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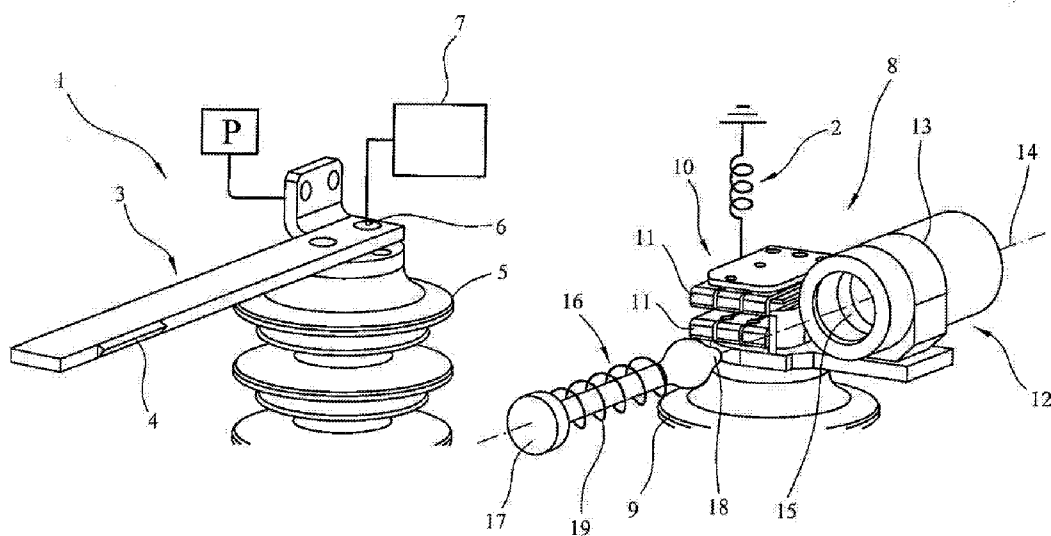


Figure 1

(57) Abstract: A switch for closing a circuit comprising a first electrically conductive switch arm, the first switch arm comprising a first electrical connector; a second electrically conductive switch arm, the second switch arm comprising a second electrical connector and a receiving receptacle, the receiving receptacle comprising an electrically conductive side wall which extends around a displacement axis to define a receiving volume, the edge of the side wall proximate to the first switch arm defining a receiving mouth; at least one electrically conductive arcing rod adapted to be displaced along the displacement axis towards and away from the receiving mouth; at least one receiving receptacle magnet arranged to provide a magnetic field which extends along the displacement axis within a portion of the receiving volume; the first switch arm being adapted to be displaced towards the second switch arm to switch the switch from an open configuration in which the first and second electrical connectors are spaced apart from each other and a closed configuration in

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which the first and second electrical connectors are in electrical contact with each other; the first switch arm being arranged such that as it is displaced towards the second switch arm to switch the switch from the open configuration to the dosed configuration it abuts the arcing rod, urging the arcing rod along the displacement axis towards the receiving mouth.

A switch for closing a circuit

The present invention relates to a switch for closing a circuit. More particularly, but not exclusively, the present invention relates to a switch for closing a circuit comprising first and second switch arms, the first switch arm comprising a first electrical connector and the second switch arm comprising a second electrical connector and receiving receptacle, the switch further comprising an arcing rod, the switch being adapted such that as the first switch arm is displaced towards the second switch arm to switch the switch from an open configuration in which the first and second electrical connectors are spaced apart to a closed configuration in which the first and second electrical connectors are in electrical contact with each other, the first arm abuts the arcing rod urging it towards the receiving mouth of the receiving receptacle.

It is known to use circuit breakers in high voltage circuits. When the circuit breaker initially opens one circuit of the circuit breaker is at a high voltage, whilst the other is at a low voltage. The two terminals are in close proximity. This difference in voltage causes arcing between the terminals which continues until they are sufficiently separated from each other. This damages the terminals so limiting the operational life of the circuit breaker. It is known to design circuit breakers to minimise the effects of this arcing. Often the terminals are arranged in an enclosure containing a gas such as SF₆ to minimise the arcing. The terminals are also designed to separate at high speed to minimise the duration of the arcing. Further, it is known to use a magnet to generate a magnetic field which causes the arc to rotate. This prevents the arc from routing at one spot on the terminals. These modifications can make the circuit breaker expensive to manufacture and unreliable. Further, despite these modifications the terminals are still damaged by the arcing. Such circuit breakers suffer from identical problems when making a circuit.

The present invention seeks to overcome the problems of the prior art.

Accordingly, the present invention provides a switch for closing a circuit comprising

a first electrically conductive switch arm, the first switch arm comprising a first electrical connector;

a second electrically conductive switch arm, the second switch arm comprising a second electrical connector and a receiving receptacle, the receiving receptacle comprising an electrically conductive side wall which extends around a displacement axis to define a receiving volume, the edge of the side wall proximate to the first switch arm defining a receiving mouth;

at least one electrically conductive arcing rod adapted to be displaced along the displacement axis towards and away from the receiving mouth;

at least one receiving receptacle magnet arranged to provide a magnetic field which extends along the displacement axis within a portion of the receiving volume;

the first switch arm being adapted to be displaced towards the second switch arm to switch the switch from an open configuration in which the first and second electrical connectors are spaced apart from each other and a closed configuration in which the first and second electrical connectors are in electrical contact with each other;

the first switch arm being arranged such that as it is displaced towards the second switch arm to switch the switch from the open configuration to the closed configuration it abuts the arcing rod, urging the arcing rod along the displacement axis towards the receiving mouth.

