May 26, 1970 J. W. RANHEIM 3,514,559

VACUUM TYPE CIRCUIT INTERRUPTER

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Fig. 1

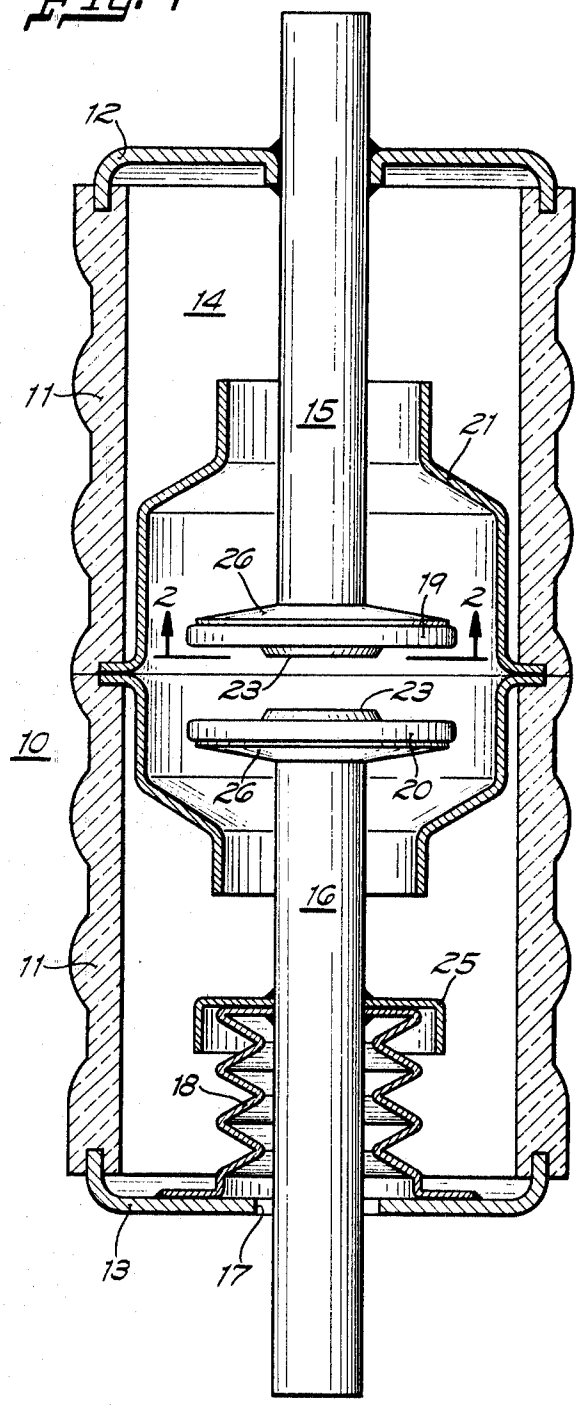


Fig. 3

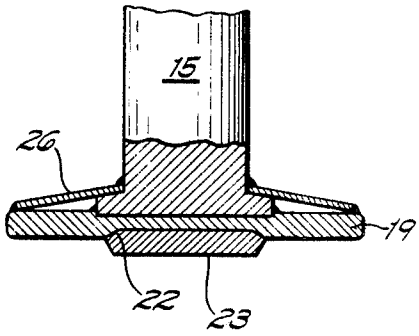
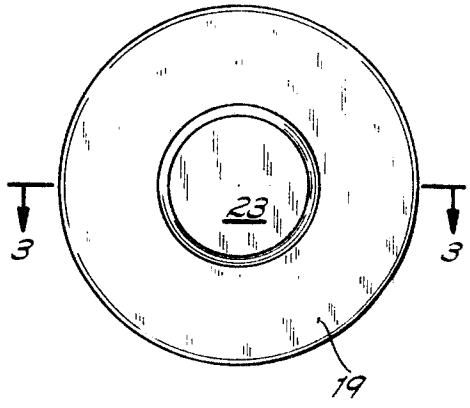


