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(54) **Vacuum circuit interrupter.**

(57) A vacuum circuit interrupter includes a cylinder (21, 111) made of a metal relatively easy to deform platically, and first and second insulating disks (22, 23, 112, 113) closing the ends of the metallic cylinder (21, 111) to form therewith an evacuated envelope (20, 110). A stationary conductive rod (31, 121) enters the envelope (20, 110) through the first disk (22, 112) in such a manner as to provide a seal therewith. A movable conductive rod (32, 122) movably enters the envelope (20, 110) through the second disk (23, 113). A bellows (39, 129) is fixed at its one end to the movable rod (32, 122) and at its other end to the second disk (23, 113) in such a manner as to provide a seal about the movable rod (32, 122) to allow for movement thereof without impairing the vacuum inside the envelope (20, 110). Stationary and movable electrodes (33, 34, 123, 124) are connected to the stationary and movable rods (31, 32, 121, 122) respectively in such a manner as to engage and disengage with each other according to the movement of the movable rod (32, 122).

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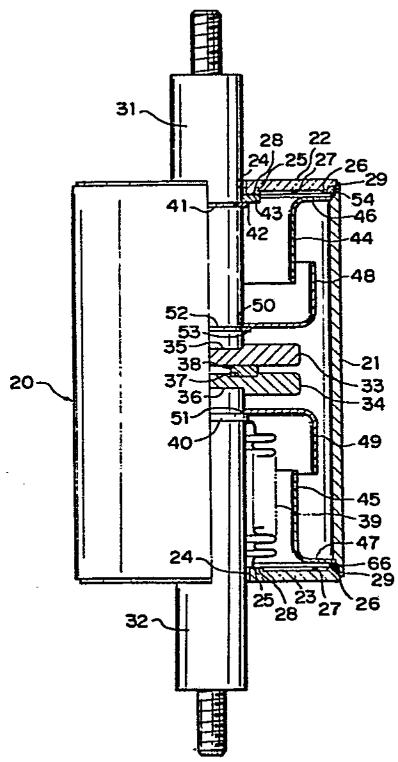
FIG. 1



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DESCRIPTION

VACUUM CIRCUIT INTERRUPTER

This invention relates to a circuit interrupter and more particularly to an interrupter of the vacuum type which includes an evacuated envelope, in which a pair of movable and stationary contact rods are arranged to open and close a circuit.

In a vacuum circuit interrupter of the prior art, a pair of contacts selectively engaging with each other are housed in an evacuated envelope composed of a proper combination of insulating and metallic members, the former being made of glass or ceramic and the latter being made of an iron-nickel or iron-nickel-cobalt alloy having a coefficient of thermal expansion which closely matches that of the glass or ceramic. However, the iron-nickel or iron-nickel-cobalt alloy is relatively expensive.

It is an object of the present invention to provide a vacuum circuit interrupter which has a relatively high reliability.

It is another object of the present invention to provide a vacuum circuit interrupter which has a relatively high durability.

It is a further object of the present invention to provide a vacuum circuit interrupter which is relatively inexpensive.

The vacuum circuit interrupter of the present invention includes a cylinder made of metal relatively easy to deform plastically, and first and second insulating disks closing the opposite ends of the metallic cylinder to form therewith an evacuated envelope. The first and second disks each have a central aperture. A stationary conductive rod coaxially enters the envelope through the central aperture of the first disk, and is fixed to the first disk in such a manner as to provide a seal therewith. A movable conductive rod coaxially and movably enters the envelope through the central aperture of the second disk without impairing the vacuum inside the envelope. Sttionary and movable electrodes are connected to the stationary and movable rods respectively in such a manner as to engage with each other when the movable rod moves toward the stationary rod and disengage when the movable rod moves away from the stationary rod.

The above and other objects, features and advantages of the present invention will be apparent from the following description of preferred embodiments thereof, taken in conjunction with the drawings, in which:

Fig. 1 is a longitudinal partly sectioned view of a vacuum circuit interrupter according to a first embodiment of the present invention;

Fig. 2 is an enlarged view of the joint between the metallic cylinder, the upper insulating disk and the upper auxiliary shield, in Fig. 1;

Fig. 3 is an enlarged view of the joint between the metallic cylinder, the lower insulating disk and the lower auxiliary shield, in Fig. 1;

Figs. 4 to 10 are each sectional views of the joints between a metallic cylinder, an insulating disk and an auxiliary shield, according to alternative embodiments of the present invention;

Fig. 11 is a graph of tensile strength and expansion rate against temperature for copper and iron, wherein the solid curves denote the tensile strengths and the broken curves denote the expansion rates;

Fig. 12 is a longitudinal partly sectioned view of a vacuum circuit interrupter according to a second embodiment of the present invention;

Fig. 13 is a longitudinal partly sectioned view of a vacuum circuit interrupter according to a third embodiment of the present invention;

Fig. 14 is a longitudinal partly sectioned view of a vacuum circuit interrupter according to a fourth embodiment of the present invention;

Fig. 15 is a longitudinally half-sectioned diagrammatic view of a vacuum circuit interrupter according to a fifth embodiment of the present invention;

Fig. 16 is a section of the insulating disk of the vacuum circuit interrupter in Fig. 15 taken along the diameter line thereof; and

Fig. 17 is a detailed and enlarged view of the engagement between the insulating disk and the cylindrical shield of the vacuum circuit interrupter in Fig. 16.

Referring to Fig. 1, there is shown a vacuum circuit interrupter of a first embodiment of the present invention which is in its closed state and has an evacuated housing or envelope 20. The envelope 20 consists of a metallic cylinder 21 and a pair of insulating disks 22 and 23 closing the opposite ends of the cylinder 21.

Each of the disks 22 and 23 has a circular central aperture 24 therein and concentrically arranged annular projections 25 and 26 on the inner surface thereof. In other words, the disks 22 and 23 each have an annular groove 27 so as to form the projections 25 and 26 on its inner and outer peripheries respectively. The projections 25 and 26 each have their surfaces ground beforehand to be covered with metalized layers 28 and 29 respectively. The grooves 27 facilitate the grinding of the projections 25 and 26 and are approximately 0.1 to 0.5 mm in depth. The metallic cylinder 21 is brazed at its opposite ends to the outer metalized layers 29 on the insulating disks 22 and 23 respectively to fix the disks 22 and 23 thereto.

The cylinder 21 is made of a plastically deformable metal, such as copper or iron, which is relatively inexpensive and is relatively easy to deform plastically, in the cooling process after brazing, to alleviate the thermal stresses generated during brazing. A non-magnetic metal such as copper is more preferable to a magnetic metal such as iron for the cylinder 11, because vibration force exerted thereon by an alternating current passing through the interrupter is weaker than that on a magnetic metal and consequently the interrupter has a relatively high durability and reliability. The disks 22 and 23 are made of an inorganic insulator, such as alumina ceramic or crystallized glass. The metalized layers 28 and 29 are made of a manganese-titanium alloy or molybdenum-manganese-titanium alloy which has a similar thermal expansion coefficient to that of alumina ceramic.

A pair of conductive, circular-section stationary and movable contact rods 31 and 32 project through the apertures 24 in the upper and lower disks 22 and 23 respectively to enter the envelope 20 in such a manner as to extend coaxially within the cylinder 21 in an aligned configuration. The rods 31 and 32 are made of copper or a copper alloy. A pair of stationary and movable disk-shaped electrodes 33 and 34 are secured coaxially to the stationary and movable contact rods 31 and 32 respectively at their inner ends. The stationary and movable electrodes 33 and 34 have circular recesses 35 and 36 respectively on their outer surfaces. The inner ends of the stationary and movable contact rods 31 and 32 are fitted into the recesses 35 and 36 respectively and brazed to the stationary and movable electrodes 33 and 34 respectively. The movable electrode 34 is formed with a coaxial annular groove 37 on its upper surface. A ring-shaped contact 38 is fitted into the groove 37 and is brazed to the movable electrode 34. The stationary contact rod 31 is secured to the upper disk 22, while the movable contact rod 32 is suitably mounted for vertical movement, as described hereinafter. When the movable contact rod 32 moves upward or toward the stationary contact rod 31, the contact 38 engages the stationary electrode 33 as shown in Fig. 1, thereby closing the interrupter. When the movable contact rod 32 moves downward or away from the stationary contact rod 31, the contact 38 disengages the stationary electrode 33, thereby opening the interrupter. Suitable actuating means (not shown) is coupled to the movable contact rod 32 to drive the same upward or downward.

A flexible metallic bellows 39, made of austenitic stainless steel, coaxially surrounds the movable contact rod 32 inside the envelope 20 to provide a seal about the rod 32 to allow for vertical movement thereof without impairing the vacuum inside the envelope 20. The bellows 39 is brazed circumferentially at its upper end to the lower surface of an annular flange 40 formed on the rod 32 near the upper end thereof, and at its lower end to the inner metalized layer 28 on the lower disk 23. The stationary contact rod 31 is provided with an annular groove 41 about its periphery just below the upper disk 12 into which a ring 42 is fitted and brazed to the rod 31. An annular supporting member 43 made of copper or iron is provided between the ring 42 and the inner metalized layer 28 on the upper disk 22 and is brazed to the ring 42 and the layer 28 to provide a seal about the rod 31. Thus the stationary contact rod 31 is secured to the upper disk 22.

