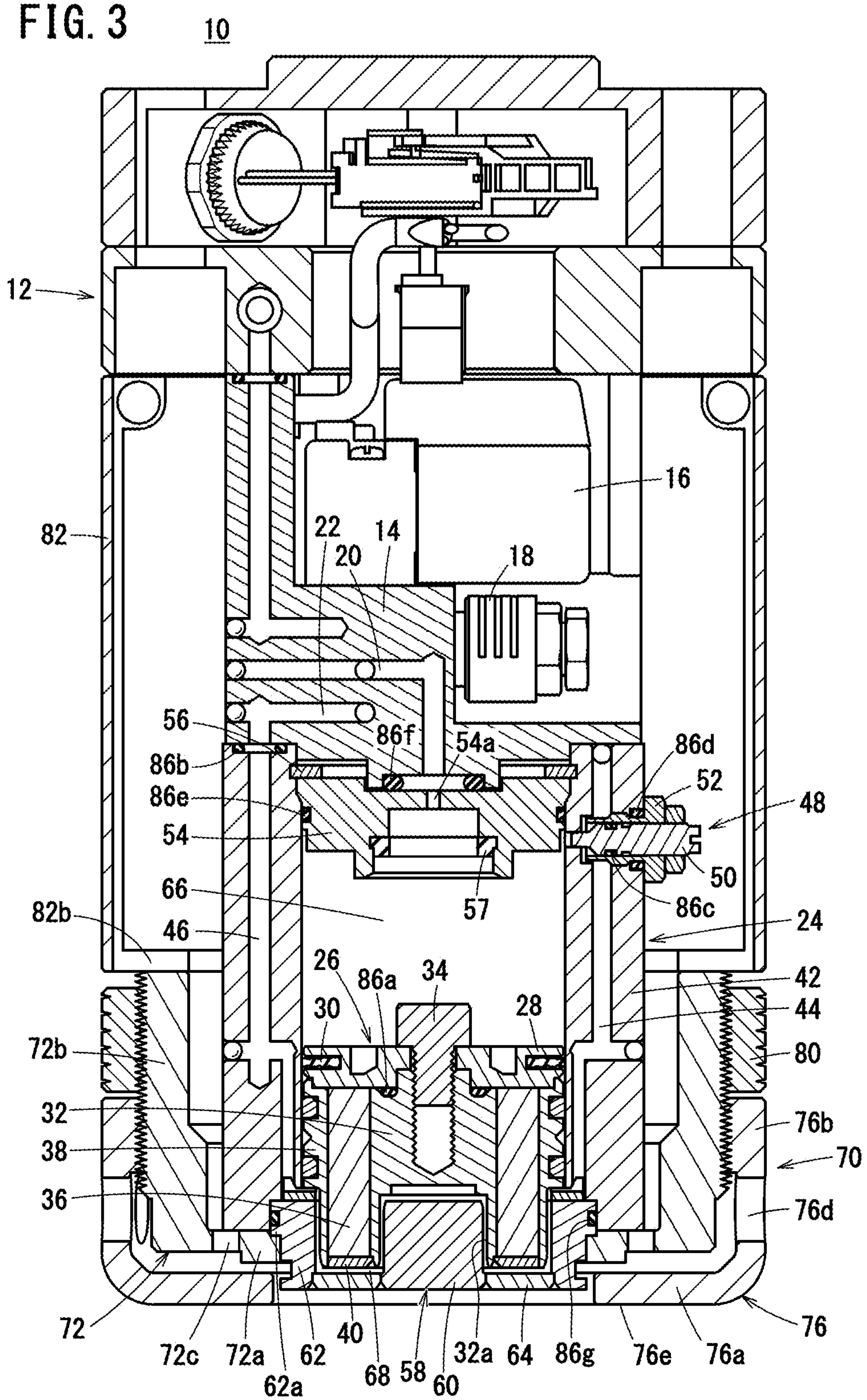
82a
82b
82a

FIG. 3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72b
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76b
38
70
36
76d
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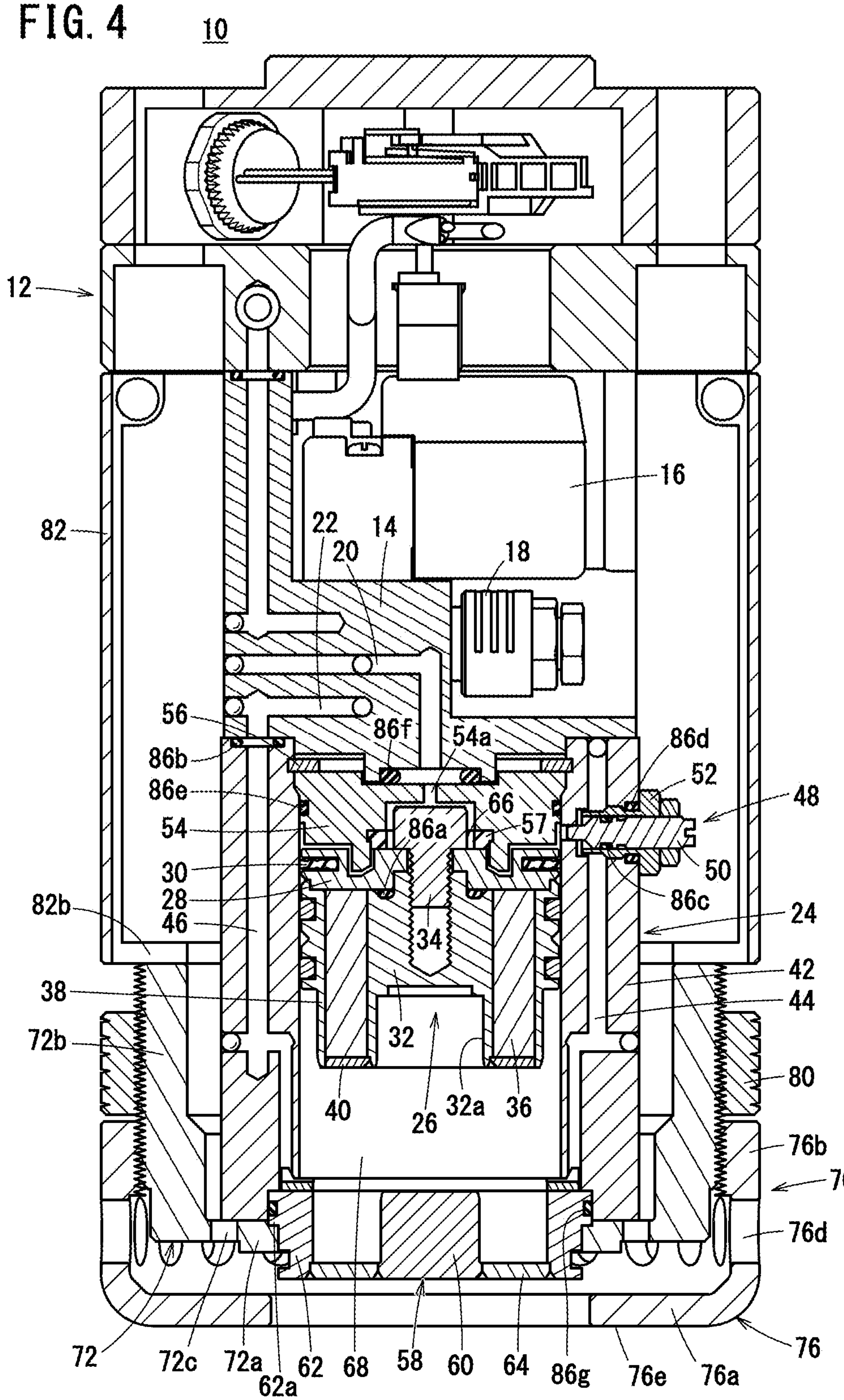
FIG. 4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36
76b
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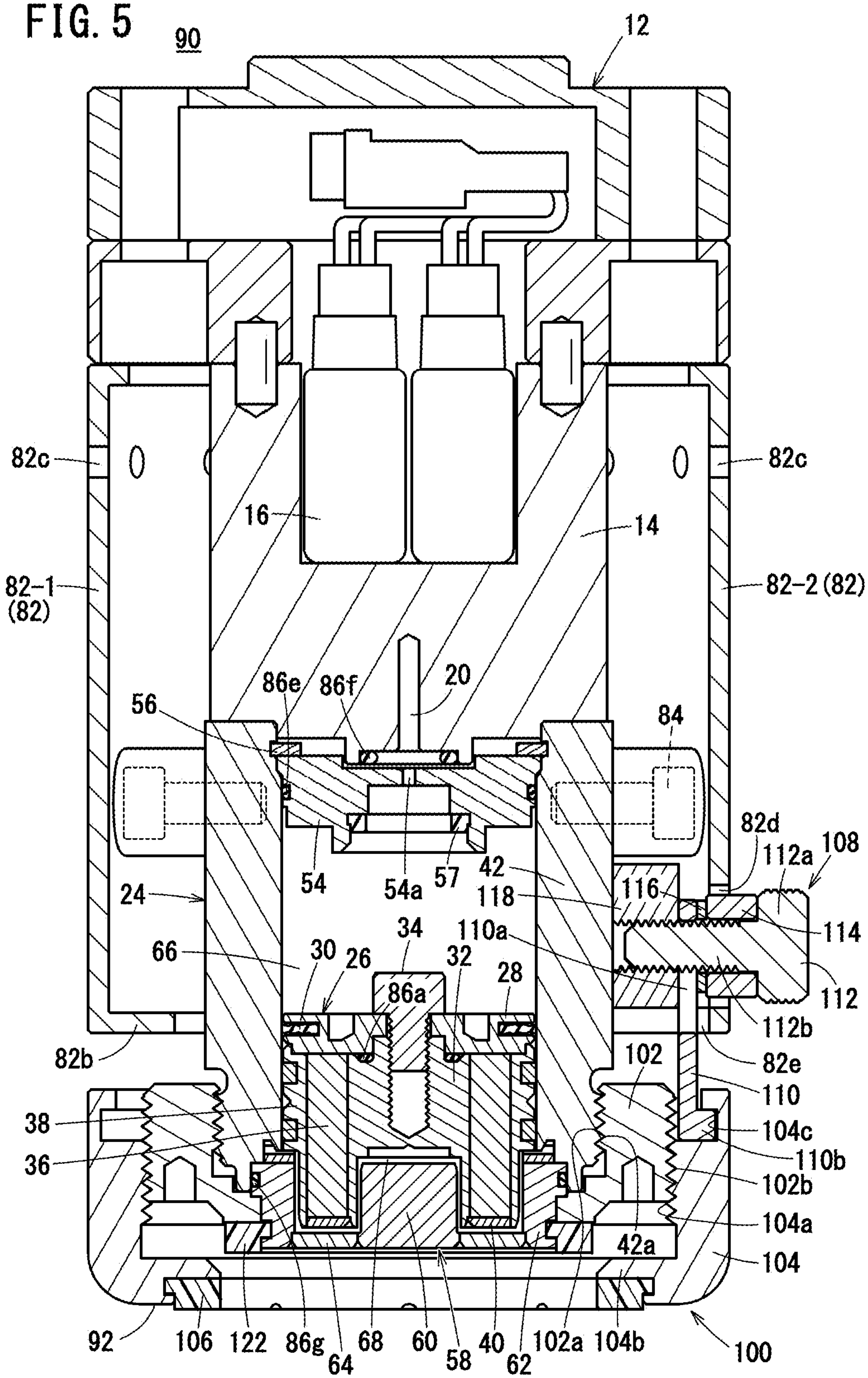
76a
76
62a

