



(12) **EUROPEAN PATENT APPLICATION**
published in accordance with Art. 153(4) EPC

(43) Date of publication:
27.01.2021 Bulletin 2021/04

(51) Int Cl.:
H01H 33/662 (2006.01) H01H 33/66 (2006.01)

(21) Application number: **19770731.8**

(86) International application number:
PCT/JP2019/004839

(22) Date of filing: **12.02.2019**

(87) International publication number:
WO 2019/181271 (26.09.2019 Gazette 2019/39)

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
KH MA MD TN

- **SATO, Takashi**
Tokyo 100-8280 (JP)
- **YABU, Masato**
Tokyo 101-0022 (JP)
- **TAMURA, Kozo**
Tokyo 101-0022 (JP)
- **TAI, Yuuki**
Tokyo 101-0022 (JP)

(30) Priority: **19.03.2018 JP 2018050985**

(74) Representative: **MERH-IP Matias Erny Reichl Hoffmann**
Patentanwälte PartG mbB
Paul-Heyse-Strasse 29
80336 München (DE)

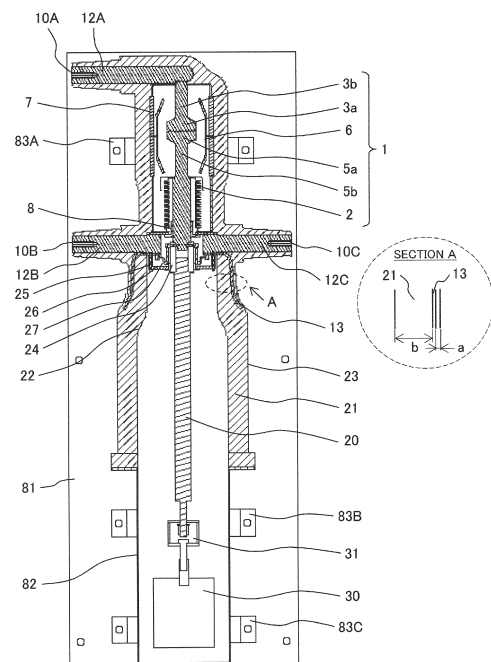
(71) Applicant: **Hitachi Industrial Equipment Systems Co., Ltd.**
Tokyo (JP)

(72) Inventors:
• **NAKAYAMA, Yasuaki**
Tokyo 100-8280 (JP)

(54) **SOLID DIELECTRIC VACUUM SWITCHGEAR**

(57) The present invention decreases an insulation distance between a vacuum switch and its peripheral components of equipment and improves the insulation characteristic of the vacuum switch. A solid dielectric vacuum switch includes a vacuum interrupter (1) having a fixed electrode (3a), a movable electrode (5a), a fixed conductor (3b) that is connected to the fixed electrode, and a movable conductor (5b) that is connected to the movable electrode; an insulated actuating rod (20) that is mechanically connected to the movable conductor; an actuator (30) that actuates the insulated actuating rod; and a solid insulator (21) covering the vacuum interrupter. A ground layer (23) covering an outer surface of the solid insulator is provided. A conductive shield (13) is provided within the solid insulator, the conductive shield covering around a connection portion between the movable conductor and the insulated actuating rod.

FIG. 6



Description

Technical Field

[0001] The present invention relates to a solid dielectric vacuum switch.

Background Art

[0002] A switch that is mounted on or in a railway car is placed on the roof or under the floor of the railway car. Dimensions of the switch, particularly their height and width dimensions are limited in terms of reducing air resistance, height of the car when passing through tunnels, and space restriction on the roof or under the floor among others.

[0003] As a down sizable switch, a solid dielectric vacuum switch is known, as described in Patent Literature 1 and Patent Literature 2.

[0004] A switch described in Patent Literature 1 includes a vacuum interrupter, a movable actuating shaft, a contact pressure spring mechanism that is disposed near a connection portion between the movable actuating shaft and a movable conductor, and a conductive box surrounding the contact pressure spring mechanism and the vacuum interrupter and the conductive box for relaxing an electric field are molded by an insulator.

[0005] In addition, in a switch described in Patent Literature 2, a ground layer is provided on the outer periphery of an insulation layer that is provided around the vacuum interrupter.

Citation List

Patent Literature

[0006]

Patent Literature 1: Japanese Patent Application Laid-Open No. 2012-69345

Patent Literature 2: Japanese Patent Application Laid-Open No. 2017-21939

Summary of Invention

Technical Problem

[0007] In the switch described in Patent Literature 1, because an insulation distance is needed when other components of equipment are placed around the switch, there will be an increase in the space for installing various components of equipment including the switch.

[0008] In addition, in the switch described in Patent Literature 2, an insulation distance to peripheral components of equipment can be reduced because the outer periphery of the insulation layer is grounded. However, no consideration is taken for an insulated actuating rod that is coupled to the movable conductor in the vacuum

interrupter, an actuator that is coupled to the insulated actuating rod, and insulation in the periphery of these components.

[0009] Accordingly, the present invention provides a solid dielectric vacuum switch enabling it to decrease the insulation distance to peripheral components of equipment and improve the insulation characteristic. Solution to Problem

[0010] To solve problems noted above, a solid dielectric vacuum switch according to the present invention includes a vacuum interrupter having a fixed electrode, a movable electrode, a fixed conductor that is connected to the fixed electrode, and a movable conductor that is connected to the movable electrode; an insulated actuating rod that is mechanically connected to the movable conductor; an actuator that actuates the insulated actuating rod; and a solid insulator covering the vacuum interrupter. A ground layer covering an outer surface of the solid insulator is provided. A conductive shield is provided within the solid insulator, the conductive shield covering around a connection portion between the movable conductor and the insulated actuating rod.

Advantageous Effects of Invention

[0011] According to the present invention, it is possible to decrease the insulation distance between a vacuum switch and its peripheral components of equipment and to improve the insulation characteristic of the vacuum switch.

[0012] Problems, configurations, and advantageous effects other than described above will be made apparent from the following description of embodiments.

Brief Description of Drawings

[0013]

Figure 1 illustrates an example of a train set of railway cars on or in which vacuum switches as Example 1 are mounted.

Figure 2 illustrates feeding circuits of the railway cars in Figure 1.

Figure 3 illustrates another example of the train set of railway cars on or in which vacuum switches as Example 1 are mounted.

Figure 4 illustrates feeding circuits of the railway cars in Figure 3.

Figure 5 illustrates an external view of a vacuum switch as Example 1 of the present invention.

Figure 6 is a cross-sectional view of the vacuum switch of Example 1 when cut along a longitudinal direction.

Figure 7 illustrates a state in which T-shape cable heads are connected to the vacuum switch of Example 1.

Figure 8 is a cross-sectional view of a vacuum switch as Example 2 when cut along a longitudinal direction.

Figure 9 illustrates an external view of a vacuum switch as Example 3.

Figure 10 illustrates an external view of a vacuum switch as Example 4.

Figure 11 illustrates an external view of a vacuum switch as Example 5.

Figure 12 illustrates an external view of a vacuum switch as Example 6.

Description of Embodiments

[0014] A vacuum switch as one embodiment of the present invention is a solid dielectric vacuum switch with its surface being covered with a ground potential. The vacuum switch is installed such that its longitudinal direction is parallel to the ground plane, for example, such that the longitudinal direction is along the traveling direction of a railway car at the top of the roof or on the floor of the railway car. Bushings to which cables are connected are disposed in any of upper, lower, left, and right positions in a direction perpendicular to the longitudinal direction. An actuating mechanics case is disposed substantially in line with a vacuum interrupter that is a switch unit. Thereby, it is possible to reduce height and width dimensions of the switch when installed. Also, because the surface is covered with the ground potential, it is possible to decrease the insulation distance between the vacuum switch and its peripheral components of equipment. Consequently, it is possible to reduce the space where the peripheral components of equipment are installed.

[0015] However, according to the study by the present inventors, when the surface of the vacuum switch is covered with the ground potential, a high electric field region is created inside the vacuum switch. Particularly, because the periphery of an insulated actuating rod is covered with atmospheric air where a breakdown electric field is low in comparison with solid insulating resin or the like, insulation performance may deteriorate potentially when a high electric field region is created.

[0016] Therefore, in the vacuum switch as one embodiment of the present invention, a conductive shield covering around the insulated actuating rod is provided and this conductive shield is disposed near to the surface ground layer. Thereby, the electric field in an air space around the insulated actuating rod inside the switch is relaxed and, consequently, the insulation characteristic of the vacuum switch improves. Moreover, according to the study by the present inventors, by these surface ground layer and conductive shield, the effect of relaxing the electric field becomes greater than when only the conductive shield is provided.

[0017] In the following, embodiments of the present invention will be described by Examples 1 to 6 set forth below and with the aid of the drawings. Note that identical reference numerals across the drawings denote identical structural elements or structural elements having a similar function.

<Example 1>

[0018] Railway cars on or in which vacuum switches as Example 1 are mounted is first described with Figures 1 to 4.

[0019] Figure 1 illustrates an example of a train set of railway cars on or in which vacuum switches as Example 1 are mounted.

[0020] The train set illustrated in Figure 1 is composed of eight cars (1st to 8th cars). High-voltage pull-through cables RC1, RC2, RC3, RC4, and RC5 are disposed on the roofs of these cars. High-voltage pull-through cables RC3, RC5 are connected to pantographs PG1, PG2, respectively. The railway cars receive electric power from a feeder (not illustrated) and the received electric power is distributed to each car through the high-voltage pull-through cables R1 to R5.

[0021] The respective cables are connected by straight joints SJ1, SJ2, SJ3, SJ4 positioned on the roofs between the cars and branched toward a car floor direction by T branch joints TJ1, TJ2 on the roofs. Here, a T branch joint TJ1 and a straight joint SJ2 are integrated into a vacuum switch which will be described later and a T branch joint TJ2 and a straight joint SJ4 are also integrated into a vacuum switch.

[0022] Figure 2 illustrates a feeder (feeding) circuit of the railway cars in Figure 1.