A pair of cylindrical upper and lower auxiliary shields 44 and 45 are coaxially secured to the upper and lower ends of the metallic cylinder 21 respectively. The upper auxiliary shield 44 has an integrally formed flange 46 at its upper end, whose periphery is brazed to the cylinder 21. The lower auxiliary shield 45 has a similar flange 47 at its lower end, whose periphery is also brazed to the cylinder 21. The auxiliary shields 44 and 45 are made of austenitic stainless steel, or may be made of copper or iron.

A pair of cup-shaped main shields 48 and 49 are coaxially secured to the stationary and movable contact rods 31 and 32 respectively near their inner ends. The shields 48 and 49 are made of a similar metal to that forming the shields 44 and 45. The main shields 48 and 49 are provided in their bases with central apertures 50 and 51 respectively through which the rods 31 and 32 pass, and have a greater diameter than that of the shields 44 and 45. The upper main shield 48 faces upward in such a manner as to cover the lower opening of the upper auxiliary shield 44 and partly overlap the lower end of the shield 44 axially. The stationary contact rod 31 is provided near its lower end with an annular groove 52 about its periphery into which a ring 53 is fitted and brazed to the rod 31. The upper main shield 48 is brazed along the periphery of its central aperture 50 to the upper surface of the ring 53. The lower main shield 49 faces downward in such a manner as to cover the upper opening of the lower auxiliary shield 45 and terminate at its lower end near the same relative axial position therewith as that of the upper end of the shield 45 when the movable rod 32 is in the closed position as shown in Fig. 1. The lower main shield 49 is brazed along the periphery of the central aperture 51 to the upper surface of the flange 40 on the rod 32. The lower shields 45 and 49 substantially enclose the bellows 39 to protect the same from the deposition of metallic vapors produced by arcing across the electrodes 33 and 34 or the contact 38. The upper shields 44 and 48, and the lower shields 45 and 49 substantially isolate the upper and lower disks 22 and 23 respectively from the electrodes 33, 34 and the contact 38 to protect the inner surfaces of the disks 22 and 23 respectively from the deposition of metallic vapors.

As best illustrated in Fig. 2 (showing the unbrazed condition), the upper end of the cylinder 21 has an annular double-step 54 on its inner surface. The inside diameter of the cylinder 21 discontinuously increases with the upward direction at the double-step 54. The upper disk 22 is fitted into the largest diameter part 55 of the double-step 54 and is brazed at the metalized layer 29 to the larger diameter shoulder 56 of the double-step 54 with a ring-shaped, rectangular section piece of brazing metal 57 interposed therebetween. The flange 46 of the upper auxiliary shield 44 is fitted into the middle diameter part 58 of the double-step 54 and is brazed to the metallic cylinder 21 in such a manner as to be parallel to but spaced away from the upper disk 22.

As best illustrated in Fig. 3 (showing the unbrazed condition), the lower end of the cylinder 21 has an annular double-step 59 on its inner surface. The inside diameter of the cylinder 21 discontinuously increases with the downward direction at the double-step 59. The lower disk 23 is fitted into the largest diameter part 60 of the double-step 59 and is brazed at the metalized layer 29 to the larger diameter shoulder 61 of the double-step 59 with a ring-shaped, rectangular section piece of brazing metal 62 interposed therebetween. The flange 47 of the lower auxiliary shield 45 is fitted into the middle diameter part 63 of the double-step 59 and is brazed to the metallic cylinder 21 with a ring-shaped wire of brazing metal 64 interposed between the upper surface of the flange 47 and the lesser diameter shoulder 65 of the double-step 59. A ring-shaped thin spacer 66 made of austenitic stainless steel, copper, or iron is provided between the lower surface of the flange 47 and the metalized layer 28 on the lower disk 23 inside the piece of brazing metal 62 to locate the lower auxiliary shield 45 so that the flange 47 of the shield 45 will be parallel to but spaced away from the lower disk 23 so as not to touch the same when the interrupter is temporarily assembled as described hereinafter.

As illustrated in Fig. 4 (showing the un-brazed condition), the upper end of the metallic cylinder 21 may be provided with an annular step 70 on its outer surface instead of the double-step 54. In this case, the outer projection 26 of the upper disk 22 is fitted and then brazed to the step 70 with a ring-shaped, rectangular section piece of brazing metal 71 interposed between the metalized layer 29 on the projection 26 and the shoulder 72 of the step 70, while the flange 46 of the shield 44 is placed on the top end of the cylinder 21. The lower end of the metallic cylinder 21 may be designed in a similar manner to the upper end thereof.

As illustrated in Fig. 5 (showing the un-brazed and inverted condition), the metallic cylinder 21 may be provided with an annular step 73 on the outer surface of its upper end instead of the double-step 54, and may be of a lesser outside diameter than that of the upper disk 22 so as to form an annular shoulder 74 outside the cylinder 21. In this case, the outer projection 26 of the disk 22 is fitted and then brazed to the step 73 with a ring-shaped, circular section piece of brazing metal 75 placed on the metalized layer 29 of the projection 26 or the shoulder 74 and abutted against the metallic cylinder 21 at the inner corner, while the flange 46 of the shield 44 is placed similarly to that shown in Fig. 4. The lower end of the metallic cylinder 21 may be designed in a similar manner to the upper end thereof.

As illustrated in Fig. 6 (showing the un-brazed condition), the upper end of the metallic cylinder 21 may be provided with an annular double-step 76 on its outer surface in such a manner that the outside diameter of the cylinder at the double-step 76 discontinuously decreases with the upward direction, and that the least diameter part 77 of the double-step 76 has a slightly less outside diameter than the inside diameter of the projection 26 of the upper disk 22 and has a slightly lower height than that of the projection 26. In this case, the outer projection 26 of the disk 22 is fitted and then brazed to the smaller and larger diameter shoulders 78 and 79 of the double-step 76 with a ring-shaped, circular section piece of brazing metal 80 interposed between the metalized layer 29 on the projection 26 and the larger diameter shoulder 79 of the double-step 76, while the flange 46 of the shield 44 is placed similarly to that shown in Fig. 4. The lower end of the metallic cylinder 21 may be designed in a similar manner to the upper end thereof.

The metallic cylinder 21 may be made of austenitic stainless steel which is a non-magnetic material and has a relatively high mechanical strength. In this case, the metallic cylinder 21 should be provided with a thermal stress relieving or absorbing structure, which is composed of an annular, semicircular section groove 81 formed on each of the end surfaces of the cylinder 21 in contact with the projections 26 of the disk 22 or 23, while the flanges 46 or 47 of the shields 44 or 45 are placed on the projections 26, as shown in Fig. 7. The structure may be constructed of a thin cylindrical segment 82 formed on each of the ends of the cylinder 21 by annular step-shaped grooves 83 on the inner end surfaces of the disk 22 or 23, as shown in Fig. 8. The end of each thin segment 82 is in contact with the projection 26 of the disk 22 or 23. As shown in Fig. 9, the structure may be constructed of an thin annular segment 84 formed on each of the ends of the cylinder 21 by an annular, rectangular groove 85 on the inner surface of the cylinder 21. The groove 85 is positioned away from the end of the cylinder 21 so that a thick cylindrical segment 86 will be provided between the thin segment 84 and the projection 26 of the disk 22 or 23 and that the end surface of the thick segment 86 or the cylinder 21 will be in contact with the projection. As shown in Fig. 10, the structure may be constructed of an thin annular, wave-shaped segment 87 formed at each of the ends of the cylinder 21. The thin segment 87 is bent inward to form a U-shaped section thereof and is in contact at the end surface thereof with the projection 26 of the disk 22 or 23.

To manufacture the vacuum circuit interrupter designed as above, the vacuum circuit interrupter is temporarily assembled with brazing metal interposed between the components and then the temporarily assembled vacuum circuit interrupter is brazed within a vacuum furnace.

In order to temporarily assemble the vacuum circuit interrupter, first the insulating disk 23 is supported horizontally so that the metalized layers 28 and 29 thereon face upward and secondly the bellows 39 is placed coaxially on the disk 23 with brazing metal interposed between the inner metalized layer 28 and the lower end of the bellows 39. Thirdly the auxiliary shield 45 is placed coaxially on the disk 23 while the spacer 66 (see Fig. 3) is interposed between the flange 47 thereof and the outer metalized layer 29. Then the movable contact rod 32 is inserted into the bellows 39 from above until the flange 40 thereof abuts on the upper end of the bellows 39 with brazing metal interposed between the flange 40 and the upper end of the bellows 39.