FIG. 5



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36
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104b
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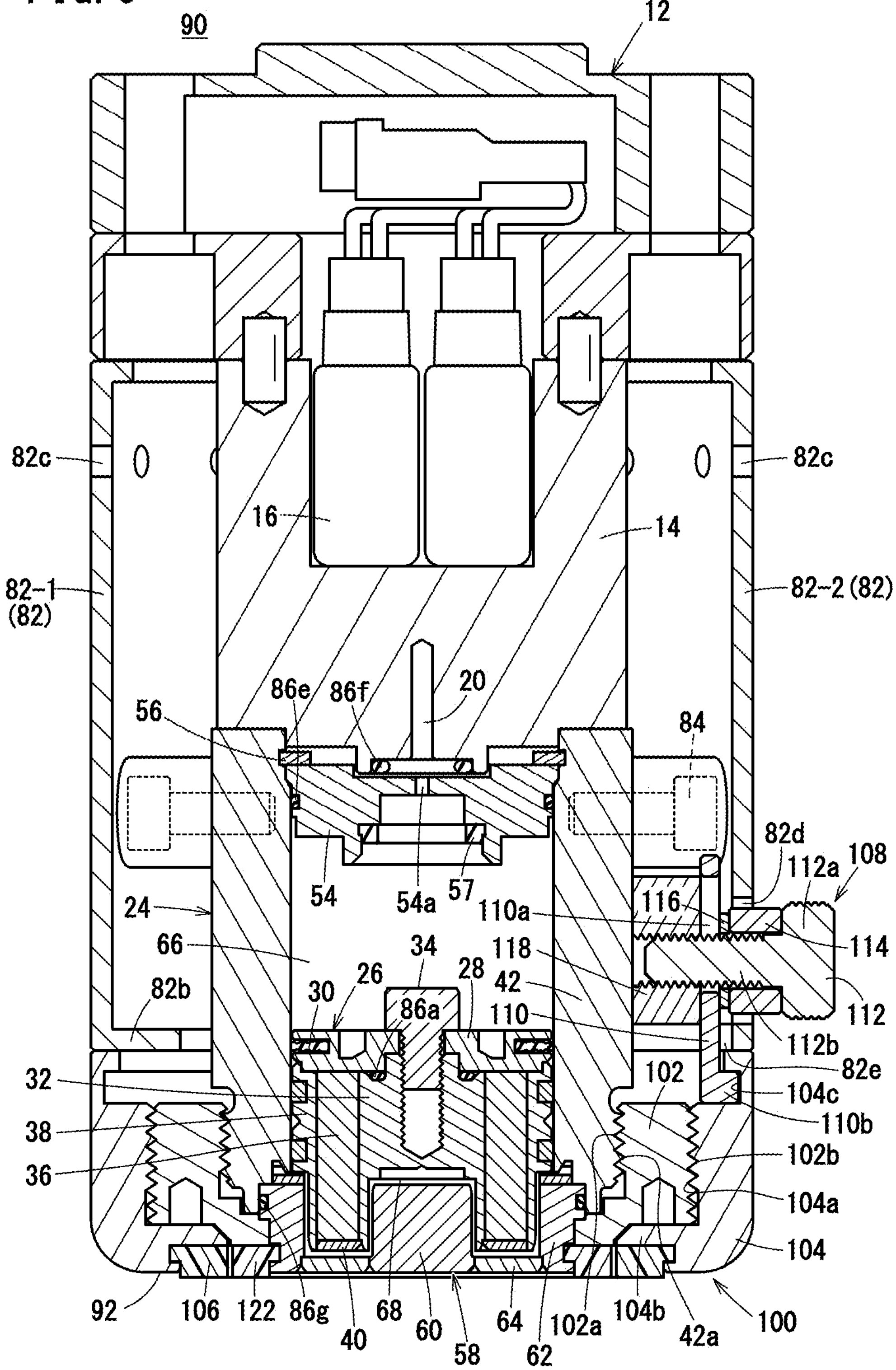
FIG. 6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102b
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FIG. 7

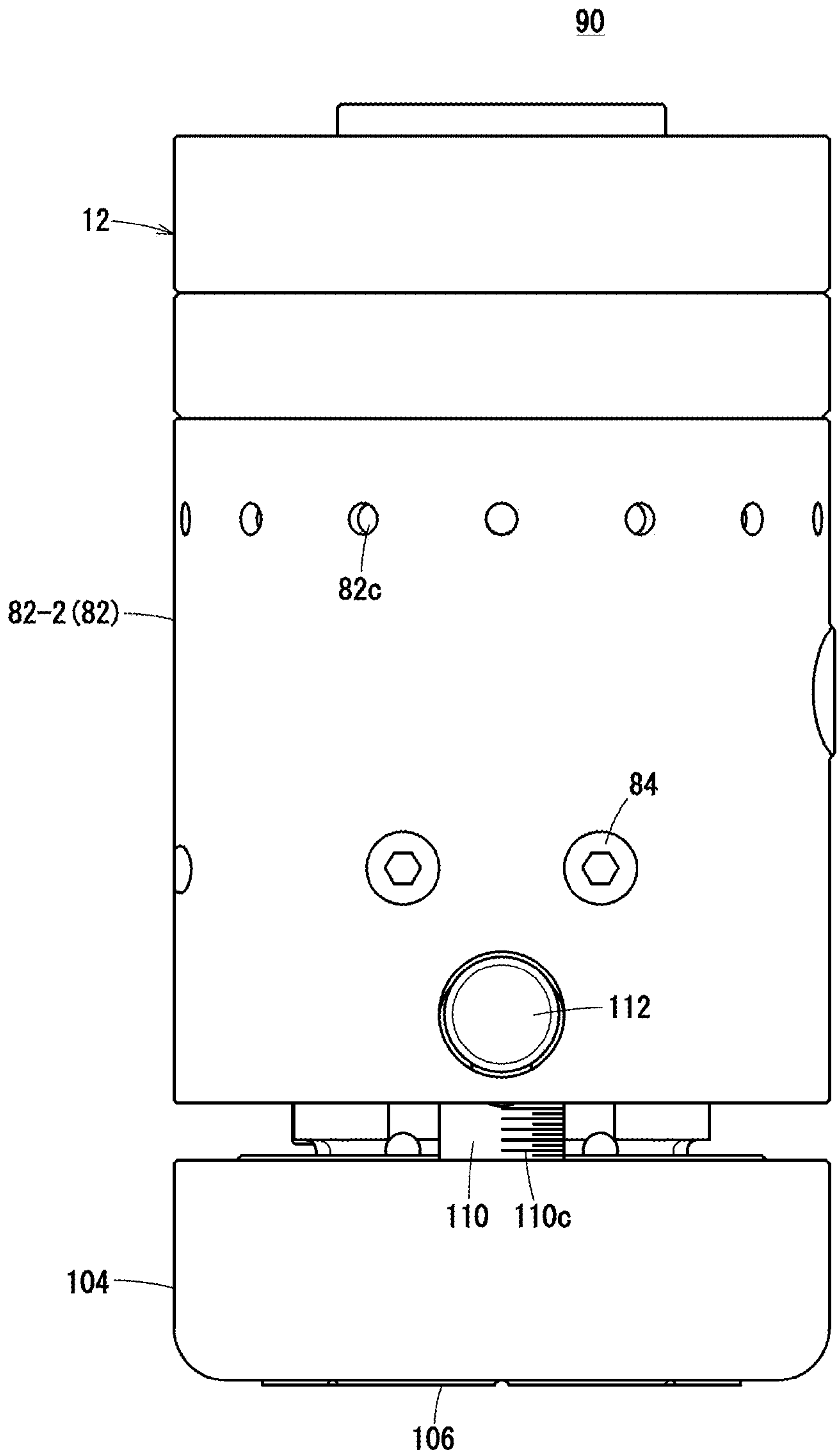
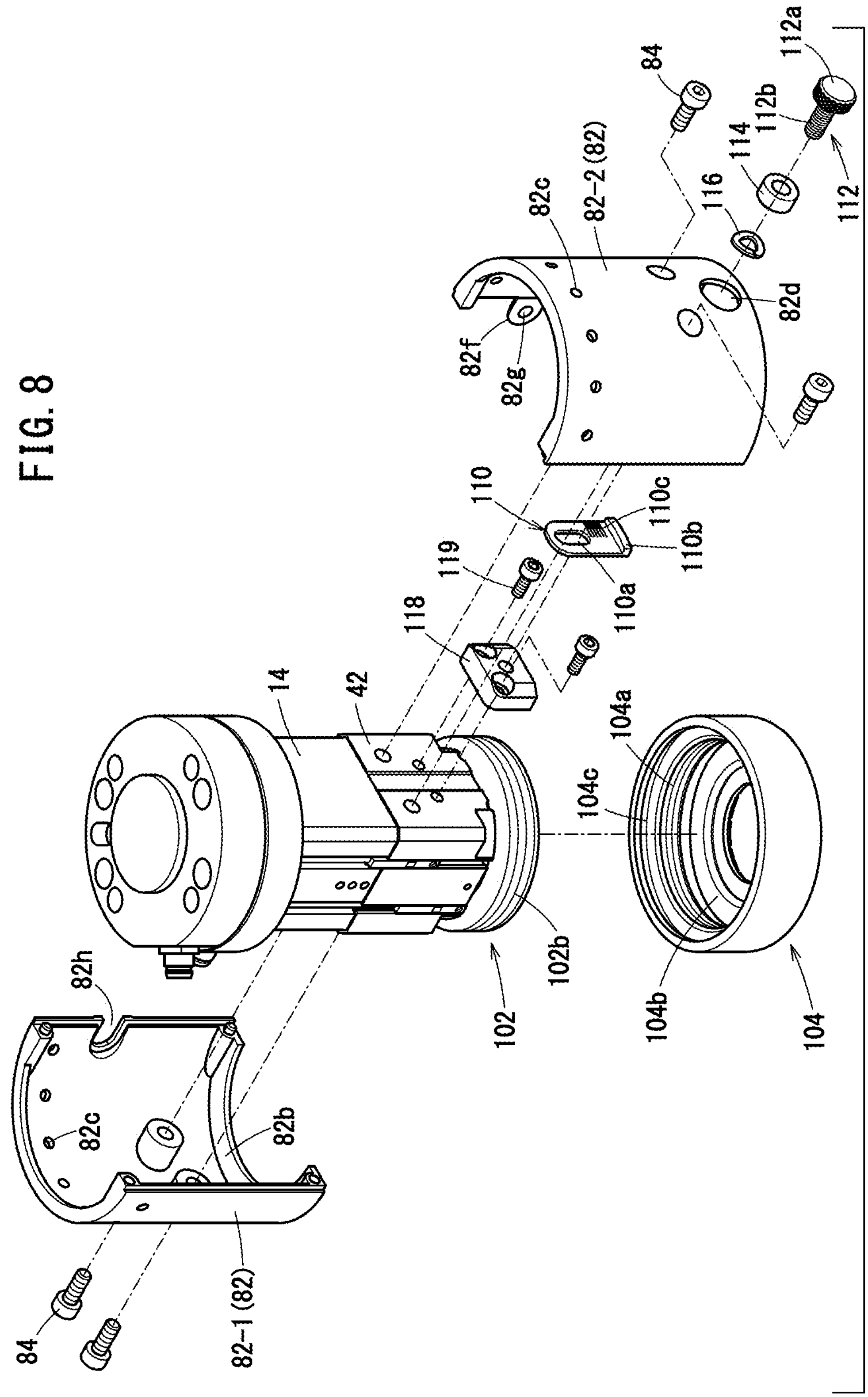


FIG. 8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112a
112b
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FIG. 9