The switch according to the invention is able to close a circuit with almost no arcing damage to the first and second electrical connectors. As the first switch arm is displaced towards the second switch arm to switch the switch from an open configuration to a closed configuration the first switch arm urges the arcing rod towards the receiving receptacle. Arcing occurs between the arcing rod and receiving receptacle bringing the potential of the second switch arm up to the potential of the first switch arm. This substantially eliminates arcing between the first and second electrical connectors as they come into electrical contact.

Preferably as the arcing rod is displaced towards the receiving mouth the distance between the arcing rod and receiving mouth is reduced to less than a predetermined arcing distance before the distance between the first and second electrical connectors is reduced to less than the predetermined arcing distance.

Preferably the switch further comprises a biasing mechanism adapted to bias the arcing rod in a direction away from the receiving mouth along the displacement axis.

Preferably the biasing mechanism is a spring.

Preferably at least one receiving receptacle magnet is a permanent magnet.

Preferably at least one receiving receptacle magnet is an electromagnet.

Preferably the electromagnet comprises at least one coil wrapped around the outside of the side wall.

Preferably the second switch arm is connected to a capacitive or inductive load.

Preferably the switch further comprises a displacement mechanism for displacing the first switch arm relative to the second switch arm to switch the switch between open and closed configurations.

Preferably the displacement mechanism is adapted to pivot the first switch arm about a pivot to switch the switch from an open configuration to a closed configuration.

Alternatively the displacement mechanism is adapted to displace the first switch arm linearly to switch the switch from the open configuration to the closed configuration.

Preferably the arcing rod comprises an electrically conductive bulge at its tip.

Preferably the bulge is spherical.

Preferably the switch further comprises a magnet at least partially arranged in the bulge, the magnet being arranged to provide a magnetic field which extends along the displacement axis.

Preferably the switch further comprises an electrically insulating cap on the bulge, the cap extending away from the arcing rod.

Preferably the magnet extends beyond the bulge into the cap.

Preferably the switch further comprises a ferromagnetic material at least partially arranged within the bulge.

Preferably the side wall is circular in a plane normal to the displacement axis.

Preferably the switch further comprises a voltage source connected to the first switch arm.

The present invention will now be described by way of example only and not in any limitative sense with reference to the accompanying drawings in which

Figure 1 shows a first embodiment of a switch for closing a circuit in perspective view;

Figure 2 shows the receiving receptacle of the switch of figure 1 in cut away view;

Figure 3 shows the arcing rod of the switch of figure 1 in cut away view;

Figure 4 shows the switch of figure 1 with the arcing rod close to the receiving receptacle;

Figure 5 shows the arcing rod received within the receiving receptacle;

Figures 6(a) and 6(b) show arcing rods of a switch according to the invention;

Figure 7 shows an alternative embodiment of a switch according to the invention; and,

Figure 8 shows receiving receptacle and receiving receptacle magnet of a further embodiment of the invention.

Shown in figure 1 in perspective view is a first embodiment of a switch 1 for closing a circuit according to the invention. The switch 1 is typically employed in the field of electric trains with one portion of the switch 1 connected to the overhead power cable and the remainder of the switch 1 connected to the drive system of the train which acts as a load 2. The switch 1 is not so limited however. More generally the load is typically a capacitive or inductive load. The switch 1 is not limited to such applications. Other typical applications include use of the switch 1 as a changeover switch, a high voltage earthing switch and also as a 'fault thrower'.

The switch 1 according to the invention comprises a first electrically conductive switch arm 3. The first switch arm 3 is connected to a high voltage power source (P). In rail applications this voltage source (P) provides a voltage typically around 25Kv and a current typically in the range of around 0 to 1000 Amps.

The first switch arm 3 comprises a first electrical connector 4. In this embodiment the first electrical connector 4 is a moulded knife edge portion of the first switch arm 3.

The first switch arm 3 is pivotally connected to an electrically insulating support post 5 by a pivot 6. A displacement mechanism 7 is connected to the first switch arm 3 and is adapted to pivot the first switch arm 3 about the pivot 6 to switch the switch 1 between open and closed configurations.

The switch 1 further comprises a second electrically conductive switch arm 8 which is again supported on an electrically insulating post 9. The second switch arm 8 comprises a second electrical connector 10. The second electrical connector 10 comprises a plurality of deformable metal fingers 11 arranged to receive and grip the first electrical connector 4 therebetween.

The second switch arm 8 further comprises a receiving receptacle 12 which is defined by a side wall 13 which extends around a displacement axis 14. The receiving receptacle 12 defines a receiving volume. Entry and exit from the receiving volume is through a receiving mouth 15. The receiving receptacle 12 is described in more detail below.

The second switch arm 8 is connected to the load 2 which in this embodiment is schematically shown as an inductive load. The load 2 could for example be a motor.

The switch 1 further comprises an electrically conductive arcing rod 16 which extends from an arcing rod base 17 to an arcing rod tip 18. The arcing rod 16 is arranged on the displacement axis 14 and is adapted to be displaced along the displacement axis 14 towards and away from the receiving receptacle 12. A biasing means 19, in this embodiment a spring, biases the arcing rod 16 away from the receiving receptacle 12.

In figure 1 the switch 1 is shown in the open configuration. In the open configuration the first and second electrical connectors 4, 10 are spaced apart. The tip 18 of the arcing rod 16 is spaced apart from the receiving volume.

Figure 2 shows the receiving receptacle 12 in more detail. The receiving receptacle 12 comprises an electrically conductive side wall 13 which extends around the displacement axis 14 to define the receiving volume. The edge of the side wall 13 proximate to the first switch arm 3 defines a receiving mouth 15. In this embodiment the receiving mouth 15 and side wall 13 are circular in cross section in a plane normal to the displacement axis 14. In alternative embodiments of the invention the receiving mouth 15 and side wall 13 may be of other shapes such as square or octagonal. Circular is preferred.