At the upper end of the movable contact rod 32, the shield 49 is first engaged to the flange 40 with brazing metal interposed therebetween, and the movable electrode 34 with the contact 38 fitted into the groove 37 with brazing metal interposed therebetween is fitted onto the upper end of the movable contact rod 32 with brazing metal placed at the bottom of the recess 36.

After the movable portions composed of the movable electrode 34 and the other parts are temporarily assembled on the disk 23 as mentioned above, the metallic cylinder 21 is fitted on the periphery of the disk 23 and the periphery of the flange 47 of the shield 45 at the double-step 59. As shown in Fig. 3, the brazing metal pieces 62 and 64 are first interposed between the cylinder 21 and the disk 23 at the metalized layer 29, and between the cylinder 21 and the flange 47 of the shield 45 respectively.

The stationary electrode 33 is fitted by the recess 35 to the end of the stationary contact rod 31 with brazing metal interposed therebetween, while the shield 48 is engaged to the ring 53 mounted on the rod 31 with brazing metal interposed therebetween. After the rod 31 with the electrode 33 and the shield 48 is inserted into the cylinder 21 so as to be carried on the movable electrode 34, the flange 46 of the upper auxiliary shield 44 is fitted to the cylinder 21 at the double-step 54 (see Fig. 2) thereof. Then the supporting member 43 is fitted to the stationary contact rod 31 and is engaged to the ring 42 with brazing metal interposed therebetween. The upper disk 22 is placed on the supporting member 43 with brazing metal interposed between the inner metalized layer 28 thereon and the supporting member 43, and lastly the disks 22 is fitted into the cylinder 21 at the double-step 54 with the piece of brazing metal 57 (see Fig. 2) interposed between the outer metalized layer 29 and the shoulder 56 of the double-step 54 of the cylinder 21.

The vacuum circuit interrupter assembled temporarily as mentioned above is placed within a vacuum furnace and heated while the furnace is evacuated to a pressure under 10^{-5} Torr. Since the heating acts to deaerate the components and also prevent oxidized films from forming on the brazed surfaces, the heating temperature is desirable to be higher if it does not cause the braze to melt and the vacuum pressure is preferably above 10^{-5} Torr. Then the temperature in the vacuum furnace is raised to a range from 900°C to 1050°C in order to activate the surface of the austenitic stainless steel, and the components are hermetically joined by the brazing metals while the vacuum furnace is evacuated so as to make the pressure therein under 10^{-5} Torr. The inside of the vacuum furnace is gradually cooled from the brazing temperature to a predetermined temperature by furnace cooling for example and then cooled gradually again to room temperature after being maintained at the predetermined temperature for a predetermined time, or is gradually cooled continuously from the brazing temperature to room temperature before the circuit interrupter is taken out from the vacuum furnace.

In the above mentioned manufacturing method, the upper limit of the heating temperature can be made under 900°C by first plating the brazing surfaces of the bellows 39 and the other parts made of austenitic stainless steel with nickel.

The joints between the disks 22 and 23, made of inorganic insulator such as alumina ceramic or the like, and the metallic cylinder 21, made of copper or iron can be made to have an adequate airtight property and mechanical strength although the thermal expansion coefficients thereof are extremely different from each other. As shown by the solid curves in Fig. 11, the tensile strengths of copper and iron increase with the fall of temperature, whereas as shown by the broken curves the expansion rates thereof approximately decrease with the fall of temperature. Therefore, when the copper or iron cylinder 21 is brazed to the disks 22 and 23 of an inorganic insulator such as alumina ceramic or the like at a high temperature of 900°C to 1050°C, the cylinder 21 is plastically deformed, according to thermal stresses induced during brazing, in the gradual cooling process since the tensile strength thereof is extremely small relative to the mechanical strength of the disks 22 and 23. Thus the airtight property of the joints thereof is not damaged and the residual thermal stresses are extremely small when the joints are cooled to room temperature.

Iron can be joined hermetically to an inorganic insulator to provide a structure with a high mechanical strength in a similar manner to copper although the tensile strength thereof at each temperature is greater than that of copper as shown by the solid curves in Fig. 11, and the creep thereof against time under constant loading is less than that of copper, since the thermal expansion coefficient thereof is roughly less than that of copper as shown by the broken curves in Fig. 11.

The joint between the lower disk 23 of an inorganic insulator such as alumina ceramic or the like and the bellows 39 of austenitic stainless steel can be made to have an adequate airtight property and mechanical strength, since the bellows 39 is approximately 0.1 to 0.2 mm in thickness and the thermal stress caused during brazing is extremely small relative to the mechanical strength of the disk 23 and consequently the bellows 39 itself deforms platically in the gradual cooling process.

In Fig. 12 is illustrated a vacuum circuit interrupter of a second embodiment of the present invention, wherein similar or corresponding elements are designated by the same numerals as those in Fig. 1. This interrupter is similar to that in Fig. 1 except for the following points.

The metallic cylinder 21 has steps 100 and 101 on each of its inner end surfaces. The upper and lower insulating disks 22 and 23 each have metalized layers 102 and 103 on their inner and outer circumferential surfaces respectively. The inner surface of each disk is flat. The outer end of the upper disk 22 is fitted and brazed, at the metalized layer 103, to the upper step 100 of the cylinder 21, while the flange 46 of the upper auxiliary shield 44 is fitted between the shoulder of the step 100 and the disk 22, so as to provide a compression seal about the upper disk 22. The outer end of the lower disk 23 is fitted and brazed, at the metalized layer 103, to the lower step 101 of the cylinder 21 so as to provide a similar seal about the lower disk 23. The flange 47 of the lower auxiliary shield 45 is engaged, by crimping, to the lower step 101 above the lower disk 22 while abutting with the shoulder of the step 101, in order to prevent it from being pulled away from the cylinder 21 when the interrupter is temporarily assembled. The flange 47 is so positioned as to be parallel to but spaced from the lower disk 22. A ring-like supporting member 104 of an L-shaped section has a coaxial aperture 105 accommodating snugly the stationary contact rod 31. The supporting member 104 is seated on and brazed to the upper surface of the ring 42, and is also seated on and brazed to the inner end of the upper disk 22 at the inner metalized layer 102, so as to provide a seal about the rod 31. The cylindrical lower end of the bellows 39 is circumferentially brazed to the lower disk 22 at the inner metalized layer 102 thereon so as to provide a seal about the movable contact rod 32 and allow for vertical movement thereof.

In Fig. 13 is illustrated a vacuum circuit interrupter of a third embodiment of the present invention, wherein similar or corresponding elements are designated by the same numerals as those in Fig. 1 or Fig. 12. This interrupter is similar to that of Fig. 1 or Fig. 12 except for the following points.

The metallic cylinder 21 is provided at its ends with a larger diameter segment or annular lip 106 each formed integrally by widening the end of the cylinder 21. The upper insulating disk 22 and the flange 46 of the lower shield 44 are fitted into the annular lip 106 at the upper end of the cylinder 21. The lower insulating disk 23 and the flange 47 of the lower shield 45 are fitted into the annular lip 106 at the lower end of the cylinder 21. The lower insulating disk 23 is cut around its upper edge to form an annular groove 107 just beneath the flange 47 of the lower shield 45. The groove 107 accommodates the braze providing a compression-seal about the disk 23.

In Fig. 14 is illustrated a vacuum circuit interrupter of a fourth embodiment of the present invention, wherein similar or corresponding elements are designated by the same numerals as those in Fig. 12 or 13. This interrupter is similar to that of Fig. 12 or 13 except for the following points. The lower end of the cylinder 21 has a constant inside diameter and the outer ends of the lower disk 23 and the flange 47 of the lower shield 45 fit within it.

Referring to Fig. 15, there is shown a vacuum circuit interrupter according to a fifth embodiment of the present invention which is in its closed state and has an evacuated housing or envelope 110. The envelope 110 consists of a metallic cylinder 111 and a pair of insulating disks 112 and 113 closing the opposite ends of the cylinder 111.

As is best illustrated in Fig. 2, each of the disks 112 and 113 has a circular center aperture 114 therein and concentrically arranged annular projections 115, 116 and 117 on the inner surface thereof. The annular projections 115, 116 and 117 are 0.1 to 0.5 mm in height and have flat surfaces covered with metalized layers 118, 119 and 120 respectively. The outermost metalized layers 120 have a diameter corresponding to that of the metallic cylinder 111, whose ends are brazed to the layers 120 to fix the insulating disks 112 and 113 thereto. The innermost metalized layers 118 are positoned on the peripheries of the apertures 114 in the disks 112 and 113.

The cylinder 111 is made of a plastically deformable metal, such as copper or iron, which is relatively inexpensive and is easy to deform plastically in the cooling process after brazing according to the thermal stress generated during brazing. Non-magnetic metal such as copper is more preferable to magnetic metal such as iron for the cylinder 111, because vibrating force exerted thereon by an alternating current passing through the interrupter is weaker than that on magnetic metal and consequently the interrupter has relatively high durability and reliability. If copper or iron supporting rings (not shown) are interposed between the cylinder 111 and the disks 112 and 113, the cylinder 111 may be made of austenitic stainless steel which is a non-magnetic material and has a comparatively high mechanical-strength. The disks 112 and 113 are made of an inorganic insulator, such as alumina ceramic or crystallized glass. The metalized layers 118, 119 and 120 are made of a manganese-titanium alloy or a molybdenum-manganese-titanium alloy which has a similar thermal expansion coefficient to that of alumina ceramic.