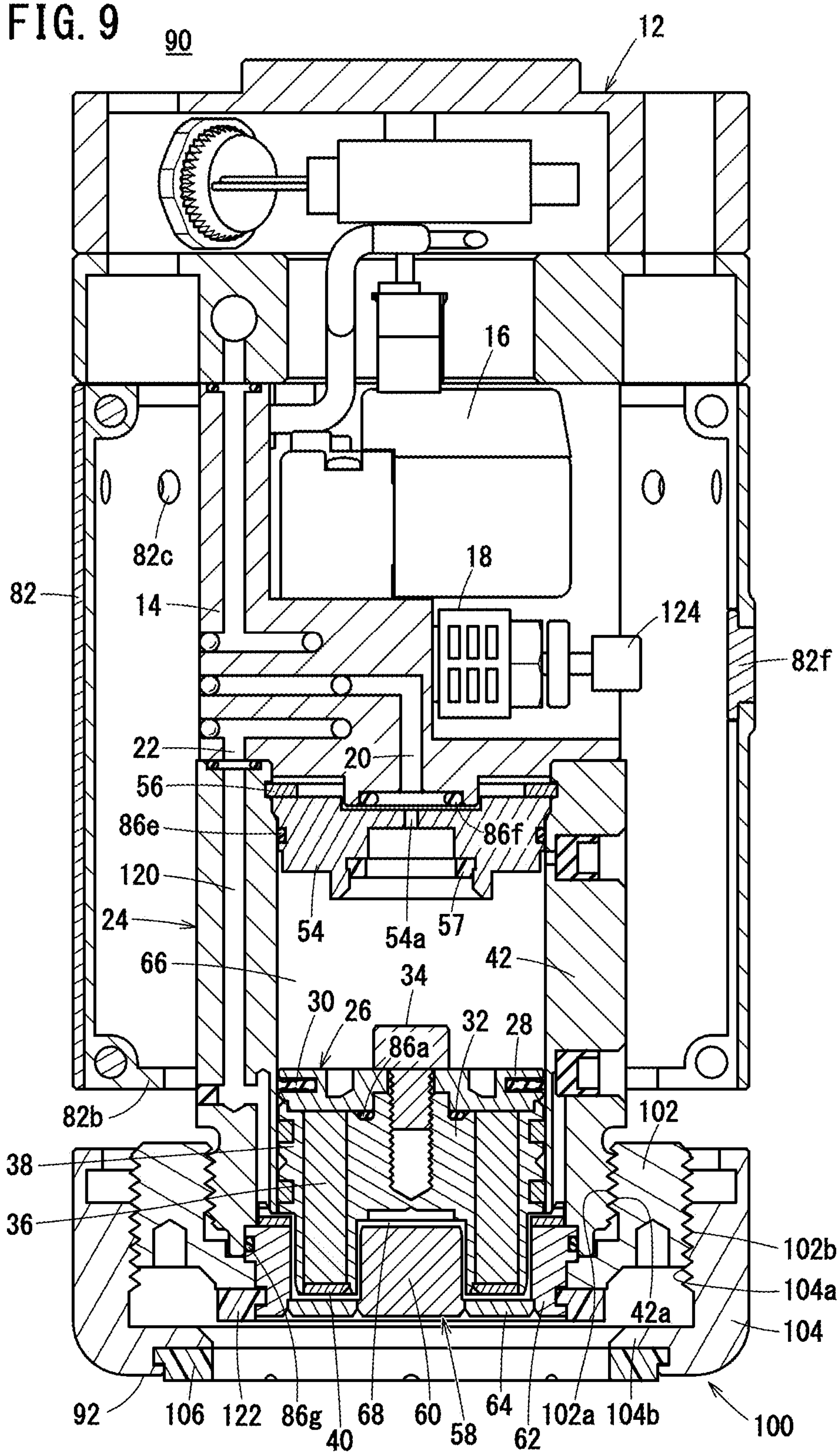
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FIG. 10

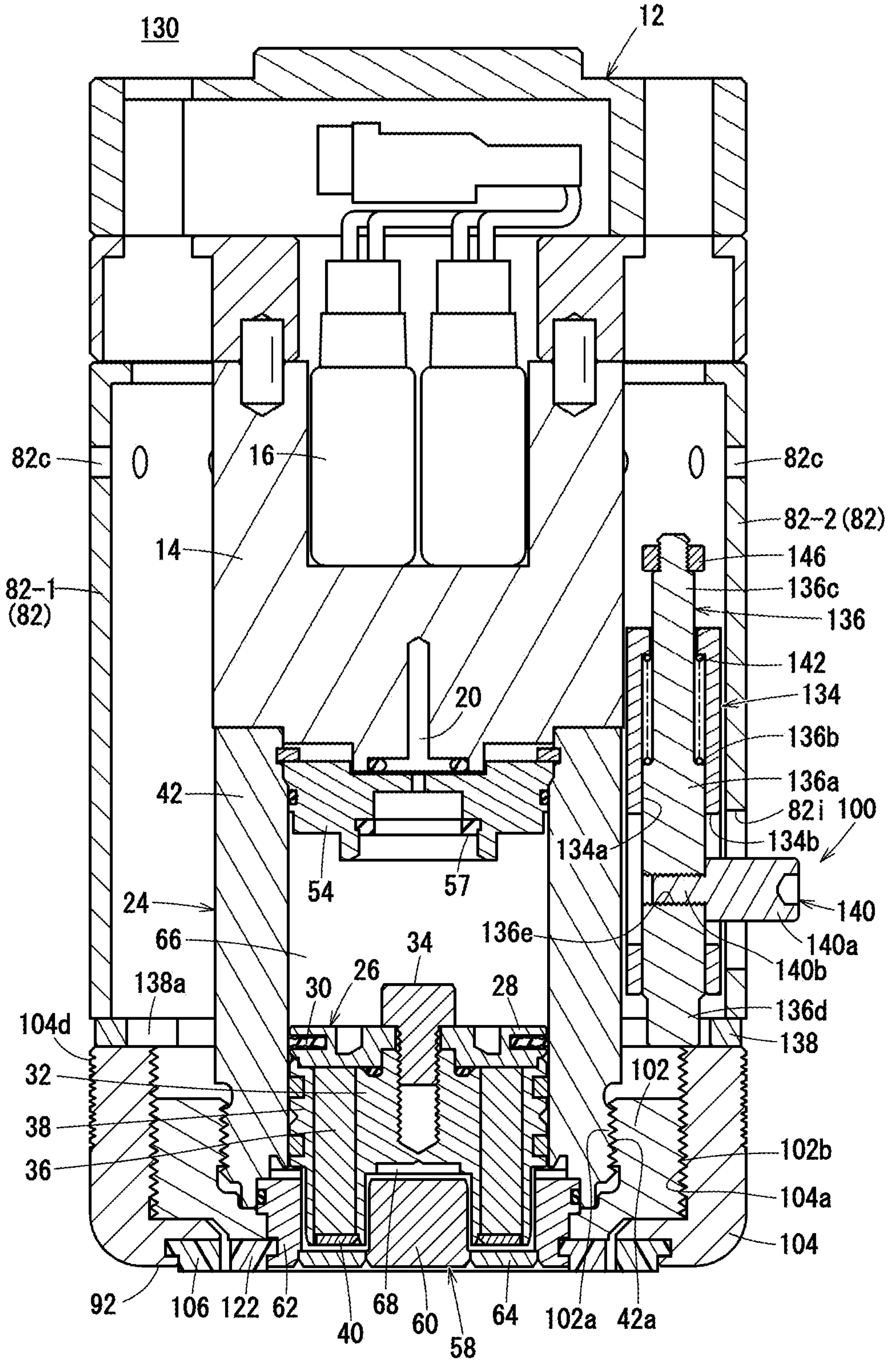
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FIG. 11

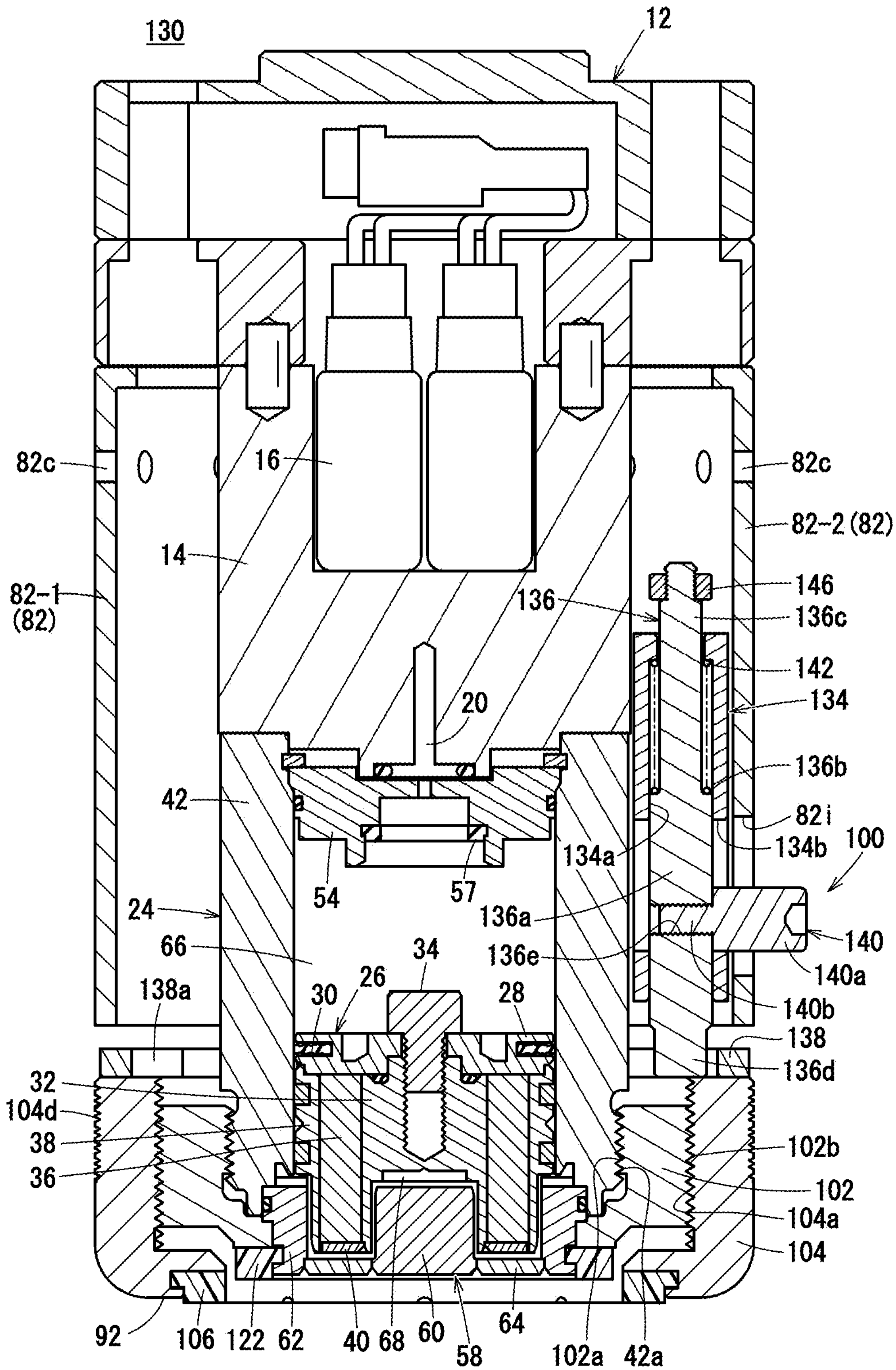
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FIG. 12