The switch 1 further comprises a plurality of receiving receptacle magnets 20. These comprise permanent magnets 20 arranged around the displacement axis 14 in fixed relation to the receiving receptacle 12 as shown. The permanent magnets 20 are arranged to provide a toroidal magnetic field which extends along the displacement axis 14 in at least a portion of the receiving volume. Each magnet 20 is a rod extending parallel to the displacement axis 14. The magnets 20 are arranged around the receiving mouth 15. The magnets 15 extend towards the receiving volume. They also extend beyond the mouth 15 in a direction away from the receiving volume as shown. The portions of the magnets 20 that extend beyond the receiving mouth 15 are coated with an insulating layer 21 to prevent arcing from the arcing rod 16 to the magnets 20 in use and also prevent arcing outside of the mouth region. The receiving mouth 15 and insulating layer 21 are shaped such that arcing occurs deep within the mouth 15 rather than round the periphery. Typically the receiving mouth 15 and insulating layer 21 are together shaped as a gently tapering cusp.

Shown in figure 3 in cut away view is the tip of the arcing rod 16. The arcing rod 16 comprises a metal rod which expands into an electrically conductive bulge 22 at its tip 18. In this embodiment the bulge 22 is substantially spherical. An insulating cap 23 covers a portion of the bulge 22 and extends away from the metal rod as shown. A rod shaped permanent magnet 24 is arranged partially within the spherical bulge 22 and insulating cap 23 as shown. The permanent magnet 24 is arranged to generate a magnetic field which extends along the length of arcing rod 16.

In use the switch 1 starts in the open configuration as shown in figure 1. The first switch arm 3 and first electrical connector 4 are at a high voltage. The arcing rod 16 is floating. The second switch arm 8, receiving receptacle 12 and second electrical connector 10 are at a low voltage, typically earth. For a given voltage difference between the first and second switch arms 8 there is an arcing

distance. If any part of the first switch arm 3 is closer to the second switch arm 8 than the arcing distance then dielectric breakdown of the air between the arms 3,8 will occur resulting in electrical arcing between the arms 3,8. In order to switch the switch 1 from the open configuration to the closed configuration the displacement mechanism 7 pivots the first switch arm 3 about the pivot 6 until the first switch arm 3 abuts the arcing rod base 17 raising the potential of the arcing rod 16 to that of the first switch arm 3. As the first switch arm 3 is pivoted further the first switch arm 3 urges the arcing rod 16 along the displacement axis 14 towards the receiving mouth 15 of the receiving receptacle 12. As pivoting continues, the distance between the arcing rod 16 and receiving receptacle 12 decreases to less than the arcing distance whilst the distance between the first and second electrical connectors 4,10 is larger than the arcing distance. The voltage difference between the arcing rod 16 and receiving receptacle 12 causes arcing between the arcing rod 16 and side wall 13 of the receiving receptacle 12. This is shown in figure 4. The magnetic field generated by the receiving receptacle magnets 20 and the permanent magnet 24 in the spherical bulge 22 of the arcing rod 16 cause the arc to rotate around the displacement axis 14. This moves the ends of the arc over the surface of the spherical bulge 22 and over the side wall 13 so reducing damage caused by the arc.

As pivoting of the first switch arm 3 continues the arcing rod 16 passes through the receiving mouth 15 and into the receiving volume. Arcing continues raising the potential of the second switch arm 8 to close to that of the first switch arm 3. When the first switch arm 3 reaches its final position the first and second electrical connectors 4,10 interengage so closing the switch 1. At this point there is little if any potential difference between them and so as they interengage there is little if any arcing between them

The final position of the arcing rod 16 is shown in figure 5. In this position the switch 1 is in the closed configuration and the arcing rod 16 is received within the receiving volume aligned with the displacement axis 14 and spaced apart from the side wall 13. Also shown in figure 5 is an optional equalising contact 25. The equalising contact 25 extends from the second switch arm 8 towards the first switch arm 3. The equalising contact 25 is arranged such that just before the first and second electrical contacts 4,10 engage the equalising contact 25 abuts the first switch arm 3. The equalising contact 25 is electrically conductive. The current which flows through the equalising contact 25 between the switch arms 3,8 ensures that any small remaining potential difference between the

switch arms 3,8 is equalised before the first and second electrical contacts 4,10 interengage. The equalising contact 25 is designed to be replaceable.

The function of the electrically insulating cap 23 on the bulge 22 and also the purpose of arranging the permanent magnet 24 partially within the insulating cap 23 can be seen with reference to figures 6a and 6b. Arranging the magnet 24 such that it extends beyond the spherical bulge 22 allows for the magnetic field to be linear and perpendicular to the arc path, creating greater torque and stable arc rotation velocities at low arc current. The insulating end cap 23 also stops the arc from rooting close to the zero point of the field at the tip 18 as can be seen by a comparison of figures 6(a) and 6(b). PTFE is a suitable material for the insulating cap 23.

Shown in figure 7 in schematic form is a further embodiment a switch 1 according to the invention. This is substantially similar to that of figures 1 to 6 except the first switch arm 3 is displaced linearly to switch the switch 1 from open to closed configurations.

In an alternative embodiment of the invention the permanent magnet 24 in the bulge 22 of the arcing rod 16 is arranged entirely within the bulge 22, as shown in figure 6(a).

In a further embodiment of the invention the permanent magnet 24 in the bulge 22 is replaced with a ferromagnetic material or alternatively is absent.