A pair of conductive, circular-section stationary and movable contact rods 121 and 122 respectively project through the apertures 114 in the upper and lower disks 112 and 113 respectively to enter the envelope 110 in such a manner as to extend coaxially along the cylinder 111, namely in an aligned configuration. The rods 121 and 122 are made of copper or a copper alloy. A pair of stationary and movable disk-shaped electrodes 123 and 124 are attached coaxially to the stationary and movable contact rods 121 and 122 respectively at the inner ends thereof. The stationary and movable electrodes 123 and 124 have circular recesses 125 and 126 respectively on their outer surfaces. The inner ends of the stationary and movable contact rods 121 and 122 are fitted into the recesses 125 and 126 respectively and brazed to the stationary and movable electrodes 123 and 124 respectively. The movable electrode 124 is formed with a coaxial annular groove 127 on its upper surface. The ring-shaped contact 128 is fitted into the groove 127 and is brazed to the movable electrode 124. The stationary contact rod 121 is secured to the upper disk 112, while the movable contact rod 122 is suitably mounted to allow vertical movement, as described hereinafter. When the movable contact rod 122 moves upward or toward the stationary contact rod 121, the contact 128 engages the stationary electrode 123 as shown in Fig. 15, thereby closing the interrupter. When the movable contact rod 122 moves downward or away from the stationary contact rod 121, the contact 128 disengages from the stationary electrode 123, thereby opening the interrupter. Suitable actuating means (not shown) is coupled to the movable contact rod 122 to drive the same upward or downward.

A flexible metallic bellows 129, made of austenitic stainless steel with a thickness of 0.1 to 0.2mm, coaxially surrounds the movable contact rod 122 inside the envelope 110 to provide a seal about the rod 122 to allow for vertical movement thereof without impairing the vacuum inside the envelope 110. The bellows 129 is brazed at its upper end circumferentially to the lower surface of an annular flange 130 formed on the rod 122 near the upper end thereof, and at its lower end to the innermost metalized layer 18 on the lower disk 113. The stationary contact rod 121 is provided with an annular groove 131 on its periphery just below the upper disk 112 into which a ring 132 is fitted and brazed to the rod 121. An annular supporting member 133 made of copper or iron is provided between the ring 132 and the innermost metalized layer 118 on the upper disk 112 and is brazed to the ring 132 and the layer 118 to provide a seal about the rod 121. Thus the stationary contact rod 121 is secured to the upper disk 112.

A pair of cylindrical upper and lower shields 134 and 135 respectively each are coaxially brazed at one end to the intermediate metalized layers 119 on the upper and lower disks 112 and 113 respectively. The shields 134 and 135 are made of austenitic stainless steel, or may be made of plastically deformable copper or iron. The shields 134 and 135 are electrically isolated from the conductive rods 121 and 122, the metallic cylinder 111, and the bellows 129 to form therein a floating voltage to raize breakdown voltages along the inner surfaces of the upper and lower disks 112 and 113 respectively and to even out the distribution of the electric field inside the envelope 110. A pair of cup-shaped shields 136 and 137 are coaxially secured to the stationary and movable contact rods 121 and 122 respectively near their inner ends. The shields 136 and 137 are made of a similar metal to that forming the shields 134 and 135. The shields 136 and 137 are provided in their bases with coaxial apertures 138 and 139 respectively through which the rods 121 and 122 respectively pass, and have a greater diameter than that of the shields 134 and 135. The upper cup-shaped shield 136 faces upward in such a manner as to cover the opening of the upper cylindrical shield 134 and overlap the end of the shield 134, so that the shields 134 and 136 may substantially isolate the inner circular portion of the inside surface of the upper insulating disk 112 from the stationary and movable electrodes 123, 124 and the contact 128. Thus the shields 134 and 136 protect the inner portion of the insulating disk 112 from the deposition of metallic vapors produced by arcing across the electrodes 123 and 124 or the contact 128. The stationary contact rod 121 is provided near its lower end with an annular groove 140 around its periphery into which a ring 141 is fitted and brazed to the rod 121. The upper cup-shaped shield 136 is brazed along the periphery of its center aperture 138 to the lower surface of the ring 141. The lower cup-shaped shield 137 faces downward in such a manner as to cover the opening of the lower cylindrical shield 135 and terminate at its lower end near the same axial position as that of the upper end of the shield 135 when the movable rod 122 is positioned in the closed state as shown in Fig. 1. The lower cup-shaped shield 137 is brazed along the periphery of its central aperture 139 to the upper surface of the flange 130 on the rod 122. Thus the shields 135 and 137 substantially isolate the bellows 129 and the inner circular portion of the inside surface of the lower insulating disk 13 from the electrodes 123, 124 and the contact 128, in order to protect them from the deposition of metallic vapors produced by arcing across the electrodes 123 and 124 or the contact 128.

To manufacture the vacuum circuit interrupter designed as above, first the cylindrical shield 134, the stationary contact rod 121, and the other parts are placed on the insulating disk 112 with brazing metal interposed therebetween to temporarily assemble the stationary section, while the cylindrical shield 135, the bellows 129, the movable contact rod 122, and the other parts are placed on the insulating disk 113 with brazing metal interposed therebetween to temporarily assemble the movable section. Secondly, the temporarily assembled stationary and movable sections are brazed within a vacuum furnace or a furnace filled with a non-oxidizing ambient gas such as hydrogen. Finally, the stationary and movable sections are attached to the respective ends of the metallic cylinder 111 with brazing metal interposed therebetween to temporarily assemble the vacuum circuit interrupter, and the temporarily assembled interrupter is brazed within the vacuum furnace.

In order to temporarily assemble the stationary section, the insulating disk 112 is supported horizontally so as to make the metalized layers 118, 119 and 120 face upward, and then the supporting member 133 is placed on the metalized layer 118 on the periphery of the aperture 114 in the insulating disk 112 with brazing metal interposed therebetween while the cylindrical shield 134 is placed on the intermediate metalized layer 119 on the disk 112 with brazing metal interposed therebetween. As shown in Fig. 3, the brazing metal 150 interposed between the intermediate metalized layer 119 on the disk 112 and the cylindrical shield 134 is formed by a press or some similar method into a ring provided with annular portions 151 and 152 extending axially at the inner and outer circumferential ends so as to have a crank-shaped section. The brazing metal 150 is provided to facilitate the positioning of the shield 134 with respect to the insulating disk 112 by fitting the annular portion 151 to the shoulder of the annular projection 116 of the disk 112 and also fitting the annular portion 152 to the outer circumference of the shield end 134. Similar crank-shaped rings of brazing metal are employed for the brazing metal interposed between the supporting member 133 and the metalized layer 118, and that interposed between the metallic cylinder 111 and the metalized layer 120. Next, the stationary contact rod 121 is inserted into the supporting member 133 from above, and is engaged with the member 133 by means of the stop ring 132 with brazing metal interposed between the supporting member 133 and the stop ring 132. The cup-shaped shield 136 is fitted to the stationary contact rod 121 and is engaged to the stop ring 141 with brazing metal interposed therebetween. Then, brazing metal is placed on the end of the stationary electrode rod 121, and the stationary electrode 123 is fitted to the rod 121 in the recess 125 thereof.

In order to temporarily assemble the movable section, the insulating disk 113 is supported horizontally so as to make the metalized layers 118, 119 and 120 face upward, and the bellows 129 is placed thereon with brazing metal interposed between its end and the metalized layer 118 on the periphery of the aperture 114 in the disk 113 while the cylindrical shield 135 is placed thereon with brazing metal placed on the intermediate metalized layer 119 on the disk 113. The movable contact rod 122 is inserted into the bellows 129 from above, and the flange 130 is placed on the other end of the bellows 129 with brazing metal interposed therebetween. The cup-shaped shield 137 is fitted to the movable contact rod 122 and is engaged to the flange 130 with brazing metal interposed therebetween. Then, brazing metal is placed on the end of the movable contact rod 122, and the movable electrode 124 is fitted to the end of the rod 122 in the recess 126 thereof. Then, the contact 128 is fitted to the groove 127 in the movable electrode 124 with brazing metal interposed therebetween.

The stationary and movable sections assembled temporarily as mentioned above are placed within the vacuum furnace and heated while the furnace is evacuated so as to make the pressure therein under 10^{-5} Torr in order to perform the deaeration treatment of each component. Next, the vacuum furnace is heated to a temperature of 900°C to 1050°C in order to activate the surfaces of the austenitic stainless steel, and the components are brazed hermetically to each other while the furnace is evacuated to a pressure lower than 10^{-5} Torr. The inside of the vacuum furnace is gradually cooled from the brazing temperature to a predetermined temperature by furnace cooling for example and then cooled gradually again to room temperature after being maintained at the predetermined temperature for a predetermined time, or is gradually cooled continuously from the brazing temperature to room temperature before the stationary and movable sections are taken out from the vacuum furnace.