[0023] As shown in Figure 2, under the floors (Under Floor) of the second car (2nd car), fourth car (4th car), and sixth car (6th car), power receiving vacuum circuit breakers VCB1, VCB2, VCB3 are provided respectively and, in addition, main transformers Tr1, Tr2, Tr3 are provided respectively.

[0024] A high-voltage pull-through cable RC1 of the 2nd car is directly connected to a primary side of a power receiving vacuum circuit breaker VCB1 and a secondary side of the power receiving vacuum circuit breaker VCB1 is connected to a primary winding of a main transformer Tr1. A secondary winding of the main transformer Tr1 supplies power to an electric motor and its tertiary winding supplies power to auxiliary equipment such as air-conditioners and illumination.

[0025] High-voltage pull-through cables that are branched by T branch joints TJ1, TJ2 of the fourth car (4th car) and sixth car (6th car) are respectively connected to the primary sides of power receiving vacuum circuit breakers VCB2, VCB3 provided under the floors. The secondary sides of the power receiving vacuum circuit breakers VCB2, VCB3 are respectively connected to the primary windings of main transformers Tr2, Tr3. The secondary windings of the main transformers Tr2, Tr3 supply power to electric motors and their tertiary windings supply power to the auxiliary equipment.

[0026] Note that power may be supplied to the electric motors and auxiliary equipment via a power converter from the main transformers.

[0027] As described above, the power receiving vacuum circuit breakers VCB1, VCB2, VCB3 and the main

transformers Tr1, Tr2, Tr3 are disposed under the floors and other components of electric equipment (RC1 to 5, SJ1 to 4, PG1 to 2, TJ1 to 2) are disposed on the roofs. Because VCB1 to 3 and Tr1 to 3 are disposed under the floors, work on the roofs for installing, maintaining, and inspecting components of electrical equipment is reduced. Also, when components of electrical equipment are disposed on the roofs, space in a height direction is much restricted. Nevertheless, as will be described later, the dimension of a vacuum switch in a height direction can be decreased according to Example 1 of the present invention and, therefore, the vacuum switch can be installed easily on the roofs.

[0028] Figure 3 illustrates another example of the train set of the railway cars on or in which vacuum switches as Example 1 are mounted. In addition, Figure 4 illustrates a feeding circuit in the railway cars in Figure 3.

[0029] As shown in Figure 3 and Figure 4, in the present Example, the high-voltage pull-through cables RC1 to 5, straight joints SJ1 to 4, and T branch joints TJ1 to 2 are installed under the floors (Under Floor). In addition, some high-voltage cables are led inside the cars from the pantographs PG1, PG2 and connected to the high-voltage pull-through cables RC3, RC5, respectively. When components of electrical equipment are installed under the floors in this way, installation space is much restricted. Nevertheless, a vacuum switch can be installed easily under the floors according to Example 1 that will be described later.

[0030] As shown in Figure 2 and Figure 4, in a case where a line-to-ground fault (Fault) has occurred at the high-voltage pull-through cable RC2 in the third car (3rd car), a vacuum switch is operated by a command from outside to open the straight joint SJ2 automatically, thereby disconnecting the main transformer Tr1 and an electric motor connected thereto that are affected by the line-to-ground fault (Fault) from the feeding circuit. At this time, the main transformers Tr2, Tr3 that are not affected by the line-to-ground fault (Fault) remain connected to the feeding circuit and, therefore, operation of the railway cars can be continued using electric motors that are connected to these transformers.

[0031] Note that a vacuum switch to be operated, i.e., a straight joint (SJ2 or SJ4) to be disconnected is selected appropriately depending on the location of the line-to-ground fault. Thereby, it is possible to separate high-voltage cables that are healthy from a high-voltage cable including the fault location automatically.

[0032] Then, a vacuum switch as Example 1 of the present invention is described with Figures 5 to 7. Note that a vacuum switch of the present Example 1 is integrated with a T branch joint (TJ1 or TJ2) and a straight joint (SJ2 or SJ4) in a case where it is mounted on or in the railway car.

[0033] Figure 5 illustrates an external view of a vacuum switch as Example 1 of the present invention. Dashed lines in Figure 5 show an internal structure. Note that Figure 5 is a plan view of the vacuum switch being in-

stalled on or in the railway car (the same is also true for Figures 6 and 7). Therefore, a longitudinal direction of the vacuum switch is along a longitudinal direction of the railway car.

[0034] As shown in Figure 5, the vacuum switch of the present Example 1 is mounted on or in the railway car with the vacuum switch being set stationary on a base 81 via stays 83A to 83C.

[0035] Figure 6 is a cross-sectional view of the vacuum switch of Example 1 when cut along the longitudinal direction. Note that the cutting plane is a plane including the central axis of a movable electrode 5a and an air insulated actuating rod 20 which will be described later.

[0036] As shown in Figure 6, the vacuum switch of Example 1 includes a vacuum interrupter 1 comprising a fixed electrode 3a, a movable electrode 5a that comes in or out of contact with the fixed electrode 3a, an arc shield 6 that covers surrounding of the fixed electrode 3a and the movable electrode 5a, a ceramic insulating cylinder 7 having a cylindrical form and forming a part of an outer container that supports the arc shield 6, and a bellows 2, as main parts.

[0037] The outer container of the vacuum interrupter 1 is comprised of the ceramic insulating cylinder 7 and end plates covering both ends of the ceramic insulating cylinder 7, and its inside is maintained in a vacuum state. The fixed electrode 3a is connected to a fixed conductor 3b and the fixed conductor 3b is extended outside the vacuum interrupter 1 and electrically connected to a bushing conductor 12A adjacent to the fixed conductor 3b. The movable electrode 5a is connected to a movable conductor 5b and the movable conductor 5b is extended outside the vacuum interrupter 1 and electrically connected to bushing conductors 12B, 12C adjacent to the movable conductor 5b.

[0038] The vacuum interrupter 1, the bushing conductor 12A adjacent to the fixed conductor 3b, and the bushing conductors 12B, 12C adjacent to the movable conductor 5b are molded and coated with a solid insulator 21 made of epoxy resin or the like. In addition, the surface of the solid insulator 21 is covered with a ground layer 23. Ground potential is given to the ground layer 23. Note that the ground layer 23 is formed by metallic spraying or applying a conductive coating material among others. The outermost ends of the respective bushing conductors toward external air are not molded with the solid insulator 21 and a conductor portion is exposed. These outermost ends make up connection ports 10A, 10B, 10C with T-shape cable heads (Figure 7).

[0039] In a movable side of the vacuum interrupter 1, the bellows 2 is disposed between the movable conductor 5b and the movable-side end plate. This bellows allows the movable conductor 5b to move, while maintaining the vacuum state of the vacuum interrupter 1. Also, in the movable side of the vacuum interrupter 1, an electromagnetic actuator 30 that actuates an air insulated actuating rod 20 is provided. A movable side actuating axis of the electromagnetic actuator 30 is coaxially con-

nected to the air insulated actuating rod 20 via an actuating link portion 31. The electromagnetic actuator 30, the actuating link portion 31, and an end portion of the air insulated actuating rod 20 connected to the electromagnetic actuator 30 are stored in a mechanics case 82 that coaxially contacts a substantially cylindrical mold part made by the solid insulator 21. Therefore, in the vacuum switch, the electromagnetic actuator 30 is disposed coaxially with the air insulated actuating rod 20.

[0040] In the electromagnetic actuator 30, for example, using a device combining a permanent magnet and an electromagnet with a spring, by turning ON/OFF electric conduction to a coil forming an electromagnet, a drive force is generated. Note that the structure of the electromagnetic actuator 30 in the present Example is publicly known and detailed description of the electromagnetic actuator 30 is omitted.

[0041] Using the electromagnetic actuator 30, by actuating a drive axis of the movable electrode 5a, provided by coupling the air insulated actuating rod 20 and the movable conductor 5b integrally and coaxially with a metallic adapter 24, it is possible to make the movable electrode 5a come in or out of contact with the fixed electrode 3a while ensuring a sufficient insulation distance between the vacuum interrupter 1 and the electromagnetic actuator 30. Moreover, between the movable conductor 5b and the bushing conductors 12B, 12C, there are the metallic adapter 24 and a flexible conductor 27 that electrically connects the metallic adapter 24 and the bushing conductors, moving with the movable conductor 5b; thereby, conductivity and movability are ensured.

[0042] Furthermore, in the present Example 1, as shown in Figure 6, within the solid insulator 21, a conductive shield 13 is provided to cover the outer periphery of a connection portion between an end portion of the air insulated actuating rod 20 toward the movable conductor 5b and the movable conductor 5b. The conductive shield 13 is electrically connected with the movable conductor 5b via the bushing conductors 12B, 12C and the flexible conductor 27. Also, an end portion of the conductive shield 13 toward the movable conductor 5b is in contact with and electrically connected with the bushing conductors 12B, 12C adjacent to the movable conductor 5b.

[0043] Within the solid insulator 21, the conductive shield 13 extends from a portion where it contacts the bushing conductors 12B, 12C adjacent to the movable conductor 5b toward a direction of the electromagnetic actuator 30. Thereby, the conductive shield 13 covers the periphery of the metallic adapter 24, a housing 25, and a shaft support 26, and the flexible conductor 27, existing around the connection portion between the air insulated actuating rod 20 and the movable conductor 5b, that is, the periphery of conductor portions around the connection portion between the air insulated actuating rod 20 and the movable conductor 5b and, in addition, the periphery of an air-exposed part of the air insulated actuating rod 20 extending from a connection portion with the metallic adapter 24 toward the direction of the elec-

tromagnetic actuator 30.

[0044] Additionally, the conductive shield 13 is made of a conductive material such as metal and conductive rubber.