The bulge 22 proximate to the tip 18 of the arcing rod 16 is not essential to the invention although this is preferred. The bulge 22 reduces the variation in air gap between the arcing rod 16 and receiving receptacle 12 as the arcing rod 16 enters the receiving receptacle 12. In particular a spherical bulge 22 optimises the tangential force on the arc at the surface of the bulge 22. It is also the optimum shape for minimising electrical field stress. A spherical bulge 22 also provides a continuous surface for the arc to traverse over a range of inclinations. Erosion caused by the arc will therefore be spread comparatively evenly maximising the life of the switch 1. Alternative shapes of bulge 22 are possible. A spherical bulge 22 may not be optimal particularly in the case where one or

more of the switch arms 3,8 is displaced linearly. Alternative shapes of bulge 22 may include conical or cylindrical with a conical tip. The bulge 22 may be absent altogether.

Shown schematically in figure 8 is the receiving receptacle 12 of an alternative embodiment of a switch 1 according to the invention. In this embodiment the receiving receptacle magnet 20 which provides the magnetic field in the receiving volume is not a permanent magnet, rather it is an electromagnet. The electromagnet comprises a coil 25 wrapped around the side wall 13 of the receiving receptacle 12. The electromagnet may be powered by a separate power source. Alternatively it may be powered by a connection to the first switch arm 3.

In a further embodiment of the invention a housing covers the mouth of the receiving receptacle 12. The housing has an aperture therein which is arranged on the displacement axis 14. The arcing rod 16 extends through the aperture. Such an arrangement has at least two advantages. Firstly the receiving receptacle 12 is protected from the elements. Water, dirt and the like is prevented from entering into the mouth of the receiving receptacle 12 by the housing. Secondly, the arcing which occurs between the arcing rod 16 and receiving receptacle 12 as the arcing rod 16 approaches the receiving receptacle 12 cannot arc over to surrounding components due to the presence of the housing.

CLAIMS

1. A switch for closing a circuit comprising

a first electrically conductive switch arm, the first switch arm comprising a first electrical connector;

a second electrically conductive switch arm, the second switch arm comprising a second electrical connector and a receiving receptacle, the receiving receptacle comprising an electrically conductive side wall which extends around a displacement axis to define a receiving volume, the edge of the side wall proximate to the first switch arm defining a receiving mouth;

at least one electrically conductive arcing rod adapted to be displaced along the displacement axis towards and away from the receiving mouth;

at least one receiving receptacle magnet arranged to provide a magnetic field which extends along the displacement axis within a portion of the receiving volume;

the first switch arm being adapted to be displaced towards the second switch arm to switch the switch from an open configuration in which the first and second electrical connectors are spaced apart from each other and a closed configuration in which the first and second electrical connectors are in electrical contact with each other;

the first switch arm being arranged such that as it is displaced towards the second switch arm to switch the switch from the open configuration to the closed configuration it abuts the arcing rod, urging the arcing rod along the displacement axis towards the receiving mouth.
2. A switch for closing a circuit as claimed in claim 1, wherein as the arcing rod is displaced towards the receiving mouth the distance between the arcing rod and receiving mouth is reduced to less than a predetermined arcing distance before the distance between the first and second electrical connectors is reduced to less than the predetermined arcing distance.

3. A switch for closing a circuit as claimed in either of claims 1 or 2, further comprising a biasing mechanism adapted to bias the arcing rod in a direction away from the receiving mouth along the displacement axis.
4. A switch for closing a circuit as claimed in claim 3, wherein the biasing mechanism is a spring.
5. A switch for closing a circuit as claimed in any one of claims 1 to 4, wherein at least one receiving receptacle magnet is a permanent magnet.
6. A switch for closing a circuit as claimed in any one of claims 1 to 4, wherein at least one receiving receptacle magnet is an electromagnet.
7. A switch for closing a circuit as claimed in claim 6 wherein the electromagnet comprises at least one coil wrapped around the outside of the side wall.
8. A switch for closing a circuit as claimed in any one of claims 1 to 7, wherein the second switch arm is connected to a capacitive or inductive load.
9. A switch for closing a circuit as claimed in any one of claims 1 to 8 further comprising a displacement mechanism for displacing the first switch arm relative to the second switch arm to switch the switch between open and closed configurations.
10. A switch for closing a circuit as claimed in claim 9, wherein the displacement mechanism is adapted to pivot the first switch arm about a pivot to switch the switch from an open configuration to a closed configuration.

11. A switch for closing a circuit as claimed in claim 9, wherein the displacement mechanism is adapted to displace the first switch arm linearly to switch the switch from the open configuration to the closed configuration.
12. A switch for closing a circuit as claimed in any one of claims 1 to 11, wherein the arcing rod comprises an electrically conductive bulge at its tip.
13. A switch for closing a circuit as claimed in claim 12, wherein the bulge is spherical.
14. A switch for closing a circuit as claimed in either of claims 12 or 13, further comprising a magnet at least partially arranged in the bulge, the magnet being arranged to provide a magnetic field which extends along the displacement axis.
15. A switch for closing a circuit as claimed in any one of claims 12 to 14, further comprising an electrically insulating cap on the bulge, the cap extending away from the arcing rod.
16. A switch for closing a circuit as claimed in claim 15, when dependent on claim 14, wherein the magnet extends beyond the bulge into the cap.
17. A switch for closing a circuit as claimed in either of claims 12 or 13, further comprising a ferromagnetic material at least partially arranged within the bulge.
18. A switch for closing a circuit as claimed in any one of claims 1 to 17, wherein the side wall is circular in a plane normal to the displacement axis.
19. A switch for closing a circuit as claimed in any one of claims 1 to 18, further comprising a voltage source connected to the first switch arm.

