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(71) Applicant: **ABB TECHNOLOGY AG** [CH/CH]; Affolternstraße 44, CH-8050 Zurich (CH).

(72) Inventors: **GENTSCH, Dietmar**; Untere Steinhauser Straße 26, 40882 Ratingen (DE). **LAMARA, Tarek**; Kirchweg 41A, CH-5415 Nussbaumen (CH). **SOKOLOV, Alexey**; Fluhmattstrasse 31, CH-5400 Baden (CH).

(74) Agent: **SCHMIDT, Karl-Michael**; c/o ABB AG/GF-IP, Oberhausener Strasse 33, 40472 Ratingen (DE).

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(54) Title: VACUUM INTERRUPTER WITH DOUBLE COAXIAL CONTACT ARRANGEMENT AT EACH SIDE

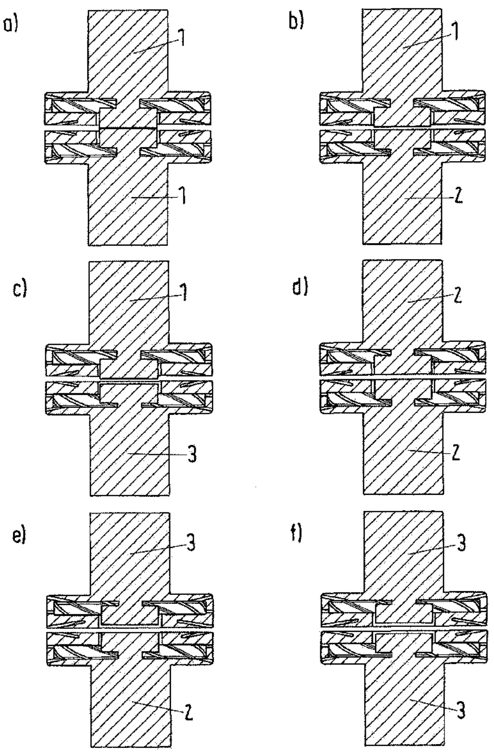

Fig.2

(57) Abstract: The invention relates to a vacuum interrupter with double coaxial contact arrangement in which the inner contact has a TMF-like or Pin shape arranged within concentrically cup shaped AMF coil with a single layer or multilayered contact parts at each side, th.m. on the side of the a fixed contact arrangement as well as on the side of a movable contact arrangement according to the preamble of claim 1. In order to enhance this special construction furthermore in order to result high conductivity and low resistance, the invention is, that the outer cup shaped contact is made from a double or multiple layer arrangement, wherein at least one layer is made from a hard steel or steel alloy and at least a second layer is made from material with high thermal conductivity.

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Vacuum interrupter with double coaxial contact arrangement at each side

The invention relates to a vacuum interrupter with double contact arrangement within concentrically arranged contact parts at each side, th.m. on the side of the a fixed contact arrangement as well as on the side of a movable contact arrangement according to the preamble of claim 1.

There have been constant improvements of many features of the double-contact Vacuuminterrupter concept designed for high current interruption and being cost effective vacuum interrupter. The most attractive feature of the double-contact assembly is the separate function between the nominal current conducting element, that means the inner contacts, and the current interrupting element that means the outer contacts. In this way each element can be designed independantly to its optimum shape and can be made from its best material.

Such a double contact arrangement is known from the **EP 2 434 513 A1**. The inner contacts are responsible for nominal current conduction and thus should have a very small total resistance (contact and bulk resistances). For this reason, the inner contacts are TMF-like or Butt contacts and made from high electrical conductive material like copper or CuCr. The inner contacts, following the state of the art description, hold the initial phase of the arc before its commutation to the outer contacts.