[0045] By this conductive shield 13 and the abovementioned ground layer 23, when high voltage is applied to the conductive shield 13 via the bushing conductors 12B, 12C, an electric field concentrates inside the solid insulator 21 between the conductive shield 13 and the ground layer 23 and electric field concentration is relaxed in the air surrounding the conductor portions around the connection portion between the air insulated actuating rod 20 and the movable conductor 5b. Moreover, a region where the electric field is concentrated between the conductive shield 13 and the ground layer 23 and in an end portion of the conductive shield 13 toward the electromagnetic actuator 30 is covered with the solid insulator 21 having higher dielectric strength than air. Owing to those above, the insulation characteristic of the vacuum switch improves even with provision of the ground layer 23. Therefore, according to the present Example 1, a decrease in insulation distance to peripheral components of equipment is enabled and the insulation characteristic of the vacuum switch improves.

[0046] Note that, because the solid insulator inner wall 22 near an end portion of the conductive shield 13 contacts air, insulation may be weakened potentially in this portion. Therefore, in the present Example 1, a thickness b of the solid insulator 21 between the solid insulator inner wall 22 and the conductive shield 13 is made larger than a thickness a of the solid insulator 21 between the ground layer 23 and the conductive shield 13 ($b > a$), as indicated in section A circled with a dashed line in Figure 6. Thereby, within the solid insulator 21, the conductive shield 13 is disposed nearer to the outer surface of the solid insulator 21, i.e., the ground layer 23 than the solid insulator inner wall 22. That is, within the solid insulator 21, the conductive shield 13 is disposed far from the solid insulator inner wall 22 or close to the outer surface of the solid insulator 21 and there can be an increase in the thickness of the solid insulator 21 between the solid insulator inner wall 22 and the conductive shield 13. Consequently, field strength at the solid insulator inner wall 22 can be decreased. Note that the thickness a is set to a dimension to adjust the field strength so that an electric field between the conductive shield 13 and the ground layer 23 does not cause deterioration in insulation of the solid insulator 21.

[0047] In addition, in the present Example 1, the end portion of the conductive shield 13 toward the electromagnetic actuator 30 bends toward the ground layer 23 within the solid insulator 21. This makes the above end portion farther from its adjacent solid insulator inner wall 22 and, consequently, electric field concentration can be relaxed at the solid insulator inner wall 22 where electric field concentration is liable to occur.

[0048] Moreover, the solid insulator inner wall 22 adjacent to the end portion of the conductive shield 13 has

a convex curved inner wall surface facing an air space in the vacuum switch. More specifically, the solid insulator inner wall 22 has a first cylindrical inner wall surface with an inner diameter being substantially constant for a section from a portion adjacent to the connection portion between the air insulated actuating rod 20 and the movable conductor 5b to a portion adjacent to the end portion of the conductive shield 13, has the convex curved surface facing the air space for a section adjacent to the end portion of the conductive shield 13, and has a second cylindrical inner wall surface with an inner diameter being substantially constant and larger than the first inner wall surface for a section extending toward the electromagnetic actuator 30 from the portion adjacent to the end portion of the conductive shield 13. These first inner wall surface, convex curved inner wall surface facing the air space, and second inner wall surface form a smoothly continuing surface.

[0049] Additionally, the entire thickness of the solid insulator 21 abutting the first inner wall surface and the entire thickness of the solid insulator abutting the second inner wall surface are approximately equal; for example, the insulator thickness is set to a thickness that is the sum of thickness dimensions a and b in section A in Figure 6 plus the thickness of the conductive shield 13 or a thickness that is the sum of thickness dimensions a and b. Thereby, the mechanical strength and insulation performance of the vacuum switch improve.

[0050] Additionally, in the present Example 1, in conjunction with the setting of the entire thickness of the solid insulator 21, the outer surface that contacts external air of the solid insulator 21, i.e., the outer surface of the ground layer 23 has a first cylindrical outer surface with an outer diameter being substantially constant for a section from the portion adjacent to the connection portion between the air insulated actuating rod 20 and the movable conductor 5b to the portion adjacent to the end portion of the conductive shield, a convex curved surface facing the external air for a section adjacent to the end portion of the conductive shield 13, and has a second cylindrical outer surface with an outer diameter being substantially constant and larger than the first outer surface for a section extending toward the electromagnetic actuator 30 from the portion adjacent to the end portion of the conductive shield 13. These first outer surface, convex curved outer surface facing the external air, second outer surface form a smoothly continuing surface. That is, the shape of the outer surface of the solid insulator 21 and the ground layer 23 is similar to the shape of the inner wall surface of the solid insulator 21.

[0051] By of the above-described shape of the solid insulator inner wall and owing to the fact that this shape allows for an increase in the thickness of the solid insulator 21 between the solid insulator inner wall 22 and the conductive shield 13 in a portion adjacent to the end portion of the conductive shield 13 toward the electromagnetic actuator 30, it is possible to relax electric field concentration at the solid insulator inner wall 22 adjacent to

the end portion of the conductive shield.

[0052] Additionally, as described previously, by setting thickness dimensions a and b of the solid insulator 21 to be $a < b$, as indicated in section A in Figure 6, so that the conductive shield is disposed nearer to the outer surface of the solid insulator 21, heat radiation performance of the vacuum switch improves.

[0053] As shown in Figure 6, in the vacuum switch of the present Example 1, a guide 8 and a shaft support 26 are provided to restrict the direction of movement of the drive axis of the movable electrode 5a and enhance smoothness of a sliding motion; the movable electrode 5a, movable conductor 5b, metallic adapter 24, and air insulated actuating rod 20 are coaxially assembled on the above drive axis. The guide 8 supports a shaft of the movable conductor 5b that is constituent of the drive axis of the movable electrode 5a. Also, the shaft support 26 that is held in the housing 25 supports a shaft of the metallic adapter 24 that is constituent of the drive axis of the movable electrode 5a. In this way, the support of shaft is provided by two components which are the guide 8 and the support shaft 26. This improves the accuracy of centering of the movable conductor 5b, metallic adapter 24, and air insulated actuating rod 20 that are assembled coaxially and, consequently, smoothness of the sliding motion improves. Note that, in the present Example 1, the guide 8 and the shaft support 26 have a shape in which a flange is placed on one end of a short tube; however, they may have another shape, not limited to this shape.

[0054] In the present Example 1, inside the vacuum switch, a space surrounding the air insulated actuating rod 20 and a space surrounding the connection portion between the air insulated actuating rod 20 and the movable conductor 5b are filled with air and ambient gas is atmospheric air; however, there is no limitation to this and such space may be filled with insulating gas such as dry air and SF₆ gas. This contributes to improvement in the insulation performance of the vacuum switch. Additionally, in this case, using sealing means such as a sealant, sealing is provided between the opening of the solid insulator 21 toward the electromagnetic actuator 30 and the opening of the mechanics case 82 abutting the solid insulator to keep in insulating gas inside the vacuum switch.

[0055] Figure 7 illustrates a state in which T-shape cable heads 40A, 40B, 40C are connected to the vacuum switch of the present Example 1.

[0056] Conductor portions inside the T-shape cable heads 40A, 40B, 40C that are respectively connected with the end portions of cables 42A, 42B, 42C are bolted onto the outermost ends of the bushing conductors 12A, 12B, 12C, respectively. The conductor portions are stored inside T-shaped insulating resin. A T-shape head has a hollow portion for mating with a bushing part and bolt fastening of a conductor portion and both ends of the head are open. An opening for bolt fastening is closed with an insulation plug (41A, 41B, 41C) and, therefore,

a connection portion between each bushing conductor and each T-shape cable head is covered with an insulator and is not exposed to outside.

[0057] As shown in Figure 7, in the vacuum switch of the present Example 1, the vacuum interrupter 1, air insulated actuating rod 20, and electromagnetic actuator 30 are disposed coaxially and substantially in line. In addition, the bushing conductors 12A, 12B, 12C protrude in a direction perpendicular to the longitudinal direction of the vacuum switch, i.e., a direction perpendicular to a direction in which the movable electrode 5a, movable conductor 5b, and air insulated actuating rod 20 moves and in a direction parallel to the plane on which the vacuum switch is set stationary on the base 81. Thereby, with the cables connected to the vacuum switch, the electromagnetic actuator 30 and the T-shape cable heads 40A, 40B, 40C do not interfere with each other and it is possible to decrease the height and width dimensions of the vacuum switch after cable connection.

[0058] As described previously, according to the present Example 1, the surface of the solid insulator 21 that molds the constituent parts of the vacuum switch is covered with the ground layer 23 and the conductive shield 13 is provided within the solid insulator to cover around the connection portion between the air insulated actuating rod 20 and the movable conductor 5b; thereby, the insulation performance of the vacuum switch can be improved even with provision of the ground layer 23. In addition, because it is possible to decrease the height and width dimensions of the vacuum switch after cable connection, it is possible to increase the degree of freedom of a location where the vacuum switch is installed on or in the railway cars or the like. In addition, owing to the fact that the surface of the vacuum switch is covered with the ground layer 23, it is possible to decrease the insulation distance between the vacuum switch and its peripheral components of equipment, and therefore, it is possible to decrease the entire space for installing the vacuum switch together with its peripheral components of equipment.

<Example 2>

[0059] Figure 8 is a cross-sectional view of a vacuum switch as Example 2 of the present invention when cut along the longitudinal direction. The following description focuses on a point that differs from Example 1.

[0060] First, in the case of the present Example 2, as with Example 1, the solid insulator inner wall 22 has a first cylindrical inner wall surface with an inner diameter being substantially constant for a section from a portion adjacent to the connection portion between the air insulated actuating rod 20 and the movable conductor 5b to a portion adjacent to the end portion of the conductive shield 13, has a convex curved surface facing the air space for a section adjacent to the end portion of the conductive shield 13, and has a second cylindrical inner wall surface with an inner diameter being substantially

constant and larger than the first inner wall surface for a section extending toward the electromagnetic actuator 30 from the portion adjacent to the end portion of the conductive shield 13. These first inner wall surface, convex curved inner wall surface facing the air space, and second inner wall surface form a smoothly continuing surface.

[0061] In the present Example 2, unlike Example 1, the entire thickness of the solid insulator 21 abutting the second inner wall surface is smaller than the entire thickness of the solid insulator 21 abutting the first inner wall surface. That is, the entire thickness of the solid insulator 21 abutting the second inner wall surface is, for example, set to a thickness that is smaller than a thickness that is the sum of thickness dimensions a and b in section A in Figure 6 plus the thickness of the conductive shield 13 or a thickness that is the sum of thickness dimensions a and b.