Fig. 2



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VACUUM TYPE CIRCUIT INTERRUPTER

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Fig. 4

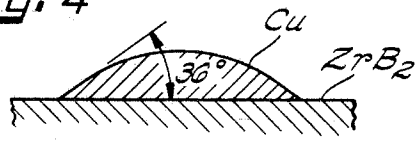


Fig. 5

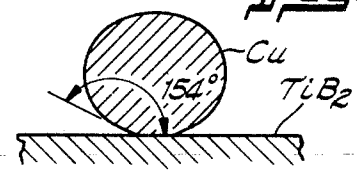


Fig. 6

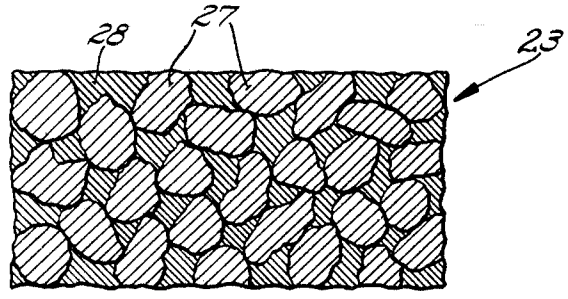
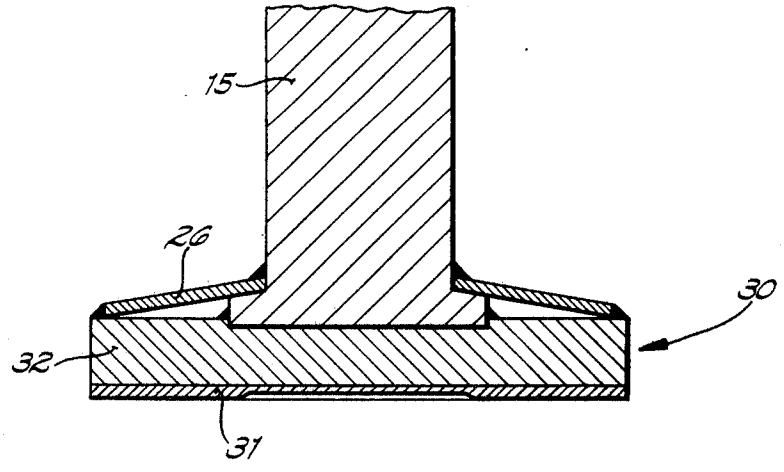


Fig. 7



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3,514,559

VACUUM TYPE CIRCUIT INTERRUPTER

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U.S. Cl. 200—144 8 Claims

ABSTRACT OF THE DISCLOSURE

A vacuum circuit interrupter comprising an evacuated insulated housing having a pair of conductive electrodes which are constructed and arranged to be moved into and out of engagement and circuit making and breaking regions on the electrodes composed of a porous refractory such as W_2B_5, for example, impregnated with a nonrefractory metal having high thermal and electrical conductivity wherein the refractory is readily wet by the nonrefractory when the latter is in its liquid state.

BACKGROUND OF THE INVENTION

Vacuum circuit interrupters generally include an evacuated insulating housing and circuit making and breaking contacts constructed and arranged to be moved into and out of engagement. In addition to the ability to interrupt fault currents and to withstand impulse crest voltages across is open contacts, vacuum circuit interrupters must be able to close against high momentary currents without producing objectionable welds between its contacts. Such welding is associated with the fluidizing of the metallic contact material as a result of the heat produced during arcing. This liquid contact material freezes after the contacts are brought into high pressure engagement, thereby forming a weld.

One prior art method for avoiding contact welds was to fabricate the contacts out of a refractory metal such as tungsten. Such contacts were not wholly satisfactory, however, because their arc interrupting ability was relatively limited as a result of the low thermal conductivity of this material. Another prior art contact comprised a porous matrix of a refractory metal, such as tungsten, and a nonrefractory metal impregnant having high thermal and electrical conductivity, such as copper. Contacts of this type were also satisfactory only for the interruption of relatively low currents. At high current values the copper would tend to evaporate from the arcing surfaces so that, after a few interruptions, there remained a region of relatively pure tungsten. This region would then heat to a relatively high temperature and emit arc sustaining electrons by thermionic emission.