The outer contacts, are only responsible for the AMF field generation, thus can be designed with a thin cup-shaped layer made from hard conductive material like stainless-steel. This option offers many advantages over the conventional AMF contacts leading to lower material cost and very robust contacts assembly. These advantages are:

1. High mechanical strength
2. Lower cost material (stainless-steel instead of copper or CuCr)
3. Lower contacts mass- reducing the driving contacts opening forces
4. Large effective AMF area leading to a larger diffuse vacuum arc distribution

So it is an object of the invention, to enhance this special construction furthermore in order to result high conductivity and low restistance.

This is resulted by the invention in that the outer cup shaped contact is made from a single, double or multiple layer arrangement, wherein at least one layer is made from a hard steel or steel alloy and at least, in case of a multilayer arrangement, a second layer is made from material with high thermal conductivity.

Advantageous is, that the material of high thermal conductivity is copper.

A further advantageous embodiment is, that the hard steel or steel alloy is stainless steel.

In a further advantageous embodiment the inner layer of the double or multiple layer contact arrangement is made of stainless steel or another material with same stiffness, and the outer layer is made of copper.

A further advantageous embodiment is, that in case of a cup shaped contact arrangement the inner layer of the contact arrangement is made of copper, and the other or in case of a cup shaped arrangement the outer layer is made of stainless steel.

A further advantageous embodiment is, that the contact parts are positioned like that only the inner contacts are in touch when the vacuum interrupter is in closed position, and the whole nominal current flows through them.

A further embodiment is, that the gap distance in opened position of the vacuuminterrupter between the inner contacts and the outer contacts is kept the same. But in closed position the quasitotality of nominal current flows through the inner contacts.

A last advantageous embodiment is, that the gap distance between the outer contacts in opened position of the vacuum interrupter is smaller than the gap distance between the inner contacts. But in closed position a big part of nominal current flows through the inner contacts.

To avoid confusion between the terminology contact and electrode, it is designated, that electrode is the whole moving or fixed parts. An electrode in this case includes the combination of the inner and the outer contacts. Firstly, the inner and/or outer contacts relative position can be classified according to the following variations:

The detailed version to realized that, are disclosed in the following description.

Detailed description of the invention

There are many possible contacts elements arrangement in respect to each other with the double-contact system Vacuum interrupter. The inner part of the double contact is designed for nominal current path thus the contacts resistance should be as low as possible. This is achieved by applying high closing forces to minimize the contact resistance. In general the contact resistance *Rc* is inversely proportional to the square of the closing forces, i.e. decreases by increasing the closing forces.

$$R_c \propto \frac{1}{\sqrt{F_c}} \qquad (1)$$

This variation can be illustrated by following Figure 1, which shows the change in total impedance of a vacuum interrupter ($R_T = R_B + R_C$) with Cu–Cr contacts as a function of the contact load.

In case of double-contact electrodes the contact resistance of each contact (inner or outer) can be adjusted by altering the contact forces distribution. This is the basical functional feature of the invention which concerns to the structural features as claimed.

Like already said above, in order to avoid confusion between the terminology contact and electrode, the electrode is designated to the whole moving or fixed parts. An electrode in this case includes the combination of the inner and the outer contacts. Firstly, the inner and/or outer contacts relative position can be classified according to the following variations, like seen in figure 2.

1.) In **the first case** only the inner contacts are in touch when the switch is in closed position and the whole nominal current flows through them. They are also used at the initial vacuum arcing phase while performing the current interruption.

a.) The inner contacts (TMF-like) of both, moving and fixed electrodes, are emerging compared to outer contacts, like shown in figure 2a.

b.) Alternatively, only one of the inner contacts (the moving or the fixed one) is emerging compared to the outer contact, while the other inner contact is at the same level as the outer contact, see figure 2b.

In this case, the total forces in closed position are held by the inner contacts. This means that the nominal current flows entirely through the inner contacts.

While opening, the arc ignites first between the inner contacts, then develops in succeeding modes as the contacts distance increased then commutes partially to the outer contacts after some milliseconds. At this time the outer contacts start to generate AMF field corresponding to the current flow through them. After that the arc takes some other milliseconds to commute to fully diffuse arc as the AMF generation starts with some delay (Note: The delay caused by the phase shift between the B-field (**AMF)** and the current due to eddy currents effect is not taken into account here; it's found to be negligible in this double-contact structure).