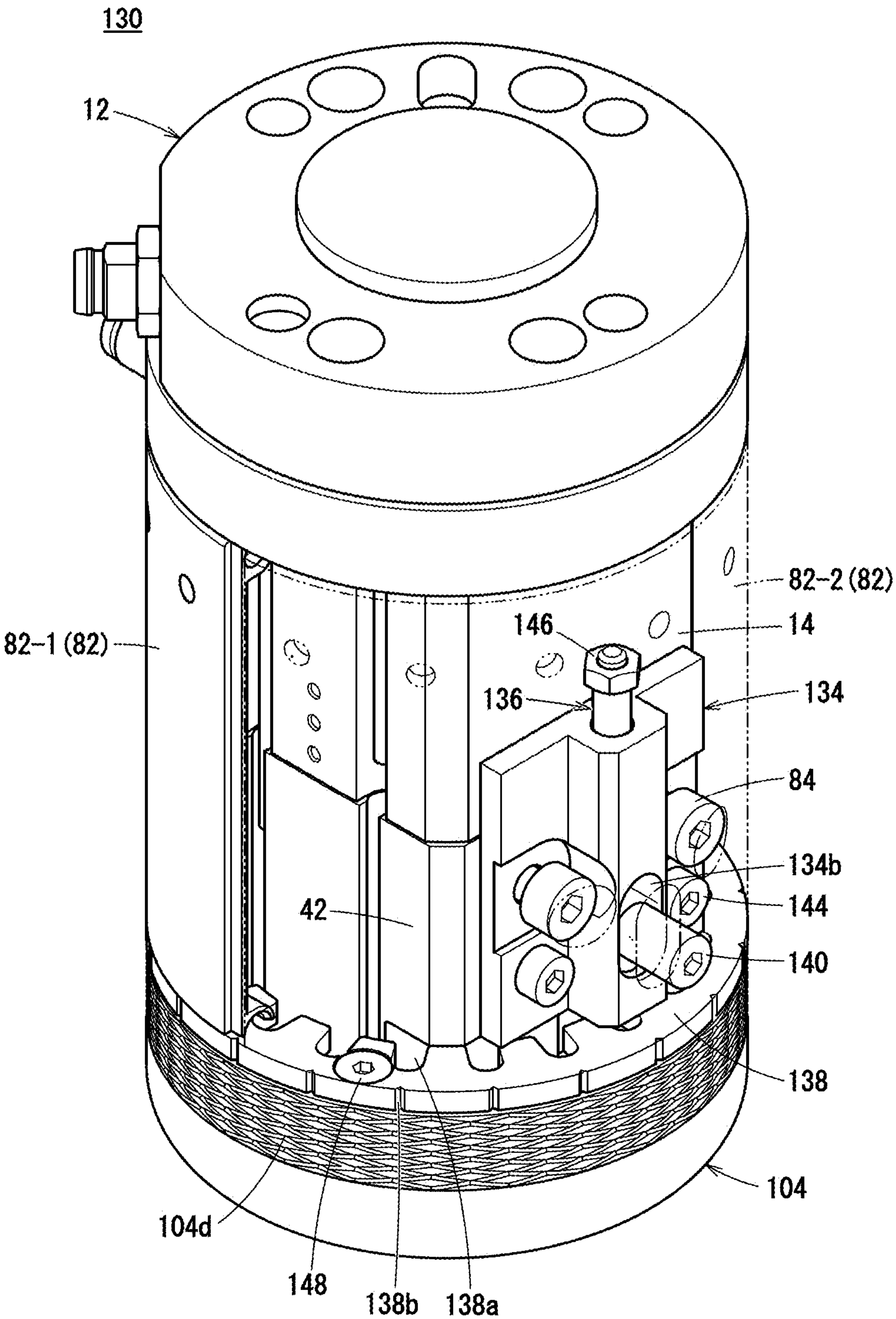

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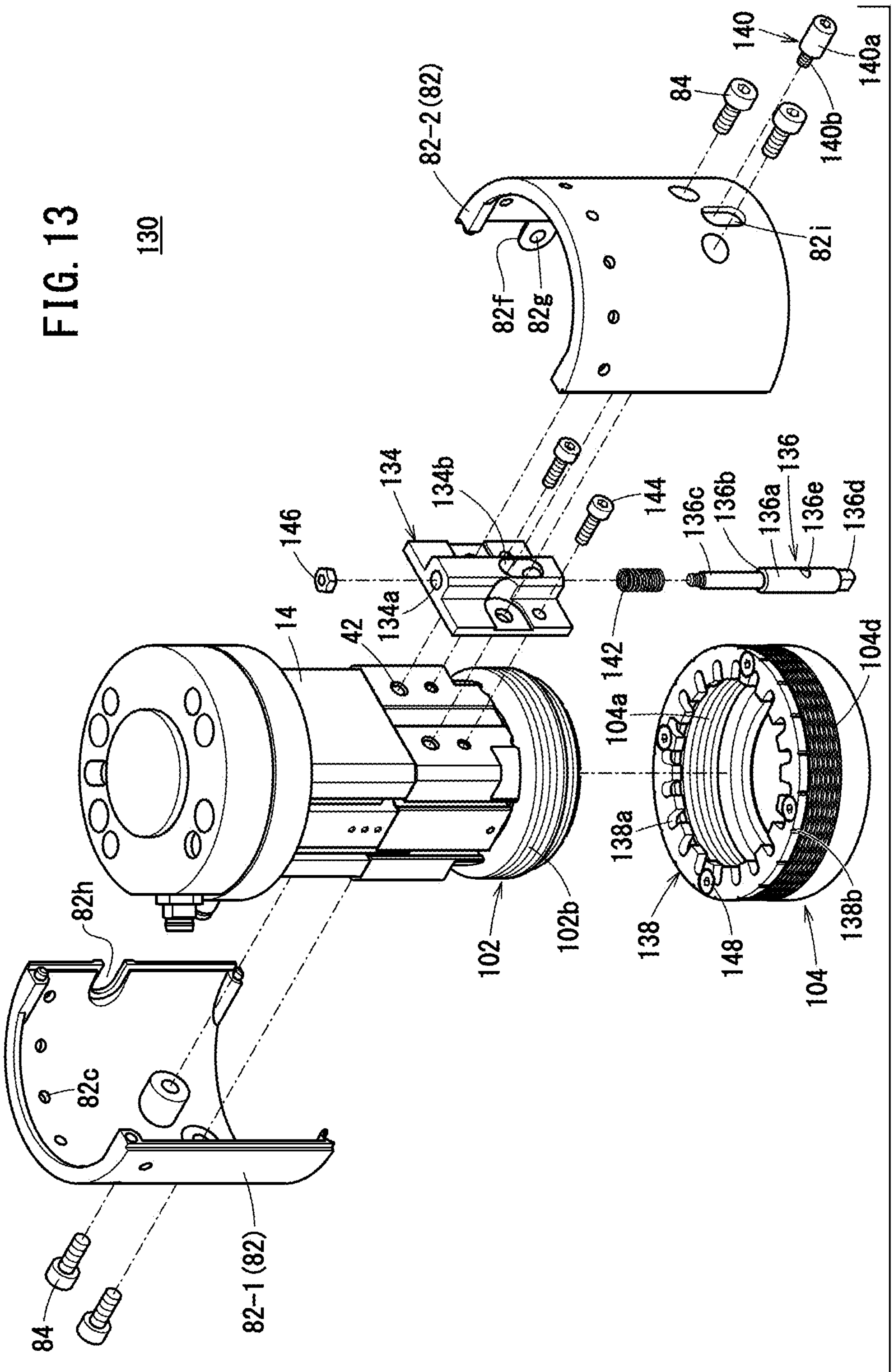
FIG. 13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82-1 (82)
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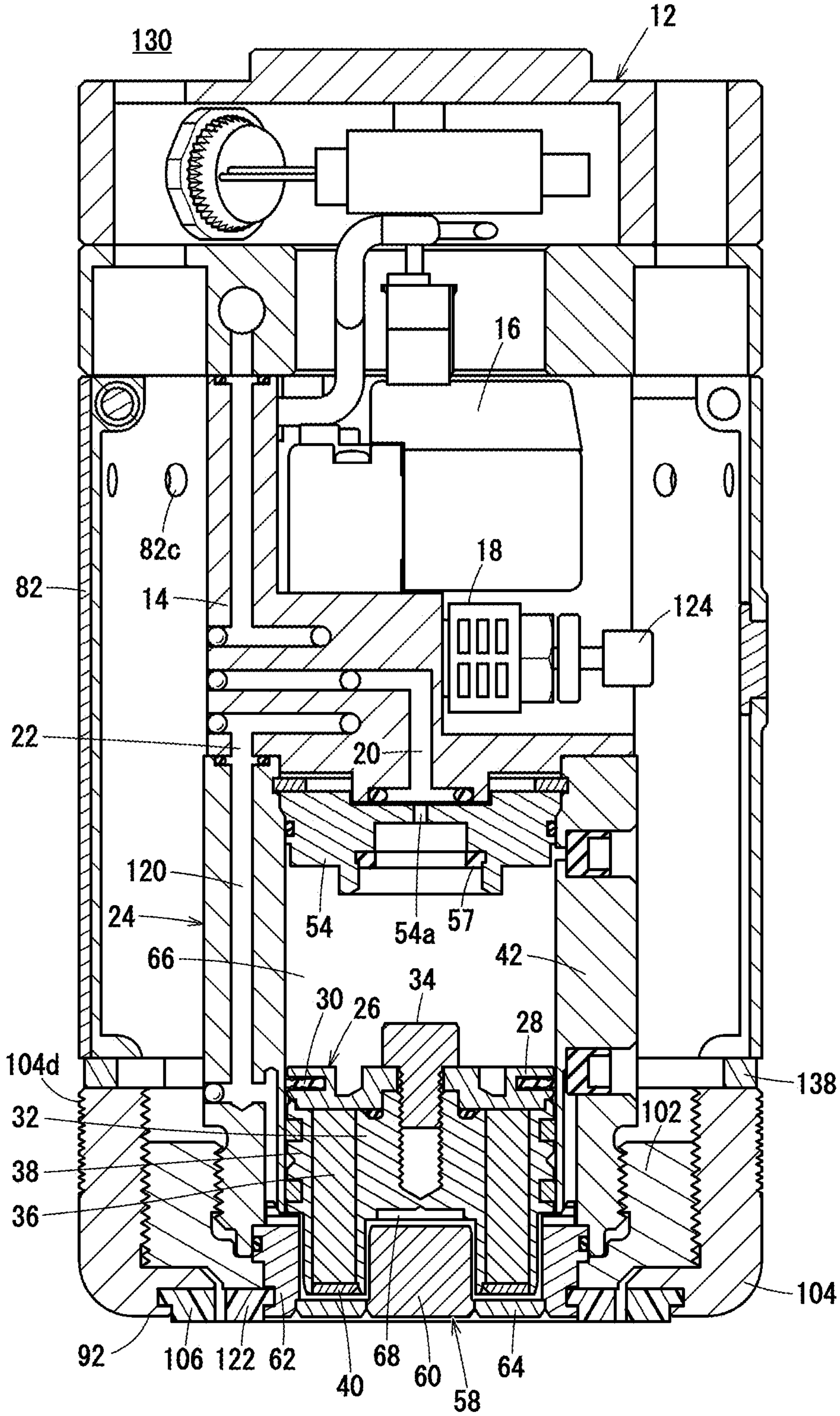
FIG. 14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MAGNETIC CHUCK

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is based upon and claims the benefit of priority from U.S. Provisional Application No. 63/552,334 filed on Feb. 12, 2024, the contents of which are incorporated herein by reference.

BACKGROUND OF THE INVENTION

Field of the Invention

[0002] The present invention relates to a magnetic chuck that is capable of changing the holding force of a workpiece.

Description of the Related Art

[0003] Conventionally, a magnetic chuck has been known in which the magnitude of magnetic attraction force for holding a workpiece can be changed. For example, JP 2019-186324 A discloses a magnetic chuck in which a rod is connected to a piston assembly including a permanent magnet, and an adjuster capable of adjusting the position of the movement end of the piston assembly is attached to the end of the rod that is exposed to the outside.

SUMMARY OF THE INVENTION

[0004] In the magnetic chuck described above, a bottom cover faces the workpiece, and the rod connected to the piston assembly extends upward from a top cover. Therefore, the magnetic chuck cannot be attached to a robot arm above the top cover. That is, a direction in which the magnetic chuck is attached to the robot arm is restricted.

[0005] The present invention has the object of solving the aforementioned problem.