In a further prior art attempt to solve the welding problem, the vacuum interrupter contacts were fabricated of an alloy of copper-bismuth. Although this material is readily melted during arcing, it is weak physically so that any resulting welds can easily be broken by the switch opening apparatus. These contacts were not wholly satisfactory, however, because they are easily eroded during arcing and, therefore, their useful life is relatively limited. In addition, a large amount of liquid contact material is lost by such contacts during arcing and this material tends to condense on the internal surfaces of the interrupter, to form sharp projections and other irregularities which tend to reduce its dielectric properties.

SUMMARY OF THE INVENTION

In general terms the invention comprises a vacuum circuit interrupter in which at least one of its engageable contact portions comprises a porous refractory including

a substantial proportion of a refractory material and an impregnant consisting of a nonrefractory high thermal and electrical conductivity material wherein the refractory is readily wet by the nonrefractory when the latter is in its liquid state.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a side elevational view, partly in section, of a vacuum circuit interrupter illustrating how the contacts, according to the instant invention, may be employed;

FIG. 2 is a view taken along lines 2—2 of FIG. 1;

FIG. 3 is a view taken along lines 3—3 of FIG. 2;

FIGS. 4 and 5 illustrate the method of determining the degree of wettability of a first metal in its solid state and a second metal in its molten state;

FIG. 6 illustrates the physical relationship between the components of the contacts according to the instant invention; and

FIG. 7 illustrates an alternate contact configuration in which the contact material according to the invention may be employed.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 1 shows a vacuum-type circuit interrupter **10** having an open-ended outer envelope **11** of any suitable electrical insulating material, such as a ceramic, and upper and lower end caps **12** and **13**, respectively, each of which is fixedly secured at its outer periphery to one of the open ends of the envelope **11** to form a vacuum chamber **14**. A fixed electrode, or contact rod, **15** is sealed to the upper end cap **12** and extends downwardly therefrom in a substantially coaxial relation to the envelope **11**. A second electrode or contact rod **16**, extends upwardly through an aperture **17** formed in the lower end cap **13** and is movable longitudinally into and out of engagement with the fixed contact rod **15** by means which are not shown but which are well known in the art. A bellows **18**, or its equivalent structure, is connected in a vacuum tight relation at each of its opposite ends to the contact rod **16** and to the lower end cap **13** in surrounding relation to the aperture **17**.

The contact rods **15** and **16** are axially aligned within the envelope **11** and respectively carry arcing contacts **19** and **20** at their inner ends. The arcing contacts **19** and **20** may be generally disc-shaped and are disposed in an opposed relation relative to each other. An arc shield **21** may be affixed to the envelope **11** in surrounding relation relative to the contacts **19** and **20** to prevent contact material, which may be vaporized during an arc interruption, from depositing on the inner surface of the envelope **11** and thereby to provide a short-circuit path around the electrodes **15** and **16**. In addition a second, generally cup-shaped shield **25**, is affixed to the rod **16** for protecting the bellows **18**.

The arcing contact **20** is preferably a mirror image of contact **19**, and accordingly, only contact **19** will be discussed in detail. Referring now to FIGS. 2 and 3, the arcing contact **19** is shown to be generally disc-shaped and to be affixed at its upper surface to the contact rod **15** in any suitable manner, such as by brazing. The lower surface of the contact **19** is provided with a generally circular recess **22** for receiving a relatively flat, circular disc-shaped member **23** which is secured in the recess in a manner which will be discussed hereinbelow. The thickness of the member **23** is greater than the depth of the recess **22** so that it will be elevated relative to the remainder of the contact **19** and thereby will engage a corresponding member **23** of the lower contact **20**.

A generally frustoconical support **26** is affixed to the back of each of the contacts **19** and **20** to provide rigidity for said contacts.