Brazing the components of the stationary and movable sections cannot only be done inside the vacuum furnace, and may be performed, for example, within deoxidizing ambient gas such as hydrogen allowing the oxidized film of austenitic stainless steel to be removed at a temperature ranging from the minimum brazing temperature determined by the melting point to 1050°C.

The insulating disks 112 and 113 of the stationary and movable sections brazed as described above are fitted to the opposite ends of the metallic cylinder 111 with brazing metal interposed therebetween to assemble temporarily the vacuum circuit interrupter. The temporarily assembled vacuum circuit interrupter is placed vertically within the vacuum furnace before the furnace is evacuated to a pressure under 10^{-4} Torr. Then, while the furnace is heated at a temperature of 500°C to 1050°C and evacuated to a pressure under 10^{-5} Torr, the stationary and movable sections are brazed hermetically to the metallic cylinder 111 simultaneously with the deaeration treatment of each component. After the inside of the vacuum furnace is gradually cooled from the brazing temperature to a predetermined temperature and then cooled gradually again to room temperature after being maintained at the predetermined temperature for a predetermined time, or after the inside of the vacuum furnace is gradually cooled continuously from the brazing temperature to room temperature, the vacuum circuit interrupter is taken out from the furnace.

In the aforementioned manufacturing method, the upper limit of the heating temperature can be made below 900°C by nickel-plating the brazed portions of the shields 134 and 135, the bellows 129, and the other parts made of austenitic stainless steel beforehand.

As will be understood from the foregoing description of the preferred embodiments of the present invention, the insulating disks and the metallic cylinder can be brazed to have an adequate mechanical-strength with a sufficient sealing performance although their thermal expansion coefficients are different from each other, because the metallic cylinder is relatively easy to deform plastically. Moreover, since the metallic cylinder may be made of copper or iron, the vacuum circuit interrupter can be manufactured at a relatively low cost. Especially in the fifth embodiment of the present invention, the breakdown voltage along the inside surfaces of the insulating disks can be raised adequately, because the conductive cylindrical shields are fixed to the inside surfaces of the disks respectively in an electrically isolated state.

It should be understood that further modifications and variations may be made in the present invention without departing from the spirit and scope of the present invention as set forth in the appended claims.

CLAIMS

1. A vacuum circuit interrupter comprising:

a) a cylinder (21, 111) made of a metal which is relatively easy to deform plastically;

b) first and second insulating disks (22, 23, 112, 113) closing the opposite ends of the metallic cylinder (21, 111) to form therewith an evacuated envelope (20, 110), the first and second disks (22, 23, 112, 113) having each a coaxial central aperture (24, 114);

c) a stationary conductive rod (31, 121) coaxially entering the envelope (20, 110) through the central aperture (24, 114) of the first disk (22, 112), the stationary rod (31, 121) being fixed to the first disk (22, 112) in such a manner as to provide a seal therewith;

d) a movable conductive rod (32, 122) coaxially and movably entering the envelope (20, 110) through the central aperture (24, 114) of the second disk (23, 113) without impairing the vacuum inside the envelope (20, 110);

e) stationary and movable electrodes (33, 34, 123, 124) connected to the stationary and movable rods (31, 32, 121, 122) respectively in such a manner as to engage with each other when the movable rod (32, 122) moves toward the stationary rod (31, 121) and disengage from each other when the movable rod (32, 122) moves away from the stationary rod (31, 121).

2. A vacuum circuit interrupter as defined by claim 1, further comprising a bellows (39, 129) surrounding the movable rod (32, 122) inside the envelope (20, 110), the bellows (39, 129) being fixed at one end to the movable rod (32, 122) and at its other end to the second disk (23, 113) in such a manner as to provide a seal about the movable rod (32, 122) to allow for movement thereof without impairing vacuum inside the envelope (20, 110).

3. A vacuum circuit interrupter as defined by claim 2, further comprising first and second cup-shaped main shields (48, 49), and first and second cylindrical auxiliary shields (44, 45) each with a flange (46, 47), the first main shield (48) being fixed to the stationary rod (31) while the first auxiliary shield (44) is fixed by its flange (46) to the metallic cylinder (21) in such a manner that the first main and auxiliary shields (48, 44) substantially isolate the first insulating disk (22) from the movable and stationary electrodes (33, 34), the second main shield (49) being fixed to the movable rod (32) while the second auxiliary shield (45) is fixed by its flange (47) to the metallic cylinder (21) in such a manner that the second main and auxiliary shields (49, 45) substantially isolate the bellows (39) and the second insulating disk (23) from the movable and stationary electrodes (33, 34).

4. A vacuum circuit interrupter as defined by claim 1, 2, or 3, wherein the stationary and movable electrodes (33, 34, 123, 124) are in the form of disks and are coaxially connected to the inner ends of the statonary and movable rods (31, 32, 121, 122) respectively, the movable electrode (34, 124) having a coaxial annular contact (38, 128) on the end adjacent to the stationary electrode (33, 123), the contact (38, 128) engaging and disengaging with the stationary electrode (33, 123) according to the movement of the movable rod (32, 122).

5. A vacuum circuit interrupter as defined by claim 1, 2, or 3, wherein the metallic cylinder (21, 111) is made of a non-magnetic metal.

6. A vacuum circuit interrupter as defined by claim 5, wherein the metallic cylinder (21, 111) is made of copper.

7. A vacuum circuit interrupter as defined by claim 1, 2, or 3, wherein the metallic cylinder (21, 111) is made of iron.

8. A vacuum circuit interrupter comprising:

a) a plastically deformable metallic cylinder (111);

b) first and second insulating disks (112,

113) closing the opposite ends of the metallic cylinder (111) to form therewith an evacuated envelope (110), the first and second disks (112, 113) each having a coaxial central aperture (114);

c) a stationary conductive rod (121) coaxially entering the envelope (110) through the central aperture (114) of the first disk (112), the stationary rod (121) being fixed to the first disk (112) in such a manner as to provide a seal thereabout;

d) a movable conductive rod (122) coaxially and movably entering the envelope (110) through the central aperture (114) of the second disk (113) in such a manner as to align with the stationary rod (121);

e) a bellows (129) surrounding the movable rod (122) inside the envelope (110), the bellows (129) being fixed at its one end to the movable rod (122) and at its other end to the second disk (113) in such a manner as to provide a seal about the movable rod (122) to allow for movement thereof without impairing the vacuum inside the envelope (110);

f) stationary and movable electrodes (123, 124) connected to the stationary and movable rods (121, 122) respectively in such a manner as to engage with each other when the movable rod (122) moves toward the stationary rod (121) and disengage from each other when the movable rod (122) moves away from the stationary rod (121);

g) a first conductive shield (134) surrounding the stationary rod (121) inside the envelope (110), the first shield (134) being fixed to the first disk (112) in such a manner as to be isolated electrically from the stationary rod (121) and the metallic cylinder (111); and

h) a second conductive shield (135) surrounding the bellows (129) inside the envelope (110), the second shield (135) being fixed to the second disk (113) in such a manner as to be isolated electrically from the movable rod (122) and the metallic cylinder (111).

9. A vacuum circuit interrupter as defined by claim 8, further comprising first and second coaxial annular metalized layers (119) formed on the inner surfaces of the first and second disks (112, 113) respectively, the first and second shields (134, 135) being shaped cylindrically and coaxially being brazed at one end to the first and second metalized layers (119) respectively.

10. A vacuum circuit interrupter as defined by claim 8, wherein the stationary and movable electrodes (123, 124) are each in the form of a disk and are coaxially connected to the inner ends of the stationary and movable rods (121, 122) respectively, the movable electrode (124) having a coaxial annular contact (128) on its end surface adjacent to the stationary electrode (123), the contact (128) engaging and disengaging with the stationary electrode (123) according to the movement of the movable

rod (122).

11. A vacuum circuit interrupter as defined by claim 9, further comprising third and fourth cup-shaped shields (136, 137) of larger diameters than those of the first and second shields (134, 135), the third and fourth shields (136, 137) coaxially connected to the stationary and movable rods (121, 122) respectively in such a manner that the third shield (136) covers the opening of the first shield (134) to substantially isolate the inner circular portion of the inside surface of the first disk (112) from the sttionary and movable electrodes (123, 124), and that the fourth shield (137) covers the opening of the second shield (135) to substantially isolate the bellows (129) and the inner circular portion of the inside surface of the second disk (113) from the stationary and movable electrodes (123, 124).