[0006] The present invention is a magnetic chuck including a base member, a cylinder member, and a holding force adjustment member, wherein the cylinder member includes a piston assembly and a cylinder tube, the piston assembly includes a permanent magnet, the holding force adjustment member includes an adjustment body fixed to the cylinder tube and an adjustment ring provided with a workpiece holding surface. The adjustment ring is screw-engaged with the adjustment body, and the magnetic chuck is configured to change a workpiece holding force by changing a screw-engagement position of the adjustment ring with respect to the adjustment body.

[0007] In the magnetic chuck according to the present invention, when the magnetic chuck is attached to a robot arm, there is no restriction on the direction of attachment. In addition, the workpiece holding force can be changed in a stepless manner.

[0008] The above and other objects, features, and advantages of the present invention will be easily understood from the following description when taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] FIG. **1** is a cross-sectional view of a magnetic chuck according to a first embodiment of the present invention;

[0010] FIG. **2** is a view in which the main portion of the magnetic chuck shown in FIG. **1** is expanded into parts;

[0011] FIG. **3** is a cross-sectional view of the magnetic chuck shown in FIG. **1** when a piston assembly is in a lower end position;

[0012] FIG. **4** is a cross-sectional view of the magnetic chuck shown in FIG. **1** when a position of an adjustment ring is changed downward;

[0013] FIG. **5** is a cross-sectional view of a magnetic chuck according to a second embodiment of the present invention;

[0014] FIG. **6** is a cross-sectional view of the magnetic chuck shown in FIG. **5** when a position of an adjustment ring is changed upward;

[0015] FIG. **7** is a side view of the magnetic chuck of FIG. **5**;

[0016] FIG. **8** is a view in which the magnetic chuck shown in FIG. **5** is expanded into parts or groups of parts;

[0017] FIG. **9** is a cross-sectional view of the magnetic chuck shown in FIG. **5**, taken along a plane different from that of FIG. **5**;

[0018] FIG. **10** is a cross-sectional view of a magnetic chuck according to a third embodiment of the present invention;

[0019] FIG. **11** is a cross-sectional view of the magnetic chuck shown in FIG. **10** when a position of an adjustment ring is changed downward;

[0020] FIG. **12** is a perspective view of the magnetic chuck shown in FIG. **10** in a state where a part of a cover body is seen through;

[0021] FIG. **13** is a view in which the magnetic chuck shown in FIG. **10** is expanded into parts or groups of parts; and

[0022] FIG. **14** is a cross-sectional view of the magnetic chuck shown in FIG. **10**, taken along a plane different from that of FIG. **10**.

DETAILED DESCRIPTION OF THE INVENTION

First Embodiment

[0023] A description will be given with reference to FIGS. **1** to **4** concerning a magnetic chuck **10** according to a first embodiment of the present invention. In the following description, when terms in relation to up and down directions are used, for the sake of convenience, such terms refer to the directions shown in FIG. **1**, FIG. **3**, and FIG. **4**. However, the actual arrangement of the constituent members and the like is not necessarily limited to this feature. As shown in FIG. **1**, the magnetic chuck **10** includes a base member **12**, a cylinder member **24** disposed below the base member **12**, and a holding force adjustment member **70** attached to the cylinder member **24**. The magnetic chuck **10**, is attached to a non-illustrated robot arm, on an upper end of the base member **12**.

[0024] The base member **12** includes a block-shaped base body **14**. A solenoid valve **16** and an air discharge port **18** are disposed in the base body **14**. The base body **14** has a first air supply and discharge hole **20** and a second air supply and discharge hole **22** therein. One end of the first air supply and discharge hole **20** is opened at the center of the lower end portion of the base body **14**, and another end of the first air supply and discharge hole **20** is connected to the solenoid valve **16**. One end of the second air supply and discharge hole **22** is opened at the center of the lower end portion of the base body **14**, and another end of the second air supply and discharge hole **22** is connected to the solenoid valve **16**.

[0025] The cylinder member **24** includes a piston assembly **26**, a cylinder tube **42**, a bottom cover **58** and a top cover **54**. The cylinder tube **42** is made of a paramagnetic material such as an aluminum alloy and formed in a tubular shape. The upper end opening of the cylinder tube **42** is closed by the top cover **54**, and the lower end opening of the cylinder tube **42** is closed by the bottom cover **58**. An upper end of the cylinder tube **42** is in contact with a lower end of the base body **14**.

[0026] The piston assembly **26** includes a seal holder **28**, a core yoke **32**, a permanent magnet **36**, a cover yoke **38**, and a ring plate **40**. The seal holder **28** is made of a paramagnetic material such as an aluminum alloy and formed in a disk shape. A piston seal **30** mounted on an outer circumference of the seal holder **28** is in sliding contact with an inner wall of the cylinder tube **42**. The core yoke **32** is made of a ferrous material that is a ferromagnetic material, and formed in a cylindrical columnar shape. A lower portion of the core yoke **32** includes a recess **32***a* that has a circular shape in cross section and opens downward. The seal holder **28** is connected to the core yoke **32** by inserting a fixing screw **34** through the center of the seal holder **28** and by the fixing screw **34** being screw-engaged with the upper end portion of the core yoke **32**. A first seal member **86***a* for sealing a gap between the seal holder **28** and the core yoke **32** is mounted on the core yoke **32**.

[0027] The permanent magnet **36** is fitted on an outer circumference of the core yoke **32**. The permanent magnet **36** is formed in a tubular shape and magnetized in a radial direction. In the present embodiment, the permanent magnet **36** has the north pole on its inner circumferential side, and the south pole on its outer circumferential side. On the contrary, the inner circumferential side may be the south pole and the outer circumferential side may be the north pole. The permanent magnet **36** is formed by combining a plurality of fan-shaped magnet pieces divided in the circumferential direction, or is formed of a single constituent element. The cover yoke **38** is fitted on an outer circumference of the permanent magnet **36**. The cover yoke **38** is made of a ferrous material that is a ferromagnetic material, and formed in a tubular shape. The ring plate **40** is made of a paramagnetic material such as an aluminum alloy and formed in an annular shape. The permanent magnet **36** is surrounded by the seal holder **28**, the core yoke **32**, the cover yoke **38**, and the ring plate **40**.

[0028] An internal space of the cylinder tube **42** is partitioned by the piston assembly **26** into a first pressure chamber **66** adjacent to the top cover **54** and a second pressure chamber **68** adjacent to the bottom cover **58**. The cylinder tube **42** has a first air passage **44** for placing the second pressure chamber **68** and the first pressure chamber **66** in communication with each other and a second air passage **46** for placing the second pressure chamber **68** and the second air supply and discharge hole **22** of the base body **14** in communication with each other. A second seal member **86***b* is mounted at a connection portion between the second air passage **46** and the second air supply and discharge hole **22** to seal a gap between the cylinder tube **42** and the base body **14**.

[0029] A flow rate regulating valve **48** for regulating the flow rate of the air flowing through the first air passage **44** is disposed in the middle of the first air passage **44**. When air flows through the first air passage **44**, a difference is generated in the pressure of the air between the upstream side and the downstream side of the flow rate regulating valve **48**. The flow rate regulating valve **48** is configured as a variable throttle valve and includes a needle valve plug **50** and a support body **52** for supporting the needle valve plug **50**. The support body **52** is attached to the cylinder tube **42**.

[0030] A tip end of the needle valve plug **50** enters the first air passage **44**, and a flow passage area of the first air passage **44** changes according to the amount of entry of the needle valve plug **50**. The needle valve plug **50** is screw-engaged with the support body **52**. By rotating the needle valve plug **50** using a tool, the amount of entry of the needle valve plug **50** can be regulated. A third seal member **86***c* in contact with the support body **52** is mounted on the needle valve plug **50**, and a fourth seal member **86***d* in contact with the cylinder tube **42** is mounted on the support body **52**.

[0031] When air is supplied to the first pressure chamber **66** and air is discharged from the second pressure chamber **68**, the piston assembly **26** is biased downward by the pressure difference between the air pressure in the first pressure chamber **66** and the air pressure in the second pressure chamber **68**. The downward biasing force of the air is changed by rotating the needle valve plug **50** of the flow rate regulating valve **48**.

[0032] The bottom cover **58** includes a bottom yoke **60**, an outer yoke **62**, and a connecting plate **64**. The bottom yoke **60** is made of a ferrous material that is a ferromagnetic material, and formed in a cylindrical columnar shape. The bottom yoke **60** enters the recess **32***a* of the core yoke **32** when the piston assembly **26** descends. The outer yoke **62** is disposed in the exterior of the bottom yoke **60**. The outer yoke **62** is made of a ferrous material that is a ferromagnetic material, and formed in a cylindrical shape. The annular connecting plate **64** is attached between the lower end of the bottom yoke **60** and the lower end of the outer yoke **62**. Accordingly, the outer yoke **62** is fixed to the bottom yoke **60**. The connecting plate **64** is made of a paramagnetic material such as an aluminum alloy.

[0033] The top cover **54** is made of a ferrous material that is a ferromagnetic material, and formed in a disk shape. The top cover **54** is fixed to an upper portion of the cylinder tube **42** via a C-ring **56**. A fifth seal member **86***e* is mounted on the top cover **54** so as to be in contact with the inner wall of the cylinder tube **42**. The top cover **54** has a hole portion **54***a* penetrating the center of the top cover **54**. The first pressure chamber **66** communicates with the first air supply and discharge hole **20** of the base body **14** through the hole portion **54***a* of the top cover **54**. A sixth seal member **86***f* is disposed between the top cover **54** and the base member **12**.

[0034] The piston assembly **26** is displaceable upward or downward between an upper end position abutting a damper **57** mounted on the top cover **54** and a lower end position abutting the bottom cover **58**. When the piston assembly **26** is in the upper end position, the magnetic flux of the permanent magnet **36** passes through the top cover **54**, and thus the piston assembly **26** is attracted toward the top cover **54** (see FIG. **1**). That is, a magnetic force acts to hold the piston assembly **26** in the upper end position. When the piston assembly **26** is in the lower end position, the magnetic flux of the permanent magnet **36** passes through the bottom yoke **60** and the outer yoke **62**, and thus the piston assembly

26 is attracted toward the bottom cover **58** (see FIG. **3**). That is, a magnetic force acts to hold the piston assembly **26** in the lower end position.

[0035] When the piston assembly **26** is in the upper end position, even if a workpiece (not shown) such as a steel plate is present near the bottom cover **58**, the magnetic force of the permanent magnet **36** does not reach the workpiece. When the piston assembly **26** is in the lower end position, if a workpiece such as a steel plate is present near the bottom cover **58**, the magnetic force of the permanent magnet **36** is applied to the workpiece, and the workpiece is attracted and held by the magnetic force of the permanent magnet **36**. In this case, most of the magnetic flux that has emitted from the inner circumferential surface of the permanent magnet **36** passes through the core yoke **32**, the bottom yoke **60**, the workpiece, the outer yoke **62**, and the cover yoke **38** in this order, and returns to the outer circumferential surface of the permanent magnet **36**.

[0036] The holding force adjustment member **70** includes an adjustment body **72**, an adjustment ring **76**, and a jam ring **80**. The adjustment body **72**, the adjustment ring **76** and the jam ring **80** are made of a paramagnetic material such as an aluminum alloy. The adjustment body **72** has an annular plate portion **72***a* and a cylindrical portion **72***b* extending upward from the plate portion **72***a*.

[0037] The cylindrical portion **72***b* of the adjustment body **72** is disposed in the exterior of the cylinder tube **42**, and a clearance serving as a passage for cooling air, which will be described later, is formed between the cylindrical portion **72***b* of the adjustment body **72** and the cylinder tube **42**. The cylindrical portion **72***b* of the adjustment body **72** has an externally threaded portion **72***d* on the outer circumference thereof. The plate portion **72***a* of the adjustment body **72** has a plurality of ventilation holes **72***c* penetrating the plate portion **72***a*. The adjustment body **72** is fixed to the cylinder tube **42** by inserting a first screw member **74** into the plate portion **72***a* of the adjustment body **72** and by the first screw member **74** being screw-engaged with the lower end portion of the cylinder tube **42** (see FIG. **2**).