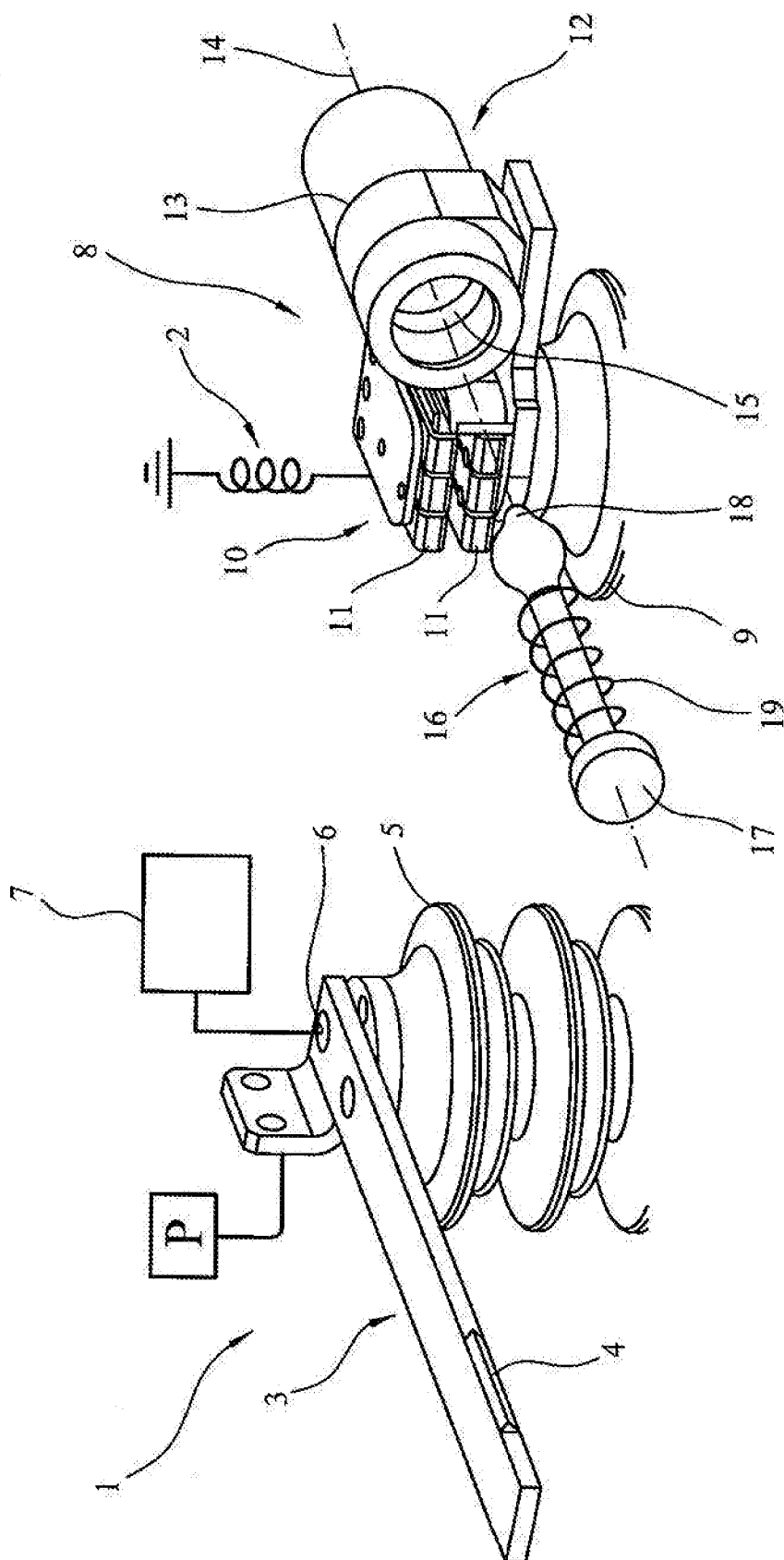


Figure 1

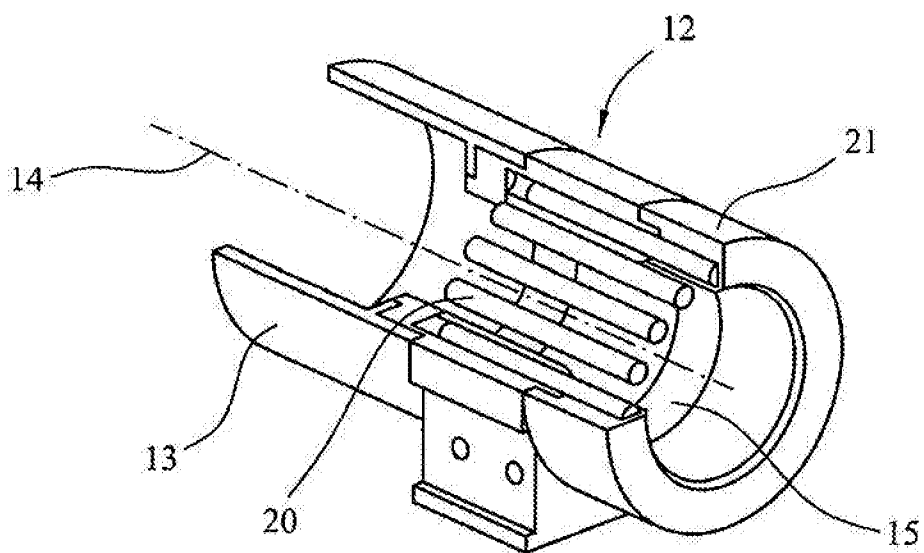


Figure 2