2.) In **the second case**, the gap distance (in open position) between the inner contacts (moving and fixed) and the outer contacts (moving and fixed) is kept the same. Two relative position cases can be distinguished.

a.) The inner contact of one electrode (moving and fixed) is rising compared to the outer contact, while the position of the inner part of the opposite electrode is lowered (or pushed inwardly); see figure 2 c.

b.) All inner and outer contacts are at the same level, see figure 2 d.

In this case, the quasi-totality of forces (99%), in closed position, is held by the inner contacts due to the elastic deformation of the outer contact as described in the case 3. This means that the contact resistance through the inner contacts is much lower than the contact resistance through the outer ones.

While opening, the elastic deformation propriety of the outer contacts ensures the arc ignition between the outer contacts as the last touching point is found between them.

These two features give to this configuration a real big asset, because it has the advantage of the low contact resistance for nominal current (between inner contacts), and the arc ignition between the outer contacts, which are responsible for the AMF field generation. The arc commutation to the fully diffuse arc takes shorter time with this arrangement.

3.) **The third case** is the inverse of the first one, i.e. the gap distance between the outer contacts (in open position) is smaller than the gap distance between the inner contacts. However this difference should be as small as **0.1 – 2.5 mm** and preferentially **0.5 – 1.5 mm**. Here also we can distinguish two cases.

a.) Both inner contacts are pushed inwardly compared to the outer ones, but with very small distance; see figure 2 e.

b.) The inner contact of one electrode is pushed inwardly while the other inner contact of the opposite electrode is kept at the same level as the outer contact , see figure 2 f.

Depending on the difference in the respective gap distances and on the elasticity of the outer contacts coil, the inner contacts can be either touching or not in closed position. In case of a big respective gap distance between the inner contacts and/or low outer contacts coil elasticity the whole forces are held by the outer contact (case1), but in case of small respective gap distance between the inner contacts and/or big outer contacts coil elesticity, a considerable amount of forces are held by the inner contacts (case2).
In this case, the arc ignition will start at the outer contact but the contact resistance of the inner contacts (for the nominal current) is increased unless **the elastic properties** of the outer contacts are changed (to increase the deformation of the outer contact).

It is important to notice that the elasticity of the outer contact can be influenced by the **outer contact diameter**, the **cup thickness** and the **cup material** as well.

According to another embodiment, the outer contact (cup-shaped) is made from a double or multiple layers in which one layer at least is made from a strong, elastic and conductive material like **stainless steel**, and at least a second layer made from high thermal conductivity material **like copper**. This combination offers both robustness and cost effectiveness criteria to the contact assembly and would guarantee a better thermal management during and after arcing (fast contacts cooling).

The multi-layer cup-shaped contact may have several various arrangements on the superposition order of the layers depending on the intended application. For example for a double-layer:

1.) The inner layer is made from stainless-steel (hard conductive material) and the outer one from copper (excellent thermal and electrical conductor). In this case the major part of the short circuit current passes through outer layer (copper), thus increasing the effective AMF area. This arrangement is favoured for **increased high current interruption performance**.

2.) The inner layer is made from copper and the outer one from stainless-steel. Here, the outer layer of the cup-shaped contact is made from stainless-steel thus could be considered for withstanding high voltage towards the shield. This arrangement can be a good option for **high voltage application**. The contacts forces distribution changes slightly by using these two arrangements due to the change in the outer contact elasticity as shown, see for example figure 3. The force between the outer contacts decreased from 100 N in case of stainless-steel monolayer to ~ 70 N by using a double layer.