[0062] That is, in the present Example 2, in the solid insulator 21, the thickness of the solid insulator 21 is decreased for a section going far from a section adjacent to the end portion of the conductive shield 13, where an electric field easily concentrates, toward the electromagnetic actuator 30, in other words, a section where field strength becomes lower than that in the section adjacent to the end portion of the conductive shield 13. Thereby, the weight of the solid insulator 21 is decreased without affecting the insulation performance of the vacuum switch, and consequently, it is possible to make the vacuum switch lighter.

<Example 3>

[0063] Figure 9 illustrates an external view of a vacuum switch as Example 3 of the present invention. Dashed lines in Figure 9 show an internal structure. Note that Figure 9 is a plan view of the vacuum switch being installed on or in the railway car. Hence, the longitudinal direction of the vacuum switch is along the longitudinal direction of the railway car. The following description focuses on a point that differs from Example 1.

[0064] In the present Example 3, unlike Example 1, only one bushing conductor 12B is provided adjacently to the movable conductor 5b. That is, in respect of functions as straight joints and T-shape joints, the vacuum switch of the present Example 3 only has a function as straight joints for connection of a cable (corresponding to the cable 42A in Figure 7) that is connected to the bushing conductor 12A and a cable (corresponding to the cable 42B in Figure 7) that is connected to the bushing conductor 12B.

[0065] According to the present Example 3, in a case where there are a location where a cable branch is present and a location where a cable branch is not present, as in the railway car, it is possible to improve the insulation performance of the vacuum switch integrated with a straight joint in the location where a cable branch is not present and to decrease the insulation dis-

tance between the vacuum switch and its peripheral components of equipment. In addition, it is possible to decrease the height and width dimensions of the vacuum switch after cable connection.

<Example 4>

[0066] Figure 10 illustrates an external view of a vacuum switch as Example 4 of the present invention. Dashed lines in Figure 10 show an internal structure. Note that Figure 10 is a plan view of the vacuum switch being installed on or in the railway car. Hence, the longitudinal direction of the vacuum switch is along the longitudinal direction of the railway car. The following description focuses on a point that differs from Example 1.

[0067] In the present Example 4, as with Example 1, two bushing conductors 12B, 12C are provided adjacently to the movable electrode 5a; whereas, unlike Example 1, two bushing conductor 12A, 12D are also provided adjacently to the fixed electrode 3a. Thereby, the vacuum switch of the present Example 3 has a function as straight joints for connection of a cable (corresponding to the cable 42A in Figure 7) that is connected to the bushing conductor 12A and a cable (corresponding to the cable 42B in Figure 7) that is connected to the bushing conductor 12B, a function as T-shape joints for branching of a cable (corresponding to the cable 42C in Figure 7) that is connected to the bushing conductor 12C in the side of the movable electrode 5a, and a function as T-shape joints for branching of a cable that is connected to a bushing conductor 12D in the fixed side.

[0068] In the present Example, because cable branching is enabled also in the side of the fixed electrode 3a in addition to the side of the movable electrode 5a, it is possible to expand the degree of freedom of circuit configurations of the feeder circuit.

<Example 5>

[0069] Figure 11 illustrates an external view of a vacuum switch as Example 5 of the present invention. Dashed lines in Figure 11 show an internal structure. Note that Figure 11 is a side view of the vacuum switch being installed on or in the railway car. Note that the longitudinal direction of the vacuum switch is along the longitudinal direction of the railway car. The following description focuses on a point that differs from Example 1.

[0070] In the present Example 5, as shown in Fig. 11, the air insulated actuating rod 20 and the electromagnetic actuator 30 are not disposed coaxially and the air insulated actuating rod 20 and the movable side actuating axis of the electromagnetic actuator 30 are placed at different heights from the base 81 in a state when the vacuum switch is installed. The air insulated actuating rod 20 and the movable side actuating axis of the electromagnetic actuator 30 are connected via a link 84 as well as the actuating link portion 31. That is, the air insulated actuating rod 20 and the movable side actuating axis of

the electromagnetic actuator 30 are coupled non-coaxially via the link 84. Thereby, strokes of the electromagnetic actuator can be made different from strokes of the air insulated actuating rod 20 and the degree of freedom of setting the strokes of both expands. Consequently, workability of stroke adjustment improves. In addition, by providing the link 84 with a mechanism acting as a lever, it is possible to decrease the output of the electromagnetic actuator 30. Thereby, the electromagnetic actuator 30 can be downsized. Consequently, the electromagnetic actuator 30 can be stored in the mechanics case 82.

<Example 6>

[0071] Figure 12 illustrates an external view of a vacuum switch as Example 6 of the present invention. Dashed lines in Figure 12 show an internal structure. Note that Figure 12 is a side view of the vacuum switch installed on the roof of the railway car along the longitudinal direction. The longitudinal direction of the vacuum switch is along the longitudinal direction of the railway car. Also, Figure 12 depicts a state when the T-shape cable heads have been connected to the vacuum switch. The following description focuses on a point that differs from Example 1.

[0072] As shown in Figure 12, in the present Example 6, the base 81 of the vacuum switch is installed on the train roof 86. In addition, two bushing conductors 12A, 12D in the side of the fixed conductor 3b and a bushing conductor 12C in the side of the movable conductor 5b are disposed in a direction perpendicular to the longitudinal direction of the vacuum switch and in a direction perpendicular to the plane of the base 81. That is, the bushing conductors 12A, 12C, 12D protrude in a direction perpendicular to the plane on which the vacuum switch is installed. Thereby, the bushing conductor 12A protrudes inside the car under the train roof 86 and the cable that is connected to the bushing conductor 12A can be wired under the train roof 86.

[0073] Note that, even by organizing the bushing conductors as in the present Example 6 (two in the fixed conductor side and one in the movable conductor side) (one in the fixed conductor side and two in the movable conductor side in Example 1), the vacuum switch can have both straight joint and T branch joint functions.

[0074] Note that a place where the base 81 is installed is not limited to on the train roof 86 as in the present Example 6 and may be, inter alia, under the roof, on the floor, or under the floor of the railway car. In each case, the bushing conductor 12A is protruded and its cable can be wired in an opposite side to the side where the vacuum switch is located with respect to the base 81. Consequently, the degree of freedom of placing the vacuum switch expands.

[0075] Now, the present invention is not limited to Examples described hereinbefore and various modifications are included therein. For example, the foregoing Examples are those described in detail to explain the

present invention clearly and the invention is not necessarily limited to those including all components described. In addition, for a subset of the components of each Example, other components may be added to the subset or the subset may be removed or replaced by other components.

[0076] For instance, a vacuum switch according to the present invention is applicable to various types of power receiving and power distribution facilities, not limited to railway car application. In addition, a vacuum switch according to the present invention may be installed such that its longitudinal direction is along a direction perpendicular to a horizontal plane of a site where it is installed.

Reference Signs List

[0077] PG1, PG2: pantographs, RC1, RC2, RC3, RC4, RC5: high-voltage pull-through cable, SJ1, SJ2, SJ3, SJ4: straight joint, TJ1, TJ2: T branch joint, Tr1, Tr2, Tr3: main transformer, VCB1, VCB2, VCB3: power receiving vacuum circuit breaker, 1: vacuum interrupter, 2: bellows, 3a: fixed electrode, 3b: fixed conductor, 5a: movable electrode, 5b: moveable conductor, 6: arc shield, 7: ceramic insulating cylinder, 8: guide, 10A, 10B, 10C, 10D: connection port, 12, 12A, 12B, 12C, 12D: bushing conductor, 13: conductive shield, 20: air insulated actuating rod, 21: solid insulator, 22: solid insulator inner wall, 23: ground layer, 24: metallic adapter, 25: housing, 26: shaft support, 27: flexible conductor, 30: electromagnetic actuator, 31: actuating link portion, 40A, 40B, 40C, 40D: T-shape cable head, 41A, 41B, 41C, 41D: insulation plug, 42A, 42B, 42C, 42D: cable, 81: base, 82: mechanics case, 83A, 83B, 83C: stay, 84: link, 86: train roof

Claims

1. A solid dielectric vacuum switch comprising:

a vacuum interrupter having a fixed electrode, a movable electrode, a fixed conductor that is connected to the fixed electrode, and a movable conductor that is connected to the movable electrode;
an insulated actuating rod that is mechanically connected to the movable conductor;
an actuator that actuates the insulated actuating rod; and
a solid insulator covering the vacuum interrupter, wherein a ground layer covering an outer surface of the solid insulator is provided; and
a conductive shield is provided within the solid insulator, the conductive shield covering around a connection portion between the movable conductor and the insulated actuating rod.

2. The solid dielectric vacuum switch according to claim 1,

wherein the conductive shield is disposed nearer to the ground layer than an inner wall of the solid insulator.

3. The solid dielectric vacuum switch according to claim 1,
wherein a thickness of the solid insulator between an inner wall of the solid insulator and the conductive shield is larger than a thickness of the solid insulator between the ground layer and the conductive shield.

4. The solid dielectric vacuum switch according to any one of claims 1 to 3,
wherein an end portion of the conductive shield bends toward the ground layer.

5. The solid dielectric vacuum switch according to any one of claims 1 to 3,
wherein an inner wall surface of the solid insulator adjacent to an end portion of the conductive shield has a convex curved surface facing an air space.

6. The solid dielectric vacuum switch according to claim 1,
wherein a thickness of the solid insulator for a section between the end portion of the conductive shield and the actuator is smaller than a thickness of the solid insulator for a section between the connection portion between the movable conductor and the insulated actuating rod and the end portion of the conductive shield, wherein these sections are contiguous.

7. The solid dielectric vacuum switch according to claim 1, comprising:

a first bushing conductor that is connected to the fixed conductor; and
a second bushing conductor that is connected to the movable conductor,
wherein the first bushing conductor and the second bushing conductor are covered with the solid insulator.