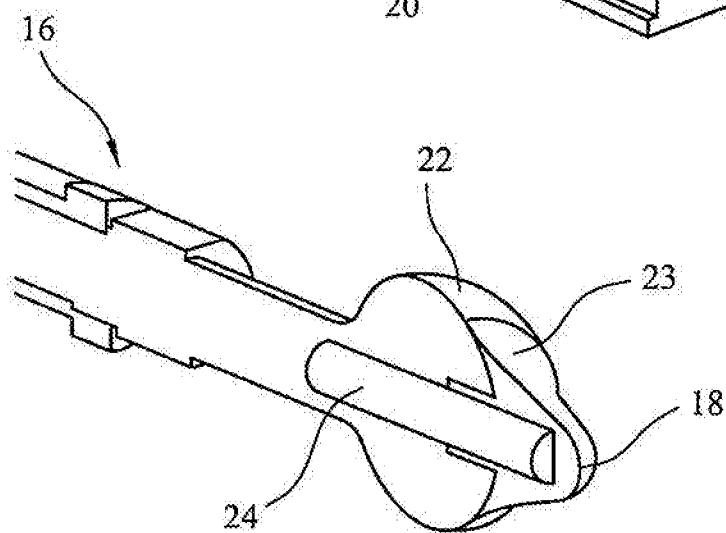


Figure 3

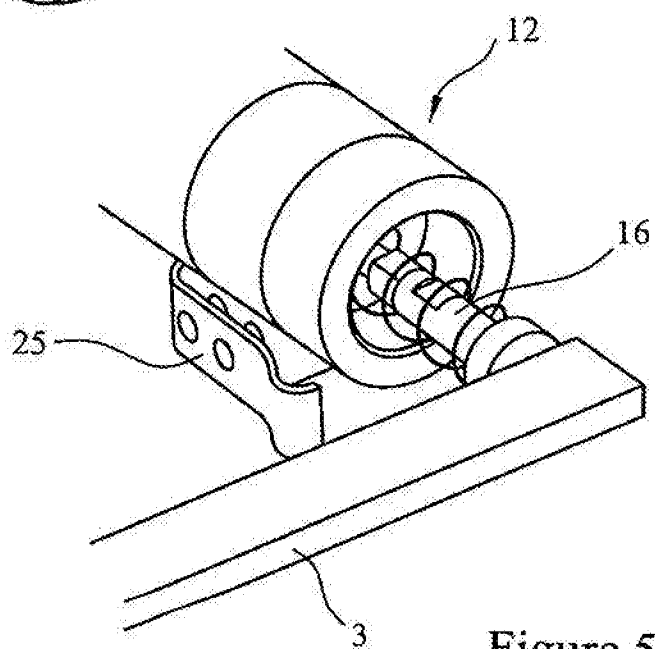


Figure 5

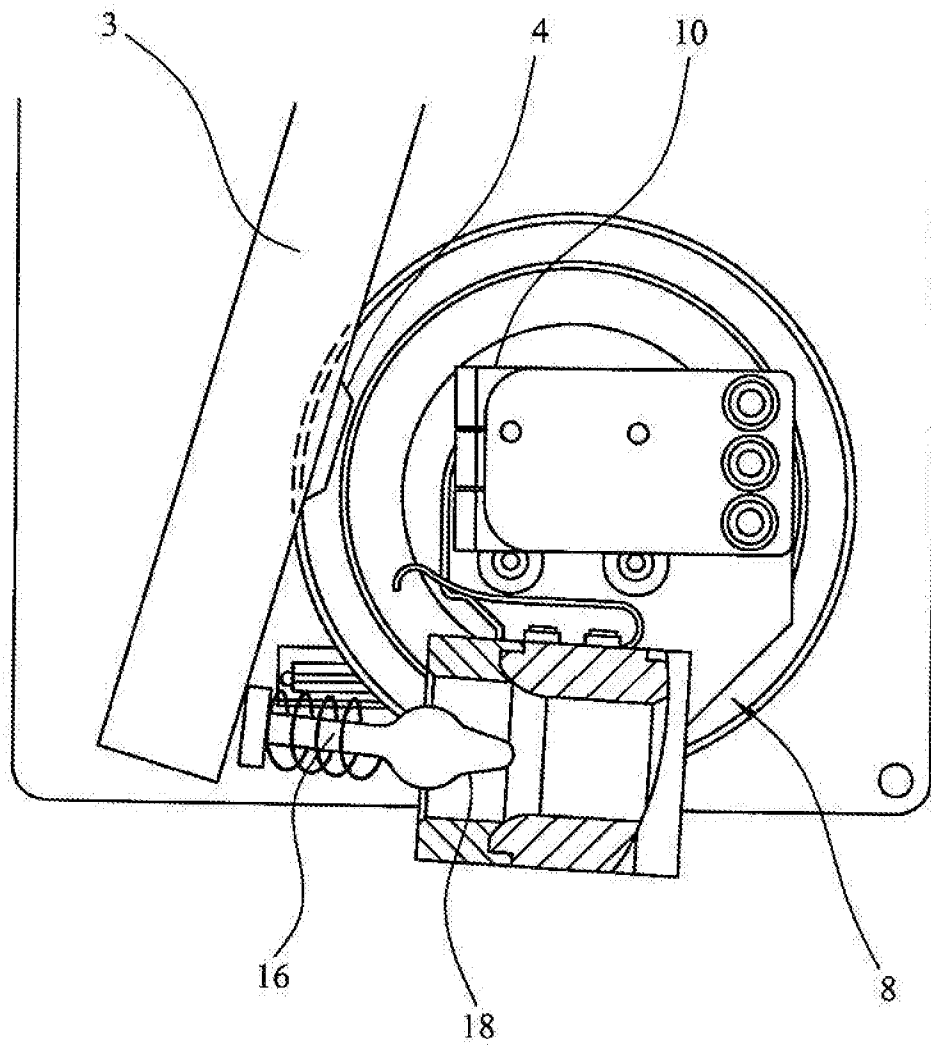