3.) Alternatively, the inner layer can be made from stainless-steel and a second layer made from copper; a third very thin layer can be superposed to the second outer layer and made from stainless-steel or another metal with good high voltage withstand properties (Nickel, steel-alloy, etc). This very thin layer can be obtained for example by coating with electroplating, electroforming or PVD processes, etc. With this multilayer structure we increase the effective AMF area during the high current interruption process, and increase the high voltage withstand performance of the vacuum interrupter.

4.) Alternatively, an inversed arrangement of the multilayer cup-shape contact is possible. The inner layer is made from copper and the outer layer from stainless-steel (the stainless-steel layer is necessary for contacts robustness). The stainless-steel layer is superposed by a very thin layer of copper which can be obtained by coating with electroplating, electroforming or PVD processes, etc.

So figures 3a, 3b, 3c and 3d show different the embodiments.

Figure 3a shows a double layer system with a stainless-steel inner layer and a copper outer layer.

Figure 3b shows a double layer system with a copper inner layer and a stainless steel outer layer.

Figure 3c shows a multilayer system with stainless steel inner layer, plus a copper outer layer with a thin coverage by steel/nickel layer.

Figure 3d shows a multilayer system with a copper inner layer plus a stainless steel outer layer with a thin coverage by a thin copper layer.

Claims

1. Vacuum interrupter with double co-axial contacts arrangement in which the inner contact has a TMF-like or Pin shape arranged within concentrically cup shaped AMF coil; with a single layer or multilayered arranged contact parts at each side, th.m. on the side of a fixed contact arrangement as well as on the side of a movable contact arrangement,
   characterized in that,
   that the outer cup shaped contact is made from a single layer, or double or multiple layer arrangement, wherein at least one layer is made from a hard steel or steel alloy and in case of multilayer arrangement at least a second layer is made from material with high thermal conductivity.

2. Vacuum interrupter according to claim 1,
   characterized in,
   that the material of high thermal conductivity is copper, silver, silver-alloy or copper-alloy.

3. Vacuum interrupter according to claim 1,
   characterized in,
   that the hard steel or steel alloy is stainless steel.

4. Vacuum interrupter according to claim 1, 2 or 3,
   characterized in,
   that the inner layer of the double or multiple layer contact arrangement is made of stainless steel or another material with similar stiffness, and the outer or the second layer is made of copper.

5. Vacuum interrupter according to claim 1, 2 or 3,
   characterized in,
   that in case of a cup shaped contact arrangement the inner layer of the contact arrangement is made of copper, and the other or the outer layer is made of

stainless steel.

6. Vacuum interrupter according to one of the aforesaid claims 1 to 4, **characterized in,** that the outer layer is covered or coated with a very thin layer up to 100 μm thickness from high voltage withstand material.

7. Vacuum interrupter according to claim 6, **characterized in,** thin layer material is Nickel, steel or steel alloy.

8. Vacuum interrupter according to one of the aforesaid claims 1 to 3 and 5, **characterized in,** that the outer layer is covered or coated with a very thin layer up to 100 μm thickness from copper, silver or copper alloy.

9. Vacuum interrupter according to one of the aforesaid claims 1 to 8, **characterized in,** that the contact parts are positioned like that only the inner contacts are in touch when the vacuum interrupter is in closed position, and the whole nominal current flows through them.

10. Vacuum interrupter according to one of the aforesaid claims 1 to 8, **characterized in,** that the respective gap distance in open position of the vacuum interrupter between the inner contacts, and between the outer contacts is kept the same.

11. Vacuum interrupter according to one of the aforesaid claims 1 to 8, **characterized in,** that the gap distance between the outer contacts in opened position of the vacuum interrupter is smaller than the gap distance between the inner contacts.

12. Vacuum interrupter according to the aforesaid claims 1, 9 to 11,
characterized in,
that in closed position of the vacuum interrupter a totality or a quasi-totality of nominal current flows through the inner contacts.