FIG. 1

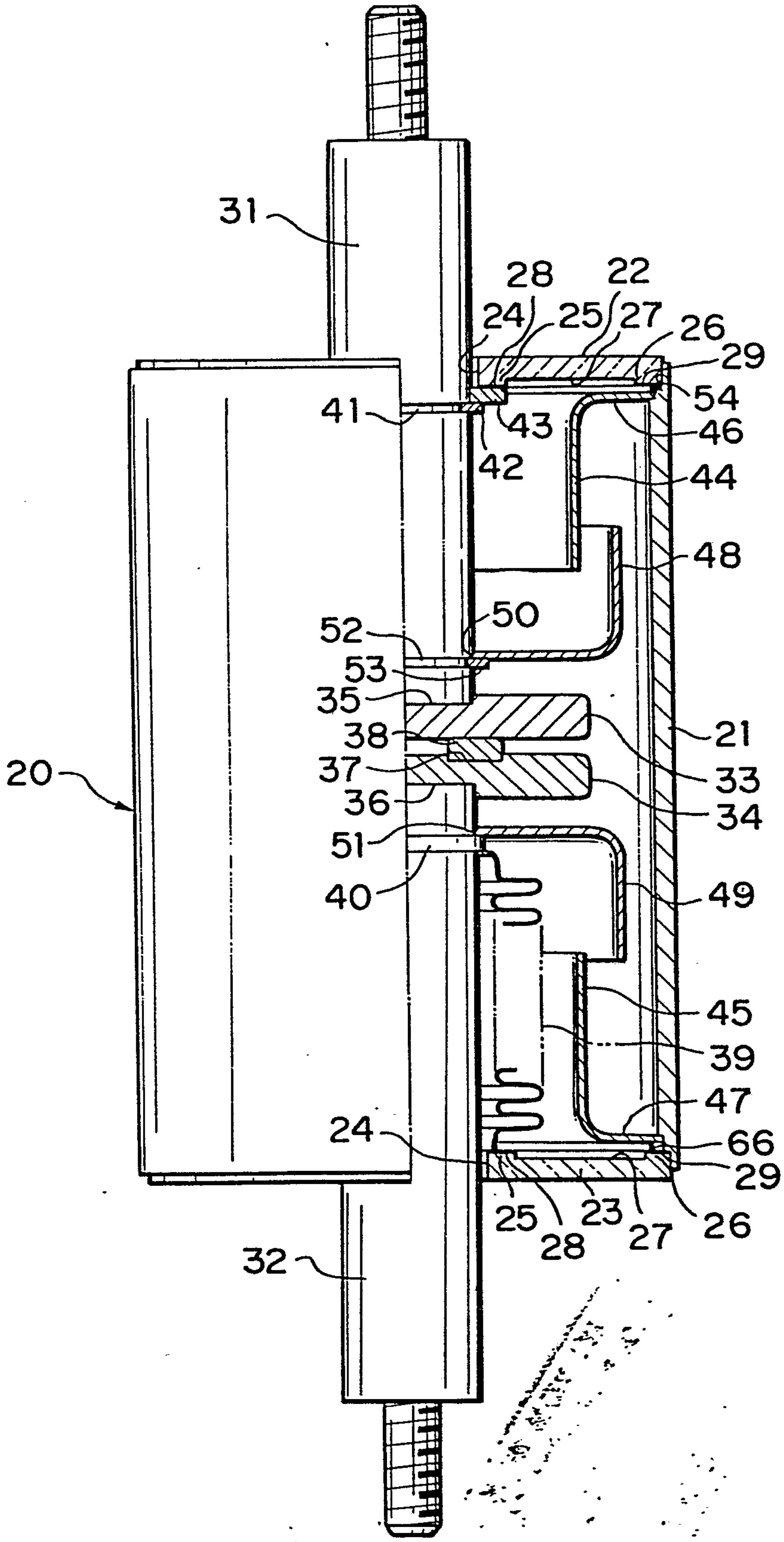
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FIG.2