8. The solid dielectric vacuum switch according to claim 7, comprising a third bushing conductor that is connected to the fixed conductor or the movable conductor,
wherein the third bushing conductor is covered with the solid insulator.

9. The solid dielectric vacuum switch according to claim 1, comprising a plurality of bushing conductors, each of which is connected to one of the fixed conductor and the movable conductor,
wherein the plurality of bushing conductors are covered with the solid insulator; and
the plurality of bushing conductors are disposed in

a direction perpendicular to a movable direction of the movable electrode, the movable conductor, and the insulated actuating rod.

10. The solid dielectric vacuum switch according to claim 9, wherein the movable electrode, the movable conductor, and the insulated actuating rod are coupled coaxially. 5
- 10
11. The solid dielectric vacuum switch according to claim 1, comprising a plurality of bushing conductors, each of which is connected to one of the fixed conductor and the movable conductor, wherein the plurality of bushing conductors are covered with the solid insulator; and the plurality of bushing conductors protrude in a direction parallel to a plane on which the vacuum switch is installed. 15
- 20
12. The solid dielectric vacuum switch according to claim 1, comprising a plurality of bushing conductors, each of which is connected to one of the fixed conductor and the movable conductor, wherein the plurality of bushing conductors are covered with the solid insulator; and the plurality of bushing conductors protrude in a direction perpendicular to a plane on which the vacuum switch is installed. 25
- 30
13. The solid dielectric vacuum switch according to claim 1, wherein the insulated actuating rod and a movable side actuating axis of the actuator are coupled coaxially. 35
- 40
14. The solid dielectric vacuum switch according to claim 1, wherein the insulated actuating rod and a movable side actuating axis of the actuator are coupled non-coaxially via a link portion. 45
- 50
- 55