[0038] The outer yoke **62** of the bottom cover **58** is provided with an annular convex portion **62***a* projecting from the outer circumferential surface of the outer yoke **62**. The convex portion **62***a* of the outer yoke **62** is sandwiched and held between the plate portion **72***a* of the adjustment body **72** and the lower end portion of the cylinder tube **42**. As a result, the bottom cover **58** is fixed to the cylinder tube **42** together with the adjustment body **72**. A seventh seal member **86***g* is mounted on the convex portion **62***a* of the outer yoke **62** so as to be in contact with the inner wall of the cylinder tube **42**. The outer yoke **62** projects downward below the plate portion **72***a* of the adjustment body **72**.

[0039] The adjustment ring **76** has an annular plate portion **76***a* and a cylindrical portion **76***b* extending upward from the plate portion **76***a*. The cylindrical portion **76***b* of the adjustment ring **76** has an internally threaded portion **76***c* on the upper inner circumferential surface thereof, and the internally threaded portion **76***c* is screw-engaged with the externally threaded portion **72***d* of the adjustment body **72**. The cylindrical portion **76***b* of the adjustment ring **76** has a plurality of ventilation holes **76***d* penetrating the cylindrical portion **76***b*. By changing the screw-engagement position of the adjustment ring **76** with respect to the adjustment body **72**, the position of the adjustment ring **76** can be changed in the up and down direction.

[0040] The cylindrical jam ring **80** is disposed above the adjustment ring **76**. The jam ring **80** has an internally threaded portion **80***a* on the inner circumferential surface thereof, and the internally threaded portion **80***a* is screwed into the externally threaded portion **72***d* of the adjustment body **72**. The position of the jam ring **80** relative to the adjustment body **72** is changed in accordance with the position of the adjustment ring **76** in the up and down direction. The jam ring **80** serves to hold the adjustment ring **76** in a desired screw-engagement position.

[0041] The lower surface of the plate portion **76***a* of the adjustment ring **76** forms a workpiece holding surface **76***e* that is in contact with the workpiece and holds the workpiece. The workpiece holding surface **76***e* is located below the lower ends of the bottom yoke **60** and the outer yoke **62**. By changing the position of the adjustment ring **76** in the up and down direction with respect to the adjustment body **72**, the force for attracting and holding the workpiece can be changed. As shown in FIG. **1**, when the adjustment ring **76** is in the upper end position, the distance from the bottom yoke **60** and the outer yoke **62** to the workpiece holding surface **76***e* is minimized, and therefore the workpiece holding force is maximized. As shown in FIG. **4**, when the adjustment ring **76** is in the lower end position, the distance from the bottom yoke **60** and the outer yoke **62** to the workpiece holding surface **76***e* is maximized, and therefore the workpiece holding force is minimized.

[0042] A cylindrical cover body **82** is disposed in the exterior of the base body **14** and in the upper exterior of the cylinder tube **42**. As shown in FIG. **2**, the cover body **82** is configured by a pair of semi-cylindrical bodies **82***a*. The cover body **82** is detachably attached to the cylinder tube **42** by using second screw members **84**. That is, the second screw members **84** are inserted into each of the semi-cylindrical bodies **82***a*, and the distal ends of the second screw members **84** are screw-engaged with the cylinder tube **42**.

[0043] The lower end of the cover body **82** has an inwardly extending annular flange portion **82***b*. The tip end of the flange portion **82***b* of the cover body **82** is aligned with the inner circumferential surface of the adjustment body **72** and faces the outer circumferential surface of the cylinder tube **42** with a predetermined clearance therebetween. As a result, the space formed between the cover body **82** and the upper portion of the cylinder tube **42** is connected to the space formed between the adjustment body **72** and the lower portion of the cylinder tube **42** in a continuous manner.

[0044] When the solenoid valve **16** is in a predetermined switching position, air is supplied to the first pressure chamber **66** and air is discharged from the second pressure chamber **68**. The air flow in this case is as follows. Air from an air supply source (not shown) is supplied to the first pressure chamber **66** through the solenoid valve **16**, after flowing in the first air supply and discharge hole **20** in the base body **14**, and the hole portion **54***a* in the top cover **54**. The air supplied to the first pressure chamber **66** flows into the second pressure chamber **68** through the first air passage **44**. The air flowing into the second pressure chamber **68** is discharged to the outside via the solenoid valve **16** after flowing through the second air passage **46** and the second air supply and discharge hole **22** of the base body **14**.

[0045] As described above, when air is supplied to the first pressure chamber **66** and air is discharged from the second pressure chamber **68**, the piston assembly **26** is biased downward. The cylinder member **24** is efficiently cooled by the air flowing through the first air passage **44**, the second pressure chamber **68** and the second air passage **46**. That is, the air supplied for the purpose of biasing the piston assembly **26** downward is also used for cooling the cylinder member **24**.

[0046] When the solenoid valve **16** is in the switching position described above, the air from the air supply source is discharged as cooling air from the air discharge port **18** via the solenoid valve **16**. The cooling air passes through the clearance between the cover body **82** and the base body **14**, the clearance between the cover body **82** and the cylinder tube **42**, and the clearance between the adjustment body **72** and the cylinder tube **42**, and thereafter passes through the ventilation holes **72***c* of the adjustment body **72**. The cooling air having passed through the ventilation holes **72***c* of the adjustment body **72** passes through the clearance between the plate portion **72***a* of the adjustment body **72** and the plate portion **76***a* of the adjustment ring **76**, and is then discharged to the outside from the ventilation holes **76***d* of the adjustment ring **76**. The cooling air is circulated through the above mentioned path, whereby the holding force adjustment member **70** including the adjustment ring **76** is efficiently cooled.

[0047] In the case that the workpiece attracted and held by the magnetic force of the permanent magnet **36** is at a high temperature, a considerable amount of heat is transmitted from the workpiece to the cylinder member **24** and the adjustment ring **76**. The heat transferred from the workpiece to the cylinder member **24**, primarily by radiation, is quickly removed by the air, which biases the piston assembly **26** downward, flowing through the first air passage **44**, the second pressure chamber **68**, and the second air passage **46**. The heat transmitted from the workpiece to the adjustment ring **76**, primarily by conduction, is rapidly removed by the cooling air flowing through the above-mentioned path. By the above actions, the piston seal **30** and the first to seventh seal members **86***a* to **86***g* are protected from heat. The adjustment ring **76** greatly limits the heat transferred from the workpiece to the cylinder member **24**.

[0048] The cylinder tube **42** has a passage (not shown) for supplying air to the second pressure chamber **68** and a passage (not shown) for discharging air from the first pressure chamber **66**, and these passages are connected to the solenoid valve **16**. When air is supplied to the second pressure chamber **68** and air is discharged from the first pressure chamber **66**, the piston assembly **26** is biased upward. The air supplied to bias the piston assembly **26** upward need not be used to cool the cylinder member **24**. This is because in the case that the piston assembly **26** is biased upward, the workpiece is released from the magnetic chuck **10** and heat is not transmitted from the workpiece to the cylinder member **24**.

[0049] The second air supply and discharge hole **22** and the second air passage **46** may be used as passages for supplying air to the second pressure chamber **68**, and the first air supply and discharge hole **20** may be used as a passage for discharging air from the first pressure chamber **66**. That is, the flow of air when the piston assembly **26** is biased upward may be opposite to the flow of air when the piston assembly **26** is biased downward.

[0050] Next, the operation of the magnetic chuck **10** according to the present embodiment will be described. As shown in FIG. **1**, an initial state is a state in which the magnetic flux of the permanent magnet **36** passes through the top cover **54** and the piston assembly **26** is held at the upper end position. In the initial state, the adjustment ring **76** is adjusted to the upper end position with respect to the adjustment body **72**.

[0051] When a command to attract and hold a workpiece such as an unillustrated iron plate placed on a floor surface or the like is issued, a robot arm to which the magnetic chuck **10** is attached is driven, and the magnetic chuck **10** approaches the workpiece. In parallel with this, the solenoid valve **16** is switched, and air is supplied to the first pressure chamber **66** and air in the second pressure chamber **68** is discharged. The piston assembly **26** is biased downward by the differential pressure between the air pressure in the first pressure chamber **66** and the air pressure in the second pressure chamber **68**. The downward biasing force of the air exceeds the force by which the piston assembly **26** is attracted to the top cover **54** by the magnetic force, and the piston assembly **26** is displaced downward. The piston assembly **26** abuts against the bottom cover **58** and reaches the lower end position (see FIG. **3**).

[0052] When the magnetic chuck **10** further approaches the workpiece and the workpiece holding surface **76***e* of the adjustment ring **76** faces the workpiece within a predetermined distance, the magnetic force of the permanent magnet **36** is applied to the workpiece. The workpiece abuts against the workpiece holding surface **76***e* of the adjustment ring **76** and is attracted and held by the magnetic force. Since the adjustment ring **76** is adjusted to the upper end position with respect to the adjustment body **72**, the workpiece is held with the maximum workpiece holding force.

[0053] The magnetic chuck **10** holding the workpiece is transported to a predetermined position by the driving of the robot arm. Thereafter, the solenoid valve **16** is switched again, and air is supplied to the second pressure chamber **68** and air in the first pressure chamber **66** is discharged. The piston assembly **26** is biased upward by air. The upward biasing force of the air exceeds the force that pulls the piston assembly **26** toward the bottom cover **58** by magnetic force, causing the piston assembly **26** to be displaced upward. The piston assembly **26** abuts against the damper **57** to reach the upper end position.

[0054] When the piston assembly **26** reaches the upper end position, the piston assembly **26** is attracted to the top cover **54** by magnetic force. Therefore, even when the supply of air to the second pressure chamber **68** is stopped, the piston assembly **26** is maintained at the upper end position. The position of the adjustment ring **76** in the up and down direction is adjusted in accordance with the thickness, weight, material (magnetic permeability), and the like of the workpiece. When the thickness and weight of the workpiece are sufficiently small, the adjustment ring **76** may be adjusted to be in the vicinity of the lower end position as shown in FIG. **4**.

[0055] In the magnetic chuck **10** according to the present embodiment, the holding force adjustment member **70** includes the adjustment body **72** fixed to the cylinder tube **42** and the adjustment ring **76** including the workpiece holding surface **76***e*, and the adjustment ring **76** is screw-engaged with the adjustment body **72**. Therefore, when the magnetic chuck **10** is attached to the robot arm, there is no restriction on the direction of attachment. In addition, the workpiece holding force can be changed in a stepless manner.

[0056] Further, the cylinder tube **42** includes the first air passage **44** for placing the second pressure chamber **68** and the first pressure chamber **66** in communication with each other and the second air passage **46** for placing the second pressure chamber **68** and the second air supply and discharge hole **22** in communication with each other, the first pressure chamber **66** communicates with the first air supply and discharge hole **20**, and the flow rate regulating valve **48** is disposed in the first air passage **44**. Thus, the air supplied to bias the piston assembly **26** downward can be used to cool the cylinder member **24**.

[0057] Furthermore, the cooling air from the air discharge port **18** is discharged to the outside from the ventilation holes **76***d* of the adjustment ring **76** through at least the clearance between the adjustment body **72** and the adjustment ring **76**. Therefore, the heat transferred from the workpiece to the adjustment ring **76** is rapidly removed, and as a result, the heat transferred from the workpiece to the cylinder member **24** is greatly limited.

Second Embodiment

[0058] Next, a magnetic chuck **90** according to a second embodiment of the present invention will be described with reference to FIGS. **5** to **9**. In the magnetic chuck **90** according to the second embodiment, constituent elements that are the same as or equivalent to those of the above-described magnetic chuck **10** may be denoted by the same reference numerals, and detailed description thereof may be omitted. In the following description, when terms in relation to up and down directions are used, for the sake of convenience, such terms refer to the directions shown in the drawings, however, the actual arrangement of the constituent members and the like is not necessarily limited to this feature.