Figure 4

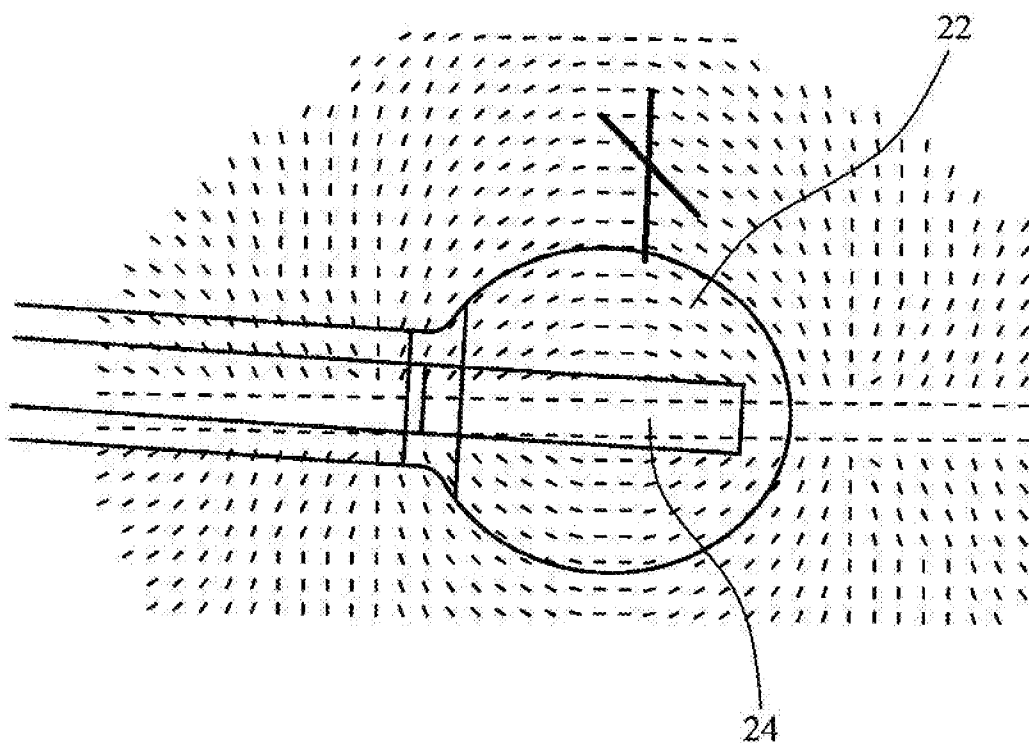


Figure 6(a)

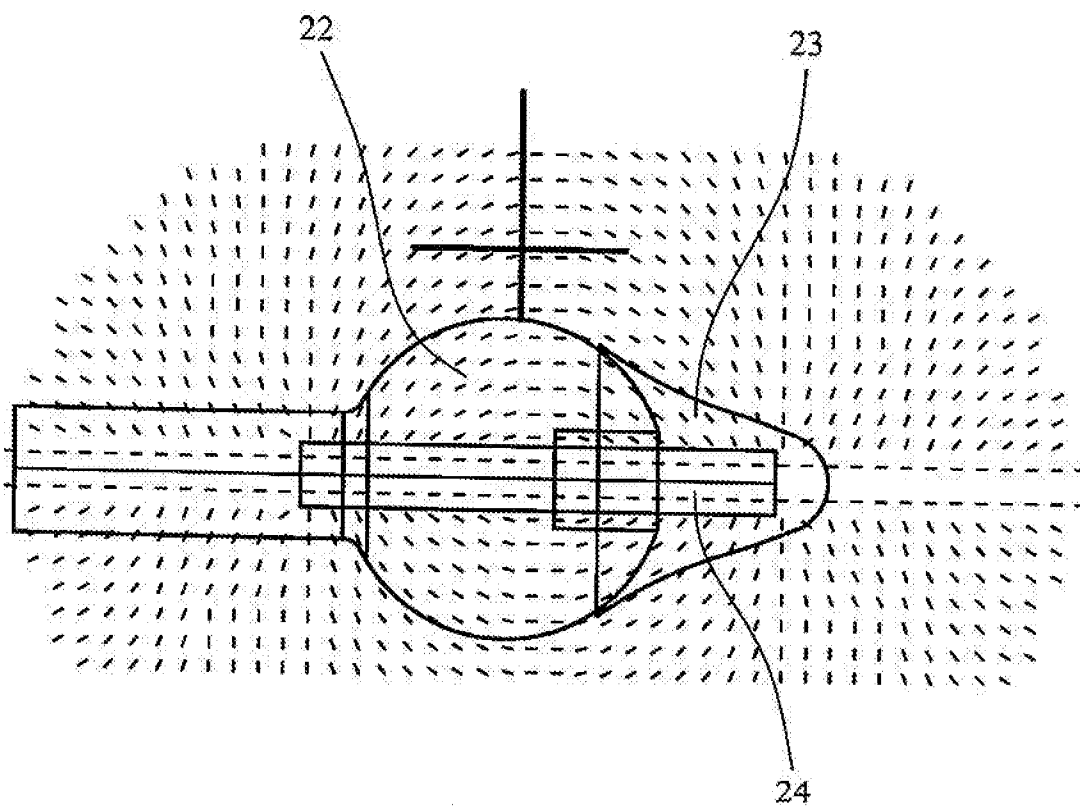


Figure 6(b)