The contact making and breaking regions **23**, according to the invention, comprise a porous body, or matrix, composed of a refractory impregnated with a nonrefractory metal having high thermal and electrical conductivity wherein the nonrefractory tends to wet the refractory. In addition, it is preferable that the solubility of the refractory in the liquid state nonrefractory metal be substantially limited so that the porous matrix of the refractory matrix will be retained after repeated arcings.

It is preferred that the refractory comprise a compound composed of a metal and a metaloid, and it is also preferable that the oxides of the metalloid be solid at the normal operating temperatures of the interrupter so that gases will not be liberated during arcing which would tend to destroy the vacuum. Two metalloids which form a refractory compound with certain metals and which exhibit these characteristics are boron and silicon. These elements are also effective getters so that when compounds of boron and a metal are employed in vacuum interrupters, it is possible to eliminate several of the expensive degassing operations employed in the fabrication of certain prior art vacuum interrupter contacts, such as those composed of copper and copper-bismuth.

The nonrefractory metal having high thermal and electrical conductivity and which impregnates the refractory compound matrix may consist, according to the invention, of copper, silver, aluminum or any high thermal and electrical conductivity mixture thereof.

Certain compounds of boron and a metallic are unsatisfactory for use in circuit interrupter contacts because they have relatively low melting points, such as NiB, which melts at approximately 1020° C. Preferably the melting point of the compound should be in excess of 1750° C.

To illustrate certain refractory compounds of a metalloid and a metallic, reference is made to Table I wherein the melting points of certain illustrative compounds which may be used in circuit interrupters of the invention are given.

TABLE I.—MELTING POINTS OF SOME ILLUSTRATIVE REFRACTORY COMPOUNDS

Compound:	Approximate melting point (° C.)
CrB_2	1850
$MoSi_2$	2050
Mo_2B	2100
MoB_2	2100
VB_2	2100
MoB	2100
WSi_2	2165
CeB_6	2190
ThB_6	2195
LaB_6	2210
SrB	2235
BaB_6	2270
UB_2	2365
W_2B	2770
WB	2900
TaB_2	2900
NbB_2	2900
WB_2	2900
VB_2	2900
WB_6	2920
W_2B_5	2980
HfB_2	3100
ZrB_2	3040

Certain of these compounds, which were tested and found to be highly satisfactory for high current applications, are ZrB_2, W_2B, WB and W_2B_5. Other compounds, such as CrB_2, Mo_2B, MoB_2 and MoB having a lower melting point, would be satisfactory at lower current applications.

Boron is known to form several other compounds with certain of these metals, such as ZrB, ZrB_2 and ZrB_{12}. For the sake of brevity, all of these compounds have not been listed.

The wetting action of a liquid metal on another material in its solid state has been discussed in the literature. This phenomenon is reported in terms of the angle that a droplet of the molten metal makes with a planar surface of the solid state metal as illustrated in FIGS. 4 and 5. In FIG. 4 a droplet of copper at 1400° C. is shown to make an angle of 36° with ZrB_2, and in FIG. 5 a droplet of copper at 1400° C. is shown to make an angle of 154° with TiB_2. Thus, because the molten droplet of copper wets ZrB_2, it spreads out to form a relatively small angle with the planar surface of the refractory. On the other hand, the molten copper droplet does not readily wet TiB_2 so that it tends to assume a spherical shape whereby a large angle is formed with the planar TiB_2 surface. The angles formed between molten copper droplets of some illustrative boron compounds as reported in the literature are set forth in Table II.

TABLE II

Compound	Temperature, °C	Angle formed by drop of pure molten Cu on planar surface of compound (deg.)
ZrB_2	1,160–1,400	123–36
TaB_2	1,100–1,400	77–47
CrB_2	1,480	50
VB_2	1,100–1,400	150–114
TiB_2	1,100–1,500	158–154

It can be seen from Table II that the ability of molten copper to wet certain of the refractory compounds increases substantially as the temperature is increased from 1100° C., which is slightly in excess of the melting point of copper, to 1400°–1500° C. The ability of molten copper to wet certain other compounds, however, such as TiB_2, is not appreciably increased by such an increase in temperature. This, while TiB_2 is sufficiently refractory, having a melting point of 2980° C., its use in the vacuum interrupter contacts according to the invention is not preferred because it is not readily wet by molten copper.