FIG. 1

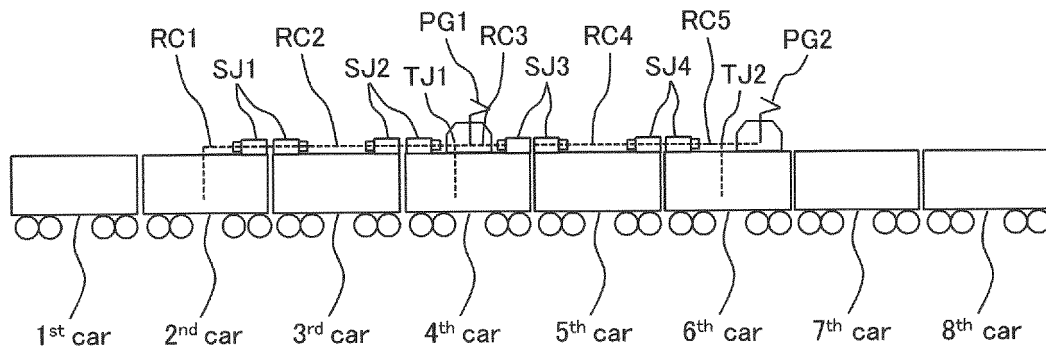


FIG. 2

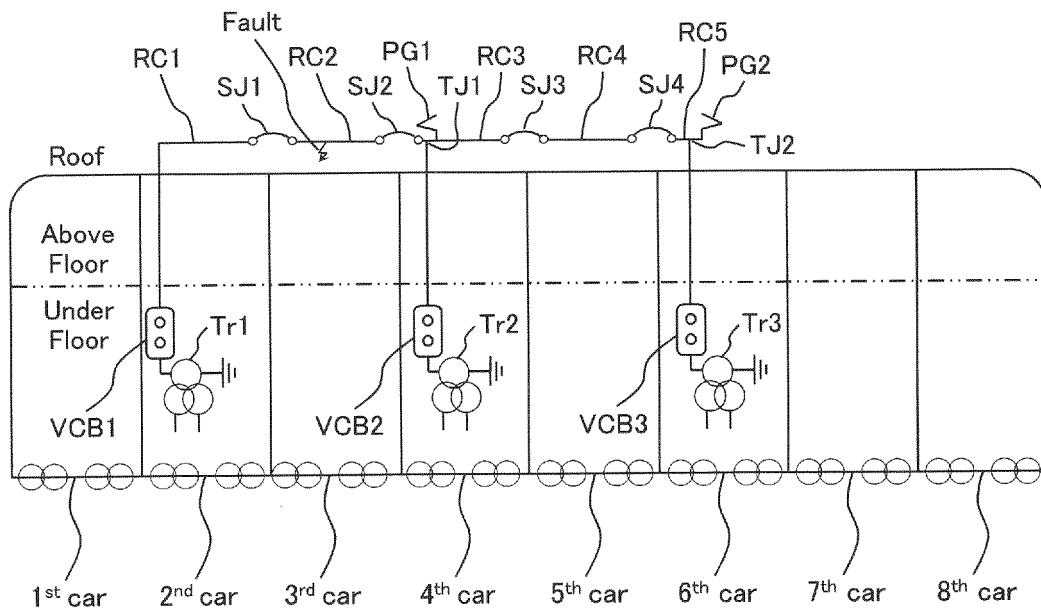


FIG. 3

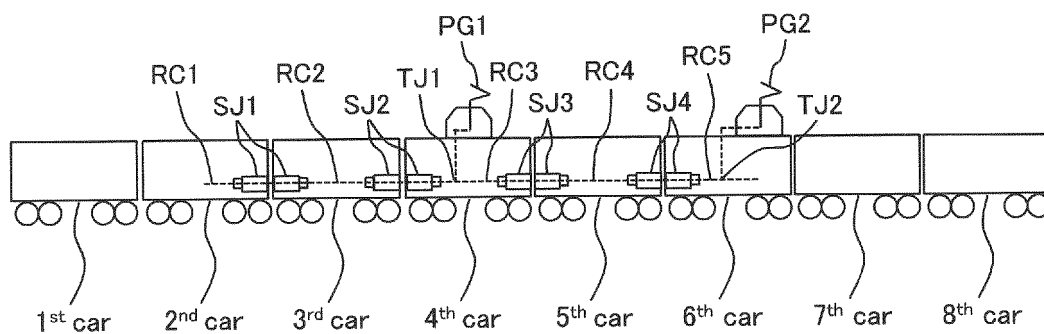


FIG. 4

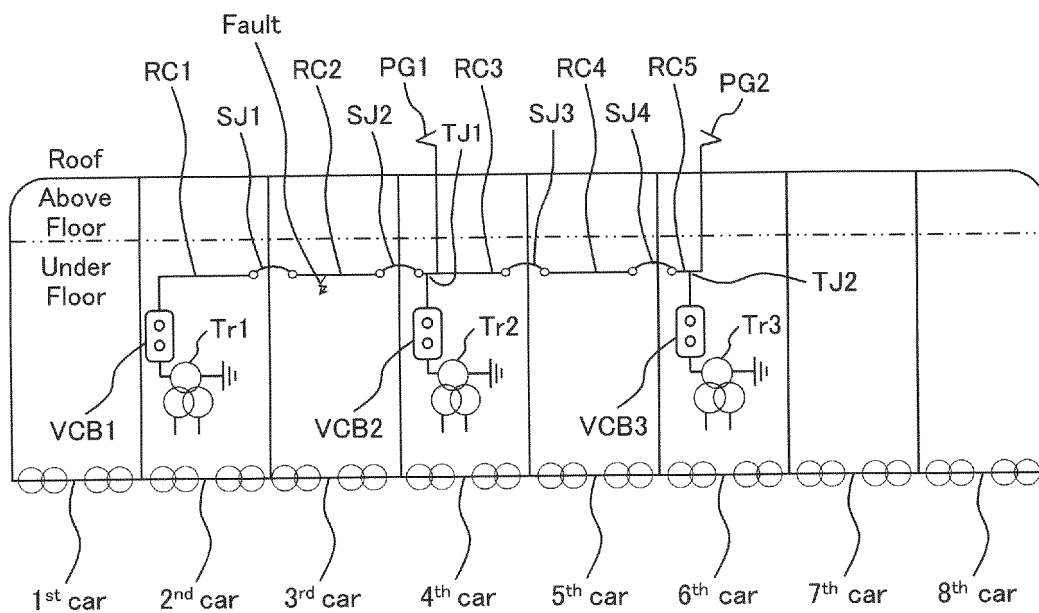


FIG. 5

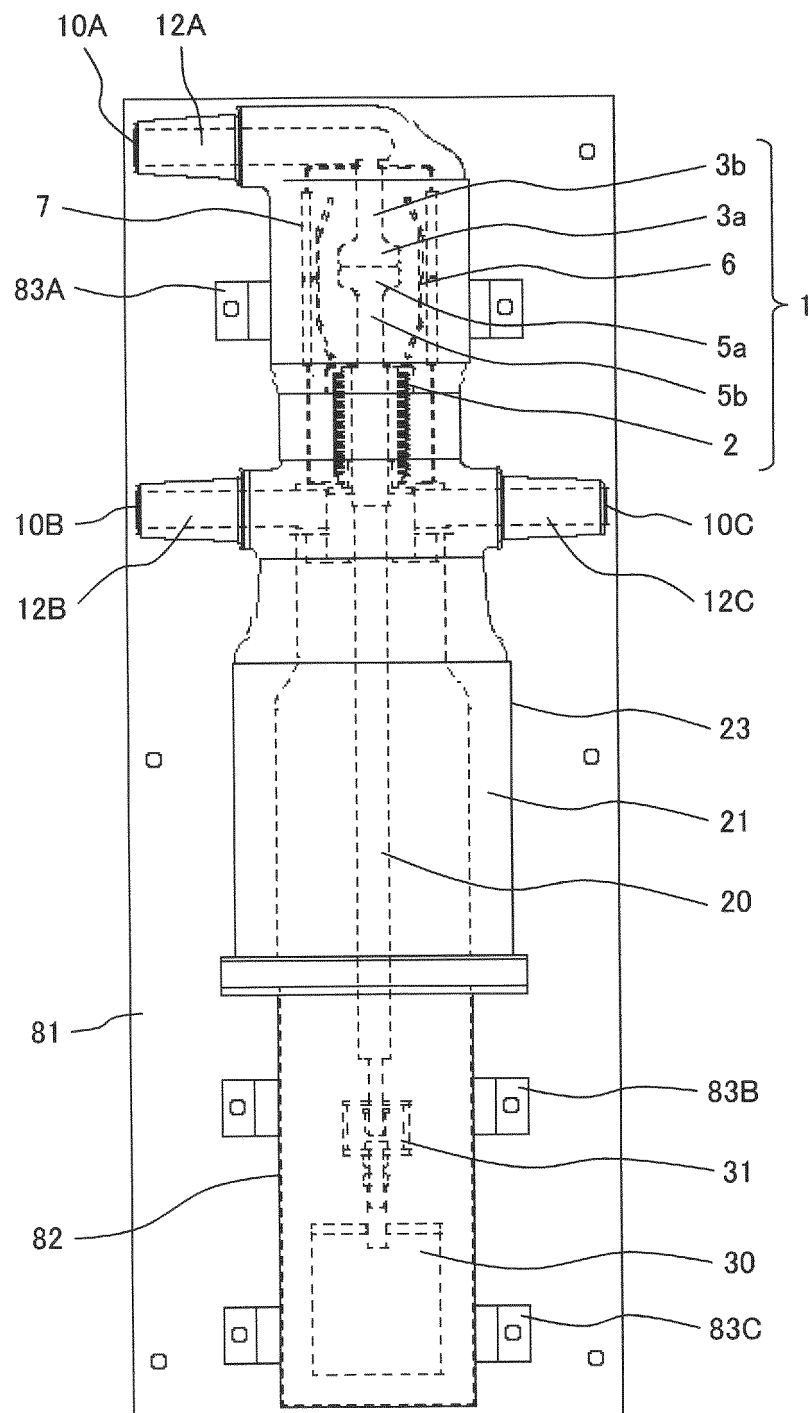


FIG. 6

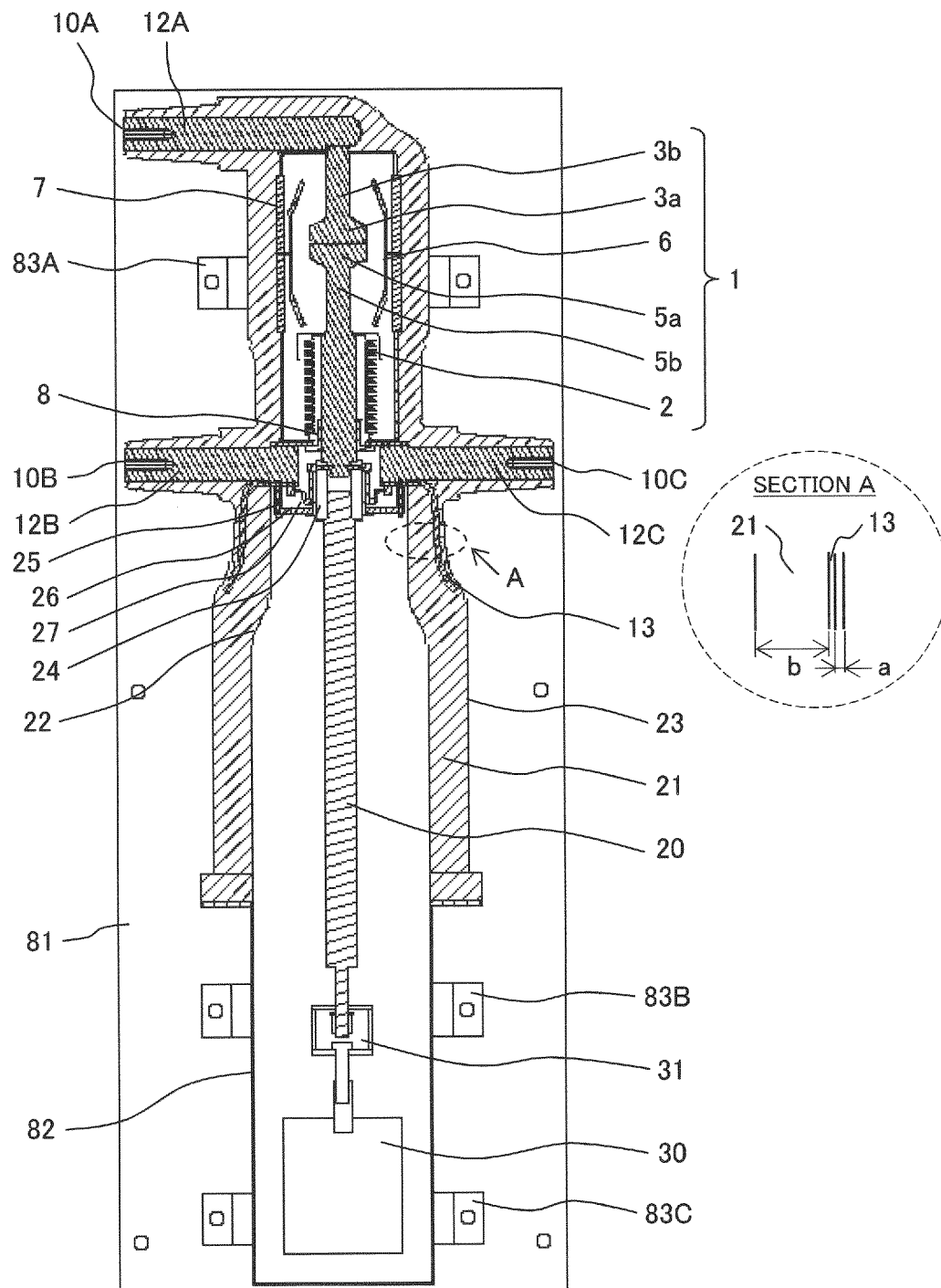


FIG. 7

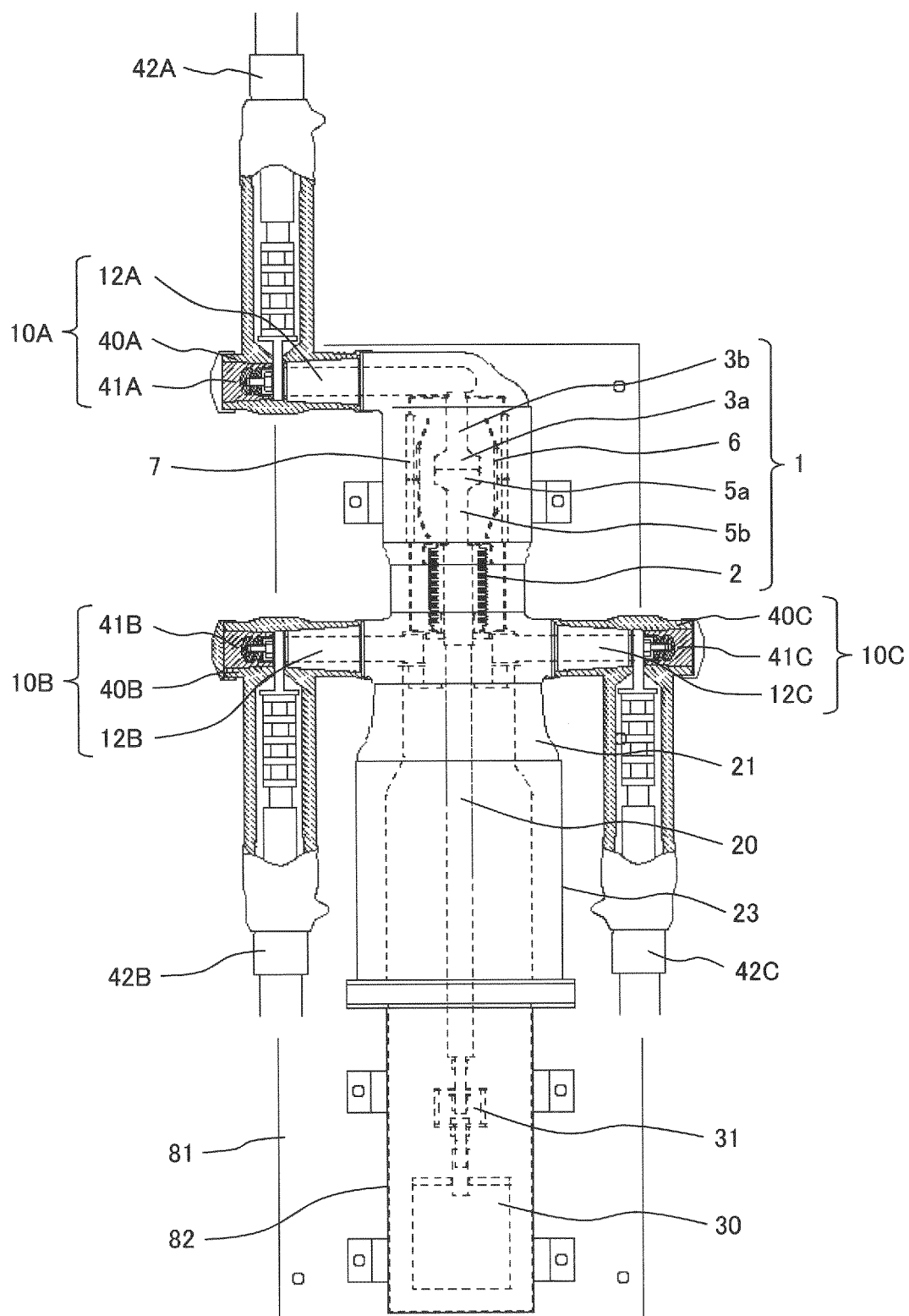


FIG. 8

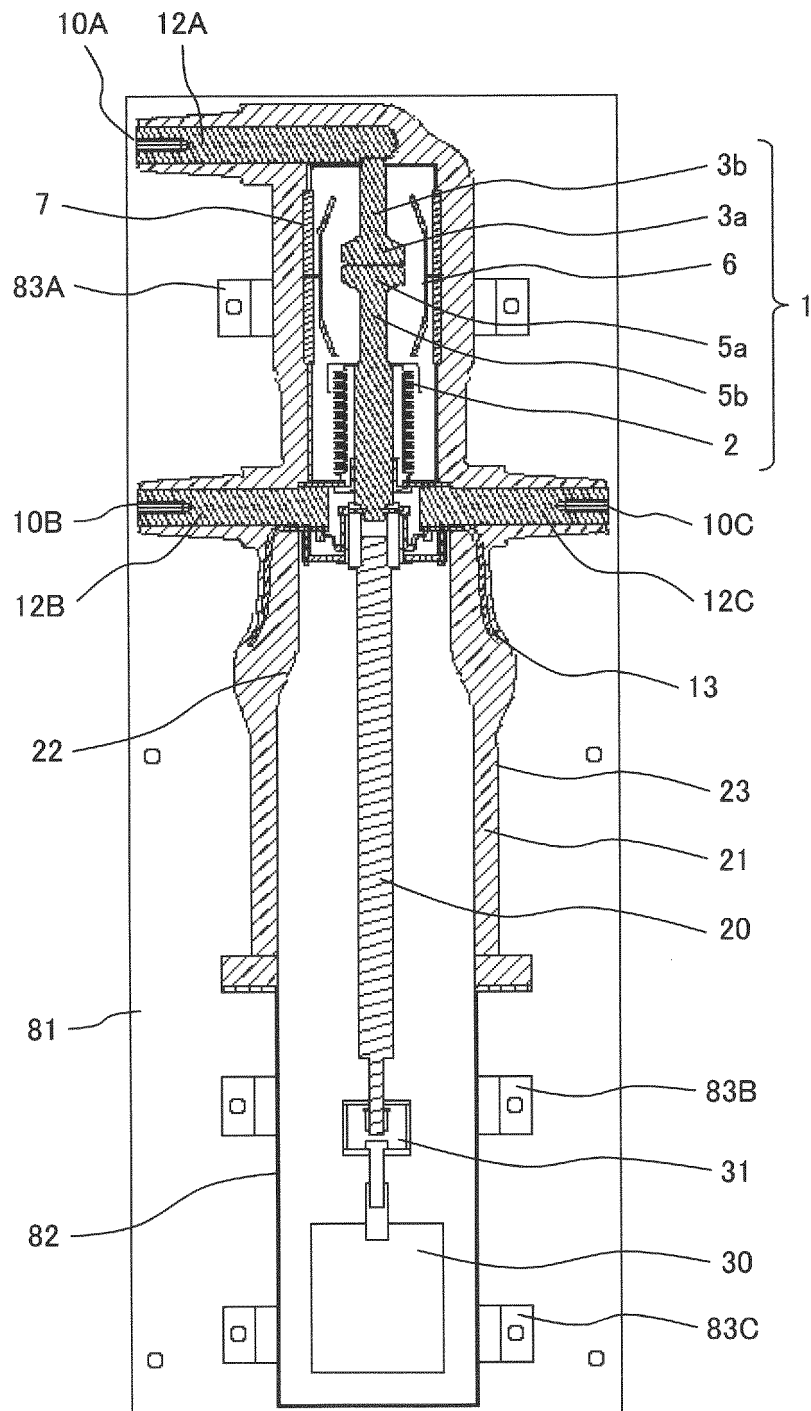


FIG. 9

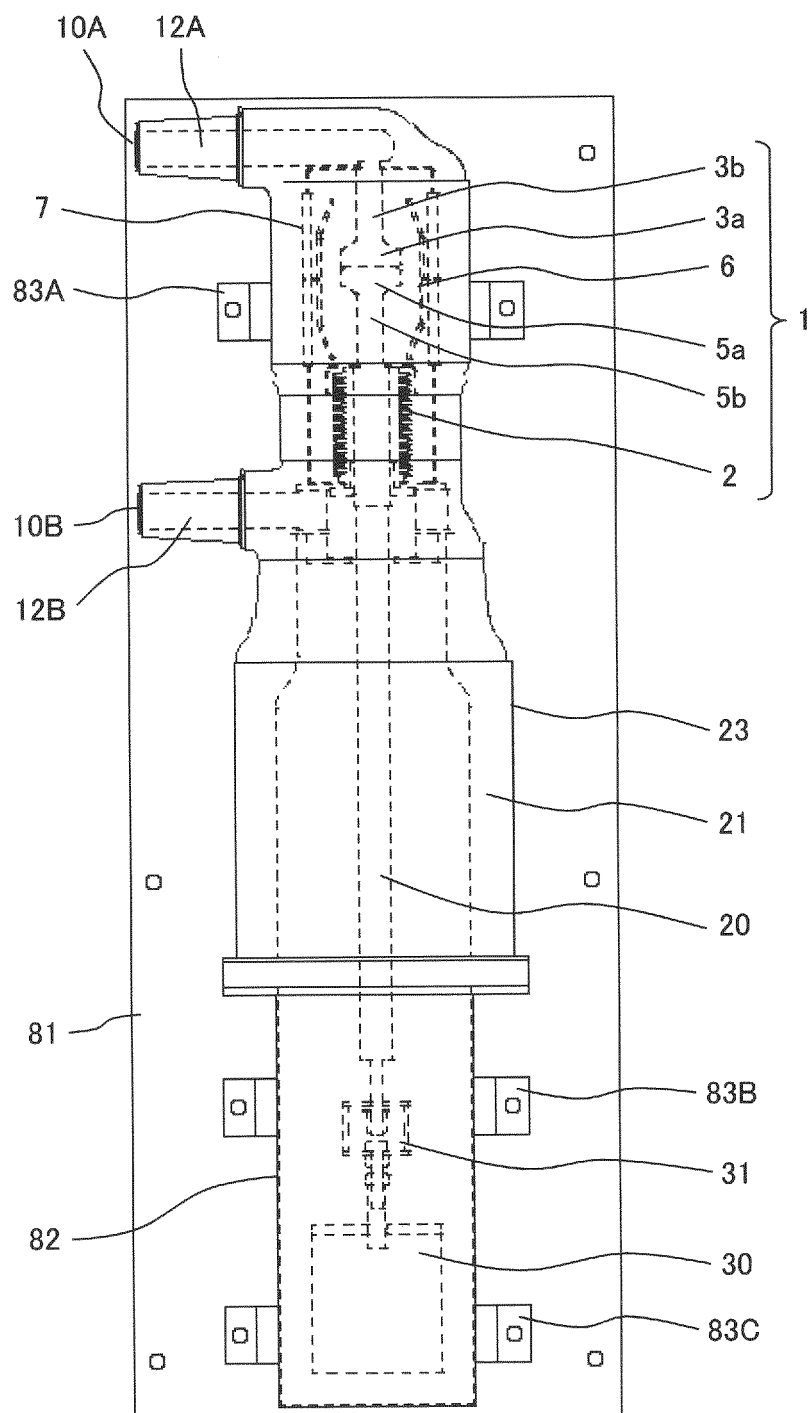


FIG. 10

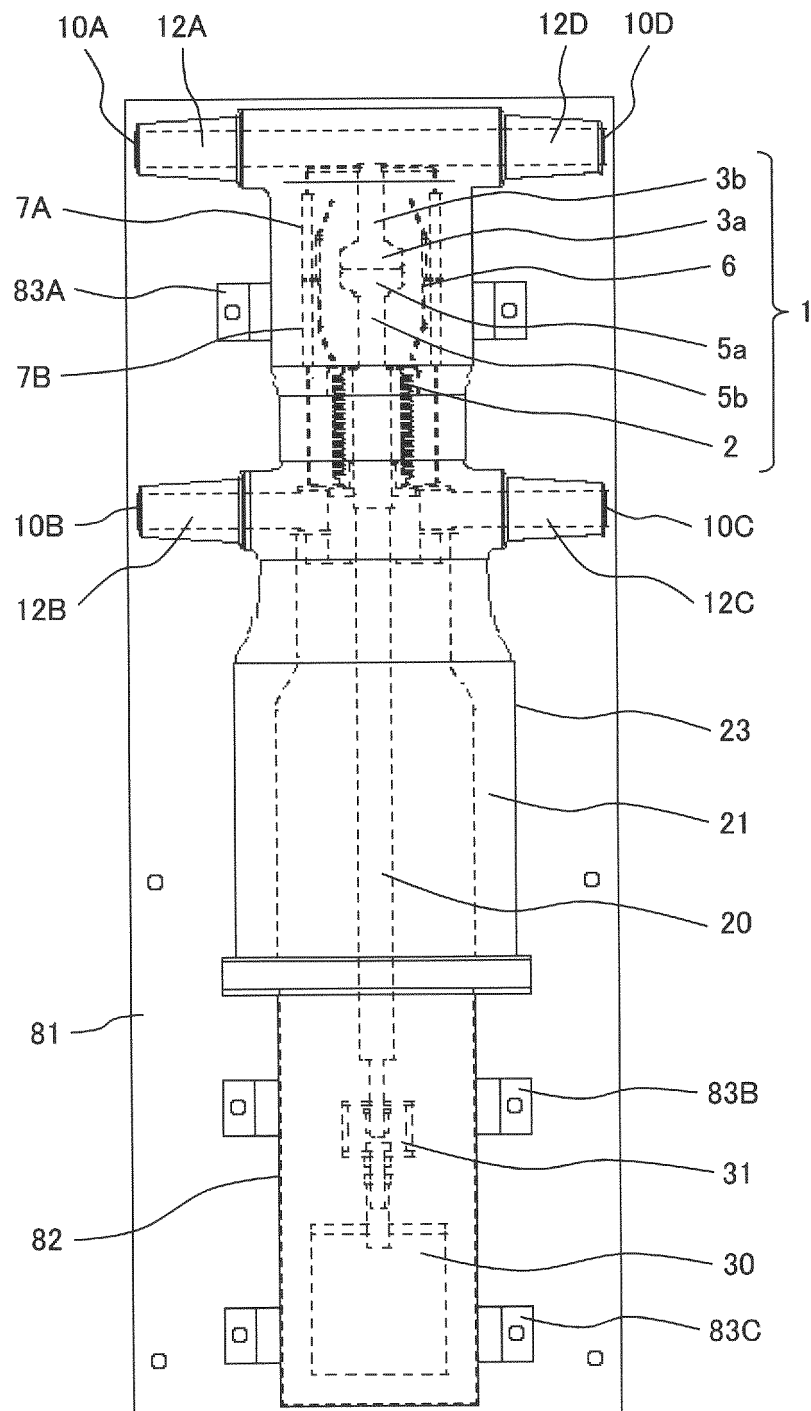


FIG. 11

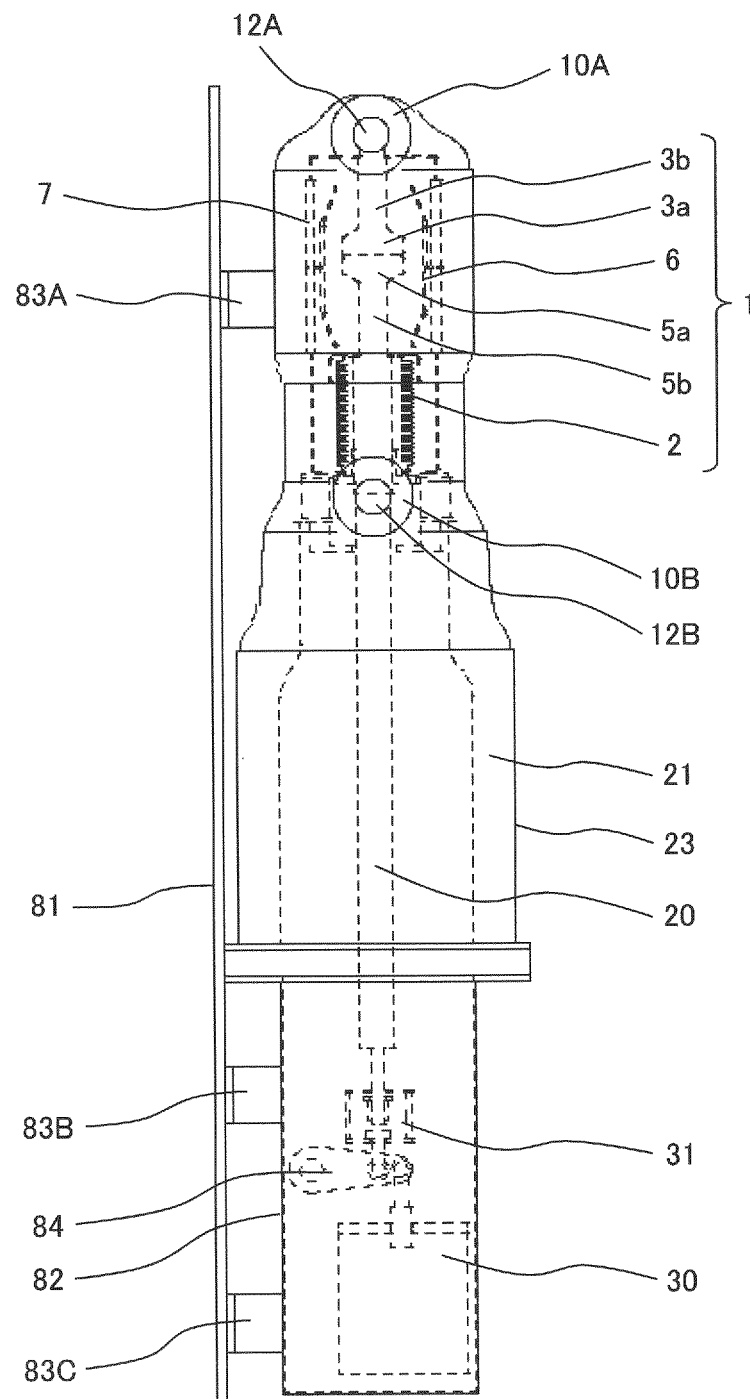
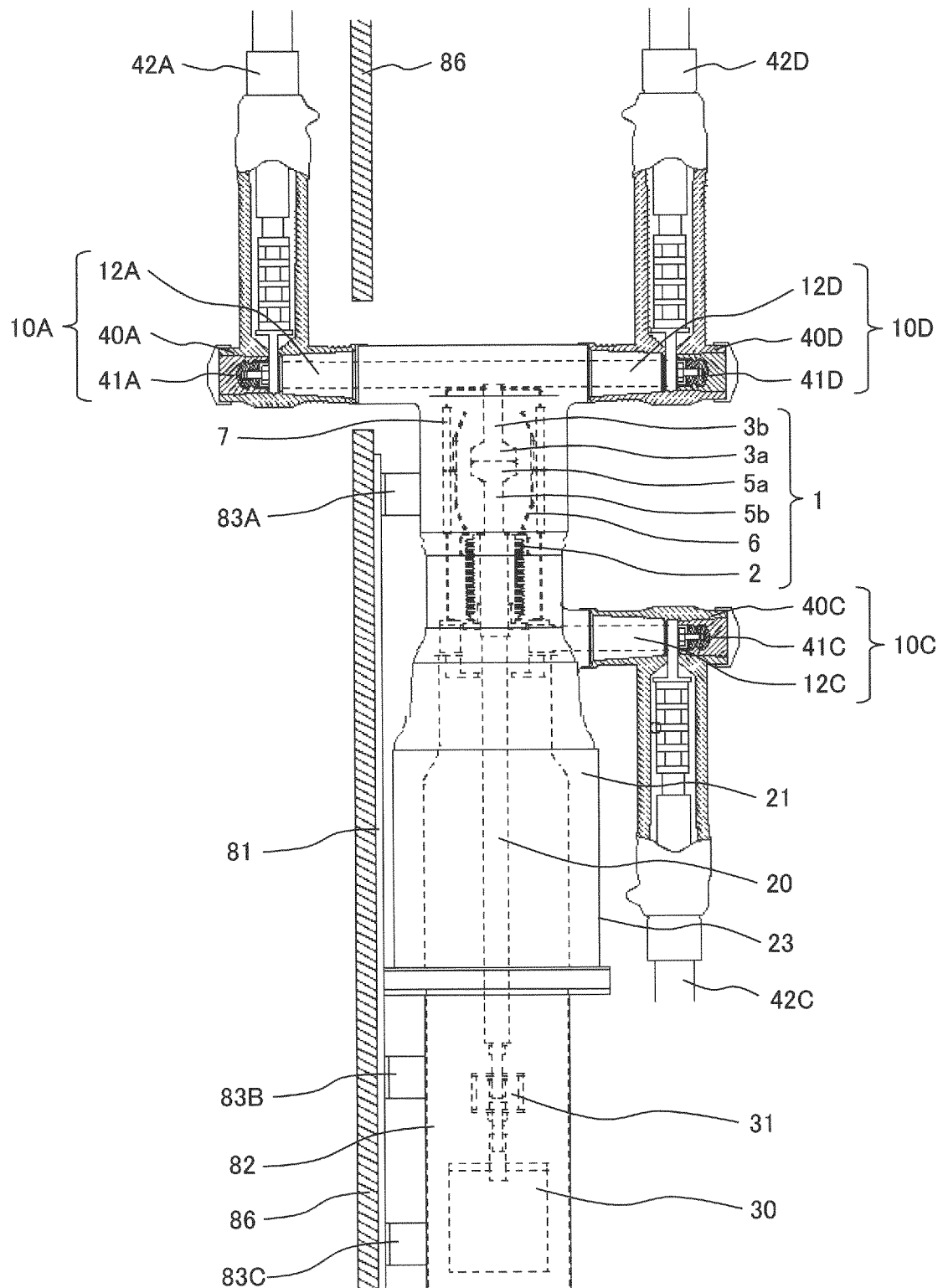


FIG. 12



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2019/004839

A. CLASSIFICATION OF SUBJECT MATTER

Int.Cl. H01H33/662 (2006.01) i, H01H33/66 (2006.01) i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Int.Cl. H01H33/662, H01H33/66

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Published examined utility model applications of Japan 1922-1996