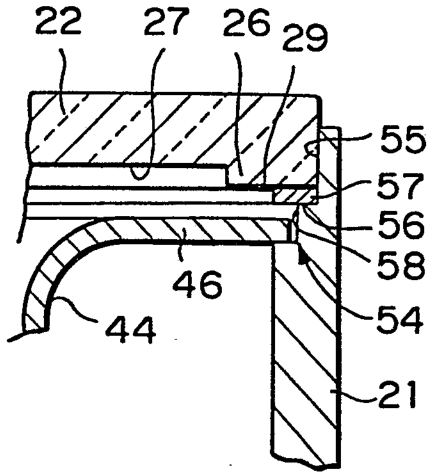


FIG.3

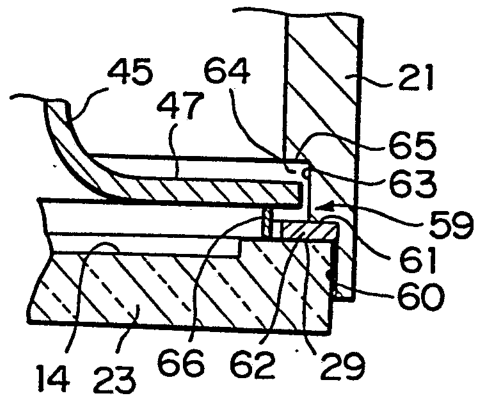


FIG.4

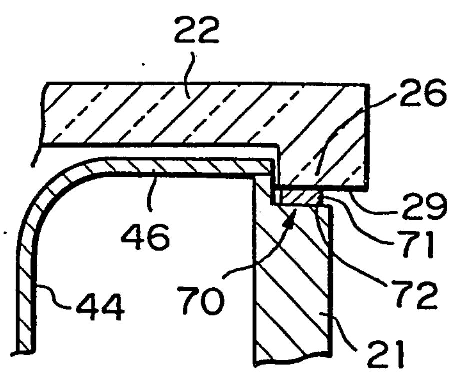


FIG.5

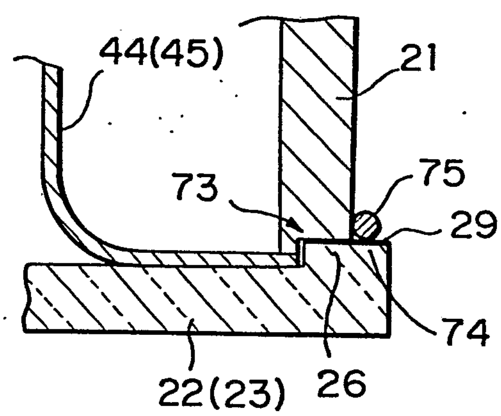


FIG.6

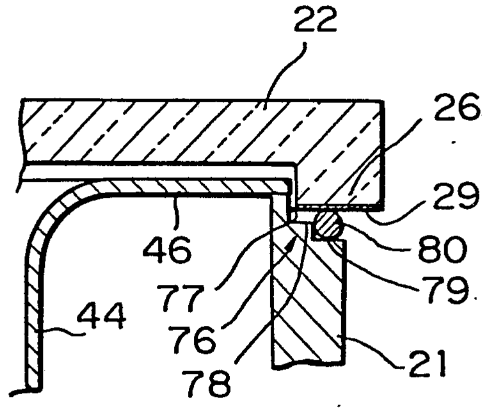


FIG.7

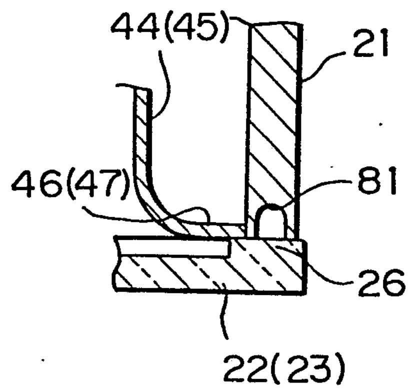


FIG.8

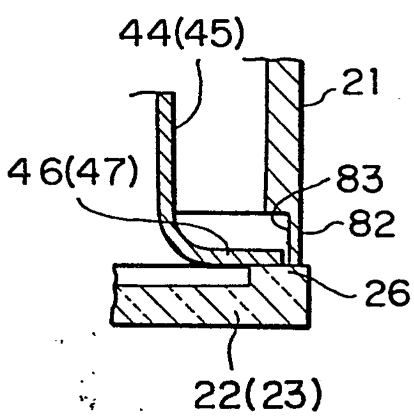


FIG.9

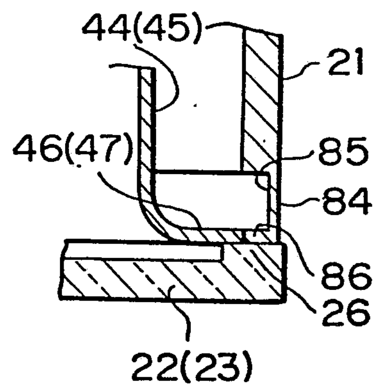


FIG. 10

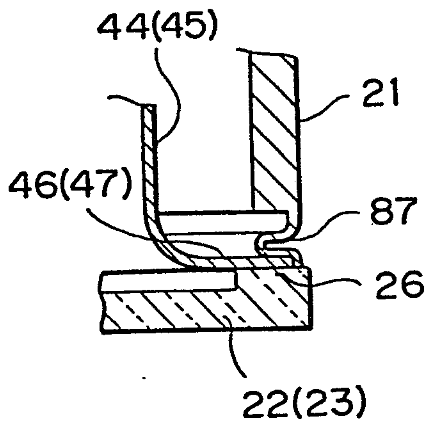
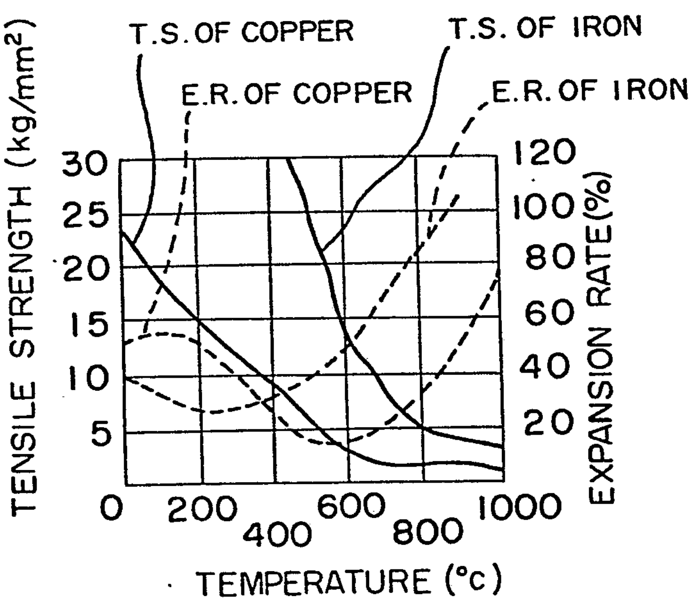

44(45)
21
46(47)
87
26
22(23)

FIG. 11


T.S. OF COPPER
T.S. OF IRON
E.R. OF COPPER
E.R. OF IRON
TENSILE STRENGTH (kg/mm²)
30
25
20
15
10
5
0
200
400
600
800
1000
120
100
80
60
40
20
EXPANSION RATE (%)
TEMPERATURE (°c)