The ability of molten copper to wet certain refractory materials may be enhanced by the addition to the copper of certain wetting agents, such as Ni. Such wetting agents should preferably be added only in amounts which will not adversely effect the thermal and electrical conductivity of the copper. It may be noted that it is well known in the prior art that the metals and metalloids which form the compounds illustrated in Table I are tightly bonded together so that very little of the boron or silicon metalloids in solid form will be free to join with nickel to form the undesirable refractory compounds such as NiB. Also, it is known that the evaporated gaseous silicon or boron which combines in the atmosphere within the arc shield **21** with nickel or oxygen will most likely deposit in solid form on the arc shield or non-contacting surfaces of contacts **19** and **20** because such surfaces are relatively large in comparison with the engaging portions of the contacts.

While the examples in the foregoing description have all involved the ability of molten copper to wet various refractories, those skilled in the art will appreciate that this will have application to silver and aluminum as well.

The arcing contact **23** is shown in FIG. 6 to comprise a porous body, or matrix, **27** of the refractory compound impregnated with a nonrefractory high thermal and electrical conductivity metal **28**.

One illustrative process for forming the circuit making and breaking contact **23** and involving the refractory compound W_2B_5 and copper will now be discussed. A mixture of powdered W_2B_5 and powdered copper is placed in a die having the shape of the current making and breaking contacts **23**, and a pressure of approximately 50,000–100,000 p.s.i. is applied, although lower pressures are acceptable if the mold is suitably heated. This compresses the powdered mixture into a relatively solid mass. The compressed member is then placed into a vacuum furnace and heated at a temperature which is in excess of 1083° C., the melting point of copper, although a temperature in the order of 1700° C. is preferred. This thoroughly wets the refractory with copper and tends to cause the refractory particles to coalesce and grow together to form a matrix. The liquefied copper tends to fill the spaces between the W_2B_5 matrix, although some copper is lost by evaporation.

The contact is then placed in a mold containing molten copper and heated under vacuum at a temperature in excess of the melting point of copper, but preferably at 1600°–1700° C., for a period of sufficient length to thoroughly degas the copper. The temperature is then reduced to approximately 1250° C. for a period of time sufficient to fill any remaining voids with copper. Because the specific gravity of the refractory is substantially greater than that of the pure copper, the matrix member impregnated with copper does not tend to float in the molten copper. When the mold is cooled, a composite contact member is then provided which consists of the contact making and breaking member **23** bonded to a backing of purse copper **19**. The copper and the copper-impregnated refractory may then be machined to the desired shape shown in FIGS. 2 and 3. Small quantities of an impurity, such as a few percentage or less of silver or zirconium may be added to the copper to improve its machinability.

This process insures that the spaces in the W_2B_5 matrix are filled with copper and also eliminates the necessity for thereafter brazing, or otherwise joining, the contact making and breaking electrode **23** to the copper body **19**.

While the foregoing process has been discussed with respect to W_2B_5, it is intended that the same process would be employed with various other higher melting point compounds such as W_2B, WB, TaB_2, NbB_2, VB_2, HfB_2 and ZrB_2.

The proportion of powdered refractory and copper in the original mixture should be such that there will be substantially continuous contact between the refractory particles. This result has been obtained with about equal portions by volume of powdered copper and W_2B_5. If the copper portion exceeds about 60% by volume, then a continuous matrix may not be obtained. If the proportion of copper falls below about 15% by volume, then the desired degree of thermal and electrical conductivity may not be achieved. The preferred grain sizes are about —350 mesh or less for both the copper and the refractory.

The desired results are also possible if mixtures of various powdered refractories are employed, such as W_2B_5 and ZrB_2. In addition, some minor proportion of a refractory metal such as tungsten may also be employed, although with less satisfactory results.