Published unexamined utility model applications of Japan 1971-2019

Registered utility model specifications of Japan 1996-2019

Published registered utility model applications of Japan 1994-2019

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2003-111225 A (TOSHIBA CORPORATION) 11 April 2003, paragraphs [0006]-[0008], fig. 1-5 (Family: none)	1, 4, 5, 7, 9, 10, 11, 12, 13, 14
A		2, 3, 6, 8

☒ Further documents are listed in the continuation of Box C.☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search
13.05.2019Date of mailing of the international search report
21.05.2019Name and mailing address of the ISA/
Japan Patent Office
3-4-3, Kasumigaseki, Chiyoda-ku,
Tokyo 100-8915, Japan

Authorized officer

Telephone No.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2019/004839

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 2012/063501 A1 (MITSUBISHI ELECTRIC CORPORATION) 18 May 2012, paragraphs [0018]-[0033], [0036]-[0039], fig. 1, 2, 4 & US 2013/0213937 A1, paragraphs [0023]-[0038], [0042]-[0045], fig. 1, 2, 4 & CN 103201918 A	1, 4, 5, 7, 9, 10, 11, 12, 13, 14
Y	JP 2002-320305 A (TOSHIBA CORPORATION) 31 October 2002, paragraphs [0039]-[0084], fig. 1-10 (Family: none)	5
Y	JP 2016-092871 A (HITACHI, LTD.) 23 May 2016, paragraphs [0011]-[0072], fig. 1-30 & WO 2016/067647 A1 & EP 3214709 A1, paragraphs [0021]-[0072], fig. 1-30 & CN 107112729 A	7, 9, 10, 14
Y	WO 2015/178072 A1 (HITACHI, LTD.) 26 November 2015, paragraphs [0014]-[0053], fig. 1-13 (Family: none)	11
Y	JP 2013-048024 A (HITACHI, LTD.) 07 March 2013, paragraphs [0013]-[0061], fig. 1-15 & EP 2565897 A1, paragraphs [0014]-[0063], fig. 1-15	12

Form PCT/ISA/210 (continuation of second sheet) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- JP 2012069345 A [0006]
- JP 2017021939 A [0006]