[0059] As shown in FIGS. **5** and **6**, the magnetic chuck **90** includes a base member **12**, a cylinder member **24** disposed below the base member **12**, and a holding force adjustment member **100** attached to the cylinder member **24**. The magnetic chuck **90** is attached to a non-illustrated robot arm, on an upper end of the base member **12**. The holding force adjustment member **100** includes an adjustment body **102**, an adjustment ring **104**, and a locking mechanism member **108**.

[0060] The cylindrical adjustment body **102** has an inner circumferential surface provided with an internally threaded portion **102***a*, and the lower end of the cylinder tube **42** has an outer circumferential surface provided with an externally threaded portion **42***a*. The adjustment body **102** is fixed to the cylinder tube **42** by the internally threaded portion **102***a* of the adjustment body **102** being screw-engaged with the externally threaded portion **42***a* of the cylinder tube **42**. The adjustment body **102** is screwed-engaged with the cylinder tube **42** by a reverse thread screw, and when the adjustment body **102** is rotated counterclockwise, the screw-engagement progresses.

[0061] The cylindrical adjustment ring **104** has an inner circumferential surface provided with an internally threaded portion **104***a*, and the adjustment body **102** has an outer circumferential surface provided with an externally threaded portion **102***b*. The internally threaded portion **104***a* of the adjustment ring **104** is screw-engaged with the externally threaded portion **102***b* of the adjustment body **102**. The adjustment ring **104** is screw-engaged with the adjustment body **102** by a standard thread screw, and when the adjustment ring **104** is rotated clockwise, the screw-engagement progresses.

[0062] The lower end of the adjustment ring **104** has an annular recess by forming a flange portion **104***b* projecting inward. An annular pad **106** having a predetermined elasticity is mounted in the recess. The lower surface of the adjustment ring **104** and the lower surface of the pad **106** form a workpiece holding surface **92**. The upper end of the adjustment ring **104** has an annular groove **104***c* in its inner circumference. A constituent element denoted by the reference numeral **122** is a pad attached to the lower end of the bottom cover **58**.

[0063] The locking mechanism member **108** includes a locking plate **110**, a knob screw **112** and a block **118**. As shown in FIG. **8**, the locking plate **110** has a slot **110***a* extending in the up and down direction. The lower end of the locking plate **110** is provided with a convex engaging portion **110***b* projecting outward. The engaging portion **110***b* of the locking plate **110** engages with the annular groove **104***c* of the adjustment ring **104**. As a result, the adjustment ring **104** is prevented from moving in the up and down direction (in a direction parallel to the axis of the adjustment ring **104**) while being allowed to rotate around the axis of the adjustment ring **104**, with respect to the locking plate **110**. As shown in FIG. **7**, a scale **110***c* visible from the outside is displayed at the lower portion of the locking plate **110**.

[0064] The knob screw **112** has a knob portion **112***a* and a shaft portion **112***b* formed with an external thread. A spacer **114** and a wave washer **116** are disposed between the knob portion **112***a* of the knob screw **112** and the locking plate **110**. The block **118** is secured to the outer surface of the cylinder tube **42** using fixing screws **119**. The shaft portion **112***b* of the knob screw **112** is inserted through the spacer **114** and the wave washer **116**, and further inserted through the slot **110***a* of the locking plate **110**, and then screw-engaged with the block **118**.

[0065] When the knob screw **112** is screw-engaged with the block **118** by a predetermined amount, the locking plate **110** is sandwiched and held between the wave washer **116** and the block **118**, and is fixed to the cylinder tube **42**. In the state where the locking plate **110** is fixed to the cylinder tube **42**, the adjustment ring **104** engaged with the locking plate **110** is not only fixed in the up and down direction but also prevented from rotating with respect to the adjustment body **102** that is integral with the cylinder tube **42**. That is, the adjustment ring **104** is locked in a predetermined screw-engagement position with respect to the adjustment body **102**.

[0066] The workpiece holding force can be changed by changing the screw-engagement position of the adjustment ring **104** with respect to the adjustment body **102**. As shown in FIG. **6**, when the upper end of the adjustment ring **104** abuts against a cover body **82** to be described later and the adjustment ring **104** is positioned at the uppermost position, the workpiece holding force is maximized. As shown in FIG. **5**, when the shaft portion **112***b* of the knob screw **112** is positioned at the upper end of the slot **110***a* of the locking plate **110** and the adjustment ring **104** is positioned at the lowermost position, the workpiece holding force is minimized.

[0067] When the adjustment ring **104** locked at the predetermined screw-engagement position is changed to another screw-engagement position, the knob screw **112** is first loosened to release the locking plate **110** from the cylinder tube **42**. In accordance with this feature, the screw-engagement position of the adjustment ring **104** can be changed with respect to the adjustment body **102**. Next, the adjustment ring **104** is rotated while the scale **110***c* of the locking plate **110** is visually recognized.

[0068] When the adjustment ring **104** is rotated, the shaft portion **112***b* of the knob screw **112** relatively moves in the slot **110***a* of the locking plate **110**, and the locking plate **110** moves in the up and down direction together with the adjustment ring **104**. After the adjustment ring **104** is rotated to the desired position, the knob screw **112** is tightened to fix the locking plate **110** to the cylinder tube **42** again. Accordingly, the adjustment ring **104** is locked relative to the adjustment body **102** in the desired screw-engagement position.

[0069] As described above, the adjustment body **102** and the cylinder tube **42** are screw-engaged by the left-hand screw thread, while the adjustment ring **104** and the adjustment body **102** are screw-engaged by the right-hand screw thread. Therefore, when the adjustment ring **104** is rotated, the screw-engagement between the adjustment body **102** and the cylinder tube **42** is prevented from being unexpectedly loosened.

[0070] A cylindrical cover body **82** is disposed in the exterior of the base body **14** and in the exterior of the cylinder tube **42**. As shown in FIG. **8**, the cover body **82** is configured by a pair of semi-cylindrical bodies **82-1** and **82-2**. The cover body **82** is detachably attached to the cylinder tube **42** by using second screw members **84**. That is, the second screw members **84** are inserted through the respective semi-cylindrical bodies **82-1** and **82-2**, and the distal ends of the second screw members **84** are screw-engaged with the cylinder tube **42**.

[0071] The lower end of each of the semi-cylindrical bodies **82-1** and **82-2** has an inwardly extending annular flange portion **82***b*. The upper portion of each of the semi-cylindrical bodies **82-1** and **82-2** has a plurality of ventilation holes **82***c* arranged in the circumferential direction. The one semi-cylindrical body **82-2** has a first hole portion **82***d* through which the spacer **114** is inserted. The flange portion **82***b* of the one semi-cylindrical body **82-2** has a second hole portion **82***e* through which the locking plate **110** is inserted, and the upper portion of the locking plate **110** is positioned inside the cover body **82**. A projecting portion **82***f* formed in the one semi-cylindrical body **82-2** is fitted into a notch portion **82***h* formed in the other semi-cylindrical body **82-1**. The projecting portion **82***f* is formed with a through hole **82***g* for insertion of a tool.

[0072] As shown in FIG. **9**, a solenoid valve **16** and an air discharge port **18** are disposed in the base body **14**. A variable throttle valve **124** capable of adjusting the flow rate of the discharged air is attached to the air discharge port **18**. By inserting a tool through the through hole **82***g* of the cover body **82**, the flow passage area of the variable throttle valve **124** can be changed from the exterior of the cover body **82**. That is, the flow rate of the air discharged from the air discharge port **18** can be adjusted without removing the cover body **82** from the cylinder tube **42**.

[0073] The base body **14** has a first air supply and discharge hole **20** and a second air supply and discharge hole **22**. One end of the first air supply and discharge hole **20** is opened at the center of the lower end of the base body **14**, and another end of the first air supply and discharge hole **20** is connected to the solenoid valve **16**. One end of the second air supply and discharge hole **22** is opened at the center of the lower end portion of the base body **14**, and another end of the second air supply and discharge hole **22** is connected to the solenoid valve **16**.

[0074] An internal space of the cylinder tube **42** is partitioned by the piston assembly **26** into a first pressure chamber **66** adjacent to the top cover **54** and a second pressure chamber **68** adjacent to the bottom cover **58**. The cylinder tube **42** includes an air passage **120** that places the second pressure chamber **68** and the second air supply and discharge hole **22** of the base body **14** in communication with each other. The top cover **54** has a hole portion **54***a* penetrating the center of the top cover **54**. The first pressure chamber **66** communicates with the first air supply and discharge hole **20** of the base body **14** through the hole portion **54***a* of the top cover **54**.

[0075] When the solenoid valve **16** is in the first switching position, air is supplied to the first pressure chamber **66** and air is discharged from the second pressure chamber **68**, thereby biasing the piston assembly **26** downward. The air discharged from the second pressure chamber **68** passes through the air passage **120** of the cylinder tube **42** and the second air supply and discharge hole **22** of the base body **14**, and is discharged from the air discharge port **18** toward the inside of the cover body **82** via the solenoid valve **16**. The air discharged from the air discharge port **18** is discharged to the outside through the ventilation holes **82***c* of the cover body **82**.

[0076] When the solenoid valve **16** is in the second switching position, air is supplied to the second pressure chamber **68** and air is discharged from the first pressure chamber **66**, so that the piston assembly **26** is biased upward. The air discharged from the first pressure chamber **66** passes through the first air supply and discharge hole **20** of the base body **14**, and then is discharged from the air discharge port **18** toward the inside of the cover body **82** via the solenoid valve **16**.

[0077] In the magnetic chuck **90** according to the present embodiment, the holding force adjustment member **100** includes the adjustment body **102** fixed to the cylinder tube **42** and the adjustment ring **104** including the workpiece holding surface **92**, and the adjustment ring **104** is screw-engaged with the adjustment body **102**. Therefore, when the magnetic chuck **90** is attached to the robot arm, there is no restriction on the direction of attachment.

[0078] The holding force adjustment member **100** includes the locking plate **110** that can be fixed to the cylinder tube **42**, and the adjustment ring **104** is prevented from moving relative to the locking plate **110** in a direction parallel to the axis of the adjustment ring **104**. The screw-engagement position of the adjustment ring **104** with respect to the adjustment body **102** can be adjusted in a stepless manner, and the adjustment ring **104** can be locked reliably at the adjusted screw-engagement position. That is, it is possible to obtain a reliable workpiece holding force that can be changed in a stepless manner.

Third Embodiment

[0079] Next, a magnetic chuck **130** according to a third embodiment of the present invention will be described with reference to FIGS. **10** to **14**. In the magnetic chuck **130** according to the third embodiment, constituent elements that are the same as or equivalent to those of the above-described magnetic chuck **10** or the above-described magnetic chuck **90** may be denoted by the same reference numerals, and detailed description thereof may be omitted. In the following description, when terms in relation to up and down directions are used, for the sake of convenience, such terms refer to the directions shown in the drawings, however, the actual arrangement of the constituent members and the like is not necessarily limited to this feature.

[0080] As shown in FIGS. **10** and **11**, the magnetic chuck **130** includes a base member **12**, a cylinder member **24** disposed below the base member **12**, and a holding force adjustment member **100** attached to the cylinder member **24**. The magnetic chuck **130** is attached to a non-illustrated robot arm, on an upper end of the base member **12**. The holding force adjustment member **100** includes an adjustment body **102**, an adjustment ring **104**, and a locking mechanism member.

[0081] The adjustment body **102** is fixed to the cylinder tube **42** by the internally threaded portion **102*a*** of the adjustment body **102** being screw-engaged with the externally threaded portion **42*a*** of the cylinder tube **42**. The internally threaded portion **104*a*** of the adjustment ring **104** is screw-engaged with the externally threaded portion **102*b*** of the adjustment body **102**. The lower surface of the adjustment ring **104** and the lower surface of the pad **106** form a workpiece holding surface **92**. The side surface of the adjustment ring **104** has a knurled portion **104*d*** to prevent slippage.