13. Vacuum interrupter according to the aforesaid claims 1 and 9,
characterized in,
that while opening (disconnecting) the contacts of the vacuum interrupter during the current interruption process, the arc ignition takes place between the inner contacts, then commutes partially or totally to the outer contacts and transforms to a diffuse arc under the effect of the generated AMF corresponding to the current flow through the outer contacts.

14. Vacuum interrupter according to the aforesaid claims 1 and 10 to 12,
characterized in,
that while opening (disconnecting) the contacts of the vacuum interrupter during the current interruption process, the arc ignition takes place between the outer contacts, then transforms quickly to a diffuse arc under the effect of the generated AMF corresponding to the current flow through the outer contacts.

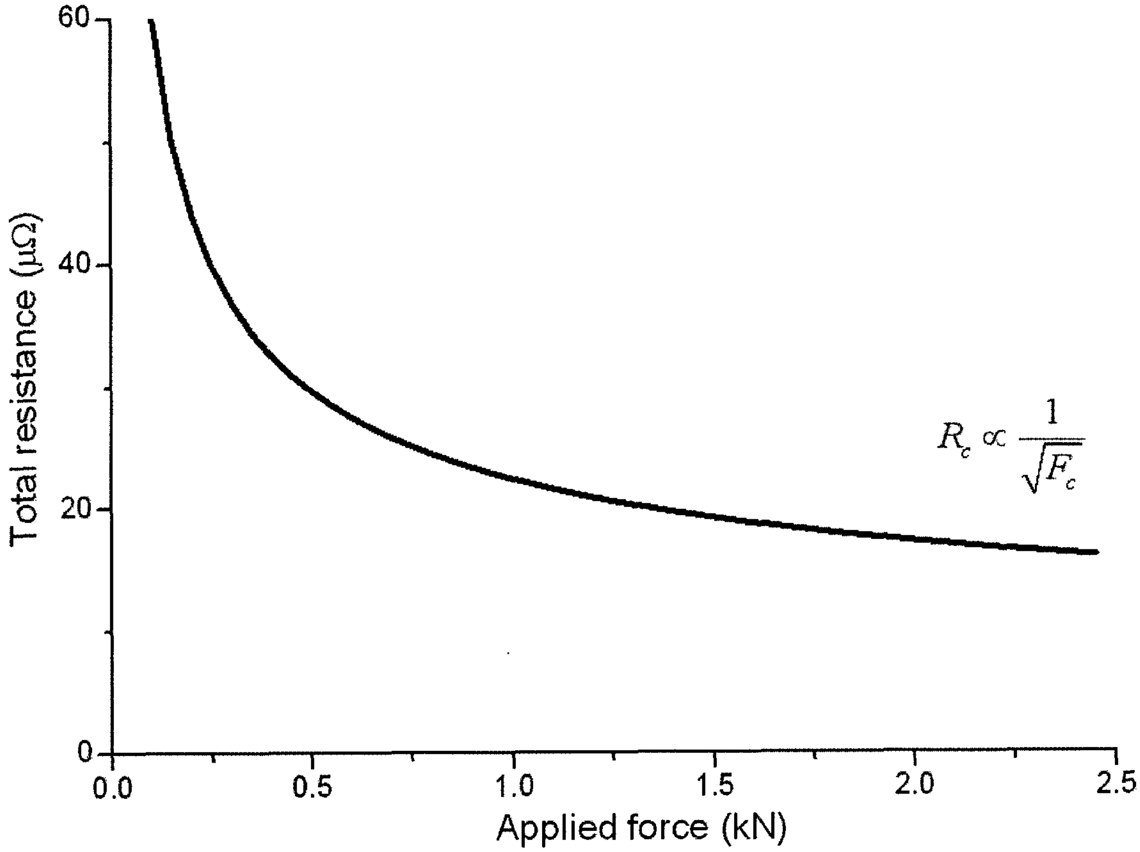
60
40
20
0
0.0
0.5
1.0
1.5
2.0
2.5
Total resistance (μΩ)
Applied force (kN)
$R_c \propto \frac{1}{\sqrt{F_c}}$