According to another embodiment of the invention illustrated in FIG. 7, the contact making and breaking material composed of the matrix of the refractory compound impregnated with a nonrefractory high thermal and electrical conductivity metal covers the entire arcing face of the contact **30**. Here the circuit making and breaking contact comprises a thin lamination **31** of the arcing material according to the invention and a relatively thicker base **32** of high thermal conductivity metal, such as copper.

The contacts, according to the instant invention, provide most of the advantages of refractory contacts and of high thermal and electrical conductivity nonrefractory contacts while eliminating most of the disadvantages thereof. Consider, for example, a contact composed of a matrix of W_2B_5 impregnated with copper. Because the refractory W_2B_5 is readily wet by liquid copper, very little copper is lost during arcing even though some of the copper may become liquid. As a result, the matrix remains impregnated with copper so that, even after repeated arcings, there is a relatively high thermal and electrical conductivity at the contacting faces of the contacts and, in addition, heat generated during arcing will be rapidly conducted away from the arcing surfaces. Because of the relatively high melting point of the refractory compound, very little metal will be melted during arcing so that there will be little tendency for contacts to weld upon re-engagement. In addition, because of the refractory nature of the matrix, there will be very little contact erosion even after repeated arcing so that a relatively long contact life is realized. Also, because the solubility of W_2B_5 in liquid copper is relatively low, the matrix will not dissolve to any great extent in any copper which may become liquid during arcing. Further, the current chopping level of contacts comprising a W_2B_5 matrix impregnated with copper compares favorably with other vacuum interrupter contact materials such as an alloy of copper-bismuth which has a current chopping level averaging between 4 and 5 amperes when the contact configurations shown herein are used.

While only a few embodiments and examples of the instant invention have been illustrated and described, these are only intended to be illustrative.

I claim:

1. A vacuum circuit interrupter comprising an evacuated envelope, a pair of contact members having engageable portions and being constructed and arranged for movement into and out of engagement, whereby a current interrupting arc is struck between said engageable portions, the improvement wherein at least one of said engageable portions comprises a porous refractory material including a compound consisting of a refractory metal and a metalloid taken from the group consisting of boron and silicon, and an impregnant consisting of a nonrefractory high thermal and electrical conductivity material, wherein the refractory material is readily wet by the nonrefractory material when the latter is in its liquid state.

2. The interrupter set forth in claim **1** wherein the oxides of said metalloid are solid at the normal operating temperatures of the interrupter.

3. The circuit interrupter set forth in claim **1** wherein said metal is taken from the group consisting of Ba, Ce, Cr, Hf, La, Mo, Nb, Sr, Ta, Th, W, U, V and Zr.

4. The circuit interrupter set forth in claim **1** wherein said metal is taken from the group consisting of Mo, Cr and W.

5. The circuit interrupter set forth in claim **1** wherein said metal comprises tungsten and said metalloid comprises boron.

6. A vacuum circuit interrupter comprising an evacuated envelope, a pair of contact members having engageable portions and being constructed and arranged for movement into and out of engagement, whereby a current interrupting arc is struck between said engageable portions, the improvement wherein at least one of said engageable portions comprises a porous refractory matrix including a compound of boron and a metal taken from the group consisting of Mo, Cr, Zr, Hf and W impregnated with a nonrefractory high thermal and electrical conductivity metal.

7. The circuit interrupter set forth in claim **6** wherein said nonrefractory consists essentially of a metal taken from the group consisting of copper, silver and high thermal and electrical conductivity mixtures thereof.

8. A vacuum circuit interrupter comprising an evacuated envelope, a pair of contact members having engageable portions and being constructed and arranged for movement into and out of engagement, whereby a current

interrupting arc is struck between said engageable portions, the improvement wherein at least one of said engageable portions comprises a porous matrix including a compound of zirconium and boron impregnated with a nonrefractory high thermal and electrical conductivity metal.

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ROBERT S. MACON, Primary Examiner

U.S. Cl. X.R.

75—202; 200—166