[0082] The locking mechanism member includes a support body **134**, a locking shaft **136**, a locking ring **138**, a release knob **140**, and a biasing spring **142**. As shown in FIG. **12**, the support body **134** is disposed over the exterior of the base body **14** and the exterior of the cylinder tube **42**, and is fixed to the outer surface of the cylinder tube **42** by using third screw members **144**. The support body **134** has a hole portion **134*a*** through which the locking shaft **136** is inserted. The support body **134** has an elongate hole **134*b*** extending in the up and down direction in a wall portion away from the cylinder tube **42**.

[0083] The locking shaft **136** has a main body portion **136*a*** having a large diameter, a small diameter portion **136*c*** extending upward from the main body portion **136*a*** through a stepped portion **136*b*,** and an engaging portion **136*d*** projecting downward from the main body portion **136*a*.** The main body portion **136*a*** of the locking shaft **136** is inserted into and supported by the hole portion **134*a*** of the support body **134**. The locking shaft **136** is displaceable in the axial direction (the up and down direction) of the locking shaft **136**, but is not displaceable in the direction intersecting the axis of the locking shaft **136**.

[0084] The main body portion **136*a*** of the locking shaft **136** has a screw hole **136*e*** penetrating in the radial direction. A part of the small diameter portion **136*c*** of the locking shaft **136** projects upward from the support body **134**, and a nut **146** is fixed to a projecting end of the small diameter portion **136*c*.** The nut **146** prevents the locking shaft **136** from slipping out of the support body **134** downward. The engaging portion **136*d*** of the locking shaft **136** has a rectangular cross section and projects downward from the support body **134**.

[0085] The locking ring **138** is secured to the upper end of the adjustment ring **104** by a fourth screw member **148**. As shown in FIG. **13**, a plurality of groove portions **138*a*** are formed at equal angular intervals on the inner circumference of the annular locking ring **138**. The engaging portion **136*d*** of the locking shaft **136** is fitted into one of the groove portions **138*a*** of the locking ring **138**. Accordingly, the rotation of the locking ring **138** and the adjustment ring **104** is restricted. That is, the adjustment ring **104** is locked in a predetermined screw-engagement position with respect to the adjustment body **102**. A plurality of notches **138*b*** extending in the up and down direction are formed in an outer circumferential surface of the locking ring **138**. Each of the notches **138*b*** is formed at a position corresponding to each of the groove portions **138*a*** in the radial direction.

[0086] The release knob **140** has a main body portion **140*a*** having a cylindrical columnar shape and a threaded portion **140*b*** projecting from the main body portion **140*a*.** The threaded portion **140*b*** of the release knob **140** is screw-engaged with the screw hole **136*e*** of the locking shaft **136**, whereby the release knob **140** is fixed to the locking shaft **136**. The main body portion **140*a*** of the release knob **140** is inserted through the elongate hole **134*b*** of the support body **134** and an elongate hole **82*i*** formed in a cover body **82**, and a part of the main body portion **140*a*** projects outward from the cover body **82**. The main body portion **140*a*** of the release knob **140** is movable up and down in the elongate hole **134*b*** of the support body **134**.

[0087] The biasing spring **142**, which is a coil spring, is disposed between the stepped portion **136*b*** of the locking shaft **136** and the inner wall of the support body **134**. The locking shaft **136** is biased downward by a biasing spring **142**, and the lower end of the engaging portion **136*d*** of the locking shaft **136** abuts against the upper end of the adjustment ring **104**. As a result, the state in which the engaging portion **136*d*** of the locking shaft **136** is fitted in the groove portions **138*a*** of the locking ring **138** is maintained.

[0088] As shown in FIG. **14**, the base body **14** has a first air supply and discharge hole **20** and a second air supply and discharge hole **22**. One end of the first air supply and discharge hole **20** and the second air supply and discharge hole **22** are opened in the lower end portion of the base body **14**, and another end of the first air supply and discharge hole **20** and another end of the second air supply and discharge hole **22** are connected to the solenoid valve **16**. An internal space of the cylinder tube **42** is partitioned by the piston assembly **26** into a first pressure chamber **66** adjacent to the top cover **54** and a second pressure chamber **68** adjacent to the bottom cover **58**. The cylinder tube **42** includes an air passage **120** that places the second pressure chamber **68** and the second air supply and discharge hole **22** in communication with each other. The first pressure chamber **66** communicates with the first air supply and discharge hole **20** through the hole portion **54*a*** of the top cover **54**.

[0089] The workpiece holding force can be changed by changing the screw-engagement position of the adjustment ring **104** with respect to the adjustment body **102**. As shown in FIG. **10**, when the locking ring **138** integral with the adjustment ring **104** abuts against the cover body **82** and the adjustment ring **104** is positioned at the uppermost position, the workpiece holding force is maximized. As shown in FIG. **11**, when the main body portion **140*a*** of the release knob **140** abuts against the lower end of the elongate hole **134*b*** of the support body **134** and the adjustment ring **104** is positioned at the lowermost position, the workpiece holding force is minimized.

[0090] When the adjustment ring **104** locked at a predetermined screw-engagement position is changed to another screw-engagement position, the release knob **140** projecting outward from the cover body **82** is gripped first, and the release knob **140** and the locking shaft **136** are displaced upward against the biasing force of the biasing spring **142**. When the locking shaft **136** is displaced upward, the engaging portion **136***d* of the locking shaft **136** is disengaged from any of the groove portions **138***a* of the locking ring **138**.

[0091] The adjustment ring **104** is rotated to a desired position while the release knob **140** and the locking shaft **136** are displaced upward. At this time, it is possible to visually confirm that a predetermined notch **138***b* of the locking ring **138** is positioned just below the release knob **140**. When the release knob **140** is released from the grip after the adjustment ring **104** is rotated to a desired position, the engaging portion **136***d* of the locking shaft **136** is fitted into the predetermined groove portion **138***a* of the locking ring **138** by the action of the biasing spring **142**. Accordingly, the adjustment ring **104** is locked relative to the adjustment body **102** in the desired screw-engagement position. That is, the adjustment ring **104** is locked relative to the adjustment body **102** in the desired position in the up and down direction.

[0092] The position in the up and down direction at which the adjustment ring **104** is locked is adjusted in small increments in units of a length (P/n) obtained by dividing the pitch (P) of the internally threaded portion **104***a* of the adjustment ring **104** by the number (n) of the groove portions **138***a* formed in the locking ring **138**. The more the number of the groove portions **138***a* is, the more finely a locking position of the adjustment ring **104** is adjusted.

[0093] In the magnetic chuck **130** according to the present embodiment, the holding force adjustment member **100** includes the adjustment body **102** fixed to the cylinder tube **42** and the adjustment ring **104** including the workpiece holding surface **92**, and the adjustment ring **104** is screw-engaged with the adjustment body **102**. Therefore, when the magnetic chuck **130** is attached to the robot arm, there is no restriction on the direction of attachment.

[0094] Further, the holding force adjustment member **100** includes the locking shaft **136** supported by the support body **134** fixed to the cylinder tube **42** and the annular locking ring **138** fixed to the adjustment ring **104**, and the plurality of groove portions **138***a* into which the engaging portion **136***d* of the locking shaft **136** is fitted are formed in the inner circumference of the locking ring **138**. Therefore, the screw-engagement position of the adjustment ring **104** relative to the adjustment body **102** can be finely adjusted, and also the adjustment ring **104** can be securely locked at the adjusted screw-engagement position. That is, it is possible to easily obtain a reliable workpiece holding force that can be finely changed.

[0095] It should be noted that the present invention is not limited to the embodiments described above, and various alternative or additional configurations could be adopted therein without departing from the essence and gist of the present invention as set forth in the appended claims.

1. A magnetic chuck comprising: a base member; a cylinder member; and a holding force adjustment member, wherein the cylinder member includes a piston assembly and a cylinder tube, the piston assembly includes a permanent magnet, the holding force adjustment member includes an adjustment body fixed to the cylinder tube and an adjustment ring provided with a workpiece holding surface, the adjustment ring is screw-engaged with the adjustment body, and the magnetic chuck is configured to change a workpiece holding force by changing a screw-engagement position of the adjustment ring with respect to the adjustment body.

2. The magnetic chuck according to claim **1**, wherein the holding force adjustment member includes a jam ring configured to be screw-engaged with the adjustment body.

3. The magnetic chuck according to claim **1**, wherein the holding force adjustment member includes a locking plate configured to be fixed to the cylinder tube, and the adjustment ring is prevented from moving in a direction parallel to an axis of the adjustment ring with respect to the locking plate.

4. The magnetic chuck according to claim **3**, wherein the holding force adjustment member includes a knob screw screw-engaged with a block fixed to the cylinder tube, a wave washer is disposed between the locking plate and a knob portion of the knob screw, and the locking plate is sandwiched and held between the wave washer and the block when the knob screw is screw-engaged with the block by a predetermined amount.

5. The magnetic chuck according to claim **4**, wherein the locking plate has a slot through which a shaft portion of the knob screw is inserted.

6. The magnetic chuck according to claim **5**, wherein a scale visible from outside is indicated on the locking plate.

7. The magnetic chuck according to claim **1**, wherein the holding force adjustment member includes: a support body fixed to the cylinder tube; a locking shaft supported by the support body; and a locking ring having an annular shape and being fixed to the adjustment ring, and wherein a plurality of groove portions into which an engaging portion of the locking shaft is fitted, are formed at equal angular intervals in an inner circumference of the locking ring.

8. The magnetic chuck according to claim **7**, wherein the holding force adjustment member includes a release knob fixed to the locking shaft, and the release knob is inserted into an elongate hole of the support body.

9. The magnetic chuck according to claim **8**, wherein the holding force adjustment member includes a biasing spring disposed between the locking shaft and the support body, and the locking shaft abuts against the adjustment ring by a biasing force of the biasing spring.

10. The magnetic chuck according to claim **1**, wherein an opening of the cylinder tube farther from the workpiece holding surface is closed by a top cover, an opening of the cylinder tube closer to the workpiece holding surface is closed by a bottom cover, an internal space of the cylinder tube is partitioned by the piston assembly into a first pressure chamber adjacent to the top cover and a second pressure chamber adjacent to the bottom cover, the base member includes a first air supply and discharge hole and a second air supply and discharge hole, the first pressure chamber communicates with the first air supply and discharge hole through a hole portion of the top cover, and the cylinder tube includes an air passage configured to place the second pressure chamber and the second air supply and discharge hole in communication with each other.

11. The magnetic chuck according to claim **10**, wherein the cylinder tube includes an air passage configured to place the second pressure chamber and the first pressure chamber in communication with each other, and a flow rate regulating valve is disposed in the air passage.

12. The magnetic chuck according to claim **10**, wherein an air discharge port is disposed in the base member, and a cooling air from the air discharge port is discharged to outside from a ventilation hole of the adjustment ring through at least a clearance between the adjustment body and the adjustment ring.

13. The magnetic chuck according to claim **12**, wherein a cover body is attached to the base member, and the cooling air passes through a clearance between the cover body and the base member, a clearance between the cover body and the cylinder tube, and a clearance between the adjustment body and the cylinder tube, and thereafter passes through the clearance between the adjustment body and the adjustment ring.

14. The magnetic chuck according to claim **10**, wherein an air discharge port is disposed in the base member, a cover body is attached to the base member, and an air discharged from the air discharge port is discharged to outside through a ventilation hole formed in the cover body.

15. The magnetic chuck according to claim **14**, wherein a variable throttle valve is attached to the air discharge port, and a through hole is formed in the cover body, a flow passage area of the variable throttle valve being changed from an exterior of the cover body through the through hole.

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