0043186

FIG. 12

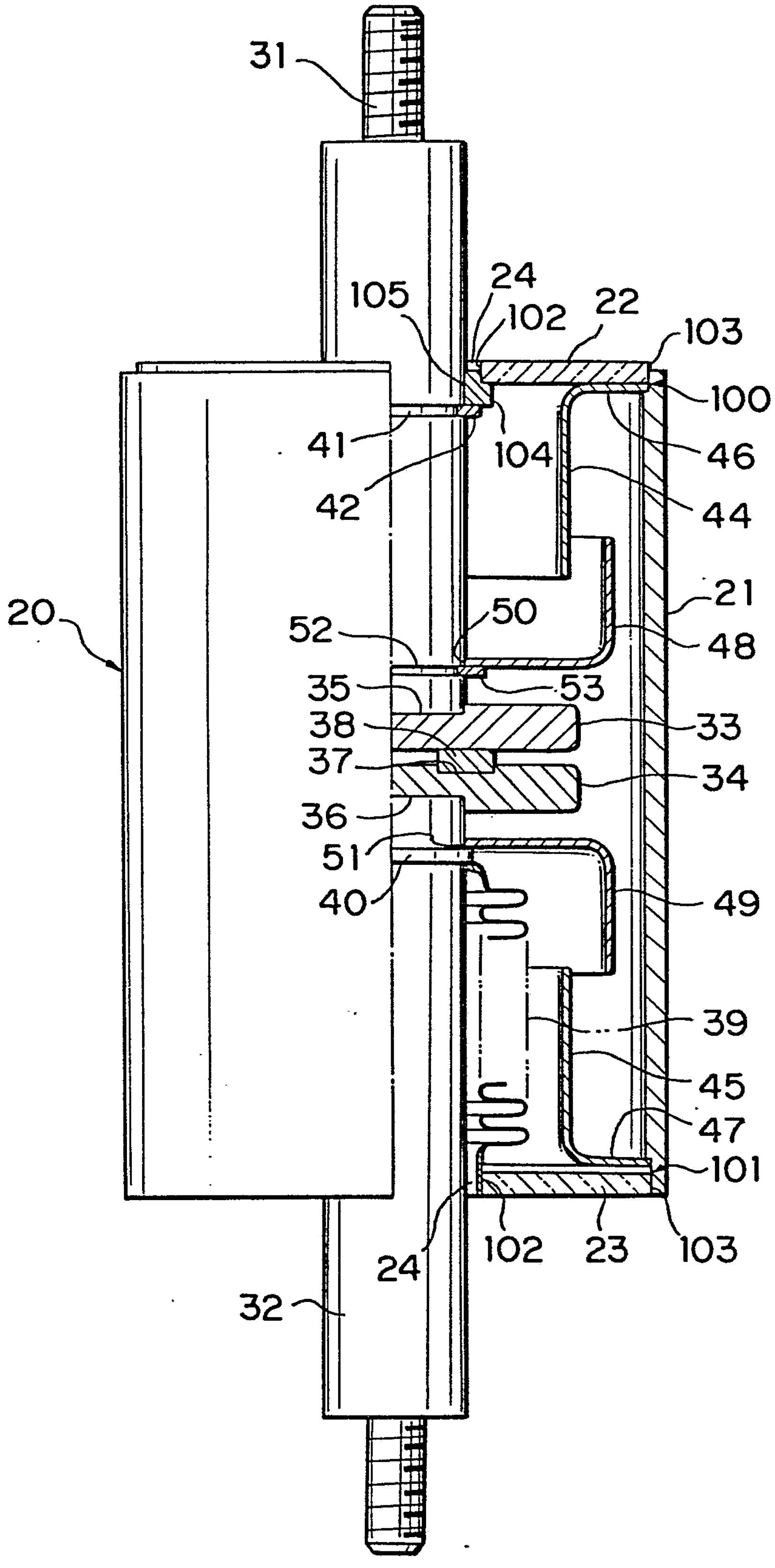


FIG.13

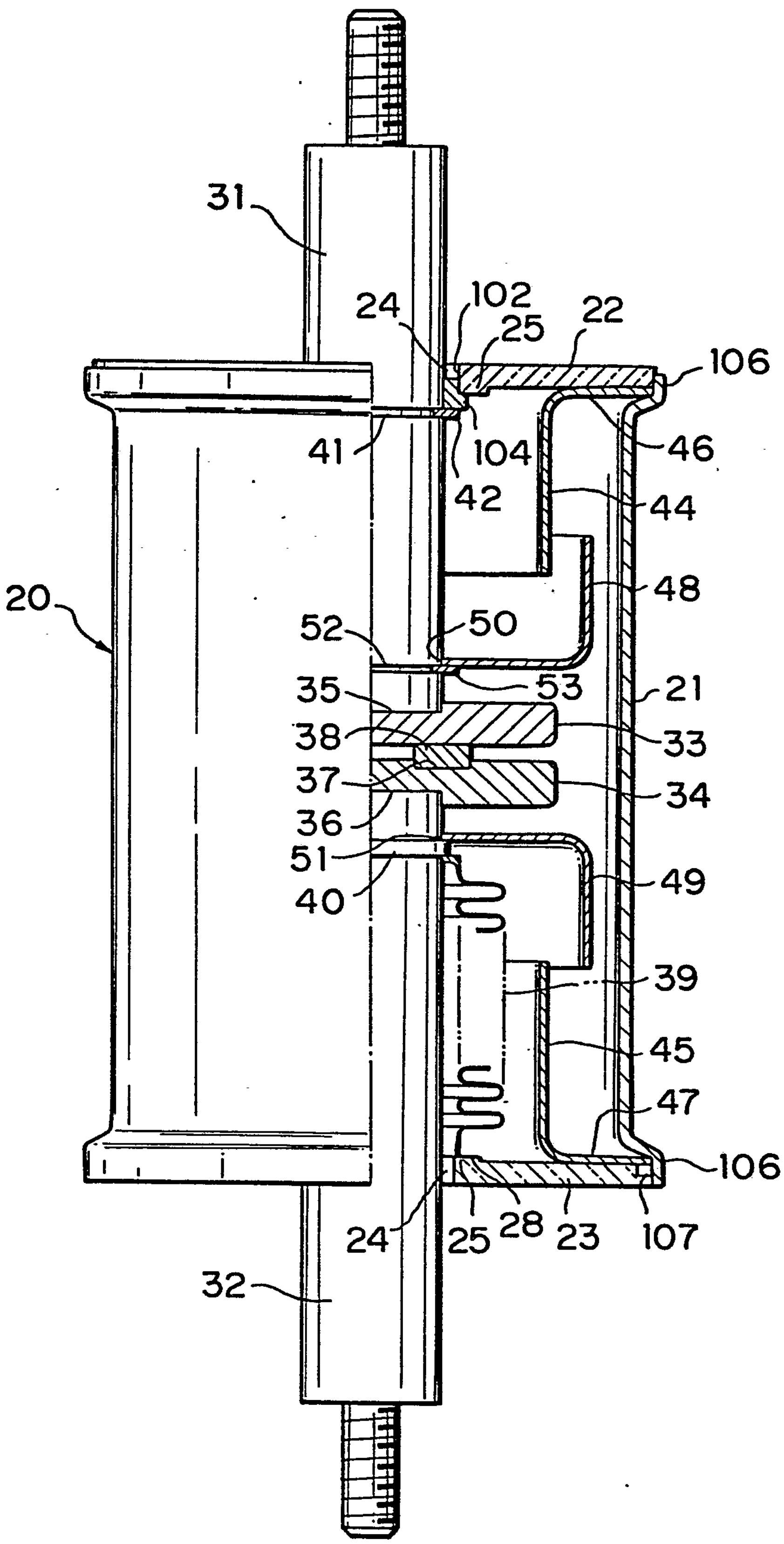

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FIG. 14

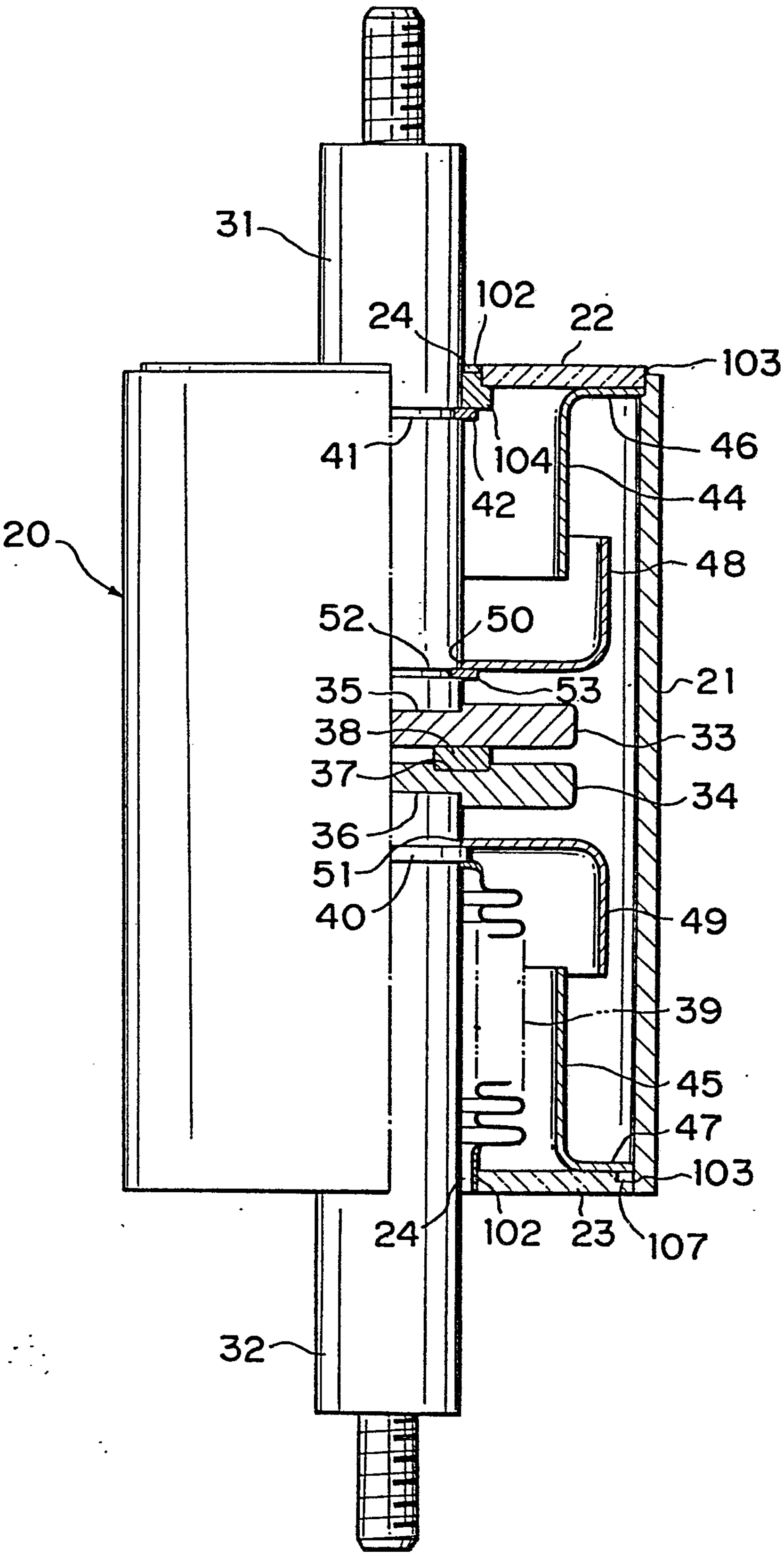
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FIG. 15

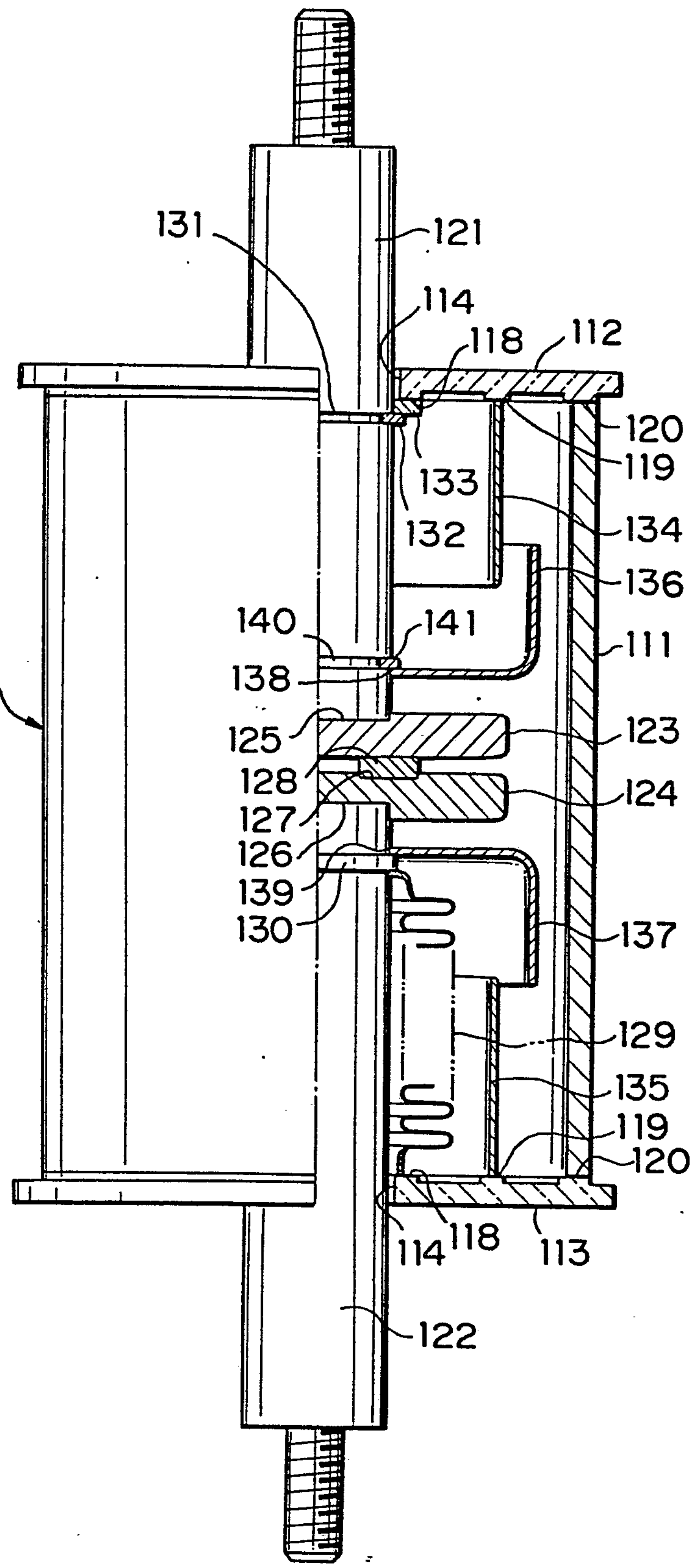
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FIG. 16

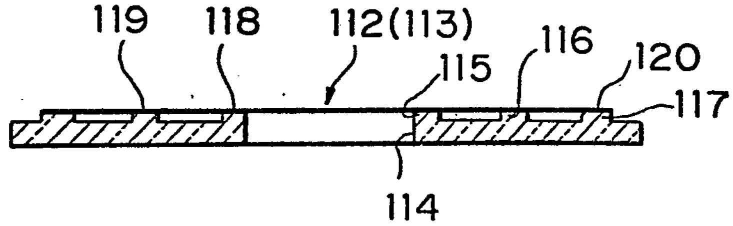

FIG. 17