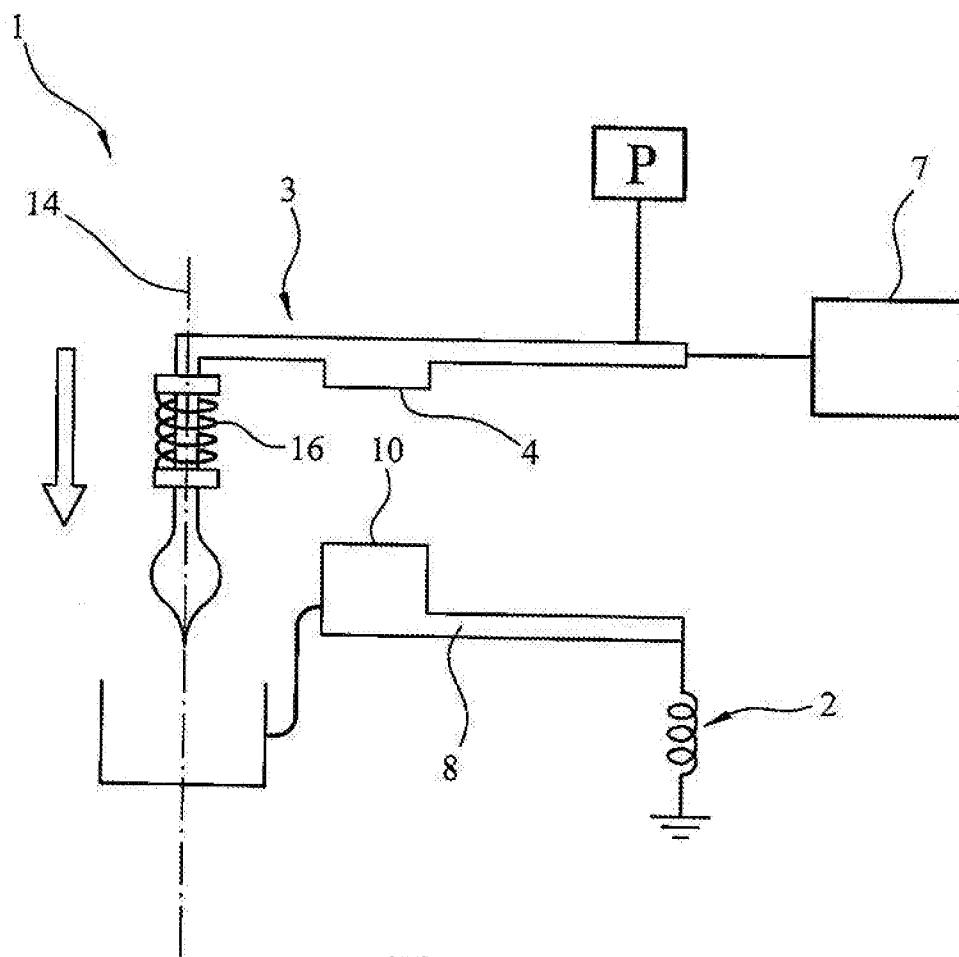


Figure 7

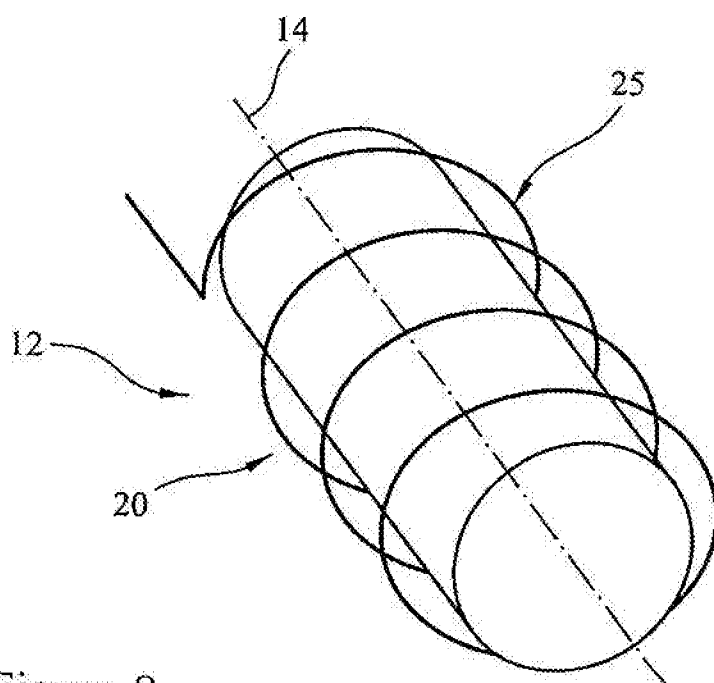


Figure 8

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2019/051526

A. CLASSIFICATION OF SUBJECT MATTER
INV. H01H33/12 H01H33/18
ADD.

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)
H01H

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

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

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 6 310 311 B1 (HAKES GARY [US] ET AL) 30 October 2001 (2001-10-30) column 2, line 40 - column 5, line 25; figures 3,7	1-19
Y	DE 10 2008 015463 B3 (SIEMENS AG [DE]) 17 September 2009 (2009-09-17) paragraphs [0014], [0015]	1-19
A	US 4 263 487 A (WELTER CLARENCE L ET AL) 21 April 1981 (1981-04-21) column 8, lines 6-33; figures 10-12	1
A	GB 2 103 018 A (INT STANDARD ELECTRIC CORP [US]; SOUTH WALES SWITCHGEAR [GB]) 9 February 1983 (1983-02-09) abstract; figures	1



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

14 August 2019

Date of mailing of the international search report

23/08/2019

Name and mailing address of the ISA/

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/GB2019/051526

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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