Fig. 1

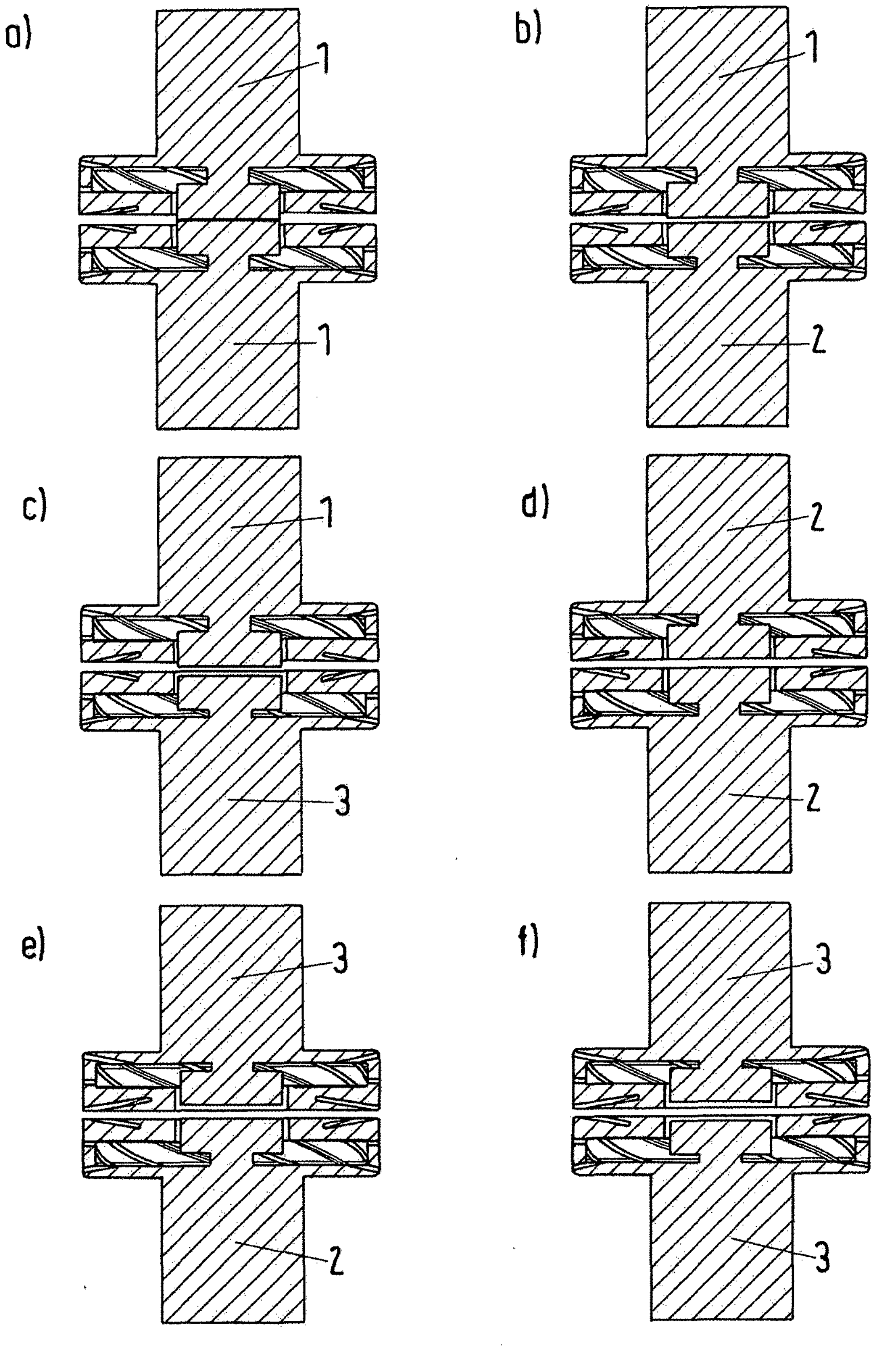

Fig.2

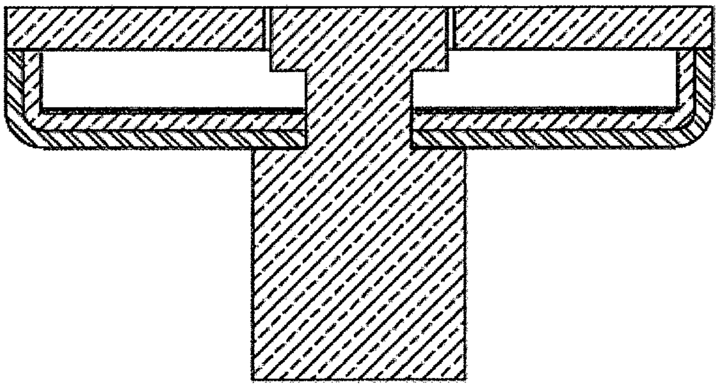

Fig. 3a

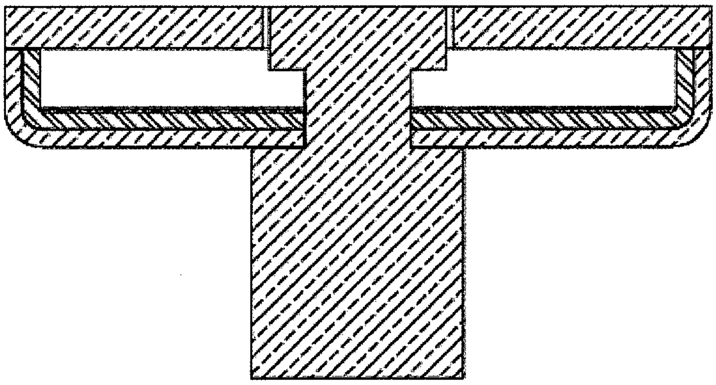

Fig. 3b

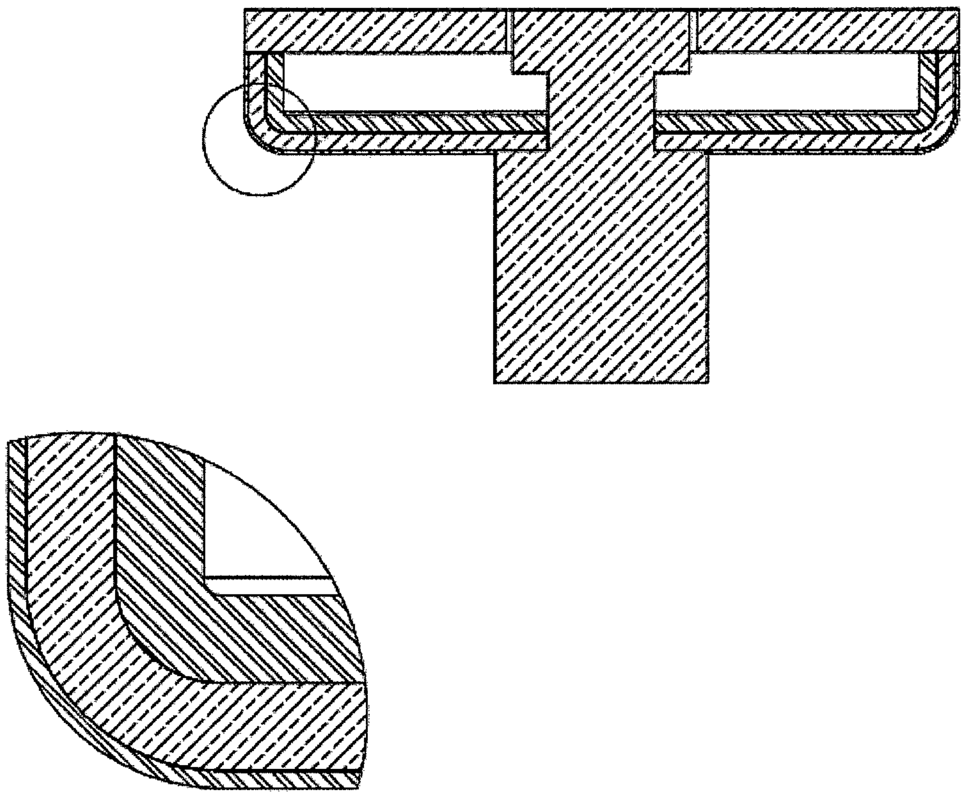

Fig. 3c

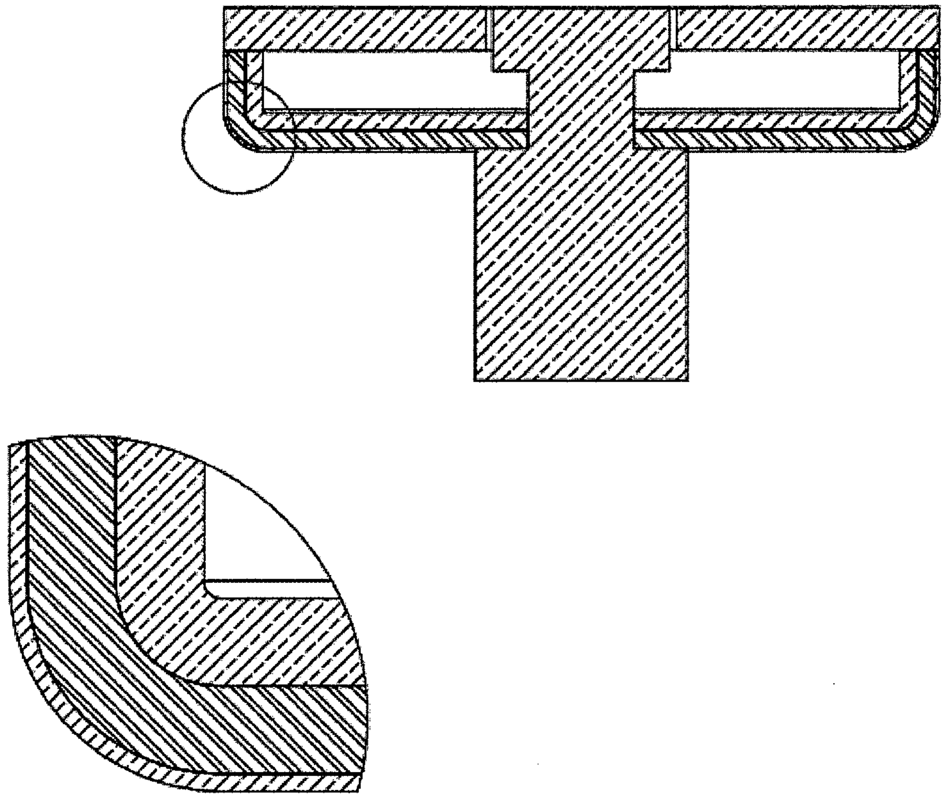

Fig. 3d

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2013/001708

A. CLASSIFICATION OF SUBJECT MATTER
INV. H01H33/664
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, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 2 434 513 A1 (ABB TECHNOLOGY AG [CH]) 28 March 2012 (2012-03-28) cited in the application	1-4,9-14
Y	paragraph [0015] - paragraph [0021]; figures 1-10	5-8
Y	DE 93 05 125 U1 (SIEMENS AG [DE]) 4 August 1994 (1994-08-04) page 3, paragraph 14 - page 4, paragraph 14; figure 2	5
Y	EP 0 660 353 A2 (HITACHI LTD [JP]) 28 June 1995 (1995-06-28) column 14, line 13 - line 48; figures 3,4	6-8

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

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"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

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
28 October 2013	06/11/2013

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Arenz, Rainer

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2013/001708

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